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2018

Upper Mississippi River Restoration Program

Habitat Needs Assessment-II: Linking Science to Management Perspectives

Kathryn N.S. McCain[1], Sara Schmuecker[2], and Nathan R. De Jager[3]

[1]U.S. Army Corps of Engineers

[2]U.S. Fish and Wildlife Service

[3]U.S. Geological Survey

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The Habitat Needs Assessment–II was a cooperative effort of the state and Federal agencies represented by their logos below. These agencies have made great strides to restore and understand river habitats under the auspices of the Upper Mississippi River Restoration Program.

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Additional Copies or Comments:
Upper Mississippi River Restoration Program Regional Manager
U.S. Army Corps of Engineers – Rock Island District
Clock Tower Building
P.O. Box 2004
Rock Island, IL 61204-2004

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ACRONYMS

AFC	Aquatic Functional Class
FWIC	Fish and Wildlife Interagency Committee
FWWG	Fish and Wildlife Work Group
HNA	Habitat Needs Assessment
HREP	Habitat Rehabilitation and Enhancement Project
IADNR	Iowa Department of Natural Resources
ILDNR	Illinois Department of Natural Resources
INHS	Illinois Natural History Survey
LiDAR	Light Detection and Ranging
LTRM	Long Term Resource Monitoring
MDC	Missouri Department of Conservation
MNDNR	Minnesota Department of Natural Resources
NGO	Non-governmental Organization
RRAT	River Resources Action Team
TMDL	Total Maximum Daily Limit
UMESC	Upper Midwest Environmental Sciences Center
UMRBA	Upper Mississippi River Basin Association
UMRR	Upper Mississippi River Restoration
UMRR CC	Upper Mississippi River Restoration Coordinating Committee
UMRS	Upper Mississippi River System
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WIDNR	Wisconsin Department of Natural Resources

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Prepared by:

Kat McCain[1], Sara Schmuecker[2], Nathan R. De Jager[3]

[1]U.S. Army Corps of Engineers
Regional Planning and Environmental Division North
1222 Spruce Street, St. Louis, MO 63103

[2]U.S. Fish and Wildlife Service
Illinois – Iowa Field Office
1511 47th Avenue, Moline, IL 61265

[3]U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road, La Crosse, WI 54603

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Prepared for:
U.S. Army Corps of Engineers
Rock Island District
Clock Tower Building
P.O. Box 2004
Rock Island, IL 61204

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Upper Mississippi River Restoration Program
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Executive Summary

The Upper Mississippi River Restoration (UMRR) Program vision statement is for *a healthier and more resilient Upper Mississippi River ecosystem that sustains the river's multiple uses.* To address this vision, the UMRR Program recently developed a suite of 12 indicators that quantify aspects of ecosystem health and resilience (i.e., connectivity, redundancy and diversity, and controlling variables). These indicators reflect the ability of large floodplain river ecosystems to adapt and respond to disturbances. The indicators use new data and information developed by the UMRR Program since the initial Habitat Needs Assessment (HNA-I) was completed in 2000. The indicators were agreed upon by the UMRR partnership and were developed using systemic data (De Jager et al., 2018) to represent the habitat needs for the Upper Mississippi River System (UMRS). The 12 indicators also represent ecosystem-based management objectives developed for the UMRS (USACE, 2011) providing a systemic evaluation of the UMRS. The primary purpose of this document is to help inform the UMRR Program in selecting, designing, and evaluating future restoration projects to achieve the UMRR Program's vision.

To identify habitat needs for the UMRS, the HNA-II effort used a series of 12 indicators that quantify the basic structure and function of the river system developed in a previous report (De Jager et al., 2018). These indicators provide an objective and scientifically sound quantification of the basic structure and function of the UMRS ecosystem. Habitat needs were defined by comparing individual indicators to the conditions desired by the management agencies of the UMRR Program. Thus, the approach for HNA-II integrated quantitative data with qualitative assessments that reflected the diverse management philosophies and resources of concern of UMRS stakeholders and management agencies to assess how the structure and function of the UMRS compares to conditions desired by the UMRR partnership. An assessment of current conditions using both quantitative data analysis and qualitative management perspectives was performed at two spatial scales (i.e., navigation pool and clusters of navigation pools that shared similar ecological attributes). In addition, a paired-comparison survey of management agencies was conducted to identify the most important indicators to target with desired future restoration actions. These spatially explicit comparisons can now be used in combination with previously calculated rates of ecosystem degradation (1-3% annually; USACE, 2016) for the entire UMRS to inform strategic implementation and monitoring of restoration projects.

In this report, a series of tables and figures are provided that assess individual navigation pools and clusters of navigation pools relative to desired conditions (see Figure ES-1) and that define the most important indicators for each cluster of navigation pools (see Table ES-1). The HNA-II identified clear differences in the importance of different indicators and their proximity to desired conditions among navigation pools and clusters of navigation pools within the Upper Mississippi and Illinois Rivers, suggesting that a 'one size fits all' management approach to the UMRS is untenable.

The HNA-II evaluation was conducted by the River Teams, USACE-District based coordinating technical groups consisting of Federal, state, local, and non-governmental participants. The River Resources Action Team (RRAT), Fish and Wildlife Interagency Committee (FWIC), and Fish and Wildlife Working Group (FWWG) correspond to the St. Louis District, Rock Island District, and St. Paul District of the USACE, respectively. The FWWG and the FWIC were most concerned about indicators of aquatic and floodplain hydrogeomorphic conditions and vegetation in the Upper and Middle Impounded clusters of navigation pools. These indicators typically deviated from desired conditions, suggesting that future management actions could focus on improving conditions related to these indicators. In the Lower Impounded cluster of navigation pools, the FWIC was also concerned about the same indicators of aquatic and floodplain hydrogeomorphic conditions and vegetation as in the Upper and Middle Impounded clusters, but considered them to be near desired conditions. Hence, future actions could focus on maintaining existing conditions related to these indicators in these pools. More broadly, many of the indicators in the Upper, Middle, and Lower Impounded clusters of the Upper Mississippi River were considered to be near desired conditions, suggesting that most future management actions in these portions of the UMRS could focus on curbing the rate of ecosystem degradation and working to maintain existing conditions in the face of future disturbances and stressors. This may be particularly important for indicators related to aquatic functional classes given projected changes in aquatic hydrogeomorphic conditions resulting from sedimentation (De Jager et al. 2018) and for floodplain vegetation, given projected changes in floodplain forest cover and species composition (De Jager et al. 2018). However, open water area was ranked as the most important indicator for the Lower Impounded cluster, and was considered to deviate from desired conditions. Hence, future actions in this reach could focus on modifying rates and directions of water movement and connectivity.

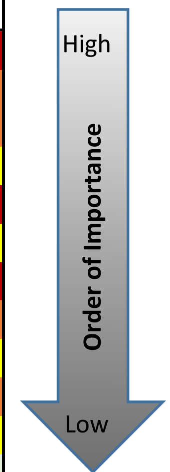
In contrast to the Upper, Middle, and Lower Impounded clusters of the UMR, the Open River cluster and the Upper and Lower clusters of the Illinois River had several indicators that substantially deviated from desired conditions and may merit actions to improve. In the Upper Illinois cluster, the FWIC was most concerned about the same indicators of aquatic and floodplain hydrogeomorphic conditions and vegetation as in the Upper, Middle, and Lower clusters of the UMR, and these indicators either deviated or substantially deviated from desired conditions. In the Lower Illinois cluster, the FWIC was primarily concerned about total suspended solids, floodplain hydrogeomorphic conditions and vegetation, and lotic aquatic habitats. The FWIC considered these indicators to either deviate or substantially deviate from desired conditions in the Lower Pools of the Illinois. Hence, future management and restoration actions in the Illinois River could focus on improving ecosystem conditions related to these indicators. Finally, the Open River cluster had the largest number of indicators considered to substantially deviate from desired conditions. However, many of these indicators were not ranked as most important by the RRAT, presumably because they were often considered to require collaboration with other partners operating at broader scales (e.g., open water area, leveed area, aquatic vegetation, and tailwater fluctuations). On the other hand, the indicators considered most important (e.g., aquatic and floodplain functional classes, and floodplain vegetation) were generally considered to be near desired conditions. Hence, future restoration and management actions in this reach could focus on maintaining existing ecosystem conditions in the face of future disturbances, stressors, and ongoing rates of ecosystem degradation, as well as seeking partnerships with other organizations operating at broader spatial scales.

The UMRR Program can use the information provided in this report to more effectively achieve the Program's goals, as stated in the UMRR Strategic Plan 2015-2025:

1) *Enhance habitat for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem*. Based on the HNA-II assessment, a number of navigation pools, and clusters of navigation pools were determined to be in less-than-desirable condition. HNA-II can help inform prioritization of restoration activities to strategically address resource concerns.
2) *Advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem.* Through the HNA-II effort, new data sets and models were developed that can further improve our understanding of how the basic structure and function of the UMRS influences and is influenced by future disturbances and stressors.
3) *Engage and collaborate with other organizations and individuals to help accomplish the UMRR vision.* Through HNA-II, indicators were developed that reflect ecosystem processes operating beyond the authorization of the UMRR Program. However, HNA-II has provided information to the UMRR Program that can be used to facilitate discussions with others in the UMRS watershed to work collaboratively and leverage resources to accomplish the UMRR vision of a healthier and more resilient UMRS.
4) *Utilize a strong, integrated partnership to accomplish the UMRR vision.* The approach used for HNA-II integrated quantitative and scientifically sound data developed by U.S. Geological Survey (USGS), the agency responsible for scientific research within UMRR Program, with the diversity of management philosophies and resources of concern of the state and Federal management agencies of the UMRR Program. HNA-II therefore utilized the entire partnership to define habitat needs. The integrated approach should help the UMRR Program foster future collaborative discussions that help the UMRR Program move from habitat needs to specific projects that address those needs.

The HNA-II effort has provided new geospatial data sets, 12 indicators of ecosystem structure and function quantifying general aspects of resilience for the UMRS and linked to ecosystem objectives. These data have been coupled with the qualitative management perspectives on the existing conditions and desired conditions of these indicators. The results provide additional information to inform habitat restoration project identification, planning, implementation, and monitoring. Future efforts could refine and further develop the ecosystem objectives, data layers, models, and indicators to improve our understanding of the UMRS and aid in the development of a more specific and strategic restoration philosophy for the UMRR Program.

Upper Impounded[A]	Middle Impounded[B]	Poo 15[B]	Lower Impounded[B]	Open River[C]	Upper Illinois[B]	Lower Illinois[B]
Aquatic Functional Class (AFC1)	**Aq Veg**	**Aq Veg**	**Open Water**	**AFC1**	**Aq Veg**	**TSS**
Aquatic Functional Class 2 (AFC2)	**FP Fxnal Class**	FP Veg	**AFC1**	**AFC2**	**FP Veg**	**FP Veg**
Floodplain Functional Class Diversity (FP Fxnal Class)	**AFC1**	FP Fxnal Class	**AFC2**	**FP Fxnal Class**	**FP Fxnal Class**	**FP Fxnal Class**
Floodplain Vegetation Diversity (FP Veg)	**AFC2**	TSS	**FP Fxnal Class**	**FP Veg**	AFC1	AFC1
Aquatic Vegetation Diversity (Aq Veg)	**FP Veg**	Nat Area	FP Veg	Open Water	AFC2	AFC2
Longitudinal Connectivity – Natural Area (Nat Area)	Nat Area	AFC1	Aq Veg	Leveed Area	TSS	Leveed Area
Total Suspended Solids Concentrations (TSS)	Open Water	AFC2	Leveed Area	Nat Area	TW Flux	Aq Veg
Lateral Connectivity – Open Water (Open Water)	TSS	TW Flux	Nat Area	Aq Veg	Nat Area	Open Water
Pool Flux Difference (Pool Flux)	TW Flux	Open Water	TSS	% Time	Leveed Area	TW Flux
Tailwater Flux Difference (TW Flux)	Pool Flux	Leveed Area	TW Flux	TW Flux	Open Water	Pool Flux
Lateral Connectivity – Leveed Area (Leveed Area)	Leveed Area	Pool Flux	Pool Flux	TSS	Pool Flux	Nat Area
% Time Gates Open (% Time)	% Time	% Time	% Time	Pool Flux (n/a)	% Time	% Time



- existing condition has substantial deviations from your defined desired condition; creating severe negative conditions that may merit actions
- existing conditions deviates from desired, and may merit action to improve
- existing condition is near your defined desired condition, but may merit actions to maintain or improve conditions
- existing condition is near desired condition, may merit action to maintain
- existing condition meets your defined desired condition, conitnuation of management and monitoring may still be needed to maintain condition

Cluster Name	Navigation Pools	River Team
Upper Impounded	Pools 3-9, 13	FWWG/FWIC
Middle Impounded	Pools 10-12, 14, 16, 19	FWIC
Pool 15	Pool 15	FWIC
Lower Impounded	Pools 17,18, 20-22, 24-26	FWIC/RRAT
Open River	OR1, OR2	RRAT
Upper Illinois	Dresden, Marseilles, Starved Rock	FWIC
Lower Illinois	Peoria, LaGrange, Alton	FWIC/RRAT

Figure ES-1: Summary of ratings of the 12 indicators of ecosystem structure and function for each of the clusters of navigation pools. The order (first row most important) of the indicators corresponds to the importance of that indicator as determined by the paired comparison conducted by the agencies. Bolded refers to high importance. Overall cluster ratings were achieved through three methods: A FWWG cluster ratings are presented in tables are averaged agency ratings, but the FWWG desired the reader to see Appendix A for individual agency ratings which captures the diversity of opinion among individual agencies. B FWIC overall ratings were agreed upon average-based. C RRAT overall ratings were consensus based.

Table ES-1. Summary of the desired future conditions for the indicators of high importance within clusters of navigation pools of the UMRS. Indicator importance was identified through pair-wise comparison of each indicator by each management agency and summarized for each cluster of navigation pools.

	Desired Future Conditions as Identified by the River Teams
Upper Impounded	• Improve function and diversity of aquatic habitat types by improving quality, depth and distribution of lotic and lentic habitats • Maintain and enhance aquatic vegetation diversity • Maintain and enhance floodplain vegetation diversity, including hard-mast trees • Restore floodplain topographic diversity and diversify inundation periods
Middle Impounded	• Maintain and enhance aquatic vegetation diversity • Restore floodplain topographic diversity and diversify inundation periods • Restore function and diversity of aquatic habitat types by improving quality, depth and distribution of lotic and lentic habitats • Restore, maintain and enhance floodplain vegetation diversity, including hard-mast (nut-producing) trees
Pool 15	• Maintain and enhance aquatic vegetation diversity
Lower Impounded	• Improve open water connectivity conditions, including island restoration • Restore function and diversity of aquatic habitat types by improving quality, depth and distribution of lotic and lentic habitats • Restore, maintain and enhance floodplain vegetation diversity, including hard-mast (nut-producing) trees
Open River	• Restore function and diversity of aquatic habitat types by improving quality, depth and distribution of lotic and lentic habitats • Restore floodplain topographic diversity (including ridge and swale) and diversify inundation periods to mimic pre-dam conditions • Restore, maintain and enhance floodplain vegetation diversity, including hard-mast (nut-producing) trees
Upper Illinois	• Maintain, enhance and restore aquatic vegetation diversity • Restore floodplain topographic diversity and diversify inundation periods • Restore, maintain and enhance floodplain vegetation diversity, including hard-mast (nut-producing) trees, where feasible
Lower Illinois	• Reduce sedimentation and total suspended solids concentrations • Restore, maintain and enhance floodplain vegetation diversity, including hard-mast (nut-producing) trees • Restore floodplain topographic diversity and diversify inundation periods

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1 INTRODUCTION

The Upper Mississippi River Restoration (UMRR) Program is one of the first large river ecosystem restoration and scientific monitoring programs in the country. The UMRR Program's geographic extent encompasses 2.7 million acres of river and floodplain along the Congressionally-defined navigable portions of the Upper Mississippi, Illinois, Minnesota, Black, Saint Croix, and Kaskaskia Rivers. For more than 30 years, the UMRR Program has combined innovative approaches to habitat restoration, planning processes, novel research, and ecosystem monitoring.

The UMRR Program was authorized in the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662), Section 1103, the Upper Mississippi River Plan. The two main elements of the UMRR Program are the (1) Habitat Rehabilitation and Enhancement Projects (HREPs), and (2) Long Term Resource Monitoring (LTRM). The original authorizing legislation has been amended several times since enactment. The 1997 Report to Congress recommended the development of a Habitat Needs Assessment (HNA) as part of a continued UMRR Program. The Upper Mississippi River Restoration Coordinating Committee (UMRR CC), comprised of representatives from the U.S. Army Corps of Engineers (USACE), the U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (USEPA), U.S. Department of Agriculture Natural Resource Conservation Service (USDA NRCS), and the five Upper Mississippi River System (UMRS) states of Minnesota, Wisconsin, Iowa, Illinois, and Missouri, supported the completion of the initial HNA (HNA-I), as well as this subsequent effort, coined HNA-II.

The HNA-I, was completed in 2000 and the primary objectives of that effort were to evaluate existing habitat conditions throughout the UMRS, forecast future habitat conditions, and quantify ecologically sustaining and socially desired future habitat conditions (Theiling et al., 2000). The primary purpose of the HNA-I was to help guide selection, design, and evaluation of HREPs under the UMRR Program. The HNA-I used a combination of data and expert opinion to describe the historical, existing, and future predicted habitat conditions of the UMRS. It further identified objectives for future habitat management; defined habitat needs at system-wide, reach, and pool scales; addressed a variety of habitat requirements including physical, chemical, and biological parameters; addressed the unique habitat needs of distinct river reaches, pools, and the UMRS; and was conducted to be collaborative, technically sound, and a consensus-based effort (Theiling et al., 2000).

During and since HNA-I, the collaborative partnership has identified information needs (Table 1-1) the UMRR Program should pursue to better understand and quantify the habitat needs of the UMRS. The UMRR LTRM element and work conducted by the UMRR Program partnership have been integral components in completing the information needs and informing the management needs identified from the HNA-I and to further the UMRR Program's understanding of the ecosystem health and resilience of the UMRS.

Since HNA-I, the UMRR Program has developed a strategic plan that outlines the UMRR Program's key approaches to enhancing restoration and advancing knowledge for a healthier and more resilient Upper Mississippi River ecosystem. The *Strategic Plan 2015-2025* focuses on the UMRR Program's efforts to continue delivering products and services that are nationally significant, regionally relevant, internationally engaged, and technically sound. The UMRR Program's vision and mission statements, shown below, provide a context for decisions regarding resource allocation, as well as the focus of UMRR Program's restoration and science work. Most importantly, the UMRR Program's vision and mission statements reflect the evolution of the UMRR Program through knowledge gained from over 30 years of monitoring and constructing habitat projects within the UMRS. The combination of monitoring and implementation has evolved into an ecosystem-based approach throughout the life of the UMRR Program. HNA-II provides the tools for assessing progress toward restoring ecosystem structures and functions that underpin the sustainability of multiple populations and ecosystem processes at multiple scales (USACE, 2011; Lubinski & Barko, 2003).

1.1 UMRR PROGRAM VISION

A healthier and more resilient Upper Mississippi River ecosystem that sustains the river's multiple uses.

1.2 UMRR PROGRAM MISSION

To work within a partnership among Federal and state agencies and other organizations; to construct high-performing habitat restoration, rehabilitation, and enhancement projects; to produce state-of-the-art knowledge through monitoring, research, and assessment; to engage other organizations to accomplish UMRR's vision.

1.3 UMRR PROGRAM GOALS

1) Enhance habitat for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem.
2) Advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem.
3) Engage and collaborate with other organizations and individuals to help accomplish the UMRR vision.
4) Utilize a strong, integrated partnership to accomplish the UMRR vision.

Table 1-1. Summary and status of information needs identified since HNA-I

Information Need Identified Since HNA-I	Additional UMRR Information	Status of Completion To Date
System-wide high resolution topographic data (LiDAR)		UMRR LTRM completed in 2011
System-wide bathymetric data	2010 survey completed; however not all areas were accessible due to water levels (e.g., Sam Goody's in Pool 6)	UMRR LTRM systemically completed in 2010; ongoing at project-scale
	Seamless topo-bathy coverage (combined high resolution topographic and bathymetric data)	UMRR LTRM systemically completed in 2016
	Third decadal land cover/land use data set	UMRR LTRM completed in 2010/2011
Systemic numerical hydraulic models	USACE 2-D numerical models	Multiple project-scale models completed through UMRR HREP; reach-scale models completed through USACE; ongoing effort
Floodplain inundation models	Research in support of restoration	UMRR LTRM ongoing effort; multiple project-scale models completed through UMRR HREP; ongoing effort
Forest succession models	Research in support of restoration	UMRR LTRM ongoing effort
Floodplain classification	Updated aquatic area classification	HNA-II effort completed in 2018
Floodplain geomorphic classification and survey	Development of floodplain reach classifications based on geomorphic features	WEST Consultants, Inc (2000); Theiling et al., (2012)
Ecosystem health	Development of indicators of ecosystem health	Johnson & Hagerty (2008); Hagerty & McCain (2013); (Anderson, Casper, & McCain, 2017)
Ecosystem resilience	Development of indicators of ecosystem resilience	UMRR LTRM; Bouska et al., 2018; (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, Applying principles of general resilience to large river ecosystems: case studies from the Upper Mississippi and Illinois Rivers, In Review); ongoing effort
Ecosystem objectives	Development of ecosystem-based management objectives for the UMRS	WEST Consultants, Inc (2000); USACE (2011)
Development of refined life history information	Research in support of restoration	Pursued through UMRR LTRM research; completion of fish life history database; ongoing effort
Surveys of existing floodplain plant communities	Systemic forest inventory	(Guyon, Deutsch, Lundh, & Urich, 2012); site-specific forest inventory completed through UMRR HREP; ongoing

Information Need Identified Since HNA-I	Additional UMRR Information	Status of Completion To Date
Conceptual Models	Resiliency; restoration designs; UMRS; adaptive management	Bouska et al., (2018); (USACE, 2012); Lubinski & Barko (2003); ongoing effort; conceptual models as part of UMRR HREPs
Characterization of the existing and pre-impoundment hydrologic regime		(Theiling & Nestler, 2010); Illinois River Basin Restoration Comprehensive Plan (2006)
Development of refined species-habitat needs	Research in support of restoration	UMRR LTRM; ongoing effort; certification/approval of existing Habitat Suitability Index models through UMRR HREP
Habitat spatial structure metrics		Not completed to date
Substrate type characterization		Systemic characterization not completed; project-specific information completed on some UMRR HREPs
Analysis of seasonal habitat availability		Systemic characterization not completed; project-specific information completed on some UMRR HREPs
Development of refined species habitat model	Research in support of restoration	Advances through UMRR HREP and UMRR LTRM; ongoing effort
Confirmation/validation of species habitat models using UMRR LTRM data	Revising Aquatic Habitat Appraisal Guide; development of new habitat models	Ongoing effort

1.4 HNA-II OVERVIEW

This report constitutes the UMRR Program's second Habitat Needs Assessment (HNA-II) and summarizes the outcomes of several processes directed at defining habitat needs at relevant spatial scales within the constraints identified by the interagency HNA-II Steering Committee (Box 1). The UMRR Program has strategically invested to better understand ecological drivers affecting the river's ability to support fish and wildlife habitat as well as its ecosystem health (Hagerty & McCain, 2013) and resilience (Bouska et al., 2018). The HNA-II seeks to make meaningful connections among the *UMRR Strategic Plan 2015-2025*, the indicators of ecosystem health and resilience, new and improved data and tools, and information gained over several decades to assess the river's health and resilience.

Box 1. HNA-II Side Boards

- Indicator development based on data and data layers available systemically
- Geographic scope based on the UMRR Program authorizing language
- Coarse level analyses dependent on resolution of the dataset and data layers. Some data sets have finer resolution capability (i.e., aquatic areas), but for consistency across all data, the finest resolution used for HNA-II was determined to be at the navigation pool scale
- Natural resource management agencies' desired conditions and indicator evaluation based on regional criteria and resources of concern
- Focus of HNA-II is incorporation of resilience indicators into HREP planning. Specific project-level habitat objectives will be developed following completion of the report as funding and staffing permit

The purpose of the HNA-II is to provide information and recommendations that help the UMRR Program select, plan, and implement habitat projects and monitoring to achieve the UMRR Program's vision of a healthier and more resilient UMRS and to develop goals and objectives for restoring a healthier and more resilient UMRS. This was achieved through the "HNA-II effort" which is described in two documents: 1) development of indicators of ecosystem structure and function for the UMRS (De Jager et al., 2018), and 2) defining habitat needs for the UMRS by comparing indicators of ecosystem structure and function of the UMRS to the socially and ecologically defined desired conditions of the natural resource management agencies of the UMRR Program (this document). Details on the indicators and data used are provided in De Jager et al. (2018). This document focuses on an assessment of the system by each regional River Team using the De Jager et al. (2018) indicators and their expertise and experience. The assessment was conducted at two spatial scales (navigation pool and clusters of navigation pools). Together, these two reports will inform the UMRR Program moving forward with identifying, selecting, and planning for the next generation of HREPs.

1.5 HNA-II GENERAL APPROACH

The HNA-II capitalizes on several unique aspects of the UMRR Program. First, HNA-II is a cooperative effort among several scientific and natural resource management agencies. The assessment utilized both scientific and management expertise found within the UMRR Program. Second, long-term monitoring and scientific research within the UMRR Program was used to develop new geospatial data layers that quantify a range of ecological components of the UMRS. These data layers were used to develop the HNA-II indicators. For a complete description of the data sets, methods for HNA-II indicator development, and results of the individual and cross-indicator syntheses, see De Jager et al. (2018). Third, HNA-II indicators were based on understanding how the principles of general ecosystem resilience apply to the UMRS (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review). The resulting collection of indicators quantify aspects of ecosystem structure and function that support the long-term sustainability of fish, wildlife, and ecosystem services that are important to the stakeholders of the UMRS. HNA-II combined this information with the diversity of management perspectives and priorities represented within the UMRR Program to assess how current conditions of individual navigation pools and clusters of navigation pools within the UMRS compare to the desired conditions represented by these indicators. Desired conditions for the system were identified by comparison of existing conditions to agency identified desired conditions for each of the 12 indicators at two spatial scales: 1) navigation pools (area between two locks and dams and two stretches of the lower (undammed) open river, and 2) clusters of navigation reaches that shared similar physical and ecological characteristics as defined by De Jager et al. (2018). These spatially explicit comparisons can be used in combination with previously calculated rates of degradation for the entire UMRS (USACE, 2016) to better inform decisions about project identification, implementation, and monitoring to improve the health and resilience of the UMRS moving forward.

1.5.1 ECOSYSTEM-BASED APPROACH

The ecosystem-based approach used during the HNA-II effort has a broader focus of restoring a healthier and more resilient UMRS. The HNA-II can be used in support of strategic restoration decisions that are consistent with the concepts of ecosystem management and ecological resilience by using quantitative information about existing and potential future ecosystem conditions across the entire UMRS with indicators of ecosystem structure and function (De Jager, et al., 2018). Twelve indicators of ecosystem structure and function were developed and linked directly to three principles of general resilience: 1) connectivity, 2) diversity and redundancy, and 3) controlling variables, and these are influenced by long-term successional processes including forest succession and sedimentation (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review; Biggs, et al., 2012)(Figure 1-1).

Figure 1-1. Twelve HNA-II Indicators as related to the three general themes of resilience. Adapted from De Jager et al. 2018 and (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review). Note: Models were developed for the long-term successional processes and provide contextual information but sedimentation and forest succession were not included as indicators for HNA-II.

In addition, the desired conditions of natural resource management agencies were informed by ongoing UMRR Program working groups and discussions that seek to operationalize concepts of ecosystem resilience (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review). The focus of the UMRR Program on ecosystem-based concepts of health and resilience makes this effort (HNA-II) different when compared to HNA-I (see De Jager et al., 2018 for more details).

1.5.2 ECOSYSTEM-BASED OBJECTIVES

The UMRR Program partnership contains many agencies, with many different management objectives. During the development of HNA-II, the focus was to lay the groundwork for using indicators of ecosystem structure and function (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review; De Jager, et al., 2018), to assess the general resilience of the UMRS, and to link these indicators with past management objective development initiatives. Central to standardizing HNA-II ecosystem objectives is the incorporation of general themes of resilience (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review) and management objectives based on the principles of essential ecosystem characteristics (EECs) (Lubinski & Barko, 2003). Through workshops, worksheets, and meetings with river scientists and natural resource managers during 2017, it was decided that a subset of 17 ecosystem-based objectives listed in the *Ecosystem Objectives Report* (USACE, 2011) and within the authority of the UMRR Program would be carried forward to aide in indicator development. The UMRR partnership agreed upon the following ecosystem-based objectives to use for the UMRR Program and the HNA-II effort:

- A more natural stage hydrograph
- Restored hydraulic connectivity
- Increase storage and conveyance of floodwater on the floodplain
- Improved water clarity
- Reduce sediment loading
- Water quality conditions sufficient to support native species
- Restore sediment transport regime
- Restore bathymetric diversity
- Restore floodplain topographic diversity
- Restore lateral hydraulic connectivity
- Restore habitat connectivity
- Restore riparian/floodplain habitat
- Restore aquatic off-channel areas
- Restore channel areas (including side channels)
- Restore native aquatic vegetation
- Restore a floodplain corridor
- Restore floodplain wetlands (including floodplain lakes)

1.6 INDICATORS OF ECOSYSTEM STRUCTURE AND FUNCTION

Indicators of ecosystem structure and function developed by De Jager et al. (2018) and Bouska et al., (In Review) (Figure 1-1) quantify a number of the above previously developed ecosystem-based objectives for the UMRS listed in section 1.5 (Lubinski & Barko, 2003; USACE, 2011). The quantification of these indicators provides the foundation for HNA-II, and they are referred to as the HNA-II indicators in this report. The indicators are organized by a series of EECs identified for the UMRS (Lubinski & Barko, 2003; USACE, 2011, De Jager et al., 2018; Figure 1-2). The EECs are broadly defined environmental categories identified as critical inter-connected components for sustaining the UMRS and also valued by society (Lubinski & Barko, 2003). The five EECs identified for the UMRS include hydraulics and hydrology, biogeochemistry, geomorphology, habitat, and biota (Lubinski & Barko, 2003). HNA-II indicators were not developed for the Biota EEC due to minimal system-wide data available to quantify status or trends in populations for many species or guilds; however, future efforts to improve habitat and biotic data and quantify this EEC for the UMRS could be conducted by the UMRR Program. Therefore, four of the five stated EECs had information and data sets developed for HNA-II indicators. In addition, each indicator quantifies at least one management objective developed for the UMRS through previous efforts (USACE, 2011; Figure 1-3; Table 1-2). Furthermore, two modelling studies were carried out to better understand and predict patterns of sedimentation in backwater habitats and changes in forest communities in the UMRS (De Jager et al., 2018). Results from these studies were used as contextual information for HNA-II, with primary consideration focused on existing environmental conditions.

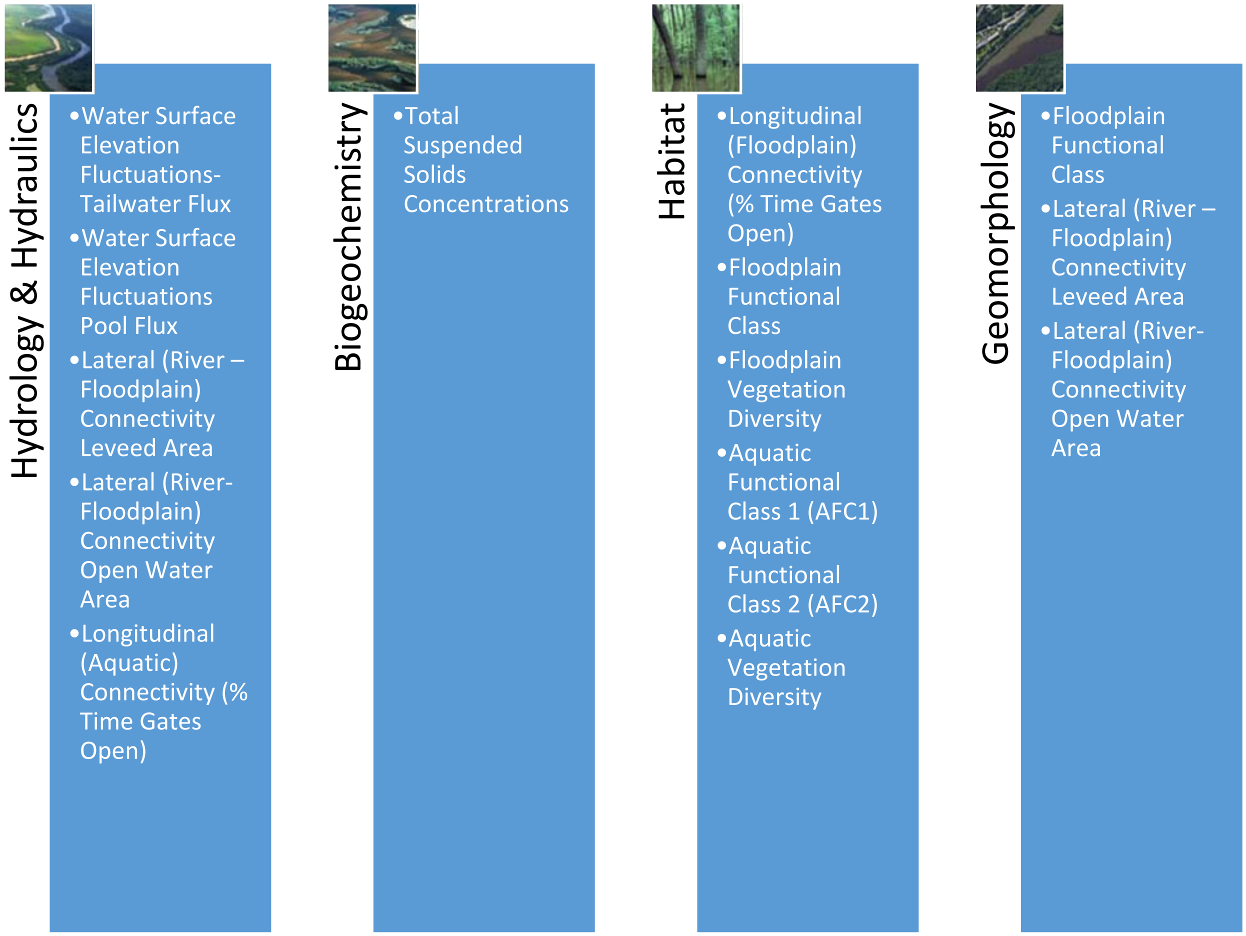


Figure 1-2. Matching the 12 HNA-II indicators of connectivity, diversity & redundancy, and controlling variables to the 4 EECs (Adapted from De Jager et al. (2018), USACE (2011), and Lubinski and Barko (2003)). Note some indicators matched to more than one EEC.

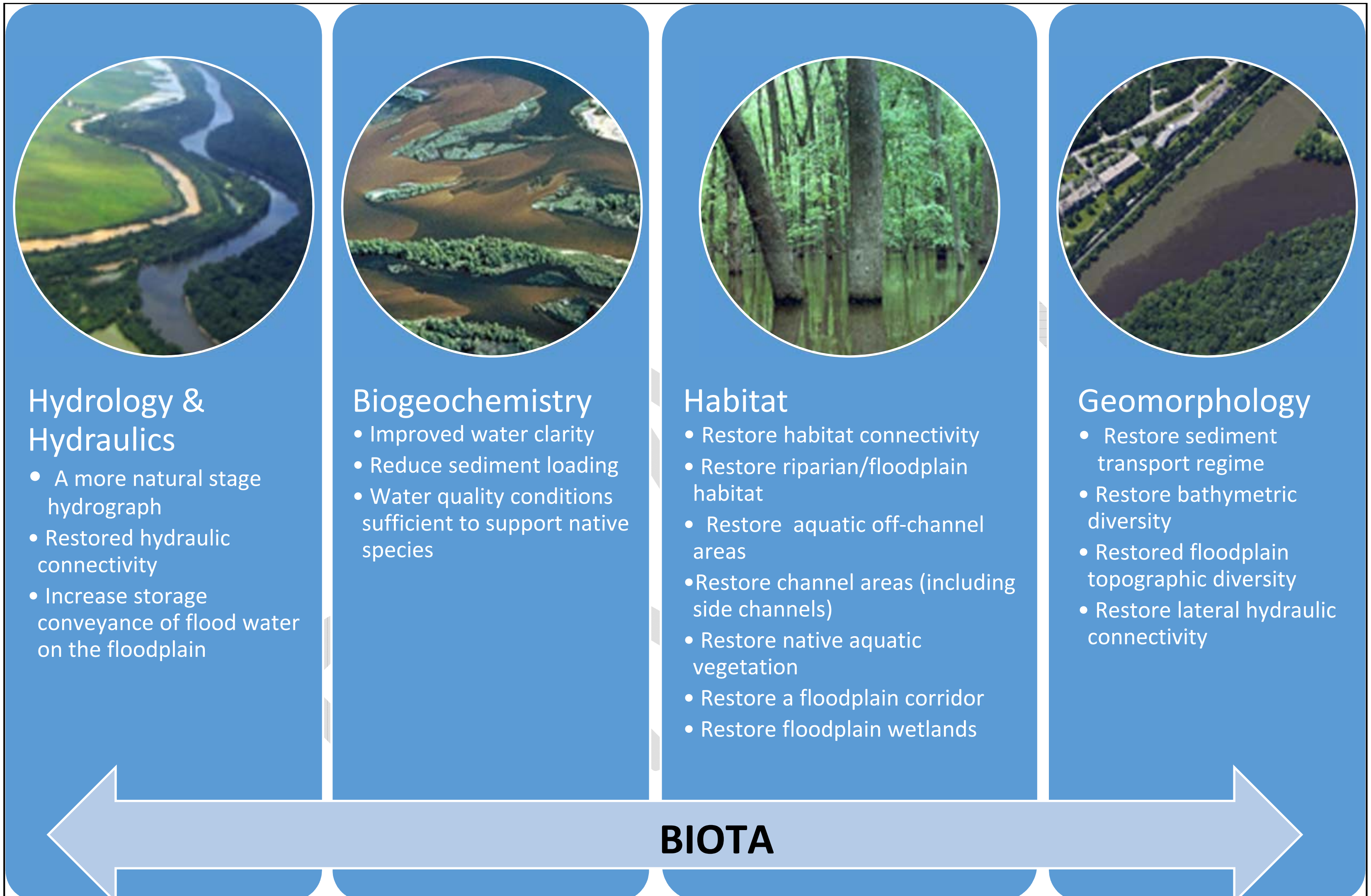


Figure 1-3. Linking the 17 UMRS Objectives to the 4 EECs; the Biota EEC indirectly is captured across all other EECs

Table 1-2. Linking the 4 EECs to 17 Ecosystem Objectives and 12 HNA-II Indicators in Relation to Resilience Themes (Modified from De Jager et al., 2018). See Appendix D for conceptual models which provided the framework for the resilience approach to HNA-II.

Essential Ecosystem Characteristic (Lubinski & Barko, 2003)	Ecosystem Objective (USACE, 2011)	HNA-II Indicator (De Jager et al, 2018)	General Theme of Resilience (Bouska et al., In Review)
Hydraulics and Hydrology	A more natural stage hydrograph	Water Surface Elevation Fluctuations (Tailwater and Pool Flux)	Controlling Variable
	Restored hydraulic connectivity	Lateral (River-Floodplain) Connectivity (Leveed and Open Water Areas)	Connectivity
	Increase storage and conveyance of flood water on the floodplain		
Biogeochemistry	Improved water clarity	Total Suspended Solids Concentrations	Controlling Variable
	Reduce sediment loading		
	Water quality conditions sufficient to support native species		
Geomorphology	Restore sediment transport regime	Sedimentation in Off-Channel Areas	Long-term Successional Processes
	Restore bathymetric diversity		
	Restore floodplain topographic diversity	Floodplain Functional Class	Diversity and Redundancy
	Restore lateral hydraulic connectivity	Lateral (River-Floodplain) Connectivity (Leveed and Open Water Areas)	Connectivity
		Floodplain Functional Class	Diversity and Redundancy
Habitat	Restore habitat connectivity	Longitudinal Floodplain Connectivity (Natural Area)	Connectivity
	Restore riparian/floodplain habitat	Floodplain Functional Class	Diversity and Redundancy
		Floodplain Vegetation Diversity	
		Floodplain Forest Succession	Long-term successional processes
	Restore aquatic off-channel areas	Aquatic Functional Classes (1 & 2)	Diversity and Redundancy
		Sedimentation in Off-Channel Areas	Long-term Successional Processes
	Restore channel areas (including side channels	Aquatic Functional Classes (1 & 2)	Diversity and Redundancy
	Restore native aquatic vegetation	Aquatic Vegetation Diversity	
	Restore a floodplain corridor	Longitudinal Floodplain Connectivity (Natural Area)	Connectivity
	Restore floodplain wetlands (including floodplain lakes)	Floodplain Vegetation Diversity	Diversity and Redundancy

1.7 REFERENCE CONDITION & DESIRED FUTURE ECOSYSTEM CONDITION

Formal ecosystem assessments often incorporate stated reference conditions, an analysis of risk, and clearly stated management objectives. Just as the UMRS has a diverse portfolio of species, habitats and ecosystem functions, the UMRR Program has a diverse portfolio of management agencies, goals and objectives, and desired future conditions for the UMRS. While each of these agencies agree on the importance of restoring and managing the general health and resilience of the UMRS, they also have unique mandates for the management of specific geographic locations and unique knowledge of the specific ecological components of the river system. Furthermore, both the ecosystem and management portfolios of the UMRS change in composition across the length of the river system. On one hand, these differences can make it challenging to define a single reference condition for the entire UMRS and for a single program like the UMRR Program, or even for a single HNA-II indicator. On the other hand, if embraced, these differences can be used to facilitate discussions among partner agencies and provide a much more detailed examination of how current river system conditions compare to a range of desired conditions. To illustrate some of the complexities that arise in defining reference conditions in a multi-agency partnership, consider two examples. First, all agencies may agree that water clarity is important for a wide-range of ecological processes. But different agencies may be primarily interested in water clarity for different ecological outcomes. An agency interested in water clarity as it relates to light penetration for the production and resilience of submersed aquatic vegetation may have a different desired condition (e.g., a specific concentration of total suspended solids) than an agency interested in water clarity for the purposes of a fish or wildlife community not dependent on submersed vegetation (e.g., main channel fisheries in the Open River). Secondly, all agencies may agree that connectivity between the river and floodplain is a defining feature of large river ecosystems and that this aspect of the UMRS should be improved. But one agency may be primarily focused on the importance of river-floodplain connectivity for fish reproduction, while another agency may be primarily interested in nutrient sequestration. The different emphases could result in different levels or duration of river-floodplain connectivity being the desired condition.

During the development of HNA-II, it was determined that it was not reasonable to expect a consensus on a single stated reference condition or desired future ecosystem condition, even for individual indicators. The HNA-II approach to tackle this complex topic relates back to the UMRR Program mission of restoring a *healthier and more resilient* Upper Mississippi River. The reference condition was not defined by a historic reference condition or an internal reference condition, rather, it was defined as *healthier and more resilient* given the existing conditions, existing system stressors, an understanding of potential future conditions, and in comparison, to the range of desired conditions for each indicator as defined by the management agencies of the UMRR Program. Therefore, information on the range of desired conditions for the indicators was collected from UMRR partner management agencies and is included in Chapter 3.

As discussed in the most recent *Report to Congress* (USACE, 2016), despite the UMRR Program's successes in improving the river's health and resilience, the stressors to the river, both natural and human-induced are ongoing. Altered hydrology related to locks and dams, invasive species, climate change, soil erosion, island erosion, sedimentation, and nutrient run-off and other stressors continue to degrade the ecosystem adversely affecting fish and wildlife habitats. Based on the UMRR Program's experience in constructing and monitoring habitat projects, the Upper Mississippi River is degrading at a rate of one to three percent, annually (USACE, 2016). At this rate, the USACE has estimated that the ecosystem is degrading one to four times faster than current restoration efforts (USACE, 2016).

2 METHODOLOGY

The methodological framework developed for HNA-II used a series of face-to-face meetings where agencies discussed the HNA-II indicators and evaluated how they deviated from agencies' desired conditions. This approach allowed each agency to apply its unique knowledge of and mandates for specific components of the river system, and for the UMRR Program to define criteria and desired conditions that apply to multiple agencies. The HNA-II effort consisted of four primary activities and included information from De Jager et al. (2018) and the HNA-II assessment (this document):

1) Assemble data sets and develop indicators that quantify different aspects of the UMRS important to its health and resilience summarized at the navigation pool scale. See De Jager et al. (2018) for more details.
2) Conduct a multivariate cluster analysis to identify groups of navigation pools within the UMRS that share similar collections of physical and ecological attributes. See De Jager et al. (2018) for more details.
3) Conduct a series of face-to-face meetings in which the partners in the UMRR Program work through each indicator as it applies to different clusters of navigation pools and determine how each cluster and each navigation pool within each cluster compare to an agency's desired conditions for each indicator as well as conduct a paired comparison survey to determine relative importance of each indicator (this document).
4) Summarize the results of each meeting for each individual navigation pool and navigation pool cluster in a way that helps the UMRR Program assess the health and resilience of the UMRS and how it compares to the desired conditions of stakeholder agencies (this document).

2.1 INDICATORS

Quantitative measures (i.e., indicators) were developed to represent a subset of the general goals and objectives of the UMRS developed in 2011 (USACE, 2011) as they relate to the concept of general ecosystem resilience. General resilience is best viewed as a collection of "rules of thumb", or principles, regarding factors that contribute to the ability of an ecosystem to adapt and respond to disturbance (O'Connell, Walker, Abel, & Grigg, 2015; Biggs, et al., 2012). Three "rules of thumb" related to the ecological components of resilience were used for HNA-II:

1) managing connectivity,

2) maintaining diversity and redundancy, and
3) managing controlling variables

Connectivity describes the interactions between different components of an ecosystem (e.g., populations, hydrogeomorphic patches) and the ability of the ecosystem to exchange materials, organisms, and energy within and across its boundaries. Diversity and redundancy of biological communities and the physical environment provide a range of options for responding to disturbances and adapting to slow successional changes. Controlling variables can strongly influence the underlying structure of a system (Biggs, et al., 2012). For HNA-II, indicators that quantify stated ecosystem objectives were placed into categories reflecting these three components of general resilience: connectivity, diversity and redundancy, and controlling variables (see Figure 1-1). In addition, it is important to consider long-term successional processes (e.g., forest succession and sedimentation) that may influence management outcomes when developing management strategies. Hence, additional indicators representing slow processes developed by De Jager et al. (2018) were used as contextual information during face-to-face meetings. Table 2-1 briefly describes the indicators organized by general resilience theme. For full details on methods of indicator development and data see De Jager et al. (2018).

Table 2-1. Definitions and Purpose for the 12 HNA-II indicators related to the resilience themes of connectivity, diversity and redundancy, and controlling variables. Indicators for long-term successional or slow variables were not included in the HNA-II assessment. For full details, see De Jager et al. (2018).

Indicator Name		Definition	Purpose
Connectivity			
Longitudinal (Aquatic)	% Time Gates Open	The average percentage of days that dams were in 'open river' conditions annually for each UMRS navigation pool (% time gates open). 'Open river' conditions mean that all dam gates are either lifted out of the water or lowered to the bottom.	Indicator of potential unobstructed flow and movement for migratory fish species
Longitudinal (Floodplain)	Natural Area (Hectares/RM)	The area (ha) per linear river mile (RM) of the floodplain within each UMRS navigation pool that was undeveloped and not in agricultural production for the years 1989, 2000, and 2010.	These areas provide habitat and a migratory corridor for many floodplain species, such as migrant birds, bats and insects, along with mobile mammals, and reptile and amphibian species. Excessive fragmentation of natural vegetation by anthropogenic land cover types such as agriculture and development may inhibit the movement of migratory species across the UMRS.
Lateral (River-Floodplain)	Open Water (Hectares/RM)	The area (ha) per linear RM in open water and behind levees.	Open water area is an index of potentially over-connected conditions resulting from L&D construction. Area behind levees represents areas that are potentially isolated from the river by levees.
	Leveed Area (Hectares/RM)		
Diversity & Redundancy			
Aquatic Functional Class 1 (AFC1)		Finer-resolution classification of aquatic areas. A multivariate index characterizing the area within navigation pools in lotic (flowing water) habitats (negative values) and the area within navigation pools in lentic (non-flowing water) habitats (positive values). Neutral values indicate a mix of lotic and lentic area.	Indicator of broad-scale difference in the amount of lentic and lotic area within navigation pools
Aquatic Functional Class 2 (AFC2)		Finer-resolution classification of aquatic areas. A multivariate index characterizing the area within navigation pools in lotic shallow habitats (negative values) and the area within navigation pools in deep lentic habitats (positive values).	Indicator of broad-scale difference in the amount of deep lentic and shallow lotic area within navigation pool.
Aquatic Vegetation Diversity		A diversity index (Simpson's) based on the area within navigation pools in five aquatic classes: deep marsh annual, deep marsh perennial, deep marsh shrub, submersed aquatic vegetation, and open water.	Indicator of aquatic vegetation composition and diversity

<table>
<tr><th colspan="2">Indicator Name</th><th>Definition</th><th>Purpose</th></tr>
<tr><td colspan="2">Floodplain Functional Class Diversity</td><td>A diversity index (Simpson’s) based on the area within navigation pools experiencing different average flooding durations during the growing season (See De Jager et al., 2018, for methods).</td><td>Indicator of inundation diversity; indicator of hydro-geomorphic variability of non-aquatic areas</td></tr>
<tr><td colspan="2">Floodplain Vegetation Diversity</td><td>A diversity index (Simpson’s) based on the area within navigation pools in different floodplain vegetation classes.</td><td>Indicator of floodplain vegetation composition and diversity</td></tr>
<tr><th colspan="4">Controlling Variables</th></tr>
<tr><td rowspan="2">Water surface elevation fluctuation</td><td>Tailwater Flux</td><td rowspan="2">The mean annual maximum growing season water surface elevation change for pool and tailwater gages, relative to pre-dam conditions.</td><td rowspan="2">Difference in water level variability from pre-L&D conditions.</td></tr>
<tr><td>Pool Flux</td></tr>
<tr><td colspan="2">Total suspended solids concentration</td><td>The concentration of total suspended solids (mg/L) from the main channel from May-September.</td><td>Indicator of water clarity, light availability, sediment regime</td></tr>
</table>

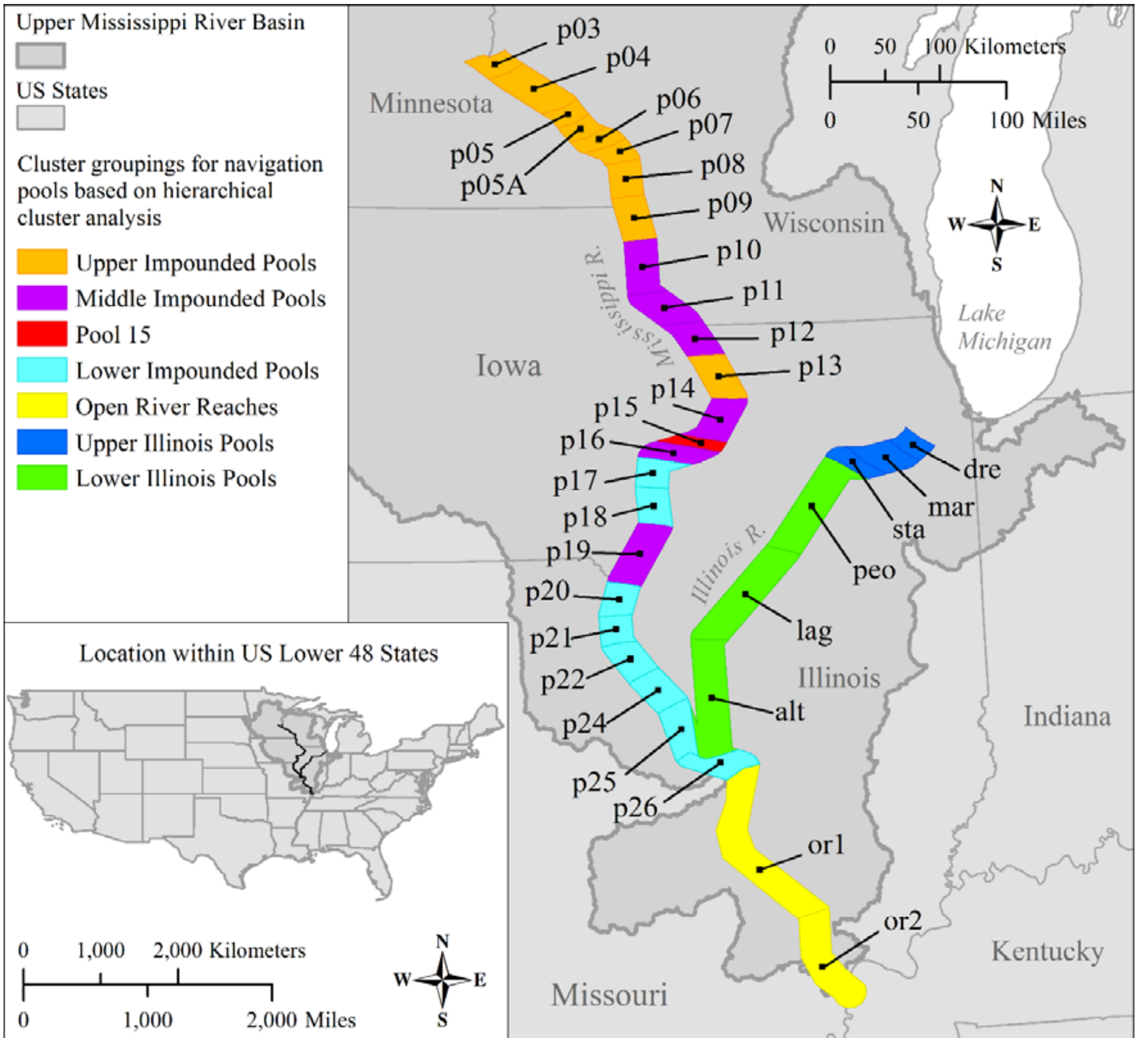
2.2 MULTIVARIATE CLUSTER ANALYSIS

De Jager et al. (2018) performed a multivariate cluster analysis across all indicators described in Table 2-1 to identify navigation pools that share similar characteristics. During this analysis, Pools 1 and 2 were not included because of limited data availability. This analysis revealed six clusters of navigation pools, along with one outlier (Pool 15) (Table 2-2; Figure 2-1). The navigation pools within each cluster group share similar characteristics across all HNA-II indicators and differ from the navigation pools in other cluster groups. The navigation pools found within the different cluster groups are somewhat comparable to previously developed geomorphic reaches defined by WEST Consultants, Inc. (2000), suggesting that the distribution of navigation pools is highly influenced by geomorphology. However, the cluster groupings identified by De Jager et al. (2018) consider a much wider-range of ecological, hydro-physical, and structural measures than those used by (WEST Consultants Inc., 2000).

The HNA-II assessment was primarily conducted on the cluster groupings shown in Figure 2-1. However, substantial variability could be found among the navigation pools within each cluster if a subset of indicators were used. For example, De Jager et al. (2018) conducted a hierarchical cluster analysis on the aquatic functional classes (AFC 1 and AFC 2) to further describe shared characteristics across the UMRS. Figure 2-2 (from De Jager et al., 2018) provides the results of this synthesis. The groupings of the aquatic functional classes (groups a-h) do not match up identically to the overall groups of navigation pools (clusters) for the indicator assessment. For instance, the Peoria Pool on the Illinois River grouped with Pools 8-11, 13, and 19. For this reason, information on individual indicators was often used to define habitat needs for individual pools within each cluster.

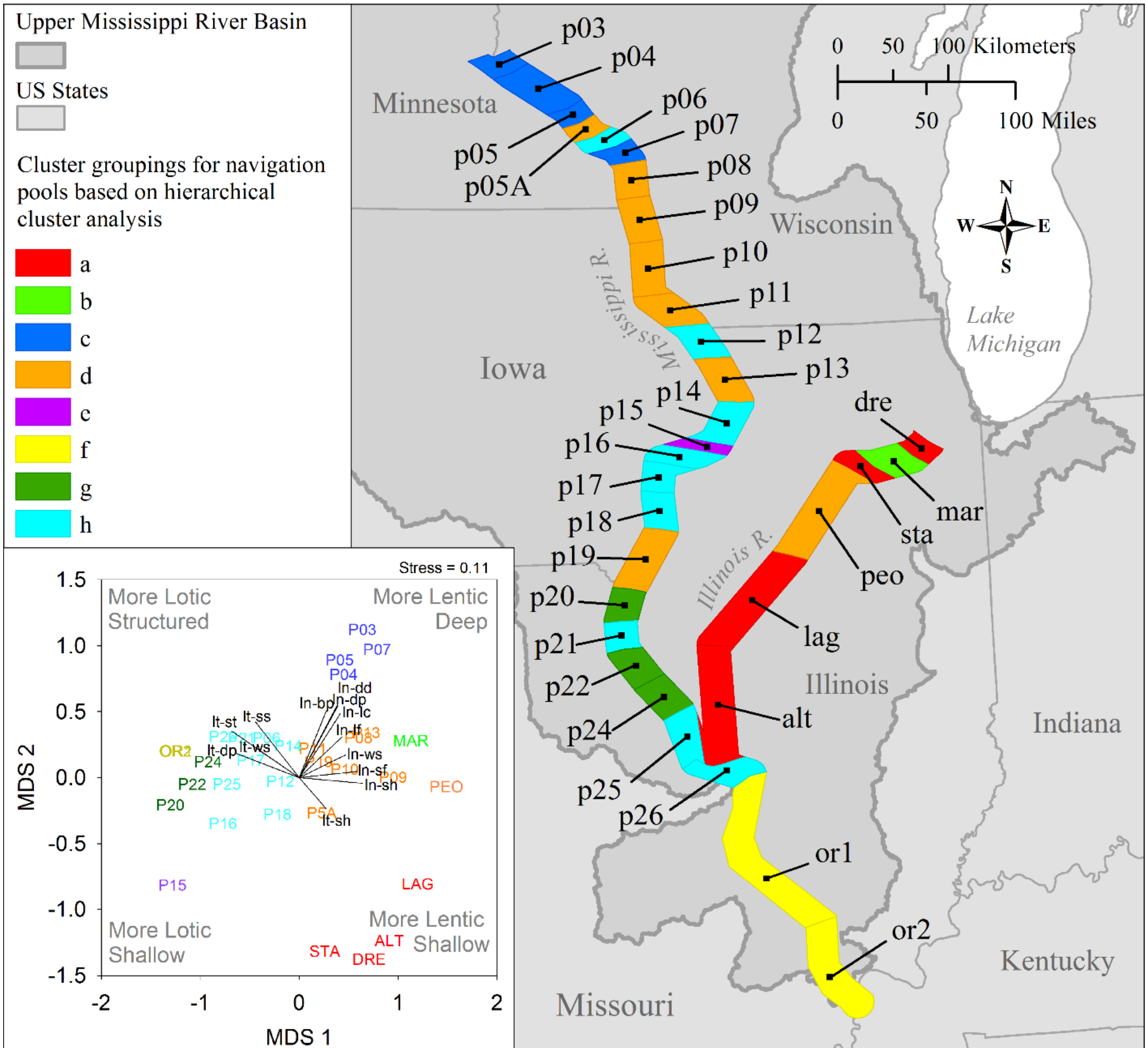
Table 2-2. Navigation Pools belonging to each cluster group used for HNA-II (see DeJager et al. 2018)

Cluster Name	Navigation Pools	Key Characteristics	Human Influence
Upper Impounded	Pools 3-9, 13	Greatest amount of deep, lentic, off-channel area, stable water levels, lowest total suspended solids concentrations, highly connected floodplain.	Dams, channel training structures, abundance of land in public ownership.
Middle	Pools 10-12, 14, 16, 19	Less lentic area, more structured channel area, reduced water clarity, and less river-floodplain connectivity than Upper Pools.	Dams, channel training structures and levees, watershed land use.
Pool 15	Pool 15	Small amount of natural floodplain land cover, lack of lentic area, some lotic-structured area, rocky substrates.	Urban and industrial development of the floodplain, modification of a historic rapids area.
Lower Impounded	Pools 17-18, 20-26	Less lentic area, more lotic area, less deep lentic area, more water surface elevation fluctuations than the upper and middle pools. Higher total suspended solids concentrations and very little aquatic vegetation. Broad floodplain containing large areas of natural land cover and large areas behind levees.	Dams, channel training structures and levees, watershed land use, agricultural land use in the floodplain.
Open River	Open River Reaches 1-2	Reduced river-floodplain connectivity, high amount structured channel area, reduced water clarity, high degree of water level variability.	Lack of dams, more levees, channel training structures, watershed land use, agricultural land use in the floodplain, abundance of floodplain in private ownership
Upper Illinois River	Upper Pools (Dresden, Marseilles, Starved Rock)	Low longitudinal aquatic connectivity, abundance of shallow lentic area, more diverse aquatic vegetation than the lower Illinois pools, constrained river channel and narrow floodplain. Dominance by short-duration flood inundation classes.	Dams, urban and industrial development; abundance of floodplain in private ownership
Lower Illinois River	Lower Pools (Peoria, La Grange, Alton)	Larger open shallow water areas, wider more diverse floodplain than Upper Illinois, less aquatic vegetation, More water surface elevation fluctuations, more longitudinal connectivity	More levees, watershed land use, agricultural land use in the floodplain, abundance of floodplain in private ownership



Label	Connectivity				Diversity					Slow Variables and Feedbacks		
	Longitudinal Aquatic Connectivity	Longitudinal Floodplain Connectivity	Lateral River-Floodplain Connectivity		Aquatic Functional Class Composition		Aquatic Vegetation Diversity	Floodplain Vegetation Diversity	Floodplain Functional Class Diversity	Water Surface Elevation Fluctuations		Total Suspended Solids
	% Time Gates Open	Natual Area (ha/rm)	Leveed Area (ha/rm)	Open Water (ha/rm)	AFCS1 (unitless)	AFCS2 (unitless)	Simpson's (unitless)	Simpson's (unitless)	Simpson's (unitless)	Tailwater fluctuations (m)	Pool fluctuations (m)	Average TSS (mg/L)
Upper Impounded Pools	9.91	234.32	44.32	300.40	0.49	0.49	0.57	0.69	0.79	-0.24	1.71	32.93
Middle Impounded Pools	11.22	125.58	60.46	212.32	-0.05	0.04	0.30	0.48	0.84	0.32	1.78	44.80
Pool 15	7.15	26.57	44.74	137.32	-1.28	0.82	0.03	0.73	0.60	-0.95	2.17	38.26
Lower Impounded Pools	29.70	247.93	579.88	178.63	-0.76	0.03	0.07	0.68	0.82	0.84	1.22	76.92
Open River Reaches	100.00	189.40	420.60	115.63	-1.25	0.20	0.10	0.76	0.79	4.83		209.97
Upper Illinois Pools	0.79	102.66	0.65	84.55	0.70	0.81	0.20	0.76	0.32			
Lower Illinois Pools	40.81	193.73	283.23	146.86	1.20	0.71	0.13	0.73	0.87	3.27	1.03	64.24

Figure 2-1. Results of multivariate cluster analyses based on all 12 indicators. Navigation pools are colored according to significant (p=0.05) differences among pool-groupings. Mean values of the indicators used in the analysis are provided in the table (inset) and characterize each group of pools. From De Jager et al. (2018). Color shading: blue bars refer to positive values for connectivity indicators; green bars refer to positive values for diversity indicators; orange bars refer to positive values for slow variables and feedbacks indicators; and red refers to negative values for the indicators.



Group	Lentic - Shallow	Lentic - Wooded Shoreline	Lentic - Deep	Lentic - Depression	Lentic - Borrow Pit	Lentic - Low Connectivity	Lentic - Shallow w/flow	Lentic - Large w/flow	Lotic - Shallow	Lotic - Wooded Shoreline	Lotic - Deep	Lotic - Structured	Lotic - Structured w/scour
Group a	21.3	18.9	3.1	1.5	0.0	2.8	18.9	0.0	28.4	5.2	0.0	0.0	0.0
Group b	2.5	9.6	7.8	7.5	6.8	1.6	1.9	0.0	9.4	1.9	0.0	0.0	0.0
Group c	14.3	26.2	125.5	122.5	19.8	11.0	21.9	59.7	15.9	16.5	1.8	46.5	22.3
Group d	32.0	47.3	42.8	37.3	6.9	12.5	43.1	75.4	33.0	20.4	3.1	43.3	21.3
Group e	0.5	0.2	0.2	0.2	0.0	1.0	0.3	0.0	11.8	1.7	0.0	44.1	0.0
Group f	2.0	1.8	0.1	0.0	0.0	1.7	0.4	0.0	30.6	10.5	16.9	65.7	60.4
Group g	3.1	3.3	1.2	0.8	0.1	2.5	1.0	0.0	15.3	27.0	28.8	75.0	23.0
Group h	12.7	19.4	12.1	10.3	4.0	7.2	12.9	1.6	17.1	34.6	9.8	81.6	29.8

Figure 2-2. Results from a multivariate cluster analysis based on the area of each aquatic functional class. Pools that clustered together have the same color and were grouped "a-h". The inset table provides the mean area (hectare by river mile) for the navigation pools in each aquatic functional class. From De Jager et al. (2018).

2.3 RIVER TEAMS

The River Teams are USACE-District based coordinating technical groups consisting of Federal, state, local, and non-governmental participants. The River Resources Action Team (RRAT), Fish and Wildlife Interagency Committee (FWIC), and Fish and Wildlife Working Group (FWWG) correspond to the St. Louis District, Rock Island District, and St. Paul District of the USACE, respectively. These teams, comprised of river managers, scientists, planners, and engineers from the UMRR partner agencies, were tasked with using the HNA-II indicators and data from De Jager et al. (2018) in conjunction with their own expertise to conduct a rapid assessment of the ecological conditions of the UMRS. Using the multivariate cluster groupings, the system was divided among the River Teams that work within the UMRR Program.

2.3.1 RIVER RESOURCES ACTION TEAM

The River Resources Action Team (RRAT) Technical is an interagency coordination technical team comprised of state and Federal agencies as well as non-governmental organizations (NGOs) for Pools 24-26 and the Open River. The RRAT Executive is the decision-making smaller group of the RRAT Technical that is co-chaired by the U.S. Fish and Wildlife Service (USFWS) and the USACE (St. Louis District), with representation from Missouri Department of Conservation (MDC) and Illinois Department of Natural Resources (ILDNR), as well as USFWS- Refuges and USFWS-Ecological Services. For the purposes of the HNA-II assessment, the RRAT Executive “extended”, which included experts in fisheries, wildlife, water quality, engineering, and planning, from the representative agencies of the RRAT Technical was determined to be the coordinating body for this effort. Representatives from these agencies worked together to provide not only their own agency’s perspective but the overall RRAT rating for the indicators for the Open River cluster, and Lower Impounded cluster (only Pools 24-26).

2.3.2 FISH AND WILDLIFE INTERAGENCY COMMITTEE

The Fish and Wildlife Interagency Committee (FWIC) is an interagency coordination technical team comprised of state and Federal agencies as well as non-governmental organizations for Pools 11-22 and the Illinois River. The FWIC is co-chaired by the U.S. Fish and Wildlife Service (USFWS) and the USACE (Rock Island District) and includes representation of fish and wildlife biologists from WINDR, IADNR, MDC, the USFWS (Refuges and Ecological Services), the USACE, and NGOs. The FWIC is designated to provide coordination regarding fish and wildlife matters associated with main channel dredging, dredged material disposal, physical river modifications, backwater modifications, and river management studies and investigations. For the purposes of the HNA-II assessment, representatives from these agencies worked together to provide not only their own agency’s perspective but the overall FWIC rating for the indicators for the Middle Impounded cluster (Pools 10-12, 14, 16, and 19), Pool 15 cluster (outlier), Lower Impounded cluster (only Pools 17, 18, 20, 21 and 22), Upper Illinois River cluster, and the Lower Illinois River cluster.

2.3.3 FISH AND WILDLIFE WORK GROUP

The Fish and Wildlife Work Group (FWWG) is an interagency coordination technical team comprised of state and Federal agencies as well as NGOs for Pools 1-10. The FWWG includes natural resource experts from MNDNR, WIDNR, IADNR, the USFWS (Refuges and Ecological Services), the USACE (St. Paul District), and NGOs. Chairmanship of the FWWG is rotated on a two-year basis amongst the state and Federal partnership. The FWWG is designated to facilitate coordination between Federal and state agencies on natural resource related issues allowing the USACE St. Paul District to effectively manage a range of management activities on the UMR. For the purposes of the HNA-II assessment, representatives from these agencies worked together to provide not only their own agency's perspective but also the overall FWWG rating for the indicators for the Upper Impounded cluster (Pools 3-9 and 13).

2.4 RIVER TEAM INDICATOR ASSESSMENT

Through a series of meetings held during January-April 2018, the River Teams were tasked with conducting a rapid assessment utilizing the information from the indicator report (De Jager et al., 2018). This assessment asked each agency to rate each indicator for each navigation pool and each cluster of navigation pools as "red", "yellow", or "green" based on quantitative results from De Jager et al. (2018) (See Figure 2-1 and Appendix A). In addition, each agency's perspective of how the quantitative data compares to the desired conditions of their agency was provided (Figure 2-3).

Each agency was asked to rate each indicator for each cluster of navigation pools as a whole and for the navigation pools individually as follows:

- Red = deviates from desired conditions and may merit restoration actions
- Yellow = near desired conditions and may merit actions to improve or maintain ecosystem conditions
- Green = meets desired conditions and may merit actions to maintain ecosystem conditions.

Each agency rated the indicators, which led to a diversity of opinions. This led to three different approaches by the River Team in terms of providing an overall rating for a given pool and the overall clusters.

1) The RRAT reached consensus and through discussions at the time of initial ratings, which led to intermediate colors being developed: "orange" and "light green", which were agreed to by the agencies for the Open River and the Lower Impounded (only for Pools 24-26).
2) The FWIC reached agreement through discussion and "averaging" of the colors (e.g., Red + Yellow = Orange) after initial ratings by individual agencies. The FWIC agreed to use the "averaged" color ratings for the Middle Impounded, Lower Impounded, Pool 15, Upper Illinois and Lower Illinois.

3) The FWWG did not reach consensus on many of the indicators and chose to retain the individual agency ratings to highlight the importance of the diversity of opinions for a given pool and for the Upper Impounded cluster. However, the UMRR CC decided to represent the Upper Impounded cluster as averages using the same methodology as the FWIC, but the reader is directed to Appendix A for the individual agency ratings.

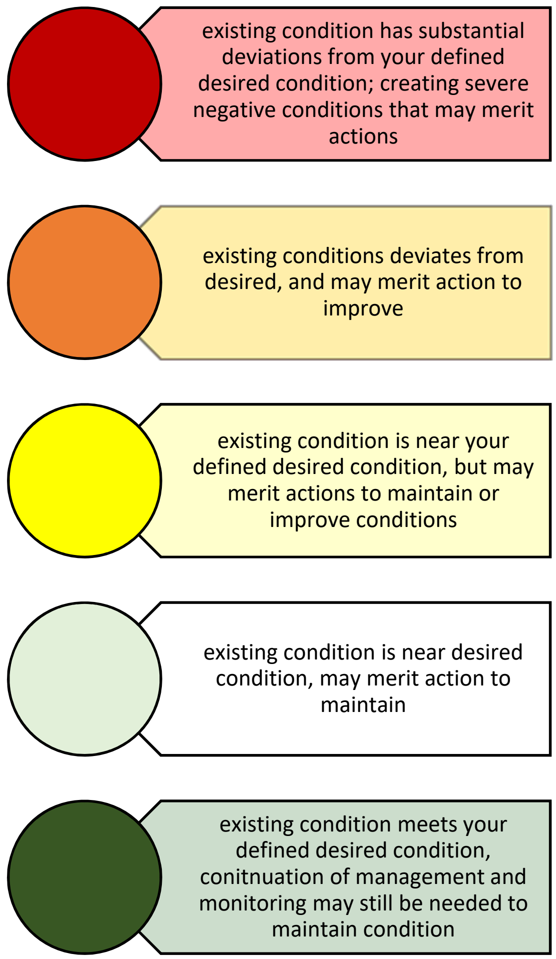


Figure 2-3. Rating definitions used to assess HNA-II Indicators

In all scenarios, the resultant color was the overall agreed upon color rating for a given indicator at the navigation pool and cluster of navigation pools and provided in the Chapter 3 tables. Values between red and yellow ("orange") were described as "deviation from desired condition, merits action to improve". Values between yellow and green ("light green") were described as "near desired condition, may merit action to maintain" (Figure 2-3). See Chapter 3 for River Team discussions that capture some of the rationale on why the partnership has a diversity of opinions.

During the exercise, the participants were asked: *What did you use to base your evaluation on? Did you use a desired condition, if so what was it?* Answers to these questions along with the discussions with the resource partners provided the rationale for the indicator rating and aided in facilitating the discussion on the differences (if any) among the resource agencies. For example, for the longitudinal aquatic connectivity indicator (i.e., % time gates open), one agency might rate it "red" because the desired future condition is to restore back to historic pre-lock and dam conditions with 100% of the time open. Another agency might rate it "red" because the desired future condition is to mimic what the river was like historically, but it is unreasonable to expect 100%. Yet another agency might rate it "red" because the desired future condition is to have the gates open less to limit expansion of Asian carps[1] and exotic invasive species. The indicator rating is red regardless of the reference condition or future desired condition used. Another example for longitudinal connectivity could be when one agency scored this indicator "green" when there was a barrier that prevented Asian carps movement, while another agency scored it "red" because the barrier prevented native migratory fish movement. Another example of differential rating is that one agency might rate an indicator 'green' when applied to fish only to have that same indicator rated 'red' when evaluated by another agency as applied to waterfowl. The exercise documented the "why" or rationale behind the ratings, and provided vital information on the management perspective (discussed more fully in Chapter 3) as the UMRR Program moves forward with discussions on selecting the next generation of habitat projects. The HNA-II effort provides additional information that can aid in those discussions.

A paired-comparison of the indicators was conducted by USACE, USFWS, MDC, ILDNR, Illinois Natural History Survey (INHS), WIDNR, IADNR and Minnesota Department of Natural Resources (MNDNR) for their given clusters of navigation pools. (Note: a similar exercise could be conducted for each pool in the future). This exercise was conducted via surveys that asked which indicator was more important when compared to each other indicator. The purpose of this exercise was to determine which of the indicators were considered the most important for a given cluster of navigation pools. Aquatic functional classes 1 and 2 were combined during the paired-comparison exercise since these indicators were more easily understood in combination rather than individually. Combining AFC1 and AFC2 was expected to reduce confusion during agency comparisons to other indicators, despite the potential loss of data (e.g., if an agency valued AFC1 more or less than AFC2 or more/less than another indicator). The feedback and comments received during the review process suggest that most participants in the partnership were able to consider these indicators together as they both represent aquatic habitats. For these two indicators, the color ratings may be different, but the importance values were the same. The color ratings were retained in the summary tables, and the importance value was applied to both. Following the paired comparison exercises, the importance (high, medium, or low) of each indicator was determined based on natural breaks in the tally scores.

[1] The use of the term Asian carp includes collectively Silver Carp, Grass Carp, Bighead Carp, and Black Carp.

3 RESULTS BY CLUSTERS OF NAVIGATION POOLS

This chapter summarizes the cooperative effort of natural resource agencies responsible for management of the UMRS to develop a partnership-based assessment of existing indicator conditions relative to deviations from desired indicator conditions for the UMRS based on systemic data sets and data layers developed by De Jager et al. (2018). The River Teams used the data, the results from the existing conditions indicator evaluation (De Jager et al., 2018), and their expertise as river managers to evaluate the UMRS. For full details on the data, data sets, and existing conditions indicator evaluation and discussion see De Jager et al. (2018).

This chapter is organized by navigation pool clusters (Upper Impounded, Middle Impounded, Pool 15, Lower Impounded, Open River, Upper Illinois, and Lower Illinois), as defined by the multivariate analysis of the HNA-II indicators (De Jager et al., 2018; Figure 2-1). Within each river segment, the results of the River Team ratings for each of the indicators (Table 2-1) describing differing aspects of connectivity, diversity and redundancy, and controlling variables are presented in summary tables illustrating the River Team agreed upon ratings for each pool and overall river segment. For individual agency ratings, see Appendix A. Following the tables, overall conclusions are summarized in a table providing an overarching snapshot of the indicator ratings for each cluster. Lastly, the discussions on desired future habitat conditions as described by the River Teams are summarized.

3.1 UPPER IMPOUNDED CLUSTER

For the Upper Impounded cluster, navigation Pools 3-9 and 13 are grouped together and shared similar characteristics. The FWIC evaluated Pool 13 while the FWWG evaluated Pools 3-9. Resource agencies individually assessed each indicator (Appendix A) using data and synthesis results from De Jager et al. (2018), management priorities, and resources of concern.

A paired comparison exercise was conducted by the agencies to assess relative importance of the indicators (Table 3-1). The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Indicators that were selected over another indicator were then tallied. The higher the tally the more times this indicator was selected in comparison to another. From this paired-comparison exercise, floodplain functional class diversity and aquatic functional classes were tallied the greatest with floodplain vegetation diversity and aquatic vegetation diversity being also of higher importance as compared to all other indicators. It should be noted that each of these indicators in the 'diversity and redundancy' resiliency category. The lowest tallied indicator was percent time gates are open. The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the WIDNR, IADNR, MNDNR, USACE-St. Paul, USACE-Rock Island, and USFWS-Refuges, and USFWS-Ecological Services (Table 3-1).

Table 3-1. Rating results of paired-comparison exercise for the Upper Impounded cluster

Resilience Theme	Indicator	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	5	Medium
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	10	Low
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	7	Medium
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	1	**High**
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	4	**High**
	Floodplain Vegetation Diversity (Simpson's)	3	**High**
	Floodplain Functional Class Diversity (Simpson's)	1	**High**
Controlling Variables	Tailwater Flux difference (m)	9	Low
	Pool Flux difference (m)	8	Medium
	Total Suspended Solids Concentrations (mg/L)	6	Medium

Resource agencies of the FWWG rated each indicator (see Appendix A), then, through averaging and agreement via the UMRR CC, overall cluster ratings were produced for indicators describing aspects of connectivity (Table 3-2), diversity and redundancy (Table 3-3), and controlling variables (Table 3-4). When there was full agreement among the agencies, a pattern is added on the table; otherwise, the resultant averaged color is due to the diversity of opinion, and the reader is directed to Appendix A to see the individual agency ratings.

3.1.1 CONNECTIVITY INDICATORS

Table 3-2. Results of River Team ratings for the Upper Impounded cluster indicators of connectivity. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating calculated from a diversity of opinions and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	Longitudinal Aquatic Connectivity		Longitudinal Floodplain Connectivity		Lateral River-Floodplain Connectivity			
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area		Open Water	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
3	17.31	9.91	249.87	234.32	0	44.32	154.01	300.40
4	5.12		151.01		18.65		321.95	
5	1.45		308.68		195.08		295.15	
5a	15.44		289.88		0.07		221.02	
6	10.89		222.97		145.94		242.47	
7	4.79		215.94		0		400.77	
8	5.58		194.24		0		366.32	
9	21.38		212.65		0		371.15	
13	7.22		263.68		39.14		330.74	

3.1.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

This indicator was primarily assessed in terms of the ability of native migratory fishes to pass through the system. However, common management practices utilize the system "pinch-points" generated by the lock and dam system to aid in blocking the passage of Asian carps and other aquatic invasive species, which had a partial influence on the rating by the River Teams.

The amount of time the gates are open impacts the passage of native fish; however, more important is the seasonal timing of increased longitudinal connectivity. Increased connectivity to better facilitate the movement of native fishes should be targeted during key life history timeframes that have influences on population reproductive success. More information is desired by the River Teams to identify when these critical movement periods are occurring to enable more informed and productive management of protected native migratory fishes. In addition to managing the percent of time gates are open, if feasible, facilitation of aquatic organism movement may be enhanced through use of structures such as fish ladders.

When interpreting this indicator, it is important to note that the operation of one dam has the ability to affect fish passage between all upstream and downstream locations. The River Teams desired to enhance this indicator by considering the connection to major tributary drainages.

3.1.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

This indicator is intended to quantify the ability of terrestrial and semi-aquatic organisms to longitudinally traverse the Upper Mississippi River floodplain. Although much of the floodplain within the Upper Impounded cluster is in public ownership and managed for fish and wildlife, the River Teams support that longitudinal floodplain connectivity and quality could be improved where there are expansive impounded areas. There is connectivity within the pool floodplains, but it is reduced between pools due to L&D embankments. The River Teams concluded that the pool mean values alone were not a good metric particularly when describing narrow floodplain areas due to inconsistent views regarding what defines the floodplain coverage. Managers noted that improving this indicator for some species may impact habitat quality for other species. For example, the extensive island restoration that would be needed in lower portions of the pools to facilitate longitudinal movement of terrestrial floodplain species may negatively impact aquatic resources used by diving ducks. The River Teams identified potential improvements to increase the utility of this metric for the Upper Impounded cluster, including consideration of areas of possible flooding and connectivity of the floodplain to bluff lands.

3.1.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - LEVEED AREA (HECTARES/RIVER MILE)

This indicator is defined by the total hectares per river mile behind Federal levees, as catalogued in the Federal Levee Database. Private and other non-Federal levees were not included (see De Jager et al., 2018 for more details). Although the Upper Impounded cluster pools benefit from the lack of levees in this reach, the River Teams concluded that there are significant influences resulting from non-levee structures that are not captured by this indicator. For example, non-levee structures that influence lateral connectivity include existing and abandoned railroad and road embankments. Pool 6 is perhaps the most impacted with embankments that bisect that floodplain, but the other pools are also impacted. Recommendations by the River Teams to improve this indicator in the future includes presenting it as a ratio of leveed area to total area with a standardized floodplain width using the 50- or 100-year flood inundation for determining the outer bounds of data used for the calculation.

3.1.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

Open water habitat is abundant in the Upper Impounded cluster pools. However, the River Teams assessed large amount of open water as both highly desirable for some species and detrimental to others. For example, these large expanses of open water have become increasingly important as critical migratory habitat for diving ducks due to human-induced changes to historical migration stops along the riverine corridor. However, the River Teams determined continued loss of bathymetric diversity, low diversity in water velocities, and lack of floodplain structure have resulted in portions of these pools having limited value for terrestrial species and year-round backwater fish communities. The River Teams suggested restoring island habitat, particularly in the lower end of navigation pools, would enhance habitat quality in many instances by reducing wind fetch and erosion conditions on open waters, aiding in the production of aquatic vegetation, diversifying water velocities across the floodplain, and slowing the rate of aquatic to terrestrial transition through sedimentation. However, USFWS refuge managers cited the critical importance of large open water areas for waterfowl and stated that the waterfowl habitat value of those areas should be maintained.

During the assessment, some agencies factored in the influence large expanses of open water have on aquatic resources in the adjacent downstream pools. For example, wind events can re-suspend sediments in the impounded sections of a pool, which are then transported by the river to pools downstream. The transport of fine sediment is contributing to increased total suspended solids which affects aquatic vegetation growth and sedimentation of backwaters in adjacent downstream pools as observed by river managers.

The River Teams recommend refining this indicator in the future to express it as a ratio of land versus water to make it more meaningful.

3.1.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-3. Results of River Team ratings for the Upper Impounded cluster indicators of diversity and redundancy. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating calculated from a diversity of opinions and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class 1 (unitless)		Aquatic Functional Class 2 (unitless)		Aquatic Vegetation Diversity (unitless)		Floodplain Vegetation Diversity (unitless)		Floodplain Functional Class Diversity (unitless)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
3	0.64	1.20	1.12	-0.71	0.47	0.13	0.69	0.73	0.89	0.87
4	0.45		0.78		0.30		0.66		0.86	
5	0.41		0.89		0.64		0.84		0.70	
5a	0.23		-0.27		0.69		0.56		0.80	
6	-0.33		0.30		0.60		0.76		0.62	
7	0.79		0.00		0.59		0.74		0.79	
8	0.60		0.30		0.62		0.71		0.79	
9	0.95		0.00		0.63		0.58		0.85	
13	0.68		0.34		0.60		0.52		0.79	

3.1.2.1 AQUATIC FUNCTIONAL CLASS 1

Generally, high values of this indicator reflect a greater abundance of lentic classes and low values reflect greater abundance of lotic classes. Island dissection and erosion have affected the distribution of lentic functional classes within the Upper Impounded cluster since lock and dam construction. Island dissection in the upper and middle portions of the pools has increased the amount of large, flow-through lentic areas and shallow lotic areas at the expense of floodplain terrestrial wet meadow, isolated wetlands and smaller, less-connected lentic areas (Figure 2-2). Management needs identified by the River Teams included increased diversity of habitat classes, improvement of physical conditions within the lotic habitats, and increased quality, depth, and distribution of lentic habitats. In impounded areas, river managers concluded that the lotic habitat is poorly defined due to loss of channel landforms. This indicator value would likely vary considerably between pool thirds (upper, middle, lower), but generally the River Teams would like to see this indicator value higher. Overall, the River Teams found this indicator difficult to rate due to many parameters within this composite indicator being interrelated. Some suggested that rating the individual parameters that went into this indicator may have been easier to assess since the discussion often focused on the quality of the various aquatic functional classes (See Figure 2-2).

3.1.2.2 AQUATIC FUNCTIONAL CLASS 2

High values of this indicator reflect high abundance of deep lentic areas and low values reflect a high abundance of shallow lotic areas. Based on management observations, significant sedimentation is occurring, resulting in undesired shallowing of deep lentic areas. The River Teams identified that there is not as much available high quality habitat present as desired. Overall, the River Teams consider the desired state to have increased diversity of aquatic functional classes, including improving physical conditions within the lotic habitats, more structured channels, and increasing the quality depths and distribution of lentic habitats. The FWWG and FWIC determined that it would help management actions to better understand the distribution of these habitats within pools. Overall, the River Teams found this indicator difficult to rate due to many parameters within this composite indicator being interrelated. Suggestions for improvement include using aquatic functional class names as described in Figure 2-3 (i.e., lentic-shallow, lentic-wooded shoreline, lentic-deep, lentic-depression, lentic-borrow pit, lentic – low connectivity, lentic shallow with flow, lentic – large with flow, lotic-shallow, lotic-wooded shoreline, lotic-deep, lotic-structured, and lotic-structured with scour).

3.1.2.3 AQUATIC VEGETATION DIVERSITY

Overall, the FWWG and FWIC would like to see more diversified classes of aquatic vegetation throughout the Upper Impounded cluster (See Figure 17 in De Jager et al., 2018 for more details). However, in some cases, increasing vegetation diversity may not be the right management action or benefit the resources utilizing them. Diversity is only one piece of aquatic vegetation health, resilience, and habitat value. The quality of the vegetation also should be considered. Additional dialogue with the river managers could help to better understand why Pool 5 was rated as an "orange" when that pool has the second highest aquatic vegetation diversity score within the Upper Impounded cluster.

3.1.2.4 FLOODPLAIN VEGETATION DIVERSITY

Floodplain forests, wet meadows, and other desirable habitats are not currently in a preferred state as described by the River Teams, due to invasive species, such as reed canary grass (*Phalaris arundinacea)*, a loss of species diversity, and a lack of regeneration of desirable tree species. Invasive species are accounted for in the diversity calculation, providing higher diversity values in lower quality habitat areas. Additionally, sometimes lower scores are indicative of preferred conditions. For example, Pool 9 is almost entirely floodplain forest, but it is scored lower because the indicator does not take into account diversity within individual classes, which was desired by the River Teams. Diversity is only one piece of floodplain vegetation health, resilience, and habitat value. The River Teams wanted to consider the quality of the vegetation. The River Teams desired to have a reference condition for pre-dam conditions of desirable vegetation types, distribution, and acreages. The River Teams decided this indicator does not account for localized/clustered high diversity versus widely distributed diversity. Management-wise, the River Teams identified the need to continue to promote floodplain vegetation diversity and to reduce invasive species. For some agencies, the assessment of floodplain vegetation diversity factored in the position within a pool and future desired conditions. Overall, each position within a given pool has a different stressor/driver affecting this indicator as observed by river managers. The River Teams concluded that in the upper portion of the pool, elevation is not necessarily limiting floodplain vegetation diversity, but regeneration may be while the middle sections of the pools are more greatly influenced by water surface elevations and many are experiencing reduced regeneration and establishment.

This indicator showed a decline in forest area and diversity, other non-aquatic areas (i.e., wet-meadow), and pool-wide distribution which indicates that regeneration may be limiting. The River Teams identified a habitat need to establish more community diversity (i.e., wet meadow, scrub shrub, etc.), not just forest. One class frequently mentioned as not meeting desired conditions was wet meadow throughout much of the cluster.

For the bigger picture of how floodplain vegetation classes change across the UMRS, refer to Figure 21 in De Jager et al. (2018). In many cases, the river managers' rating of a pool does not match up with the data. Further discussions should be undertaken to better understand how the data and management perspectives can be better aligned. Additional dialogue with the river managers should occur to better understand why Pool 5 was rated as "yellow" when that pool has highest floodplain vegetation diversity score within the Upper Impounded cluster.

3.1.2.5 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

Although this indicator was calculated from areas inside the Federal levee database only, the FWWG and FWIC primarily considered floodplain functional class diversity, looking at areas both inside and outside all known levees within this reach. From a forestry standpoint, the River Teams concluded it would be best if there were more high-elevation (low amount of inundation) areas throughout the pools. Most of the forested areas represented in the indicator are likely in lower elevation sites that are inundated for 60 to more than 100 days annually.

3.1.3 CONTROLLING VARIABLES INDICATORS

Table 3-4. Results of River Team ratings for the Upper Impounded cluster indicators of controlling variables. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating calculated from a diversity of opinions and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Water Surface Elevation Fluctuation				Total Suspended Solids (mg/L)	
	Tailwater Flux Difference (m)		Pool Flux Difference (m)			
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
3	-0.00	-0.24	-1.21	-1.71	41.88	32.93
4	0.18		-1.91		No data	
5	-0.70		-2.04		23.06	
5a	-0.67		-1.38		No data	
6	-0.45		-1.77		No data	
7	0.76		-2.03		17.16	
8	-0.33		-1.89		30.07	
9	0.09		-1.27		28.5	
13	0.48		-1.91		56.89	

3.1.3.1 WATER SURFACE ELEVATION FLUCTUATIONS – TAILWATER FLUX

The FWWG was concerned that this variable does not take into account frequency of changes. For example, river managers observe rapid changes up and down in the tailwaters of Pool 3. Although dams influence tailwaters, the River Teams decided that climatic and seasonal weather conditions may have larger and more uncontrolled influences. Generally, the River Teams agreed that all pools may benefit from more frequent gate adjustments and a more gradual rate of change.

3.1.3.2 WATER SURFACE ELEVATION FLUCTUATIONS - POOL FLUX

The FWWG desires more variability in pool flux, particularly during the growing season and in sync with the seasonal hydrograph; however, there are benefits in stability during certain points of the year. As observed by river managers, excessive winter variability can result in large losses of mussels, amphibians, reptiles and fish. Additionally, River Teams' ratings considered the present state of aquatic vegetation and fisheries with regards to whether changes in the indicator were needed to meet life history needs. The FWWG questioned how much the indicator values are influenced by hinge-point[2] vs. dam-point operating plans. Future refinement of this indicator was recommended to include current-day rates of change rather than comparing to "historic pre-dam" fluctuations.

[2] For more information refer to: http://www.mvs.usace.army.mil/Missions/Navigation/Locks-and-Dams/Operation-Limits/ Accessed 09 October 2018

3.1.3.3 TOTAL SUSPENDED SOLIDS CONCENTRATION

Overall, the FWWG and FWIC would like to see sedimentation and total suspended solids (TSS) reduced within the Upper Impounded cluster. The River Teams concluded that the indicator TSS values did not reflect what they understand about the UMRS and questioned whether the seasons and/or events during which the samples were collected influenced the values. For some agencies, the ratings of a given pool were based on using the South Metro Mississippi total maximum daily limit (TMDL) of 32 mg/L[3], a value commonly used to guide actions around Lake Pepin. If a pool was greater than 32 mg/L it was rated red. Other agencies considered how TSS affects native vs. non-native fish biomass and used 16 mg/L as a benchmark.

3.1.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Teams' ratings for the Upper Impounded cluster are summarized in Figure 3-1. De Jager et al. (2018) characterized the Upper Impounded cluster by an abundance of unleveed natural floodplain land cover, and high diversity of aquatic functional classes, floodplain functional classes, and vegetation types. However, these pools also tend to have floodplain inundation periods of greater than 80 days, which supports a higher abundance of wet meadows dominated by an invasive grass, reed canary grass (De Jager, Rohweder, & Hoy, 2017).

Overall, for the Upper Impounded cluster, the future desired habitat condition captured during discussions with the River Teams (and which may reflect individual agency priorities) include:

- Maintain and enhance existing open water area for waterfowl habitat
- Improve quality, depth, and distribution of lentic habitat
- Reduce sedimentation
- Improve lotic habitat
- Maintain and enhance floodplain vegetation
- Restore floodplain vegetation diversity in conjunction with diversifying floodplain inundation periods
- Improve navigation dam gate management for native fish passage, deter invasive fish species, as well as adjust operation to allow for more gradual rate of change, when feasible

[3] For more information refer to: https://www.pca.state.mn.us/water/tmdl/south-metro-mississippi-%E2%80%94-turbidity-tmdl-project Accessed 09 October 2018

Upper Impounded Indicators	River Team Importance
Total Suspended Solids	Medium
Tailwater Flux	Low
Aquatic Vegetation	High
Leveed Area	Low
Floodplain Vegetation	**High**
Open Water	Medium
Natural Area	Medium
Pool Flux	Medium
Floodplain Functional Class	**High**
Aquatic Functional Class 2	**High**
Aquatic Functional Class 1	
% Gates Open	Low

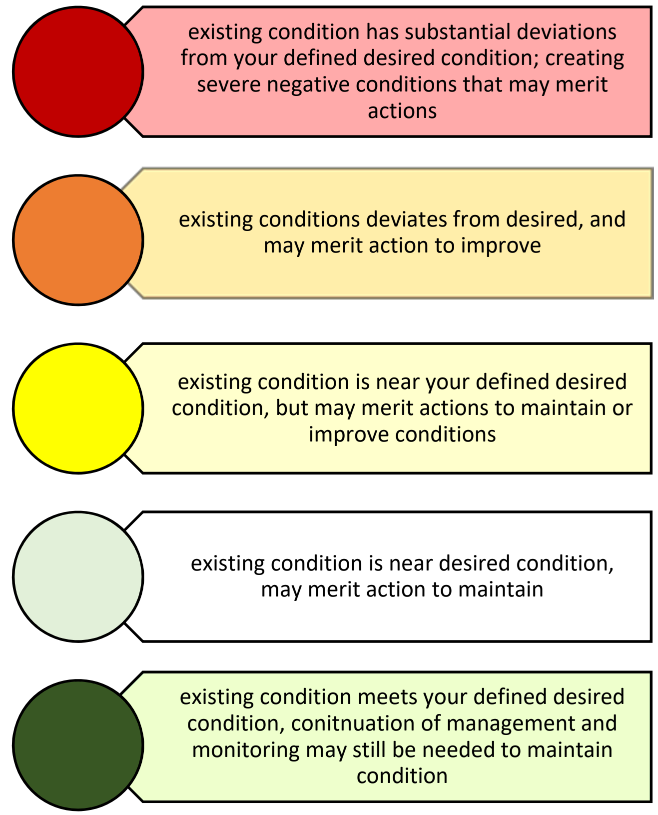


Figure 3-1. Summary of indicator of ecosystem structure and function for the Upper Impounded Cluster

3.2 MIDDLE IMPOUNDED CLUSTER

Navigation pools 10, 11, 12, 14, 16, and 19 were grouped together, sharing similar characteristics. The Middle Impounded cluster was evaluated by the FWIC.

A paired comparison exercise was conducted by the agencies of the FWIC to assess relative importance of the indicators (Table 3-5). The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Then indicators that were selected over another indicator were tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, aquatic vegetation diversity was tallied the most with floodplain functional class diversity, aquatic functional classes 1 & 2, and longitudinal floodplain connectivity associated with natural area being also of higher importance as compared to all other indicators. The lowest tallied indicator was percent time gates are open. The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the IADNR, WIDNR, USACE-Rock Island, USFWS-Refuges, and USFWS-Ecological Services (Table 3- 5).

Table 3-5. Ranking results of paired-comparison exercise for the Middle Impounded Cluster.

Resilience Theme	Indicator	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	5	**High**
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	10	Low
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	6	Medium
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	3	**High**
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	1	**High**
	Floodplain Vegetation Diversity (Simpson's)	4	**High**
	Floodplain Functional Class Diversity (Simpson's)	2	**High**
Controlling Variables	Tailwater Flux difference (m)	8	Low
	Pool Flux difference (m)	8	Low
	Total Suspended Solids Concentrations (mg/L)	7	Medium

Resource agencies individually rated each indicator, then through averaging and discussion, agreement on an overall River Team ratings was reached for the indicators describing aspects of connectivity (Table 3-6), diversity and redundancy (Table 3-7), and controlling variables (Table 3-8).

3.2.1 CONNECTIVITY INDICATORS

Table 3-6. Results of River Team ratings for the Middle Impounded cluster indicators of connectivity. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	Longitudinal Aquatic Connectivity		Longitudinal Floodplain Connectivity		Lateral River-Floodplain Connectivity			
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area (ha/RM)		Open Water (ha/RM)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
10	22.02	11.22	148.39	125.58	3.01	60.46	237.83	212.32
11	5.18		90.32		2.23		257.65	
12	16.76		93.29		11.70		166.71	
14	0.90		117.40		35.53		152.43	
16	22.15		125.10		8.01		193.00	
19	0.30		178.95		302.30		266.33	

3.2.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

This indicator was primarily assessed in terms of the ability of native migratory fishes to pass through the system. Overall, the FWIC desired increased connectivity to facilitate the movement of native fishes. However, common management practices use the system "pinch-points" generated by the lock and dam system to aid in blocking the passage of Asian carps and other aquatic invasive species, which had a partial influence on the rating, particularly Lock and Dams 14 and 19. For Pool 19 (which Lock and Dam 19 gates are never open) was rated "yellow" when balancing movement of aquatic invasive species versus native fish passage. In terms of invasive species, Lock &and Dam 19 restricts movement, so it could be considered a desired condition ("green"); however, it also restricts movement of native fish which is not desired ("red"); therefore, the river managers agreed to rate it "yellow".

River managers noted that the amount of time the gates are open impacts the passage of native fish; however, more important as identified by the river managers is the seasonal timing of increased longitudinal connectivity. Increased connectivity to better facilitate the movement of native fishes, during key life history and migration timeframes that have influences on population reproductive success, was identified as a need by the river managers. More information is desired by the FWIC to identify when these critical movement periods are occurring to enable more informed and productive management of protected native migratory fishes.

Based on river manager observations, out of season extreme rainfall events are occurring more frequently which may affect fish migration. Additionally, construction of fish passage structures, such as fish ladders, may facilitate passage of native fishes and eels more so than changes to gate operations.

For longitudinal connectivity, the FWIC rated Pools 10 and 16 as “light green” and Pools 11, 12, 14 and 19 as “yellow”. The Middle Impounded cluster was rated “yellow” (Table 3-6).

3.2.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

The river managers considered floodplain connectivity within the Middle Impounded cluster to vary from good to poor across pools. Pools 10 and 12 have more structure dam to dam than other pools, such as Pool 11. The River Team identified that evaluating only the mean of the metric has its limitations due to varying widths of the floodplain. An addition to this indicator could capture the accessibility to adjacent natural areas, such as bluff lands, uplands, tributary valleys, etc.

For longitudinal floodplain connectivity, the FWIC rated Pools 10 and 12 as “light green”, Pool 11 as “yellow”, Pool 14 as “orange” and Pools 16 and 19 as “red”. The Middle Impounded cluster was rated as “yellow” (Table 3-6).

3.2.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - LEVEED AREA (HECTARES/RIVER MILE)

There are very few leveed areas within Pools 10, 11, 12 and 16. The FWIC noted that there is a small portion of Pool 14 that is leveed and managed as a moist soil unit. The FWIC identified that the lateral river-floodplain connectivity indicator could benefit by including the extent of other (non-levee) infrastructure, and including a ratio of leveed to total floodplain acreage. The FWIC based its ratings on total acreage of leveed areas.

For lateral river-floodplain connectivity (leveed area), the FWIC rated Pools 11 and 16 as “green,” Pool 14 as “light green” and Pools 10, 12 and 19 as “yellow.” The Middle Impounded cluster was rated “light green” (Table 3-6).

3.2.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

The Middle Impounded pools show the greatest effects of impoundment with high amounts of open water as observed by the river managers. However, the open water areas in Pools 11 and 19 are important habitat areas for waterfowl and should be maintained as identified by the FWIC. In other pools, such as Pools 10, 12 and 16, it may be beneficial to restore habitats such as flowing channels, islands, and lentic backwaters in areas that are currently open water habitats or that are converting to open water habitats. The FWIC also noted that Lower Pool 14 is the beginning of the Rock Island gorge, which is a narrow channel, and has fewer opportunities for habitat management and restoration.

The acreages represented by the indicator were not necessarily in line with the river managers’ professional experience. The FWIC desired a different metric defining lateral connectivity, such as a ratio of open water to total acreage.

For lateral river-floodplain connectivity (open water), the FWIC rated Pool 19 as “light green”, Pools 10, 11, 12, and 14 as “yellow” and Pools 16 as “orange”. The Middle Impounded cluster was rated “yellow” (Table 3-6).

3.2.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-7. Results of River Team ratings for the Middle Impounded cluster indicators of diversity and redundancy. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class 1 (unitless)		Aquatic Functional Class 2 (unitless)		Aquatic Vegetation Diversity (unitless)		Floodplain Vegetation Diversity (unitless)		Floodplain Functional Class Diversity (unitless)	
Nav Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
10	0.46	-0.05	0.06	0.04	0.54	0.30	0.41	0.48	0.88	0.84
11	0.14		0.22		0.43		0.44		0.88	
12	-0.19		-0.03		0.40		0.52		0.81	
14	-0.11		0.24		0.17		0.38		0.77	
16	-0.77		-0.82		0.11		0.49		0.81	
19	0.20		0.12		0.13		0.64		0.86	

3.2.2.1 AQUATIC FUNCTIONAL CLASSES 1 & 2

Island dissection and erosion has affected both lentic and lotic environments within the Middle Impounded cluster. As observed by river managers, island dissection in the upper and middle portions of pools has increased the amount of lotic habitat in some areas at the expense of floodplain terrestrial wet meadow, isolated wetlands and lentic areas. River managers identified habitat needs to include increased diversity of habitat classes, improvement of physical conditions within the lotic habitats and side channels, and increased quality, depth, and distribution of lentic habitats. Specifically, Pool 11 is lacking in quality lotic habitat. Overall, the River Teams found these indicators difficult to rate due to interrelations.

For aquatic functional class 1, the FWIC rated Pools 10, 12 and 14 as “yellow” and Pools 11, 16 and 19 as “orange.” The Middle Impounded cluster was rated “orange” (Table 3-7).

For aquatic functional class 2, the FWIC rated Pools 11 and 19 as “yellow”, Pools 10, 12 and 14 as “orange” and Pool 16 as “red”. The Middle Impounded cluster was rated as “orange” (Table 3-7).

3.2.2.2 AQUATIC VEGETATION DIVERSITY

Overall, the FWIC determined that the aquatic vegetation diversity indicator is in relative good shape for the Middle Impounded cluster, with submersed aquatic vegetation in most pools, but the current trend as observed by river managers is showing a decline in abundance and diversity. Therefore, the FWIC desires management actions to maintain the vegetation diversity. Although, in some instances, conversion of monotypic areas may not necessarily be the right thing to do. The FWIC identified the need to consider the community's distribution within a pool/reach to better evaluate the habitat need for aquatic vegetation diversity.

For aquatic vegetation diversity, the FWIC rated Pool 10 as "light green", Pools 11 and 12 as "yellow," Pool 14 as "orange" and Pools 16 and 19 as "red". The Middle Impounded cluster was rated "orange" (Table 3-7).

3.2.2.3 FLOODPLAIN VEGETATION DIVERSITY

According to river managers, forests and wet meadows are presently not in a desired state due to conversion to reed canary grass, over-mature forest, and reduced percentage and limited distribution of less flood tolerant species. The FWIC has observed a decline in forest health, which is leading to an overall decline in species diversity. Overall, the FWIC considered the floodplain vegetation diversity indicator value as good relative to the other pools within the system, although the Middle Impounded cluster are not necessarily meeting desired conditions. The FWIC would like to see continued promotion of floodplain vegetation diversity and a decrease in invasive species prevalence.

For floodplain vegetation diversity, the FWIC rated all of the individual Lower Impounded cluster as "orange", as well as the Middle Impounded cluster (Table 3-7).

3.2.2.4 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

Although the pools within the Middle Impounded cluster rated high for hydro-geomorphic variability of non-aquatic areas, the quality is low in many areas as observed by river managers. As a result, the FWIC considered both the numeric indicator values along with the local distribution when evaluating this indicator. Overall, local knowledge versus data driven differences and how they influence each other is important. The FWIC noted that there are many caveats associated with utilizing diversity indices. The FWIC would like to see improvements in this indicator.

For floodplain functional class diversity, the FWIC rated Pools 14, 16 and 19 as "yellow" and Pools 10, 11 and 12 as "orange". The Middle Impounded cluster was rated "yellow" (Table 3-7).

3.2.3 CONTROLLING VARIABLES INDICATORS

Table 3-8. Results of River Team ratings for the Middle Impounded cluster indicators of controlling variables. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Water Surface Elevation Fluctuation				Total Suspended Solids Concentrations (mg/L)	
	Tailwater Flux Difference (m)		Pool Flux Difference (m)			
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
10	0.38	0.32	-1.29	-1.78	30.54	44.80
11	0.22		-1.96		37.48	
12	0.26		-1.45		35.24	
14	0.34		-2.15		63.63	
16	0.40		-0.97		47.66	
19	0.30		-2.82		54.23	

3.2.3.1 WATER SURFACE ELEVATION FLUCTUATION – TAILWATER FLUX

The water surface elevation fluctuation (tailwater) showed little change in fluctuation compared to pre-lock and dam conditions across all pools within the cluster. The FWIC identified that improvements may be made by more frequent gate operations.

For water surface elevation fluctuation (tailwater flux), the FWIC rated Pools 10, 11, 12 and 14 as “light green”, Pool 16 as “yellow” and Pool 19 as “orange”. The Middle Impounded cluster was rated “light green” (Table 3-8).

3.2.3.2 WATER SURFACE ELEVATION FLUCTUATION – POOL FLUX

The FWIC would like to see more variability, particularly during the growing season; however, there are some benefits to seasonal stability, especially during winter. Excessive variability during winter can result in adverse effects to mussels, amphibians, reptiles, and fish. The FWIC agreed that all pools would benefit from a more gradual rate of change through more frequent gate adjustments.

The FWIC questioned how much the indicator values were influenced by hinge-point versus dam-point operation of the gates. Additionally, it was noted that the area immediately above the dams will show the least effect from drawdown management. More fluctuation would be observed at the mid-pool area. Future consideration to refine this indicator should include how the pools are operated.

For water surface elevation fluctuation (pool flux), the FWIC rated all of the individual Middle Impounded pools as “yellow”, as well as the Middle Impounded cluster (Table 3-8).

3.2.3.3 TOTAL SUSPENDED SOLIDS CONCENTRATIONS

The FWIC would like to see a decrease in total suspended solids across all pools to promote the growth of aquatic vegetation. The FWIC questioned whether the indicator values for total suspended solids (TSS) concentrations may be an artifact of the gage placement (i.e., Pool 14 samples taken right at the dam, so turbidity from Pool 13 may be influencing the mean value), particularly since Pool 16 is known to be more turbid than Pool 14. Timing issues may also influence indicator value, such as collecting a reading just as a barge is leaving the lock.

For TSS, the FWIC rated Pools 10, 11 and 12 as "yellow" and pools 14, 16 and 19 as "orange." The Middle Impounded cluster was rated "orange" (Table 3-8).

3.2.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team ratings for the Middle Impounded cluster are summarized in Figure 3-2. De Jager et al. (2018) characterized the Middle Impounded navigation pools as having a high diversity of floodplain functional classes and inundation periods, and water surface elevations fluctuating less than they did historically. Overall, for the Middle Impounded, the future desired habitat condition captured during discussions with the River Team (and may reflect individual agency priorities) included:

- Maintain and enhance existing open water area for waterfowl habitat
- Restore diversity of aquatic habitat types
- Improve quality, depth and distribution of lentic habitat
- Improve lotic habitat
- Maintain and enhance floodplain vegetation
- Restore floodplain vegetation diversity in hand with diversifying floodplain inundation periods
- Improve gate management for native fish passage, deter invasive fish species, as well as adjust operation to allow for more gradual rate of change, when feasible

Color Rating	Middle Impounded Indicators	River Team Importance
Light Green	Tailwater Flux	Low
	Leveed Area	Low
Yellow	Pool Flux	Low
	Floodplain Functional Class	**High**
	Natural Area	**High**
	% Time Gates Open	Low
Orange	Total Suspended Solids	Medium
	Floodplain Vegetation	**High**
	Aquatic Vegetation	**High**
	Aquatic Functional Class 2	**High**
	Aquatic Functional Class 1	
	Open Water	Medium

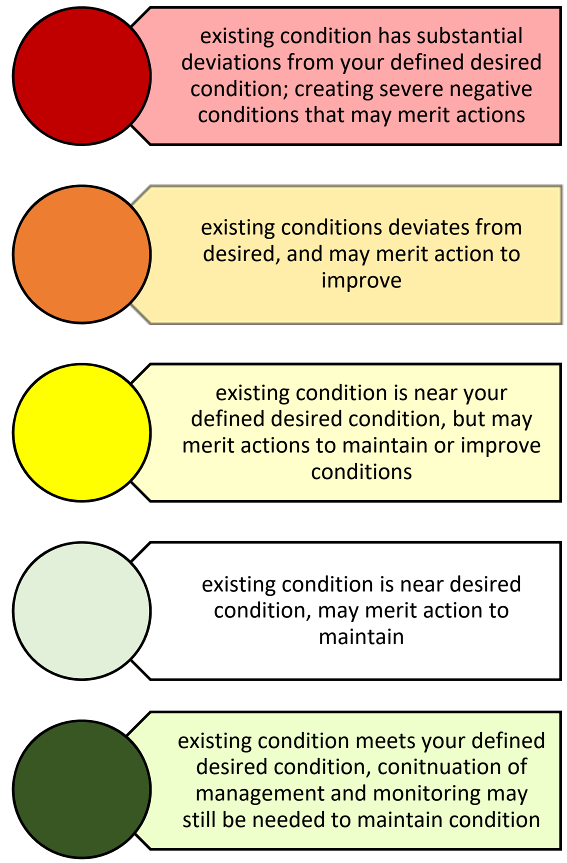


Figure 3-2. Summary of ratings for the 12 indicators of ecosystem and structure for the Middle Impounded cluster provided by the FWIC ratings as determined by averaging the individual agency ratings.

3.3 POOL 15

Navigation Pool 15 did not group with any other navigation pools and was evaluated by the FWIC. Pool 15 is a unique section of the Upper Mississippi River, being the shortest pool in length (only 8 miles in length) and formerly containing a gorge and rapids. These characteristics, in addition to this pool nearly lacking all aquatic functional classes (De Jager et al., 2018) and position within an urban area make the ecological needs of this Pool different from the other impounded pools within the UMRS.

A paired comparison exercise was conducted by the agencies of the FWIC to assess relative importance of the indicators (Table 3-9). The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Then indicators that were selected over another indicator were tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, aquatic vegetation diversity was by far tallied the most. The lowest tallied indicator was percent time gates are open. The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the IADNR, USACE-Rock Island, and USFWS-Ecological Services. Resource agencies individually rated each indicator then produced an overall River Team rating through discussion and agreement for indicators describing aspects of connectivity, diversity and redundancy, and controlling variables (Table 3-9).

Table 3-9. Results of River Team ratings for Pool 15 for indicators describing different aspects of connectivity, diversity and redundancy, and controlling variables. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators. The rank order reflects the results of the paired comparison exercise.

Resilience Theme	Indicator	Pool Value	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	7.15	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	26.57	3	Medium
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	44.74	9	Low
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	137.32	8	Low
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	-1.28	6	Medium
	Aquatic Functional Class 2 (unitless)	-0.82		
	Aquatic Vegetation Diversity (Simpson's)	0.03	1	**High**
	Floodplain Vegetation Diversity (Simpson's)	0.73	2	Medium
	Floodplain Functional Class Diversity (Simpson's)	0.60	3	Medium
Controlling Variables	Tailwater Flux difference (m)	-0.95	7	Low
	Pool Flux difference (m)	-2.17	9	Low
	Total Suspended Solids Concentrations (mg/L)	38.26	3	Low

3.3.1 CONNECTIVITY INDICATORS

3.3.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

The FWIC noted that Pool 15 does harbor a diverse and unique freshwater mussel community (unpublished observation), signifying the importance of native fish host species movement within and through this pool. However, with this cluster being represented by a single pool, the FWIC determined that this indicator is not directly applicable to Pool 15 and its ecological needs.

For longitudinal aquatic connectivity, the FWIC rated Pool 15 as “yellow” (Table 3-9).

3.3.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY – NATURAL AREA (HECTARES/RIVER MILE)

The FWIC determined that longitudinal floodplain connectivity is lacking in this section of the UMR and increased connectivity could benefit terrestrial wildlife movement. However, the urbanization of this Pool may limit restoration potential and the short length of the pool may reduce the need for migratory stop-over and resting areas between floodplain forest patches in adjacent pools.

For longitudinal floodplain connectivity, the FWIC rated Pool 15 as “orange” (Table 3-9).

3.3.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY – LEVEED AREA (HECTARES/RIVER MILE)

Currently, a lack of lateral movement across the river-floodplain is observed. This section of the UMRS formerly consisted of a gorge and rapids.

For lateral river-floodplain connectivity (leveed area), the FWIC rated Pool 15 as “light green” (Table 3-9).

3.3.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY – OPEN WATER (HECTARES/RIVER MILE)

Pool 15 primarily consists of open water with a few rock and urbanized islands. The existing open water areas within Pool 15 are considered to be low quality by the FWIC; however, due to the hydrogeomorphology in this section of the UMRS, high quality open water habitat was not historically present, and therefore, restoration potential may be limited.

For lateral river-floodplain connectivity (open water), the FWIC rated Pool 15 as “yellow” (Table 3-9).

3.3.2 DIVERSITY & REDUNDANCY INDICATORS

3.3.2.1 AQUATIC FUNCTIONAL CLASSES 1 & 2

Pool 15 is highly lotic resulting from the former rapids with little to no lentic acreage. The amount of lotic habitat is similar to historic condition, but the quality of the lotic habitat is different as noted by the FWIC. The FWIC identified the habitat could benefit from increased aquatic habitat diversity where feasible.

For aquatic functional class 1, the FWIC rated Pool 15 as "orange" (Table 3-9).

For aquatic functional class 2, the FWIC rated Pool 15 as "yellow" (Table 3-9).

3.3.2.2 AQUATIC VEGETATION DIVERSITY

The substrate of Pool 15 is primarily comprised of gravel, rock and bedrock making it difficult to sustain aquatic vegetation as noted by the FWIC. As reflected by the indicator value, Pool 15 has limited aquatic vegetation diversity. However, there are localized patches of American wild celery (*Vallisneria)* and American lotus (*Nelumbo lutea*) beds throughout the Pool that would benefit from maintenance and protection as identified by the FWIC.

For aquatic vegetation diversity, the FWIC rated Pool 15 as "yellow" (Table 3-9).

3.3.2.3 FLOODPLAIN VEGETATION DIVERSITY

Although this indicator value reflected relatively high floodplain vegetation diversity, the majority of the floodplain vegetation throughout Pool 15 is urban and not representative of floodplain habitat. The FWIC would like to see continued maintenance and promotion of floodplain vegetation diversity.

For floodplain vegetation diversity, the FWIC rated the Pool 15 cluster as "yellow" (Table 3-9).

3.3.2.4 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

The FWIC viewed this indicator similarly to floodplain vegetation diversity in respect to this Pool being highly urban. The FWIC would like to see continued promotion of floodplain inundation diversity where feasible.

For floodplain functional diversity, the FWIC rated Pool 15 as "yellow" (Table 3-9).

3.3.3 CONTROLLING VARIABLES INDICATORS

3.3.3.1 WATER SURFACE ELEVATION FLUCTUATION - TAILWATER FLUX

The water surface elevation fluctuation (tailwater flux) indicator showed less variability in fluctuation during the growing season compared to pre-lock and dam conditions. Due to the short length of Pool 15, the potential to manage tailwater fluctuation was characterized as 'limited' by the FWIC.

For water surface elevation fluctuation (tailwater flux), the FWIC rated Pool 15 as "yellow" (Table 3-9).

3.3.3.2 WATER SURFACE ELEVATION FLUCTUATION - POOL FLUX

The water surface elevation fluctuation (pool flux) indicator showed less variability in fluctuation during the growing season compared to pre-lock and dam conditions. Due to the short length of Pool 15, the potential to manage tailwater fluctuation was characterized as 'limited' by the FWIC.

For water surface elevation fluctuation (pool flux), the FWIC rated Pool 15 as "yellow" (Table 3-9).

3.3.3.3 TOTAL SUSPENDED SOLIDS CONCENTRATION

Due to the lack of backwaters and side channels, Pool 15 generally lacks areas for sediment accumulation as noted by the FWIC. Additionally, there is not enough aquatic vegetation throughout the Pool to effectively trap passing sediment as noted by the FWIC. Pool 15 could benefit from a decrease of total suspended solids to maintain and enhance areas of aquatic vegetation.

For total suspended solids concentrations, the FWIC rated Pool 15 as "orange" (Table 3-9).

3.3.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team ratings for Pool 15 are summarized in Figure 3-3. De Jager et al. (2018) characterized Pool 15 as having very little natural land cover, the most heavily developed of all navigation pools, and as having only lotic-structured and lotic-shallow aquatic functional classes.

Overall, for Pool 15, the future desired habitat condition captured during discussions with the River Team (and may reflect individual agency priorities) included:

- Restore island and other floodplain habitat diversity where feasible
- Restore diversity of aquatic habitat types
- Maintain and enhance floodplain vegetation
- Improve water clarity
- Reduce sedimentation

Color Rating	Pool 15 Indicators	River Team Importance
Light Green	Leveed Area	Low
Yellow	Pool Flux	Low
	Tailwater Flux	Low
	Floodplain Functional Class	Medium
	Floodplain Vegetation	Medium
	Aquatic Vegetation	**High**
	Aquatic Functional Class 2	Medium
	% Time Gates Open	Low
	Open Water	Low
Orange	Total Suspended Solids	Medium
	Aquatic Functional Class 1	Medium
	Natural Area	Medium

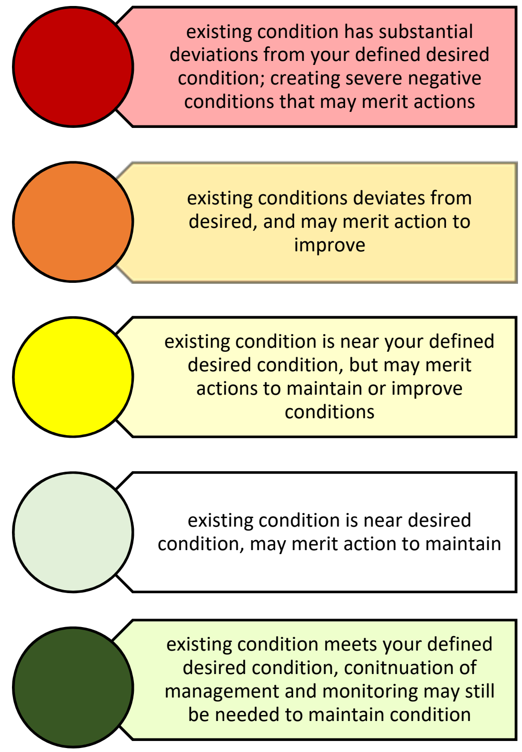


Figure 3-3. Summary of ratings for the 12 indicators of ecosystem structure and function for Pool 15 provided by the FWIC ratings as determined by averaging the individual agency ratings.

3.4 LOWER IMPOUNDED CLUSTER

For the Lower Impounded cluster, Navigation Pools 17, 18, 20, 21, 22, 24, 25, and 26 are grouped together, sharing similar characteristics, and were evaluated by the FWIC and the RRAT.

A paired comparison exercise was conducted by the agencies of the FWIC and the RRAT to assess relative importance of the indicators (Table 3-10). The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Then indicators that were selected over another indicator were tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, lateral river-floodplain connectivity associated with open area was tallied the greatest with aquatic functional classes 1 and 2, floodplain functional class diversity, and floodplain vegetation diversity also being of higher importance compared to all other indicators. The lowest tallied indicator was percent time gates are open. The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the IADNR, MDC, USACE-Rock Island, USACE – St. Louis, USFWS-Refuges, and USFWS-Ecological Services (Table 3-10).

Table 3-10. Ranking results of paired-comparison exercise for the Lower Impounded Cluster

Resilience Theme	Indicator	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	7	Medium
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	5	Medium
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	1	**High**
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	2	**High**
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	5	Medium
	Floodplain Vegetation Diversity (Simpson's)	4	**High**
	Floodplain Functional Class Diversity (Simpson's)	3	**High**
Controlling Variables	Tailwater Flux difference (m)	9	Low
	Pool Flux difference (m)	10	Low
	Total Suspended Solids Concentrations (mg/L)	8	Low

Resource agencies individually rated each indicator, then through averaging and discussion, agreement for an overall River Team rating was produced for the indicators describing aspects of connectivity (Table 3-11), diversity and redundancy (Table 3-12), and controlling variables (Table 3-13).

3.4.1 CONNECTIVITY INDICATORS

Table 3-11. Results of River Team ratings for the Lower Impounded cluster indicators of connectivity. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	Longitudinal Aquatic Connectivity		Longitudinal Floodplain Connectivity		Lateral River Floodplain Connectivity			
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area (ha/RM)		Open Water (ha/RM)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
17	37.66	29.70	162.48	247.93	327.94	579.88	139.28	178.63
18	17.94		383.06		650.32		259.70	
20	39.27		203.65		881.33		156.32	
21	28.01		249.32		752.00		164.07	
22	25.40		197.39		949.80		150.50	
24	28.48		208.40		382.76		167.25	
25	33.22		366.79		462.36		199.20	
26	27.58		212.38		232.51		192.73	

3.4.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

Overall, both the FWIC and the RRAT desired increased connectivity to facilitate the movement of native fishes. For further details on how this indicator was interpreted, see Section 3.2.1.1.

For longitudinal aquatic connectivity, the FWIC rated Pool 17 as “light green” and Pools 18, 20, 21, 22, 24, 25 and 26 as “yellow”. The Lower Impounded cluster rated “yellow.” The RRAT also rated Pools 24, 25, and 26 and “yellow” and the overall cluster as “yellow” (Table 3-11).

3.4.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

As observed by FWIC, the longitudinal floodplain connectivity conditions vary significantly throughout the Lower Impounded cluster, with Pool 18 having a good complex of islands and quite a bit of connectivity, but Pool 22 lacking floodplain connectivity due to levees. The River Teams attribute the good conditions present in Pool 18 to the lock and dams making “natural areas” that cannot be farmed. Additionally, the Henderson Creek area (approximately 2,000 acres) within Pool 18 consists of unique and high-quality habitat without active management. The FWIC identified that Pools 20 and 21 have substantial areas of low quality habitat that is undesirable from a forestry, wildlife, and wetlands perspective. Parts of Pool 22 are unleveed and Pool 24 has abundant natural sloughs and high-quality habitat on private lands (duck clubs, etc.) which may not be reflected in the indicator score.

For Pools 24, 25, and 26, even though overall acres in natural areas are mid-range when compared to the rest of the system, the proportion of available area on the floodplain is much greater. The RRAT based its ratings of these pools on the “unused potential”, and for the greater opportunity to perform restoration work.

For longitudinal floodplain connectivity, the FWIC rated Pool 18 as “light green”, pools 17, 20, 21, and 25 as “yellow,” Pools 22, 24, and 26 as “orange”. The RRAT rated Pools 24 and 26 as “red” and Pool 25 as “yellow”. Both River Teams rated the Lower Impounded cluster as “orange” (Table 3-11).

3.4.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - LEVEED AREA (HECTARES/RIVER MILE)

This indicator is defined by the total hectares per river mile behind Federal levees, as catalogued in the Federal Levee Database. This data source results in a limitation of applicability for this indicator within the Lower Impounded cluster because of the extensive network of private levees, particularly throughout Pools 20 and 26. The River Teams note that this indicator likely is an underestimation of leveed acres within each of these pools. Although the extensive levee network in the Lower Impounded cluster limits lateral connectivity, Pools 20 and 24 are known to have a lot of good habitat behind levees resulting from duck clubs and other habitat management. The River Teams identified that this section of the river would benefit from removal of levees in some areas to restore connectivity to floodplain habitat lost to agricultural and other levees.

For lateral river-floodplain connectivity (leveed area), the FWIC rated Pool 17 as “orange” and Pools 18, 20, 21, 22, 24, 25 and 26 as “red”. The RRAT rated Pools 24, 25, and 26 as “red”. Both River Teams rated the Lower Impounded cluster as “red” (Table 3-11).

3.4.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

The pools within the Lower Impounded cluster have greater open water acreage than historically present. Although open water acreage is available, river managers noted that it consisted mostly of lower quality habitat. Too much open water and over-connection results in wind fetch, erosion, and suppressed aquatic vegetation, but too little open water habitat has negative effects as well. Although some remnant islands remain, such as within Pool 17, the significant levee network within the Lower Impounded cluster results in a lack of connection to and diversity of water environments on the floodplain.

The River Teams recommended that the UMRR Program could benefit the Lower Impounded cluster pools by focusing on restoring habitat to conditions similar to Pool 19 and restoration of islands in the lower pool areas.

For lateral river-floodplain connectivity (open water), the FWIC rated Pool 17 as “yellow,” Pools 18, 20, 21 and 22 as “orange” and Pools 24, 25 and 26 as “red”. The RRAT rated Pools 24, 25, and 26 as “orange”. Both River Teams rated the Lower Impounded cluster as “orange” (Table 3-11).

3.4.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-12. Results of River Team ratings for the Lower Impounded cluster indicators of diversity and redundancy. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class 1 (unitless)		Aquatic Functional Class 2 (unitless)		Aquatic Vegetation Diversity (unitless)		Floodplain Vegetation Diversity (unitless)		Floodplain Functional Class Diversity (unitless)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
17	-0.49	-0.76	0.13	0.03	0.04	0.07	0.62	0.68	0.83	0.82
18	-0.22		-0.28		0.19		0.74		0.86	
20	-1.30		-0.21		0.01		0.73		0.79	
21	-0.58		0.30		0.01		0.62		0.81	
22	-1.08		-0.05		0.06		0.70		0.82	
24	-0.92		0.12		0.17		0.76		0.83	
25	-0.73		-0.05		0.05		0.73		0.85	
26	-0.77		0.31		0.03		0.52		0.75	

3.4.2.1 AQUATIC FUNCTIONAL CLASS 1

Overall, the aquatic functional class diversity indicator scores were fairly favorable for the Lower Impounded cluster; however, the FWIC would like to see a shift towards more diverse lentic and lotic habitats. The pools within the Lower Impounded cluster have some side channels, but little lotic habitat acreage (deep or shallow), and the existing lentic habitat is shallow and of low quality. The FWIC identified opportunities to restore and enhance existing habitats. The River Teams desire more lentic and backwater habitats, preferably deep lentic.

For aquatic functional class 1, the FWIC rated Pools 17, 20, 21, 22, 25 and 26 as "yellow" and Pools 18 and 24 as "orange." The RRAT rated Pools 24, 25, and 26 as "yellow". Both River Teams rated Lower Impounded cluster as "yellow" (Table 3-12).

3.4.2.2 AQUATIC FUNCTIONAL CLASS 2

De Jager et al. (2018) found the Lower Impounded cluster to be lacking in deep water fish habitat in the backwater pools. All of the Lower Impounded cluster has been negatively impacted by sedimentation and are in need of maintenance according to the FWIC. The existing shallow water habitats are of low quality as observed by river managers. The River Teams would like to see an increase in habitat diversity, including both shallow lotic areas and deep lentic areas.

For aquatic functional class 2, the FWIC rated Pools 17 and 18 as “orange” and Pools 20, 21, 22, 24, 25 and 26 as “yellow”. The RRAT rated Pools 24, 25, and 26 as “yellow”. Both River Teams rated the Lower Impounded cluster as “yellow” (Table 3-12).

3.4.2.3 AQUATIC VEGETATION DIVERSITY

Aquatic vegetation is for the most part non-existent within the fully and semi-connected areas of Lower Impounded cluster. Backwater habitats that promote and protect vegetation growth are limiting and TSS is too high to support aquatic vegetation. Promotion of aquatic vegetation coverage and diversity is desired by the River Teams. Specifically, it would be beneficial to have more aquatic vegetation in transitional areas in place of terrestrial wetland vegetation as noted by the River Teams. When evaluating Pools 24-26, the RRAT was not expecting the indicator value to be as low as it was, even though it recognizes that there are not many places where aquatic vegetation grows in these pools. However, there are opportunities and a desired need to improve aquatic vegetation through restoration work.

For aquatic vegetation diversity, the FWIC and RRAT rated all individual Lower Impounded as “red”, as well as the Lower Impounded cluster (Table 3-12).

3.4.2.4 FLOODPLAIN VEGETATION DIVERSITY

Overall, floodplain vegetation diversity within the Lower Impounded cluster is good where vegetation is present. Removing invasive species from inclusion in the indicator diversity values would provide a more accurate representation of diversity for management purposes; high diversity scores do not necessarily mean good quality. In terms of floodplain forest, there is an overall lack of tree species diversity throughout the Lower Impounded cluster. River managers have observed that species such as oaks, walnuts, and pecans used to be in the system, but have either disappeared or are drastically reduced. Most of the floodplain now consists of flood tolerant species such as willow, silver maple, and cottonwood. Threats from the invasive Emerald Ash Borer on floodplain forest should be considered as the UMRR Program seeks to make the floodplain more resilient through restoration efforts. The River Teams noted that there are numerous additional threats to vegetation diversity throughout the Lower Impounded cluster that should be addressed through management. Despite current and future threats, there are opportunities to restore and enhance floodplain vegetation.

For floodplain vegetation diversity, the FWIC rated Pools 18, 20 and 22 as “light green”, Pools 17, 21, 24 and 25 as “yellow”, and Pool 26 as “yellow”. The RRAT rated Pools 24 and 25 as “yellow” and Pool 26 as “yellow”. Both River Teams rated the Lower Impounded cluster as “yellow” (Table 3-12).

3.4.2.5 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

The Lower Impounded cluster contains some good areas of hydro-geomorphic diversity where there is access to the river, but overall there is a lack of historic topographic diversity. Although the indicator values reflect relatively high diversity, the FWIC has determined there is room for improvement. Overall, the FWIC concluded that this was a difficult indicator to understand.

The RRAT identified an opportunity to restore more ridge and swale floodplain topography within Pools 24, 25, and 26. There is a desired need to restore and enhance existing floodplain topography and inundation periods. Environmental Pool Management[4] is resulting in a diversity of inundation periods from year-to-year, and the RRAT supports continued environmental pool management into the future.

For floodplain functional class diversity, the FWIC rated Pools 17, 18 and 22 as "light green" and Pools 20, 21, 24, 25 and 26 as "yellow". The RRAT rated Pools 24 and 25 as "light green" and Pool 26 as "yellow". Both River Teams rated the Lower Impounded cluster as "yellow" (Table 3-12).

3.4.3 CONTROLLING VARIABLES INDICATORS

Table 3-13. Results of River Team ratings for the Lower Impounded cluster indicators of controlling variables. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Water Surface Elevation Fluctuation				Total Suspended Solids Concentrations (mg/L)	
	Tailwater Flux Difference (m)		Pool Flux Difference (m)			
Navigation Pool	Pool Average	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
17	0.67	0.84	-0.51	-1.22	52.68	76.92
18	0.93		-1.62		54.06	
20	0.72		-0.49		79.17	
21	0.82		-0.77		64.65	
22	1.36		-1.24		121.25	
24	0.90		-1.40		No data	
25	0.85		-1.54		89.69	
26	0.44		-2.18		No data	

[4] The USACE-St. Louis District's Environmental Pool Management (EPM) implemented in 1994 attempts to create thousands of acres of critical wetland vegetation in the navigation pools, while still maintaining a safe and dependable navigation channel. A successful environmental pool management year is to keep the already drawn down pools (due to high flows), continued drawn down 0.5 to 2.0 feet for at least 30 days. This pool drawdown occurs between May and August, with the May-June period being the most desirable for vegetation growth and seed production. It should be noted that maximum drawdown (4-6 feet) at the pools are not related to EPM.

3.4.3.1 WATER SURFACE ELEVATION FLUCTUATION - TAILWATER FLUX

The individual navigation pools of the Lower Impounded cluster are similar in variability today compared to pre-lock conditions. The FWIC would like to see the indicator values move closer to zero to better represent historic conditions despite these pools being close to the pre-lock and dam condition. The existing condition still has too much variability according to the River Teams. The FWIC primarily based its ratings on moving the water level flux towards historic conditions and did not consider complexity of dam operations in its ratings. The RRAT would desire less variability and mimic the pre-dam condition. Overall, there is room for improvement especially during the growing season.

For water surface elevation fluctuation (tailwater flux), the FWIC rated Pools 17, 18, 20, 21, 22, 25 and 26 as “orange” and Pool 24 as “red”. The RRAT rated Pools 24, 25, and 26 as “orange”. Both River Teams rated the Lower Impounded cluster as “orange” (Table 3-13).

3.4.3.2 WATER SURFACE ELEVATION FLUCTUATION - POOL FLUX

The FWIC desires more predictable pool flux, primarily a more predictable spring flood, summer drawdown, and fall season rise. According to river managers, there are some benefits in stability during certain points of the year, but seasonal flooding has caused an impact on fish populations. The FWIC would like the pool fluctuation conditions to better reflect pre-impoundment conditions, in addition to the flexibility to conduct drawdowns, particularly in Pools 18 and 22. Additionally, the FWIC questioned how much the indicator values may be influenced by hinge-point versus dam-point operation. The RRAT concurs with the FWIC and would like pool fluctuation conditions to better mimic pre-impoundment conditions. Overall, in terms of indicator importance, the RRAT was not as concerned with this indicator as compared to tailwater flux.

For water surface elevation fluctuation (pool flux), the FWIC rated all of the individual Lower Impounded pools as “orange”, as well as the Lower Impounded cluster. The RRAT rated Pools 24, 25, and 26 as “yellow”, as well as the Lower Impounded cluster (Table 3-13).

3.4.3.3 TOTAL SUSPENDED SOLIDS CONCENTRATIONS

The high amount of total suspended solids (TSS) within the Lower Impounded cluster is likely causing the lack of aquatic vegetation observed in off-channel areas. However, if TSS from backwater and side channel areas were included in the indicator, the resulting values may be significantly different as noted by the River Teams. Both River Teams agree that TSS is too high and there is room for improvement; however, it may be difficult to address TSS through UMRR actions due to the sediment load sources (uplands and watershed modifications).

For TSS, the FWIC rated Pools 20 and 21 as “yellow” and Pools 17, 18, 22, 24, 25 and 26 as “orange”. The RRAT rated Pools 24, 25, and 26 as “yellow”. The FWIC rated the Lower Impounded Cluster as “orange”, while the RRAT rated the cluster as “yellow” (Table 3-13).

3.4.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team rating for the Lower Impounded cluster are summarized in Figure 3-4. De Jager et al. (2018) characterized the lower impounded pools as having much less lentic area and more lotic area compared to the Upper and Middle Impounded clusters. Below Pool 19, TSS concentrations increase and aquatic vegetation decreases. The navigation pools of the Lower Impounded cluster contain the greatest amount of forest cover in early successional communities (e.g., cottonwood).

Overall, for the Lower Impounded cluster, the future desired habitat condition captured during discussions with the River Teams (and may reflect individual agency priorities) included:

- Improve gate management for native fish passage
- Restore floodplain habitat and connectivity to the main channel
- Restore islands
- Restore diversity of aquatic habitat types with desire for more lentic and backwater habitats, preferably shallow lotic areas and deep lentic areas
- Restore aquatic vegetation in backwater areas
- Restore floodplain forest diversity, including hard-mast (nut-producing trees)
- Enhance floodplain topographic diversity
- Restore floodplain vegetation diversity in hand with diversifying floodplain inundation periods
- Restore water level fluctuation to mimic pre-dam conditions
- Improve water clarity

Color Rating	Lower Impounded Indicators	River Team Importance
Yellow	**Floodplain Functional Class**	**High**
	Floodplain Vegetation	**High**
	Aquatic Functional Class 2	**High**
	Aquatic Functional Class 1	
	% Time Gates Open	Low
Orange	Total Suspended Solids	Medium
	Pool Flux	Low
	Tailwater Flux	Low
	Open Water	**High**
	Natural Area	Medium
Red	Aquatic Vegetation	Medium
	Leveed Area	Medium

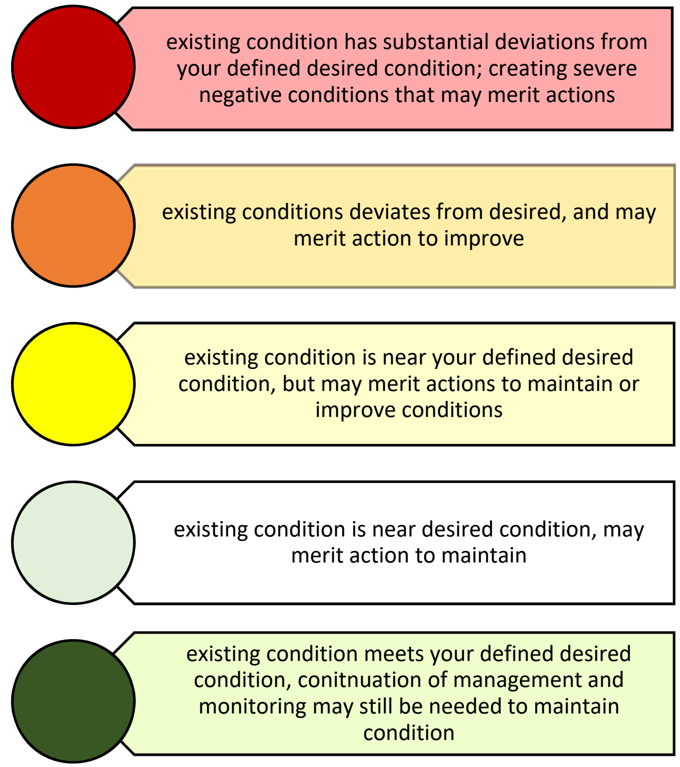


Figure 3-4. Summary of ratings for the 12 indicators of ecosystem structure and function for the Lower Impounded Cluster as provided by the FWIC ratings as determined by averaging the individual agency ratings.

3.5 OPEN RIVER CLUSTER

The Open River cluster is comprised of two reaches (OR1 and OR2). This cluster is unique in that it has no lock and dams, dominated by lotic conditions, has a wide floodplain with large amounts behinds levees, and has the greatest abundance of structural channel area while having minimal area of lentic habitats (De Jager et al., 2018).

The agencies of the RRAT assessed HNA-II indicators for the Open River cluster during a January 23, 2018, workshop. Additional email communications followed the workshop to refine the ratings for each of indicators shown in Table 3-14, as well as a paired-comparison exercise among all indicators to assess their relative importance. The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Indicators that were selected over another indicator were then tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, floodplain and aquatic functional classes were considered most important indicators for the Open River cluster whereas total suspended solids was determined the least important indicator (Table 3-14). The importance (high, medium, or low) of each indicator was determined based on natural breaks in the tallied scores from the MDC, USFWS, ILDNR, and USACE – St. Louis.

Table 3-14. Ranking results of paired-comparison exercise for the Open River Cluster

Resilience Theme	Indicator	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	8	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	6	Medium
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	5	Medium
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	4	Medium
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	1	**High**
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	6	Medium
	Floodplain Vegetation Diversity (Simpson's)	3	**High**
	Floodplain Functional Class Diversity (Simpson's)	1	**High**
Controlling Variables	Tailwater Flux difference (m)	9	Low
	Pool Flux difference (m)	n/a	n/a
	Total Suspended Solids Concentrations (mg/L)	10	Low

Resource agencies individually rated each indicator, and through averaging and discussion, consensus for an overall River Team rating was produced for the indicators describing aspects of connectivity (Table 3-15), diversity and redundancy (Table 3-16), and controlling variables (Table 3-17).

3.5.1 CONNECTIVITY INDICATORS

Table 3-15. Results of River Team rating for the Open River cluster indicators of connectivity. The colors correspond to the River Team consensus based ratings for the Pool and the Open River cluster. Patterned colors represent complete agreement among the agencies. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	Longitudinal Aquatic Connectivity		Longitudinal Floodplain Connectivity		Lateral River-Floodplain Connectivity			
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area (ha/RM)		Open Water (ha/RM)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
OR1	100	100.00	205.52	189.40	540.80	420.60	138.17	115.63
OR2	100		173.28		300.40		93.08	

3.5.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

The Open River cluster supports the highest degree **of** longitudinal aquatic connectivity in the UMRS because there are no locks and dams within this reach of river. Percent of time that gates are open was rated by RRAT to be lower in importance when compared to other indicators, but it was viewed as more important than tailwater flux and total suspended solids (Table 3-14). The RRAT noted that even though this indicator was rated green, there are localized longitudinal connectivity issues that are not captured by this indicator, such as those created by wing dikes and closing structures. The RRAT identified that opportunities do exist in the Open River cluster to restore aquatic connectivity and the UMRR Program could continue to seek restoration projects to restore aquatic connectivity, such as, side channels and in proximity to existing river training structures.

For longitudinal aquatic connectivity, the RRAT rated this indicator as “green” for each reach (OR1 and OR2) as well as for the overall cluster grouping (Table 3-15).

3.5.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

This indicator represents the ability of an organism to traverse the system north to south, e.g., migratory birds. This indicator does not encompass quality of the natural area, and invasive species within the existing natural areas are not captured.

Compared to the rest of the UMRS, the Open River indicator value for natural area was halfway between the extremes. The Open River cluster has natural area in the floodplain, but it is often limited to the narrow batture areas (land on the river-side of levees). Opportunities to restore natural vegetation on the floodplain are ample in the Open River as noted by the RRAT. Restoring the floodplain natural areas could also benefit water quality and fisheries.

For longitudinal floodplain connectivity, the RRAT rated this indicator "orange" for both OR1 and OR2 as well as the overall cluster due to natural areas being disconnected from each other and to the river (Table 3-15).

3.5.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY- LEVEED AREA (HECTARES/RIVER MILE)

This indicator is defined by the total hectares per river mile behind Federal levees, as catalogued in the Federal Levee Database. This data source results in a limitation of applicability for this indicator within the Open River cluster as a result of an extensive network of private levees. The RRAT noted that this indicator likely is an underestimation of leveed acres.

Compared to the rest of the UMRS, the Open River indicator value was midway between the extremes for the system. This was unexpected by the RRAT, since the majority of this reach is leveed. However, this is a limitation of the indicator, which only used the system-wide Federal levee database. Numerous levees that are not included in the Federal levee database exist in the Open River. Opportunities to restore lateral connectivity through modification of levees is desired by the RRAT.

For lateral river-floodplain connectivity (leveed area), the RRAT rated this indicator "red" for OR1, OR2, and the overall cluster and acknowledge that the indicator value is underestimate for the reach (Table 3-15).

3.5.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

This indicator represents the over-connectedness and is used to indicate the ability of water, energy, nutrients, and organisms to move laterally across the river-floodplain. Within the Open River cluster, the main channel of the Mississippi River is constrained by levees; therefore, the RRAT would desire to seek out opportunities to restore lateral floodplain connectivity.

The RRAT rated lateral river-floodplain connectivity (open water) as "red" for OR1, OR2, and the overall cluster (Table 3-15).

3.5.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-16. Results of River Team ratings for the Open River cluster indicators of diversity and redundancy. The colors correspond to the River Team consensus based ratings for the Pool and the Open River cluster. Patterned colors represent complete agreement among the agencies. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class 1		Aquatic Functional Class 2		Aquatic Vegetation Diversity		Floodplain Vegetation Diversity		Floodplain Functional Class Diversity	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
OR1	-	-1.25	0.20	0.20	0.07	0.10	0.77	0.76	0.80	0.79
OR2	-		0.20		0.14		0.74		0.79	

3.5.2.1 AQUATIC FUNCTIONAL CLASSES 1 & 2

The aquatic functional class indicators (AFC1 and AFC2) were viewed as the most important by the RRAT when compared to other indicators when evaluating the Open River cluster (Table 3-14). The Open River cluster is characterized by a lack of lentic areas and high abundance of lotic areas with structure (e.g., wing dikes) and scour areas. The indicator value is in a desirable range, but there is desire from the RRAT for an increase in deep lentic and shallow lentic areas (e.g., backwaters) within the Open River cluster.

The RRAT rated AFC1 (measure of lotic vs. lentic) as "orange" for OR1, OR2, and the overall cluster since there is a need to increase lentic areas and improve the existing lotic habitat function. The RRAT rated AFC2 (measure of structured vs. shallow) as "yellow" for OR1, OR2, and the cluster group (Table 3-16).

3.5.2.2 AQUATIC VEGETATION DIVERSITY

For the Open River cluster, aquatic vegetation diversity was scored lower in importance than other diversity indicators (Table 3-14). The Open River cluster is not expected to have abundant aquatic vegetation in the main channel of the river as observed by river managers, but there are opportunities for restoration in off-channel areas. In the Open River cluster, most of the off-channel areas that would support aquatic vegetation are disconnected behind levees as noted by the RRAT. Opportunities to restore aquatic vegetation in off-channel areas is desired by the RRAT.

For aquatic vegetation diversity, the RRAT rated OR1, OR2 and the overall cluster as "red" (Table 3-16).

3.5.2.3 FLOODPLAIN VEGETATION DIVERSITY

Floodplain vegetation diversity (based on interpretation of land cover classes) within the Open River cluster is not as diverse as desired by the RRAT. Overall, this indicator was considered important to use when evaluating this reach (Table 3-14). The RRAT noted that there are opportunities to improve this indicator for the Open River cluster, which could include restoration work on the landward side of levees and forest enhancements within the batture lands of levees. With expected concerns with future invasive species (i.e., Emerald Ash Borer) this indicator may decrease in value in the future as noted by the RRAT. There is opportunity for the UMRR Program to be pro-active with floodplain vegetation restoration through strategic floodplain vegetation restoration projects. The RRAT identified restoring and enhancing the floodplain vegetation would also benefit other wildlife of concern, including migratory birds and bats.

For floodplain vegetation diversity, the RRAT rated OR1, OR2, and the overall cluster as "yellow" (Table 3-16).

3.5.2.4 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

This indicator was scored as one of the highest in importance compared to other indicators (Table 3-14) for the Open River cluster. Compared to the rest of the system, the Open River cluster had a high indicator value for floodplain functional class diversity; however, the RRAT determined there is not an even mix of the inundation periods. The RRAT's future desired condition for this indicator would be to improve hydrologic routing across the floodplain and allow for a variety of inundation periods to meet the needs of a suite of vegetation, fish, and wildlife. To do this, the RRAT identified a need to restore inundation diversity, including duration periods greater than 60 days.

For floodplain functional class diversity, the RRAT rated the OR 1, OR2, and overall cluster as "yellow" (Table 3-16).

3.5.3 CONTROLLING VARIABLES INDICATORS

Table 3-17. Results of River Team ratings for the Open River cluster indicators of controlling variables. The colors correspond to the River Team consensus based ratings for the Pool and the Open River cluster. Patterned colors represent complete agreement among the agencies. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Water Surface Elevation Fluctuation				Total Suspended Solids Concentrations (mg/L)	
	Tailwater Flux Difference (m)		Pool Flux Difference (m)			
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
OR1	5.07	4.83	n/a	n/a	209.97	209.97
OR2	4.59		n/a		No data	

3.5.3.1 WATER SURFACE ELEVATION FLUCTUATION - TAILWATER FLUX

This indicator was scored second lowest in terms of importance for the Open River cluster (Table 3-14). Even though the Open River cluster has no lock and dams, the indicator was developed using data within the Open River cluster and was grouped as "tailwater flux" for naming consistency with the other river segments. The Open River cluster is experiencing higher flows and faster velocities as compared to pre-lock and dam conditions, which has led to habitat degradation. The RRAT identified opportunities to improve this indicator through restoration efforts that could include levee setbacks, watershed improvements, and/or modifying lock and dam operations upstream of the Open River cluster.

For water surface elevation fluctuation (tailwater flux), the RRAT rated it “red” for the OR1, OR2, and for overall cluster (Table 3-17).

3.5.3.2 TOTAL SUSPENDED SOLIDS CONCENTRATIONS

The RRAT rated this indicator the lowest in terms of importance for the Open River cluster (Table 3-14) when compared to all other indicators. The Open River is expected to have higher TSS compared to the rest of the system. Overall, the RRAT rated TSS as “yellow” for the OR1 and the overall cluster. Main channel TSS values are “normal”; but how main channel TSS impact off-channel TSS is the bigger question to address when looking to restore the Open River cluster. The RRAT identified opportunities to restore connectivity and hydrogeomorphology throughout the Open River cluster, which would help address the problems of higher TSS values in the off-channel areas.

Overall, the RRAT rated TSS as “yellow” for the OR1, OR2, and the overall cluster (Table 3-17).

3.5.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team ratings for the Open River cluster are summarized in Figure 3-5. De Jager et al. (2018) characterized the Open River as having the highest degree of longitudinal aquatic connectivity, greatest abundance of structured channel areas, and the highest total suspended solids concentrations for the UMRS. The Open River cluster has an expansive floodplain but it is laterally isolated from the river due to levees.

Overall, for the Open River cluster, the future desired habitat condition captured during discussions with the River Team (and may reflect individual agency priorities) included:

- Restore floodplain habitat and connectivity to the main channel
- Restore lentic areas (both shallow and deep areas) and improve lotic function
- Restore aquatic vegetation in backwater areas
- Restore ridge and swale floodplain topography
- Restore floodplain vegetation diversity in hand with diversifying floodplain inundation periods (i.e., greater than 60 days)
- Restore water level fluctuation to mimic pre-dam conditions
- Improve water clarity in off-channel areas

Color Rating	Open River Indicators	River Team Importance
n/a	Pool Flux n/a	n/a
Dark Green	% Time Gates Open	Low
Yellow	Total Suspended Solids	Low
	Floodplain Functional Class	**High**
	Floodplain Vegetation	**High**
	Aquatic Functional Class 2	**High**
Orange	**Aquatic Functional Class 1**	**High**
	Natural Area	Medium
Red	Tailwater Flux	Low
	Aquatic Vegetation	Medium
	Open Water	Medium
	Leveed Area	Medium

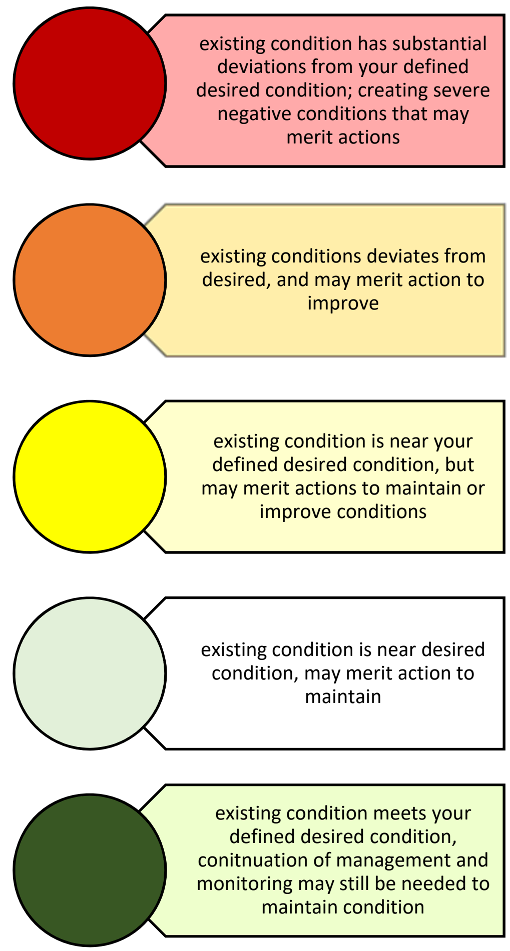


Figure 3-5. Summary of ratings for the 12 indicators of ecosystem structure and function for the Open River cluster as agreed upon by a consensus-based discussion within the RRAT

3.6 UPPER ILLINOIS RIVER CLUSTER

Navigation pools Dresden, Marseilles, and Starved Rock on the Illinois River were grouped together, sharing similar characteristics and were evaluated by the FWIC. A paired comparison exercise was conducted by the agencies of the FWIC to assess relative importance of the indicators (Table 3-18). The paired comparison exercise asked each agency to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Indicators that were selected over another indicator were then tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, aquatic vegetation diversity was tallied the highest as well as floodplain vegetation diversity and floodplain functional class diversity being considered more important when compared to all other indicators. The lowest scored indicator was percent time gates are open with pool flux also ranking lower when compared to the other indicators (Table 3-18). The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the ILDNR, USACE-Rock Island, and USFWS-Ecological Services (Table 3-18).

Table 3-18. Ranking results of paired-comparison exercise for the Upper Illinois Cluster

Resilience Theme	Indicator	Rank Order	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	7	Medium
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	8	Medium
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	8	Medium
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	4	Medium
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	1	**High**
	Floodplain Vegetation Diversity (Simpson's)	2	**High**
	Floodplain Functional Class Diversity (Simpson's)	2	**High**
Controlling Variables	Tailwater Flux difference (m)	6	Medium
	Pool Flux difference (m)	10	Low
	Total Suspended Solids Concentrations (mg/L)	5	Medium

Resource agencies individually rated each indicator then through averaging and discussion, agreement for an overall River Team rating was produced for the indicators describing aspects of connectivity (Table 3-19), diversity and redundancy (Table 3-20), and controlling variables (Table 3-21).

3.6.1 CONNECTIVITY INDICATORS

Table 3-19. Results of River Team ratings for the Upper Illinois River cluster indicators of connectivity. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area (ha/RM)		Open Water (ha/RM)	
Navigation Pool	Pool l	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Dresden	0.22	0.79	66.95	102.66	0	0.65	67.33	84.55
Marseilles	0.38		124.4		0		84.24	
Starved Rock	1.78		116.5		1.95		102.0	

3.6.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

The indicator values for longitudinal aquatic connectivity within the Upper Illinois River cluster show that the gates are open only a very small percentage of the time. Since aquatic invasive species management is a priority for the State of Illinois, the reduced connectivity resulted in a higher rating than would have otherwise been provided had only native fish species been considered. However, the lack of gate opening is limiting for native migratory fishes and other aquatic species movement throughout the Dresden, Marseilles, and Starved Rock pools of the Upper Illinois River cluster. As identified by the FWIC, the overall ecological health of the Upper Illinois River cluster pools could benefit from increased connectivity; however, it is a tradeoff between the ecological benefits of nutrient flow and native fish movement versus the enhanced movement of aquatic invasive species (e.g., Asian carps). The FWIC recommends that future management actions should weigh the benefits of native aquatic organism passage versus the facilitation of invasive species movement.

Additionally, the FWIC identified that effluent water from Chicago remains an issue for water quality, particularly after storm events, and that effluent water degrades the water quality of much of the Upper Illinois River. The FWIC noted that although water quality has improved over the past few decades, poor water quality remains an issue. The reduced connectivity helps limit the downstream movement of waters degraded by the effluent, decreasing impacts to downstream aquatic communities.

For longitudinal aquatic connectivity, the FWIC rated the entire individual Upper Illinois River pools as "yellow, "as well as the Upper Illinois River cluster (Table 3-19).

3.6.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

Due to the highly channelized geomorphology within the Upper Illinois River cluster, there is a lack of floodplain and natural area. The FWIC noted that all pools in the Upper Illinois River cluster have some quantity of recreation and/or private lands containing natural areas, but the total natural area is limited. The Dresden pool, in particular, has a highly industrialized floodplain further reducing the acreage of floodplain habitat and available connectivity. The FWIC concluded all floodplain areas that could be connected presently were, and there would be limited opportunities in the future to increase the natural area in the floodplain of Dresden pool.

For longitudinal floodplain connectivity, the FWIC rated all of the individual Upper Illinois River pools as "orange", as well as the Upper Illinois River cluster (Table 3-19).

3.6.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - LEVEED AREA (HECTARES/RIVER MILE)

The Upper Illinois River cluster has a much higher gradient and smaller floodplain area compared to the Lower Illinois River cluster pools. The existing floodplain within the Dresden, Marseilles, and Starved Rock pools is highly connected and does not handle as much water as the Lower Illinois River cluster pools, reducing the need for levees as observed by the FWIC. The channel within the Upper Illinois River cluster pools is naturally constrained with bluffs, particularly the Starved Rock pool, and very little floodplain area occurs naturally either inside or behind levees. These qualities reduce the applicability and utility of the lateral river floodplain connectivity indicator for this cluster as noted by the FWIC. Overall, the Upper Illinois River cluster pools are considered highly connected, meaning what floodplain was historically available and is currently physically available is already connected.

For lateral river-floodplain connectivity (leveed area), the FWIC rated all of the individual Upper Illinois River pools as "green", as well as the Upper Illinois River cluster (Table 3-19).

3.6.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

Impoundment of the Upper Illinois River cluster pools, particularly the Dresden and Marseilles pools, created off-channel aquatic habitat areas that were not present under pre-impoundment conditions. Additionally, the FWIC noted that it is likely the floodplain in this reach was also artificially created by impoundment and diversion of Lake Michigan waters. The existing open water habitats are suitable for waterfowl and other bird species, but do not serve as significant fish habitat as noted by the river managers.

The FWIC rated the Dresden pool as high (green) due to the physical environment providing very little room for improvement. River managers noted that the Marseilles and Starved Rock pools have more open water and off-channel habitats compared to the Dresden pool; however, these open areas have high wind fetch and suffer from sedimentation leading to shallow depths, overall resulting in lower quality habitat. Although open water lateral floodplain connectivity is present, the FWIC recommended improvements could be made to increase the quality of the habitat.

For lateral river-floodplain connectivity (open water), the FWIC rated the Dresden pool as "light green" and the Marseilles and Starved Rock pools as "yellow". The Upper Illinois River cluster was rated "yellow" (Table 3-19).

3.6.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-20. Results of River Team ratings for the Upper Illinois River cluster indicators of diversity and redundancy. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class 1 (unitless)		Aquatic Functional Class 2 (unitless)		Aquatic Vegetation Diversity (unitless)		Floodplain Vegetation Diversity (unitless)		Floodplain Functional Class Diversity (unitless)	
Nav Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Dresden	0.71	0.70	-1.38	-0.81	0.47	0.20	0.80	0.76	0.23	0.32
Marseilles	1.13		0.28		0.07		0.71		0.47	
Starved Rock	0.26		-1.32		0.05		0.76		0.26	

3.6.2.1 AQUATIC FUNCTIONAL CLASS 1

Overall, the dams impounding the Upper Illinois River cluster pools are rarely open, resulting in the pools being fairly lentic as noted by river managers. The Dresden and Starved Rock pools are short in length, concentrating the water and making them appear more lotic than they really are as observed by river managers. Currently, the low flows at normal and flat pool conditions result in significant sedimentation of the existing off-channel areas. The lentic areas, particularly in the Starved Rock pool are highly degraded and of low habitat quality as observed by river managers. The FWIC recommended that these pools could benefit from increased flows. However, the Marseilles pool is slightly longer than the Dresden and Starved Rock pools and contains areas that are too lentic as noted by river managers. The FWIC recommended that the Marseilles pool would benefit with the addition of quality backwater habitat.

For AFC1, the FWIC rated The Dresden and Marseilles pools as "light green" and the Starved Rock pool as "yellow." The Upper Illinois River cluster was rated as "light green" (Table 3-20).

3.6.2.2 AQUATIC FUNCTIONAL CLASS 2

Historically, it is unlikely that the pools within the Upper Illinois River cluster ever had a significant amount of depth diversity or quality deep water habitat. Currently, river managers have noted that although the Dresden and Starved Rock pools have backwater wetland habitat available, this habitat is primarily shallow and could benefit from increased depth and depth diversity.

The Marseilles pool was rated higher (green) than the Starved Rock and Dresden pools (red) for this category due to the presence of privately owned, large gravel pit/strip mines, which are fully connected to the main channel of the river.

For AFC2, the FWIC rated the Marseilles pool as “light green” and the Dresden and Starved Rock pools as “red”. The Upper Illinois River cluster was rated as “orange” (Table 3-20).

3.6.2.3 AQUATIC VEGETATION DIVERSITY

The Dresden pool does produce a significant amount of vegetation; however, the vegetation diversity is low. As observed by river managers, aquatic vegetation begins to decline as you move downstream, with the Marseilles pool having a limited amount of aquatic vegetation and the presence of aquatic vegetation diminishing by the downstream end of the Starved Rock pool. Overall, the FWIC recommended that all three pools would benefit from increased aquatic vegetation and diversity.

For aquatic vegetation diversity, the FWIC rated the Dresden pool as “orange” and the Marseilles and Starved Rock pools as “red”. The Upper Illinois River cluster was rated as “red” (Table 3-20).

3.6.2.4 FLOODPLAIN VEGETATION DIVERSITY

The floodplain vegetation diversity indicator values for the Upper Illinois River pools were high, comparatively; however, there is an overall lack of floodplain vegetation quality within the Dresden, Marseilles, and Starved Rock pools. The FWIC noted that the indicator values may over-estimate benefits of diversity for these pools due to the invasive species that are included in the diversity index. For this cluster, a high floodplain vegetation diversity score does not necessarily indicate high quality habitat. For example, a significant part of the floodplain is comprised of reed canarygrass, silver maple, cottonwood, and willow, which are not desirable vegetation types to support managed wildlife.

For floodplain vegetation diversity, the FWIC rated all of the individual Upper Illinois River pools as “orange”, as well as the Upper Illinois River cluster (Table 3-20).

3.6.2.5 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

The Upper Illinois River cluster pools are significantly influenced by anthropogenic land uses and development. Very little natural floodplain remains within the Dresden, Marseilles, and Starved Rock pools, resulting in a “red” rating. Overall, the FWIC felt that this was a difficult indicator to understand.

For floodplain functional class diversity, the FWIC rated all of the individual Upper Illinois River pools as “red“, as well as, the Upper Illinois River cluster (Table 3-20).

3.6.3 CONTROLLING VARIABLES INDICATORS

Table 3-21. Results of River Team ratings for the Upper Illinois River cluster indicators of controlling variables. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Tailwater Flux Difference		Pool Flux Difference		Total Suspended Solids Concentrations	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Dresden	No data	No data	No data	No data	No data	No data
Marseilles	No data		No data		No data	
Starved Rock	No data		No data		No data	

3.6.3.1 WATER SURFACE ELEVATION FLUCTUATION - TAILWATER FLUX

No water surface elevation fluctuation data were available during indicator development (De Jager et al., 2018). The FWIC noted that the increased urban development and associated impervious surfaces, in addition to a significant amount of agricultural land bordering the Dresden, Marseilles, and Starved Rock pools, likely have resulted in tailwater and pool fluctuations that have significantly higher variability than historic pre-diversion conditions.

Although indicator values were not provided for water surface elevation fluctuation (tailwater flux) for the Upper Illinois River cluster, the FWIC provided ratings based on professional experience. The FWIC rated the Dresden and Marseilles pools as “orange” and the Starved rock as “red”, and the overall Upper Illinois River cluster as “orange” (Table 3-21).

3.6.3.2 WATER SURFACE ELEVATION FLUCTUATION - POOL FLUX

No water surface elevation fluctuation data were available during indicator development (De Jager et al., 2018). The FWIC noted that the increased urban development and associated impervious surfaces, in addition to a significant amount of agricultural land bordering the Dresden, Marseilles, and Starved Rock pools, likely have resulted in tailwater and pool fluctuations that have significantly higher variability than historic pre-impoundment conditions.

Although indicator values were not provided for water surface elevation fluctuation (pool flux), the FWIC provided ratings based on professional experience. The FWIC rated the Dresden and Marseilles pools at “orange” and the Starved Rock as “red”, and the overall Upper Illinois River cluster as “orange” (Table 3-21).

3.6.3.3 TOTAL SUSPENDED SOLIDS CONCENTRATION

No total suspended solids data were available during indicator development (De Jager et al., 2018) for the Upper Illinois. Although indicator values were not provided, the FWIC provided ratings based on professional experience.

Although indicator values were not provided for TSS, the FWIC provided ratings based on professional experience. The FWIC rated the Dresden as “light green”, Marseilles and Starved Rock as “orange”, and the overall Upper Illinois River cluster as “orange” (Table 3-21).

3.6.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team ratings for the Upper Illinois are summarized in Figure 3-6. De Jager et al. (2018) characterized the Upper Illinois River pools as having low longitudinal aquatic connectivity with dam gates rarely open, abundant shallow lentic areas, and lacking a mix of floodplain vegetation types.

Overall, for the Upper Illinois River, the future desired habitat condition captured during discussions with the River Team (and may reflect individual agency priorities) included:

- Restore seasonal fish passage for native fish; deter aquatic invasive species movement
- Improve quality of open water habitat
- Increase lotic habitat diversity
- Improve lentic backwaters
- Restore aquatic vegetation
- Restore floodplain forest, including hard-mast (i.e., nut-producing trees), where feasible

Color Rating	Upper Illinois Indicators	River Team Importance
Dark Green	Leveed Area	Medium
Light Green	Aquatic Functional Class 1	Medium
Yellow	Open Water	Medium
	% Time Gates Open	Low
Orange	Pool Flux	Low
	Tailwater Flux	Medium
	Floodplain Vegetation	**High**
	Aquatic Functional Class 2	Medium
	Natural Area	Medium
	Total Suspended Solids	Medium
Red	**Floodplain Functional Class**	**High**
	Aquatic Vegetation	**High**

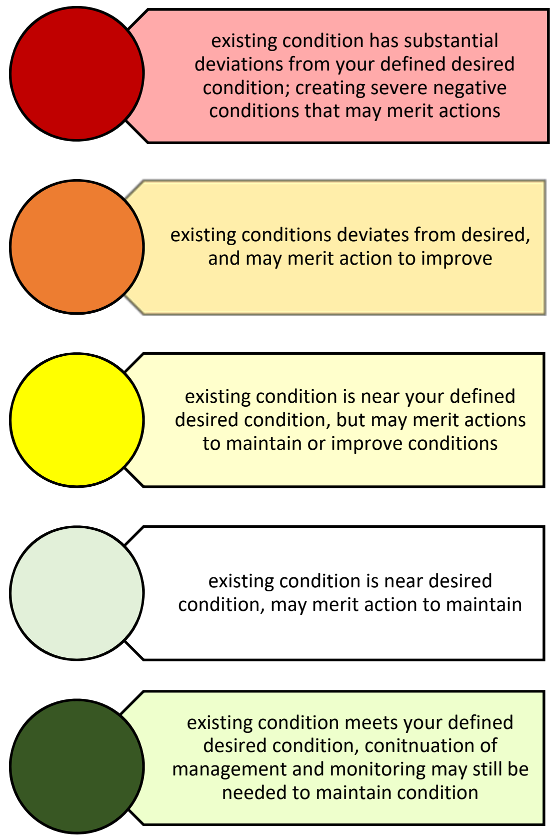


Figure 3-6. Summary of ratings for the 12 indicators of ecosystem structure and function for the Upper Illinois cluster as provided by the FWIC ratings as determined by averaging the individual agency ratings.

3.7 LOWER ILLINOIS RIVER CLUSTER

Navigation pools Peoria, LaGrange, and Alton on the Illinois River were grouped together, sharing similar characteristics and were evaluated by the FWIC.

A paired comparison exercise was conducted FWIC agencies to assess relative importance of the indicators (Table 3-22). The paired comparison exercise asked the agencies to select between two indicators in terms of importance. Every combination of indicators was created for comparison. Indicators that were selected over another indicator were then tallied. The higher the tally the more times this indicator was selected in comparison to another. From this pair-comparison exercise, the presence of TSS was tallied the most, with total floodplain vegetation diversity and floodplain functional class diversity being of higher importance compared to all other indicators. The lowest tallied indicators included natural area and percent time gates are open. The importance (high, medium, or low) of each indicator was determined based on natural breaks in the combined tally scores from the IADNR, INHS, USACE – Rock Island, and USFWS-Ecological Services (Table 3-22).

Table 3-22. Rating of paired-comparison exercise for the Lower Illinois Cluster

Resilience Theme	Indicator	Rank	Importance
Connectivity	Longitudinal Aquatic Connectivity - % Time gates open	11	Low
	Longitudinal Floodplain Connectivity – Natural Area (ha/RM)	10	Low
	Lateral River-Floodplain Connectivity – Leveed Area (ha/RM)	4	Medium
	Lateral River-Floodplain Connectivity – Open water (ha/RM)	7	Medium
Diversity & Redundancy	Aquatic Functional Class 1 (unitless)	4	Medium
	Aquatic Functional Class 2 (unitless)		
	Aquatic Vegetation Diversity (Simpson's)	6	Medium
	Floodplain Vegetation Diversity (Simpson's)	2	**High**
	Floodplain Functional Class Diversity (Simpson's)	3	**High**
Controlling Variables	Tailwater Flux difference (m)	8	Low
	Pool Flux difference (m)	9	Low
	Total Suspended Solids Concentrations (mg/L)	1	**High**

Resource agencies individually rated each indicator and through averaging and discussion, produced an overall River Team rating for the indicators describing aspects of connectivity (Table 3-23), diversity and redundancy (Table 3-24), and controlling variables (Table 3-25).

3.7.1 CONNECTIVITY INDICATORS

Table 3-23. Results of River Team ratings for the Lower Illinois River cluster indicators of connectivity. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. Lack of color represents lack of agreement among the agencies. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Connectivity							
	% Time Gates Open		Natural Area (ha/RM)		Leveed Area (ha/RM)		Open Water (ha/RM)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Peoria	45.56	40.81	200.44	193.73	16.79	283.23	182.92	146.86
LaGrange	49.29		225.59		312.62		165.62	
Alton	27.58		155.16		520.28		92.05	

3.7.1.1 LONGITUDINAL AQUATIC CONNECTIVITY - % TIME GATES OPEN

The FWIC primarily considered this indicator from the perspective of the ability for native fishes and other organisms of management interest to traverse the UMRS system longitudinally. Aquatic invasive species were considered when assigning the rating, but since Asian carps are already present in high numbers in every Lower Illinois pool it was deemed not to be a driving issue at this time. It is unlikely that the indicator values as presented will have much influence on aquatic organism movement. The FWIC decided the pool means near 50 percent (Cluster Range: 27.57 – 49.29, Cluster Average: 40.81) for this indicator (% time gates open) were sufficient to support native fish and other aquatic organism movement (De Jager et al., 2018). However, from a resource management perspective, the timing of native fish movement is critical and should be considered when interpreting this indicator. Enhanced fish passage during periods of key life stages that are dependent on dispersal could be targeted for increased longitudinal connectivity through management actions.

For longitudinal connectivity, the FWIC rated the Peoria and La Grange pools, which do not have gates, “light green”, but this indicator is a function of the dam wickets being up or down; while the Alton pool was rated “orange”. The Lower Illinois River cluster was rated “light green” (Table 3-23).

3.7.1.2 LONGITUDINAL FLOODPLAIN CONNECTIVITY - NATURAL AREA (HECTARES/RIVER MILE)

Overall, the FWIC agrees there is fairly good longitudinal floodplain connectivity throughout the Lower Illinois River cluster. However, this cluster could benefit from connectivity improvement, particularly where agricultural land has replaced natural areas and in areas where the habitat is narrow and isolated. Although the indicator values suggest a significant amount of longitudinal floodplain connectivity, a portion of the natural area acreage is of lower quality habitat and would benefit from improvements according to river managers. Additionally, the FWIC identified some of the values for this indicator may be misleading as a result of fluctuating river levels exposing and connecting varying acreage of floodplain seasonally.

The FWIC rated all of the individual Lower Illinois River pools as “yellow,” as well as the Lower Illinois River cluster (Figure 3-23).

3.7.1.3 LATERAL RIVER-FLOODPLAIN CONNECTIVITY- LEVEED AREA (HECTARES/RIVER MILE)

This indicator is defined by the total hectares per river mile behind Federal levees, as catalogued in the Federal Levee Database. This source of data results in a limitation of applicability for this indicator within the Lower Illinois River cluster, as a result of an extensive network of private levees throughout the Peoria, La Grange, and Alton Pools; therefore, the FWIC viewed this indicator as an underestimation of leveed area and concluded that this indicator was not very useful. For example, the Peoria Pool includes private levees and levees that surround the City of Peoria that were not captured with this indicator. For this reason, several agencies within the FWIC did not provide a rating for the Peoria Pool for this indicator since it was a poor representation of the pool. Those that did based their ratings primarily on the indicator values, as presented.

Within the Lower Illinois River cluster reaches, a significant portion of the floodplain is behind levees and isolated from the rivers. Much of this area is used for agriculture practices and is not high quality or useable habitat for managed wildlife resources as observed by river managers. However, some floodplain areas behind the levee, such as within the La Grange pool, have improved ecological conditions compared to similar areas in other pools. According to the FWIC, management actions and other planned activities, such as Conservation Reserve Enhancement Program (CREP) projects, have resulted in improved ecological conditions and habitat.

For lateral river-floodplain connectivity (leveed area), the FWIC rated the La Grange pool as “orange” and the Alton pool as “red”. No score from the FWIC was provided for the Peoria pool. For this pool, the USFWS provided a score of “green” while INHS found this indicator to be a very poor representation of the pool and did not provide a score. The Lower Illinois River cluster was rated “yellow” (Table 3-23).

3.7.1.4 LATERAL RIVER-FLOODPLAIN CONNECTIVITY - OPEN WATER (HECTARES/RIVER MILE)

Although there is a significant amount of area in open water habitat within the Lower Illinois River cluster, allowing for lateral river-floodplain movement, the quality of these areas is significantly reduced when compared to historic conditions pre-diversion, resulting in a lower over-all rating from the FWIC. The FWIC recommended that improvements could be made to increase the quality of open water habitat in this cluster by addressing sedimentation, lack of deep water habitat, depth diversity, and reducing conversion of aquatic areas to terrestrial habitats.

For lateral river-floodplain connectivity (open water), the FWIC rated the Peoria and La Grange pools as “orange” and the Alton pool as “red”. The Lower Illinois River cluster was rated “orange” (Table 3-23).

3.7.2 DIVERSITY & REDUNDANCY INDICATORS

Table 3-24. Results of River Team ratings for the Lower Illinois River cluster indicators of diversity and redundancy. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Diversity & Redundancy									
	Aquatic Functional Class		Aquatic Functional Class		Aquatic Vegetation		Floodplain Vegetation Diversity		Floodplain Functional Class	
Nav Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Peoria	1.49	1.20	-0.07	-0.71	0.06	0.13	0.74	0.73	0.87	0.87
LaGrange	1.20		-0.81		0.25		0.73		0.88	
Alton	0.91		-1.24		0.07		0.73		0.86	

3.7.2.1 AQUATIC FUNCTIONAL CLASS 1

The Lower Illinois River cluster is a shallow, low-flow system with a low diversity of lentic and lotic habitat areas. Much of the shallow, lentic habitat has been lost over the decades and very little deep, lotic habitat remain as observed by river managers. The FWIC noted that the shallow lentic areas are transitioning into terrestrial lands and much of the deep lentic areas transitioned into shallow lentic. Although this cluster is still able to support biota, the FWIC agreed that there is significant room for improvement. Improvement opportunities as recommended by the FWIC include increasing off-channel and floodplain lentic areas to improve the diversity of habitats.

For AFC1, the FWIC rated the Peoria and Alton pools as “yellow” and the La Grange pool as “orange”. The Lower Illinois River cluster was rated as “yellow” (Table 3-24).

3.7.2.2 AQUATIC FUNCTIONAL CLASS 2

The FWIC noted that there is very little lentic and lotic diversity with an abundance of shallow, low-flowing waters within the Lower Illinois River cluster. The FWIC recommended that significant improvement would benefit the pools within the Lower Illinois River cluster, including increasing the amount of and balance between deep lentic areas, shallow waters and deep lotic areas.

For AFC2, the FWIC rated all of the individual Lower Illinois River pools as “red“, as well as the Lower Illinois River cluster (Table 3-24).

3.7.2.3 AQUATIC VEGETATION DIVERSITY

As observed by river managers, very few vegetated areas exist in the Lower Illinois River cluster, with none known to be present in connected areas of the river. Although there is some aquatic vegetation diversity, as identified by the indicator, the patches of aquatic vegetation are fragmented and few, and are primarily managed for migratory waterfowl as noted by the FWIC. Overall, there was high agreement among the FWIC that aquatic vegetation is gone in the Lower Illinois and there is significant room for improvement of aquatic vegetation presence and diversity.

For aquatic vegetation diversity, the FWIC rated the Alton pool as "orange" and the Peoria and La Grange pools as "red". The Lower Illinois River cluster was rated as "red" (Table 3-24).

3.7.2.4 FLOODPLAIN VEGETATION DIVERSITY

The floodplain vegetation diversity indicator values reflect high diversity scores for the pools within the Lower Illinois River cluster; however, there is a lack of high quality floodplain forest habitat and acreage, resulting in a lower rating as noted by the FWIC. Much of the Illinois River system, including the pools within the Lower Illinois River cluster, lacks quality trees, with less desirable flood-tolerant tree species being the most abundant as observed by river managers. The FWIC noted that areas that historically supported high quality forest have been drastically reduced over the years. The FWIC recommended that restoration is necessary to maintain and improve the remaining floodplain vegetation diversity within the Lower Illinois River cluster.

For floodplain vegetation diversity, the FWIC rated the Peoria and La Grange pools as "orange" and the Alton pool as "red". The Lower Illinois River cluster was rated as "orange" (Table 3-24).

3.7.2.5 FLOODPLAIN FUNCTIONAL CLASS DIVERSITY

In general, the hydro-geomorphic variability of the non-aquatic floodplain areas within the Lower Illinois River is diverse. However, improvements to expand and maintain the floodplain areas and associated hydro-geomorphic variability could benefit this reach and is desired by the river managers. The FWIC struggled to understand this indicator.

For floodplain functional class diversity, the FWIC rated the Alton pools as "yellow" and the Peoria and La Grange pools as "orange." The Lower Illinois River cluster was rated "orange" (Table 3-24).

3.7.3 CONTROLLING VARIABLES INDICATORS

Table 3-25. Results of River Team ratings for the Lower Illinois River cluster indicators of controlling variables. The colors correspond to the River Team agreed upon averaged rating for the Pool and the River Segment Cluster. The patterned colors represent complete agreement among agency ratings. Solid colors represent averaged rating and the reader is directed to Appendix A for individual agency ratings. The numerical values in the table correspond to the raw data from De Jager et al. (2018) and were used to assess the indicators.

	Controlling Variables					
	Tailwater Flux Difference (m)		Pool Flux Difference (m)		Total Suspended Solids Concentrations (mg/L)	
Navigation Pool	Pool	Cluster Mean	Pool	Cluster Mean	Pool	Cluster Mean
Peoria	3.44	3.27	1.05	1.03	No data	64.24
LaGrange	3.09		1.00		64.24	
Alton	No data		No		No data	

3.7.3.1 WATER SURFACE ELEVATION FLUCTUATION - TAILWATER FLUX

The FWI identified tailwater surface elevation fluctuation as one of the biggest issues negatively affecting the Lower Illinois River cluster. The current water surface elevation fluctuation (tailwater flux) compared to historic conditions within the Illinois River system is much too variable, surpassing that seen on the Upper Mississippi River as noted by river managers. The FWIC recommended management actions to reduce this variability would provide system-wide benefits.

For water surface elevation fluctuation (tailwater flux), the FWIC rated the Peoria and La Grange pools as “yellow” and the Alton pool as “red”. The Lower Illinois River cluster was rated as “yellow” (Table 3-25).

3.7.3.2 WATER SURFACE ELEVATION FLUCTUATION - POOL FLUX

The FWIC identified pool surface elevation fluctuation as one of the biggest issues negatively affecting the Lower Illinois River cluster. The current water surface elevation fluctuation (pool flux) compared to historic conditions within the Illinois River system is much too variable, surpassing that seen on the Upper Mississippi River as noted by river managers. The FWIC recommended management actions to reduce this variability would provide system-wide benefits.

For water surface elevation fluctuation (pool flux), the FWIC rated the Peoria and La Grange pools as “orange” and the Alton pool as “red”. The Lower Illinois River cluster was rated as “orange” (Table 3-25).

3.7.3.3 TOTAL SUSPENDED SOLID CONCENTRATIONS

The FWIC identified TSS concentrations as a significant management problem needing to be addressed. The FWIC concluded the load of TSS within the Lower Illinois River cluster is significantly too high, reducing the ability of the system to support growth of submersed aquatic vegetation and other food and habitat resources for managed fish and waterfowl species, as well as continuing to degrade backwater and off-channel habitat.

For TSS, the FWIC rated the Alton pool as “orange” and the Peoria and La Grange pools as “red”. The Lower Illinois River cluster was rated as “red” (Table 3-25).

3.7.4 OVERALL CONCLUSIONS & DESIRED FUTURE HABITAT CONDITION

The River Team ratings for the Lower Illinois cluster are summarized in Figure 3-7. De Jager et al. (2018) characterized the Lower Illinois River cluster as having moderate longitudinal connectivity with gates open about 30-50% of the time, a large amount of shallow lentic area, scarce aquatic vegetation likely due to high total suspended solids, and lack of both deep lotic and deep lentic aquatic habitats.

Overall, for the Lower Illinois River cluster, the future desired habitat condition captured during discussions with the River Team (and may reflect individual agency priorities) included:

- Enhance native fish passage during time periods of key life stages
- Restore former agricultural areas to native floodplain vegetation
- Reduce sedimentation
- Restore deep, lentic and lotic habitats
- Restore open water areas
- Increase off-channel and floodplain lentic areas
- Restore aquatic vegetation
- Restore floodplain topographic diversity and associated inundation periods
- Reduce variability in water surface elevations
- Restore floodplain vegetation diversity

Color Rating	Lower Illinois Indicators	River Team Importance
Light Green	% Time Gates Open	Low
Yellow	Tailwater Flux	Low
	Aquatic Functional Class 1	Medium
	Leveed Area	Medium
	Natural Area	Low
Orange	Pool Flux	Low
	Floodplain Functional Class	**High**
	Floodplain Vegetation	**High**
	Open Water	Medium
Red	**Total Suspended Solids**	**High**
	Aquatic Vegetation	Medium
	Aquatic Functional Class 2	Medium

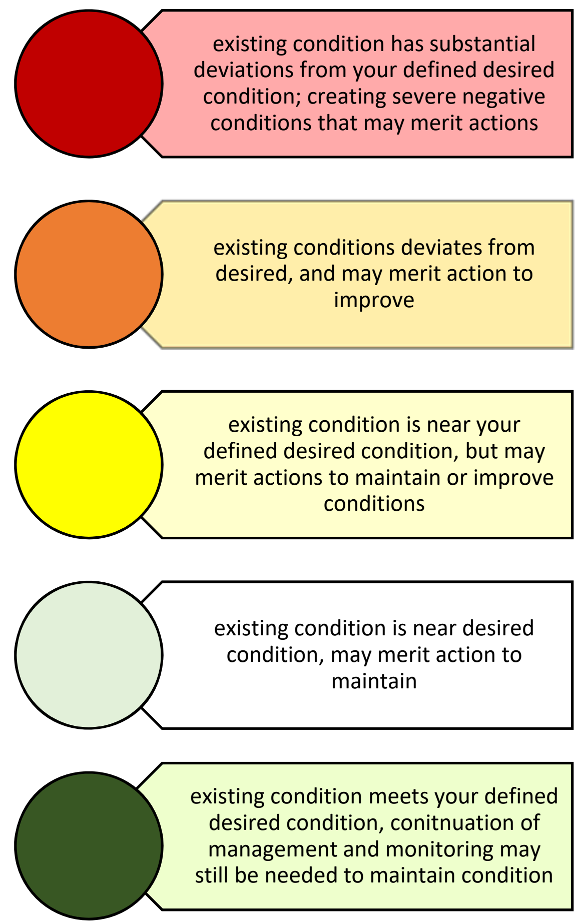


Figure 3-7. Summary of ratings for the 12 indicators of ecosystem structure and function for the Lower Illinois cluster.

4 IMPLICATIONS FOR THE UMRR PROGRAM

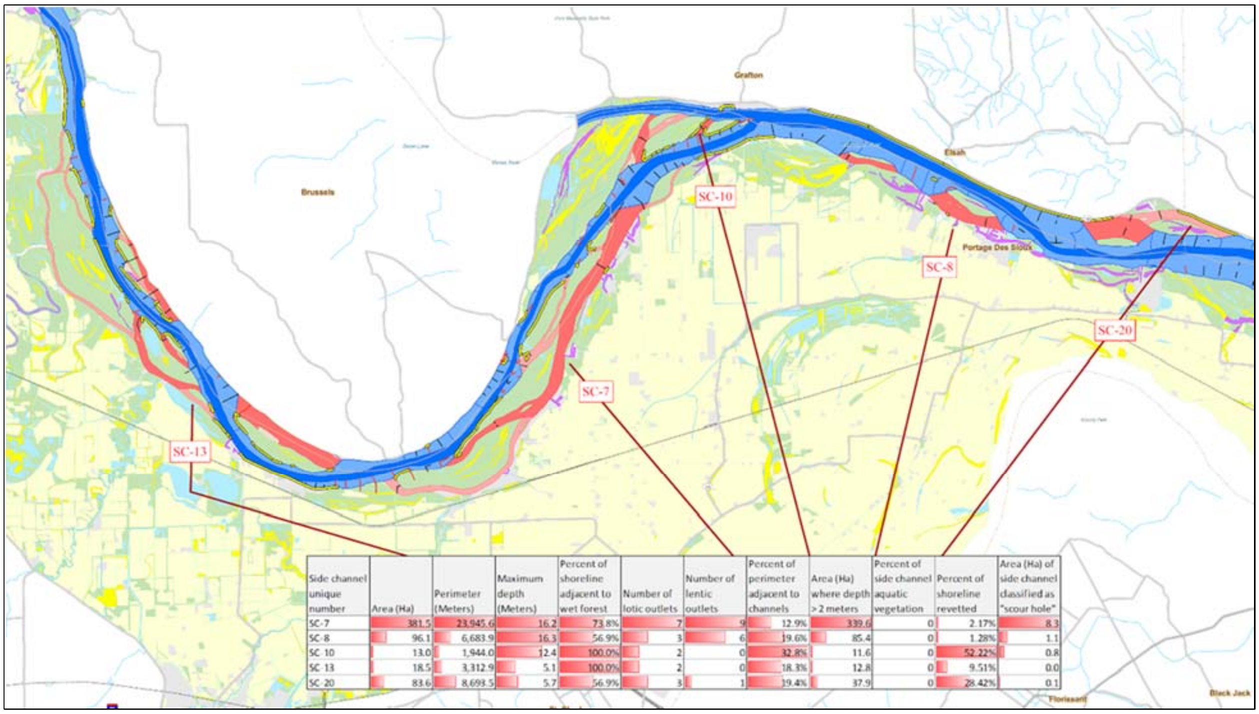
The HNA-II was developed to provide the UMRR Program partnership a system-wide accounting of existing conditions based on indicators describing different aspects of resilience including connectivity, diversity and redundancy, and controlling variables (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review). HNA-II identified areas within the river system that deviate from desired stakeholder conditions as defined by the individual agencies of the UMRR Program, collaboratively discussed by the River Teams, and agreed to by the UMRR CC. This document reports the results of combining scientifically rigorous data and indicators developed by De Jager et al. (2018), with the varied management objectives of the agencies that comprise the UMRR Program. The HNA-II effort, therefore, lays the foundation for data-informed decision-making for the UMRR Program related to habitat project identification, selection, planning, and implementation, as well as achievement of the UMRR Program goals (Table 4-1). Furthermore, the HNA-II effort lays out potential science and data gaps that could be addressed in the future by the UMRR Program.

Table 4-1. Relating HNA-II efforts to meeting UMRR Program Goals

UMRR Program Goal	HNA-II efforts completed to support goal
Enhance habitat for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem	Identification of areas within the system at the navigation pool scale and larger that deviate from the desired conditions for ecosystem health and resilience and therefore may merit action to improve or maintain current conditions. Qualitative descriptions compiled from managers that identify indicators most important to their stakeholders and desired future conditions for those indicators.
Advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem	Development of indicators of resilience describing connectivity, diversity and redundancy, and identification of controlling variables that provide a scientific basis for system-wide assessments. Identification of system-wide data sets including aquatic area functional classes and floodplain functional classes (De Jager et al., 2018) that can be used for habitat objective development, habitat project planning, monitoring, and modeling. Development of floodplain inundation and forest succession models.
Engage and collaborate with other organizations and individuals to help accomplish the UMRR Program vision	A number of indicators will require collaboration with other organizations within the watershed since the source of the external stressors are outside of the jurisdiction of the UMRR Program. Collaborating with other organizations to address both internal and external stressors should be considered moving forward.
Utilize a strong, integrated partnership to accomplish the UMRR Program vision	Partnership agreed upon ecosystem-based objectives for restoring a healthier and more resilient UMRS. Linking data to management perspectives to aid in identifying areas of agreement for the existing conditions of individual navigation pools and clusters of navigation pools based on the resilience indicators.

The information contained within this report can be used by the UMRR Program to more efficiently achieve its four main goals. As described in the *UMRR Strategic Plan 2015-2025,* the first goal of the UMRR Program is *to enhance habitat for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem*. The assessment described in this report clearly identifies navigation pools and clusters of navigation pools of the UMRS that: 1) deviate from desired indicator conditions and may merit restoration actions, 2) are near desired indicator conditions and may merit actions to improve or maintain ecosystem conditions, and 3) meet desired indicator conditions and may merit actions to maintain ecosystem conditions. Moving forward, the UMRR Program can use this information to facilitate the discussion for identifying and selecting the next generation of habitat restoration projects. Future restoration projects, as well as, monitoring of existing projects can benefit from the HNA-II by including evaluations of how projects may influence the characteristics described by these indicators. In addition, these indicators could be incorporated into project monitoring plans to better evaluate project success. The number of indicators, navigation pools, and clusters of navigation pools in less-than desirable conditions (red to yellow) suggests that the need for ecosystem restoration in the UMRS is considerable throughout the system. Hence, the information contained within this document should be used to inform ecosystem restoration planning and project implementation and to track progress throughout the UMRS in attaining desired ecosystem conditions (or to slow departure from desired conditions).

The second goal of the UMRR Program is *to advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem*. In the process of developing HNA-II indicators, the UMRR Program developed new data sets and models that can be used to improve understanding of the UMRS. For example, the aquatic areas database used to develop aquatic functional classes includes over 500 metrics that describe the environmental conditions found within different aquatic habitat patches (Figure 4-1). These metrics can be used to understand associations among environmental variables thought to underpin the health and resilience of local habitat patches as well as the broader UMRS mosaic. In addition, a new surface water connectivity model was developed to better quantify inundation dynamics on the UMRS floodplain. This model can be used to further understand patterns of floodplain vegetation and other ecosystem processes. Furthermore, both the aquatic areas database and the surface water connectivity model can be used to more strategically develop sampling strategies for collecting additional data to better understand ecological patterns and processes within the river and floodplain. Finally, two new models were developed to characterize patterns of sedimentation in off-channel areas and forest succession on the floodplain. These models can be used to identify areas of uncertainty and to make predictions about the effects of alternative management and/or environmental scenarios.



Side channel unique number	Area (Ha)	Perimeter (Meters)	Maximum depth (Meters)	Percent of shoreline adjacent to wet forest	Number of lotic outlets	Number of lentic outlets	Percent of perimeter adjacent to channels	Area (Ha) where depth >2 meters	Percent of side channel aquatic vegetation	Percent of shoreline revetted	Area (Ha) of side channel classified as "scour hole"
SC-7	381.5	23,945.6	16.2	73.8%	7	9	12.9%	339.6	0	2.17%	8.3
SC-8	96.1	6,683.9	16.3	56.9%	3	6	19.6%	85.4	0	1.28%	1.1
SC-10	13.0	1,944.0	12.4	100.0%	2	0	32.8%	11.6	0	52.22%	0.8
SC-13	18.5	3,312.9	5.1	100.0%	2	0	18.3%	12.8	0	9.51%	0.0
SC-20	83.6	8,693.5	5.7	56.9%	3	1	19.4%	37.9	0	28.42%	0.1

Figure 4-1. Example of the aquatic functional classes GIS data layer and attribute table.

The third goal of the UMRR Program is *to engage and collaborate with other organizations and individuals to help accomplish the UMRR vision*. A number of indicators developed for HNA-II reflect patterns and processes operating at a much broader scale and effectively addressing them will require collaboration between the UMRR Program and other programs and organizations. For example, since reducing TSS and improving water clarity is a primary restoration objective for the UMRS, the UMRR Program will need to build collaborative relationships with other entities working within the UMRS watershed. Similarly, since improving lateral river-floodplain connectivity and/or natural area in the floodplain is a priority for the UMRR Program, the Program should work with other agencies and programs to better address complex levee and land ownership constraints on restoration projects.

The fourth goal of the UMRR Program is *to utilize a strong, integrated partnership to accomplish the UMRR vision*. Our approach to HNA-II identified indicators that were evaluated for the navigation pools and clusters of navigation pools by the UMRR Program partnership. This evaluation clarified how the current status of the indicators compared to the desired conditions throughout the UMRS. The HNA-II effort provided information to help the UMRR Program determine how existing conditions related to desired conditions. Where there are unanimous red, yellow, or green ratings, the UMRR Program may be able to more readily propose habitat restoration projects that meet the management needs for a broad stakeholder group. In other areas, where there are differences among the agencies (i.e., red vs. green), which could be resultant from different desired indicator condition, or perhaps different level of value on a particular indicator, or even a different future desired condition, the UMRR Program now has additional information to help facilitate and better understand why there are differences. In these cases, the UMRR Program can use the existing interagency working groups to discuss and better understand how the priorities and mandates of agencies compare with each other and how they relate to the general resilience of the UMRS. In the process of HNA-II, several agency-specific narrative statements were compiled that can be used to help strengthen the UMRR Program partnership by collaboratively working through the connections between general ecosystem health and resilience and the specific mandates of UMRR Program partnership agencies.

4.1 INCORPORATING HNA-II INTO HABITAT RESTORATION PROJECT PLANNING

4.1.1 PROJECT IDENTIFICATION & SELECTION

HNA-II provides information that managers and policymakers can use at multiple scales across the river system and within USACE Districts to more effectively define the types and locations for restoration projects, and to more efficiently sequence restoration, monitoring, and research activities. Currently, the UMRR Program identifies restoration and management projects within the same interagency working groups (i.e., River Teams) that conducted the HNA-II. The broad-scale information provided in this report can facilitate a more systematic approach to project identification and selection by identifying the primary concerns in each of the major river reaches.

The information contained within HNA-II could also help the UMRR Program more effectively implement traditional UMRR restoration projects by better matching them to specific places on the landscape. The broad-scale assessment conducted here can be used to identify potential gaps in desired conditions throughout the system, but also within navigation pools, where the restoration of specific aquatic and floodplain functional classes could improve or maintain diversity of aquatic and floodplain functional classes. Currently, the UMRR Program implements projects that are designed to enhance and/or restore ecosystem structure (i.e., functional classes), function, and dynamic processes based on local or regional resource concerns. HNA-II can be used to evaluate broader ecosystem conditions (within navigation pools, across navigation pools or sets of navigation pools) to better identify potential future locations of restoration projects where they are most needed to improve the resilience of the UMRS.

In contrast, some of the indicators identified as important by the UMRR Program require projects and approaches that are much larger in scale than previous approaches. For example, restoring lateral river-floodplain connectivity via levee modifications, modifying water-level variability, reducing total suspended solids and sedimentation in off-channel areas, modifying long-term trajectories for forest succession and vegetation diversity all require ecosystem-based management approaches that have yet to be implemented widely by the UMRR Program, and many that are outside the Congressionally-authorized limits of the UMRR Program. Thus, the HNA-II effort could help foster a multi-funding/multi-agency approach to restoration that is more in-line with the concepts of ecosystem management, health, and resilience.

However, before the information contained within this report can be made actionable, the UMRR Program should improve the way it defines when and where restoration actions are “most needed”. The HNA-II indicators provide an assessment of where system conditions deviate from desired conditions, where they are close to desired conditions, and where they meet desired conditions. This information, is only part of what is needed for defining the locations or types of future restoration projects. Additional discussions based on this information are needed to fully identify priority restoration projects. For example, future projects could be formulated to address indicators that are very far from desired conditions which may require substantial investments to improve ecosystem conditions. Or restoration projects could be formulated for indicators and locations that are very close to desired conditions which may only require modest investments to improve. Or perhaps restoration projects could be formulated for areas and indicators that meet desired conditions but may require investment to maintain current conditions, especially in consideration of future trajectories of sedimentation and forest succession reported in De Jager et al. (2018). Thus, the UMRR Program can now more specifically define and quantify the goals and objectives for different indicators and parts of the river system as they relate to maintaining and or improving existing conditions. Therefore, the UMRR Program should better define the trajectory to improve resilience of the UMRS (i.e., maintain or restore); quantify a restoration philosophy (e.g., when to restore degraded vs. maintain good) in terms of specific indicators, places on the landscape, and magnitudes of changes it wishes to see; and finally use the quantifications provided here to inform the types of projects and their locations. The process could result in identifying restoration projects that are much broader in scale and scope than previous UMRR projects and/or in strategic placement of more traditional restoration projects. Nevertheless, the information contained within this report should be used as a foundation for effective discussions by the UMRR Program to more specifically define its restoration philosophy and subsequently identify goals and objectives for specific indicators and areas of the UMRS.

The current list of indicators may be considered during the USACE planning process of habitat projects and during development of study objectives and/or success criteria in the monitoring plans. The data sets and data layers developed through the HNA-II effort and the partnership responses should be included to help identify resource problems, aid in inventory of existing conditions, assist in evaluating alternatives, and aid in selecting a recommended plan for implementation. In addition, several of the geospatial data layers developed through the HNA-II effort (De Jager et al. 2018) can be generated at a finer resolution than what was displayed in this document. The data developed through HNA-II should be used to identify projects and should be integrated into habitat project planning.

4.1.2 HABITAT RESTORATION PROJECT PLANNING

Once a restoration trajectory (e.g., restore damaged vs. maintain good) has been agreed upon at the programmatic level, the information and data from the HNA-II effort could be used for project planning. For example, the floodplain vegetation data layer could be queried for a given floodplain vegetation type (Box 2) to produce a map showing current distribution of the given floodplain vegetation. This would show where habitat projects could help maintain that desired condition, where there are less desirable areas that may benefit from a habitat restoration project, or where a combination of both maintenance and restoration could be implemented to improve resilience. The results of the indicator assessment could aid in partnership discussions to help prioritize areas given the management ratings of the pools and cluster of navigation pools.

Habitat restoration project planning is a complex process of problem identification, site selection, detailed site assessment, goal and objective prioritization, engineering design, and construction. The HNA-II will not replace nor override the detailed planning process necessary to implement the next round of UMRR habitat project selection and sequencing or the USACE risk-informed planning process. The HNA-II effort has provided the UMRR partnership standardized terminology with the updated aquatic area classification and floodplain classification (De Jager et al., 2018) as well as provided new data available systemically that could help build new habitat planning models required for USACE project alternative evaluation and comparison. Furthermore, the indicators could be incorporated into the development of habitat project study objectives to make project objectives more specific, measurable, attainable, risk-informed, and timely (SMART objectives).

4.1.3 HABITAT PROJECT MONITORING AND ADAPTIVE MANAGEMENT

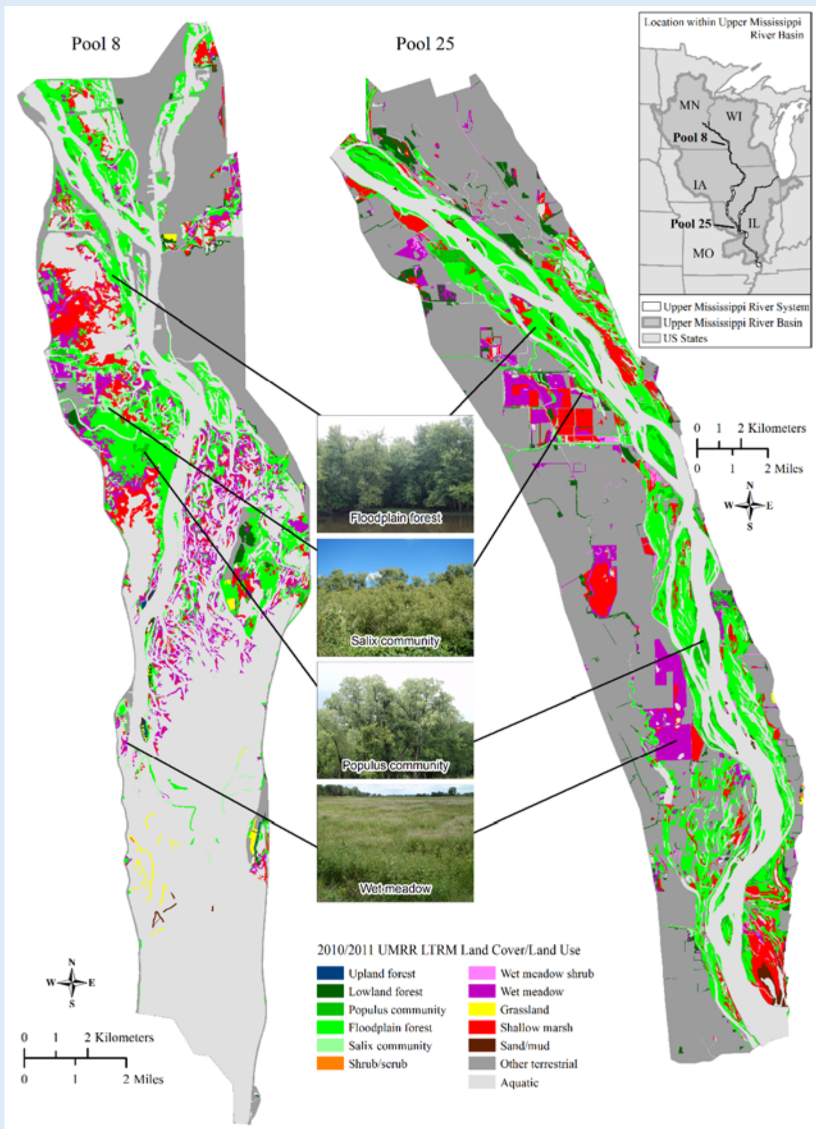
Project monitoring and adaptive management are required components for USACE restoration projects. The HNA-II effort has developed indicators that could be used to inform habitat restoration project pre- and post-construction monitoring, and has provided standard metrics for assessing the effects of these projects. The broad-scale indicators used for the HNA-II could be further refined to derive project-scale indicators appropriate for use as monitoring targets, or to evaluate project success, or to identify triggers that would warrant adaptive management. For example, setting a monitoring target based on the desired indicator condition for a given pool could be used as success criteria, while an undesirable indicator condition for a given pool could be used as the target that would trigger adaptive management. The HNA-II effort has provided systemic data, data layers, and management perspectives to help facilitate these discussions.

4.1.4 INTEGRATION OF RESTORATION AND SCIENCE

A key component of the UMRR Program is the integration of science and restoration. The HNA-II effort has fostered this integration by linking resilience concepts (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review) and indicators of ecosystem structure and function (De Jager et al., 2018) to the management perspectives presented in this document. The data and data layers developed through the HNA-II effort can continue to support the UMRR Program as one of the leaders in large river restoration and monitoring, as well as increase the understanding of the UMRS by having data-informed decision making for the habitat restoration projects implemented through the UMRR Program.

Box 2. Potential use of HNA-II results during Project Planning

Below is an example using the floodplain vegetation diversity indicator for Pools 8 and 25 to assess the vegetation condition and restoration needs in those pools. These data were mapped across the floodplain for Pool 8 and 25 (from De Jager et al., 2018). The River Teams rated Pool 8 and Pool 25 as "yellow" for floodplain vegetation diversity using the Simpson's index of 0.71 and 0.73, respectively. This information suggests that both pools merits action to improve floodplain vegetation at the navigation pool-scale. Using the floodplain vegetation data layer, the planning team could further refine the geospatial data layers to query where in each pool a desired floodplain vegetation community merits action to maintain or to identify areas where restoration could be pursued to restore a given floodplain vegetation community.



Map illustrating the distribution of different floodplain vegetation types in Pool 8 and Pool 25. From De Jager et al. (2018)

4.2 NEXT STEPS

The Upper Mississippi River ecosystem is continually challenged by multiple and changing stressors, and understanding how these stressors impact the ecosystem is important. The UMRR Program's scientific expertise, extensive body of research, data, monitoring protocols, analytical capabilities, and data management provide a foundation to better understand the river ecosystem structure and function, and how to more effectively address management and restoration needs. Long term monitoring allows the UMRR Program to assess and detect changes in the river ecosystem's health via a suite of ecosystem health indicators (not discussed in detail here, please see (Johnson & Hagerty, 2008)); that assessment concluded that in general, the ecological health of the river has improved in the northern reaches, but remains less healthy in the southern reaches. The HNA-II supports the conclusions from Johnson & Hagerty (2008) with the southern reaches of the Mississippi River and the Illinois River having substantial deviation from the desired condition, which may merit action to improve. HNA-II, however, identified that all reaches have several indicators that could merit action to improve or maintain resilience.

The HNA-II effort has advanced the knowledge and understanding of the UMRS and satisfied several of the information needs identified during HNA-I (Theiling et al., 2000); however, through conducting the HNA-II additional information needs and future work were identified. The following list (see Appendix B for additional detail) of information needs compiled through discussions among the River Teams and HNA-II Steering Committee should be considered by the UMRR Program to help improve our knowledge and understanding of the UMRS into the future:

1. Development of species or community-habitat models
2. Refinement of data layers for project-scale application
3. Development of more specific restoration habitat objectives
4. Improvement of system-wide biological data
5. Development of models to forecast future habitat conditions

Based on the past efforts of systemic monitoring and construction of habitat restoration projects, the UMRR Program has gained a better understanding of factors affecting the Upper Mississippi River's health and resilience. The indicator assessments, monitoring, and research conducted by scientists, engineers, and river managers to date can provide the foundation for future research and restoration work. The UMRR Program's role to restore the ecosystem structure and function of the river will be needed in the future as the stressors continue to degrade the river ecosystem. The work that the UMRR Program provides can continue to help inform design of restoration projects, select future restoration projects for implementation, provide greater benefits to localized habitat needs, and continue to build our understanding of the dynamic UMRS.

Moving forward, the following items compiled through discussions with HNA-II Steering Committee and River Teams should be considered by the UMRR Program:

1. **Restoration Philosophy or Trajectory.** The HNA-II (this report) has provided a series of tables and figures illustrating where in the system, based on the indicators of connectivity, redundancy and diversity, and controlling variables (De Jager et al., 2018), there is deviation from the desired conditions meriting action to improve or maintain resilience. The HNA-II should be used to assist the UMRR Program partnership in a developing a more specific restoration philosophy or trajectory of either improving (e.g., going from “red” to “green”) or maintaining (e.g., keeping “green” as “green”) the resilience of the UMRS or define a combination of both.

2. **Refinement of Indicators.** The indicators developed for the HNA-II (De Jager et al., 2018) were developed to represent general aspects of physical and ecological conditions applicable to a wide-range of organisms and processes, and were developed at the navigation pool scale. However, these indicators may not accurately reflect species-specific requirements; nor were they developed to be sensitive to site-specific management actions that might impact the river system; nor was the spatial and temporal variability within navigation pools accounted for (De Jager et al., 2018). The datasets developed during the HNA-II effort do provide the information to further elaborate on many of the indicators and it is recommended that more specific indicators be developed to detect changes in specific species, habitats, water residence times, and management actions, as well as, be used to zoom in at a finer spatial scale to help inform future site-specific planning efforts (De Jager, et al., 2018). Appendix C provides recommendations that could be taken into consideration to improve understanding or applicability of the indicators moving forward.

4.3 CONCLUSIONS

In this document, geospatial data sets and 12 indicators of ecosystem structure and function (De Jager et al., 2018) developed to quantify general themes of resilience for the UMRS (Bouska K. L., Houser, De Jager, Van Appledorn, & Rogala, In Review) were linked to management perspectives through an assessment of the existing conditions as related to desired conditions of these indicators. The HNA-II effort provides the UMRR Program with system-wide quantitative information coupled with qualitative management perspectives to set management and restoration goals, and aid in habitat restoration project identification, selection, planning, and monitoring into the future. HNA-II can help the UMRR Program achieve its primary goal at a broad scale by identifying restoration and management priorities and at a local scale by identifying the local ecosystem conditions in need of restoration or management actions.

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APPENDIX A: SUMMARY OF AGENCY INDICATOR RATINGS BY NAVIGATION POOL AND CLUSTER OF NAVIGATION POOLS

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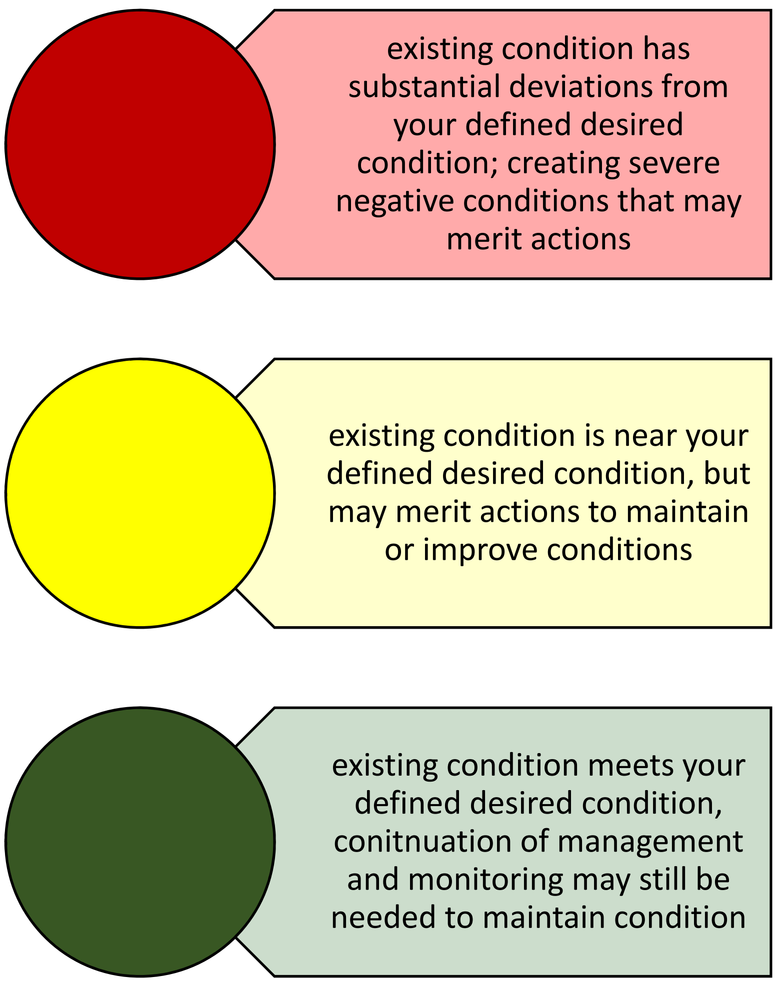
INTRODUCTION

This appendix is organized by cluster of navigation pools as defined by the indicator cluster analysis (De Jager et al., 2018). For the below clusters of navigation pools, each indicator was rated by individual agencies (Figure A-1). Not every agency within the UMRR Program Partnership rated every navigation pool or cluster of navigation pools. If a color (red, yellow, green) is present then that agency rated that given navigation pool. In some instances, an agency may have added an additional assessment level (i.e., orange, or light green) if they felt the navigation pool fell somewhere between the red-yellow or yellow-green definitions. If no color is present, then that agency did not rate that given navigation pool.

Figure A-1. Indicator ratings definitions provided to the Agencies and River Teams during rapid semi-quantitative assessment



UPPER IMPOUNDED

NOTE: No overall FWWG RATING DUE to Diversity of Opinions

Indicator	Navigation Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE
Longitudinal Aquatic Connectivity - % Time Gates Open	3							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Longitudinal Floodplain Connectivity - Natural Area	3							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Lateral River-Floodplain Connectivity – Leveed Area	3							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Lateral River-Floodplain Connectivity – Open Water	3							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Aquatic Functional Class 1	3							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							

UPPER IMPOUNDED								
Indicator	**Navigation Pool**	**IADNR**	**ILDNR**	**MDC**	**MDNR**	**WIDNR**	**USFWS**	**USACE**
Aquatic Functional Class 2	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Aquatic Vegetation Diversity	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Floodplain Vegetation Diversity	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Floodplain Functional Class Diversity	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Water Surface Elevation Fluctuation – Tailwater Flux	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							

UPPER IMPOUNDED								
Indicator	**Navigation Pool**	**IADNR**	**ILDNR**	**MDC**	**MDNR**	**WIDNR**	**USFWS**	**USACE**
Water Surface Elevation Fluctuation – Pool Flux	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							
Total Suspended Solids Concentrations	**3**							
	4							
	5							
	5a							
	6							
	7							
	8							
	9							
	13							

MIDDLE IMPOUNDED

Average Based River Team Ratings

Indicator	Nav Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	FWIC	FWIC CLUSTER
Longitudinal Aquatic Connectivity - % Time Gates Open	10									
	11									
	12									
	14									
	16									
	19									
Longitudinal Floodplain Connectivity - Natural Area	10									
	11									
	12									
	14									
	16									
	19									
Lateral River-Floodplain Connectivity – Leveed Area	10									
	11									
	12									
	14									
	16									
	19									
Lateral River-Floodplain Connectivity – Open Water	10									
	11									
	12									
	14									
	16									
	19									
Aquatic Functional Class 1	10									
	11									
	12									
	14									
	16									
	19									
Aquatic Functional Class 2	10									
	11									
	12									
	14									
	16									
	19									
Aquatic Vegetation Diversity	10									
	11									
	12									
	14									
	16									
	19									

MIDDLE IMPOUNDED										
Indicator	**Nav Pool**	**IADNR**	**ILDNR**	**MDC**	**MDNR**	**WIDNR**	**USFWS**	**USACE**	**FWIC**	**FWIC CLUSTER**
Floodplain Vegetation Diversity	**10**									
	11									
	12									
	14									
	16									
	19									
Floodplain Functional Class Diversity	**10**									
	11									
	12									
	14									
	16									
	19									
Water Surface Elevation Fluctuation – Tailwater Flux	**10**									
	11									
	12									
	14									
	16									
	19									
Water Surface Elevation Fluctuation – Pool Flux	**10**									
	11									
	12									
	14									
	16									
	19									
Total Suspended Solids Concentrations	**10**									
	11									
	12									
	14									
	16									
	19									

POOL 15

Averaged Based River Team Ratings

Indicator	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	FWIC
Longitudinal Aquatic Connectivity - % Time Gates Open								
Longitudinal Floodplain Connectivity - Natural Area								
Lateral River-Floodplain Connectivity – Leveed Area								
Lateral River-Floodplain Connectivity – Open Water								
Aquatic Functional Class 1								
Aquatic Functional Class 2								
Aquatic Vegetation Diversity								
Floodplain Vegetation Diversity								
Floodplain Functional Class Diversity / Floodplain Inundation Diversity								
Water Surface Elevation Fluctuation – Tailwater Flux								
Water Surface Elevation Fluctuation – Pool Flux								
Total Suspended Solids Concentrations								

LOWER IMPOUNDED

Average Based River Team Ratings

Indicator	Nav Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	FWIC/ RRAT	Cluster
Longitudinal Aquatic Connectivity - % Time Gates Open	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Longitudinal Floodplain Connectivity - Natural Area	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Lateral River-Floodplain Connectivity – Leveed Area	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Lateral River-Floodplain Connectivity – Open Water	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Aquatic Functional Class 1	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Aquatic Functional Class 2	17									
	18									
	20									
	21									
	22									
	24									
	25									
	26									

LOWER IMPOUNDED										
Indicator	**Nav Pool**	**IADNR**	**ILDNR**	**MDC**	**MDNR**	**WIDNR**	**USFWS**	**USACE**	**FWIC/ RRAT**	**Cluster**
Aquatic Vegetation Diversity	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Floodplain Vegetation Diversity	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Floodplain Functional Class Diversity	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Water Surface Elevation Fluctuation – Tailwater Flux	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Water Surface Elevation Fluctuation – Pool Flux	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									
Total Suspended Solids Concentrations	**17**									
	18									
	20									
	21									
	22									
	24									
	25									
	26									

OPEN RIVER

Consensus Based River Team Ratings

Indicator	Navigation Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	RRAT	Cluster
Longitudinal Aquatic Connectivity - % Time Gates Open	OR1									
	OR2									
Longitudinal Floodplain Connectivity - Natural Area	OR1									
	OR2									
Lateral River-Floodplain Connectivity – Leveed Area	OR1									
	OR2									
Lateral River-Floodplain Connectivity – Open Water	OR1									
	OR2									
Aquatic Functional Class 1	OR1									
	OR2									
Aquatic Functional Class 2	OR1									
	OR2									
Aquatic Vegetation Diversity	OR1									
	OR2									
Floodplain Vegetation Diversity	OR1									
	OR2									
Floodplain Functional Class Diversity	OR1									
	OR2									
Water Surface Elevation Fluctuation – Tailwater Flux	OR1									
	OR2									
Total Suspended Solids Concentrations	OR1									
	OR2									

UPPER ILLINOIS

Average Based River Team Ratings

Indicator	Navigation Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	FWIC	Cluster
Longitudinal Aquatic Connectivity - % Time Gates Open	dre									
	mar									
	sta									
Longitudinal Floodplain Connectivity - Natural Area	dre									
	mar									
	sta									
Lateral River-Floodplain Connectivity – Leveed Area	dre									
	mar									
	sta									
Lateral River-Floodplain Connectivity – Open Water	dre									
	mar									
	sta									
Aquatic Functional Class 1	dre									
	mar									
	sta									
Aquatic Functional Class 2	dre									
	mar									
	sta									
Aquatic Vegetation Diversity	dre									
	mar									
	sta									
Floodplain Vegetation Diversity	dre									
	mar									
	sta									
Floodplain Functional Class Diversity	dre									
	mar									
	sta									
Water Surface Elevation Fluctuation – Tailwater Flux	dre									
	mar									
	sta									
Water Surface Elevation Fluctuation – Pool Flux	dre									
	mar									
	sta									
Total Suspended Solids Concentrations	dre									
	mar									
	sta									

LOWER ILLINOIS

Average Based River Team Ratings

Indicator	Navigation Pool	IADNR	ILDNR	MDC	MDNR	WIDNR	USFWS	USACE	FWIC	Cluster
Longitudinal Aquatic Connectivity - % Time Gates	peo									
	lag									
	alt									
Longitudinal Floodplain Connectivity - Natural Area	peo									
	lag									
	alt									
Lateral River-Floodplain Connectivity – Leveed Area	peo									
	lag									
	alt									
Lateral River-Floodplain Connectivity – Open Water	peo									
	lag									
	alt									
Aquatic Functional Class 1	peo									
	lag									
	alt									
Aquatic Functional Class 2	peo									
	lag									
	alt									
Aquatic Vegetation Diversity	peo									
	lag									
	alt									
Floodplain Vegetation Diversity	peo									
	lag									
	alt									
Floodplain Functional Class Diversity	peo									
	lag									
	alt									
Water Surface Elevation Fluctuation – Tailwater Flux	peo									
	lag									
	alt									
Water Surface Elevation Fluctuation – Pool Flux	peo									
	lag									
	alt									
Total Suspended Solids Concentrations	peo									
	lag									
	alt									

APPENDIX B: SUMMARY OF AGENCY DISCUSSIONS ON FUTURE NEEDS

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The following list compiled through discussions among the River Teams and HNA-II Steering Committee could be considered by the UMRR Program to help improve our future knowledge and understanding of the UMRS Program.

A. **Develop and Validate Species or Community-Habitat Models.** The UMRR Program has made advances on this information need, identified in HNA-I (Theiling, et al., 2000), but further development of species or community-based habitats models is still desired by the partnership. Models associating species and life stages with habitat types could beneficially continue to be developed using the best available scientific literature and expertise and leverage the data and research from the UMRR LTRM where possible. The indicators used for HNA-II can be incorporated, if feasible, during model development to evaluate attributes of resilience.
B. **Refine Data Layers for Project-Scale Application and Improve Indicator Understanding.** The HNA-II effort has provided updated and new data, geospatial data layers, models, and aquatic and floodplain classifications (De Jager et al., 2018) to help inform restoration planning for the UMRR Program. Moving forward, refinement of these data layers and model applications for project-scale applications is desired to help inform management decisions. Continual improvements of the data used to develop the indicators would help reduce the uncertainty and improve the applicability of the indicators posed by the River Teams (See Chapter 3 for detailed discussions on River Team perspective of applicability and usefulness of some of the indicators).
C. **Develop More Specific Restoration Habitat Objectives.** The HNA-II effort re-confirmed the use of ecosystem objectives previously developed for the UMRS (USACE, 2011); however, moving forward using the current list of indicators and how they were quantified could be used to develop more specific restoration objectives. For example, what is a natural stage hydrograph? How should that be quantified? As the UMRR Program develops more specific objectives the indicators can become more specific.
D. **Refine Hydrologic Models.** An essential component of characterizing river habitat is the hydrologic regime. Since HNA-I, many project-scale and regional hydraulic and hydrologic models have been developed by UMRR Program partners to characterize the river hydrologic regime; however, further development and refinement of hydrologic models should consider connectivity, varying discharge with water surface elevations, lower tributary effects (including sediment and pollutants), watershed land cover/land use, and incorporate impacts of climate change to hydrology. Great efforts have been made in hydrologic modeling within the UMRS, but may be limited in regional scope. Hydraulic and hydrologic modeling efforts should continue and be compiled to better understand the entire UMRS.
E. **Improve System-Wide Data.** This includes physical, chemical and biotic data. Some system-wide data needs identified included, but not limited to: velocity, substrate, nutrient, residence time, seasonal data, other biota (e.g., reptiles and amphibians, invertebrates), bathymetry, and sedimentation. Future efforts to quantify the biotic essential ecosystem component should be conducted to the UMRR Program. Improving our understanding of how populations of species or guilds is doing throughout the UMRS would help inform the UMRR Program in answering the

question of "habitat for what?" In addition, the UMRR Program could consider applying UMRR LTRM monitoring to non-trend pools as funding allows to improve our understanding of the UMRS.

F. Develop Model to Forecast Future Habitat Conditions. Continual development of models to forecast future conditions is desired. This would include, but is not limited to, climate change. Many of the indicators are sensitive to climate change and future understanding of how climate change may affect these indicators is needed. There is an opportunity to include the project-specific climate assessment requirements conducted by the USACE on a given habitat to the broader climate change models for the UMRS.

APPENDIX C: MANAGEMENT RECOMMENDATIONS TO REFINE INDICATORS MOVING FORWARD

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De Jager et al. (2018) developed the indicators for the HNA-II to represent general aspects of physical and ecological conditions applicable to a wide range of organisms and processes, and were developed at the navigation pool scale. However, these indicators may not accurately reflect species-specific requirements; nor were they developed to be sensitive to site-specific management actions that might impact the river system; nor was the spatial and temporal variability within navigation pools accounted for (De Jager et al., 2018). But, the datasets developed during the HNA-II effort do provide the information to further elaborate on any of the indicators, and it is recommended that more specific indicators be developed to detect changes in specific species, habitats, water residence times, and management actions, as well as to zoom in at a finer spatial scale to help inform future site-specific planning efforts (De Jager, et al., 2018).

The following items were compiled through discussions and reviews with the HNA-II Steering Committee and River Teams. Recommendations to refine the HNA-II indicators moving forward are also included.

A. **Leveed Area:** This indicator could be refined and be presented as a ratio of leveed: unleeved area rather than just hectares per river mile. The lack of non-Federal levees in the data set used led to an underestimate of the existing state of the system and to questioning the utility of this indicator. Including other data sets into refining this indicator should be considered.
B. **Aquatic Functional Classes:** Due to the difficulty of interpretation of unitless scores, revision of these indicators should be considered. Changing the names to Deep: Shallow Index and Lentic: Lotic Index or focus in on priority cover types as provided in Figure 2-2 should be considered.
C. **Floodplain Vegetation Diversity:** Further refinement of this indicator is warranted to take into account how invasive species impact diversity index values and how to include small, diverse patches. In addition, a desired condition of for this indicator may be low diversity.
D. **Floodplain Functional Class Diversity:** Further refinement of this indicator should be considered since the existing indicator was restricted to leveed areas. This led to confusion among the River Teams and the utility of how the indicator was presented was questioned.
E. **Water Surface Elevations:** Further refinement of this indicator should include studies, data, and models previously developed and work towards improving the system-wide data available as related to hydrologic modeling.
F. **Total Suspended Solids Concentrations:** Further refinement of this indicator should include additional data sources to fill in the gaps of missing data for some reaches. Interpolating the gaps between UMRR LTRM field stations could be used to fill in the gaps. In addition, including different strata or season of collection should be considered based on management needs.

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APPENDIX D: CONCEPTUAL MODELS

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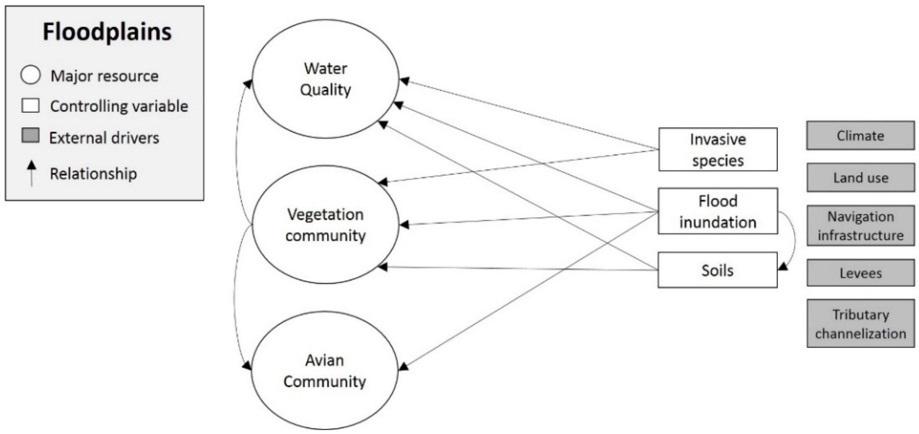

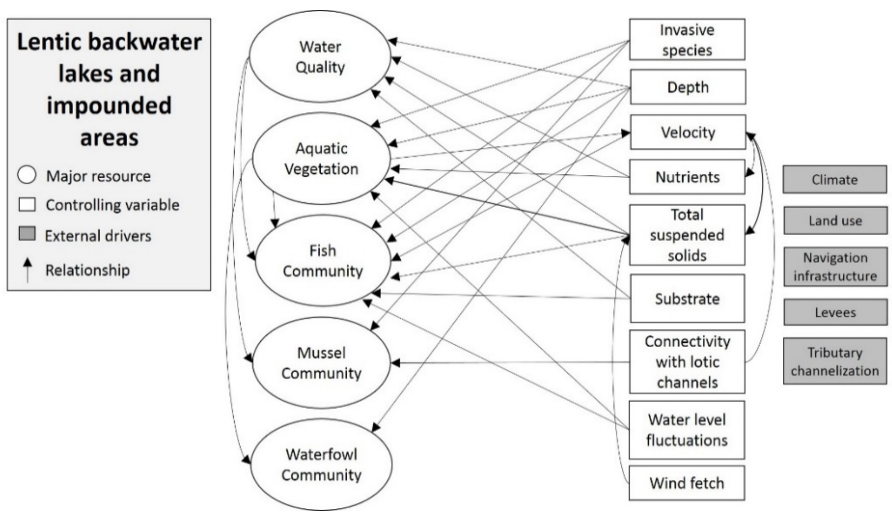

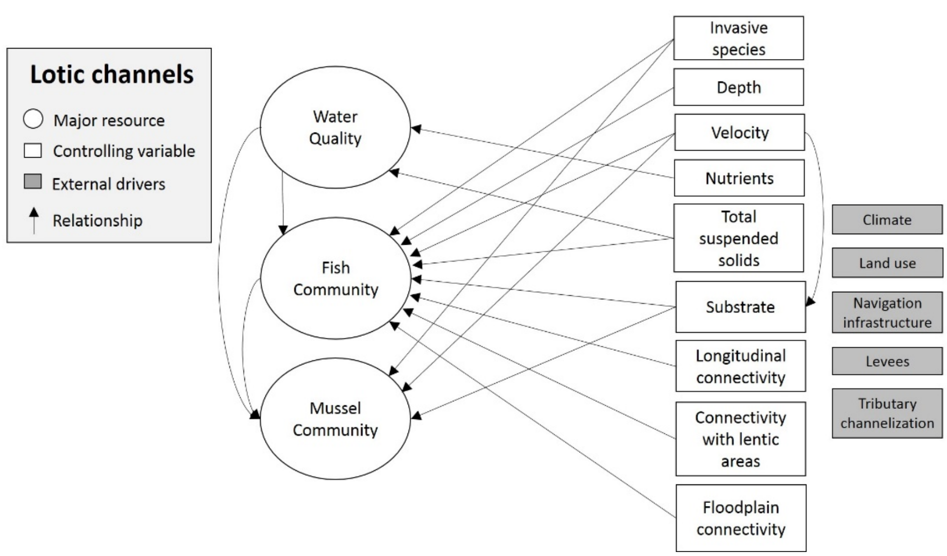

These conceptual models were developed as part of the resilience assessment for the UMRR Program. For more information on the conceptual models please see Bouska et al., (2018).

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