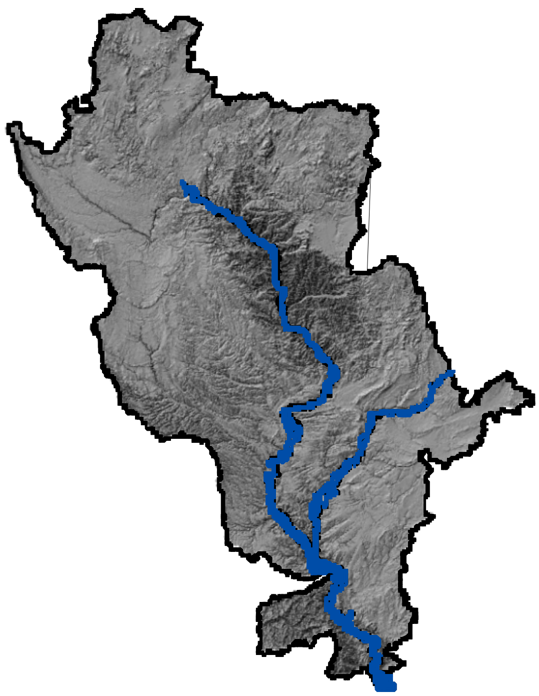
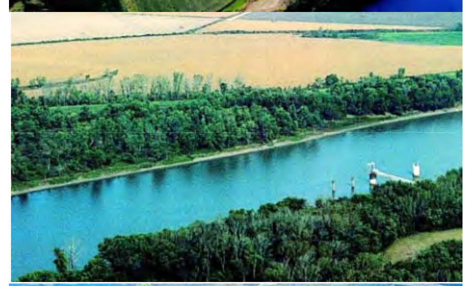
Upper Mississippi River System Ecosystem Restoration Objectives 2009





US Army Corps of Engineers®

OVERVIEW

The *Upper Mississippi River System – Ecosystem Restoration Objectives 2009* report (Report) is the final product of a planning process initiated in 2008 for the purpose of identifying areas for new restoration projects and identifying knowledge gaps at a system scale. The Report will serve as a technical basis for investment decisions through 2013. The Report serves as a backdrop for the formulation of specific restoration projects and their adaptive ecosystem management (AEM) components. Follow-on cycles of reach planning will be completed in 2013 and every 4 years thereafter as part of the AEM process.

For the AEM process (shown in Figure 2) to be most effective, it must be integrated across multiple scales. In relationship to Figure 2, the reach planning process that resulted in this Report defined "goals and objectives for condition of the river ecosystem" at the reach and system scales. In addition, the reach planning process began the process toward "the sequencing and combining of management and restoration actions" by identifying high priority subareas throughout the system. The identification of knowledge gaps will serve as a basis for formulating AEM strategies and initiatives at multiple scales (system, reach, project scales, and points in between) and system scale considerations.

The Reach Planning process enhances prior planning efforts by:

- incorporating results from previous planning efforts;
- utilizing the most up to date knowledge about the UMRS;
- linking objectives at the project and reach scales with essential ecosystem characteristics;
- encompassing AEM at multiple scales; and
- adopting a system orientation that will serve the interests of multiple programs and entities.

The reach planning process leads to the identification of high priority areas for restoration of natural river processes (as required by Section 8004 of WRDA 2007). The reach planning process also provides context for formulating project features, defining performance measures, and designing monitoring plans. Lessons learned from this planning cycle will be incorporated into the next cycle.

This scale and complexity of planning would not be possible without highly developed inter-organizational arrangements for collaboration and partnership. The Regional Support Team, a regional team of Corps river ecologists and engineers, served as the interface with the Science Panel and program managers. The Regional Support Team led interagency planning teams drawn from the Fish and Wildlife Work Group; the Fish and Wildlife Interagency Committee; the River Resources Action Team; and the Illinois River Work Group. The Interagency River Teams, which included the River Resources Forum; the River Resources Coordinating Committee; and the River Resources Action Team – Executive Component, endorsed recommendations appropriate to their reaches of the river. The Upper Mississippi River Basin Association was kept informed throughout the process. The Navigation Environmental Coordinating Committee and the Environmental Management Program Coordinating Committee endorsed recommendations, insuring a holistic perspective for integrated program management.

All involved are applauded for advancing the ability to manage the Upper Mississippi River System toward the vision of long-term sustainability of the economic uses and ecological integrity.

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UPPER MISSISSIPPI RIVER SYSTEM ECOSYSTEM RESTORATION OBJECTIVES

2009

Executive Summary

Formal planning for UMRS ecosystem management and restoration has been an ongoing process that was institutionalized in the 1970's with a Comprehensive Master Plan completed by the Upper Mississippi River Basin Commission in 1982. The Master Plan proposed an outline for the Environmental Management Program (EMP) which was authorized in WRDA 1986. The EMP has been a National leader in ecosystem restoration planning and implementation for 25 years. EMP partners have participated in several project planning cycles to develop regional ecosystem restoration needs and priorities. Their prior experience and strong interagency relationships provided the foundation to develop the ecosystem restoration component of the Navigation and Ecosystem Sustainability Program (NESP) which was authorized in WRDA 2007. Program partners understand the interrelated information needs of multiple navigation and ecosystem restoration programs, so Reach Planning was conducted to identify ecosystem objectives and subareas where they can be achieved in a program-neutral fashion.

Reach Planning was initially undertaken to support an anticipated $100 million/year ecosystem restoration program authorized in WRDA 2007, but was subsequently expanded to apply to all UMRS ecosystem restoration programs. Reach Planning relied on participants from River Management Team workgroups including the Fish and Wildlife Work Group (FWWG) in the Upper Impounded Reach (UIR); the Fish and Wildlife Interagency Committee (FWIC) in the Lower Impounded Reach (LIR); the Illinois River Work Group (IRWG) in the Illinois River (IR), and the River Resources Action Team (RRAT) in the Unimpounded Reach (and also LIR and IR). Reach Planning teams were established in four floodplain reaches to refine ecosystem restoration objectives and to develop a Reach Plan for ecosystem restoration for the first NESP 4-year planning cycle. In recognition of the longitudinal differences that exist over 1,100 river miles, additional spatial organization was achieved by dividing the reaches into 12 distinct geomorphic reaches.

Prior planning efforts were site-based, meaning they were designed to identify high priority project areas. The plans were viewed as bottom-up approaches, an "if you build it (i.e., habitat) they will come (i.e., critters)" approach to managing fish and wildlife. A "top-down," system-scale approach was recommended for Reach Planning because it emphasizes the physical hydraulic and geomorphic processes that maintain ecosystem structure, habitat, and populations. The "top-down" ecosystem restoration planning process for the Upper Mississippi River System (UMRS) began with a vision statement that acknowledges the multiple-use nature of the UMRS. A hierarchy of goals and objectives includes a system goal for environmental and economic sustainability, system-wide ecosystem goals, and system and reach-scale ecosystem objectives. Ecosystem goals were adopted by the Navigation Environmental Coordination Committee (NECC) and Environmental Management

Program Coordinating Committee (EMPCC) in 2008, the reach-scale ecosystem objectives are a significant product of this planning effort that were adopted by the River Resources Forum (RRF), River Resources Coordination Team (RRCT), RRAT, and IRWG in 2010.

The Reach Planning framework emphasized system-wide environmental goals, implementation guidance to achieve objectives, considerations of scale and connectivity, and then identified a stepwise process for setting ecosystem restoration objectives that included: identifying unique characteristics, historic, existing, and future conditions, stressors, objectives, performance criteria, and indicators. Goals and objectives for condition of the river ecosystem are central to river management, and are linked to other elements of the framework.

Regional Support Team members compiled data and information for each geomorphic reach to support Reach Planning. A series of workshops were conducted in 2009 and 2010 with the Reach Planning teams to develop ecosystem objectives (Table ES-1) and the initial Reach Plans (Figures ES-1 through ES-4). The decision to shift to physiographic-based planning areas (i.e., floodplain reaches) instead of agency jurisdiction caused overlap of traditional planning entities which required significant additional coordination, especially in the St. Louis District in Missouri and Illinois which is split among three of the four Floodplain Reaches.

Reach Planning also emphasized the philosophy that restoration activities must restore ecosystem processes to achieve system-wide sustainability. Understanding and restoring important ecosystem processes and functions will make the UMRS ecosystem more productive of native life forms and resilient to human and natural disturbances. UMRS river managers have long used process-based management actions in both channel maintenance and habitat rehabilitation efforts with structures such as wing dams that use river flow to move sediment or moist soil units that simulate natural hydrology to manage wetlands. Institutionalization of the process-based philosophy through Adaptive Ecosystem Management (AEM) is important for long term project success and learning.

The Reach Planning process is part of the UMRS partnership commitment to AEM. AEM is a decision process that promotes hypothesis testing through project implementation which allows for flexible decision making that can be adapted as outcomes from management actions become better understood. Careful monitoring of outcomes advances scientific understanding and helps adjust policies and operations as part of an iterative learning process. The principles of AEM are set forth in the UMR-IWW System Navigation Feasibility Study, the Science Panel 2008 goals and objectives report, and in WRDA 2007. From the programmatic perspective, restoration projects should have a high likelihood for success, help achieve one or more of the reach objectives, and add to a cumulative body of knowledge. WRDA 2007 authorizes almost 20 percent of ecosystem restoration funding for monitoring and adaptive ecosystem management. Commitment to AEM in the future will enhance the monitoring and learning from experience (i.e. passive adaptive management) that was established by EMP.

Reach Planning teams compiled unique characteristics, stressors, and ecosystem restoration objectives for each geomorphic reach. They also identified subareas within each Geomorphic Reach that would contribute to attaining the ecosystem objectives. This process is summarized in four Reach Plans, one for each UMRS Floodplain Reach, presented in this report as Appendix A, *Upper Impounded Reach Plan*; Appendix B, *Lower Impounded Reach Plan*; Appendix C, *Unimpounded (Middle Mississippi) Reach Plan*; and Appendix D, *Illinois River Reach Plan*. This *Upper Mississippi River System Ecosystem Restoration Objectives 2009* report presents a system-scale overview and summary of the reach planning process and results. Objectives that can be analyzed at a system scale are discussed in detail (Table ES-2). Some objectives are very site specific and must be considered at a project scale and other objectives address basin-scale material transport which must be addressed by management actions applied in watersheds beyond the river-floodplain itself (Table ES-2).

The review of ecosystem processes and functions helped identify significant differences in river-floodplain geomorphology, hydrology, habitat, and biota among the reaches. The Reach Planning teams identified important subareas for restoration, but each ecosystem restoration project will require detailed site-specific planning and design. There are many broad recommendations to be considered, however, that have emerged from the reach planning process. The first five recommendations consider ecosystem processes or structure objectives, the others consider management actions applicable system-wide or regionally.

- Restoring stage variation keyed to natural discharge variability should benefit shallow littoral and wetland habitats in the Upper Impounded Reach. Advance dredging can be conducted to accommodate drawdowns simulating summer low flow, while also maintaining the navigation channel in much of the Upper Impounded Reach. Small-scale drawdowns can also be applied in individual backwater lakes.

- Partial restoration of more natural hydrologic connectivity is desirable throughout the system. In the Northern reaches of the UMRS this often involves reducing hydrologic connectivity between channels and backwaters. In the Southern reaches of the UMRS this will involve increasing connectivity between channels and floodplains.

- Reducing constituent transport (i.e., sediment and nutrients) will benefit aquatic habitat system-wide.

- Structural diversity (geomorphic pattern) is an important system-wide geomorphic objective that can be achieved through multiple projects. Planners may consider incorporating specific types of geomorphic features and habitat patch types into future restoration projects to restore a more complete pattern of river and floodplain habitats.

- Land conversion from crops to native communities has large ecosystem benefits. Long term land use improvement plans are helpful because they can be used to target resources effectively when opportunities like flood buyouts, year-end surpluses, or stimulus spending arise.

- A mixed use floodplain management plan can achieve multiple benefits within the existing levee and drainage district infrastructure. Integrated floodplain management can provide increased ecosystem benefits and may help manage risk for economic interests and landowners.

- Secondary channels are critically important off-channel habitat throughout the UMRS. In the Middle Mississippi Reach and Alton Pool secondary channels represent some of the limited remaining aquatic habitat outside the main channel. These secondary channels should be protected and restored.

- Opportunities for restoring tributary confluences are, by nature, site-specific projects, but there are different restoration opportunities among reaches. Managers have sought to increase the diverse habitat provided by natural tributary deltas, so active deltas need to be protected. Channelized tributaries are a more common problem in the South, but occur throughout the river.

- Reach Planning Teams have identified future restoration subareas that are important to meet objectives set for each Geomorphic Reach. Projects below the ordinary high water mark are generally the easiest to implement because much of the land is in public ownership and there are many opportunities to blend navigation system maintenance with ecosystem restoration projects. The partnership also needs to be alert and continue to coordinate well to be able to respond effectively to environmental, policy, and funding opportunities.

The ecosystem process-based intent of the Upper Mississippi-Illinois Waterway System Navigation Feasibility Study, WRDA 2007, the Science Panel, the Illinois Basin Comprehensive Plan, EMP strategic plans, and AEM in general is important to achieve long term sustainability of the multiple uses of the Upper Mississippi River System.

Table ES-1. Upper Mississippi River System ecosystem restoration objectives for hydrology, biogeochemistry, geomorphology, habitat, and biota essential ecosystem characteristics in four floodplain reaches

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
Hydraulics & Hydrology: Manage for a More Natural Hydrologic Regime			
A more natural stage hydrograph	A more natural stage hydrograph		A more natural stage hydrograph
Restored hydraulic connectivity		Restored hydraulic connectivity	
	Naturalize the hydrologic regime of tributaries		
	Increase storage & conveyance of flood water on the floodplain		
Biogeochemistry: Manage for Processes That Input, Transport, Assimilate, & Output Material Within UMR Basin River Floodplains: e.g., Water Quality, Sediments, & Nutrients			
Improved water clarity	Increased water clarity		
Reduced nutrient loading	Reduced nutrient loading from tributaries to rivers		
Reduced sediment loading from tributaries & sediment resuspension in & loading to backwaters	Reduced sediment loading & sediment resuspension in backwaters		Reduced sediment loading & sediment resuspension in backwaters. **NOTE:** There are several objectives dealing with tributary loading
Reduced contaminants loading & remobilization of in-place pollutants			
		Water quality conditions sufficient to support native aquatic biota & designated uses	Water quality conditions sufficient to support aquatic biota
Geomorphology: Manage for Processes That Shape a Physically Diverse & Dynamic River Floodplain System			
Restore rapids			
	Restored backwater areas		Restored backwaters
	Restored lower tributary valleys		
Restore a sediment transport regime so that transport, deposition, & erosion rates & geomorphic patterns are within acceptable limits	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored secondary channels & islands
	Restored floodplain topographic diversity		
			Restored lateral hydraulic connectivity

Table ES-1 (cont). Upper Mississippi River System ecosystem restoration objectives for hydrology, biogeochemistry, geomorphology, habitat, and biota essential ecosystem characteristics in four floodplain reaches

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
Habitat: Manage for a Diverse & Dynamic Pattern of Habitats to Support Native Biota			
Restored habitat connectivity	Restored habitat connectivity		Restored habitat connectivity
Restored riparian habitat	Restored riparian habitat	Restored riparian habitat	
Restored aquatic off-channel areas		Increase the extent & number of sand bars, mud flats, gravel bars, islands, & side channels towards a more historic abundance & distribution.	
Restored terrestrial floodplain areas			
Restored channel areas			
	Diverse & abundant native aquatic vegetation communities (SAV, EAV, RFV)		
		Restored large contiguous patches of native plant communities to provide a corridor along the UMR	Restored floodplain areas
		Restored floodplain wetland areas	
		Restored degraded & rare native habitats	
			Restored lower tributary valleys
Biota: Manage for Viable Populations of Native Species Within Diverse Plant & Animal Communities			
Diverse & abundant native aquatic vegetation communities (SAV, EAV, R/F)			
Diverse & abundant native floodplain forest & prairie communities			
Diverse & abundant native fish community		Diverse & abundant native fish community	
Diverse & abundant native mussel community			
Diverse & abundant native bird community			
	Restored diversity & extent of native communities throughout their range in the UMRS	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential
	Reduced adverse effects of invasive species	Reduced adverse effects of invasive species	
			Restored diversity & extent of native communities throughout their range in the UMRS

Table ES-2. Upper Mississippi River System system-wide ecosystem restoration objectives can be addressed in many ways at different scales. System scale fits the this Reach Planning framework, site specific is too detailed for this stage of planning, and many watershed processes are beyond the control of UMRS managers

System Scale	Site Specific, Not Evaluated	Beyond UMRS
A more natural stage hydrograph	Reduced sediment loading and Sediment resuspension in backwaters	Reduced nutrient loading from tributaries to rivers
Restored hydraulic connectivity	Restored lateral hydraulic connectivity	Reduced contaminants loading and remobilization of in-place pollutants
Increase storage and conveyance of flood water on the floodplain	Water quality conditions sufficient to support native aquatic biota and designated uses	
Restored backwaters	Restore rapids	
Restored secondary channels and islands	Restored bathymetric diversity, and flow variability in secondary channels, islands, sand bars, shoals and mudflats	
Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits	Restored floodplain topographic diversity	
Improved water clarity		
Naturalize the hydrologic regime of tributaries		
Restored lower tributary valleys		
Forest Plan / Floodplain Landscape*		
Fish Passage*		
Water Level Management*		

* = System-wide evaluation completed previously

Upper Impounded Reach

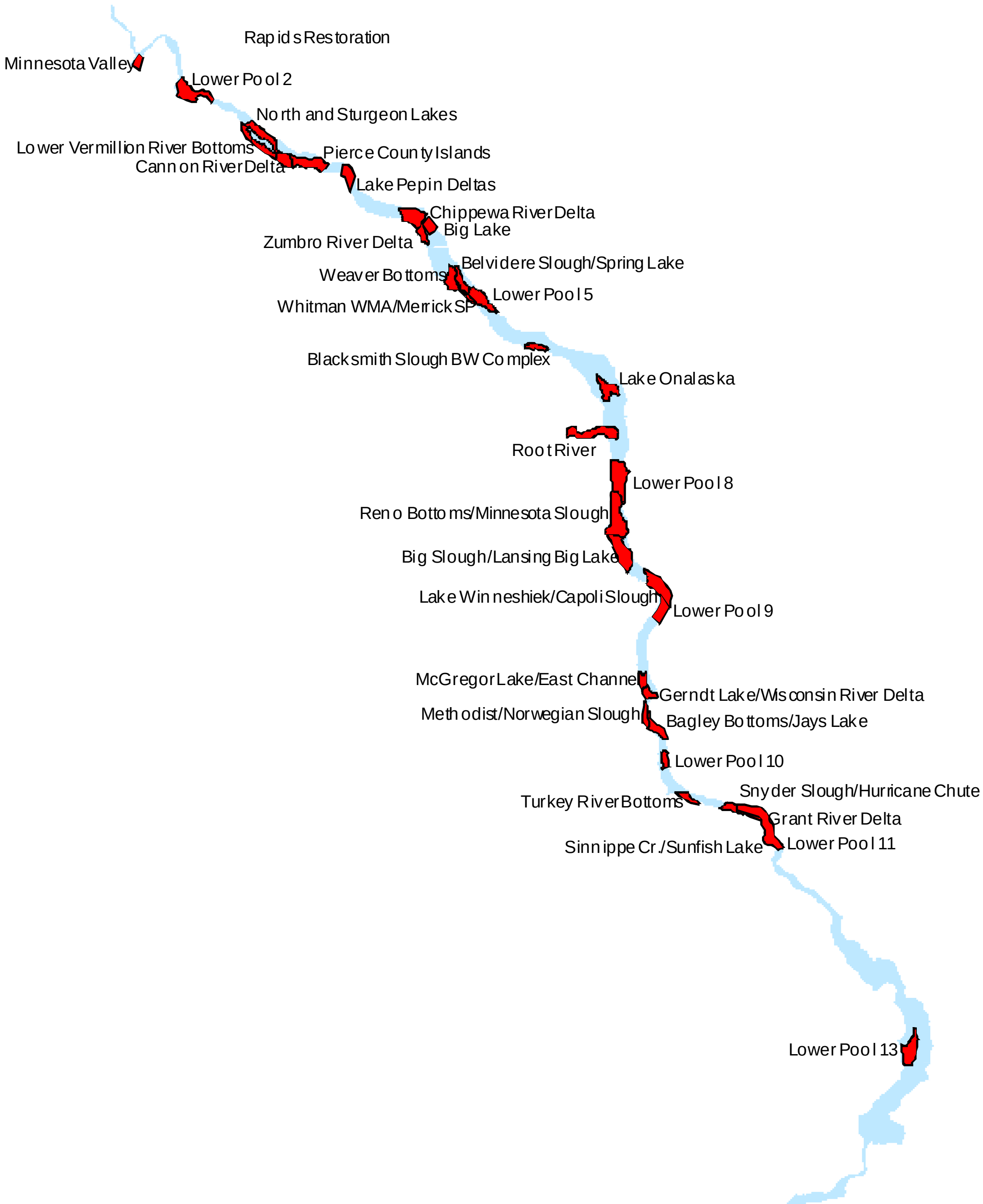


Figure ES-1. Upper Impounded Reach ecosystem restoration subarea priorities

Lower Impounded Reach

Figure ES-2. Lower Impounded Reach ecosystem restoration subarea priorities

Figure ES-3. Unimpounded (Middle Mississippi) Reach ecosystem restoration subarea priorities

Illinois River Reach

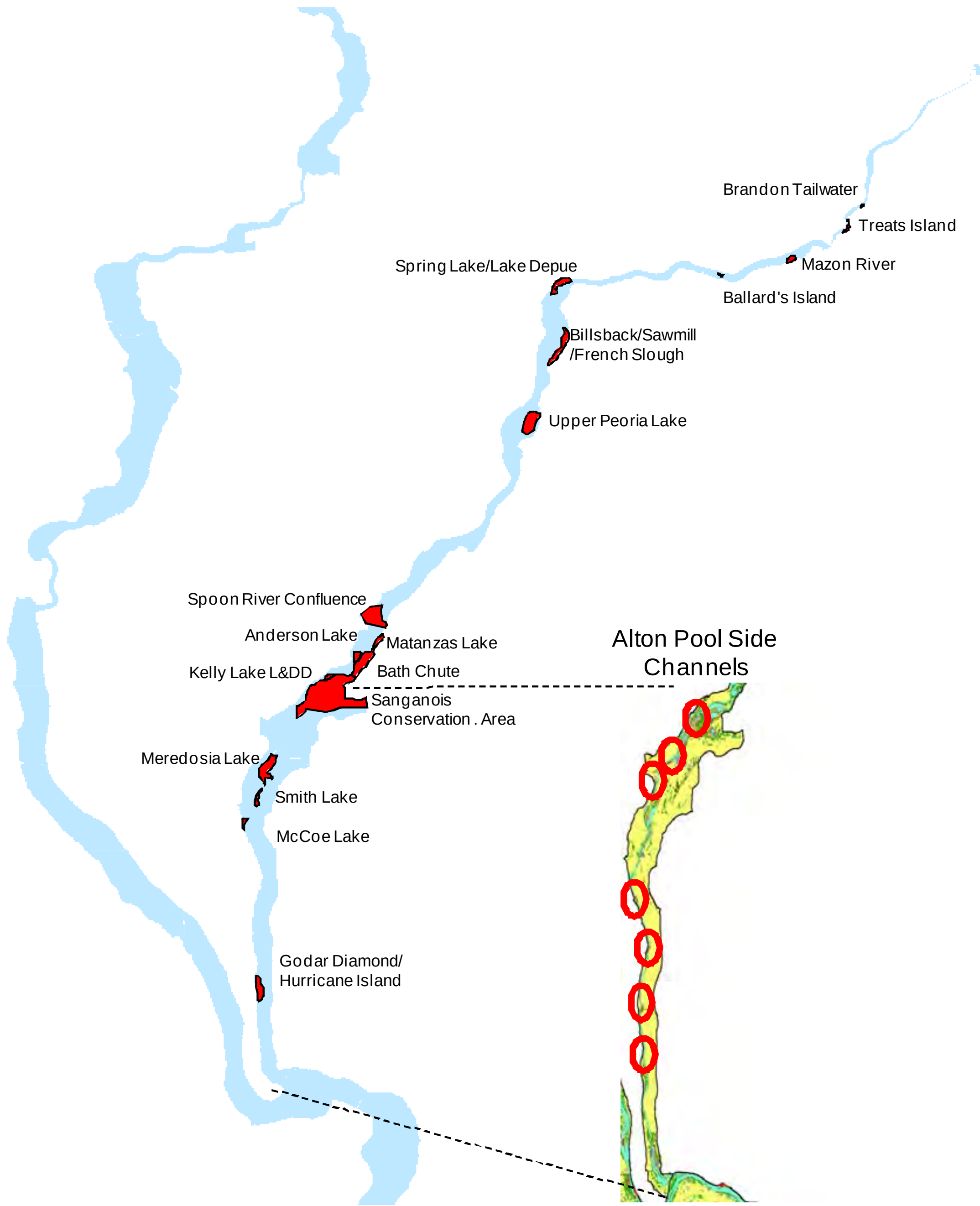


Figure ES-4. Illinois River Reach ecosystem restoration subarea priorities

UPPER MISSISSIPPI RIVER SYSTEM
ECOSYSTEM RESTORATION OBJECTIVES 2009

CONTENTS

UPPER MISSISSIPPI RIVER SYSTEM
ECOSYSTEM RESTORATION OBJECTIVES 2009

1.0. INTRODUCTION AND OVERVIEW

The Upper Mississippi River System (UMRS) (Figure ES-1) is recognized by Congress as a nationally-significant transportation system and a nationally-significant river ecosystem. The UMRS is a multi-purpose river system that provides economic, environmental, and cultural benefits to the nation. Upper Mississippi River System stakeholders are a diverse group of interests, spread over 1,200 miles of river and a 190,000-square-mile basin, with interests ranging from transportation and agriculture to tourism, recreation, and conservation of natural resources. The many agencies charged with aspects of river-floodplain management have individual missions and geographic areas of operation, and the need for integrated management of the UMRS has long been recognized. A myriad of interagency work teams and standing committees have been active in UMRS policy and management for many years.

The US Army Corps of Engineers (Corps) uses integrated, multidisciplinary Project Delivery Teams (PDTs) to plan and implement individual projects. However, the UMRS, like most Corps projects, needs to be planned and executed at a large geographic scale over a long time period. Planning for the UMRS ranges in scale from single projects to system-wide across several ecosystem restoration programs. The Corps, in collaboration with the Navigation and Ecosystem Sustainability Program (NESP) Science Panel, River Management Teams, and agency decision makers, is defining ecosystem restoration objectives at the river reach and system level in this planning effort.

1.1. PURPOSE OF THE PLAN

Upper Mississippi River System Reach Planning was undertaken to support multiple ecosystem restoration programs, including the Environmental Management Program (EMP), Illinois River Ecosystem Restoration Comprehensive Plan (IRER), and Navigation and Ecosystem Sustainability Program (NESP). The Reach Plans can be integrated with other Corps missions including inland navigation and flood damage reduction to promote more comprehensive river-floodplain management.

This document describes the outcomes of setting reach- and system-scale objectives for river-floodplain ecosystem restoration. The plans identify and sequence projects that are integral to the formal adaptive ecosystem management plan that also includes monitoring, assessment, and learning to develop better ecosystem restoration tools. The intended audiences are Corps project managers and PDT members, the UMRS natural resources management and science community, and UMRS decision makers.

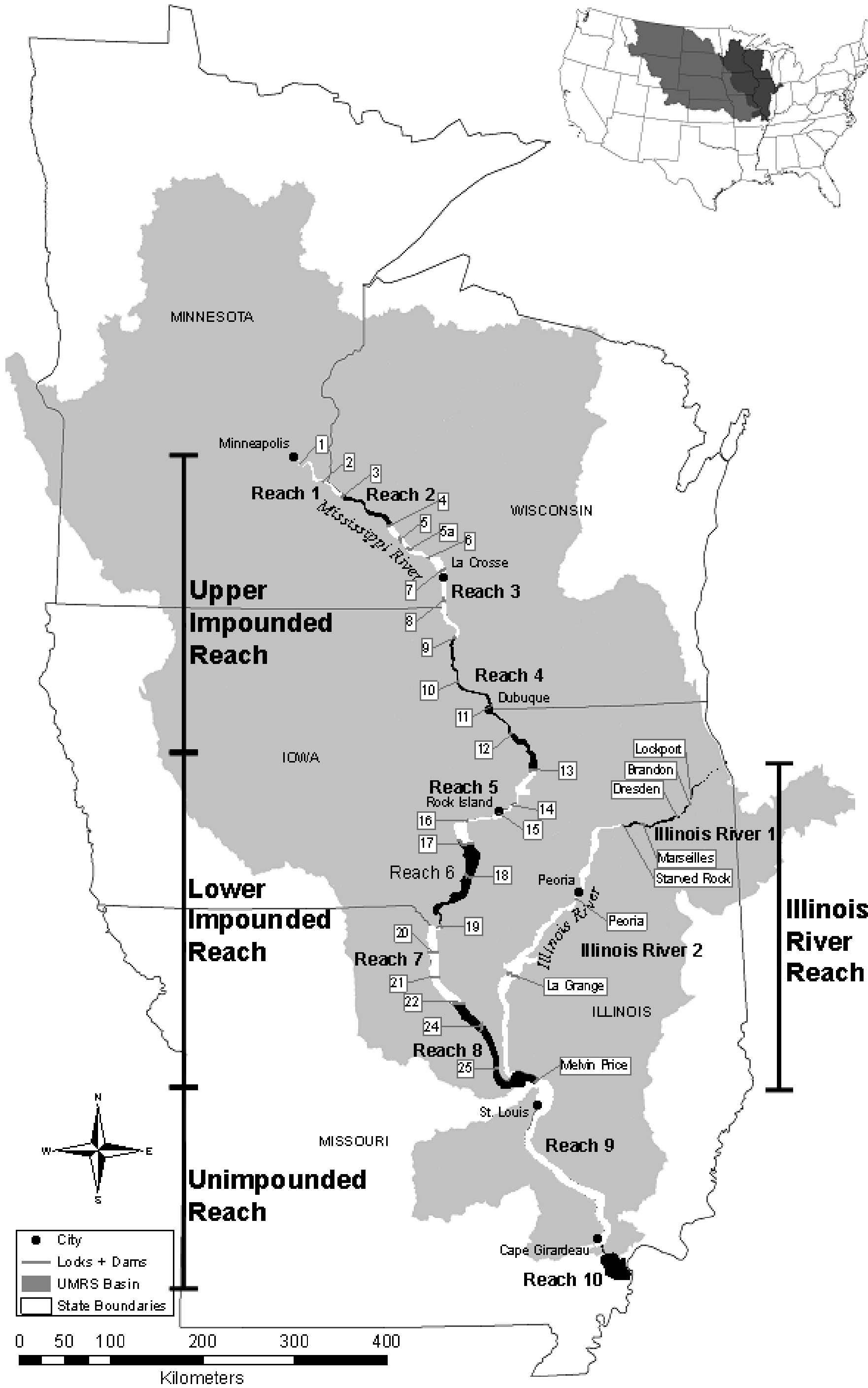


Figure 1. Upper Mississippi River System basin, dams, geomorphic reaches, and floodplain reaches

1.2. ADAPTIVE ECOSYSTEM MANAGEMENT

Management and restoration of the large and complex UMRS ecosystem will be conducted through a long-term commitment to a policy of adaptive management (Figure 2). Adaptive management is a process that promotes informed and flexible decision making that can be adjusted as outcomes from management actions and other events become better understood. Adaptive management is a process that uses management and restoration actions as tools to probe the functioning of an ecosystem. Successful adaptive management uses information from monitoring to continually evaluate and adjust management relative to predicted responses, management objectives, and predetermined thresholds of acceptable change. Information and linkages within ecosystems can be organized and evaluated using conceptual and simulation models.

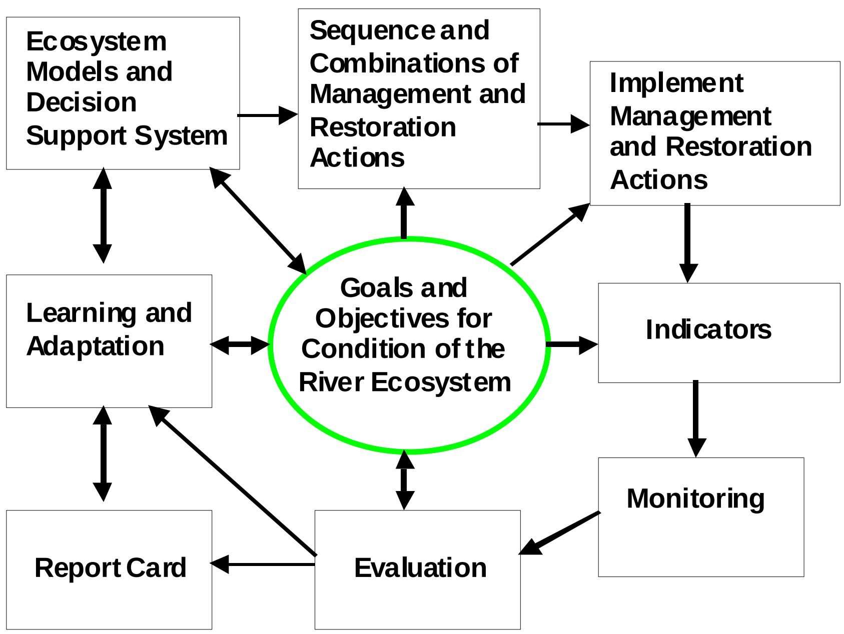


Figure 2. Goals and objectives are central to Upper Mississippi River System adaptive ecosystem management

Restoration planning for UMRS ecosystem restoration programs has progressed from site specific project identification (DeHaan et. al. 2003) to a more comprehensive regional Habitat Needs Assessment (HNA), and to the current Reach Planning process. Most recently, science advisors recommended a river reach and system-wide approach (Figure 3) that will help river managers plan and implement individual projects that will contribute to restoration success at larger spatial scales. They recommended a "top-down" process that starts with a vision statement and ecosystem goals for the entire system that assist regional program managers and individual project teams in developing reach- and project-scale objectives to achieve these goals.

A system-wide approach emphasizes restoring ecosystem functions and processes over ecosystem structure (pattern of habitats, life forms) at individual project areas. A system-wide approach ensures logical connections between vision, goals, and objectives at different scales. This approach will strengthen the scientific basis for ecosystem restoration efforts, provide clear linkage across scales of the system, provide a logical basis for identifying and sequencing projects, and will support adaptive ecosystem management.

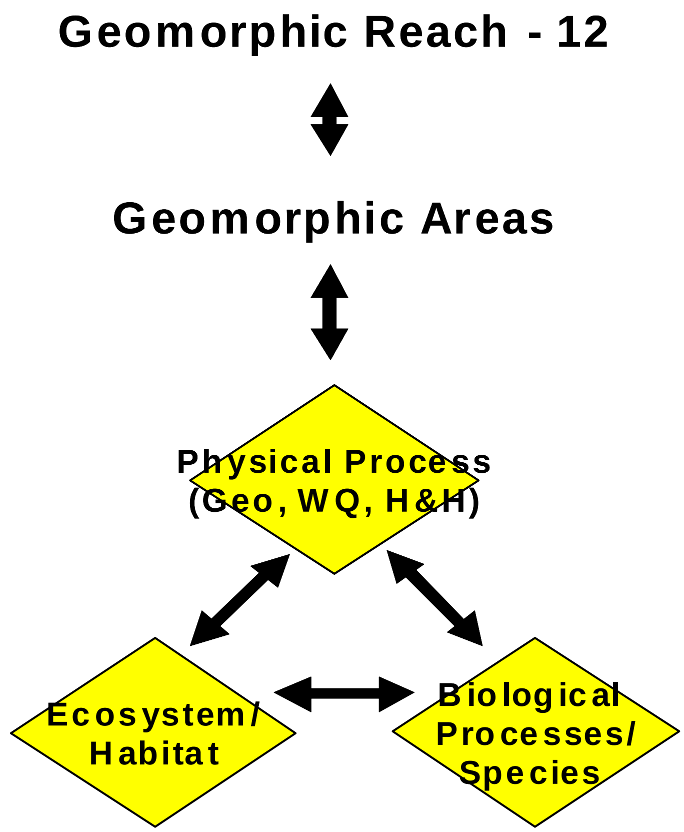


Figure 3. Conceptual representation of longitudinal space (geomorphic reaches); lateral space (geomorphic areas); and ecosystem processes and functions (Geo = geomorphology, WQ = water quality or biogeochemistry, H&H = hydrology and hydraulics) for the Upper Mississippi River System

Many ecological principles apply throughout the large river-floodplain ecosystem, but geomorphic and hydrologic characteristics change downstream and laterally across the floodplain. Local hydrologic and geomorphic conditions (i.e., hydro-geomorphology) then interact to determine regional and local habitat characteristics and potential plant and animal communities. Ecologically equivalent species may be apparent in the large system, stretching across several eco-regions. Geomorphic Reach Planning Teams established ecosystem objectives, performance criteria, and identified future restoration projects within reaches to best meet objectives, capturing local conditions, knowledge, and opportunities. The process also captures large-scale objectives such as animal migrations and sediment dynamics that may not appear in individual project plans.

Goals and objectives for condition of the river ecosystem are central to river management (Figure 2). Goals and objectives are logically linked to management actions, indicators of ecosystem conditions, monitoring activities, reporting on ecosystem conditions, and learning.

1.3. CONCEPTUAL MODEL

Modeling and understanding ecological mechanisms to estimate environmental benefits and outcomes are important elements of adaptive management. A simple ecosystem conceptual model (Figure 4) is used to illustrate linkages among UMRS Essential Ecosystem Characteristics (EECs): geomorphology, biogeochemistry, hydrology, habitat, and biota. The model considers boundary condition drivers like glacial geology and climate that establish general ecosystem characteristics at the larger scales. There are numerous natural and anthropogenic stressors that perturb ecosystems and cause spatial and temporal variation throughout the river-floodplain system. Some are minor seasonal stressors like floods or cold weather, others are extreme natural events like great floods, droughts, or fire that are uncommon but strongly influence ecosystems. Human caused stressors, management actions, include large, permanent physical changes like dams, levees, and urbanization as well as smaller disturbances like local land clearing or channel modifications whose cumulative impacts may cause large change.

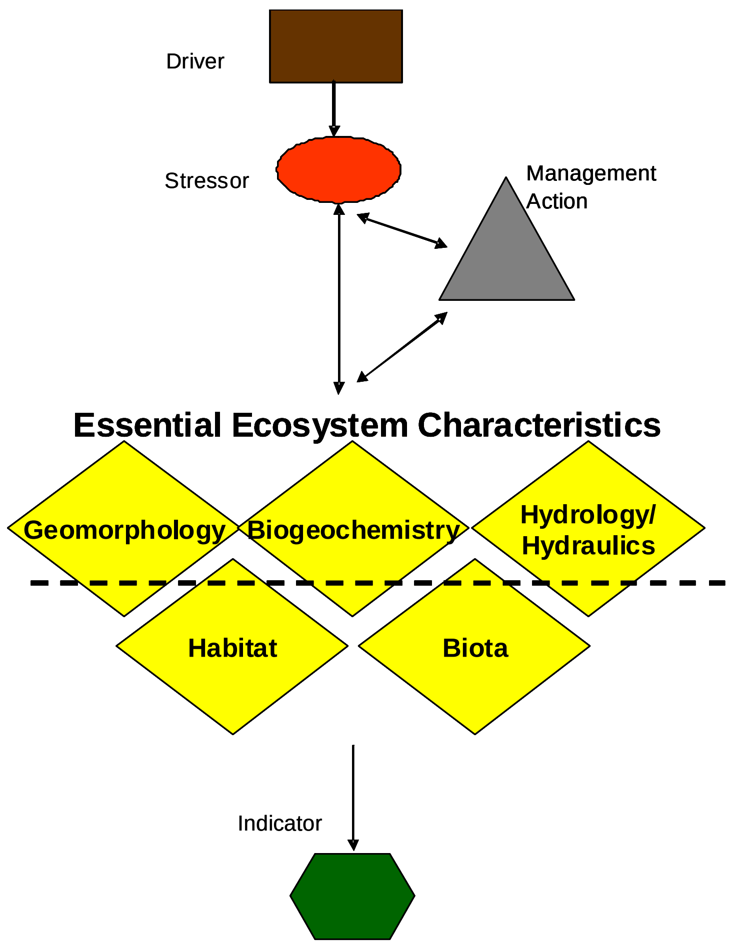


Figure 4. Upper Mississippi River System ecosystem conceptual mode

Management actions also include a range of activities meant to improve or maintain ecosystem condition. Ecosystem condition and response to management actions can be characterized by indicators (Table 1) representing individual Essential Ecosystem Characteristics (EECs) or perhaps as a habitat or biological outcome reflecting the condition of several EECs. Physical structure and processes strongly influence habitat structure which supports plant and animal species, but there are also feedbacks (Figure 5). This simple conceptual model is referenced throughout the Reach Planning process. It was used to categorize system-wide objectives and to focus in on specific reaches and subareas. It is used to organize ecological parameters and relationships among them in a Decision Support System (DSS) with relevant spatial data from multiple historic, contemporary, and modeled reference conditions.

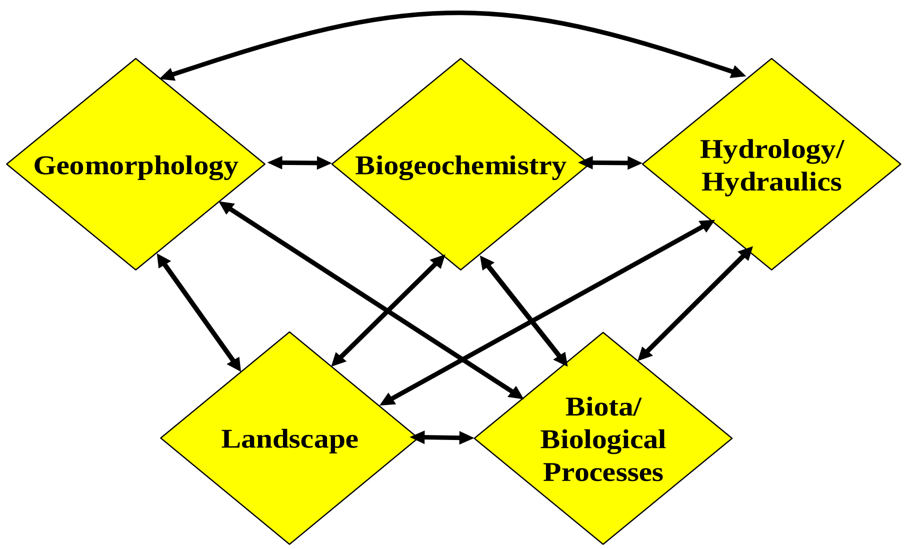


Figure 5. Upper Mississippi River System essential ecosystem characteristics interact mostly as physical processes and structure (geomorphology, biogeochemistry, H&H) influencing habitat and biological outcomes

Table 1. Ecological indicators applicable at several spatial scales for Upper Mississippi River System essential ecosystem characteristics

	Boundary Condition	Reach Scale	Local Scale
Geomorphology	glacial geology	• land sediment assemblages • impoundment effects • levee effects • aquatic area change • geomorphic change	• elevation • soil • geomorphic change
Hydrology and Hydraulics	Climate/Discharge • magnitude • frequency • timing • duration • rate of change	Water Surface Elevation • magnitude • frequency • timing • duration • rate of change	• flow distribution • direction • depth • velocity • inundation magnitude • frequency • timing • duration • rate of change • pool scale hydrologic gradient
Biogeochemistry	• basin geology • basin land cover • non-point pollution	Major Watershed • geology • land cover • non-point pollution	• nutrient abundance • water clarity • dissolved oxygen • sediment quality • point source pollution • non-point pollution
Habitat	• climate • biodiversity • geomorphology • hydrology	• regional climate • eco-regions • land use • ecosystem/community type • disturbance	• land cover • ecosystem/community type • geomorphology • hydrology • aquatic areas
Biota	• biodiversity • long distance migrants	• populations • communities	• species composition
Biotic Processes	• biochemistry	• climate • genetics	• production • growth

1.4. HIERARCHY OF VISION, GOALS, AND OBJECTIVES FOR THE RIVER ECOSYSTEM

Logical and scientifically-supported connections between Vision, Goals, and Objectives are needed to ensure ecological and cost effectiveness of system management and restoration. Much effort has gone into establishing goals and objectives for the UMRS over the last 30 years. An initial Comprehensive Master Plan for the Upper Mississippi River Basin established a baseline understanding of the condition of the entire system and system-wide economic, environmental, and recreational objectives. Since then iterative planning has emphasized different system components or was conducted in response to advances in knowledge or occurrence of extreme events, such as floods and droughts. The cumulative work of many planning studies has resulted in a hierarchy of Vision, Goals, and Objectives for the UMRS ecosystem developed with UMRS natural resource managers:

Vision Statement for the Upper Mississippi River System

> ***To seek long-term sustainability of the economic uses and ecological integrity of the Upper Mississippi River System***

This vision statement has its origins with UMRS Interagency Planning Committee meetings and was inspired by the United Nations World Commission on Environment and Development. The vision has been incorporated into recent planning documents and authorities.

The NESP Science Panel reviewed the status of environmental goals three times. The first review recommended an adaptive management process that was integrated into the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study and authorizing language in the Water Resources Development Act of (WRDA) 2007. The Panel synthesized over 2,800 site-specific objectives for condition of the river system into 81 ecosystem objectives organized under five Essential Ecosystem Characteristics (EEC's, Figure 3). The review established the concept of EECs firmly in the UMRS planning lexicon.

The second NESP Science Panel review refined the ecosystem objectives and made them more practical and quantitative to apply Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) performance criteria to them. The resulting list of 43 ecosystem objectives (Appendix A, *Upper Impounded Reach Plan*) is broad so they may apply at different geographic scales and locations in the system. Many physical objectives are precursors that, if attained, would support biotic objectives. For example, sufficient water clarity (Objective 1.9) and reduced wind fetch (Objective 3.7) would contribute to increased abundance of submersed aquatic plants (Objective 4.4). The list of ecosystem objectives was developed as a guide to help project planning teams consider a wide range of important ecosystem functions.

The third NESP Science Panel review of goals and objectives was at the Navigation and Environmental Coordinating Committee's (NECC) request for a set of system goals and objectives to frame their local planning activity. The result of the most recent review presented an over-arching ecosystem goal for the UMRS and a series of ecosystem goals addressing essential ecosystem characteristics (EECs). The adaptive management approach guiding the most recent review recommended an explicit consideration of ecosystem process and function attributes where prior planning emphasized structural indicators (e.g., habitat).

Over-Arching Ecosystem Goal

> ***To conserve, restore, and maintain the ecological structure and function of the Upper Mississippi River System to achieve the vision***

Ecosystem Goals

1. Manage for a more natural hydrologic regime (Hydrology & Hydraulics)
2. Manage for functions that shape diverse and dynamic channels and floodplain (Geomorphology)
3. Manage for more natural materials transport and processing functions (Biogeochemistry)
4. Manage for a diverse and dynamic pattern of habitats to support native biota (Habitats)
5. Manage for viable populations of native species and diverse plant and animal communities (Biota)

1.5. DECISION SUPPORT TOOLS

The UMRS is a data rich environment where a common problem is access to data. Many data layers representing the EECs in the UMRS ecosystem conceptual model were integrated into a Geographic Information System (GIS) Decision Support System where they can be queried and overlain to enhance the utility of the layers individually. The geomorphology, hydrology and hydraulics, and habitat EECs are best represented in system-wide GIS coverages (Table 2). The attributes within GIS data layers (Figure 6) form the basis of queries of the condition of ecosystems. The ecosystems represented may be existing conditions, historic conditions or they may be modeled future alternative conditions (Figure 7). They are useful for environmental benefits analysis where baseline conditions can be compared against alternative future conditions. All results presented in this report were derived from the DSS data layers.

Table 2. System-wide GIS data sets integrated in the Upper Mississippi River System Decision Support System. In addition, there are many site specific data, other data layers, and imagery

Geomorphology	Biogeochemistry	Hydrology/Hydraulics	Habitat	Biota
Land Sediment Assemblage		Aquatic Areas	<1850	
Land-Water		1890 Aquatic Areas	1890	
Leveed Area		Existing Flood Inundation Area	1975	
Future Geomorphic Condition		Modeled Flood Inundation Area	1989	
Hydraulic Structures		Modeled Pool Inundation Area (No Pumps)	2000	
Elevation			Potential Future	

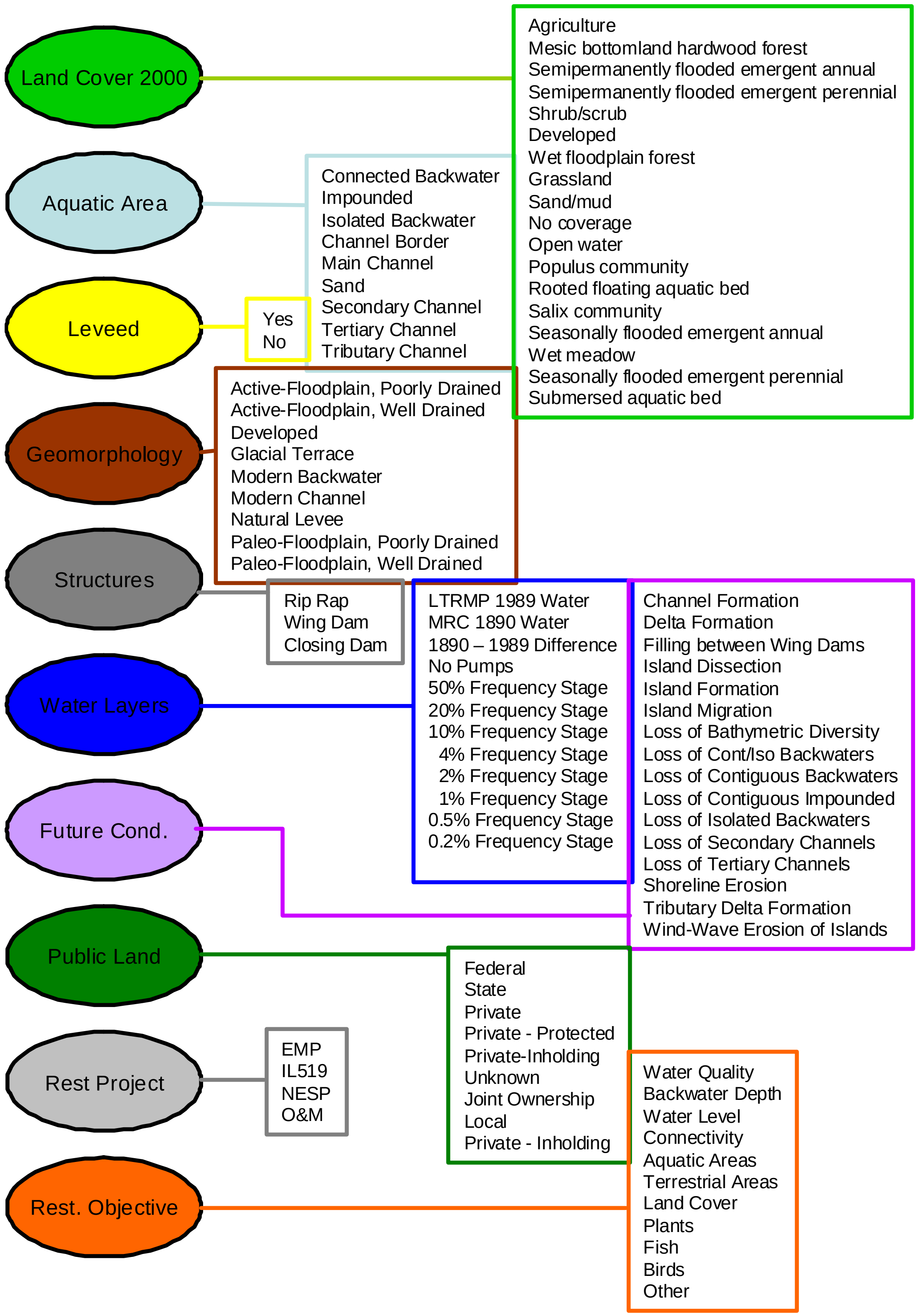


Figure 6. An example of the attributes in the Upper Mississippi River System Decision Support System

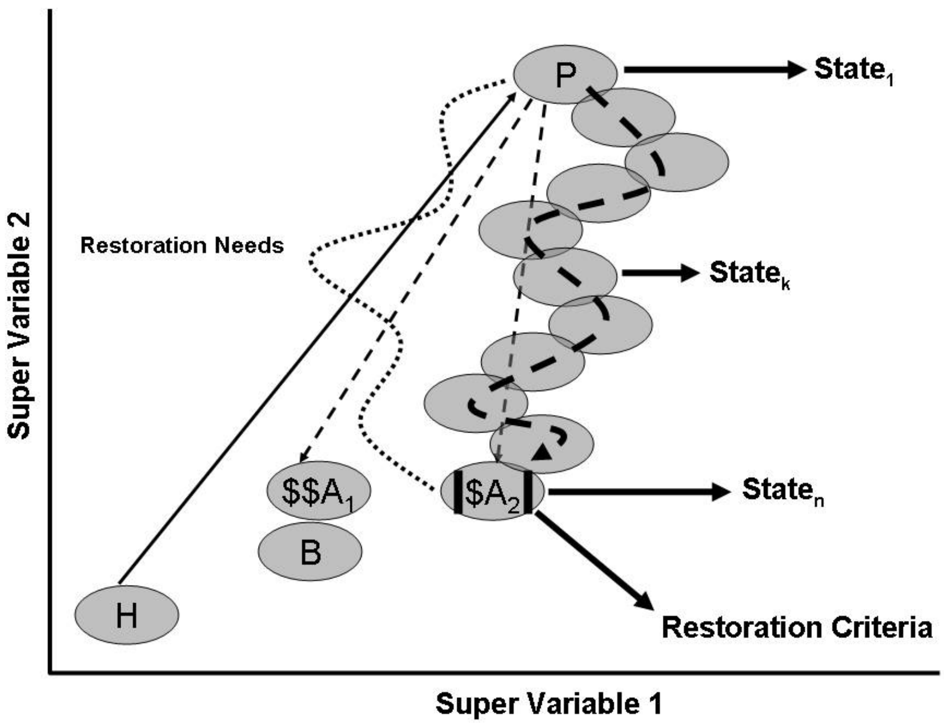


Figure 7. Multiple reference condition analysis for ecosystem restoration evaluation compares ecological parameters among historic (H), existing (P), alternative future (A_n), and best attainable (B) condition

2.0. GEOGRAPHIC SCALES FOR PROGRAM MANAGEMENT, PROJECT PLANNING AND IMPLEMENTATION

Large rivers like the Mississippi are unique in that they integrate large watersheds, each of which influences the character of the mainstem river and floodplain. Development at many scales has changed the relationship between modern rivers and their watersheds, and the UMRS is no exception with more than 80 percent of the watershed developed. Natural resource managers recognize the importance of tributaries on the mainstem, but have historically had little authority to integrate watershed and river management; the UMRS has been defined by Congress as the Upper Mississippi and Illinois Rivers and navigable portions of the Minnesota, St. Croix, Black and Kaskaskia Rivers. Congress provided the Corps of Engineers and partner agencies with authority to manage the navigation system and to manage, monitor and restore natural resources in the channels and floodplains of the system. Given existing authorities, we can plan for and implement management and restoration actions only within the channels and floodplains of the UMRS and in tributary confluences. Authority does not extend up tributary river basins or throughout the UMRS Basin except for the Illinois River Basin Ecosystem Restoration authority. Recent policy changes among many agencies are changing this relationship and making mainstem and watershed planning more integrated (e.g., Illinois River, Minnesota River, St. Croix River, Wisconsin River and Iowa-Cedar River watershed programs).

The UMRS is organized as a hierarchy of scales for program management, planning and implementation because consideration of geographic scale pervades our work. The hierarchy is reviewed below and scale-relevant ecological process and functions are discussed. Following the Science Panel's top-down approach, the discussion focuses from large regional glacial and climatological processes to more regional geomorphology and hydrology, to local floodplain and aquatic areas that define surface and floodwater distribution and retention that determines local plant communities. The elements of the conceptual model are emphasized. Ecological change in response to development is analyzed at the system scale with local examples for illustration.

2.1. UPPER MISSISSIPPI RIVER BASIN

The UMRS Basin is the entire drainage basin of the Mississippi River (excluding the Missouri River) above the confluence of the Ohio River at Cairo Illinois (Figures 1 and 8). The topographic relief map (Figure 8) helps understand the geologic and glacial processes that formed the 190,000 square mile watershed. Several glacial outwash events in the upper valleys of the Mississippi and Illinois River are responsible for the Holocene land surfaces present prior to large human intervention. Ancient glacial events from the West cut through the driftless area as a marginal stream of the Kansan Glacier while events in Iowa shaped the river valley south from Muscatine to Keokuk, Iowa and then down to the Great Rivers confluence near St. Louis, Missouri. The Missouri River is a very large influence below St. Louis. The Illinois River has two prominent reaches separated where the ancient Mississippi River flowed during several glacial sequences. The Mississippi River migrated to the Illinois valley from an area north of the Quad Cities across Northeast Illinois to the Great Bend at Hennepin, Illinois. The Lower Impounded Reach (LIR) is thus much different from the Upper Impounded Reach (UIR). The entire Illinois Basin is influenced by sand bars and splays from the Kankakee Torrent. Most of the river basin is currently in agricultural use through Southwest Minnesota, Iowa, Illinois, and Northeast Missouri. The northern parts of the basin in Wisconsin and Northeast Minnesota are reforested (Figure 9). A potential presettlement vegetation map estimated more prairie, savanna, and wider forest buffers along waterways (Figure 9).

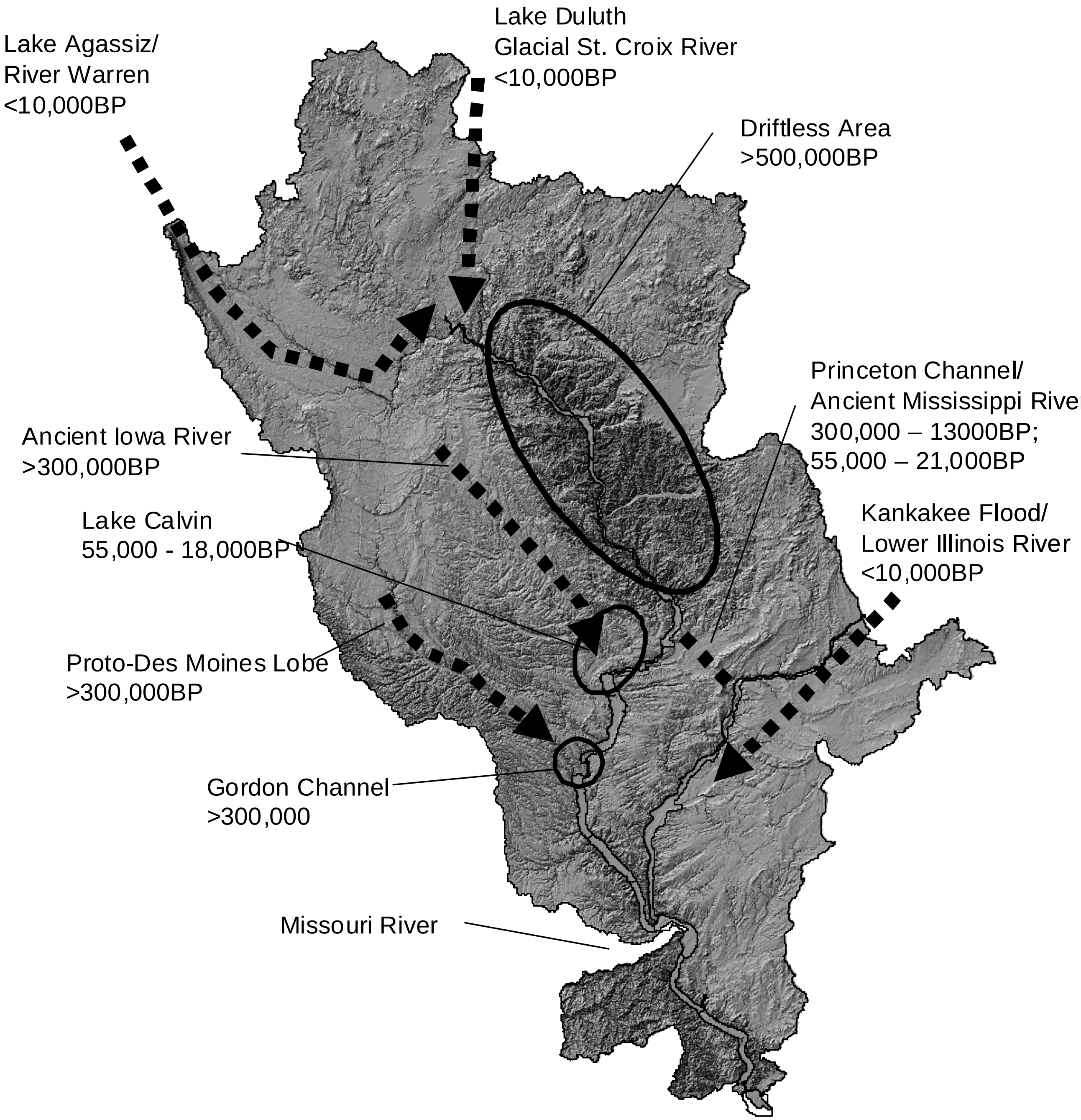


Figure 8. Glacial features that formed the Upper Mississippi River System Basin

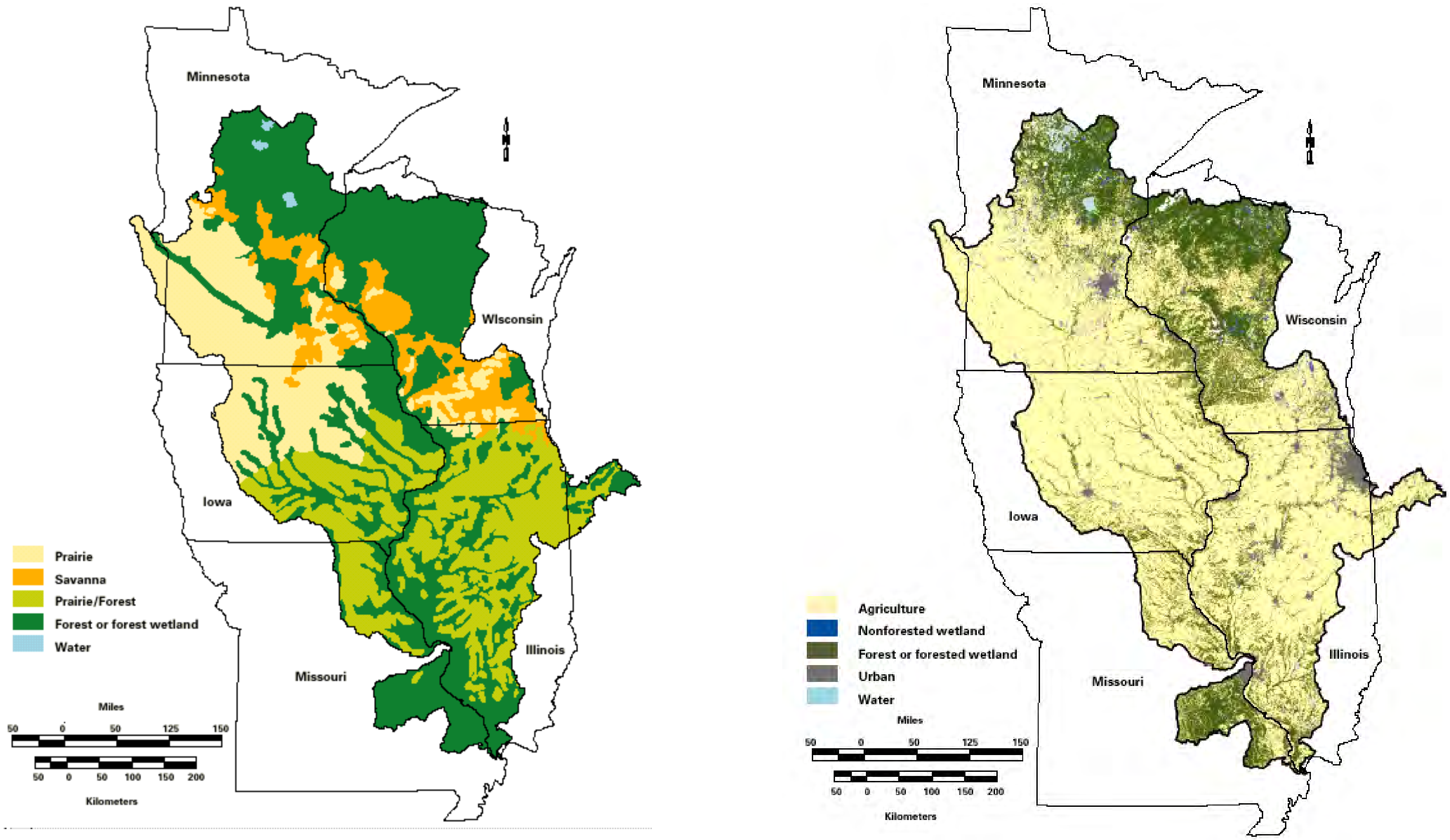


Figure 9. Potential presettlement land cover in the Upper Mississippi River System Basin (left) and contemporary land cover (right)

2.2. TRIBUTARY BASINS

There are 11 large tributary watersheds, excluding the Missouri River, that influence the UMRS (Figure 10). These large watersheds have different geologic origins and characteristics, but the northern tributaries mostly drain coarse glacial till and mid-basin tributaries drain loess plains. Large tributary confluences help define river reaches, small tributaries adjacent to the bluffs strongly influence floodplain habitat and habitat characteristics within reaches (Figures 10). Sedimentation was greatly increased by deforestation and land use conversion from grassland to row crop agriculture, but soil conservation practices improved over time. Terrace farming and retention basins in the northern basin checked early erosion problems following widespread deforestation. Sheet and rill erosion common in row crop agriculture was reduced with no-till cropping practices, and stream buffers have helped control gully erosion, sediment transport, and nutrient delivery in the Corn Belt. Streambank erosion is a watershed resource issue that is being targeted now through programs like the Natural Resources Conservation Service Environmental Quality Incentives Program. The concentration of suspended sediment in the rivers increases and water clarity declines in a southern direction.

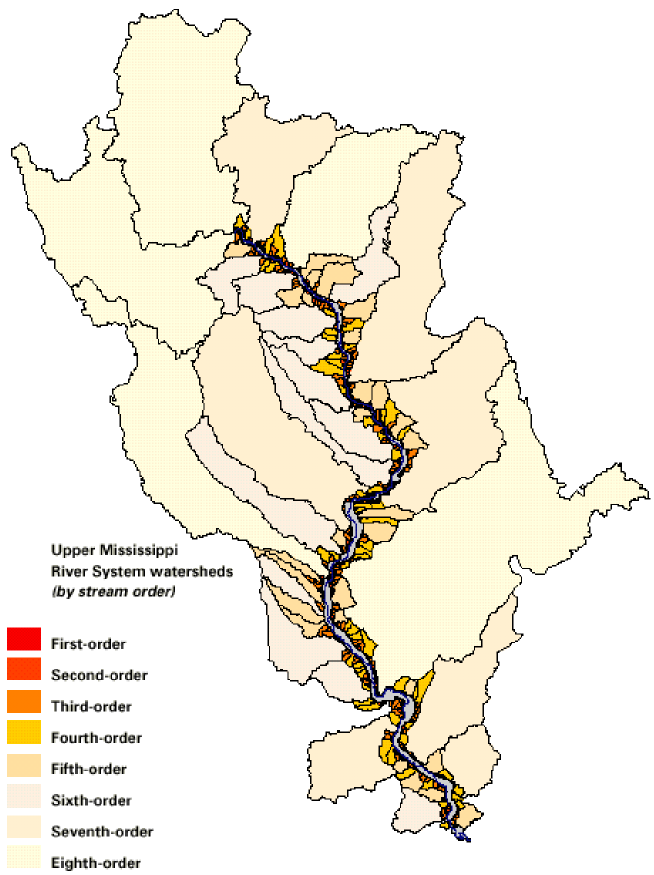


Figure 10. Upper Mississippi River System tributary river basins

2.3. FLOODPLAIN REACHES

Four UMRS floodplain reaches have been defined by their general geomorphology, the characteristics of river-floodplain development, and the ecological response to development (Figure 11). The floodplain reaches are ecologically distinct from one another based on land cover (Figures 12a and 12b), longitudinal profile of the river, floodplain geomorphology, hydrology, land use in the floodplain, channel form and even climate. The reaches are defined by navigation pools and include:

- Upper Impounded Reach (St. Anthony Falls through Pool 13)
- Lower Impounded Reach (Pools 14 through 26)
- Unimpounded (Middle Mississippi)Reach (Melvin Price Locks & Dam to the Ohio River)
- Illinois River Reach

2.3.1 Upper Impounded Reach. The UIR is characterized as an island-braided reach with good water quality, sand and gravel substrates, abundant public land, and few levees (Figure 13). Considering geology only, the reach should be extended through much of Pool 14 to the Rock Island Gorge, but reach delineations have been made at dams for convenience of Corps planners and state partners. Aquatic and wetland vegetation is common in the UIR, but may fluctuate among years and locations. Forests are even-aged and low diversity, but generally contiguous through the entire reach. The UIR shows the most increase in surface water area due to impoundment among floodplain reaches (Figure 14). The reach has high public use.

2.3.2 Lower Impounded Reach. The LIR has the Rock Island and Keokuk valley reaches that separate broad floodplain reaches. Channel sediments are sandy and LIR backwaters have flocculent silt over clay that is easily resuspended. Pool 19 stands out unique in the amount of water area impounded, most of the LIR shows little surface water change from impoundment (Figure 14). Water clarity decreases and river stage variation increases in the reach and aquatic plants are thus uncommon in LIR backwaters. The LIR has many Levee and Drainage Districts (L&DDs) that amount to over 50 percent of the total floodplain area (Figures 14 and 15). Land use is predominantly row crop agriculture (Figures 12a and 12b) with public land concentrated in a couple of patches. Public use is intermediate in the LIR.

2.3.3 Unimpounded (Middle Mississippi) Reach. The Unimpounded (Middle Mississippi) Reach (MMR) is highly influenced by the Missouri River which increases discharge by more than 50 percent and greatly increases sediment load. The Middle Mississippi Reach (MMR) is presently classified as a straight, sandbed channel, but historic meanders are a prominent feature of the floodplain geomorphology. The lowest reaches show the characteristic bends and alluvial swamp habitats of the Mississippi Alluvial Valley. The reach is not impounded because the Missouri River adds enough flow to maintain the navigable water depths with dredging and channel training structures alone. The MMR floodplain is protected by large mainstem levees that are part of the Mississippi Rivers and Tributaries Project in the Lower Mississippi River (Figure 16). Floodplain development also included the loss of many floodplain lakes in addition to flood protection and other land conversion. The St. Louis Metropolitan area is a large influence in the upper part of the reach and agriculture dominates downstream. Public land is very rare, but increasing over the last couple of decades. Floodplain vegetation was completely altered (Figure 17), but native communities remain in limited spaces. Secondary channel aquatic habitat loss is an urgent habitat management concern. Public use is very low and access is restricted.

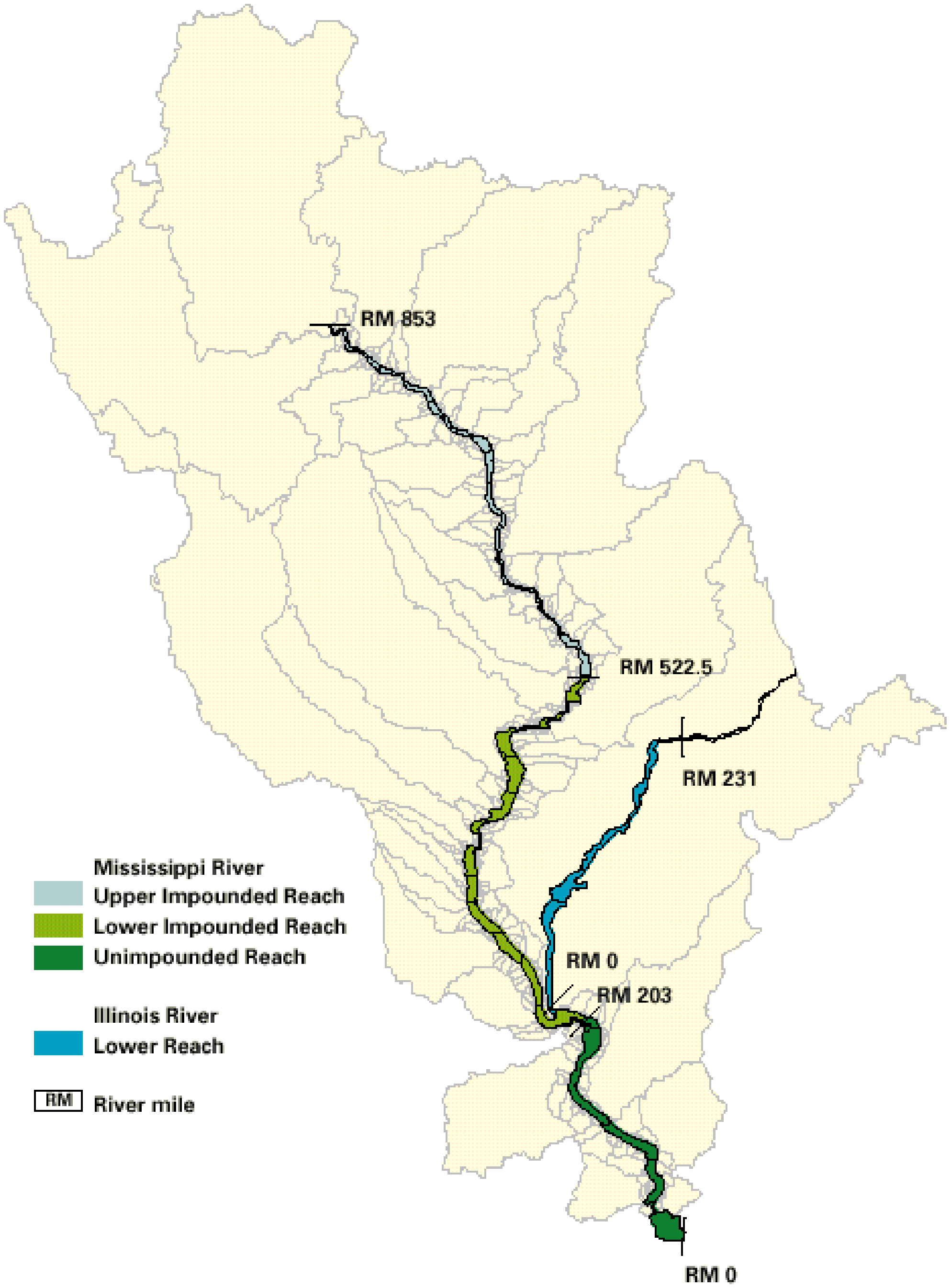


Figure 11. Floodplain Reaches of the Upper Mississippi River System

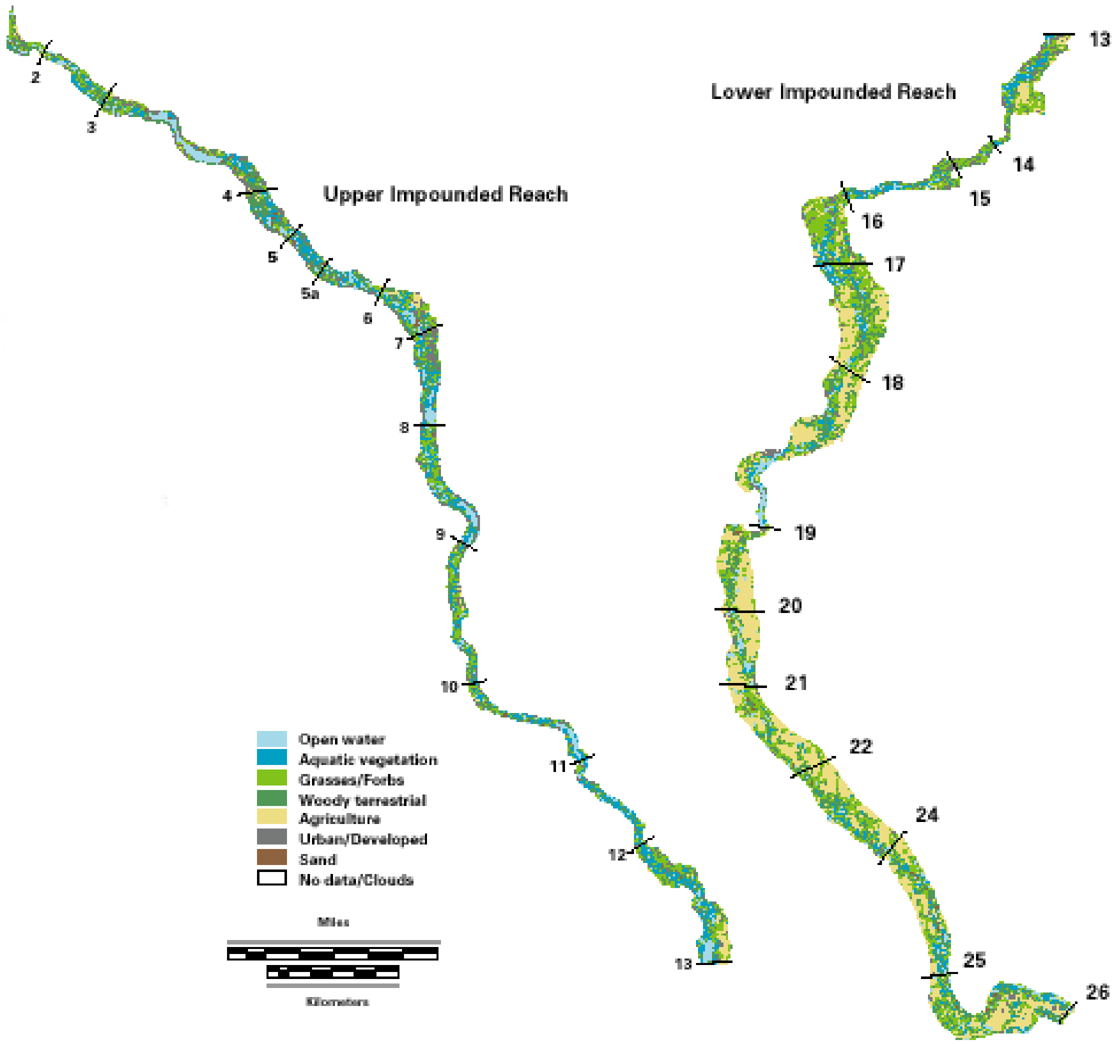


Figure 12a. Land cover in the Upper Mississippi River System floodplain reaches

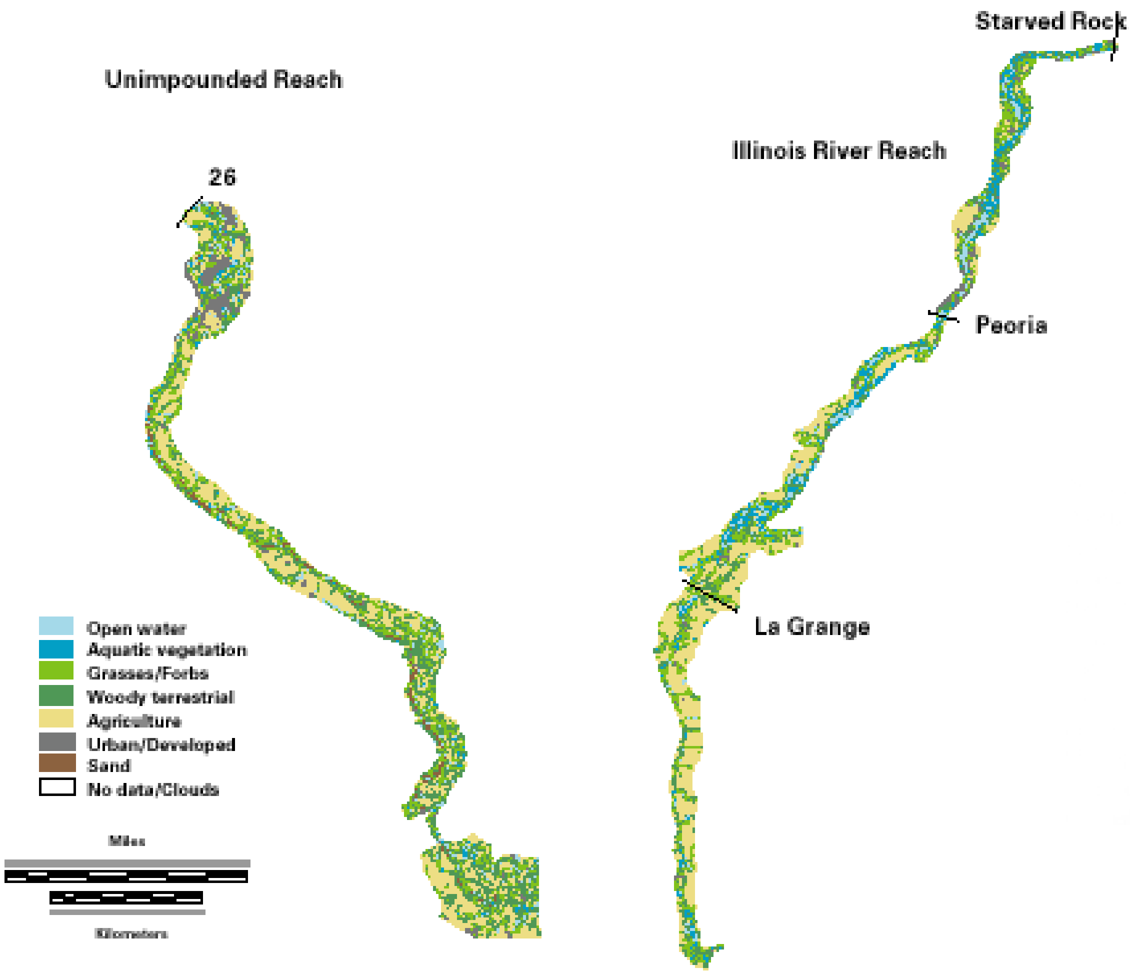


Figure 12b. Land cover in the Upper Mississippi River System floodplain reaches

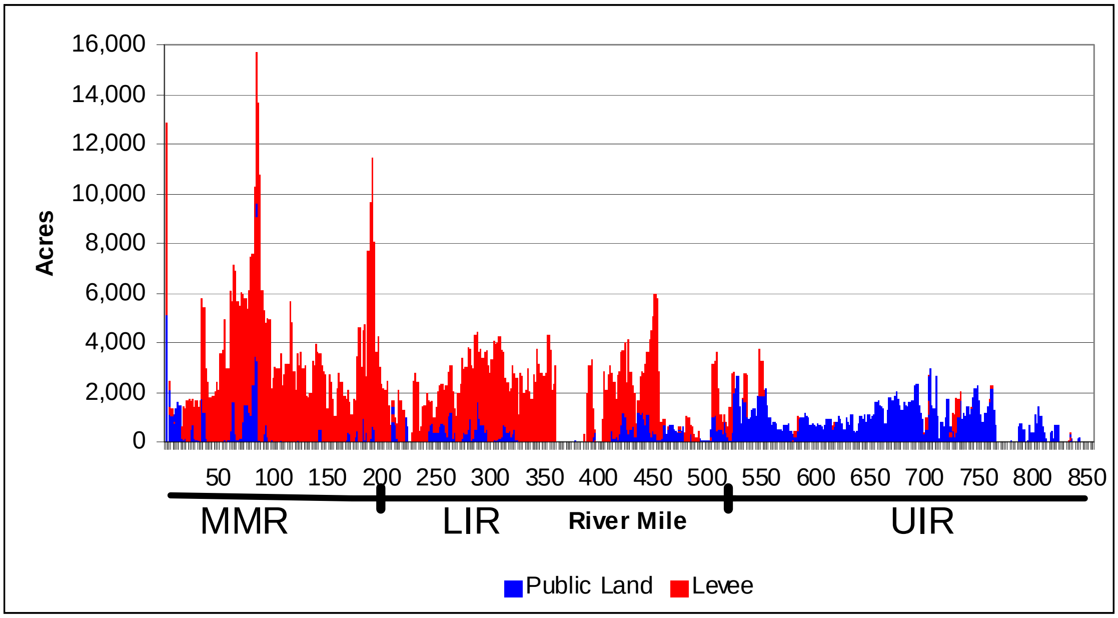


Figure 13. Public land and leveed area distribution by river mile and Mississippi River Floodplain Reaches (MMR – Middle Mississippi Reach; LIR – Lower Impounded Reach; UIR – Upper Impounded Reach)

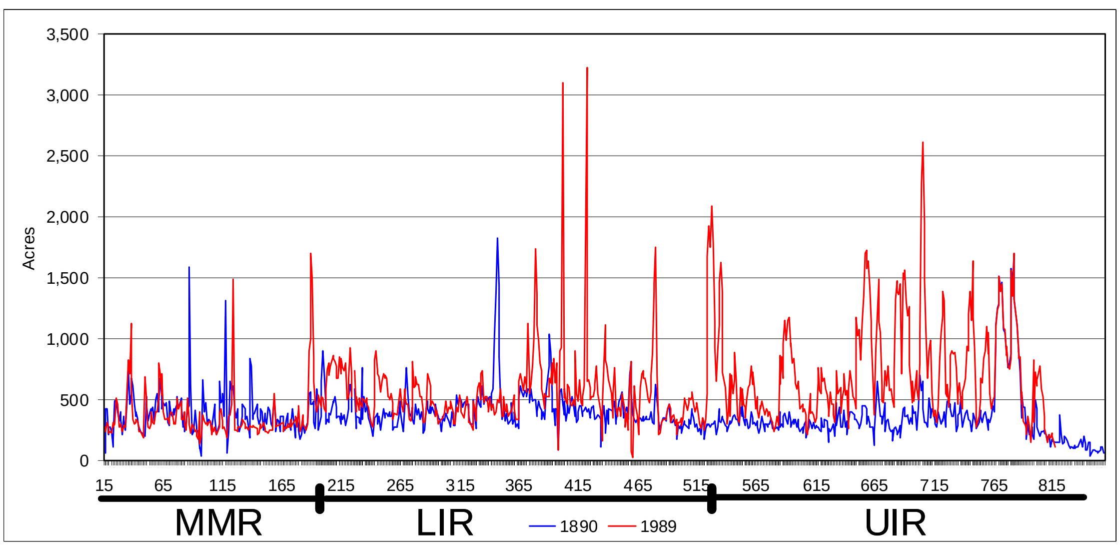


Figure 14. Open water area in acres for each river mile during pre-dam (ca. 1890) and contemporary conditions (MMR – Middle Mississippi Reach, LIR – Lower Impounded Reach, UIR – Upper Impounded Reach)

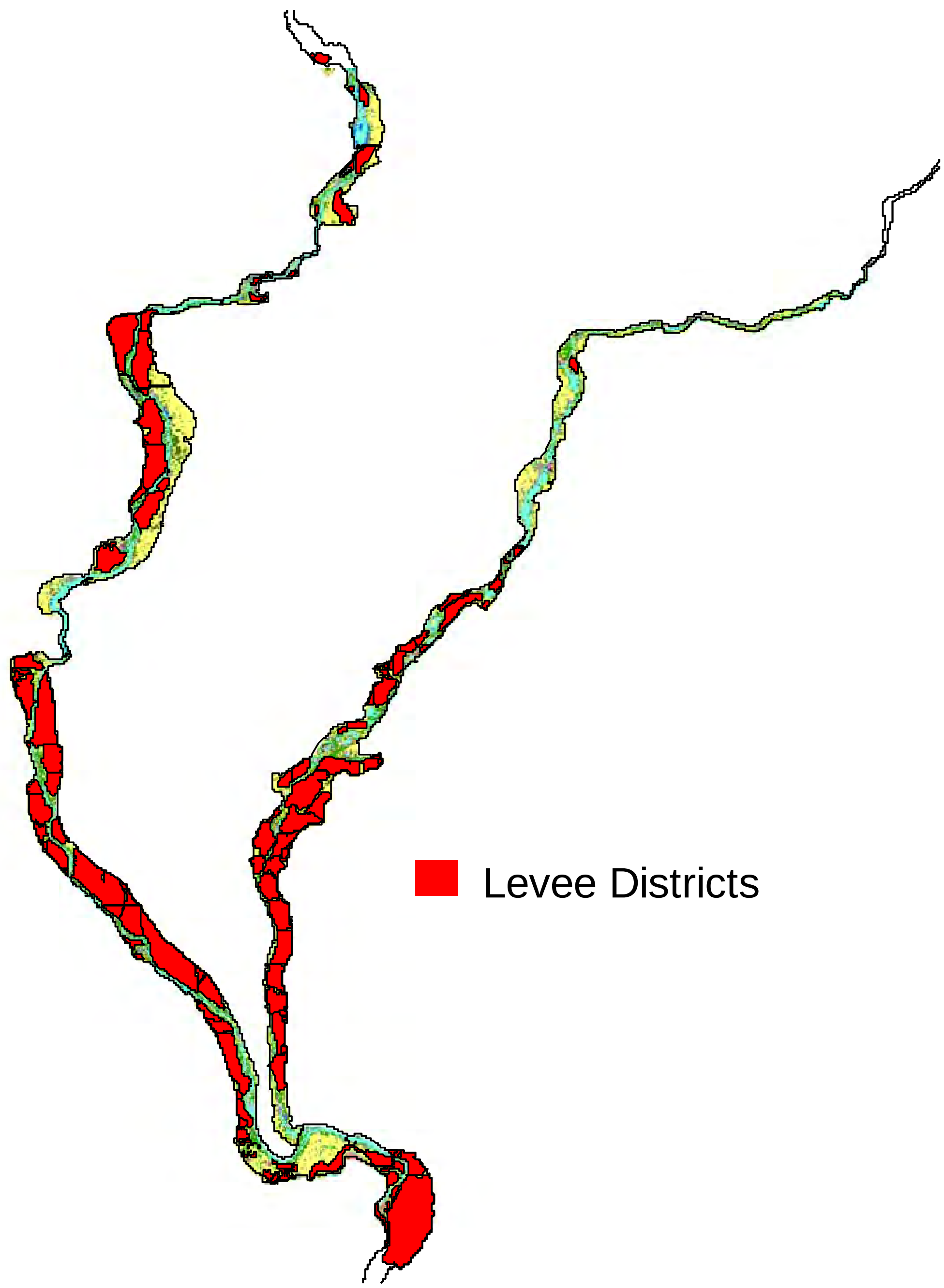


Figure 15. Upper Mississippi River System, Lower Impounded Reach, and Lower Illinois River Reach levee district distribution

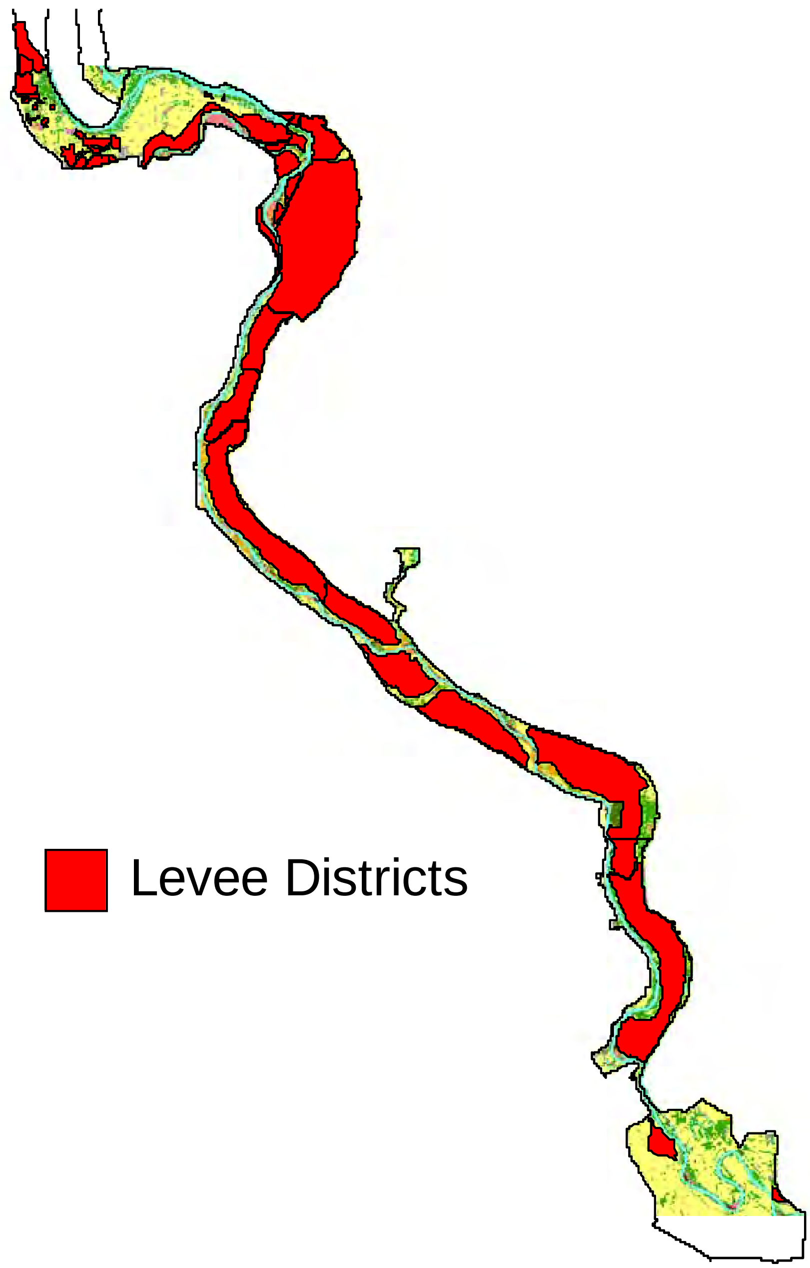


Figure 16. Upper Mississippi River System, Middle Mississippi River Reach levee district distribution

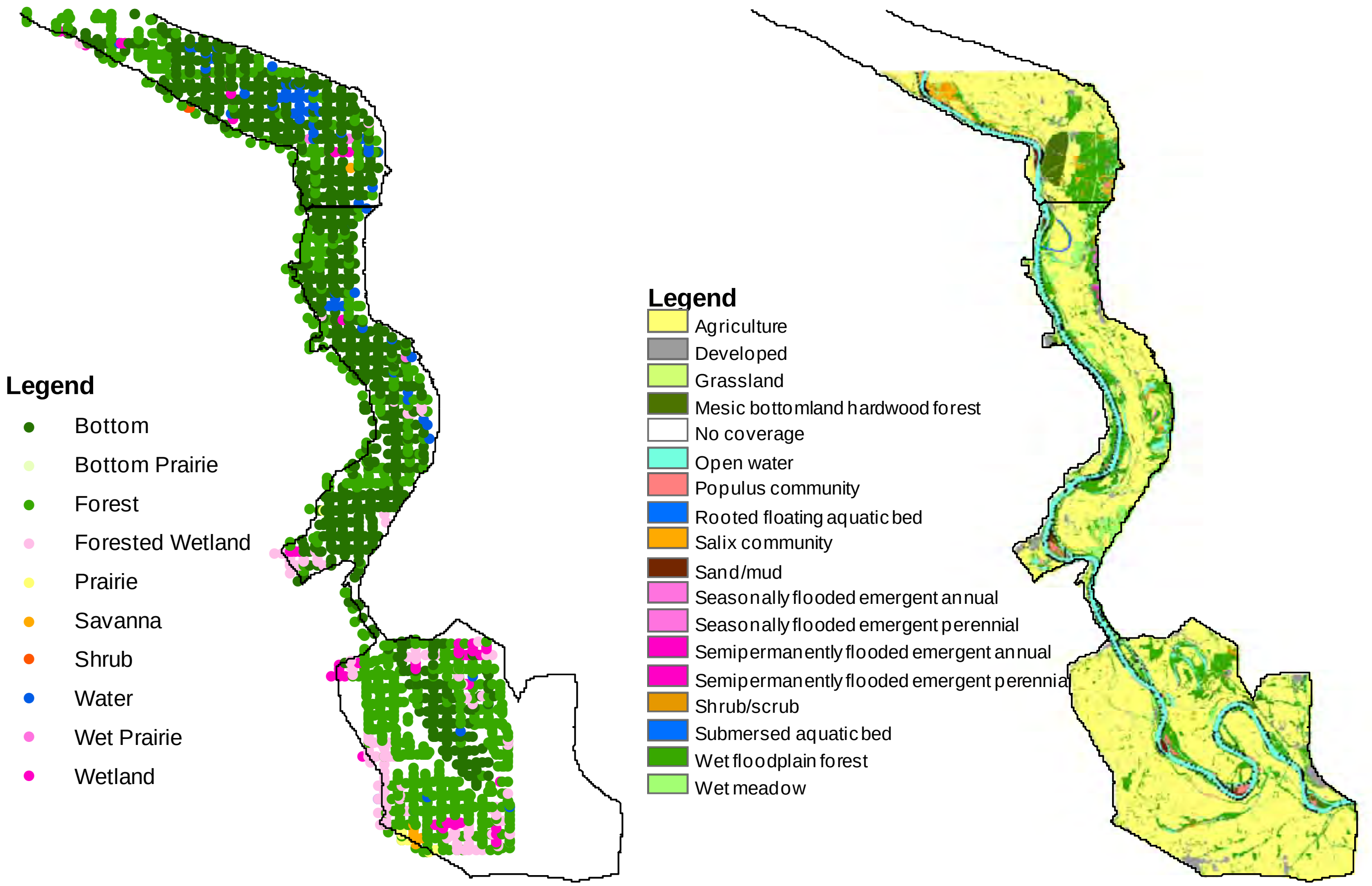


Figure 17. Middle Mississippi River Reach presettlement (left) and contemporary (right) land cover

2.3.4. Illinois River Reach. The Illinois River has two reaches with the upper being a younger stream in a steep rocky gorge that is now highly impounded and urbanized. The Lower Illinois Reach is an alluvial floodplain river similar to the Mississippi but with an exceptionally low gradient (Figure 18). The low gradient and abundant tributaries promoted the formation of seasonal floodplain lakes as floodwaters were blocked and backed up to form Peoria Lake and the numerous small backwater lakes that fueled notoriously high production for waterfowl market hunting, freshwater mussel harvest, and commercial fisheries. The channel has sand and gravel, but modern overbank areas and backwaters are extremely silty because of excessive erosion in the watershed and bluffs. Peoria Lake and upper Peoria backwaters are not leveed, but they are degraded by sedimentation. La Grange Pool has several conservation areas, but the Alton Pool is entirely leveed to the confluence with the Mississippi River (Figure 15). The Illinois River is unique in the level of urban pollution and more recently exotic nuisance species. It has shown a great restorative capacity to recover from multiple perturbations.

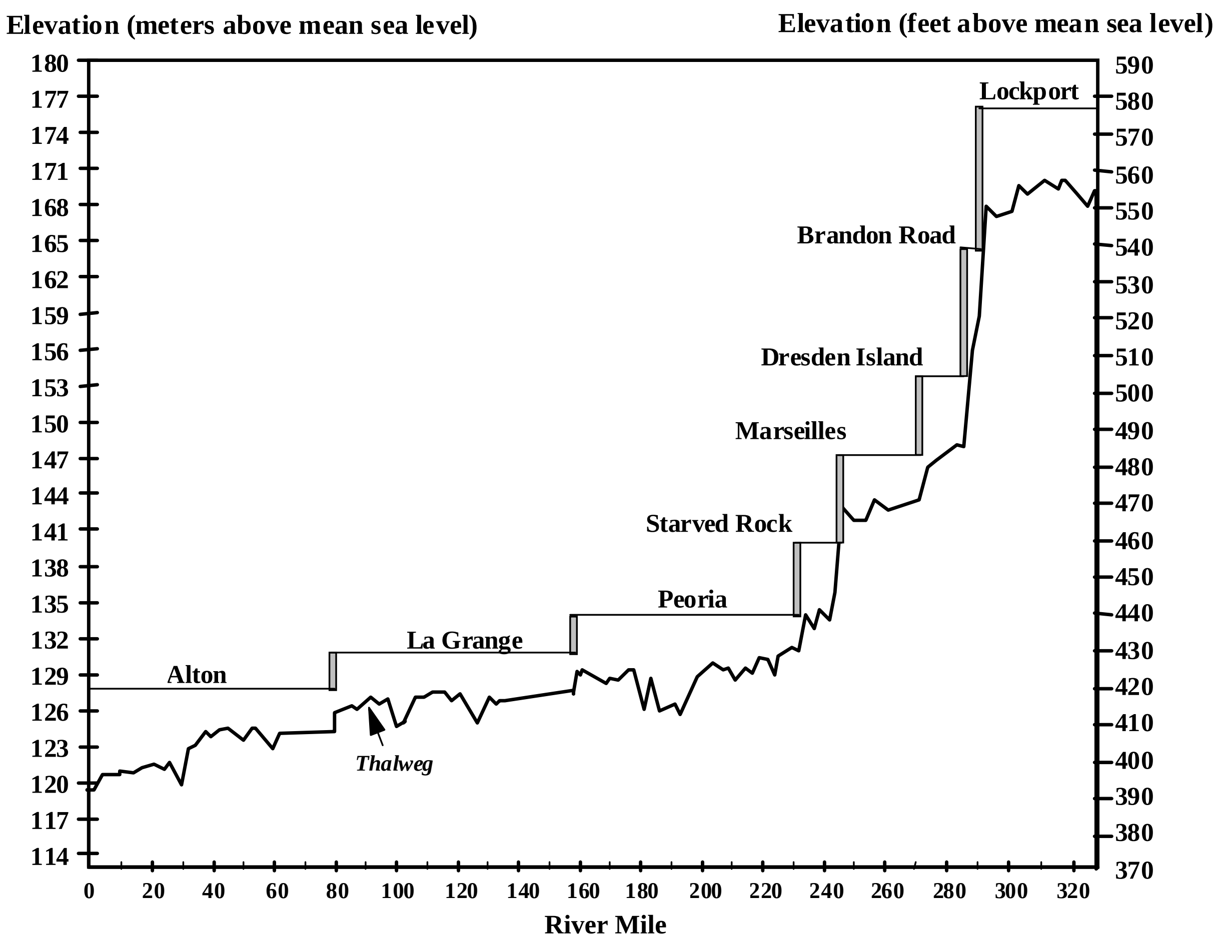


Figure 18. The Illinois Waterway riverbed profile displays the unique low profile, dropping less than 0.1 foot per mile, of the Lower Illinois Reach

2.4. GEOMORPHIC REACHES

The Geomorphic Reaches of the UMRS hierarchical classification (Figure 1) are defined by valley and floodplain glacial morphology (Figure 10), large tributary confluences, local geomorphology (Figure 19), longitudinal profile (Figure 20) and sediment transport. Geomorphic Reaches were initially defined using dams as reach demarcations (Table 3), but it is possible to revise the scheme to more closely reflect actual geomorphic controls (Figure 21, Table 3). The two classifications are similar enough at the large scale that the original classification is used for planning, while the finer classification is appropriate for scientific and engineering investigations. The definition of geomorphic reaches assists in understanding the existing physical conditions of the river system, underlying geologic and hydrologic controls (Figure 22) and possible future conditions. The geomorphic reaches are ecologically distinct and provide a scientifically appropriate scale for setting ecosystem objectives.

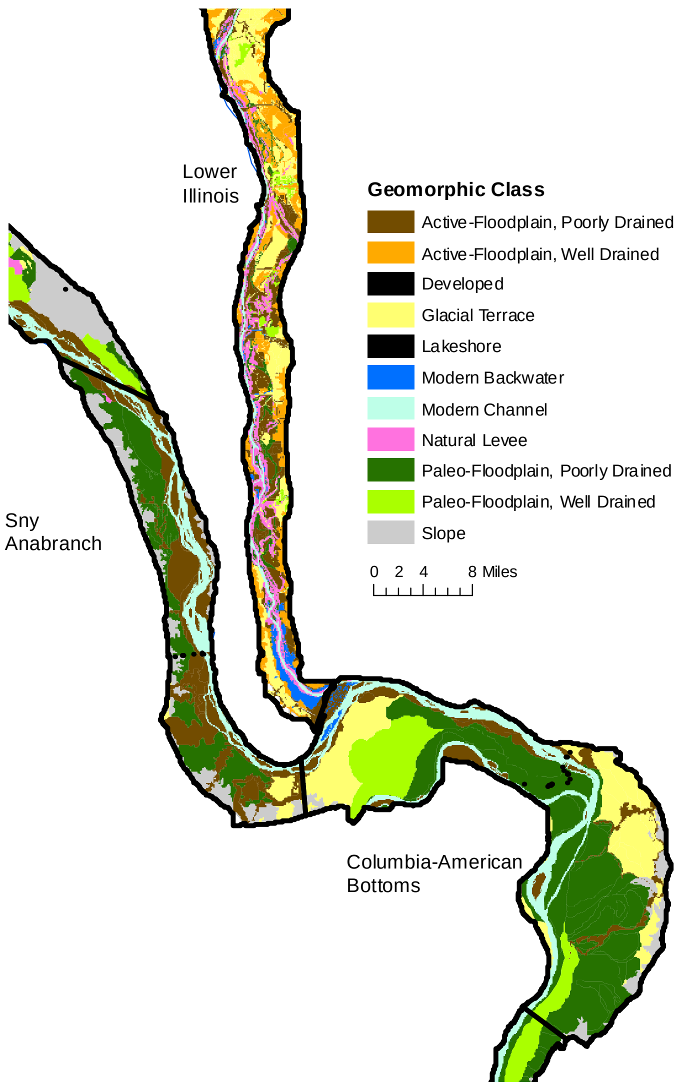


Figure 19. A large scale geomorphic classification for the system helps identify distinct Geomorphic Reaches like the Sny Anabranch, Columbia-American Bottoms, and Lower Illinois Reaches

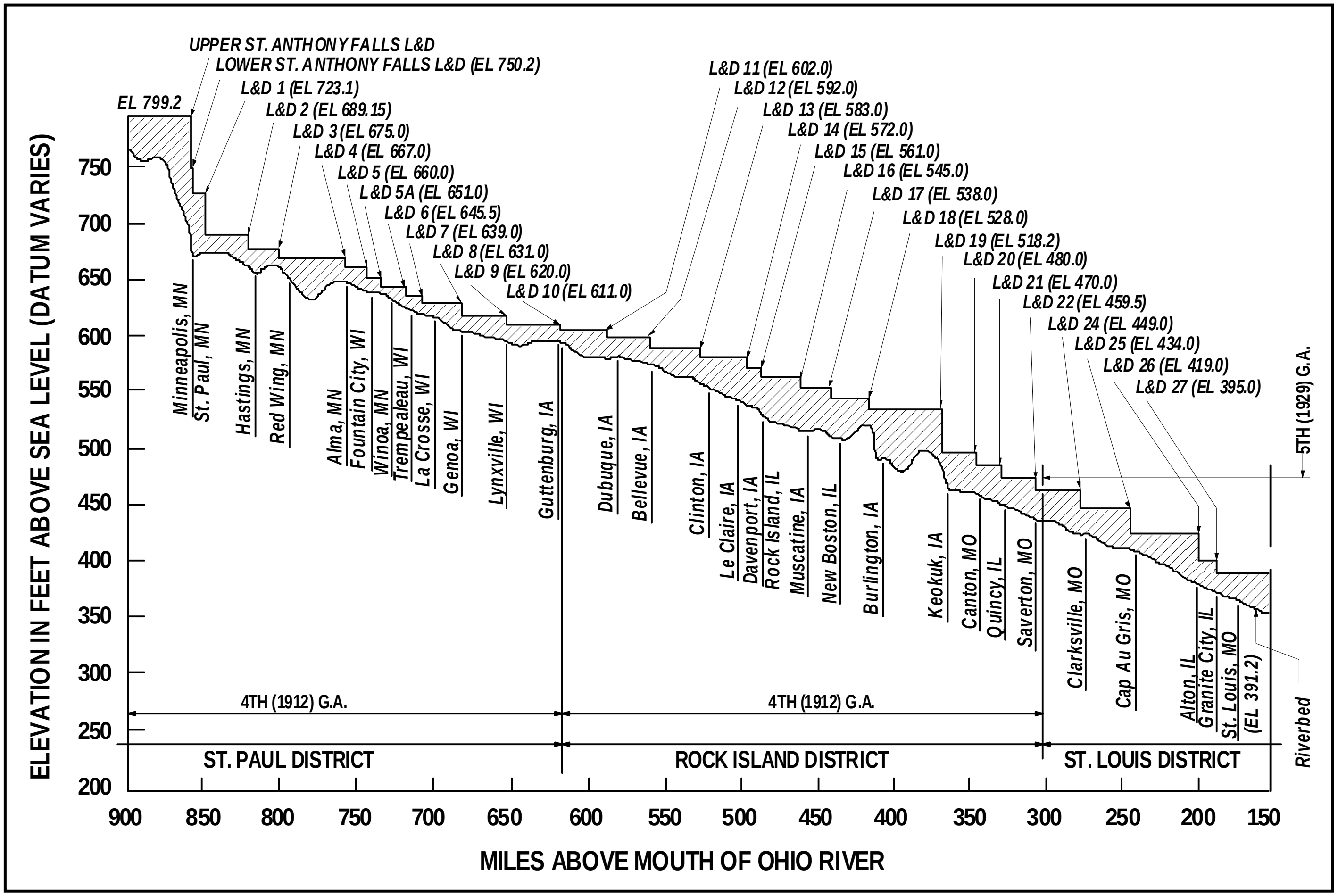


Figure 20. Longitudinal profile of the Upper Mississippi River

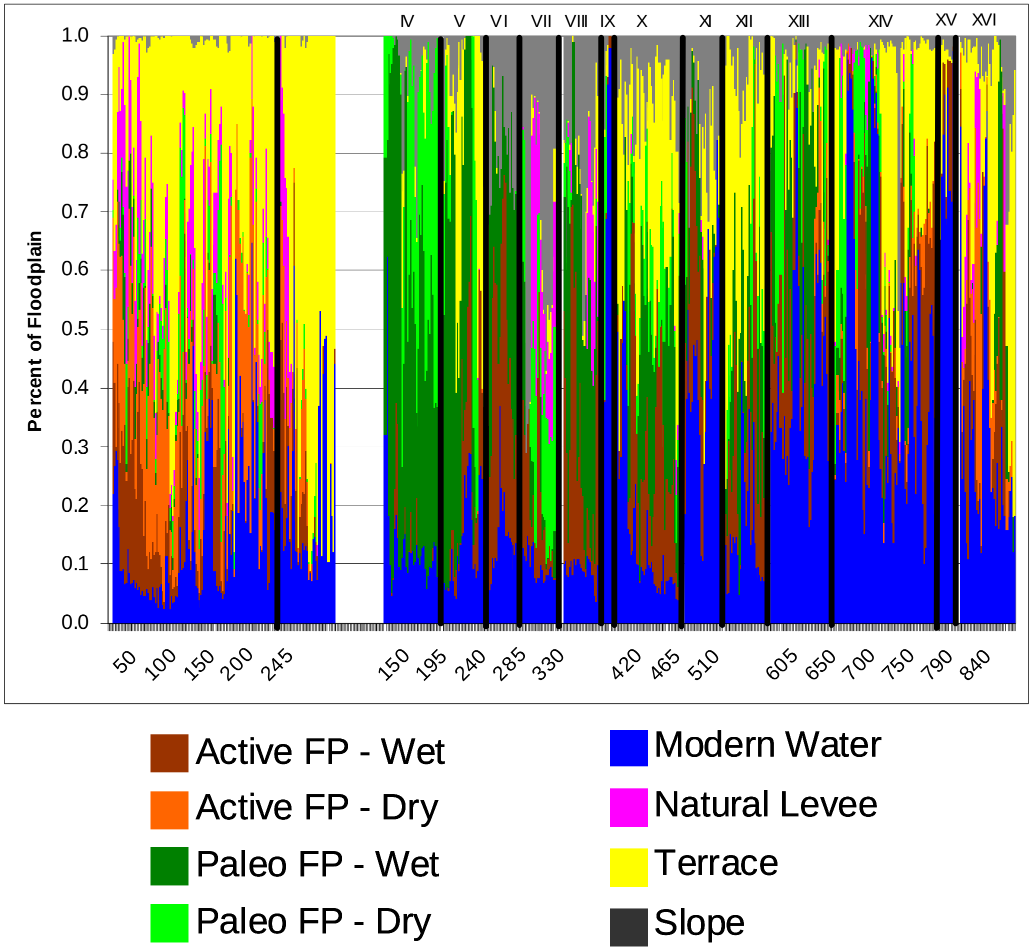


Figure 21. Geomorphic class distribution by river mile with the fine scale geomorphic reaches delineated

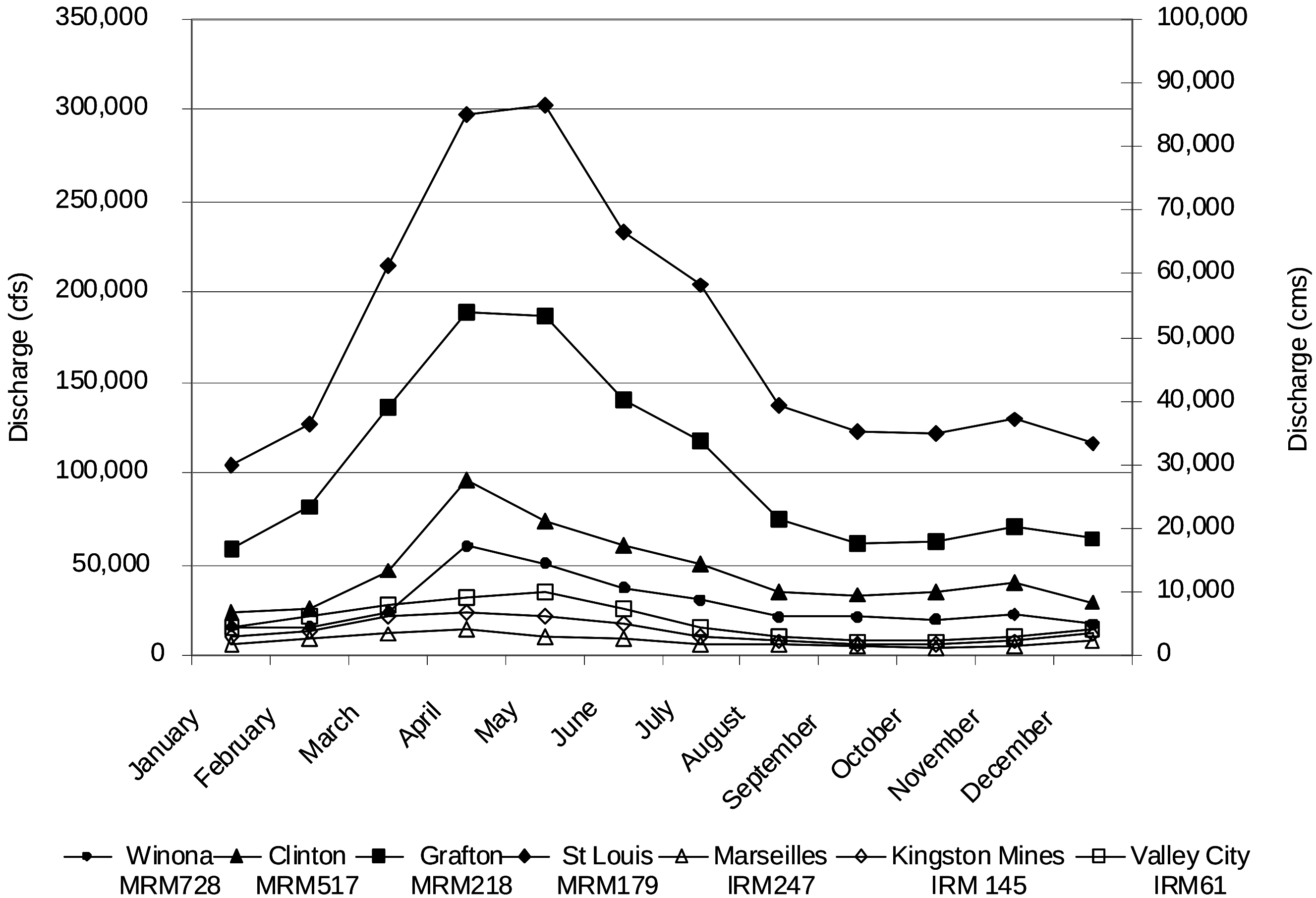


Figure 22. Average annual hydrographs for long term discharge gauges throughout the Upper Mississippi River System (MRM – Mississippi River Mile, IRM – Illinois River Mile)

Table 3. Geomorphic, engineered, and administrative reaches of the Upper Mississippi River System

River	Floodplain Reach	District	Pool Reach	Geomorphic Reach (River Mile)	Lock & Dam	Dam Location (River Mile)
Upper Mississippi River	Upper Impounded Reach	St. Paul	N/A	N/A	USAF	854.7
					LSAF	853.4
			1	Minnesota River (786 - 858)	1	847.6
					2	815.2
					3	796.9
			2	Lake Pepin	4	752.8
			3	Chippewa River (634 - 765)	5	738.1
					5A	728.5
					6	714.3
					7	702.5
					8	679.2
					9	647.9
		Rock Island	4	Wisconsin River (558 - 633)	10	615.1
					11	583.0
					12	556.7
				Maquoketa River (503 - 557)	13	522.5
	Lower Impounded Reach		5		14	493.3
				Rock Island Gorge (456 - 502)	15	482.9
					16	457.2
				Iowa River (375 - 455)	17	437.1
			6		18	410.5
				Keokuk Gorge (364 - 375)	19	364.2
			7	Des Moines River (315 - 363)	20	343.2
					21	324.9
				Quincy Anabranch (268 - 314)	22	301.2
		St. Louis	8	Sny Anabranch (229 - 267)	24	273.4
					25	241.4
				Columbia-American Bottoms (177 - 228)	Mel Price	201.1
	Unimpounded Reach		9 & 10		N/A	0.0
				Jefferson Barracks (122 - 176)		
				Kaskaskia River (48 - 121)		
				Thebes Gap (41 - 47)		
				Lower Mississippi (0 - 40)		

River	Floodplain Reach	District	Pool Reach	Geomorphic Reach (River Mile)	Lock & Dam	Dam Location (River Mile)
Illinois Waterway (Illinois & Des Plaines Rivers)	Illinois Reach	Rock Island	11	Upper Illinois (216 - 327)	Lockport	291.0
					Brandon Road	286.0
					Dresden Island	271.5
					Marseilles	247.0
					Starved Rock	231.0
			12	Lower Illinois (0 - 215)	Peoria	157.7
					LaGrange	80.2
		St. Louis			Mel Price	0.0

2.5. NAVIGATION POOLS

Navigation pools are the riverine reservoirs formed by the navigation dams on the UMRS (Figure 23). Most were constructed as a single large project during the 1930s and are usually named by number of the dam at the downriver end of the pool (e.g., Pool 3 is impounded by Lock and Dam 3, Figure 2). Illinois River navigation pools are named after communities near the dams that impound them, there are two dams in the vicinity of St. Anthony Falls in Minneapolis, and the Melvin Price Dam replaced Lock and Dam 26 at Alton, Illinois in 1990. There is a Pool 5a, but there is no Pool 23, and Pool 27 is a low water weir and separate lock in a by-pass canal. The MMR (RM 201 to 0) is maintained with hydraulic structures, dredging, and flow augmentation from Missouri River reservoirs.

Most of the UMR navigation pools have several characteristics in common, primarily their intended purpose which is to maintain a minimum low flow river stage resulting in channel depths at least 9-feet deep to support commercial navigation. They have little effect on floods because they are designed to raise their gates (or lower them on the Peoria and La Grange Dams) during moderate-high river stage. The range of control at each dam depends on local hydrologic, geomorphic, and engineering constraints. The average effect at long term gauges shows generally higher and more stable river stages, but there is a range of responses depending on location in the system (Figure 24 or within each pool (Figure 25). Surface water response to impoundment generally created a riverine upper part of the pool, a transitional middle part of the pool and a more open impounded area in the lower part of the pool, but alternative water regulation strategies can modify that to some degree for natural resource management (Figure 26).

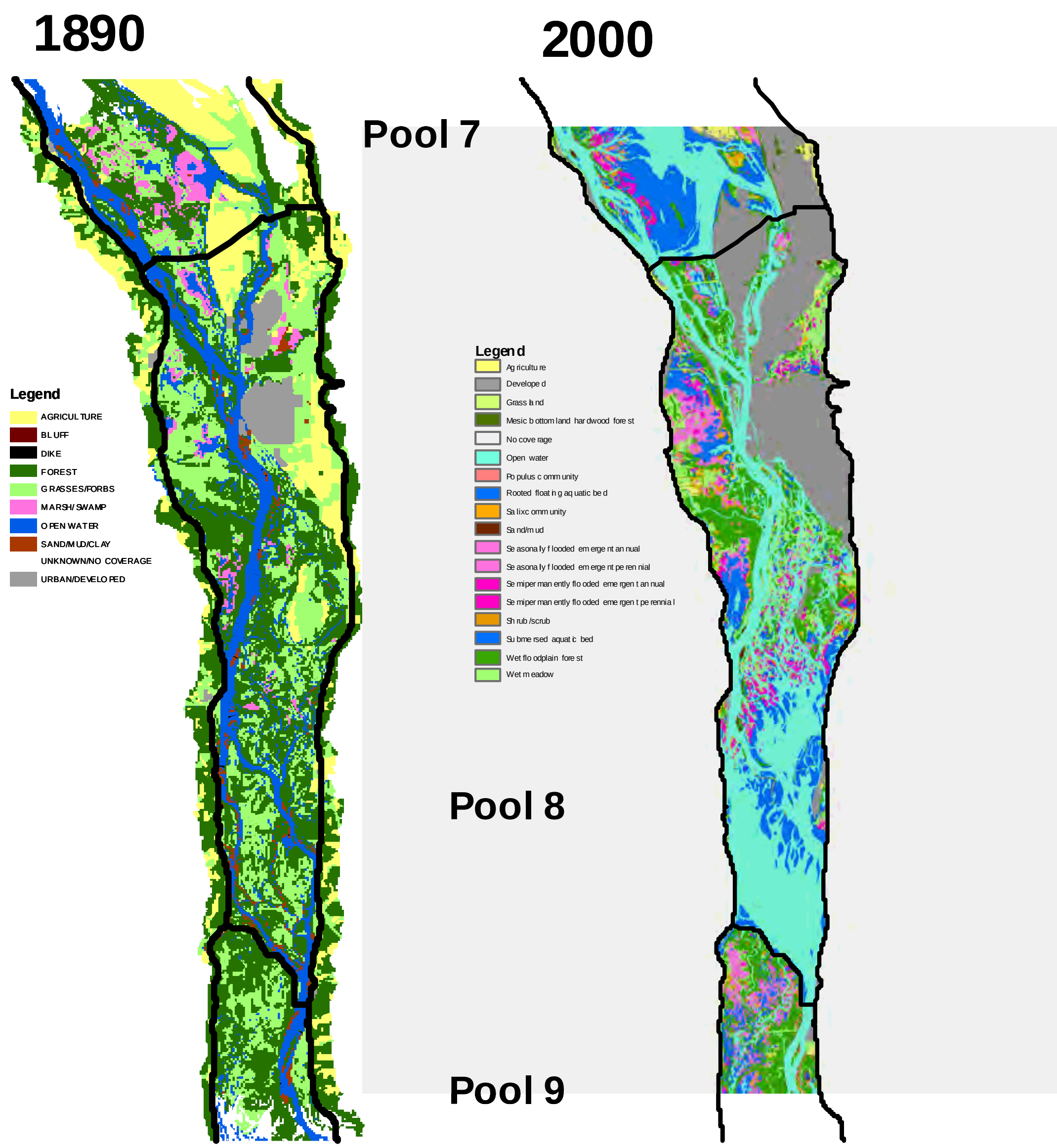


Figure 23. Upper Mississippi River System Pool 8 clearly illustrates the within-pool surface water response to impoundment

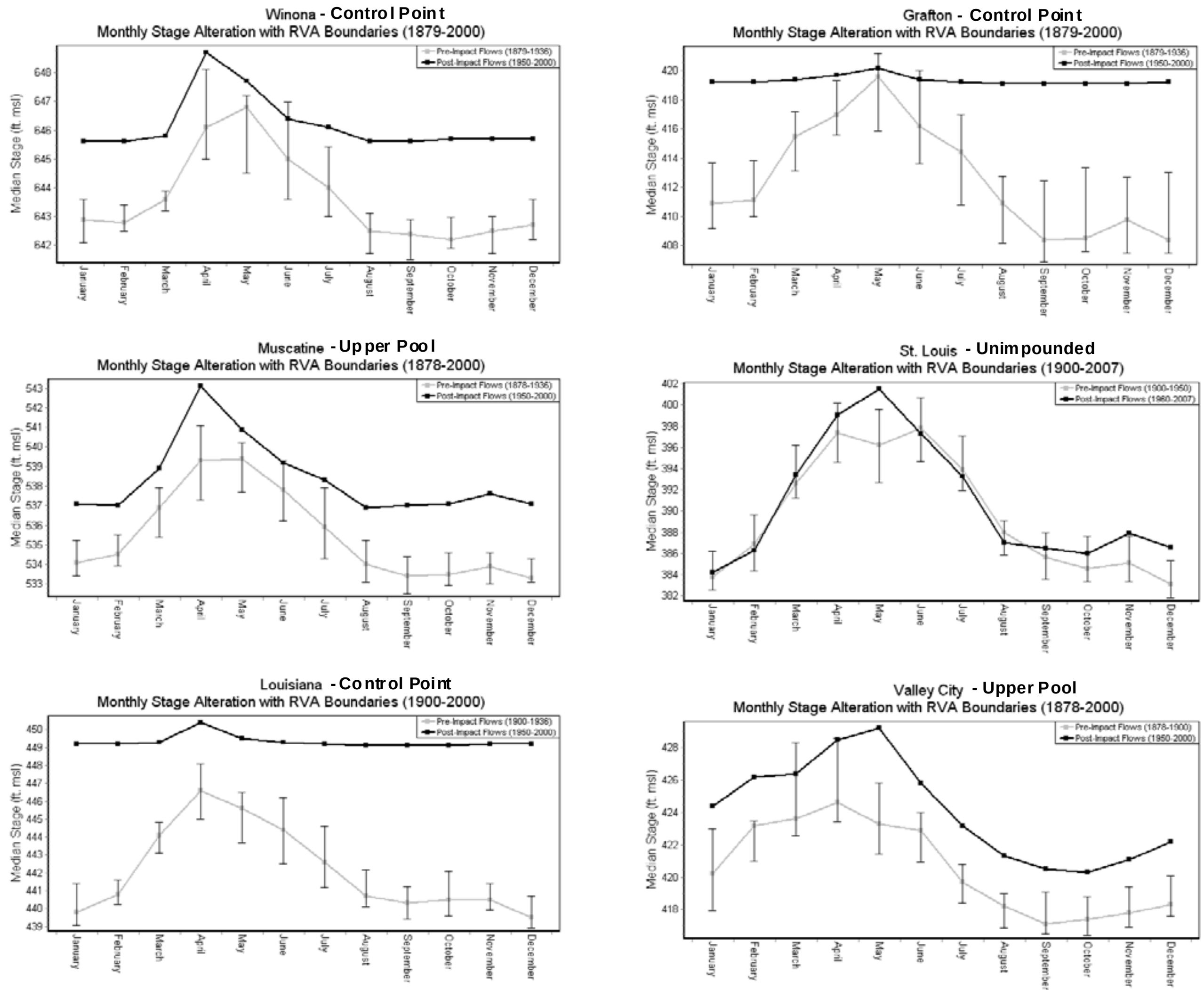


Figure 24. Long term average annual pre-development and contemporary hydrographs reveal the relative hydrologic alteration from development of Upper Mississippi River System waterways which includes dams, diversions, channelization, and flow augmentation

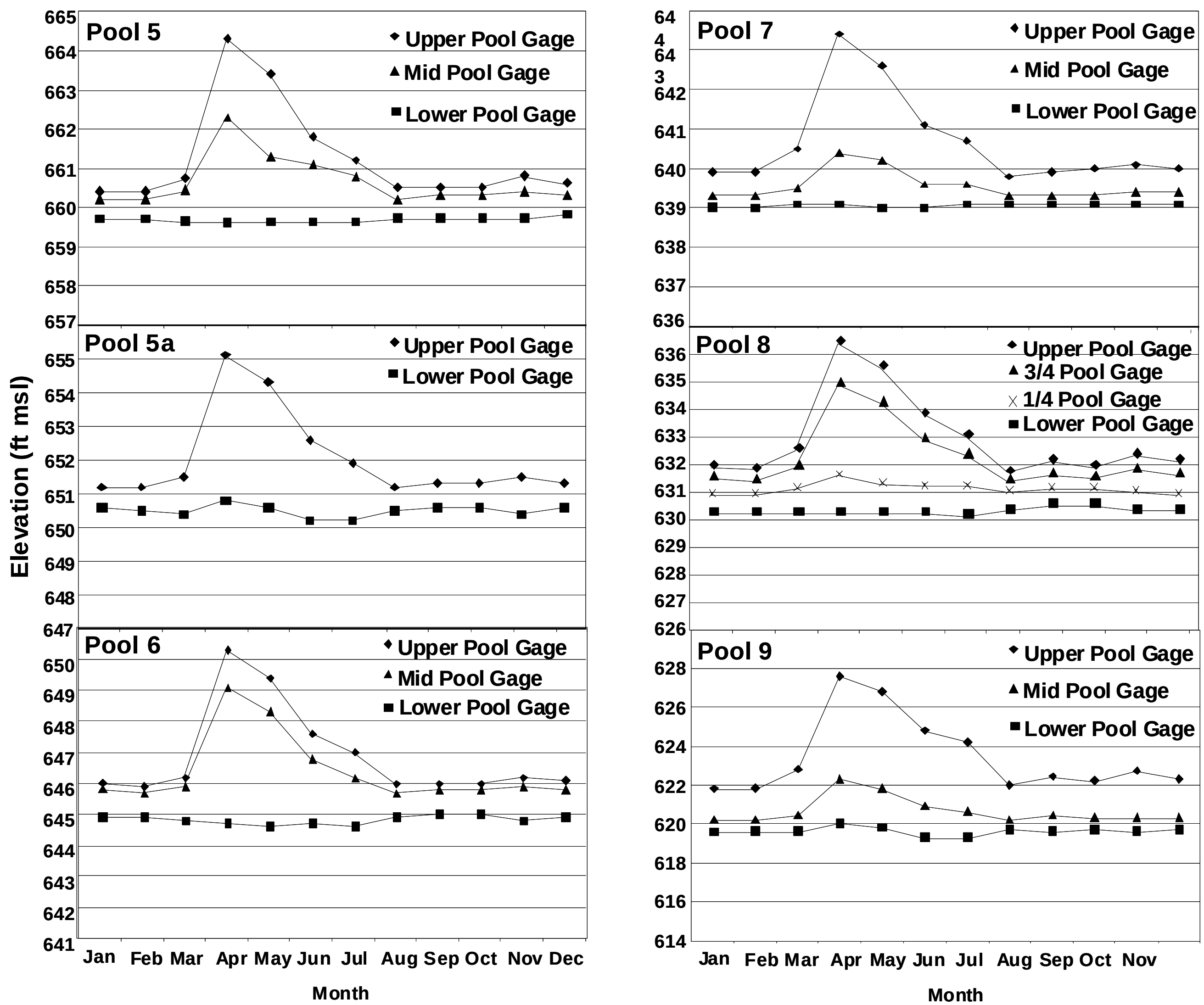


Figure 25. Within pool average annual stage hydrographs in Geomorphic Reach 3 show the characteristic hydrologic variation of Upper Mississippi River system Navigation Pools.

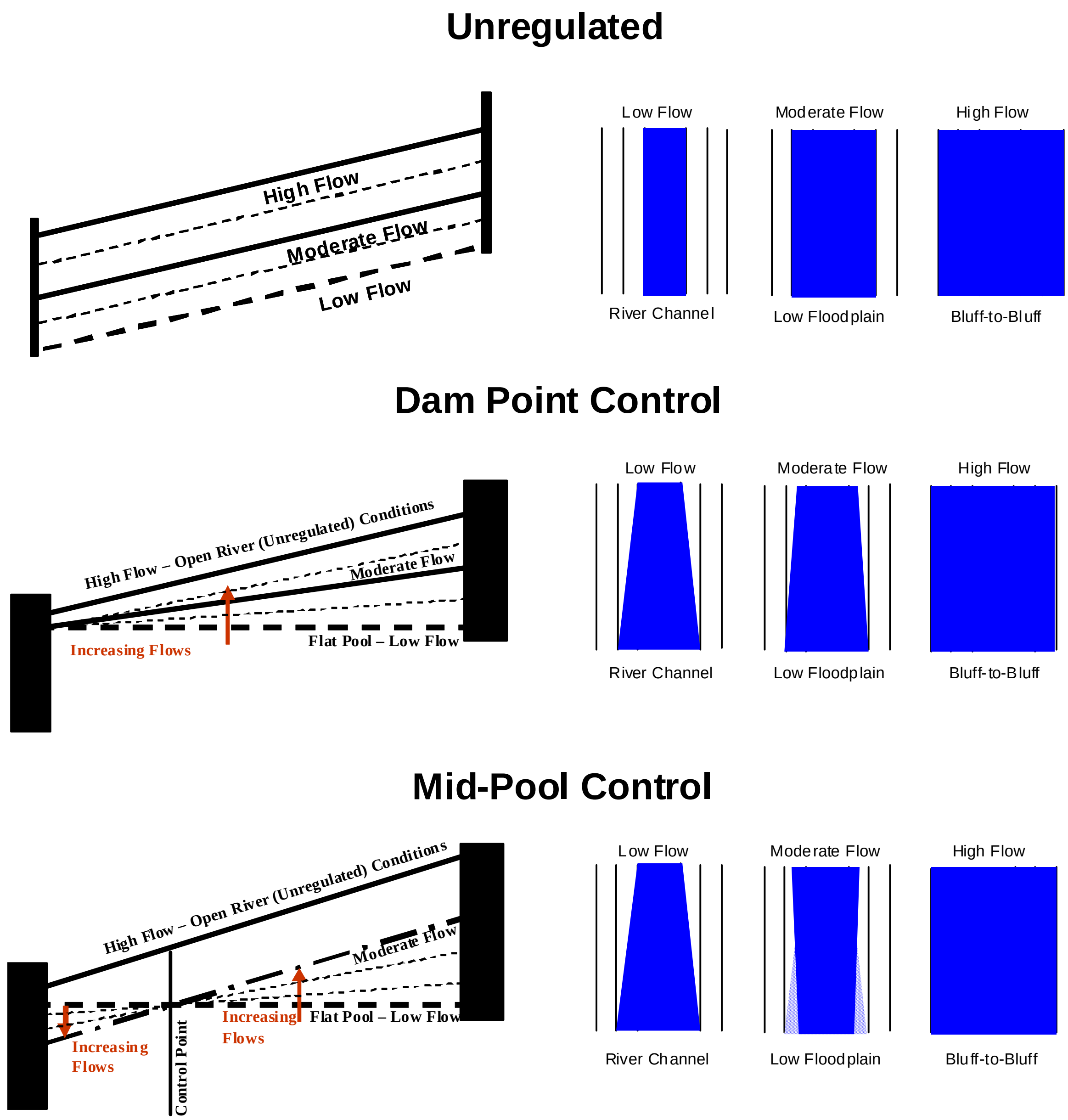


Figure 26. Schematic representation of the relative differences in water surface profile (left) and surface area distribution (right) in response to alternative dam operating strategies

2.6. SUB-AREAS

Sub-areas are local regions defined by resource managers considering the logical hydrologic and geomorphic connections and habitat conditions within navigation pools and in the MMR (Figure 27). They include features like island-secondary channel complexes, backwater complexes, refuges, etc. that are well known to local managers and the public. They are typically hundreds to several thousand acres in area and are named after local features. Subareas were defined during locally-led Pool Planning exercises to help bound ecosystem restoration project areas and conceptualize project features. Sub-areas within the navigation pools and in the MMR have been delineated and are available as GIS maps system-wide. An update of the subareas included District's levee delineation as unique polygons to help consider floodplain management issues.

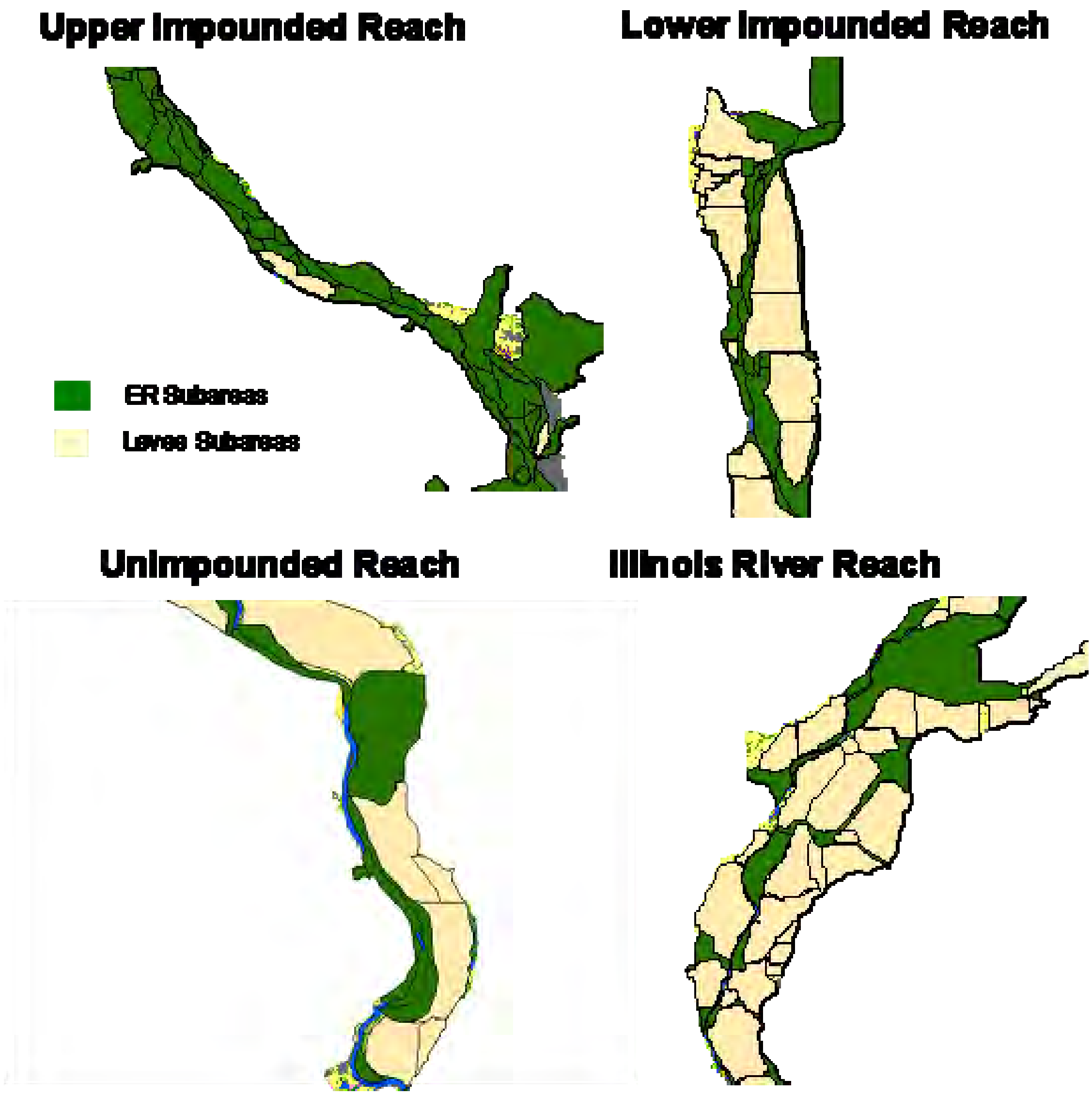


Figure 27. Representative subareas in Upper Mississippi River System Floodplain Reaches (ER=Ecosystem Restoration)

2.7. PROJECT AREAS

Project areas are geographic areas where ecosystem management and restoration projects are implemented. Project areas generally correspond to sub-areas, but subareas may have several projects or project phases. Project features include constructed islands and hydraulic control structures, backwater dredging, managed wetlands, and many others that have been refined while executing the EMP. Project areas include the actual footprint of construction disturbance as well as the area affected by the project (e.g., the backwater lake managed by a single pump). New project features and opportunities continue to emerge in large scale water manipulation and floodplain restoration, and proven techniques are refined and adapted for application in other reaches. The affected area may extend well beyond the immediate construction zone, as determined by flow alteration, water levels, wave attenuation, water quality effects, or movement of biota. Evaluating direct (i.e., project area) and indirect (i.e., area of influence) environmental benefits of ecosystem restoration projects is an important research topic that could be enhanced by a thorough review of Habitat Rehabilitation and Enhancement Project (HREP) benefits (Figure 28).

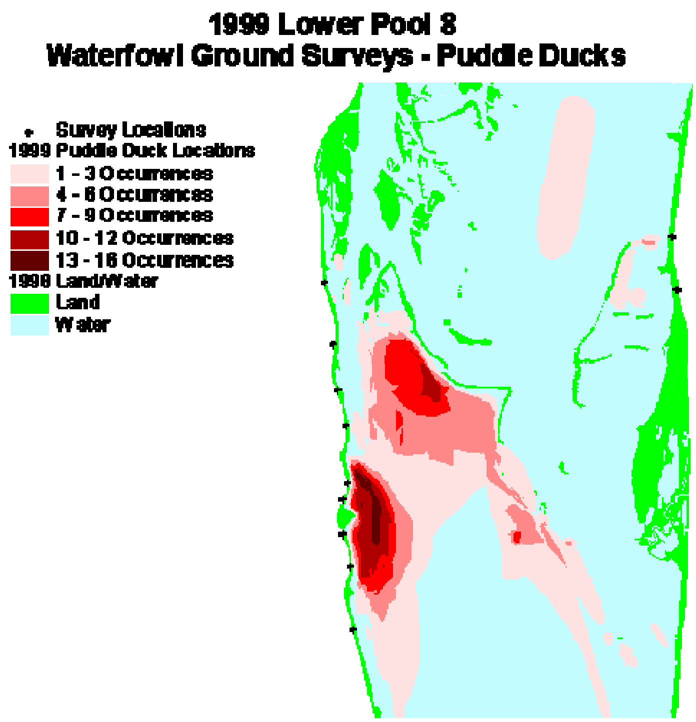


Figure 28. Waterfowl monitoring results in the Upper Mississippi River System, Pool 8 Islands, Phase I Habitat Rehabilitation and Enhancement Project, one of the earlier, more highly monitored restoration projects

2.8. HABITAT AREAS

Habitat areas are regions within the river landscape defined by the life requisites of plant and animal species or communities. Aquatic areas and generalized plant communities in their late summer, peak vegetation production condition are mapped as surrogates for species suitability maps (Figure 29). Plant community patches are typically smaller in size than sub-areas; defined by combinations and ranges of abiotic and biotic conditions. Dynamic emergent wetland habitat may change seasonally and inter-annually. Resident animal species may barely move in the case of freshwater mussels and insects, may have local movements like bluegills, bass, or mammals, or may be highly mobile species like paddlefish, sturgeon, and migratory birds whose habitat areas are extensive and the UMRS only serves part of their life history needs. Habitat areas in the river landscape mosaic are important structural and compositional attributes of the river ecosystem. There are numerous historic and contemporary land cover data sets, the earliest (<1850) and most recent (2000) comprehensive data sets frame the historic reference conditions for UMRS river habitats (Figure 30).

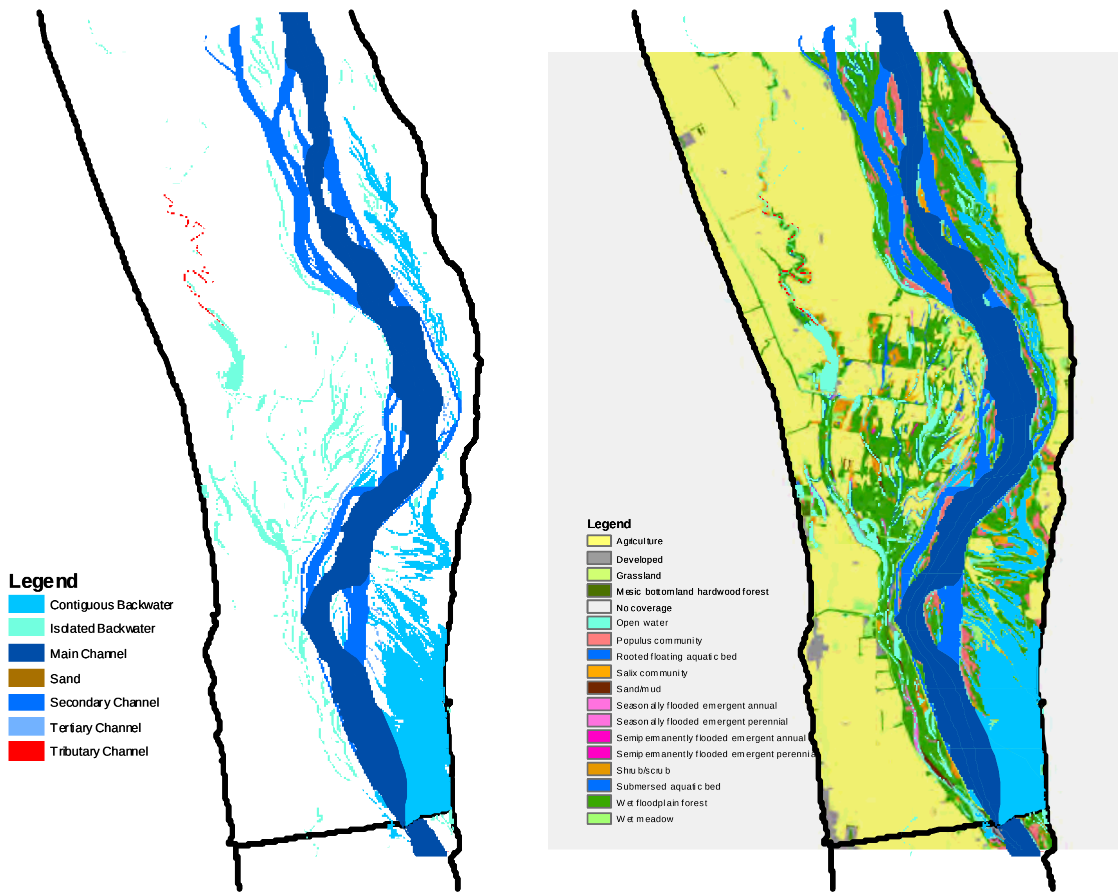


Figure 29. Representative classes for Upper Mississippi River System aquatic areas and plant communities, Lower Pool 25

Aquatic areas of the UMRS were classified in a hierarchical structure to facilitate habitat mapping and inventory at different spatial scales and varying levels of resolution (Figure 29). The system-wide classification system is based on geomorphic and constructed features of large floodplain rivers and physical and chemical characteristics of aquatic habitat. Pre-dam aquatic areas were derived from the Mississippi River Commission (ca. 1890) maps between Pool 4 and 26 (Figure 31). The Corps completed a comprehensive evaluation of the MMR (Figure 31), and the State of Illinois and the Corps (Figure 32) evaluated the lower Illinois River. We anticipate extending high resolution hydro-geomorphic classification to include floodplain areas. Recent floodplain inundation mapping and a seamless topographic and bathymetric elevation layer under development by the EMP - Long Term Resource Monitoring Program (LTRMP) will greatly facilitate floodplain habitat evaluations.

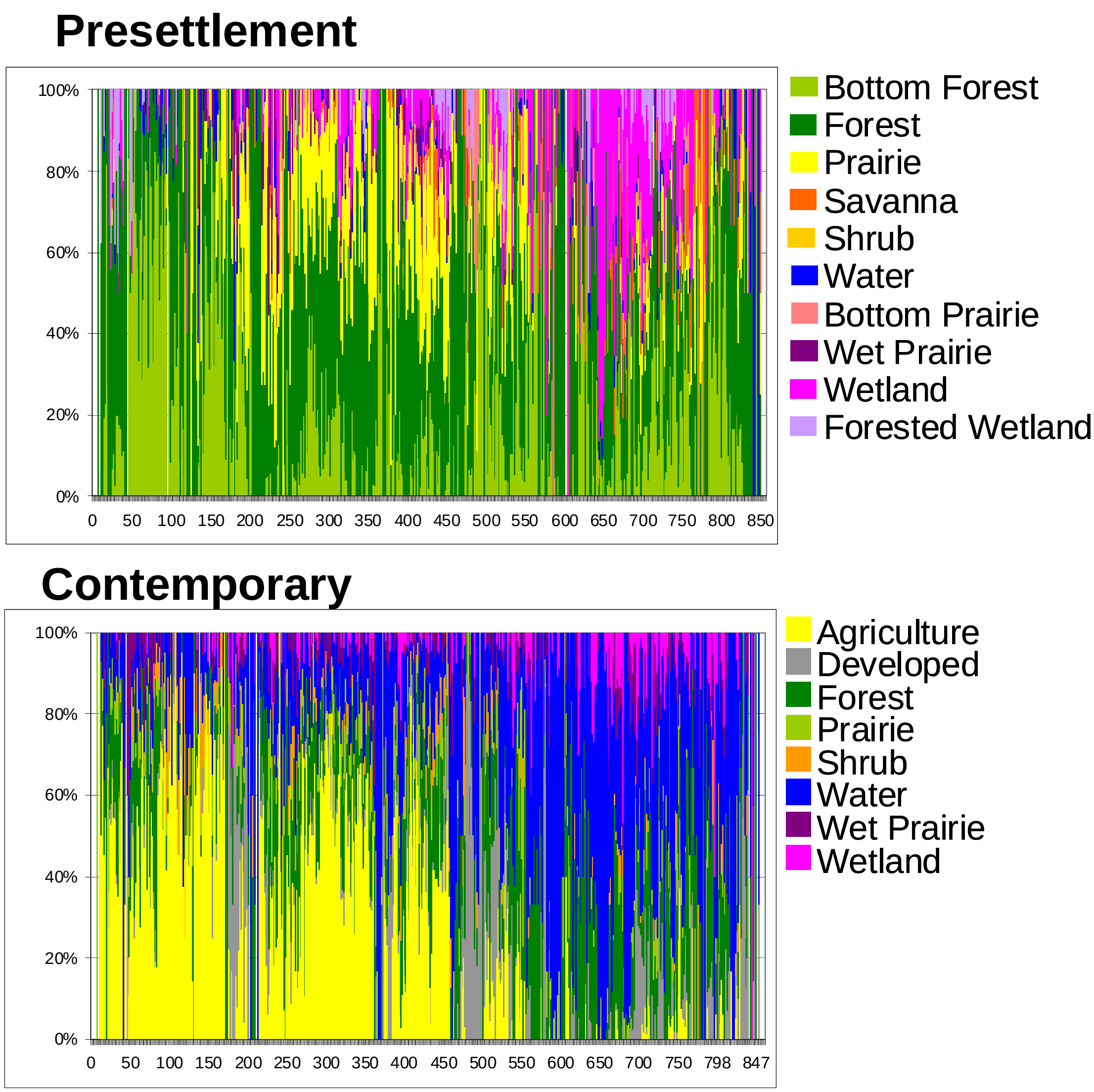


Figure 30. Upper Mississippi River Land Cover distribution by river mile during presettlement and contemporary periods (presettlement data courtesy of Paul West, The Nature Conservancy, Madison, WI)

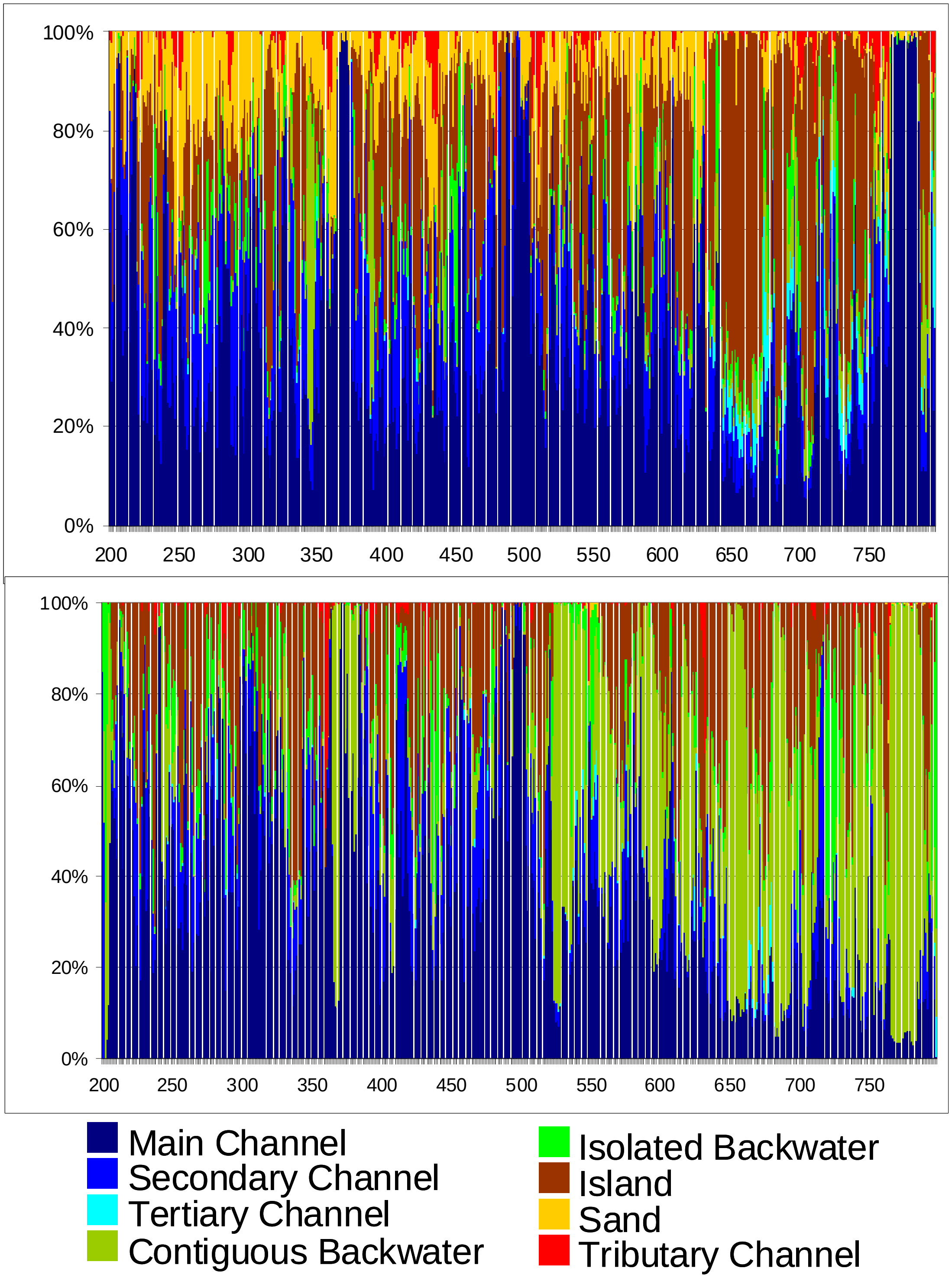


Figure 31. Upper Mississippi River aquatic area class distribution by river mile during pre-dam (upper bar graph) and contemporary (lower bar graph) periods

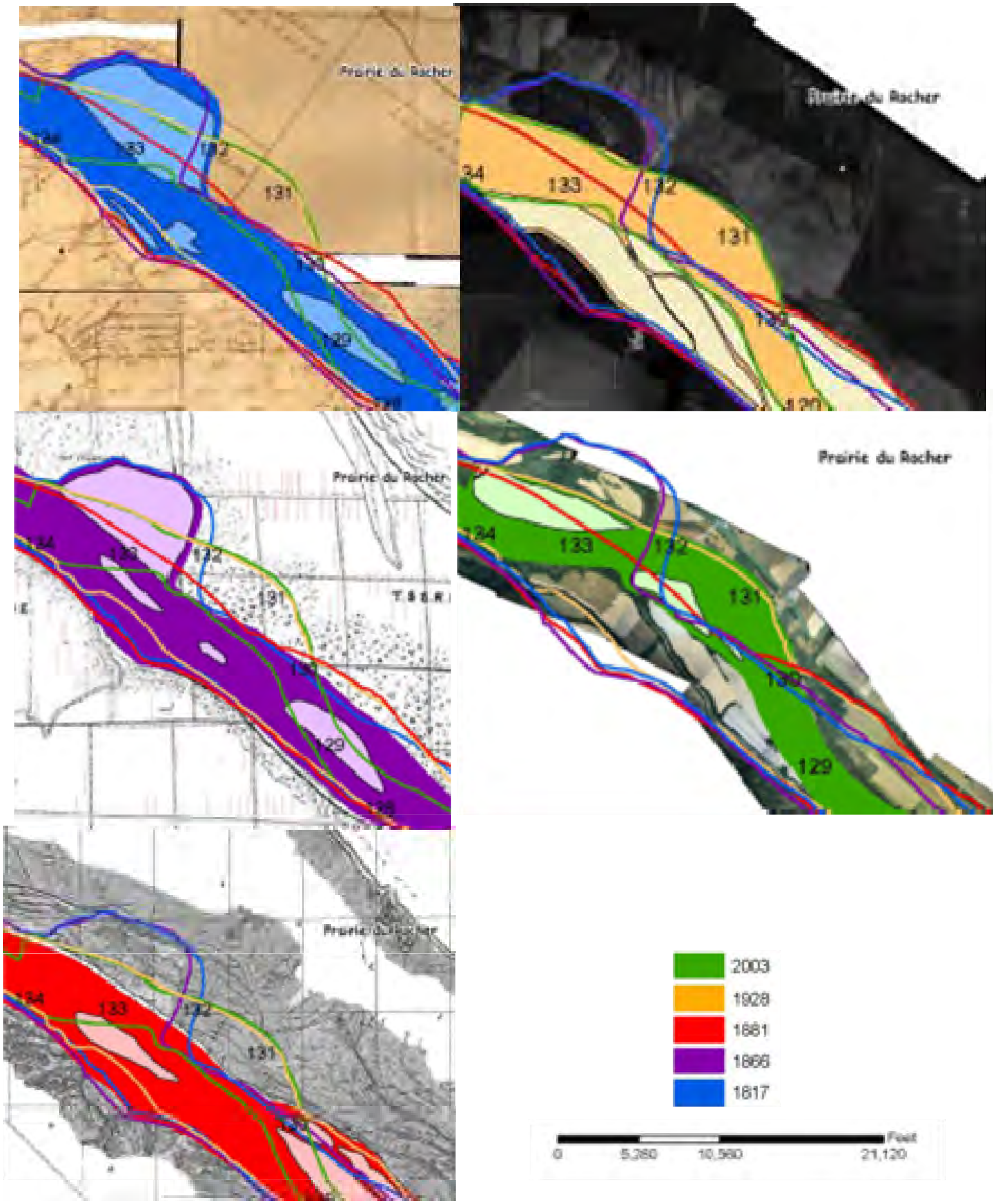


Figure 32. An example of secondary channel status for five historical reference conditions available for the entire Middle Mississippi River south of St. Louis, MO

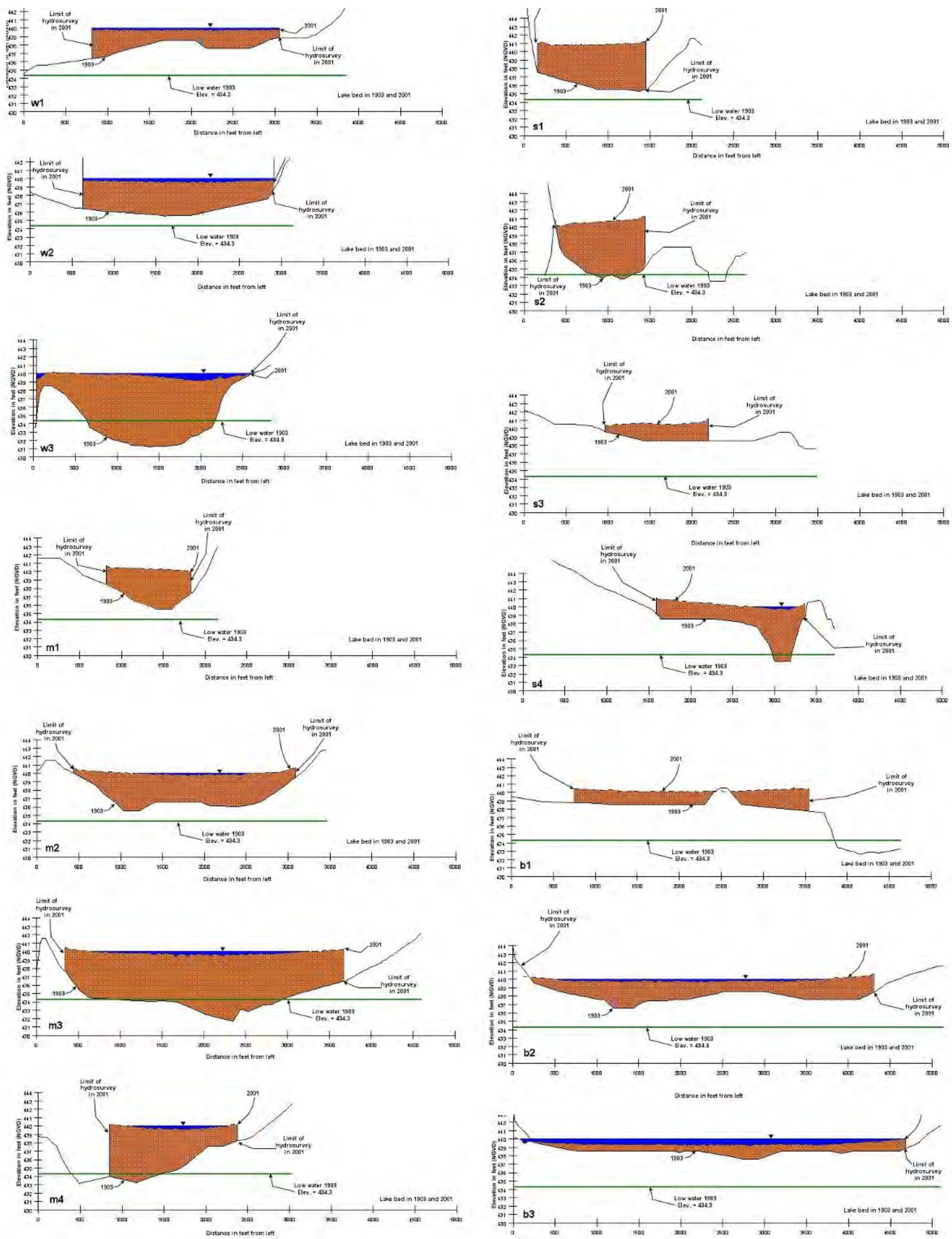


Figure 33. Illinois River backwater sedimentation survey

3.0 ECOLOGICAL PROCESS AND FUNCTIONS FOR PROGRAM MANAGEMENT, PROJECT PLANNING AND IMPLEMENTATION

The NESP Science Panel emphasized the point that restoration activities must be process based to achieve system-wide sustainability. Understanding and restoring important ecosystem process and functions will make the UMRS ecosystem more resilient to human and natural disturbances. Conveying ecosystem process and function in a conceptual model or textbook is a complex task because they are so numerous, ranging from cellular processes like photosynthesis to large scale fluvial processes like sediment transport. Quantifying processes in the field with statistical rigor is challenging as well. Thus, advanced ecological simulation models of the UMRS are rare despite the fact that the UMRS is a data rich environment with vast amounts of system-wide data for river levels and discharge, land cover, topography, soils, sediments, and nutrients. Process-based hydrologic and hydraulic simulation models are becoming more common. Hydrodynamic models which are the fundamental base to other models have become commonly applied ecosystem restoration design tools that allow alternative benefits evaluation and design optimization for most projects.

The approach pursued to incorporate ecological process and function into restoration planning in the past was to imply ecosystem function from the dominant land cover classes (i.e., a forest supports predictable bird species, wetlands require specific hydroperiods, levees impede connectivity, etc.) and plan for specific habitat benefits. Seasonal habitat attributes like flooding were implied rather than modeled. The approach was reinforced by Federal planning guidance that promoted “habitat units” derived from habitat suitability models as ecosystem benefits for project evaluation. Late summer land cover became a planning “currency” on the UMRS. As planners gained experience, the “everything” project (many alternative measures affecting many habitat types) faired well in benefits evaluation and competition for funding. Large projects affecting many habitat classes were common.

Several early HREPs were evaluated to understand the ecological relationships and responses of common restoration actions, and an active restoration practitioner community continually adds to the body of knowledge which gets communicated in periodic reviews like this report. The physical and biological processes of Centrarchid overwintering, island effects, backwater water level management and flow regulation, pool-scale drawdowns, MMR hydraulics, and other actions are well understood. Restoration actions that are well known can be modeled for benefit analysis, but development of ecological simulation models has not been common. Cost and time constraints preclude ecological model development on most projects. Ecological models incorporating hydrodynamic model output are becoming more common (see below); the best process-based models will be integrated eco-hydrodynamic models that simulate sediment transport, plant growth, adjust to floods or structures, etc. These integrated numerical hydraulic and ecosystem process models should be developed for use on the UMRS and other large rivers.

Monitoring, evaluation, and modeling are often expensive tasks that add time and cost to restoration projects. The work tends to be ad hoc and short term when funded as individual projects which is why Active Adaptive Management has been promoted as a separate component of UMRS ecosystem restoration programs. An adaptive management strategy to promote learning and implementation efficiency is outlined later in this report.

The Reach Planning Teams’ collective objectives (described in Section 4 below) were summarized using the conceptual model to illustrate components of each EEC (Figure 34). The objectives were classified as Process and Function Objectives that affect Composition and Structure Objective outcomes. Processes and functions associated with some EECs are more easily monitored and modeled, using comprehensive hydrologic models, spatial floodplain inundation simulations, 2-dimensional hydrodynamic models, wind fetch models, submersed aquatic plants models, and floodplain vegetation models that will be discussed. Sediment transport models and coupled hydrodynamic, water quality, and ecological models will be developed using the extensive data and scientific knowledge on the UMRS.

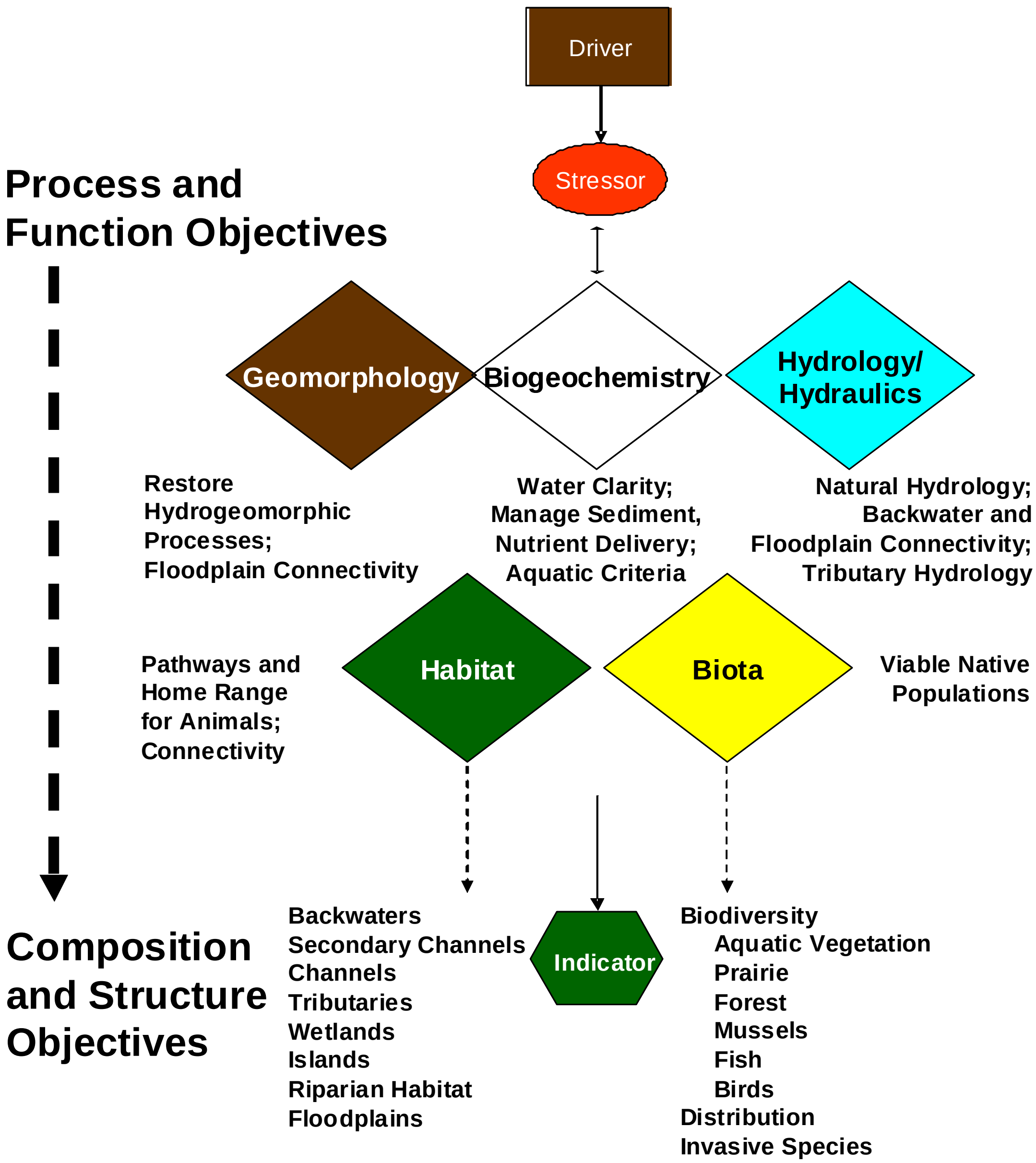


Figure 34. System-wide ecosystem restoration objectives compiled from separate planning team for four Upper Mississippi River System Floodplain Reaches

3.1. HYDROLOGIC AND HYDRAULIC MODELS

One-dimensional hydraulic models simulate water levels (i.e., river stage) at river valley cross sections in a downstream to upstream direction. River stage is a function of the discharge, cross section geometry, and boundary roughness due to substrate and vegetation characteristics. Models are run in a computer simulated grid representing geometric features of the river-floodplain (i.e., shoreline, thalweg, bluffs, etc.). Tributary deltas, floodplain vegetation, bridges, levees, and dams all act to alter stage-discharge relationships. One-dimensional steady state hydraulic models for the entire UMRS were updated following the Great Flood of 1993. They were recently overlayed on high resolution topography to simulate potential floodwater distribution. The inundation mapping exercise is entirely hypothetical, it interprets ground elevation only and does not consider effects of levees (Figure 35). However, existing levees, dams, bridges, etc. were boundary conditions for the river stage estimates. The output from these models and mapping helps estimate distribution of ecological processes related to flooding, which are perhaps one of the strongest and most radically altered, drivers in the UMRS. Information from pre-dam conditions helps evaluate change from development (Figure 36). Hydrologic summary tools are becoming more common and Average Daily Flooded Area calculations should be available soon (Kilgore et al., in preparation). The 2-year flood extent is ecologically relevant, whereas traditional flood inundation studies focused on larger floods and were concerned with stage relative to levee height rather than floodwater distribution for frequent floods. The two-year flood inundates more than 50 percent of the floodplain, much more in some areas (Figure 37).

Two-dimensional hydraulic models simulate river stage, current direction, and current velocity among many other things in both the upstream to downstream direction and laterally across the river valley. They are used to evaluate flow in channels, the exchange of water between channels and backwaters or floodplains, and flow around structures. They require extensive bathymetric data and field calibration. Earlier model versions ran constant discharges, while new model versions can simulate an entire hydrograph. They are increasingly available in UMRS pool-wide application. They have become a standard design tool for most river construction projects. The value of 2-dimensional models is in their capacity to define aquatic habitat and their ability to simulate restoration alternatives (Figure 38). The ability to simulate sediment transport with these models has improved significantly in recent years, though developing these sediment models requires a significant amount of effort. Three-dimensional models are becoming more common, and will greatly increase capacity to stratify the water column into distinct habitat layers or to simulate bed scour for example. Again, some of these tools are routine and easy to apply but others are still developmental and limited in availability.

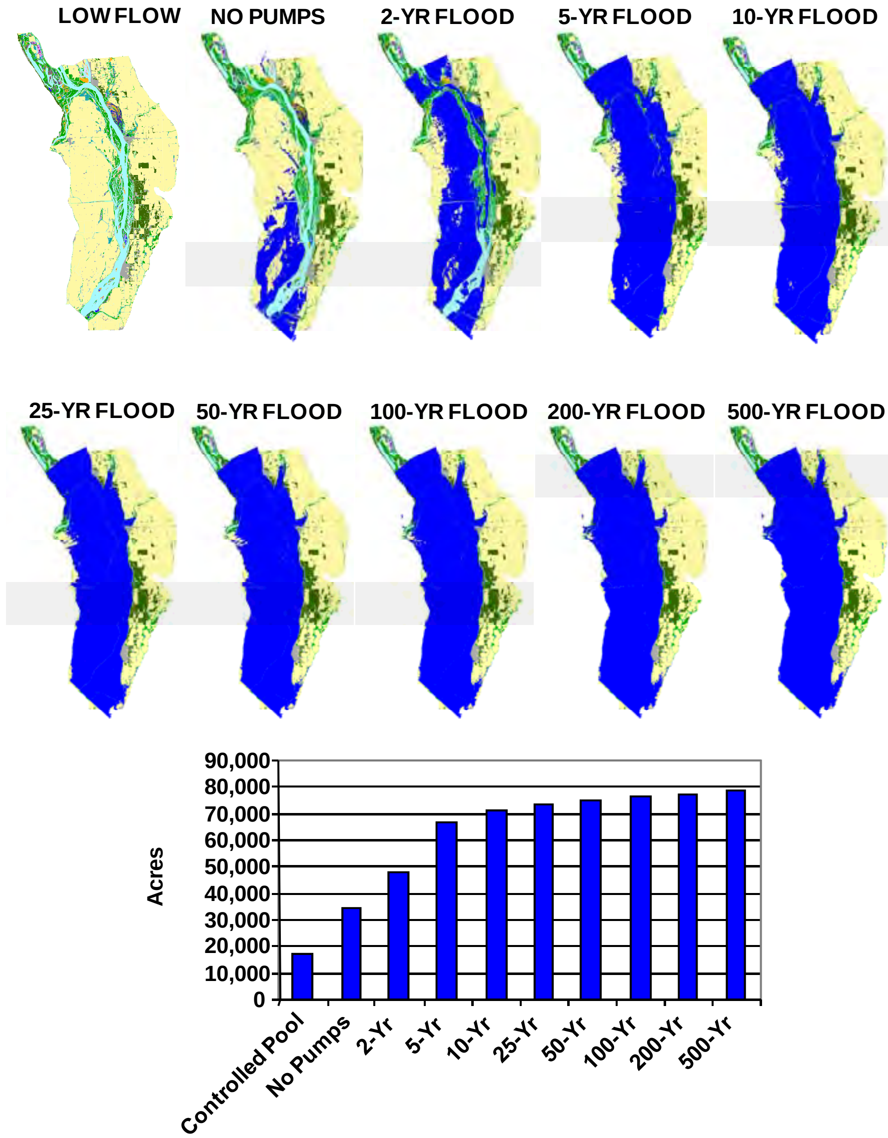


Figure 35. Flood inundation mapping for Upper Mississippi River System, Pool 18

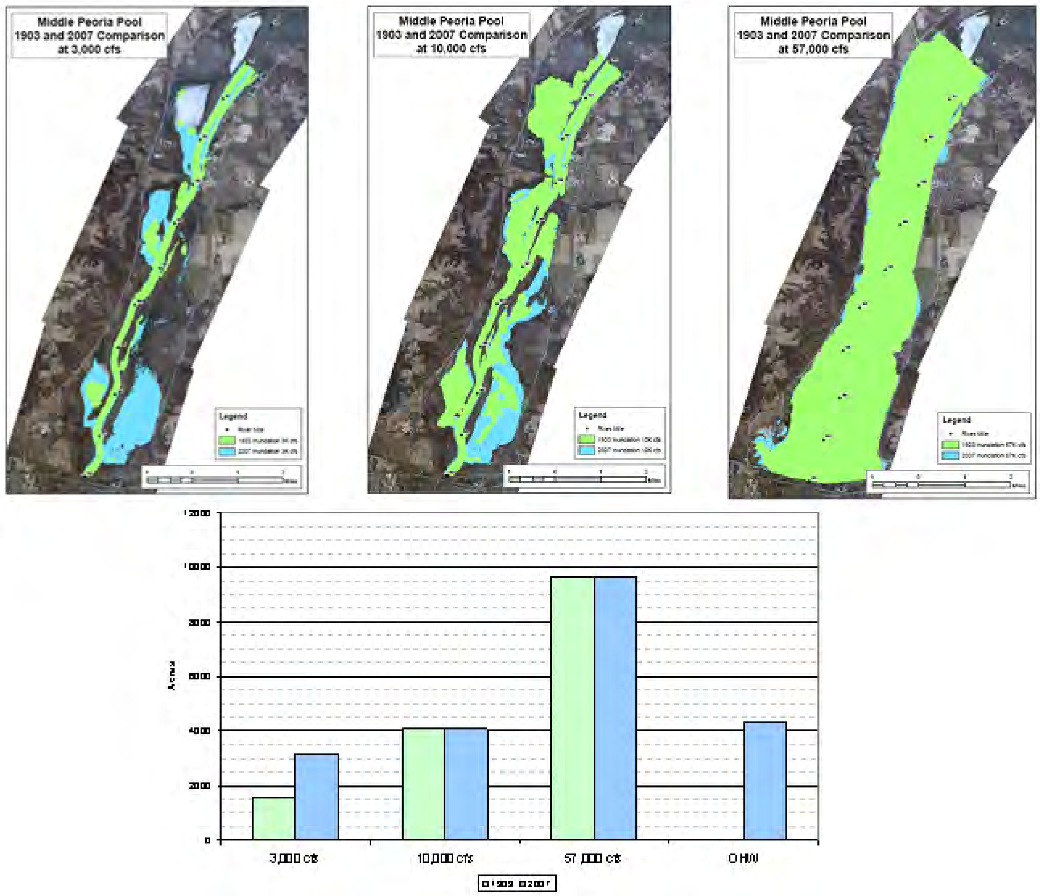


Figure 36. Historic and contemporary flood inundation patterns in Upper Peoria Pool

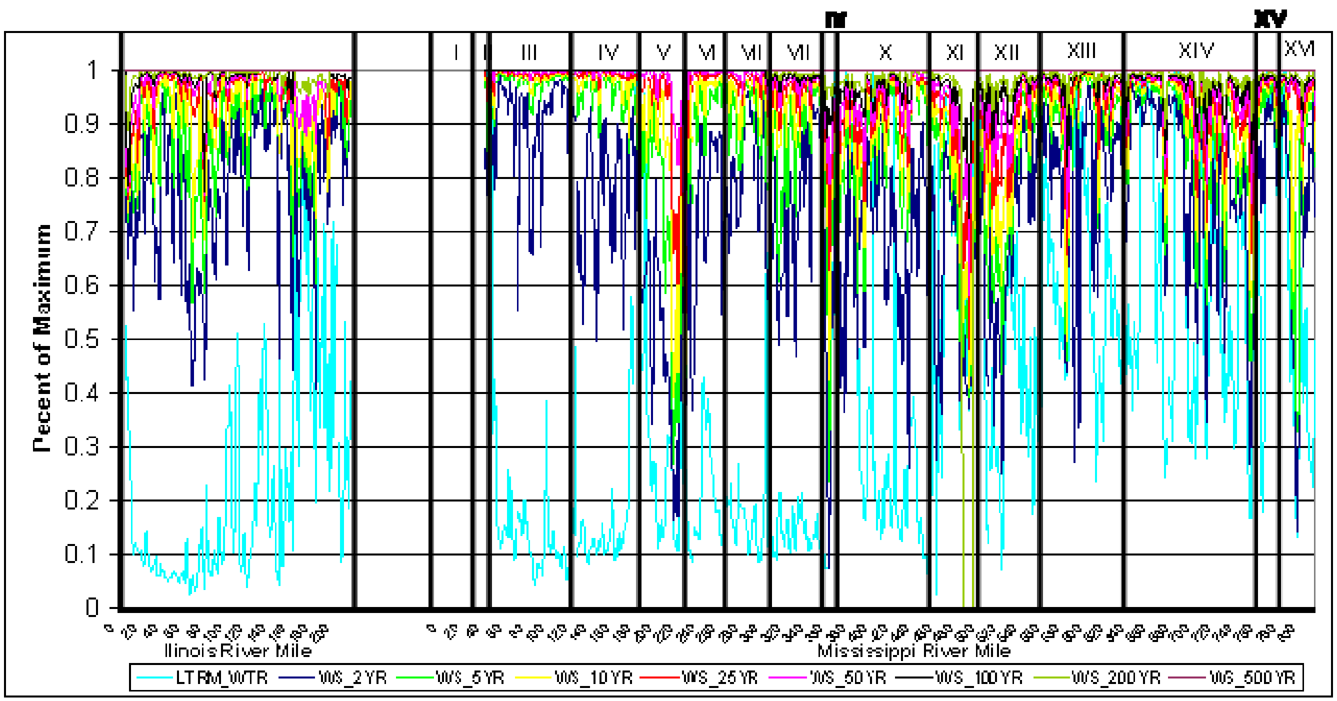
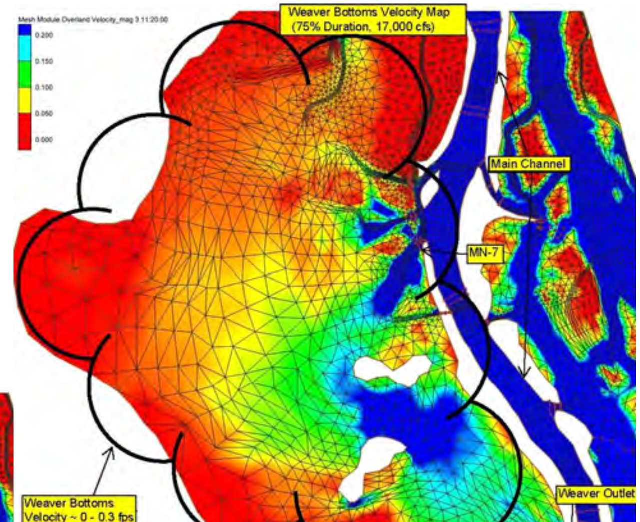
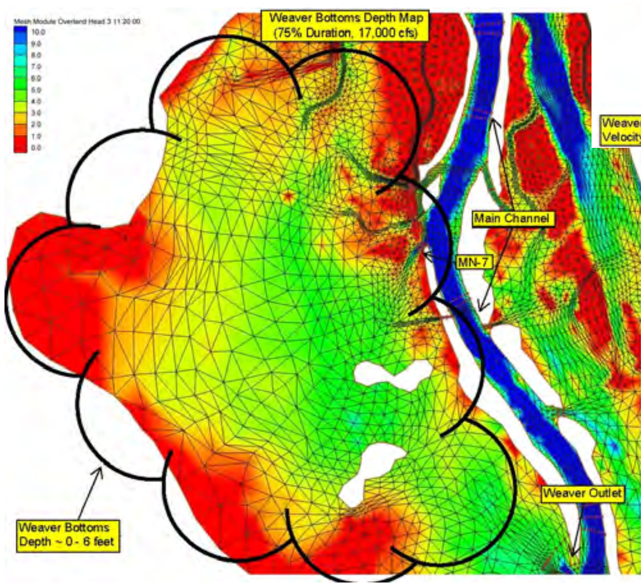


Figure 37. Proportional inundation area by river mile and geomorphic reach (Roman Numerals) for nine inundation profiles (0 to 500-year flood). Long colorful spikes represent diverse inundation patterns, narrow bands reveal a dominance by the frequent floods





Floodplain Lakes in Winter

Sites	Velocity	Existing Co. Area	1.5' Drawd. Area	2.5' Drawd. Area
Objective:	*< 0.01 fps*	*> 80%*	*> 80%*	*> 80%*
Finger Lakes	< 0.01 fps	100%	100%	100%
Weaver Bottoms	< 0.01 fps	~ 20%	~ 20%	~ 20%
Lost Island Lake	< 0.01 fps	~ 10%	**~ 15 %**	**~ 15 %**
Spring Lake	< 0.01 fps	~ 40 %	**~ 45 %**	**~ 80 %**
	Depth	Area	Area	Area
Objective:	*> 4 feet*	*> 40%*	*> 40%*	*> 40%*
Finger Lakes	> 4 feet	~ 70 %	~ 70 %	~ 70 %
Weaver Bottoms	> 4 feet	~ 60 %	**~ 40 %**	**~ 30 %**
Lost Island Lake	> 4 feet	~ 70 %	**~ 60 %**	**~ 60 %**
Spring Lake	> 4 feet	~ 60 %	**~ 20 %**	**~ 15 %**

Notes:

[1]Assume 75% Duration Event (17,000cfs)

[2]Assume open river (no ice cover)

Figure 38. Water depth and current velocity for contemporary conditions in Pool 5, Weaver Bottoms illustrate the types of physical processes simulated in 2-dimensional hydrodynamic simulations of alternative drawdown scenarios, the table compares model runs for alternative drawdown scenarios

3.2. WIND FETCH MODEL

Wind generated waves rolling across shallow open-water areas caused substantial post dam island erosion in Geomorphic Reach 3. Waves also resuspend sediment which blocks light for aquatic plants. The EMP-LTRMP developed a GIS based wind fetch model to refine island design criteria necessary to reduce wind generated waves in large open water areas. The model has been applied in many site specific restoration planning studies (Figure 39) and is available as a GIS extension for other applications.

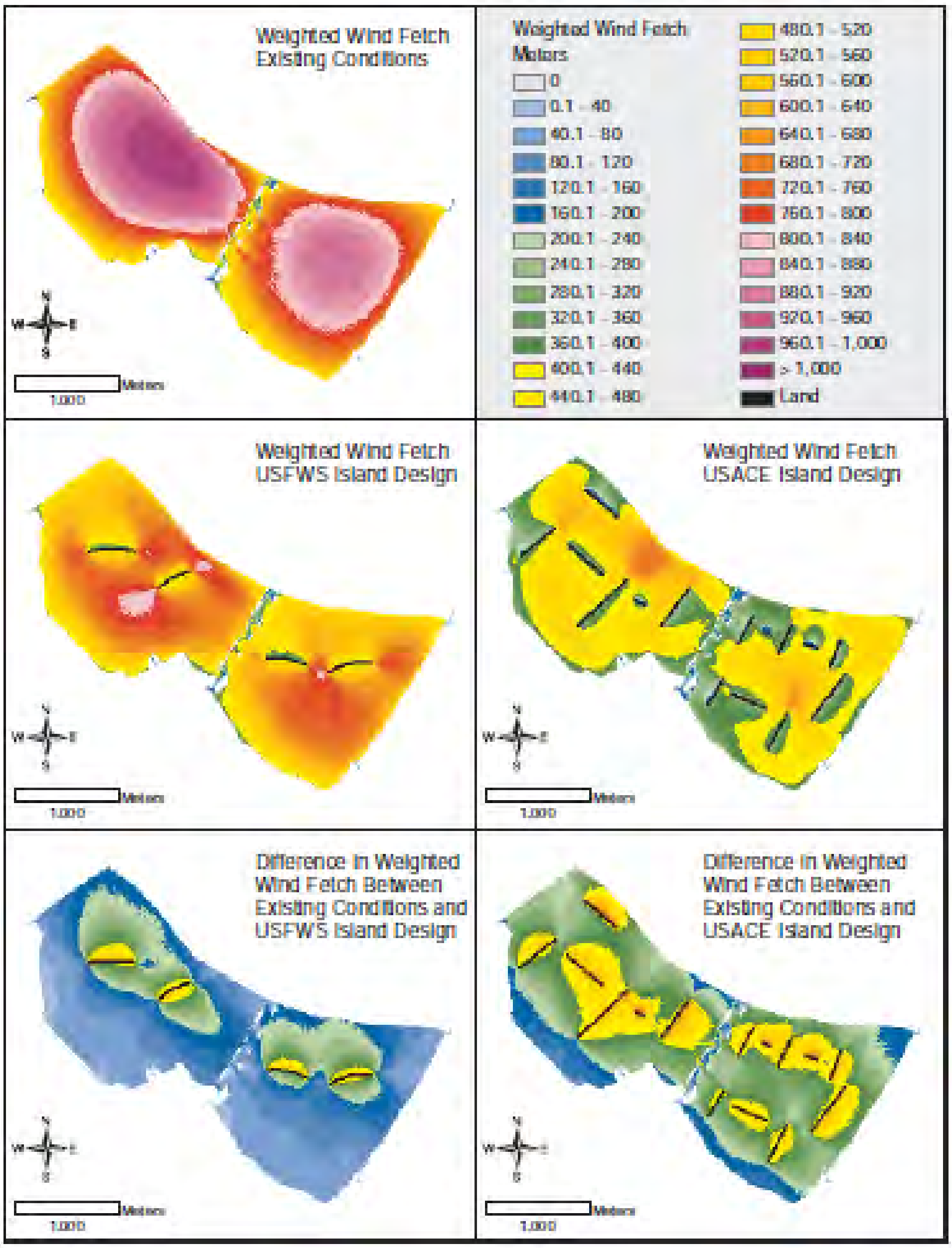


Figure 39. The US Geological Survey Swan Lake, Illinois River wind fetch model helps evaluate the potential for wind to resuspend sediment in backwaters

3.3. LAND COVER PREDICTIVE MODELS

Land cover maps have been an important part of UMRS natural resource planning for the last 20 years. They have become surrogates for more detailed botanical and fish and wildlife surveys in that biotic communities and ecological functions are implied from static land cover maps. Availability of spatially explicit topography, hydrology, geomorphology, and soils, combined with an understanding of plant species physiologic needs has helped advance the state of predictive vegetation modeling. The Hydrogeomorphic Methodology approach is well suited to the UMRS where several large river reaches have been modeled (Figure 40). Current land cover models are static estimates based on a few physical attribute conditions; there are no hydrogeomorphic feedbacks nor prospects for such in the near future. There is a great need to expand hydraulic models into the floodplain to model river/floodplain interactions and material transport.

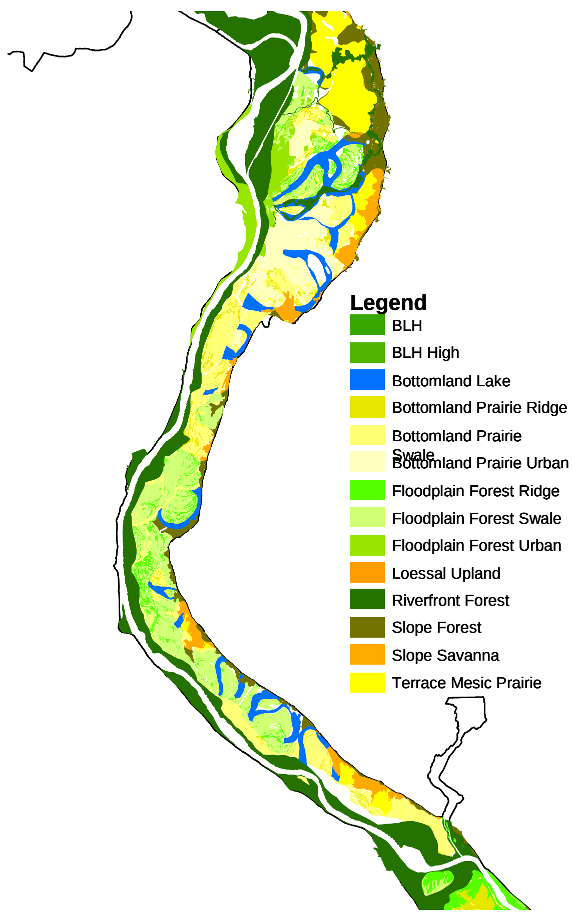


Figure 40. The hydrogeomorphic methodology which incorporates flood frequency, geomorphology, and soils to estimate potential habitat has great potential for application throughout the Upper Mississippi River System

3.4. HABITAT SUITABILITY MODELS

Habitat suitability models range from very deterministic models using few environmental parameters (Figure 41) to very explicit models that require water flow or chemistry to derive estimates of species distribution. The HNA query tool was the first UMRS system-wide suitability model. The models used land cover and aquatic area only, but they estimated the potential distribution of hundreds of species. The simple models inferred functions of broad habitat classes and greatly over-represented habitat. They can be applied to alternative land cover references to estimate animal response to restoration. Mussel habitat suitability modeling has advanced rapidly with the availability of more hydrodynamic model results (Figure 42). In the mussel habitat modeling, dynamic parameters like bed sheer augment structural parameters to refine habitat estimates. Very recent fish movement modeling is incorporating individual fish response to flow variables in complex two- and three-dimensional hydrodynamic models. Initial investigations show great applicability in the UMRS (Figure 43).

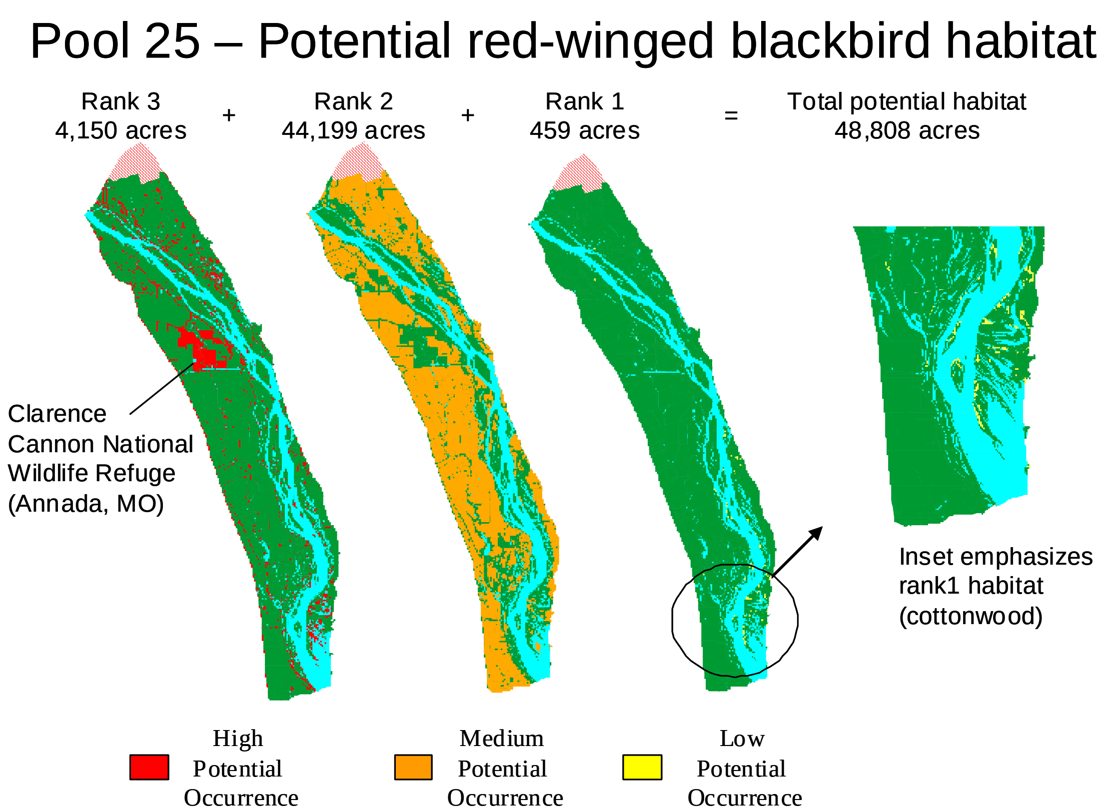


Figure 41. The Habitat Needs Assessment Query Tool estimates potential animal habitat from land cover and aquatic area maps

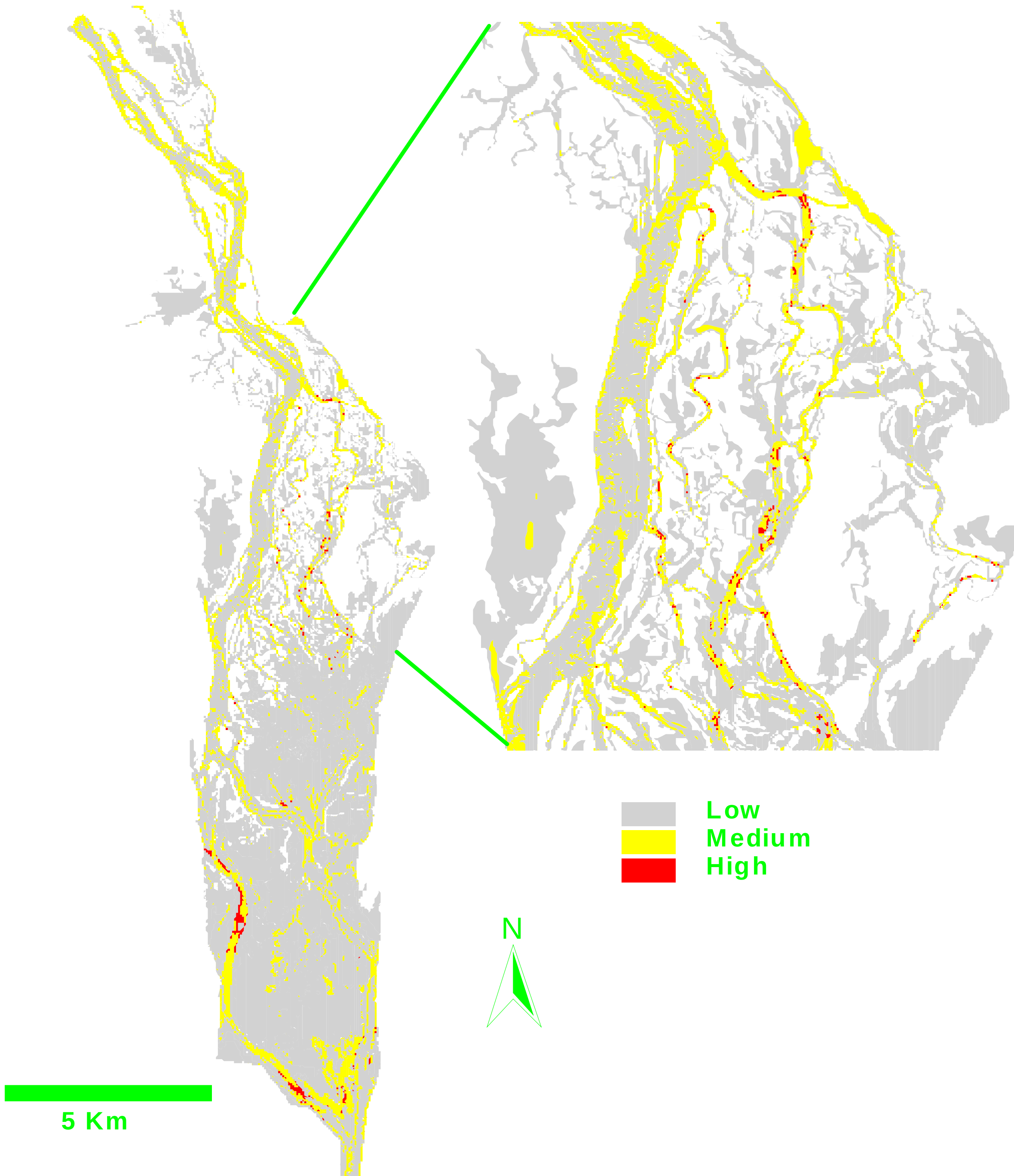


Figure 42. A freshwater mussel hydrodynamic habitat suitability model uses model derived hydraulic process parameters to predict mussel distribution

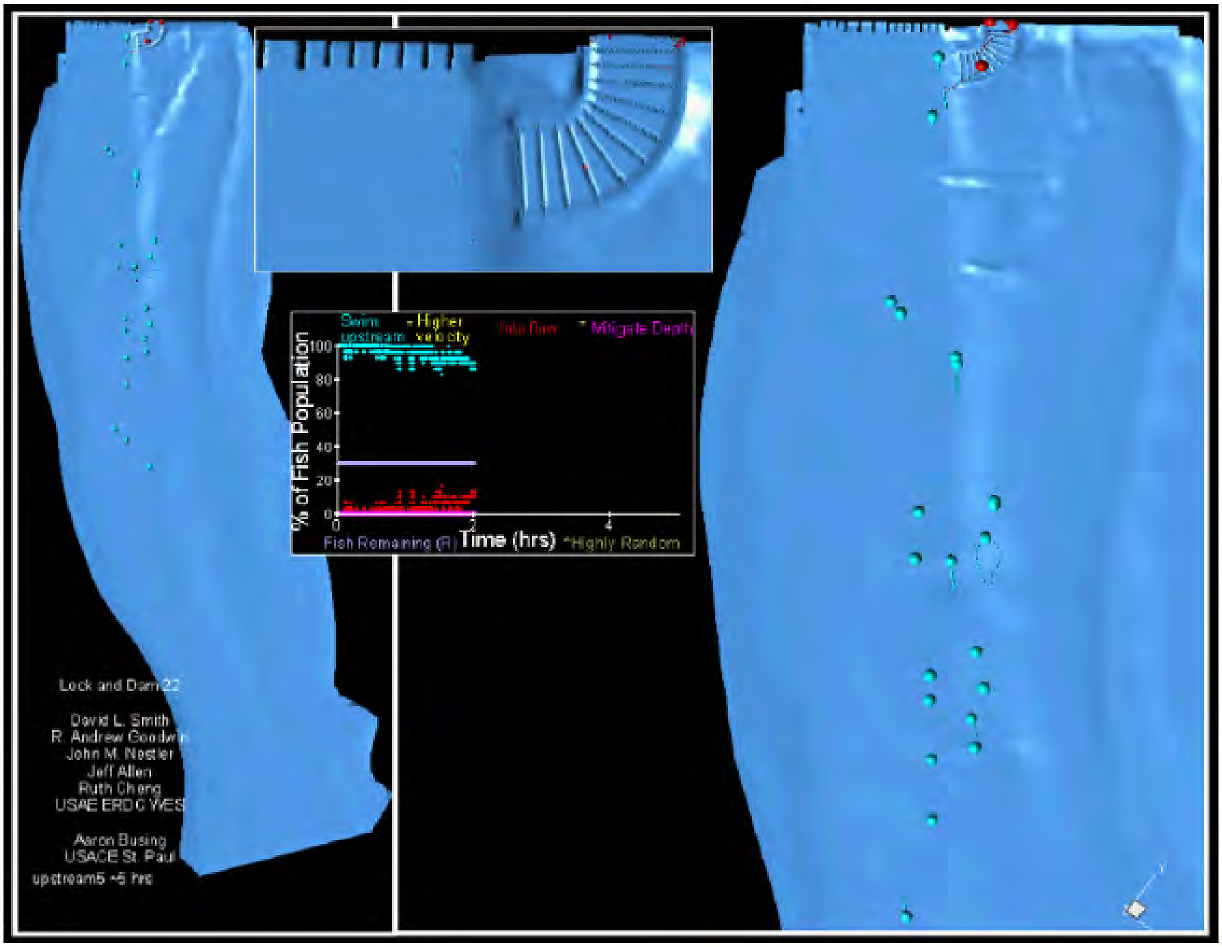


Figure 43. The eularian lagrangian agent model uses fish response to hydraulic flow parameters to estimate their movement in response to structures

To close the discussion on process and function considerations in ecosystem restoration planning it is important to consider the impacts of making a mistake (i.e., a risk-based approach). Most individual ecosystem restoration actions are small actions on the scale of Federal projects. It is unlikely that health and welfare will be jeopardized if an ecosystem restoration project fails, so simple projects should be executed with a minimum of overhead. From the programmatic sense, however, individual projects should have a high likelihood for success and each project should add to a cumulative body of knowledge. Information and lessons learned from planning and constructing habitat projects through the ongoing UMRS EMP are good starting points for future efforts. There is a balance between learning and project execution in the recommended plan for UMRS ecosystem restoration that allocates almost 20 percent of restoration funding for monitoring and adaptive management. The principles of adaptive management set forth in the Feasibility Study, NESP Science Panel guidance, and WRDA 07 must be a priority for river managers.

4.0 OUTCOMES OF SETTING SYSTEM AND REACH-SCALE ECOSYSTEM OBJECTIVES

4.1. TEAM APPROACH

Formal planning for UMRS ecosystem management and restoration has been an ongoing process that was institutionalized in the 1970's with a Comprehensive Master Plan completed by the Upper Mississippi River Basin Commission in 1982. The Master Plan proposed an outline for the Environmental Management Program (EMP) which was authorized in WRDA 1986. The EMP has been a National leader in ecosystem restoration planning and implementation for 25 years. EMP partners have participated in several project planning cycles to develop regional ecosystem restoration needs and priorities. Their prior experience and strong interagency relationships provided the foundation to develop the ecosystem restoration component of the Navigation and Ecosystem Sustainability Program (NESP) which was authorized in WRDA 2007. Program partners understand the interrelated information needs of multiple navigation and ecosystem restoration programs, so Reach Planning was conducted to identify ecosystem objectives and subareas where they can be achieved in a program-neutral fashion.

Reach Planning was initially undertaken to support an anticipated $100 million/year ecosystem restoration program authorized in WRDA 2007, but was subsequently expanded to apply to all UMRS ecosystem restoration programs. Reach Planning relied on participants from River Management Team workgroups including the Fish and Wildlife Work Group (FWWG) in the Upper Impounded Reach (UIR); the Fish and Wildlife Interagency Committee (FWIC) in the Lower Impounded Reach (LIR); the Illinois River Work Group (IRWG) in the Illinois River (IR), and the River Resources Action Team (RRAT) in the Unimpounded Reach (and also LIR and IR). Reach Planning teams were established in four floodplain reaches to refine ecosystem restoration objectives and to develop a Reach Plan for ecosystem restoration for the first NESP 4-year planning cycle. In recognition of the longitudinal differences that exist over 1,100 river miles, additional spatial organization was achieved by dividing the reaches into 12 distinct geomorphic reaches.

Reach Planning teams compiled unique characteristics, stressors, and ecosystem restoration objectives for each geomorphic reach. They also identified subareas within each Geomorphic Reach that would contribute to attaining the ecosystem objectives. This process is summarized in four Reach Plans, one for each UMRS Floodplain Reach, presented in this report as Appendix A, *Upper Impounded Reach Plan*; Appendix B, *Lower Impounded Reach Plan*; Appendix C, *Unimpounded (Middle Mississippi) Reach Plan*; and Appendix D, *Illinois River Reach Plan*.

4.2. UNIQUE AND IMPORTANT ECOLOGICAL CHARACTERISTICS

Unique and important characteristics of each geomorphic reach were identified and given primary consideration in setting ecosystem objectives. The list of characteristics includes geomorphic features, land parcels, fish and wildlife resources, commercial issues, and recreation. These characteristics are discussed in detail in Appendices A, B, C, and D.

There are some ecological characteristics and development impacts that are relevant system-wide, or nearly so. They are not necessarily unique to the UMRS, but they are very important ecological impacts. Impoundment, levee and drainage districts, off-channel habitat degradation, and tributary impacts will be summarized below as part of the system-wide approach to determine ecosystem restoration opportunities.

4.3. ECOLOGICAL STRESSORS AND LIMITING FACTORS

Ecological stressors for Geomorphic and Floodplain Reaches were identified with Reach Teams familiar with local sites. There are many stressors that apply system-wide (Table 4); individual reach plans emphasize the most important stressors in each reach. Several important stressors can be documented with system-wide data.

The ecological process and function objectives discussed below are based on observed change in ecosystem structure and composition resulting from the many stressors affecting the river-floodplain. The UMRS Conceptual Model helps identify the connectedness among ecosystem components to estimate what stressors can be manipulated to affect change in ecosystem condition.

4.4. ECOSYSTEM RESTORATION OBJECTIVES

River Teams developed ecosystem restoration objectives for future environmental condition in each geomorphic reach using the 43 NESP Ecosystem Restoration Objectives as a guide. Reach scale ecosystem objectives were compiled for the four Floodplain Reaches and compared system-wide (Table 5), they are presented in full detail in each Reach Plan appendix. Many of the objectives are not applicable to this reach plan because they can only be achieved from outside the floodplain (i.e., tributary sediment and nutrients), they are part of another plan (e.g., Forest Plan, Channel Dredging), or they operate on a scale that cannot be evaluated at the reach scale (e.g., bathymetric diversity, sediment transport, local water quality, local habitat (Table 6). Many of the smaller scale physical characteristics and process such as depth and current velocity can be generalized for aquatic classes or land cover classes at the reach scale, but site specific processes affecting local habitat and subareas must be considered at smaller scales. The environmental objectives that do apply system-wide are discussed in detail in Sections 4.4.1 through 4.4.4.

4.4.1. Objectives Beyond the Floodplain. Objectives for sediment and nutrient transport to the mainstem are included because they are vitally important components of the river-floodplain ecosystem. Over glacial time the tributaries have defined the very shape and function of the floodplain landscape, in the policy arena programs managing floodplains operate at smaller temporal and spatial scales. Agency programs and vision is spatially compartmentalized, and even programs with broad spatial vision like the Illinois Basin Ecosystem Restoration program must be applied at local scales. Restoring the entire UMRS watershed is an immense challenge, one that was set aside beyond mainstem floodplain for the purpose of UMRS Reach Planning. Contaminants were not considered because they are generally well known and controlled by other entities.

Table 4. Ecological stressors that apply throughout the Upper Mississippi River System

Impoundment by locks and dams
River – Marsh – Pool sequence
River – Marsh – Pool sequence
Lateral hydraulic connectivity changing
Impoundment effects and ambient water quality
Historic loss of many habitats due to floodplain development
Hypoxia during summer stratification
Levees, floodplain development
Shoreline development
Floodplain encroachments limiting hydraulic connectivity
Littoral processes in impounded areas eroding islands
Wind-driven sediment
Sedimentation in off-channel areas
Dynamics of river bar scour and ephemeral islands
Altered sediment transport and deposition
Sediment trapping
Dredging, sand/gravel mining removing bed material
Legacy sediment in tributaries
Channel training structures - riprap, wing dams, closing dams
Long shorelines with riprap
Port facilities, floodwalls affecting main channel borders
Impacts of recreational boating traffic
Altered tributary hydrology
Sediment loading
Nutrient loading
Contaminants from non-point urban runoff
Contaminant point sources
In-place pollutants
Pool aging
Historic loss of Submerged Aquatic Vegetation (SAV)
Public land (lack of)

Table 5. Reach scale ecosystem objectives for the four floodplain reaches and compared system-wide

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
Hydraulics & Hydrology: Manage for a More Natural Hydrologic Regime			
A more natural stage hydrograph	A more natural stage hydrograph		A more natural stage hydrograph
Restored hydraulic connectivity		Restored hydraulic connectivity	
	Naturalize the hydrologic regime of tributaries		
	Increase storage & conveyance of flood water on the floodplain		
Biogeochemistry: Manage for Processes That Input, Transport, Assimilate, & Output Material Within UMR Basin River Floodplains: e.g., Water Quality, Sediments, & Nutrients			
Improved water clarity	Increased water clarity		
Reduced nutrient loading	Reduced nutrient loading from tributaries to rivers		
Reduced sediment loading from tributaries & sediment resuspension in & loading to backwaters	Reduced sediment loading & sediment resuspension in backwaters		Reduced sediment loading & sediment resuspension in backwaters. **NOTE:** There are several objectives dealing with tributary loading
Reduced contaminants loading & remobilization of in-place pollutants			
		Water quality conditions sufficient to support native aquatic biota & designated uses	Water quality conditions sufficient to support aquatic biota
Geomorphology: Manage for Processes That Shape a Physically Diverse & Dynamic River Floodplain System			
Restore rapids			
	Restored backwater areas		Restored backwaters
	Restored lower tributary valleys		
Restore a sediment transport regime so that transport, deposition, & erosion rates & geomorphic patterns are within acceptable limits	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored secondary channels & islands
	Restored floodplain topographic diversity		
			Restored lateral hydraulic connectivity

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
Habitat: Manage for a Diverse & Dynamic Pattern of Habitats to Support Native Biota			
Restored habitat connectivity	Restored habitat connectivity		Restored habitat connectivity
Restored riparian habitat	Restored riparian habitat	Restored riparian habitat	
Restored aquatic off-channel areas		Increase the extent & number of sand bars, mud flats, gravel bars, islands, & side channels towards a more historic abundance & distribution.	
Restored terrestrial floodplain areas			
Restored channel areas			
	Diverse & abundant native aquatic vegetation communities (SAV, EAV, RFV)		
		Restored large contiguous patches of native plant communities to provide a corridor along the UMR	Restored floodplain areas
		Restored floodplain wetland areas	
		Restored degraded & rare native habitats	
			Restored lower tributary valleys
Biota: Manage for Viable Populations of Native Species Within Diverse Plant & Animal Communities			
Diverse & abundant native aquatic vegetation communities (SAV, EAV, R/F)			
Diverse & abundant native floodplain forest & prairie communities			
Diverse & abundant native fish community		Diverse & abundant native fish community	
Diverse & abundant native mussel community			
Diverse & abundant native bird community			
	Restored diversity & extent of native communities throughout their range in the UMRS	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential
	Reduced adverse effects of invasive species	Reduced adverse effects of invasive species	
			Restored diversity & extent of native communities throughout their range in the UMRS

Table 6. Upper Mississippi River System system-wide ecosystem restoration objectives sorted by their appropriate planning scale

System Scale	Site Specific, Not Evaluated	Beyond UMRS
A more natural stage hydrograph	Reduced sediment loading and Sediment resuspension in backwaters	Reduced nutrient loading from tributaries to rivers
Restored hydraulic connectivity	Restored lateral hydraulic connectivity	Reduced contaminants loading and remobilization of in-place pollutants
Increase storage and conveyance of flood water on the floodplain	Water quality conditions sufficient to support native aquatic biota and designated uses	
Restored backwaters	Restore rapids	
Restored secondary channels and islands	Restored bathymetric diversity, and flow variability in secondary channels, islands, sand bars, shoals and mudflats	
Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits	Restored floodplain topographic diversity	
Improved water clarity		
Naturalize the hydrologic regime of tributaries		
Restored lower tributary valleys		
Forest Plan / Floodplain Landscape*		
Fish Passage*		
Water Level Management*		

* = System-wide evaluation completed previously

4.4.2. Objectives With System-Wide Plans. Several UMRS ecosystem restoration objectives have been considered in great detail and documented as system plans. Impediments to longitudinal fish migrations were evaluated to estimate the feasibility of increasing opportunities for year-round fish passage system-wide. The conclusion was that there is a need for improved connectivity and that nature-like bypass channels were a suitable alternative. Fish passage at several dams was specifically authorized in WRDA 07.

A UMRS Forest Management Plan was developed by a system-wide team representing many state and Federal agencies. The forest plan sets forth objectives for condition of forests and other landscapes, includes monitoring and learning, and recommends management plans for public lands. It also recognizes that forests and other landscape issues can be considered as part of every project. Projects can reference the forest plan for opportunities to improve projects, or the forest plans may form the basis of a project (e.g., Reno Bottoms). Predictive landscape modeling (i.e., hydrogeomorphic methodology) has been successful in several reaches and is being implemented system-wide.

Increasing topographic diversity to enhance floodplain vegetation diversity should be implemented in coordination with other ecosystem restoration and channel maintenance activities that include dredging and dredged material management. The action is specifically stated in only a few sites, but it has potential for broad application. There is no formal system-wide plan for topographic diversity, but traditional dredging coordination could support the activity. Rock Island District 404 Studies produced a very detailed investigation of the type of habitats that develop on dredged material.

4.4.3. Site Specific Objectives. Fluvial-geomorphic processes creating bathymetric diversity, flow variability, secondary channels, islands, sand bars, shoals, mudflats, etc. are important objectives that operate on many spatial and temporal scales. Floodplain Reach scale hydro-geomorphology was changed and a new baseline landscape was established when the early channel projects, dams, and L&DDs were constructed. The hydro-geomorphic response to development (i.e., each dam, diversion, or structure) is similar within Floodplain Reaches, but site specific characteristics determine local habitat response and succession. As the dams create repeating water-marsh-channel habitat sequences, ecosystem restoration problems and solutions change. Flow diversion works well in upper pool channels and backwaters, islands and other structures reduce wind fetch in lower pool open water areas. Some restoration techniques are applicable system-wide, others are emphasized in one or two reaches. These types of site-specific projects in aquatic habitats were the ones considered for the 200+ projects authorized in WRDA 07.

Sediment loading and resuspension in backwater, water clarity, and lateral hydraulic connectivity are hydro-geomorphic processes that can be considered at a similar scale. These processes are critically important determinants of local habitat that can be altered on the scale of hundreds to thousands of acres within a single project. Identifying and prioritizing ecosystem restoration needs can be complex because it is difficult to quantify small, physical differences or biological abundance among subareas or sites. The differences at geomorphic reach scale are generally sufficient to estimate the expected hydro-geomorphic and water quality characteristics of subareas. Local knowledge compiled in the Pool Plans, HNA, and Future Geomorphic Conditions database and in Reach Planning workshops helps prioritize subareas that may be selected for more detailed feasibility studies.

4.4.4. Habitat and Biota Objectives. Habitat and Biota objectives are the endpoint of most ecosystem restoration activities, but the interjurisdictional management of the UMRS has not provided information to systematically compare the habitat quality and biotic abundance of the system. The

EMP-LTRMP's first complete land cover data set was a fantastic aid to our understanding of the system, similar to the first pictures of Earth from space, and they have provided many enhancements since. It is now possible to document historic and existing habitat and conceptualize alternative conditions in land cover maps. The EMP-LTRMP 10-year Reports documented river habitats for fishes, aquatic invertebrates, and aquatic plants, and they characterized forests and water quality. The response of these ecological indicators can be compared across multiple habitat reference conditions. As with the site-specific objectives, however, quantifying species abundance and habitat relationships with statistical rigor is challenging.

State Departments of Natural Resources and the U.S. Fish and Wildlife Service (USFWS) are the traditional biological survey agencies responsible for quantifying animal populations. Biological surveys are challenging, thus system-wide surveys for all but a few groups (e.g., waterfowl, shorebirds, bald eagles, colonial nesters) are lacking. In the case of these migratory species, the UMRS supports only part of their life history needs, so it is difficult to identify the relative importance of migration habitat which may only be used for several months each year. Similarly, for local species it may be difficult to evaluate the relative importance of direct project effects from changes in ambient conditions. Indirect project effects such as production benefits accumulating through food webs are even harder to evaluate. The approach to most biological benefits evaluation has been through table-top habitat suitability analysis (i.e., HEP). The recommended adaptive management plan calls for a much more rigorous evaluation early in the NESP program. Applied research is needed to estimate production of characteristic biota in habitat patch types to establish biological potential and refine biota objectives.

5.0. SYSTEM-WIDE ECOSYSTEM RESTORATION EVALUATION

5.1. A MORE NATURAL STAGE HYDROGRAPH

The annual and inter-annual timing, frequency, magnitude, duration, and rate of change of hydrologic events are important ecological drivers. They have all been altered to some degree in the impounded reaches of the UMRS and by diversions and channelization in others. Evaluating change in the natural hydrograph is limited by the number of historic gauges, but mapping during summer low flow can be used to classify, quantify, and visualize surface water on a large scale between static reference conditions (Figure 44 and 45). Impacts to the dynamic stage hydrograph can be implied conceptually or modeled (Figure 46). Tools are available to make reasonably accurate 2-dimensional models of historic conditions, high fidelity hydrodynamic modeling for future alternative conditions will be an element of any subarea feasibility study.

Significant increases in surface water distribution are concentrated in the UIR (Figure 45). Impoundment prevents backwater drying during low flow, which degrades backwaters throughout the system. From a spatial perspective, however, the greatest potential to affect change in the altered hydrology is in the UIR (Figure 45). A no-dam scenario (Figure 46) can be conceptualized or simulated, but environmental drawdowns less than 2-feet deep, that also maintain navigation are a more likely environmental restoration scenario.

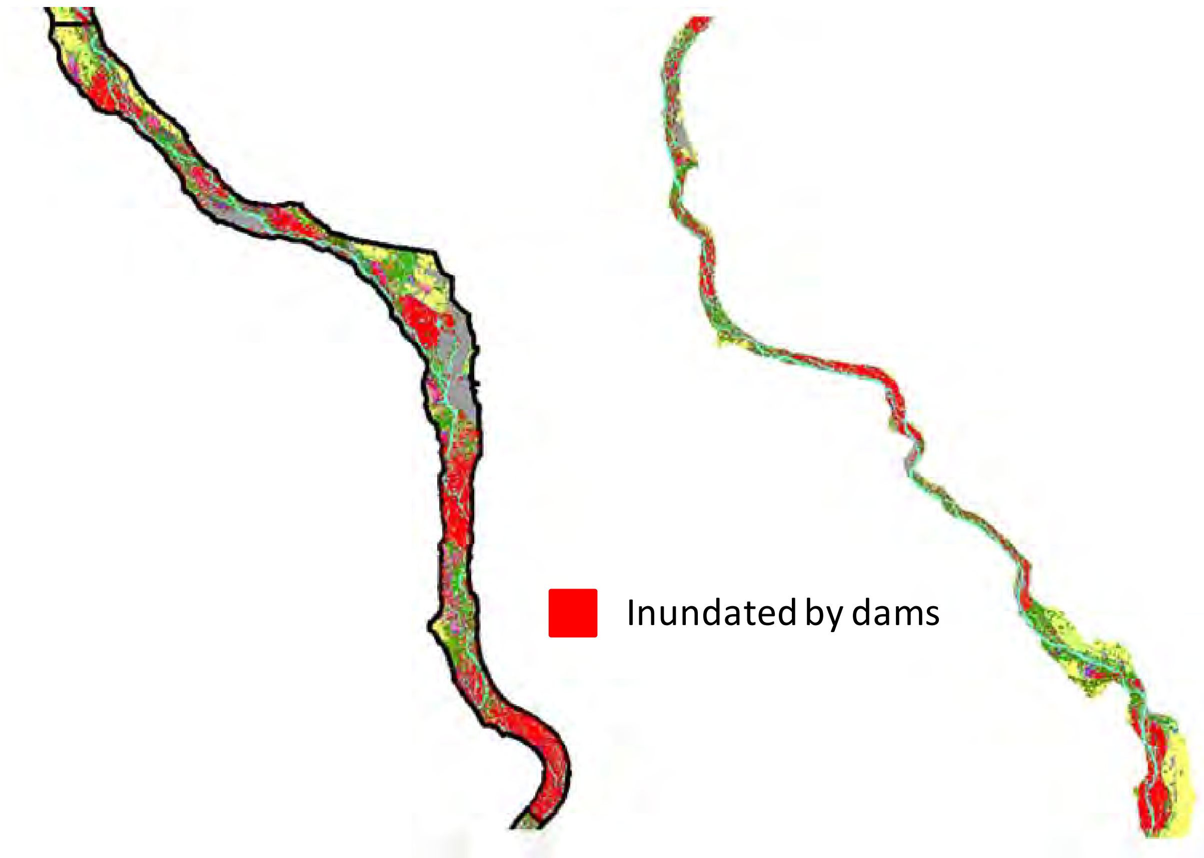


Figure 44. Increased surface water distribution from impoundment is most pronounced in the Upper Mississippi River System, Upper Impounded Reach

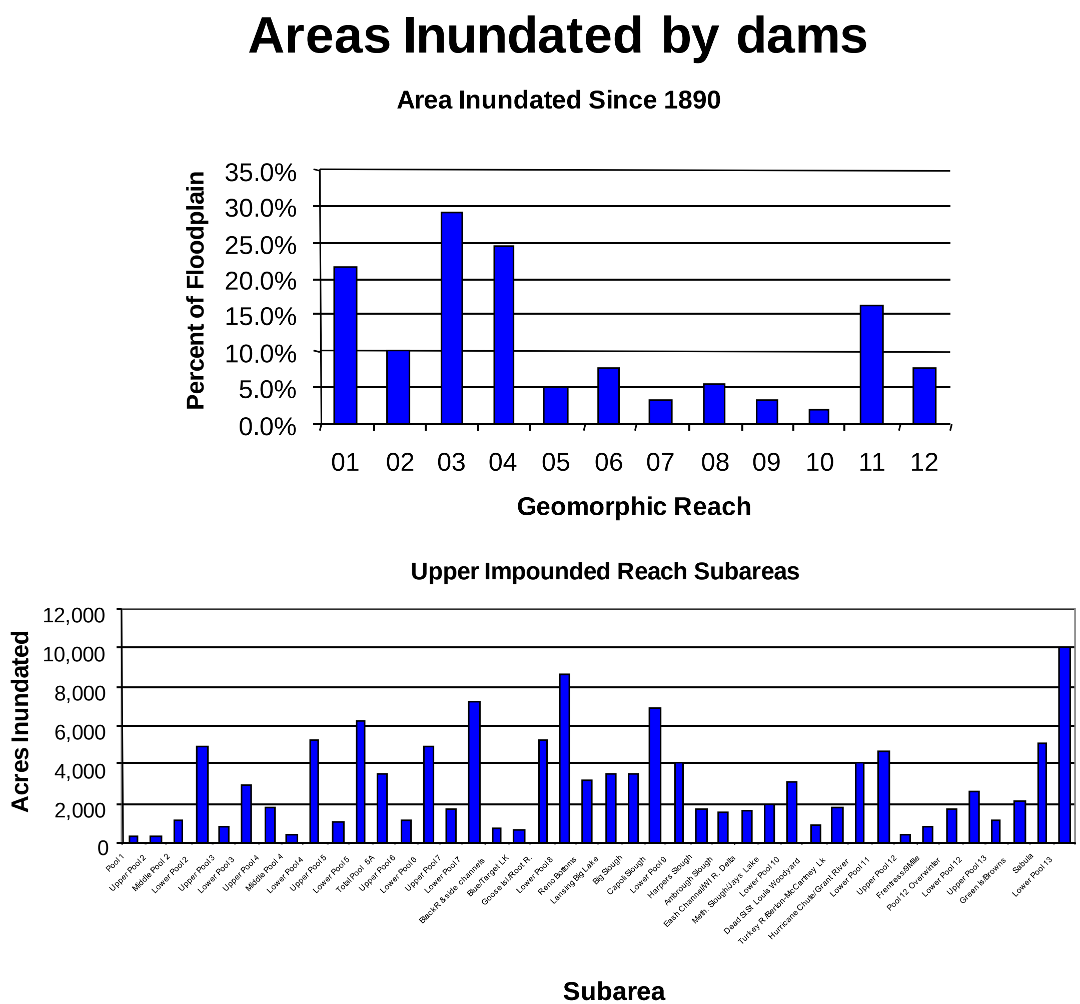


Figure 45. Impoundment effects as percent of floodplain area are most pronounced in UMRS Geomorphic Reaches 1, 3, and 4, (UIR; top). The effects can be subdivided within the UIR to identify subareas and sets of subareas that may benefit from pool-scale water level management

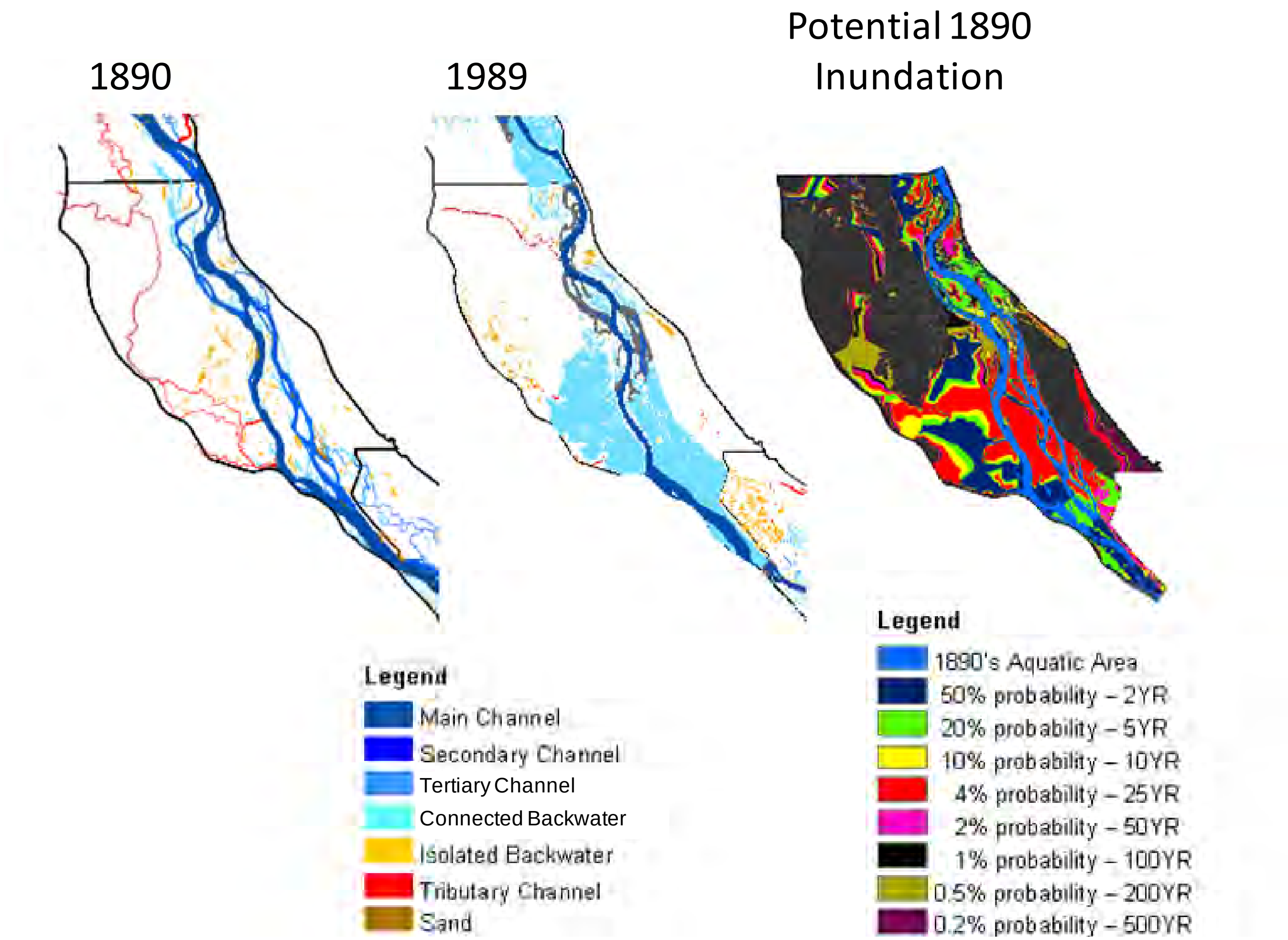


Figure 46. A pool scale perspective of aquatic areas can help understand hydrologic changes from impoundment (two left maps); simulated alternative conditions (right map) can help bound the expectations for restoration

5.2. RESTORED HYDRAULIC CONNECTIVITY

Impoundment effects on surface water distribution increased aquatic connectivity on the floodplain in the UIR (Figure 44). Diversion effects, then impoundment, had a similar effect on the Lower Illinois River, but the effects are not large in the LIR. Increased aquatic connectivity is most pronounced in the lower two-thirds of navigation pools (Figures 23 and 27). Hydraulic changes also created low current velocities that allow sediments to drop out into deeper, low velocity environments. Former channel features get filled with sediment and off-channel aquatic habitats become more uniform. Initially a variety of aquatic littoral benefits, such as deep marsh, aquatic vegetation, furbearer, and sunfish overwintering habitat, were created, but negative effects of increased wind fetch and sedimentation degraded these benefits over time. Most eroding islands are already gone and some island growth is occurring where sediment transport is high. Aquatic habitat connectivity in impounded areas will decrease in the future if sediment and vegetation fills alluvial impoundments; site specific plant succession can be managed to achieve desirable outcomes that are cost effective and sustainable. Aquatic connectivity in open backwater lakes may be addressed by flow manipulation, introduction, or exclusion, as well as island wave breaks. Restored structural diversity (geomorphic pattern) is an important system-wide geomorphic objective that is achieved through multiple site specific projects.

5.3. INCREASED FLOODPLAIN CONNECTIVITY

Increased floodplain connectivity implies levee removal, but there are many intermediate comprehensive floodplain management alternatives that can increase habitat benefits, reduce crop production costs, balance flood protection between agricultural and mixed uses, and increase recreation opportunities. There are indeed individual L&DDs at tributary confluences, for example, that offer high hydro-geomorphic diversity which would support high biodiversity and water quality objectives. Conversely, there are others that would simply become large open lakes if they were managed for aquatic resources (Figure 47). These conditions are familiar in places like Lake Chautauqua, Illinois River, which was a failed L&DD nearly from inception. These large scale backwater, moist soil management opportunities have long-standing success for wetland management, but large open aquatic areas are not necessarily the desired objective. Land acquisition for floodplain restoration is authorized, but will likely be opportunistic in lieu of an established funding source. Long-term acquisition plans are helpful because they can be used to target resources effectively when opportunities like flood buyouts, year end surpluses, or stimulus spending arise. Land acquisition could be coordinated by the system-scale Floodplain Restoration planning team which includes a wide range of commercial, public, and agency participation. Floodplain restoration, including crop land conversion, was informally evaluated to be the most cost effective restoration technique in the Navigation Feasibility Study.

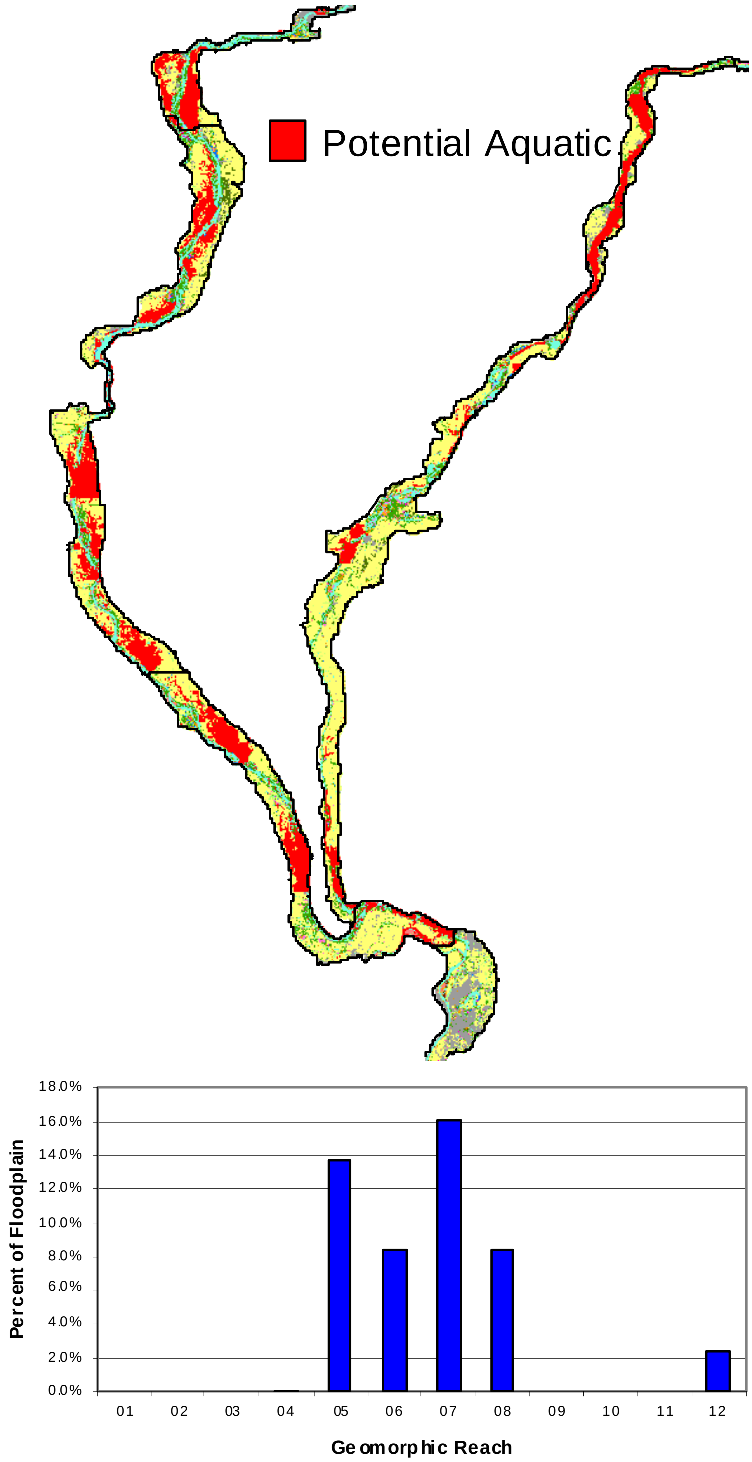


Figure 47. Potential floodplain aquatic area from reduced ground water pumping is much greater than existing conditions in the Upper Mississippi River System, Lower Impounded Reach because levee and drainage districts pump significant amounts of groundwater compared to other river reaches

A mixed use floodplain management plan can achieve multiple benefits within the existing infrastructure (Figure 48). Complete year-round aquatic river-floodplain habitat connectivity is unlikely without significant modification of L&DD infrastructure, but there may be larval fish export to the river from floodplain wetlands that can be managed with L&DD water management infrastructure. There will definitely be an energetic input to the river from the managed wetlands. Wetland dependent fauna (mammals, birds, reptiles, and amphibians) thrive in such conditions. Conservation easements could be structured so seasonal wetlands can be hayed for feed or fuel to minimize financial impact to landowners. Flood protection for crops can be provided at a high enough level to support economic opportunity, but low enough to discourage structures in the floodplain. Crop insurance and flood easements could be structured to pay for crop losses when floods occur. The L&DD lands managed for aquatic habitat might be purchased outright, but they may also be accessed through a variety of flood and conservation easements. The L&DD wetland management benefits are concentrated in the LIR and some places in the Lower Illinois River, but similar habitat benefits can be achieved in most agricultural environments (Figure 49).

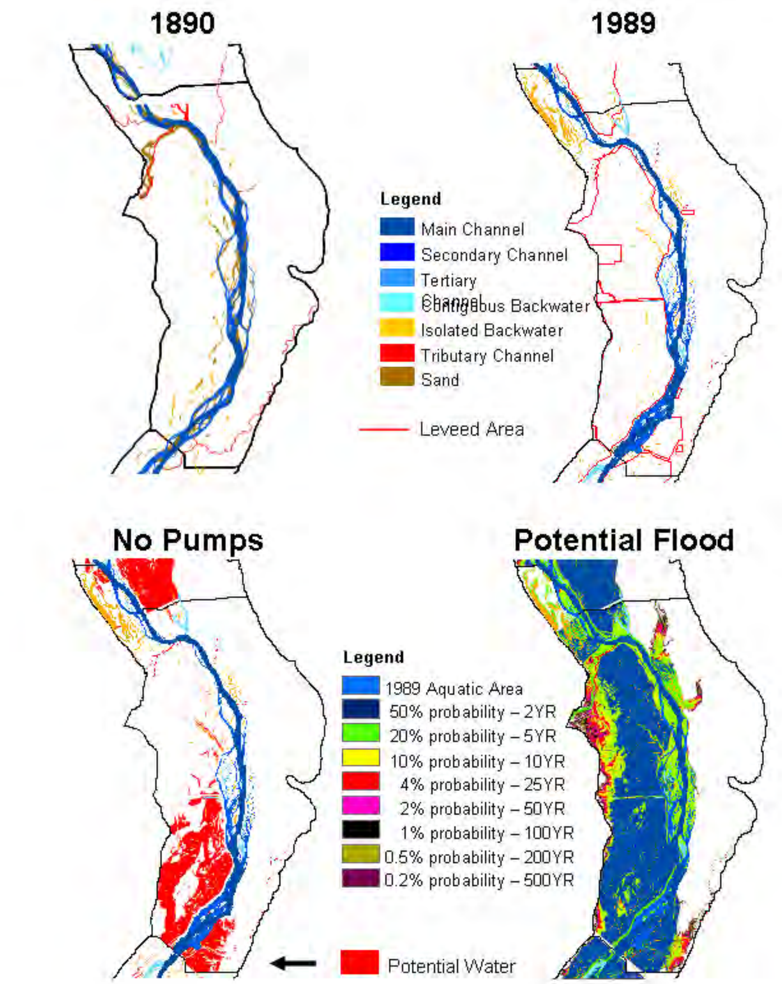


Figure 48. Historic, contemporary, and modeled alternative future (virtual) reference conditions help visualize and quantify alternative floodplain management scenarios in UMRS. (Pool 18 - 1890 aquatic areas, 1989 aquatic areas and levees, No Pumps hypothetical inundation to pool stage, simulated flood inundation spatial distribution)

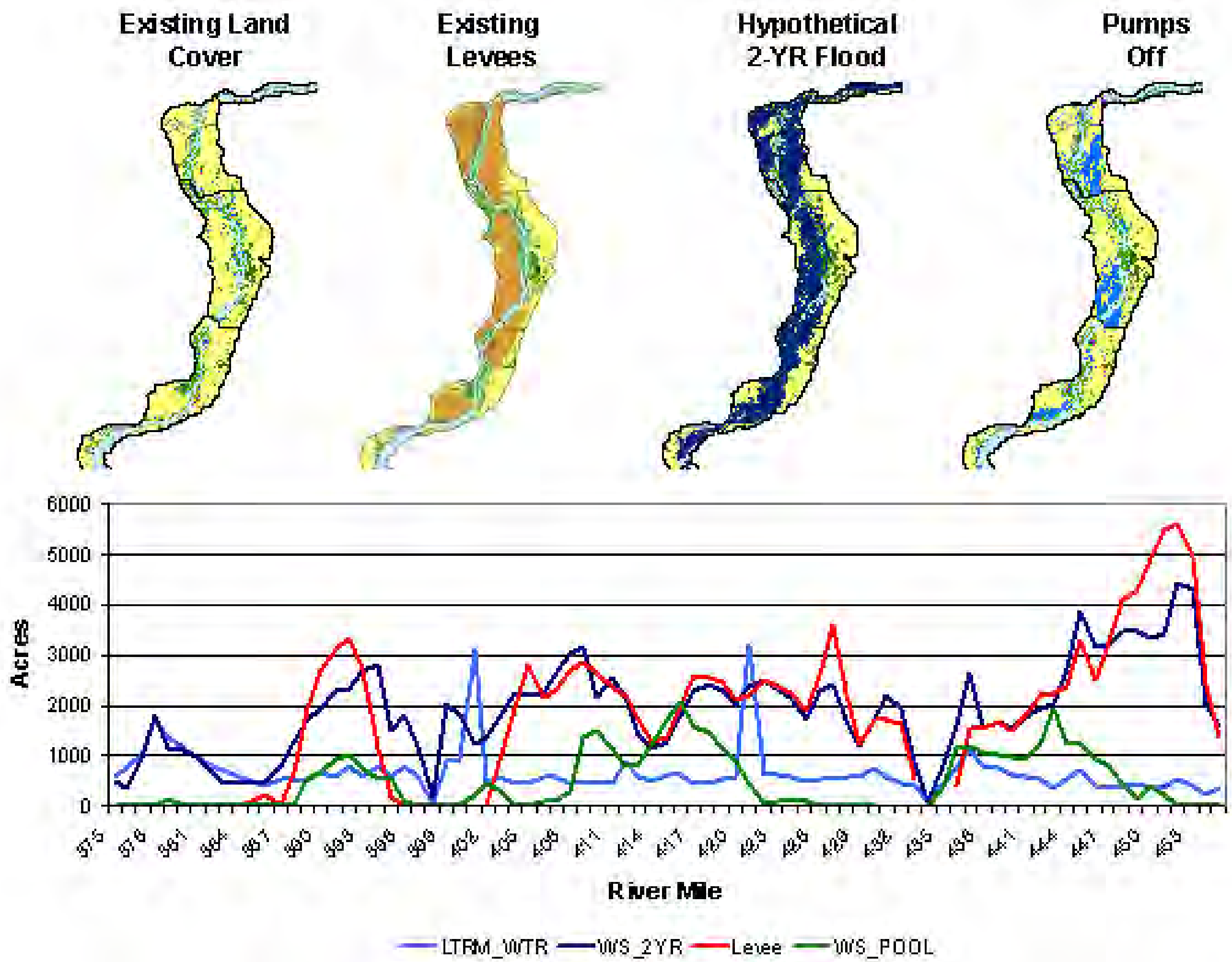


Figure 49. Ecosystem restoration benefits were calculated for the Iowa River Geomorphic Reach by comparing the area inundated by different river stage profiles and area protected by levee and drainage districts. Leveed area and the potential 50 percent recurrence flood area (WS_2YR) track very closely indicating their intent to protect from frequent floods. Low flow river stage (LTRM_WTR) is the existing aquatic area, and the potential new floodplain aquatic area (WS_POOL) is the area under the green line

5.4. RESTORED BACKWATERS

Degraded backwaters and side channels were the most prominent resource concern emerging from the 1982 Master Plan, and the motivation for the EMP HREP. They were expected to be a large proportion of the 200+ projects approved in WRDA 07. Degraded backwaters occur throughout the system, any reach could be mapped and show many individual lakes filling with sediment (Figure 50). There are many basin-wide material transport processes effecting backwater filling and many regional generalizations to be considered, but each lake eventually requires site-specific analysis to determine the hydrologic, active channel transport, and watershed transport processes affecting floodplain lakes.

Quantifying the estimated loss of backwater area or depth as total acres reveals an abundance of backwaters in the UIR and the Lower Illinois River, but fewer in the LIR and MMR. Comparing the proportion of floodplain area as backwaters (Figure 50), a similar pattern is revealed with proportionally more lakes in the UIR. As proportion of total aquatic area, however, the backwater lakes are more evenly distributed in the impounded reaches. Backwater quality is much better in the UIR compared to other reaches. There appears to have been a shift from clear, macrophyte, and Centrarchid dominated lakes to turbid, algal and carp dominated lakes in southern river reaches.

Management to restore emergent wetlands with water level management in backwaters is effective, but expensive and subject to damage in floods. Restoring stage variability in backwaters can also be pursued with minimal infrastructure. Pool scale drawdowns are not predictable because they rely on proper discharge ranges, backwater scale water level management is more predictable. Small-scale drawdowns would close-off narrow openings in backwater lakes with material dredged from within the lake and pump them dry through the summer growing season to simulate summer low flow river stages. Equipment and crews would likely be very cost effective and their annual activity would ensure a management visibility on the river and project outcomes. It is easy to imagine a scenario where several backwaters per reach are managed each year to simulate a variable annual hydrology such that most backwaters are drawndown every decade or so. Lakes with large openings can be partitioned with peninsulas and islands that can be easily closed-off to allow temporary water level management.

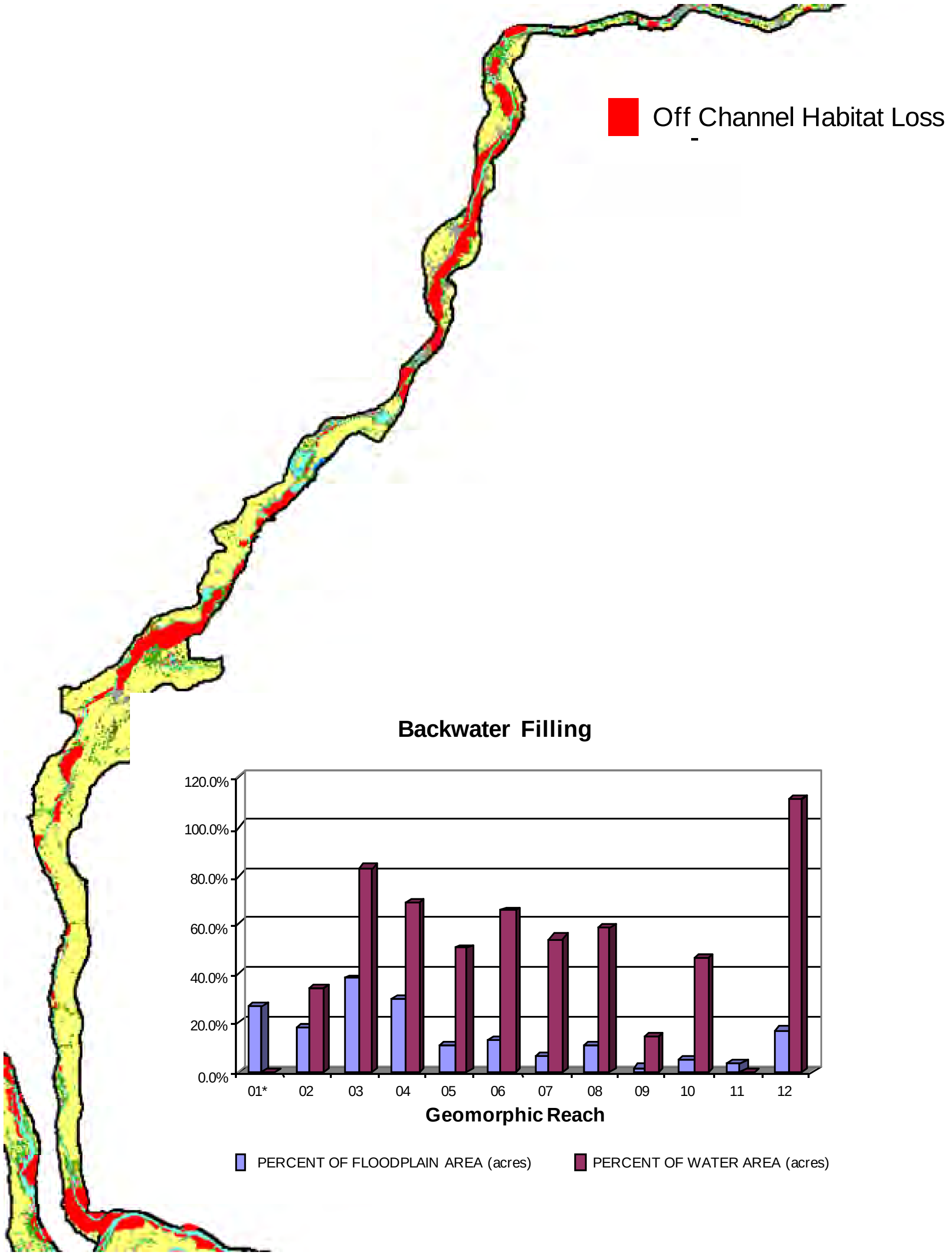


Figure 50. Predicted backwater habitat loss in the Upper Mississippi River System

5.5. RESTORED SECONDARY CHANNELS, ISLANDS, GEOMORPHIC PATTERNS

Secondary channel loss was an important resource concern motivating EMP HREPs because they provide off-channel fish habitat and serve important material transport functions. The scale that individual secondary channels or channel complexes operate is too small to consider at the system scale, but there are very important differences in their characteristics and relative importance among Floodplain Reaches. Secondary channels are critically important off-channel habitat in the MMR and Alton Pool especially, and the LIR and Illinois Reach generally. The LIR and MMR secondary channels are generally large and may be associated with large island-backwater complexes. Secondary and tertiary channels are more common, higher quality, and physically diverse in the UIR where their restoration is usually considered as part of a subarea complex restoration plan. Secondary channel restoration and channel border dike alteration are the most feasible aquatic restoration techniques available in the MMR and Alton Pool unless new floodplain opportunities arise.

Restored geomorphic processes have been investigated with great rigor in the MMR, which is a highly engineered channel. A combination of stakeholder coordination to identify ecosystem restoration sites (Figure 51) coupled with extensive field survey and modeling (Figure 52) have been used to develop comprehensive plans for secondary channel restoration and dike alteration that are available to guide restoration opportunities. Prioritization among sites has been considered within several MMR geomorphic reaches. Advance coordination allows the flexibility to respond to environmental and channel maintenance funding opportunities.

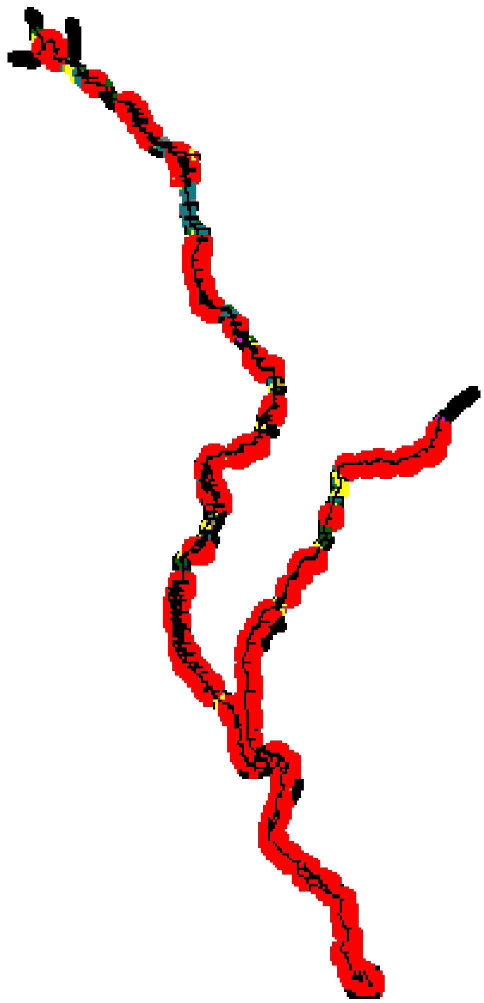


Figure 51. Secondary channel restoration objectives established during the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study

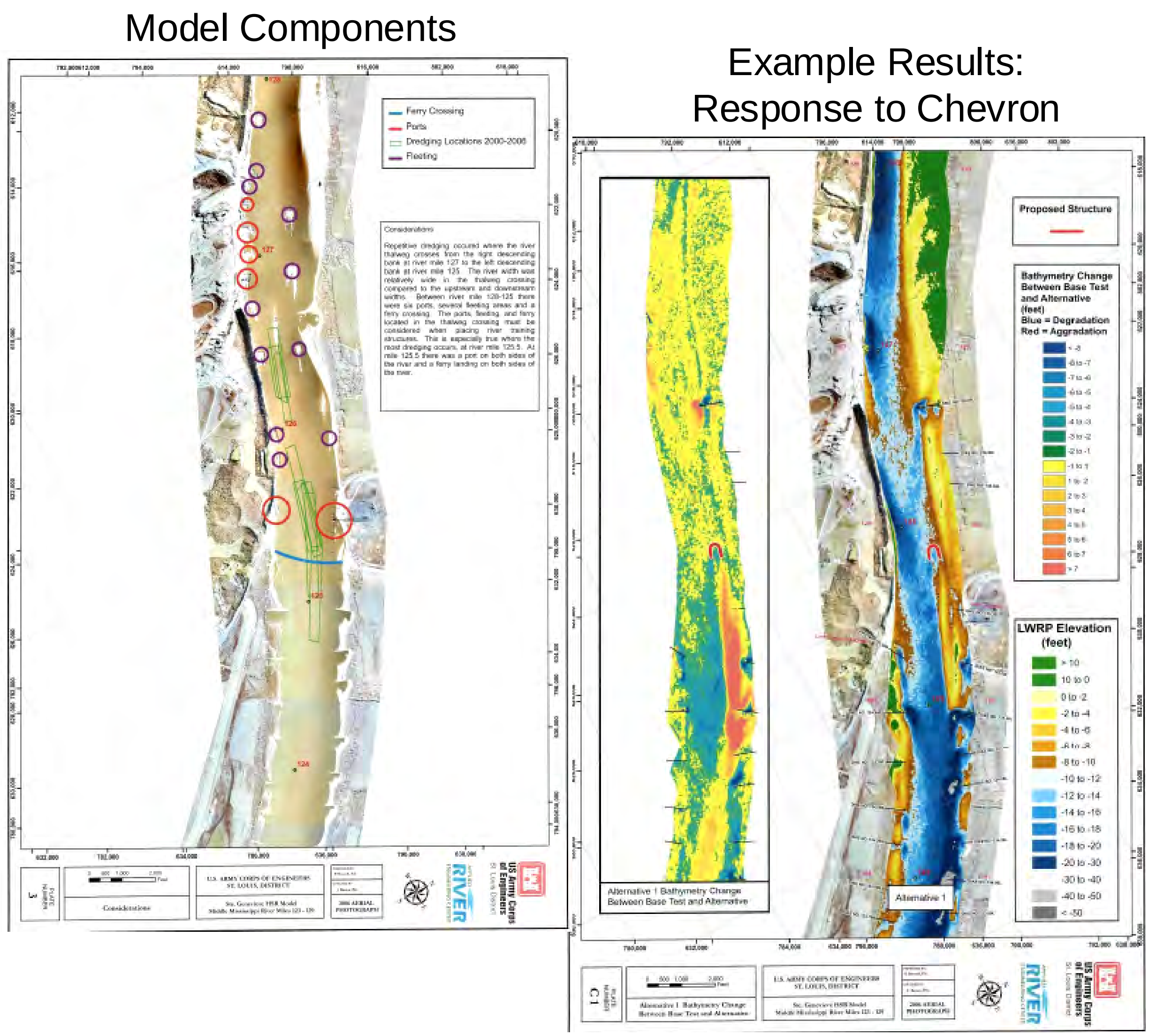


Figure 52. Hydraulic sediment response modeling in the Middle Mississippi River, St. Genevieve Reach (RM 123 to 129) and many other reaches has been used to evaluate navigation and ecosystem restoration alternatives with stakeholders

5.6. NATURALIZED HYDROLOGIC REGIME AND LOWER TRIBUTARY VALLEYS

Tributary influences on the UMRS are important for many ecological, economic, and social reasons, but are beyond the scope of discussion here. The source of the problems are widespread (Figure 53), but the results can be summarized at the mainstem by indicators such as the timing, frequency, magnitude, rate of change, and distribution of water coming from the watersheds. There are many other indicators to help target restoration toward the most degraded watersheds or those whose degradation poses risks to the river downstream. River managers and planners need to be aware of policies and activities in watersheds, but field level activity using river restoration funding needs to be targeted to the lower tributary valleys. The opportunities will be integral components of watershed plans, as proposed n many subareas,

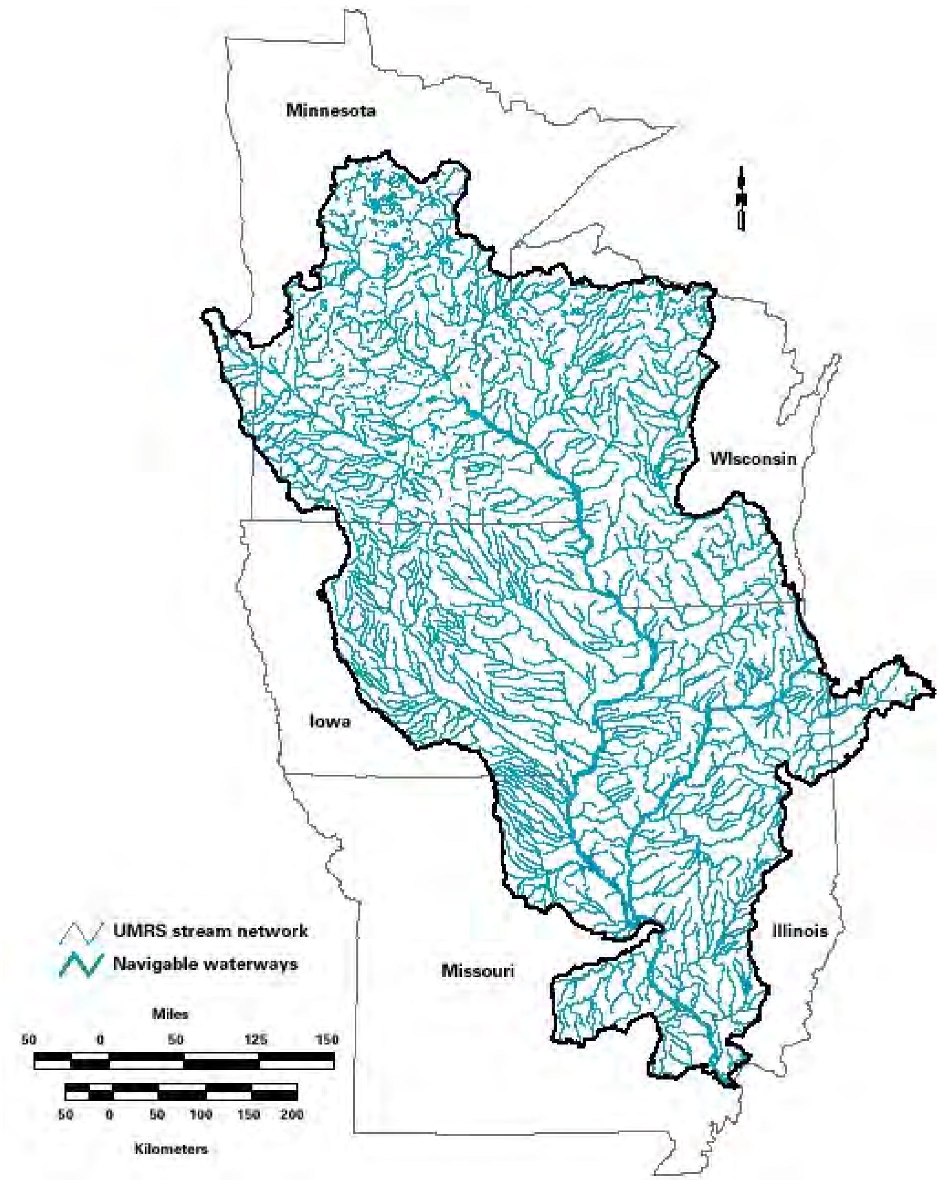


Figure 53. The Upper Mississippi River System watershed is immense; there are more than 30,000 miles of primary streams in the Illinois River watershed alone

Opportunities for restoring tributary confluences are, by nature, site specific investigations, but there are different opportunities to affect hydrology, sediment, and nutrient transport among reaches. Managers in the UIR have sought to increase the diverse habitat provided by natural tributary deltas, so active deltas need to be promoted and protected in some areas. Channelized tributaries with high suspended sediment transport are a more common problem in the South. The hydro-geomorphic influence of the Fabius River is an excellent example of the changes in lower tributaries (Figure 54). The natural topographic diversity of the delta coming off the bluffs created a hydrologic diversity that resulted in high plant biodiversity. Levees now confine tributaries and shunt sediments directly to the river where they accumulate in homogenous flats on the connected floodplain downstream. The effects of tributary channelization are profound because they affect all the important ecological functions at these nodes in the hydraulic network. A GIS buffering exercise highlights L&DDs that are within a 500 foot buffer of a tributary that has likely been channelized as part of the levee project (Figure 55).

Large-scale floodplain restoration projects are extremely complex and require a full cadre of agricultural, engineering, environmental, economic, archeological, and regional planners. Several notable recent examples of farmland conversion on the Illinois River offer good examples for the success that can be achieved and the coordination that is required to make projects get implemented. Large scale floodplain restoration is not going to happen by public acquisition, it is going to happen from the ground up if economic advantage can be realized through emerging renewable energy and recreation markets and incentives for alternative land management. Existing river-floodplain hydro-geomorphic constraints need to be reviewed holistically and integrated with priority watersheds and L&DDs to maximize their success and ecosystem restoration objectives.

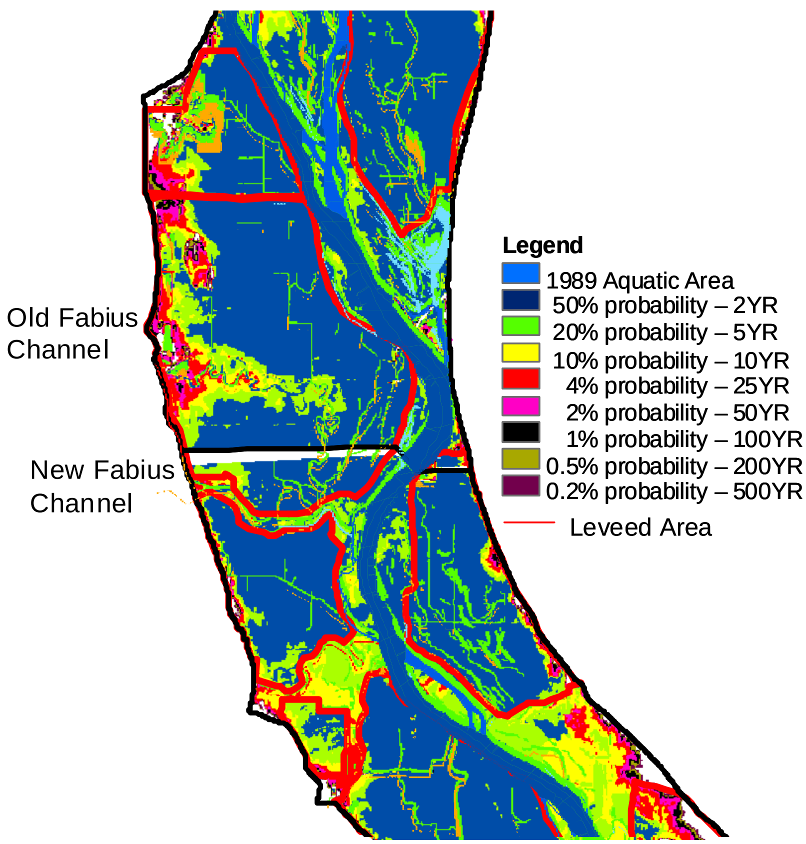


Figure 54. Simulated floodplain inundation profiles at the Fabius River confluence in Missouri across from Quincy, Illinois demonstrates the influence of the topographically diverse river delta before it was channelized between levees. Green and yellow areas downstream of the new channel occur because sediments are concentrated between levees

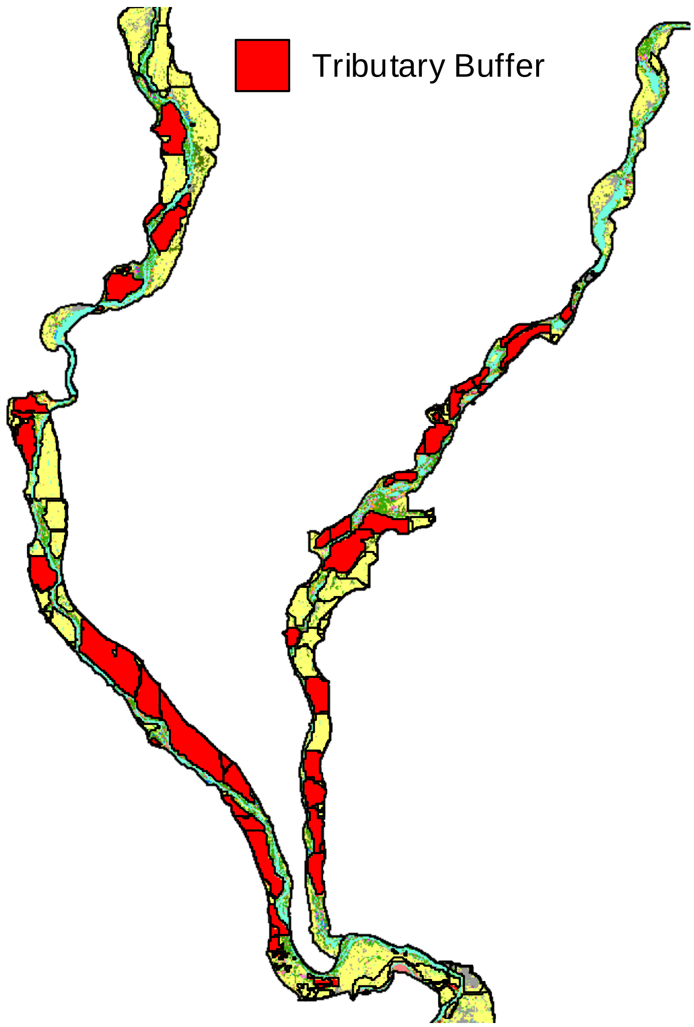


Figure 55. Levee districts adjacent to Upper Mississippi River System levees offer opportunities to naturalize lower tributary valleys

6.0. IDENTIFYING PERFORMANCE CRITERIA AND INDICATORS

6.1. ECOSYSTEM PERFORMANCE CRITERIA

Quantitative performance criteria for each objective will be identified using the UMRS ecosystem conceptual model, ecological literature about the UMRS, and other similar systems; EMP-LTRMP data; water quality criteria; state Total Maximum Daily Loads; lessons learned from EMP HREP projects; the St. Louis District Avoid and Minimize Program; and reach planning work. Performance criteria provide information associated with objectives that can be used to establish linkages between the five EECs (Table 7). For instance, increasing light penetration (a biogeochemistry objective) becomes more relevant when it is linked to biota (e.g., SAV) objectives. This linkage also leads to the development of quantitative values for the performance criteria (e.g., increase June through September average secchi depth to some value so that SAV frequency of occurrence exceeds some value). Performance criteria helps PDTs identify monitoring and modeling needs, and establish indicators for success.

The performance criteria will be SMART - Specific, Measurable, Achievable, Relevant, and Time-bound.

6.2. INDICATORS OF ECOSYSTEM CONDITION

The RST and the River Management Teams will identify a small set of indicators for condition of the river ecosystem appropriate for each geomorphic reach. The indicators will be selected or derived from the performance criteria for the ecosystem objectives. The indicators should be practicable to measure, readily understood, sensitive to change over time and suitable for status and trends reports.

Table 7. Examples of ecosystem restoration performance criteria established by the Upper Impounded Reach Planning Team

Hydraulics & Hydrology: Manage for a more natural hydrologic regime		
Improved water clarity	TSS (mg/L) - To achieve SAV targets, summer average TSS concentrations will need to be reduced about 32% (47 to 32 mg/L) from existing conditions based on the combined monitoring data for Locks and Dams 2 and 3. It is suggested that attainment be based on achieving a median and 90th percentile summer average TSS concentrations of 32 and 44 mg/L, respectively, based on combined bi-weekly monitoring at Locks and Dams 2 and 3. Achieve a Secchi depth based on June through September averages at Locks and Dam 3 and in Lake Pepin of 47 and 80 cm respectively by 2025. **Backwaters:** Achieve a Secchi depth of 80 cm for the June through September averages.	TSS performance criteria are based on the proposed site specific standard for the Lake Pepin Turbidity TMDL developed by Sullivan, et al., 2009. To achieve the above SAV targets, summer average TSS concentrations will need to be reduced about 32% (47 to 32 mg/L) from existing conditions based on the combined monitoring data for Locks and Dams 2 and 3 (Table 3). It is suggested that attainment be based on achieving a median and 90th percentile summer average TSS concentrations of 32 and 44 mg/L, respectively, based on combined bi-weekly monitoring at Locks and Dams 2 and 3. The 90th percentile was derived for main channel summer average data (1998-2007) for Pool 13, a desirable reference pool that was used to derive the SAV targets (Table 3). Achieving these TSS criteria will improve the conditions for SAV growth throughout the turbidity impaired reach and result in reduced sediment infilling of Lake Pepin. Secchi depth performance criteria for Locks and Dam 3 and Lake Pepin are based on Dakota County Soil and Water Conservation District, Mississippi Makeover Project Indicator Targets. See http://www.dakotaswcd.org/wshd_missmak.html) Secchi depth performance criteria for backwaters developed by Upper Impounded Floodplain Reach Planning Team for aquatic vegetation conceptual model (April 09)

<table>
<tr><th colspan="3">Habitat: Manage for a diverse and dynamic pattern of habitats to support native biota</th></tr>
<tr>
<td>Restored aquatic off-channel areas</td>
<td>
Isolated wetlands and floodplain lakes: Maintain or create a spatial distribution and physical characteristics approaching the following criteria
<table>
<tr><td>Parameter</td><td>Bluegills</td><td>Largemouth Bass</td></tr>
<tr><td>Size</td><td>>10 ac</td><td>>10 ac</td></tr>
<tr><td>Depth</td><td>> 4 in 30 to 60% of lake</td><td>> 6' in 40 to 70% of lake</td></tr>
<tr><td>Distribution</td><td>1 to 6 per square mile</td><td>1 to 4 per 2,000 acres of floodplain</td></tr>
<tr><td>Total Area</td><td>> 10% of aquatic area</td><td>> 10% of aquatic area</td></tr>
<tr><td>Quality Areas</td><td>< 2 miles apart</td><td>< 4 miles apart</td></tr>
<tr><td>Habitat Connectivity</td><td>80% of lakes accessible</td><td>80% of lakes accessible</td></tr>
</table>
Hydraulic Connectivity LHC approaches zero for flow less than the 2-year flood. Additional physical requirements based on the needs of lentic fish can be found in the TAB labeled “Lentic Fish” that is part of this excel file.
Backwaters: 1) Restore hydraulic and sediment transport conditions in existing backwaters to desired range of variation and 2) Decrease connectivity between existing deep water (greater than 4 feet deep) areas of backwaters and sediment sources to reduce sediment deposition and delta migration into these areas.
Impounded areas, Lower Pool 2: Restore areas that are permanently inundated to a desired pattern of contiguous backwaters, isolated wetlands, and floodplain lakes.
Vermillion River Bottoms: Restore hydraulic and sediment transport conditions in the Vermillion River Bottoms to desired range of variation
Achieve wind fetch criteria based on water depth in aquatic off-channel areas.
<table>
<tr><td>Water Depth (ft)</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Fetch (ft)</td><td>1500</td><td>3500</td><td>6000</td><td>9000</td></tr>
</table>
</td>
<td>
Isolated wetland and floodplain lake performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).
Wind fetch criteria was developed by the NESP Pool 5 Ecosystem Restoration Team (May 06)
</td>
</tr>
</table>

7.0. ADAPTIVE ECOSYSTEM MANAGEMENT

Adaptive ecosystem management (AEM) is a decision process that promotes flexible decision making and implementation that can be adapted as outcomes from management actions become better understood. Careful monitoring of outcomes advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.

Adaptive management aims to enhance scientific knowledge and to reduce uncertainty. Uncertainty arises from natural variability of ecosystems and the interpretation of data as well as social and economic events that affect ecosystems. A key component in adaptive management is the establishment of a feedback mechanism wherein characterization of current conditions (monitoring) can be used in conjunction with an understanding (model) of the system to alter management actions, if necessary, to produce future system conditions compatible with the desired state. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits.

7.1. PASSIVE VS. ACTIVE ADAPTIVE MANAGEMENT

Passive adaptive management uses current understanding and management of the system of interest to evaluate ecosystem condition and make changes if needed. Passive adaptive management addresses variability and uncertainty by using historical and existing information to model cause-and-effect relationships between the management action and the anticipated system response to alternative management actions. Actual system response, determined by project monitoring, is used to adjust (adapt) the management actions to more effectively achieve goals and objectives. The results of systemic monitoring like the Long Term Resource Monitoring Program can also be used to increase understanding of the system. UMRS management and restoration has historically applied passive AEM.

Passive adaptive management includes learning to manage effectively by monitoring system conditions, undertaking management actions in light of current understanding, and assessing the effectiveness of the management actions in relation to achieving outcomes consistent with management goals and objectives. The primary limitation of this approach lies in developing management capabilities that are effective only within the range of conditions measured during the program or project. The passive approach might provide effective management over a historic range of system conditions, yet preclude the development of management skills necessary to correctly respond to highly unusual or future circumstances that were not encountered during the project period.

In contrast, active adaptive management views management actions as purposeful and scientific experimental manipulations of the managed system to increase understanding of system responses to manipulation in the short term and as a result, increase the chances of achieving management goals and objectives in the long term. Active adaptive management addresses uncertain outcomes by designing management actions (i.e., field tests, physical models) to test multiple hypotheses about concerning system responses to management.

Active AEM requires a more scientifically rigorous experimental design in order to discriminate cause-and-effect relationships among the management actions and ecosystem drivers. Active adaptive management is often referred to as “experimental management” because it views management actions as opportunities to learn. Active adaptive management is used less often, but it offers greater potential for rapid learning and acquisition of new management skills than does passive adaptive management. Active adaptive management encompasses an integrated process of modeling, monitoring, and assessment to compare the outcomes of multiple management alternatives (i.e., testing hypotheses of ecosystem response to restoration and management actions).

7.2. INTERAGENCY COMMITMENT TO AEM OF THE UMRS ECOSYSTEM

The Upper Mississippi River – Illinois Waterway Navigation Study Final Feasibility Report and Programmatic EIS (U.S. Army Corps of Engineers 2004) recommended a commitment to AEM. " Making decisions to address and resolve the complex assortment of ecological needs and objectives within the UMRS should be conducted in the context of a long-term commitment to a policy of adaptive management. "

The concepts and methods of adaptive management will play an increasingly important role in the planning and implementation of USACE projects. The widespread reference to adaptive management in recent USACE authorities and policy guidance underscores the need for a formal commitment to adaptive management across USACE missions, programs, and projects on the Upper Mississippi River System (UMRS).

The U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the U.S. Geological Survey and stakeholders represented by the Navigation and Ecosystem Coordinating Committee, the Environmental Management Program Coordinating Committee and the Upper Mississippi River Basin Association are committed to active AEM in future management and restoration of the UMRS ecosystem.

7.3. USACE AUTHORITIES FOR AEM ON THE UMRS

7.3.1. WATER RESOURCES DEVELOPMENT ACT 1986

In 1986 Congress recognized the UMRS as a nationally-significant transportation system and a nationally significant river ecosystem. The UMRS-Environmental Management Program (EMP) was authorized by the Water Resources Development Act (WRDA) of 1986, amended by WRDA 1990 and WRDA 1992. Section 509, WRDA 1999, reauthorized and amended the program to extend it without a termination date and required a report to Congress every 6 years. To implement the program, a partnership has been formed among the Corps of Engineers; U.S. Fish and Wildlife Service; U.S. Geological Survey; and the States of Minnesota, Iowa, Wisconsin, Missouri, and Illinois. The program emphasizes habitat rehabilitation and enhancement projects and long-term resource monitoring.

7.3.2. WRDA 2007

Congress authorized the Navigation and Ecosystem Sustainability Program (NESP) in the Water Resources Development Act of 2007 (WRDA 2007). The ecosystem restoration and management component of the program is an ambitious 50-year effort based on recommendations from the Upper Mississippi River – Illinois Waterway Navigation Study (USACE 2004). Language includes directives about sustainability and selecting projects that restore natural river processes. Excerpts from the USACE Headquarters WRDA 2007 implementation guidance emphasize adaptive management:

> "g. Monitoring and Adaptive Management. The authorized ecosystem restoration plan includes systemic and project specific monitoring and adaptive management at a total cost of about $300 million. The systemic program will include ecosystem modeling, biological data and physical data collection and adaptation of the plan in response to the results of systemic evaluation. On an individual project level monitoring will assess the project's success in meeting goals and performance measures. The results will be used to adapt the project or future projects to the lessons learned. The construction phase of a project extends through the project-specific monitoring and adaptive management. For cost shared projects, project monitoring and adaptive management are shared as a project cost. The one percent limit on monitoring costs and five year limit on duration of monitoring, the prohibition on adaptive management applicable to CAP projects, and the three percent limit on adaptive management costs do not apply, but monitoring and adaptive management must be accomplished within the framework and cost authorized for those purposes as reflected in the feasibility report. In accordance with Section 8004 (c) of WRDA 2007, long term resource monitoring, computerized data inventory and analysis and the applied research program will be carried out at 100% Federal cost and shall consider and adopt the monitoring program established for the Environmental Management Program. The Long Term resource Monitoring Program authorization is limited to $10,420,000 per fiscal year if such sum is not appropriated for the EMP Program. The long term resource monitoring is only one part of the authorized systemic monitoring and adaptive management program.

7.4. LEARNING OBJECTIVES FOR UMRS ECOSYSTEM MANAGEMENT

7.4.1. IMPROVING MANAGEMENT ACTIONS THROUGH LEARNING

Management actions on the UMRS range from low cost, frequent actions like daily dam gate operations to high cost large-scale restoration projects. EMP partners conducted several large biological response studies of the effects of Habitat Rehabilitation and Enhancement Projects (HREPs) in Browns Lake, Swan Lake, Finger Lakes, and Lake Onalaska and more recently in Pools 11 and 12. There have also been small scale bio-response monitoring efforts at many projects and all are evaluated for their physical performance. The EMP partnership examined the design considerations and field response for a number of different HREP project types in the Environmental Design Handbook which is maintained as a "living" document that is continually updated.

Some types of restoration actions are well understood and have been proven ecologically and cost-effective. Others are less well-understood or novel and will need to be more fully evaluated through AEM. The Science Panel noted that the physical process responses to many management actions are fairly well-understood while the biological process responses remain more uncertain. They recommended that some restoration and management actions be selected specifically to learn through careful experimental design, monitoring, and evaluation.

7.4.2. INCORPORATING LEARNING INTO ECOSYSTEM MANAGEMENT

A systematic AEM process links ecosystem objectives, performance criteria, the UMRS Conceptual Ecosystem Model, monitoring condition of the river ecosystem, and hypothesis testing about restoration actions. This can best be documented using the UMRS Conceptual Ecosystem Model with narrative discussion and supporting literature citations describing the various ecosystem structures, processes, stressors and drivers. The conceptual model can become part of an online Decision Support System, a good example is the San Joaquin River Dissolved Oxygen Total Maximum Daily Load Conceptual Model, available on the Internet at: http://www.sjrdotmdl.org/concept_model/bio-effects_model/effects_home.htm

Information is needed to support learning about biological response to ecosystem management and restoration for three primary purposes: 1) to assess and report on ecosystem status with respect to the objectives, 2) evaluating the effectiveness of management and restoration actions in achieving the objectives, and 3) gaining increased understanding of ecosystem structures and processes to inform planning and design of management and restoration activities. All these AEM activities contribute to increased understanding of the river ecosystem, increasing potential for attaining ecosystem objectives, increasing efficiency of investments in river restoration and management, and opening the river management community to learning when inevitable unexpected events occur. AEM activities will not reduce uncertainties, but will enable better decision-making with greater awareness of uncertainties inherent in the UMRS social-ecological system.

7.4.3. LEARNING OBJECTIVES

Some discussion about what is known about the various floodplain reach and system-scale ecosystem objectives is provided in Sections 4 and 5 above. The reach planning teams did not set learning objectives concurrently with the ecosystem objectives in this initial reach planning process. Learning objectives and associated applied research efforts should be developed in a deliberative process, considering the objectives and information needs. An information needs assessment should be conducted, considering available information and current understandings of UMRS ecosystem structure and processes as they pertain to the ecosystem objectives. Areas where our spatial survey data and understandings of ecosystem structures and processes are limited will be emphasized for attention through AEM. The applied research descriptions will include the hypotheses for testing and the recommended approach. Some applied research activities may be implemented in conjunction with individual project planning and implementation. Others may be implemented at larger geographic scales and over longer time than can be accommodated by an individual project.

7.5. PROJECT-SCALE CONSIDERATIONS

Project teams should set ecosystem objectives appropriate for the project areas and that would contribute to attaining the reach and system objectives. The project objectives and associated performance criteria should be used to design project monitoring plans. Project PDTs or contractors will prepare project completion reports. PDT members, interested agencies and members of the public will be interviewed about the project. The project completion reports will be posted to the UMRS DSS.

7.6. UMRS DECISION SUPPORT SYSTEM

The Science Panel recommend that a decision support system (DSS) be developed using the ecosystem objectives and a family of ecosystem models to assist project planning, design, monitoring, evaluation, and reporting on progress and on condition of the river ecosystem. The DSS is a geographic information system (GIS) database to enable visualization and analysis of the spatial arrangement of ecosystem conditions, projects and management measures. The GIS-based DSS could enable spatially explicit application of ecosystem models (or their compiled results) in project planning.

The DSS could incorporate incremental analysis techniques to identify the best value sequence of management measures to apply within project areas to attain objectives for condition of the ecosystem and to increase ecosystem services. The DSS could incorporate the UMRS Conceptual Ecological Model including narrative description of relationships between ecosystem structural components and processes with literature citations documenting the current level of scientific understandings. The DSS is available to project teams, resource managers, and decision-makers via the Internet. The UMRS Internet site would include information about the program, ongoing projects, a synthesis of ecosystem modeling results, instructions for use of the DSS, and the Ecosystem Restoration and Management Plan. The Internet site would be designed to enable tracking implementation of management and restoration measures and system response as revealed by monitoring. We recommend that an integrated UMRS AEM Internet site be developed with direct links to the UMRS DSS and the LTRMP web site. An example is the web site for the Chesapeake Bay Restoration Program: http://www.chesapeakebay.net/bayrestoration.aspx?menuitem=13989.

8.0. FLOODPLAIN REACH ECOSYSTEM RESTORATION OBJECTIVES AND HIGH PRIORITY SUBAREAS

River Management Teams considered the unique characteristics, stressors, and existing and future predicted condition of the ecosystem to establish ecosystem restoration objectives. They also identified important subareas where ecosystem objectives can be managed for. The teams reviewed many subareas and had to cull many from their lists to achieve a first increment plan. The objectives, the spatial distribution of stressors, and high priority subareas are all presented in t Appendix A, *Upper Impounded Reach Plan*; Appendix B, *Lower Impounded Reach Plan*; Appendix C, *Unimpounded (*also known as Middle Mississippi*) Reach Plan*; and Appendix D, *Illinois River Reach Plan.*

This UMRS Ecosystem Restoration Reach Plan will be maintained as a living document that will be revisited on four-year planning cycles established in WRDA 2007.