Cover Sheet

Project Title: Mississippi River Between the Ohio and Missouri Rivers (Regulating Works)

Proposed Action: The St. Louis District of the U.S. Army Corps of Engineers proposes to continue construction, operation, and maintenance of the 9-foot navigation channel on the Middle Mississippi River.

Location: Missouri and Illinois

Type of Statement: Draft Supplemental Environmental Impact Statement

Lead Agency: U.S. Army Corps of Engineers

For further Information:

Kip Runyon
U.S. Army Corps of Engineers – St. Louis District
1222 Spruce St.
St. Louis, MO 63103-2833
(314)331-8396
RegWorksSEIS@usace.army.mil

Date by which comments must be received: December 19, 2016

Abstract: The St. Louis District of the U.S. Army Corps of Engineers (Corps) is charged with obtaining and maintaining a navigation channel on the Middle Mississippi River (MMR) that is nine feet deep and 300 feet wide with additional width in bends as necessary (commonly called the Regulating Works Project). As authorized by Congress, the Project is obtained by construction of revetment, rock removal, and river training structures to maintain bank stability and ensure adequate, reliable navigation depth and width. The Regulating Works Project is maintained through dredging and any needed maintenance to constructed features. The long-term goal of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of river training structures. This document is intended to provide an update to the Project's 1976 Environmental Impact Statement by analyzing the impacts of the Project in the context of new circumstances and information that currently exist. Based on the Project's Congressional authority and continued benefit of the remaining construction, the Preferred Alternative is to continue with new construction of the Project with the future potential addition of compensatory mitigation for unavoidable adverse effects to main channel border habitat, if deemed necessary on a site-by-site basis.

REGULATING WORKS PROJECT

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

November 2016

US Army Corps
of Engineers
St. Louis District

U.S. Army Corps of Engineers
St. Louis District
1222 Spruce St.
St. Louis, MO 63103-2833

Executive Summary

Purpose and Need. The St. Louis District (District) of the U.S. Army Corps of Engineers (Corps) is charged with operating and maintaining a navigation channel on the Middle Mississippi River (MMR) that is nine feet deep, 300 feet wide with additional width in bends as necessary. The MMR is defined as that portion of the Mississippi River that lies between its confluence with the Ohio and the Missouri Rivers (Figure ES-1). This ongoing Project is also commonly referred to as the Regulating Works Project. As authorized by Congress, the Regulating Works Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetment and river training structures, while sediment management is achieved by river training structures. The Regulating Works Project is maintained through dredging and any needed maintenance to already constructed features. The long-term goal of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually identifies and monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable. The District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

The environmental impacts of the Regulating Works Project were originally documented in the 1976 Environmental Impact Statement (1976 EIS) *Mississippi River between the Ohio and Missouri Rivers (Regulating Works)*, (USACE 1976). The 1976 EIS was recently reviewed by the District and by the Corps' Planning Center of Expertise for Inland Navigation (PCXIN) to determine whether or not the document should be supplemented. The District and the PCXIN concluded that, although the Project had not changed substantially, there were significant new circumstances and information relevant to the Regulating Works Project and its potential impacts that warranted consideration of a supplement. The significant new circumstances and information on the potential impacts of the Regulating Works Project include the following:

- New federally threatened and endangered species have been listed since preparation of the 1976 EIS.
- The District has implemented new programs to restore fish and wildlife habitat on the MMR.
- New information exists on the changes in average river planform width in response to river training structure placement.
- New information exists on the impacts of river training structures on water surface elevations.
- New information exists on the impacts of river training structures and dredging on fish and macroinvertebrates.
- New information exists on the effects of navigation on fish and wildlife resources.
- New information exists on the status of MMR side channels.

Therefore, the purpose of this Supplemental EIS (SEIS) is to provide an update to the 1976 EIS by analyzing the impacts of the Regulating Works Project in the context of the new circumstances and information that currently exist.

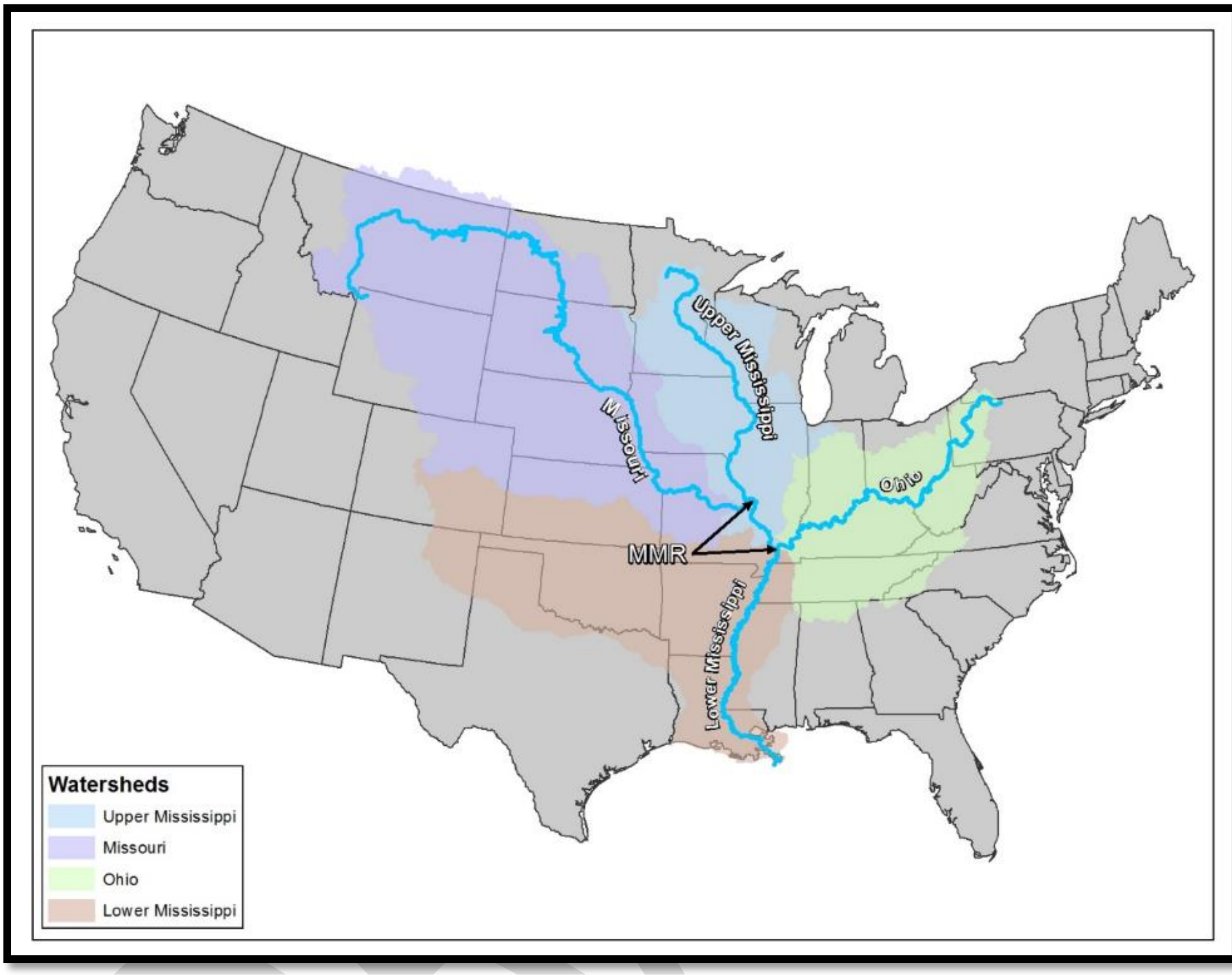


Figure ES-1. Location of the MMR within the Upper Mississippi River watershed.

Alternatives. Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS.

Accordingly, this document examines the impacts of two Alternatives:

The **Continue Construction Alternative (No Action) –** This Alternative would involve continuing with construction of new river training structures or revetment for navigation purposes until such time as the cost of placing more structures is no longer justified by the resultant reduction in repetitive dredging quantities and associated costs. This is currently estimated to require approximately 4.4 million tons (2.9 million cubic yards) of rock. This estimate is based on assumptions of Congressional funding levels, rock prices, dredging costs, sediment loads, etc. and therefore could differ from actual implementation. Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. Placement of river training structures is expected to increase the acreage of low-velocity habitat that is considered important habitat for many MMR fish species. However, placement of river training structures is also expected to reduce shallow to moderate-depth, moderate- to high-velocity habitat which is important for some MMR fish guilds that have seen declines in abundance since the mid-1900s. Analysis of the impacts of the Continue Construction Alternative to main channel border habitat suggests that future construction of river training structures will potentially result in the need for compensatory mitigation measures.

The Continue Construction Alternative would also involve continuing to dredge as necessary, completing known bankline stabilization projects to reduce the risk of a channel cutoff, placing additional revetment, and continuing to maintain existing structures. Dredge quantities would be expected to decrease from their current average annual quantity of approximately 4 million cubic yards to approximately 2.4 million cubic yards after construction of new river training structures is complete.

In keeping with Council on Environmental Quality (CEQ) guidance, this Alternative is considered the No Action Alternative as it represents no change from the current implementation of the Project. Although this Alternative includes the potential need for compensatory mitigation measures, this fact does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained. Therefore, the Continue Construction Alternative is still considered to be the No Action Alternative.

The **No New Construction Alternative –** This Alternative would involve not constructing any new river training structures for navigation purposes, but continuing to maintain the navigation channel only by dredging and maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Under this alternative, maintenance dredging would continue at roughly the current average rate of approximately 4 million cubic yards per year.

Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. It is not anticipated that this alternative would have any unavoidable significant impacts that would result in the need for compensatory mitigation.

The following table provides a brief summary comparison of the impacts of the No New Construction Alternative and the Continue Construction Alternative.

Summary of Environmental Consequences.

Resource Category	No New Construction Alternative	Continue Construction Alternative
Fishery Resources	• Minor effects to adult/juvenile/larval fish from dredge entrainment • Continued creation of islands/sandbars with flexible dredge pipe	• Conversion of estimated 8% (1,100 acres) of remaining unstructured main channel border habitat to structured habitat, potentially necessitating compensatory mitigation* • Minor effects to adult/juvenile/larval fish from dredge entrainment • General increase in fish use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity • Continued creation of islands/sandbars with flexible dredge pipe
Stages	• No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue	• No impacts on stages anticipated at average and high flows • At low flows, river training structure construction would contribute an unknown amount to continuing trend of small reductions in stages
Geomorphology	• No impacts to geomorphology anticipated	• Cross sectional area, hydraulic depth, conveyance, and channel volume will remain constant or generally increase.
Side Channels	• No impacts to side channels anticipated • District side channel restoration projects would continue	• River training structure construction would contribute an unknown amount to small reductions in stage at low flows that would have minor adverse effects on side channel habitat by reducing quantity and connectivity of habitat • District side channel restoration projects would continue
Water Quality	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites and at river training structure construction sites
HTRW	• No HTRW impacts anticipated	• No HTRW impacts anticipated
Air Quality and Climate Change	• Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions expected to remain at approximately 27,950 tons per year from dredging and maintenance activities	• Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions reduced by approximately 40% (to 16,970 tons per year) after completion of construction of new river training structures due to reduced dredging requirement
Benthic Macro-invertebrates	• Dredging impacts limited to approximately 2% of riverine habitat on average, per year, indefinitely	• Increased benthic macroinvertebrate use of river training structure placement locations due to increased bathymetric, flow, and substrate diversity • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, decreasing to 1% with construction of new river training structures

Resource Category	No New Construction Alternative	Continue Construction Alternative
Threatened and Endangered Species	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • *No effect* or *may affect but not likely to adversely affect* for species listed since 2000	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • *No effect* or *may affect but not likely to adversely affect* for species listed since 2000
Human Resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources
Navigation	• Continued requirement for periodic maintenance dredging at an annual average rate of approximately 4 million cubic yards indefinitely • Higher risk of channel closures due to the sole use of just-in-time dredging to keep the navigation channel open once chronic dredging locations impact the channel	• Reduction in the amount and frequency of periodic maintenance dredging from 4 million cubic yards to 2.4 million cubic yards • Reduction in barge grounding rates • Increased channel reliability and decreased risk of channel closures due to decreased frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages.
Historic and Cultural Resources	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely

*The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation needs will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

Implementation of the Project. One of the recurring challenges with characterizing the impacts of the Regulating Works Project on the human environment is the fact that the timing, location, and configuration of future construction sites are currently unknown. This uncertainty is due to the dynamic nature of the flows and sedimentation patterns of the MMR and the fact that chronic dredging sites are addressed, by necessity, on an ongoing, as-needed basis. Accordingly, this SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward. The specific impacts associated with each future river training structure construction area would be covered in Tier II site specific Environmental Assessments (SSEAs). SSEAs would also detail any compensatory mitigation planning and associated adaptive management and monitoring that is required based on the impact assessments in the SSEAs.

Compensatory Mitigation. Although construction of river training structures does benefit some MMR fish species by providing low-velocity habitats, this does not offset or compensate for the anticipated adverse effects to shallow to moderate-depth, moderate- to high-velocity habitat. The adverse effects impact a different habitat type with a different function for a different group of fish than do the benefits. Due to these potential unavoidable adverse effects to main channel border habitat associated with future construction of river training structures, the District anticipates that these impacts will result in the need for compensatory mitigation. Potential mitigation measures may include, but are not limited to, the following: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. Compensatory mitigation planning would be accomplished with the aid of a main channel border habitat model that is currently under development by the Corps.

Areas of Controversy

Flood Heights. There is research claiming that the construction of river training structures affects flood heights. The Corps takes these claims very seriously, so the Corps conducted several studies on the issue, completed a thorough analysis of all available research (included in this SEIS as Appendix A), and concluded that river training structures do not affect water surface elevations at higher flows.

Mitigation. Federal and state natural resource agency partners have maintained the position that the Corps should mitigate for adverse effects going back to at least 1976. In general, the Corps only plans for and implements mitigation associated with proposed future actions because of budgetary constraints. Therefore, compensatory mitigation for the Regulating Works Project would only be conducted for adverse effects that have occurred or will occur since publication of the Notice of Intent to prepare this SEIS in the Federal Register in December 2013. However, the Corps' standing ecosystem restoration mission and associated authorities, outside of the Regulating Works authority, could be used to restore ecological resources from past activities of the Corps and others.

1976 Post Authorization Change Alternative. Federal and state natural resource agency partners have continued to ask that the Corps seek the Post Authorization Change (PAC) referenced in the 1976 EIS to add fish and wildlife as a Project purpose. The District fulfilled the commitments made in the 1976 EIS; however, this purpose was never added to the Project by Congress. Additionally, all of the activities described in the 1976 EIS for the PAC can now be accomplished through other authorities. See supplement to Appendix F for details.

Geographic Scope of Analysis. The District received scoping comments indicating that the SEIS should address all of the navigation channel operation and maintenance activities in the Upper Mississippi River – Illinois Waterway System (UMR-IWW) instead of focusing only on the MMR. Recognizing the dynamic nature of the river in certain regions, Congress authorized many different navigation projects throughout the UMR-IWW. The Congressional authority for and management of the navigation channel on the MMR is very different from other projects within the UMR-IWW, primarily because the MMR is open river and the rest of the UMR-IWW consists of a series of pools created and managed through locks and dams. As such, the District concluded that a separate analysis for the MMR is appropriate.

Preferred Alternative. Based on the Project's Congressional authority and continued benefit of the remaining construction, the Continue Construction Alternative with the described potential need for compensatory mitigation is the Preferred Alternative. With implementation of the Continue Construction Alternative, the District anticipates constructing future river training structures that equate to approximately 4.4 million tons of rock, which will reduce dredging to approximately 2.4 million cubic yards on an average annual basis. This reduction in dredging will result in a more reliable channel. The economic viability of the Regulating Works Project will continue to be evaluated as part of the Corps budget process and therefore the actual remaining quantity of construction may vary due to changes in rock prices, dredging costs, mitigation costs, etc.

Table of Contents

Acronyms and Abbreviations

AEP	Annual Exceedance Probability
APE	Area of Potential Effect
AQCR	Air Quality Control Region
ASTM	American Society for Testing and Materials
ATR	Agency Technical Review
BGEPA	Bald and Golden Eagle Protection Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CH_4	Methane
CO_2 Eq	Carbon Dioxide Equivalent
CPUE	Catch per Unit Effort
dB	Decibels
DOE	Determination of Eligibility
DQC	District Quality Control
EA	Environmental Assessment
EC	Engineering Circular
ECP	Environmental Condition of Property
EIS	Environmental Impact Statement
EO	Executive Order
ERDC	Engineering Research and Development Center
ESA	Environmental Site Assessment
et al.	And Others
ft	Feet
GHG	Greenhouse Gases
hp	Horsepower
HSR	Hydraulic Sediment Response
HTRW	Hazardous, Toxic, and Radioactive Waste
IDPH	Illinois Department of Public Health
IEPA	Illinois Environmental Protection Agency
IWW	Illinois Waterway
kPa	Kilopascals
LDB	Left Descending Bank
LMR	Lower Mississippi River
LTRM	Long Term Resource Monitoring
LWRP	Low Water Reference Plane

m/s	Meters per Second
m^2	Square Meters
MDHSS	Missouri Department of Health and Senior Services
MDNR	Missouri Department of Natural Resources
mg/L	Milligrams per Liter
MMR	Middle Mississippi River
MRC	Mississippi River Commission
MSD	Metropolitan Sewer District
MVD	Mississippi Valley Division
N/A	Not Applicable
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
NESP	Navigation and Ecosystem Sustainability Program
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxides
NRHP	National Register of Historic Places
NTU	Nephelometric Turbidity Units
O&M	Operations and Maintenance
PAC	Post Authorization Change
PCB	Polychlorinated Biphenyl
PCXIN	Planning Center of Expertise for Inland Navigation
PM	Particulate Matter
RDB	Right Descending Bank
REC	Recognized Environmental Condition
RIAC	River Industry Action Committee
RIETF	River Industry Executive Task Force
RM	River Mile
RMO	Review Management Organization
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RRAT	River Resources Action Team
RTS	River Training Structures
SEIS	Supplemental Environmental Impact Statement
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SO_2	Sulfur Dioxide
SPL	Sound Pressure Level
SSEA	Site-Specific Environmental Assessment

STL	Saint Louis
TOCs	Total Organic Compounds
UMR	Upper Mississippi River
UMR-IWW	Upper Mississippi River – Illinois Waterway
UMRS	Upper Mississippi River System
USACE	U.S. Army Corps of Engineers
USC	United States Code
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOCs	Volatile Organic Compounds
yd^3	Cubic Yards
YOY	Young-of-the-Year
µg/L	Micrograms per Liter
µPa	Micropascals

Chapter 1. Purpose of and Need for Action

1.1 Purpose of and Need for the Regulating Works Project

1.1.1 History, Authority, and Purpose of the Regulating Works Project

Beginning in 1824, the Congress of the United States authorized the Secretary of the Army, by and through the U.S. Army Corps of Engineers (Corps), to make improvements to the Mississippi River, and some of its major tributaries, for the purpose of obtaining and maintaining an inland navigation channel for waterway commercial transportation throughout the United States. Ultimately for the Mississippi River, Congress authorized obtaining and maintaining at least a nine foot deep navigation channel from the Gulf of Mexico to Minneapolis, Minnesota, through multiple projects by various methods and management. Early on in the Chief of Engineers' reports and Congress' authorizations, it was evident that there were distinct areas of the Mississippi River that would require different management techniques, and thus, different projects, in order to provide a suitable navigation channel. These differences resulted in three distinct segments of the river governed by the influx of major tributaries: the Lower Mississippi (from the Gulf of Mexico to the confluence of the Ohio River (LMR)); the Middle Mississippi (from the confluence of the Ohio River to the confluence of the Missouri River (MMR)); and the Upper Mississippi (from the confluence of the Missouri River to Minneapolis, Minnesota (UMR)) (Figure 1-1).

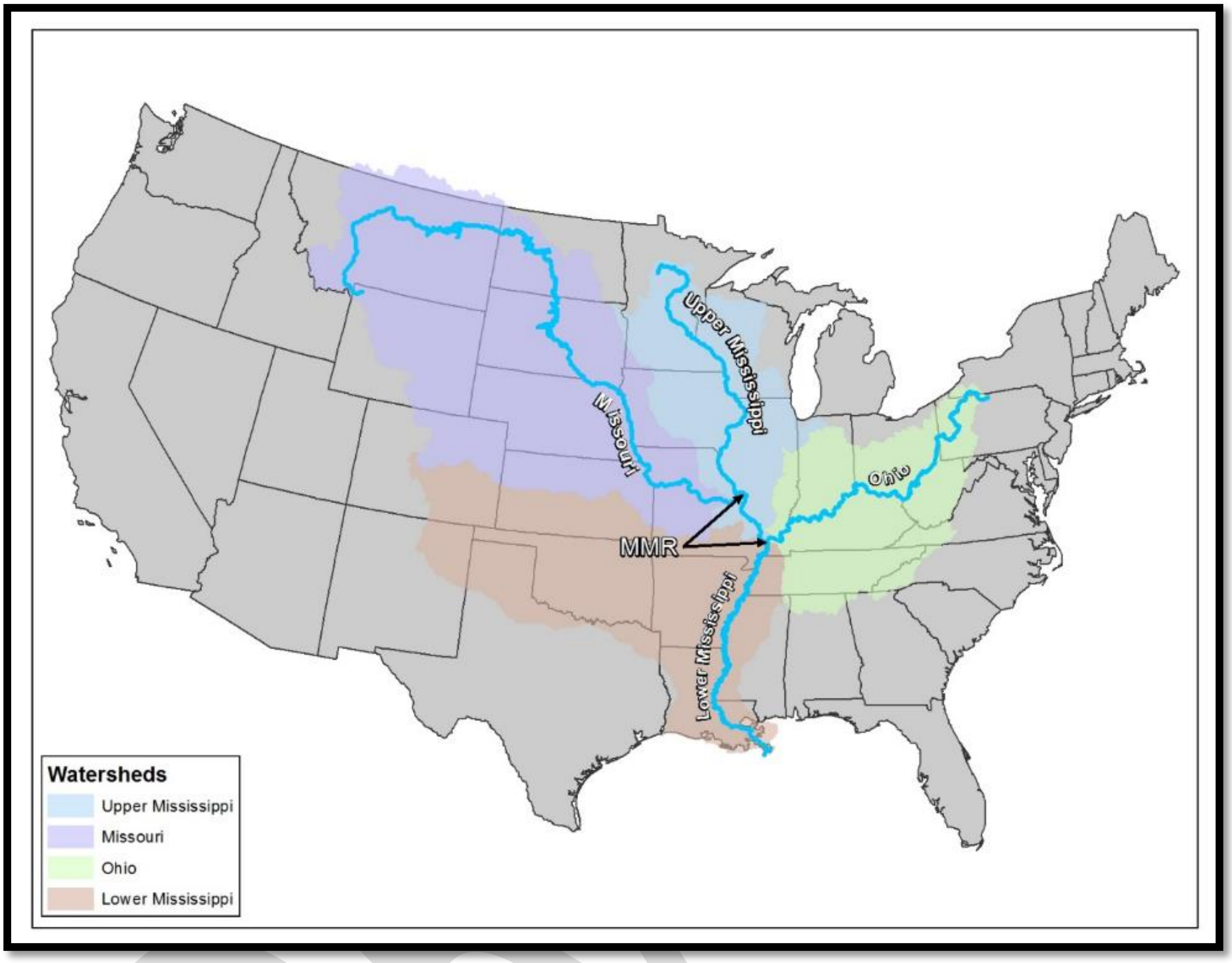


Figure 1-1. Location of the MMR within the Upper Mississippi River watershed.

While the MMR has sometimes been included when referring to the Upper Mississippi River, the Congressional authority and management of these two segments of the navigation channel are very different. While it took until 1930 for Congress to authorize the ultimate plan for the navigation channel in the UMR (construction of a series of locks and dams),[1] Congress authorized the ultimate plan for how the navigation channel should be obtained and maintained

[1] *See* Rivers and Harbors Acts dated July 3, 1930 and August 30, 1935 and the following Chief of Engineers reports: House Document No. 290, 71st Congress, 2nd Session and House Document No. 137, 72nd Congress. These references provide the general framework for the authority and development of the UMR to obtain and maintain a navigation channel through a series of locks and dams. These reports further divided the UMR into segments that were unique and presented different challenges and issues for obtaining and maintaining a suitable navigation channel. There are also additional authorities and projects within the UMR. For a discussion of the UMR authorities and projects and how the various segments' ecosystems differ, see US Army Corps of Engineers, Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study, §§ 1.5.1, 1.5.2, and 1.6.1, Sept. 24, 2004, commonly referred to as NESP.

for a majority[2] of the MMR in 1910 and eventually established the current navigation channel dimensions of 9 feet deep and not less than 300 feet wide, with additional width in the bends as required, in 1927.

In the Rivers and Harbors Act of 1910, Congress authorized obtaining and maintaining the MMR to be carried out in accordance with the plan in 1881, which was described in detail in the Mississippi River Commission (MRC) progress report dated November 25, 1881 (the MMR as defined above being that portion of the Mississippi River that lies between its confluence with the Ohio and the Missouri Rivers (hereinafter referred to as the Project; Figure 1-2)). The MRC's specific plan in 1881 for the MMR stated that "the system to be pursued is that of contraction, thus compelling the river to scour out its bed; this process being aided, if necessary by dredging. Wherever the river is causing any serious caving of its banks, the improvement will not be permanent until the bank has been protected and the caving has been stopped" and that "it may be advisable to remove some bowlders [sic] and perhaps to cut off some points of rocks, which at low-water hamper navigation" (Senate Executive Doc. No. 10 (47th Congress, 1st Session) (hereinafter referred to as the 1881 Report)). The Congressionally authorized modification to the Project in the Rivers and Harbors Act of 1927, changing the depth and width of the authorized navigation channel, was based upon the Chief of Engineers' report dated December 17, 1926. This Chief of Engineers report described the current and future status of the Project as follows: "Although great benefits have resulted from the work already done, it is essential that additional regulating works and bank protection be carried to a point where a minimum of dredging is required and a stable channel is available at all times... [The Chief of Engineers also concurred in the District Engineers' recommendation that] the regulating works and revetment be completed and that dredging, which affords only temporary relief, be resorted to only when and to the extent that the needs of navigation then existing require" (House Committee Doc. No. 12 (70th Cong., 1st Session)). For a detailed history of the Regulating Works Project and its authorization, see Appendix F.

[2] See Section 1.1.6 and the Supplement to Appendix F for discussion about the Chain of Rocks area of the MMR.

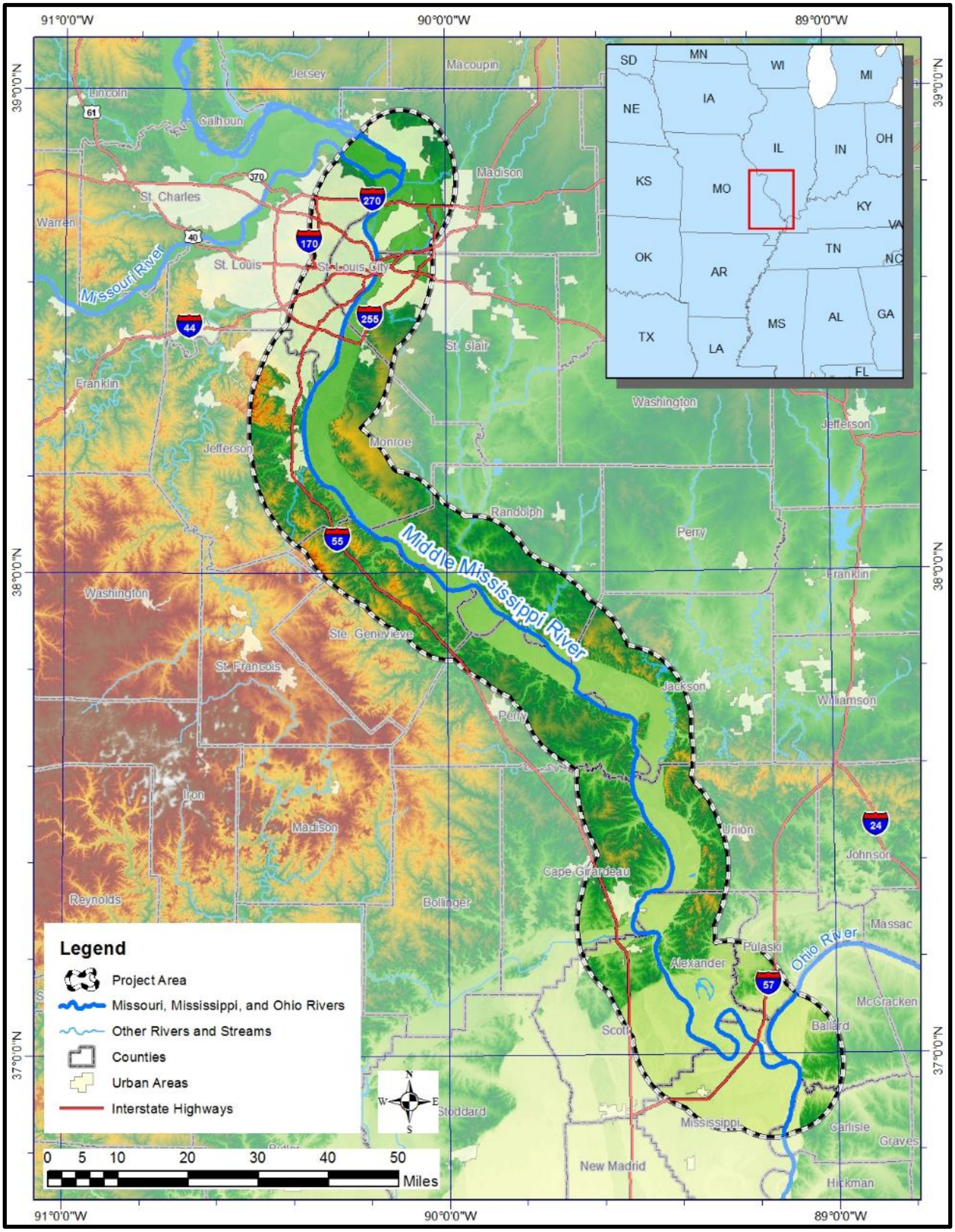


Figure 1-2. General location of the Project Area.

Therefore, since 1910 the plan described in the 1881 Report and in the 1926 Chief of Engineers report, as Congressionally authorized, has been ongoing by 1) constructing and maintaining regulating works, also called river training structures, to scour the river bed for the purpose of reducing maintenance dredging to a minimum; 2) constructing and maintaining bank protection/stabilization, also called revetment; and 3) removing rock hindering navigation all to obtain and maintain a navigation channel in the MMR nine feet deep, and at least 300 feet wide, with additional width in bends. This ongoing Project is commonly referred to as the Regulating Works Project, and the Project is carried out by the Corps' St. Louis District (District). River training structures are structures constructed for the purpose of re-directing the river's energy to achieve a desired velocity and/or scour pattern to deepen or provide better alignment for the navigation channel. Revetment is bank protection placed on or along the bankline to prevent bankline erosion and maintain bankline integrity. Today, river training structures and revetment are normally constructed with stone as found over the years to be the most effective and cost efficient, although other materials have been and can be used (see Appendix F for more details on the history and current construction of river training structures and revetment, as well as all rock removal efforts to date). Since the long-term goal and purpose of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of regulating works, the District continually identifies and monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable. The District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

1.1.2 Process for New Construction under the Regulating Works Project

Given the dynamic nature of the flows and sediment characteristics of the MMR, work sites are, by necessity, developed on an ongoing basis as dredging issues arise. The District continually monitors navigation channel depths in the MMR to determine what locations may require dredging. Chronic dredging sites are analyzed to determine if the construction of river training structures would offer a more practical and cost effective long-term solution than continued dredging. For each site where river training structures may be the best solution, the District develops alternatives using widely recognized and accepted river engineering guidance and practice. Also, to the extent possible under existing authorities, environmental laws, regulations, and policies, the District considers the environmental consequences of its activities as it constructs and operates the Project and acts accordingly to avoid and minimize impacts. Different configurations of regulating works are frequently screened and analyzed with the assistance of a Hydraulic Sediment Response model (HSR model). HSR models are small-scale physical sediment transport models used by the District to replicate the mechanics of river sediment transport. HSR models allow the District to develop multiple configurations of river training structures for addressing the specific objectives of the work area in question in a cost-effective and efficient manner. Various configurations of river training structures are then applied to the models to determine their effectiveness in addressing the needs of the chronic dredging site, improving the navigation channel alignment (if applicable), and avoiding and minimizing environmental impacts. HSR models are not necessary in all situations and other engineering solution development techniques may be used as appropriate. Regardless of what process is used to develop alternatives to address repetitive dredging locations, an important component of each activity is the use of scientific, economic, and social knowledge to understand the environmental context and effects of the Project in a collaborative manner, employing an open, transparent process that respects the views of federal and state stakeholders, individuals, and groups interested in District activities (Figure 1-3).

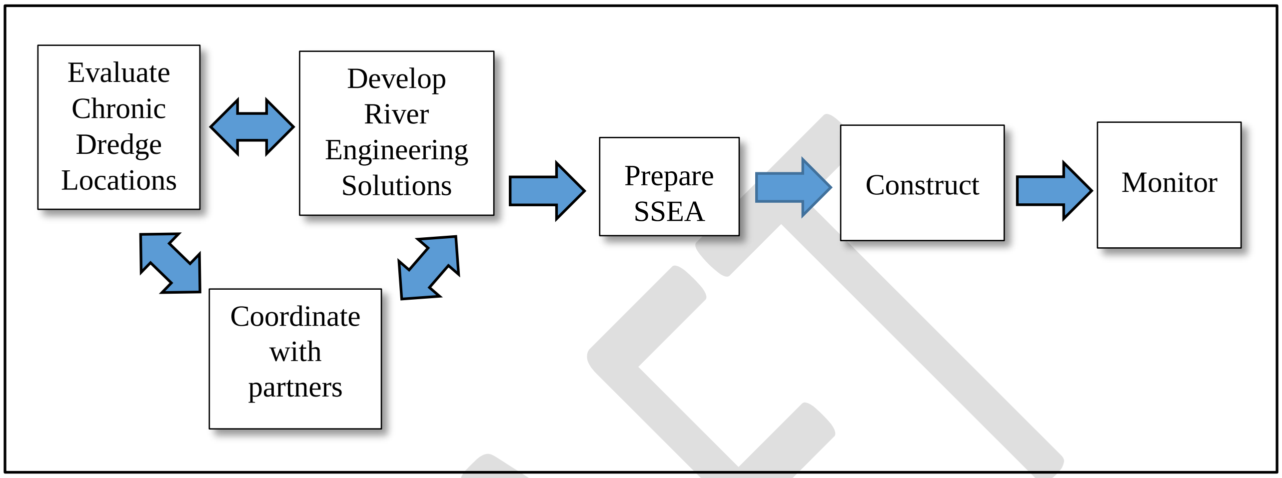


Figure 1-3. Flow chart of river training structure development process for maintaining the MMR navigation channel.

The review of regulating works projects follows the requirements of the Corps Engineering Circular EC 1165-2-214, which established an accountable, comprehensive, life-cycle review strategy for Civil Works products by providing a seamless process for review from initial planning through design, construction and operation, maintenance, repair, replacement and rehabilitation.

The Master Plan, general work plan and typical plans and specifications are reviewed annually. Under District Quality Control (DQC), the general work plans are submitted to senior members of the Hydraulics and Hydrology and River engineering disciplines in the District office not involved in the plans' development for review and comment.

Agency Technical Reviews (ATR) on the District's proposals are conducted by Mississippi Valley Division (MVD) personnel, Channel Improvement Coordinators and Design and Operations personnel associated with the Channel Improvement Project from each District within MVD, and MVD Civil Works Integration Division personnel. MVD serves as the Review Management Organization (RMO). This usually takes place at the annual Engineering Actions (E-Actions) meeting. Team members objectively review the proposals and provide comments which are resolved and documented into a report.

The objectives of the ATR, as outlined in the Mississippi River and Tributaries Project Channel Improvement Feature Regulating Works Project Review Plan, are to ensure that (1) the project meets the Government's scope, intent and quality objectives, (2) design concepts are valid, feasible, safe, functional and constructible, (3) appropriate methods of analysis were used and basic assumptions are valid and used for the intended purpose, (4) the source, amount and level of detail of the data used in the analyses are appropriate for the complexity of the project, (5) the project complies with accepted practice and design criteria within the industry, (6) all relevant engineering and scientific disciplines have been effectively integrated, (7) content is sufficiently complete for the current phase of the project and provides an adequate basis for future development effort, and (8) project documentation is appropriate and adequate for the project phase.

1.1.3 Process for Dredging under the Regulating Works Project

The first step in the dredging process (Figure 1-4) is to determine which locations require dredging. A Channel Patrol Boat performs channel reconnaissance surveys using depth soundings in order to identify possible dredging locations. If the surveys show areas that could be problematic for navigation based off of the river forecast, a more detailed pre-dredge survey of the areas is completed. Engineers can also narrow down which areas might require dredging based on past experience and knowledge of historically problematic areas. The pre-dredge survey is analyzed to determine if dredging is required. If dredging is required, the surveys are used to lay out the dredge cuts and estimate the volume of material to be moved. Dredge material disposal practices must be in compliance with the Federal Standard (33 CFR §335-338), requiring the least costly, environmentally acceptable option that is consistent with engineering requirements. Accordingly, disposal is typically accomplished with unconfined, in-river placement. Upland disposal is cost-prohibitive and is generally only considered when in-channel disposal would violate water quality certification conditions. Illinois Environmental Protection Agency and Missouri Department of Natural Resources Clean Water Act Section 401 water quality certification permit conditions require analysis of the composition of dredged material to ensure it does not exceed 20% silt and clay, thereby increasing the likelihood of sediment contamination. If material to be dredged is found to be greater than 20% fine-grained, further chemical testing is required to ensure contaminants are not present in quantities that would exceed water quality standards. All dredging is coordinated with state and Federal natural resource agency partners (Illinois Department of Natural Resources, Missouri Department of Conservation, and U.S. Fish and Wildlife Service) to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits. Once the dredging is complete, a post-dredge survey is done to determine if the problematic area has been removed.

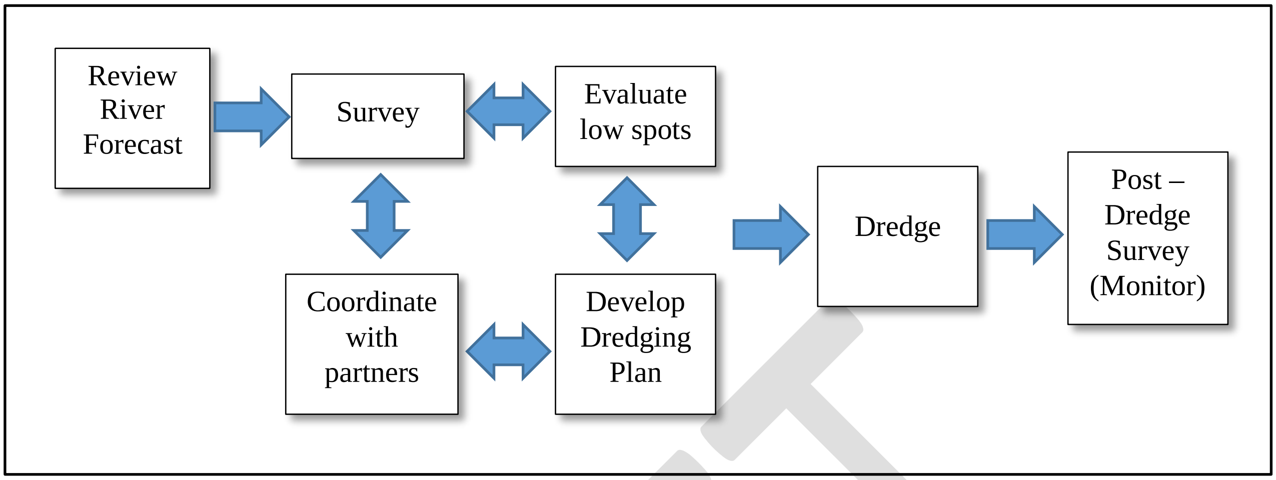


Figure 1-4. Flow chart of dredging development process for maintaining the MMR navigation channel.

Dredging is done with two types of hydraulic dredges: dustpan and cutterhead dredges. The dustpan dredge was specifically designed by the Corps for use on the Mississippi River as it is very efficient at excavating sand material from the riverbed. Water jets at the end of the suction head agitate the sand into a slurry which is then pumped into the dredge and discharged outside the navigation channel through a rigid pipe that is typically 800 to 1,000 feet long (Figure 1-5). A cutterhead dredge works in a similar way as it sucks up material and deposits it outside the channel, but it has an auger head that allows it to cut through harder material than the dustpan and it can deposit material further downstream with a pipeline of up to 3,000 feet long.

Some MMR dredging is now accomplished using floating flexible dredge disposal pipe (Figure 1-5). The St. Louis District recently purchased floating flexible dredge pipe to facilitate construction of sandbar/island habitat in association with dredging activities and in compliance with the District's Endangered Species Act obligations. Floating flexible dredge pipe is advantageous over typical rigid dredge pipe because the discharge end of the pipe can be kept in a fixed location instead of moving parallel to the dredge cut. With flexible pipe, as long as the discharge location is within a certain distance of the dredge, the position of the discharge can be fixed irrespective of the location of the dredge. Fixed-point discharge allows the buildup of material to higher elevations than is normally possible with rigid discharge pipe. This technique can be used to discharge "piles" of material to create expanses of shallow sandbar and/or ephemeral island habitat. Sandbar and island habitat is considered to be important fish habitat that is less abundant in the MMR than it was historically.

Figure 1-5. Dredged material disposal in the MMR using standard rigid discharge pipe (top) and floating flexible discharge pipe (bottom).

Implementation of the flexible dredge pipe into the District's dredging program is an ongoing process. Since its first use in 2011, the flexible dredge pipe has been utilized for approximately 8% of the District's dredging workload, based on cubic yards dredged. There are a range of variables such as cost, efficiency, stability of constructed habitats, ecological benefits, safety, etc. that factor into what percentage of the District's maintenance dredging work ends up being conducted with flexible dredge pipe. It is unknown at this time what that percentage will be in the future and the percentage will likely vary considerably from year to year depending on river levels, dredge requirements, etc. As with standard rigid pipe, all dredge cut and disposal areas using flexible dredge pipe are coordinated with natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits. In addition, all dredging operations are required to meet Clean Water Act permit conditions put in place to minimize environmental impacts.

1.1.4 Dredging Reduction under the Regulating Works Project

As discussed above, the purpose of the Regulating Works Project is to obtain and maintain the authorized navigation channel through regulating works and dredging, with a goal of reducing costly dredging to a minimum. Comprehensive dredging data date back to 1964 (Figure 1-6). The amount dredged in any particular dredge season is dependent on a number of independent factors. The need for dredging and quantity of dredged material is directly related to the hydrograph. Generally, less dredging is observed in dredge seasons where higher flows were observed. Conversely, in dredge seasons with low water, more dredging is observed. The amount of material dredged is also related to the rise and fall in the hydrograph. More dredging has been observed following a flood with a faster rate of fall in the hydrograph. In addition, the amount of sediment entering the MMR is dependent on the origin of the flow. A simple plot of dredging quantity versus year does not adequately account for these factors. In an attempt to account for the dependency of dredge data on the days under low water, the dredge quantities were plotted against the number of days below zero (Figure 1-7).

Changes in dredging criteria, improvements in the ability to measure quantity of dredged material, changes in the decision-making process, and the dependent nature of the dredging data make it difficult to develop trends solely from the dredging data set. To help illustrate the reduction of dredging resulting from the construction of river training structures, an analysis of three recent low water dredging seasons, 1988/89, 2003 and 2012 was conducted. During the 1988-1989 drought, the river dropped below 0.0 feet at the St. Louis gage for 206 days, with a minimum daily stage of -5.4 ft., and the District needed to dredge approximately 38.1 million cubic yards of material. During the 2003 low-water event, the St. Louis gage dropped below 0.0 for 136 days, with a minimum daily stage of -4.5 ft., but only 7.6 million cubic yards of material needed to be dredged. Between July 2012 and February 2013, when the river dropped below 0.0 feet at the St. Louis gage for 160 days, with a minimum daily stage of -4.6 ft, the District had to dredge just under 9.3 million cubic yards of material. It is important to note that to this point funding for dredging has been available, through redirecting O&M funding from other O&M needs, for maintaining the channel to the authorized dimensions during low water periods.

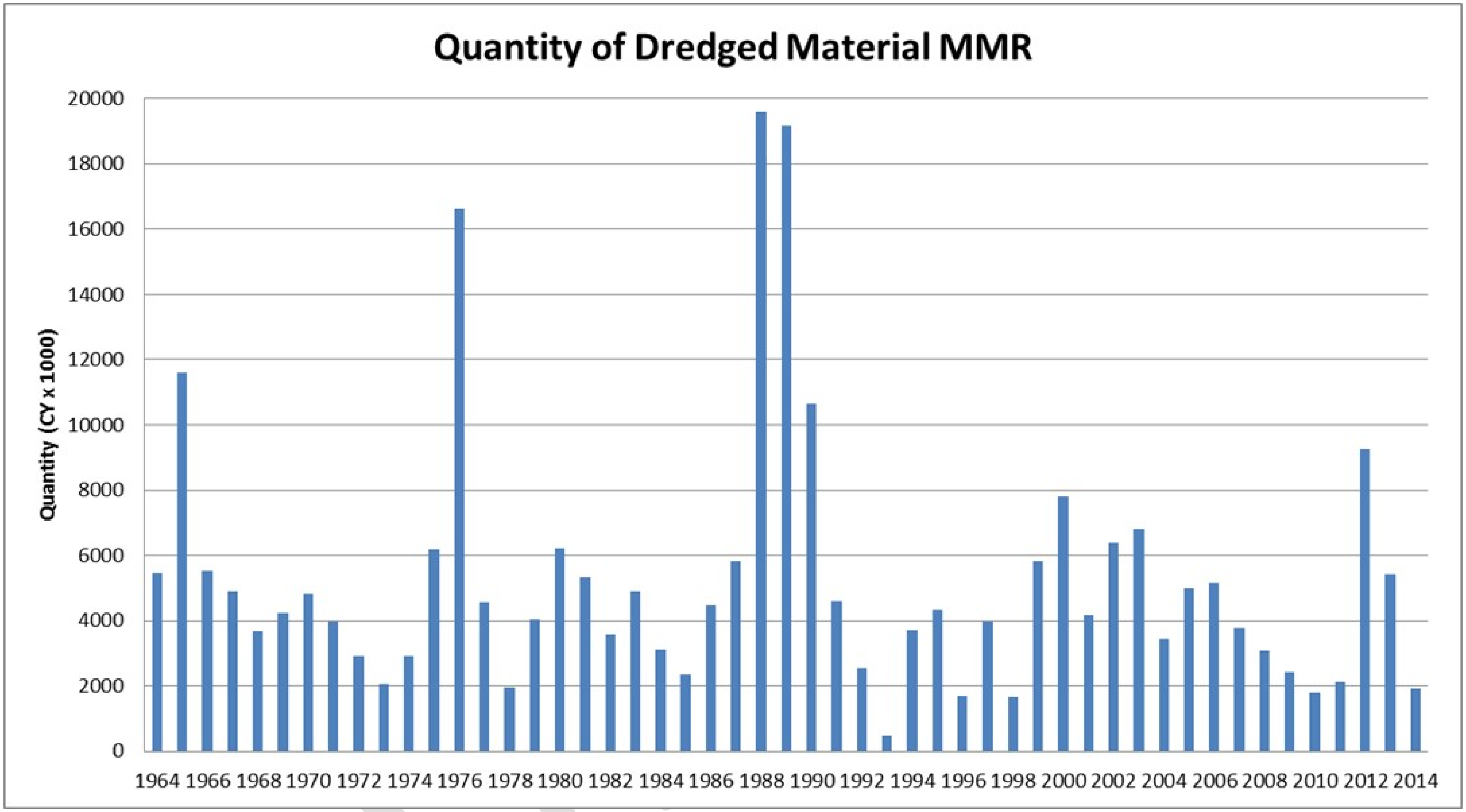


Figure 1-6. Volume of material (yd3) dredged from the MMR by year from 1964 to 2014. Includes both Corps and contract dredges.

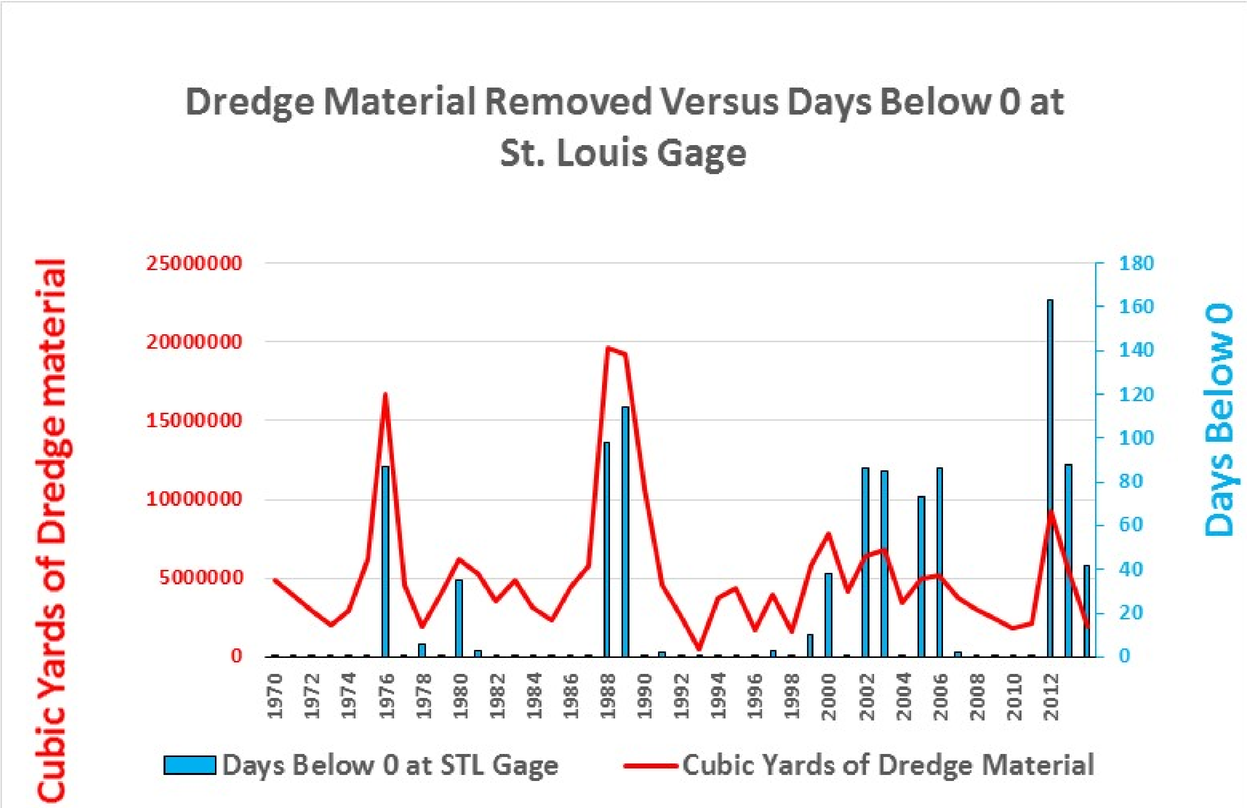


Figure 1-7. Comparison of quantity of material dredged to number of days stage was below 0 ft on St. Louis gage.

1.1.5 Process for Bank Stabilization

Banklines along the river are maintained using revetment and in some cases river training structures as part of the Regulating Works Project. The channel has been stabilized from meandering, a key component of navigation design and sustainability. Between RM 0 and 200, approximately 1,473,000 linear feet of bankline has been protected. Based on comparative bankline analysis on the Middle and Lower Mississippi Rivers, the average natural erosion rate has been found to be approximately 10 feet per year. This equates to approximately 338 acres per year of land that would be mobilized without the Regulating Works Project. In addition to navigation, there is important infrastructure in or along the river that are sustainable because of the revetment. These would include bridge abutments, loading and unloading facilities, water supply intakes, pump stations, pipe crossings, and others. Floodwalls for major towns and cities and earthen levees are also protected in many areas because of the revetment incorporated from the Regulating Works Project. Although important, infrastructure protection is considered a secondary benefit of revetment and is not a factor in the selection of areas for revetment construction.

Bankline monitoring and revetment placement is a continuous process. Bankline erosion is detected either by issues reported by land owners and field representatives, aerial reconnaissance via helicopter or evaluation of aerial photographs. Once it is determined that bankline erosion exists that could impact the navigation channel a design for the revetment is developed. This design is then coordinated with environmental partners. Once revetment is approved it is placed accordingly. Bankline revetment is also placed during the construction and maintenance of existing and new structures to ensure that erosion does not occur.

On the MMR there exist locations where a major river cutoff could form and greatly impact the navigation channel and cause disastrous environmental and economic consequences. One such location is at Thompson Bend (river mile 22). Beginning in 1980 the District, local land owners, and other organizations teamed together in an effort to prevent a cut off from occurring across the neck of the Dry Bayou – Thompson Bend peninsula along the Mississippi River. The creation of a riparian buffer at key locations along with management plans and some other repairs were implemented in an effort to force the Mississippi River to maintain its current course.

The formation of a channel cutoff creating a new course of the Mississippi River would have disastrous environmental and economic consequences. Navigation on the Mississippi River could be disrupted indefinitely, with significant navigation shutdowns lasting months at a time depending upon the severity of the event and availability of dredges. It is estimated that without the above measures, a permanent cutoff could have occurred in the past or would occur in the future due to an event with as little as a 10% annual exceedance probability (AEP)

A permanent cutoff would cause an upstream migrating headcut in the navigation channel at the cutoff source point on the river. This headcut would not only impact navigation and increase dredging, but would severely impact existing revetment and river training structures. Structures would be compromised, and maintenance repairs or complete redesign and construction would be required.

Another site that has shown the potential of a channel cutoff is at Dogtooth Bend at river mile 33. A cutoff at Dogtooth Bend would reduce the length of the MMR by approximately 16 – 18 miles. The consequences of a channel cutoff at Dogtooth Bend would be similar to those at Thompson Bend.

1.1.6 Rock Removal and Chain of Rocks

Pursuant to the 1881 Report, the Regulating Works Project also has the authority to address particularly troublesome parts of the MMR where rock is hindering the navigation channel. This has been addressed in various areas of the MMR in the past, and in 1945, Congress modified the Regulating Works Project by authorizing the construction of a lateral canal with locks to completely bypass the Chain of Rocks area of the MMR (river mile 190), where rock formations were hindering the navigation channel at low water (commonly referred to as Chain of Rocks Canal and Locks 27). See the 1976 EIS and the Supplement to Appendix F for more information about the history and authority of rock removal and the Chain of Rocks area, as well as the low water dam constructed at Chain of Rocks to address issues hindering navigation at the former Lock and Dam 26. The Chain of Rocks Canal and Locks 27 are still in operation, and any major modifications or repairs to the locks and canal or their operations undergo separate National Environmental Policy Act (NEPA) analysis. The operation of Locks 27 is also included in the

Master Plan. After completion of the rock removal contract awarded in 2013, the District does not currently foresee any future rock removal needed at this time; however, the District continually monitors the MMR for any unknown rock hindrances to confirm that no additional rock removal work is necessary.

1.2 Purpose of and Need for NEPA Supplement

The environmental impacts of the Regulating Works Project were originally documented in the 1976 Environmental Impact Statement (1976 EIS) *Mississippi River between the Ohio and Missouri Rivers (Regulating Works)*, (USACE 1976). In response to the Government Accountability Office Report 12-41, recommending that action be taken to resolve environmental and flooding concerns with the use of river training structures, the District formed two teams: one to begin an environmental assessment on river training structures and another to take a hard look at the 1976 EIS. The focus of the District review of the 1976 EIS was to determine whether or not the document should be supplemented. The District also engaged the Corps' Planning Center of Expertise for Inland Navigation (PCXIN) to review the 1976 EIS and analyze the new information and circumstances to provide additional expertise outside of the District on whether or not the 1976 EIS should be supplemented. Council on Environmental Quality (CEQ) regulations (40 CFR §1502.9(c)) provide direction on circumstances requiring agencies to supplement environmental impact statements:

(c) Agencies:

1. *Shall prepare supplements to either draft or final environmental impact statements if:*
    - *(i) The agency makes substantial changes in the proposed action that are relevant to environmental concerns; or*
    - *(ii) There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.*
2. *May also prepare supplements when the agency determines that the purposes of the Act will be furthered by doing so.*

Accordingly, the District analyzed the Regulating Works Project and associated circumstances and information to determine whether or not a supplement should be pursued. In its analysis of whether or not substantial changes had occurred to the Regulating Works Project, the District concluded that, although the configurations of river training structures had evolved over time to generate more effective results and to generate enhanced environmental benefits, the purpose and function of the structures themselves (sediment management) had changed very little since the 1976 EIS was written. Likewise, the District concluded that dredging and disposal occurs in basically the same manner as in 1976. The equipment used to dredge sediment from the bottom of the river is the same basic technology that was widely used in the 1970s. The methods and placement of dredge disposal are also very similar to the 1970s. The PCXIN likewise concluded that there had been no substantial changes to the Regulating Works Project.

In its analysis of new circumstances or information since 1976 along with the scoping comments received for the environmental assessment on river training structures, in 2013 the District concluded that there were significant new circumstances and information relevant to the Regulating Works Project and its potential impacts. The PCXIN concluded that there was persuasive evidence of a substantial body of information related to environmental concerns. Taken in total, the identified new circumstances and information formed a basis for considering an update to the 1976 EIS. The significant new circumstances and information on the potential impacts of the Regulating Works Project include the following:

- New federally threatened and endangered species have been listed since preparation of the 1976 EIS.
- The District has implemented new programs to restore fish and wildlife habitat on the MMR.
- New information exists on the changes in average river planform width[3] in response to river training structure placement.
- New information exists on the impacts of river training structures on water surface elevations.
- New information exists on the impacts of river training structures and dredging on fish and benthic macroinvertebrates[4].
- New information exists on the effects of navigation on fish and wildlife resources.
- New information exists on the status of MMR side channels.

Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the Project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS and with information from recent analyses the District has conducted to address data gaps relevant to potential impacts. Analyses include:

- Analysis of the effects of river training structures on stages;
- 3-D Numerical Hydraulic Model to clarify impacts of river training structures on MMR depth and velocity characteristics;
- Channel geometry and geomorphology analyses to determine changes in channel shape characteristics over time;
- Side channel geometry analyses to determine changes in side channel depth and connectivity characteristics over time;

[3] The planform of a river is defined as the outline or shape of the river as viewed from above. The planform width in this analysis was measured from tree line to tree line.

[4] Macroinvertebrates by definition are animals without backbones that can be seen with the naked eye. Benthic refers to organisms that that live in or on the bottom of a body of water. Benthic macroinvertebrates in the Middle Mississippi River typically consist of various life stages of flies, caddisflies, mayflies, worms, damselflies, dragonflies, and various other organisms. Benthic macroinvertebrates colonize most surfaces and substrates in river systems and provide an important food source for fish and other animals.

- Analysis of areal extent of MMR habitats and river training structures to document changes in channel configuration over time; and
- Larval fish sampling to provide densities of larval fish in the MMR.

When the District began the process to consider supplementing the 1976 EIS in 2013, a decision was made to complete site-specific environmental assessments (SSEAs) for all new Regulating Works Project construction prior to completion of the SEIS, including work associated with the District's Endangered Species Act obligations, in order to evaluate the new information and circumstances on a site-specific basis. These SSEAs made a commitment that should the analyses undertaken as part of the SEIS process reveal any new impacts on the resources, ecosystem, and human environment not accounted for in the SSEAs, measures would be taken within the Corps' authority to avoid, minimize, and/or compensate for the impacts during the SEIS process as appropriate. These SSEAs finalized to date include the following:

- Mosenthein-Ivory Landing Phase 4 (April 2014)
- Eliza Point-Greenfield Bend Phase 3 (April 2014)
- Dogtooth Bend Phase 5 (April 2014)
- Mosenthein-Ivory Landing Phase 5 (June 2015)
- Boston Bar Side Channel Restoration and Island Creation Project (April 2016)
- Grand Tower Phase 5 (June 2016)
- Dogtooth Bend Phase 6 (July 2016)

Prior to the decision to supplement the 1976 EIS, SSEAs were prepared as needed for rock removal activities (for locations between river miles 82 and 38) and Locks 27 rehabilitation (river mile 185) conducted under the Regulating Works Project. Rock removal and Locks 27 rehabilitation are covered by the Regulating Works authorization but were not specifically evaluated in the 1976 EIS. Accordingly, SSEAs for rock removal were completed in 1983, 1988, 2006, 2009, and 2013 and an SSEA was prepared for major rehabilitation of Locks 27 in 2002. Measures to avoid and minimize adverse effects were included in the SSEAs, as appropriate. No adverse effects necessitating compensatory mitigation were identified. SSEAs would continue to be prepared for site-specific activities in the future, as necessary.

1.3 Identification of 1976 EIS Updates

Much of the information in the 1976 EIS is still relevant today and does not require supplementing in this document. The following is a breakdown of what information found in the 1976 EIS is still considered relevant and what information is updated in this SEIS.

Table 1-1. Comparison of information contained in the 1976 EIS and information being updated in this SEIS.

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
1. Project Description and History	Update	1. Purpose of and Need for Action 2. Appendix F
2. Existing Environmental Setting		
2.1 Physical Elements		
2.1.1 River Channel Configuration and Stages	Update	3.2.1 Stages 3.2.2 Geomorphology
2.1.2 Regional Geologic Elements	No update necessary	N/A
2.1.3.1 Soils – General	No update necessary	N/A
2.1.3.2 Surficial Soils	No update necessary	N/A
2.1.3.3 Riverbed Soils	No update necessary	N/A
2.1.4 Water Quality	Update	3.2.4 Water Quality
2.1.5 Climatological Elements	Update	3.2.6 Air Quality and Climate Change
2.1.6 Air Quality	Update	3.2.6 Air Quality and Climate Change
2.2 Biological Elements		
2.2.1 Aquatic Communities	Update	3.3.1 Benthic Macroinvertebrate Resources 3.3.2 Fishery Resources
2.2.2 Terrestrial Communities	No update necessary	N/A
2.2.3 Rare and Endangered Species	Update	3.3.4 Threatened and Endangered Species
2.3 Cultural Elements		
2.3.1 Demography	Update	3.4.1 Human Resources
2.3.2 Economic Characteristics	Update	3.4.1 Human Resources
2.3.3 Land Use	Update	3.4.1 Human Resources
2.3.4 Outdoor Recreation	Update	3.4.1 Human Resources
2.3.5 Cultural resources	Update	3.5 Historic and Cultural Resources
3. Relationship of the Proposed Action to Land Use Plans	No update necessary	
4. Impact of the Action on the Environment		
4.1 Physical Impacts		
4.1.1 Impact to River Regime		
4.1.1.1 Early Alterations to the River	No update necessary	N/A
4.1.1.2 Existing Channel Configuration	Update	3.2.2 Geomorphology
4.1.1.3 Effect of Channel Maintenance Dredging	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
4.1.1.4 Narrowing of River Width and Decrease in surface Area	Update	4.2.2 Impacts on Geomorphology
4.1.1.5 Lowering of Riverbed Elevation	Update	4.2.1 Impacts on Stages 4.2.2 Impacts on Geomorphology 4.2.3 Impacts on Side Channels
4.1.1.6 Effect on Flows	Update	4.2.1 Impacts on Stages
4.1.1.7 Changes in Sediment Discharge	No update necessary	
4.1.1.8 Effect on River Stages	Update	4.2.1 Impacts on Stages
4.1.1.9 Existing Side Channels and Future Configurations of the River	Update	4.2.3 Impacts on Side Channels
4.1.2 Impacts on Geologic Elements	No update necessary	N/A
4.1.3 Impacts on Soils	No update necessary	N/A
4.1.4 Impact of Operation and Maintenance of Present Navigation Channel on Water Quality	Update	4.2.4 Impacts on Water Quality 4.6 Cumulative Impacts
4.2 Biological Impacts		
4.2.1 Aquatic Communities		
4.2.1.1 Dikes and Revetment	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources
4.2.1.2 Maintenance Dredging and Disposal of Dredged Material	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources
4.2.1.3 Tow Boat Operations	Update	4.6 Cumulative Impacts
4.2.2 Terrestrial Communities	No update necessary	N/A
4.2.3 Impact on Rare and Endangered Species	Update	4.3.4 Impacts on Threatened and Endangered Species
4.3 Cultural Impacts	Update	4.4.1 Impacts on Human Resources 4.4.2 Impacts on Navigation 4.5 Impacts on Historic and Cultural Resources
5. Adverse Environmental Effects which are not Avoidable	Update	Chapter 4. Environmental Consequences
6. Alternatives	Update	2. Alternatives Including the Proposed Action
7. The Relationship between Local Short-term Uses of Man's Environment and the	Update	4.7 Relationship of short-term uses and long-term productivity

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
Maintenance and Enhancement of Long-term Productivity		
8. Any Irreversible and Irretrievable Commitments of Resources which are Involved in the Continuing Action	Update	4.8 Irreversible and irretrievable commitments of resources
9. Coordination with Others	Update	Chapter 5. Consultation, Coordination, and Compliance

The analyses provided in Chapters 3 and 4 of this document focus on the significant resources for which new circumstances and information exist and also provide updated information on the environmental setting of the Project Area to provide updated context for the analysis of impacts.

1.4 Scoping/Public Involvement

The National Environmental Policy Act (NEPA) affords all persons, organizations, and government agencies the right to review and comment on proposed major federal actions that are evaluated by a NEPA document. This is known as the "scoping process." The scoping process was the initial step in the preparation of the SEIS and helped identify (1) the range of actions (project, procedural changes), (2) alternatives (both those to be rigorously explored and evaluated and those that may be eliminated), and (3) the range of environmental resources considered in the evaluation of environmental impacts.

A Notice of Intent to prepare a Supplemental Environmental Impact Statement was published in the Federal Register on December 20, 2013. On the same date a special public notice (Public Notice No. 2013-744) requesting comments regarding the scope of the SEIS was sent to federal, state, and local agencies and interested groups and individuals. A media advisory announcing the scoping meetings was provided to more than 35 media outlets on January 8, 2014, including regional print and broadcast outlets and wire services. Announcements for the public scoping meetings appeared on the Corps web and social media pages and in the following publications the week prior to the events:

- *The Alton Telegraph*
- *The Southern Illinoisan*
- *The Southeast Missourian*

The public scoping meetings were held on:

- Tuesday, January 14, 2014
  National Great Rivers Museum, Classroom #2
  Locks and Dam Way
  Alton, IL 62002

- Wednesday, January 15, 2014
  Chester City Hall
  1330 Swanwick St.
  Chester, IL 62233

- Thursday, January 16, 2014
  Missouri Dept. of Conservation
  Cape Girardeau Nature Center, Multipurpose Room
  2289 County Park Dr.
  Cape Girardeau, MO 63701

A total of 17 participants signed in for the scoping meetings, with 5 at Alton, IL, 5 at Chester, IL, and 7 at Cape Girardeau, MO.

Natural resource partner agencies were invited to participate in the Scoping Process via the River Resources Action Team (RRAT) Executive Board[5]. A meeting with the RRAT Executive Board was held on February 20, 2014. Each agency decided in the meeting that they would provide comments on the SEIS via agency letters to the Corps. Letters received are included in the Scoping Report which is available on the SEIS website at the following address:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

River Industry personnel were invited to participate in the Scoping Process via a conference call on April 23, 2014, with River Industry Executive Task Force (RIETF) and River Industry Action Committee (RIAC) personnel.

A total of 79 unique comments were received during the comment period. However, the total number of communications generating these comments was 17,731. Table 1-2 provides a breakdown of the comments received.

[5] The RRAT was established in 2002 as a partnership between the District, the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Missouri Department of Conservation to promote coordination among the agencies and to facilitate sustainable management of the Mississippi River within the St. Louis District.

Table 1-2. Scoping comments by organization / comment method.

Commenter	**No. of Communications**	**No. of Unique Comments**
National Wildlife Federation Action Alert System Emails	17,154	5*
Izaak Walton League of America Congress Web System Emails	464	4*
Traditional Mail	1	1
Izaak Walton League of America	1	4
National Wildlife Federation, American Rivers, Great Rivers Environmental Law Center, Missouri Coalition for the Environment, Prairie Rivers Network, River Alliance of Wisconsin	1	4
USEPA Region 7	1	9
Missouri Coalition for the Environment	2	6
United States Fish and Wildlife Service	1	6
Missouri Department of Conservation	1	22
Public Meeting Comment Cards	5	17
Total	17731	79

*Template email. Three percent or less of emails were modified.

The comments were categorized according to their applicability to the SEIS. SEIS categories include: Purpose and Need; Alternatives; Affected Environment; Environmental Consequences; and Consultation, Coordination, and Compliance with Regulations. An individual scoping comment may have been categorized under more than one SEIS subject matter heading.

Purpose and Need

A majority of the comments received in this category indicated that the Corps should expand the scope of the SEIS to include the entire Upper Mississippi River - Illinois Waterway (UMR-IWW) System instead of focusing on the Middle Mississippi River portion of that system and that a moratorium should be imposed on construction of new river training structures until the analyses of impacts are complete.

Alternatives

The most frequent comment in the Alternatives category suggested that the Corps should fully evaluate all reasonable alternatives. It was suggested that an alternative that protects and restores the Mississippi River should be selected. It was also suggested that the No Action Alternative should be defined.

Affected Environment

Comments related to the Affected Environment covered a broad range of topics. The most frequent dealt with the claim that river training structures increase flood heights, the need to expand the scope of the SEIS to the entire UMR-IWW, and the need to initiate a National Academy of Sciences study to evaluate the impacts of river training structures on flood risks.

Environmental Consequences

Comments related to Environmental Consequences covered a broad range of topics. As with the Affected Environment comments, the most frequent dealt with the claim that river training structures increase flood heights, the need to expand the scope of the SEIS to the entire UMR-IWW, and the need to initiate a National Academy of Sciences study to evaluate the impacts of river training structures on flood risks.

Consultation, Coordination, and Compliance with Regulations

Two comments were received that fell under this category. The comments indicated that the Corps should specify the manner by which it intends to permit individual projects under the Clean Water Act and that the SEIS should include external independent review.

Chapter 2. Alternatives Including the Proposed Action

This chapter describes the alternatives or potential actions that were considered as ways to proceed with the Regulating Works Project construction, operation, and maintenance as authorized in light of the new information and circumstances since 1976. In this chapter, the alternatives are described and their environmental impacts and usefulness in achieving the Project objectives are summarized and compared. For a detailed discussion of the environmental impacts of both alternatives, see Chapter 4. For clarification, the Alternatives considered in the 1976 EIS are also briefly discussed in this chapter.

As described in Section 1.2 Purpose of and Need for NEPA Supplement, this SEIS is not a study or re-evaluation of how a project should be carried out, but an updated analysis of the impacts of an already authorized, on-going project; Congress has already provided the manner in which the navigation channel for the MMR is to be obtained and maintained via the Regulating Works Project authorization. Any alternatives outside of this authorization to be considered in detail would require a planning study for either modification of the Project or new authorization from Congress on how to obtain and maintain navigation within the MMR. While alternatives outside of this authorization were not immediately dismissed, the analysis and evaluation of the new information and circumstances during the process of supplementing the 1976 EIS did not lead to a reasonable or feasible alternative that warranted transitioning this SEIS to such a planning document. Therefore, alternatives outside of the scope of this authorization are not evaluated in detail for purposes of this document.

2.1 Alternatives Considered

Alternative 1 – No Action Alternative: The No Action Alternative for this SEIS represents no change in the current implementation of the Regulating Works Project. Under a normal feasibility study seeking authorization for a new project, the No Action Alternative would mean that no action is to be taken. However, in the instance of an ongoing program, the No Action Alternative refers to no change in program direction. According to CEQ guidance (CEQ 1981):

> *There are two distinct interpretations of "no action" that must be considered, depending on the nature of the proposal being evaluated. The first situation might involve an action ... where ongoing programs initiated under existing legislation and regulations will continue, even as new plans are developed. In these cases "no action" is "no change" from current management direction or level of management intensity. To construct an alternative that is based on no management at all would be a useless academic exercise. Therefore, the "no action" alternative may be thought of in terms of continuing with the present course of action until that action is changed.*

Accordingly, the No Action Alternative for this SEIS represents continuing with construction, operation, and maintenance of the Regulating Works Project as it is currently being implemented, described in Chapter 1, with the addition of analyzing the potential need for and implementation of compensatory mitigation[6] on a site-specific basis as described in 2.2, Chapter 4, and Appendix C. The potential addition of compensatory mitigation measures to this Alternative does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained. Therefore, this Alternative is still considered to be the No Action Alternative. The alternative of not maintaining the navigation channel on the MMR is not a viable option. This alternative was fully evaluated in the 1976 EIS and is not considered further here. However, the impacts of the No Action Alternative (continuing current construction, operation, and maintenance activities of the Regulating Works Project) still need to be considered and evaluated in detail given that the reason for completing an SEIS was that new circumstances and information on the impacts of the Project exist. To avoid confusion, the No Action Alternative will be referred to as the **Continue Construction Alternative** from here forward in this document.

Alternative 2: Alternative 2 consists of not constructing any new river training structures for navigation purposes but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Maintenance dredging would continue at roughly the current average rate, which is approximately 4 million cubic yards per year. To avoid confusion, this Alternative will be referred to as the **No New Construction Alternative** from here forward in this document. Under this alternative, should major bankline stabilization work become necessary, e.g., to avoid a channel cutoff, the proper procedures and policies for requesting funding and insuring compliance of the work would be taken, including preparation of an SSEA.

Alternatives Considered in the 1976 EIS. The 1976 EIS included an analysis of the following array of alternative methods for obtaining and maintaining the 9-foot navigation channel on the MMR:

- Maintain existing actions – This alternative is equivalent to the Continue Construction Alternative discussed above.
- Cease all operation and maintenance activities – This alternative was a “no action” alternative in that no dredging and no maintenance of existing structures would occur. The 9-foot navigation channel on the MMR, and consequently navigation in general, would eventually cease to exist under this scenario.
- Locks and Dams – This alternative considered construction of a series of locks and dams along the length of the MMR.
- Post-authorization change – This alternative considered the modification of the authority for the Regulating Works Project to include fish and wildlife habitat restoration as a project purpose to allow the District to compensate for adverse effects of the Project. This modification would have facilitated environmental dredging of side channels, beneficial use of dredged material, construction of wooden pile dikes, and dike alterations to benefit MMR fish and wildlife resources. See the supplement

[6] Use of the term ‘compensatory mitigation’ is pursuant to the National Environmental Policy Act Regulations in 40 CFR 1508.20 and refers to compensating for an impact that cannot be avoided or minimized by replacing or providing substitute resources or environments. This should not be confused with ‘compensatory mitigation’ used for wetland impacts under Section 404 of the Clean Water Act.

to Appendix F for a full discussion on the post-authorization change described in the 1976 EIS.

Ceasing all operations and maintenance activities on the Project is not considered a reasonable or feasible alternative due to the fact that it would not satisfy the Project purpose of providing a 9-foot navigation channel on the MMR. This Alternative will not be considered further in this document. Constructing locks and dams will not be considered further because it is beyond the scope of this analysis of new circumstances and information and would require new Congressional authority. The components considered as part of the post-authorization change alternative in the 1976 EIS have been incorporated over time as components of the Regulating Works Project or are addressed under other authorities currently available to the District for the purposes of ecosystem restoration. See the Supplement to Appendix F for details on these additional authorities. Accordingly, the post-authorization change alternative is not considered further here.

Chain of Rocks Canal, Locks 27, Low Water Dam 27, and Rock Removal (See the Supplement to Appendix F for a full description of these features). These features of the Regulating Works Project are unique in that they are not matters that need to be continually addressed for obtaining and maintaining the navigation channel. Further rock removal is not expected to be needed after completion of the current contract; if additional need arises in the future, the work would be evaluated under a SSEA. The general operation and maintenance of the Chain of Rocks features of the Regulating Works Project have not changed since they were constructed in the mid-20th century. The 1976 EIS generally addressed their construction and impacts, noting that Low Water Dam 27 is basically self-operating. There is no actively managed water control at Chain of Rocks, and the baseline condition and impacts of the UMR locks were described in detail in the Navigation and Ecosystem Sustainability Program (NESP) feasibility study and Environmental Impact Statement documentation. SSEAs for any major rehabilitation or repairs to the canal or Locks 27 have been and will continue to be prepared. Further, the operation and maintenance of the locks are included in the Rivers Project Master Plan, which is circulated for public review when updated. Therefore, there are no new significant circumstances or information relative to these features of the Regulating Works Project to be addressed in detail in this SEIS. Additional construction for rock removal will be addressed as needed in the future, and the continued operation and maintenance of the Chain of Rocks features are not specifically discussed in this SEIS but are part of both alternatives considered.

Endangered Species Act Compliance. As part of the Endangered Species Act compliance for operation and maintenance of the Regulating Works Project, the District minimizes the impacts to endangered species and enhances habitat where possible, typically through construction of side channel enhancement features, modification of existing structures, and creation of ephemeral islands with the flexible dredge pipe. See 3.3.4 and 4.3.4 below, Appendix B, and the Supplement to Appendix F for more information on the Project's Endangered Species Act compliance. Both alternatives will continue to be in compliance with the Endangered Species Act as legally required, and actions as part of this compliance are not specifically discussed in this SEIS.

2.2 Evaluation of Alternatives

Continue Construction Alternative. The Continue Construction Alternative consists of future River Training Structure (RTS) construction that is equivalent to approximately 4.4 million tons of additional rock placed, a reduction of average maintenance dredging from the current level of approximately 4 million cubic yards per year to approximately 2.4 million cubic yards per year, completion of currently known bankline stabilization projects to reduce the risk of a channel cutoff, additional revetment, and maintenance of existing structures. The amount of estimated remaining RTS construction under this alternative is based on the expected quantity of reduced dredging per increment of RTS construction, estimated construction costs, estimated dredging costs, and estimated mitigation. A more detailed description of how the remaining quantity of construction was estimated for this alternative can be found in Appendix C.

While the avoid and minimize mitigation measures implemented to date have been effective, the new information and circumstances further studied and analyzed as part of this SEIS reveal that the continued construction of RTS under this alternative would be expected to have a significant impact on main channel border habitat due to the potential loss of approximately 1,100 acres (8%) of the remaining unstructured main channel border habitat. Although construction of river training structures does benefit some MMR fish species by providing low-velocity habitats, this does not offset or compensate for the anticipated adverse effects to shallow to moderate-depth, moderate- to high-velocity habitat due to the fact that the adverse effects impact a different habitat type with a different function for a different group of fish than the benefits do.

This impact is considered significant on technical, institutional, and public merits. The impact is technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. In addition, the species of fish that utilize this habitat have declined in abundance over time in the MMR (Pflieger 1997). Remnant habitats with these depth and velocity attributes are biologically important for the continued existence of these species (USFWS 2008). This impact is considered significant on institutional grounds due to the importance that the Corps, through its Environmental Operating Principles, places on environmental sustainability, proactive consideration of the environmental consequences of Corps activities, and the creation of mutually supporting economic and environmental solutions. Likewise, natural resource agency partners place high priority on protecting and sustaining the aquatic resources of the Mississippi River. The impact is considered significant to the public due to the intrinsic value the public places on the environment and its continued protection.

While impacts would continue to be avoided and minimized to the extent practicable, it is expected that unavoidable impacts would potentially result in the need for compensatory mitigation. Appendix C provides a detailed discussion, including key assumptions, of how impacts and associated mitigation were estimated.

The primary benefit provided by this alternative is the reduction in average annual maintenance dredging per the Project's Congressional authorization. Maintaining reliable navigation on the MMR is dependent upon a reliable channel. While it is not feasible (technically or economically) to completely eliminate dredging, reducing the average annual quantity results in a more passively managed channel. A reduced quantity of "just-in-time" dredging[7] occurrences reduces the chances that these needs will not be met in the future.

No New Construction Alternative. The No New Construction Alternative consists of average maintenance dredging of approximately 4 million cubic yards per year, completion of bankline stabilization projects to reduce the risk of a channel cutoff, additional revetment, and maintenance of existing structures. Under this alternative, no additional RTS would be constructed for navigation purposes.

Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. It is not anticipated that this alternative would have any unavoidable significant impacts that would result in the need for compensatory mitigation.

Uncertainty. The evaluation of both alternatives is based on the best available information at the time this document was prepared. Because the exact location and quantity of future dredging needs as well as the future RTS locations and designs are unknown, programmatic analysis was used to estimate remaining construction and associated impacts. The process used to develop a remaining construction estimate, the underlying assumptions used to determine impacts, and the programmatic approach to potential mitigation is described in Appendix C.

The overall economic analysis of the Regulating Works Project is updated periodically (approximately every 5 years) as part of the internal Corps budgeting process and these economic updates are used to justify future expenditures. While the analysis of both alternatives assumed that sufficient operations and maintenance as well as construction funding will be available in the future, the actual funding that is provided will be dependent on future economic analyses of the Project. The purpose of this document is to analyze the environmental impacts of the Regulating Works Project in the context of the new circumstances and information that has become available since the 1976 EIS was produced. Accordingly, this SEIS does not include a detailed economic evaluation of the Regulating Works Project. The future economic updates that are performed for the Project will include current information on construction costs, dredging costs, and any mitigation costs. These future economic updates may also result in an updated estimated quantity of construction and mitigation, which will be appropriately evaluated and assessed when completed.

[7] Just-in-time dredging refers to dredging during low water to ensure that problematic areas are dredged prior to the river levels falling to critical depths. This process entails proper scheduling and sequencing of the dredge projects using the best available survey data and forecast data to ensure that the dredge will arrive on each project site just prior to the river reaching critical depth. There are several risks involved when just-in-time dredging is used to maintain the navigation channel. Due to the dynamic nature of the river, survey data are only good at the time of survey and depths can change rapidly, the forecasts can change based on new information, the dredge equipment is prone to mechanical breakdowns, and new dredging locations can affect the schedule. Just-in-time dredging requires that the schedule, sequencing, and project parameters are constantly adjusted to account for the changing variables. Advanced maintenance dredging is the preferred method but changing channel conditions sometimes dictate that just-in-time dredging is required.

2.3 Comparison of Alternatives

The table below summarizes the main components, key assumptions, extent of achievement of project objectives, and impacts to environmental resources of each alternative. See Chapter 4 for a more detailed description of the environmental consequences of each alternative.

	No New Construction Alternative	**Continue Construction Alternative**
Summary	• No new river training structures constructed • Navigation channel maintained through dredging • Bankline erosion monitored and new revetment constructed as needed to stabilize bankline • Existing river training structures maintained as needed • No compensatory mitigation would be required	• Construction of new river training structures in chronic dredging locations • Approximately 4.4 million tons of rock used for construction of new river training structures • Bankline erosion monitored and new revetment constructed as needed to stabilize bankline • Existing river training structures and revetment maintained as needed • Adverse effects would continue to be avoided and minimized to the greatest extent practicable • Would increase amount of low-velocity habitat and would increase bathymetric, flow, and substrate diversity • Would potentially result in the need for compensatory mitigation for unavoidable adverse effects of new construction. • Potential mitigation measures may include, but are not limited to: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. • Compensatory mitigation is addressed programmatically in this document. Specifics of mitigation planning would be addressed in tiered site-specific Environmental Assessments

	No New Construction Alternative	**Continue Construction Alternative**
Assumptions	• Average annual dredge quantity would remain at approximately 4 million cubic yards throughout project life with substantial year to year variation	• Average annual dredge quantity would gradually decrease from the current 4 million cubic yards to an estimate of 2.4 million cubic yards as river training structures are built to reduce dredging in chronic dredging areas until construction economically justified to completion
Achievement of Project Objectives	• Does not achieve Congressionally authorized project objective of reducing federal expenditures by reducing dredging to a minimum	• Achieves project objective of reducing annual maintenance dredging to a technically and economically achievable minimum
Impacts on Stages	• No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue	• No impacts on stages anticipated at average and high flows • At low flows, river training structure construction would contribute an unknown amount to continuing trend of small reductions in stages
Impacts on Geomorphology	• No impacts to geomorphology anticipated beyond continued provision of 9-foot navigation channel.	• Cross sectional area, hydraulic depth, conveyance, and channel volume will remain constant or generally increase. • Continued provision of 9-foot navigation channel
Impacts on Side Channels	• No impacts to side channels anticipated • District side channel restoration projects would continue	• No direct adverse effects to side channel quantity or quality anticipated • River training structure construction would contribute an unknown amount to small reductions in stage at low flows that would have minor adverse effects on side channel habitat by reducing quantity and connectivity of habitat • District side channel restoration projects would continue
Impacts on Water Quality	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites and at river training structure construction sites
Impacts on HTRW	• No HTRW impacts anticipated	• No HTRW impacts anticipated

	No New Construction Alternative	Continue Construction Alternative
Impacts on Air Quality and Climate Change	• Minor and local impacts to air quality due to use of dredging equipment and equipment used for maintenance of existing structures • Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions expected to remain at approximately 27,950 tons per year from dredging and maintenance activities	• Temporary, minor, local impacts to air quality due to one-time use of construction equipment • Reduction in future emissions due to dredging reduction • Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions reduced by approximately 40% (to 16,970 tons per year) after completion of construction of new river training structures due to reduced dredging requirement
Impacts on Benthic Macroinvertebrate Resources	• Entrainment of benthic macroinvertebrates at dredge locations • Burial of benthic macroinvertebrates at disposal locations • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, indefinitely	• Increased benthic macroinvertebrate use of river training structure placement locations due to increased bathymetric, flow, and substrate diversity • Entrainment of benthic macroinvertebrates at dredge locations • Burial of benthic macroinvertebrates at disposal locations • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, decreasing to 1% with construction of new river training structures
Impacts on Fishery Resources	• Estimated dredge entrainment of less than 0.06% of adult and juvenile fish per year, on average • Estimated dredge entrainment of approximately 0.002% of larval fish per year • Creation of islands/sandbars with flexible dredge pipe	• Avoidance of sites during construction activities • General increase in fish use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity • Future construction would result in conversion of estimated 8% (1,100 acres) of remaining unstructured main channel border habitat to structured, leading to potential loss of fish movement corridors and loss of shallow to moderate-depth, medium- to high-velocity main channel border habitat important to some guilds of MMR fish community and potentially necessitating compensatory mitigation*

	No New Construction Alternative	**Continue Construction Alternative**
		• Estimated entrainment of less than 0.06% of adult and juvenile fish per year, on average, decreasing to less than .04% with construction of new river training structures • Estimated entrainment of approximately 0.002% of larval fish per year, on average, decreasing to approximately 0.001% with construction of new river training structures • Creation of islands/sandbars with flexible dredge pipe
Impacts on Threatened and Endangered Species	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • *No effect* or *may affect but not likely to adversely affect* for species listed since 2000	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • *No effect* or *may affect but not likely to adversely affect* for species listed since 2000
Impacts on Human Resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources
Impacts on Navigation	• Continued provision of 9-foot navigation channel • Continued requirement for periodic maintenance dredging at an annual average rate of approximately 4 million cubic yards indefinitely • Higher risk of channel closures due to the sole use of just-in-time dredging to keep the navigation channel open once chronic dredging locations impact the channel.	• Continued provision of 9-foot navigation channel • Reduction in the amount and frequency of periodic maintenance dredging from current annual average of approximately 4 million cubic yards to approximately 2.4 million cubic yards as river training structures are built to reduce dredging in chronic dredging locations • Reduction in barge grounding rates • Increased channel reliability and decreased risk of channel closures due to decreased frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages
Impacts on Historic and Cultural Resources	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely

*The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation needs will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

2.4 Identification of the Preferred Alternative

Based on the Project's Congressional authority and the continued benefit of the remaining construction, the Continue Construction Alternative with the described potential compensatory mitigation is the Preferred Alternative. With implementation of the Continue Construction Alternative, the District anticipates constructing future river training structures that equate to approximately 4.4 million tons of rock, which will reduce dredging to approximately 2.4 million cubic yards on an average annual basis. This reduction in dredging will result in a more reliable channel. The economic viability of the Regulating Works Project will continue to be evaluated as part of the Corps budget process and therefore the actual remaining quantity of construction may vary due to changes in rock prices, dredging costs, mitigation costs, etc.

2.5 Future Implementation of the Regulating Works Project

Under the Preferred Alternative, the Regulating Works Project would still be implemented in substantially the same way as described in Chapter 1 with the addition of determining the need for and implementation of compensatory mitigation. Given that the exact locations, configurations, and types of river training structures to be implemented at future chronic dredging sites are not known at this time and would not be known until future planning is conducted site by site as described in Chapter 1, this SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward. The specific impacts associated with each work area would be covered in Tier II SSEAs. SSEAs would also detail any compensatory mitigation planning and associated adaptive management and monitoring that is required based on the impact assessment in the SSEAs (see Appendix C for further details on compensatory mitigation planning). SSEAs would also include discussion of the contributions of the site-specific work to the cumulative impacts of the Project. Any and all required Clean Water Act, Rivers and Harbors Act, and other permits and authorizations would be sought during the SSEA process, as necessary. SSEAs would normally be posted for a 30-day public comment period. Dredging activities and revetment construction are not anticipated to require SSEAs as the impacts of these activities are adequately characterized and quantified in the 1976 EIS and in this SEIS.

Chapter 3. Affected Environment

3.1 Introduction

This chapter presents details on the historic and existing conditions of significant resources within the Project area that would potentially be impacted directly, indirectly, or cumulatively by Project-related activities. The resources described in this section are those recognized as significant by laws, executive orders, regulations, and other standards of federal, state, or regional agencies and organizations; technical and scientific agencies, groups, and individuals; and the general public. The emphasis in this document is on significant resources that may be impacted by the action or that are not likely to be impacted by the action but provide important context for the analysis of impacts.

The chapter is broken into four general resource categories: Physical Resources, Biological Resources, Socioeconomic Resources, and Historic and Cultural Resources. This chapter does not address impacts of the Alternatives, but provides a background or baseline against which Alternatives can be compared in Chapter 4, Environmental Consequences.

The Project Area, commonly referred to as the Middle Mississippi River, is that portion of the Mississippi River that lies between the confluence with the Missouri River and the confluence with the Ohio River. Counting of river miles on the Middle Mississippi River begins at mile 0 at the Ohio River confluence near Cairo, IL and ends at mile 195 at the Missouri River confluence north of St. Louis, MO. The Missouri River contributes almost 50 percent of the flow of the MMR (USGS 1999) and contributes approximately 75% to 95% of the suspended sediment load (Davinroy 2006). The average flow of the Middle Mississippi River, during the period 1931-2000, at St. Louis is approximately 200,000 cubic feet per second (cfs). Other major tributaries to the MMR include the Meramec River at RM 160, the Kaskaskia River at RM 117, and the Big Muddy River at RM 75 (Figure 3-1) which contribute average flows of approximately 3,200 cfs, 3,800 cfs, and 1,900 cfs, respectively (WEST 2000).

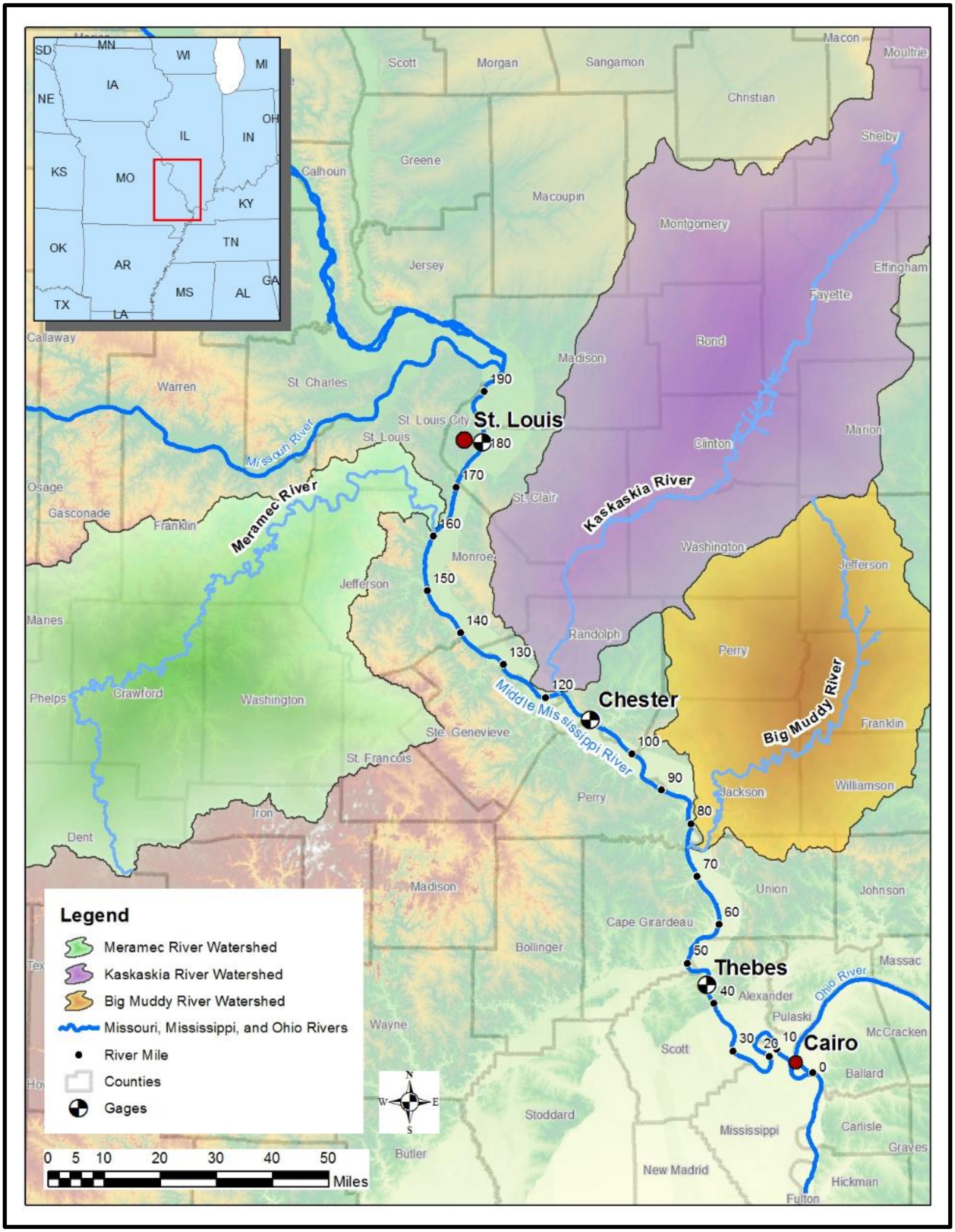


Figure 3-1. Major tributary watersheds in the Middle Mississippi River.

Average annual precipitation for St. Louis is approximately 38 inches (NOAA 2014). Average annual snowfall for St. Louis is approximately 19 inches (NOAA 2014). Average temperature for St. Louis is 56.3 degrees Fahrenheit. The average daily high and low temperatures in July, the hottest month of the year, are 89 and 71 °F. The average daily high and low temperatures in January, the coldest month of the year, are 40 and 24 °F (NOAA 2014). Precipitation is typically greatest in spring and summer and lowest in fall and winter (NOAA 2014). The highest flows and stages on the Middle Mississippi River typically occur in April and May and the lowest tend to be in December and January (Figure 3-2 and Figure 3-3). The stage and corresponding flow for flood stage, approximate elevation of the top of river training structures and the Annual Exceedance Probability (AEP) for the Mississippi River at St. Louis, MO and Chester, IL can be found in Table 3-1.

Recently, a GIS analysis was conducted to quantify the amount of dike construction that has occurred on the Middle Mississippi River throughout history. Existing dikes were digitized from historic surveys from the years 1876, 1881, 1908, 1914, 1929, 1942, 1956, 1968, 1977, 1983, and 2014. To measure the total amount of dike construction each structure was measured from the original, earliest starting point. In later years it is possible that part of the structure was covered with sediment, vegetation and part of the floodplain.

Figure 3-4 and Figure 3-5 show dike construction trends over time. For a thorough history of the Regulating Works Project and general discussion of construction of river training structures and revetment in the MMR, see Appendix F. As detailed in Appendix F, the combination of a series of major floods in 1943, 1945, and 1951 and ice destroyed many existing regulating works structures. This time period saw a net decrease in the number and length of structures on the MMR.

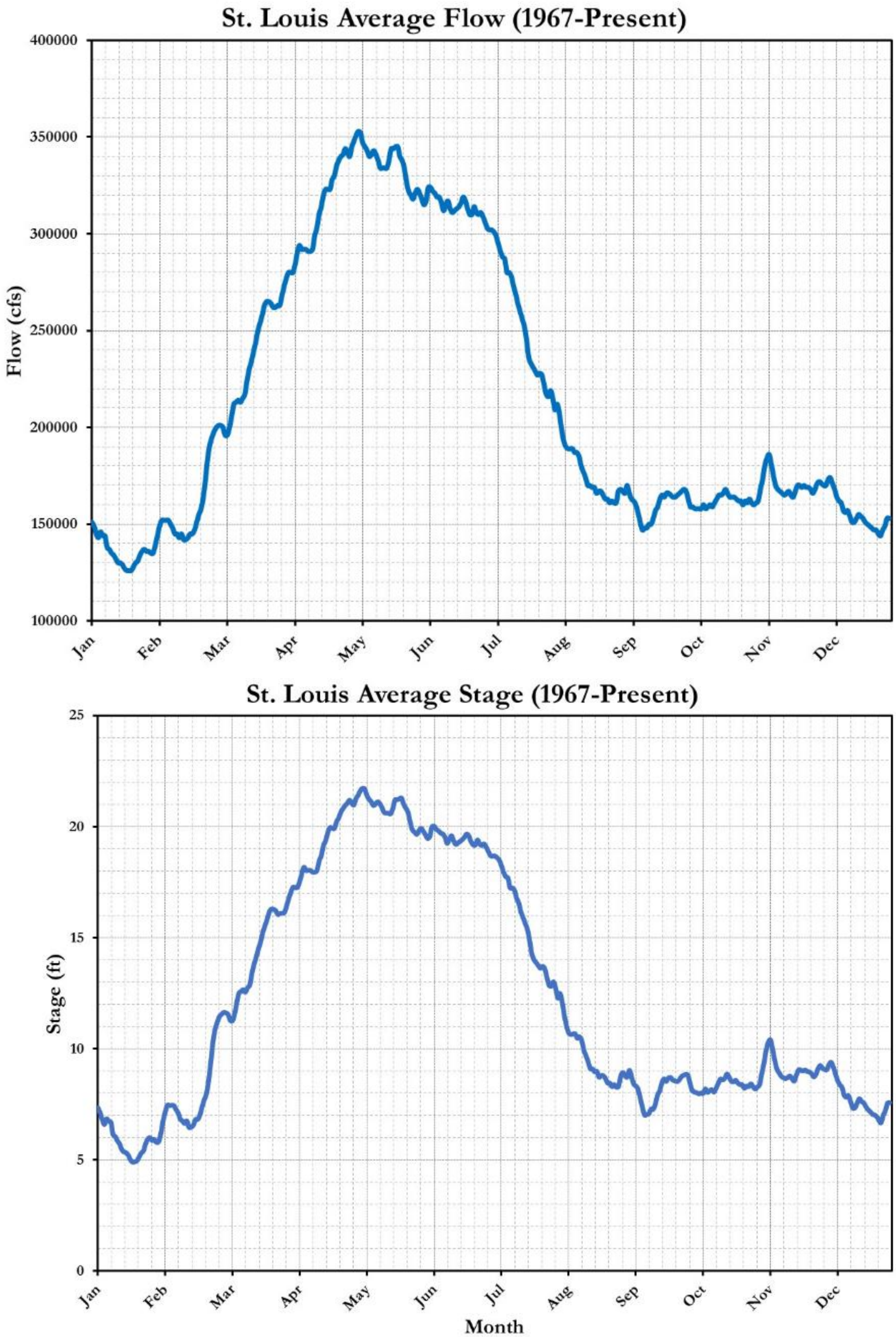


Figure 3-2. Daily average MMR flows and stages at St. Louis over the period 1967-present.

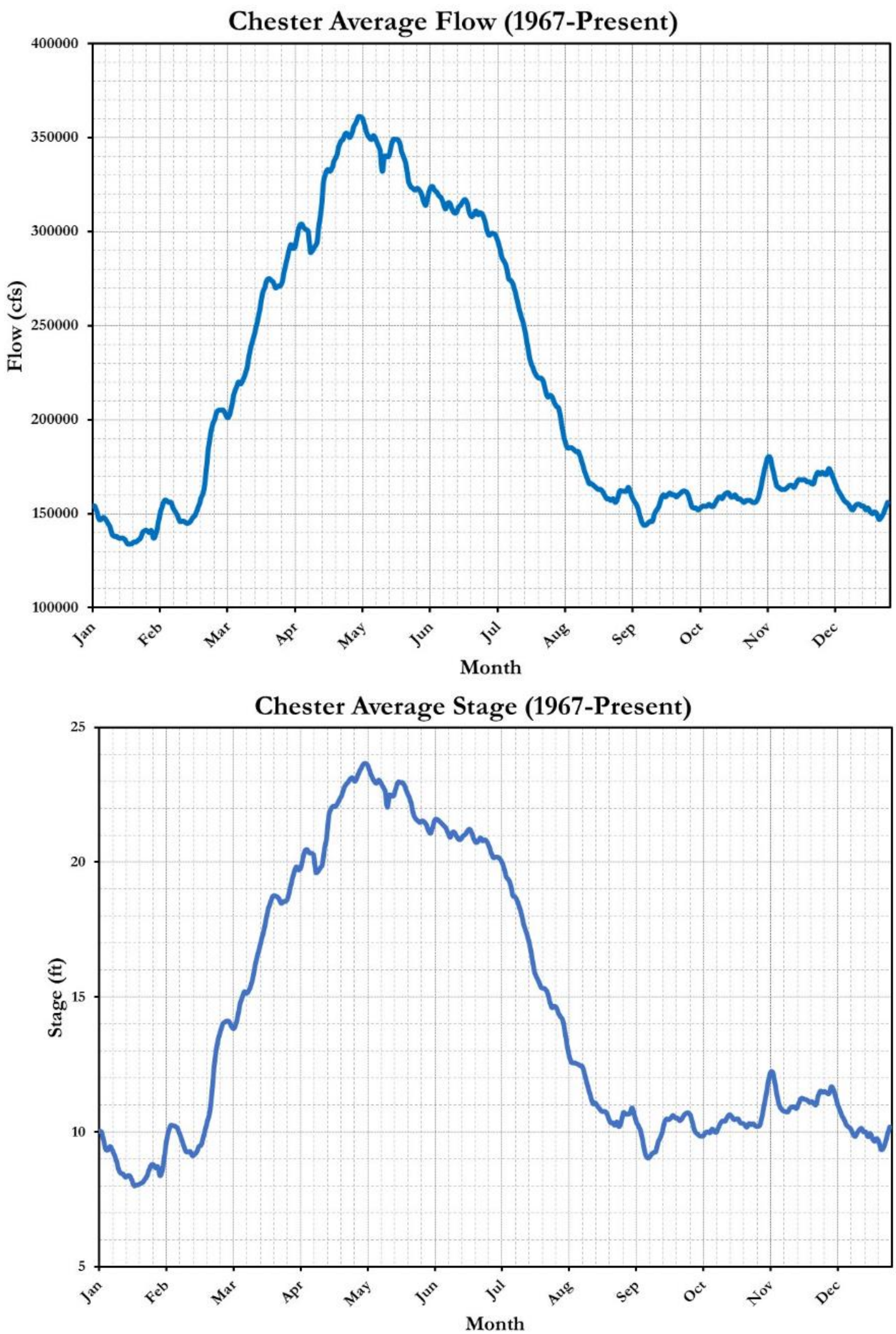


Figure 3-3. Daily average MMR flows and stages at Chester over the period 1967-present.

Table 3-1. Annual Exceedance Probability (AEP): Mississippi River at St. Louis, MO and Chester, IL. Period of Record: 1898 – 1998 (USACE 2004)

Annual Exceedance Probability (AEP): Mississippi River at St. Louis, MO	Stage (ft)	Flow (cfs)
Structure Top Elevation	15.00	247,000
0.50 (2- year)	29.96	450,000
Flood Stage	30.00	510,000
0.20 (5 – year)	35.76	590,000
0.10 (10 – year)	38.46	670,000
0.04 (25 – year)	41.96	780,000
0.02 (50 – year)	44.06	850,000
0.01 (100 – year)	46.06	910,000
0.005 (200 – year)	47.86	1,000,000
0.002 (500 – year)	50.56	1,120,000

Annual Exceedance Probability (AEP): Mississippi River at Chester, IL	Stage (ft)	Flow (cfs)
Structure Top Elevation	15.55	225,000
0.50 (2- year)	31.15	480,000
Flood Stage	27.0	422,000
0.20 (5 – year)	36.65	622,000
0.10 (10 – year)	39.75	707,000
0.04 (25 – year)	43.05	805,000
0.02 (50 – year)	46.05	893,000
0.01 (100 – year)	47.95	948,000
0.005 (200 – year)	50.15	1,020,000
0.002 (500 – year)	51.15	1,140,000

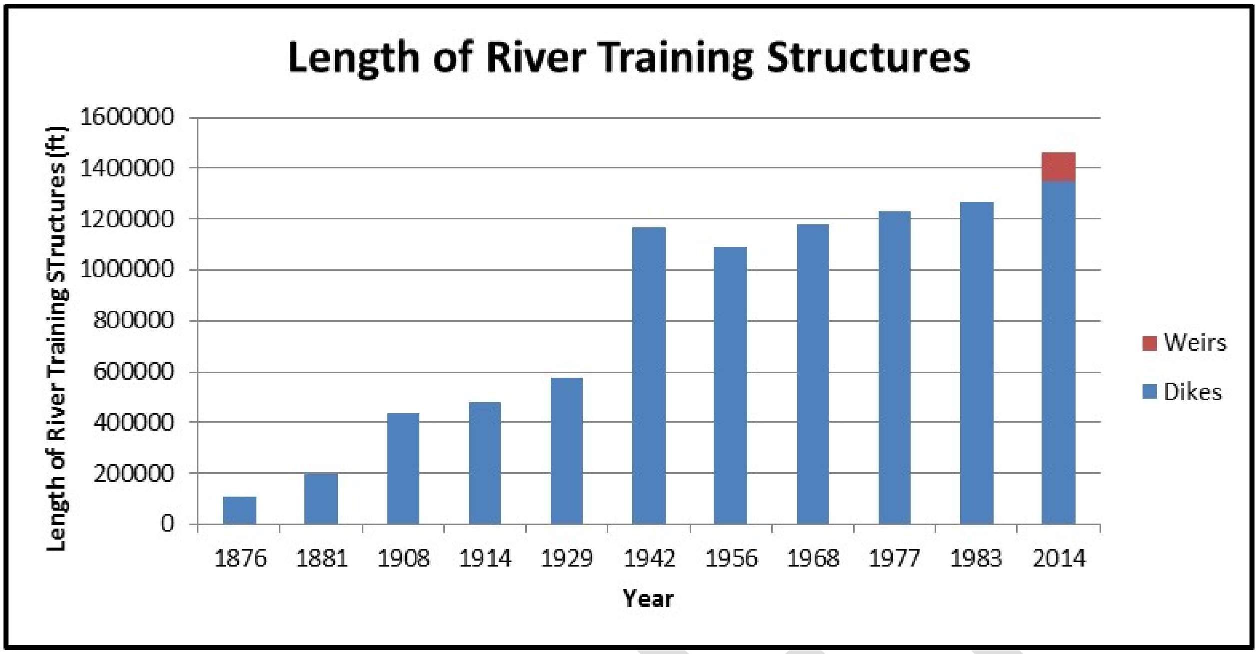


Figure 3-4. Total length (linear feet) of MMR river training structures constructed from 1876 to 2014.

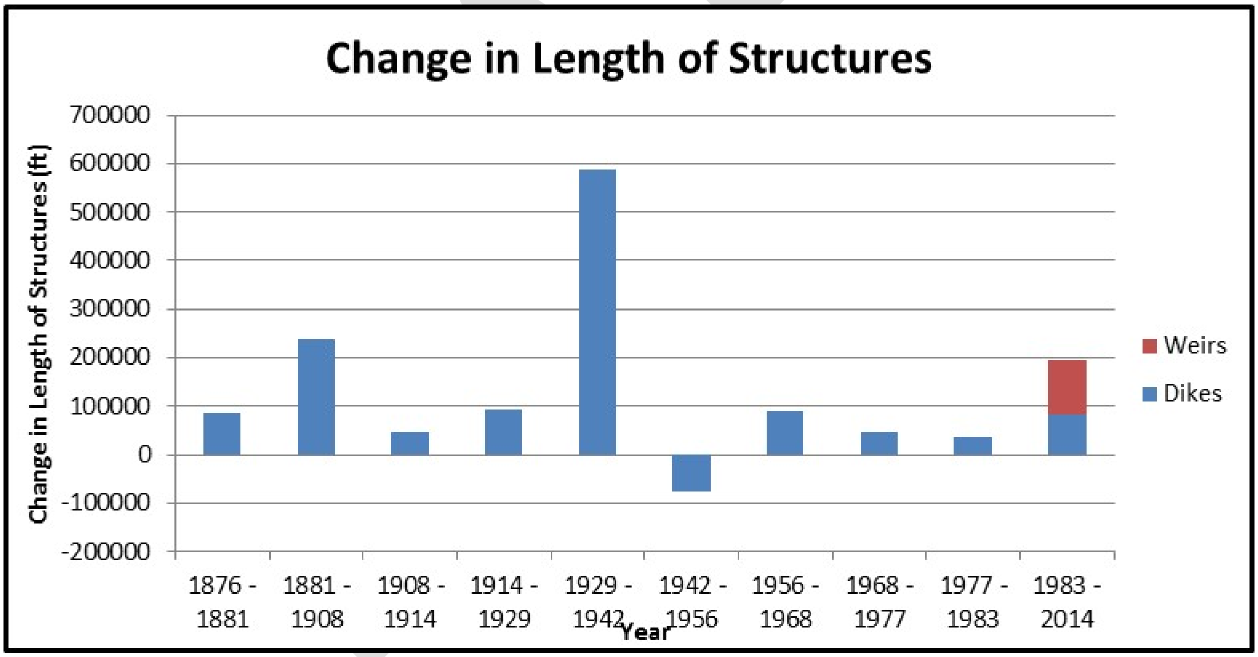


Figure 3-5. Change in total length of MMR river training structures from 1876 to 2014.

3.2 Physical Resources

3.2.1 River Stages

Rated gages, locations where both discharge and stage are collected and combined to create a rating curve, are good sources of long term stage and discharge data. Only three rated gages exist on the MMR: St. Louis (River Mile 179.6), Chester (River Mile 109.9), and Thebes (River Mile 43.7). Due to backwater effects from the Ohio River the gage at Thebes is not a good indicator of changes in stage over time. Throughout the period of record (1866 to present), the two agencies that have been responsible for the collection of gage data on the MMR are the Corps and U.S. Geological Survey (USGS). The Corps has collected stage and discharge data dating back to the mid nineteenth century. The USGS has been the primary agency responsible for stream gaging since 1933. Due to discrepancies in methodology and instrumentation used by the Corps and the USGS, it is impossible to analyze the entire period of record with confidence; therefore, only data collected by the USGS will be used here to describe the changes in stage for fixed discharges over time (Watson et al. 2013a; Watson et al. 2013b; Huizinga 2009; Munger et al. 1976).

Stages have been decreasing over time for flows below 200,000 cfs at the St. Louis gage (Figure 3-6). For other in-bank flows between 200,000 cfs and 500,000 cfs there has been no change over time. There is a slight upward but statistically insignificant trend for stages at the overbank flow of 700,000 cfs. Stages at Chester for lower in-bank flows up to 200,000 cfs have decreased with time (Figure 3-6). There was no change in stages at flows of 200,000 cfs and 400,000 cfs. There was a slightly increasing trend at 300,000 cfs. For overbank flows of 500,000 cfs and 700,000 cfs, there were slight increasing trends observed at the Chester gage.

In general, at both the St. Louis and Chester gages there has been a decrease in stage over time for lower flows, no change in stages over time for flows between midbank and bankfull, and a slight increase in stages for high overbank flows (Huizinga 2009). The decrease in stage over time for lower flows could be a result of river training structure placement and/or a decrease in the sediment load in the river due to construction of reservoirs on Mississippi River tributaries (Huizinga 2009). Huizinga (2009) and Watson et al. (2013a) attribute the slight increase in out of bank flows to the construction of levees and the disconnection of the river from the floodplains. Both Watson et al. (2013a) and Huizinga (2009) observed a shift occurring in the out of bank flows in the mid-1960s and attributed it to the completion of the Alton to Gale levee system which paralleled the entire MMR. At these high flows navigation structures are submerged by 7 to 15 feet.

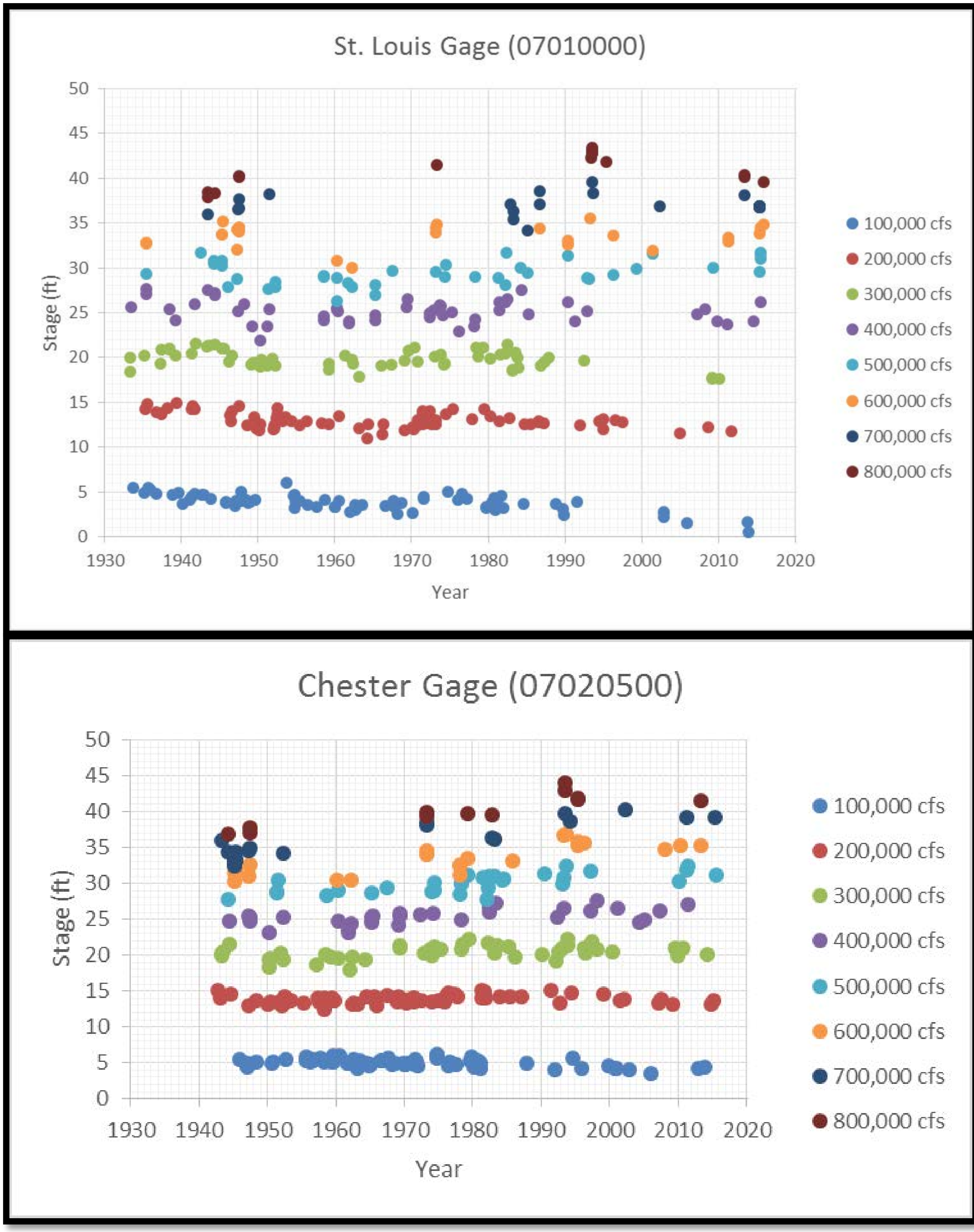


Figure 3-6. Stage for a given discharge range with time from measurements made at the streamgages at St. Louis, Missouri (top) and Chester, Illinois (bottom) on the MMR. Data retrieved from usgs.gov on 15 March 2016.

3.2.2 Geomorphology

An analysis of changes in river planform in the MMR was recently conducted by the District (Brauer et al. 2005; Brauer et al. 2013). The analysis utilized historic and modern maps, surveys, and aerial photography to calculate changes through time in planform width, channel width, channel surface area, side channel width, etc. The analysis demonstrates that the MMR went through a period of planform widening in the mid-nineteenth century followed by a period of planform narrowing from the end of the nineteenth century through the mid-twentieth century (Figure 3-7). These trends were observed throughout the MMR on both the planform and main channel (Figure 3-8 and Figure 3-9). The period of narrowing corresponded to the widespread use of river training structures and bank protection for navigation improvements. The dramatic increase in planform and channel width in 1881 found between River Miles 110.25 and 120.0 is the result of the channel cutoff that occurred on the Mississippi River when it captured the Kaskaskia River. The first training structures were mainly permeable wooden structures which focused the river's energy into the main channel by reducing the velocities between the structures, causing sediment to deposit in channel border areas. This sediment deposition caused a significant narrowing effect on the channel. Since 1968, however, the channel width appears to have reached dynamic equilibrium with very little change. In the 1960s, the Corps began constructing impermeable dikes primarily out of stone. The use of impermeable dikes reduced the rate of deposition between the structures when compared to the previously used permeable structures. Another change was the reduction of the design elevation of dike fields. Unlike in the past, the area between the structures did not fill with sediment, grow vegetation and become part of the floodplain. In the 43 years between 1968 and 2011, the average planform width remained relatively steady with a net reduction in average planform width of 167 feet. This was the result of the changes in structure material, structure elevation, and bank protection.

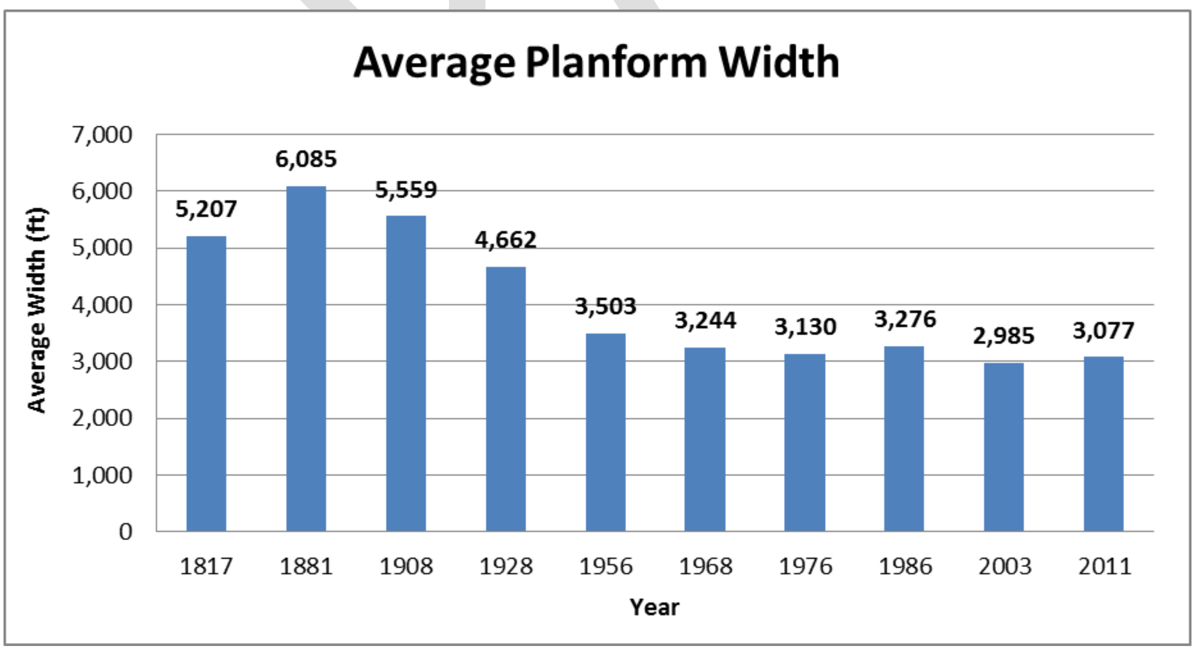


Figure 3-7. Average planform width of the MMR from 1817 to 2011.

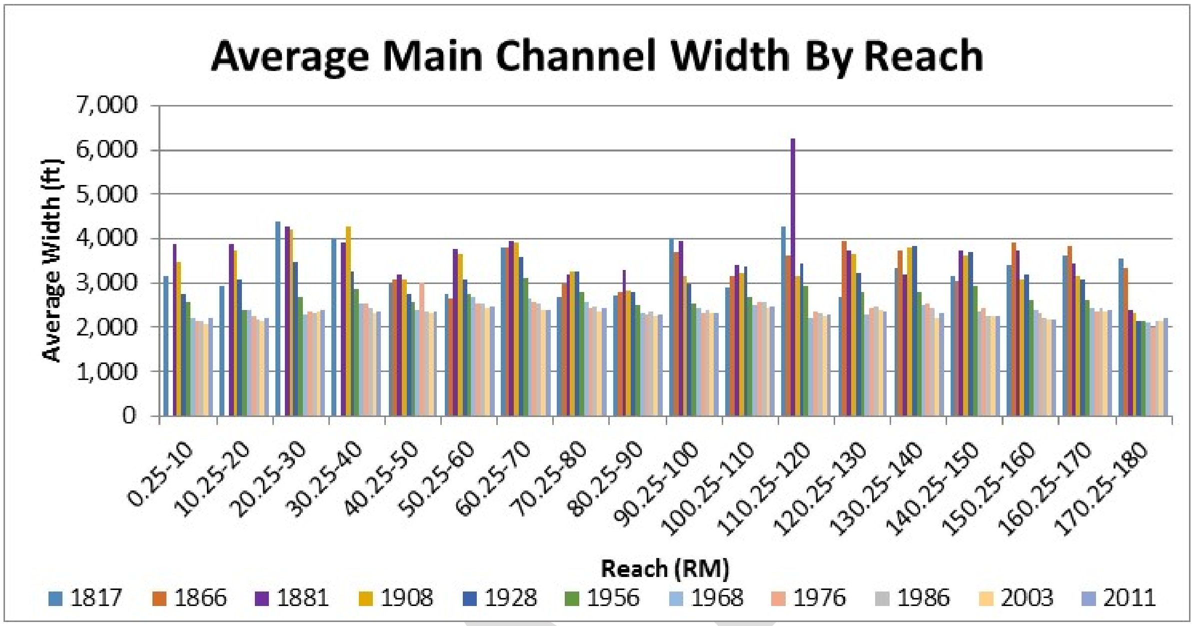


Figure 3-8. Average planform width of the MMR by 10-mile reach from 1817 to 2011.

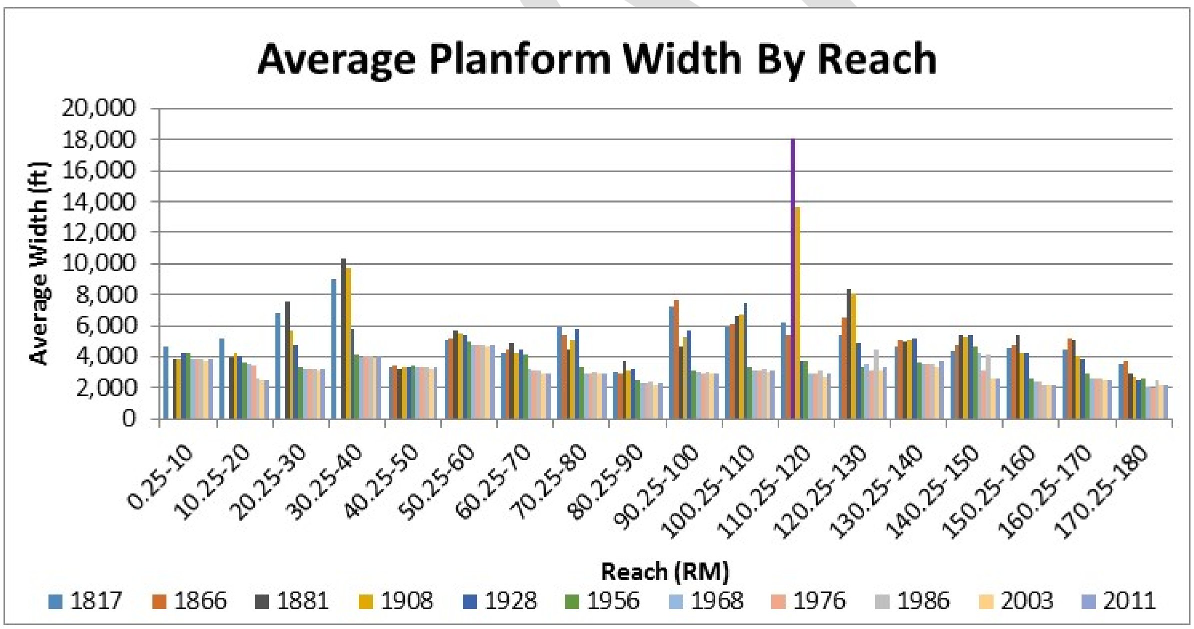


Figure 3-9. Average planform width of the main channel of the MMR by 10-mile reach from 1817 to 2011.

Changes in cross sectional area, hydraulic depth, conveyance and channel volume were studied using historical channel surveys from the years 1956, 1977, 1986, 1993, and 2013. Generally there has been an increase in cross sectional area, hydraulic depth[8], conveyance[9] and volume

[8] Hydraulic depth is defined as the cross sectional area of the water perpendicular to the direction of flow in the channel divided by the width of the free surface.
[9] Conveyance is defined as the carrying capacity of a channel.

throughout the period of record (Little et al. 2016). The Regulating Works Project has contributed to these changes, although it is uncertain to what extent. The purpose of dike construction is to manipulate the channel cross section to achieve the authorized navigation channel dimensions. In many cases, the new channel dimensions have resulted in a channel with increased conveyance.

3.2.3 Side Channels

Side channels have been shown to be extremely important fish habitat in the Middle Mississippi River. With the draining of floodplain lakes for agricultural development and the reduction of overbank flooding during high flows due to levee construction, side channels represent the major source of off-channel water bodies on the MMR. Side channels typically provide a well-defined gradient between flowing to non-flowing water depending on their level of connectivity to the main channel. Based on the level of water flow, side channels can function as wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels. Level of connectivity also affects substrates, water quality conditions (Crites et al. 2012), benthic macroinvertebrate communities (Bij de Vaate et al. 2007; Paillex et al. 2009) and fish faunas (Barko and Herzog 2003; Barko et al. 2004a). Flowing side channels, those connected to the main channel, generally have course bottom substrates (i.e., sand and gravel) and support large river aquatic species (suckers, minnows, and darters) tolerant of current and/or turbidity. Disconnected side channels generally have finer substrate types (sand and silt) and support lentic species that prefer moderate to low current and low turbidity levels (Barko and Herzog 2003). This diversity of habitat provides important feeding, spawning, nursery, and overwintering habitat for fish (Scheaffer and Nickum 1986; Lowery et al. 1987; Grift et al. 2001), and habitat for other environmentally sensitive macroinvertebrates, fish, and wildlife (Eckblad et al. 1984; Siegrest and Cobb 1987; Barko and Herzog 2003). Side channels also export nutrients, detritus, plankton, invertebrates, and fish to the main channel and the Gulf of Mexico (Eckblad et al. 1984; Cellot 1996; Simons et al. 2001; Hein et al. 2004; Preiner et al. 2008). As such, side channels are important to the health of the river ecosystem as a whole, and are even more important in the Middle Mississippi River because of the loss of hydraulic connectivity to the floodplain.

Side channels are also important because they are a refuge for fish escaping navigation related disturbances. Galat and Zweimuller (2001) and Wolter and Bischoff (2001) hypothesize that commercial navigation traffic may push fish toward the littoral zone or into side channels. Gutreuter et al. (2006) estimated the magnitude of traffic-induced reduction of fishes in the main channel of the Upper Mississippi River by comparing fish abundance in the navigation channel relative to abundance in side channels. They found the presence of some species was unaffected by traffic disturbances, whereas the presence of others was reduced. Thus, side channels contribute to the overall health of the riverine system (Baker et al. 1991; Simons et al. 2001).

For preparation of the 1976 EIS, the District conducted several studies (Johnson et al. 1974; Ragland 1974; Schramm and Lewis 1974) of side channel characteristics that documented the formation processes, existing biological and physical conditions, and importance of Middle Mississippi River side channels. Simons et al. (1974) concluded that, unless steps were taken to prevent it, "...ultimately nearly all natural and man-induced side channels should completely fill with sediment and become undistinguishable from the flood plain." However, the EIS cautioned that the Simons et al. findings were based on dike specifications from the previous decade and "...it is now the current practice of the St. Louis District to construct dikes to a lower elevation than previously used. It is anticipated that the lower dike elevations will cause numerous channels to be perpetually maintained along and between these structures because of regime changes in the channel between low and high flow and the associated scouring effects over and around the low dikes."

There are currently 32 side channels existing in the MMR (Figure 3-10). As outlined in the following sections, the District has undertaken several recent analyses on these side channels to document the historic and current conditions of the side channels and to help determine whether or not they are deteriorating as predicted in the 1976 EIS. Analyses include:

- Geomorphology study of the MMR using historic and modern maps, surveys, and georeferenced aerial photography to calculate changes in side channel planform through time described in Section 3.2.2;
- Calculation of side channel volumes and mean depths using survey data from the 1950s, 1980s, 1990s, 2000s, and 2010s to determine if changes have occurred over time in overall side channel size and depth characteristics; and
- Calculation of side channel connectivity using recent survey data and period of record hydrograph data to provide information on the accessibility of side channel habitat to fish.

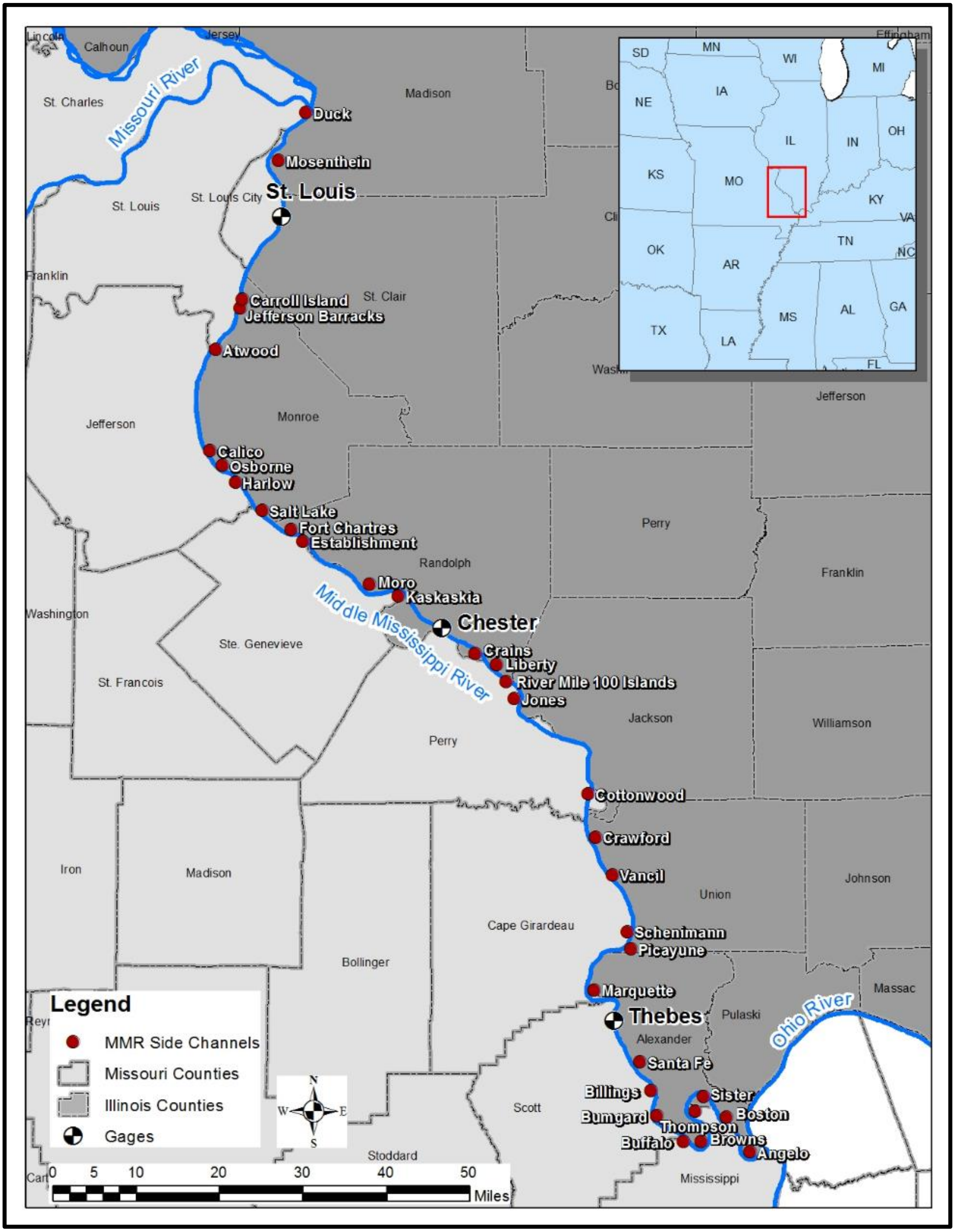


Figure 3-10. Locations and names of all existing Middle Mississippi River side channels.

Geomorphology study

As described in Section 3.2.2, an analysis of changes in river planform in the MMR was recently conducted by the District (Brauer et al. 2005; Brauer et al. 2013). The analysis utilized historic and modern maps, surveys, and aerial photography to calculate changes through time in planform width, channel width, channel surface area, side channel width, etc. With respect to side channel condition, the analysis provides information on the changes through time in side channel width and recent stability, or lack thereof. The analysis demonstrates that side channels generally went through a period of narrowing from the mid-1800s through the mid-1900s, followed by relative stability since the 1950s (Figure 3-11). The planform widening that occurred in the early 1800s was the result of major changes in the watershed and bank erosion due to clearing of riparian vegetation. As can be seen in the images of Angelo Chute in Figure 3-12, MMR side channels typically went through a period of rapid development and change from the late 1800s through the mid-1900s in response to river training structure placement that started in the late 1800s. By the mid-1900s, the positions of most side channels were relatively fixed with very little change in planform occurring since the 1980s. A full record of time series maps similar to Figure 3-12 for all MMR side channels can be found at:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

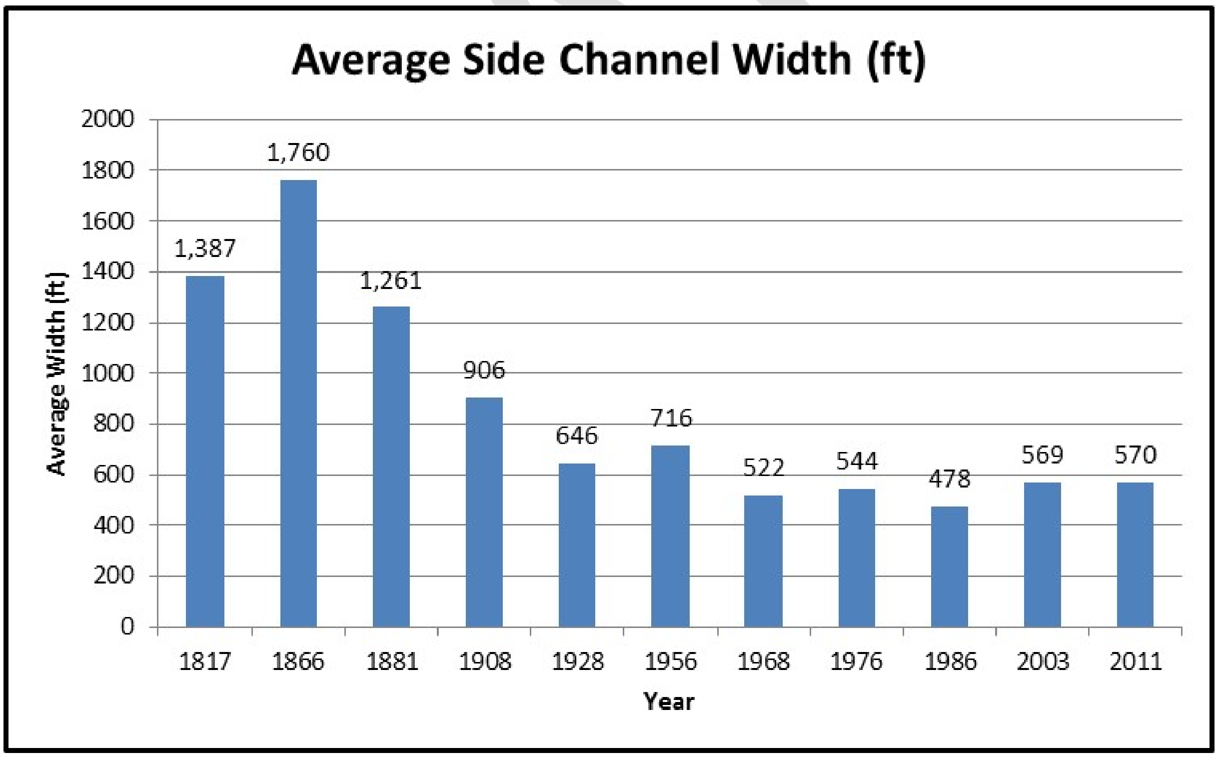


Figure 3-11. Average planform width of MMR side channels from 1817 to 2011 (from Brauer et al. 2013).

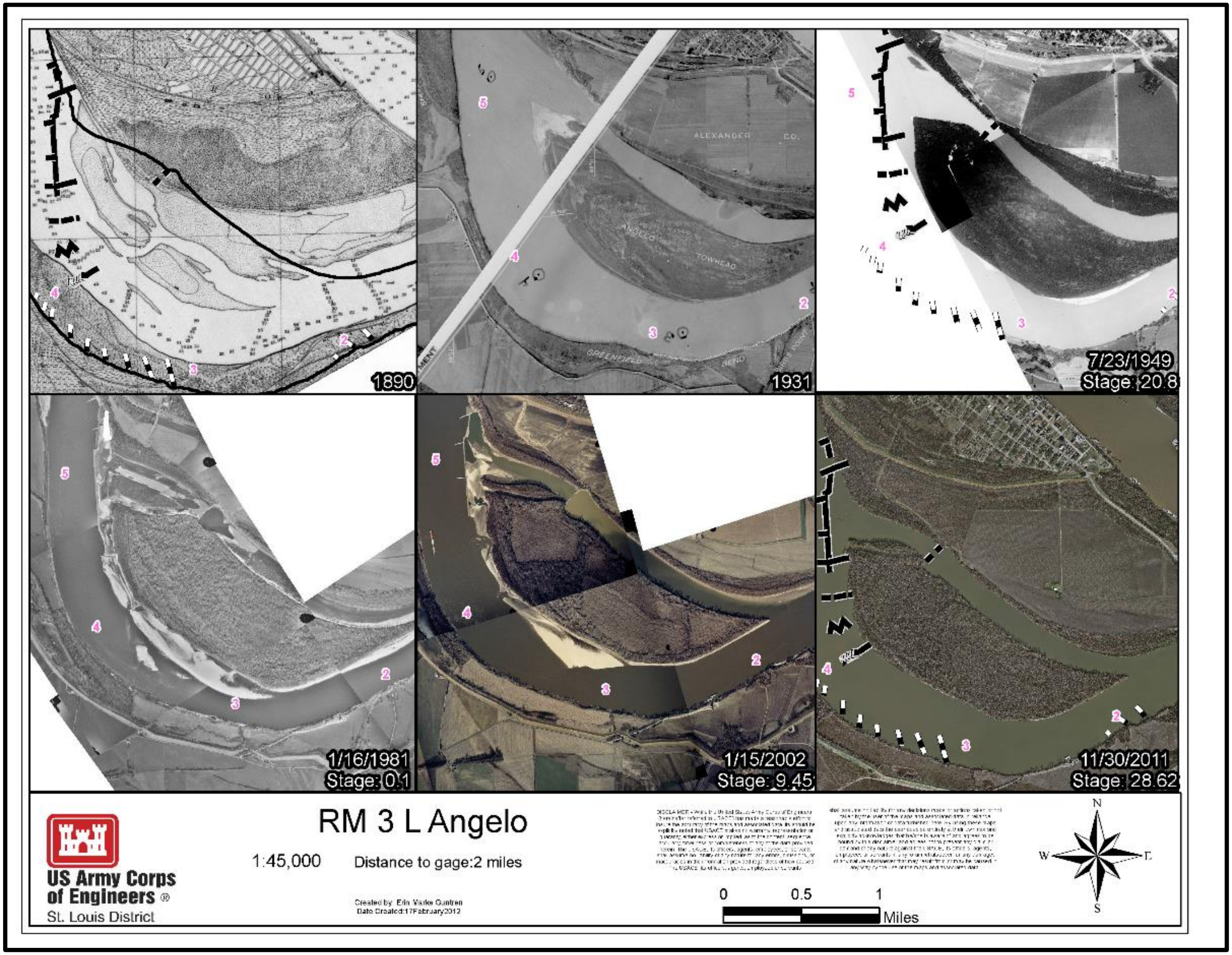


Figure 3-12. Time series imagery showing the formation and recent stability of Angelo Chute.

Bathymetric Analyses

Based on the geomorphology study and historic photography, most MMR side channels have not changed significantly in planform characteristics since the mid-1900s. However, it is possible that the depth characteristics could change without any change in planform characteristics – the side channels could be shallowing or deepening without any associated change in width. The quality and quantity of habitat provided by an individual side channel is closely tied to its depth characteristics. Accordingly, a series of analyses were conducted by the District to determine what changes have been occurring to side channel depth characteristics. For historic bathymetry, side channel transect surveys from 1956, 1986, 1993, and 2001 were used. Historic data sets do not exist for all side channels and some side channels are too shallow and/or remote to be easily accessible by survey boats. In addition, transect surveys by their very nature do not provide complete coverage of the surveyed side channels, only providing depth information at regular intervals throughout the side channel, depending on the spacing of each particular survey (e.g., see 1000-ft. transect spacing in Figure 3-13). However, transect surveys are the only quantitative information available on the historic depth conditions of MMR side channels, and are, therefore, the best available information for determining historic trends in MMR side channel bathymetric characteristics.

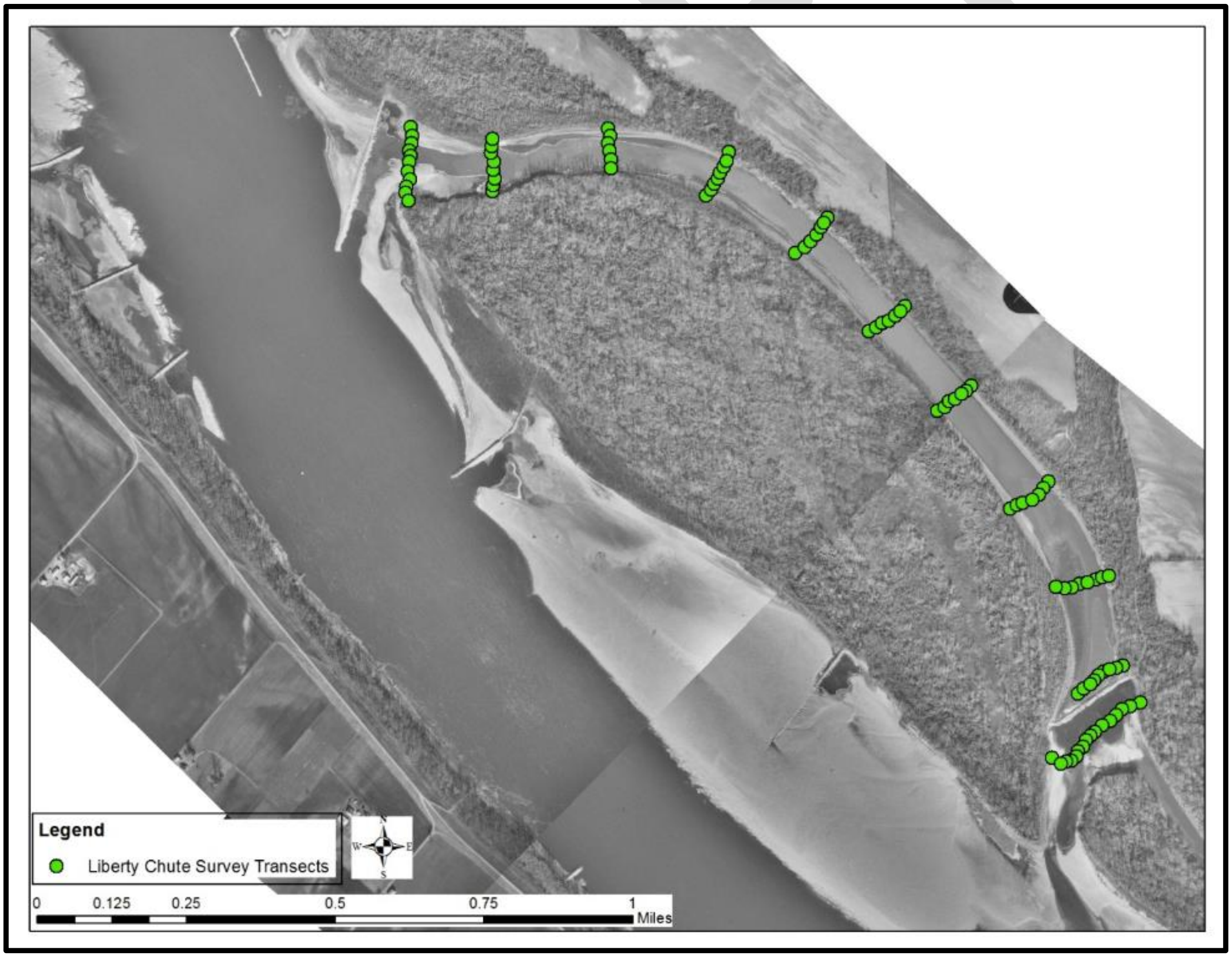


Figure 3-13. Example of spacing of historic transect survey data (Liberty Chute, 1986 survey, 1000-ft. intervals, 1981 imagery).

From the historic transect data, volume and mean depths were calculated for each time period for which surveys were available. Mean depth was determined to provide the best overall indicator of changes in depth characteristics of side channels over time, and is presented here. The results of the transect mean depth data analysis can be found in Table 3-2. In order to facilitate comparisons of volume and mean depth measurements between years, the analysis for each side channel was limited to the common area that was covered by all survey years. This eliminated the possibility of data skewing due to differing survey footprints among years.

In addition to the historic transect data analysis, the District also analyzed recent high quality multi-beam side channel survey data. Multi-beam surveys provide 100% coverage of the survey area (Figure 3-14) and can provide hyper-accurate bathymetric detail, lending to a better ability to accurately track changes in depth through time. This could provide information on potential recent trends in side channel depths as well as provide an indication of the amount of short-term variability in side channel bathymetry. Multi-beam surveys were available for MMR side channels starting in 1999. Availability of multi-beam data between 1999 and 2014 varied by side channel with some having as many as seven surveys and some having as few as two. Regardless of the number of surveys available, very accurate comparisons could be made between years for which multi-beam surveys were available. Similar to transect data, volume and mean depth were calculated for all multi-beam surveys. Mean depth results can be found in Table 3-2. Side channel volume results can be found in Figure 3-15. Again, in order to facilitate comparisons between survey years, the analysis was limited to the common footprint covered by all survey years.

Based on the analysis of transect and multi-beam data, overall depth characteristics of MMR side channels appear to be stable or increasing, although a considerable amount of interannual variability occurs due to shifting sandbar formations in response to changing river stages and flows. Of the 20 side channels for which bathymetric surveys were available for a period spanning at least 15 years, 13 showed an increase in average depth over the period of record and 7 showed a decrease. Likewise, total volume of MMR side channels has increased in the last 15 years.

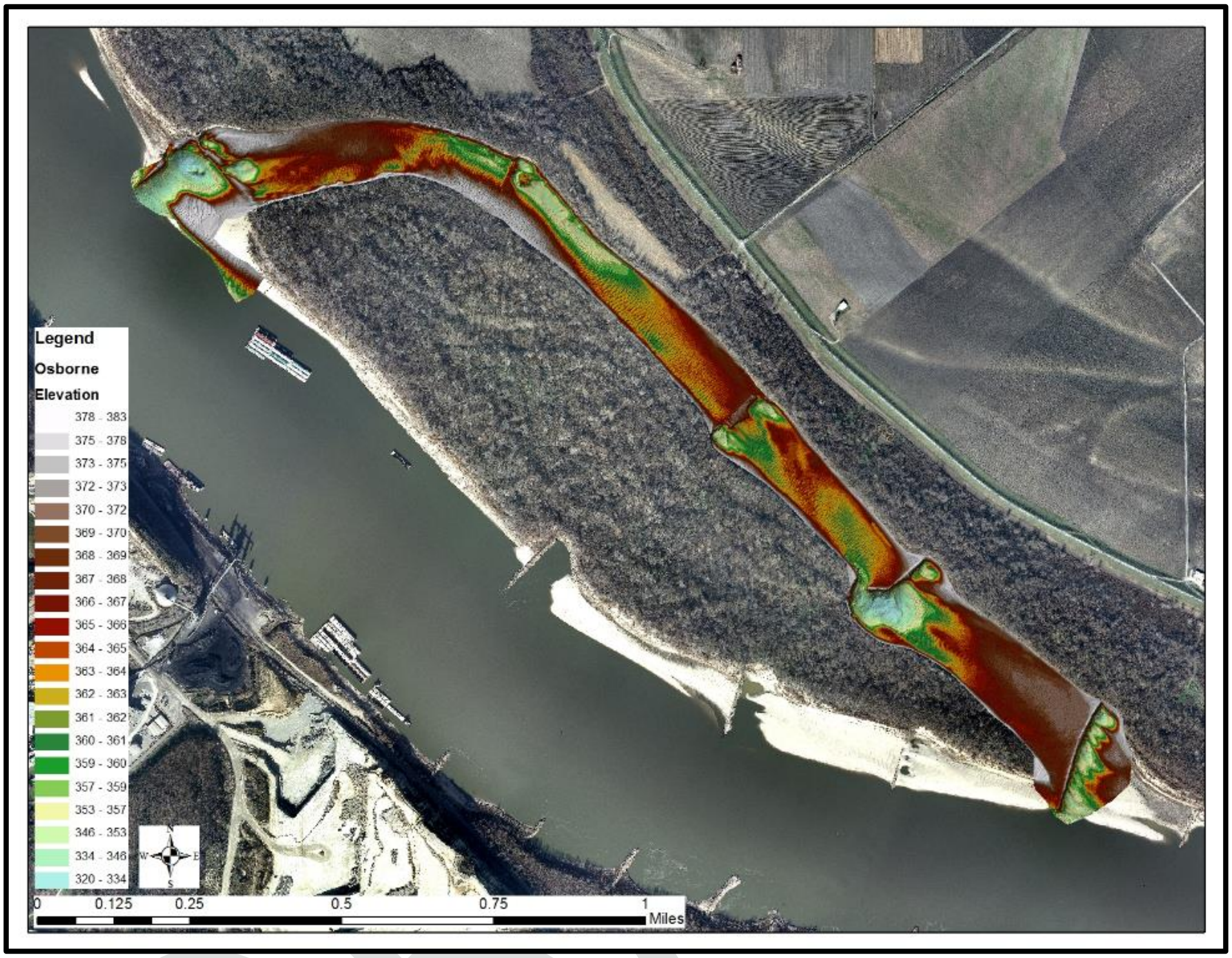


Figure 3-14. Example of multi-beam survey data (Osborne Chute, 2014 survey, 2012 imagery).

Table 3-2. Results of bathymetric analysis. Values are mean depth (in feet below April median water surface elevation to provide an estimate of average water depth during high water). Red-shaded cells denote a decrease in mean depth from the previous survey. Green-shaded cells denote an increase in mean depth from the previous survey.

Name	River Mile**	1956	1986	1993-1996	1998-1999	2001-2004	2011	2014
Duck*	195R	No Data						
Mosenthein	188L	No Data						
Carroll	168L	No Data						
Jefferson Barracks	167L			9.43	11.18	12.96	15.60	17.02
Atwood	161L	6.58		10.61		15.28	18.51	18.78
Calico	148L	12.53		10.72	9.95	10.43	10.86	11.26
Osborne	145L	11.17	12.97	10.29	11.38	12.17	13.88	16.08
Harlow	143R	No Data						
Salt Lake	138L	8.17	11.82	9.43	8.75		11.03	12.08
Fort Chartres	133L	17.45	8.65	6.30		6.93	7.19	6.83
Establishment*	131R		10.09	11.50	15.15		17.30	17.83
Moro	122L		11.56		10.63	10.60	12.76	9.16
Kaskaskia	118R	No Data						
Crains	104R				9.14		7.89	7.52
Liberty	101L		19.45		17.37	15.63	15.22	13.81
River Mile 100 Islands	100R	No Data						
Jones*	97R			13.07	14.60	12.75	18.18	18.50
Cottonwood	78R	20.95	15.27	15.62		15.69	13.37	12.34
Crawford	73L		8.77	7.95	7.72	7.48	10.67	11.64
Vancil	68R	No Data						
Schenimann	60R			16.13		19.17	21.31	22.28
Picayune	58L					20.98	23.48	24.76
Marquette*	49L	16.20		17.70		14.51	19.99	19.26
Santa Fe*	38L			16.52		18.02		
Billings	33R	No Data						
Bumgard*	30L				17.18		20.20	19.79
Buffalo	25R	21.12		22.98	19.09	19.35	21.00	21.83
Browns	23L	21.44	20.14	20.95		18.25	20.47	20.51
Thompson	17R	No Data						
Sister*	12R			21.56		18.40	20.45	22.42
Boston	9L						19.49	19.19
Angelo	3L			24.47		24.93	28.31	27.83

*Denotes side channels that have had restoration measures implemented (Table 3-4).

****** R and L denote Right Descending Bank and Left Descending Bank, respectively, indicating the side of the river the side channel occupies (as viewed by a person looking downstream).

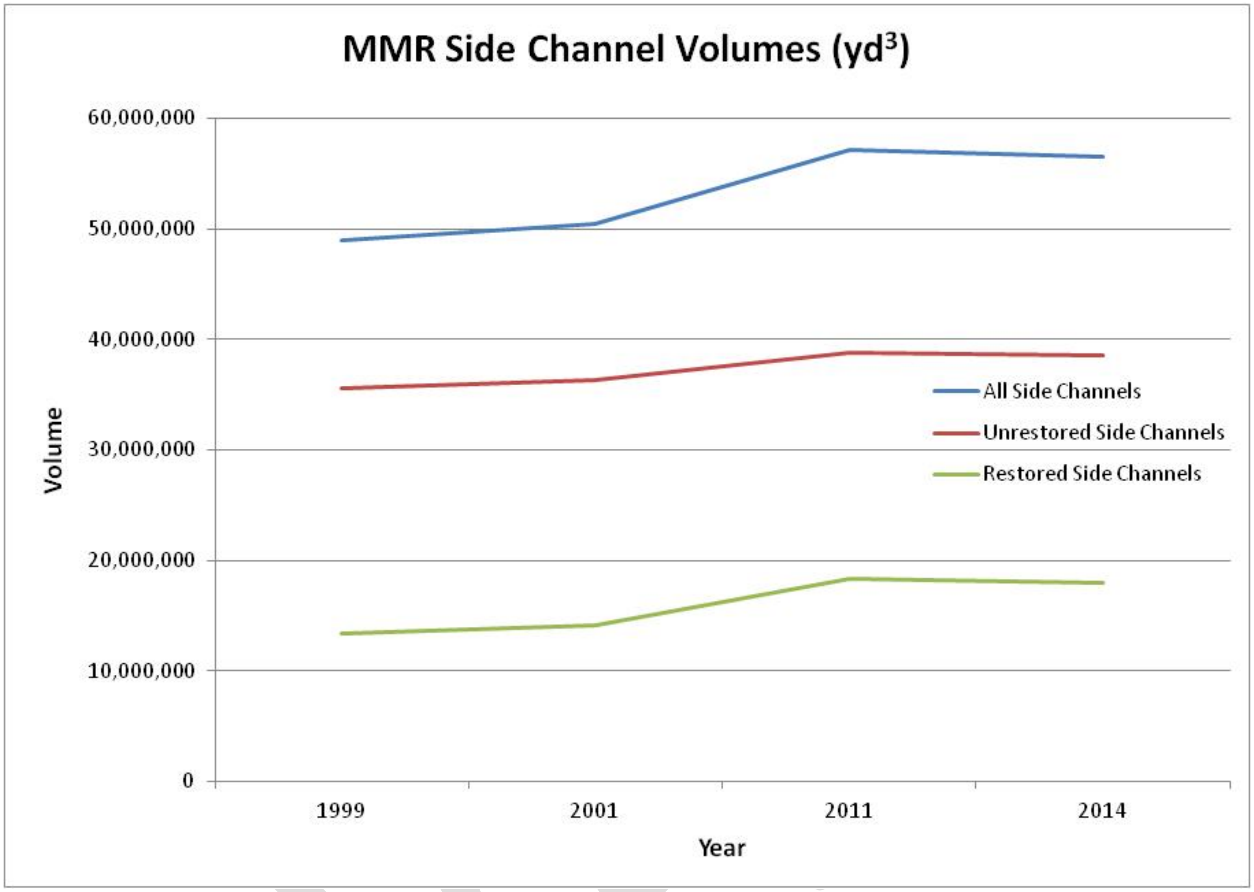


Figure 3-15. Total volume in cubic yards of MMR side channels for which multibeam datasets were available.

Connectivity Analysis

The District also recently conducted a connectivity analysis of MMR side channels to determine to what degree side channel habitat is accessible to fish from the main channel and vice versa. The connectivity of side channels is an important factor in determining the habitat they provide to fish. Due to the placement of rock closing structures, almost all MMR side channels are isolated from the main channel at certain river stages dependent upon the top elevation of the closing structure and any associated sedimentation patterns (Figure 3-16). The original purpose of closing structures was to shunt water to the main channel to support navigation flows. Of the existing thirty-two side channels, only one, Cottonwood, does not have a closing structure. The remaining MMR side-channels are in various successional stages, including wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels. The successional stage is related to side channel bed elevation and river stage, which translate into the level of connectivity to the main channel.

Figure 3-16. Low-water (left, 2012) and high-water (right, 2009) imagery of Sister Chute showing the difference in side channel connectivity based on river stage.

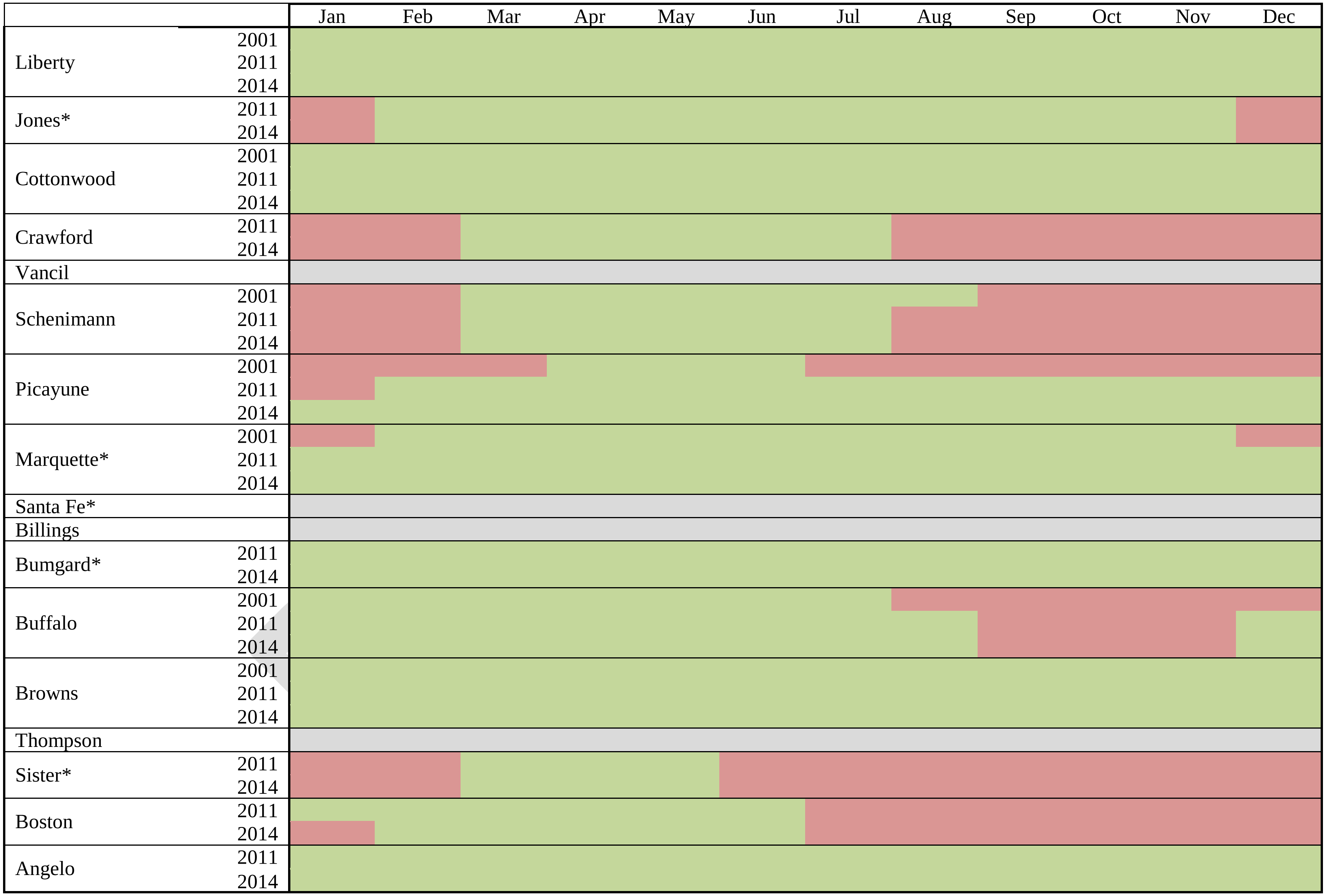
To determine the degree of connectivity of MMR side channels, multi-beam bathymetric surveys and median monthly river stages based on the period of record hydrograph were used. Bathymetric surveys were used to determine the choke points, or points that control the flow of water based on their elevation, of all side channels to determine at what river stage the side channels would be connected to the main channel. These choke point elevations were then compared to median monthly river stages to determine during which months the side channels would be connected. Median monthly river stages were used in order to provide an analysis of 'typical' connectivity conditions by month. This analysis was conducted for each side channel for every year that a multi-beam survey was available. An example of the choke points in one side channel can be found in Figure 3-17. The results of the connectivity analysis can be found in Table 3-3. In addition to the degree of connectivity, rates of change for choke point elevations were also considered to determine how quickly choke points were changing. Only those side channels for which multibeam datasets from 2001 and 2014 existed were used to calculate average annual changes in choke point elevations to avoid drawing conclusions from short time periods. The results of this analysis can be found in Figure 3-18.

Similar to average depth and volume characteristics, connectivity of MMR side channels reflects the expected variability in bathymetry but also holds to the general trend of stability or improvement. Of the 25 side channels for which connectivity was calculated for more than one year, 14 showed improved connectivity, 8 remained the same, and 3 showed decreased connectivity. Of the 15 side channels for which choke point elevations were available for 2001 and 2014, 13 showed improved chokepoints and 2 showed worsening chokepoints.

Figure 3-17. Example of connectivity analysis (Establishment Chute). Blue shading indicates the areas of the side channel that would be inundated at the point when the side channel becomes connected to the main channel. Yellow lines and yellow numbers indicate choke points and elevations. In this case, flow through the side channel would only occur at elevations of 13.8 or higher, as that is the highest of the three choke point elevations. This choke point elevation was then compared to mean monthly stages at the site to determine connectivity by month (see Table 3-3).

Table 3-3. A visual representation of flow conditions for Middle Mississippi River side channels showing months when channels are connected to the river and flowing (green) and when they are not flowing (red) based on median monthly stages and 2001, 2011, and 2014 bathymetric data. Gray represents side channels with insufficient data and/or with high barriers restricting flow during all but extremely high water events (modified from Keevin et al. 2016).

Side Channel		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duck*	2001												
	2011												
	2014												
Mosenthein	2011												
	2014												
Jefferson Barracks	2001												
	2011												
	2014												
Atwood	2001												
	2011												
	2014												
Calico	2011												
	2014												
Osborne	2001												
	2011												
	2014												
Harlow													
Salt Lake	2001												
	2011												
	2014												
Fort Chartres	2001												
	2011												
	2014												
Establishment*	2011												
	2014												
Moro	2001												
	2011												
	2014												
Kaskaskia	2001												
	2011												
	2014												
Crains	2011												
	2014												



*Denotes side channels that have had restoration measures implemented (Table 3-4).

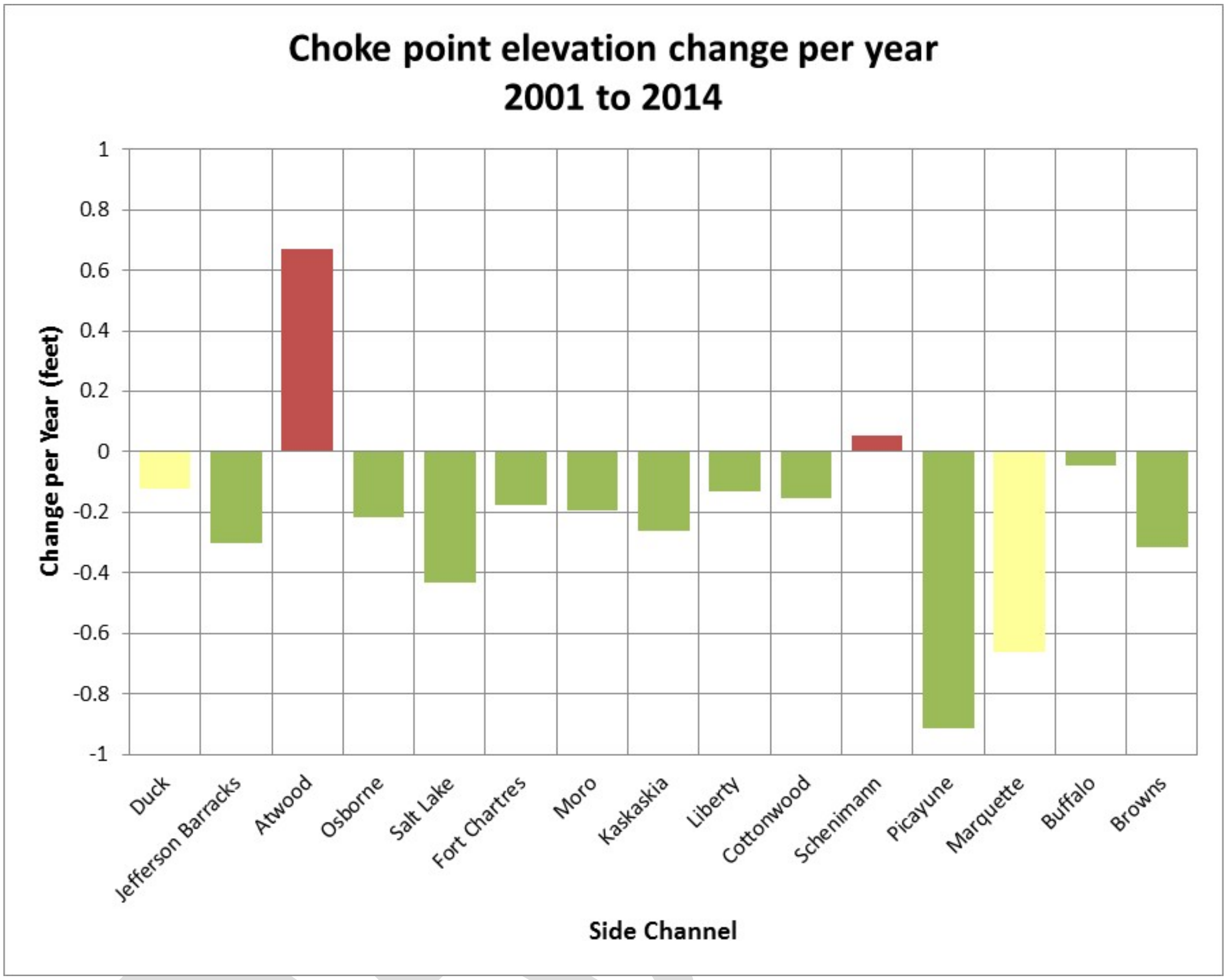


Figure 3-18. Recent changes in elevations of choke points of MMR side channels. Changes are provided for only those side channels for which 2001 and 2014 multibeam bathymetric datasets were available. Changes are in feet per year, with green representing a decrease in elevation and red representing an increase. Yellow shading indicates side channels where restoration activities occurred.

Side Channel Restoration Efforts

Beginning in the late 1990s, the District started to undertake side channel restoration projects under various authorities. These efforts typically consist of features to improve the connectivity of the side channel and/or improve the habitat within the side channel. Improvements have involved the removal or notching of closing structures and other dikes, placement of hard points within the side channel to increase habitat diversity, and dredging to deepen and improve the connectivity of the side channel. Table 3-4 provides details of all side channel restoration efforts undertaken in the MMR by the District to date. Clear before-and-after differences can be seen in the mean depth and connectivity characteristics of some of the restored side channels, particularly those that involved closing structure notching and/or dike removal (Table 3-2 and Table 3-3 above). For example, subsequent to dike removal and closing structure notching in 2008, Jones Chute's mean depth increased by approximately 5.5 feet. Similarly, after closing structure and dike notching in 2012, Establishment Chute's connectivity improved substantially.

Based upon available funding and continued authority, it is expected that the District will continue to plan and implement MMR side channel restoration projects.

Table 3-4. Middle Mississippi River side channel restoration efforts.

Side Channel	Year Restoration Initiated	Features Implemented
Santa Fe	1997	Hardpoint construction
Bumgard	1999	Hardpoint construction
Duck	2001	Hardpoint construction
Marquette	2001	Closing structure notching
Sister	2006	Environmental dredging
Jones	2008	Dike Removal, closing structure notching, dike construction, hardpoint construction
Establishment	2012	Dike/closing structure notching, side channel enhancement dike construction to increase volume of water flowing through side channel

Summary of Findings on Side Channels

Drawing broad, general conclusions about the status of MMR side channels is difficult due to the unique characteristics of each individual side channel and due to the dynamic nature of the system of which they are a part. Trends can be difficult to discern when clouded by the variability that is added by extreme flood and drought events that are part of every large river system. However, focusing on long-term trends helps to eliminate the noise imparted by short-term anomalies and some general trends can be seen in the long-term records. Based on aerial photography and geomorphology characteristics, most MMR side channels appear to be very stable in planform characteristics, with very little change occurring since the mid-1900s. Based on bathymetric surveys, overall depth characteristics likewise appear to be stable or improving, although a considerable amount of interannual variability occurs. Connectivity of MMR side channels reflects the variability in depth characteristics as well but also holds to the general trend of stability or improvement.

These trends were also considered without inclusion of side channels that have undergone any type of restoration activity in order to gain an understanding of the “natural” trends of MMR side channels without intervention (see Table 3-4 for a list of side channels where restoration projects have occurred). A total of 32 side channels exist in the MMR, 25 of which would be considered unrestored. Of the 25 unrestored side channels, 15 have bathymetric surveys available for a period spanning at least 15 years. Of those 15, 8 showed an increase in average depth over the period of record and 7 showed a decrease (Table 3-2). Total volume of unrestored MMR side channels has increased slightly in the last 15 years (Figure 3-15). Of the 19 unrestored side channels for which connectivity was calculated for more than one year, 9 showed improved connectivity, 6 remained the same, and 4 showed decreased connectivity (Table 3-3).

The above general conclusions about MMR side channel characteristics hold true for the majority of MMR side channels. However, there are several side channels that are typically inaccessible due to log jams or tree encroachment and consequently cannot be readily surveyed. Carroll Island Chute underwent a fairly rapid transition to what is now largely terrestrial habitat (Figure 3-19). Harlow Island Chute has undergone a similar transformation. Within the last 10 years, Crains and Billings Chutes have become partially filled with log jams. Some of the log jams cleared from Crains during a recent high water event, but others remained. The long-term fate of these side channels is difficult to predict with any degree of certainty.

Figure 3-19. Imagery of Carrol Island Chute (river mile 168) showing filling and conversion to terrestrial habitat from 1981 to 2012.

Thompson Chute has experienced tree encroachment on the upper and lower ends, but appears to be stable in planform throughout the rest of the channel. Without the ability to obtain bathymetric surveys it is difficult to say whether or not Thompson is maintaining its depth. Vancil is a very small side channel that is difficult to access for surveying purposes and it is difficult to predict whether or not Vancil is filling in.

It should be noted that the River Mile 100 Islands side channel (Figure 3-20) is not a naturally formed side channel and is dissimilar in morphology to other MMR side channels. The islands associated with this particular side channel were formed as a result of the wing dikes being constructed with notches in them to encourage sandbar/island formation. Similar results may be possible in other locations on the MMR either through dike notching and/or with the use of the floating flexible dredge pipe currently in use by the District (see Section 4.3.2 Impacts on Fishery Resources for information on the floating flexible dredge pipe).

Figure 3-20. River Mile 100 Islands side channel during high water (looking downstream).

3.2.4 Water Quality

Consideration of water quality encompasses a wide range of physical, hydrologic, and biological parameters. Watershed influences, including tributary streams, point and non-point pollution sources, flow alteration due to navigation structures, and drought and flood events all influence water quality. Variations in land use practices, cover types, and watershed area will determine the level and type of sediment, nutrient, and contaminant inputs into the Mississippi River and its tributaries.

The Mississippi River has a long history of water quality impairment due to contamination from industrial, residential, municipal, and agricultural sources. However, recent changes in wastewater treatment laws and technologies, regulation of point source discharges, and changes in public awareness have contributed to dramatic overall improvements in water quality since the

1970s. Water quality monitoring has been conducted in the MMR through the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring (LTRM) element since 1991. Analysis of LTRM data (Johnson and Hagerty 2008) shows that although the MMR has improved, it currently exceeds suggested nutrient (total nitrogen and phosphorus) guidelines either part of the time (nitrogen) or most of the time (phosphorous). During major storm events, raw sewage still enters the river because of sewage treatment plant overloads due to combined (sewage/stormwater) sewage systems.

Although the USEPA has oversight authority, particularly with regard to interstate water quality, it is the responsibility of the individual states to implement most of the Clean Water Act, including the establishment of water quality standards. Section 303(d) of the Clean Water Act requires states to generate lists of impaired water bodies every two years. Impaired water bodies are those that do not meet state water quality standards for the water bodies' designated uses. However, there are inconsistencies among state water quality standards. Specific water quality criteria for individual pollutants may vary depending on the designated use for a specific segment of the Mississippi River. The Middle Mississippi River was included on the 2014 state of Missouri 303(d) list for St. Louis City, St. Louis County and St. Genevieve County due to fecal coliform contamination from point and non-point sources of wastewater treatment plant effluent and urban storm water. The 2014 state of Illinois 303(d) list places use restrictions for human contact-recreation due to fecal coliform contamination and fish consumption due to mercury and PCB contamination along the length of the Middle Mississippi River.

There are also fish consumption advisories for the MMR for both Missouri and Illinois. Missouri has fish consumption advisories for the Mississippi River for Shovelnose Sturgeon (one meal per month) and for Flathead Catfish, Blue Catfish, Channel Catfish, and Common Carp (one meal per week) due to PCB, chlordane, and mercury contamination (MDHSS 2015). Illinois has fish consumption advisories for the Mississippi River for Channel Catfish (one meal per week), Common Carp (one meal per week), and sturgeon (one meal per month) due to PCB contamination (IDPH 2014).

3.2.5 HTRW

Environmental Site Assessments

Corps regulations (ER 1165-2-132 and ER 200-2-3) and District policy require procedures be established to facilitate early identification and appropriate consideration of potential hazardous, toxic, or radioactive waste (HTRW) in reconnaissance, feasibility, preconstruction engineering and design, land acquisition, construction, operations and maintenance, repairs, replacement, and rehabilitation phases of water resources studies or projects by conducting Environmental Condition of Property (ECP) Assessments. The Corps specifies that these assessments follow the process/standard practices for conducting Phase I Environmental Site Assessments (ESA) published by the American Society for Testing and Materials (ASTM).

This assessment was prepared using the following ASTM Standards:

- E1527-13: Standard Practice for Environmental Site Assessments – Phase I Environmental Site Assessment Process

- E1528-06: Standard Practice for Limited Environmental Due Diligence – Transaction Screen Process (interview questionnaires)
- E2247-08: Standard Practice for Environmental Site Assessments – Phase I Environmental Site Assessment Process for Forestland or Rural Property

The purpose of an ECP is to identify, to the extent feasible in the absence of sampling and analysis, the range of contaminants (i.e., Recognized Environmental Conditions[10] or RECs) within the scope of the U.S. Environmental Protection Agency's (EPA) Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and petroleum products.

All proposed improvements and construction projects are evaluated for potential soil contamination, groundwater quality, surface water quality and issues related to hazardous substance uptake by biota. Site visits are conducted to observe present conditions and check for the presence of chemical spill residue, die-back of vegetation, and prior environmentally hazardous activities. Historical aerial photography of the vicinity and U.S. Geological Survey (USGS) maps are also used to study drainage patterns and topography.

Information is obtained through reviews of records and reports, reviews of environmental databases, site reconnaissance, and interviews of persons knowledgeable of the property history. The readily available electronic records of the U.S. Environmental Protection Agency (USEPA) EnviroMapper and state and local databases are reviewed to identify Superfund sites, toxic releases, or hazardous waste sites within or directly adjacent to the potential project sites.

Records Review
A modified Phase I- Environmental Site Assessment records search was conducted to identify superfund sites, toxic chemical spills, or hazardous waste sites directly adjacent to or within the banks of the Middle Mississippi River. The readily available electronic records of the USEPA, the Missouri Department of Natural Resources (MDNR), the Illinois Environmental Protection Agency (IEPA), and the USGS found numerous permitted, regulated, and documented sources of chemical pollutants along both banks of the Middle Mississippi River. This review also found areas which could potentially be impacted by the alternatives.

Findings of Records Review

Sauget Area 2 Superfund Site
The Sauget Area 2 Superfund Site is located on the left descending bank (LDB) near river mile (RM) 178 (Figure 3-21). The site consists of four landfills and four backfilled lagoons. The sites contain hazardous wastes that resulted from treatment and disposal of industrial, municipal, and chemical wastes. In 2005, USEPA contractors collected and analyzed sediments from the Mississippi River for total organic carbon, volatile organic carbon, polychlorinated biphenyl (PCB), pesticides, herbicides and sediment grain-size. Core samples collected from 28 sample locations along the river adjacent to the site had elevated levels of organochlorine pesticides,

---

[10] Recognized Environmental Conditions are defined by ASTM E1527-13 as "...the presence or likely presence of any hazardous substances or petroleum products in, on, or at a property..."

aromatic hydrocarbons, and PCBs. Samples collected from the left descending bank of the river near Jefferson Barracks chute at RM 170 and from the right descending bank at RM 172 contained concentrations of pesticides and PCBs exceeding Ecological Screening Levels. In 2006, USEPA completed the installation of a 3,500-foot long, 140-foot deep jet grouted barrier wall between the down gradient boundary of the site and the Mississippi River. Measures were put in place to protect the shoreline from erosion along with controls to prevent disturbance of soil and waste. The soil and waste on the site were capped with layers of soil, asphalt, crushed rock and other materials to contain contamination. A pumping system was installed to collect and store oil, petroleum products and liquids including chlorinated solvents present on the site. Continued cleanup is planned for the site including further capping of waste sites with soil, asphalt, crushed rock and other materials to contain contamination; installation of a pumping system to collect contaminants in a well at the site; and further measures to prevent Mississippi River shoreline erosion adjacent to the site.

Doe Run Lead Smelter

Runoff from the area around the Doe Run lead smelter in Herculaneum, Missouri, flows into Joachim Creek and discharges into the Mississippi River along the RDB at RM 151.4. The runoff from this area carries with it lead- and zinc-contaminated fine sediment from the smelter facility and the slag pile adjacent to the creek. The contaminated sediments are most likely washed into the river during high flow events since these metals have been detected below the confluence of Joachim Creek.

Laboratory tests were performed on sediment samples collected up and down river of Herculaneum at varying times between 1999 and 2009 by the USGS, IEPA, and MDNR. The average lead and zinc concentrations upstream between Joachim Creek and St. Louis were 15.2 and 62.2 µg/L respectively. The average concentrations at the Joachim Creek outfall were measured at 1710 and 4920 µg/L respectively and far exceeded the values commonly reported as toxic to aquatic life. The average lead and zinc concentrations recorded between 0.2 and 6 miles below the outfall were 15.3 and 50.9 µg/L respectively and 50 miles downstream the averages were 14.1 and 63.3 µg/L respectively. These test results indicate that the insoluble lead and zinc particles settle less than a mile from where they are discharged and are not transported farther downstream by the river.

The company reached a comprehensive settlement with the USEPA and the state of Missouri to discontinue its smelting operations in Herculaneum. Cleanup activities were undertaken to remedy the lead- and zinc-contaminated fine sediments leaving the Herculaneum Smelter site. The selected removal action included engineering measures to contain and treat water runoff, control erosion, provide flood protection, provide long-term stability, and mitigate wetland disturbance. This remedial action also included construction of a flood protection berm, a storm water retention basin, and an engineered cover for the slag material.

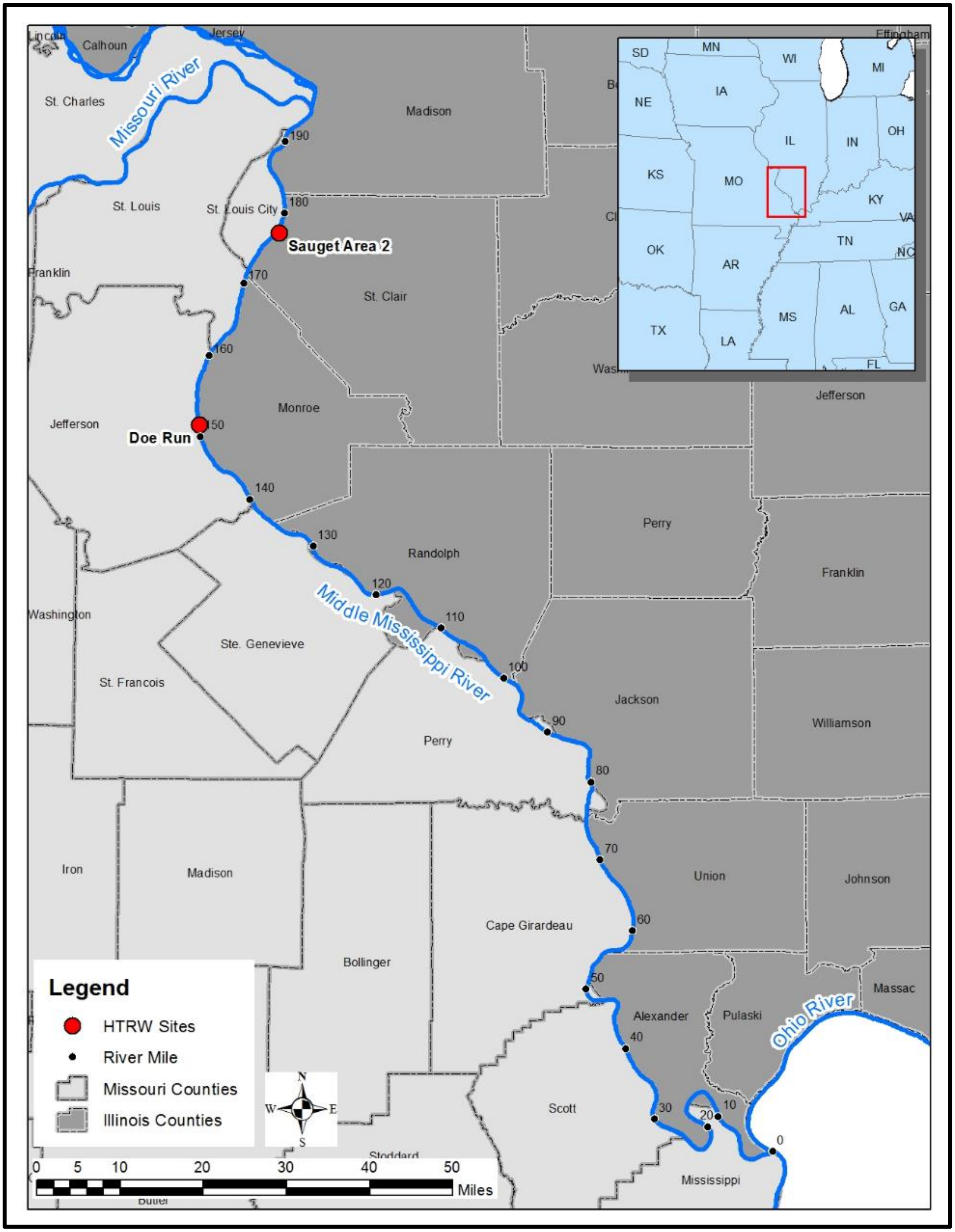


Figure 3-21. Locations of potential HTRW issues within the Project Area discovered through a modified Phase I Environmental Site Assessment records search.

3.2.6. Air Quality and Climate Change

Air Quality. The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants: ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead. EPA regulates these pollutants by developing human health-based or environmentally-based permissible pollutant concentrations. EPA then publishes the results of air quality monitoring, designating areas as meeting (attainment) or not meeting (nonattainment) the standards or as being maintenance areas. Maintenance areas are those areas that have been redesignated as in attainment from a previous nonattainment status. A maintenance plan establishes measures to control emissions to ensure the air quality standard is maintained in these areas.

Figure 3-22 and Table 3-5 contain information on the nonattainment areas in Missouri and Illinois counties in the Project Area. All of the nonattainment areas are located in close proximity to the St. Louis Metropolitan area and include St. Louis City, St. Louis County, Jefferson County, Madison County, St. Clair County, Monroe County, and Randolph County.

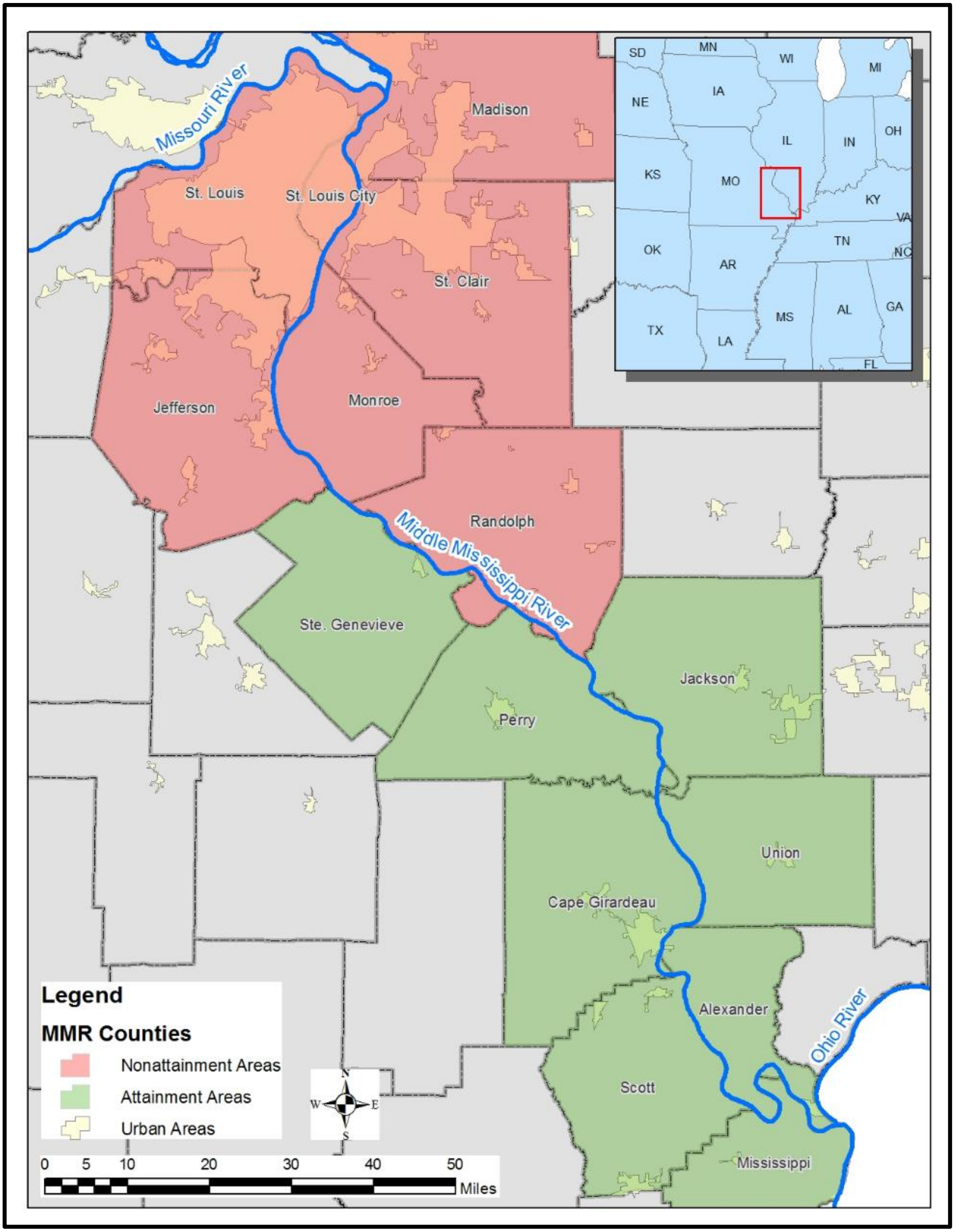


Figure 3-22. Attainment/Nonattainment status of Missouri and Illinois MMR counties for six criteria air pollutants (based on 5 December 2013 USEPA data).

Table 3-5. Nonattainment areas in Missouri and Illinois within the Project Area (based on 5 December 2013 USEPA data).

County	Pollutant	Classification*
Missouri		
St. Louis County	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
St. Louis City	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Jefferson County	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Lead (1978 Standard)	N/A
	Lead (2008 Standard)	N/A
	Particulate Matter – 2.5 (1997 Standard)	N/A
	Sulfur Dioxide (2010 Standard)	N/A
Illinois		
Madison County	8-hour Ozone (2008 Standard)	Marginal
	Lead (2008 Standard)	N/A
	Particulate Matter – 2.5 (1997 Standard)	N/A
St. Clair County	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Monroe County	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Randolph County	Particulate Matter – 2.5 (1997 Standard)	N/A

*Nonattainment area designations based on Environmental Protection Agency classification system of marginal, moderate, serious, severe 15, severe 17, or extreme. See https://www3.epa.gov/airquality/greenbook/define.html for more information.

Climate Change.

A large body of scientific evidence indicates that increases in greenhouse gases[11] (GHG) in the Earth's atmosphere are contributing to changes in national and global climatic conditions (Melillo et al. 2014). These changes include such things as increases in average temperature, changes in precipitation patterns, and increases in the frequency and intensity of severe weather events. These changes have the potential to impact a wide sector of the human environment including water resources, agriculture, transportation, human health, energy, and aquatic and terrestrial ecosystems. Therefore, it is important to understand the potential impacts of federal actions on GHG emissions and climate change and the potential changes that may occur to the human environment which could subsequently affect the assumptions made when determining the impacts and efficacy of the federal action in question.

[11] A greenhouse gas is any gas that absorbs infrared radiation in the atmosphere. The major GHGs are carbon dioxide, methane, and nitrous oxide. Less prevalent greenhouse gases include hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (UNFCCC 2014).

GHG emissions in the United States in 2014, the most recent year for which data were available, totaled 6.9 billion metric tons CO_2 Equivalent[12] (CO_2 Eq). As shown in Figure 3-23, CO_2 accounted for the majority of that total at 81%. The vast majority of U.S. CO_2 emissions come from the combustion of fossil fuels (94% in 2014, the latest year for which information was available). Fossil fuel combustion in the U.S. is largely for electricity generation, transportation, and industrial activities (Figure 3-24). Current data and analysis of regional climate change can be found in Section 4.2.6 Impacts on Air Quality and Climate Change.

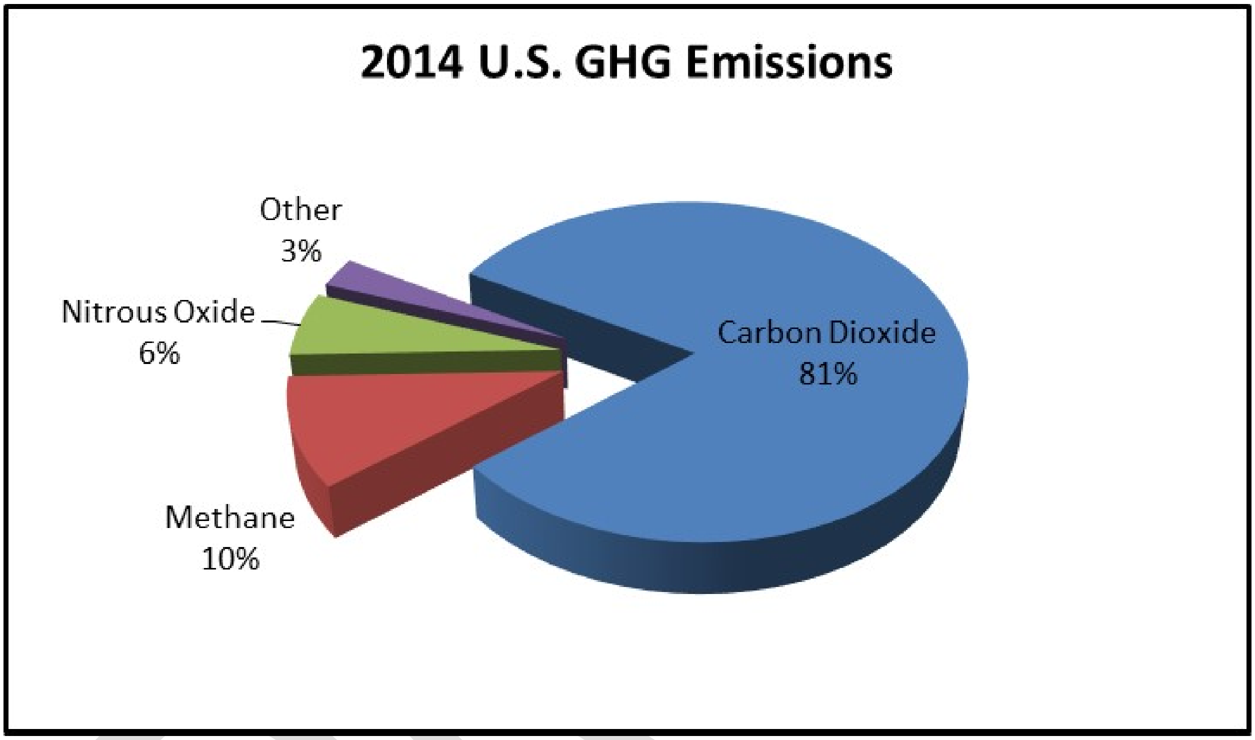


Figure 3-23. 2014 U.S. GHG Emissions (percentages based on metric tons of CO2 Eq; from USEPA 2016).

[12] CO_2 Eq is a standard metric used to express the globing warming potential of different greenhouse gases. The energy absorbing capabilities of gases are converted to the equivalent energy absorbing capability of carbon dioxide in order to make emissions information more readily compared and understood (USEPA 2014).

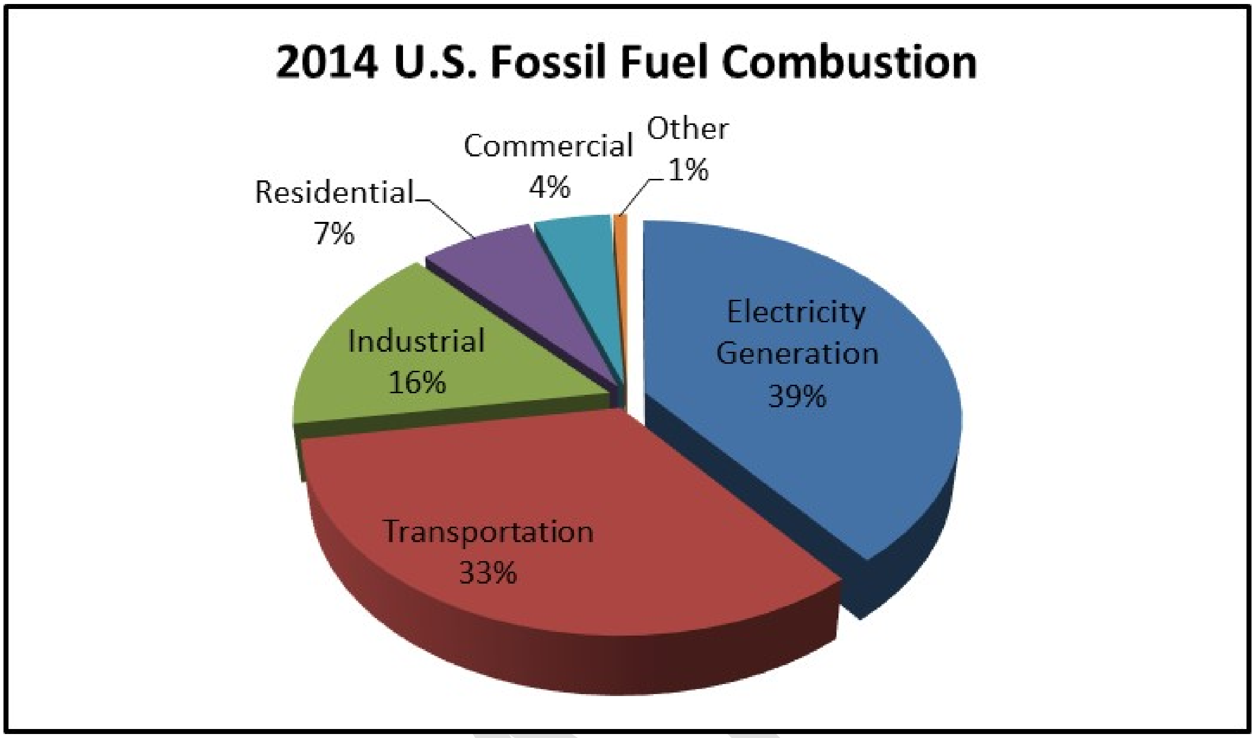


Figure 3-24. 2014 U.S. Fossil Fuel Combustion (percentages based on metric tons of CO2Eq; from USEPA 2016).

3.3 Biological Resources

The following discussion of the biological resources of the Project Area is broken into three broad habitat categories: main channel, main channel border, and side channels. For reference, the relative abundance of these habitats is provided in Table 3-6.

Table 3-6. Acreage of main channel, main channel border, and side channel habitat in the MMR in 1976 and 2014.

	1976 Acreage	2014 Acreage
Main Channel	20,834	25,134
Main Channel Border	29,911	24,592
Side Channels	3,893	4,128

3.3.1 Benthic Macroinvertebrate Resources

Macroinvertebrates feed predominantly on fine particulate organic matter, bacteria, phytoplankton, and zooplankton. They are an extremely important part of the MMR food web and serve as a food source for a variety of fish and wildlife species. They are at the base of the food web and are eaten by almost every larger organism. Harrison and Morse (2012) compiled a list of benthic invertebrates that inhabit the Mississippi River based on the published literature and recorded 215 total taxa. They note that the benthic invertebrate fauna of the Mississippi River has been poorly documented and existing records are patchy with some macrohabitats being sampled extensively, while others, such as the main channel, remain largely unknown. The total number of taxa will undoubtedly increase substantially and understanding of their life history and ecology will increase as new studies are conducted.

Prior to the implementation of the Clean Water Act (1972), the MMR acted as an open sewer and a convenient place to dump solid waste (Bi-State Development Agency 1954; U.S. Public Health Service 1958). Raw sewage, untreated industrial waste, and ground garbage were discharged into the MMR. In 1952, approximately 212 tons/day of garbage (animal and vegetable waste) were collected in St. Louis, ground, and discharged. This resulted in high oxygen demand and low dissolved oxygen levels (< 5 mg/l) and a benthic fauna that was dominated by a pollution tolerant benthic macroinvertebrate community. During a water pollution study (Bi-State Development Agency 1954) conducted in the MMR during 1951 and 1952, only 13 species of benthic macroinvertebrates were collected at 14 sites from St. Louis (RM 196.2) to below Cape Girardeau (River Mile 48.0), and pollution-tolerant tubificid worms completely dominated the benthic fauna. Tubificid worms are often referred to as sewer worms or sludge worms because they are often found in sewage sludge below sewage outfalls. Tubificids survive with little oxygen by waving hemoglobin-rich tail ends to exploit all available oxygen.

During the fall of 1952, tubificid worms reached their maximum abundance when they averaged 2,764 per square yard. For comparison, six relatively clean-water stations on the Mississippi River between LaCrosse, Wisconsin, and Dubuque, Iowa, averaged 28 per square yard. Although historic benthic macroinvertebrate collection data are sparse, poor water quality conditions undoubtedly persisted into the late 1970s or early 1980s. In a recent benthic macroinvertebrate study in the MMR near Cape Girardeau, Battle et al. (2007) collected 68 taxa from fine sediments and 50 taxa from rock substrate, indicating that water quality has improved considerably.

In the Programmatic EIS for the UMR-IWW System Navigation Feasibility Study (USACE 2004), freshwater mussels (as a specialized group of benthic macroinvertebrates) were considered a significant resource and the potential impacts of increased navigation traffic were evaluated for this specialized group of organisms. Freshwater mussels were certainly deserving of the “significant resource” status because of their high density (mussel beds) and ecological importance in parts of the UMR (Newton et al. 2011); the large number of native U.S. mussel species that are considered extinct, endangered, threatened or of special concern (Williams et al. 1993); recent changes in UMR mussel assemblages (Ziegler et al. 2012); the fact that about 60% of the 50 species present in the UMR historical record are now state or federally listed species (Tucker and Theiling 1999); and the multitude of potential anthropogenic factors that may be responsible for their population declines (Downing et al. 2010).

Although the MMR does support scattered mussels along the main channel border, within side channels, and in floodplain lakes (Keevin et al., 2015, submitted; Tiemann 2014), the densities in the river and side channels are extremely low, with no known mussel beds. This is the presumed historic condition in the MMR due to the unstable sand substrate, constantly moving sand waves, and high turbidity levels. Bartsch (1916) suggested that “the heavy load of mud” from the Missouri River was responsible for the lack of freshwater mussels in the MMR. Ellis (1931) concluded that silt was prohibitive for many species in the MMR. Van der Schalie and van der Schalie (1950) indicated that the Mississippi River, below the mouth of the Missouri River, was “poor in mussel production because of the tremendous loads of erosion silt carried into it from the extensive treeless plains draining the Missouri River.” This condition is not unexpected; sand bed rivers normally do not support mussel populations because of their unstable substrates (Hagg 2012).

The four most abundant species collected from MMR side channels and floodplain lakes (borrow pit lakes) during 1989-1990, representing 92% of the total number of specimens collected, were the Giant Floater (*Pyganodon grandis)*, Fragile Papershell (*Leptodea fragilis)*, Pink Papershell (*Potamilus ohiensis)*, and Flat Floater (*Anodonta suborbiculata)* (Keevin et al., 2016, submitted). These are all short-lived, thin-shelled species that are either habitat generalists or show a preference for sluggish water found in floodplain lakes, sloughs, and oxbows (Parmalee 1967; Oesch 1995; Cummings and Mayer 1992).

Young mussels, called glochidia, are gill/skin parasites on fish. They can be moved long distances by migrating fish. They drop off the host fish when they mature and their survival depends on dropping on suitable habitat (Haag 2012). It is quite possible that the giant floater, fragile papershell, pink papershell and flat floater are the only resident mussels of the MMR and that the other species collected in small numbers were transported to the MMR by fishes from the Upper Mississippi River and tributary rivers to the MMR that support a diverse mussel fauna. In summary, the main channel and main-channel border of the MMR do not provide suitable mussel habitat. It is possible that the MMR supports only four resident mussel species in side channels and floodplain lakes. Due to the lack of a significant mussel resource in the MMR, an impact analysis for this important group of macroinvertebrates will not be conducted.

Main Channel

The bottom substrate of the main channel of the MMR consists of course, shifting sand with a minimum amount of fine organic particulate matter. The sand is constantly moving in a down-stream direction as sand waves. The height and periodicity of the sand waves change in response to water velocity and temperature (water density). This constantly shifting sand habitat with minimal food resources for resident benthic macroinvertebrates does not support a diverse benthic macroinvertebrate community; however, organisms do live in this habitat. Dettmers et al. (2001a) found that benthic macroinvertebrates were abundant in the main channel of the Mississippi River (Pool 26). Organisms in the sediments consisted primarily of a few specialized larval chironomids (primarily *Robackia* and *Rheosmittia*), nematodes, and sand-dwelling oligochaetes (*Barbidrilus* spp.). The mean density of macroinvertebrates in the upper, free-flowing portions of Pool 26 was greater than 80,000/m^2 in the main channel. The upper reaches of UMR pools are free-flowing and provide physical conditions (flow velocities and sediments) that are similar to the MMR. Solomon et al. (1974) sampled recently dredged main channel sites on the MMR and found extremely low densities of only one genus of chironomids (nonbiting midges) and a few individuals of two genera of Trichoptera (caddisflies). Some chironomids are referred to as blood worms because of their blood color due to high hemoglobin content used to obtain oxygen in hypoxic conditions (Figure 3-25). No oligochaete worms were collected by Solomon et al. (1974) in the main channel whereas Battle et al. (2007) found them to be the most abundant macroinvertebrate in channel border habitat. This discrepancy (no oligochaetes found by Solomon et al. in the main channel) is likely due to the size mesh used in the sieves to screen samples. Solomon et al. (1974) used a mesh size almost twice as large as Battle et al. (2007).

Figure 3-25. Larval chironomid. This group of benthic macroinvertebrates is referred to as blood worms because of their high hemoglobin levels, which is an adaptation for low oxygen conditions. Photo from Sauer (2004).

Although densities of main channel macroinvertebrates in shifting sand areas can be high, the total biomass per unit of area is generally small. For example, in the Sand River (Alberta, Canada), benthic macroinvertebrate density ranged from 12,000 to 78,000 individuals/m^2 (*Robackia* and *Rheosmittia* contributed a mean of 80.6% of the biomass and 92.8% of the total numbers of macroinvertebrates), while the total biomass was low (50–490 mg/m^{2}dry mass). However, when you consider that 44% of the MMR is main channel habitat, representing approximately 24,000 acres, the total number, density, and biomass of benthic macroinvertebrates that live in the MMR main channel is extremely large.

Main Channel Border

Common macroinvertebrate fauna encountered in the main channel border of the MMR consist of a variety of oligochaete worms, flies, mayflies, caddisflies, and stoneflies. Sampling by Battle et al. (2007) near Cape Girardeau, Missouri, shows densities of macroinvertebrates in fine substrates downstream from wing dikes ranging from approximately 3,700 to 11,700 individuals per square meter. Sixty-eight taxa were collected from fine sediments with the dominant groups being oligochaete worms, midges, and mayflies. Densities on rocks on the upstream side of wing dikes ranged from 57,800 to 163,000 individuals per square meter. Fifty taxa were collected from rock substrate with the dominant group being caddisflies. Poulton and Allert (2012) demonstrate that the size of dike pools (the scour holes below training structures) and the chemistry of sediments and overlaying water best explain the diversity and productivity of aquatic macroinvertebrates in lower Missouri River dike pools. So, it would be expected that the diversity and density of macroinvertebrates would differ somewhat below each MMR dike depending on the size of the scour hole, sediment characteristics, and flow.

Macroinvertebrates were also collected from rock surfaces in bendway weir fields in the MMR at RM 164 near Oakville, Missouri (Ecological Specialists 1997a) and at RM 30 near Commerce, Missouri (Ecological Specialists 1997b). Twenty-nine taxa were collected at RM 164 with caddisflies being the overwhelmingly dominant group; midges were also abundant. Density averaged 14,662 individuals per square meter. Thirty-four taxa were collected at RM 30 with caddisflies again the overwhelmingly dominant group; midges were present but not as abundant as at RM 164. Density averaged 16,240 individuals per square meter. Sampling conducted in sand substrate at a nearby bendway without weirs (RM 20) yielded seven taxa and 965 individuals per square meter with oligochaete worms being the overwhelmingly dominant group. Rock training structures have been shown to support high densities of aquatic macroinvertebrates, when compared to the natural substrate of the main channel border, which in turn provides high quality foraging habitat for fish.

Side Channels

The most recent survey of benthic macroinvertebrates in MMR side channels was conducted by Ragland (1974) in three side channels (Liberty, River Miles 100.2.-102.8; Ft. Chartres, R.M. 132.3-134.2; and Osborne, R.M. 144.5-146.4) and three adjacent main channel border locations. Aquatic insects comprised 96% of the total organisms collected. Oligochaetes represented another 3%, with a large number of other organisms in lesser numbers representing the final 1%. Oligochaetes, damselflies, and larval chironomids were consistently captured in greater numbers from side channels than from the main channel border habitat. Mayfly nymphs, pupal chironomids and larval caddisflies were captured in greater numbers from main channel border locations than from side channels. Considering that every MMR side channel currently has a different level of connectivity to the main channel (see Section 3.2.3 Side Channels) and associated flow characteristics, it would be expected that the species composition, diversity, and density of macroinvertebrates would be somewhat different in each side channel. For example, isolated side channels would be expected to support more lake-like faunas while free-flowing side channels would support more riverine faunas. The more isolated side channels would also be expected to have poorer water quality and support fewer species (e.g., Crites et al 2012). Cellot (1996) found that certain macroinvertebrate species were more abundant in the main channel downstream of the more lotic (flowing water) of two side channels studied on the Upper Rhône River (France) than upstream of the side channel, indicating that side channels provide drifting macroinvertebrates to the main channel. This was not found to be the case in the main channel below the more lentic (lake-like) side channel. Thus, side channels are important in providing macroinvertebrate drift to the main channel depending on the degree of connectivity to the river.

3.3.2 Fishery Resources

Historically, Smith et al. (1971) reported that 134 fish species had been collected from the Upper Mississippi River, with 30 of those species being stragglers that are accidental in the Mississippi River. An evaluation of their species distribution maps indicates that historically 84 fish species had been collected from the MMR, with 19 of those species being stragglers or tributary species and one exotic (Common Carp, *Cyprinus carpio*). The Missouri Department of Conservation (MDC) has conducted a comprehensive fish sampling program as part of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element in the Cape Girardeau, Missouri, area since 1993. During that period, they have collected a total of 110 species (range of species collected = 45-68 per year, average = 61 species per year), of which 39 are stragglers or tributary species and six are exotic species (USGS 2014a). In 1971 there were 64 native MMR species and two exotic species and in 2014 there were 65 native species and seven exotic species. Since the original establishment of the Common Carp, six additional exotic species have become established or have expanded their ranges into the MMR: the Grass Carp (*Ctenopharyngodon idella*), Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*H. nobilis*), Striped Bass (*Morone saxatilis*), Striped Mullet (*Mugil cephalus*), and Rainbow Smelt (*Osmerus mordax*). In addition, it is likely only a matter of time before the exotic Black Carp (*Mylopharyngodon piceus*) and the Round Goby (*Neogobius melanostomus*) become part of the MMR fish fauna. Three species have been extirpated from the MMR since the Smith et al. (1971) publication: the Alligator Gar (*Lepisosteus spatula*), the Flat Head Chub (*Platygobio gracilis*) and the Plains Minnow (*Hybognathus placitus*), last collected during annual sampling in 1996. A number of species not collected in the MMR by Smith et al. (1971) are now considered residents (e.g., Western Sand Darter, *Ammocrypta clara*) based on more extensive sampling by the MDC.

The MMR sees some commercial and recreational fishing pressure. The number of commercial fishermen from Missouri has been declining since 2000 as has the commercial fish harvest (Tripp et al. 2012). The most commonly harvested fish are buffalofishes, catfishes, asian carp, and Common Carp. Asian carp have recently overtaken Common Carp as the fourth most harvested group of fish by weight (Tripp et al. 2012). Recreational fishermen typically target catfish.

The Main Channel

The importance of the main channel to aquatic organisms has been poorly studied (Baker et al. 1991) and aquatic ecologists are only recently gaining a better understanding of the importance of the main channel to the overall structure and function of large-river ecosystems. Additional studies have been recommended (Dettmers et al 2001a; Galat and Zweimmuller 2001) to resolve this lack of understanding. At the time that the 1976 EIS was prepared, the consensus of aquatic ecologists was that the main channel was “generally poor habitat for aquatic biota” and project-related impacts would be minor. Subsequently, from the 1980s to the 1990s, the flood pulse concept (Junk et al. 1989) envisioned the main channel as being “used principally as a route for gaining access to adult fish feeding areas, nurseries, spawning grounds, or as refuge at low water or during winter in temperate zones.” This was referred to as the “*highway analogy*” where the main channel served as a highway, fish were the vehicles, and the flood-plain provided off-highway services.

The consensus that the main channel is poor habitat or serves only as a highway for fish movement between aquatic habitat types has changed based on recent research. The suggestion that the main channel serves only as a highway for fish movement has been evaluated and rejected (Galat and Zweimmuller 2001; Dettmers et al 2001b). Research indicates that the main channel is used by a variety of fish species ranging from single-season users to permanent residents (Dettmers et al. 2001a, 2001b; Galat and Zweimuller 2001; Wolter and Bischoff 2001). An evaluation of the fish assemblages of seven large rivers in North America and Europe revealed that 38-58% of native fishes depend on channel habitat for one or more of their primary life functions (Galat and Zweimuller 2001). Wolter and Bischoff (2001) found that in the River Oder (Germany), of the 30 species of fish captured during their study, 20 species were found in the main channel and 27 species at the shoreline. Three species were exclusively main channel species and an additional six species were more frequent there. Dettmers et al. (2001b) collected 26 fish species in the main channel of the Mississippi River (Pool 26). Over half (58%) of the 26 fish species they collected were present in the main channel during either three or four seasons, whereas only 31% (8 species) were collected during a single season (Dettmers et al. (2001a). The Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) was a persistent resident of the main channel. Dettmers et al. (2001b) suggested that there are four patterns of fish use of main channel troughs in the Upper Mississippi River. Some species (e.g., Black Crappie (*Pomoxis nigromaculatus*) and Shortnose Gar (*Lepisosteus platostomus*)) appear to use the main channel trough to move among various habitats. These species were collected only in the autumn, and only a single individual was collected each year. A second group of fishes (Bigmouth Buffalo (*Ictiobus cyprinellus*) and carpsuckers (*Carpiodes spp*.)) used the main channel trough primarily during a single season, usually autumn. These fishes remain in the main channel trough for 1-2 months, but were not collected in the main channel during the remainder of the year. The third group of fishes (e.g., Freshwater Drum (*Aplodinotus grunniens*) and Smallmouth Buffalo (*I. bubalus*)) used the main channel trough for multiple, but not all, seasons within the year. These species leave the main channel for such life-history requirements as spawning or overwintering. The final group (e.g., Shovelnose Sturgeon) are residents and are present during the entire year. Thus, the main channel is not “poor habitat” as outlined in the 1976 EIS (USACE 1976) and many fish species depend on it to a much greater degree than previously thought.

Based on limited sampling of the MMR main channel (USGS 2014a) due to safety issues related to sampling the high-velocity, turbulent main channel, the common species were Blue Catfish (*Ictalurus furcatus*), Channel Catfish, Freshwater Drum, Shovelnose Sturgeon and Gizzard Shad.

Main Channel Border

As with the main channel, there are Upper Mississippi River fish species that clearly select the main channel border as their preferred habitat (Gutreuter et al. 2010). Habitat preference is based on seasonal considerations (spawning, food availability, overwintering, etc.), including temperature and flow conditions. There undoubtedly is also a temporal component, with fish moving to different water depths and habitat types during different times of the day (diurnal vs. nocturnal conditions).

The most commonly encountered native species in the main channel border include (USGS 2014a): Gizzard Shad, Channel Catfish, Freshwater Drum, Emerald Shiner (*Notropis atherinoides*), Smallmouth Buffalo, Channel Shiner (*Notropis wickliffi*), White Bass, Shortnose Gar, Blue Catfish, and River Carpsucker. These species accounted for approximately 70% of the fish captured, by number. Also included in the collection were 4 species of non-native fish including Common Carp, Silver Carp, Grass Carp, and Bighead Carp. These species accounted for approximately 11% of the fish captured, by number, with the vast majority being Common Carp. Silver Carp were likely underrepresented in the collection due to the sampling methodologies employed.

Side Channels

With the draining of floodplain lakes for agricultural development and the reduction of overbank flooding during high flows due to levee construction, side channels represent the major source of off-channel water bodies on the MMR. Side channels typically provide a well-defined gradient between flowing to non-flowing water depending on their level of connectivity to the main channel. Based on the level of water flow, side channels can function as wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels.

Flowing side channels, those connected to the main channel, generally have course bottom substrates (i.e., sand and gravel) and support large river aquatic species (suckers, minnows, and darters) tolerant of current and/or turbidity. Disconnected side channels generally have finer substrate types (sand and silt) and support lentic species that prefer moderate to low current and low turbidity levels (Barko and Herzog 2003). The degree of connectivity to the river also affects side channel water quality and fish species composition (Crites et al. 2012). This diversity of habitat provides important feeding, spawning, nursery, and overwintering habitat for fish (Lowery et al. 1987; Scheaffer and Nickum 1986; Grift et al. 2001) and habitat for other environmentally sensitive macroinvertebrates, fish, and wildlife (Eckblad et al. 1984; Siegrest and Cobb 1987; Barko and Herzog 2003). Side channels also export nutrients, detritus, plankton, invertebrates, and fish to the main channel and the Gulf of Mexico (Eckblad et al. 1984; Cellot

1996; Simons et al. 2001; Hein et al. 2004; Preiner et al. 2008). Side channels are also important because they are a refuge for fish escaping navigation related disturbances (Galat and Zweimuller 2001; Wolter and Bischoff 2001; Gutreuter et al. 2006). Information on the status of MMR side channels can be found in Section 3.2.3 Side Channels above.

3.3.3 Terrestrial Communities

River planform analyses conducted by the District (Brauer et al. 2005; Brauer et al. 2013; see Section 3.2.2 Geomorphology of this document for details) indicate that the MMR planform is no longer narrowing and creating new riparian habitat as it had been in the late 19th and early 20th centuries. Planform width has been relatively stable since the 1960s. This fact, in combination with the fact that construction techniques no longer utilize bank scraping when placing rock on the bank, leads to the conclusion that potential impacts of the Project on terrestrial communities are minimal. Accordingly, the information in the 1976 EIS on terrestrial communities is incorporated by reference and no further analysis will be conducted in this Supplement.

3.3.4 Threatened and Endangered Species

In 1999 the Corps prepared a Tier I Biological Assessment for the Operation and Maintenance of the Upper Mississippi River Navigation Project within the St. Paul, Rock Island, and St. Louis Districts to determine the impacts of operation and maintenance of the 9-foot navigation channel on threatened and endangered species (USACE 1999b). The Corps chose to prepare one Biological Assessment for the Upper Mississippi River Navigation System, defined as the commercially navigable portions of the Mississippi, Illinois, Kaskaskia, Minnesota, St. Croix, and Black Rivers north of the confluence of the Ohio and Mississippi rivers, although this area contains multiple Congressionally authorized projects to obtain and maintain a navigation channel in various ways. Subsequently, the Fish and Wildlife Service prepared a Biological Opinion on the O&M of the 9-foot navigation channel (USFWS 2000). The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

In their Biological Opinion, the Service analyzed the impacts of impoundment and water level regulation, dredging and disposal, clearing and snagging, channel structures and revetment, tow traffic, and other direct, indirect, and cumulative actions on the Indiana Bat (*Myotis sodalis*), Decurrent False Aster (*Boltonia decurrens*), Bald Eagle (*Haliaeetus leucocephalus*), Higgins' Eye Pearlymussel (*Lampsilis higginsi*), Winged Mapleleaf Mussel (*Quadrula fragosa*), Least Tern (*Sterna antillarum*), and Pallid Sturgeon (*Scaphirhynchus albus*). The Higgins' Eye Pearlymussel and Winged Mapleleaf Mussel are not found in the MMR and, therefore, are not impacted by the Regulating Works Project. With respect to species currently relevant to the Regulating Works Project, the Service concluded that the continued operation and maintenance of the 9-foot navigation channel:

- would jeopardize the continued existence of the Pallid Sturgeon;
- would not jeopardize the continued existence of the Least Tern, but would result in incidental take;

- would likely adversely affect the Indiana Bat, but impacts would be offset by management actions or would be negligible and would not rise to the level of incidental take; and
- would adversely affect the Decurrent False Aster, but would not jeopardize its continued existence.

Based on these determinations, the Service recommended appropriate actions for the Corps to take in order to avoid impacts to Pallid Sturgeon and Least Terns.

For Pallid Sturgeon, the Service recommended a Reasonable and Prudent Alternative (RPA) for O&M of the 9-foot navigation channel that the Corps could implement to avoid the likelihood of jeopardizing the continued existence of the species. The RPA consisted of four components:

1. Conduct a Pallid Sturgeon habitat study in the MMR.
2. Facilitate development of a Pallid Sturgeon conservation and restoration plan that includes:
    a. A habitat restoration plan for each river reach and
    b. A population and habitat restoration monitoring plan.
3. Implement, as described in the conservation and restoration plan, a long-term aquatic habitat restoration program in the MMR. Annual Reports must be submitted by 30 June each year.
4. Until the conservation and restoration plan is implemented, implement short-term aquatic habitat restoration measures and studies.

The Service also recommended Reasonable and Prudent Measures (RPMs) necessary to minimize the incidental take of Pallid Sturgeon until the RPAs are fully implemented:

1. Incorporate modifications to channel training structures to improve diversity (e.g. notching, woody debris).
2. Beneficially use dredge material when possible and use thalweg[13] disposal otherwise.
3. Do not maintenance dredge during the presumed Pallid Sturgeon spawning window (12 April to 30 June).
4. Release live Pallid Sturgeon after data/tissue samples have been collected.
5. Review data collected with implementation of RPAs to further minimize incidental take.

Finally, the Service imposed Terms and Conditions associated with the Pallid Sturgeon RPMs:

1. At beginning of each fiscal year, provide a list of new construction projects for which Tier II evaluation is needed.
2. Submit channel training structure maintenance projects to the Service for 30-day review and incorporate their habitat improvement recommendations.
3. Conduct monitoring to measure loss of main channel and side channel habitat.
4. Coordinate dredging and disposal with the Service, IDNR, and MDC.
5. If dredging from 12 April to 30 June, prepare a tier II Biological Assessment.

[13] Thalweg is defined as a line drawn along a river channel that connects its deepest points.

6. Implement monitoring of thalweg disposal.
7. Provide an annual dredge material management report to the Service.
8. Preserve dead Pallid Sturgeon on ice and give to the University of Alabama.

For the Least Tern, the Service recommended RPMs to minimize take:

1. Incorporate modifications to channel training structure maintenance projects to maintain flow between sandbars and the adjacent shoreline and to reduce conversion of bare sandbar habitat to woody vegetation.
2. Evaluate dredge material disposal techniques in the MMR to examine opportunities and develop recommendations for restoring/enhancing sandbar habitat and aquatic habitat. Implement the recommendations where feasible and appropriate.
3. Utilize existing authorities to reduce the accretion of existing and/or newly established sandbars to the bankline and to reduce woody vegetation colonization.

The Service also imposed Terms and Conditions associated with the Least Tern RPMs:

1. Provide the Service with a list of new construction projects at the beginning of each fiscal year.
2. Submit channel training structure maintenance projects to the Service for a 30-day review period. Incorporate Service recommendations where feasible and appropriate.
3. Monitor sandbar habitat trends in the MMR.
4. Continue to coordinate dredging and disposal activities with the Service, Illinois Department of Natural Resources (IDNR), and Missouri Department of Conservation (MDC).
5. Provide a dredge material management report to the Service annually.
6. Provide the Service an annual report of actions taken regarding implementation of RPMs.

The Corps initiated implementation of the Pallid Sturgeon and Least Tern RPA, RPMs, and Terms and Conditions as recommended by the Service in 2000 subsequent to the issuance of the Biological Opinion. Since that time the District has implemented a variety of studies aimed at increasing understanding of the status and needs of the species in the MMR and has implemented numerous habitat restoration projects aimed at improving conditions for the species in the MMR. Habitat restoration undertaken by the District includes a variety of dike alteration, side channel restoration, and island and sandbar creation projects. The District prepares annual reports summarizing all Biological Opinion activities. These reports can be found on the District's web site at:

http://mvs-wc.mvs.usace.army.mil/arec/Bio_Op.html

Implementation of the recommendations of the Biological Opinion is coordinated extensively and continually with the Service, IDNR, MDC, and other experts and interested parties. Implementation of the District's Biological Opinion activities is expected to continue until such time as the species are considered recovered or it is determined that the District's actions are no longer jeopardizing the species or resulting in incidental take.

Due to this recent analysis of the impacts of operation and maintenance activities on endangered species, the fact that no additional impacts are anticipated beyond those addressed in the 2000 Biological Opinion, and due to the associated ongoing habitat restoration, monitoring, and coordination that the St. Louis District continues to undertake, a Biological Assessment was not prepared in conjunction with this SEIS for the species covered by the previous consultation process. However, site-specific Tier II Biological Assessments covering all appropriate species have been and will continue to be prepared for construction of specific work areas in the MMR. Relevant new information on threatened and endangered species has been and will continue to be included in these site-specific Tier II Biological Assessments, as appropriate. For example, new information and guidance on protection of Indiana Bat habitat is included in site-specific Tier II Biological Assessments, as appropriate, through close coordination with the Service. With respect to new threatened and endangered species that have been listed since issuance of the 2000 Biological Opinion (Table 3-7), a Biological Assessment has been prepared in conjunction with this SEIS (Appendix B).

Table 3-7. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 January 2016).

Species Covered by Previous Consultation	Federal Status
Least Tern (*Sterna antillarum*)	Endangered – listed in 1985
Piping Plover (*Charadrius melodus*)	Threatened – listed in 1985
Pink Mucket (*Lampsilis abrupta*)	Endangered – listed in 1976
Illinois Cave Amphipod (*Gammarus acherondytes*)	Endangered – listed in 1998
Pallid Sturgeon (*Scaphirhynchus albus)*	Endangered – listed in 1990
Decurrent False Aster (*Boltonia decurrens*)	Threatened – listed in 1988
Eastern Prairie Fringed Orchid (*Platanthera leucophaea*)	Threatened – listed in 1989
Mead’s Milkweed (*Asclepias meadii*)	Threatened – listed in 1988
Price’s Potato-bean (*Apios priceana*)	Threatened – listed in 1990
Running Buffalo Clover (*Trifolium stoloniferum*)	Endangered – listed in 1987
Small Whorled Pogonia (*Isotria medeoloides*)	Threatened – listed in 1982
Gray Bat (*Myotis grisescens*)	Endangered – listed in 1976
Indiana Bat (*Myotis sodalis*)	Endangered – listed in 1967
Species Listed Since Issuance of 2000 Biological Opinion	**Federal Status**
Red Knot (*Calidris canutus rufa*)	Threatened – listed in 2015
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016

3.4 Socioeconomic Resources

3.4.1 Human Resources

This Section provides an overview of the socioeconomic characteristics of the Project Area. Information on population densities, employment and income statistics, and race characteristics is provided in order to characterize the socioeconomic status of the inhabitants of the MMR corridor.

A total of fifteen Missouri and Illinois counties are immediately adjacent to the MMR (Figure 3-26). The total population of these 15 counties in 2014 was approximately 2.4 million (Table 3-8), with the vast majority of that total (2.1 million) living in the St. Louis area (St Louis City and St. Louis, Jefferson, Madison, and St. Clair Counties; Figure 3-27; U.S. Census Bureau 2014). Most of the remaining Project Area counties are rural in nature with low population densities and few cities over 10,000 people.

Employment statistics for counties adjacent to the MMR indicate that the primary employment sector for Project Area counties is Educational Services, Health Care, and Social Assistance, accounting for 25.5% of employment on both the Missouri and Illinois sides of the river (Table 3-9; U.S. Census Bureau 2014). High Agriculture, Forestry, Fishing and Hunting, and Mining sector numbers in the counties in the southern portion of the Project Area reflect the rural nature of those counties. In general, overall Project Area employment statistics are similar to the overall employment statistics for the states of Missouri and Illinois, with all employment sector percentages being within 2.5% of statewide averages.

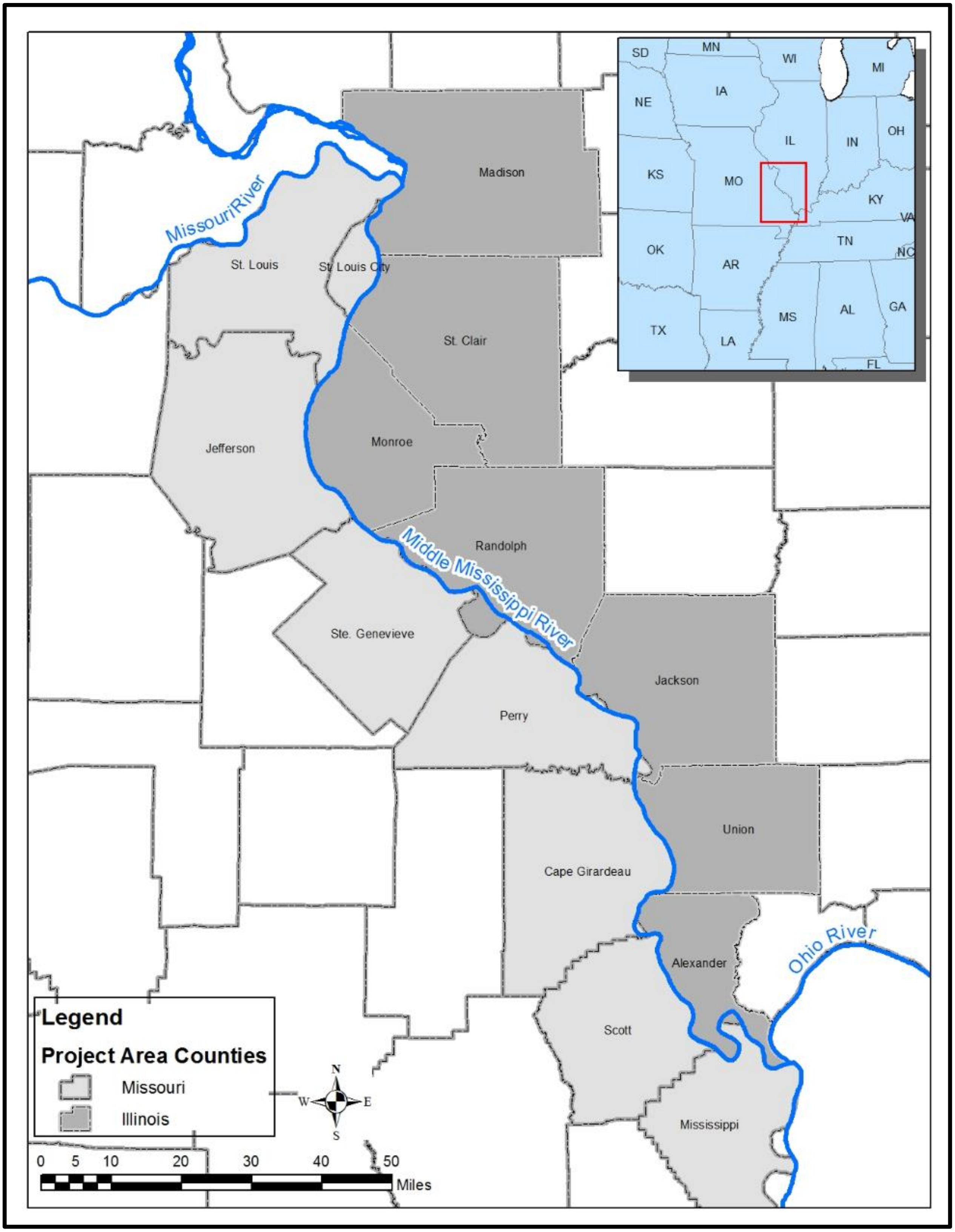


Figure 3-26. Missouri and Illinois counties adjacent to the Middle Mississippi River.

Table 3-8. Population statistics for Project Area counties.

Area	2000 Population	2014 Population	2000 to 2014 % Change in Population
Missouri			
St. Louis County	1,016,315	1,000,423	-1.6
St. Louis City	348,189	318,727	-8.5
Jefferson County	198,099	220,558	11.3
St. Genevieve County	17,842	18,017	1.0
Perry County	18,132	19,042	5.0
Cape Girardeau County	68,693	77,031	12.1
Scott County	40,422	39,137	-3.2
Mississippi County	13,427	14,276	6.3
State of Missouri	5,595,211	6,028,076	7.7
Illinois			
Madison County	258,941	267,937	3.5
St. Clair County	256,082	268,415	4.8
Monroe County	27,619	33,373	20.8
Randolph County	33,893	33,091	-2.4
Jackson County	59,612	60,125	0.9
Union County	18,293	17,620	-3.7
Alexander County	9,590	7,821	-18.4
State of Illinois	12,419,293	12,868,747	3.6

Source: U.S. Census Bureau 2014.

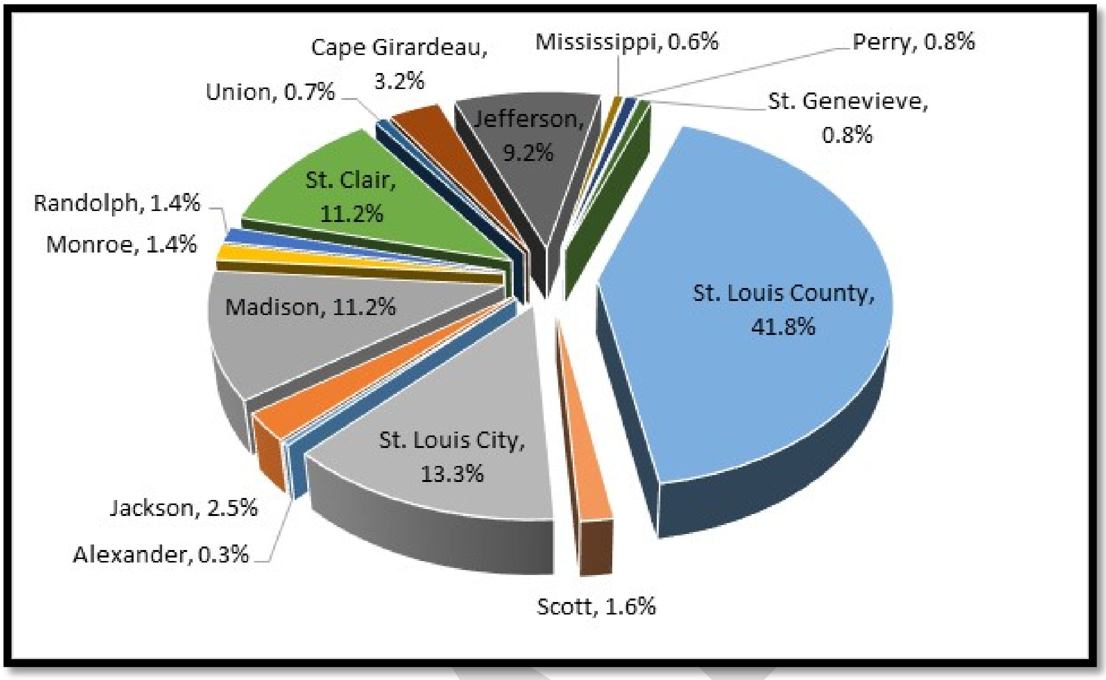


Figure 3-27. 2014 population statistics for Project Area counties – percent of total Project Area population. Source: U.S. Census Bureau 2014.

Table 3-9. Employment statistics for Project Area counties (in percent of total employment).

	Missouri										Illinois								
Occupation	St. Louis County	St. Louis City	Jefferson County	St. Genevieve County	Perry County	Cape Girardeau County	Scott County	Mississippi County	Project Area	State of Missouri	Madison County	St. Clair County	Monroe County	Randolph County	Jackson County	Union County	Alexander County	Project Area	State of Illinois
Agriculture, Forestry, Fishing and Hunting, and Mining	0.5	0.3	0.5	6.6	4.7	1.3	3.8	8.9	**0.7**	**1.8**	0.7	0.7	1.8	5.1	2.2	4.0	2.6	**1.2**	**1.1**
Construction	4.2	3.6	9.3	10.2	9.0	6.1	6.3	5.4	**5.0**	**5.9**	5.7	5.2	7.9	8.3	4.7	7.7	4.7	**5.7**	**5.1**
Manufacturing	10.0	7.8	11.7	22.8	25.1	10.7	15.4	9.5	**10.3**	**11.3**	12.9	8.5	10.8	19.3	5.5	10.2	10.5	**10.7**	**12.5**
Wholesale Trade	3.0	2.6	3.0	1.6	0.8	2.8	2.3	3.0	**2.9**	**2.7**	2.4	2.3	4.2	1.8	1.0	0.9	2.5	**2.3**	**3.0**
Retail Trade	11.4	9.0	12.4	9.4	12.4	12.8	13.8	12.6	**11.2**	**12.1**	11.7	11.3	11.3	10.1	13.2	10.5	11.7	**11.5**	**11.0**
Transportation and Warehousing and Utilities	4.3	4.2	5.2	6.0	4.4	3.9	7.7	6.8	**4.5**	**5.0**	6.3	6.7	5.6	7.3	3.1	6.9	7.2	**6.2**	**5.9**
Information	2.5	2.6	1.7	1.8	1.0	2.0	2.3	0.3	**2.3**	**2.1**	1.7	1.3	2.8	1.8	1.6	1.7	0.7	**1.6**	**2.1**
Finance and Insurance and Real Estate, Rental, and Leasing	9.2	6.4	7.6	3.4	3.4	5.9	4.4	4.4	**8.1**	**6.8**	6.6	6.7	8.9	3.4	3.2	3.9	4.7	**6.3**	**7.3**
Professional, Scientific, Management, and Administrative	12.2	11.4	10.1	4.3	4.9	6.5	4.7	5.1	**11.2**	**9.2**	10.0	10.6	10.0	5.2	4.8	5.8	5.3	**9.4**	**11.3**
Educational Services, Health Care, and Social Assistance	25.7	27.6	21.1	22.0	20.2	29.5	24.5	24.1	**25.5**	**24.4**	22.9	25.5	22.2	22.9	41.0	30.4	22.5	**25.5**	**23.1**
Arts, Entertainment, and Recreation, and Accommodation and Food Services	9.3	13.7	8.4	6.2	6.4	10.7	7.3	5.8	**9.9**	**9.3**	10.0	9.1	6.6	5.6	9.7	5.3	11.7	**9.1**	**9.0**
Public Administration	2.9	5.7	3.5	3.2	3.2	3.3	4.6	9.6	**3.6**	**4.6**	4.3	7.7	3.4	5.3	5.5	8.9	10.9	**5.8**	**3.9**
Other	4.8	5.0	5.5	2.6	4.5	4.5	2.8	4.4	**4.9**	**4.8**	4.8	4.7	4.5	3.8	4.6	3.8	4.9	**4.7**	**4.8**
Unemployed	8.2	14.1	9.2	6.4	4.1	7.3	7.4	13.9	**10.3**	**8.4**	8.9	9.0	5.4	6.5	10.3	9.7	16.7	**9.7**	**10.0**

Source: U.S. Census Bureau 2014.

Median household income and per capita income data for the Project Area show most income levels to be below statewide averages (Table 3-10; U.S. Census Bureau 2014). Median household incomes for Project Area counties were below statewide averages for all counties except St. Louis County, Jefferson County, Perry County, and Monroe County. Per capita incomes were below statewide averages for all counties except St. Louis County and Monroe County.

Table 3-10. Income statistics for Project Area counties.

Area	Median Household Income	Per Capita Income
Missouri		
St. Louis County	$59,520	$35,388
St. Louis City	$34,800	$23,244
Jefferson County	$55,563	$25,034
St. Genevieve County	$46,244	$23,780
Perry County	$50,817	$23,539
Cape Girardeau County	$45,849	$23,684
Scott County	$39,076	$20,637
Mississippi County	$28,436	$15,032
State of Missouri	**$47,764**	**$26,006**
Illinois		
Madison County	$53,912	$28,093
St. Clair County	$50,728	$26,459
Monroe County	$69,592	$33,059
Randolph County	$48,901	$22,771
Jackson County	$32,681	$20,729
Union County	$41,849	$22,430
Alexander County	$25,495	$14,052
State of Illinois	**$57,166**	**$30,019**

Source: U.S. Census Bureau 2014.

Environmental Justice (EO 12898)

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs federal agencies to identify and address any disproportionately high adverse human health or environmental effects of federal actions to minority and/or low-income populations. CEQ guidance on conducting Environmental Justice analyses in NEPA documents (CEQ 1997) indicates that a minority population exists where the percentage of minorities in an affected area either exceeds 50 percent or is meaningfully greater than in the general population or other appropriate unit of geographic analysis. The CEQ guidance also recommends utilizing the Census Bureau's statistical poverty thresholds in determining low-income populations. The Census Bureau defines a "poverty area" as a Census tract with 20 percent or more of its residents below the poverty threshold.

Accordingly, a potential disproportionate impact could occur anywhere the percent minority and/or percent low-income population in a project area is greater than the recommended threshold percentages and/or is meaningfully greater than those in the reference community. For purposes of this analysis, minority and low income population information for the states of Missouri and Illinois, all Project Area counties, and all Census Block Groups[14] immediately adjacent to the MMR was acquired.

The most recent minority and low-income data available for this analysis (U.S. Census Bureau 2014) can be found in Table 3-11. The demographic profile records indicate that the minority population in the Missouri Project Area counties (32.0%) is lower than the 50% threshold but is significantly higher than the general population in the state of Missouri (21.0%). St. Louis County (32.6%), St. Louis City (58.2%), and Mississippi County (27.7%) have minority population densities higher than the state average. The minority population in the Illinois Project Area counties (24.5%) is lower than the 50% threshold and is lower than the general population in the state of Illinois (43.8%). No Illinois counties in the Project Area have minority population densities higher than the state average. The low-income populations in the Missouri Project Area counties (14.3%) and the Illinois Project Area counties (16.3%) are both below the 20% threshold and are similar to the general populations of Missouri (15.6%) and Illinois (14.4%). St. Louis City, Missouri (27.8%), Mississippi County, Missouri (29.7%), Jackson County, Illinois (32.3%), and Alexander County, Illinois (36.8%), have low-income populations above the 20% threshold.

To further refine the Environmental Justice analysis, Census Block Group information was analyzed to determine the status of minority and low-income populations immediately adjacent to the MMR. By utilizing Census Block Group data, minority or low-income populations that may not have been revealed when looking at the broader county-wide information could be analyzed. In addition, comparisons of minority and low-income populations among different parts of the Project Area could more accurately be conducted to ensure that potential disproportionate impacts within the Project Area itself were considered.

[14] Census Block Groups are small geographical population units used by the U.S. Census Bureau that typically contain 600 to 3,000 people. Census Block Groups were the smallest population unit for the Project Area for which the most up to date population information was available.

Seventy-four Census Block Groups exist adjacent to the MMR, 50 in Missouri and 24 in Illinois (Figure 3-28). Of those 74, 30 in Missouri and 11 in Illinois contain populations that meet the minority and/or low-income criteria (Figure 3-28). Potential impacts to minority and low-income populations in the Project Area will be discussed in Chapter 4, Environmental Consequences.

Table 3-11. Minority and low-income populations in Project Area counties.

Area	Total Population	Total Minority Population (%)	African American (%)	American Indian and Alaska Native (%)	Asian (%)	Native Hawaiian and other Pacific Islander (%)	Other (%)	Multi-Race (%)	Hispanic or Latino (%)	Low-Income (%)
Missouri										
St. Louis	1,000423	32.6	23.3	0.1	3.6	0.0	0.6	2.4	2.6	10.8
St. Louis City	318,727	58.2	48.1	0.2	2.8	0.0	0.8	2.6	3.7	27.8
Jefferson	220,558	5.2	0.9	0.2	0.6	0.1	0.3	1.4	1.7	11.1
St. Genevieve	18,017	3.9	0.5	0.0	0.0	1.6	0.1	0.8	0.9	14.6
Perry	19,042	4.7	0.4	0.2	0.1	0.0	0.5	1.5	2.0	11.7
Cape Girardeau	77,031	13.4	7.4	0.2	1.3	0.2	0.4	1.8	2.1	17.3
Scott	39,137	16.0	11.1	0.3	0.5	0.0	0.2	1.9	2.0	19.4
Mississippi	14,276	27.7	24.0	0.2	0.0	0.0	0.0	1.7	1.8	29.7
Project Area	**1,707,211**	**32.0**	**23.5**	**0.2**	**2.8**	**0.0**	**0.6**	**2.3**	**2.6**	**14.3**
State of Missouri	**6,028,076**	**21.0**	**11.5**	**0.4**	**1.7**	**0.1**	**1.1**	**2.4**	**3.8**	**15.6**
Illinois										
Madison	267,937	14.4	8.0	0.2	0.8	0.0	0.4	2.1	2.9	13.9
St. Clair	268,415	38.5	30.1	0.2	1.2	0.0	0.8	2.6	3.6	17.8
Monroe	33,373	3.4	0.3	0.0	0.8	0.0	0.0	0.8	1.5	5.4
Randolph	33,091	14.5	10.2	0.1	0.3	0.0	0.5	0.7	2.7	12.3
Jackson	60,125	26.6	14.6	0.4	3.3	0.0	0.8	3.3	4.2	32.3
Union	17,620	10.0	1.6	0.1	0.5	0.0	1.5	1.3	5.0	18.0
Alexander	7,821	41.1	35.9	0.4	0.3	0.0	0.0	2.4	2.1	36.8
Project Area	**688,382**	**24.5**	**17.1**	**0.2**	**1.2**	**0.0**	**0.6**	**2.2**	**3.2**	**16.3**
State of Illinois	**12,868,747**	**43.8**	**14.4**	**0.2**	**4.9**	**0.0**	**5.8**	**2.2**	**16.3**	**14.4**

Source: U.S. Census Bureau 2014.

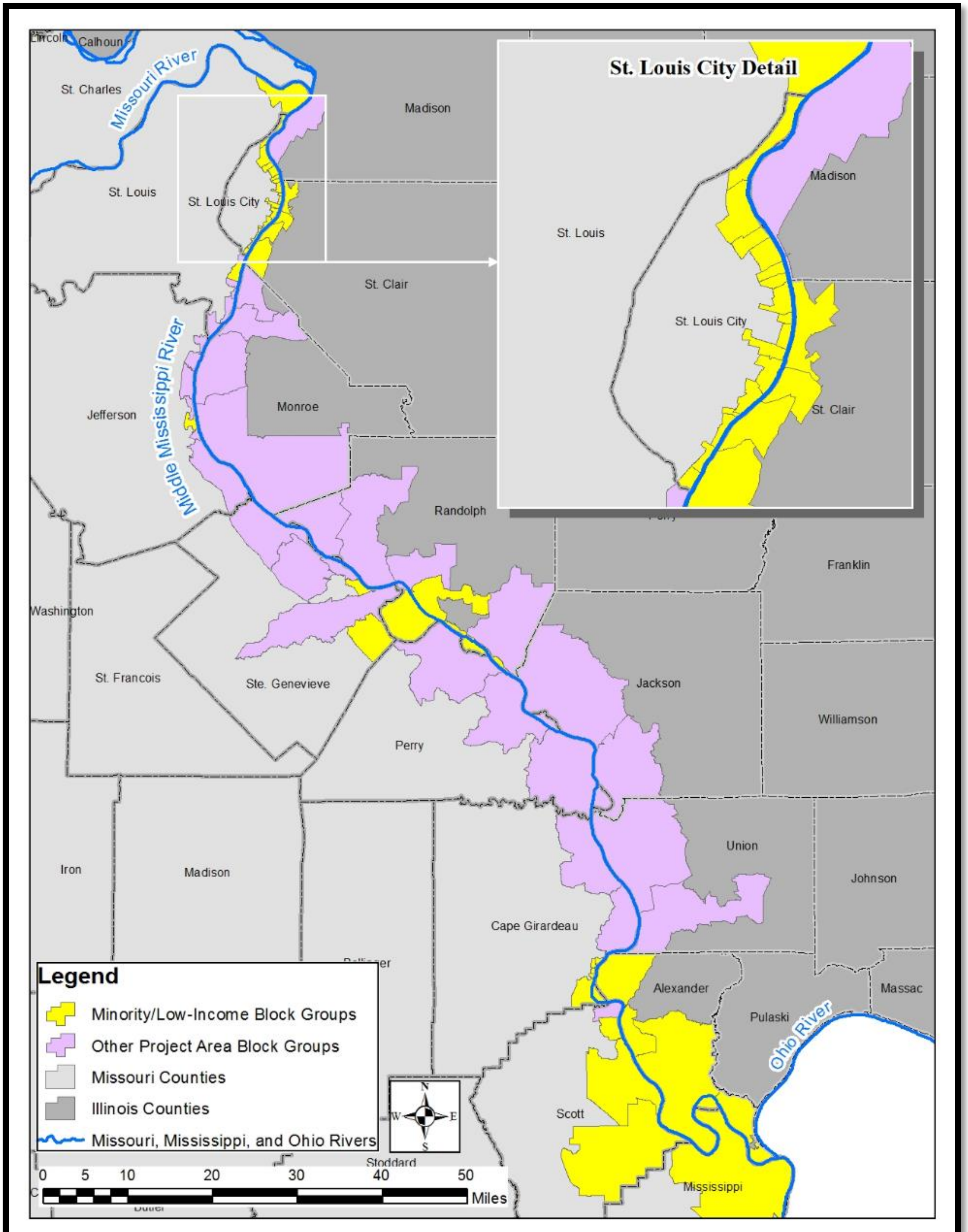


Figure 3-28. Minority and low-income population Census Block Groups within the Project Area.

Land Cover/Land Use

The Middle Mississippi River floodplain area encompasses approximately 670,000 acres (Table 3-12). The majority of the land in the floodplain can be generally categorized as rural and agrarian in nature with isolated areas of highly developed industrialized urban pockets, the St. Louis metropolitan area being by far the largest among them (Figure 3-29). Approximately 50 percent of the floodplain is currently used for agriculture. These areas are generally protected by an extensive levee and drainage system. Forest is the second most abundant land cover class, occupying 18 percent of the area. Open water and developed lands occupy 12 and 9 percent of the area, respectively. The remaining three categories, marsh, grass/forbs, and sand/mud, each account for less than 5 percent of the area.

Comparisons of current land cover distribution to that of past years can be difficult due to differing data coverage. Datasets from the 1800s frequently have large areas where no land cover delineation exists. The only available land cover datasets for the time period around 1976 cover only the portion of the MMR that lay riverward of the levee system at the time instead of covering the entire bluff to bluff floodplain as current analyses do. For these reasons, comparisons of land cover classifications between time periods necessarily cover only the portions of the MMR and its floodplain common to both dates being compared. When comparing current land cover to that of 1890 (Table 3-13), general trends that can be seen are large increases in agriculture and developed areas and large decreases in forested land. When comparing current land cover to that of 1975 (Table 3-14), there are large decreases in agriculture acreage and increases in open water, forest, and marsh.

Table 3-12. MMR floodplain land cover categories, acreages, and percentages (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

Land Cover Category	2011 Acreage (% of Total)
Agriculture	341,665 (51.1%)
Forest	120,404 (18.0%)
Open Water	82,575 (12.4%)
Developed	62,760 (9.4%)
Marsh	29,801 (4.5%)
Grass/Forbs	29,618 (4.4%)
Sand/Mud	1,755 (0.3%)
Total	668,576

Table 3-13. MMR land cover categories, acreages, and percentages for 1890 and 2011 (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

Land Cover Category	1890 Acreage (% of Total)	2011 Acreage* (% of Total)
Agriculture	136,638 (38.2%)	157,568 (44.1%)
Forest	110,062 (30.8%)	68,857 (19.3%)
Open Water	71,935 (20.1%)	67,539 (18.9%)
Developed	3,909 (1.1%)	25,440 (7.1%)
Marsh	6,757 (1.9%)	20,769 (5.8%)
Grass/Forbs	Not delineated	15,452 (4.3%)
Sand/Mud	27,958 (7.8%)	1,634 (0.5%)
Total	357,259	357,259

* 1890 dataset did not contain complete coverage of the floodplain. Therefore, acreage covers only the portions of the MMR and its floodplain common to both dates.

Table 3-14. MMR land cover categories, acreages, and percentages for 1975 and 2011 (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

Land Cover Category	1975 Acreage (% of Total)	2011 Acreage* (% of Total)
Open Water	58,599 (29.0%)	66,688 (33.1%)
Agriculture	78,267 (38.8%)	56,334 (27.9%)
Forest	47,321 (23.5%)	54,566 (27.0%)
Marsh	6,861 (3.4%)	14,605 (7.2%)
Grass/Forbs	1,360 (0.7%)	4,291 (2.1%)
Developed	3,744 (1.9%)	3,664 (1.8%)
Sand/Mud	5,573 (2.8%)	1,578 (0.8%)
Total	201,725	201,725

* 1975 dataset did not contain complete coverage of the floodplain. Therefore, acreage covers only the portions of the MMR and its floodplain common to both dates.

Outdoor recreation

The Middle Mississippi River provides opportunities for a variety of recreational activities including fishing, hunting, boating, birdwatching, sightseeing, etc. and there are public and private boat ramps throughout the 195-mile area affording access opportunities. There are also several state and federal properties on the MMR that facilitate land-based access to the river. However, very little quantitative information is available on the number of users who take advantage of MMR recreational opportunities. Compared to the pooled areas of the Upper Mississippi River which are more conducive to boating related activities, the MMR sees relatively little recreational pressure. Sport fishing is the most popular recreational activity with catfish being the most frequently targeted species.

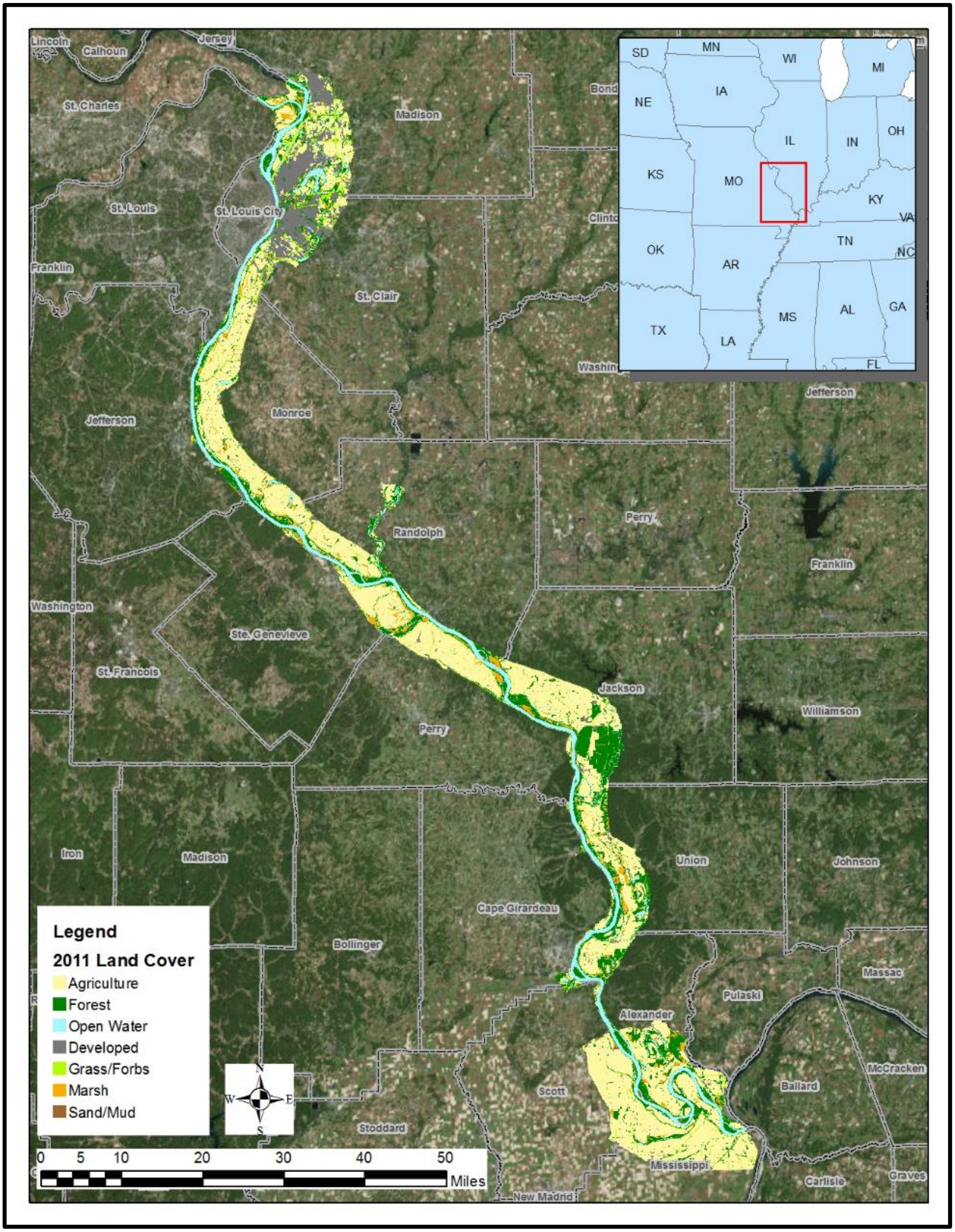


Figure 3-29. 2011 land cover classification for the MMR and its floodplain.

3.4.2 Navigation

The Port of Metropolitan St. Louis plays a key role in meeting the bulk transportation needs of Greater St. Louis and the Midwest with a competitive advantage over other regions because of its central location on the U.S. Inland Waterways System. St. Louis is the third largest inland port in the U.S. by tonnage (USACE 2014e).

The Port is the northernmost ice-free port on the Mississippi River remaining open throughout the year and provides a direct avenue to the Gulf of Mexico and other world markets. The Port is centrally located on the 25,000-mile U.S. Inland Waterway System connecting the markets and industrial centers located along the St. Lawrence Seaway; the Missouri, Ohio, Illinois and Tennessee Rivers; the Gulf of Mexico and beyond to international markets. Intermodal transportation facilities provide industrial and agricultural users within Greater St. Louis cost effective and competitively priced transportation access to and from the U.S. Inland Waterway System and world markets. Because of its location within the agricultural and industrial Midwest, the Port is a major shipper of grain, coal, petroleum products and chemicals (Table 3-15). It provides dependable, efficient, environmentally sound, low-cost transportation particularly for the shippers of bulk commodities where rates and freight cost considerations are the critical ingredient in the competitiveness of their operations.

The Port spans 70 miles and includes five public Port Authorities and dozens of private independent company docks and wharves. Of the five Port Authorities within the Port of St. Louis, only two have active harbor operations. America's Central Port (Tri-City) and St. Louis Port Authority are the operating ports. Jefferson County Port Authority, St. Louis County Port Authority and Southwest Regional Port District are primarily involved in economic development activities and do not have waterside operations. America's Central Port (Tri-City) on the Chain of Rocks Canal typically moves the most tonnage from a single port location. The St. Louis Port Authority leases city-owned land to private companies along the port's 19-mile stretch of the Mississippi River.

Table 3-15 displays the waterborne tonnage that passed through the MMR from 2005 to 2014. During this 10-year period an average of approximately 104 million tons traversed the MMR, with the maximum tonnage (110.3 million tons) in 2006 and the minimum tonnage (89.7 million tons) in 2013. Since the onset of the most recent economic recession in 2008, waterborne shipments on the MMR have settled in around 104 million tons per year. 80% of this tonnage has been in the downstream direction. Of the eight major commodity groups, only three – chemicals, non-metallic ores and minerals, and iron ore and iron and steel products – have seen the majority of shipments head upstream.

Table 3-15. Tonnage of commodities passing through the Middle Mississippi River over the last ten years.

Middle Mississippi River Waterborne Tonnage
2005 to 2014
(millions of tons)

Commodity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Last 10 Years (avg)	Last 5 Years (avg)
COAL	22.91	26.34	26.43	26.23	27.13	22.26	25.59	22.41	17.35	15.54	23.22	20.63
PETROLEUM PRODUCTS	7.25	8.28	8.48	7.20	7.34	6.99	7.07	7.79	8.23	9.35	7.80	7.89
CRUDE PETROLEUM	0.02	0.10	0.37	0.73	0.68	0.89	3.23	4.83	5.75	4.80	2.14	3.90
AGGREGATES	7.14	10.34	9.74	8.70	8.43	8.34	7.95	9.79	10.90	11.48	9.28	9.69
GRAINS & GRAIN PRODUCTS	39.11	40.56	41.68	32.53	40.01	41.52	36.26	33.82	23.11	38.04	36.66	34.55
CHEMICALS	8.22	7.42	9.20	8.64	8.58	10.37	11.59	11.16	10.38	12.39	9.80	11.18
NON-METALLIC ORES & MINERALS	3.63	3.58	3.13	4.87	4.80	2.81	3.58	2.56	2.66	4.88	3.65	3.30
IRON ORE & IRON & STEEL PRODUCTS	6.66	6.69	5.04	4.93	3.21	3.31	3.99	4.24	3.43	4.55	4.61	3.90
OTHERS	7.24	6.96	5.75	4.85	4.16	6.47	7.37	8.18	7.85	8.35	6.72	7.64
TOTAL	102.17	110.26	109.81	98.67	104.32	102.97	106.63	104.77	89.67	109.37	103.86	102.68

Source: Waterborne Commerce Statistics Center (USACE 2014e)

On a commodity level, the distribution of goods on the MMR has held fairly steady since 2005. The emergence of crude petroleum shipments has provided the largest single gain in volume shipped of any commodity. Crude shipments have increased from zero tons in 2005, to almost 5 million tons in 2014. The largest decrease in volume occurred in coal shipments, which have generally been declining since 2009. While some of these commodity fluctuations are quite significant, it is important to note the total tons shipped has remained relatively steady as the maximum and minimum are both within 9 percent of the 10 year average.

Of all of the shipments made on the MMR, grains and grain products accounted for between 26 and 40 percent of the total tonnage. From 2005 to 2014, corn led all other grains with 55% of the tonnage, followed by soybeans (27%), wheat (5%), and oil seeds or oleaginous fruits (5%). Roughly 18% of all corn and soy beans produced in the U.S. are shipped using the MMR.

Commodities by Draft[15]

Draft depth is driven by the demand for waterborne shipping and river conditions. Table 3-16 shows the 10-year distribution of commodities shipped by draft depth. The vast majority of

[15] The draft of a vessel is defined as the vertical distance between the water line and the lowest point on the vessel, or the depth of water to which a vessel sinks based on its load.

tonnage is shipped on barges with a draft of 8-9 feet. During favorable river conditions, high demand can be met by loading barges in excess of 9 feet, resulting in fewer trips and a lower shipping cost. If there is low demand or unfavorable river conditions, the carrier may be forced to partially load a barge, resulting in draft depths of less than 9 feet. During this period, 95% of the MMR tonnage was shipped on barges with at least 8 feet of draft.

Table 3-16. MMR Commodities by Draft.

Commodities by Draft Depth
2005 to 2014
(thousands of tons)

DRAFT (ft)	COAL	PETROLEUM PRODUCTS & CRUDE PETROLEUM	AGGREGATES	GRAINS & GRAIN PRODUCTS	CHEMICALS	NON-METALLIC ORES & MINERALS	IRON ORE & IRON & STEEL PRODUCTS	OTHERS	Total
Less than 5	72	92	8	47	525	165	54	121	1,083
6	85	104	12	532	213	79	17	81	1,122
7	412	450	22	686	693	373	92	339	3,067
8	4,549	1,260	218	2,623	13,852	4,760	1,837	2,101	31,202
9	15,518	3,785	1,068	4,019	14,852	3,340	1,024	1,684	45,289
10	802	1,565	501	818	1,871	565	210	120	6,452
11 or more	1,031	544	310	539	4,505	494	403	155	7,980
All Drafts	**22,469**	**7,800**	**2,139**	**9,263**	**36,511**	**9,775**	**3,638**	**4,601**	**96,195**

Source: Waterborne Commerce Statistics Center

Value of Commodities
The U.S. Department of Transportation Commodity Flow Survey for 2012 estimated that a total of 374.2 million tons of goods were shipped by inland waterways, valued at approximately $202.3 billion. The MMR accounted for almost 28% of this tonnage and roughly 10% of the value. The low MMR value, compared to the total inland waterway tonnage, is driven by the relatively low cost of grains.

Using current prices for the commodities, the total estimated value for the commodities shipped on the MMR is $20.9 billion per year, with agricultural products ($8.2 billion) and chemicals ($8.1 billion) making up 78% of the total value. The sources for the unit prices for these commodity groups were found on the U.S. Geological Survey, U.S. Department of Agriculture, Platts (futures), Energy Information Agency, and CME Group (futures) websites. This represents a rough estimate based on approximations for the value of a wide range of products within each commodity type.

3.5 Historic and Cultural Resources

3.5.1 Cultural Resources Policy

The National Historic Preservation Act of 1966 (NHPA) directs that federal agencies consider an undertaking's effects on cultural resources. Section 106 of the act requires that federal agencies assess the effects of the undertaking on historical properties and consult with the relevant State Historic Preservation Officer (SHPO), affected Tribes, and other interested parties. The regulation implementing Section 106, 36 CFR Part 800, encourages coordination with the environmental review process required by NEPA and other statutes.

Properties protected under Section 106 are those that are listed, or are eligible to be listed, on the National Register of Historic Places (NRHP). Eligible properties must be, generally, fifty years old and considered to have integrity of location, design, setting, materials, workmanship, feeling, and association. They must be significant under one or more specified criteria:

(a) They must be associated with events that have made a significant contribution to the broad patterns of our history; or
(b) They are associated with the lives of persons significant in our past; or
(c) They embody distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
(d) They have yielded, or may be likely to yield, information important in prehistory or history.

3.5.2 Cultural and Historical Setting

Documentation of the Mississippi River Valley prehistoric and historical sequence is extensive and only a brief outline is presented here. Prehistoric human occupation of the area is generally broken into four inclusive periods: Paleo-Indian, Archaic, Woodland, and Mississippian. Each period is characterized by differing degrees of social complexity and changes in subsistence technologies and pursuits. The Paleo-Indian period represents the first populating of North America. The earliest evidence for the occupation of mid-continental United States are fluted points made around 13,500 to 12,700 years ago (Morrow 2014; Fiedel 1999). Paleo-Indians are generally characterized as consisting of smaller groups of hunter and gatherers following migrating herds of large game. The period lasted until the end of the Wisconsin glaciation around 8000 B.C. when the stabilizing climate led to the different ecological adaptations of the Archaic period. While hunting and gathering continued, there was some cultivation of native plants. Larger communities formed as a more sedentary culture developed. The subsequent Woodland culture (1000 B.C. to 900 A.D.) is characterized by the widespread use of pottery, increasing use of agriculture, and development of long-distance trade. The sociocultural traits generally ascribed to the following Mississippian period (900 to 1400 A.D.) include intensive agricultural adaptations, increasingly large fortified towns, pyramidal mounds, increased interregional trade, and highly stratified sociopolitical organization. The most elaborate and famous expression of the culture is the extensive settlement of Cahokia Mounds located on the American Bottom near modern Collinsville, Illinois.

European exploration of the Middle Mississippi began with the voyage of Jacques Marquette and Louis Joliet down the river in 1673. A trading establishment and mission were built at “Grand Village of the Illinois” in 1675. Kaskaskia was established in 1703, Sainte Genevieve around 1750, and St. Louis in 1764. For much of the 18th and 19th centuries commerce on the river was driven by the fur trade, while there was some limited trade in salt and lead. The introduction of steamboats in the early 19th century, along with the increasing development of the region, greatly expanded the volume of the trade in general commodities and the transportation of people. The number of vessels engaged in river traffic increased yearly along with their size and the number of round trips each took in a given year (Haites and Mak 1971).

3.5.3 Area of Potential Effect

36 CFR Part 800.16 defines area of potential effect (APE) as "the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character of use of historic properties, if any such properties exist." For cultural resources, the APE for the Middle Mississippi River Regulating Works Project is from bankline (mean high water) to bankline of the river between the Ohio and Missouri River confluences (RM 0 and RM 195, respectively).

3.5.4 Shipwreck Background

Before contact with Europeans, Native American communities used the Mississippi as a means of transportation by several types of watercraft. Many descriptions are readily available from early European documents and illustrations, while archaeology provides more limited evidence.

Many of the native forms of water transport are now known as canoes; the term is derived from the Arawakan word *canot*, first borrowed by the Spanish and later Anglicized. It is a general term used for many structurally different types of watercraft including those with bark, sewn-plank, skin, and dugout construction styles. From ethno-historical sources, however, it appears that throughout much of North America by that time bark canoes were the most widely used rivercraft (Gamble 2002).

After the arrival of Euroamericans a number of smaller vessel types were introduced. The terms used, such as pirogue, bateau and skiff, are often ambiguously applied and should not be taken to describe a single and unique style of construction.

By the late 18th century, however, two general classes of vessels dominated navigation on the Middle Mississippi River: flatboats and keelboats. Both classes incorporated many sub-varieties and were known by different names. Flatboats, for example, were also known as arks, flats, Kentucky boats, and broadhorns.

Flatboats were, in essence, floating rectangular boxes. Flat bottomed and usually roofed for protection from inclement weather, they were generally around sixty feet long and twenty feet wide (Hoagland 1911). A unique archaeological example was recorded on the Ohio just above the confluence with the Mississippi in 2002 (Wagner 2003). The remains consisted of a shell-built edge-joined flat bottomed structure, and probably dated to the first quarter of the 19th century.

Flatboats were ungainly vessels only partially guided by long broad sweeps. Carrying any number of different bulk goods, flatboats were only used for downstream commerce and were generally broken up as lumber once at their destination. Due to the dangers resulting from being only controlled to a degree during their descent, flatboat traffic was limited to a few months of the year during high water, except on the Lower Mississippi (Hoagland 1911). Even then insurance companies generally refused to insure this type of vessel (Mak and Walton 1973).

Keelboats were generally long, narrow, and shallow craft with pointed ends, a planked deck, and a cabin which covered the majority of the boat. The key difference from the earlier bateau was the introduction of a keel either added externally or, more usually, as part of its interior construction (Baldwin 1941). Made of plank construction with interior frames, they generally were from forty to sixty feet long and seven to ten feet wide (Hoagland 1911). They drew about two feet of water when loaded. Traveling downstream they were rowed, but to travel upstream they were generally poled at the rate of eight to ten miles per day. If the water was too deep for poling, the crew would tow the boat from the shoreline.

The use of steamboats on the western rivers was inaugurated when the *Orleans* traveled from Pittsburg down the Ohio and Mississippi and arrived in New Orleans in January of 1812. The advantages of steam propulsion are as obvious as they are revolutionary. Trips took a fraction of the time, allowing for more tonnage to be carried by a vessel, or fleet, in a given period. Moreover, steam power reduced navigational risks compared to floated, rowed, or sailed vessels. The vessel loss rate, however, continued to be high compared with modern standards. The combination of advantages cut the cost of transportation in half (Landon 1960).

Steamboats rapidly replaced keelboats and flatboats. By the beginning of the 1820s some 70 steam vessels were in operation on the Mississippi River system and by the middle of the century the number had risen to over 700 (Tuttle and James 2005). The introduction of steamboat technology made the Mississippi River system one of the most heavily trafficked in the world. In the 1840s the tonnage of its boats accounted for half the register amount of the nation as a whole, and during the 1850s it was greater than all transported by the merchant ships of the British Empire at that time (Landon 1960).

The earliest steamboats were side-wheelers, but by 1880 stern-wheelers outnumbered them (Landon 1960). The latter had several advantages. On the Ohio, stern-wheelers were almost a necessity after the opening of the Louisville canal in 1830. The canal was only 82 feet wide and while the larger stern-wheelers could slip through the channel, wider side-wheel boats of the same tonnage were shut out from trade above Louisville. Moreover, when the river was low boats could not carry full cargos and found it useful to lay freight barges along each side of the steamer (Hall 1884). One would carry cargo and the other would carry fuel. On such a “light water trip” on the Ohio, when the vessel arrived in Cairo, the cargo was transferred to the steamer for the remaining voyage down the Mississippi (Figure 3-30). The use of lighters was a common way to reduce a vessel’s draft on all the rivers. Screw (i.e., propeller) propulsion was introduced on maritime vessels in the 1840s and 1850s, but was not used on the rivers until 1930. The shallow river depths made the equipment more vulnerable and less efficient. The introduction of the more powerful and cost efficient diesel engines hastened their adoption as they could not be used to advantage with a paddle wheel (Landon 1960).

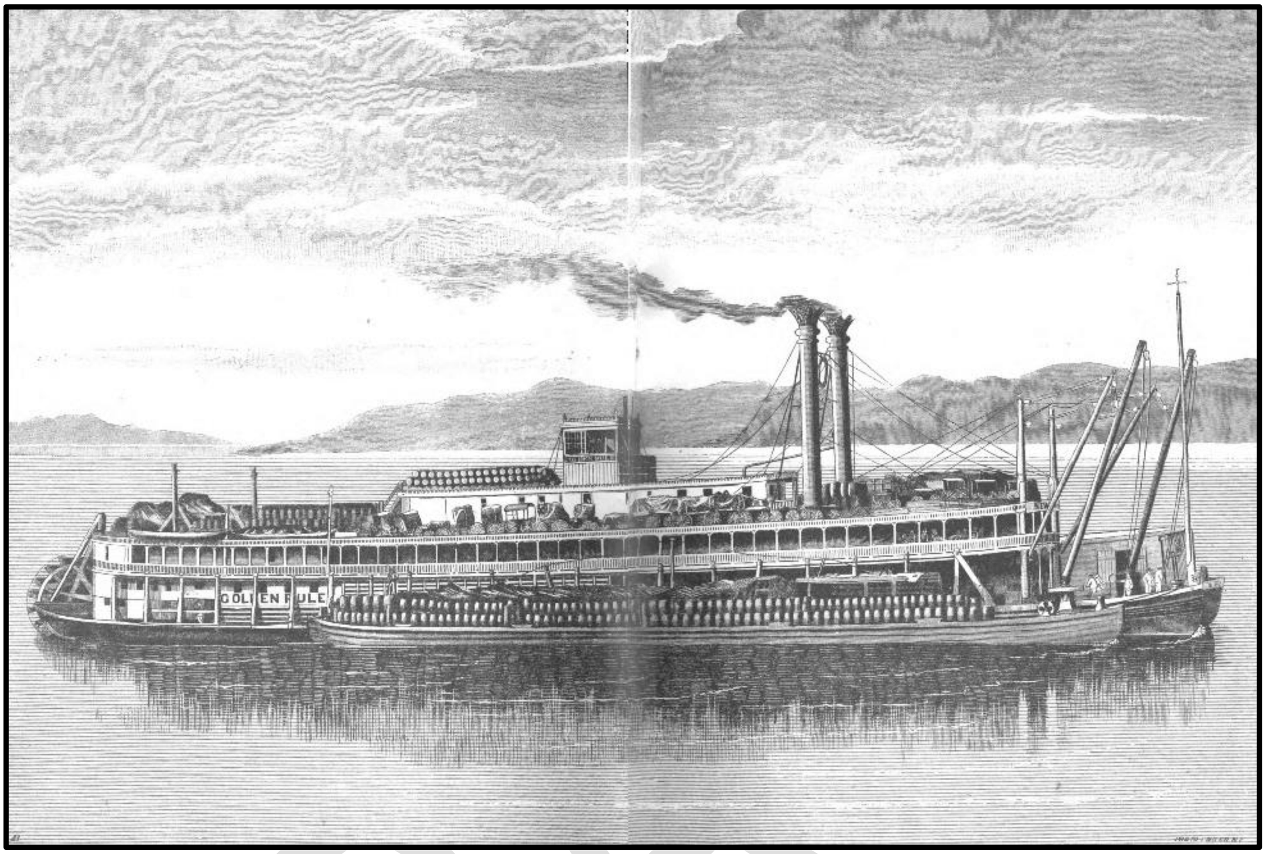


Figure 3-30. Stern-wheel freight boat Golden Rule with barge lashed alongside (from Hall 1885, Figure 53).

The number of steamboats arriving at New Orleans reached a high of 3566 in 1860 (Landon 1960) before the Civil War disrupted commerce (Landon 1960). After the war the trade quickly recovered and was profitable until about 1875. In 1882 there were 1198 vessels on the western rivers for a total of 251,793 tons (Hall 1885). Additionally there were 5397 flat boats and barges measuring 1,251,529 tons. A long term danger to the industry, however, was the rise in competition from the railways. After 1890 there was a rapid decline in the number of vessels engaged in trade. The nadir of Mississippi River commerce came in 1918 when about five-and-a-half million tons were shipped (Landon 1960).

From their inception, steamboats were used to tow non-powered craft. Indeed, in maritime settings their earliest use was to tow sailing vessels in and out of harbors when the wind was not advantageous. It was common for steam vessels on the Mississippi to tow a barge or two alongside, either as lighters (as outlined above), or simply for extra cargo.

By 1880 there were four recognized classes of barges (Hall 1884). The smallest was the flatboat. Related in function to the earlier flatboat, they were the smallest barge being 90 feet long by 16 feet wide and registering about 75 tons. They were square and box-like with a raking bow and stern. Unlike their earlier namesakes they were undecked and not intended to be disposable. They were generally used for short trips on small streams. The second type was the coal barge, another open boat, about 130 feet long, 24 feet wide, and registering around 225 tons. Most of these were employed on the Ohio River bringing coal from Pennsylvania and West Virginia to locations south. The main difference between them and the flatboats was their size and higher construction standards. The third type, also found on the Ohio, was a smaller cheaper version of the coal barge.Produce boats were around 122 feet long by 22 feet wide and were designed to be broken up upon reaching their destination. After its introduction in the 1860s, the pride of the barge fleet was the model barge. There were four sizes carrying 600, 800, 1000, and 1200 tons respectively. The 1200 ton version was 225 feet long, 36 feet wide and with a depth of nine-and-a-half feet. Their defining hull characteristic was their "pinkie stern," which made them double-ended (Figure 3-31). After the introduction of the towing knee in 1865, barges were generally pushed in the western rivers (Landon 1960). By 1880 it was not uncommon for fleets of eight barges wide and four barges long to be lashed together ahead and alongside the bow of a steamer (Hall 1884). Until the 1930s the typical towboat was a steam stern-wheeler of 600 to 1000 horse power. Since then they have been replaced by diesel powered screw propeller vessels.

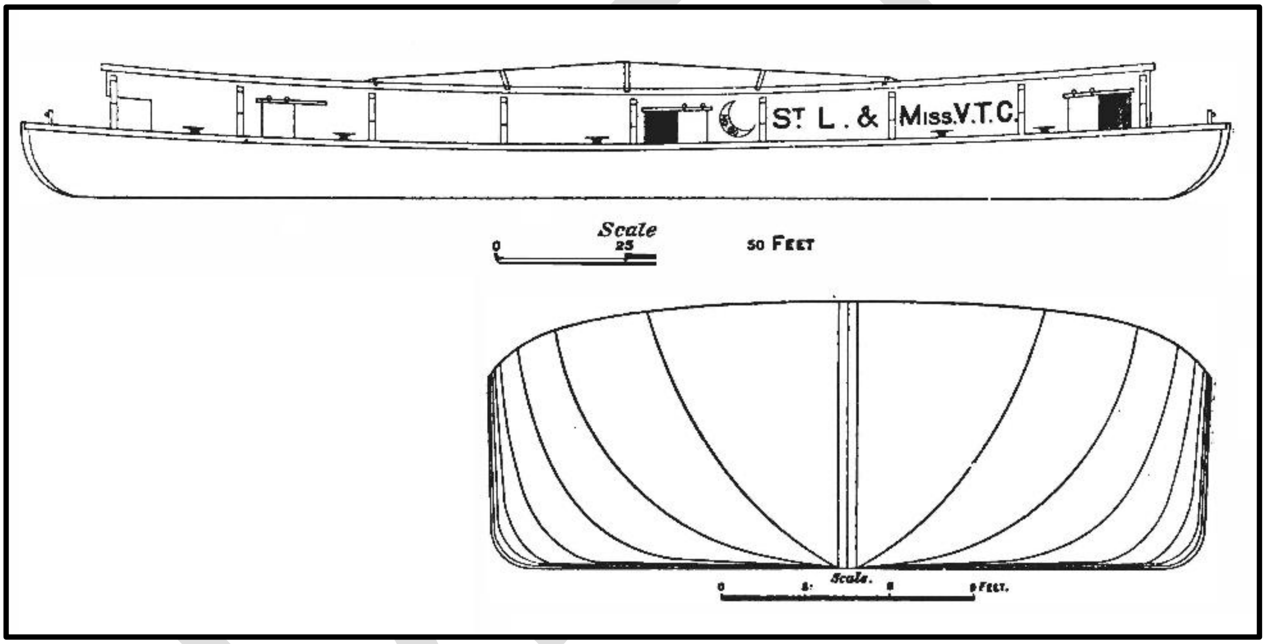


Figure 3-31. 1200 ton class model barge (from Hall 1885, Figures 56 and 57).

3.5.5 Shipwreck Inventory

Losses among steamboats were high. Primary reasons for their destruction were snags, fires, and explosions. Indeed, the average longevity for steamboats has been calculated to be only six (Haites and Mak 1971) or seven (Hall 1884) years. For this reason insurance rates were high and many operators carried none; those that did typically only did so for two-thirds or three-quarters the value of the boat (Haites and Mak 1971).

As part of a 2003 Corps study, archival research documented six hundred and eighty seven (687) ships abandoned or reported lost prior to 1940 between Saverton, Missouri, and the confluence of the Mississippi and Ohio Rivers. The information was obtained by James V. Swift from a variety of sources, including unsigned, undated wreck data in the files of the Waterways Journal

(St. Louis), nineteenth century correspondence and newspaper accounts, insurance records, official government surveys and reports, private accounts, and published research (Norris 2003). Generally, most losses were reported with a general location (e.g., Scudder Towhead, Brewer Point), which was researched and when possible converted to approximate river miles (Figure 3-32). The yearly mean for reported losses is just over five-and-a-half (5.5) with a peak in the 1850s to 1860s (Figure 3-33). A number of individual historic events, such as the St. Louis Fire of 1849, are responsible for some of the peak years.

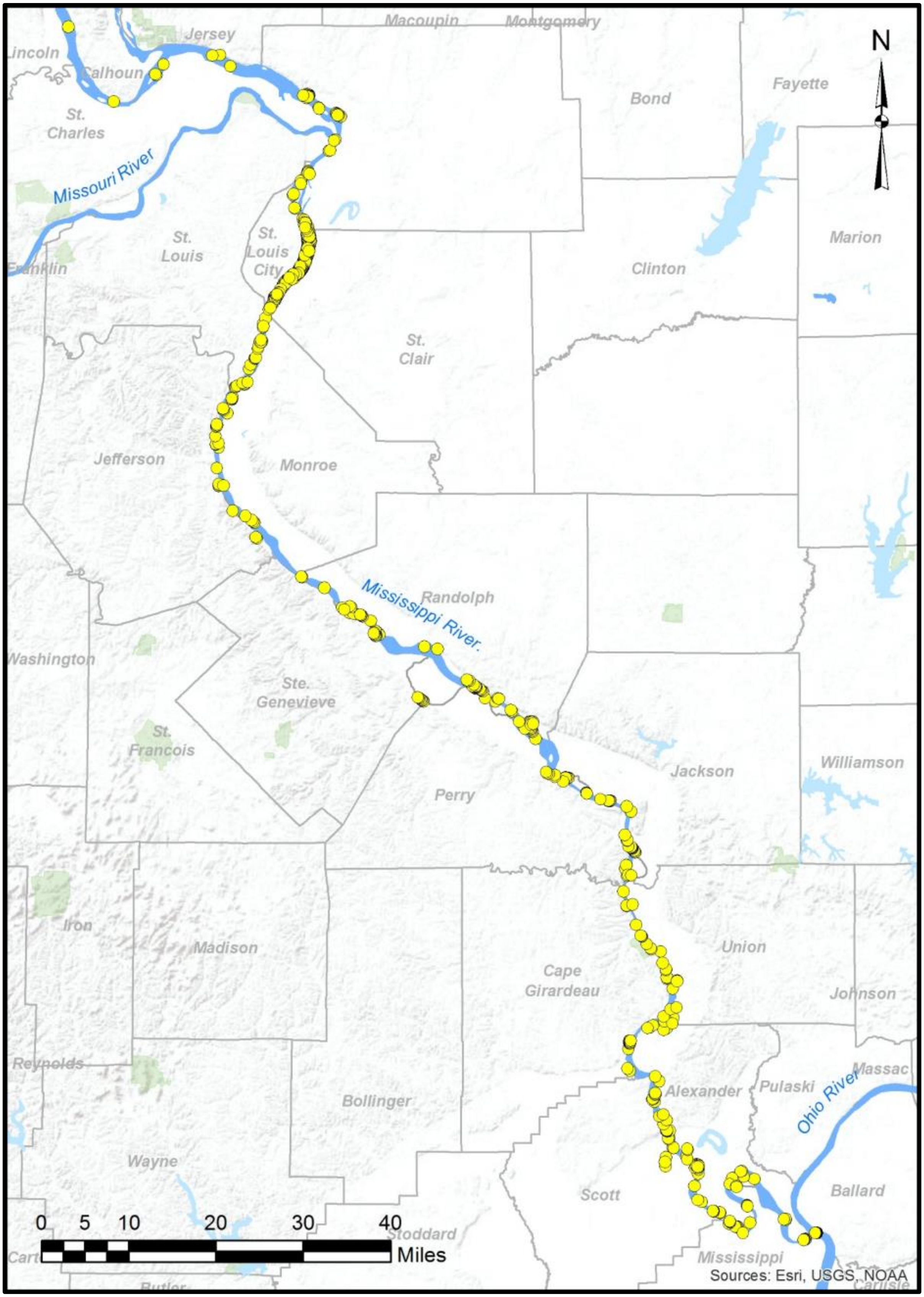


Figure 3-32. Approximate locations of documented vessel losses on the Middle Mississippi River.

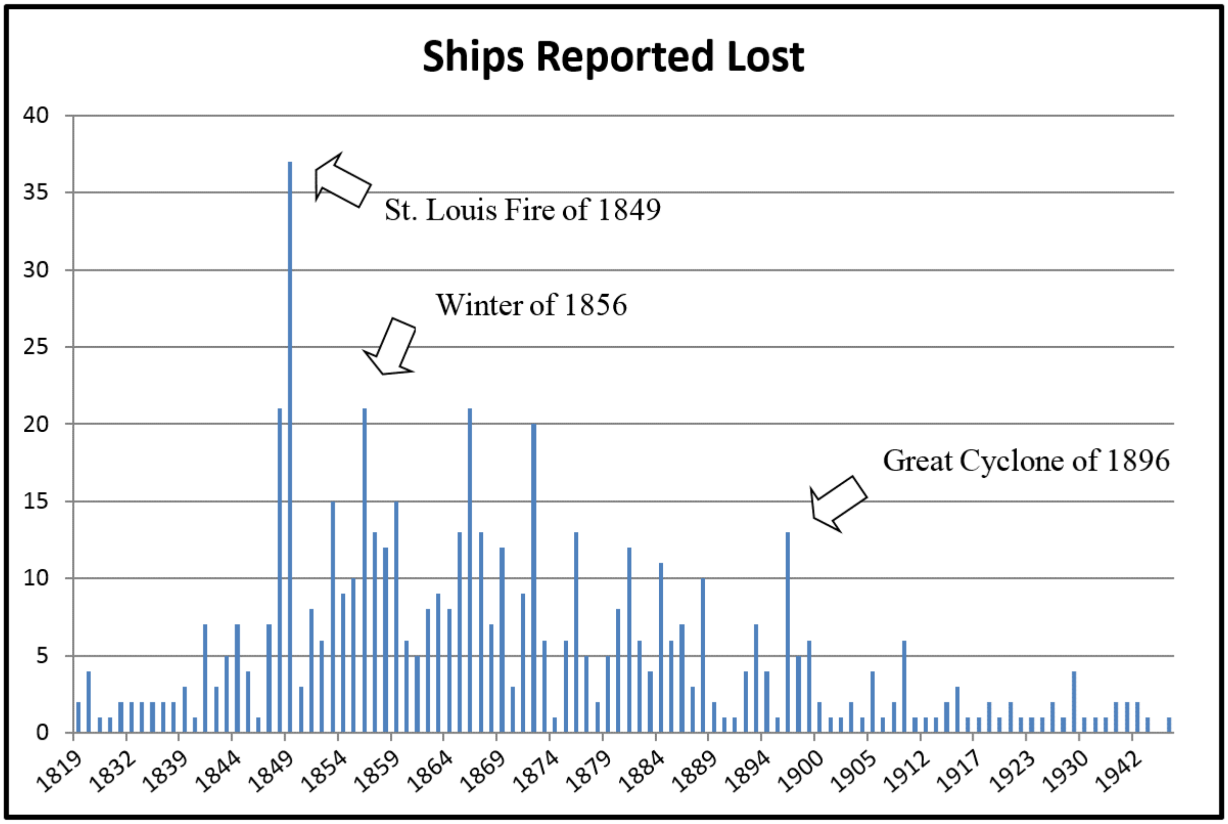


Figure 3-33. Recorded ship losses per year.

The database should not be considered exhaustive of all watercraft losses, however, as smaller vessels and the more numerous barges were less likely to make accounts. Indeed, only forty nine (49) of the entries are identified as barges, or groups of barges, even though we know from archival records they were more numerous than steamboats by a considerable margin. No keelboats or other early vessel types are identified. The descriptions are a mix of functions and forms (Table 3-17).

Table 3-17. Vessel descriptions in losses database.

Vessel Description	Count	Vessel Description	Count
Barge	49	Stern-wheel boat	49
Canal boat	2	Stern-wheel towboat	2
Dredge	1	Tinclad	1
Excursion boat	2	Towboat	15
Ferry	9	Transfer boat	3
Gunboat	1	Tug	1
Recessed-wheel boat	1	Wharf boat	4
Side-wheel boat	119	Wrecking boat	1
Side-wheel ferry	1	None Given	425
Side-wheel snagboat	1		

The most frequent cause of loss was burning, especially if one includes explosions within that category (Table 3-18). The second most frequent cause was ice damage, followed by snags.

Table 3-18. Vessel cause of loss in loss database.

Cause	Count
Abandoned	25
Burned	184
Capsized	5
Collision	12
Dismantled	1
Exploded	13
Hit bridge/tower	6
Hit obstruction/wreck/rocks	7
Ice	85
Sank (unspecific)	75
Snagged	81
Stranded	18
Tornado	15
Wind	5

3.5.6 Known Shipwrecks

The St. Louis District maintains two databases of shipwrecks which are updated periodically as new wrecks are discovered by the Corps, other government agencies, or independent research groups (Figure 3-34). The first is comprised of historical shipwrecks, most of which are relatively insubstantial and located in normally shallow water outside of the navigation channel. The second documents more significant, and generally more recent, wrecks that may pose a risk to navigation.

The nucleus of the historical wreck database was created during a 1988 aerial survey of the Mississippi River, between Saverton, Missouri and the mouth of the Ohio River, when it was at a particularly low level (Norris 2003). Since then surveying techniques have improved with the use of a variety of sonographic tools, such as single and multi-beam surveys, as appropriate. The district conducts bathymetric surveys on the MMR bi-annually and in conjunction with dredging cycles and/or other Regulating Works Project activities. As outlined in Section 4.5, as part of the Tier II SSEAs multi-beam sonar surveys are conducted before the construction of structures associated with the Regulating Works Project. To date, no wrecks have been discovered by the latter surveys.

In total, approximately 90 wreck locations have been identified, and while few shipwrecks have been discovered in recent years, if discovered during the above mentioned surveys consultation with the appropriate SHPO and other interested parties would be undertaken to determine appropriate measures for their documentation and/or preservation.

Of the known wrecks in the Middle Mississippi River only one was on the National Register of Historic Places. The USS Inaugural (AM-242), an Admirable class fleet minesweeper, was listed on 14 January 1986 with NPS Reference Number 86000091. The vessel was berthed at the northern leg of the Gateway Arch in St. Louis. During the 1993 flood, she broke loose from her moorings, suffered a breach, and sank on the Missouri side of the river at approximately RM 178.75. Determined a total loss, her Landmark designation was withdrawn on 7 August 2001. Scrapping efforts began in 2013.

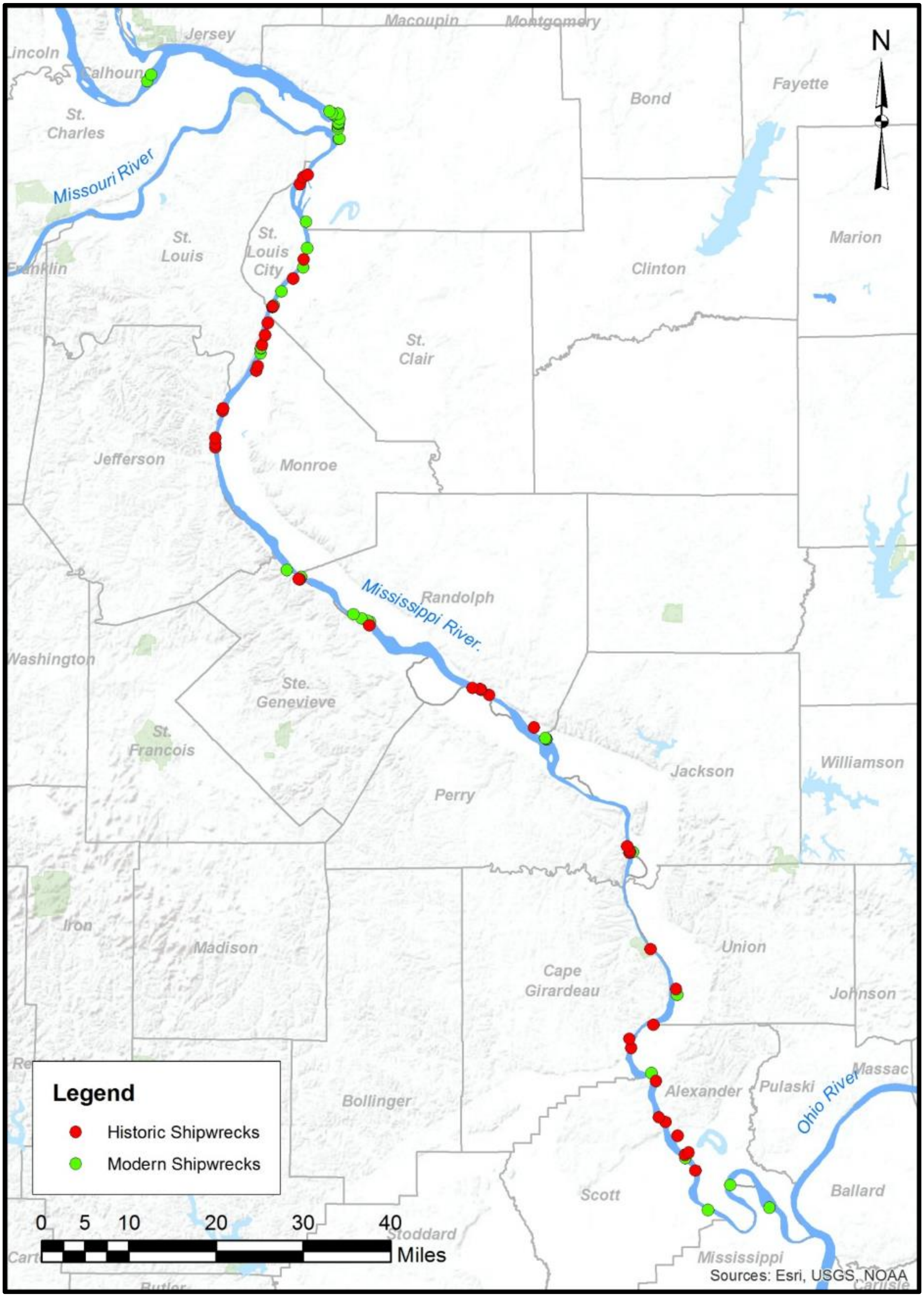


Figure 3-34. Known shipwrecks on the Middle Mississippi River.

3.5.7 Regulating Works Project

The District, in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), prepared a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River Regulating Works Project. Given that the Project contains structures of sufficient age to be considered for the National Register, and that some of these structures may be modified or removed by future engineering efforts, it was considered appropriate to address the Project's National Register eligibility (See full report as Appendix F).

The DOE assesses the historic and engineering significance of the Project and its associated built features. It includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. Key sources included Corps annual reports; authorizing legislation concerning the MMR; and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also consulted, along with the MMR features catalog, providing location data from 1881 to the present for dikes constructed as part of the Project.

The Project is recommended, due to a loss of integrity, as *not eligible* for the National Register. The study indicates that the Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR is demonstrated to be immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. To be eligible for the National Register, however, a property must also possess integrity, i.e., the ability of a property to convey significance. The study demonstrates that due to continual, but necessary, modifications of various river training structures, the Project no longer retains integrity of materials and workmanship from its period of significance (1881-1965). With most, if not all, of its associated structures constructed or modified since 1965, the Project is unable to convey its considerable national significance as necessary to be considered eligible for the National Register.

3.5.8 Other Cultural and Historic Resources

Other anthropogenic structures within the project APE may include remnants of historic mooring piles, quays, railroad inclines, and river training structures. Prehistoric sites and their features are not expected to survive in the reworked underwater environment, except for on occasions when a feature is non-perishable (i.e., not likely to decay or breakdown). A unique example of such a feature is a periodically submerged boulder with a petroglyph panel at the Commerce Quarry and Petroglyph site (23ST255) (Norris and Pauketat 2008).

While the Middle Mississippi alluvial plain is the location of literally thousands of known archaeological sites, only a relatively few are within the project APE. In the Missouri SHPO database there are nine (9) sites mapped within 100 feet of the Mississippi River bankline. In the

Illinois equivalent database there are fifteen (15) such sites. Of the combined twenty four sites (24), one is a wreck recorded in the Corps database (Table 3-19).

Table 3-19. Known archaeological sites within 100 feet of Project APE.

Period	Type	Number
Prehistoric	Habitation/Scatter	10
	Habitation (Rock Shelter)	3
	Mound	1
Historic	Habitation/Scatter	6
	Cemetery	1
	Industrial	1
	Wreck	1
Multi-component	Habitation	1

Twelve (12) districts or locations on the National Register of Historic Places are within 100 feet of the project APE (Table 3-20; Figure 3-35). Two of these sites, Eads Bridge and Fort de Chartres, are also National Historic Landmarks.

Table 3-20. National Register sites within 100 feet of Project APE.

Item	NPS Reference
Chain of Rocks Bridge	06001091
Eads Bridge	66000946
Fort de Chartres	66000329
Grand Tower Mining, Manufacturing and Transportation Company Site	79000839
Green’s Ferry (Cherokee Trail of Tears MPS)	07000571
Greystone-Meissner, Gustave House	74001078
Jefferson Barracks Historic District	72001492
Jefferson National Expansion Memorial National Historic Site	66000941
Laclede’s Landing	76002262
North Riverfront Industrial Historic District	70000344
Steins Street District	64000390
Tower Rock	70000344

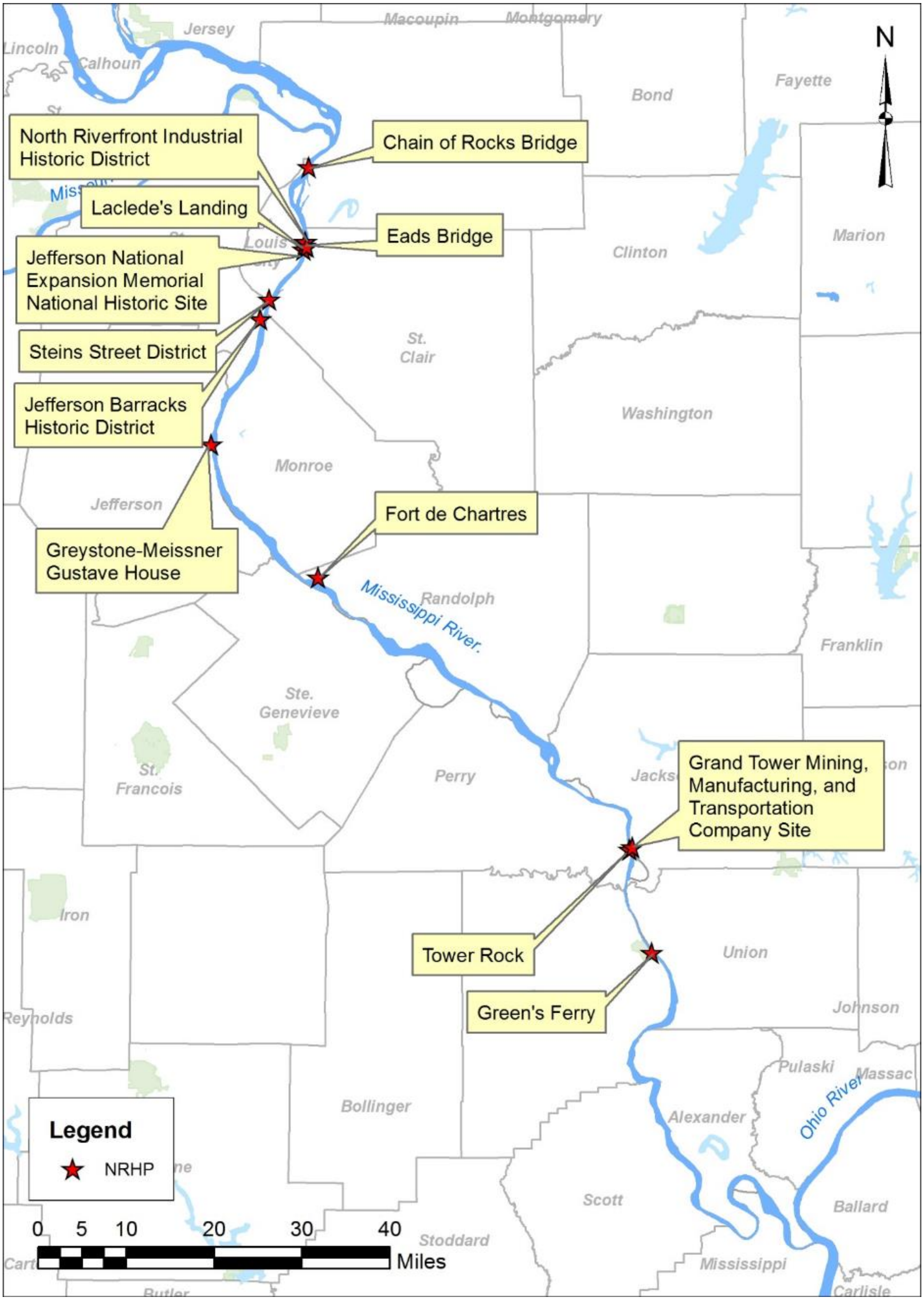


Figure 3-35. Locations of NRHP sites/districts within 100 feet of APE.

Chapter 4. Environmental Consequences

4.1 Introduction

This chapter describes the potential environmental consequences of implementing the alternative plans considered. A comparison of direct, indirect, and cumulative impacts of alternatives is presented. Direct impacts are those that are caused by the action taken and occur at the same time and place (40 CFR §1508.8(a)). For example, an increase in turbidity associated with dredging would be a direct impact on water quality. Indirect impacts are those that are caused by the action but are later in time or further removed in distance, but are still reasonably foreseeable (40 CFR §1508.8(b)). For example, the increase in macroinvertebrates as a food source due to colonization of rock surfaces would be an indirect impact of river training structure construction on fish. Cumulative impacts are impacts that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such actions (40 CFR §1508.7). Cumulative impacts would be the aggregate of impacts to the environment resulting from the proposed action in combination with other ongoing actions, and actions being considered within the reasonably foreseeable future. Cumulative impacts can result from actions that are individually minor but collectively significant over time (40 CFR 1508.7). For example, the construction of one dike in the MMR might have little impact when considered by itself, but the combined construction of all dikes in the MMR since the 1800s, and the resultant narrowing of the river channel, would be a cumulative impact. Cumulative impacts are more readily conveyed and understood when considered together rather than separately by resource category. Therefore, the cumulative impacts discussion for all resources can be found in Section 4.6 Cumulative Impacts at the end of this chapter.

As with Chapter 3, this chapter is organized by general resource categories: Physical Resources, Biological Resources, Socioeconomic Resources, and Historic and Cultural Resources. The impacts of both alternatives are combined under each resource heading. The impacts of implementation of each Alternative are evaluated relative to the baseline condition of each resource category. The baseline conditions of all resources are discussed in Chapter 3, Affected Environment, and reflect the current environmental and socioeconomic condition of the Middle Mississippi River.

Summary of Alternatives:

Continue Construction Alternative (No Action Alternative): The Continue Construction Alternative for this SEIS represents no change in the current implementation of the Regulating Works Project, with the addition of analyzing the potential need for and implementation of compensatory mitigation. Under a normal feasibility study seeking authorization for a new project, the No Action Alternative would mean that no action is to be taken. However, in the instance of an ongoing program, the No Action Alternative refers to no change in program direction (CEQ 1981). Accordingly, the No Action Alternative for this SEIS represents continuing with implementation of the Regulating Works Project as it is currently being implemented. The potential addition of compensatory mitigation measures to this Alternative does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained. Therefore, this Alternative is still considered to be the No Action Alternative. Truly taking “no action” in this case and, thereby, not maintaining the navigation channel on the MMR, is not a viable option and will not be considered, as discussed in Chapter 2.

Based on current estimates, the Continue Construction Alternative would entail placement of an estimated 4.4 million tons (2.9 million cubic yards) of rock at a rate of approximately 260,000 tons per year. This estimate is based on assumptions of Congressional funding levels, rock prices, dredging costs, etc. and could differ markedly from actual implementation. The Continue Construction Alternative would also involve continuing to dredge as necessary, completing known bankline stabilization projects to reduce the risk of a channel cutoff, placing additional revetment, and continuing to maintain existing structures. Dredge quantities would be expected to decrease from their current average annual quantity of approximately 4 million cubic yards to approximately 2.4 million cubic yards after construction of new river training structures is complete.

No New Construction Alternative: The No New Construction Alternative consists of not constructing any new river training structures for navigation purposes, but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to perform their intended functions. Maintenance dredging would continue at roughly the current level of approximately 4 million cubic yards per year. Maintenance of river training structures and revetment would be completed based upon need and annual funding received.

Both alternatives would continue to be in compliance with the Endangered Species Act as legally required. Actions as part of this compliance are not specifically discussed in this SEIS.

4.2 Impacts on Physical Resources

4.2.1 Impacts on Stages

Impacts of the Continue Construction Alternative on Stages

With implementation of the Continue Construction alternative, stages at average and high flows on the MMR are expected to be similar to current conditions. An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research has analyzed historic gage data, velocity data, and cross sectional data. Physical and numerical models have also been used to determine the effects of dikes on water surfaces. Some of this research purports that river training structures raise flood heights. A summary of all of the available research on the effects of river training structures on flood heights can be found in Appendix A. Based on an analysis of this research by the Corps and other external reviewers, the District has concluded that river training structures do not affect water surface elevations at higher flows.

With respect to water surface elevations at low flows, analysis of the data shows a trend of decreasing stages over time. This decrease could be a result of river training structure placement and/or a decrease in the sediment load in the river due to construction of reservoirs on Mississippi River tributaries (Huizinga 2009). The same conclusion regarding decreasing stages at low flows was reached in the 1976 Regulating Works EIS (USACE 1976). The 1976 EIS concluded that, as a result of stage decreases, many of the remaining side channels in the MMR might be lost at some point in the future due to sedimentation. While much research has been performed on the impacts of river training structures at high flows, similar research has not been performed on the impacts at low flows.

Impacts of the No New Construction Alternative on Stages

Stages for high flows are expected to be similar to current conditions under the No New Construction Alternative. The stages at low flows are less straightforward. The decreasing trend in stages for low flows can be attributed to a number of factors potentially including the construction of regulating works structures. It is expected that there would continue to be a decrease in stage for lower flows in the future even without any additional regulating works construction. However, the magnitude of this change attributable to regulating works cannot be determined.

4.2.2 Impacts on Geomorphology

Impacts of the Continue Construction Alternative on Geomorphology

Through the period of structure construction from the 1960s to present very little change has occurred to the planform. It is expected that this would continue moving forward with the Continue Construction Alternative. It is also expected that the average planform width, planform surface area and channel surface area would continue to be in a state of dynamic equilibrium.

It is expected that the cross sectional area, hydraulic depth, channel volume and channel conveyance would continue to increase due to continued construction of river training structures. This is the result of the changes in channel cross section to a narrower, deeper and more efficient shape due to the construction of river training structures. The magnitude of these changes is uncertain due to the other factors that can impact the channel geometry.

A channel cutoff similar to the capture of the Kaskaskia River in 1881 could result in major changes to channel geomorphology. However, one of the objectives of the Regulating Works Project is to prevent a channel cutoff from occurring. One example of a project developed to prevent a cutoff is Thompson Bend. It is expected that there will be other locations on the MMR that will need to be addressed to prevent a channel cutoff. Future projects will be addressed with SSEAs.

Impacts of the No New Construction Alternative on Geomorphology

It is expected that under the No New Construction Alternative there would be no changes to the planform dimensions. Due to the other factors impacting channel geometry, channel cross sectional area, hydraulic depth, channel volume and channel conveyance would continue to increase. The magnitude of these changes is uncertain due to the other factors that can impact the channel geometry.

Similar to the Continue Construction Alternative, if the threat of a channel cutoff were to occur, it would be addressed by the Regulating Works Project and addressed with SSEAs. However, once the construction portion of the Regulating Works Project is closed out, any new construction necessary after that point would require a formal request for additional construction funding for the Project.

4.2.3 Impacts on Side Channels

Impacts of the Continue Construction Alternative on Side Channels

Chapter 3, Section 3.2.3 Side Channels, presents information on the historic and existing conditions of MMR side channels. As detailed there, in order to predict Project impacts on, and future conditions of, MMR side channels, the District conducted multiple analyses on the depth and area characteristics of MMR side channels. In general the analyses showed that there is a high degree of natural variability in conditions from year to year within individual side channels and between side channels. However, side channel habitat in the MMR appears to be maintaining at a relatively stable level. Side channel planform widths have remained relatively stable since the 1960s. Side channel depths are highly variable both within and between side channels, but on the whole are stable or improving. With implementation of the RPAs, RPMs, and Terms & Conditions of the Project's Biological Opinion discussed in Section 3.3.4 Threatened and Endangered Species, and other restoration authorities, the District would continue to restore MMR side channels that exhibit deteriorating conditions in habitat, contingent upon available funding and continued authority.

Despite the anticipated stability in the overall acreage, depth, and volume of side channel habitat in the future, another area of potential adverse effect to MMR side channel habitat from the Regulating Works Project is decreasing river stages at low flows associated with river training structure placement. As detailed in Section 4.2.1 Impacts on Stages, no changes in river stages are anticipated from river training structure placement at higher flows; however, at flows below 425,000 cfs, analysis of the St. Louis gage data shows a trend of decreasing stages over time while the trends at the Chester gage are less clear (Figure 3-6). Huizinga (2009) summarized the trends in St. Louis and Chester gage data as follows:

> *The apparent decrease in stage with time for lower discharges (less than one-half bankfull) at the St. Louis streamgage ... appears to be linked to the general lowering of the average bed elevation ... The top widths and average velocities from measurements have remained relatively constant at each of the measurement locations at the St. Louis streamgage ... so the lowering of the average bed elevation with time results in a lowering of the stage with time for in-channel flows. The lowering of the average bed elevation with time likely is caused by a combination of dikes in the channel, which cause channel deepening in the thalweg of the channel at the end of the dikes, and a general*

> *decrease in sediment flux into the MMR, which results in less incoming sediment to replace outgoing sediment in the MMR...*
>
> *...The apparent decrease in stage with time for lower discharges is less pronounced at the Chester streamgage ... than at the St. Louis streamgage, because there is less lowering in average bed elevations with time at the Chester streamgage ... However, the average velocities from measurements increase slightly with time for in-channel flows ... and this offsets the relatively constant top widths and average bed elevations from measurements ... resulting in a decrease in measured and rated stages with time for in-channel flows.*

As mentioned above by Huizinga (2009), the observed decreases in stages at low flows is likely a result of a combination of river training structures deepening the channel and a decrease in the sediment load in the river. It is not possible to determine the relative contributions of these two likely causes of stage decreases.

Regardless of the cause, the decrease in stages could result in loss of side channel habitat by reducing side channel stages. A reduction in stage at any given side channel, assuming a constant side channel bottom elevation, would result in less side channel depth and volume available as aquatic habitat. In order to determine the magnitude of potential impacts of decreasing stages to side channels, the District analyzed trends in stages for various flows at the St. Louis and Chester gages. Scatter plots for flows and stages at the St. Louis and Chester gages from the early 1900s to present can be found in Figure 3-6. Table 4-1 summarizes the projected changes in stage, by discharge, which are anticipated over the course of the remaining Regulating Works construction, estimated to be 17 years[16]. The projections are based on differences between the current and year 2000 rating curves for St. Louis and Chester. In addition to a potential reduction in the quantity of side channel habitat, a reduction in stage could also result in decreased availability of that habitat to fish due to the loss of connectivity to the main channel at lower flows.

The quantity of side channel habitat in the MMR appears to be stable or improving based on current analyses of trends in side channel depth, width, and volume. River training structures constructed as part of the Regulating Works Project going forward are not anticipated to directly affect the quantity or quality of aquatic habitat provided by MMR side channels as they did prior to the 1970s. The current methods of construction used by the District, in consultation with natural resource agency partners, are specifically implemented in ways that avoid and minimize impacts to side channels. In addition, based upon available funding and continued authority, it is expected that the District will continue to plan and implement MMR side channel restoration projects. Discussion of potential adverse effects to individual side channels as a result of specific Regulating Works construction sites and any avoidance, minimization, and/or compensatory mitigation measures necessary to address adverse effects would continue to be covered on a case by case basis in SSEAs.

[16] This estimate of the number of years of construction remaining is based on assumptions of future congressional funding levels per year, rock prices, dredging costs, mitigation costs, etc. Actual values for these variables are likely to differ from the assumptions made, thereby affecting the actual duration of remaining construction. See Appendix C for a full discussion of the assumptions associated with the remaining quantity of construction.

With respect to the indirect impact that river training structures may have on side channels by way of reduction of river stages, based on the assumption that construction of new river training structures would continue for approximately 17 years, stage changes are expected to remain similar to past trends over that period of time. Based on current projections (Table 4-1), decreases in stage of 0.24 to 0.94 feet can be anticipated at St. Louis across the range of non-flood flows (less than 500,000 cfs). Stages at Chester are anticipated to decrease 0.34 to 1.10 feet at flows between 50,000 and 100,000 cfs, increase 0.11 feet at 150,000 cfs, remain stable at 200,000 cfs, and decrease 0.40 to 0.63 feet at flows between 300,000 and 500,000 cfs. These projections are based on the assumption that the trends would continue at a pace similar to what they have in the past and that the trends are linear. It is not possible to determine what portion of the past or projected future decreases in stage are the result of river training structures versus a reduction in tributary sediment load, or other geomorphological factors including response to the 1881 shortening of the channel due to a channel cutoff at the Kaskaskia River. Therefore, it is not possible to project how much the effect might decrease after construction of river training structures ends. Analysis of dike systems on the Lower Mississippi River has shown that following the initial response period (10 – 15 years) the annual percentage rate of change in scour or fill approaches zero indicating that the systems are approaching an equilibrium condition (Biedenharn et al. 2000).

In light of the quantity of additional stone to be placed on the MMR being less than 5% of what currently exists and the degree of variability in side channel depths and associated choke points (see 3.2.3 Side Channels), whatever proportion of the small reduction in stage that future river training structures are responsible for is anticipated to be minor and inconsequential. In addition, the compensatory mitigation that would be implemented to address potential future adverse effects to MMR main channel border habitat would be anticipated to reduce the magnitude of any stage reductions that additional river training structures cause (see 4.3.2 and Appendix C).

Maintenance dredging activities associated with the Continue Construction Alternative are not anticipated to have any adverse effects on MMR side channel habitat.

Impacts of the No New Construction Alternative on Side Channels

No new construction of river training structures would occur with implementation of the No New Construction Alternative. Consequently, any future reduction in stages would likely be due to a reduction in tributary sediment load, residual effect from past river training structure construction, or other geomorphological factors including response to the 1881 shortening of the channel due to a channel cutoff at the Kaskaskia River. Maintenance dredging activities are not anticipated to have any adverse effects on MMR side channel habitat.

Table 4-1. Projected reductions/increases in stages through the projected end of new construction for the Regulating Works Project (17 years) for discharges up to 500,000 cfs at St. Louis and Chester gages. Red shading indicates a projected reduction in stage and green shading indicates a projected increase in stage. Projected stage change was calculated using the difference between the current rating curve and the rating curve from 2000 for St. Louis and Chester. Current stage data from USGS rating curve 17 for St. Louis (07010000) and 19 for Chester (07020500) . Year 2000 stage data from USGS rating curve 13 for St. Louis (07010000) and 16 for Chester (07020500).

Gage Location	Discharge	Projected Change in Stage over 17 years
St. Louis	50,000	-0.94
	70,000	-0.79
	100,000	-0.59
	150,000	-0.50
	200,000	-0.39
	300,000	-0.31
	400,000	-0.24
	500,000	-0.24
Chester	50,000	-1.10
	70,000	-0.68
	100,000	-0.34
	150,000	0.11
	200,000	0.00
	300,000	-0.40
	400,000	-0.63
	500,000	-0.40

4.2.4 Impacts on Water Quality

Impacts of the Continue Construction Alternative on Water Quality

Construction activities associated with placement of all future river training structures and with maintenance of existing structures would cause temporary increases in turbidity and suspended sediment concentrations in the immediate vicinity of the structure locations. The impacts would be localized and would dissipate quickly. Sediments are typically sand with little associated fines and would, therefore, not be expected to release contaminants into the water column at concentrations that alone or in combination with other contaminants would cause toxic effects to aquatic organisms.

River training structures are designed to change sedimentation patterns and would, therefore, cause some minor temporary changes in the suspended sediment concentration in the immediate vicinity of placement locations as the river bed adjusts to the altered flow patterns. When compared to the typical sediment load in the MMR, this increase in suspended sediment concentration from all future river training structure construction and maintenance is expected to be negligible.

Revetment is designed to reduce bankline erosion and would, therefore, reduce suspended sediment concentration in the immediate vicinity of placement locations indefinitely. When compared to the typical sediment load in the MMR, this reduction in suspended sediment associated with reduced bankline erosion from all future revetment construction is considered negligible.

Limestone material used for construction and maintenance of structures could potentially affect local water chemistry (e.g., alkalinity, hardness, and pH). However, given the prevalence of limestone in the watershed geology and the quick dissipation of any associated fine materials in the water column, the impact is expected to be negligible.

Maintenance dredging activities would be expected to temporarily increase suspended sediment concentrations in the immediate vicinity of the dredge and disposal locations and for a short distance downstream. However, the degree of increase in turbidity is directly related to the proportion of fine-grained sediment in the material to be dredged (Herbich and Brahme 1991). Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. Given that the vast majority of dredged material is sand and not fine-grained material that would stay in suspension longer, the impact would be localized and would dissipate quickly. Turbidity plumes from dredging operations in the Upper Mississippi River are generally undetectable one-half mile downstream from the dredging location (WEST 2000). The Corps' St. Paul District monitored dredging operations in the main channel of the Mississippi River in the 1970s (Anderson et al. 1981a; Anderson et al. 1981b) and found that dredging operations had only minor, localized effects on turbidity. The Corps' Kansas City District monitored dredging operations on the Lower Missouri River in the 1980s (USACE 1990) and found that the plume from dredging operations returned to background levels within approximately 1,300 feet.

The impacts of such short-term changes in turbidity are further diminished when compared to the variability in background suspended sediment levels in a river such as the MMR that naturally experiences dramatic fluctuations in turbidity. Water quality measurements taken in the main channel of the MMR from 1991 to 2013 (Upper Mississippi River Restoration Program Long Term Resource Monitoring element) show that turbidity averages approximately 99 NTUs[17] but ranges between 6 NTUs and 755 NTUs. The average annual minimum value during that time period was 21 NTUs and the average annual maximum was 396 NTUs.

There is also potential for mobilization of contaminants in the dredged material due to the ability of contaminants to attach to silt and clay particles that may be present. However, IEPA and MDNR water quality certification conditions require analyses of the composition of dredged material to ensure that materials do not exceed 20% silt and clay material. As noted above,

[17] Nephelometric Turbidity Units (NTUs) are a standard unit of measure for quantifying the turbidity or cloudiness of water. Higher values indicate more turbidity. As a point of reference, USEPA generally requires drinking water turbidity to be less than 1 NTU.

sediments in dredge and disposal areas in the MMR are predominantly sand and gravel. If material to be dredged is found to be greater than 20% fine-grained, further chemical testing is required to ensure contaminants are not present in quantities that would exceed water quality standards. All testing to evaluate dredged material is done in accordance with the Inland Testing Manual (USEPA and USACE 1998).

Maintenance dredging activities would gradually decrease over the life of the Project but would never be completely eliminated. Likewise, the short-term increases in turbidity associated with dredging activities would decrease over the life of the Project. Dredging effort would fluctuate from year to year based on a range of factors, but is estimated to decrease from a current average of approximately 4 million cubic yards per year to an average of approximately 2.4 million cubic yards per year after completion of river training structure construction.

Programmatic authorization for construction, maintenance, and dredging activities under Section 404 of the Clean Water Act would be sought as part of the Continue Construction Alternative. In addition, authorization for construction activities under Sections 404 and 401 of the Clean Water Act would be sought on a site-specific basis as work areas are planned and implemented. Authorization for dredging activities under Section 401 of the Clean Water Act is sought on a programmatic basis every 5 years from the states of Illinois and Missouri. All permits and approvals necessary for completion of work would be obtained prior to implementation. See Appendix D for the Draft Programmatic 404(b)(1) Evaluation.

Impacts of the No New Construction Alternative on Water Quality

Since no new construction would occur with implementation of this Alternative, there would be no construction-related water quality impacts beyond those associated with maintenance of existing structures. As with construction of new river training structures, maintenance of existing structures would cause temporary increases in turbidity and suspended sediment concentrations in the immediate vicinity of the structure locations. The impacts would be localized and would dissipate quickly. Sediments are typically sand with little associated fines and would, therefore, not be expected to release contaminants into the water column at concentrations that alone or in combination with other contaminants would cause toxic effects to aquatic organisms.

Impacts associated with maintenance dredging activities under the No New Construction Alternative would be similar to those outlined above under the Continue Construction Alternative. However, maintenance dredging under the No New Construction Alternative would be required at approximately the same rate as is currently necessary and would not be expected to decrease in the future as under the Continue Construction Alternative since no new river training structures would be constructed to reduce dredging. Dredging effort under the No New Construction Alternative would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would average approximately 4 million cubic yards per year based on average dredge quantities over the last 10 years.

4.2.5 Impacts on HTRW

Impacts of both Alternatives on HTRW

All future construction and maintenance activities associated with both Alternatives would avoid impacts to the known HTRW locations outlined in Section 3.2.5 HTRW. In addition, site-specific work areas would be screened for potential HTRW issues in accordance with standard practices for conducting Phase I Environmental Site Assessments (ESA) as outlined in Section 3.2.5 HTRW. As such, no impacts to HTRW from river training structure construction or maintenance activities are anticipated.

Likewise, future dredging activities associated with both Alternatives are not anticipated to impact the known HTRW locations outlined in Section 3.2.5 HTRW. Dredging could, however, mobilize unknown contaminants associated with fine sediments in dredged material or disposal locations. However, as outlined in Section 4.2.4 Impacts on Water Quality, sediments in dredge and disposal areas in the MMR are typically sand and gravel with very little fine sediment. Permit conditions require analysis of the composition of dredged material to ensure that materials do not exceed 20% silt and clay material. Sediments with higher proportions of silt and clay are more likely to contain contaminants. If material in dredge or disposal locations is found to be greater than 20% fine-grained, further chemical testing is required. All testing is done in accordance with the Inland Testing Manual (USEPA and USACE 1998). As such, no impacts to HTRW from dredging activities are anticipated.

4.2.6 Impacts on Air Quality and Climate Change

Impacts of both Alternatives on Air Quality

When a federal action is being undertaken in a nonattainment area, the federal agency responsible for the action is required to determine if its action conforms to the applicable State Implementation Plan (SIP). An SIP is a plan that provides for implementation, maintenance, and enforcement of the NAAQS and includes emission limitations and control measures to attain and maintain the NAAQS. As outlined in Section 3.2.6. Air Quality and Climate Change, there are several counties on both the Missouri and Illinois sides of the MMR designated as nonattainment areas for multiple criteria pollutants. Excluding Randolph County, Illinois, these counties are known collectively as the Metropolitan St. Louis Interstate Air Quality Control Region (AQCR). In accordance with the final rule of the EPA, *Determining Conformity of General Federal Actions to State or Federal Implementation Plans* (final rule), a conformity determination has been prepared for the Metropolitan St. Louis Interstate AQCR and Randolph County, Illinois.

Federal actions occurring in air basins that are in attainment for criteria pollutants are not subject to the conformity rule, except for those basins that recently met attainment and are being managed through a maintenance plan. As such, this conformity determination only addresses emissions of the criteria pollutants for which attainment is not being met within the Metropolitan St. Louis Interstate AQCR (RM 136-195) and Randolph County, Illinois (RM 98.4-136). The specific criteria pollutants included in this analysis are ozone, particulate matter (PM), and sulfur dioxide (SO_2). Although parts of the Metropolitan St. Louis Interstate AQCR are currently designated as being in nonattainment for lead, this criteria pollutant was omitted from this analysis under the assumption that the Regulating Works Project will not produce lead emissions.

To focus conformity requirements on those Federal actions with the potential to have significant air quality impacts, threshold (*de minimis*) rates of emissions were established in the final rule (Table 4-2). With the exception of lead, the *de minimis* levels are based on the Clean Air Act's major stationary source definitions for the criteria pollutants (and precursors of criteria pollutants) and vary by the severity of the nonattainment area. If annual direct and indirect emissions resulting from a federal action within a nonattainment or maintenance area are below the *de minimis* levels set by the EPA, the federal action is considered in conformity with the SIP. However, when a federal action equals or exceeds the annual *de minimis* levels, a more rigorous analysis of emissions from the federal action and conformity to the applicable SIP must be demonstrated.

A federal action that does not exceed the *de minimis* levels of criteria pollutants may still be subject to a general conformity determination. The direct and indirect emissions from the action must not exceed 10 percent of the total emissions inventory for a particular criteria pollutant in a nonattainment or maintenance area. If the emissions exceed this 10 percent *de minimis*, the federal action is considered to be a "regionally significant" activity, and thus, general conformity rules apply. The concept of regionally significant is to capture those federal actions that fall below the *de minimis* levels but have the potential to impact the air quality of a region.

The analysis described herein will demonstrate that emissions from both Alternatives would be well below the annual *de minimis* levels set by the EPA for the aforementioned criteria pollutants, and would not represent a regionally significant source of pollutants for the Metropolitan St. Louis Interstate AQCR and Randolph County, Illinois.

The methodology for the general conformity analysis consists of the following steps: 1) determine pollutants of concern based on attainment status of the AQCR; 2) define the scope of the federal action to include timing and location; 3) calculate emissions based on the scope; 4) review net emission changes for threshold levels and regional significance; and 5) determine conformity for applicable criteria pollutants.

Table 4-2. Annual Emissions threshold (*de minimis*) levels for Criteria Pollutants (40 CFR 93.153).

Criteria Pollutant	Designation	Tons per Year
Ozone*	Serious nonattainment	50
	Severe nonattainment	25
	Extreme nonattainment	10
	Other nonattainment areas outside ozone transport region	100
	Marginal and moderate nonattainment areas inside ozone transport region	50/100**
Carbon Monoxide	All nonattainment areas	100
Sulfur Dioxide	All nonattainment areas	100
Lead	All nonattainment areas	25
Nitrogen Dioxide	All nonattainment areas	100
Particulate Matter	Moderate nonattainment	100
	Serious nonattainment	70

* Includes precursors of volatile organic compounds (VOCs) and nitrogen oxides (NOx).
** VOCs / NOx

The Project consists of river training structure construction and maintenance, as well as channel maintenance dredging. Given the process that is utilized by the District in determining where construction of new project features are needed, what the exact features will be, and what methods will be used to construct the features, site-specific impacts in nonattainment areas would not be known until projects are developed. Since the exact designs of such projects are not known at this time, the analysis relied on estimates of average annual emissions based on past dredging quantities and the amount of rock projected to be used for future construction of river training structures.

To estimate the emission levels from future dredging, the District utilized records of dredging activities from the years 2002-2013, which include the location and duration of each dredging event. Dredging that occurred at river miles adjacent to Randolph County, Illinois, were separated from those that occurred in the Metropolitan St. Louis Interstate AQCR, and were analyzed independently because this area is designated as being in nonattainment only for particulate matter. Average annual durations of dredging activities were calculated for each of the nonattainment areas. Estimates of future annual emissions from dredging were based on these average durations. It was assumed that all future dredging events for the Regulating Works Project would be completed with the District-owned dredge, the Potter, which is equipped with three Caterpillar 3516B diesel engines. Two of the engines are active during dredging events, and the third is in reserve.

Regarding construction and maintenance of river training structures and revetment, the District projects that an average of 260,000 tons of rock would be used annually for new construction, and 90,000 tons would be used annually for maintenance of existing structures. Because the specific locations of future construction and maintenance activity have not yet been identified, it was assumed that the 350,000 tons of rock would be dispersed evenly across river miles and that rock placement would occur at an average production rate of 350 tons/hr. Furthermore, the majority of construction and maintenance activity completed under the Regulating Works Project is done by contractors, and the District does not have access to the details of contractors' operations (e.g., equipment, activity duration, fuel consumption, etc.), which can also vary from year to year. Therefore, in order to fully calculate the emissions from new construction or maintenance of river training structures and revetment, equipment generally used for construction and maintenance of river training structures was selected from the Corps document *Construction Equipment Ownership and Operating Expense Schedule Region V*. This equipment used in the analysis consisted of a dragline crane, 40 ft. inland tug, and a 22 ft. inland tug, all with diesel engines.

Details of the equipment used for new construction or maintenance of river training structures and revetment were used in conjunction with exhaust emissions factors taken from U.S. EPA sources. The primary source used was the *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition, Report No. NR-009d* (2010), which describes the exhaust emission factors used in the EPA's NONROAD2008a emission inventory model, as well as a *Compilation of Air Pollutant Emission Factors AP-42 Fifth Edition* (1995). Annual emissions from the Regulating Works Project were calculated based on equations and instructions outlined in the former document.

It should be noted that ozone emissions were not calculated directly. Rather, the primary precursor compounds for ozone were calculated, those being volatile organic compounds (VOCs) and nitrogen oxides (NOx), and then the *de minimis* level for ozone was applied to each precursor. Furthermore, rather than calculate the emissions of specific VOCs, the District calculated annual emissions of the total organic compounds (TOCs), which include the VOCs. The Regulating Works Project is located in areas designated as moderate and marginal nonattainment for ozone (outside an ozone transport region).

Table 4-3 summarizes the results of the analysis. Average annual emissions of the criteria pollutants within the nonattainment areas, Metropolitan St. Louis Interstate AQCR, and Randolph County, Illinois, are well below the *de minimis* levels set by the EPA. Furthermore, these emission levels do not represent a regionally significant source of criteria pollutants. The calculated average annual emissions were compared to recent emissions inventories for both the Missouri portion and the Illinois portion of the Metropolitan St. Louis Interstate AQCR, as well as Randolph County, Illinois, and are well below ten percent of the total emissions for any of the criteria pollutants. The results of this analysis demonstrate that emissions of this magnitude would not be in violation of the Clean Air Act, and further analysis to demonstrate conformity to the Missouri and Illinois SIPs is not required. This analysis was conducted using current average annual dredging quantities. Emissions associated with the Continue Construction Alternative would be expected to gradually decrease in the future as average annual dredging requirements decrease. Emissions associated with the No New Construction Alternative would be less than those calculated due to reduced construction emissions.

Table 4-3. Summary of average annual emissions from the Regulating Works Project (tons/year).

Activity	TOC	NOx	SO2	PM*
Channel Maintenance Dredging	3.45	20.44	2.46	1.52
Dike Construction and Maintenance	0.34	1.45	0.24	0.08
Total	**3.79**	**21.89**	**2.70**	**1.60**

* Includes emissions occurring in Randolph County, Illinois.

Climate Change. In 2016 CEQ released *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* in order to assist federal agencies in improving their consideration of GHG emissions and climate change in NEPA evaluations. In the guidance, CEQ recommended that...

> *... agencies use the projected GHG emissions associated with proposed actions as a proxy for assessing proposed actions' potential effects on climate change in NEPA analysis. This approach, together with providing a qualitative summary discussion of the impacts of GHG emissions based on authoritative reports...allows an agency to present the environmental and public health impacts of a proposed action in clear terms and with sufficient information to make a reasoned choice between no action and other alternatives and appropriate mitigation measures, and to ensure the professional and scientific integrity of the NEPA review.* (CEQ 2016)

Accordingly, the following analysis summarizes information on the anticipated impacts of GHG emissions from the best available climate science literature and provides an estimate of GHG emissions for the Regulating Works Project.

The Corps is undertaking climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available climate science and climate change information. The Corps is preparing concise and broadly-accessible summary reports of the current climate change science with specific attention to Corps missions and operations for the continental United States, Alaska, Hawaii, and Puerto Rico. Each regional report summarizes observed and projected climate and hydrological patterns cited in reputable peer-reviewed literature and authoritative national and regional reports. The following information on climate trends and future climate projections comes from the climate change and hydrology literature synthesis report for the Upper Mississippi River region (USACE 2015b). A graphical summary of the findings can be found in Figure 4-1.

Summary of Observed Climate Findings (USACE 2015b):

> *The general consensus in the recent literature points toward moderate increases in temperature and precipitation, and streamflow in the Upper Mississippi Region over the past century. In some studies, and some locations, statistically significant trends have been quantified. In other studies and locales within the Upper Mississippi Region, apparent trends are merely observed graphically but not statistically quantified. There has also been some evidence presented of increased frequency in the occurrence of extreme storm events (Villarini et al., 2013). Lastly, a transition point in climate data trends, where rates of increase changed significantly, was identified by multiple authors at approximately 1970.*

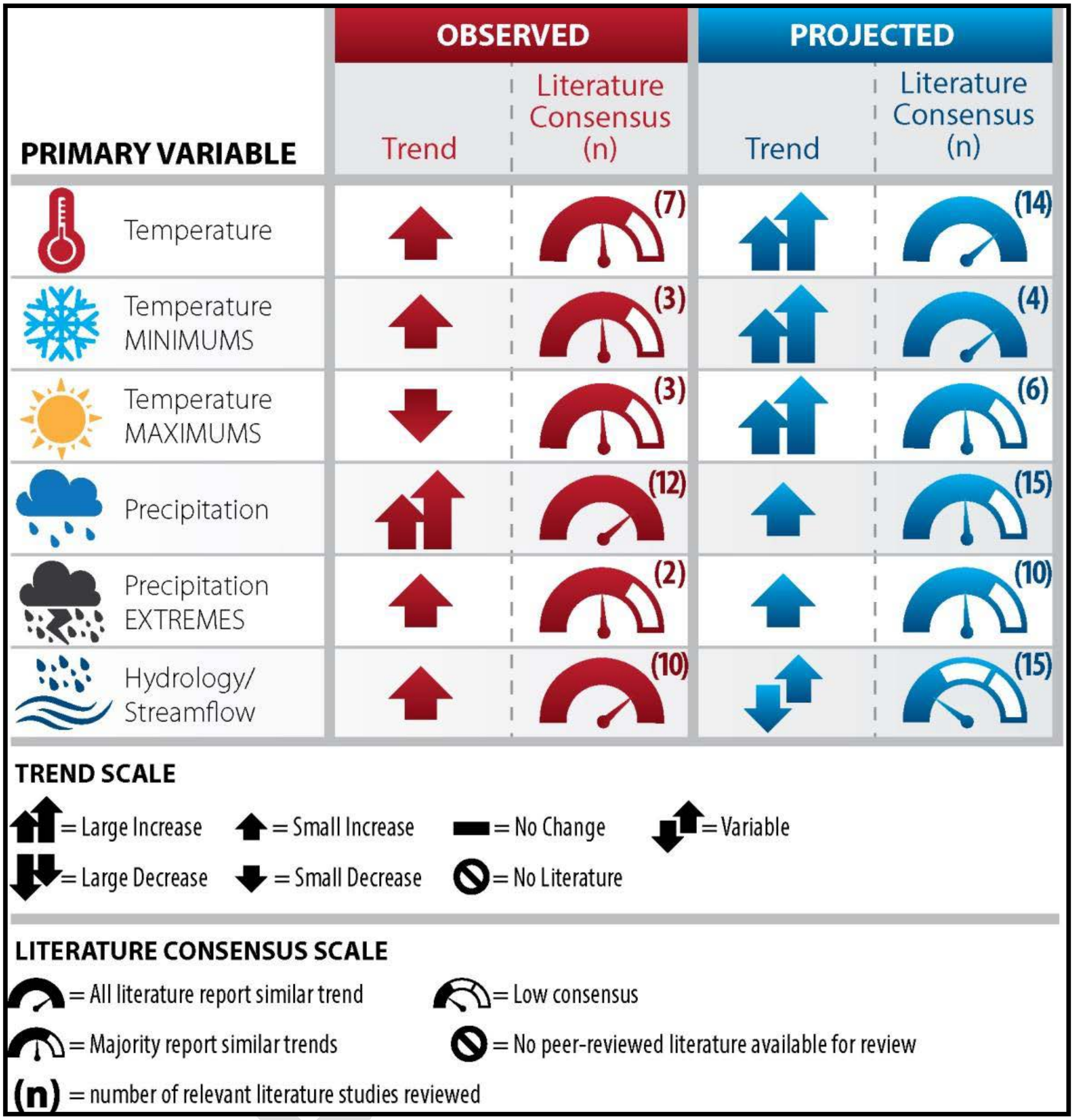


Figure 4-1. Summary matrix of observed and projected regional climate trends and literature consensus (from USACE 2015b).

Summary of Future Climate Projection Findings (USACE 2015b):

> *There is strong consensus in the literature that air temperatures will increase in the study region, and throughout the country, over the next century. The studies reviewed here generally agree on an increase in mean annual air temperature of approximately 2 to 6 ºC (3.6 to 10.8 ºF) by the latter half of the 21st century in the Upper Mississippi Region. Reasonable consensus is also seen in the literature with respect to projected increases in*

> *extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long term future compared to the recent past.*
>
> *Projections of precipitation found in a majority of the studies forecast an increase in annual precipitation and in the frequency of large storm events. However, there is some evidence presented that the northern portion of the Upper Mississippi Region will experience a slight decrease in annual precipitation. Additionally, seasonal deviations from the general projection pattern have been presented, with some studies indicating a potential for drier summers. Lastly, despite projected precipitation increases, droughts are also projected to increase in the basin as a result of increased temperature and* [evapotranspiration] *rates.*
>
> *A clear consensus is lacking in the hydrologic projection literature. Projections generated by coupling* [Global Climate Models] *with macro scale hydrologic models in some cases indicate a reduction in future streamflow but in other cases indicate a potential increase in streamflow. Of the limited number of studies reviewed here, more results point toward the latter than the former, particularly during the critical summer months.*

Given the high degree of variability and uncertainty in weather patterns in general and in predictions of future weather patterns in particular, quantifying future Project impacts is inexact. As summarized above, there is no consensus with respect to forecasts for future streamflow in the basin. Whether future climate patterns in the Upper Mississippi River basin result in a reduction or increase in streamflow compared to current conditions, the basic functionality of river training structures and their ability to change sedimentation patterns should not be affected going forward. Also, given that the District has concluded that river training structures do not increase flood heights (see Section 4.2.1 Impacts on Stages and Appendix A), river training structures would not contribute any increase to potential future flood events. Nonetheless, climate change could impact navigation by changing sedimentation patterns and associated impediments to navigation, increasing the need for dredging, and decreasing the dependability of the navigation channel due to floods and droughts (Moser et al. 2008; Karl et al. 2009). Therefore, this could also affect the assumptions on the future construction needed for cost-effective dredging reduction for the Regulating Works Project discussed in Chapter 2.

With respect to impacts of Project-related emissions on climate change, the District conducted an analysis of the GHG emissions of the Regulating Works Project and the alternatives under consideration. The analysis was completed with the same methodology used to calculate average annual emissions of criteria pollutants previously discussed. However, the geographic scope of the analysis was not limited strictly to the nonattainment areas, but was expanded to encompass the entire MMR. The GHG equivalents analyzed were carbon dioxide (CO2), methane (CH4), and nitrous oxides (NOx).

Table 4-4 summarizes the results of the analysis. Based on the average annual operation time and the equipment used to complete project activities discussed above, the Continue Construction Alternative would be expected to produce an average of approximately 29,400 tons of CO_2 Eq per year currently, gradually decreasing to approximately 16,970 tons per year after construction is complete. The vast majority of these annual emissions would be produced by the Potter during dredging activities and the reduced dredging requirement expected with the Continue Construction Alternative accounts for the decrease in emissions after completion of construction. Conversely, emissions associated with the No New Construction Alternative, while slightly lower than the Continue Construction Alternative initially due to a lack of emissions from construction of new dikes, would not be expected to decrease in the future due to dredging requirements remaining stable.

Table 4-4. Summary of the average annual GHG emissions projected for the Regulating Works Project (tons of CO_2 Eq/year).

Time Period	Activity	GHG	Continue Construction Alternative	No New Construction Alternative
Current	Dredging	Carbon Dioxide	5,724.77	5,724.77
		Methane	7.75	7.75
		Nitrous Oxide	21,715.26	21,715.26
	Dike Construction and Maintenance	Carbon Dioxide	523.23	134.52
		Methane	2.50	0.64
		Nitrous Oxide	1,427.42	366.99
		Total	**29,400.93**	**27,949.93**
After Completion of Construction	Dredging	Carbon Dioxide	3,434.86	5,724.77
		Methane	4.65	7.75
		Nitrous Oxide	13,029.16	21,715.26
	Dike Maintenance	Carbon Dioxide	134.52	134.52
		Methane	0.64	0.64
		Nitrous Oxide	366.99	366.99
		Total	**16,970.82**	**27,949.93**

4.3 Impacts on Biological Resources

4.3.1 Impacts on Benthic Macroinvertebrate Resources

The benthic macroinvertebrate resources impact analysis addresses direct and indirect impacts to benthic macroinvertebrates and their habitat that would occur as a result of dredging and river training structure placement. The analysis provides the basis for understanding the context and intensity of the impacts of each of the Alternatives considered.

Impacts of the Continue Construction Alternative on Benthic Macroinvertebrate Resources

Dredging Impacts - Periodic maintenance dredging and dredged material disposal operations would have the potential to affect benthic macroinvertebrate resources through direct removal of individual organisms (entrainment) at the dredging site and by burying organisms at the disposal site. The degree to which macroinvertebrate resources are impacted is largely a factor of the density of the organisms in the area of the dredge cut and disposal location at the time of dredging operations. Benthic macroinvertebrate densities tend to increase with greater sediment stability, lower water velocities, and higher silt and organic matter concentrations (Galat et al. 2005). Given the shifting nature of the sediments, high water velocities, and low silt concentrations in the main channel of the MMR, the area is not ideal habitat for colonization by bottom-dwelling macroinvertebrates (Koel and Stevenson 2002; Sauer 2004) but likely provides habitat for low densities to exist.

The majority of dredging and dredge placement in the MMR takes place within repetitive dredging areas and placement areas that are located in the main channel, where low densities of benthic organisms are found. Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the Continue Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel habitat are impacted by dredged material disposal. These are anticipated to decrease to approximately 330 acres each after completion of construction associated with implementation of the Continue Construction Alternative. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the low densities of macroinvertebrates found in these habitats, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, decreasing to 1% after completion of river training structure construction, adverse effects to benthic macroinvertebrates associated with dredging are anticipated to be minor.

River Training Structure Impacts - Although there are areas of rock outcrops, rock bottoms, and gravel bars in the MMR, the natural (without river training structures) main channel border substrate is predominantly sand with some finer depositional materials. As described above in Section 3.3.1 Benthic Macroinvertebrate Resources, the rock material that is used for construction of river training structures provides an excellent substrate for colonization by benthic macroinvertebrates. Although a relatively small number of benthic macroinvertebrates in the footprint of river training structure locations would be lost during construction or maintenance activities, this loss would be offset by the benefits of increased substrate for colonization associated with new rock placed in the river. This exchange of habitat types could be reversed in areas where river training structures are removed for any future compensatory mitigation purposes (see Section 4.3.2 Impacts on Fishery Resources below). Areas of high concentrations of benthic macroinvertebrates could be modified and replaced by areas of low concentrations. Overall, the impact on benthic macroinvertebrates from construction, maintenance, and removal of river training structures associated with the Continue Construction Alternative is anticipated to be negligible, but detailed analysis of this impact would be provided in future Tier II site-specific EAs.

Impacts of the No New Construction Alternative on Benthic Macroinvertebrate Resources

Dredging Impacts – Periodic maintenance dredging and dredged material disposal operations associated with the No New Construction Alternative would be similar to those associated with the Continue Construction Alternative but would remain at a relatively stable level over the remainder of the Project. Based on the current average annual dredge quantity of approximately

4 million cubic yards, roughly 1,100 acres of main channel habitat would be impacted each year. Due to the low concentration of benthic macroinvertebrates in these areas, adverse effects are anticipated to be minor.

Dike Impacts – No new construction of river training structures under the Regulating Works Project would occur with this Alternative with the exception of potential construction pursuant to implementation of the Biological Opinion. No removal of structures for compensatory mitigation would be required. However, maintenance and repair of existing river training structures would continue for the remainder of the Project. Maintenance and repair activities are anticipated to have a negligible effect on benthic macroinvertebrates.

4.3.2 Impacts on Fishery Resources

The fishery resources impact analysis addresses direct and indirect impacts to fish and to the quality and quantity of fish habitat that would occur as a result of dredging and river training structure placement. The analysis provides the basis for understanding the context and intensity of the impacts of each of the Alternatives considered. General impacts of dredging on fishery resources are discussed first, followed by specific impacts of the two Alternatives considered. General impacts of river training structures are then discussed, followed by specific impacts of the two Alternatives considered.

Dredging Impacts on Fishery Resources – Potential impacts of dredging on fish include entrainment[18] of individual fish into the dredge head, behavioral changes of individual fish due to increased turbidity and noise at the dredge and disposal locations, and habitat changes due to river bed elevation changes at the dredge or disposal locations (LaSalle et al. 1991).

Dredge Entrainment – Due to the amount of suction needed by the dredge head to remove sediment from the river channel and transport it to the disposal site, fish in the vicinity of the dredge head may be entrained into the dredge pipe and be transported, along with the sediment/water slurry, to the disposal location. Fish exposed to these physical stresses are at a high risk of mortality; however, entrainment may vary based on the species, size and age of the fish in question (Ault et al. 1998). The degree to which fish populations are impacted by dredging entrainment is largely a factor of the density of fish in the area of the dredge cut at the time of dredging operations. For fish that are in the vicinity of the dredge cut, intake water velocity is the primary determinant for likelihood of entrainment, but other factors such as fish size, water temperature, light cycles, feeding regime, and attraction or avoidance of dredge noise could affect entrainment susceptibility of individual fish or species of fish (Hoover et al. 2005; Boysen and Hoover 2009).

Accurate estimates of the number of fish present or the number of fish entrained through maintenance dredging operations on the MMR do not exist. As covered in Section 3.3.2 Fishery Resources, limited fish sampling has been conducted in the main channel of the MMR where maintenance dredging occurs. Sampling conducted in the MMR in support of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element showed adult

[18] Dredge entrainment is defined as the direct uptake of organisms by the suction field generated at the dredge intake (Reine and Clarke 1998).

and/or juvenile Blue Catfish, Channel Catfish, Freshwater Drum, Shovelnose Sturgeon, and Gizzard Shad as the most common species caught in the main channel of the MMR.

Although not specifically related to channel maintenance dredging, the St. Louis District recently contracted a dredge entrainment monitoring study for the Chain of Rocks East Canal Levee Project (Ecological Specialists 2010). The project involved the use of sand dredged from the main channel of the MMR for construction of a seepage berm on the Chain of Rocks Canal Levee. Because there was concern that dredging operations could entrain endangered pallid sturgeon in the project area, monitoring of dredged material was conducted to quantify impacts of dredging operations on the fish community. Fish entrainment monitoring at the outflow of the dredged material settling area was conducted during approximately 15% of the operation. Forty-seven individual fish were captured during the sampling. Based on the number of cubic yards of material dredged during sampling (171,263), the entrainment rate was calculated to be .00027 fish/cubic yard of material dredged, or approximately 1 fish entrained for every 4,000 cubic yards of material dredged.

The estimated entrainment rate for the Chain of Rocks East Canal Levee Project is at the lower end of other published dredging entrainment rates. The Corps' Engineer Research and Development Center published a Technical Note in 1998 that summarized existing literature regarding potential impacts to aquatic organisms from dredging operations (Reine and Clarke 1998). Fish entrainment rates varied widely among species and studies and were reported as ranging from <0.001 to 0.594 fish/cubic yard of material dredged, with the vast majority of entrainment rates being near the lower end of this range. In general, the authors concluded that, although the assessment of entrainment impacts poses serious technical challenges and precise estimates and consequences of entrainment rates have been difficult to determine, much of the evidence suggests that entrainment is not a significant problem for many species of fish in many bodies of water that are dredged periodically (Reine and Clarke 1998).

In addition to larger fish, fish eggs and larvae are also susceptible to entrainment by dredges. No estimates of entrainment rates of fish eggs or larvae exist for the MMR. However, estimates of larval fish densities in the main channel of the MMR range from 0.12 to 6.17 fish per cubic yard of water (UEC 1979; Foley and Dunn 2014). These estimates are based on sampling conducted during the peak larval fish months in spring and summer when densities are typically highest. The volume of water entrained with each cubic yard of substrate can vary considerably based on the specific dredging conditions at each dredge location, but, on average, approximately 80 percent of the dredge slurry is water. Based on this information, estimates of the number of larval fish entrained by maintenance dredging can be achieved by extrapolating from the number of cubic yards of material dredged. It should be noted that maintenance dredging operations on the MMR normally only take place from July through January each year and larvae are generally only present in appreciable numbers in the water column April through August (Bartell and Campbell 2000). Accordingly, larval fish entrainment estimates for the MMR should be calculated using July and August average dredge quantity and larval fish density data (see entrainment estimates in Alternatives impact assessment below).

Dredging Related Habitat Impacts – Channel maintenance dredging in the MMR generally occurs in channel crossover areas, areas where the thalweg shifts from one side of the channel to the other. These areas, and most other areas in the main channel of the MMR, are areas with a high degree of variability in habitat conditions. River bottom habitat in these areas is in a constant state of flux as waves of bed load sand are transported down river. The more naturally variable the impacted habitat, the less the anticipated effect that dredging would be expected to have on the organisms that utilize that habitat (USACE 1978). Organisms utilizing these naturally unstable areas are more adapted to unstable conditions and would be expected to better withstand the stresses imposed by dredging and recover more quickly (USACE 1978; USACE 1983). While the exact depth of material removed from a dredge cut varies with each dredging event and also varies across an individual dredge cut based on natural riverbed elevation variations, the average amount of material removed from dredge cuts in the MMR is approximately 4.5 feet. In other words, a dredged area is, on average, 4.5 feet deeper immediately after a dredging event. Assuming hydraulic conditions remain unchanged, this deeper area typically fills back in with sediment gradually and requires dredging again at some point in the future. The purpose of river training structures is to alter the hydraulic patterns of the river channel in these chronic dredging locations, thereby reducing the need for repetitive dredging.

Dredge disposal areas generally become shallower to approximately the same degree that the associated dredged areas become deeper. Material is typically deposited through a rigid pipeline with a disposal location that moves up and down the river as the dredge moves up and down the dredge cut. This results in a disposal area that is similar in size and shape to the dredge cut. Disposal of dredged material in the MMR typically takes place adjacent to the dredge cut, in the main channel of the river, but outside of the navigation channel and riverward of existing river training structures, if present (Figure 4-2). Due to specific conditions at each dredging location, e.g. the presence of barge fleeting areas, there are instances when dredge material cannot be placed in the main channel and must be placed in main channel border areas. Some of the District's dredging is accomplished with a floating flexible dredge pipe which allows for more adaptability in disposal area location, elevation, and size (see Section 1.1.3 Process for Dredging under the Regulating Works Project for more information on the flexible dredge pipe). Regardless of the disposal technique or placement location, all dredging is coordinated with natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits.

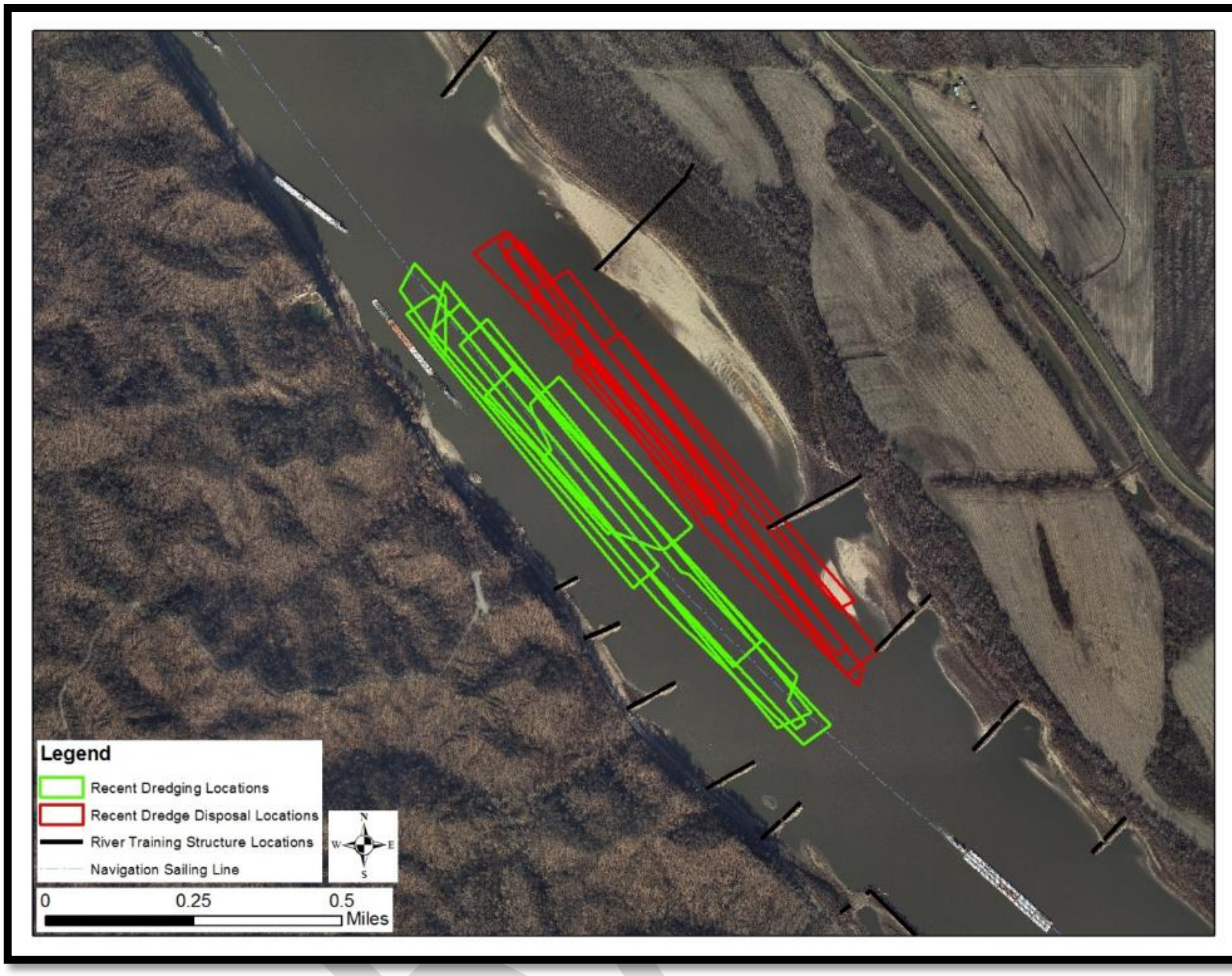


Figure 4-2. Example of recent dredging (green boxes) and dredge disposal (red boxes) locations on the MMR (2010 through 2014 dredging at river mile 68).

Dredging Related Noise - Much of the sound produced during hydraulic dustpan or cutterhead dredging is associated with pumps and generators, with additional sounds from the injection of water into the substrate by the dustpan dredge or the rotation of the cutterhead in the substrate and movement of material through the pipeline. Sounds emitted are dependent on substrate type. For example, movement of sand/gravel through the pipeline would produce more intense sounds than slurry comprised of mostly water and sandy dredged material that would be expected on the MMR. These sounds are omnidirectional and continuous in nature during dredging operations.

Although there have been a number of studies of sound production by a variety of dredge types dredging a variety of materials (e.g., Reine and Dickerson 2014; Reine et al. 2014a; Reine et al. 2014b), there have been no studies of hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. The *Veracious*, although a cutterhead dredge, provides sound pressure level (SPL) data for pumps used for suction with horse power ratings closest to the *Potter* (2,500 hp), the St. Louis District's dredge. Sound production by the *Veracious* (Reine and Dickerson 2014), with a 1,000 hp main pump, ranged from 151.48 to

157.43 dB[19] re 1 μPa at 1m from the noise source. These SPLs at the dredge (1 meter) are well below the levels responsible for fish mortality (228.9 dB re 1 μPa) cited in the literature (Hubbs and Rechnitzer 1952) or 180 dB re 1 μPa shown to cause temporary or permanent hearing loss due to sensory epithelia damage (Hastings et al. 1996; McCauley et al. 2003). SPLs are also below levels (160–170 dB re 1 μPa) responsible for temporary threshold shifts in hearing and stress responses (increased cortisol levels; Smith et al. 2004). It should be noted that these impact metrics would attenuate relatively quickly in water – at short distances from the dredge, SPLs would be reduced considerably.

Dredging Related Turbidity - Information on the potential impacts of dredging on water quality is provided above in Section 4.2.4 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

Impacts of Dredging associated with the Continue Construction Alternative on Fishery Resources

Under the Continue Construction Alternative, maintenance dredging effort would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would decrease from a current average of approximately 4 million cubic yards per year based on dredge quantities over the last 10 years to an average of approximately 2.4 million cubic yards per year after new construction completion associated with the Regulating Works Project. These figures are based on the best available information on forecasted reductions in dredging associated with river training structure placement and assumptions on funding levels for program implementation, rock prices, fuel prices, etc.

Dredge Entrainment Impacts – Direct measurements of the number of adult and juvenile fish entrained through maintenance dredging operations on the MMR do not exist. However, estimates have been developed based on the amount of dredging anticipated in the future and the number of fish entrained by other dredging conducted on the MMR as discussed above. Based on this information, the number of adult and juvenile fish lost to dredge entrainment would gradually decrease from a current level of approximately 1,080 fish per year to approximately 650 fish per year after new construction completion associated with the Regulating Works Project. Entrainment levels would remain at approximately this level indefinitely. These numbers are only approximations based on the best available information specific to the MMR. However, impacts on this order of magnitude are extremely small in relation to the total number of fish existing in the MMR. Estimates of fish densities for the Middle and Upper Mississippi River vary widely but range from 35 fish per acre to 24,000 fish per acre with an average of approximately 3,500 fish per acre (Christenson and Smith 1965; Dettmers et al. 2001b; Pitlo

[19] The decibel (dB) is the typical system used to describe the relative loudness of sound. Sounds in water have different reference levels than sounds in air due to differing behavior characteristics of sound in water vs. air. Therefore, it is important to know if a dB reference is for a sound in water or air. For sounds in water, the reference level is expressed as dB re 1 μPa (IAGC 2016).

1987). Even at the extreme lower end of this density range, the loss of 1,080 fish per year would represent less than 0.06% of the total number of MMR fish. If the average density is used, the impact declines to less than 0.0006%. Impacts of this magnitude would be considered minor and would not be anticipated to appreciably adversely affect the viability of the MMR fish community.

Similar to adult and juvenile fish, direct measurements of the number of larval fish entrained through maintenance dredging on the MMR do not exist. However, estimates have been developed based on measurements of larval fish densities in the main channel of the MMR. Based on these densities, the number of larval fish currently lost to dredge entrainment per year is estimated to be between 366 thousand and 19 million. These estimates decrease to 220 thousand and 11 million based on the predicted dredging reduction associated with the Continue Construction Alternative. These are very broad ranges due to the fact that the two available larval density estimates for the MMR are so different. Regardless of the total number of larval fish entrained, the potential impact needs to be considered in the context of the total number of larval fish in the MMR as a whole. This can be estimated by contrasting the amount of water dredged versus the overall amount of water passing through the MMR.

In comparison to the amount of water flowing through the MMR at any given point in time, the amount that actually passes through the dredge is minute. The average river discharge of the MMR at St. Louis in July and August is approximately 193,000 cfs, or approximately one trillion cubic feet of water in the two-month period. An average of approximately 83 million cubic feet of water passes through the dredge in July and August, or approximately 0.01% of the total volume of water carried by the river. This would decrease to approximately 50 million cubic feet of water passing through the dredge in July and August if dredging decreases to 2.4 million cubic yards per year with the Continue Construction Alternative. This would represent approximately 0.006% of the total volume of water carried by the river. The average amount of water passing through the MMR during months when larval fish are typically present is approximately 3.4 trillion cubic feet. Approximately 0.002% of that flow passes through the dredge in an average year. In other words, in an average year roughly 1 of every 50,000 larval fish might be entrained by maintenance dredging in the MMR. This would decrease to approximately 1 of every 80,000 after new construction completion associated with the Regulating Works Project. It must also be recognized that the reproductive strategy of fish involves producing large numbers of young, an extremely small percentage of which are expected to reach adulthood (Bartell and Campbell 2000). In addition, fish populations appear to exhibit density-dependent population response processes that increase survivorship of remaining individuals in the population when individuals are removed (Bartell and Campbell 2000). The potential impacts of larval entrainment associated with the Continue Construction Alternative are anticipated to be negligible.

Dredging Related Habitat Impacts – Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the Continue Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel and main channel border habitat are impacted by dredged material disposal. These are anticipated to decrease to approximately 330 acres each with the Continue Construction Alternative. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the fact that the areas almost immediately return to a state that is available as fish habitat subsequent to dredging and disposal, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, decreasing to 1.3% with the Continue Construction Alternative, adverse habitat impacts associated with dredging are anticipated to be minor. In addition, beneficial use of dredged material through use of the District's floating flexible dredge pipe is expected to increase the quantity of shallow sandbar and ephemeral island habitat available in the MMR. The exact locations and quantities associated with flex pipe projects on the MMR vary from year to year as dredging requirements fluctuate and as the District begins to fully implement the flex pipe's use.

Dredging Related Noise Impacts – There are no known studies of underwater sound production associated with hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. Based on information from a similar hydraulic dredge ((Reine and Dickerson 2014), dredges used on the MMR are not anticipated to produce sound levels that would kill, injure, or cause stress in fish. Dredging related sound may disturb fish in the immediate vicinity of dredging operations, but this disturbance is anticipated to be short-term and localized in nature.

Dredging Related Turbidity Impacts – Information on the potential impacts of dredging on water quality is provided above in Section 4.2.4 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

Impacts of Dredging associated with the No New Construction Alternative on Fishery Resources

Under the No New Construction Alternative, maintenance dredging effort would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would remain indefinitely at the current average of approximately 4 million cubic yards per year based on dredge quantities over the last 10 years.

Dredge Entrainment Impacts – The number of adult and juvenile fish lost to entrainment per year under the No New Construction Alternative would be expected to remain similar to the current level which is estimated to be approximately 1,080 fish per year. This is estimated to represent less than 0.06% of the total number of MMR fish. This number would be expected to remain unchanged, on average, over the entire Project life. Impacts of this magnitude would be considered minor and would not be anticipated to appreciably adversely affect the viability of the MMR fish community.

The number of larval fish lost to entrainment under the No New Construction Alternative would be expected to remain similar to the current level which is estimated to be 1 of every 50,000 larval fish. This number would be expected to remain unchanged, on average, over the entire Project life. Impacts of this magnitude are anticipated to be negligible.

Dredging Related Habitat Impacts – Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the No New Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel habitat are impacted by dredged material disposal. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the fact that the areas almost immediately return to a state that is available as fish habitat subsequent to dredging and disposal, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, adverse habitat impacts associated with dredging are anticipated to be minor. In addition, beneficial use of dredged material through use of the District's floating flexible dredge pipe is expected to increase the quantity of shallow sandbar and island habitat available in the MMR. The exact locations and quantities associated with flex pipe projects on the MMR vary from year to year as dredging requirements fluctuate and as the District begins to fully implement the flex pipe's use.

Dredging Related Noise Impacts – There are no known studies of underwater sound production associated with hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. Based on information from a similar hydraulic dredge (Reine and Dickerson 2014), dredges used on the MMR are not anticipated to produce sound levels that would kill, injure, or cause stress in fish. Dredging related sound may disturb fish in the immediate vicinity of dredging operations, but this disturbance is anticipated to be short-term and localized in nature.

Dredging Related Turbidity Impacts – Information on the potential impacts of dredging on water quality is provided above in Section 4.2.4 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

River Training Structure Impacts on Fishery Resources

Dike Effects – The hydrodynamics around training structures are complex and vary greatly depending upon the type of training structure in question, location within the river channel, height and length, and the river stage. A traditional wing dike constructed perpendicular to flow and tied in to the river bank would be expected to deepen the adjacent navigation channel, cause a scour hole to develop at the dike tip, and cause sediment accretion downstream from the structure near the river bank. Traditional wing dikes cause both increased velocities and turbulent flow patterns near the tip of the dike and shear flows extending downstream (Yossef and de Vriend 2011). When river levels are below the top elevation of dikes, a complex flow pattern forms within the dike field (Maynord 2000d; Uijttewaal et al. 2001; Yossef and de Vriend 2011; Figure 4-3). The flow is characterized by: 1) a primary eddy that forms in the downstream part of the dike field, rotates in a counter clockwise direction to the channel flow on the left descending bank (or clockwise on the right descending bank), covers approximately 2/3 of the area between dikes, and has a circulation velocity approximately 30-40% of the main channel mean velocity; 2) A secondary eddy driven by the primary eddy with the opposite rotation and a much smaller flow velocity; and 3) A dynamic eddy that sheds regularly from the tip of the upstream dike. The dynamic eddy migrates in a downstream direction and merges with the primary eddy, which in return changes in size due to the interaction with the migrating eddy. During high flows, when wing dikes are submerged, the eddies disappear when dikes reach a high enough submergence level (Maynord 2000d; Yossef 2002).

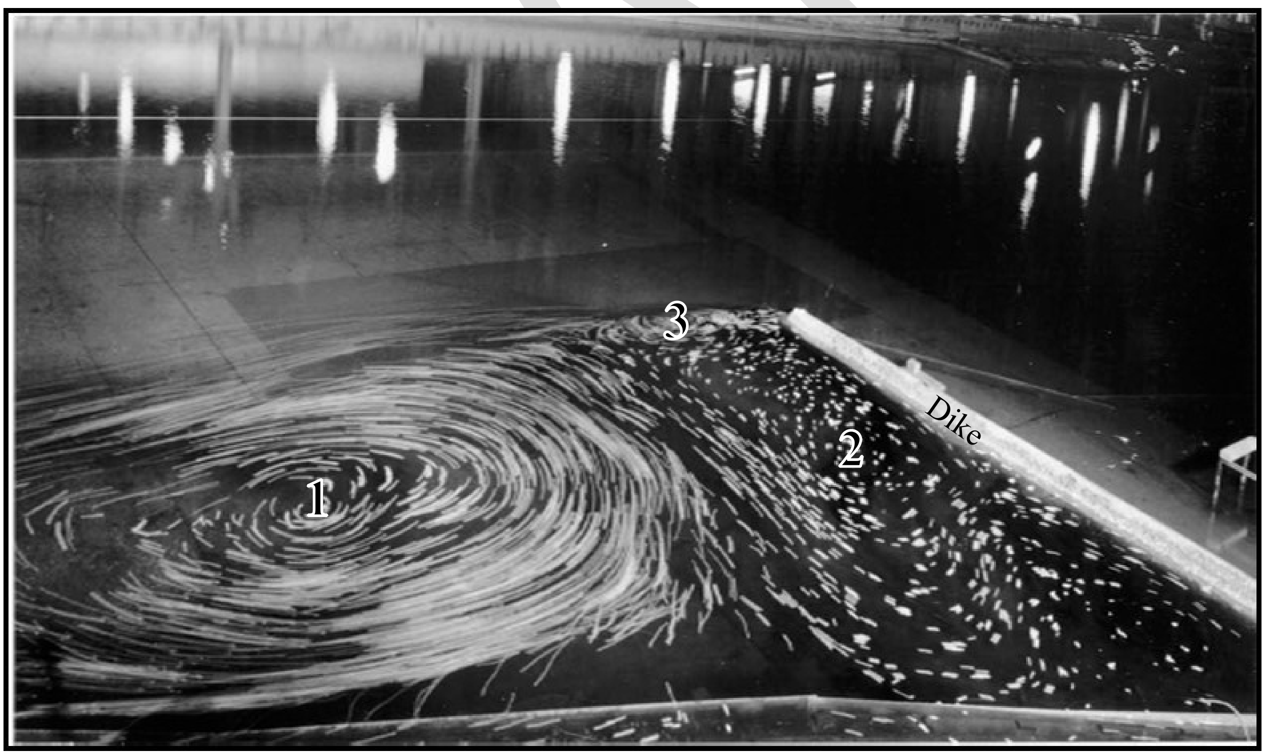


Figure 4-3. Physical model study representation of eddy formation within a "typical" MMR dike field when dikes are emergent (out of water; from Maynord 2000d). Water flow is from right to left. 1. Primary eddy; 2. Secondary eddy; 3. Dynamic eddy

Yossef and de Vriend (2011) modeled sediment exchange mechanisms and sediment transport patterns in dike fields. They found that under all flow conditions (submerged and emergent wing dikes) there is a net import of sediment into a dike field. So, traditional dike fields accumulate sediment and are generally shallower than the adjacent river (Uijttewaal et al. 2001). Shields (1995) studied 26 groups of traditional dikes in the Lower Mississippi River and determined that the aquatic volume and area of associated low-velocity habitat (important aquatic habitat) were reduced by 38% and 17%, respectively, after placement of the structures. Most of the changes occurred shortly after construction, and after initial adjustment, habitat area and volume fluctuated around a condition of dynamic equilibrium. As detailed in Section 3.2.2 Geomorphology above, dike construction on the MMR has, historically, caused a narrowing of the river planform over time due to this sediment accretion process followed by growth of terrestrial vegetation. However, the analysis of changes in river planform in the MMR recently conducted by the District (Brauer et al. 2005; Brauer et al. 2013) demonstrates that channel widths in the MMR appear to have reached a state of dynamic equilibrium where very little conversion to terrestrial habitat is occurring subsequent to river training structure placement. In addition, the suite of innovative river training structures currently used by the District is intended to provide bathymetric diversity, flow refuge, and split flow conditions that differ from traditional wing dikes.

As described above, traditional wing dikes cause increased velocities and turbulent flow patterns near the tips of dikes; shear flows extending downstream; and eddies within the dike field with flows moving in a reverse direction to the channel flows along the shoreline. Fish making short-distance movements for feeding or long-distance spawning migrations have to navigate these anthropogenic flow fields. It has been suggested that fish select migration pathways to minimize energy expenditure during migrations. McElroy et al. (2012) telemetrically tracked a federally endangered pallid sturgeon (*Scaphirhynchus albus*) migrating upstream in the Missouri River. They found that the pathway taken by the sturgeon had a lower energy cost than one hundred thousand randomly generated paths through the study reach. Fish migrating upstream to spawn or making shorter upstream feeding movements must navigate natural complex flow fields. The modification of flow fields by training structures, especially typical wing dikes, makes the choice of a pathway with the least energy expenditure difficult and may impede movement along routes that would normally minimize energy expenditure. This is a relatively new area of scientific study and the implications for MMR fish populations are unknown, but it is possible that species may currently be impacted at some unknown level.

Regardless of the specific configuration of the river training structures utilized, rock structures can provide improved habitat for fish by providing areas of reduced flow, a more diverse substrate, and additional cover. In addition, they can provide more suitable substrate for a wide variety of benthic organisms (see 4.3.1 Impacts on Benthic Macroinvertebrate Resources above). Barko et al. (2004a) found that species richness was greatest at wing dikes in the Middle Mississippi River for both adult and age-0 fishes when compared with main channel borders. However, they did find differences in species composition. At the family level, Cyprinidae, Clupeidae, and Centrarchidae were more abundant in wing dike physical habitat, while Catostomidae and Ictaluridae were more abundant in main-channel border habitat. Individual species and life stages also showed preferences for dike vs. natural main channel border habitat.

Madejczyk et al. (1998) studied differences in fish assemblages among various artificial and natural habits within the main channel border of Pool 6 in the Upper Mississippi River. In their study, nine species of fish preferred specific types of near-shore habitat. Fish abundance and diversity measures differed little among habitat types, but significantly larger fish were present at locations with structure (wing dikes and woody snags) than at sites without (bare shoreline). They found that ten fish species showed nonrandom distributions among the three habitats sampled. Redhorses (*Moxostoma*) and Channel Catfish (*Ictalurus punctatus*), were significantly more common at wing dike habitats. In addition to providing habitat for redhorses and Channel Catfish, Madejczyk et al. (1998) suggested that they may be important for other fish species (i.e., Flathead Catfish (*Pylodictis olivaris*), Walleye (*Sander vitreus*), and Sauger (*Sander canadensis*)) because wing dikes provide rocky substrates, higher current velocities, and shallow depths relative to the adjacent main channel areas. Other species such as Paddlefish (*Polyodon spathula)* and Pallid Sturgeon may frequent areas near wing dikes because of scour holes, sand bars, or eddies created by these structures (Southall and Hubert 1984; Koch et al. 2012). Similarly, Bischoff and Wolter (2001) found that groyne-heads (the tips of wing dikes) were an important habitat for both age 0+ and age 1+ juvenile rheophilic fish (fish species adapted to current) in the River Oder in Germany during the summer, but habitat use was limited by stochastic availability due to varying discharges. On a negative note, Calkins et al. (2012) found that the Silver Carp (*Hypophthalmichthys molitrix*), an exotic Asian carp species, actively selected wing dike areas with moderate flow (about 0.3 m/s) and elevated chlorophyll a (about 7 μg/L) in Pool 26 of the UMR, relative to random sites. Wing dikes were preferred while the main channel was avoided.

Hartman and Titus (2010) studied dikes and reference sites on the Kanawha River, West Virginia and found that fish used dikes as much as or more than sites without dikes and that differences in taxonomic composition occurred. The study results suggest that dike habitat favors some taxa and certain taxa benefited more from those habitats than others. Members of the Catostomidae and Cyprinidae were more abundant at dikes and high-quality references areas than in low-quality reference areas. They conclude that dikes "appear to provide comparable habitat for these groups as high-quality reference areas." Wing dike use was most important among Centrarchidae species, especially juveniles, including black bass and several species of *Lepomis*. Centrarchids are important sport fish as adults and are foraged upon by larger fish when small. Poizat and Pont (1996) found dike use was highest by centrarchids in the *Rhône River, France (exotic species in France),* and Barko et al. (2004b) found slightly more centrarchids at wing dikes than main channel borders on the MMR.

A study of larval fish use of dike structures on the Kanawha River (Niles and Hartman 2009) found that overall taxonomic composition did not differ between dike sites and reference sites. However, larval fish were captured at significantly higher capture rates at dike sites than at high- and low-quality reference sites. Water velocities were significantly lower at dike sites than at reference areas, suggesting that greater larval fish use of dike sites may be attributed to reduced velocity provided by the structures. Niles and Hartman (2011) found that catch per unit effort (CPUE) of larval fish along dike structures was higher than CPUE along other shoreline sites. Percidae CPUE was significantly higher on artificial dike structures than reference sites. Niles and Hartman (2009; 2011) suggest that dikes can serve as shelters and retention areas for larval fish and provide habitats that increase larval fish diversity in rivers impacted by commercial navigation traffic.

Braun et al. (2015) compared standardized CPUE and overall community structure for 50 fish species among un-notched wing dikes, notched wing dikes, and L-dikes in the MMR, sampled as part of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element. There were no differences in standardized CPUE for 64% of the fish species examined. Five species known to be associated with lotic habitats were most abundant near L-head dikes. Seven species were more abundant at un-notched dikes than notched dikes, while six species were more abundant at notched dikes than un-notched dikes.

Schloesser et al. (2012) compared species occupancy and fish community composition at natural sandbars and at notched and un-notched rock dikes along the lower Missouri River to determine if notching dikes increases species diversity or occupancy of fish. Few differences in species richness and diversity were evident among engineered dike structures and natural sandbars. Notching a dike structure had no effect on abundance of proportional fluvial dependents, fluvial specialists, and macrohabitat generalists. Occupancy at notched dikes increased for two species but did not differ for the other 17 species (81%). The authors suggest that dike structures may provide suitable habitats for fluvial species compared with channel sand bars, but notching of dikes did not increase abundance or occupancy of most Missouri River species.

Limited sampling conducted by the St. Louis District at an offset dike field in the MMR at RM 60.0 to 57.5 (USACE 2012a) showed an increase in bathymetric, flow, and sediment diversity from pre-construction to post-construction and showed similar fish community composition pre- and post-project.

Chevron Dike Effects - Remo et al. (2013) studied habitat diversity (depth and water velocities) in a series of three chevron dikes for pre- and post-construction conditions in the MMR's St. Louis Harbor. A comparison of pre- and post-construction conditions revealed an increase in deep to very deep (> 3.0 m), slow (<0.6 m/s) water downstream of the chevrons during emergent flow conditions. Chevrons added approximately 7.6 ha of potential over-wintering habitat (deep, > 3.0 m with low velocity, <0.6 m/s). Chevrons also created 0.8-3.8 ha of shallow-water habitat (0-1.5 m depth with a 0-0.6 m/s) for flows ≤ 2.0 times mean annual flow and contributed to an 8-35% increase in physical-aquatic habitat diversity compared to pre-construction conditions.

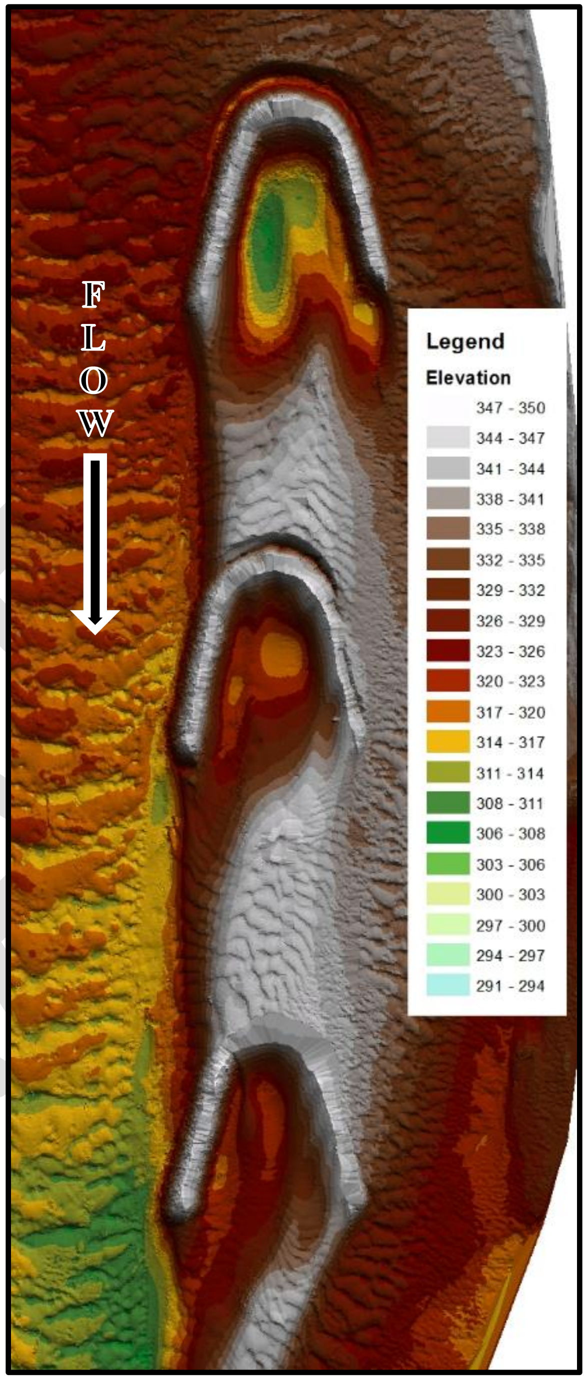


Figure 4-4. Example of bathymetry around MMR chevron dikes.

Schneider (2012) tracked the habitat changes in the same chevrons as the Remo et al. (2013) study from pre-construction bathymetry in 2007 to changes seen in 2008, 2009, and 2010. Immediately following construction, a deep scour hole formed behind each of the three chevron dikes creating ephemeral islands downstream at all dike locations. The right descending bank (RDB) maintained a large portion of its shallow water habitat. In 2008, as a result of high flows, the scour holes grew larger, but the flows nearly completely removed the ephemeral islands. A large portion of shallow water habitat on the RDB was lost, moving downstream. In early 2009, during lower flows, the islands started to reform and the scour holes shrank. Shallow water habitat again formed on the RDB. Another high water event occurred in 2009 reducing islands and the shallow-water habitat on the RDB was again reduced. In 2010, another high water event removed islands and shallow water habitat still occurred further downstream on the RDB. It is obvious that the chevrons create greater habitat diversity when compared to pre-construction bathymetry and habitat type and availability is stage dependent. Schneider (2012) also investigated fish communities associated with chevron dikes and found increased fish diversity as compared to pre-construction conditions and open water control sites. Only 11 fish species were caught at the chevron construction site during two years of pre-construction sampling, while 33 species were collected during post-construction sampling. There was a reduction of benthic chubs after chevron construction. Schneider (2012) suggests that this was due to the reduction of shallow water areas with strong currents along the RDB. He indicates that suitable habitat may have shifted downstream of the chevrons as demonstrated by bathymetric surveys, but this area was outside his pre- and post-construction fish sampling areas.

Bendway Weir Effects - Bendway weirs are designed to reduce dredging requirements in river bends by controlling point bar development (Davinroy 1990). They consist of a series of low-level submerged dikes constructed around the outer edge of a river bend. Each bendway weir is angled 30 degrees upstream of perpendicular to divert flow, in progression, toward the inner bank. The result is hydraulically controlled point bar development, reduced erosion of the outside bank, and a wider and safer navigation channel.

While providing benefits for navigation and channel maintenance, bendway weirs also provide complex habitat for macroinvertebrate and fish communities. Extreme main channel water depths found at outside bends without bendway weir fields are thought to be of little fisheries value (Baker et al. 1991).The bendway weir fields themselves provide a more heterogeneous environment than the surrounding homogenous sand substrate, resulting in greater species richness and diversity of benthic macroinvertebrates (Ecological Specialists, Inc. 1997a, 1997b).

Hydroacoustic surveys of fishes were conducted by Kasul and Baker (1996) in four river bends of the Middle Mississippi River between Cairo, Illinois, and Cape Girardeau, Missouri (RM 2-50). Comparisons of fish density based on the hydroacoustic surveys suggest that bendway weirs increase the local abundance of fishes in affected areas of the river channel more than two-fold when compared to bends without weirs. Keevin et al. (2002) sampled fish in a 152-meter section over a bendway weir (RM 30.0) at Price Towhead weir field using explosives to document fish use. In total, 217 fish were captured representing 12 different species. Freshwater Drum (*Aplodinotus grunniens*) dominated the catch comprising 35.5% of the total, followed by Gizzard Shad (*Dorosoma cepedianum*) (27.2%), and Blue Catfish (*Ictalurus furcatus*) (16.6%). The small section of rock dike supported a fairly diverse species assemblage and a large number of fish.

While the presumed benefits of bendway weir fields on fish communities at outside bends are acknowledged by natural resource agency partners, there is also concern that there may be an associated negative impact on fish communities at the adjacent inside bend point bar. The effects of bendway weirs on point-bar fishery habitat were studied on the Lower Mississippi River (Schramm et al. 1998) by comparing the changes in late-falling and low-river stage electrofishing catch rates of prevalent fishes before (1994) and after (1996) installation of bendway weirs at Victoria Bend relative to the changes in catch rates of the same fishes at Rosedale Bend, a nearby reference site without bendway weirs. Large interyear variation in catch rates was observed and, for most prevalent species, catch rates declined from 1994 to 1996 in sandbar habitats. However, significant declines in catch rates of prevalent species at Victoria Bend relative to changes in catch rates at the reference site were only noted for Gizzard Shad. Conversely, catch rates of Goldeye (*Hiodon alosoides*), Channel Catfish, and Flathead Catfish at sandbar habitat during late-falling river stage significantly declined from 1994 to 1996 at Rosedale Bend while catch rates remained similar at Victoria Bend. Based on this limited study, the bendway weirs appeared to reduce Gizzard Shad abundance but, at certain river stages, may have improved habitat conditions for Threadfin Shad (*Dorosoma petenense*), Goldeye, Channel Catfish, and Flathead Catfish.

In order to attempt to address resource agency partner concerns about the potential impacts of bendway weir fields on inside bend point bar habitat, the District completed a study in 2011 entitled "*Analysis of the Effects of Bendway Weir Construction on Channel Cross-Sectional Geometry*" (USACE 2011). The study utilized bathymetric data collected before and after weir construction at 21 bendways in the MMR and one in Pool 24. The bathymetric data were used to analyze the cross-sectional changes in channel bed geometry associated with the bendway weirs. Area, width, wetted perimeter, and slope were compared pre- to post-weir installation. The inner bend longitudinal slope was of particular interest due to concerns that the slopes were increasing, threatening shallow water habitat. The study showed that channel width at Low Water Reference Plane (LWRP)[20] increased for 77% of the cross sections with an average increase of approximately 330 ft. The average slope decreased for 59% of all cross sections, with an average decrease of 1.27 ft. per 100 ft. The study concluded that bendway weirs are largely achieving their primary goal of widening the navigable portion of the channel without a serious detrimental effect on inside bar slopes.

Revetment Effects – Revetment is designed to prevent erosion of the underlying river bank, thereby preventing migration of the river channel and potential disruption of commercial navigation. Prevention of channel migration also eliminates the formation of new habitats including side channels. Florsheim et al. (2008) argue that bank erosion, which is obviously restricted by revetment, is a desirable ecological attribute of rivers and is integral to the functioning of river ecosystems. Their argument focuses on four principles that illustrate the significance of bank erosion:

1. Bank erosion provides a sediment source that creates riparian habitat.
2. Active banks create and maintain diverse structure and habitat functions.
3. Riparian vegetation promotes bank stability and contributes large woody debris.
4. Bank erosion modulates changes in channel morphology and pattern.

Fischenich (2003) summarized the existing literature on the impacts of revetment on five general functions of riverine systems: evolution through morphological processes, maintenance of

[20] The datum to which the navigation channel is maintained for the open river portion of the MMR is the Low Water Reference Plane, commonly abbreviated as LWRP. LWRP is a 3D hypothetical model of the water surface developed to approximate a common "low water" river level at all points on the Mississippi River between river mile 200 and 0. In 1975 to provide uniformity and continuity throughout the Division, the Lower Mississippi Valley Division established a methodology for computing LWRP for the open portion of the Mississippi River. This standardized the datum to which the navigation channel was maintained for each District. To calculate LWRP, the 97 percent discharge was calculated for the period 1954 through 1973. Flows prior to 1954 were not used due to changes in the effects of the reservoirs up to that point. LWRP was calculated for each gaging station and the latest low water profiles were used to shape the LWRP profile between gaging stations. In 2014 LWRP was recalculated on the MMR utilizing the additional gage data collected since the previous LWRP was established and recent low water profiles. The time period 1967 through 2014 was selected to reflect the time that the entire Missouri River reservoir system was complete and in full operation. The new LWRP was also calculated in reference to the North American Vertical Datum 88 (NAVD 88).

hydrologic balance, continuity of sediment processes, provision of habitat, and maintenance of chemical processes and pathways. Revetment was determined to most likely affect morphological evolution, sediment processes, and habitat. Morphological evolution is impacted by prevention of lateral migration and interruption of riparian succession processes. Sediment processes are affected in the reduced overall bank erosion with some increased local scour at the toe of the revetment. Habitat impacts tend to favor species that use interstitial spaces between rocks which can result in population shifts and usually result in increased macroinvertebrate biomass and density.

Bank erosion may be desirable from an ecological perspective, and channel migration was an integral part of the historic condition of the MMR (Heitmeyer 2008), but current social and economic factors provide hard constraints on the acceptability of bankline migration (Jacobson and Galat 2006). Allowing bankline erosion and migration in today's MMR would have the potential to adversely affect agricultural areas, levees protecting agriculture as well as residential and business developments, water supplies, and the location and reliability of the navigation channel.

Similar to other rock river training structures, revetment can improve fish habitat by providing substrate diversity, additional cover, and more substrate for a wide variety of benthic macroinvertebrate colonization (Beckett et al. 1983; Bingham 1982; Dardeau et al. 1995; Fischenich 2003; Nord and Schmulbach 1973; Payne et al. 1989; White et al. 2010). Farabee (1986) studied fish at two revetted and two natural main channel border sites in Pool 24 of the Mississippi River over a 3-year period. Although the number of species at each bankline type were similar, total fish collected was greater on banklines with revetment, especially where larger stone was present. On the Lower Mississippi River, Pennington et al. (1983) sampled fish populations using hoop nets and electroshocking along two natural and two revetted banks near Greenville, MS. They found that the numbers of fish species taken from natural and revetted banks were similar. Twenty-four species were collected from natural banks and 27 from revetted banks. However, the relative abundance of individual species was different in the two habitats, with sport and commercial species more abundant by weight on revetted banks. Mean catch per unit effort (CPUE) in numbers and weight were greater on natural banks during one of four sampling periods (June), but greater on revetted banks during the other sampling periods (April, September, and November). In a similar study on the Lower Mississippi River, Pennington et al. (1985) sampled fish populations using hoop nets along natural and revetted banks near Eudora, AR. During months prior to revetment placement Freshwater Drum was the most abundant species (32% of total catch), followed in abundance by Flathead Catfish (9.6%), Common Carp (*Cyprinus carpio*, 7.8%), and Blue Catfish (3.3%). After revetment placement Freshwater Drum remained the most abundant species (9.7% of the catch), followed by Gizzard Shad (*Dorosoma cepedianum*, 8.9%), Flathead Catfish (4.1%), and Blue Catfish (3.4%). There was no significant difference in CPUE between natural and revetted banks.

White et al. (2010) compared fish assemblage structure in engineered (revetment) and natural habitat in the Kansas River. They found that mean species diversity and richness were significantly higher in revetment than log jams and mud banks. Mean relative abundance (CPUE, number of fish collected per hour electrofishing) of six of the 15 most abundant fishes were most abundant in revetment, two were most abundant in log jams, and none in mud banks.

Revetment had the highest relative abundance of fluvial specialists and macrohabitat generalists, whereas mean CPUE of fluvial dependents was highest in log jams. There was a high degree of fish assemblage overlap among habitats.

Construction and Maintenance Effects – In addition to the potential broad scale impacts of river training structures and revetment discussed above, construction and maintenance activities associated with river training structures and revetment also have the potential to impact fishery resources. Construction and maintenance activities would typically consist of placement of limestone rock using barge mounted track hoes or dragline cranes. Most construction would be accomplished from the river and would be performed below ordinary high water. Potential impacts to fishery resources include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur.

3-D Numerical Hydraulic Model

As outlined above, there is a reasonable amount of information available in the scientific literature on the potential impacts of river training structures on fishery resources. Existing information adequately characterizes the qualitative changes in fish community structure that might be anticipated with further construction of river training structures. However, in order to properly characterize the programmatic physical impacts of future river training structure construction on fishery resources, the District needed to develop a quantitative methodology. Previous analyses of physical aquatic habitat have been conducted using two-dimensional hydraulic models (e.g., Jacobsen et al. 2009, Remo et al. 2013). Such models can provide a good approximation of two-dimensional flow fields around traditional river training structures but are unable to replicate the three dimensional flow patterns around complex innovative structures[21] used extensively on the MMR. The District determined that a three-dimensional numerical hydraulic model would be the most appropriate tool for quantifying changes in velocity distribution throughout the water column.

Modeled Reach. Since it was not feasible to model the entire MMR due to budget, time, and technological constraints, the District had to determine which section of the 195-mile MMR should be modeled in order to adequately characterize impacts of future river training structure construction. Factors taken into consideration included:

- Locations of rated gages (locations where both discharge and stage are collected) – proximity to a rated gage was important in order to ensure proper model calibration.
- Number of different types of river training structures and habitats in the area (e.g. traditional dikes, chevron dikes, notched dikes, offset dikes, bendway weirs, point bars,

[21] Innovative structures are river training structures designed in unique configurations to achieve the primary objective of deepening the navigation channel while also increasing depth and flow diversity for fish and wildlife when compared to traditional wing dikes. The District has designed and implemented many different configurations of innovative structures including notched dikes, rootless dikes, L-dikes, W-dikes, chevron dikes, multiple roundpoint structures, etc.

side channels, etc.) – a variety of structure and habitat types was necessary to ensure that an adequate range of future construction scenarios would be covered by the model

- Length of the modeled area – the size of the modeled area needed to be large enough to cover an adequate range of habitats and structure types but small enough to make analysis of multiple scenarios realistically feasible given computing power and time required.
- Available bathymetric datasets – model velocity calculations around structures are dependent on bathymetry. To get the most accurate velocity patterns around structures it is critical to have the most dense and detailed bathymetric data available.

A 19-mile stretch of the MMR from river mile 110 near Chester, IL to river mile 92 was selected for analysis (Figure 4-5). This stretch of river includes a rated gage at the upstream end (allowing the model to be calibrated to observed water surface and velocity data), contains the majority of structure and habitat types in the MMR, has good coverage of bathymetric data, and is of an appropriate length for maximizing data output and minimizing computation requirements.

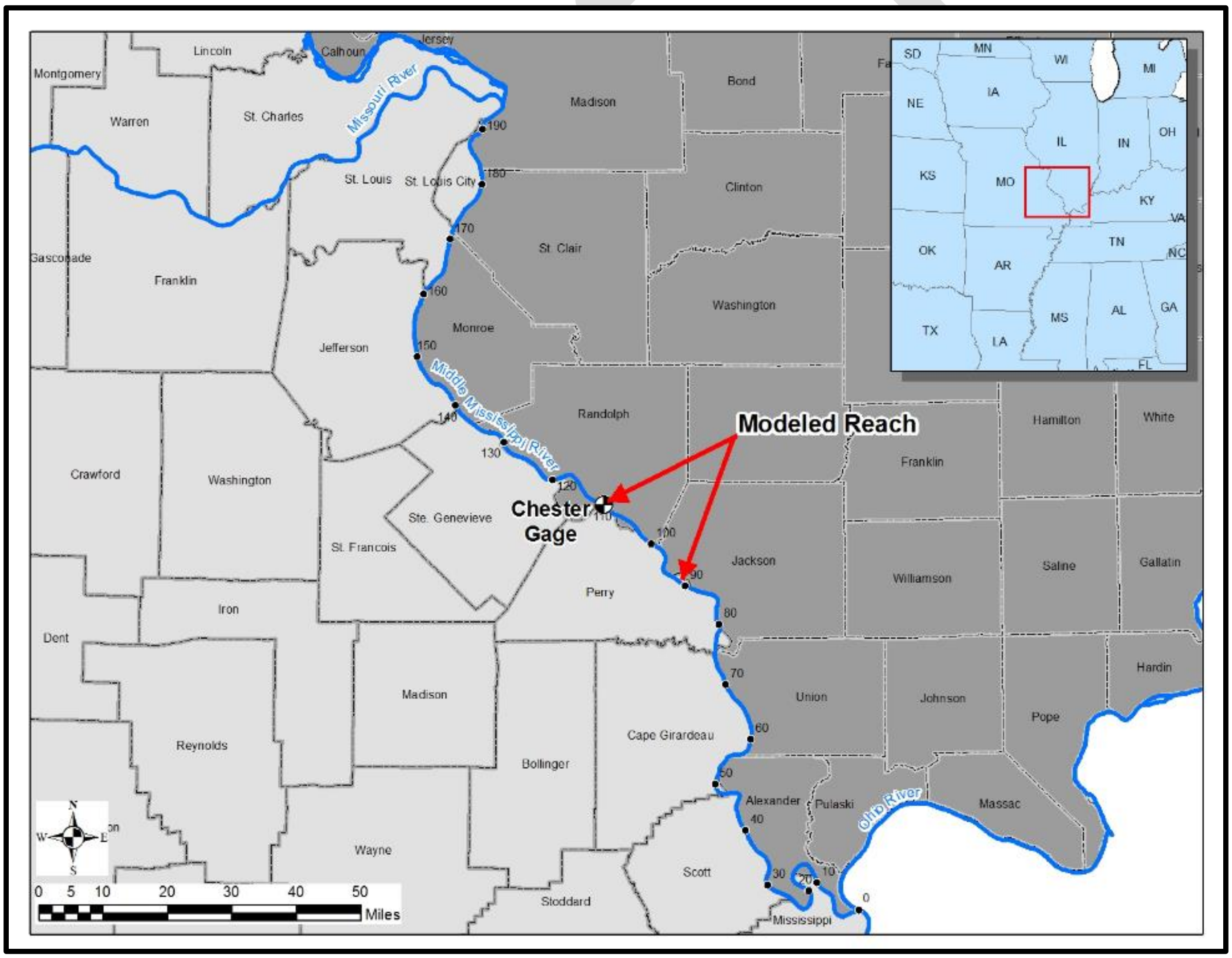


Figure 4-5. Location of the modeled portion of the MMR.

Analysis Methodology. The model was used to analyze velocities for three separate discharges: average annual low discharge (111,000 cfs), average annual discharge (213,000 cfs), and average annual high discharge (303,000 cfs). These discharges correspond to structures being emerged by 10 feet, emerged by 2 feet, and submerged by 4 feet, respectively. These discharges were chosen because they cover the full range of flows occurring in a typical year and cover a broad enough range to adequately capture the full range of velocity and depth profiles in the modeled reach. They were also chosen because they correspond to flows for which recent field measurements of water surface and velocity have been collected, thereby increasing model accuracy.

For each of the discharges, 6 depth categories and 5 velocity categories were computed. Depth and velocity categories were assigned to 1-m by 1-m by 1-m volumes within the modeled area. Depth categories were assigned based on the total water depth of the location, not by the depth of the cube within the water column. In other words, all individual $1m^3$ volumes at a particular point in the river were assigned the same depth category, irrespective of where they fell within the water column at that location. This was done to avoid classifying, for example, surface waters over shallow sandbars the same as surface waters over deep water in the main channel.

The depth and velocity classifications were developed with input from natural resource agency partners. The number of depth and velocity categories had to be limited to a reasonable number so that processing of model data did not become exceedingly time consuming. The chosen depth and velocity categories are skewed toward higher resolution at shallower and lower velocity habitat due to the fact that those areas are, in general, considered more likely to provide better fish habitat in the MMR. The following categories were used:

Depths (meters)

- 0-1.0
- 1.0-2.0
- 2.0-3.0
- 3.0-5.0
- 5.0-10.0
- >10.0

Velocities (m/s)

- 0.0-0.1
- 0.11-0.25
- 0.26-0.5
- 0.51-1.0
- >1.0

One of the recurring challenges with determining the future impacts of implementation of the Regulating Works Project on the human environment is the fact that the exact locations of future work sites and the exact set of structures to be used are not known. Given the dynamic nature of the MMR, work sites are developed on an ongoing basis as dredging issues arise and the set of structures to be used to address dredging issues at each location is developed based on the unique characteristics of each site. Because of these uncertainties in location and configuration of future structures, it was necessary to use existing dike fields within the modeled reach to serve as surrogates for work sites to estimate future impacts. Groups of dikes were selected as work sites based on typical Regulating Works construction site configurations and sizes. In selecting areas of the modeled reach to use as work sites, it was also necessary to select areas that could serve as surrogate control sites so that a before and after comparison could be conducted to quantify impacts. Due to the fact that detailed bathymetry for previous years did not exist for most of the modeled reach, the model could not be used to analyze true before construction and after construction conditions for work sites. Therefore, areas of the modeled reach that were representative of likely future work sites before construction were used as surrogate control sites. Eight areas were selected as control sites and nine were selected as work sites. Depth and velocity information for each site for all three discharges was calculated. This resulted in a dataset of volumes of the various combinations of depth and velocity occurring in each area for each discharge. These volumes were then converted to percentages to account for differing acres and volumes of each site and to allow for direct comparison.

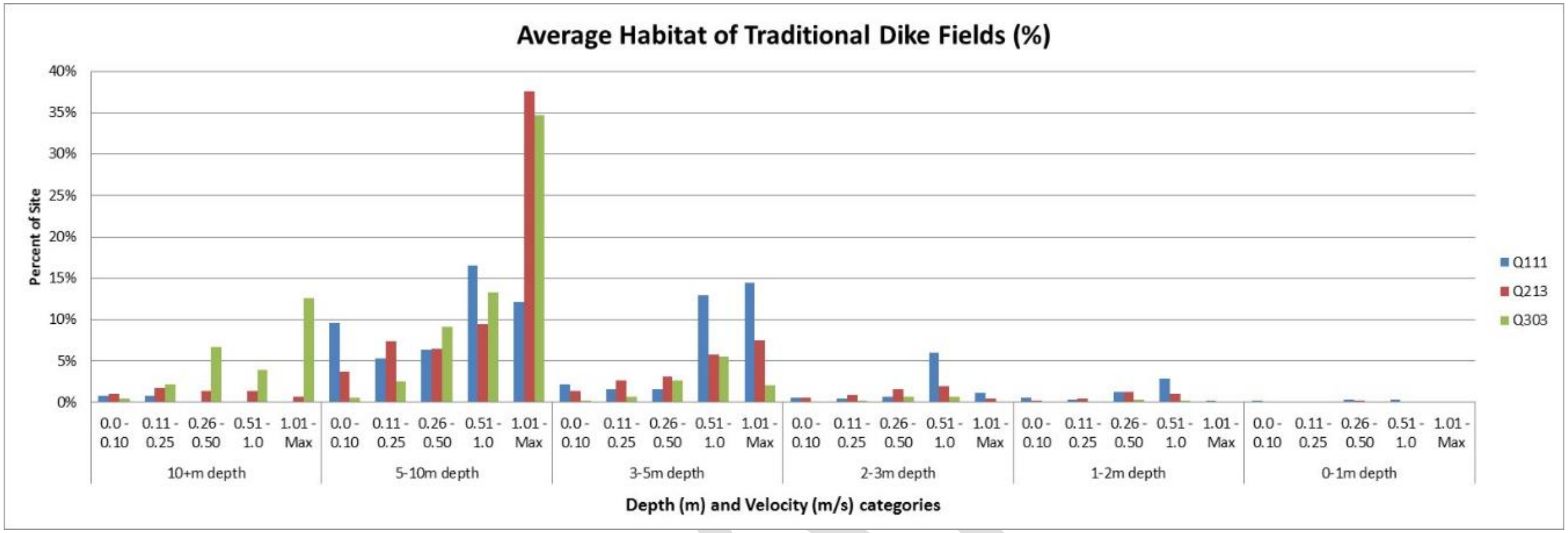
Results. Analysis of the 3D model outputs resulted in a few key conclusions:

1. **Use of innovative structures is accomplishing the intended goal of increasing habitat diversity.** The analysis of model results for areas with innovative structures compared to areas with traditional dikes shows an increase in diversity of depth and velocity categories. In the modeled reach, innovative structures consist of chevrons, offset dikes, and notched dikes. As can be seen in Figure 4-6, the innovative structure fields tend to provide a more even distribution of habitat categories, particularly on the shallow end of the habitat scale. Another way to consider this is by comparing the gains in relative habitat percentage of innovative vs. traditional dikes. This can be done by comparing the amount of each habitat category in the work site or control site to the total amount of that habitat type in the entire modeled reach. Using this method highlights differences based on scarcity – small increases in scarce habitat categories show up as large relative percent increases. This comparison can be seen in Figure 4-7. Again, innovative structures appear to increase habitat diversity when compared to traditional dikes. This is an important validation that the use of innovative structures yields the desired habitat benefits as intended.

2. **Construction of river training structures generally results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat.** When comparing model results for work sites to control sites (Figure 4-8), a general increase in the relative percent of low-velocity habitat can be seen, particularly shallow, low-velocity habitat. This is intuitively reasonable given that river training structure construction, whether traditional or innovative, generally results in some sediment accretion downstream of the structures in an area of low current velocity.

3. **Construction of river training structures generally results in a decrease in shallow to moderate-depth, moderate- to high-velocity habitat which is important habitat to some MMR fish guilds.** Offsetting the gain in low-velocity habitat discussed in conclusion 2 above, model results indicate that river training structure construction causes a loss in shallow to moderate-depth, moderate- to high-velocity habitat (Figure 4-8). The loss appears to be relatively small, but given the limited quantity of habitat of this type in the MMR, the relative loss is more meaningful. The depth and velocity characteristics of this loss are reasonable given the locations in which river training structures are generally constructed – shallow to moderate-depth unstructured main channel border habitat. This habitat would typically be expected to exhibit moderate to high velocities given its location in the river channel and presumed lack of river training structures to act as current breaks. Indeed,

modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.



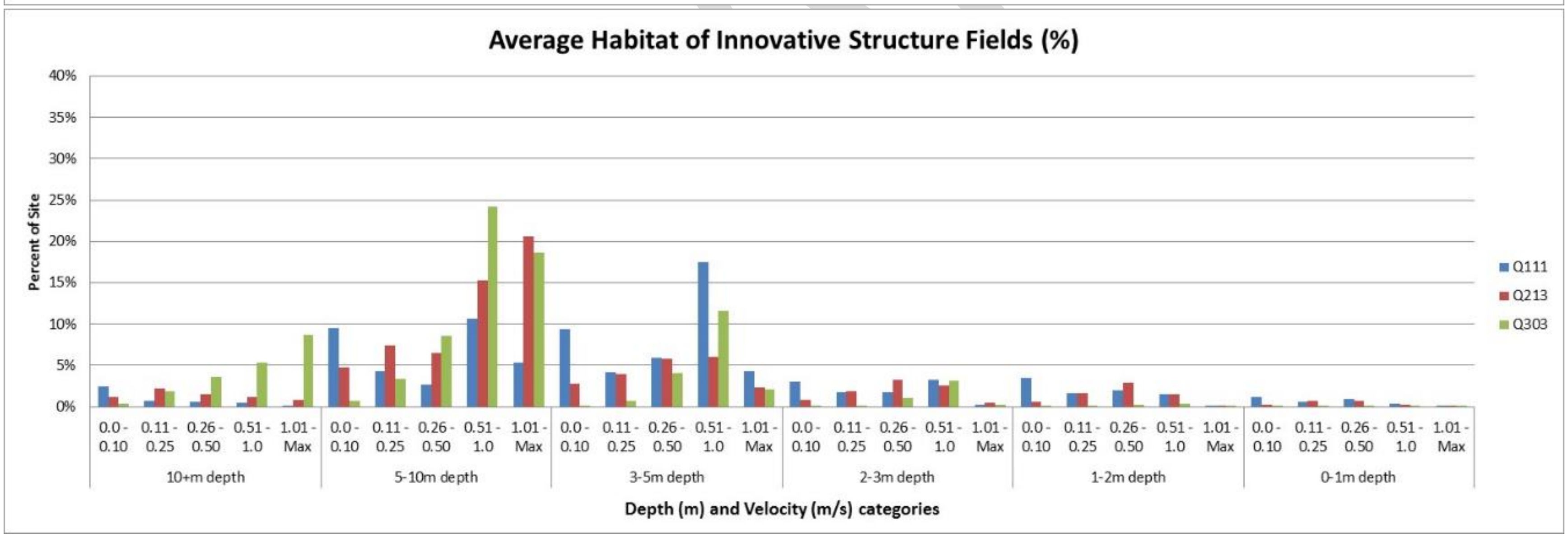


Figure 4-6. Comparison of habitat categories provided by traditional dikes (top) vs. innovative structures (bottom) expressed as a percent of the site. Three discharges analyzed represented by three colors.

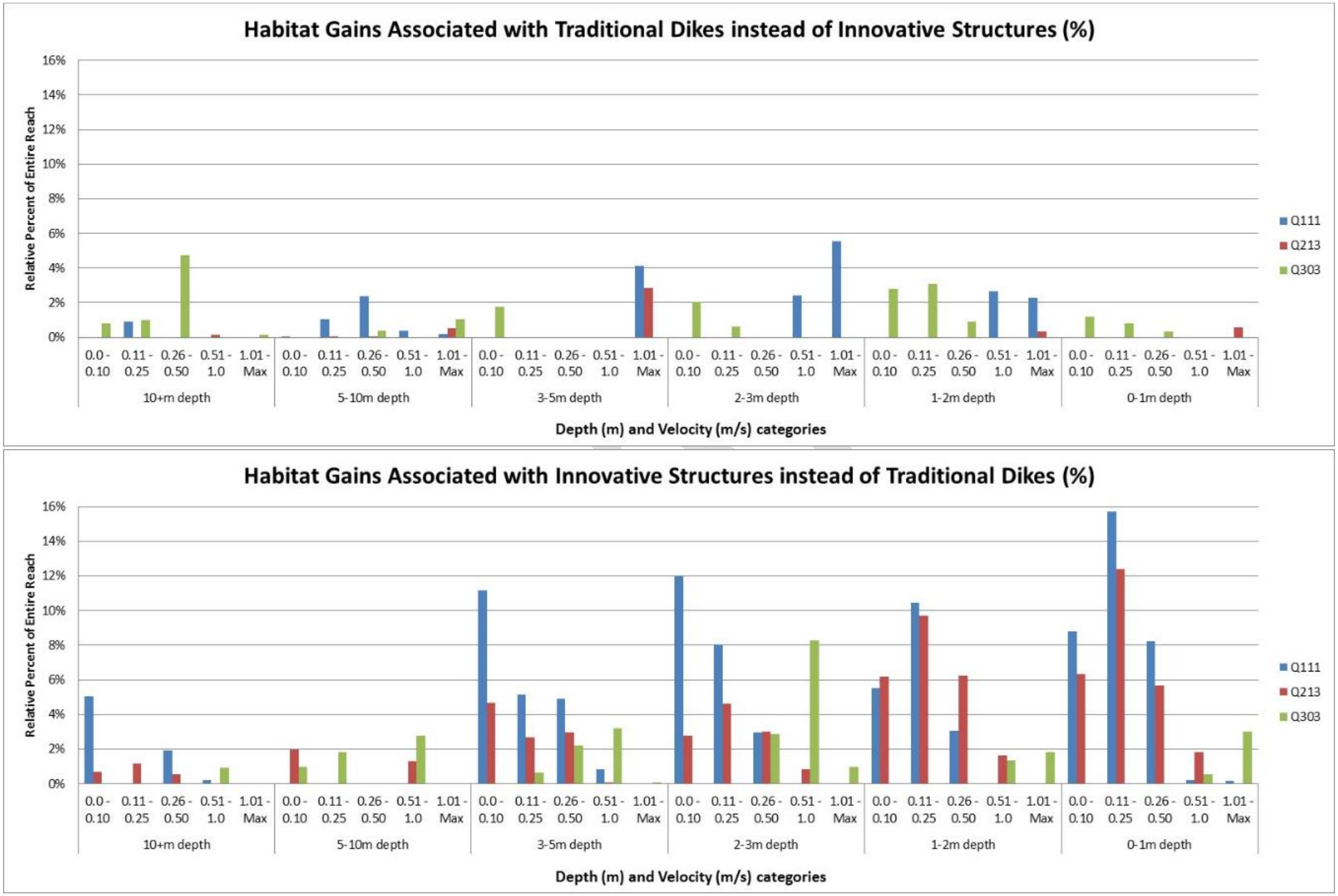
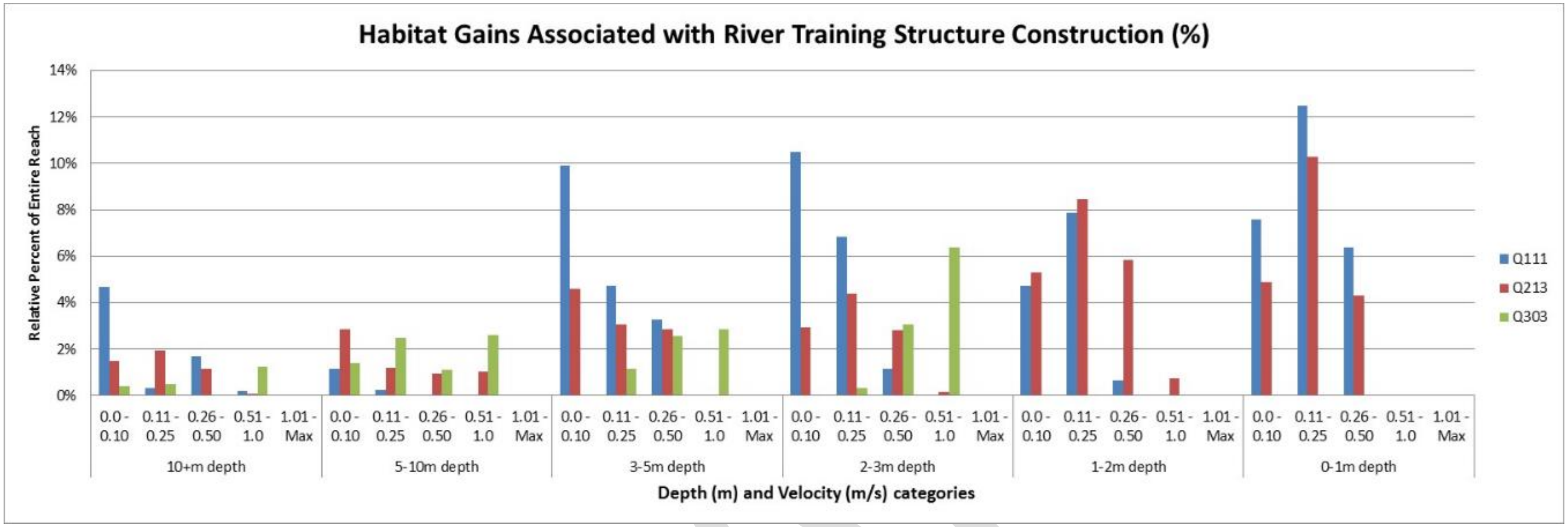


Figure 4-7. Comparison of habitat gains associated with construction of traditional dikes (top) vs. innovative structures (bottom) expressed as a relative percent of each habitat category.



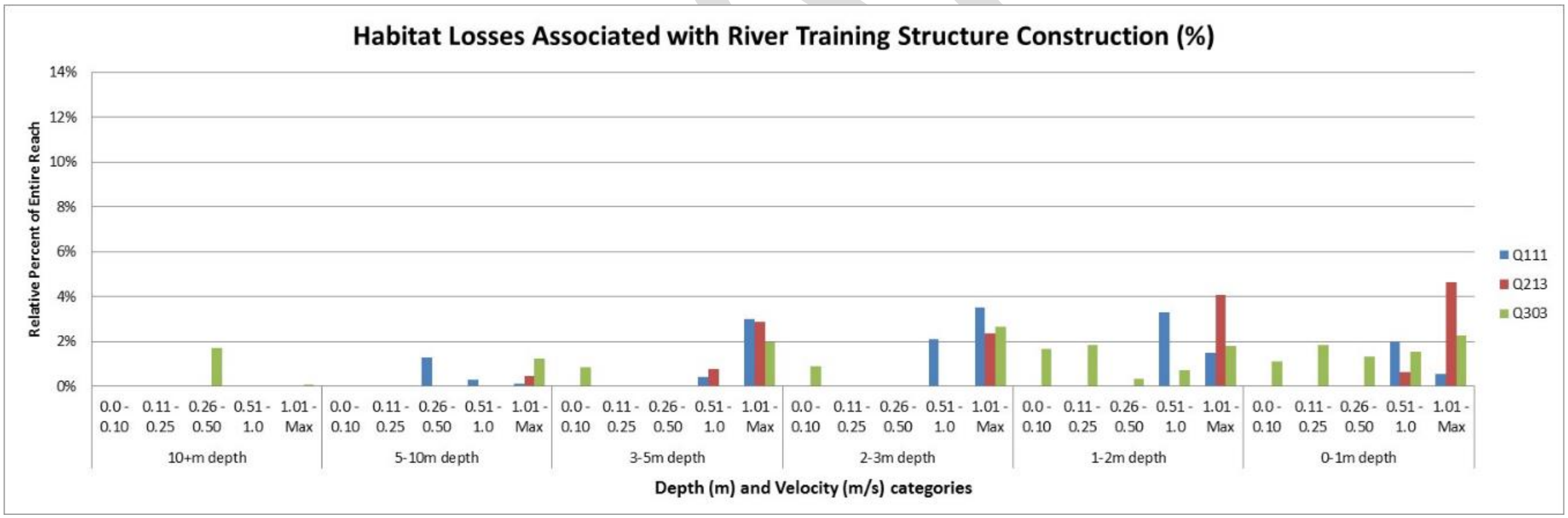


Figure 4-8. Habitat gains (top) and losses (bottom) associated with construction of river training structures expressed as a relative percent of each habitat category.

Impacts of River Training Structure Construction associated with the Continue Construction Alternative on Fishery Resources

Under the Continue Construction Alternative, an estimated 4.4 million tons of rock is expected to be placed for construction of river training structures to address repetitive dredging areas. The exact locations, configurations, and types of river training structures are not known at this time and would not be known until planning is conducted work area by work area over the remainder of the construction phase of the Project. The specific impacts associated with each work area would be covered in Tier II site specific Environmental Assessments. However, the generalized, programmatic impacts that can reasonably be anticipated to occur as a result of all future construction activities are summarized herein. To quantify the programmatic impacts of future river training structure construction on fish habitat, the assumption was made that for the remaining work areas in the MMR, impacts would be comparable to those in the modeled reach.

As a result of river training structure placement in future work areas, the adjacent navigation channel is expected to deepen and the main channel border area is expected to become shallower, on average. However, based on river planform trends over the past 50 years, very little conversion of the main channel border area to terrestrial habitat is expected to occur. River planform area is expected to remain similar to what it is today, with some variation from year to year. Future placement of river training structures is expected to increase areas of shallow, low-velocity main channel border habitat important to a wide variety of MMR fish species. Continued use of innovative river training structure designs is expected to increase depth and velocity diversity in main channel border areas. Continued construction of bendway weirs is anticipated to improve habitat on outside bends for many fish species. The impacts on fish habitat on inside bends opposite the bendway weirs are uncertain. Studies to date do not provide conclusive results for predicting fish community response to bendway weir placement at adjacent inside bends. Continued construction of revetment on areas of MMR bankline is expected to prevent erosion of any adjacent riparian corridor, thereby reducing woody debris inputs. Approximately 60% of the MMR bankline has already been revetted to date. This revetment covers the vast majority of MMR bankline areas that might require revetment to prevent bankline erosion. The precise amount of revetment required going forward is unknown but is not anticipated to have an appreciable adverse effect on the MMR fish community. All rock material used for construction of river training structures and revetment is expected to increase habitat diversity, flow complexity, and the quantity of stable substrate available for macroinvertebrate colonization, thereby improving the overall quality of fish habitat.

Despite any apparent increase in overall habitat diversity associated with river training structures, there are potential adverse effects anticipated with future construction. One area of potential adverse effect is the modification of flow fields by training structures and the potential implications for fish movement patterns either for migration or as part of daily foraging patterns. The velocity and turbulence patterns around river training structures may impede fish movement along routes that would normally minimize energy expenditure. There are also potential adverse effects to fishery resources from river training structure construction and maintenance activities. These include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur.

Another area of potential adverse effect is the loss of shallow to moderate-depth, moderate- to high-velocity habitat. Habitat with these depth and velocity combinations is important habitat for some MMR fluvial specialists, or species that are found almost exclusively in flowing water throughout their life cycles. Some species of fluvial specialists in the MMR have seen declines in abundance since the mid-1900s. For example, Sturgeon Chub (*Macrhybopsis gelida*) and Sicklefin Chub (*Macrhybopsis meeki*) are typically found in medium- to high-velocity sand and gravel bar habitat in the MMR and have declined in abundance over time in the MMR (Pflieger 1997). Remnant habitats with these depth and velocity attributes are important biologically for the continued existence of the chub species (USFWS 2008).

In order to determine the magnitude of this potential adverse effect, the District conducted an analysis of MMR habitat classifications. Results of the 3-D numerical hydraulic model indicated that the depth and velocity profile of the shallow to moderate-depth, moderate- to high-velocity habitat that is lost with placement of river training structures is very similar to the depth and velocity profile of unstructured main channel border habitat in the modeled reach. Accordingly, the District analyzed the past and present quantities of unstructured main channel border habitat and projected future quantities. The analysis showed that the amount of unstructured main channel border habitat in the MMR (defined as areas shallower than LWRP -10 without river training structures) decreased from approximately 19,800 acres in 1976 to approximately 12,900 acres in 2014. In other words, river training structure construction affected approximately 6,900 acres of main channel border habitat from 1976 to 2014. Based on the current programmatic estimate of the amount of remaining construction, it is anticipated that river training structure construction could potentially affect another 1,100 acres of unstructured main channel border habitat[22]. This represents approximately 8% of the remaining unstructured main channel border habitat in the MMR. Although these unstructured main channel border habitats are part of a river system that is highly modified compared to its original state, they likely more closely resemble some of the habitats of the historic MMR. The continued conversion to structured habitat is expected to result in the continued functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat. This analysis also provides insight into the magnitude of the potential adverse effect to fish movement described above. Areas of unstructured main channel border habitat are more likely to provide the necessary movement and migration pathways required by the MMR fish community. Overall, the continued conversion to structured main channel border habitat is expected to have a significant adverse effect on the MMR fish community and the District has concluded that this would warrant compensatory mitigation.

This impact is considered significant on technical, institutional, and public merits. The impact is technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. Likewise, it is technically significant due to the decline in abundance of the species of fish that utilize the habitat and the fact that remnant

[22] Actual acreages affected would not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis. See Appendix C for a full discussion of the assumptions associated with the remaining quantity of construction.

habitats with these depth and velocity attributes are important biologically for the continued existence of these species. The impact is considered significant on institutional grounds due to the importance that the Corps, through its Environmental Operating Principles, places on environmental sustainability, proactive consideration of the environmental consequences of Corps activities, and the creation of mutually supporting economic and environmental solutions. Congress recognized the Upper Mississippi River System as a "…nationally significant ecosystem and a nationally significant commercial navigation system" in Section 1103 of the Water Resources Development Act of 1986. Natural resource agency partners place high priority on protecting and sustaining the aquatic resources of the Mississippi River. The State of Illinois recognizes the Sturgeon Chub as significant in listing it as a state endangered species. The State of Missouri recognizes the Sturgeon Chub as a vulnerable species due to a restricted range, relatively few populations or occurrences, recent and widespread declines, or other factors making it vulnerable to extirpation. The impact is considered significant to the public due to the intrinsic value the public places on the environment and its continued protection. Specific public interest in the Sturgeon Chub and the Sicklefin Chub is demonstrated by formal petitions by the public in 1994 and in 2016 to list the species as threatened or endangered under the Endangered Species Act.

Compensatory Mitigation

In order to compensate for the projected future unavoidable adverse effects of future river training structure placement associated with the Continue Construction Alternative, potential mitigation measures may include, but are not limited to: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, or other activities. Removal, shortening, notching, etc. of existing river training structures would facilitate the replacement of lost function with a similar amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the MMR reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel.

Dikes on the MMR have been added and extended over time to reduce dredging, increase safety, and add environmental diversity throughout the Regulating Works Project. Initially these structures were designed using design criteria that specified dike spacing as a function of dike length. Early river engineering practice was to extend existing structures to achieve greater channel contraction when necessary (see Appendix F). The result of extending existing dikes is that the structure spacing is no longer optimized, resulting in structures that have little or no effect on maintaining navigation channel depths.

In addition, many of the structures on the MMR were designed by engineers without the assistance of modern numerical and physical model studies that are now used to optimize structure locations, configurations, spacing, etc. Adaptive management was used in cases when there was a need for additional constriction from what was initially designed; however, in cases where constructed projects deepened the navigation channel by more than what was needed or expected, structures were not normally removed.

These factors have created a situation where opportunities now exist within the MMR to remove, shorten, notch, or otherwise alter the configuration of existing river training structures without adversely affecting the adjacent navigation channel to compensate for the 1,100 acres of main channel border habitat estimated to be impacted. The St. Louis District has, in fact, successfully altered existing dike configurations in multiple locations in the MMR to provide environmental benefits pursuant to the commitments made in the Record of Decision for the EIS for the second lock at Mel Price Lock and Dam in the UMR and the RPAs, RPMs, and Terms and Conditions of the Biological Opinion. A preliminary evaluation of where further opportunities exist to remove, shorten, and/or notch existing structures could be done by comparing current main channel depth profiles to the profile for a navigation channel of nine-foot depth below LWRP. Once potential sites are identified, more detailed H&H modeling or analysis would be used to develop a recommended plan and verify that there would be no impact to the adjacent navigation channel, providing identified areas that could be used if necessary for potential compensatory mitigation for future construction.

Impacts of River Training Structure Construction associated with the No New Construction Alternative on Fishery Resources

The only Regulating Works Project construction activities associated with the No New Construction Alternative would be for maintenance of existing structures and for any construction associated with implementation of the Biological Opinion. Potential impacts to fishery resources include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur. Fishery resources impacts associated with the No New Construction Alternative are anticipated to be minor and short-term in nature.

4.3.3 Impacts on Threatened and Endangered Species

As discussed in Section 3.3.4 Threatened and Endangered Species above, due to the existing Biological Assessment and Biological Opinion that cover the Regulating Works Project, a Biological Assessment was not prepared in conjunction with this SEIS for the species covered by the previous consultation process. However, for new threatened and endangered species that have been listed since issuance of the 2000 Biological Opinion (Table 4-5), a Biological Assessment has been prepared in conjunction with this SEIS. The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

The Biological Assessment for this SEIS covering recently listed species can be found in Appendix B. Site-specific Tier II Biological Assessments for all appropriate species are currently prepared and would continue to be prepared for construction of specific work areas in the MMR.

Table 4-5. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 January 2016).

Species	Federal Status	Consultation Status and District Determination of Effect
Red Knot (*Calidris canutus rufa*)	Threatened – listed in 2015	Covered in this document; No effect (see Appendix B);
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013	Covered in this document; No effect (see Appendix B)
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001	Covered in this document; No effect (see Appendix B)
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013	Habitat not found in Project Area. No further analysis required.
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015	Covered in this document; May affect but not likely to adversely affect (see Appendix B)
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016	Habitat not found in Project Area. No further analysis required.

Although the Bald Eagle was removed from the federal list of threatened and endangered species in 2007, it continues to be protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (BGEPA). The BGEPA prohibits unregulated take of Bald Eagles, including disturbance. The U.S. Fish and Wildlife Service developed the National Bald Eagle Management Guidelines (USFWS 2007) to provide landowners, land managers, and others with information and recommendations regarding how to minimize potential project impacts to Bald Eagles, particularly where such impacts may constitute disturbance. Tiered site-specific Environmental Assessments prepared for specific work areas would address any potential impacts to Bald Eagles. If any nest trees were identified in specific work areas, the National Bald Eagle Management Guidelines would be implemented to minimize potential impacts and appropriate coordination with the U.S. Fish and Wildlife Service would be conducted.

4.4 Impacts on Socioeconomic Resources

4.4.1 Impacts on Human Resources

Environmental Justice

Impacts of the Continue Construction Alternative and the No New Construction Alternative

As outlined above in Section 3.4.1 Human Resources, parts of the Project Area have minority or low-income populations that meet the defined thresholds and/or are meaningfully greater than the general population. St. Louis County, St. Louis City, and Mississippi County have minority population densities higher than the state average in Missouri. No Illinois counties in the Project Area have minority population densities higher than the state average. St. Louis City, Missouri, Mississippi County, Missouri, Jackson County, Illinois, and Alexander County, Illinois, have low-income populations above the 20% threshold.

In addition to county information, Census Block Group information was utilized to refine minority and low-income information for populations immediately adjacent to the MMR. Of the 74 Census Block Groups in Missouri and Illinois that are adjacent to the MMR, 30 in Missouri and 11 in Illinois have populations that meet the minority and/or low-income criteria (Figure 3-28).

Given that the population statistics for the Project Area counties and Census Block Groups indicate that certain areas within the Project Area do contain minority and/or low-income population groups, the possibility exists for the Project to disproportionately affect those populations. Accordingly, the Environmental Justice analysis looked at the locations of Project actions in relation to minority and low-income populations to determine if disproportionately high adverse human health or environmental effects would occur to those populations.

River training structure construction and dredging activities have historically occurred throughout the entire 195-mile Project Area. While dredging has been reduced by placement of river training structures, dredging still occurs throughout the Project Area and future river training structure construction is expected to be distributed throughout the entire length of the Project Area. Given that river training structure construction activities as well as dredging operations are anticipated to occur at locations along the entire length of the Project Area, no one area is expected to be impacted more than any other, and, as a result, minority and low-income populations are not expected to be impacted disproportionately by either of the alternatives considered. Any potential impacts are also minimized by the fact that residential areas are not generally located immediately adjacent to the river channel. Therefore, construction and dredging activities associated with the alternatives considered, and any associated disturbances, would not generally be in close proximity to residences. Likewise, given that the District has concluded that river training structures do not impact flood heights, the Project is not expected to impact areas in the floodplain. Further, most work occurs within the river, so no minority or low income population real estate would be impacted. For any work that did require obtaining real estate interests, proper analysis would take place in a Tier II site-specific EA to insure that these rights were not disproportionately impacted.

Outdoor Recreation

Impacts of the Continue Construction Alternative on Outdoor Recreation

As described in Section 3.2.2 Geomorphology and Section 4.2.2 Impacts on Geomorphology above, no further loss of surface area of the MMR would be anticipated with implementation of the Continue Construction Alternative. Likewise, as described in Section 3.2.3 Side Channels and Section 4.2.3 Impacts on Side Channels above, the amount of side channel habitat available is anticipated to remain stable or increase going forward. Accordingly, no loss of aquatic habitat suitable for recreation would be anticipated.

Continued construction of river training structures would be expected to result in increased availability of shallow and deep low-velocity habitat which would provide areas for recreational fishing. Some loss of shallow to moderate-depth, moderate- to high-velocity habitat would also be anticipated. However, this potential adverse effect would be offset by the proposed compensatory mitigation (see Section 4.3.2 Impacts on Fishery Resources above).

Maintenance dredging, construction, and structure maintenance activities associated with this Alternative could lead to disturbance of fish in the immediate vicinity of work locations. These actions could also directly interfere with recreational activities by interfering with access and/or by detracting from the aesthetic value of the experience. However, these impacts would be considered very localized, temporary, and minor in nature.

Impacts of the No New Construction Alternative on Outdoor Recreation

Insofar as maintenance dredging and structure maintenance activities associated with the No New Construction Alternative could lead to disturbance of fish in the immediate vicinity of work locations, there could be a small adverse effect on recreational fishing activities. Dredging and structure maintenance activities could also directly interfere with recreational activities by interfering with access and/or by detracting from the aesthetic value of the experience. However, these impacts would be considered very localized, temporary, and minor in nature.

4.4.2 Impacts on Navigation

The Continue Construction Alternative would be expected to reduce average annual dredging quantities from approximately 4 million cubic yards to approximately 2.4 million cubic yards. This anticipated reduction in dredging would be expected to reduce barge grounding rates and result in a safer and more reliable navigation channel.

The reduction in dredging needs would result in increased channel reliability and a decrease in the risk of channel closures due to reduced frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages. The reduction in need for just-in-time dredging would reduce the likelihood of a failure to find problematic locations and get the dredge to the location when needed.

The District's ability to respond to extreme dredging situations would also be improved with implementation of the Continue Construction Alternative. During the recent low-water event of 2012/2013, the Corps had to redirect O&M funding from other O&M needs as well as bring on an additional dredge boat to meet dredging demands. The availability of additional funding and dredging resources cannot be assumed for future low-water events. Implementation of the Continue Construction Alternative would be expected to reduce the dredging requirements during any such future events and would increase the likelihood of avoiding adverse effects to navigation.

Any potential adverse effects to navigation associated with new river training structure construction or dredging would be avoided to the greatest extent practicable by coordination with navigation industry stakeholders.

4.5 Impacts on Historic and Cultural Resources

Impacts of the Continue Construction Alternative on Historic and Cultural Resources

Terrestrial Resources

The construction of revetment can potentially have adverse effects on terrestrial cultural resources. As with other river training structures, most placement of revetment is conducted via barge, without recourse to land access. The placement of the rock, however, has the potential to damage or destroy any resource on the bankline surface. Dredge material is deposited in the river thalweg and not in upland disposal areas and therefore has no impact on terrestrial resources.

The initial step in reviewing potential impacts to terrestrial cultural resources is to determine the age of the landforms where any new revetment would be placed by examining historic maps and written accounts. Landforms which have formed in historic times have little to no chance of possessing prehistoric cultural resources whereas older landforms do.

Historic and cultural resources within and in proximity to the Middle Mississippi River have been, and continue to be, subjected to natural riverine processes (e.g., bankline and riverbed erosion). Prior to the introduction of bankline stabilization efforts, the Middle Mississippi River meandered across the landscape causing both the erosion and accretion of land. Rarer, but more dramatic, than this slow lateral migration across the landscape, was the occurrence of major avulsions, or shifts in course. These could take the form of river capture when one river migrated into and diverted the waters of another. The most dramatic example of the latter in historical times was the capture of the lower Kaskaskia by the Mississippi during the great flood of 1881, which resulted in the creation of Kaskaskia Island between two branches of the river.

The former lower Kaskaskia River ultimately became the main course of the Mississippi, and after the closing of the latter's western branch (i.e., the Doolan Slough), the only course.

Anthropogenic changes to the MMR system have also impacted historic and cultural resources since at least the 18th century. As Euro-American settlements developed along the river, levee systems began to be constructed by landowners and communities for flood control. Before stabilization efforts, islands tended to shift downstream over time as their upstream head eroded and newly deposited alluvium accumulated downstream. Thus, many islands, as they are currently situated, are relatively recent landforms. Beginning in the mid-19th century, structures were constructed in the river to modify water-flow to either decrease or increase sedimentation in specific locations. Dikes directed the water current to eliminate sandbars, and hurdles were used to close off chutes between towheads and riverbanks causing them to fill with sediment, and effectively narrow the river. While specific cultural resources might have been adversely impacted by increased waterflow and resulting erosion, others were protected by increased sedimentation.

In 1879 the Mississippi River Commission (MRC) was created by Congress to promote commerce and prevent flooding. Historically, river regulating structures and practices led to a significant narrowing of the MMR with accretion of land, largely along the Illinois bank. While early dikes and other structures had site-specific functions and goals (e.g., Lt. Robert Lee's project to improve St. Louis harbor in 1830s), after the formation of the MRC, more systematic efforts were made to use structures to aid navigation. In order to procure a navigation channel with a minimum depth of eight feet, it was a stated project of the District Engineer approved by the Chief of Engineers on March 31, 1881:

> *To make the improvement continuous, working downstream from St. Louis, by reclaiming land and building up new banks (using for the purpose preamble dikes of hurdles of piling to collect and hold the solid matter carried in suspension or rolled on the bottom of the river), thus reducing the width of the river to the uniform width of 2,500 feet* (Annual Report of the Chief 1881:1536).

The construction of dikes and revetment has greatly reduced bankline erosion and halted river migration, thereby protecting cultural resources, both known and unknown, from destruction by erosion. The current Regulating Works Project continues this mission with similar generally positive impacts to cultural resources.

To address the potential adverse effects to cultural and historic resources, and in compliance with Section 106 of the National Historic Preservation Act, as part of site-specific Tier II Environmental Assessments the following measures would be undertaken in consultation with the appropriate state and federal agencies:

- If the project design includes the placement of revetment, historic maps and aerial photographs would be consulted to attempt to identify any former or current structures and features that are in the project footprint.
- SHPO databases would be consulted for the presence of known archaeological or historic sites and to see if the area has previously been surveyed and, if so, by what means.

- If necessary, pedestrian surveys would be undertaken to further determine if any visible structures would be adversely affected by the placement of rock.
- If any grading would be necessary, an archaeological survey would be undertaken to determine if any archaeological site would be adversely affected.

Submerged Resources

All construction and modification work on dikes and weirs is carried out using barges, without recourse to land access; therefore, any potential effects are limited to submerged cultural resources. Primary among these are historic period shipwrecks. Given the continual river flow and associated sedimentary erosion, deposition, and reworking, it is highly unlikely that any more ephemeral cultural material remains on the river bed. However, it is possible that isolated and less-perishable prehistoric cultural items such as petroglyphs could be located within the Area of Potential Effect.

Potential site-specific effects on submerged historic and cultural resources would be addressed in Tier II Environmental Assessments in consultation with the appropriate state and federal agencies:

- As outlined in Section 3.5 Historic and Cultural Resources, the St. Louis District maintains databases of known and historically recorded shipwrecks. Both would be consulted to determine if the construction of dikes, chevrons, or other in-river structures may impact wreck sites.
- Recent high resolution multi-beam bathymetric surveys undertaken in the normal course of pre-construction planning would be examined for the presence of any anomalies that suggest the presence of a wreck. If it is determined that a prehistoric or historic resource would be adversely affected by proposed construction, consultation with the appropriate SHPO would be undertaken to determine appropriate measures.
- If cultural resources are encountered during construction, all work would stop in the affected area and appropriate consultation would take place.

Maintenance dredging is undertaken in the navigation channel where there is minimal chance any wreck would survive in-situ without having been removed by salvagers, dispersed by channel flow, or destroyed in historical dredging efforts. All known historical wrecks are located outside the navigation channel. Consequently, no adverse effects to historic and cultural resources are anticipated from maintenance dredging activities.

Bathymetric surveys are conducted before and after each dredging operation. They are, however, single-beam sonar surveys typically with a standard 200-foot distance between cross section lines and therefore do not produce a model with a resolution high enough to likely identify unknown historical wrecks. Dredge spoil is placed back in the river outside the navigation channel and not on the riverbanks or upland.

Impacts of the No New Construction Alternative on Historic and Cultural Resources

Maintenance of river training structures and revetment would occur in previously disturbed areas and consequently no adverse effects to historic and cultural resources are anticipated. Maintenance dredging activities under the No New Construction Alternative would be undertaken in the navigation channel where there is very little chance any wreck would survive in-situ without having been removed by salvagers, dispersed by channel flow, or destroyed in historical dredging efforts. Consequently, no adverse effects to historic and cultural resources are anticipated from maintenance dredging activities.

4.6 Cumulative Impacts

The Council on Environmental Quality (CEQ) regulations define cumulative impacts as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.” (40 CFR §1508.7).

4.6.1 Prior Studies

Cumulative impact analyses were recently conducted for Environmental Assessments with signed Findings of No Significant Impact for the Regulating Works Project (USACE 2014a, 2014b, 2014c, 2015c). A comprehensive analysis of the cumulative impacts of the Upper Mississippi River Navigation Project on the geomorphic and biological resources of the UMR has been described in two publications (WEST Consultants, Inc. 2000) prepared for the Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study (USACE 2004). These studies provided a cumulative effects analysis of the 9-foot Navigation project for the entire UMR and the MMR. West Consultants, Inc. (2000) provided a geomorphic assessment of the cumulative effects on geomorphology, sediment transport, and dredging. West Consultants, Inc. (2000) also provided a biological assessment of the cumulative effects of geomorphic changes, physical habitat changes, impoundment and river regulation, channel training structures, dredging and material placement, the Environmental Management Program habitat projects, connectivity of UMRS habitats, changes in the UMRS Basin, changes in UMR floodplain land use and land cover, effects of both point and non-point-source discharges to the UMRS, fish entrainment and impingement at electrical generating plants, and exotic and nuisance species. In addition, the UMR-IWW System Navigation Feasibility Study and Integrated Programmatic EIS (USACE 2004) contains a comprehensive description of the environmental impacts of navigation traffic.

In addition to the above National Environmental Policy Act documents, there currently exists an extensive literature describing the historic, current, and future geomorphic and ecological condition of the UMR, either including or specific to the MMR. The U.S. Geological Survey (USGS) conducted two (USGS 1999; Johnson and Hagerty 2008) ecological status and trends analyses of the UMR. The initial Status and Trends Report (USGS 1999) provided a thorough introduction to the UMRS including extensive descriptions of historical context, watershed geology and land use, floodplain forests, bird populations, water quality, fishes, aquatic vegetation and macroinvertebrates. The 1999 report (USGS 1999) provided the background information upon which the 2008 report (Johnson and Hagerty 2008) built. The 2008 Status and Trends Report focused on measuring changes in potential indicators of system health as derived from Long Term Resource Monitoring Program data. Twenty-four ecosystem indicators were chosen because they relate to many of the primary resource problems or outcomes important to managers. The 24 indicators were grouped into seven categories: hydrology, sedimentation, water quality, land cover, aquatic vegetation, invertebrates, and fish. Each indicator was evaluated for status across locations, including the MMR, and for trends over time, with estimates of uncertainty, when possible. The USGS also conducted a Habitat Needs Assessment for the UMR as part of the Environmental Management Program (Theiling et al. 2000). The primary objectives of the Habitat Needs Assessment were the evaluation of existing conditions throughout the UMRS, forecasting future habitat conditions, and quantifying ecologically sustaining and socially desired future habitat conditions. Heitmeyer (2008) provided a detailed description of the historic physical and biological conditions specific to the MMR, changes to those conditions, and restoration and management recommendations.

Pursuant to 40 CFR 1502.21 and CEQ Guidelines, the above documents and analyses are incorporated by reference into this analysis for the purpose of reducing the size of this document and not duplicating applicable analyses. 40 CFR § 1502.21 requires that material incorporated by reference must be "reasonably available for inspection". The documents are available for review at:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

In determining the cumulative impact of the SEIS Alternatives on resources in the Project Area, information from the above documents was considered in addition to the information provided below. As with the impact analysis presented in Chapter 4 above, the cumulative impacts analysis is presented under four general resource categories: physical resources, biological resources, socioeconomic resources, and historic and cultural resources. In general, the geographic scope of the cumulative impacts analysis encompassed the 195-mile length of the MMR from its confluence with the Missouri River to its confluence with the Ohio River, from tree line to tree line. Depending on the resource at issue, however, the analysis required extending beyond the physical limits of the MMR. For example, the water quality discussion includes information on the Missouri River basin due to its influence on MMR water quality concerns. Likewise, the discussion of biological resources extends into the MMR floodplain to incorporate the influences of floodplain access, or lack thereof, on MMR biological resources. The temporal scope of the cumulative impacts analysis is generally from the 1800s to the mid-2000s.

4.6.2 Impacts to Physical Resources

Water Quality

Consideration of water quality encompasses a wide range of physical, hydrologic, and biological parameters. Watershed influences, including tributary streams, point and non-point pollution sources, flow alteration due to navigation structures, and drought and flood events all influence water quality. Variations in land use practices, cover types, and watershed area determine the level and type of sediment, nutrient, and contaminant inputs into the Mississippi River and its tributaries. The Mississippi River, especially below metropolitan areas, has a long history of water quality impairment due to contamination from industrial, residential, municipal, and agricultural sources. Prior to the implementation of the Clean Water Act in 1972, the MMR acted as an open sewer and a convenient place to dump solid waste (Bi-State Development Agency 1954; U.S. Public Health Service 1958). Raw sewage, untreated industrial waste, and ground garbage were discharged directly into the MMR. In 1952, approximately 212 tons/day of garbage (animal and vegetable waste) were collected in St. Louis, ground, and discharged. The disposal of ground garbage into the MMR continued into the 1970s. These water quality stressors resulted in high oxygen demand; extremely high fecal coliform levels; low dissolved oxygen levels (< 5 mg/l); transport of toilet paper, animal entrails, and other solid wastes; elimination of aquatic life below St. Louis and reduction of aquatic life for a large portion of the MMR; and unpalatable fish where they did exist (Ellis 1934; Platner 1946; Bi-State Development Agency 1954; U.S. Public Health Service 1958). Severely degraded water quality conditions in the MMR rose to the level of a human health hazard and a conference was convened in St. Louis (U.S. Public Health Service 1958) to discuss remedies.

Water quality in the MMR has improved dramatically since implementation of the Clean Water Act in 1972. Water quality monitoring has been conducted in the MMR through the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring (LTRM) element since 1991. Analysis of LTRM data (Johnson and Hagerty 2008) shows that although the MMR has improved, it currently exceeds suggested nutrient (total nitrogen and phosphorus) guidelines either part of the time (nitrogen) or most of the time (phosphorous). During major storm events, raw sewage still enters the river because of sewage treatment plant overloads due to combined (sewage/stormwater) sewage systems in the St. Louis Metropolitan area. Johnson and Hagerty (2008) indicated that future changes in nutrient inputs to the river are difficult to predict, and largely a function of outputs from sewage treatment plants and runoff from fertilizer application on land.

There are ongoing efforts in the St. Louis area to improve wastewater treatment and alleviate the problems associated with combined (wastewater and stormwater) sewage systems. These efforts should improve nutrient loading and eventually eliminate raw sewage overflow events. In 2013, the Metropolitan St. Louis Sewer District (MSD) launched Project Clear as part of a consent decree agreement between MSD, the EPA, and the Missouri Coalition for the Environment that went into effect on April 27, 2012. Project Clear is a 23-year, $4.7 billion initiative to plan, design, and build system-wide improvements to address water quality and alleviate many wastewater concerns in the St. Louis area. Throughout MSD's service area, there are hundreds of points where a combination of stormwater and wastewater discharges into local waterways from the wastewater sewer system during moderate to heavy rainstorms. These sewage overflow points act as relief valves when too much stormwater enters the sewer system (MSD 2013). Unfortunately, this means that untreated sewage, high in fecal coliform, nutrients, and other untreated wastes, either enter the MMR directly or indirectly from tributary streams. Stormwater runoff, or urban runoff, also contributes to a laundry list of problems where there are no storm sewer systems or where there are combined sewage systems. Additionally, rainwater and melting snow also carry sediment, pet waste, and chemicals from roads, parking lots, and lawns into streams that feed the MMR. It is anticipated that Project Clear will help alleviate these problems over the next two decades and these efforts should improve nutrient loading to the MMR and eventually eliminate MSD raw sewage overflow events. It is not anticipated that nutrients from agriculture will rise; however, this is driven by agricultural economics.

Although the USEPA has oversight authority, particularly with regard to interstate water quality, it is the responsibility of the individual states to implement most of the Clean Water Act, including the establishment of water quality standards. Section 303(d) of the Clean Water Act requires states to generate lists of impaired water bodies every two years. Impaired water bodies are those that do not meet state water quality standards for the water bodies' designated uses. However, there are inconsistencies among state water quality standards and specific water quality criteria for individual pollutants may vary depending on the designated use for a specific segment of the Mississippi River. The MMR was included on the 2014 state of Missouri 303(d) list for St. Louis City, St. Louis County and St. Genevieve County due to fecal coliform contamination from point and non-point sources of wastewater treatment plant effluent and urban storm water. The 2014 state of Illinois 303(d) list places use restrictions for human contact-recreation due to fecal coliform contamination and fish consumption due to mercury and PCB contamination along the length of the Middle Mississippi River.

There are also fish consumption advisories for the MMR for both Missouri and Illinois. Missouri has fish consumption advisories for the Mississippi River for Shovelnose Sturgeon (one meal per month) and for Flathead Catfish, Blue Catfish, Channel Catfish, and Common Carp (one meal per week) due to PCB, chlordane, and mercury contamination (MDHSS 2015). Illinois has fish consumption advisories for the Mississippi River for Channel Catfish (one meal per week), Common Carp (one meal per week), and sturgeon (one meal per month) due to PCB contamination (IDPH 2014).

Figure 4-9. A 2012 photo of the mouth of the Missouri River showing the heavy suspended sediment load entering the Middle Mississippi River.

High suspended sediment loads coming out of the Missouri River and flowing into the MMR was the natural condition prior to the construction of large reservoirs on the Missouri River (Kesel 1988; Meade and Moody 2010; Heimann et al. 2011). The highly turbid Missouri River earned its' nickname "Big Muddy" due to these naturally high suspended sediment loads. Large reservoirs on the Missouri River trap approximately 100-150 million metric tons of sediment per year, which represents approximately half of the current decrease in sediment discharge at the mouth of the Mississippi River (Meade and Moody 2010). The completion of Fort Randall Dam in the upper Missouri River in 1952 was the single largest event in the recorded historical decline of suspended sediment loads in the Mississippi River Basin (Heimann et al. 2011). In addition, reduced peak streamflows and construction of reservoirs on the UMR, river training structures, bank revetment, and soil erosion controls have trapped sediment, eliminated sediment sources, or protected sediment that was once available for transport episodically throughout the year (Meade and Moody 2010). Although suspended sediment loads from the Missouri have been tremendously reduced, the suspended sediment levels of the Missouri River still remain much higher than the MMR as shown in Figure 4-9.

The aquatic fauna of the MMR is highly adapted to high turbidity levels which is reflected in their distribution patterns. A number of fish species (e.g., Sicklefin Chub [*Macrhybopsis meeki*], Flathead Chub [*Platygobio gracilis*] Pallid Sturgeon [*Scaphirhynchus albus*]) occur in the Missouri River and in the Mississippi River below the mouth of the Missouri, but not above the mouth of the Missouri (Pflieger 1997) where the suspended sediments are much lower. These fish species have evolved specialized characteristics as adaptations to turbid conditions and all have experienced declining populations during historic times. For example, the Sicklefin Chub, which shows a strong preference for turbid water (Everett et al. 2004), has reduced eye size and reduced optic lobes (Davis and Miller 1967), as well as numerous cutaneous sensory papillae ventrally, within their buccal cavities and on their heads and fins (Davis and Miller 1967; Pflieger 1997). Conversely, the high MMR turbidity levels, as well as the downstream movement of sand waves, are historically responsible for the low diversity and extremely low density of freshwater mussels in the MMR. The high turbidity levels not only control aquatic organism distributions, such as freshwater mussels and fish in the MMR, but recent reductions in suspended sediment levels may be partially responsible for the decline of some fish species. There is too little information to speculate on the effects of turbidity reductions on other aquatic organisms such as phytoplankton, zooplankton, and benthic invertebrates (e.g., aquatic worms, immature insect larvae, etc.).

Project related impacts to MMR water quality fall into three broad categories: 1. Operation and maintenance of the 9-ft. navigation project which includes dredging and related increases in suspended sediment; 2. Construction impacts that could result in increased suspended sediment suspension; and 3. Navigation traffic related suspended sediment. Dredging results in a temporary and localized increase in downstream suspended solids concentration. However, dredging does not add significantly to ambient suspended solids concentrations in the MMR (WEST 2000). Over 90% of the material dredged from main channel dredge cuts on the MMR is sand-sized material or larger, carrying very small concentrations of contaminants (e.g., heavy metals and organics). Contaminants are primarily attached to finer silt and clay sized particles that typically are found in lower velocity areas downstream of metropolitan areas. Construction of river training structures in the MMR (bank protection and dikes) no longer involves bank or river bed recontouring, so the resuspension of bank or bed material would result in minor, short-term, localized, increases in suspended sediment from rock placement.

Navigation traffic can result in a suspended sediment plume downstream of a moving tow. The level of suspended sediment depends on such factors as the river depth, type of bed sediment, and towboat speed (Copeland et al. 2001). Towboat generated waves can also suspend sediments along the shoreline (Parchure et al. 2000). Again, the level and duration of suspended sediment depends on a number of factors including: the wave height, type of shoreline sediments, depth of water along the shoreline, and the ambient suspended sediment levels. Pokrefke et al. (2003) analyzed the potential impact (e.g., loss of habitat) of towboat induced suspended sediment movement into MMR backwaters/side channels. They determined that all suspended sediment levels would have negligible potential for impacts to MMR backwaters/side channels from towboats for the without project and proposed alternatives evaluated as part of the UMR-IWW System Navigation Study (USACE 2004). So other than short-term, minor effects of suspended sediments, long-term impacts or impacts on important habitat types are not anticipated.

Due to the placement of rock closing structures, almost all MMR side channels are isolated from the main channel based on river stages and the crown elevation of the closing structure(s). The purpose of closing structures is to shunt water to the main channel to support navigation flows. Of the existing side channels, only one (Cottonwood Side Channel) does not have a closing structure. The remaining MMR side-channels are in various successional stages, including wetlands, isolated backwater, connected backwaters, isolated side channels (at low stages), and flowing side channels (see 3.2.3). The level of connectivity between side channels and the river affects the water quality of the side channel and subsequently its biota (Barko and Herzog 2003; Crites et al. 2012). Crites et al. (2012) found that water quality conditions in Buffalo Chute (River Mile 26) during isolation from the river channel (mid-June through March during their study) were not conducive to supporting healthy native fish communities. Thermal and chemical stratifications coupled with high water temperatures and anoxic conditions were observed during the summer months during two years of study. The St. Louis District has conducted side channel restoration planning (USACE 1999a; Nestler et al. 2016) and has been restoring side channels under various authorities which should help alleviate this problem.

Stages – See Section 3.2.1 River Stages, Section 4.2.1 Impacts on Stages, and Appendix A for a complete analysis.

Geomorphology – See Section 3.2.2 Geomorphology and Section 4.2.2 Impacts on Geomorphology for a complete analysis.

Side Channels – See Section 3.2.3 Side Channels and Section 4.2.3 Impacts on Side Channels for a complete analysis.

Air Quality and Climate Change – See Section 3.2.6. Air Quality and Climate Change and Section 4.2.6 Impacts on Air Quality and Climate Change for a complete analysis.

4.6.3 Impacts to Biological Resources

Loss of Middle Mississippi River Floodplain

There are a number of competing theories on how river ecosystems operate (Johnson et al. 1995; McCain 2013). The flood pulse concept (Junk et al. 1989) is currently the most widely accepted theory for explaining the ecology of large floodplain rivers like the Mississippi River (Heiler et al. 1995; Gutreuter et al. 1999), but some aspects of large river ecosystems are not adequately considered (Johnson et al. 1995). The flood pulse concept states that floodplain inundation is "the principle driving force responsible for existence, productivity, and interactions of the major biota in river-floodplain systems (Junk et al. 1989). Regardless of inability of any single theory to completely explain the complex workings of large flood-plain rivers (Johnson et al. 1995; McCain 2013), one thing is clear – periodic inundation of the floodplain is extremely important and many organisms, both aquatic and terrestrial, are not only adapted to pulsed flooding, but require it.

A considerable number of scientific papers have been published describing the ecological importance of connectivity between the river and its floodplain for the Mississippi River and major tributary rivers. Periodic inundation (pulsed flooding) of the floodplain results in both sequestering and transport of nutrients (e.g., Schramm, Jr. et al. 2009); increased productivity of phytoplankton, zooplankton, and benthic invertebrates (e.g., Galat et al. 1998; Gosch et al. 2014); and spawning, feeding, and nursery areas for riverine fish (Barko et al. 2006). Floodplain inundation and connectivity with the river has been shown to be related to increased fish growth rates (Gutreuter et al. 1999; Schramm Jr. and Eggleton 2006; Jones and Noltie 2007; Phelps et al. 2014). Miranda (2005) found that the level of floodplain lake connectivity with the river plays an important role in structuring the fish fauna that is correlated with variables such as lake size, depth, distance from the river, and age. Annual floods homogenize the floodplain and provide connectivity to various degrees, allowing exchange of fish faunas between the river and floodplain that directly affect the fish species assemblages.

There are specific MMR examples of the importance of periodic flooding of the MMR for resident species. For example, the Alligator Gar (*Lepisosteus spatula*), a species extirpated from the MMR, historically used the floodplain during spring high water periods, most likely for spawning and rearing of young (Keevin and Lopinot 2016). The disconnection of the Mississippi River from its floodplain by agricultural levees may be partially responsible for the extirpation of this species in the northern portion of its range. The Decurrent False Aster (*Boltonia decurrens*), a federally threatened plant species, is adapted to periodic inundation (Smith and Keevin 1998) and persistence of the species requires flooding to reduce competition (Smith et al. 1998).

Heitmeyer (2008) provides a detailed description of the historic physical and biological conditions of the MMR floodplain, changes to those conditions, and provides restoration and management recommendations. The MMR floodplain and river channel area encompasses approximately 660,000 acres (Table 4-6), with approximately 202,000 acres (Table 4-7) of the river channel and the floodplain in the narrow strip of land between the river and the levees known as batture lands. The majority of the land in the floodplain can generally be categorized as rural and agrarian in nature. These areas are protected by an extensive levee and drainage system. Levees are prominent features and provide urban and agricultural flood protection for almost the entire length of the MMR, resulting in about 67% of floodplain area behind levees, while 33% of the land is outside of levee protection in the batture. In the MMR, almost all of the active (frequently flooded) floodplain is in the batture lands. The percentage of floodplain protected by levees is unlikely to change greatly because no new major realignment of levees is anticipated. The establishment of the Middle Mississippi River Refuge (USFWS 2015) has resulted in re-establishment of floodplain connectivity in limited areas where levees were not repaired after the flood of 1993.

Currently, approximately 51% of the total floodplain is in agricultural production (Table 4-6), while 28% of the batture is in agriculture (Table 4-7). The only available land cover dataset for the time period around 1976 covers only the portion of the MMR that lay riverward of the levee (batture lands), limiting a comparison of changes between 1975 and 2011 to the batture. Between 1975 and 2011, agricultural land in the batture was reduced by 28% from 78,267 acres to 56,334 acres.

Forest is the second most abundant land cover class, currently occupying 18 percent of the total floodplain area (Table 4-6) and approximately 27% of the batture lands (Table 4-7). Between 1975 and 2011, forest cover increased by 15.3% in the batture. Area of floodplain forest declined in 24 of 31 reaches of the UMRS between 1989 and 2000 with a system-wide decrease of 5%, or 17,000 acres (Johnson and Hagerty 2008). In contrast, there was a slight increase of 1,200 acres (2%) in the MMR. The trend for floodplain forest is considered to be degrading in the impounded UMRS, but stable in the MMR.

Open water and developed lands currently occupy 12 and 9% of the total MMR floodplain, respectively. Between 1975 and 2011 open water increased 13.8% and developed land decreased 2.1% within the batture. The remaining three categories, grass/forbs, marsh, and sand/mud, each currently account for less than 5 percent of the floodplain. Between 1975 and 2011, marsh increased 7,744 acres (113%), grass/forbes area increased 2,931 acres (216 %), and sand/mud decreased 3,995 acres (72%), within the batture.

Table 4-6. MMR floodplain land cover categories, acreages, and percentages (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014).

Land Cover Category	2011 Acreage (% of Total)
Agriculture	341,665 (51.1%)
Forest	120,404 (18.0%)
Open Water	82,575 (12.4%)
Developed	62,760 (9.4%)
Marsh	29,801 (4.5%)
Grass/Forbs	29,618 (4.4%)
Sand/Mud	1,755 (0.3%)
Total	668,576

Table 4-7. MMR land cover categories, acreages, and percentages of the narrow strip of land between the river and levees known as batture lands for 1975 and 2011 (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014).

Land Cover Category	1975 Acreage (% of Total)	2011 Acreage (% of Total)
Open Water	58,599 (29.0%)	66,688 (33.1%)
Agriculture	78,267 (38.8%)	56,334 (27.9%)
Forest	47,321 (23.5%)	54,566 (27.0%)
Marsh	6,861 (3.4%)	14,605 (7.2%)
Grass/Forbs	1,360 (0.7%)	4,291 (2.1%)
Developed	3,744 (1.9%)	3,664 (1.8%)
Sand/Mud	5,573 (2.8%)	1,578 (0.8%)
Total	201,725	201,725

The U.S. Fish and Wildlife Service established the Middle Mississippi River National Wildlife Refuge on May 31, 2000 (USFWS 2015). The refuge lands were purchased in response to the flood of 1993. The refuge currently consists of seven divisions that total nearly 7,000 acres (Meissner Island Division, River Mile (RM) 153.5–155.5L – 78 acres; Harlow Island Division, RM 140.5-144R - 1,255 acres; Beaver Island Division, RM 116-118R - 245 acres; Horse Island Division, RM 111-112R - 2,110 acres; Rockwood Island Division RM 99-104L – 722 acres; Crain Island Division, RM 104-107; Wilkinson Island Division, RM 88.5-93L - 2,532 acres) spread out along the MMR. Much of the refuge land had previously been cut off from the floodplain by private levees protecting agricultural land. Most of the levees were breached by the 1993 flood and have not been repaired. The refuge now provides access to the floodplain for native fish during high water stages and creates a corridor of floodplain forest habitat for migratory birds and resident wildlife. The refuge was designated as an important Bird Area in 2008.

Frequent flooding occurs on refuge tracts due to their position in the river floodplain. As part of the U.S. Fish & Wildlife Service's plans for managing the refuge, modifications to man-made structures such as levees are proposed to promote healthy and diverse fish habitat for native Mississippi River fishes. Where possible, old river channels and swales will be managed with passive water control structures to provide for seasonal wetlands for migratory birds. By allowing these lands to flood and re-connect with the river, the refuge contributes to the overall health of the ecosystem. Former agricultural lands are allowed to return to forested habitat, with the occasional tree plantings to promote species diversity and abundant food for native wildlife. Many species of fish and wildlife benefit from the habitat restoration, and the public has increased opportunities for wildlife-dependent outdoor recreation.

Impacts from Navigation Traffic

The movement of commercial navigation traffic produces both physical and biological effects (Table 4-8) that affect the ecosystem health of the MMR. These impacts are summarized in great detail in USACE (2004) and Söhngen et al. (2008). A considerable number of original research studies on the physical and biological impacts of commercial navigation traffic were conducted as part of the UMR-IWW System Navigation Feasibility Study (USACE 2004) and can be found at http://www2.mvr.usace.army.mil/UMRS/NESP/. In addition, there are a growing number of navigation effects studies, much of it conducted in the United States and Europe, that have been published in the scientific literature.

Table 4-8. Potential Aquatic Impacts Associated with the Movement of Tows on the Middle Mississippi River.

Impact	Reference
Fish Recruitment	Nielsen et al. 1986; Arlinghaus et al. 2002; Huckstorf et al. 2011
Propeller Mortality	
Adult Fish	Gutreuter et al. 2003; Killgore et al. 2005;Killgore et al. 2011; Miranda & Killgore 2013
Adult Fish during Lockage	Keevin et al. 2005
Larval Fish	Holland and Sylvester 1983; Holland 1987; Odum et al., 1992; Holland 1986; Killgore et al. 2001; Bartell & Campbell 2000
Fish Disturbance (Displacement from Channel)	Todd et al. 1989; Wolter and Bischoff 2001; Gutreuter et al. 2006
Wave Wash	
Physical	Bhowmik et al. 1999
Fish	Sheehan et al. 2004a, 2004b; Wolter & Arlinghaus 2003; Wolter et al. 2004; Kucera-Hirzinger et al. 2009; Gabel et al. 2011b
Invertebrates	Bishop & Chapman 2004; Gabel et al. 2008, 2011a, 2011b, 2012
Shoreline Drawdown/Dewatering	Adams et al. 1999; Maynord 2005; Maynord & Keevin 2005
Towboat Induced Turbidity	
Channel	Smart et al. 1985; Savino et al. 1994; In addition, there are numerous publications on the adverse effects of turbidity on benthic invertebrates and fish.
Phytoplankton	Munawar et al. 1991
Side Channels/Backwaters	Pokrefke et al. 2003
Hull Sheer	
Larval Fish	Morgan II et al. 1976; Maynord 2000b, 2000c; Keevin et al. 2002
Turbulence	Killgore et al. 1987; Mazumder et al. 1993; Deng et al. 2005
Towboat Dispersal of Exotic Species	Keevin et al. 1992
Towboat Noise & Fish Disturbance	Wysocki et al. 2006
Bank Erosion	Bhowmik et al. 1999; Nanson et al. 1993
Risk of Accidents & Hazardous Spills	University of Memphis 1998; Marmorstein 2000
Changed Velocities	Maynord 2000a; Sheehan et al. 2004a; Sheehan et al. 2004b

The Effects of Pressure Changes

Commercial navigation traffic is responsible for rapid mixing of the water column (Stefan and Riley 1985). Both drifting invertebrates and fish can be drawn from the surface and transported to the river bottom resulting in increased ambient pressure or drawn from the river bottom and moved to the surface, resulting in decreased ambient pressure. There are no studies on the effects of navigation related pressure changes on phytoplankton, zooplankton, or benthic invertebrates (drifting), but since they lack air-containing organs it is anticipated that they are relatively immune to major pressure changes when compared to fish. In a controlled laboratory study (Keevin et al. 2000), mortality of fish early life stages was measured in a pressure vessel to simulate three pressure change scenarios (simulating both pressure decreases and increases) associated with entrainment in the propwash of a towboat and subsequent vertical displacement within the water column. Mortality was measured for five fish species: larval Bigmouth Buffalo (*Ictiobus cyprinellus*), larval Blue Catfish (*Ictalurus furcatus*), larval Walleye (*Sander vitreus*), juvenile Bluegill *(Lepomis macrochirus*), and juvenile Largemouth Bass (*Micropterus salmoides*).

There was no significant difference between fish exposed to any of the three pressure regimes and controls. The maximum pressure change tested, 344.8 kPa, equivalent to a 35.2 m displacement of fish within the water column, did not cause significant mortality of larval or juvenile fish. Since 35.2 m exceeds depths in the MMR navigation channel, the range of pressure changes that could be experienced by early life stages during towboat mixing of the water column would not result in significant mortality.

The Effects of Hull Shear

It has been suggested that the fluid shear field adjacent to the hull of a tow may impact aquatic organisms. Shear force is the force per unit area that results from differences in velocity from one point in the water to an adjacent point. Shear is defined as the velocity difference between two adjacent points divided by their distance.

In a controlled laboratory study (Keevin et al. 2002), mortality of fish early life stages was measured in a Couette cell for three shear stress levels at three exposure times for five fish species: larval Shovelnose Sturgeon (*Scaphirhynchus platorynchus*), larval Bigmouth Buffalo, larval Blue Catfish, juvenile Bluegill, and juvenile Largemouth Bass. Larval fish mortality values (Keevin et al. 2002) were then compared with calculated barge hull shear stress levels (Maynord 2000b) to determine the potential for mortality of fish early life stages due to commercial navigation traffic. There was no significant mortality of Shovelnose Sturgeon, Blue Catfish, Bluegill and Largemouth Bass at shear stress levels produced by barges in the MMR. However, the hull of a high-speed tow (4.0 m/sec) with a 1.22 depth/draft ratio would produce a shear stress of 250 dynes/cm^2 in 5% of the zone beneath the tow. This is the only area in the water column where hull shear stress values approached, but did not exceed, levels causing significant ($P<0.05$) mortality of bigmouth buffalo larvae. Therefore, it is unlikely that barge hull shear stress would result in substantial mortality of larval or juvenile fishes. There are no studies on the effects of hull shear stress on phytoplankton, zooplankton, or benthic invertebrates (drifting).

The Effects of Shoreline Drawdown

Water flow dynamics associated with moving commercial navigation vessels results in shoreline drawdown (water recedes from the shoreline; Bhowmik et al. 1993). These brief dewatering periods generally last 2-3 min (Holland 1987). The magnitude of drawdown depends on vessel speed, submerged cross-sectional area of the vessel, and channel cross-section. Shallow and constricted channels increase drawdown. If a vessel travels close to the riverbank, drawdown would be higher in the region between the vessel and bank than it would have been if the vessel were in the middle of the channel (Bouwmeester et al. 1977). Bhowmik et al. (1981) measured vertical drawdown for eight tow passage events during 1980-81 on the UMR. Drawdown elevation averaged 0.06 m (range 0.02-0.10 m) on the UMR. The drawdown resulting from vessel passage is followed by a rise in water level back to ambient levels. Typical rates of drawdown (vertical fall of water level per unit time) for channel sizes, tow sizes, and tow speeds found on the UMR are about 0.25-0.5 cm/sec based on field data presented in Bhowmik et al. (1998). Higher speed tows closer to the shoreline produce values around 0.75 cm/sec.

Maynord and Keevin (2005) determined that the average shoreline area exposed or dewatered decreases in a downstream direction as the UMR channel becomes larger. The MMR was not evaluated during this study, but results would be expected to approximate those experienced in the smaller channel of the upper pools in the UMR. Peak larval density and diversity occur during the months of May and June. During May, there was a 90% probability that 3.9 hectares or less of shoreline would be dewatered by a passing towboat in Pool 4, 5.5 hectares or less in Pool 8, 4.4 hectares or less in Pool 13, and 0.5 hectares or less in the portion of Pool 26 above the IWW confluence. During the month of June, there was a 90% probability that 4.4 hectares or less of shoreline would be dewatered in Pool 4, 5.8 hectares or less in Pool 8, 4.5 hectares or less in Pool 13, and 0.6 hectares or less in Pool 26. Typical values decrease from 0.49 m in Pool 8 (May, 90% exceedance tow) to 0.05 m in Pool 26 (May, 90% exceedance tow). The width of the dewatered zone is less in May than in July. The higher flows in May cause larger cross sections which result in less drawdown.

Commercial vessel passage may strand young fishes during drawdown and subsequent dewatering of littoral areas (Holland and Sylvester 1983; Nielsen et al. 1986), but actual field observations of stranding are sparse. In laboratory studies, Holland (1987) evaluated the effects of experimental dewatering on eggs and larvae of walleye and Northern Pike (*Esox lucius*). Eggs and larvae were exposed to air for 2 min at intervals of either 12, 6, 3, or 1 hr. (representing 2-24 tows/day) from the time just after fertilization to 10-14 days post-hatch. A single dewatering event (2 min air exposure) did not cause mortality of eggs of walleye or northern pike, but significant mortality of larvae of both species occurred at dewatering frequencies of 1 and 3 hours, the latter being equivalent to mean passage of eight tows per day. Holland (1987) used a flow-through aquarium system that prevented fish from moving out of the dewatered zone as water receded. Adams et al. (1999) evaluated the potential for stranding during simulated shoreline drawdown in a laboratory flume for larval Shovelnose Sturgeon, Paddlefish (*Polyodon spathula*), Bigmouth Buffalo, Largemouth Bass, and Bluegill. Stranding was measured at three vertical drawdown rates (0.76, 0.46, and 0.21 cm/s) and two bank slopes (1:5 and 1:10). Blue Catfish, Shovelnose Sturgeon, and Paddlefish were not tested at both bank slopes. Susceptibility to stranding varied among species and was independent of drawdown rate. At a slope of 1:5, Shovelnose Sturgeons had the highest stranding percentage (66.7%), followed by Paddlefish (38.0%), Bluegill (20.0%) Bigmouth Buffalo (2.2%), and Largemouth Bass (0.0%). At 1:10, Blue Catfish had the highest stranding percentage (26.7%), followed by Largemouth Bass (15.3%), Bluegills (5.3%), and Bigmouth Buffalo (0.0%).

Holland (1987) found significant mortality of larval walleye and northern pike using a flow-through aquarium system that prevented fish from moving out of the dewatered zone as water receded. Under natural conditions, it is not known if individual larvae or eggs would be subject to repeated dewatering. Adams et al. (1999) found that the likelihood of stranding was related to the behavioral response of fishes to drawdown. Species that typically occur in littoral and backwater areas swam with the current or passively drifted; whereas, the young of main-channel fishes, such as sturgeons and paddlefish, exhibit positive rheotaxis (i.e., movement into flowing water) and were more likely to become stranded. Adams et al. (1999) suggested that main-channel species such as Shovelnose Sturgeon and Paddlefish larvae that were highly vulnerable to stranding in their study are usually found in the main channel and not in the littoral zone where they would be susceptible to stranding. In addition, the dewatered zone itself is very narrow possibly limiting repeated stranding. During May and June, the peak larval fish density period, the dewatering zone ranges from 0.05 m (Pool 26, May) to 0.53 m (Pool 8, June) for 90% of tow passages. With the exception of Pool 8, the average width of dewatered shoreline during May and June is less than 0.4 m for 90% of tow passages.

The Effects of Shoreline Currents and Wave Wash

The passage of commercial navigation traffic results in changes in river flow patterns especially along the shoreline which is exposed to wave wash, changes in flow directions and velocities, and drawdown (Söhngen et al. 2008).

Invertebrates: Gabel et al. (2008) conducted a study in a wave tank to evaluate ship-induced wave disturbance of benthic invertebrates. They studied five benthic invertebrates and found that detachment of invertebrates was significantly related to shear stress. Detachment was lower in habitats with a high degree of structural complexity, decreasing in the habitat sequence: sand, coarse woody debris, stones, reeds, and tree roots. In the MMR, sheer would be greater for a fully loaded towboat, moving at high speed, and close to the shore-line. Gabel et al. (2012) found that waves from recreational boats had similar invertebrate detachment impacts. Both Gabel et al. (2008) and Gabel et al. (2012) conclude that management and protection of complex shoreline habitats is important in the maintenance of a littoral invertebrate community in navigated waters.

Gabel et al. (2011a) conducted a series of wave exposure tests in treatment flumes comparing physiological and behavioral response variables of two native (Rhine River) invertebrates (*Gammarus roeselii* and *Bithynia tentaculata*) and two non-native invertebrates (*Dikerogammarus villosus* and *Physella acuta*). Growth and energy storage were significantly reduced after exposure to waves in native invertebrates, but not in non-native invertebrates. They suggested that the differing vulnerability of native and non-native invertebrates to wave-stress was expected to shift community composition toward domination by non-native species. This study points out that changes in hydrodynamic wave stress can cause invertebrate community shifts that would not be anticipated by casual impact analysis. In a second wave-tank study, Gabel et al. (2011b) studied the differential effects of ship- and wind-induced waves on the foraging success of littoral fish on benthic invertebrates. They found that the number of invertebrates suspended in the water column was higher in the wave treatment test compared to a no-wave control treatment. This was especially true during pulse waves mimicking ship-induced waves in comparison to continuous waves mimicking wind-induced waves. They found differences in how different fish species exploited the invertebrates during wave exposure. Waves influenced predator (fish) -prey (invertebrates) interactions differently depending on wave type and fish type.

Fishes: With respect to fish, Kucera-Hizinger et al. (2009) suggested that ship-induced wave wash resulted in the following impacts on fish during their early life history stages: 1) Short-term dislocation of suitable larval and juvenile fish habitats due to wake and splash; 2) Water velocities during ship passages frequently exceeding maximum swimming performance of age 0+ fish; and, 3) Suspended solids concentrations increasing dramatically in the inshore habitats and limiting the foraging efficiency of young-of-the-year (YOY) fish. Wolter et al. (2004) compared computed navigation traffic current velocities and compared those values with maximum fish swimming performance to determine the impact of commercial navigation on freshwater fish. They found that the "absolute magnitude of navigation-induced current limits the availability of littoral habitats for small fish." Wolter and Arlinghaus (2003) suggested that swimming performance of juvenile freshwater fish is the major bottleneck for fish recruitment in German waterways, as a result of their inability to withstand bank-directed navigation-induced physical forces.

Many MMR fishes, especially YOY, require low-velocity habitats for overwintering due to their diminished swimming ability at low water temperatures. Low-velocity habitats in river channels include the downstream side of wing dams and scour holes at the distal ends of wing dams, scour holes or sand ridges in channels, and downstream of any structures which obstruct water currents. During Navigation and Ecosystem Sustainability Program studies (USACE 2004), natural resource agencies expressed concern that hydraulic disturbances resulting from increased navigation traffic might cause fish displacement from these low-velocity habitats during cold-water periods. Displaced fish would continue to drift with the river current or they would actively or passively find and utilize another low-velocity habitat. If fish continue to drift, survival is doubtful. Loss of volitional control over swimming is the standard endpoint used in acute temperature tolerance tests. Risks to vessel propeller entrainment, predation, and other lethal factors would greatly increase. If fish find and utilize another low-velocity habitat after displacement, then increases in traffic levels may have little additional effect on over wintering fish (Sheehan et al. 2004a).

Studies were designed to determine if navigation traffic was capable of displacing fish from protected near-shore areas (Sheehan et al. 2004a). Studies were conducted to determine the velocities required to move YOY Channel Catfish and Bluegill from protected areas under cold-water conditions (Sheehan et al. 2004b). Physical force studies were then conducted in a laboratory flume to determine velocity conditions behind a wingdam with and without towboat traffic.

In laboratory studies, Sheehan et al. (2004a) determined the following median displacement velocities (DV50) for Channel Catfish and Bluegill.

Table 4-9. DV50 (Displacement Velocity) determinations at 1, 2 and 4°C for Channel Catfish and Bluegill. DV50's are the peak velocity (m/s) of a velocity change profile, similar to that of a passing barge, necessary to displace 50% of fish from their position within a test chamber. DV50s determined using Probit analysis, p=probability of Pearson's Chi-square test of goodness-of-fit.

Species	Temperature (°C)	DV 50 (m/s)	95% C.I.	p
Channel Catfish	1	0.08	0.01-0.36	0.33
	2	0.18	0.11-0.23	0.25
	4	0.30	0.25-0.35	095
Bluegill	1	0.09	0.06-0.95	0.38
	2	0.09	0.00-0.17	0.11
	4	0.16	0.13-0.20	0.04

Maynord (2000d) conducted a physical model study to measure velocity downstream of a typical UMR dike before and during passage of a model tow for typical winter flow conditions. Up bound versus down bound tows near the dike and far from the dike were evaluated. The results of Maynord's study, when compared to Sheehan's displacement velocities, indicate that large areas existing behind the study wing dike currently experience velocities that exceed displacement velocities under ambient conditions without navigation traffic for YOY Channel Catfish and Bluegill during periods when the water is in the 1-2°C range. With the exception of an area immediately behind the wingdam, close to the shoreline, all ambient velocities exceeded 0.10 m/sec and ranged from 0.10-0.50 m/sec. Maynord (2000d) found that upbound tows near the dike (77 m from the centerline of the tow to the waterline on the dike) produced only minor changes with large areas near the bankline showing no velocity changes. Downbound tows in the thalweg produced little effect with large areas showing no velocity change.

If ambient velocities are great enough to displace YOY Channel Catfish and Bluegill under existing conditions (without navigation traffic) it is quite possible that fish seek out low-velocity microhabitat behind wing dikes during cold-water conditions. Because fish are continuously exposed to navigation traffic-induced velocity changes, they may also seek out low-velocity habitats protected from navigation-related velocities.

Sheehan's displacement values were established for small YOY fish. Larger fishes may not be affected by what amounts to minor velocity changes under worst case conditions (upbound tows near the dike). It is known that scour holes at wingdam tips and areas behind wingdams are "packed" with fish during the winter months. It is assumed that fish use these low-velocity habitats during the winter as their swimming abilities decrease with decreasing water temperatures (Beamish 1978).

The Effects of Backwater and Side Channel Drawdown

During passage of commercial tow traffic in navigation channels, the water level is lowered alongside the tow, which is commonly referred to as drawdown. Drawdown magnitude increases with increasing tow speed, increasing tow size, and decreasing channel size. Drawdown duration is about twice the time required for a tow to pass a fixed location. This duration relationship results in a large fast tow producing a large but short-lived drawdown while the same large tow traveling at a lesser speed would produce a lesser maximum drawdown but having a longer duration.

Drawdown from tow traffic is one of the few physical effects of tows that can propagate large distances from the main navigation channel. Drawdown can extend up backwaters, side channels, and tributaries entering the main channel. Maynord (2005) measured drawdown at ten backwaters and side channels in the La Grange Pool of the IWW. Drawdown decayed with distance from the entrance channel within the backwater/chute but could be measured at considerable distances from the entrance. At the longest channel, Bath Chute, drawdown could be clearly detected at ll.6 km from the point of origin, although the magnitude was significantly reduced. Sangamon River measurements provide an example of the decay rate. At the entrance to the Sangamon River the drawdown was 0.138 m, at 600 m from the entrance it was 0.042 m, and at 1,350 m from the entrance it was 0.013 m.

Drawdown along the length of backwaters and side channels has the potential to make otherwise suitable habitat unavailable for nesting and to strand larval and juvenile fishes during drawdown events. The amount of habitat within side channels and backwaters that would otherwise have been suitable for spawning but is impacted by repeated drawdowns is unknown due to the lack of adequate bathymetric survey data for those habitats on the UMR-IWW. However, spawning fish, especially centrarchids, generally tend to spawn at water depths greater than the navigation induced drawdowns observed on the UMR-IWW (Maynord 2005) and they generally avoid spawning in areas that are repeatedly dewatered. As previously noted in the shoreline dewatering discussion, larval and juveniles of typical backwater fish species have behavioral adaptations to avoid being stranded by receding water levels (Adams et al. 1999), thus minimizing adverse effects.

The Effects of Towboat Propeller Entrainment

Although, there are many potential impacts associated with the movement of towboats through the system as described in USACE (2004) and Söhngen et al. (2008) and summarized in Table 4-8, the impact of greatest concern in the MMR is larval and adult fish mortality associated with towboat propeller entrainment.

Existing (2000) traffic in the MMR was responsible for the annual equivalent adult mortality of 262,853 fish, based on the number of larval fish killed passing through towboat propellers (USACE 2004, page 91). Annual equivalent adult mortality resulting from the incremental increase in traffic due to the construction of 1,200 foot locks on the Upper Mississippi River

(USACE 2004 - a project not funded for construction) was projected to be between 11,612 and 79,274 fishes in the MMR for the year 2040 (USACE 2004, 396-397).

Killgore et al. (2011) published a towboat propeller entrainment paper for adult fish for the pooled portion of the UMR. It indicated that fish entrainment was low (< 1 fish/km) in wide, deep and fast sections of the river, while it was variable and occasionally high (> 30 fish/km) in narrow, shallow, and slow reaches of the UMR. Based on the value of 1 fish/km injured or killed (this would overestimate mortality because the MMR is wide, deep and fast.), then approximately 151,161 fish would be injured or killed per year (313.822 km x 19,938 towboats/year x .024 injury-mortality rate) in the MMR under existing traffic conditions. This number overestimates mortality, because only a fraction of towboats/year actually navigate the entire length of the system (only 7,750 locked through Locks 27).

Additionally, another 34,972 adult fish are estimated to be killed per year locking through Locks 27 (4.5125 average fish mortality per lockage x 7,750 commercial lockages in 2001) (Keevin et al. 2005). Entrainment mortality of some fish species, for example the Shovelnose Sturgeon, combined with other mortality factors (commercial fishing) may be responsible for unsustainable population levels in the Upper Mississippi River (Miranda and Killgore 2013).

In addition to the above projected mortality numbers, an unknown number of fish would be killed due to egg mortality from propeller entrainment (Holland and Sylvester 1983; Odum et al., 1992), shoreline dewatering (Adams et al 1999; Maynord & Keevin 2005), hull shear (Morgan II et al. 1976; Maynord 2000b; Keevin et al. 2002), and fish being washed out of protected areas (especially during the winter) due to wave wash (Sheehan et al. 2004a, 2004b; Wolter and Arlinghaus 2003; Wolter et al. 2004; Kucera-Hirzinger et al. 2009).

With respect to cumulative impacts (past, present, and future actions), the impacts of commercial navigation traffic resulted from the original development of the navigation project and subsequent operation and maintenance of the navigation channel. Because none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Fleeting

A fleeting area is defined as "Facilities where the barges are dropped off for loading, unloading, or awaiting other vessels, including barge warehousing whether a temporary or permanent barge location. This type of facility is an origin or destination and economic activity is taking place." Barge fleeting is a vital component of commercial river navigation on the Upper Mississippi River. Its role in commercial river traffic is very similar to that of a switching yard in a railroad system. Typically, barges are placed in fleeting areas to await loading or unloading at nearby terminals. Sometimes fleeting areas are merely used as staging areas where towboats leave full barges heading one direction on the river and take empties back in the other direction or vice versa. Without the use of fleeting areas, commercial river navigation would be much less efficient, if possible at all. In the St. Louis vicinity, where there is the highest concentration of fleeting areas on the UMR (Figure 4-10), the majority of the fleeting areas are engaged in staging operations. There are two major reasons that such extensive staging takes place in St. Louis: The region is centrally located on the river, and towboats below St. Louis commonly push 25 barges, while above St. Louis the largest typical tow size is only 15. Fleeting areas operating north of St. Louis rarely, if ever, engage in staging. These areas are mainly used for the servicing of terminals.

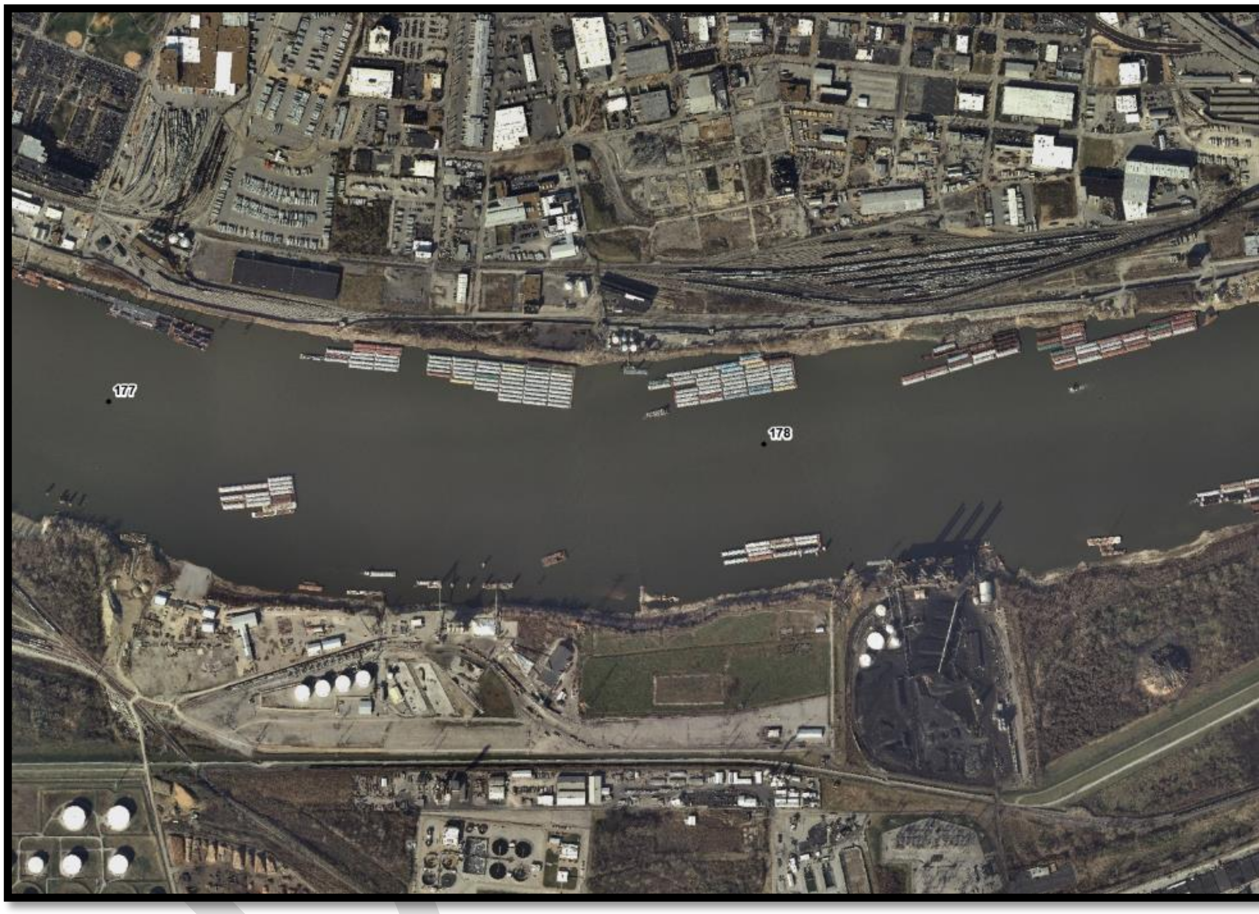


Figure 4-10. Aerial photograph of MMR showing a high concentration of fleeting areas within the St. Louis Harbor used for both staging of towboats and terminal loading and unloading.

The U.S. Fish and Wildlife Service listed 72 fleeting areas between Melvin Price Locks and Dam and the Ohio River (Miller and Mahaffy 1989) while unpublished data collected by the Corps in 1994 as part of the Upper Mississippi River-Illinois Waterway System Navigation Study listed 93 fleeting areas for this same reach. In 2015, there were 157 permitted fleeting areas in the MMR covering 894.83 acres.

To the best of the District's knowledge, there is only one primary scientific study (Sparks and Blodgett 1985), with acknowledged study problems, on the impacts of fleeting on aquatic organisms (i.e., benthic invertebrates, fishes, etc.). Impact assessments (USACE 1985) and literature reviews of potential impacts (Miller and Mahaffy 1989) of fleeting in the UMR have been based on observed impacts, knowledge of construction techniques, or known physical impacts (i.e., movement of the fleet by towboats, “parking” the barge fleet, deadmen construction, etc.) and their perceived environmental impacts. For example on the UMR, a major concern of resource agencies has been the potential development of fleeting areas over mussel beds. This concern developed because of the importance of freshwater mussels to riverine ecosystems and the occurrence of the federally endangered Higgins’ Eye Pearly Mussel (*Lampsilis higginsii*). This concern is based on the observation by commercial mussel fishermen and researchers of crushed/broken shells resulting from fleeting in shallow water over mussel beds.

Potential impacts associated with fleeting fall into seven general categories: aesthetic issues associated with the fleet; how the towboat fleet is moored; fleeting areas utilizing space that would be used for other activities; fleeting areas moored in too shallow of water (i.e., crushing invertebrates/fish); physical forces associated with moving the fleet; dredging areas during extremely low flow conditions, especially those associated with terminals/docks; and potential water quality issues (barge cleaning, accidental spills).

Aesthetics: Aesthetics is a matter of human perception. One person viewing barges being moved in a fleeting area might view the scene as the wheel of industry turning, while another would see rusting barges “parked” in the river that obscure their view of the natural world. In addition, the assembly and disassembly of tow fleets produces sounds of barges banging into each other. The noise would be perceived by some people as unwanted.

Towboat Mooring: Properly permitted (Section 10 of the Rivers & Harbors Act/Section 404 of the Clean Water Act) barge fleeting areas are required to moor their barges to either deadmen, usually constructed on the shore, or anchored barges. Impacts would be restricted to minor short-term construction impacts. Deadmen placement could require a small amount of vegetation removal and excavation (less than one tenth of an acre per site). Loss of vegetation potentially impacts food/cover and reproductive requirements of various wildlife species, and excavation potentially affects subsurface dwellers. Permitted fleets do not tie off their barges to trees.

Alternative Use of Space: Stationary barge fleets would eliminate light passage into the water; this affects the food chain via reduced phytoplankton production (although this is a very minor impact in turbid river systems like the MMR), and in addition, sight feeding fish may have problems securing food in these darkened waters. The placement of fleeting in prime sport fishing and commercial fishing areas would reduce access to these areas and thus have adverse effects on their use. Fleeting areas are also not conducive to pleasure boating.

Fleeting in Shallow Water: Fleeting areas are generally chosen in deep water where barges would normally not be grounded. The major impact of grounding would be the potential to kill benthic invertebrates. As previously noted, freshwater mussel damage and mortality was a major concern in the UMR. However, there are no mussel beds in the MMR and mussel density is extremely low (Keevin et al. 2016).

Physical Forces Generated while Moving the Fleet: Some of the physical forces associated with commercial navigation traffic (i.e., drawdown, wavewash, turbulence and propeller entrainment of fish) would also be associated with movement of towboats and barges within a fleeting area. The impacts would occur to a lesser degree because fleeting activities typically use harbor boats with less horse power, moving at much slower speeds, and with fewer barges (2-3 barges) than typical line-haul tow traffic. The impacts of tow physical forces have been fully discussed above.

Dredging (terminals/docks) During Low Water: Fleeting areas are normally in deep-water habitats where dredging is normally not an issue. During low flows dredging may be necessary at terminals/docks or their approaches. The impacts of dredging have been fully discussed above.

Water Quality Issues: Water pollution related to boat sewage and barge cleaning is not believed to be a significant effect. Harbor boats have their own sewage collection systems and discharges from barge cleaning activity would be minimal. There is always the potential for toxic spills, but the probability is small.

With respect to cumulative impacts (past, present, and future actions), the impacts of fleeting resulted from the original development of the navigation project and subsequent operation and maintenance of the navigation channel. Because none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic and associated fleeting sites beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Commercial Dredging and Dredged Material Disposal

The historic trend in MMR dredging and dredge material disposal is fully discussed in Chapter 1 of the SEIS. Chapter 4 addresses in detail the environmental impacts of existing and future levels of MMR dredging. As such, Corps dredging will not be discussed again in the cumulative impact analysis. There is currently private sector (commercial) sand dredging taking place in the MMR to provide sand for construction related activities.

Commercial sand dredgers within the St. Louis District use suction type dredges. Suction dredging removes sand materials from naturally replenishing deposits like a vacuum cleaner. The size of each company's suction pipe and dredge pump varies. One end of the suction pipe is attached to the dredge vessel with a pivot mount while the opposite end is attached to a cabled winch system that raises and lowers the intake pipe. Bars are welded in a grid pattern on the end of the flared suction pipe to minimize intake of debris and other materials that could damage the dredge pump.

When the dredge vessel reaches the work area it spuds or anchors into a stationary position. The winch holding the suction pipe lowers it into the water. The suction pipe then free-falls and buries the intake head beneath the surface into the sand deposit. A small auxiliary pump is turned on to prime water into the suction pipe. A larger dredge pump is then activated to initiate dredging. There are no rotating cutter heads or other mechanized excavation attachments associated with suction dredging. Suction dredging causes negligible turbidity at the subsurface work area due to the clean, coarse characteristics of sand. In addition, turbidity remains minimally altered as the intake pipe sucks itself deeper into the subsurface sand deposit.

Dredged materials travel up the intake pipe and pass over screens sized with maximum 3/8-inch openings. Materials larger than 3/8-inch (rock, debris…) pass over the screen and are returned to the river. Smaller sized sand particles fall through the screen openings and land in attached hopper barges. Suction dredging continues until the intake pipe encounters undesirable materials, reaches its maximum depth based on the pipe length or when the hopper barge is full. The larger dredge pump is turned off just before the winch raises the suction pipe's intake out of the sand deposit. If enough sand has not been collected, the dredge vessel relocates to repeat the process.

When the attached hopper barge is full, a workboat is dispatched to transfer the barge to existing unloading docks. The sand is unloaded using machinery equipped with a swing arm and clamshell bucket. Conveyor systems transfer the sand to stockpiles at the existing river terminal facilities. The stockpiled sand is typically sold to the construction industry for use in ready-mix concrete, asphalt and fill material.

The following river reaches and dredge material quantities have been permitted by the Corps in the main channel of the MMR under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. Most operators generally dredge within a five mile reach of their terminal and conveyor to save fuel and time. It's very rare for the commercial dredgers to actually reach the maximum allowed annual dredge material quantities.

RM 48-75, 135,000 cubic yards annual quantity. Permit abandoned within past 5 years.
RM 78-155, maximum permitted annual quantity 200,000 cubic yards.
RM 154-170, max permitted annual quantity 333,000 cubic yards.
RM 166-171, max permitted annual quantity 400,000 cubic yards.
RM 172-177, max permitted annual quantity 66,666 cubic yards.
RM 182-188, max permitted annual quantity 50,000 cubic yards.
RM 195-218, max permitted annual quantity 500,000 cubic yards.
RM 280-282, max permitted annual quantity 100,000 cubic yards.

The environmental effects of commercial dredging operations are similar to those described above for the Regulating Works Project, but at a smaller scale. Each dredging permit has special conditions which were developed in coordination with the U.S. Fish and Wildlife Service and state natural resource agencies in the state(s) where the dredging was permitted. These special conditions are provided to the dredger to protect the natural environment (e.g., No dredging or placement of dredged material shall be conducted within ¼ mile upstream or downstream of any chute, tributary mouth, park or refuge area, plus others) and to protect the human (constructed) environment (e.g., No dredging shall be conducted within 200 feet of any structure built or authorized by the Federal Government, nor within 500 feet of any bridge, pier or abutment, plus others).

With respect to cumulative impacts (past, present, and future actions), none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase dredging beyond the existing conditions. The Continue Construction Alternative would be expected to reduce dredging requirements and the No New Construction Alternative would be expected to have no impact on dredging requirements. Commercial dredging operations are not anticipated to grow dramatically. Currently, there are no known plans for new commercial dredging operations in the MMR.

Boat-Generated & Navigation Infrastructure Related Anthropogenic Sound

There is a very recent awareness and growing concern in the scientific community over the effects of man-made noise in the aquatic environment (e.g., Popper and Hastings 2009a, 2009b; Slabbekoorn et al. 2010). These noise sources in the MMR include, but are certainly not limited to, pleasure boating, commercial navigation traffic, fishing, dredging for channel and harbor maintenance, construction of bridges and navigation infrastructure, and demolition of structures. Currently, the biggest contributor to anthropogenic noise in the MMR is navigation traffic and work associated with operation and maintenance of the navigation channel. There is a growing concern that these sound sources may be impacting aquatic life, especially fish.

<u>The Effects of Boat Traffic Noise</u>

Anthropogenic sound from all types of boat traffic (e.g., canoes, pleasure boats, and commercial navigation traffic) have been shown to cause subtle physiological responses in fish such as increased cortisol (endocrinological stress response) levels in a number of European freshwater fishes studied (Wysocki et al. 2006), an increase in cardiac output in Largemouth Bass (*Micropterus salmoides*), associated with a dramatic increase in heart rate and a slight decrease in stroke volume (Graham and Cooke 2008), and increased auditory thresholds (an auditory threshold is the sound level at which an organism can first hear a sound)(Scholik and Yan 2002). Fish behavioral responses include disrupted auditory communication by decreasing the ability to detect conspecific acoustic signals (Vasconcelos et al. 2007); changes in schooling behavior (Sarà et al. 2007) which may be important in feeding, predator avoidance, and spawning; reduced foraging success (Voellmy et al. 2014); compromised antipredator behavior (Simpson et al. 2014); and diminished ability of resident fish to maintain territories (Sebastianutto et al. 2011).

It has been suggested that navigation traffic causes disturbance and side channels may be used as a refuge for fish escaping navigation related disturbances. Although the causes of these movements were not noted, it is possible that noise, in addition to physical disturbances (e.g., drawdown, wave wash, turbulence, etc.) may be partially responsible for displacement of fish. Galat and Zweimuller (2001) and Wolter and Bischoff (2001) hypothesize that commercial navigation traffic may push fish toward the littoral zone or into side channels. Gutreuter et al. (2006) estimated the magnitude of traffic-induced reduction of fishes in the main channel of the Upper Mississippi River by comparing fish abundance in the navigation channel relative to abundance in side channels. They found the presence of some species was unaffected by traffic disturbances, whereas, the presence of others was reduced.

As previously noted, the study of the impacts of boat-generated noise, or anthropogenic noise in the aquatic environment in general, and its effect on aquatic organisms is a very recent area of study and there are large data gaps in the knowledge base (Hawkins et al. 2015). For example, to the best of the District's knowledge there are no publications on the Sound Pressure Level (SPL) of operating tows similar to those operating on the MMR and there have been no studies of biological effects on aquatic organisms at those SPLs and durations. So our brief, potential "generic" impact analysis is based on the best available information from a variety of boat types.

With respect to cumulative impacts (past, present, and future actions), because none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic and associated anthropogenic noise levels beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Construction Noise

Future in-water construction activities by the Corps would involve the construction of additional river training structures and could involve construction activities associated with operation and maintenance of Lock and Dam 27 and the Chain-of-Rocks low-water structure. Private sector development could involve construction related to barge fleeting areas, harbor maintenance and development, and docks/piers. Most of these activities would produce low-level, short-term noise that would have minimal, localized impacts. Activities that involve pile-driving related impulse sounds have the greatest potential to affect aquatic resources. The level of impact depends on the size of the pile, size of pile-driver (energy being delivered to the pile), depth to which the pile is being driven, and the substrate. In addition, fish size, condition factor, reproductive condition, depth during exposure, distance from the sound source, type of airbladder (i.e., species lacking an airbladder, physostomous vs. physoclistous, and thickness of the airbladder, etc.) are additional biological conditions that can affect mortality. Impacts could range from no effect, minor behavioral effects, minor injury, to mortality (Bolle et al. 2012; Halvorsen et al. 2012a; Halvorsen et al. 2012b). There are potential mitigation measures that have been developed (e.g., warning sounds, seasonal or hourly schedule adjustments, bubble curtains) to reduce pile-driving effects that could be utilized for projects with a potential to have high impact levels (e.g., very large diameter piles with large pile-drivers) (Würsig et al. 2000).

With respect to cumulative impacts (past, present, and future actions) of construction noise, under the No New Construction Alternative, impacts would remain the same. Under the Continue Construction Alternative additional training structures would be constructed which would result in construction related noise. However, construction noise is generally short-term and transitory in nature. For example, noise generated by rock placement during construction of training structures might move fish from the construction site, but they would return after the noise stopped. Even if sound pressure levels are high enough to injure or kill fish (e.g., pile driving with high-energy pile drivers), the impact zone would be relatively small and impacts would be to individual fish and would have little or no impact on MMR fish populations.

4.6.4 Impacts to Socioeconomic Resources

The Mississippi River is essential to the economies of the counties and states that border it. The people living and working in those places rely on the river system for their livelihood. Water transportation supports thousands of jobs throughout the river corridor, and the Nation, in a variety of industries. Agricultural, mining, and manufacturing industries; public utilities; waterside commercial development; and water-based recreational activities depend on the inland waterway for their livelihood. The Regional Economic Development study conducted as part of the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study (USACE 2004) traced expenditures and transportation cost savings throughout the economy in terms of additional full-time employment, wage and salary income, and output of the value of the goods produced. The analysis reported that within the study area states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, 21,891 man-years of employment are generated by water based industries. This benefit also has an impact on other regions as well as the entire United States. In the states bordering the study area, income generated by these business activities was estimated to be over $509 million, and for the entire United States it was estimated to be over $1.2 billion. Inland water transportation generates thousands of jobs and millions of dollars in taxes for state and federal governments.

The Middle Mississippi River Regulating Works Project is an integral part of the inland water transportation system. The long-term goal of the Project, as authorized by Congress, is to provide a sustainable and safe navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging and the occurrence of vessel accidents through the construction of regulating works. Past Regulating Works Project actions have been successful in providing a sustainable and safe navigation channel, reducing vessel accidents, and reducing the average annual dredging requirements in the MMR. Present and reasonably foreseeable future actions are expected to continue this trend.

4.6.5 Impacts to Historic and Cultural Resources

Historic and cultural resources within and in proximity to the Middle Mississippi River have been, and continue to be, subjected to natural riverine processes (e.g., bankline and riverbed erosion). Anthropogenic changes to the system have also impacted those resources since at least the 18th century. As Euro-American settlements developed along the river, levee systems began to be constructed by landowners and communities for flood control. Beginning in the mid-19th century, structures were constructed in the river to modify water-flow to either decrease or increase sedimentation in specific locations. Dikes, for example, directed the water current to eliminate sandbars, and hurdles were used to close off chutes between towheads and riverbanks causing them to fill with sediment. Sedimentation within dike fields also contributed to the narrowing of the river (see Section 3.2.2 for full discussion). In areas where the river’s planform width was narrowed, archaeological and historical sites on or near the riverbank that might have been subject to erosion from high water events, wave action (or other effects) from increased commercial navigation, or river migration, were essentially insulated by the newly formed land.

Wrecked riverine vessels originally located on the river bankline or in side channels were also essentially buried under a protective blanket of sediment. The river's planform width has stabilized since the 1960s, but long term impacts of the Regulating Works Project include continued bankline stability, reducing the likelihood of cultural resources being damaged or destroyed by erosion.

4.6.6 Cumulative Impacts Analysis Conclusion

The Regulating Works Project, in combination with other actions throughout the watershed, has had past impacts, both positive and negative, on the resources, ecosystem and human environment of the MMR. However, this analysis is meant to characterize the incremental impacts of the current action in the broader context of other past, present, and future actions affecting the same resources. Although past actions associated with the Regulating Works Project likely adversely affected some segments of the MMR environment, the current practices employed in obtaining and maintaining a navigation channel integrate lessons learned from past experience and emphasize avoiding and minimizing environmental impacts to the greatest extent practicable. The District works closely with natural resource agency and navigation industry stakeholders throughout the project development process to ensure that all potential issues are addressed appropriately. This process, in conjunction with innovative river training structure designs and District restoration efforts, has contributed to a substantial reduction in adverse effects and equilibrium in many habitat conditions. Construction of river training structures is expected to continue to increase important low velocity habitat and increase bathymetric, flow, and substrate diversity. These improvements in Project implementation notwithstanding, the District has concluded that the adverse effects to shallow to medium-depth, moderate- to high-velocity main channel border habitat, as discussed in Section 4.3.2 Impacts on Fishery Resources above, are potentially significant and warrant compensatory mitigation. No further incremental impacts associated with the Alternatives analyzed, in the context of other past, present, and reasonably foreseeable future actions, are anticipated to rise to a level of significance. See Table 4-10 below for a summary of cumulative impacts.

Table 4-10. Summary of Cumulative Impacts.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Stages	Flows and stages impacted by watershed land use changes, levee construction, mainline and watershed dam construction, river training structure construction (low flow stage impacts), consumptive water use, climate change.	Continued impacts due to land use changes in watershed, continued operation of mainline and watershed dams, river training structure construction (low flow stage impacts), consumptive water use, levee construction, climate change.	Continued impacts due to land use changes in watershed, continued operation of mainline and watershed dams, river training structure construction (low flow stage impacts), consumptive water use, levee construction, climate change.	No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue.	No impacts on stages anticipated at average and high flows. At low flows, current trend of decreasing stages expected to continue.
Geomorphology	Widening of overall river planform and side channel planform from early 1800s to late 1800s due to floodplain land use changes; narrowing of overall river planform and side channel planform from late 1800s to mid-1900s due to river training structure construction for navigation; loss of side channels due to river training structure construction; stabilization of overall river planform and side channels mid-1900s to present; general increase in cross-sectional area, hydraulic depth, conveyance, channel volume since 1950s; restoration of side channel	General stabilization of overall river planform and side channel planform; continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel; continued restoration of side channels through Corps authorities.	Maintenance of stable overall planform and side channel planform; continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel; continued restoration of side channels through Corps authorities.	No impacts to geomorphology anticipated beyond continued provision of 9-foot navigation channel.	Continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel.

	habitat through Corps authorities.				
Resource	**Past Actions**	**Present Actions**	**Future Actions**	**No New Construction Alternative**	**Proposed Action (Continue Construction Alternative)**
Water Quality	Increasing human populations and industrialization result in increased water quality problems; establishment of Clean Water Act, NEPA, USEPA, state environmental agencies and associated regulations greatly improve conditions.	Continued population growth and development result in increased potential for water quality impacts; continued regulation enforcement and societal recognition prevent water quality degradation.	Continued population growth and development result in increased potential for water quality impacts; continued regulation enforcement and societal recognition prevent water quality degradation.	Localized, temporary increase in suspended sediment concentrations at dredge material discharge sites.	Localized, temporary increase in suspended sediment concentrations during construction activities.
Air Quality and Climate Change	Increasing human populations and industrialization result in deterioration of air quality; establishment of Clean Air Act, NEPA, USEPA, air quality standards improve conditions; non-attainment status in parts of Project Area; increasing global greenhouse gas emissions lead to climate change.	Continued population growth and development result in increased potential for air quality impacts; continued non-attainment status in parts of Project Area; continued regulation enforcement; increasing societal recognition of climate change causes and consequences; global greenhouse gas emissions continue to increase	Continued population growth and development result in increased potential for air quality impacts; continued non-attainment status in parts of Project Area; continued regulation enforcement potentially results in improvements in non-attainment areas; increasing societal recognition of climate change causes and consequences; possible stabilization/reduction in global greenhouse gas emissions through societal recognition and regulation.	Minor and local impacts to air quality due to use of dredging equipment and equipment used for maintenance of existing structures; greenhouse gas emissions approximately 27,950 tons per year from dredging and maintenance activities.	Temporary, minor, local impacts to air quality due to one-time use of construction equipment; reduction in future emissions due to dredging reduction.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Fish and Wildlife (including threatened and endangered species)	Transformation of river system from natural condition to pooled lock and dam system above Chain of Rocks; in MMR, loss of floodplain habitat due to levees, agriculture, urbanization; loss of natural river habitat – loss of dynamic habitat due to river channel stabilization with dikes/ revetment; loss of side channel habitat; dredging impacts; navigation impacts; Corps, other federal, state, and private habitat restoration and land mgmt programs reverse habitat loss; introduction of exotic species/reduced native species biomass; implementation of innovative river training structures to provide habitat diversity; recognition of T&E species through Endangered Species Act; listing of multiple T&E species in MMR.	Maintenance of current habitat conditions due to maintenance of lock and dam system above Chain of Rocks and existing dikes/revetment; continued implementation of Regulating Works Project; continued use of innovative river training structures to provide habitat diversity; habitat restoration and land mgmt through Corps, other federal, state, and private programs; habitat changes associated with recent and current innovative dike construction; maintenance of current floodplain habitat conditions due to continued agriculture use/ maintenance of existing levees / urbanization; dredging impacts; navigation impacts; native species continue to be impacted by exotic species; restoration/maintenance of side channel habitat.	Continued maintenance of habitat conditions due to maintenance of lock and dam system above Chain of Rocks and maintenance of existing dikes/revetment; dredging impacts; navigation impacts; continued implementation of Regulating Works Project; continued use of innovative river training structures to provide habitat diversity; continued habitat restoration and land mgmt through Corps, other federal, state, and private programs; maintenance of current floodplain habitat conditions due to continued agriculture use/ maintenance of existing levees/ urbanization; new exotic species likely to be introduced; restoration/ maintenance of side channel habitat.	Entrainment of some fish and macroinvertebrates at dredge locations; avoidance of dredge and disposal areas by mobile organisms; some loss of fish and macroinvertebrates at disposal sites; creation of islands/sandbars with flexible dredge pipe; impacts to threatened and endangered species consistent with 2000 Biological Opinion; no effect or may affect but not likely to adversely affect for species listed since 2000.	Avoidance of sites during construction; no conversion of aquatic habitat to terrestrial; increased fish and macroinvertebrate use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity; loss of shallow to moderate-depth, medium- to high-velocity main channel border habitat potentially necessitating compensatory mitigation; creation of islands/sandbars with flexible dredge pipe; impacts to threatened and endangered species consistent with 2000 Biological Opinion; no effect or may affect but not likely to adversely affect for species listed since 2000.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Navigation	1927 River and Harbor Act authorized the Corps to provide a 9-foot channel on MMR; Corps transformed free-flowing Mississippi River system into navigable waterway with 37 lock and dam complexes above Chain of Rocks, some dredging, dikes, revetment; growth of port facilities and inland waterways and traffic throughout Mississippi River system provided for movement of commodities with local, national, and international importance.	Operation of lock and dam system above Chain of Rocks continues; traditional and innovative stone dike, revetment construction, rock removal, and dredging continue to obtain and maintain the navigation channel; navigation continues to be an important part of local, national, and international transportation and commerce activities.	Operation of lock and dam system above Chain of Rocks continues; traditional and innovative stone dike, revetment construction, rock removal, and dredging continue to obtain and maintain the navigation channel; navigation continues to be an important part of local, national, and international transportation and commerce activities.	Continued requirement for periodic maintenance dredging at rates similar to recent history; potential reduction in reliability of navigation channel during extreme low water events.	Reduction in the amount and frequency of repetitive maintenance dredging in the Project Area; reduction in barge grounding rates; safer and more reliable navigation channel.
Historic and Cultural Resources	Historic and cultural resources subjected to natural processes and manmade actions (e.g., erosion, floodplain development); recognition of importance of historic and cultural resources through National Historic Preservation Act (and others).	Historic and cultural resources continue to be impacted by human activities as well as natural processes; continued societal recognition of importance of historic and cultural resources.	Historic and cultural resources continue to be impacted by human activities as well as natural processes; continued societal recognition of importance of historic and cultural resources.	No known historic resources would be affected. Impacts to unknown historic and cultural resources unlikely.	No known historic resources would be affected. Impacts to unknown historic and cultural resources unlikely.

4.7 Relationship of short-term uses and long-term productivity

40 CFR 1502.16 requires that an EIS include a discussion of the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity. The intent of this analysis is to outline tradeoffs in the relationship between short-term uses of the environment and maintenance and enhancement of long-term productivity of resources. An important consideration when analyzing the effects of an action is whether it would result in short-term environmental effects to the detriment of achieving long-term productivity.

Implementation of the Proposed Action would specifically be implemented to benefit the long-term productivity of the District's navigation mission by facilitating commercial navigation in the most cost-effective fashion possible. This would come at the expense of some minor, short-term effects to water quality, air quality, and fish and wildlife associated with construction activities necessary to achieve the Project objectives. These construction-related effects are not expected to alter the long-term productivity of the environment. The Proposed Action would also result in long-term adverse effects to main channel border fish habitat that would potentially necessitate compensatory mitigation measures.

4.8 Irreversible and irretrievable commitments of resources

40 CFR 1502.16 requires that an EIS include a discussion of the irreversible or irretrievable commitment of resources associated with an action. An irreversible or irretrievable commitment of resources refers to an adverse effect to the human environment which cannot be recovered or reversed. Irreversible impacts are those that cause, through direct or indirect effects, use or consumption of nonrenewable resources in such a way that they cannot be restored or returned to their original condition despite mitigation. Irretrievable impacts refers to the loss of production or use of natural resources for a period of time. The production or use of the resource could return in the future if the action is reversed, but the production lost is irretrievable.

Irreversible commitments of resources associated with the Proposed Action would include such things as consumption of fossil fuels necessary for construction and operation and maintenance activities. If unknown historic or cultural resources were impacted by implementation of the Proposed Action, this would also be considered an irreversible effect. Most of the impacts (both positive and negative) to fish and wildlife associated with placement of river training structures would be considered irretrievable impacts. These impacts would be incurred for the period of time that the structure existed, but would return to normal if the structure were removed.

Chapter 5. Consultation, Coordination, and Compliance

National Environmental Policy Act. This SEIS, in conjunction with the 1976 EIS, is meant to satisfy the programmatic NEPA requirements of the Regulating Works Project. Tiered site-specific Environmental Assessments are prepared for specific work areas as they are implemented. See Section 1.1.2 Process for New Construction under the Regulating Works Project, Section 2.5 Future Implementation of the Regulating Works Project, and Appendix F for discussion on how the Regulating Works Project is implemented. Whereas this SEIS covers the programmatic impacts of the Regulating Works Project across the entire MMR, site-specific EAs contain information on the specific configuration of river training structures to be implemented, quantities of fill material required, amount of compensatory mitigation required, as necessary, specific biological resources of concern in the area, and other such information relevant to the particular work area that could not be covered in this programmatic document. Site-specific impacts can only be determined subsequent to detailed planning, modeling, analysis, etc. to address the unique issues at each work area. Site-specific EAs will be prepared on an ongoing, as-needed basis as dictated by Congressional appropriation levels, Project priorities, etc.

Clean Water Act. Under Section 404 of the Clean Water Act of 1972, authorization is required to excavate in or discharge dredged or fill material into the Waters of the United States. Accordingly, the District has prepared a programmatic Section 404(b)(1) evaluation as part of this SEIS (see Appendix D) and is seeking programmatic Section 404 authorization for the Regulating Works Project. In addition, the District will continue to seek site-specific authorization for individual Regulating Works Project work areas under Section 404 of the Clean Water Act as part of the tiered NEPA document process.

Under Section 401 of the Clean Water Act of 1972, any applicant for a federal license or permit for an activity that may result in discharge into the Waters of the United States must seek certification from the appropriate state that the discharge will not violate applicable water quality standards. Accordingly, programmatic Clean Water Act Section 401 water quality certifications are sought from Illinois EPA and Missouri DNR for District dredging operations every five years. In addition, the District will continue to seek site-specific water quality certifications for individual Regulating Works Project work areas under Section 401 of the Clean Water Act as part of the tiered NEPA document process.

Rivers and Harbors Act. Under Section 10 of the Rivers and Harbors Act of 1899, authorization is required for construction of any structure in or over any navigable water of the United States, or the accomplishment of any other work affecting the course, location, condition, or physical capacity of such waters. Accordingly, the District is seeking programmatic authorization for the Regulating Works Project under Section 10 of the Rivers and Harbors Act as part of this SEIS. In addition, the District will continue to seek site-specific authorization for individual Regulating Works Project work areas under Section 10 of the Rivers and Harbors Act as part of the tiered NEPA document process.

Federal Laws[1]	**Compliance Status**
Abandoned Shipwreck Act of 1987, as amended, 43 USC § 2101, et seq.	Full
American Indian Religious Freedom Act, as amended, 42 USC § 1996	Full
Archaeological and Historic Preservation Act, as amended, 54 USC § 312501, et seq.	Full
Bald and Golden Eagle Protection Act, as amended, 16 USC § 668, et seq.	Full
Clean Air Act, as amended, 42 USC § 7401, et seq.	Full
Clean Water Act, as amended, 33 USC § 1251, et seq.	Partial[2]
Comprehensive Environmental Response, Compensation, and Liability Act, as amended, 42 USC § 9601, et seq.	Full
Endangered Species Act, as amended, 16 USC § 1531, et seq.	Full
Farmland Protection Policy Act, as amended, 7 USC § 4201, et seq.	Full
Federal Water Project Recreation Act, as amended, 16 USC §460l-12, et seq. and 16 USC § 662	Full
Fish and Wildlife Coordination Act, as amended, 16 USC § 661, et seq.	Full[3]
Flood Control Act of 1944, as amended, 16 USC § 460d, et seq. and 33 USC § 701, et seq.	Full
Food Security Act of 1985, as amended, 16 USC § 3801, et seq.	Full
Land and Water Conservation Fund Act of 1965, as amended, 16 USC § 460l-4, et seq.	Full
Migratory Bird Treaty Act of 1918, as amended, 16 USC § 703, et seq.	Full
National Environmental Policy Act, as amended, 42 USC § 4321, et seq.	Partial[4]
National Historic Preservation Act, as amended, 54 USC § 300101, et seq.	Full
National Trails System Act, as amended, 16 USC § 1241, et seq.	Full
Noise Control Act of 1972, as amended, 42 USC § 4901, et seq.	Full
Resource Conservation and Recovery Act, as amended, 42 USC § 6901, et seq.	Full
Rivers and Harbors Appropriation Act of 1899, as amended, 33 USC § 401, et seq.	Partial[2]
Wilderness Act, as amended, 16 USC § 1131, et seq.	Full
Executive Orders[5]	
Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, EO 12898, February 11, 1994, as amended	Full
Floodplain Management, EO 11988, May 24, 1977, as amended	Full
Invasive Species, EO 13112, February 3, 1999, as amended	Full
Protection and Enhancement of Environmental Quality, EO 11991, May 24, 1977	Full
Protection and Enhancement of the Cultural Environment, EO 11593, May 13, 1971	Full
Protection of Wetlands, EO 11990, May 24, 1977, as amended	Full
Recreational Fisheries, EO 12962, June 7, 1995, as amended	Full
Responsibilities of Federal Agencies to Protect Migratory Birds, EO 13186, January 10, 2001	Full
Trails for America in the 21st Century, EO 13195, January 18, 2001	Full

[1] Also included for compliance are all regulations associated with the referenced laws. All guidance associated with the referenced laws were considered. Further, all applicable Corps laws, regulations, policies, and guidance have been complied with but not listed fully here.
[2] Full compliance will be obtained on a site by site basis prior to construction activities.
[3] Notice of Intent indicated that a Fish and Wildlife Coordination Act Report (CAR) would be obtained from the U.S. Fish and Wildlife Service. However, per the Fish and Wildlife Coordination Act of 1958 (Section 662.g) a CAR is not required for projects when sixty percent or more of the estimated construction cost has been obligated for expenditure. Therefore, a CAR was not required for this SEIS. However, coordination with the Service was conducted and all Fish and Wildlife Coordination Act requirements are being fulfilled.
[4] Full compliance after submission for public comment and signing of Record of Decision.
[5] This list of Executive Orders is not exhaustive and other Executive Orders not listed may be applicable.

Chapter 6. Areas of Controversy

Flood Heights. There is research claiming that the construction of river training structures affects flood heights. The Corps takes these claims very seriously, so the Corps conducted several studies on the issue, completed a thorough analysis of all available research (see Appendix A), and concluded that river training structures do not affect water surface elevations at higher flows.

Mitigation. Federal and state natural resource agency partners have maintained the position that the Corps should mitigate for adverse effects going back to at least 1976. In general, the Corps only plans for and implements mitigation associated with proposed future actions because of budgetary constraints. Therefore, compensatory mitigation for the Regulating Works Project would only be conducted for adverse effects that have occurred or will occur since publication of the Notice of Intent to prepare this SEIS in the Federal Register in December 2013. However, the Corps' standing ecosystem restoration mission and associated authorities, outside of the Regulating Works authority, could be used to restore ecological resources from past activities of the Corps and others.

1976 Post Authorization Change Alternative. Federal and state natural resource agency partners have continued to ask that the Corps seek the Post Authorization Change (PAC) referenced in the 1976 EIS to add fish and wildlife as a Project purpose. The District fulfilled the commitments made in the 1976 EIS; however, this purpose was never added to the Project by Congress. However, all of the activities described in the 1976 EIS for the PAC can now be accomplished through other authorities. See supplement to Appendix F for details.

Geographic Scope of Analysis. The District received scoping comments indicating that the SEIS should address all of the navigation channel operation and maintenance activities in the Upper Mississippi River – Illinois Waterway System (UMR-IWW) instead of focusing only on the MMR. Recognizing the dynamic nature of the river in certain regions, Congress authorized many different navigation projects throughout the UMR-IWW. The Congressional authority for and management of the navigation channel on the MMR is very different from other projects within the UMR-IWW, primarily because the MMR is open river and the rest of the UMR-IWW consists of a series of pools created and managed through locks and dams. As such, the District concluded that a separate analysis for the MMR is appropriate.

Chapter 7. List of Preparers

Name	Role	Experience
Greg Kohler	Project Manager	6 years planning/project management
Edward Brauer	Engineering Lead	14 years, hydraulic engineering, Regional Technical Specialist - River Engineering
Keli Broadstock	Legal Review	4 years Corps, 6 years private sector law
Elliott Stefanik	Mitigation Planning	19 years, biology
Kip Runyon	Environmental Lead	18 years, biology
Thomas Keevin	Cumulative Impacts and Aquatic Resources	35 years, aquatic ecology
Shane Simmons	Air Quality and Climate Change	4 years, biology
Michelle Kniep	Planning	20 years, water resources planning, Regional Technical Specialist - Plan Formulation
Mike King	HTRW	25 years, environmental engineering
Mark Smith	Historic and Cultural Resources	22 years, archaeology
Erin Guntren	GIS	7 years, geography
Diane Karnish	Economics	27 years, economics
Danny McClendon	Regulatory	29 years, regulatory compliance and biology
Brian Rentfro	History	10 years, history

Chapter 8. Literature Cited

Adams, S. R., T. M. Keevin, K. J. Killgore, and J. J. Hoover. 1999. Stranding potential of young fishes subjected to simulated vessel-induced drawdown. Transactions of the American Fisheries Society 128:1230-1234.

Anderson, D.D., R.J. Whiting, and B. Jackson. 1981a. An assessment of water quality impacts of maintenance dredging on the Upper Mississippi River in 1978. US Army Engineer District, St. Paul, MN.

Anderson, D., R. Whiting, and J. Nosek. 1981b. An assessment of water quality impacts of maintenance dredging on the Upper Mississippi River in 1979. US Army Engineer District, St. Paul, MN.

Arlinghaus, R., C. Engelhardt, A. Sukhodolov, and C. Wolter. 2002. Fish recruitment in a canal with intensive navigation: implications for ecosystem management. Journal of Fish Biology 61:1386-1402.

Ault, J.S., K.C. Lindeman, and D.G. Clarke. 1998. FISHFATE: Population dynamics models to assess risks of hydraulic entrainment by dredges. DOER Technical Notes Collection (TN DOER-E4), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Baker, J.A., K.J. Killgore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the Lower Mississippi River. Reviews in Aquatic Sciences 3(4):313-356.

Baldwin, L. D. 1941. The Keelboat Age on Western Waters. University of Pittsburg Press, Pittsburg.

Barko, V. A., and D. P. Herzog. 2003. Relationship among side channels, fish assemblages, and environmental gradients in the unimpounded Upper Mississippi River. Journal of Freshwater Ecology 18:377-382.

Barko, V.A., M.W. Palmer, and D.P. Herzog. 2004a. Influential environmental gradients and spatiotemporal patterns of fish assemblages in the unimpounded Upper Mississippi River. American Midland Naturalist 152:369-385.

Barko, V. A., D. P. Herzog, R. A. Hrabik, and J. S. Scheibe. 2004b. Relationship among fish assemblages and main-channel-border physical habitats in the unimpounded Upper Mississippi River. Transactions of the American Fisheries Society 133:371-384.

Barko, V. A., D. P. Herzog, and M. T. O'Connell. 2006. Response of fishes to floodplain connectivity during and following a 500-year flood event in the unimpounded Upper Mississippi River. Wetlands 26:244-257.

Bartsch, P. 1916. The Missouri River as a faunal barrier. Nautilus 30:92.

Bartell, S.M., and K.R. Campbell. 2000. Ecological risk assessment of the effects of the incremental increase of commercial navigation traffic (25, 50, 75, and 100 percent increase of 1992 baseline traffic) on fish - ENV Report 16. Interim report for the Upper Mississippi River – Illinois Waterway Navigation Feasibility Study. Report prepared for the U.S. Army Corps of Engineers.

Battle, J. M., J. K. Jackson, and B. W. Sweeney. 2007. Annual and spatial variation for macroinvertebrates in the Upper Mississippi River near Cape Girardeau, Missouri. Fundamental and Applied Limnology 168:39-54.

Beamish, F. W. H. 1978. Swimming capacity. Pages 101-107. *In*: W. S. Hoar and D. J. Randall, editors. Fish Physiology. Volume VII: Locomotion. Academic Press, New York.

Beckett, D.C., C.R. Bingham, and L.R Sanders. 1983. Benthic macroinvertebrates of selected habitats of the lower Mississippi River. Journal of Freshwater Ecology 2: 247-261.

Bhowmik, N. D., M. Demissie, and C. Y. Guo. 1981. Waves and drawdown generated by river traffic on the Illinois and Mississippi rivers. Report of Illinois Natural History Survey (SWS Contract Report 271) to Upper Mississippi River Basin Commission, Environmental Work Team, Master Plan Task Force, St. Paul.

Bhowmik, N. D., A. C. Miller, and B. S. Payne. 1993. Techniques for studying the physical effects of commercial navigation traffic on aquatic habitats. U. S. Army Engineer Waterways Experiment Station, Technical report EL-90-10. Vicksburg, MS.

Bhowmik, N. D., T. W. Song, J. R. Ada,s. R. Xia, and B. S. Mazumder. 1998. Physical changes associated with navigation traffic on the Illinois and Upper Mississippi rivers. Special Report 98-S001 A. U.S. Geological Survey Upper Midwest Environmental Sciences Center Long Term Resource Monitoring Program. La Crosse, Wisconsin.

Bhowmik, N. D., T. W. Soong, T. Nakato, M. Spoor, J. Anderson, and D. Johnson. 1999. Bank erosion field survey report of the Upper Mississippi River and Illinois Waterway. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 8.

Biedenharn, D.S, L.C. Hubbard, and P.H. Hoffman. 2000. Historical Analysis of Dike Systems on the Lower Mississippi River (Draft). U.S. Army Engineer Research and Development Center.

Bij de Vaate, A., A.G. Klink, M. Greijdanus-Klaas, L.H. Jans, J. Oosterbaan, and F. Kok. 2007. Effects of habitat restoration on the macroinvertebrate fauna in a foreland along the River Waal, the main distributary in the Rhine Delta. River Research and Applications 23:171-183.

Bingham, C.R. 1982. Benthic macroinvertebrate study of a stone dike. Environmental and Water Quality Operational Studies Information Exchange Bulletin, Bol. E-82-4.

Bischoff, A., and C. Wolter. 2001. Groyne-heads as potential summer habitats for juvenile rheophilic fishes in the lower Oder, Germany. Limnologica 31:17-26.

Bishop, M. J., and M. G. Chapman. 2004. Managerial decisions as experiments: an opportunity to determine the ecological impacts of boat-generated waves on macrobenthic infauna. Estuarine Coastal and Shelf Science 61:613-622.

Bi-State Development Agency. 1954. Mississippi River water pollution investigation. St. Louis Metropolitan Area. 378 pp.

Bolle, L. J., C. A. F. De Jong, S. M. Bierman, P. J. G. Van Beek, O. A. Van Keeken, P. W. Wessels, C. J. G. Van Damme, H. V. Winter, D. De Haan, and R. P. A. Dekeling. 2012. Common sole larvae survive high levels of pile-driving sound in controlled exposure experiments. *PLoS One* 7, e33052.

Bouwmeester, J., E. J. van de Kaa, H. A. Nuhoff, and R. G. J. Orden. 1977. Various aspects of navigation in restricted waterways. Pages 139-158. *In*: Twenty-fourth International Navigation Congress. Permanent International Association of Navigation Congresses, Section 1, 3, Leningrad, Russia.

Boysen, K.A. and J.J. Hoover. 2009. Swimming performance of juvenile white sturgeon (*Acipenser transmontanus*): training and the probability of entrainment due to dredging. Journal of Applied Ichthyology 25 (Suppl. 2): 54-59.

Brauer, E.J., D.R. Busse, C. Strauser, R.D. Davinroy, D.C. Gordon, J.L. Brown, J.E. Myers, A.M. Rhoads, and D. Lamm. 2005. Geomorphology study of the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri.

Brauer, E.J., R.D. Davinroy, L. Briggs, and D. Fisher. 2013. Draft supplement to *Geomorphology study of the Middle Mississippi River (2005)*. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri.

Braun, A.P., M.J. Sobotka, and Q.E. Phelps. 2015. Fish associations among un-notched, notched and L-head dikes in the Middle Mississippi River. River Research and Applications DOI: 10.1002/rra.2892

Calkins, H. A., S. J. Tripp, and J. E. Garvey. 2012. Linking silver carp habitat selection to flow and phytoplankton in the Mississippi River. Biological Invasions 14: 949-958.

Cellot, B. 1996. Influence of side-arms on aquatic macroinvertebrate drift in the main channel of a large river. Freshwater Biology 35:149-164.

CEQ (Council on Environmental Quality). 1981. Memorandum to Agencies: Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations. 46 Federal Register 18026.

CEQ (Council on Environmental Quality). 1997. Environmental justice: guidance under the National Environmental Policy Act. CEQ, Washington, D.C.

CEQ (Council on Environmental Quality). 2016. Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews. CEQ, Washington, D.C.

Christenson, L.M. and L.L. Smith. 1965. Characteristics of fish populations in upper Mississippi River backwater areas. Circular 212, U.S. Fish and Wildlife Service, Washington, D.C.

Copeland, R. R., D. D. Abraham, G. H. Nail, R. Seal, and G. L. Brown. 2001. Entrainment and transport of sediments by towboats in the Upper Mississippi River and Illinois Waterway, Numerical model study. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 37.

Crites, J. W., Q. E. Phelps, K. N. S. McCain, D. P. Herzog, and R. A. Hrabik. 2012. An investigation of fish community and water quality compositions in an isolated side channel of the Upper Mississippi River. Journal of Freshwater Ecology 27:19-29.

Cummings, K.S. and C.A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manual 5, Champaign.

Dardeau, E.A., Jr., K.J. Killgore, Jr., and A.C. Miller. 1995. Using riprap to create or improve riverine habitat. Pp. 609-620 in C. R. Thorne, S.R. Abt, F.B.J. Barends, S.T. Maynord, and K.W. Pilarczyk (eds.). River, coastal and shoreline protection: Erosion control using riprap and armourstone. John Wiley & Sons Ltd.

Davinroy, R.D. 1990. Bendway weirs, a new structural solution to navigation problems experienced on the Mississippi River. Permanent International Association of Navigation Congresses 69:5-18.

Davinroy, R.D. 2006. Sedimentation in the Upper Mississippi River Basin. U.S. Army Corps of Engineers, Applied River Engineering Center, St. Louis, Missouri.

Davis, B. J. and R. J. Miller. 1967. Brain patterns in minnows of the genus *Hybopsis* in relation to feeding habits and habitat. Copeia 1967:1-39.

Deng, Z., G. R. Guensch, C. A. McKinstry, R. P. Mueller, D. D. Dauble, and M. C. Richmond. 2005. Evaluation of fish-injury mechanisms during exposure to turbulent shear flow. Canadian Journal of Fisheries and Aquatic Sciences 62:1513-1522.

Dettmers, J. M., D. H. Wahl, D. A. Soluk, and S. Gutreuter. 2001a. Life in the fast lane: fish and food webs in the main channel of large rivers. Journal of the North American Benthological Society 20:255-265.

Dettmers, J. M., S. Gutreuter, D. H. Wahl, and D. A. Soluk. 2001b. Patterns in abundance of fishes in main channels of the Upper Mississippi River system. Canadian Journal of Fisheries and Aquatic Sciences 58:933-942.

Downing, J. A., P. Van Meter, and D. A. Woolnough. 2010. Suspects and evidence: a review of the causes of extirpation and decline in freshwater mussels. Animal Biodiversity and Conservation 33:151-185.

Eckblad, J.W., C.S. Volden, and L.S. Weilgart. 1984. Allochthonous drift from backwaters to the main channel of the Mississippi River. American Midland Naturalist 111:16-22.

Ecological Specialists, Inc. 1997a. Final Report: Macroinvertebrates associated with bendway weirs at Mississippi River Mile 30. Report Prepared for the St. Louis District, U.S. Army Corps of Engineers. 20pp.+Appendix.

Ecological Specialists, Inc. 1997b. Final Report: Macroinvertebrates associated with Carl Baer bendway weirs in the Mississippi River. Report Prepared for the St. Louis District, U.S. Army Corps of Engineers. 28pp.+Appendix.

Ecological Specialists, Inc. 2010. Final Report: Monitoring of Dredged Material for Fish Entrainment with Special Emphasis on the Pallid Sturgeon, Phase III North Berms Dredging, Chain of Rocks Canal, Mississippi River, Madison County, IL. Prepared by Ecological Specialists, Inc. for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

Ellis, M. M. 1931. Some factors affecting the replacement of commercial fresh-water mussels. U.S. Department of Commerce, Bureau of Fisheries. Fishery Circular No. 7. 10 pp.

Ellis, M. M. 1934. A study of the Mississippi River from Chain of Rocks, St. Louis, Missouri, to Cairo, Illinois, with special reference to the proposed introduction of ground garbage into the river by the City of St. Louis. U.S. Fish and Wildlife Service Special Science Report 8. 22 pp.

Everett, S. R., D. L. Scarnecchia, and L. F. Ryckman. 2004. Distribution and habitat use of sturgeon chubs (*Macrhybopsis gelida*) and sicklefin chubs (*M. meeki*) in the Missouri and Yellowstone Rivers, North Dakota. Hydrobiologia 727:183-193.

Farabee, G. F. 1986. Fish species associated with revetted and natural main channel border habitats in Pool 24 of the Upper Mississippi River. North American Journal Fisheries Management 6: 504-508.

Fiedel, S. J. 1999. Older than we thought: implications of corrected dates for Paleoindians. American Antiquity 64(1):95-115.

Fischenich, J.C. 2003. Effects of riprap on riverine and riparian ecosystems. ERDC/EL TR-03-4, U.S. Army Engineer Research and Development Center: Vicksburg, MS.

Florsheim, J. L., J. F. Mount, and A. Chin. 2008. Bank erosion as a desirable attribute of rivers. BioScience 58:519-529.

Foley, R.P. and H.L. Dunn. 2014. Final Report: Evaluation of Larval Fish Density and Diversity within Main Channel and Main Channel Border Habitats of the Middle Mississippi River. Prepared by Ecological Specialists, Inc. for U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

Gabel, F., M. T. Pusch, P. Breyer, V. Burmester, N. Walz, and X.-F. Garcia. 2011a. Differential effect of wave stress on the physiology and behavior of native versus non-native benthic invertebrates. Biological Invasions 13:1843-1853.

Gabel, F. S. Stoll, P. Fischer, M. T. Pusch, X.-F. Garcia. 2011b. Waves affect predator-prey interactions between fish and benthic invertebrates. Oecologia 165:101-109.

Gabel, F., X.-F. Garcia, M. Brauns, A. Sukhodolov, M. Leszinski, and M. T. Pusch. 2008. Resistance to ship-induced waves of benthic invertebrates in various littoral habitats. Freshwater Biology 53:1567-1578.

Gabel, F., X. –F. Garcia, I. S., Schnauder, and M. T. Pusch. 2012. Effects of ship-induced waves on littoral benthic invertebrates. Freshwater Biology 57:2425-2435.

Galat, D.L., and I. Zweimuller. 2001. Conserving large-river fishes: is the highway analogy an appropriate paradigm? Journal of the North American Benthological Society 20:255-265.

Galat, D. L., C. R. Berry, Jr., E. J. Peters, and R. G. White. 2005. Missouri River Basin. Pp. 427–480 in A. C. Benke and C. E. Cushing (eds.). Rivers of North America, Elsevier, Oxford.

Galat, D. L., L. H. Fredrickson, D. D. Humburg, K. J. Bataille, J. R. Bodie, J. Dohrenwend, G. T. Gelwicks, J. E. Havel, D. L. Helmers, J. B. Hooker, J. R. Jones, M. F. Knowlton, J. Kubisiak, J. Mazourek, A. C. McColpin, R. B. Renken, and R. D. Semlitsch. 1998. Flooding to restore connectivity of regulated, large-river wetlands. BioScience 48:721-733.

GlobalSecurity.org. 2015. Dustpan Dredges. Accessed March 2015. http://www.globalsecurity.org/military/systems/ship/dredge-dustpan.htm

Gosch, N. J. C., M. L. Milller, A. R. Dzialowski, D. M. Morriis, T. R. Germeinhardt, J. L. Bonneau. 2014. Assessment of Missouri River floodplain invertebrates during historic inundation: implications for river restoration. Knowledge and Management of Aquatic Ecosystems DOI: 10.1051/kmae/2013087

Graham, A. L., and S. J. Cooke. 2008. The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiac physiology of a freshwater fish, the largemouth bass (*Micropterus salmoides*). Aquatic Conservation: Marine and Freshwater Ecosystems 18:1315-1324.

Grift, R.E., A.D. Buijse, W.L.T. Van Densen, and J.G.P. Klein Breteler. 2001. Restoration of the river-floodplain interaction: benefits for the fish community in the River Rhine. Archiv für Hydrobiologie 12:173-185.

Gutreuter, S., A. D. Bartels, K Irons, and M. B. Sandheinrich. 1999. Evaluation of the flood-pulse concept based on statistical models of growth of selected fishes of the Upper Mississippi River system. Canadian Journal of Fisheries and Aquatic Sciences 56:2282-2291.

Gutreuter, S., J. M. Dettmers, and D. H. Wahl. 2003. Estimating mortality rates of adult fish from entrainment through the propellers of river towboats. Transactions of the American Fisheries Society 132:646-661.

Gutreuter, S., J.M. Vallazza, and B.C. Knights. 2006. Persistent disturbance by commercial navigation alters the relative abundance of channel-dwelling fishes in a large river. Canadian Journal of Fisheries and Aquatic Sciences 63:2418-2433.

Gutreuter, S., J. M. Vallazza, and B. C. Knights. 2010. Lateral distribution of fishes in the main-channel trough of a large floodplain river: implications for restoration. River Research and Applications 26:619-635.

Haag, W. R. 2012. North American Freshwater Mussels: Natural History, Ecology and Conservation. Cambridge University Press. 538 pp.

Haites, E. F. and J. Mak. 1971. Steamboating on the Mississippi, 1810-1860: a purely competitive industry. The Business History Review 45(1):52-78.

Hall, H. 1884. Report on the Ship-Building Industry of the United States. Government Printing Office, Washington, D. C.

Halvorsen, M. B., B. M. Casper, C. M. Woodley, T. J. Carlson, and A. N. Popper. 2012a. Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. PlosOne 7(6)e38968

Halvorsen, M. B., B. M. Casper, F. Matthews, T. J. Carlson, and A. N. Popper. 2012b. Effects of exposure to pile-driving sounds on the lake sturgeon, Nile tilapia and hogchoker. Proceedings of the Royal Society B: Biological Sciences, rspb20121544.

Hariot, T. 1590 [1871]. A Briefe and True Report on the New Found Land of Virginia. Accessed September 2014. http://docsouth.unc.edu/nc/hariot/hariot.html

Harrison, A. B., and J. C. Morse. 2012. The macroinvertebrate fauna of the Mississippi River. Transactions of the American Entomological Society 138:55-72.

Hartman, K.J. and J.L. Titus. 2010. Fish use of artificial dike structures in a navigable river. River Research and Applications. 26: 1170-1186.

Hastings, M. C., A. N. Popper, J. J. Finneran, J. J. and P. J. Lanford. 1996. Effects of low frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. Journal of the Acoustics Society of America 99:1759–1766.

Hawkins, A. D., A. E. Pembroke, and A. N. Popper. 2015. Information gaps in understanding the effects of noise on fishes and invertebrates. Reviews in Fish Biology and Fisheries 25:39-64.

Heiler, G., T. Hein, F. Schiemer, and G. Bornette. 1995. Hydrological connectivity and flood pulses as the central aspects for the integrity of a river-floodplain system. Regulated Rivers: Research and Management 11:351- 361.

Heimann, D.C., L. A. Sprague, and D. W. Blevins. 2011. Trends in suspended-sediment loads and concentrations in the Mississippi River Basin, 1950–2009. U.S. Geological Survey Scientific Investigations Report 2011–5200. 33 pp.

Hein, T., C. Baranyi, W. Reckendorfer, and F. Schiemer. 2004. The impact of surface water exchange on nutrient and particle dynamics in side-arms along the River Danube, Austria. Science of the Total Environment 328:207-218.

Heitmeyer, M. 2008. An evaluation of ecosystem restoration options for the Middle Mississippi River Regional Corridor. Greenbrier Wetland Services Report 08-02. 81 pp.

Herbich, J. B. and S. B. Brahme. 1991. Literature review and technical evaluation of sediment resuspension during dredging. Contract Report HL-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hoagland, H. E. 1911. Early transportation on the Mississippi. Journal of Political Economy 19(2):111-123.

Holland, L. E. 1986. Effects of barge traffic on distribution and survival of ichthyoplankton and small fishes in the Upper Mississippi River. Transactions of the American Fisheries Society 115:162-165.

Holland, L. E. 1987. Effects of brief navigation-related dewatering on fish eggs and larvae. North American Journal of Fisheries Management 7:145-147.

Holland, L. E., and J. R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the upper Mississippi River, Pool 7. Transactions of the American Fisheries Society 112:293-301.

Hoover, J.J., K.J. Kilgore, D.G. Clarke, H. Smith, A. Turnage, and J. Beard. 2005. Paddlefish and Sturgeon Entrainment by Dredges: Swimming Performance as an Indicator of Risk. DOER Technical Notes Collection (ERDC TN-DOER-E22). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Hubbs, C. L., and A. B. Rechnitzer. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38:333-366.

Huckstorf, V., W.-C. Lewin, T. Mehner, and C. Wolter. 2011. Impoverishment of YOY-fish assemblages by intensive commercial navigation in a large lowland river. River Research and Applications 27:1253-1263.

Huizinga, R. J. 2009. Examination of direct discharge measurement data and historic daily data for selected gages on the Middle Mississippi River, 1861-2008. U.S. Geological Survey Scientific Investigations Report 2009-5232. 60pp. http://pubs.usgs.gov/sir/2009/5232/

IAGC (International Association of Geophysical Contractors). 2016. Fundamentals of sound in the marine environment. Accessed January 2016. http://www.iagc.org/free-resources.html

IDPH (Illinois Department of Public Health). 2014. 2014 Illinois Fish Advisory. Accessed September 2014. http://www.idph.state.il.us/envhealth/fishadvisory/index.htm

Jacobson, R. and D. Galat. 2006. Flow and form in rehabilitation of large-river ecosystems: an example from the Lower Missouri River. Geomorphology 77:249-269.

Jacobson, R.B., H.E. Johnson, III, and B.J. Dietsch. 2009. Hydrodynamic simulations of physical aquatic habitat availability for pallid sturgeon in the Lower Missouri River, at Yankton, South Dakota, Kenslers Bend, Nebraska, Little Sioux, Iowa, and Miami, Missouri, 2006–07: U.S. Geological Survey, Scientific Investigations Report 2009–5058, 67 p.

Johnson, J. H., R. C. Solomon, C. R. Bingham, B. K. Colbert, W. P. Emge, and D. P. Mathis. 1974. Environmental analysis and assessment of the Mississippi River 9-ft. channel project between St. Louis, Missouri, and Cairo, Illinois. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johnson, B. L., W. R. Richardson, and T. J. Naimo. 1995. Past, present, and future concepts in large river ecology. Bioscience 45:134–141.

Johnson, B. L., and K. H. Hagerty, editors. 2008. Status and trends of selected resources of the Upper Mississippi River System. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, December 2008. Technical Report LTRMP 2008-T002. 102 pp + Appendixes A-B.

Jones, B. D. and D. B. Noltie. 2007. Flooded flatheads: evidence of increased growth in Mississippi River *Pylodictis olivaris* (Pisces: Ictaluridae) following the Great Midwest Flood of 1993. Hydrobiologia 592:183-209.

Junk, W. J. P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127. *In*: D. P. Dodge (editor). Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Karl, T.R., J.M. Melillo, and T.C. Peterson, (eds.). 2009. Global Climate Change Impacts in the United States, Cambridge University Press.

Kasul, R. L., and J. A. Baker. 1996. Results of September 1995 hydroacoustic surveys of fishes in five reaches of the Middle Mississippi River (RM 2-50). Waterways Experiment Station Report prepared for the St. Louis District, U.S. Army Corps of Engineers.

Keevin, T.M., E. Marks Guntren, and R. Barkau. 2016. Middle Mississippi River side channels: Existing hydraulic connectivity to the river with implications for restoration planning. Report, in preparation.

Keevin, T. M., and N. H. Lopinot. 2016, Submitted. Historic record of Alligator Gar (Atractoteus spatula) captured on the floodplain of the Mississippi River at Columbia, Illinois.

Keevin, T. M., R. E. Yarbrough, and A. C. Miller. 1992. Long-distance dispersal of zebra mussels (*Dreissena polymorpha*) attached to hulls of commercial vessels. Journal of Freshwater Ecology 7: 437.

Keevin, T. M., B. L. Johnson, E. A. Laux, T. B. Miller, K. P. Slattery, and D. J. Schaeffer. 2005. Adult fish mortality during lockage of commercial navigation traffic at Lock and Dam 25, Upper Mississippi River. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 58. 14 pp.

Keevin, T. M., S. R. Adams, and K. J. Killgore. 2000. Effects of pressure changes induced by commercial navigation traffic on mortality of fish early life stages. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 34. 11 pp.

Keevin, T. M., S. T. Maynord, S. R. Adams, and K. J. Killgore. 2002. Mortality of fish early life stages resulting from hull shear stress associated with passage of commercial navigation traffic. Upper Mississippi River - Illinois Waterway System Navigation Study ENV Report 35. 17 pp.

Keevin T.M., G.L. Hempen, R.D. Davinroy, R.J. Rapp, M.D. Peterson, and D.P. Herzog. 2002. The use of high explosives to conduct a fisheries survey at a bendway weir field on the Mississippi River. International Society of Explosive Engineers 1: 382–393.

Keevin, T. M., J. S. Tiemann, and K. S. Cummings. 2016, Submitted. The Freshwater mussel fauna of the Middle Mississippi River. Northeastern Naturalist.

Kesel, R. H. 1988. The decline in the suspended load of the Lower Mississippi River and its influence on adjacent wetlands. Environmental Geology and Water Sciences 11:271-281.

Killgore, K. J., A. C. Miller, and K. C. Conley. 1987. Effects of turbulence on yolk-sac larvae of paddlefish. Transactions of the American Fisheries Society 116:670-673.

Killgore, K. J., L. W. Miranda, C. E. Murphy, D. M. Wolff, J. J. Hoover, T. M. Keevin. S. T. Maynord, and M. A. Cornish. 2011. Fish entrainment through towboat propellers in the Upper Mississippi-Illinois Waterway System. Transactions of the American Fisheries Society 140:570-581.

Killgore, J., C. Murphy, D. Wolff, and T. Keevin. 2005. Evaluation of towboat propeller-induced mortality of juvenile and adult fishes. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 56. 14 pp.

Killgore, K. J., S. T. Maynord, M. D. Chan, and R. M. Morgan II. 2001. Evaluation of propeller-induced mortality on early life stages of selected fish species. North American Journal of Fisheries Management 21:947-955.

Koch, B., R. C. Brooks, A. Oliver, D. Herzog, J. E. Garvey, R. Hrabik, R. Colombo, Q. Phelps, and T. Spier. 2012. Habitat selection and movement in naturally occurring Pallid Sturgeon in the Mississippi River. Transactions of the American Fisheries Society 141:112-120.

Koel, T. M., and K. E. Stevenson. 2002. Effects of dredge material placement on benthic macroinvertebrates of the Illinois River. Hydrobiologia 474:229-238.

Kucera-Hizinger, V., E. Schludermann, H. Zornig, A. Weissenbacher, M. Schabuss, and F. Schiemer. 2009. Potential effects of navigation-induced wave wash on the early life history stages of riverine fish. Aquatic Science 71:94-102.

Landon, C. E. 1960. Technological progress in transportation on the Mississippi River system. The Journal of Business 33(1):43-62.

LaSalle, M., D. Clarke, J. Homziak, and J. Fredette. 1991. A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Little, C.D., Jr., D.S. Biedenharn, C.C. Watson, M.A. Allison, T. McCullough, and K. Wofford. 2015. Channel geometry trends of Mississippi River, Old River Control Complex to St. Louis, MO. U.S. Army Corps of Engineers Engineer Research and Development Center, Vicksburg, MS.

Lowery, D. R., R. W. Pasch, and E. M. Scott. 1987. Hydroacoustic survey of fish populations of the lower Cumberland River. Final Report to the U.S. Army Corps of Engineers. U.S. Army Corps of Engineers, Nashville, TN.

Madejczyk, J.C., N.D. Mundahl, and R.M. Lehtinen. 1998. Fish assemblages of natural and artificial habitats within the channel border of the Upper Mississippi River. American Midland Naturalist, Vol. 139, No. 2, pp. 296-310.

Mak, J. and G. M. Walton. 1973. The persistence of old technologies: the case of flatboats. The Journal of Economic History, 33(2):444-451.

Marmorstein, J. 2000. Analysis of the impact of infrastructure improvements on the risk of accidents and hazardous spills. Report Prepared for the U.S. Army Corps of Engineers.

Maynord, S. T. 2000a. Physical forces near commercial tows. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 19.

Maynord, S. T. 2000b. Shear stress on the hull of shallow draft barges. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 24.

Maynord, S. T. 2000c. Concentric cylinder experiments of shear mortality of eggs and larval fish. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 23.

Maynord, S.T. 2000d. Velocity patterns downstream of Mississippi River dikes with and without tow traffic. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 21.

Maynord, S. T. 2005. Decay of tow-induced drawdown in backwaters and secondary channels. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 45.

Maynord, S. T., and T. M. Keevin. 2005. Commercial navigation traffic induced shoreline dewatering on the Upper Mississippi River: Implications for larval fish stranding. Upper Mississippi River - Illinois Waterway System Navigation Study ENV Report 55. 14 pp.

Mazumder, B. S., N. G. Bhowmik, and T. W. Soong. 1993. Turbulence in rivers due to navigation Traffic. Journal of Hydraulic Engineering 119:581-597.

McCain, K. N. S. 2013. Moving large river ecology from past theories to future actions: a review. Reviews in Fisheries Science 21:39-48.

McCauley, R. D., J. Fewtrell, and A. N. Popper. 2003. High intensity anthropogenic sound damages fish ears. Journal of the Acoustical Society of America 113:638–642.

McElroy, B., A. DeLonay, and R. Jacobson. 2012. Optimum swimming pathways of fish spawning migrations in rivers. Ecology 93:29-34.

Meade, R. H., and J. A. Moody. 2010. Causes for the decline of suspended-sediment discharge in the Mississippi River system, 1940-2007. Hydrological Processes 24:35-49.

MDHSS (Missouri Department of Health and Senior Services). 2015. 2015 Missouri fish advisory: a guide to eating Missouri fish. Accessed April 2015 http://health.mo.gov/living/environment/fishadvisory/pdf/fishadvisory.pdf

Melillo, J. M., T. C. Richmond, and G. W. Yohe, Eds. 2014. Climate change impacts in the United States: the third National Climate Assessment. U.S. Global Change Research Program. doi:10.7930/J0Z31WJ2.

Metropolitan St. Louis Sewer District (MSD). 2013. MSD launches Project Clear. Accessed February 2015. http://www.projectclerstl.org/2013/02/msd-launches-project-clear/

Millar, J. G., and M. S. Mahaffy. 1989. Background study on the environmental impacts of barge fleeting. EMTC 89/04. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin. Vii + 49 pp.

Miranda, L. E. 2005. Fish assemblages in oxbow lakes relative to connectivity with the Mississippi River. Transactions of the American Fisheries Society 134:480-489.

Miranda, L. E., and K. J. Killgore. 2013. Entrainment of shovelnose sturgeon by towboat navigation in the Upper Mississippi River. Journal of Applied Ichthyology 29:316-322.

Morgan II, R. P., R. E. Ulanowicz, V. J. Rasin, Jr., L. A. Noe, and G. B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis*, and white perch, *M. Americana*. Transactions of the American Fisheries Society 105:149-154.

Morrow, J. E. 2014. Early paleoindian mobility and watercraft: an assessment from the Mississippi River Valley. Midcontinental Journal of Archaeology 39(2):103-129.

Moser, H., P.J Hawkes, K.D. White, S. Mai, O.A. Arntsen, P. Gaufres, and G. Pauli. 2008. Waterborne transport, ports and waterways—A review of climate change drivers, impacts, responses and mitigation: Brussels, PIANC, 58 p.

Munawar, M., W. P. Norwood, and L. H. McCarthy. 1991. A method for evaluating the impacts of navigationally induced suspended sediments from the Upper Great Lakes Connecting Channels on primary productivity. Hydrobiologia 219:325-332.

Munger, P.R., G.T. Stevens, S.P. Clemence, D.J. Barr, J.A. Westphal, C.D. Muir, F.J. Kern, T.R. Beveridge, and J.B. Heagler, Jr. 1976. SLD Potamology Study (T-1). University of Missouri-Rolla, Institute of River Studies, Rolla, Missouri.

Nanson, G. C., A. von Krusenstierna, E. A. Bryant, and M. R. Renilson. 1993. Experimental measurements of river-bank erosion caused by boat-generated waves on the Gordon River, Tasmania. Regulated Rivers: Research and Management 9:1-14.

Nestler, J. M., D. L Galat, and R. A. Hrabik. 2016. Side channels of the impounded and Middle Mississippi River: opportunities and challenges to maximize restoration potential. ERDC/EL CR-16-4, U.S. Army Engineer Research and Development Center: Vicksburg, MS. 42 pp. + Appendixes A-D.

Newton, T. J., S. J. Zigler, J. T. Rogala, B. R. Gray, M. Davis. 2011. Population assessment and potential functional roles of native mussels in the Upper Mississippi River. Aquatic Conservation: Marine and Freshwater Ecosystems 21:122-131.

Nielsen, L. A., R. J. Sheehan, D. J. Orth. 1986. Impacts of navigation on riverine fish production in the United States. Polish Archives of Hydrobiology 33:277-294.

Niles, J.M. and K.J. Hartman. 2009. Larval fish use of dike structures on a navigable river. North American Journal of Fisheries Management. 29: 1035-1045.

Niles, J. M., and K. J. Hartman. 2011. Temporal distribution and taxonomic composition differences of larval fish in a large navigable river: a comparison of artificial dike structures and natural habitat. River Research and Applications 27:23-32.

NOAA (National Oceanic and Atmospheric Administration). 2014. National Weather Service Forecast Office. Accessed October 2014. http://www.nws.noaa.gov/climate/local_data.php?wfo=lsx

Nord, A.E., and J.C. Schmulbach. 1973. A comparison of the macroinvertebrate attached communities in the unstabilized and stabilized Missouri River. Proceedings, South Dakota Academy of Science 52:127-139.

Norris, F. T. 1997. Where did the villages go? Steamboats, deforestation, and archaeological loss in the Mississippi Valley. Pp. 73-89. *In:* A. Hurley (ed.). Common Fields. An Environmental History of St. Louis, Missouri. Historical Society Press, St. Louis, Missouri.

Norris, F. T. 2003. Historical Shipwrecks on the Middle Mississippi and Lower Illinois Rivers. Curation and Archives Analysis Branch, U. S. Army Corps of Engineers, St. Louis District.

Norris, F. T. and T. R. Pauketat. 2008. A pre-Columbian map of the Mississippi? Southeastern Archaeology 27(1):78-92.

Odum, M. C., D. J. Orth, and L. A. Nielsen. 1992. Investigation of barge-associated mortality of larval fishes in the Kanawha River. Virginia Journal of Science 43:41-45.

Oesch, R.D. 1995. Missouri naiads: a guide to the mussels of Missouri. Missouri Department of Conservation, Jefferson City, MO.

Paillex, A, S. Dolédec, E. Castella, and S. Mérigoux. 2009. Large river floodplain restoration: predicting species richness and trait responses to the restoration of hydrological connectivity. Journal of Applied Ecology 46:250-258.

Parchure, T. M., W. H. McAnally, and A. M. Teeter. 2000. Wave-induced sediment resuspension near the shorelines of the Upper Mississippi River system. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 20.

Parmalee, P. W. 1967. The fresh-water mussels of Illinois. Illinois State Museum Popular Science Series 8:1-108.

Payne, B.S., C.R. Bingham, and A.C. Miller. 1989. Life history and production of dominant larval insects on stone dikes in the Lower Mississippi River. Lower Mississippi River Environmental Program Report 18. U.S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, Mississippi.

Pennington, C.H., J.A. Baker, and M.E. Potter. 1983. Fish populations along natural and revetted banks on the Lower Mississippi River. North American Journal of Fisheries Management 3: 204-211.

Pennington, C. H., S. S. Knight, and M. P. Farrell. 1985. Response of fishes to revetment placement. Arkansas Academy of Science Proceedings 39:95-97.

Pflieger, W. L. 1997. The Fishes of Missouri. Missouri Department of Conservation, Jefferson, City, MO. 372 pp.

Phelps, Q. E., S. J. Tripp, D. P. Herzog, and J. E. Garvey. 2014. Temporary connectivity: The relative benefits of large river floodplain inundation in the lower Mississippi River. Restoration Ecology DOI: 10.1111/rec/12119.

Pitlo, J.Jr. 1987. Standing stock of fishes in the upper Mississippi River. Iowa Department of Natural Resources, Fish Technical Section, Upper Mississippi River Conservation Committee, Rock Island, IL.

Platner, W. S. 1946. Water quality studies of the Mississippi River. U.S. Fish and Wildlife Service Special Science Report 30. 77 pp.

Poizat, G., and D. Pont. 1996. Multi-scale approach to species–habitat relationships: juvenile fish in a large river section. Freshwater Biology *36*:611-622.

Pokrefke, T. J., C. Berger, J. P. Rhee, S. T. Maynord. 2003. Tow-induced backwater and secondary channel sedimentation, Upper Mississippi River System. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 41. 47 pp. + Appendix A-C.

Popper, A. N., and M. C. Hastings. 2009a. The effects of anthropogenic sources of sound on fishes. Journal of Fish Biology 75:455-489.

Popper, A. N., and M. C. Hastings. 2009b. The effects of human-generated sound on fish. Integrative Zoology 4:43-52.

Poulton, B. C. and A. L. Allert. 2012. An evaluation of the relative quality of dike pools for benthic macroinvertebrates in the lower Missouri River, USA. River Research and Applications 28:1658-1679.

Preiner, S., I. Drozdowski, M. Schagerl, F. Schiemer, and T. Hein. 2008. The significance of side-arm connectivity for carbon dynamics of the River Danube, Austria. Freshwater Biology 53:238-252.

Ragland, D. V. 1974. Evaluation of three side channels and the main channel border of the Middle Mississippi River as fish habitat. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Contract Report Y-74-l. 63 pp + Appendix.

Reine, K., and D. Clarke. 1998. Entrainment by hydraulic dredges–A review of potential impacts. Technical Note DOER-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Reine, K. J., and C. Dickerson. 2014. Characterization of underwater sounds produced by a hydraulic cutterhead dredge during maintenance dredging in the Stockton Deepwater Shipping Channel, California. U.S. Army Corps of Engineers, Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. ERDC TN-DOER-E38. 23 pp.

Reine, K. J., D. Clarke, and C. Dickerson. 2014a. Characterization of underwater sounds produced by hydraulic and mechanical dredging operations. Journal of the Acoustical Society of America 135:3280-3294.

Reine, K. J., D. Clarke, C. Dickerson, and G. Wikel. 2014b. Characterization of underwater sounds produced by trailing suction hopper dredges during sand mining and pump-out operations. U.S. Army Corps of Engineers, Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. ERDC/EL TR-14-13. x + 96 pp.

Remo, J. W. F., A. Khanal, and N. Pinter. 2013. Assessment of chevron dikes for the enhancement of physical-aquatic habitat within the Middle Mississippi River, USA. Journal of Hydrology 501:146-162.

Sarà, G., J. M. Dean, D. D'Amato, G. Buscaino, A. Oliveri, S. Genovese, S. Ferro, G. Buffa, M. Lo Martire, and S. Mazzola. 2007. Effect of boat noise on the behaviour of bluefin tuna *Thunnus thynnus* in the Mediterranean Sea. Marine Ecology Progress Series 331: 243-253.

Sauer, J. 2004. Multiyear synthesis of the macroinvertebrate component from 1992 to 2002 for the Long Term Resource Monitoring Program. 2004. Final report submitted to U.S. Army Corps of Engineers from the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, December 2004. Technical Report LTRMP 2004-T005. 31 pp. + Appendixes A–C.

Savino, J. F., M .A. Blouin, B. M. Davis, P. L. Hudson, T. N. Todd, and G. W. Fleischer. 1994. Effects of pulsed turbidity and vessel traffic on lake herring eggs and larvae. Journal Great Lakes Research 20:366-376.

Scheaffer, W.A., and J.G. Nickum. 1986. Backwater areas as nursery habitats for fishes in Pool 13 of the Upper Mississippi River. Hydrobiologia 136:131-140.

Schloesser, J. T., C. P. Paukert, W. J. Doyle, T. D. Hill, K. D. Steffensen, and V. H. Travnichek. 2012. Fish assemblages at engineered and natural channel structures in the lower Missouri River: implications for modified dike structures. River Research and Applications 28: 1695-1707.

Schneider, B. 2012. Changes in fish use and habitat diversity associated with placement of three chevron dikes in the Middle Mississippi River. M.S. thesis, Southern Illinois University Edwardsville.

Scholik, A. R., and H. Y. Yan. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63:203-209.

Schramm, H. D., Jr., and W. M. Lewis. 1974. Study of Importance of backwater chutes to a riverine fishery. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Contract Report Y-74-4.

Schramm, H.L., Jr., L.H. Pugh, M.A. Eggleton, and R.M. Mayo. 1998. Lower Mississippi River Fisheries Investigations 1996 Annual Report. Report prepared by the Mississippi Cooperative Fish and Wildlife Research Unit for the Lower Mississippi Valley Division, U.S. Army Corps of Engineers.

Schramm, Jr., H. L., and M. A. Eggleton. 2006. Applicability of the flood-pulse concept in a temperate floodplain river ecosystem: thermal and temporal component. River Research and Applications 22:543-553.

Schramm, Jr., H. L., M. S. Cox, T. E. Tietjen, and A. W. Ezell. 2009. Nutrient dynamics in the lower Mississippi River floodplain: comparing present and historic hydrologic conditions. Wetlands 29:476-487.

Sebastianutto, L. M. Picciulin, M. Costantini, and E. A. Ferrero. 2011. How boat noise affects an ecologically crucial behavior: the case of territoriality in *Gobius cruentatus* (Gobiidae). Environmental Biology of Fishes 92:207-215.

Sheehan, R.J., P. S. Wills, M. A. Schmidt, and J. M. Hennessy. 2004a. Determination of the fate of fish displaced from low-velocity habitats at low temperatures. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 32.

Sheehan, R. J., P. S. Wills, M. Schmidt, and J. M. Hennessy. 2004b. Determination of tolerance of fish in low-velocity habitats to hydraulic disturbance at low temperatures. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 33.

Shields, Jr., F. D. 1995. Fate of Lower Mississippi River habitats associated with river training dikes. Aquatic Conservation and Freshwater Ecosystems 5:97-108.

Siegrest, J.M., and S.P. Cobb. 1987. Evaluation of bird and mammal utilization of dike systems along the Lower Mississippi River. USACE Lower Mississippi River Environmental Program. Report 10.

Simons, D. B., S. A. Schumm, and M. A. Stevens. 1974. Geomorphology of the Middle Mississippi River. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Contract Report Y-74-2. 110 pp + Transparent Overlays.

Simons, J. H. E. J., C. Bakker, M. H. I. Schropp, L. H. Jans, F. R. Kok, and R. E. Grift. 2001. Man-made secondary channels along the River Rhine (The Netherlands); results of post-project monitoring. Regulated Rivers: Research & Management 17:473-491.

Simpson, S. D., J. Purser, and A. N. Radford. 2014. Anthropogenic noise compromises antipredator behavior in European eels. Global Change Biology doi: 10.1111/gcb.12685

Slabbekoorn, H, N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A. N. Popper. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution 25:419-427.

Smart, M. M., R .G. Rada, D. N. Nielsen, and T. O. Clafin. 1985. The effect of commercial and recreational traffic on the resuspension of sediment in navigation pool 9 on the Upper Mississippi River. Hydrobiologia 126:263-274.

Smith, M., and T. M. Keevin. 1998. Achene morphology, production and germination, and potential for water dispersal in *Boltonia decurrens* (decurrent false aster), a threatened floodplain species. Rhodora 100:69-81.

Smith, M., T. Keevin, P. Mettler-McClure, and R. Barkau. 1998. Effects of the flood of 1993 on *Boltonia decurrens*, a rare floodplain plant. Regulated Rivers: Research & Management 14:191-202.

Smith, M. E., A. S. Kane, and A. N. Popper. 2004. Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). Journal of Experimental Biology 207:427–435.

Smith, P. W., A. C. Lopinot, and W. L. Pflieger. 1971. A distributional atlas of Upper Mississippi River fishes. Illinois Natural History Survey, Biological Notes 73:1-20.

Söhngen, B., J. Koop, S. Knight, J. Rythönen, P. Beckwith, N. Ferrari, J. Iribarren, T. Keevin, C. Wolter, S. Maynord. 2008. Considerations to Reduce Environmental Impacts of Vessels. Permanent International Navigation Congress (PIANC) Report Series #99: 113 pp. + CD Appendices.

Solomon, R. C., J. H. Johnson, C. R. Bingham, and B. K. Colbert. 1974. Physical, biological and chemical inventory and analysis of selected dredged and disposal sites, Middle Mississippi River. U.S. Army Engineer Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, MS. Miscellaneous Paper Y-74-6. 75 pp + Appendixes.

Southall, P. D., and W. A. Hubert. 1984. Habitat use by adult paddlefish in the Upper Mississippi River. Transactions of the American Fisheries Society 113:125-131.

Sparks, R. E., and K. D. Blodgett. 1985. Effects of fleeting on mussels. Illinois Natural History Survey, Aquatic Biology Technical Report, 1985(8). 94 pp.

Stefan, H. G., and M. J. Riley. 1985. Mixing of a stratified river by barge tows. Water Resources Research 21:1085-1084.

Theiling, C. H., C. Korschgen, H. De Haan, T. Fox, J. Rohweder, and L. Robinson. 2000. Habitat Needs Assessment for the Upper Mississippi River System: Technical Report U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. Report prepared for U.S. Army Corps of Engineers, St. Louis District. 248 pp.

Tiemann, J. 2014. Freshwater mollusks of the middle Mississippi River. Illinois Natural History Survey Prairie Research Institute, Technical Report 2014 (03). 70 pp.

Todd, B. L., F. S. Dillon, and R. E. Sparks. 1989. Barge effects on channel catfish. Illinois Natural History Survey, Aquatic Ecology Technical Report 89/5, Champaign, Illinois.

Tripp, S., D. Herzog, S. Reinagel, and J. McMullen. 2012. Final Report: Missouri Commercial Fish Harvest 2000-2012. Missouri Department of Conservation, Jefferson City, Missouri.

Tucker, J., and C. Thieling. 1999. Freshwater mussels. In: Ecological Status and Trends of the Upper Mississippi system, Lubinski, K., and C. Theiling (Eds.). U.S. Geological Survey Report LTRMP 99-T001, La Crosse, WI. Accessed September 2014. http://www.umesc.usgs.gov/reports_publications/status_and_trends.html

Tuttle, M. C. and S. R. James, Jr. 2005. Limited Inventory of Historic Steamboat Losses on the lower Mississippi River within the Memphis District. Panamerican Consultants, Inc., Memphis.

UEC (Union Electric Co.). 1979. Rush Island Plant Evaluation of Cooling Water Intake Impacts on the Mississippi River. Union Electric Co. Environmental Services Department, St. Louis, MO.

Uijttewaal, W. S. J., Lehmann, D., and A. van Mazijk. 2001. Exchange processes between a river and its groyne fields: model experiments. Journal of Hydraulic Engineering 127:928-936.

UNFCCC (United Nations Framework Convention on Climate Change). 2014. United Nations Framework Convention on Climate Change glossary. Accessed June 2014. http://unfccc.int/essential_background/glossary/items/3666.php

University of Memphis. 1998. Accidents and hazardous spills analysis for Upper Mississippi River Basin. Transportation Studies Institute, prepared for the U.S. Army Corps of Engineers, Rock Island District.

USACE (U.S. Army Corps of Engineers). 1976. Final Environmental Statement: Mississippi River Between the Ohio River and Missouri Rivers (Regulating Works). St. Louis District, St. Louis, Missouri.

USACE (U.S. Army Corps of Engineers). 1978. Effects of Dredging and Disposal on Aquatic Organisms. Technical Report DS-78-5. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

USACE (U.S. Army Corps of Engineers). 1983. Dredging and dredged material disposal. Engineer Manual 1110-2-5025. U.S. Army Corps of Engineers, Washington, DC.

USACE (U.S. Army Corps of Engineers). 1985. Final Supplement I to the Final Environmental Impact Statement of March 1976: Operation and Maintenance Pools 24, 25, 26, Mississippi and Illinois Rivers. St. Louis District, St. Louis, Missouri.

USACE (U.S. Army Corps of Engineers). 1990. Final Regulatory Report and Environmental Impact Statement: Commercial Dredging Activities on the Kansas River, Kansas. January 1990.

USACE (U.S. Army Corps of Engineers). 1995. Environmental River Engineering on the Mississippi. U.S. Army Corps of Engineers, St. Louis District.

USACE (U.S. Army Corps of Engineers). 1999a. Middle Mississippi River Side Channels: A Habitat Rehabilitation and Conservation Initiative. U.S. Army Corps of Engineers, St. Louis District. 31 pp. + Appendices.

USACE (U.S. Army Corps of Engineers). 1999b. Tier I biological assessment for operation and maintenance of the Upper Mississippi River navigation project within the St. Paul, Rock Island, and St. Louis Districts. USACE, Rock Island, IL.

USACE (U.S. Army Corps of Engineers). 2004. Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study. U.S. Army Corps of Engineers, St. Paul, Rock Island, and St. Louis Districts.

USACE (U.S. Army Corps of Engineers). 2004. Upper Mississippi River System Flow Frequency Study. http://www.mvr.usace.army.mil/Portals/48/docs/FRM/UpperMissFlowFreq/Upper%20Mississippi%20River%20System%20Flow%20Frequency%20Study%20Main%20Report.pdf

USACE (U.S. Army Corps of Engineers). 2011. Analysis of the effects of bendway weir construction on channel cross-sectional geometry. U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

USACE (U.S. Army Corps of Engineers). 2012a. Devils Island offset dikes: pre- and post-construction monitoring completion report. U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

USACE (U.S. Army Corps of Engineers). 2014a. Final Environmental Assessment with Finding of No Significant Impact: Regulating Works Project, Dogtooth Bend Phase 5, Middle Mississippi River Miles 40.0-20.0, Alexander County, IL, Mississippi and Scott Counties, MO. U.S. Army Corps of Engineers, St. Louis District.

USACE (U.S. Army Corps of Engineers). 2014b. Final Environmental Assessment with Finding of No Significant Impact: Regulating Works Project, Eliza Point/Greenfield Bend Phase 3, Middle Mississippi River Miles 4-0, Alexander County, IL, Mississippi County, MO. U.S. Army Corps of Engineers, St. Louis District.

USACE (U.S. Army Corps of Engineers). 2014c. Final Environmental Assessment with Finding of No Significant Impact: Regulating Works Project, Mosenthein/Ivory Landing Phase 4, Middle Mississippi River Miles 175-170, St. Clair County, IL, St. Louis City, MO. U.S. Army Corps of Engineers, St. Louis District.

USACE (U.S. Army Corps of Engineers). 2014e. Waterborne commerce of the United States. U.S. Army Corps of Engineers Navigation Data Center Waterborne Commerce Statistics Center. Accessed July 2016. http://www.navigationdatacenter.us/wcsc/wcsc.htm

USACE (U.S. Army Corps of Engineers). 2015a. Dredge & Channel Maintenance. Accessed March 2015. http://www.mvs.usace.army.mil/Missions/Navigation/Dredge_Channel_Maintenance.aspx

USACE (U.S. Army Corps of Engineers). 2015b. Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Water Resources Region 07, Upper Mississippi. Civil Works Technical Report, CWTS-2015-13, USACE, Washington, DC.

USACE (U.S. Army Corps of Engineers). 2015c. Final Environmental Assessment with Finding of No Significant Impact: Regulating Works Project, Mouth of the Meramec, Mosenthein Reach – Ivory Landing, Phase V, RM 160-162.5, Monroe County, IL, St. Louis County, MO, on the Middle Mississippi River System. U.S. Army Corps of Engineers, St. Louis District.

USACE (U.S. Army Corps of Engineers). 2015d. Expert opinion elicitation for USACE St. Louis District Regulating Works. USACE Risk Management Center, Pittsburgh, PA.

U.S. Census Bureau. 2014. 2014 American Community Survey 5-year estimates. Data downloaded through the Missouri Census Data Center. Accessed July 2016. http://mcdc.missouri.edu/

USEPA (U.S. Environmental Protection Agency). 2014. Glossary of climate change terms. Accessed June 2014. http://www.epa.gov/climatechange/glossary.html.

USEPA (U.S. Environmental Protection Agency). 2016. Draft inventory of U.S. greenhouse gas emissions and sinks: 1990-2014. USEPA, 430-R-16-002, Washington, DC.

USEPA (U.S. Environmental Protection Agency) and USACE (U.S. Army Corps of Engineers). 1998. Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual. Inland Testing Manual. EPA-823-B-98-004, Washington, DC.

USFWS (U.S. Fish and Wildlife Service). 2000. Biological opinion for the operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River System. U. S. Department of the Interior, Fort Snelling, Minnesota.

USFWS (U.S. Fish and Wildlife Service). 2007. National Bald Eagle Management Guidelines. U.S. Fish and Wildlife Service, Arlington, VA.

USFWS (U.S. Fish and Wildlife Service). 2008. Three year summary age and growth report for Sicklefin Chub (*Macrhybopsis meeki*). Pallid Sturgeon population assessment project and associated fish community monitoring for the Missouri River. Report prepared for the U.S. Army Corps of Engineers – Northwest Division.

USFWS (U.S. Fish and Wildlife Service). 2015. Middle Mississippi River National Wildlife Refuge, Illinois and Missouri. Accessed January 2015. http://www.fws.gov/refuge/Middle_Mississippi_River/about.html and http://www.fws.gov/uploadedFiles/MiddleMissBrochure.pdf

USGAO (U.S. Government Accountability Office. 2012. Mississippi River: Actions are needed to help resolve environmental and flooding concerns about the use of river training structures. Government Printing Office, Washington, D.C. GAO-12-41.

USGS (U.S. Geological Survey). 1999. Ecological status and trends of the Upper Mississippi River System 1998: A report of the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. LTRMP 99-T001. 236 pp.

USGS (U.S. Geological Survey). 2014a. Upper Mississippi River Restoration Program Long Term Resource Monitoring element fishery database. Accessed September 2014. http://www.umesc.usgs.gov/data_library/fisheries/fish1_query.shtml

USGS (U.S. Geological Survey). 2014b. Upper Mississippi River Restoration Program Long Term Resource Monitoring element land cover/use data. Accessed January 2016. http://www.umesc.usgs.gov/data_library/land_cover_use/land_cover_use_data.html

USPHS (U.S. Public Health Service). 1958. Transcript of conference. Pollution of interstate waters: Mississippi River, St. Louis Metropolitan Area. 121 pp + Appendix.

Van der Schalie, H., and A. van der Schalie. 1950. The mussels of the Mississippi River. American Midland Naturalist 44:448-466.

Vasconcelos, R. O., M. C. P. Amorim, and F. Ladich. 2007. Effects of ship noise on the detectability of communication signals in the Lasitanian toadfish. The Journal of Experimental Biology 210:2104-2112.

Voellmy, I. K., J. Purser, D. Flynn, P. Kennedy, S. D. Simpson, and A. N. Radford. 2014. Acoustic noise reduces foraging success in two sympatric fish species via different mechanisms. Animal Behaviour 89:191-198.

Wagner, Mark J. 2003. The Flatboat America (11Pu280): An Early Nineteenth Century Flatboat Wreck in Pulaski County, Illinois. Center for Archaeological Investigations, Southern Illinois University Carbondale.

Watson, C.C., D.S. Biedenharn, and C.R. Thorne. 2013a. Analysis of the impacts of dikes on flood stages in the Middle Mississippi River. Journal of Hydraulic Engineering 139:1071-1078.

Watson, C.C., R.R. Holmes, and D.S. Biedenharn. 2013b. Mississippi River streamflow measurement techniques at St. Louis, Missouri. Journal of Hydraulic Engineering 139:1062-1070.

WEST Consultants, Inc. 2000. Upper Mississippi River and Illinois Waterway Navigation Feasibility Study – Cumulative Effects Study, Volumes 1-2. Prepared by WEST Consultants, Inc. for the U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois.

White, K., J. Gerken, C. Paukert, and A. Makinster. 2010. Fish community structure in natural and engineered habitats in the Kansas River. River Research and Applications 26: 797-805.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-9.

Wolter, C., and R. Arlinghaus. 2003. Navigation impacts on freshwater fish assemblages: the ecological relevance of swimming performance. Reviews in Fish Biology and Fisheries 13:63-89.

Wolter, C., and A. Bischoff. 2001. Seasonal changes of fish diversity in the main channel of the large lowland river Oder. Regulated Rivers: Research and Management 17:595-608.

Wolter, C., R. Arlinghaus, A. Sukhodolov, and C. Engehardt. 2004. A model of navigation-induced currents in inland waterways and implications for juvenile fish displacement. Environmental Management 34:656-668.

Würsig, B., C. R. Greene, and T. A. Jefferson. 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. Marine Environmental Research 49: 79-93.

Wysocki, L. E., J. P. Dittami, and F. Ladich. 2006. Ship noise and cortisol secretions in European freshwater fishes. Biological Conservation 128:501-508.

Yossef, M.F.M. 2002. The effect of groynes on rivers – literature review. Delft University of Technology, Delft, Netherlands.

Yossef, M., and H. de Vriend. 2011. Flow details near river groynes: experimental investigation. Journal of Hydraulic Engineering 137:504-516.

Ziegler, S. J., T. J. Newton, M. Davis, and J. T. Rogala. 2012. Patterns in species richness and assemblage structure of native mussels in the Upper Mississippi River. Aquatic Conservation: Marine and Freshwater Ecosystems 22:577-587.

Index

Appendix A: Effects of RTS on Flood Levels

Summary of Research on the Effects of River Training Structures on Flood Levels

1. Introduction

An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research includes numerical and physical models as well as analyses of historic gage data, velocity data, and cross sectional data. In addition to continued monitoring and analysis, the U.S. Army Corps of Engineers (Corps) has conducted a literature review of all available literature on the impact of river training structures on flood levels. A summary of research on the topic is detailed below. Based on an analysis of this research by the Corps and other external reviewers, the District has concluded that river training structures do not impact flood levels.

2. Studies concluding no impact on flood levels

2.1 Historic Research

One of the early studies specifically addressing the effect of river training structure construction on water surfaces was conducted during the extreme high water of June and July 1935 (Ressegieu 1952). This study was prompted by the differences in observed streamflow for equal stages following the transfer of streamgaging responsibility from the Corps to the United States Geological Survey (USGS) in March 1933. When observed field data showed a major change in the stage for which a specific discharge was passing, the Corps and USGS initiated a study to determine the cause. This study addressed the accuracy of the standard equipment and method of observation between the two agencies. Similar simultaneous streamflow studies were conducted between 1935 and 1948. In 1952, the results of all of the studies were analyzed and it was concluded that, on average, the discharges measured by the Corps generally exceeded those measured by the USGS by zero percent at mean stage to slightly more than ten percent at high stages. Ressegieu (1952) concluded that "the reduction in floodway capacity was not an actual physical reduction but an apparent reduction caused by a discrepancy in the accuracy of measuring streamflow by older methods and equipment". The conclusions by Ressegieu (1952) were analyzed along with new information and confirmed by Watson et al. (2013a).

Monroe (1962) conducted a comprehensive analysis of all factors which are believed to have had some effect on the St. Louis rating curve including: accuracy of discharge measurements, man-made obstructions and hydrology and hydraulic changes. Monroe (1962) observed a spread in stage for equivalent discharge at flows with stages of about 35 and 40 ft on the St. Louis gage. The analysis concluded that the change in stage for higher flows was due to the construction and raising of levees between 1935 and 1951. In an analysis of river training structures, Monroe (1962) found that "the contraction by permeable dikes has had a negligible effect on the increase in flood heights." A number of natural factors were found to affect stages for equivalent discharge including: season (water temperature), rapidity of rise of the flood wave, amount of flow contribution by the upper Mississippi River and the amount of bed material carried by the Missouri River.

In a comprehensive study of hydrologic, hydraulic, geologic and morphologic factors which relate to the Mississippi River downstream of Alton, IL, Munger et al. (1976) studied the changes in hydraulics on the Mississippi River resulting from river confinement by levees and the construction of river training structures. As was the case in previous studies using gage data, the reliability of early discharge data collected by the Corps was brought into question. In a study of velocity, stage and discharge data, Munger et al. (1976) concluded that “generalizations about the effect of dikes on stage-discharge relations are not justified.” When examining cross section shape and velocity distributions at the St. Louis gage, it was observed that there had been no striking changes in cross-section shape or velocity distributions at the section between 1942 and 1973.

Dyhouse (1985, 1995) found through numerical and physical modeling that published discharges for historic floods, including 1844 and 1903, were overestimated by 33 and 23 percent, respectively. Dyhouse concluded that the use of early discharge data collected by the Corps, including historic peak flood discharges in conjunction with streamflow measurements by the USGS, will result in incorrect conclusions.

Other reach scale numerical and physical models studying the effect of river training structures on water surfaces include USACE (1996) which used a Hydrologic Engineering Center (HEC-2) model used to analyze pre- and post- construction water surface elevations for the Nebraska Point Dike field on the Lower Mississippi River. For each cross section analyzed, the dike field construction lowered water surface elevations and reduced overbank discharges for the 50%, 20%, and 10% annual chance exceedance events. Xia (2009) used an Adaptive Hydraulics (AdH) model to study the changes in water surface resulting from the construction of a dike field. In this fixed bed analysis, Xia found that changes in water surface elevation due to the dikes was greatest at average flows and decreased with increasing and decreasing river flow. Azinfar and Kells (2007) developed a multiple function model to predict the drag coefficient and backwater effect of a single spur dike in a fixed bed. This study concluded that increasing submergence levels resulted in a decreasing backwater effect.

In a moveable bed model study conducted to develop structural alternatives for a power plant on the Minnesota River, Parker et al. (1988) measured water surface changes from a baseline for a series of dikes and determined that construction of the structures had a negligible effect on flood stages compared to calibration values. Yossef (2005) used a 1:40 scale fixed bed physical model of the Dutch River Waal to study the morphodynamics of rivers with groynes (dikes are referred to as groynes in other parts of the world including the Netherlands) including their effect on water surface. Yossef found that on the River Waal, the effect of groynes decreased with increasing submergence. It was also observed that the maximum possible water level reduction of the design flood (378,000 cfs) by lowering all of the groynes in the system was 0.06 meters (2.4 inches).

Other international research supports the conclusion that river training structures do not impact flood levels. An international technical working group made up of experts from around the world organized by PIANC, the World Association for Waterborne Transport Infrastructure, analyzed the impact of dikes on high discharges. It was determined that dikes can be designed to avoid high water impacts by having a top elevation below mean high water (similar to what is used on the Middle Mississippi River (MMR)). The report describes that although dikes may increase hydraulic resistance, the erosion of the low water bed may compensate for the water level upset entirely. The report also cites conventional practice that requires dikes to be designed so they do not increase stage during high discharges (PIANC 2009). As an engineering organization, the Corps follows this conventional practice and ethical code to ensure that dike construction does not cause an impact to public safety.

2.2 Updated Evaluations

2.2.1 Watson & Biedenharn

To update ongoing evaluations of the physical effects of river training structures, the Corps initiated a new study on the possible effect of these structures on water surfaces in 2008. This series of studies included an analysis of past research, an analysis of the available gage data on the MMR, an analysis of historic measurement technique and instrumentation and its effect on the rating curve, specific gage analysis, numerical and physical modeling. In addition to the research conducted by the Corps, the St. Louis District engaged with external technical experts in the fields of river data collection, river engineering, geomorphology, hydraulics and statistics.

In a review of historic streamflow data collected prior to the USGS, Watson & Biedenharn (2010) determined that pre-USGS data should be omitted for the following reasons: (1) It has been confirmed through simultaneous measurement comparisons that there is much uncertainty in the historic data due to differences in methodology and equipment; (2) there is much uncertainty with respect to the location of the discharge range; (3) there is insufficient measured data at the higher flow ranges to produce reliable specific gage records; and (4) the homogeneous data set containing all discharges collected by the USGS provides an adequate long-term, consistent record of the modern-day river system including periods of significant dike construction. A more detailed description of the limitations of early discharge measurements can be found in Watson et al. (2013a).

In their analysis, Watson & Biedenharn (2010) studied the specific gage records at the three rated gages on the MMR: St. Louis, Chester and Thebes. A summary of the analysis techniques used and a detailed analysis of the specific gage record at St. Louis can be found in Watson et al. (2013b). The analysis for the gage at Thebes was omitted due to the effect of backwater from the Ohio River. For each streamgage studied, the specific gage record was analyzed and compared with a record of river training structure construction for a reach extending 20 river miles downstream. All data used in their study were collected by the USGS and retrieved from the USGS website (http://www.usgs.gov).

Bankfull stage at the St. Louis gage is approximately +30 feet with a corresponding discharge of approximately 500,000 cubic feet per second (cfs). Flows below 400,000 cfs are contained within the top bank and flows above 700,000 cfs are well above the top-bank elevation. The time period 1933-2009 was studied. The top elevation of training structures in this reach was between +12 and +16 feet referenced to the St. Louis gage. All structures are completely submerged at discharges exceeding 280,000 cfs. In their analysis, Watson and Biedenharn (2010) found a statistically significant slightly decreasing trend in stages for streamflows below 200,000 cfs. In streamflows between 300,000 cfs and 500,000 cfs, a statistically significant horizontal trend in stages was observed. At 700,000 cfs a non-statistically significant, slightly increasing trend in stages was observed. The slight upward trend in stages at 700,000 cfs had considerable variability in the data and was strongly influenced by the 1993 flood.

Bankfull stage at the Chester gage is approximately +27 feet with a corresponding discharge of approximately 420,000 cfs. The time period 1942-2009 was studied. The top elevation of navigation structures in this reach was +14 to +17 feet referenced to the Chester gage. All structures are completely submerged at discharges exceeding 280,000 cfs. The only statistically significant trend found was a slightly decreasing trend for streamflows below 100,000 cfs. There was a horizontal trend for 200,000 and 400,000 cfs. There was a slightly increasing trend at 300,000 cfs. For both overbank flows, 500,000 cfs and 700,000 cfs, there were slight increasing trends in stage.

After a closer examination of the specific gage trends it was apparent that the long term stage trends for both St. Louis and Chester were not continuous and there was a shift in stages that occurred in 1973. This year was significant because (1) 1973 was marked by the occurrence of a major flood event that is documented as having significant impacts on the morphology of the MMR, (2) the year 1973 marked the end of a remarkably flood free period and (3) the pre-1973 period was characterized by extensive dike construction whereas the post-1973 period saw 50% less dike construction. When the record was broken into pre- and post-1973 sections, different trends in stage were observed. Prior to 1973 at all gages studied, there were no increasing stage trends for any of the flows. Post-1973 there were no increasing stage trends for within-bank flows at any of the gages. A slightly increasing stage trend occurred for overbank flows of 500,000 cfs (statistically significant) and 700,000 cfs (not statistically significant) at the Chester gage. A majority of the construction of river training structures on the Middle Mississippi was performed prior to 1973.

In conjunction with the specific gage record, Watson & Biedenharn (2010) and Watson et al. (2013) analyzed the record of training structure construction including an analysis of the top elevation of the structures. The typical top elevation of the structures was 10-16 feet below the top bank. Since the top elevation is so far below top-bank elevations, the most dramatic impacts of the structures should be in the low to moderate stages below top bank where the specific gage analysis revealed decreasing or no trends in stage (Sukhodolov, 2013; Watson & Biedenharn 2010; USGAO 2011, PIANC 2009, Azinfar & Kells 2007, Stevens et al. 1975, Chow 1959).

Watson & Biedenharn (2010) concluded that, "based on the specific gage records, there has been no significant increase in stages for within-bank flows that can be attributable to river training structure construction. Any increase in overbank flood stages may be the result of levees, floodplain encroachments, and extreme hydrologic events; and cannot be attributed to river training structures based solely on specific gage records."

2.2.2 United States Geological Survey

Huizinga (2009) conducted a specific gage analysis using the direct step method on only data collected by the USGS for the gages at St. Louis and Chester. Similar to Watson & Biedenharn (2010), an apparent decrease of stage with time for smaller, in bank discharges was observed at both the St. Louis and Chester gages. This decrease in stage was attributed to the construction of river training structures and/or a decrease in sediment load available for transport on the Mississippi River due to the construction of reservoirs on the main stem tributaries of the Mississippi River, particularly the Missouri River.

Huizinga (2009) found a slight increase in stage over time for higher flows at both St. Louis and Chester over the entire period of record. The transitional discharge was 400,000 cfs and 300,000 cfs for the St. Louis and Chester gages respectively. These discharges correspond to stages of +25 feet at St. Louis and +22 feet at Chester. At these stages the navigation structures are submerged by 5-13 feet. Huizinga (2009) attributed the slight increase in out of bank flows to the construction of levees and the disconnection of the river to the floodplains. Similar to Watson & Biedenharn (2010), Huizinga (2009) observed a shift occurring in the out of bank flows in the mid-1960s and attributed it to the completion of the Alton to Gale levee system which paralleled the entire Middle Mississippi River on the Illinois bank.

In an analysis of cross sectional data collected at the St. Louis and Chester gages, it was found that although the shape of the cross section had changed, the cross sectional area for moderate (400,000 cfs) and high (600,000 cfs) flows remained relatively constant throughout the period of record. The construction of river training structures immediately upstream of the Chester gage provided a case study on the effect of the absence and construction of structures on the cross section over time. Prior to the construction of the structures, the channel thalweg repeatedly shifted between the left and right banks. Following the construction of the structures, the cross sections displayed much less variability. An overall stabilizing effect of the structures was seen on the cross section for discharges of 100,000 cfs and 400,000 cfs. The cross sectional area for the first and last measurements of the period of record remained similar despite the river training structure construction upstream for all discharges.

Huizinga (2009) conducted a study of all rating curves developed for St. Louis and Chester, including those developed prior to 1933 by the Corps. When comparing daily values from the Corps from 1861-1927 to the original USGS rating in 1933 there appeared to be an abrupt change in the upper end of the ratings used before 1933. When these daily values developed by the Corps were adjusted to compensate for the overestimation of Corps discharge measurements detailed in the simultaneous discharge measurement studies between the Corps and USGS, the adjusted daily discharge values plotted in line with the original USGS rating. This study is further evidence of the overestimation of early discharges.

2.2.3 Statistical Evaluation

A critical review of the statistical analysis used to support specific gage analyses by Pinter et al., (2001) and Pinter and Thomas (2003) was conducted by V.A. Samaranayake (2009) from the department of Mathematics and Statistics at Missouri University of Science and Technology. Samaranayake (2009) concluded that the analysis presented by Pinter et al., (2001) and Pinter and Thomas (2003) did not support the conclusions that river training structures are increasing stages for higher discharges. In an evaluation of the two types of specific gage analysis, Samaranayake (2009) concluded that the direct step method was the most appropriate on the MMR. This is due to the data points being more homogeneous than those obtained from the rating method as far as variance is concerned and therefore they can be considered devoid of simultaneity bias and other such artifacts.

Samaranayake (2009) also found that, when using computed daily discharge values, the researcher is essentially recreating the original USGS rating curves used to obtain the daily discharges. The computed daily discharge data lacks the natural variability found in measured streamflow and can lead to conclusions that are due to artifacts created by errors in the original rating curves. This error is compounded by the fact that the USGS uses the same rating curves for several years producing results that, rather than being independent, are correlated across several years.

Samaranayake (2009) questioned the cause and effect relationship concluded by Pinter et al., (2001). The straight trend lines concluded by Pinter et al. (2001) revealed an increasing trend in stages reflecting a smooth gradual increase. Dike construction was not constant throughout history. The history of dike construction revealed much variability in magnitude throughout the period of record and did not directly correlate with the trends observed by Pinter (2001). Pinter et al., (2001) failed to prove that the relationship between stage trends on the MMR and dike construction was statistically significant.

2.2.4 Numerical and physical modeling studies

IIHR-Hydroscience & Engineering at the University of Iowa performed a series of hydrodynamic simulations of a recently constructed chevron field and dike extension using the United States Bureau of Reclamation Sedimentation and River Hydraulics Two- Dimensional (SRH-2D) modeling software (Piotrowski et al. 2012). Simulations studied the impact of the construction on water surfaces and the magnitude of natural variation on water surfaces. The results indicated that structures did not cause significant differences in reach- scale water surface elevations. The simulations also found that the differences in pre- and post- construction water surface elevations were less than the differences resulting from natural variability in two post-construction scenarios.

In a hydrodynamic study of the Vancill Towhead reach of the Middle Mississippi River, USACE (2016) evaluated the impact of a proposed set of river training structures on water surfaces for a discharge with a 1% annual chance of exceedance using an Adaptive Hydraulics (AdH) model. These structures included weirs and S-shaped dikes. The AdH model study incorporated sediment transport by evaluating water surfaces for pre- and post- construction scenarios from a physical sediment transport model. The study concluded that the proposed structures in the Vancill Towhead reach have no impact on water surfaces for a 1% of annual chance of exceedance (ACE) discharge of 949,011 cfs.

A physical sediment transport model at the University of Illinois, Urbana-Champaign was used to test the effect of submerged dikes and dike fields on water surfaces (Brauer 2013). The study tested flows and stages along a rating curve from ½ bankfull to a flow with a 0.5% annual chance exceedance. The study concluded that the magnitude of the effect of dikes on water surfaces was smaller than the natural variability in the stage and discharge relationship and decreased with increasing flow/submergence. The study also found that there was no direct cumulative effect for up to four structures.

2.2.5 Analysis of Updated Evaluations

Dike elevation information relative to the gages at St. Louis, Chester and Thebes are important in the interpretation of the specific gage results. On the MMR, dike elevations are well below the top-bank elevations and are submerged by over thirty feet during major floods. The most dramatic impacts of the dikes are expected to be observed in the low to moderate stages below top bank (Sukhodolov, 2013; Watson & Biedenharn, 2010; USGAO, 2011; PIANC, 2009; Azinfar & Kells, 2007; Stevens et al., 1975; Chow 1959). Once the flows spill overbank, the specific gage trends are impacted by changes in the floodplain including bridge abutments, levee construction, vegetation changes, etc. (Huizinga 2009, Heine and Pinter 2012). The effect of levees on the stages of larger floods is more pronounced than at lesser floods due to the additional conveyance loss of the floodplain (Simons et al. 1975, Heine and Pinter 2012).

The magnitude of the stage changes for overbank discharges observed by Watson & Biedenharn (2010), Watson et al. (2013), and Huizinga (2009) are consistent with the expected changes due to the construction of levees along the MMR. The Upper Mississippi River Comprehensive Plan (USACE 2008) calculated that levees contributed an increase of up to 2.9 feet at St. Louis, Missouri and up to 7.3 feet at Chester, Illinois of the 1% annual chance exceedance flood (100-year). The Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries report (USACE 1995) calculated that agricultural levees contributed an average peak stage increase of up to 4.9 feet on the MMR between St. Louis and Cape Girardeau. The Mississippi Basin Model (MBM) tests showed an increase of up to 4 feet compared to 1820 conditions, depending on discharge and location of flooding (Dyhouse 1995). The magnitude of levee impact is dependent on the roughness of the floodplain being protected. The values detailed above generally assume agricultural land.

Through the use of numerical and physical models, Piotrowski (2012) and Brauer (2013) reinforced the conclusion that river training structures do not impact flood flows. Additionally, Piotrowski (2012) and Brauer (2013) quantified the impact of natural variability in the channel on stage. Brauer (2013), through the use of a moveable bed model, demonstrated the importance of sediment transport and bed changes when analyzing how river training structures influence stages. In a study specific to the Middle Mississippi River, USACE (2016) found that construction of a series of S- dikes does not impact water surfaces for a discharge with a 1% annual chance of exceedance.

3. Analysis of research proposing a link between instream structures and an increase in flood levels.

In contrast to the above, there is research concluding that the construction of river training structures affects flood heights. The Corps has researched and analyzed all available literature that either purports or has been claimed to purport that river training structures increase flood heights.
Some of the analyses reaching this conclusion are presented in multiple papers. For instance, the analysis in Pinter et al. (2000) is the basis for Pinter et al. (2001a), Pinter et al. (2001b), Pinter et al. (2002), Pinter et al. (2003), Pinter and Heine (2005), Pinter et al. (2006b) and Szilagyi et al. (2008), so only Pinter et al. (2000) will be discussed in detail. Similarly, the analysis in Jemberie et al. (2008) is the basis for Pinter et al. (2008), Pinter (2009), and Pinter et al. (2010). Only Jemberie et al. (2008) will be discussed in detail.

The studies concluding there is a link between instream structure construction and an increase in flood levels have been grouped below into three categories: specific gage analysis, numerical simulations and physical fixed bed modeling.

3.1 Specific Gage Analysis

3.1.1 Description

Specific gage analysis is a graph of stage for a specific fixed discharge at a particular gaging location plotted against time (Watson et al 1999). The use of specific gage analysis is a simple and straightforward method to illustrate aggradation and degradational trends in a river or the response of a river to various alterations in the channel. Similar to most engineering analyses, the interpretation of specific gage records can be complex.

Specific gage analysis is an analysis of field data collected at gage locations along a river. The measurements that are collected at the gage locations are stage (water height), velocity (speed of the water) and cross sectional area (area of the channel). Velocity and area are multiplied together to calculate the discharge which is the volume of water passing a fixed location. It is important to ensure that the methodology and instrumentation used to collect velocity and cross sectional area has not changed during the period of record being examined. If it has changed, it is important to understand how those changes in instrumentation and methodology impact the results. As detailed above, the period of record on the MMR includes two distinctly different data sets.

3.1.2 Papers using specific gage analysis to link instream structure construction to flood level increases

The first use of specific gage analysis to link instream structures to apparent changes to the stage-discharge relationship on the Middle Mississippi River dates back to Stevens et al. (1975) and Belt (1975). Flaws in the source data, methodology and analysis used by Stevens et al. (1975) were addressed by Stevens (1976), Dyhouse (1976) Strauser & Long (1976) and Westphal & Munger (1976). These include the following: use of limited cross-sectional data from one highly engineered reach of the MMR (St. Louis harbor) to represent the entire Middle Mississippi River; use of the unmeasured 1844 flood discharge and the 1903 flood discharge, which was measured only at Chester and Thebes using a different analysis to draw sweeping conclusions; use of early inaccurate and overestimated discharge measurements in conjunction with more accurate contemporary measurements; and the lack of a direct correlation between dike construction and trends in water surface changes.

Through a comparison of trends in stage and streamflow measurements from floods from 1862-1904 to those after the 1980s, Criss & Shock (2001) concluded that stages have increased over time on rivers due to the construction of river training structures. Criss & Shock (2001) also analyzed rivers with and without river training structures to determine the impact structures have on water surfaces. The conclusions of Criss & Shock (2001) are driven by the comparison of two distinctly different data sets: early discharges collected by the Corps and contemporary discharges collected by the USGS. As detailed above, combining early Corps discharge measurements with contemporary USGS discharge measurements without appropriately accounting for the differences in accuracy of those measurements can result in flawed conclusions.

Pinter et al. (2000) used specific gage analysis to study changes to the stage-discharge relationship, cross-sectional area and velocity on the Middle Mississippi River. A specific gage trend was developed using daily stage and discharge data from the Middle Mississippi River gages at St. Louis, Chester, and Thebes. Pinter et al. (2000) concluded that engineering modifications on the Middle Mississippi River have caused changes in the cross-sectional geometry and flow regime leading to a decrease in stages for low discharges and rising stages for water levels starting at 40%-65% of bankfull discharge and above. Since their analysis shows rises in stages are greater for larger discharges, the authors conclude that the impact of the changes is greatest for large flood events.

One limitation of specific gage analysis is that it can only be performed on rated gages (gages with a discharge record). Jemberie et al. (2008) developed a refined specific gage approach attempting to overcome this limitation by developing “synthetic discharges” at stage only gages. The synthetic discharges were created by interpolating discharge values at nearby gages to create a stage- discharge relationship at stage only gages. Rare discharges were created using "enhanced interpolation" to formulate a continuous specific gage time series for large, rare discharges. The results of the refined specific gage study were that stages that correspond to flood discharges increased substantially at all stations consistent with what was documented by Pinter (2001).

3.1.3 Errors in specific gage papers

3.1.3.1 Use of a non-homogeneous data set

The analysis in Pinter et al. (2000) and Jemberie et al. (2008) includes data, assumptions and analysis techniques that have been brought into question by engineers and scientists within the Corps, USGS and academia. The period of record data set used by Pinter et al. (2000) and Jemberie et al. (2008) combines daily discharge measurements from rating curves developed by both the Corps and USGS. The use of daily discharge data from the entire period of record implies the assumption that the rating curves have been developed using the same methods throughout the period of record and the measured discharges used to develop the rating curves were collected similarly throughout the period of record. On the MMR, this assumption is not valid since the period of record of discharge measurements is two distinctly different data sets as discussed above.

In an effort to disprove the long standing joint conclusion of the Corps and USGS that Corps measurements overestimated discharges compared to the USGS standard used after 1933 (Ressegieu 1952, Huizinga 2009, Watson et al. 2013a, Dyhouse 1976, Dyhouse 1985, Dyhouse 1995, Dieckmann & Dyhouse 1998), Pinter (2010) analyzed 2,015 measurements collected by the Corps on the Middle Mississippi River. The author concluded that early Corps discharges were not overestimated but were, in fact, underestimated. Based on this conclusion, the author questions the adjustment of early data in the Upper Mississippi River System Flow Frequency Study and the flood frequencies and flood profiles used by the Corps on the Middle Mississippi River.

However, upon review and analysis, Pinter (2010) did not analyze a data set sufficient to prove this hypothesis. The source data used by the author, *Corps of Engineers, 1935, Stream-flow measurements of the Mississippi River and its Tributaries between Clarksville, MO., and the Mouth of the Ohio River 1866-1934*, included only early Corps measurements using different instruments and methodologies employed by the Corps. The author did not analyze any measurements collected using USGS instruments and methodology or compare any early Corps measurements to ones collected by the USGS.

3.1.3.2 Use of Daily Discharge Values

The analysis by Pinter et al. (2000) used daily discharge values instead of measured discharges. Daily discharge values are values of discharge that are extracted from the rating curve using a measured value of stage for a specified gage location. A rating curve is a relationship between stage and discharge that is developed by creating a smooth equation using observed measured data. Rating curves usually incorporate data from multiple years to develop their relationship and therefore are not reflective of the river for one particular year.

The use of daily discharge data over direct measured discharges for the creation of a specific gage record is discouraged by many experts including Stevens (1979), Samaranayake (2009), Huizinga (2009) and Watson and Biedenharn (2010). Stevens (1979) recommended that "measured discharges should gain quick acceptance over estimates obtained from rating curves because they reveal the relationship that exists between discharge and the controlling variables at the time of measurement." Samaranayake (2009) cautioned against the use of data obtained from rating curves since "such data lacks the natural variability one finds in actual data and can lead to conclusions that are due to the artifacts created by errors in the original rating curves." Watson and Biedenharn (2010) acknowledged that it is often tempting to use the computed daily discharge values since they increase the number of data points and improve the statistics of the rating curve, but caution that these values are not valid and risk masking actual trends.

3.1.3.3 Analysis of early Corps and USGS rating curve development

Compounding the issues with using daily discharge measurements is the use of rating curves developed by multiple agencies using different standards and practices. Over the sixty-six years between 1861-1927, the Corps created five independent rating curves for the St. Louis gage. Curves were developed for the time periods 1861-1881, 1882-1895, 1896-1915, 1916-1918 and 1919-1927. Each curve was created with discharges collected within that time period. In most cases, the discharge measurements were not collected continuously through the rating period. For example, the first rating period which spans 1861 to 1881 was created using only 181 discharge measurements. All but four of the measurements were made in 1880 and 1881 (Huizinga 2009).

The rating curves employed by the USGS (starting in 1933 in St. Louis) are not as static as the early ratings used by the Corps. USGS rating curves are often shifted and changed to account for changes in the shape, size, slope and roughness of the channel. To keep the ratings accurate and up to date, USGS technicians visit each streamgage about once every 6 weeks to measure flow directly. The USGS also emphasizes measuring extreme high and low flows since they are less common and can greatly impact the ends of the rating curve.

Regardless of whether the early Corps or contemporary USGS rating curves are used, daily discharge measurements extracted from a rating curve do not represent the characteristics of the river at the gage location for a particular year. To analyze changes over time it is recommended by many experts, including ones from academia and other federal agencies, to create independent annual rating curves using measured discharges all collected in a specific year or analyze measured discharges for specific discharge ranges over time.

3.1.3.4 Statistical Errors

There are significantly fewer points associated with the larger discharge values of the specific gage records than the more frequent discharges. For example, as of March 2014 there have been approximately 3,435 discharge measurements collected at the St. Louis gage since 1933. Only 253 measurements (7.4 percent) have been collected for flows above bankfull (500,000 cfs). Only 80 measurements (2.3 percent) have been collected for flows above 700,000 cfs. Forty percent of the measurements observed for flows greater than 700,000 cfs were collected during the 1993 flood.

When using the direct step method of specific gage analysis, the uncertainty for the flows with limited data is revealed in the statistics (Watson & Biedenharn 2010). Pinter et al. (2000) used the rating curve method of specific gage analysis using daily discharge which the author called "a powerful tool for reducing scatter in hydrologic time-series" (Pinter 2001). As with most dependent variable values predicted using a regression equation, the error in the regression equation is less close to the mean of the independent variable and increases toward the more extreme values (small and large discharge values). The net result is that Pinter et al. (2000) generated data that has varying degrees of error variance and the use of ordinary least squares estimation under such circumstances has led to incorrect results (Samaranayake 2009).

3.1.3.5 Physical Changes on the MMR

Inherent in the use of a specific gage that spans a long time period is the understanding that errors and inconsistencies associated with the measurement of discharge and stage are captured in the record. Substantial changes in the river, if not accounted for, would all render the specific gage record unreliable.

For example, Pinter et al. (2000) uses a single linear regression to represent the trend for a given discharge value curve. This is problematic since it does not accurately represent all the time periods in the record. There are shorter periods of time observed in the presented specific gage records when stages are decreasing rather than increasing, and the linear trend sorely misrepresents the observed changes. Other problems with this approach include major physical changes that occurred throughout the period of record which are reflected by changes in the stage-discharge record. These include the capture of the Kaskaskia River which shortened the MMR by 5 miles, the construction of reservoirs which reduced the sediment load in the MMR, and the construction of levees throughout the period of record including the completion of the Alton to Gale levee system.

3.1.3.6 Creation and use of "Synthetic Discharges" and "enhanced interpolation"

Much of the analysis of Jemberie et al. (2008) is similar to the analysis of Pinter et al. (2000) and has the same issues as described above. The new contributions of Jemberie et al. (2008) are the development of 'synthetic discharges' for unrated gages and 'enhanced interpolation' to calculate continuous specific-stage time series for rare discharges.

The development of 'synthetic discharges' is simply the development of a discharge record for gages where discharge was not measured by interpolating between rated gages. The purpose of creating a discharge record is so a specific gage analysis can be performed at that gage. Since the discharge record at the 'synthetic gages' is inherently dependent on the discharge record at the legitimately rated gages, the data at the 'synthetic' gages are not independent and should not be treated as such. The creation of a rating for the 'synthetic gages' incorporates an abundance of uncertainty due to the many assumptions that need to be made.

Compounding the problems with interpolating between gages to create a discharge value at an unrated gage is the use of daily discharges as the source data for the interpolation. As detailed above, daily discharges are not measured values. The use of daily discharge values incorporates more error and uncertainty into the fabricated rating at the 'synthetic gages'.

For rare high flows, the true rating curve for an unrated gage may be heavily influenced by levee overtopping or other phenomena which would only be reflected through discharge measurements. The author does not detail or account for the impact of the assumptions made on the 'data' created for the 'synthetic gages'.

The practice of using 'enhanced interpolation' to generate a continuous time series for a particular fixed discharge is not supported by the Corps and many other engineers and scientists. Similar to the 'synthetic gage' data, the data created using 'enhanced interpolation' is based off of an interpolation scheme and is not measured data. The fabricated values are dependent on the other values used to create the time series trend.

To create the data using 'enhanced interpolation' one must assume that the time series for Q and Q_t^* is continuous and linear. Watson et al. (2013b), Watson and Biedenharn (2010), Huizinga (2009) and Brauer (2009) have all shown that this assumption is not valid. Another assumption necessary is that there is only one specific stage value for each independent discharge, specifically at the highest and lowest discharges. Analyses of measured discharges have shown that stage is dependent not only on discharge but other physical characteristics of the channel (bed roughness, vegetation, sediment load, temperature, etc.). The use of 'enhanced interpolation' masks the natural variability in the relationship between stage and discharge.

Jemberie et al. (2008) does not make any attempt to verify the validity of the 'enhanced interpolation' technique by proving the relationship using stage and discharge relationships at rated gages.

3.1.4 Summary

A majority of the journal articles, technical notes, book chapters, and conference papers whose conclusions claim a link between instream structure construction and an increase in flood levels rely on specific gage analysis. The specific gage analyses that conclude that instream structures impact flood levels are all driven by the use of source data and methodology not supported by many engineers and scientists in the fields of river data collection, river engineering, geomorphology, hydraulics and statistics. Specific gage analysis studies conducted on the MMR also conclude that instream structures do not impact flood levels (Huizinga 2009, Watson & Biedenharn 2010 and Watson et al. 2013).

3.2 Papers using numerical simulations to link instream structure construction to flood level increases

3.2.1"Retro-Modeling"

Remo and Pinter (2007) developed a one-dimensional unsteady-flow "retro-model" of the Middle Mississippi River using historical hydrologic and geospatial data to assess the magnitude and types of changes in flood stages associated with twentieth century river engineering. Comparison of the retro-model results with the 2004 Upper Mississippi River System Flow Frequency Study (UMRSFFS) revealed increases in flood stages of 0.7 – 4.7 m. The difference in flood stages between the UMRSFFS and retro-model increased with increasing discharge.

3.2.1.1 Errors in "Retro-Modeling" studies

3.2.1.1.1 Source Data

The large stage differences between current and early discharge estimates are partly due to the use of incorrect discharge values for historic hydrographs and floods occurring prior to 1933 as discussed above. The retro-modeling period of 1900-1904 includes one major flood in 1903 and a small one in 1904. The original estimated historic discharge of 1,020,000 cfs at St. Louis is used for the peak of the 1903 flood. This flow was originally developed for St. Louis from discharge measurements made at Chester. Tests conducted with the Mississippi Basin Model in the late 1980s found that a match of the 1903 high water marks through the entire reach of stream at St. Louis occurred for a discharge of about 790,000 cfs. The actual value of the 1903 discharge at St. Louis is likely to be approximately 230,000 cfs (or 23 percent) less than the value used by Remo and Pinter (2007) in the model calibration (Dyhouse 1995).

3.2.1.1.2 Channel Roughness

Manning's 'n' is the value most often modified to achieve a calibration of the model results to known stages. Manning's 'n' represents the relative roughness of a channel. The larger the Manning's 'n' the more resistance there is to flow. Forcing a calibration of the high and incorrect discharge of the 1903 flood would require a surprisingly low 'n' value for the channel of about 0.02, as used by Remo and Pinter (2007). The authors observe that the 'n' values for the historical period were systematically at the lower end of the published ranges. In practice, this usually indicates a problem with the model geometry or input data.

The authors describe HEC-RAS as only allowing a single roughness coefficient value in the channel and separate values for the floodplains. The limitation of having "fixed" values was described as a source of model uncertainty. This statement by the authors is untrue — not only does HEC-RAS have the ability to vary the 'n' value horizontally across the cross sections, but it can also be varied for flow or season. All of these techniques are standard hydraulic engineering practice. Horizontal variation of the roughness may be necessary to generate reasonable model results and has a solid foundation in the literature, as noted by Remo and Pinter (2007).

3.2.1.1.3 Model Assumptions

One assumption that could affect model results is the absence of flows from tributaries in the model calibration. Another problematic model assumption is that land use in unmapped areas was forested. Large tracts of timber in the Mississippi Valley were harvested in the late 1800s and early 1900s. The 'retro-model' also does not appear to consider how under the natural (before levee construction) conditions, flood water entering the floodplain over natural levees likely returned to the channel through a series of backwater swamps and channels. This may explain the apparent tendency of the model to over predict stages on the falling limb of the hydrograph. This natural drainage system was likely altered during conversion of the floodplain to agricultural production.

3.2.1.2 Corps Conclusions and Analysis

The calibration of the "retro-model" has been questioned by the Corps due to the use of early Corps discharges, surprisingly low 'n' values used, and other model assumptions detailed above. Upon review and analysis, the Corps concludes that the surprisingly low Manning's roughness values were necessary to compensate for the overestimated flows used in the model and are not representative of the characteristics of the historic channel. To further verify model results and gain a full understanding of the physical processes driving the concluded increase in flood stage in Remo and Pinter (2007), the Corps has requested the authors provide the model, data or any other supporting materials, but the authors have refused to share this information with the Corps. Therefore, due to the concerns described above, the Corps does not support the conclusions in Remo and Pinter (2007).

3.2.2 Retro and Scenario Modeling

Remo et al. (2009) is an expansion of Remo and Pinter (2007). In addition to the comparison of the 'retro-model' to the UMRSFFS, Remo et al. (2009) run a series of scenario models to quantify the impact of levees, channel change and land cover. Remo et al. (2009) concluded that on the MMR in the "St. Louis Reach" (which extends from St. Louis just below the Eads Bridge to Commerce, MO) levees accounted for 0.1 – 1.0 m of increase in stage, changes in channel geometry accounted for a stage increase of 0.1-2.9 m, changes in total roughness accounted for a stage increase of 0.1 – 1.4 m, and changes in land cover accounted for a stage increase of up to 0.4 m.

Similar to the model effort of Remo and Pinter (2007), the Corps has attempted to work with the authors to verify the model results and gain a full understanding of the physical processes driving their concluded increase in flood stage. To date the authors have refused to provide a copy of the model and associated data used to develop the conclusions of Remo et al. (2009) for review by the Corps.

Remo et al. (2009) concludes that "changes in total roughness (channel and floodplain Manning's n) between the ca. 1900 retro-model and the values used in the UMRSFFS UNET model explained much of the increases in stage observed along St. Louis Study reach." The Corps believes these stage changes are due to errors in the modeling process as detailed above for Remo and Pinter (2007) and are not representative of physical changes on the MMR.

3.2.3 Theoretical Analysis

Huthoff et al. (2013) used a simplified theoretical analysis to test the impact of wing dikes on flood levels. This analysis used a simplified cross section to test three scenarios: with no wing dikes, with wing dikes without bed response, and with wing dikes including bed response. The overall channel discharge is calculated for each stage using Manning's equation for steady uniform flow. The discharge for separate flow compartments is calculated using the divided channel method. The Manning's roughness for the dike region is calculated using a flow resistance equation from Yossef (2004, 2005). The author concludes that although the roughness in the dike reach decreases with increasing water levels, the submergence is not great enough for the roughness to return to the base roughness. The authors conclude that the increase in stage for four times the average flow ($4Q_{ave}$) due to the wing dikes is 0.6 m, 0.7 m, 1.1 m and 0.6 m at St. Louis, Chester, Grand Tower and Thebes, respectively.

3.2.3.1 Errors in Theoretical Analysis

3.2.3.1.1 Applicability of Effective Roughness Equation

The theoretical analysis proposed by Huthoff et al. (2013) is an oversimplified method to quantify an extremely complex and dynamic hydraulic problem. The basis of this analysis is the effective 'n' value formula developed by Yossef (2004, 2005) which was developed using a fixed bed physical model scaled to represent a reach of the Dutch River Waal which has much different geometry, dike size, and dike spacing than those used on the Middle Mississippi River. The Middle Mississippi River is wider with smaller structures that are spaced further from each other. Although this relationship can be used to give insight into the effective roughness in the dike zone and submergence, it is only suitable to deduce trends rather than quantify accurate magnitudes of change.

3.2.3.1.2 Bank Roughness

As detailed in the editor's note, Huthoff et al. (2013) initially submitted a manuscript with an error in the calculation of Manning's roughness which resulted in an overestimation of the roughness by a factor of 10. Due to the theoretical model's sensitivity to the bank roughness value, this overestimation was the primary driver for the stage changes concluded. A simple correction of the calculation error with no additional manipulation in input data results in stage changes of -0.12 m at St. Louis, +0.21 m at Chester, +0.84 m at Grand Tower, and -0.00 m at Thebes for $4Q_{ave}$. In addition to correcting the error, the authors changed the input values of bank roughness, mean dike crest elevation, and assumed bed level changes. The impact of each of these input changes in the model was an increase in stage for $4Q_{ave}$.

The bank roughness values used in Huthoff et al. (2013) were much lower than what is typically used for the MMR and much lower than those used for the main channel. The authors used a combination of 'n' values from different sources: the bank values were arbitrarily taken from literature whereas the values for other zones were taken from a hydraulic model. This resulted in velocity distribution in the channel that had high velocities along the bank and lower velocities in the channel at high flow. This is contrary to observed and theoretical velocity patterns in an open channel (Chow 1959).

3.2.3.1.3 Model Verification

The model used in this analysis did not have adequate validation to prove that it has the ability to reproduce empirical results. The attempt of validation showed that the model matched the empirical values to which it was calibrated. The author did not validate the model to an independent observed flow, which is customary engineering practice. The author also did not attempt to verify the ability of the model to reproduce any flood flows.

3.2.3.2 Discussion

Since the relationship by Yossef (2004, 2005) was developed studying a river with geometry and structures very different to those used on the MMR, it cannot be used to quantify accurate magnitudes of change on the MMR. Although the model used by Huthoff et al. (2013) has many limitations preventing it from being used quantitatively, insight can be gained by the shape of the relationship between water level and dike roughness. The reduction of roughness with an increase in submergence is consistent with what has been observed by many scientists and engineers (Sukhodolov 2013; Watson & Biedenharn 2010; GAO 2011; PIANC 2009; Azinfar & Kells 2007; Stevens et al. 1975; Chow 1959) and in conflict with what has been concluded by Pinter (2000) and Remo & Pinter (2007).

3.2.4 Physical Fixed Bed Modeling

Azinfar and Kells (2009, 2008, and 2007) use the results of fixed bed physical model studies to analyze flow resistance and backwater effect of a single dike. The authors use the conclusions of Criss & Shock (2001), Pinter et al. (2001) and Pinter (2004) as a foundation for their research. The purpose of the analysis in Azinfar and Kells (2009, 2008, and 2007) was to "quantify the amount of backwater effect that occurs so that the impacts of spur dike construction can be determined by those charged with managing the river system."

Azinfar and Kells (2007) developed a multi-functional backwater model calibrated to fixed bed physical model studies by Oak (1992) to study the backwater effect due to a single spur dike in an open-channel flow. Parameters analyzed using the model include the spur dike aspect ratio (height/length), spur dike opening ratio (1-length/channel width), spur dike submergence ratio (water depth/height) and upstream Froude number. Azinfar and Kells (2007) found that the parameter that has the greatest effect on the drag coefficient of a spur dike was the submergence ratio— the more the structure is submerged, the less the drag coefficient and therefore the less impact it has on water surfaces. This conclusion is contrary to the conclusion of Pinter (2000) and Remo and Pinter (2007) that conclude that the impact of dikes on water surfaces increases with increasing discharge and are highest at flood stage.

Azinfar and Kells (2008) propose a predictive relationship developed in Azinfar and Kells (2007) that can be used to obtain a first-level estimate of the backwater effect due to a single, submerged spur dike in an open channel flow. Azinfar and Kells (2009) conclude that in a rigid flume an increase in blockage due to a spur dike is the main parameter responsible for an increase in the drag coefficient and associated flow resistance.

There is no debate that in a fixed bed scenario any channel blockage will produce a backwater effect. This is due to the decrease in cross sectional area resulting from the presence of the structure. The conclusions of Azinfar and Kells (2009, 2008, and 2007) reinforce why incorporating sediment transport is critical in having a full understanding of the impacts of dikes on water surfaces, particularly flood levels. The purpose of dikes is to induce bed scour and deepen the channel. Analysis of cross sectional changes on the Mississippi River has shown that once equilibrium is reached, although the dimensions of the channel may be different (i.e., deeper and narrower), the cross sectional area is preserved.

3.3 Papers using physical observations to link instream structure construction to flood level increases

Criss and Luo (2016) is an analysis of the December 2015/January 2016 flood on the Meramec and Middle Mississippi Rivers that presents arguments that although the Meramec Basin, lower Missouri River Basin and parts of the Mississippi River basin received record or near record rainfall, the record flooding observed in December 2015 and January 2016 was a result of isolation of the rivers from their floodplains by levee construction and channelization of the Mississippi River. The paper was submitted for publication within days after floodwaters had receded. The authors detail preliminary observations and do not present any analysis on instream structures and how they impact flood levels.

The Authors omit relevant data and analysis, mischaracterize the antecedent ground and river conditions, and evaluate incorrect data. The authors do not evaluate channel conveyance on the Mississippi River. Had they evaluated conveyance, the author would have recognized through a comparison of measured stage and discharge data that stages at Chester for the same discharges were lower in 2015 than in the 1993 and 1973 floods. For example, for a flow of 824,000 cfs at the Chester gage the observed stage on December 29, 2015 was 41.0 feet. The stages for similar discharges on July 14, 1993 (824,000 cfs) and on May 2, 1973 (833,000 cfs) were 43.13 feet and 42.36 feet respectively. The authors also mischaracterize the antecedent ground and river conditions. The St. Louis area received above normal rainfall throughout the month of December, resulting in record daily river stages. For example, on December 26, 2015, the St. Louis gage was nearly 1.5 feet above the previous record for this day set in 1982. The authors also use incorrect information in their analysis. For instance, the authors state that the stage on the Meramec at Pacific was slightly lower in 2015 than in 1982. This is not true; the stage at Pacific hit a new record of 33.42 on December 30, 2015, which surpassed the previous record of 32.71 on December 6, 1982.

Therefore, this analysis is not further considered by the Corps to prove the broad conclusion that river training structures impact flood heights.

4. Other studies provided to the Corps that do not link the construction of instream structures to increases in flood levels

Other journal articles, editorials and conference papers have been provided to the Corps at various times by the public, claiming to conclude that instream structures increase flood levels. However, the Corps has reviewed and analyzed these references and concluded that they have been incorrectly referenced as linking the construction of instream structures to increases in flood levels as follows:

1. Chen and Simmons (1986), Roberge (2002), Pinter et al. (2006a), Sondergaard and Jeppesen (2007), Theiling and Nestler (2010), and Borman et al. (2011) simply reference the research detailed in the aforementioned papers as background but do not present any new analysis.

2. Bowen et al. (2003), Wasklewicz et al. (2004), Ehlmann and Criss (2006), Criss and Vinston (2008), Criss (2009) and Pinter et al. (2012), Criss (2016) analyze flow frequency and/or propose changes to the way flow frequency is calculated. They do not present any new analysis linking instream structures to increasing flood levels.

3. Struiksma and Klaasen (1987), Ettema and Muste (2004), and Maynord (2006), are about physical modeling and model scaling and distortion and do not discuss instream structure construction or flood levels.

4. Pinter (2005) and Van Ogtrop et al. (2005) present arguments linking the construction of levees to increases in flood levels. These papers do not present any analysis on instream structures and how they impact flood levels.

5. Maher (1964) presents changes in river regime of the Mississippi River and the variations in rating curves with respect to time and stage. The analysis includes causes for some of the stage-discharge relationship changes. The author analyzes the changes of three reaches of the MMR over three different time periods. Maher (1964) concludes that “the construction of levees in the

Mississippi River floodplain during the period 1908-1927 has been the main factor in reducing floodway capacity to approximately 54% of the 1908 area. Between 1927 and 1943, when no additional levees were constructed, the floodway capacity remained practically constant, being reduced in area by only an additional ½ of 1%." Maher (1964) does not attempt to link the construction of instream structures to increases in flood levels.

6. Paz et al. (2010) describes a HEC-RAS model study of the Paraguay River and its tributaries with limited data.

7. Doyle and Havlick (2009) examines current infrastructure and current understanding of environmental impacts for different types of infrastructure. This paper discusses the impact of levees on flooding.

8. Remo et al. (2008) discusses a database compiled by the authors with hydrologic and geospatial data on the Mississippi, lower Missouri and Illinois rivers. No analysis is conducted or conclusions drawn.

9. Remo and Pinter (2007b) is a conference paper that discusses the database compiled by the authors detailed in Remo et al. (2008) and summarizes "retro-modeling" as a tool to analyze historic changes.

10. O'Donnell and Galat (2007) discusses river enhancement projects on the Upper Mississippi River and recommends improvement in management practices and project data collection, entry, management, and quality control/assurance across agencies.

11. Jai et al. (2005) used CCHE3D, a three-dimensional model for free surface turbulent flows developed at the National Center for Computational Hydroscience and Engineering, to study the helical secondary current and near-field flow distribution around one submerged weir. The model was validated using flow data measured during a physical model study conducted at the Coastal and Hydraulic Laboratory of ERDC. The models used in this study did not simulate sediment transport and channel change. Although water surface elevation contours are discussed near the submerged weir, the paper does not present a detailed analysis of the structures' impact on water surfaces.

12. Pinter et al. (2004) provides an evaluation of dredging on a particular reach of the Middle and Upper Mississippi River based on dredging records obtained from the USACE St. Louis District. Although references to the impact of river training structures on flood stages are made several times, Pinter et al. (2004) does not have any analysis, discussion or conclusions on the topic.

13. Smith and Winkley (1996) examine the response of the Lower Mississippi River to a variety of engineering activities. This paper presents a brief history of engineering investigation on the Lower Mississippi River, analyzes the impact of artificial cutoffs on the channel geometry and water surface profiles, analyzes the impact of channel alignment activities on channel

morphology and the apparent impact of all of the Lower Mississippi River engineering activities on sediment dynamics in the channel. There is no discussion or analysis by Smith and Winkley (1996) on how the construction of river training structures impacts flow levels.

14. Huang and Ng (2006) use a CCHE3D model calibrated to a fixed bed physical model to study basic flow structure around a single submerged weir in a bend. Conclusions are made on the near field changes in water surface. With the weir installed, the water surface elevation reflected the existence of the weir in the whole channel with an increase in the water surface elevation upstream of the weir due to an increase in resistance when the flow approaches the weir. Downstream of the weir the model found a decrease in water surface due to the acceleration of the flow after passing through the weir. Huang and Ng (2006) describe the changes in water surface as a "local effect." The scenario analyzed in Huang and Ng (2006) is for a single weir added to a fixed bed channel with no change in channel bathymetry, thus presenting an obstruction to flow. The author does not test flood flows or attempt to extrapolate his results to conclude that instream structures raise flood levels.

15. Clifford et al. (2002) evaluates the use of the SSIMM 3-D numerical model to simulate flow velocities for eco-hydraulic design and evaluation of river rehabilitation projects. There is no discussion or analysis by Clifford et al. (2002) on how the construction of river training structures impacts flow levels.

5. Conclusion

Based upon all of the research analyzed above, the Corps has concluded that river training structures do not impact flood levels. The research efforts, as detailed in the published papers, book chapters, editorials and conference proceedings that conflict with the Corps' conclusions all rely on analysis, assumptions and data that is not supported by engineers and scientists within the Corps, other Federal Agencies with expertise in water resources, and academia.

The claims in the literature detailed above that river training structures have an impact on flood flows are not new. The Corps was concerned in the 1930s that the construction of dikes may have reduced the floodway capacity of the MMR (Ressegieu 1952). The Corps worked with the USGS and other experts to understand the issue and determined that there was not a change in floodway capacity rather a change in the way data was collected. Through the incorrect use of early Corps discharge data (Watson et al. 2013a), scientists in the 1970s again claimed that dikes have increased flood levels. In response, the Corps worked with experts from academia to understand the issue and study the problem using the latest technology. The conclusions of the experts reinforced previous conclusions that river training structures do not increase flood levels.

Recently, the Corps worked with experts from other agencies and academia to evaluate the impact of river training structures on flood levels. The conclusions of these studies reinforce the previous conclusions that river training structures do not increase flood levels. As has been the case throughout the history of the Regulating Works Project, the Corps will continue to monitor and study the physical effects of river training structures using the most up-to-date methods and technology as it becomes available. The majority of current research finding a link between river training structures and an increase in flood heights is based off of research efforts primarily by researchers from three academic institutions: Washington University (Criss, Shock), Southern Illinois University –Carbondale (Pinter, Remo, Jemberie, Huthoff), and University of Saskatchewan (Azinfar, Kells). The Corps takes the claims of these researchers very seriously and has made repeated attempts to engage and collaborate with them to fully understand their conclusions that link river training structures to increases in flood levels. These efforts have had limited success (USGAO 2011). Therefore, the Corps has concluded that there is no impact to flood heights from the construction of river training structures, and thus, no impact from the Regulating Works Project outside of the MMR banks to warrant further study or analysis on this issue.

6. References

Azinfar, H., and J.A. Kells, 2009. Flow resistance due to a single spur dike in an open channel. Journal of Hydraulic Research, 47: 755-763.

Azinfar, H., J.A. Kells, 2008. Backwater prediction due to the blockage caused by a single, submerged spur dike in an open channel. Journal of Hydraulic Engineering, 134: 1153-1157.

Azinfar, H., and J.A. Kells, 2007. Backwater effect due to a single spur dike. Canadian Journal of Civil Engineering, 34: 107-115.

Belt, C.B. 1975. The 1973 flood and man’s constriction of the Mississippi River. Science, 189: 681-684.

Brauer, E.J., and Duncan, D.L., in press. Discussion of “Theoretical Analysis of Wing Dike Impact on River Flood Stages” by Fredrik Huthoff, Nicholas Pinter and Jonathan W.F. Remo. Journal of Hydraulic Engineering

Brauer, E.J. 2009. The limitations of using specific gage analysis to analyze the effect of navigation structures on flood heights in the Middle Mississippi River. Vienna, Austria, Proceedings of the 4th international congress of Smart Rivers ’21. Sept 6-9. p156-163.

Brauer, E.J. 2012. The effect of river training structures on flood heights on the Middle Mississippi River. San Jose, Costa Rica. Proceedings of the 6th edition of the International Conference on Fluvial Hydraulics. Sept 5-7. CRC Press.

Brauer, E.J. 2013. The Effect of Dikes on Water Surfaces in a Mobile Bed. MS Thesis. University of Illinois, Urbana-Champaign.

Bormann, H., N. Pinter, and S. Elfert, 2011. Hydrological signatures of flood trends on German Rivers: Flood frequencies, flood heights, and specific stages. Journal of Hydrology 404 (2011) 50–66.

Bowen, Z.H., Bovee, K.D., Waddle, T.J. 2003. Effects of Regulation on Shallow-Water Habitat Dynamics and Floodplain Connectivity. Transactions of the American Fisheries Society 132, 809-823.

Chen Y.H., and Simmons D.B., 1986. Hydrology, hydraulics, and geomorphology of the Upper Mississippi River system. Hydrobiologia 136, 5-20.

Chow, V.T., 1959. Open-channel hydraulics: New York, McGraw-Hill.

Clifford, N.J., Soar, P.J., Gurnell, A.M., Petts, G.E., 2002. Numerical flow modeling for eco-hydraulic and river rehabilitation applications: a case study of the River Cole, Birmingham, U.K. In River Flow 2002, Bousmar D, Zech Y (eds). Swets & Zeitlinger/Balkema: Lisse; 1195-1204.

Criss, R.E., 2009. Increased flooding of large and small watersheds of the central USA and the consequences for flood frequency predictions. In R. E. Criss and Timothy M. Kusky (Eds.), Finding the Balance between Floods, Flood Protection, and River Navigation, pp. 16-21. Saint Louis University, Center for Environmental Sciences.

Criss, R.E., and W.E. Vinston, 2008. Public Safety and Faulty Flood Statistics. Environmental Health Perspectives, 116: A516.

Criss, R. E., & Shock, E. L. 2001. Flood enhancement through flood control. Geology, 29 (10), 875-878.

Criss, R. E., 2016. Statistics of evolving populations and their relevance to flood risk. Journal of Earth Science, 27(1): 002-008. DOI:10.1007/s12583-015-0641-9. http://en.earth-science.net

Criss, R. E., & Luo, M., 2016. River management and flooding: The lesson of December 2015 – January 2016, Central USA. Journal of Earth Science, 27(1): 117-122. doi 10.1007/s12583-016-0639-y. http://en.earth-science.net

Doyle, M.W., D.G. Havlick, 2009. Infrastructure and the Environment. Annual Review of Environment and Resources, 34: 349-373.

Dieckmann, R.J., Dyhouse, G.R. 1998. Changing history at St. Louis – adjusting historic flows for frequency analysis. First Federal Inter-Avency Hydrologic Modeling Conference, April 20-22, 1998. Las Vegas, NV.

Dyhouse, G.R. 1995. Effects of Federal Levees and Reservoirs on 1993 Flood Stages in St. Louis. Washington, DC. National Research Council, Transportation Research Board, Record No. 1483. 7p.

Dyhouse, G.R. 1985. Comparing flood stage-discharge data- Be Careful! In Hydraulics and Hydrology in the Small Computer Age: Proceedings of the Specialty Conference. Waldrop WR (ed.) American Soc. Of Civil Engineers Hydraulics Divison: New York; 73-78.

Dyhouse, G.R. 1976. Discussion of “Man-induced changes of Middle Mississippi River”. Journal of the waterways harbors, and coastal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 277-279.

Ehlmann, B.L., and R.E. Criss, 2006. Enhanced stage and stage variability on the lower Missouri River benchmarked by Lewis and Clark. Geology, 34: 977-980.

Ettema, R., Muste, M. 2004. Scale effects in flume experiments on flow around a spur dike in a flat bed channel. Journal of Hydraulic Engineering. 130 (7), 635-646.

Heine, R.A., Pinter, N. 2012. Levee effects upon flood levels: an empirical assessment. Hydrological Processes, 26, 3225-3240. DOI: 10.1002/hyp.8261.

Huang, S.L., Ng C. 2007. Hydraulics of a submerged weir and applicability in navigational channels: Basin flow structures. International Journal for Numerical Methods in Engineering 69, 2264-2278.

Huizinga, R.J. 2009. Examination of measurement and historic daily data for several gaging stations on the Middle Mississippi River, 1861-2008. U.S. Geologicial Survey Scientific Investigations Report 2009-5232. 60p. (Also available at http://pubs.usgs.gov/sir/2009/5232/)

Huthoff, F., N. Pinter, J.W.F. Remo, 2013. Theoretical analysis of wing dike impact on river flood stages. Journal of Hydraulic Engineering. 139(5), 550-556. DOI: 10:1061/(ASCE)HY.1943-7900.0000698.

Jai, Y., Scott S., Xu, Y., Huang, S. and Wang, S.S.Y. 2005. Three-dimensional numerical simulation and analysis of flow around submerged weir in a channel bendway. Journal of Hydraulic Engineering. 131, 682-693.

Jemberie, A.A., N. Pinter, and J.W.F. Remo, 2008. Hydrologic history of the Mississippi and Lower Missouri Rivers based upon a refined specific-gage approach. Hydrologic Processes, 22: 7736-4447, doi:10.1002/hyp.7046.

Maher, T.F. 1964. Study of regulation works on stream flow. Paper presented at ASCE Meeting, Cincinnati, Ohio, February, 1-24.

Maynord, S.T. 2006. Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model. Journal of Hydraulic Engineering 132, 343-353. Monroe, R.H. 1962. U.S. Geological Survey, unpublished data.

Munger, P.R., Stevens, G.T., Clemence, S.P., Barr, D.J., Westphal, J.A., Muir, C.D., Kern, F.J., Beveridge, T.R., and Heagler, Jr., J.B. 1976. SLD Potamology Study (T-1). University of Missouri-Rolla, Institute of River Studies, Rolla, Missouri.

O' Donnell, K.T. Galat D.L., 2007. River Enhancement in the Upper Mississippi River Basin: Approaches Based on River Uses, Alterations, and Management Agencies. Restoration Ecology, 15, 538-549.

Parker, G., Garcia, MH, Joannesson, J. and Okabe, K. 1988. Model Study of the Minnesota River near Wilmarth Power Plant, Minnesota, Project Report No. 284, Saint Anthony Falls Hydraulic Laboratory, University of Minnesota.

Paz, A.R., J.M. Bravo, D. Allasia, W. Collischonn, and C.E.M. Tucci, 2010. Large-scale hydrodynamic modeling of a complex river network and floodplains. Journal of Hydrologic Engineering, 15: 152-165.

PIANC, 2009. Sustainable waterways within the context of navigation and flood management. Envi-Com Report n°107-2009.

Pinter, N., J. Dierauer, and J.W.F. Remo, 2012. Flood-loss modeling for assessing impacts of flood-frequency adjustment, Middle Mississippi River, USA. Hydrologic Processes, doi:10.1002/hyp.9321.

Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Cumulative impacts of river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications, 26: 546-571.

Pinter, N., 2010. Historical discharge measurements on the Middle Mississippi River, USA: No basis for "changing history." Hydrological Processes, 24: 1088-1093.

Pinter, N., 2009. Non-stationary flood occurrence on the Upper Mississippi-Lower Missouri River system: Review and current status. In R. E. Criss and Timothy M. Kusky (Eds.), Finding the Balance between Floods, Flood Protection, and River Navigation, pp. 34-40. Saint Louis University, Center for Environmental Sciences.

Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.S. Ickes, 2008. Flood trends and river engineering on the Mississippi River system, Geophysical Research Letters, 35, L23404, doi: 10.1029/2008GL035987.

Pinter, N., R.R. van der Ploeg, P. Schweigert, and G. Hoefer, 2006. Flood Magnification on the River Rhine. Hydrological Processes, 20: 147-164.

Pinter, N., B.S. Ickes, J.H. Wlosinski, and R.R. van der Ploeg, 2006. Trends in flood stages: Contrasting trends in flooding on the Mississippi and Rhine river systems. Journal of Hydrology, 331: 554-566.

Pinter, N., 2005. Policy Forum: One step forward, two steps back on U.S. floodplains. Science, 308: 207-208.

Pinter, N., and R.A. Heine, 2005. Hydrodynamic and morphodynamic response to river engineering documented by fixed-discharge analysis, Lower Missouri River, USA. Journal of Hydrology, 302: 70-91.

Pinter, N., K. Miller, J.H. Wlosinski, and R.R. van der Ploeg, 2004. Recurrent shoaling and dredging on the Middle and Upper Mississippi River, USA. Journal of Hydrology, 290: 275-296.

Pinter, N., and R. Thomas, 2003. Engineering modifications and changes in flood behavior of the Middle Mississippi River. In R. Criss and D. Wilson, (eds.), At The Confluence: Rivers, Floods, and Water Quality in the St. Louis Region, pp. 96-114.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2002. Reply to U.S. Army Corps of Engineers Comment on "Assessing flood hazard on dynamic rivers." Eos: Transactions of the American Geophysical Union, 83(36): 397-398.

Pinter, N., J.H. Wlosinski, and R. Heine, 2002. The case for utilization of stage data in flood-frequency analysis: Preliminary results from the Middle Mississippi and Lower Missouri River. Hydrologic Science and Technology Journal, 18(1-4): 173-185.

Pinter, N., R. Thomas, and N.S. Philippi, 2001b. Side-stepping environmental conflicts: The role of natural-hazards assessment, planning, and mitigation. E. Petzold-Bradley, A. Carius, and A. Vincze (eds.), Responding to Environmental Conflicts: Implications for Theory and Practice, p. 113-132. Dordrecht: Kluwer Academic Publishers.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2001a. Flood-hazard assessment on dynamic rivers. Eos: Transactions of the American Geophysical Union, 82(31): 333-339.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2000. Regional impacts of levee construction and channelization, Middle Mississippi River, USA. In J. Marsalek, W.E. Watt, E. Zeman, and F. Sieker (eds.), Flood Issues in Contemporary Water Management, p. 351- 361. Dordrecht: Kluwer Academic Publishers.

Piotrowski, J.A., Young, N.C., Weber, L.J. 2012. Supplemental Investigatoin of the Influence of River Training Structures on Flood Stages From River Mile 179.5 to 190.0 of the Middle Mississippi River. Submitted to the U.S. Army Corps of Engineers, St. Louis, Missouri.

Remo, J.W.F., N. Pinter, and R.A. Heine, 2009. The use of retro- and scenario- modeling to assess effects of 100+ years river engineering and land cover change on Middle and Lower Mississippi River flood stages. Journal of Hydrology, 376: 403–416.

Remo, J.W.F., N. Pinter, B. Ickes, and R. Heine, 2008. New databases reveal 200 years of change on the Mississippi River System. Eos, 89(14): 134-135.

Remo, J.W.F., and N. Pinter, 2007. Retro-modeling of the Middle Mississippi River. Journal of Hydrology. doi: 10.1016/j.hydrol.2007.02.008.

Remo, J.W.F, and Pinter, N., 2007b. The use of spatial systems, historic remote sensing and retro-modeling to assess man-made changes to the Mississippi River System. In: Zaho, P. et al. (eds.), Proceedings of International Association of Mathematical Geology 2007: Geomathematics and GIS Analysis of Resources, Environment and Hazards. State Key Laboratory of Geological Processes and Mineral Resources, Beijing, China, pp. 286-288.

Ressegieu, F.E. 1952. Comparative discharge measurements, Mississippi River by USGS and Corps of Engineers. St. Louis District, U.S. Army Corps of Engineers.

Roberge, M., 2002. Human modification of the geomorphically unstable Salt River in metropolitan Phoenix. Professional Geographer, 54: 175-189.

Samaranayake, V.A. 2009. The statistical review of three papers on specific gage analysis. Report to U.S. Army Corps of Engineers, St. Louis District.

Smith, L. M., and Winkley, B.R. 1996. The response of Lower Mississippi River to river engineering. Engineering Geology. 45, 433-455.

Sondergaard, M., and E. Jeppesen, 2007. Anthropogenic impacts on lake and stream ecosystems, and approaches to restoration. Journal of Applied Ecology, 44: 1089-1094.

Stevens, M. A., Simons, D. B., & Schumm, S. A. 1975. Man-induced changes of Middle Mississippi River. Journal of the Waterways Harbors and Coastal Engineering Division, 119-133.

Stevens, G.T. 1976. Discussion of “Man-induced changes of Middle Mississippi River”. Journal of the waterways, harbors, and costal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 280.

Strauser, C.N. and N.C. Long. 1976. Discussion of "Man-induced changes of Middle Mississippi River". Journal of the waterways, harbors, and costal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 281-282.

Struiksma, N. Klaasen, G.J., 1987. On scale effects in moveable river models. Communication No. 381, Delft Hydralics Laboratory, Delft, The Netherlands.

Sukhodolov, A.N. 2014. Hydrodynamic of groyne fields in a straight river reach: insight from field experiments. Journal of Hydraulic Research. 52:1, 105-120. DOI: 10.1080/00221686.2014.880859.

Szilagyi, J., N. Pinter, and R. Venczel, 2008. Application of a routing model for detecting channel flow changes with minimal data. Journal of Hydrologic Engineering, 13: 521-526.

Theiling, C.H., and J.M. Nestler, 2010. River stage response to alteration of Upper Mississippi River channels, floodplains, and watersheds. Hydrobiologia, 640: 17-47.

USACE. 1996. Barfield Bend Potomology Study Update, Mississippi River, Hydraulics and Hydrology Branch.

USACE. 2008. Upper Mississippi River Comprehensive Plan. U.S. Army Corps of Engineers Rock Island District, St. Louis District, St. Paul District.

USACE 2016. Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District.

USACE. 1995. Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries.

USACE. 1942. Mississippi River flood discharge capacity. Prepared by U.S. Army Engineer District, St. Louis.

USACE. 1935. Stream-flow measurements of the Mississippi River and its Tributaries between Clarksville, MO and the Mouth of the Ohio River 1866-1934, Hydrologic Pamphlet No. 1, U.S. Engineer Office, St. Louis, MO. U.S. Government Printing Office: Washington, D.C.

U.S. Government Accountability Office (USGAO). 2011. "Mississippi River: Actions are needed to help resolve environmental and flooding concerns about the use of river training structures". Rep. GAO-12-41, Washington, DC.

Van Ogtrop, F.F., A.Y. Hoekstra, and F. van der Meulen, 2005. Flood management in the Lower Incomati River Basin, Mozambique: Two alternatives. Journal of the American Water Resources Association, 41: 607-619.

Wasklewicz T.A., J. Grubaugh, and S. Franklin, 2004. 20th century stage trends along the Mississippi River. Physical Geography, 25: 208-224.

Watson, C.C. and Biedenharn, D.C. 2010. Specific gage analyses of stage trends on the Middle Mississippi River. Report to U.S. Army Corps of Engineers, St. Louis District.

Watson, C.C., R.R. Holmes, D.S. Biedenharn. 2013a. Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri. J. Hydraulic Engineering: 139:1062-1070.

Watson, C.C., Holmes, R.R., Jr., and Biedenharn, D.S., 2013a. Mississippi River streamflow measurement techniques at St. Louis, Missouri. Journal of Hydraulic Engineering, 139(10), 1062-1070.

Watson, C.C., D.S. Biedehnarn, C.R. Thorne. 2013b. Analysis of the Impacts of Dikes on Flood Stages in the Middle Mississippi River. J. Hydraulic Engineering. 139:1071-1078.

Watson, C.C., and Biedenharn, D.S. 2010. Specific gage analysis of stage trends on the Middle Mississippi River. Report to U.S. Army Corps of Engineers, St. Louis District.

Watson, C.C, Biedenharn, D.S., Scott, S.H., 1999. Channel Rehabilitation: Process, Design, and Implementation. U.S. Army Corps of Engineers.

Westphal, J.A. and P.R. Munger. 1976. Discussion of “Man-induced changes of Middle Mississippi River”. Journal of the waterways, harbors, and costal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 283-284.

Xia, R. 2009. “Using computational model- ADH to evaluate relationship of water surface elevation to wing dikes”. World Environmental and Water Resource Congress. ASCE.

Yossef, M.F. 2002. The effect of groynes on rivers: Literature review. Delft Cluster project no. 03.03.04.

Yossef, M.F.M. 2005. Morphodynamics of rivers with groynes, Delft University Press, Delft.

Appendix B: Biological Assessment

Appendix B. Biological Assessment

This Biological Assessment, prepared for the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project, only covers newly listed threatened and endangered species potentially occurring in the Project Area that were not covered by the Endangered Species Act consultation process for the 1999 Biological Assessment and associated 2000 Biological Opinion for the Upper Mississippi River System which addressed multiple projects, including the Regulating Works Project (see Table 1 below). The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx

Table 1. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 January 2016).

Species	Federal Status	Consultation Status
Red Knot (*calidris canutus rufa*)	Threatened – listed in 2015	Covered in this document
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013	Covered in this document
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001	Covered in this document
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012	Covered in this document
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012	Covered in this document
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012	Covered in this document
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013	Habitat not found in Project Area. No further analysis required.
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015	Covered in this document
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016	Habitat not found in Project Area. No further analysis required.

Red Knot. The Red Knot was listed as a federally threatened species in 2015 (Federal Register, Volume 79, Number 238, pp. 73706-73748). The following information comes from the information contained in the final rule (USFWS 2014a).

The Red Knot is a medium-sized shorebird that annually migrates from the Canadian Arctic to southern Argentina. Changing climate conditions are already affecting the bird's food supply, the timing of its migration and its breeding habitat in the Arctic. The shorebird also is losing areas along its range due to development. New information shows some knots use interior migration flyways through the South, Midwest and Great Lakes. Small numbers (typically fewer than 10) can be found during migration in almost every inland state over which the Red Knot flies between its wintering and breeding areas. This shorebird is irregularly observed feeding on mudflats, sandbars, shallowly flooded areas and pond margins along the Missouri and Mississippi Rivers from May 1 through September 30.

There is no known Red Knot nesting habitat in the Project Area. This bird is a rare migrant along the Middle Mississippi River, and during migration, exposed substrates and shallow water in the Project Area likely provide temporary feeding habitat. The Project would not eliminate or substantially reduce exposed substrates or shallow water within the Project Area.

Determination. It is our determination that the Project will have no effect on the Red Knot.

Rabbitsfoot. The Rabbitsfoot was listed as a federally threatened species in 2013 (Federal Register, Volume 78, Number 180, pp. 57076-57097). The following habitat information comes from the U.S. Fish and Wildlife Service's Rabbitsfoot Species Assessment (USFWS 2009):

> *Parmalee and Bogan (1998, pp. 211-212) described the following habitat requirements for the rabbitsfoot. The rabbitsfoot is primarily an inhabitant of small to medium-sized streams and some larger rivers. It usually occurs in shallow areas along the bank and adjacent runs and shoals where the water velocity is reduced. Specimens may also occupy deep water runs, having been reported in 9-12 feet of water. Bottom substrates generally include sand and gravel. This species seldom burrows but lies on its side (Watters 1988, p. 13; Fobian 2007, p. 24).*

The Rabbitsfoot historically occurred in 39 streams and rivers within the lower Great Lakes Sub-basin and Mississippi River Basin, including some streams and rivers in eastern Illinois and southern Missouri (USFWS 2009). Although the county threatened and endangered species lists include this species as potentially occurring in the Project Area, this is due to the fact that it is known to occur in Alexander County, IL. However, the records of occurrence for the Rabbitsfoot in Alexander County, Illinois are historical records for the Ohio River. This species is considered extirpated from Alexander County, IL and no records exist of the Rabbitsfoot occurring in the Mississippi River portion of Alexander County or any other part of the Middle Mississippi River (USFWS 2009).

Determination. It is our determination that the Project will have no effect on the Rabbitsfoot.

Scaleshell Mussel. The Scaleshell Mussel was listed as a federally endangered species in 2001 (Federal Register, Volume 66, Number 195, pp. 51322-51339). The following habitat information comes from the U.S. Fish and Wildlife Service's Scaleshell Mussel Recovery Plan (USFWS 2010):

> *The scaleshell occurs in medium to large rivers with low to medium gradients. It inhabits a variety of substrate types, but is primarily found in stable riffles and runs with slow to moderate current velocity. Buchanan (1979, 1980, 1994) and Gordon (1991) reported it from riffle areas with substrate consisting of gravel, cobble, boulder, and occasionally mud or sand. Call (1900), Goodrich and Van der Schalie (1944), and Cummings and Mayer (1992) reported collections from muddy bottoms of medium-sized and large rivers. Oesch (1995) considered the scaleshell a typical riffle species, occurring only in clear,*

> *unpolluted water with good current. Oesch also noted that it frequently buries itself in gravel to a depth of four to five inches.*

The Scaleshell historically occurred in 56 rivers in 13 states within the Mississippi River Drainage including the States of Illinois and Missouri. The Scaleshell is believed to be extirpated from Illinois. In Missouri, the Scaleshell can be found consistently in the Meramec, Bourbeuse, and Gasconade Rivers (USFWS 2010). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Scaleshell in Jefferson and St. Louis Counties. However, these are due to its occurrence in the Meramec River basin. No records of occurrence in the Middle Mississippi River exist for the Scaleshell.

Determination. It is our determination that the Project will have no effect on the Scaleshell Mussel.

Sheepnose Mussel. The Sheepnose Mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 49, pp. 14914-14949). The following habitat information comes from the U.S. Fish and Wildlife Service's Sheepnose Status Assessment Report (USFWS 2002a):

> *The following habitat requirements of the sheepnose are generally summarized from Oesch (1984) and Parmalee and Bogan (1998). The sheepnose is primarily a larger-stream species. It occurs primarily in shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984). Habitats with sheepnose may also have mud, cobble, and boulders. Specimens in larger rivers may occur in deep runs (Parmalee and Bogan 1998). Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives.*

The Sheepnose historically occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system and most lowland tributaries in the lower Mississippi River system. The species is known from the Mississippi, Ohio, Cumberland, and Tennessee main stems, as well as many tributary streams throughout its range (USFWS 2002a). Recent sampling shows the Sheepnose to be extremely rare in the Mississippi River main stem and is thought to be extant in very low numbers only in pools 3, 7, 15, 20, and 22. Recent records also show the Sheepnose to be extant in the Meramec River and Ohio River basins (USFWS 2002a). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Sheepnose in Jefferson and St. Louis Counties in Missouri and Alexander County in Illinois. However, the Jefferson and St. Louis County records are due to its occurrence in the Meramec River basin and the Alexander County records are due to its occurrence in the Ohio River. No records of occurrence in the Middle Mississippi River exist for the Sheepnose (USFWS 2002a).

Determination. It is our determination that the Project will have no effect on the Sheepnose Mussel.

Snuffbox Mussel. The Snuffbox Mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 30, pp. 8632-8665). The following comes from information contained in the final rule (USFWS 2012).

Historically the Snuffbox Mussel was widespread, occurring in 210 streams and lakes in 18 U.S. states and Ontario, Canada. The population has been reduced to 79 streams and lakes in 141 states and Ontario, representing a 62 percent range wide decline. The Snuffbox is currently found in Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Wisconsin, and Ontario, Canada. Most populations are small and geographically isolated from one another, further increasing their risk of extinction (USFWS 2012). The Snuffbox is found in small- to medium- sized creeks, to larger rivers, and in Missouri it is known in the Meramec River, Bourbeuse River, St. Francis River, and Black River.

The threatened and endangered species lists for counties in the Project Area indicate the presence of the Snuffbox in Jefferson and St. Louis Counties in Missouri. However, these records are due to its occurrence in the Meramec River basin. There are no recent records of the Snuffbox in the MMR.

Determination. It is our determination that the Project will have no effect on the Snuffbox Mussel.

Spectaclecase. The Spectaclecase mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 49, pp. 14914-14949). The following habitat information comes from the U.S. Fish and Wildlife Service's Spectaclecase Status Assessment Report (USFWS 2002b):

> *Primarily a large-river species, Baird (2000) noted its occurrence on outside river bends below bluff lines. It appears to most often inhabit riverine microhabitats sheltered from the main force of current... It occurs in substrates from mud and sand to gravel, cobble, and boulders in relatively shallow riffles and shoals with slow to swift current (Buchanan 1980, Parmalee and Bogan 1998, Baird 2000). According to Stansbery (1967), this species is usually found in firm mud between large rocks in quiet water very near the interface with swift currents. Specimens have also been reported in tree stumps, root masses, and in beds of rooted vegetation (Stansbery 1967, Oesch 1984). Similar to other margaritiferids, spectaclecase occurrences throughout much of its range tend to be aggregated (Gordon and Layzer 1989), particularly under slab boulders or under bedrock shelves (Call 1900, Hinkley 1906, Buchanan 1980, Parmalee and Bogan 1998, Baird 2000), where they are protected from the current...Unlike most species that move about to some degree, the spectaclecase may seldom if ever move except to burrow deeper, and may die from stranding during droughts (Oesch 1984).*

The Spectaclecase historically occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system, the uppermost Ohio River system, the Cumberland and Tennessee River systems, and some lowland tributaries in the Mississippi Delta region of Mississippi and Louisiana. The species is known from the Mississippi, Ohio, and

Missouri main stems, as well as many other tributary streams throughout its range (USFWS 2002b). Recent sampling shows the Spectaclecase to be extremely rare in the Mississippi River main stem and is thought to be extant in very low numbers only in pools 15, 16, 19, 22, 24, and 25. There is one recent record of the Spectaclecase being found in the Mississippi River just above the confluence with the Missouri River (ESI 2014) and at least one historic record of the Spectaclecase being found in the MMR (Tiemann 2014). A weathered, relict Spectaclecase shell was recently found in the MMR (Keevin et al. 2016); however, the shell was found downstream of the Meramec River and may have originated there. Recent records show the Spectaclecase to be extant in the Meramec River basin (USFWS 2002b). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Spectaclecase in Jefferson and St. Louis Counties in Missouri and Madison County in Illinois. The Jefferson and St. Louis County records are due to its occurrence in the Meramec River basin. The Madison County record is due to its occurrence in the Mississippi River just above the confluence with the Missouri River.

Most mussels that are found in the MMR are scattered and of very low density and may not represent viable populations (Keevin et al. 2016). Individual mussels may have been transported to the MMR as glochidia by host fishes from other water bodies in the surrounding watershed that do support viable mussel populations (e.g. the Meramec, Big Muddy, Kaskaskia, Upper Mississippi, and Ohio Rivers; Keevin et al. 2016). Due to the influx of sediment from the Missouri River and associated unstable sand substrates and high turbidity levels, the MMR does not generally provide the stable habitats required by most mussel species and no permanent mussel beds have been reported in the MMR (ESI 2014; Keevin et al. 2016).

Determination. It is our determination that the Project will have no effect on the Spectaclecase.

Northern Long-Eared Bat. The Northern Long-Eared Bat (NLEB) was listed as a federally threatened species throughout its range in 2015 (Federal Register, Volume 80, Number 63, pp. 17974-18033).

The following information on NLEB habitat and ecology comes from the U.S. Fish and Wildlife Service's Northern Long-Eared Bat Interim Conference and Planning Guidance (USFWS 2014b):

> ***NLEB Species Range***
> *The NLEB is found in the United States from Maine to North Carolina on the Atlantic Coast, westward to eastern Oklahoma and north through the Dakotas, extending southward to parts of southern states from Georgia to Louisiana, even reaching into eastern Montana and Wyoming. In Canada it is found from the Atlantic Coast westward to the southern Yukon Territory and eastern British Columbia. Historically, the species has been found in greater abundance in the northeast and portions of the Midwest and Southeast, and has been more rarely encountered along the western edge of the range.*
>
> ***NLEB Winter Habitat and Ecology***
> *Suitable winter habitat (hibernacula) for the NLEB includes underground caves and cave-like structures (e.g. abandoned or active mines, railroad tunnels). These hibernacula typically have large passages with significant cracks and crevices for roosting; relatively*

constant, cool temperatures (0-9 degrees Celsius) and with high humidity and minimal air currents. Specific areas where they hibernate have very high humidity, so much so that droplets of water are often seen on their fur. Within hibernacula, surveyors find them in small crevices or cracks, often with only the nose and ears visible. NLEBs will typically hibernate between mid-fall through mid-spring each year. NOTE: there may be other landscape features being used by NLEB during the winter that have yet to be documented.

NLEB Summer Habitat and Ecology

During summer NLEBs roost singly or in colonies in cavities, underneath bark, crevices, or hollows of both live and dead trees and/or snags (typically ≥3 inches dbh). Males and non-reproductive females may also roost in cooler places, like caves and mines. This bat seems opportunistic in selecting roosts, using tree species based on presence of cavities or crevices or presence of peeling bark. NLEBs has also been occasionally found roosting in structures like barns and sheds (particularly when suitable tree roosts are unavailable). NLEB emerge at dusk to forage in upland and lowland woodlots and tree-lined corridors, feeding on insects, which they catch while in flight using echolocation. This species also feeds by gleaning insects from vegetation and water surfaces.

Suitable summer habitat for NLEB consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and may also include some adjacent and interspersed non-forested habitats such as emergent wetlands and adjacent edges of agricultural fields, old fields and pastures. This includes forests and woodlots containing potential roosts (i.e., live trees and/or snags ≥3 inches dbh that have exfoliating bark, cracks, crevices, and/or cavities), as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Individual trees may be considered suitable habitat when they exhibit characteristics of suitable roost trees and are within 1000 feet of other forested/wooded habitat. NLEB has also been observed roosting in human-made structures, such as buildings, barns, bridges, and bat houses; therefore, these structures should also be considered potential summer habitat. NLEBs typically occupy their summer habitat from mid-May through mid-August each year and the species may arrive or leave some time before or after this period.

NLEB maternity habitat is defined as suitable summer habitat used by juveniles and reproductive (pregnant, lactating, or post-lactating) females. NLEB home ranges, consisting of maternity, foraging, roosting, and commuting habitat, typically occur within three miles of a documented capture record or a positive identification of NLEB from properly deployed acoustic devices, or within 1.5 miles of a known suitable roost tree...

Suitable NLEB Roost Trees

Suitable NLEB roosts are trees (live, dying, dead, or snag) with a diameter at breast height (DBH) of three inches or greater that exhibits any of the following characteristics: exfoliating bark, crevices, cavity, or cracks. Isolated trees are considered suitable habitat when they exhibit the characteristics of a suitable roost tree and are less than 1000 feet from the next nearest suitable roost tree within a woodlot, or wooded fencerow.

> ***NLEB Spring Staging/Fall Swarming Habitat and Ecology***
> *Suitable spring staging/fall swarming habitat for the NLEB consists of the variety of forested/wooded habitats where they roost, forage, and travel, which is most typically within 5 miles of a hibernaculum. This includes forested patches as well as linear features such as fencerows, riparian forests and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Isolated trees are considered suitable habitat when they exhibit the characteristics of a suitable roost tree and are less than 1000 feet from the next nearest suitable roost tree, woodlot, or wooded fencerow. NLEBs typically occupy their spring staging/fall swarming habitat from early April to mid-May and mid- August to mid-November, respectively.*
>
> ***NLEB Migration***
> *As with many other bat species, NLEBs migrate between their winter hibernacula and summer habitat. The spring migration period likely runs from mid-March to mid-May, with fall migration likely between mid-August and mid-October. Overall, NLEB is not considered to be a long-distance migrant (typically 40-50 miles) although known migratory distances vary greatly between 5 and 168 miles.*
>
> ***Potential Threats and Impacts to NLEB***
> *No other threat is as severe and immediate for the NLEB as the disease, white-nose syndrome (WNS). If this disease had not emerged, it is unlikely the northern long-eared population would be declining so dramatically. Since symptoms were first observed in New York in 2006, WNS has spread rapidly in bat populations from the Northeast to the Midwest and the Southeast. Population numbers of NLEB have declined by 99 percent in the Northeast, which along with Canada, has been considered the core of the species' range. The degree of mortality attributed to WNS in the Midwest and Southeast is currently undetermined. Although there is uncertainty about how WNS will spread through the remaining portions of the species' range, it is expected to spread throughout the United States. In general, the FWS believes that WNS has reduced the redundancy and resiliency of the species...*

Recent Bat Surveys. The St. Louis District's Rivers Project Office recently conducted bat surveys on Corps lands in Calhoun, Jersey, and Madison Counties in Illinois and St. Charles and Pike Counties in Missouri. The surveys were conducted to inventory bat species utilizing Corps lands, document any threatened and endangered species encountered, and to better inform management decisions that may impact bat species on Corps lands. The majority of the surveyed areas were outside of the Regulating Works Project Area in the pooled portion of the Upper Mississippi River but did include the Chain of Rocks area located at the northern end of the Project Area.

The surveys were conducted in 2010, 2012, and 2014 (Walters et al. 2010; USACE 2012; SCI Engineering, Inc. 2014) and utilized both mist nets for capturing live bats and acoustic receivers for recording and identifying bat echolocation calls. Two individual NLEBs were captured during the surveys, although neither was within the Project Area. Thirty-two NLEB echolocation calls were identified during the surveys, including two within the Project Area at the Chain of Rocks location.

Given that NLEBs were captured in riparian corridor habitat in relatively close proximity to the Project Area, that NLEBs were acoustically located in the Chain of Rocks area within the Project Area, and that similar suitable NLEB habitat exists at many locations along the MMR corridor which lies within the NLEB range, it is reasonable to assume that NLEBs utilize or at least have the potential to utilize the riparian corridor throughout the Project Area.

Potential Impacts to the NLEB from Project Actions
Direct Effects
Dredging and Dredged Material Placement. Due to the fact that dredging and dredged material placement in the MMR take place within the main channel and main channel border areas of the river and do not impact adjacent bottomland forest areas, there is very little opportunity for impacts to the NLEB. Every dredging and dredged material placement location is coordinated with resource agency partners including the Service. Should disposal in adjacent bottomland forest habitat ever be required, a Tier II assessment would be considered through coordination with the Service. There is the remote possibility that dredging or disposal activities could disturb bats foraging or roosting in the vicinity of dredging operations, but this impact would be minor and short-term in nature and would not significantly disrupt normal behavior patterns. Dredging and dredged material placement may affect but are not likely to adversely affect the NLEB.

River Training Structure/Revetment Construction. There is the potential to affect roosting or nursery trees through bankline grading or placement of stone for river training structures and revetment. Maintenance of existing structures could also affect habitat if it requires shoreline modification. Current construction practices typically include placing stone from the river without the need for terrestrial staging areas and without the need for clearing or grading of bankline areas. In cases where shoreline modification is required, it is usually minor, and the long-term effect is preservation of the shoreline and reduction in erosion and tree loss. In most cases, construction of river training structures and revetment would not affect potential NLEB roost trees. In instances where clearing might be required, clearing should occur outside the roosting season and surveys may be necessary if work is conducted during the roosting season. The planning and design of all river training structures and revetment includes close coordination with resource agency partners including the Service. Close coordination helps to ensure that potential impacts are avoided. Should grading or clearing of banklines be required or there is a need for terrestrial staging areas, a Tier II assessment would be considered through coordination with the Service. There is the also the remote possibility that river training structure or revetment construction could disturb bats foraging or roosting in the vicinity of construction activities, but this impact would be minor and short-term in nature and would not significantly disrupt normal behavior patterns.

Indirect Effects
Tow Traffic. The movement of tow traffic up and down the MMR may affect the foraging or roosting behavior of an occasional individual NLEB. However, this impact would be minor and short-term in nature and would not significantly disrupt normal NLEB behavior patterns.

Fleeting/Terminal Facilities. Barge fleeting areas are those areas where barges are continuously moved in and out for loading and unloading, or stored. They are generally located in close proximity to terminal facilities. Terminal or port facilities are usually within urban or industrial areas, and since their purpose is to provide river access, they are constructed in areas that were once floodplain habitat. Since the majority of fleeting and terminal facilities are in developed areas, it is likely that the amount of potential habitat affected is small.

Under Section 10 of the Rivers and Harbors Act of March 3, 1899, the placement of any permanent structure below the ordinary high water mark on navigable waterways requires a permit. Where installation involves the discharge of dredged or fill materials, permits are required under Sections 401, 402, and 404 of the Clean Water Act of 1977. Future expansion of fleeting areas or terminals will be subject to regulation and environmental review. Therefore, if expansion should occur in the future, evaluation of potential endangered species impacts will be assessed through the permit process. The States of Illinois and Missouri regulate barge fleeting through review of the Federal permitting process. In addition, trespass laws may be enforced on Federal property should inappropriate fleeting occur there.

Fleeting and terminal facilities may affect individual NLEBs through disturbance or minor habitat alteration but should not significantly disrupt normal behavior patterns.

Contaminants. Although contaminants may be a possible cause of insectivorous bat decline due to direct impacts to bats or due to impacts to their food supply (Clark 1981), the discussion here is focused on navigation-related contaminants. Environmental contaminants from accidental spills on the MMR could potentially affect the NLEB by affecting its food supply or by direct toxic affects to individual bats. However, this impact is considered negligible due to the low likelihood of occurrence.

Interrelated Effects

Management of Corps Lands. Corps lands in the MMR consist of the Chain of Rocks Management Area and the Thompson Bend Riparian Corridor Project. The Chain of Rocks Management Area encompasses 17 distinct management areas as shown in Table 4-3 below. Management of these areas varies depending on the intended use of the land with some forest management occurring in the vegetative management and mitigation areas.

Table 4-1. Chain of Rocks Management Area lands.

Management Area Classification	Number of Areas	Acres
Project Operations	2	1926
Low Density Recreation Areas	4	8
Mitigation Areas	2	234
Vegetative Management Areas	6	990
Easements	5	222
Total	**17**	**3380**

The Thompson Bend Riparian Corridor Project is located between river miles 32 and 19 on the right descending bank of the MMR. The project consists of a 300-foot-wide continuous permanent easement adjacent to the river channel, isolated blocks and strips of perpetual easement land off the main river corridor, river training structures, blew holes, and revetments. The purpose of the project is to maintain top bank control and to minimize over bank scour, which could lead to a channel cut-off, which would effectively close this reach of river to navigation, threaten the integrity of the Birds Point to Commerce levee, and affect thousands of acres of valuable agricultural land. The main feature of this project is a 300-foot-wide, 11-mile-long tree screen along the top bank of the river. Tree species selected for this feature are water-tolerant, fast-growing species. Where appropriate, tree species are selected that supply greater wildlife benefits.

Although some land management practices may cause temporary adverse impacts, there will be long-term benefits to the habitat. Prior to carrying out management actions, sites are evaluated for presence of threatened or endangered species and other natural resources of concern, and actions are taken to avoid impacts to these species. This includes designating special management zones, observing seasonal restrictions, and providing buffers. Forest management is carried out through close coordination with State and Federal resource agencies, including the U.S. Fish and Wildlife Service. Forestry practices diversify the habitat and strive to maintain size class diversity. Specific actions are described in the Rivers Project Master Plan (USACE 2014). Forest management practices that maintain forest age class and diversity contribute to the conservation of the species through providing and maintaining suitable future habitat.

Recreation on Corps Lands. Recreational activities on Corps lands have the potential to disturb roosting bats. However, these impacts are expected to be minor and would not significantly disrupt normal behavior patterns.

Section 4(d) Rule

In conjunction with the listing of the NLEB as threatened, the U.S. Fish and Wildlife Service (Service) published a 4(d) rule in 2016 (Federal Register, Volume 81, Number 9, pp. 1900-1922). Section 4(d) of the Endangered Species Act allows the Service to implement special rules for threatened (not endangered) species that provide flexibility in implementing the Act. Section 4(d) rules are used to reduce Endangered Species Act conflicts by allowing some activities that do not harm the species to continue, while focusing efforts on the threats that make a difference to the species' recovery.

In the case of the NLEB, the Service determined that white-nose syndrome is such an overwhelming threat to the species that regulating most other sources of harm or mortality would not help conserve the species. The NLEB 4(d) rule focuses prohibitions on protecting bats when and where they are most vulnerable: maternity roost trees during June and July pup-rearing and at hibernation sites.

For Federal agencies seeking Section 7 consultation on their actions, the Service provided an optional framework to streamline the NLEB consultation process. The framework requires the agency to notify the Service 30 days prior to implementing an action that may affect the NLEB. The notification is to include a determination that the action would not cause prohibited incidental take. Prohibited incidental take under the NLEB 4(d) rule consists of take within a hibernaculum or certain tree removal activities near a known hibernaculum or maternity roost tree. Service concurrence is not required, but the Service may advise the agency whether additional information indicates project-level consultation is required. If prohibited take may occur as a result of the agency action, standard Section 7 consultation procedures should be followed. The optional framework is not required and agencies can choose to follow standard Section 7 procedures.

Determination

Several components of the Project could have site-specific impacts on NLEBs and NLEB habitat, but are not anticipated to individually or cumulatively have an adverse impact on the population as a whole. Tier II Biological Assessments will be considered through coordination with the Service for future site-specific actions that may impact NLEB habitat. Use of the Section 4(d) rule optional framework will also be considered for future site-specific actions. It is our determination that the Project may affect but is not likely to adversely affect the NLEB.

Literature Cited

Clark, D.R. 1981. Bats and Environmental Contaminants: A Review. United States Department of the Interior, Fish and Wildlife Service Special Scientific Report – Wildlife No. 235.

ESI (Ecological Specialists, Inc.). 2014. Final Report: Unionid Mussel Habitat Construction/Creation Summary. Report prepared for the St. Louis District, U.S. Army Corps of Engineers. 64 pp. +Appendices.

Keevin, T. M., J. S. Tiemann, and K. S. Cummings. 2016, Submitted. The Freshwater mussel fauna of the Middle Mississippi River. Northeastern Naturalist.

SCI Engineering, Inc. 2014. Bat monitoring report – Summer 2014. RPO bat monitoring services, Illinois and Mississippi Rivers. Report prepared for the St. Louis District, U.S. Army Corps of Engineers. 8pp.+Appendixes.

Tiemann, J. 2014. Freshwater mollusks of the middle Mississippi River. Illinois Natural History Survey Technical Report 2014 (03).

USACE (U.S. Army Corps of Engineers). 2012. Summer bat mist net survey and acoustic monitoring, US Army Corps of Engineers, Mississippi River Complex, Illinois and Missouri, June 2012. Report prepared for the St. Louis District, U.S. Army Corps of Engineers. 8pp.+Appendixes.

USACE (U.S. Army Corps of Engineers). 2014. Rivers Project Master Plan, Design Memorandum No. 3. U.S. Army Corps of Engineers, St. Louis District.

USFWS (U.S. Fish and Wildlife Service). 2002a. Status assessment report for the sheepnose, *Plethobasus cyphyus*, occurring in the Mississippi River system (U.S. Fish and Wildlife Service Regions 3, 4, and 5). U.S. Fish and Wildlife Service, Asheville, North Carolina.

USFWS (U.S. Fish and Wildlife Service). 2002b. Status assessment report for the spectaclecase, *Cumberlandia monodonta*, occurring in the Mississippi River system (U.S. Fish and Wildlife Service Regions 3, 4, 5, and 6. U.S. Fish and Wildlife Service, Asheville, North Carolina.

USFWS (U.S. Fish and Wildlife Service). 2009. Rabbitsfoot species assessment and listing priority assignment form. Accessed November 2014. http://www.fws.gov/midwest/endangered/clams/pdf/rabbistfoot_cand_elevation.pdf

USFWS (U.S. Fish and Wildlife Service). 2010. Scaleshell mussel recovery plan (*Leptodea leptodon*). U.S. Department of the Interior, Fort Snelling, Minnesota.

USFWS (U.S. Fish and Wildlife Service). 2012. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Rayed Bean and Snuffbox Mussels Throughout Their Ranges; Final Rules. Federal Register. Dated February 14, 2012. Accessed May 2016. http://www.fws.gov/midwest/endangered/clams/rayedbean/FR_FinalRuleList_RayedBeanSnuffboxFeb2012.html

USFWS (U.S. Fish and Wildlife Service). 2014a. Endangered and Threatened Wildlife and Plants; Threatened Species Status for the Rufa Red Knot. Federal Register. Dated December 11, 2014. Accessed January 2016. http://www.fws.gov/northeast/redknot/pdf/2014_28338_fedregisterfinalrule.pdf.

USFWS (U.S. Fish and Wildlife Service). 2014b. Northern long-eared bat interim conference and planning guidance. USFWS Regions 2, 3, 4, 5, and 6.

Walters, B.L., J. Helms, and J.O. Whitaker, Jr. 2010. Survey for the federally endangered Indiana Myotis (*Myotis sodalis*) and other bat species on the Rivers Project lands in Madison and Calhoun Counties, Illinois. 16 July 2010. Center for North American Bat Research and Conservation, Department of Biology, Indiana State University, Terre Haute, Indiana. Report prepared for the St. Louis District, U.S. Army Corps of Engineers. 12pp.+Appendixes.

Appendix C: Mitigation Plan

1. OVERVIEW

In the Water Resources and Development Act of 1986 (WRDA 1986), Section 906(b), Congress gave the Corps the discretionary authority to mitigate for fish and wildlife damages for any water resources project that was completed or under construction at the time of the passing of WRDA 1986. This authority is in contrast to Section 906(a) of WRDA 1986, which made mitigation mandatory for any newly authorized projects or those where construction had not started. Because the Regulating Works Project was already under construction at the time WRDA 1986 passed, it fell under 906(b). Therefore, since 1986, efforts have been made to avoid and minimize project impacts by modifying designs of river training structures. This has included various designs such as chevron dikes, notched dikes, offset dikes, W-dikes, L-dikes, multiple roundpoint structures, and bendway weirs. Compared to only using traditional dikes, these designs generally create more diverse main channel border habitat for the benefit of aquatic biota.

However, even with these alternative designs, recent analyses suggest that river training structures would still result in the losses of main channel border habitat with certain depth, velocity, slope, and other functional characteristics. While the severity of these effects to biota is difficult to pinpoint, the losses are concerning given the cumulative condition of main channel border habitat and the lack of specific habitat areas that meet these various conditions. For these reasons, the Corps has decided that mitigation will be implemented to offset losses to the greatest extent practicable in accordance with Section 906(b) of WRDA 1986, subject to the availability of future funding.

Corps regulations (Engineering Regulation 1105-2-100) require assessment of environmental impacts and associated mitigation actions in a manner that addresses changes in ecological resource condition. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Various mitigation actions also need to be compared to each other through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Corps regulations also require projects take an adaptive approach to implementing, monitoring and modifying mitigation actions to ensure they are offsetting significant project impacts (USACE Implementation Guidance for Section 2036(a) of WRDA 2007, Aug 2009). This guidance requires mitigation plans include: 1) a description of the mitigation action; 2) a description of the type and amount of habitat to be restored; 3) ecological success criteria including specific metrics to quantify success; 4) a monitoring plan; 5) a Contingency Plan; and 6) a Real Estate Plan. The mitigation plan also will establish a consultation process with appropriate federal and State agencies to evaluate mitigation effectiveness, including monitoring and determining the success of mitigation.

This appendix provides a programmatic discussion on habitat impacts quantification, mitigation and adaptive management, all of which are intended to ensure adverse effects from the project are offset. As outlined in the SEIS, specific project impacts cannot be definitively identified until specific future plans are developed. These future designs will allow planners to verify where, when and to what extent project features will alter river habitat. These details will be outlined within future Tier II site specific Environmental Assessments that will address future construction and mitigation needs for new river training structures. However, this appendix will outline the general programmatic approach for assessing impacts and mitigation needs in the future, including how an adaptive approach will be followed.

It should be noted that the District has completed site specific Environmental Assessments for Regulating Works construction sites since publication of the Notice of Intent for the SEIS. In these site-specific EAs, the District has committed to implementing measures in the future to avoid, minimize, and/or compensate for any new significant impacts revealed through preparation of the SEIS. For these projects, impacts will be reviewed by the methods outlined below and compensatory mitigation will be reconsidered. NEPA documents will be updated, as appropriate, and any warranted mitigation plans will be developed and coordinated through the adaptive approach. Any necessary compensatory mitigation will be implemented concurrent with construction to the extent practicable.

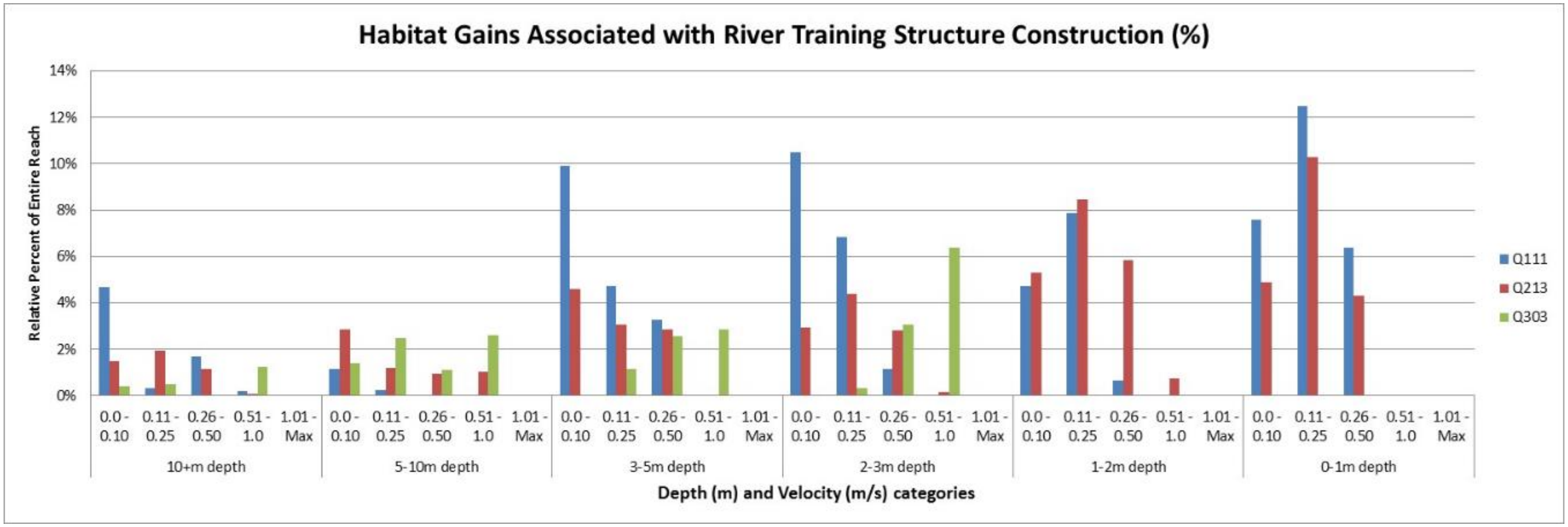
2. ASSESSMENT OF IMPACTS AND HABITAT LOSS

Future Conditions Under the Recommended Action

Future Regulating Works Projects will potentially have various effects to physical habitat. These changes to river habitat are complex. Based on the hydraulic analysis, use of innovative structures vs. traditional dikes is accomplishing the intended goal of increasing habitat diversity. In general, construction of river training structures results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat. However, model output also suggests a decrease in shallow to moderate depth, moderate to high velocity habitat (Figure 1) which is important to some MMR fish guilds. This type of habitat would often be similar to “unstructured” sand bar habitat given that it’s typically found in main channel border locations with a lack of river training structures to act as current breaks. Indeed, modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.

The analysis detailed in the SEIS suggests that approximately 1,100 acres[1] of unstructured main channel border habitat in the MMR (defined as areas shallower than LWRP -10 without river training structures) could be affected as a result of future construction which is estimated to require placement of approximately 4.4 million tons of rock. This estimate includes the projects that have already been constructed since publishing the Notice of Intent for the SEIS.

[1] The stated impact of 1,100 acres is a programmatic estimate based on the best available information (see Attachment 1 below). Actual impact acreages and mitigation needs will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.



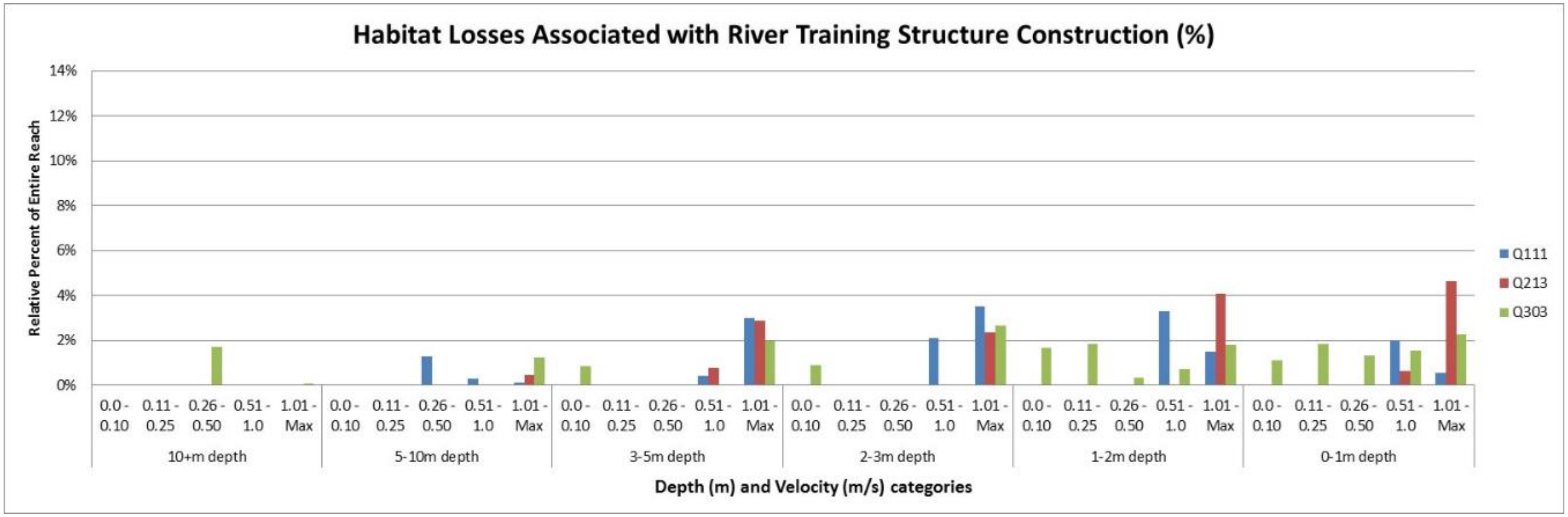


Figure 1. Habitat gains (top) and losses (bottom) associated with construction of river training structures expressed as a relative percent of each habitat category.

Resulting changes to these 1,100 acres of habitat are complex. Based on the hydraulic analysis, use of innovative structures vs. traditional dikes is accomplishing the intended goal of increasing habitat diversity. In general, construction of river training structures results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat. However, model results suggest that river training structure construction causes a decrease in shallow to moderate depth, moderate to high velocity habitat which is important habitat to some MMR fish guilds (Figure 1). This habitat would typically be expected to exhibit moderate to high velocities given its location in the river channel and presumed lack of river training structures to act as current breaks. Indeed, modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.

An area of 1,100 acres represents approximately 8% of the remaining unstructured main channel border habitat in the MMR. Although these unstructured main channel border habitats are part of a river system that is highly modified compared to its original state, they may more closely resemble some of the historic habitats of the MMR. The continued conversion to structured habitat is expected to result in the functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat. Overall, this conversion is expected to have a potentially significant adverse effect on the MMR fish community and compensatory mitigation is warranted. The level of significant adverse effect and needed amount of mitigation will need to be verified, as outlined below, within future Tier II site specific Environmental Assessments.

Detailed Future Assessment of Habitat Loss and Mitigation Needs

Forecast conditions above are based on a “best guess” of likely impacts resulting from additional river training structures. Unfortunately specific locations and design of structures are not known at this time due to the changing nature of the river (the exception being the projects already constructed). Future site-specific NEPA documents will be developed that outline in detail the plans for additional training structures within a certain river reach, including the anticipated changes in terms of depth, velocity and substrate that will result. This will be related to changes in aquatic habitat with impacts quantified as follows.

First, the quantity of habitat impacted will be determined in terms of its area, likely measured in acres. This measurement will be based on actual future project designs and estimated resulting hydraulic conditions. The total amount of impacted future habitat will likely differ from the 1,100 acres estimated. Moreover, the adverse effects may not occur over the entire area of main channel border habitat influenced by future structures. The specific location and amounts of habitat with significant adverse project-related effects will be updated with detailed future plans and tracked to ensure accurate accounting of both impacts and potential mitigation needs.

After the location and quantity of aerial impact is identified, the quality of that habitat will be determined. Pursuant to Corps policy, habitat quality will be assessed through some type of ecological habitat model. Typically this has been done with tools such as the USFWS Habitat Evaluation Procedures (HEP) Habitat Suitability Index models (HSI). These HSI models generate a general habitat quality score between 0 and 1. This HSI score is then multiplied by the acres impacted to derive a total number of Habitat Units (HUs) lost. Those HUs lost that are determined to be a "significant" impact would require mitigation. It should be noted that what level of loss is significant is a judgment determined by the Corps after collaboration with resource agencies and utilizing all information that is readily available. The simple loss of HUs does not in and of itself constitute a significant impact requiring mitigation to offset an equal amount of HUs. However, the Corps does anticipate pursuing mitigation for the types of habitat change forecasted within the SEIS. The levels of impact, impact significance and mitigation needs (including the type and amount) would be developed and documented in these future Tier II site specific Environmental Assessments.

Main Channel Border Habitat Model and Future Projects

The above approach is how habitat losses will be calculated. However, no appropriate habitat model(s) currently exists to capture the unique aspects of Middle Mississippi main channel border aquatic habitat. To assist future impact assessment and mitigation planning, the Corps is attempting to develop a new main channel border habitat model. This model will focus on the specific aspects of main channel border habitat that this Project impacts. The model will function much like an HSI model to quantify habitat quality, and will be created collaboratively with input from natural resource agency partners. Model development was initiated early in 2016 with the bulk of preparation during spring and early summer. The model will go through the Corps model review process and is scheduled to be approved for regional use later in 2016. This model could be used not only for future projects under Regulating Works, but other projects that could impact main channel border habitat on the Middle Mississippi River.

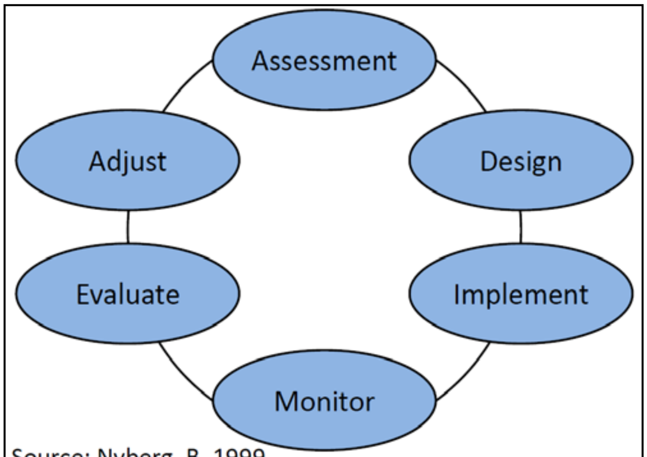
3. ASSESSMENT OF MITIGATION ALTERNATIVES

Once the specific amount of significant adverse future impact that warrants mitigation has been identified, the Corps must consider multiple alternatives to mitigate these impacts. This includes consideration of the cost for different mitigation alternatives, and the amount of mitigation benefits generated by each alternative. Mitigation benefits will be estimated and quantified using the main channel border habitat model that is under development. Mitigation costs and benefits will be annualized and a Cost Effectiveness/Incremental Cost Analysis performed to compare the alternatives. This helps ensure the Corps is making an informed selection on the most cost-effective mitigation approach.

Potential mitigation actions may include, but are not limited to, the following: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. Mitigation will be tailored toward the specific habitat features that are significantly impacted. This habitat likely includes shallow to moderate depth, moderate to high velocity main channel border habitat. Such habitat may be challenging to design and effectively implement. The ability to design for such habitat, including the associated costs, may need to be carefully considered within the context of the impacts. Impacts will be mitigated to the extent practicable.

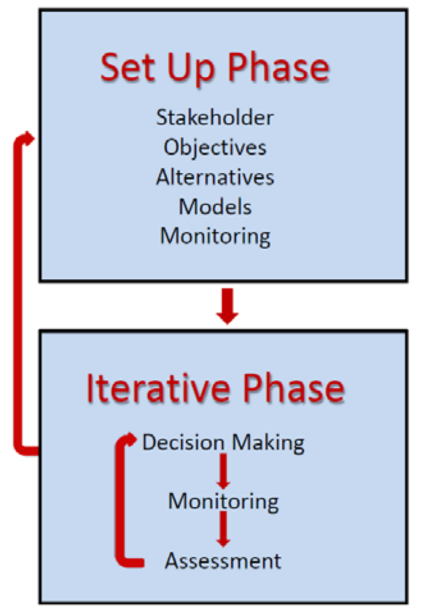
4. MONITORING AND ADAPTIVE MANAGEMENT

Adaptive Management Approach



Source: Nyberg, B. 1999.

The purpose of this section is to begin laying out an adaptive strategy for a successful monitoring program in support of the project. Adaptive management (AM) is a "learning by doing" management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004). It is used to address the uncertainties often associated with complex, large-scale projects. In AM, a structured process is used so that the "learning by doing" is not simply a "trial and error" process.



Source: Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007

The basic elements of an AM process are: (1) Assess; (2) Design; (3) Implement; (4) Monitor; (5) Evaluate; and (6) Adjust. In practice, AM is implemented in a non-linear sequence, in an iterative way, starting at various points in the process and repeating steps based on improved knowledge.

Application of AM should occur in two phases as suggested by the *Adaptive Management: U.S. Department of the Interior Technical Guide (2007)*. A setup phase would involve the development of key components and an iterative phase would link these components in a sequential decision process.

Elements of the set-up phase include: stakeholder involvement, defining management or mitigation objectives, identifying potential management or mitigation actions, identifying or building predictive modeling or assessment tools, specifying performance measures and/or risk endpoints, and creating monitoring plans. In addition, values for the monitored measures that would trigger AM should be determined in this phase. The iterative phase uses these elements in an ongoing cycle of learning about system structure and function, and managing based on what is learned. The elements of the iterative phase include decision making, follow-up monitoring, and assessment.

Adaptive Management Team

An Adaptive Management Team (AMT) would provide essential support to meeting our goals and objectives through the application of a systemic approach to evaluating project impacts, mitigation and mitigation effectiveness. The AMT would consist of a multi-agency (State and Federal) staff from the appropriate disciplines, including engineering, planning, environmental science and resource management. As the project sponsor, the Corps serves as the AMT leader. The exact members of the AMT will be determined during development of detailed project plans, but would likely include: the Corps, U.S. Fish and Wildlife Service (FWS), Missouri Department of Conservation (MDC), and Illinois Department of Natural Resources (ILDNR). The AMT would oversee the decision–making processes to plan and evaluate project features and mitigation.

Goals, Objectives and Performance Standards/Metrics

Clearly focused and quantitative goals and objectives are essential to AM. They should be logically linked to mitigation actions, action agencies, indicators/metrics, monitoring activities, and ecosystem values. Goals and objectives will be specifically identified during detailed mitigation planning. These goals and objectives will be critical elements of the project, with implementation concurrent with overall project construction.

Performance metrics would be used during two AM processes: planning mitigation actions (evaluating mitigation actions and metrics like those described above to predict project impacts) and assessment of actual mitigation performance following implementation. In many cases, these processes would be the same, allowing predictions to be compared to actual responses.

Performance standards/metrics include potential metrics for quantifying impacts following project construction, and measuring mitigation effectiveness. These standards/metrics will be fully developed based on input from the AMT during future Tier II site specific Environmental Assessments. Ideally, these metrics will line up with the Main Channel Border habitat model that is under development (e.g., the model would serve to both plan for and help measure mitigation effectiveness). The general goal of mitigation will be to replace the habitat value lost through significant project impacts. Performance standards/metrics will allow for evaluation of mitigation effectiveness.

Develop and Implement Monitoring Plans

The CEQ NEPA Task Force (CEQ 2003) suggests that the effectiveness of adaptive management hinges upon an effective monitoring program to establish objectives, thresholds, and baseline conditions. This will be achieved through a stepwise process that includes pre- and post-construction studies of physical habitat. These studies would likely occur for both impact and mitigation sites, allowing impacts to be verified, and for mitigation effectiveness to be evaluated.

Monitoring programs are a key component of AM. Monitoring provides feedback between decision making and system response relative to management goals and objectives. An essential element of AM is the development and execution of scientifically rigorous monitoring and assessment to analyze and understand system response to project implementation. It is recognized that project level monitoring would be limited by cost and duration based on current regulations and that project level AM plans would need to be designed to reflect this constraint. However, post project monitoring would be a part of project implementation.

Following the adaptive framework of this document, impacts would be monitored over time and performance of measures would be assessed to determine whether additional avoidance, minimization, or mitigation measures are needed. Future monitoring will provide information on the accuracy of the conclusions reached on the extent of impacts from the project features and evaluate the effectiveness of mitigation. Monitoring activities, including review of results, will be performed collaboratively with the AMT.

Future Tier II site specific Environmental Assessments will include the specific plan for monitoring and evaluation of the effectiveness of associated mitigation. The monitoring plan will need to outline the specific methodologies and frequencies for monitoring, as well as a cost estimate for all monitoring activities. The St. Louis District would be responsible for funding and executing this monitoring. Potential monitoring activities will be directly tied to the performance standards/metrics discussed above to measure mitigation effectiveness. Possible monitoring activities might include (but are not limited to) bathymetry observations, hydraulic measurements and/or modeling, and other measurements of physical habitat.

5. CONTINGENCY PLANS

Post-project monitoring will include an evaluation of mitigation effectiveness. Should mitigation prove ineffective, or should impacts prove more significant than previously anticipated, then additional mitigation may be warranted.

The AMT must first identify which resources still have remaining impacts needing mitigation. This remaining impact should be quantified. Potential mitigation can then be identified to offset this remaining impact.

Funding mechanisms for implementing additional mitigation must then be identified. Depending on the amount of mitigation needed, funds may be available through the Regulating Works Project. This is especially the case for smaller activities. However, if large levels of funding are needed to address failed mitigation implemented in association with this SEIS, it may require additional action by Congress for either appropriation, or possibly even authorization. Thus, funding would be provided for construction of planned mitigation projects, and post-project monitoring. It cannot be guaranteed that federal funds would be available, specific to this project, for contingency mitigation.

6. REAL ESTATE PLANS

Real Estate needs are not applicable to mitigation associated with this project. The only proposed mitigation is for impacts in main channel border aquatic habitat. Mitigation would almost certainly be located in similar habitat areas. All land in main channel border habitat is under federal jurisdiction. As such all real estate would be available. Should work outside the Federal jurisdiction be considered, cooperation from real estate owners would be necessary since the mitigation authority under 906(b) does not allow for condemnation.

Literature Cited

Council on Environmental Quality (CEQ). 2003. Considering Cumulative Effects Under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, DC.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Attachment 1

Methodology to Estimate Remaining Construction and Associated Impacts

Methodology to Estimate Remaining Construction and Associated Impacts

To estimate the quantity and cost of potential compensatory mitigation required by future dike construction it was necessary to estimate the amount of future construction, estimate the impact of future construction, assume and evaluate possible mitigation measures, estimate the quality of mitigation measures and estimate a construction cost. Due to the dynamic nature of the Middle Mississippi River (MMR) the quantity, location and types of structures to be used for the remainder of the project are unknown. These specifics are dependent on future sediment load into the system, future dredging locations, impacts of climate change and other natural factors. Since an environmental planning model has not been certified for use yet, programmatic estimates of impacts and anticipated mitigation needs were developed for this SIES. The actual amount of environmental impact of future construction and the quality of future mitigation measures will be defined in future site-specific environmental assessments (SSEAs).

Estimation of future construction

To estimate the amount of future construction that would be necessary to address chronic dredging sites in the MMR, generic designs were developed for all locations where recent dredging has occurred or where main channel depths were less than ten feet below the low water reverence plane (-10 LWRP[2]). Two sets of designs were developed – one using traditional dikes perpendicular to the bankline and another using chevron-shaped dikes. Generic, typical structure designs were used to determine the spacing of the structures. The quantity of material was estimated using length of structure, recent hydrographic surveys, and an assumed standard dike cross section with a crown width of 6 ft and an elevation of +18.5 ft LWRP. The quantity of material necessary to construct enough dikes on the MMR to reduce dredging to a minimum

[2] The datum to which the navigation channel is maintained for the open river portion of the MMR is the Low Water Reference Plane, commonly abbreviated as LWRP. LWRP is a 3D hypothetical model of the water surface developed to approximate a common "low water" river level at all points on the Mississippi River between river mile 200 and 0. In 1975 to provide uniformity and continuity throughout the Division, the Lower Mississippi Valley Division established a methodology for computing LWRP for the open portion of the Mississippi River. This standardized the datum to which the navigation channel was maintained for each District. To calculate LWRP, the 97 percent discharge was calculated for the period 1954 through 1973. Flows prior to 1954 were not used due to changes in the effects of the reservoirs up to that point. LWRP was calculated for each gaging station and the latest low water profiles were used to shape the LWRP profile between gaging stations. In 2014 LWRP was recalculated on the MMR utilizing the additional gage data collected since the previous LWRP was established and recent low water profiles. The time period 1967 through 2014 was selected to reflect the time that the entire Missouri River reservoir system was complete and in full operation. The new LWRP was also calculated in reference to the North American Vertical Datum 88 (NAVD 88).

(there will always be a residual amount of dredging due to the dynamics of the hydrograph and fluctuation of sediment load) was calculated to be approximately 6 million tons if traditional perpendicular dikes are used and 8 million tons if chevrons are used. The average quantity if an equal distribution of chevrons and traditional dikes are used is 7.5 million tons of stone. This equates to approximately 106,000 linear feet of structure.

To develop the dredging assumptions used in the Continue Construction Alternative, the District conducted an expert opinion elicitation (USACE 2015). A panel of District, regional, national and academic river engineering experts evaluated all available data to determine the current dredging requirements on the MMR, dike efficiency in reducing dredging, the relationship between dike construction and dredging and time considerations related to the dredging and dike efficiency values. The relationship between dredging and structure construction can be found Figure 1. This figure was derived by a cumulative comparison of existing dredging locations and the quantity of stone necessary to reduce dredging in these locations.

Through the evaluation of previous projects, dredging records, and the prototype reach[3], it was determined that the 'efficiency' of Regulating Works to decrease dredging is 85%. This estimate means that, on average, after the completion of a Regulating Works project there is still a residual dredging requirement of 15% due to the natural variability of the channel and dynamic nature of the hydrograph.

The Continue Construction Alternative assumes that there is very little structure construction in the St. Louis Harbor reach of the MMR which spans from RM 184.0 to 168.5. Construction in St. Louis Harbor is difficult because of limited access due to high river traffic, fleeting, narrow channel width, and facilities along the banklines. The annual average dredging requirement in this reach will not likely change from the current quantity of 800,000 cubic yards/year. The dredging requirement for the remainder of the MMR can be reduced from the current amount of 3.2 million cubic yards/year to as low as 500,000 cubic yards/year depending on the amount of future construction. If maximum dredging reduction is achieved through the placement of approximately 7.5 million tons of material, a remaining dredging amount of 1.3 million cubic yards/year would exist on the MMR.

[3] The prototype reach is a formerly troublesome portion of the Middle Mississippi River between RM 154.0-140.0 in which a channel with a 1,200-foot constriction width between dike ends was constructed for the purpose of developing additional empirical design criteria which would assure successful implementation of the 9-ft channel project. The prototype reach was approved in 1966 and construction was initiated in July 1967 and completed in March 1969. Limited dredging has been necessary within the prototype reach since its completion.

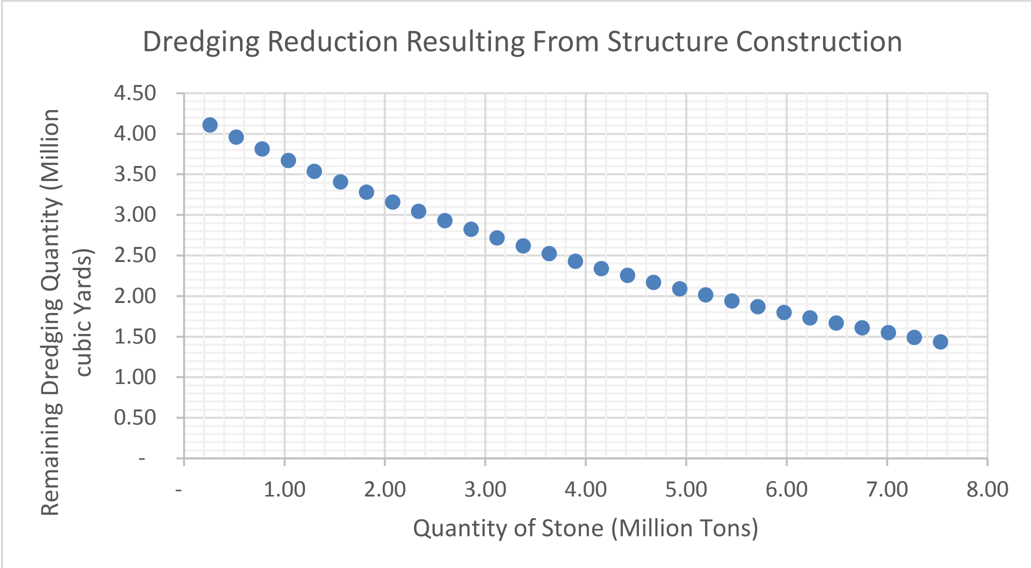


Figure 1. Relationship between dredging and structure construction.

Estimation of Impacted Habitat

The footprint of proposed structures was delineated using Cobb classification rules. If a structure already existed directly upstream or downstream, the footprint of the new structures would extend to that structure. If no structure existed, the footprint was assumed to extend to the bankline or adjacent dike field at a forty-five degree angle as seen in Figure 2. The intersection of the dike footprint with the existing habitat types was evaluated to determine how much main channel border was impacted by the proposed structures.

Using the process described in the paragraph above, the impact of all of the generic structures developed as part of the expert elicitation was calculated. This value represents the maximum potential impact of future regulating works construction. It was calculated that the impact of all construction necessary to achieve the maximum dredging reduction as determined by the Expert Elicitation was 1774 acres of main channel border. The process for estimating the impact of new construction was also applied to existing structure designs. The evaluation of six designed work locations allowed for the comparison of the percent of the footprint that impacted channel border and a comparison of the relationship between structure length and impact to channel border. See Table 1 and Figure 3.

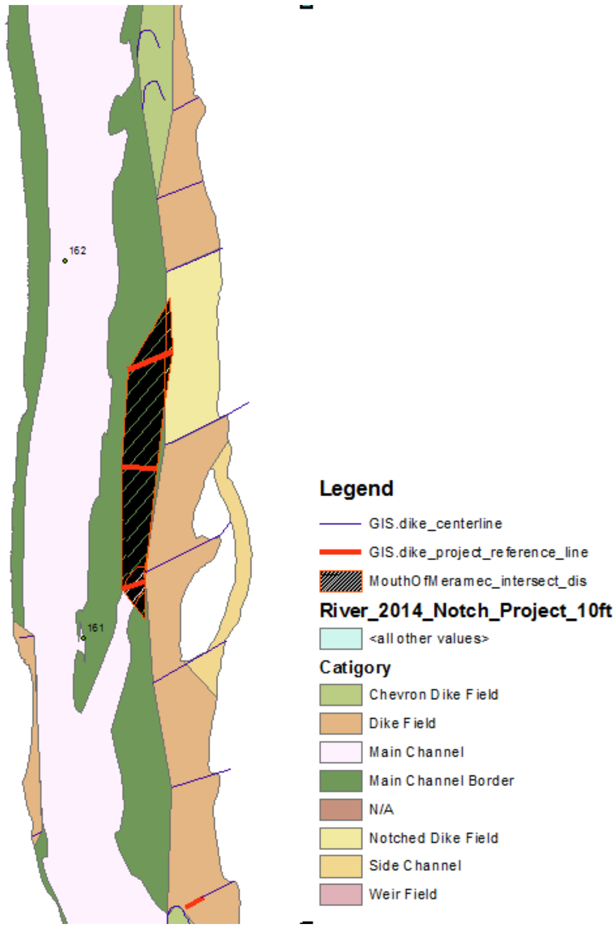


Figure 2

		Habitat Type Impacted (Acre)				Channel Border/ Total Impacted Area	Structure Length (ft)	Structure Length/ Channel Border Impacted
		Channel Border	Main Channel	Dike Field	Total			
Work Locations With SSEA's	Mosenthein- Ivory Landing Phase 4	7.16	-	-	7.16	1.00	488	68.18
	Dogtooth Bend Phase 5	1.65	0.53	-	2.18	0.76	295	178.80
	Grand Tower Phase 5	63.70	8.95	4.66	77.31	0.82	4,039	63.41
	Eliza Point/Greenfield Bend Phase 3	7.93	-	-	7.93	1.00	606	76.45
	Mosenthein- Ivory Landing Phase 5	35.06	2.29	2.08	39.43	0.89	1,442	41.13
Estimate For Remaining Construction		1,774.00	784.96	345.95	2,904.91	0.61	106,097	59.81

Table 1:Habitat Types Impacted

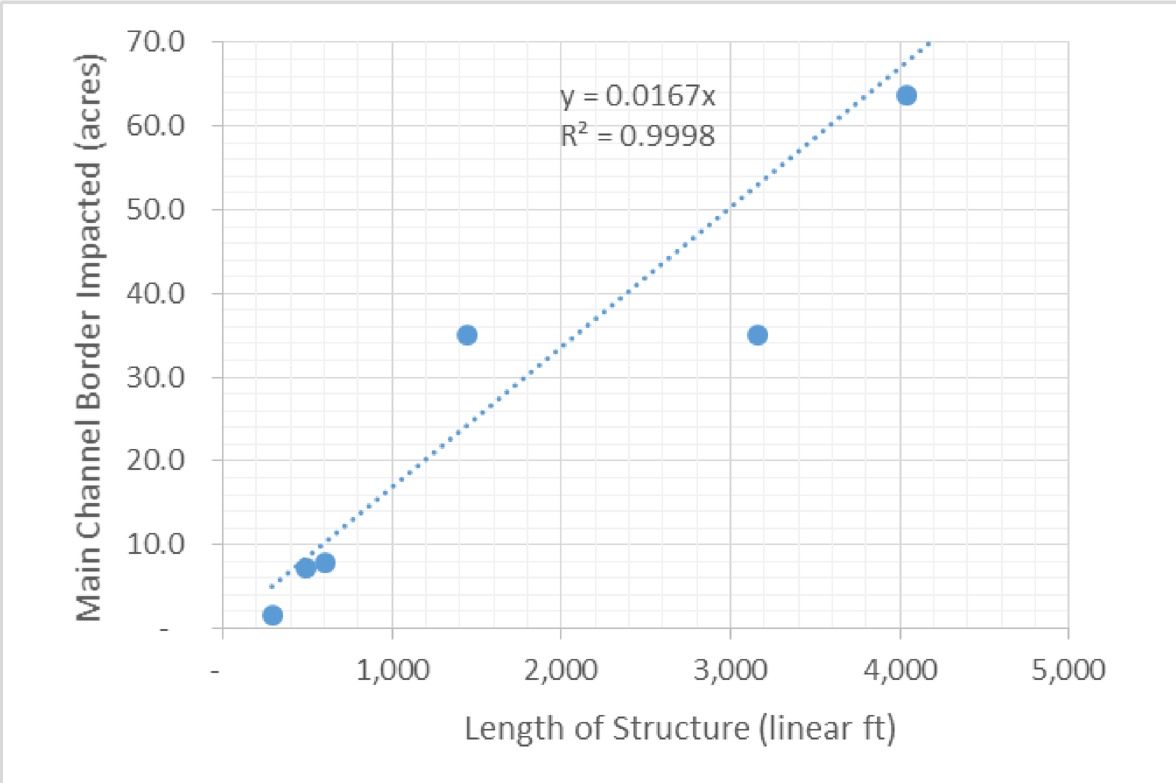


Figure 3: Relationship Between length of structure and channel border habitat impacted
Estimation of Quantity of Stone removed for Mitigation

For the purposes of this programmatic analysis, it was assumed that mitigation will be accomplished through the partial or complete removal of existing river training structures.

The average spacing and length of river training structures on the MMR was calculated to be 1200 ft and 680 ft respectively. For this analysis it is assumed that the depth at the river side of the structure is -10 ft LWRP with a constant slope to the crown elevation of +18 ft LWRP. The average height of the structure based off of the generic geometry is 14 ft. Based off of established quantity estimate information, the multiplier for a structure with an average height of 14 ft and a crown width of 6 ft is 20.9 Tons/lf. The amount of stone for a dike of average dimensions detailed in figure 4 is 14,212 Tons.

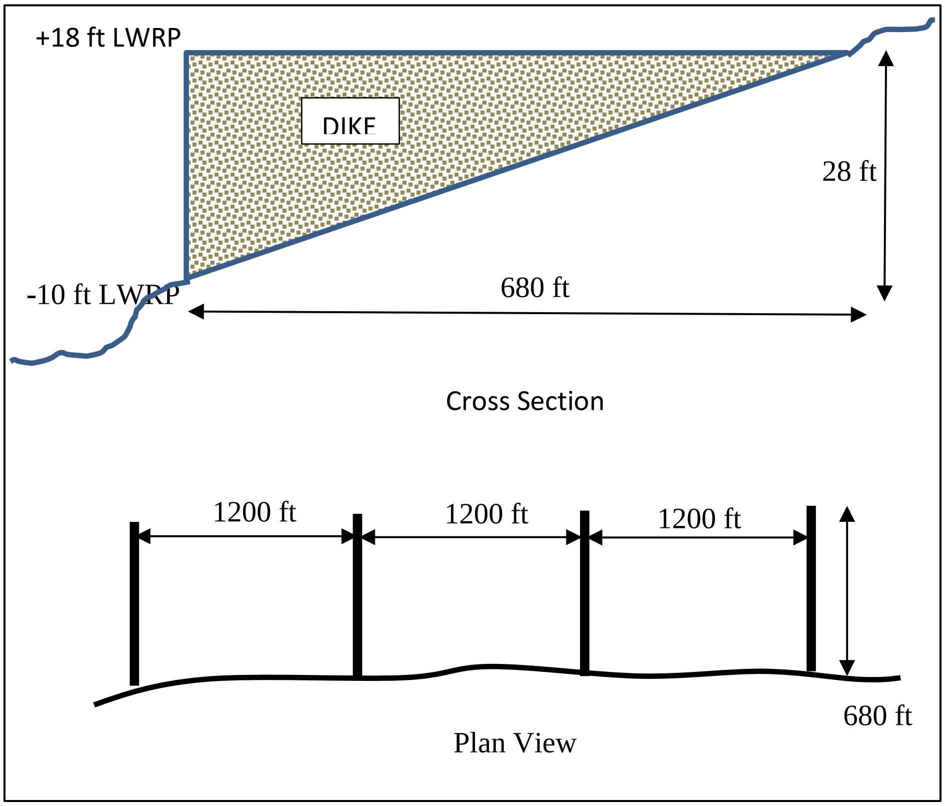


Figure 4: Generic dike cross section and spacing

The quantity of stone in a dike notch is dependent on the length of the notch and the average depth of the notch which is related to the notch location (i.e., river side, center, bankline) (see Figure 5). To estimate the average quantity of stone, the average structure dimensions were divided into three and stone quantity was calculated. It was assumed that all notches would be to the riverbed. The quantity of each notch is detailed in Table 2.

Type of Notch	Rock Quantity (Tons)
Full Structure	14,212
Bank side (rootless)	739
Middle	3,780
River Side	9,693

Table 2: Quantity of Rock required to remove to notch a dike 226.7 ft to the bed

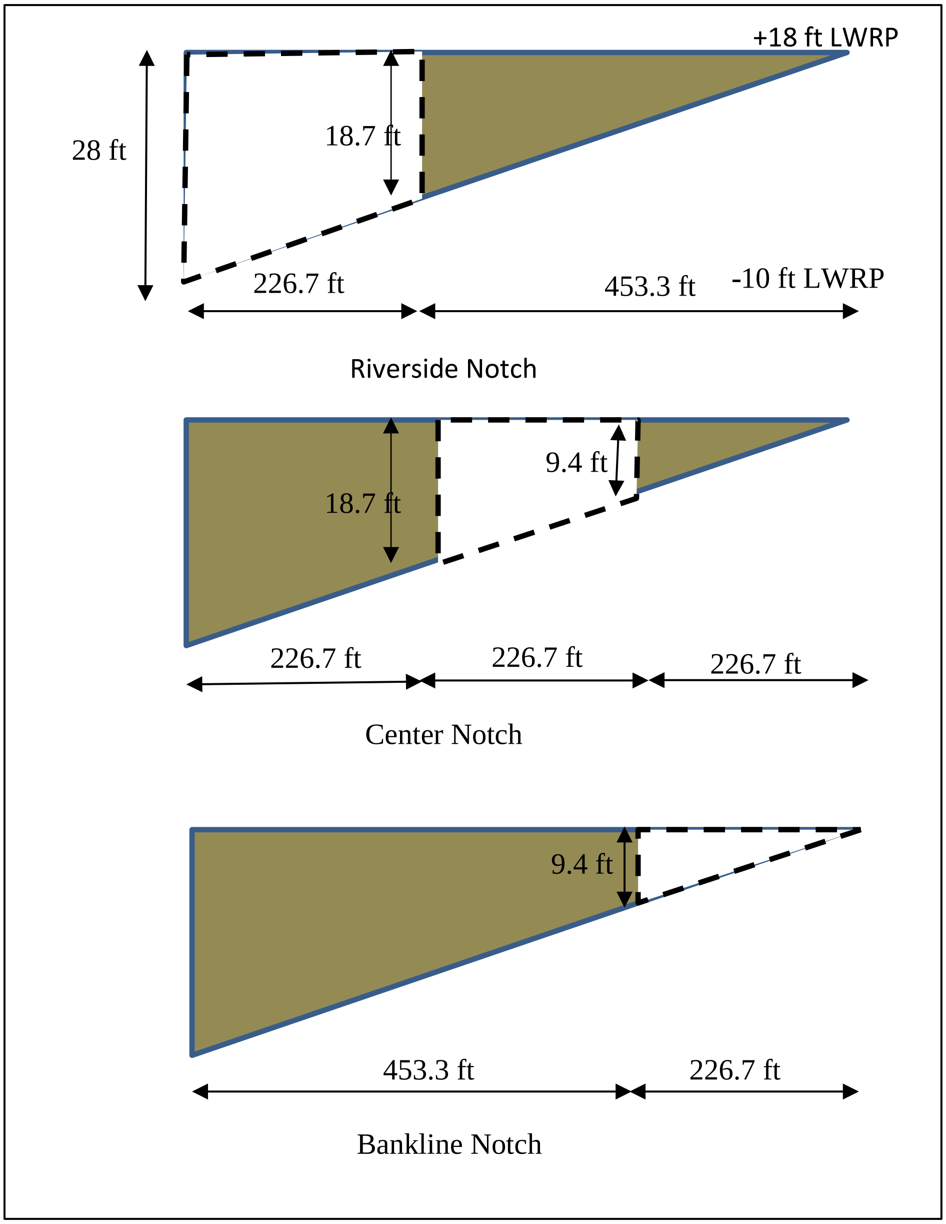


Figure 5

Estimation of Quantity of Habitat Created by Mitigation

The area of mitigation resulting from the removal of parts or all of a structure was defined as the additional unstructured area created by the structure removal as shown in Figure 6.

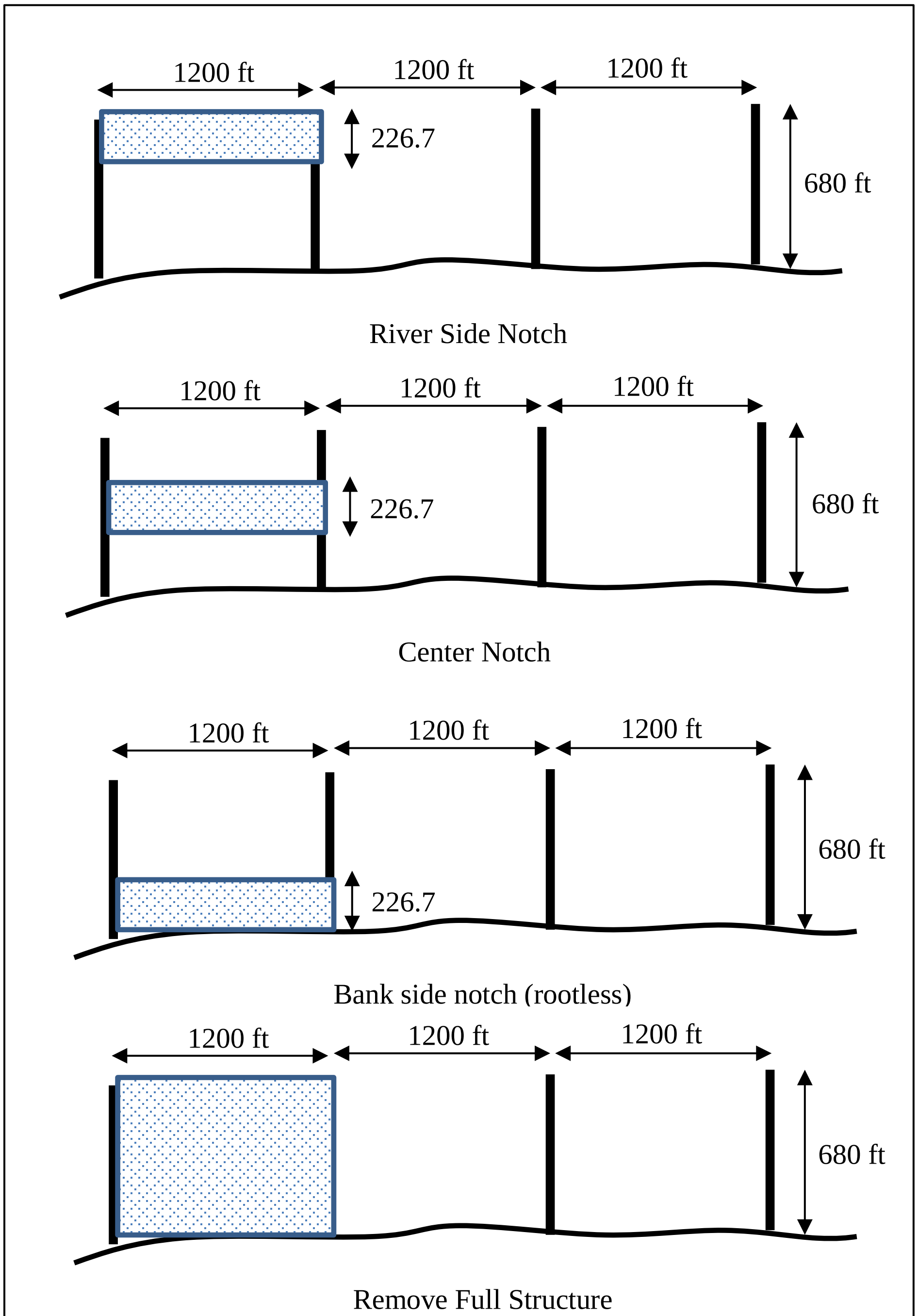


Figure 6: Amount of habitat created by notching or removing a structure

Since the amount of created habitat was equal for each type of notch (bankline, riverside, center) a relationship was developed between the quantity of rock removed and the amount of habitat created by each notch type (see Figure 7). This relationship was used for each notch type to calculate the amount of habitat created for the equivalent amount of stone removed when removing a typical structure.

Estimation of Average Mitigation Costs

To calculate the average cost of mitigation, a cost of $15.40 per ton of stone removed was assumed and the relationship between mitigation cost and amount of habitat created was developed. The four methods of creating habitat were averaged and a habitat suitability index (HIS) of 0.5 was applied. See Figure 8. In the average mitigation cost calculation it was assumed that the costs to make a dike rootless is the same as a center notch. This assumption was made to account for the uncertainty in the height of the structure in this location and the potential additional cost of construction dredging which may be required to access the structure. The cost of revetment to prevent bank erosion after a structure is removed was also added into the mitigation cost estimate. It was assumed that revetment was placed on the banks adjacent to the removed or notched structure for 50 ft upstream and 100 ft downstream. The average cost of 17 tons/linear ft was used to estimate revetment cost.

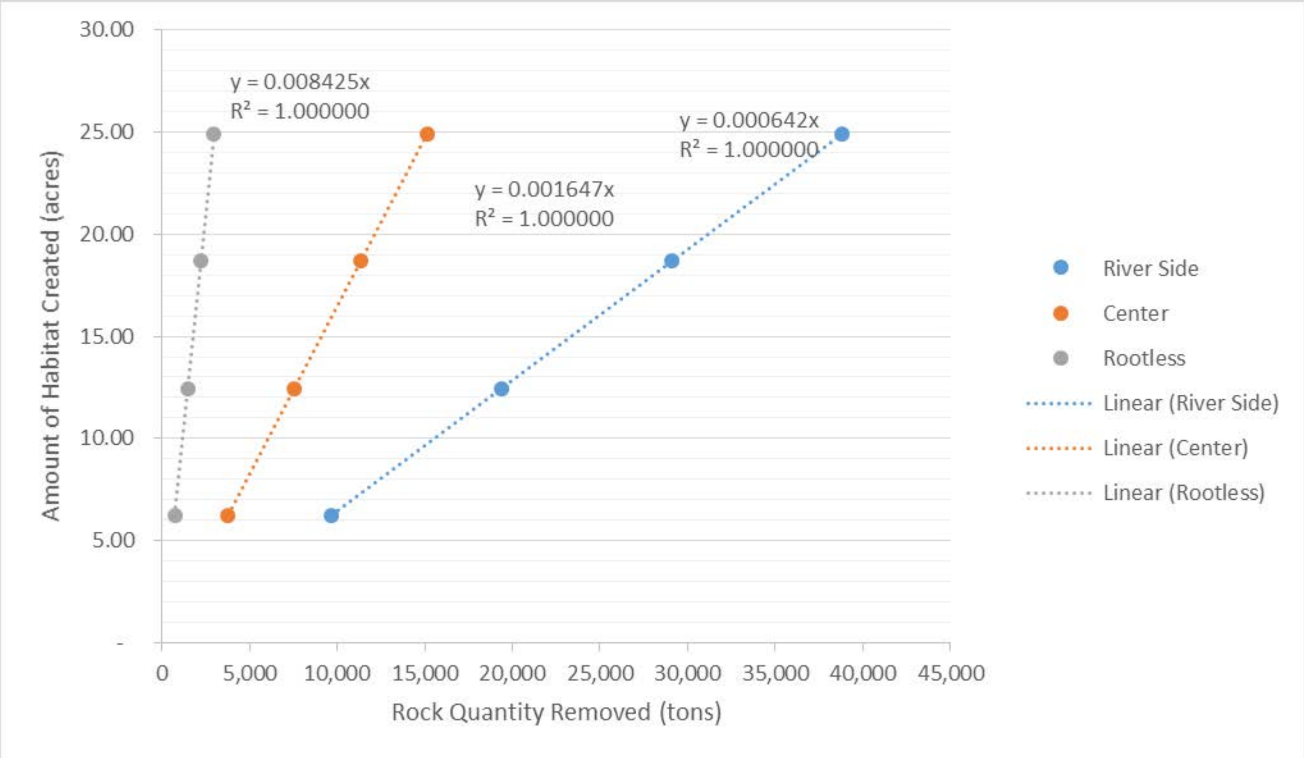


Figure 7: Amount of habitat created by notching dikes in different locations

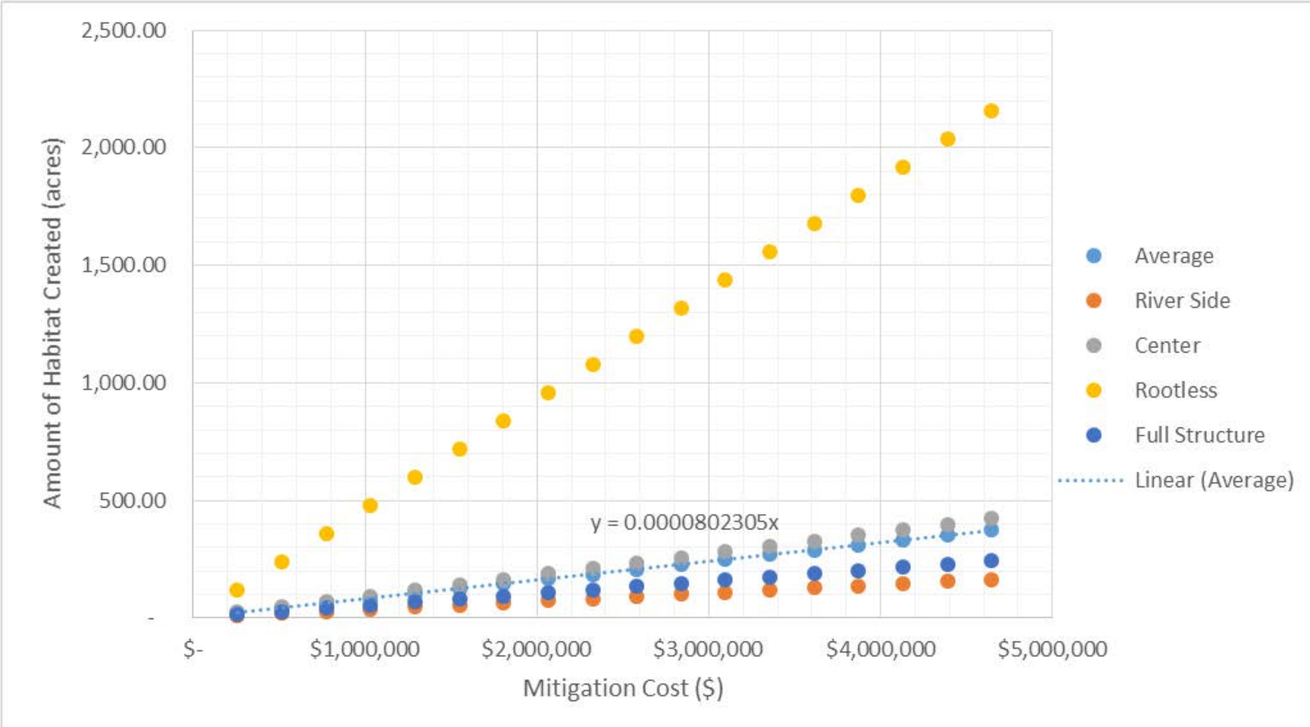


Figure 8: Cost of Mitigation by removing full dikes and different notch types

From the generic design analysis developed in the expert elicitation, a relationship between structure length and structure quantity was developed as shown in figure 9.

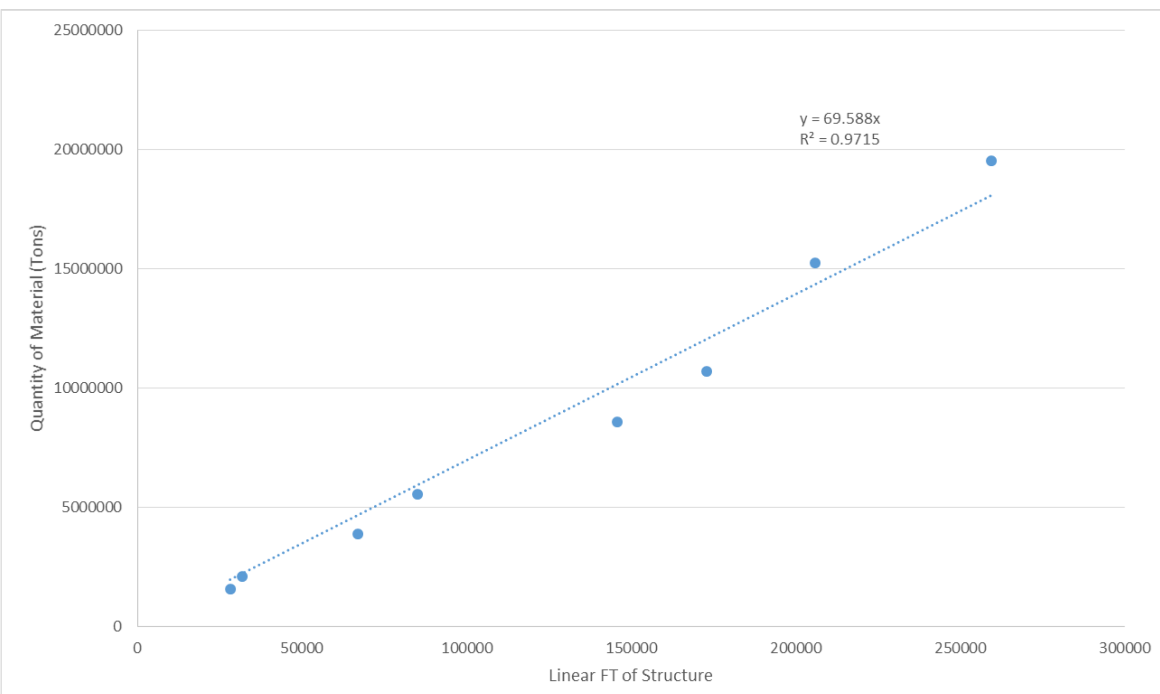


Figure 9: Relationship between strucutre quantity and length

Using the relationships above, a mitigation cost vs new structure construction cost could be developed. This relationship is shown in figure 10. This relationship is dependent on the cost of stone, habitat suitability index, footprint of constructed structures and length, depth and spacing of existing structures being removed and new structures being constructed. This cost only represents construction cost and does not account for costs associated with design, review, contracting, monitoring etc.

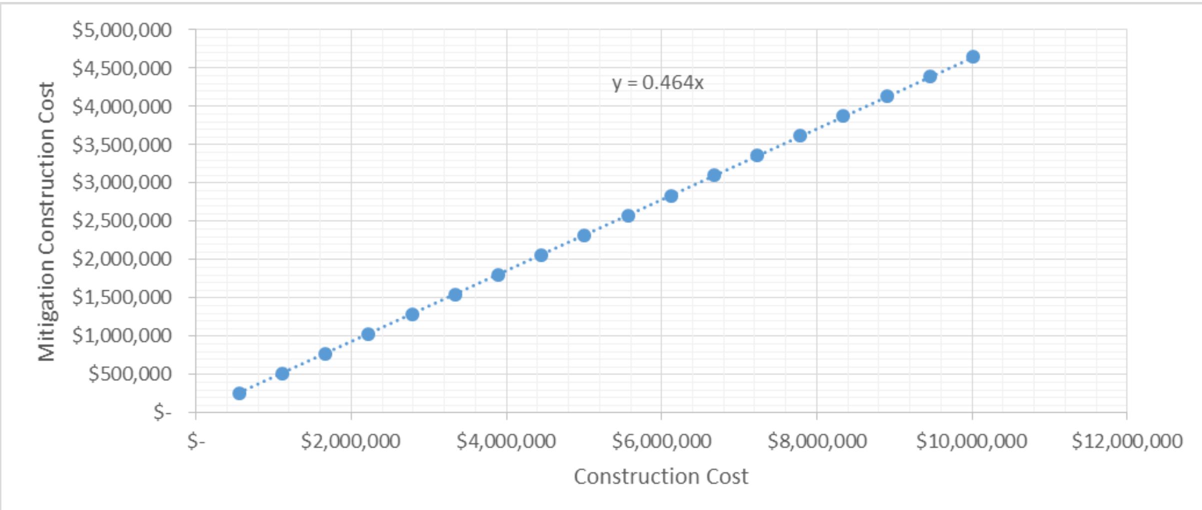


Figure 10: Cost of mitigation per dollar of dike construction

Estimation of remaining Regulating Works Dike Construction and Associated Mitigation

While reducing dredging to 1.3 million cubic yards per year is technically feasible, there will be a point where it is no longer economical to build additional structures. To estimate this approximate point, recent dredging costs and structure construction costs along with estimated mitigation costs were used to analyze the dredging reduction benefits of various increments of additional construction (up to 7.5 million tons). Using a 50-year period of analysis, a 3.125% discount rate, and FY16 price level, the increment of construction with the greatest net benefits is estimated to be 4.4 million tons.

Using the analysis presented in the previous sections, this quantity of construction would result in approximately 1,100 acres of mitigation for main channel border habitat impacts and would reduce dredging to an estimated average annual requirement of 2.6 million cubic yards. While these programmatic estimates utilized the best available information and assumptions at this time, the actual quantity of structures that are constructed, the impacts of that construction with associated mitigation, and the remaining average annual dredging requirements will depend on actual future conditions. As future projects are identified with specific construction sites, designs and cost estimates, SSEAs will detail the impacts to main channel border habitat of those projects along with the proposed mitigation. The cost of those projects, the quantity and cost of the associated mitigation, and the future cost of dredging will be incorporated into future economic updates of the Regulating Works Project.

Appendix D: Clean Water Act Section 404(b)(1) Evaluation

APPENDIX D

CLEAN WATER ACT

SECTION 404(b)(1) EVALUATION

CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION
MIDDLE MISSISSIPPI RIVER REGULATING WORKS PROJECT

I. INTRODUCTION

A. Authority, Purpose, Location, and General Description.

The St. Louis District (District) of the U.S. Army Corps of Engineers (Corps) is charged with operating and maintaining a nine-foot navigation channel on the Middle Mississippi River (MMR). The MMR is defined as that portion of the Mississippi River that lies between its confluence with the Ohio and Missouri Rivers (Figure 1 and Figure 2). This ongoing Project is also commonly referred to as the Regulating Works Project. As authorized by Congress in 1910, the Regulating Works Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetments, while sediment management is achieved by river training structures. The Regulating Works Project is maintained through dredging and any needed maintenance to already constructed features. The long-term goal of the Project, as authorized by Congress, is to provide a sustainable and safe navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging and the occurrence of vessel accidents through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable, and the District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

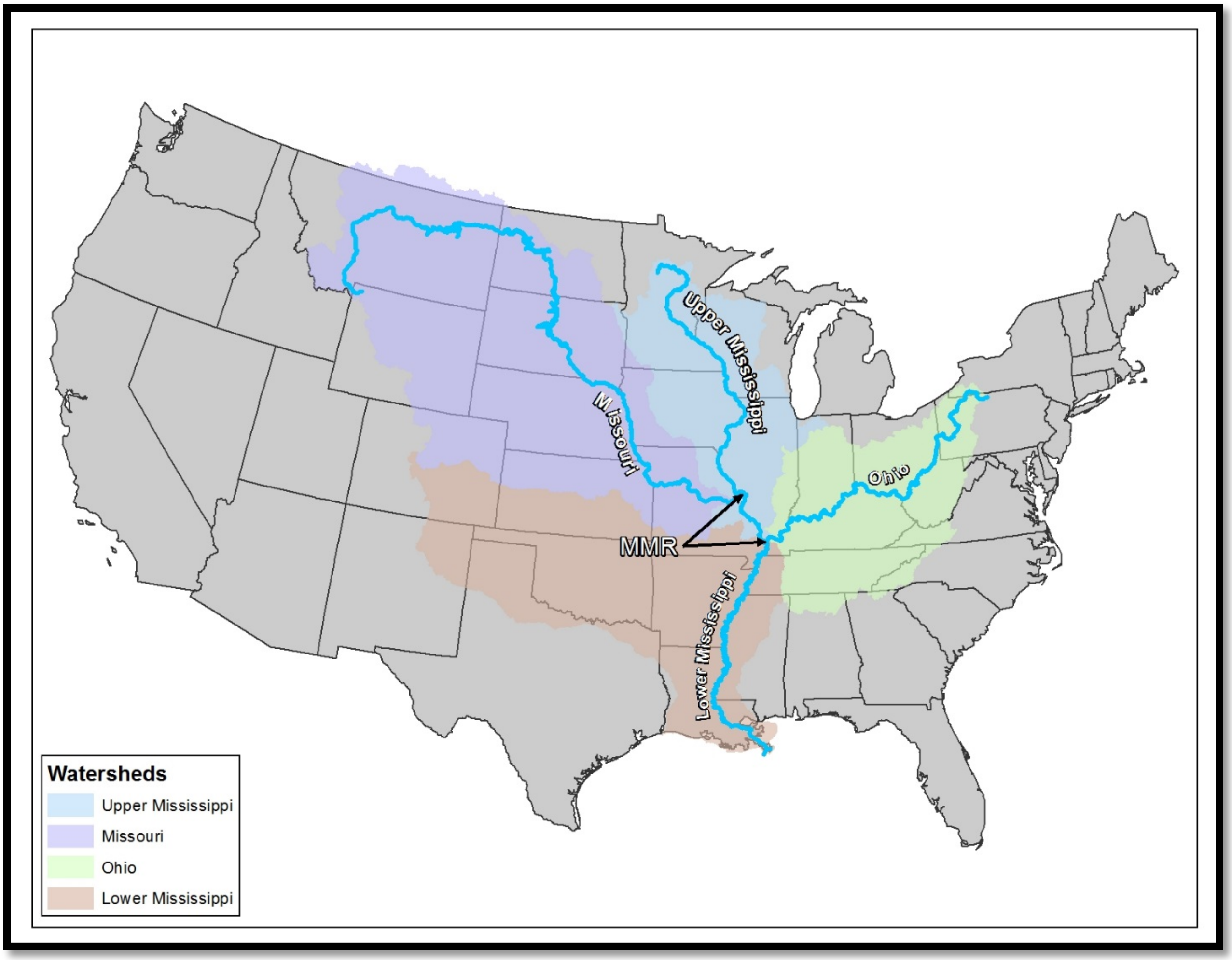


Figure 1. Location of the MMR within the Upper Mississippi River watershed.

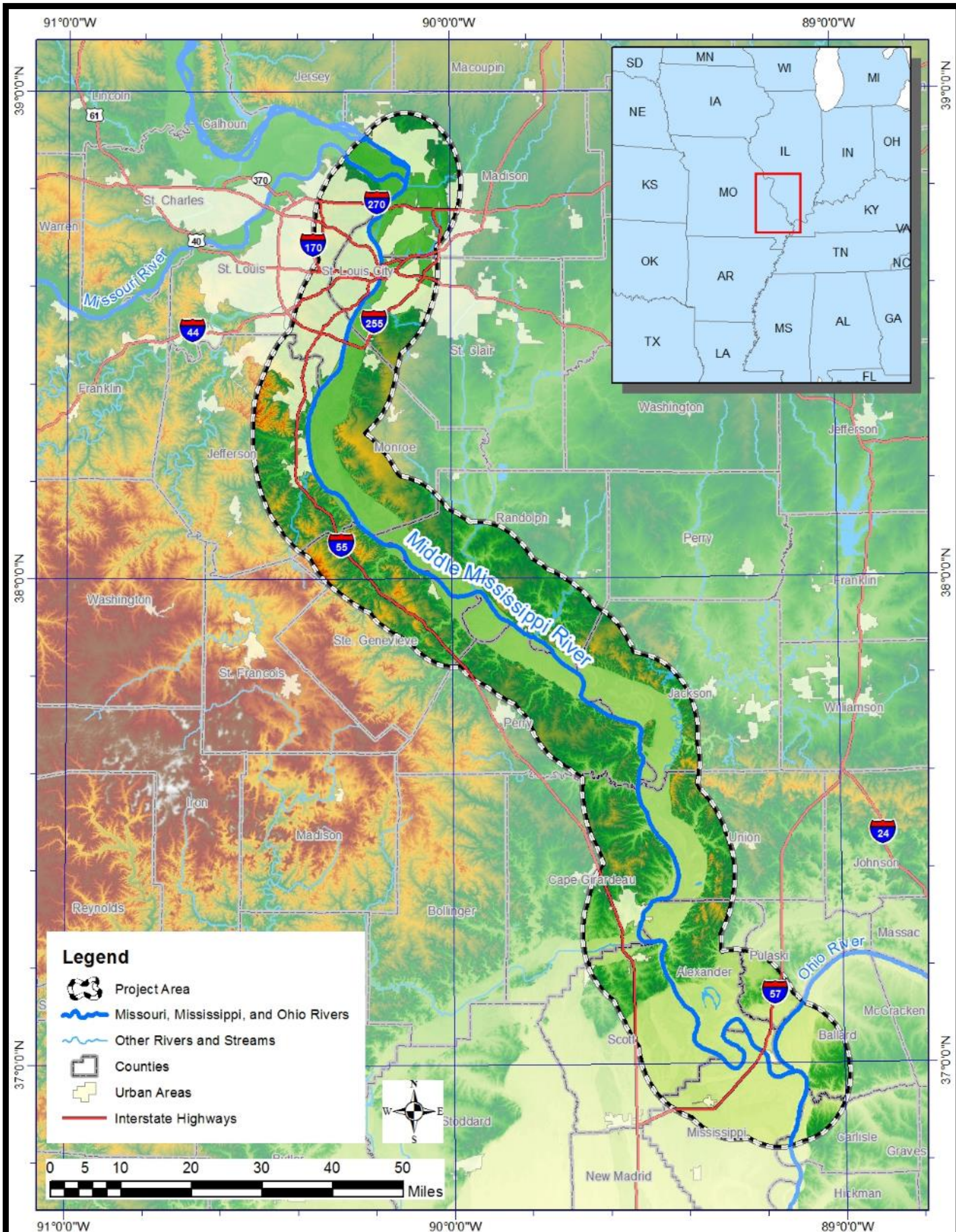


Figure 2. General location of the Project Area.

Dredging. The District currently dredges an average of approximately 4 million cubic yards of material per year from the MMR in order to maintain adequate navigation channel depths. This quantity is expected to decrease to approximately 2.4 million cubic yards per year, on average, after completion of construction of the remaining river training structures. The dredged material is generally placed in relatively close proximity to the dredge cut, outside of the navigation channel, riverward of existing river training structures, if present. Due to specific conditions at each dredging location, there are instances when dredged material cannot be placed in the main channel and must be placed closer to the bankline in main channel border areas. The District has also recently begun using a floating flexible dredge pipe to facilitate construction of sandbar/island habitat in association with dredging activities. Floating flexible dredge pipe is advantageous over typical rigid dredge pipe because the discharge end of the pipe can be kept in a fixed location instead of moving parallel to the dredge cut. With flexible pipe, as long as the discharge location is within a certain distance of the dredge, the position of the discharge can be fixed irrespective of the location of the dredge. Fixed-point discharge allows the buildup of material to higher elevations than is normally possible with rigid discharge pipe. This technique can be used to discharge “piles” of material to create expanses of shallow sandbar and/or ephemeral island habitat. Sandbar and island habitat is considered to be important fish habitat that is less abundant in the MMR than historically.

Dikes. The District utilizes various configurations of rock dikes to address repetitive dredging issues in the MMR. Dikes concentrate flows in the navigation channel, thereby inducing scour and reducing dredging. In response to natural resource agency partner concerns about the potential impacts of traditional dikes on fish and wildlife habitat, the St. Louis District developed innovative dike configurations that provide depth and flow diversity while still maintaining the primary function of deepening the navigation channel. The District has designed and implemented many different dike configurations including notched dikes, rootless dikes, L-dikes, W-dikes (see Figure 3), chevron dikes, multiple roundpoint structures (see Figure 3), etc. The District currently builds very few traditional wing dike structures in the MMR and continues to develop new configurations of innovative structures.

Figure 3. Multiple roundpoint structure and W-dike on the MMR (River Mile 4 near Cairo, IL).

Bendway Weirs. Bendway weirs are low-level, submerged rock structures positioned from the outside bankline of a riverbend, angled upstream toward the flow. These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening, reduce adjacent riverbank erosion on the outside bendway and align the thalweg toward the center of the channel away from the outside of the bend. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging.

Revetment. Rock revetment is primarily used to prevent bank erosion and channel migration on the banks of the river and to establish or maintain a desired channel alignment.

B. General Description of Dredged and Fill Material.

(1) General Characteristics of Material

Dredged Material. Material dredged from the main channel of the MMR is predominately sand. As a requirement associated with Clean Water Act Section 401 Water Quality Certification, the District is required to conduct grain size analysis on all dredge locations to ensure that less than 20 percent of the material is silt and clay. Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. If any sample contains more than 20 percent silt and clay, further chemical testing is required to analyze for potential contaminants.

Rock. Rock used for construction and maintenance of dikes, weirs, and revetment consists of quarry run limestone consisting of graded “A” stone. Size requirements for graded “A” stone are shown below in Table 1.

Table 1. Composition of graded "A" stone.

Stone Weight (pounds)	Cumulative % Finer by Weight
5,000	100
2,500	70-100
500	40-65
100	20-45
5	0-15
1	0-5

(2) Quantity of Material.

Dredged Material. The amount of material dredged in the MMR to maintain the navigation channel fluctuates greatly from year to year based on a range of factors, river stage being foremost among them. The average quantity currently dredged is approximately 4 million cubic yards per year. This quantity is expected to decrease to approximately 2.4 million cubic yards per year, on average, after the remaining construction of river training structures at chronic dredging sites is completed.

Rock. The amount of stone used each year for construction of dikes, weirs, and revetment will be specified in future site specific Environmental Assessments and associated 404(b)(1) analyses. An average of approximately 260,000 tons (175,000 cubic yards) of rock placed per year is anticipated over the remaining period of construction, for a total of 4.4 million tons (2.9 million cubic yards). The amount of stone used each year for maintenance of existing structures is anticipated to be approximately 90,000 tons (60,000 cubic yards).

(3) Source of Material.

Dredged Material. The main channel of the MMR is the source of all material dredged for maintenance of the navigation channel.

Rock. Rock required for construction and maintenance is obtained from commercial stone quarries in the vicinity of the work sites capable of producing stone which meets USACE specifications (see Table 1 above).

C. Description of the Proposed Discharge Sites.

(1) Location and Size.

Dredged Material. Dredged material is generally placed in the main channel of the MMR adjacent to the location of the dredge cut. Placement in main channel border areas is occasionally necessary based on specific site conditions. Dredging and disposal has the potential to take place anywhere in the 195 miles of the MMR, but typically occurs repeatedly in the same locations. Dredging and placement locations for 2006 through 2015 can be found below in Plate 1 through Plate 13. Based on an average dredge quantity of 4 million cubic yards per year, approximately 550 acres of main channel and main channel border habitat are impacted by dredged material placement. This is expected to decrease to approximately 330 acres after completion of new construction of river training structures. When using the floating flexible dredge pipe for disposal, the placement sites would be similar in location, but would be smaller in aerial extent than sites using rigid pipe.

Rock. The exact locations and sizes of future river training structures are determined on a site by site basis and will be specified in future Environmental Assessments and associated 404(b)(1) analyses. The typical elevations, slopes, configurations, etc. of MMR river training structures can be found in the typical section drawings at Plate 14.

(2) Type of Habitat.

Habitats affected by dredged material placement and by dike and weir placement are main channel and main channel border riverine habitats. Impacts to side channel habitat are avoided and minimized to the greatest extent possible. Revetment is typically placed on the bankline of the river up to the ordinary high water line. No grading of river bank habitat is required. All dredging and river training structure placement activities are coordinated with natural resource agency partners in order to minimize adverse effects.

(3) Timing and Duration of Discharge.

Dredged Material. Any dredging that occurs in any given year typically occurs during the period of July through December; however, the actual start and end dates and the total number of days dredged varies considerably from year to year depending on water levels and sedimentation patterns. The average number of days of dredging over the last 10 dredging seasons is approximately 115. Likewise, the duration of activity at each dredge and discharge location varies considerably based on site conditions, but the average number of days spent dredging at a location over the last 10 dredging seasons is approximately 5.

Rock. Placement of rock material for river training structure construction and maintenance is highly dependent on water levels and can occur at any time of year. The duration of each construction activity is highly variable as it is dependent on the size and configuration of the structure(s) being constructed and site conditions at the time of construction.

D. Description of Disposal Method.

Dredged Material. Two methods are used for placement of dredged material in the MMR: traditional side casting of material with rigid pipeline (see Figure 4 below), and fixed location disposal with floating flexible dredge pipe (see Figure 5 below). With traditional side casting, dredged material is placed in rows parallel to the dredge cut. As the dredge moves up and down the dredge cut, the discharge pipe moves up and down the placement area resulting in long, narrow disposal areas similar in size and shape to the dredged area. The majority of dredged material disposal conducted in the District still utilizes traditional rigid pipeline. Since its first use in 2011, the floating flexible dredge pipe has been utilized for approximately 8% of the District’s dredging, based on total cubic yards dredged. Dredged material placement using the floating flexible dredge pipe allows disposal at a fixed location. This allows flexibility in the height and shape of the disposal location, providing opportunity to improve fish and wildlife habitat. The percentage of dredged material disposal in the MMR using the floating flexible dredge pipe is expected to increase as the District fully implements its use; however, it is unknown what percentage of the District’s dredged material disposal will be conducted with the floating flexible pipe going forward and the percentage will likely vary considerably from year to year depending on river levels, dredge requirements, etc.

Figure 4. MMR side-cast dredging using rigid disposal pipe.

Figure 5. MMR fixed-point discharge dredging using floating flexible disposal pipe.

Rock. Placement of rock material for dike, weir, and revetment construction and maintenance is accomplished by track hoe (see Figure 6 below) and/or dragline crane (see Figure 7 below). Stone is transported to placement sites by barges. All construction is accomplished from the river and all work is performed below the ordinary high water elevation.

Figure 7. Construction of MMR dike with barge-mounted track hoe.

Figure 6. Construction of MMR dike with barge-mounted dragline crane.

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations.

(1) Comparison to Existing Substrate and Fill.

Dredged Material. Dredged material placed in main channel and main channel border areas is very similar in composition to the existing substrate, consisting primarily of sand with little gravel, silt, or clay content.

Rock. Rock fill material used in construction and maintenance of dikes, weirs, and revetment is graded limestone from local quarries. Rock fill material is placed on existing substrate that consists largely of sand with little gravel, silt, or clay content. Rock fill material used in future construction and maintenance operations will be similar in size and composition to existing dike, weir, and revetment material in the MMR.

(2) Changes to Disposal Area Elevation.

Dredged Material. Placement of dredged material using traditional rigid discharge pipeline generally results in a disposal area that is shallower to approximately the same degree that the associated dredged area is deeper. While the exact depth of material placed in a disposal area varies with each dredging event and also varies across an individual placement site based on natural riverbed elevation variations, the average amount of material removed from dredge cuts and placed in disposal areas in the MMR is approximately 4.5 feet. When floating flexible dredge pipe is used, the change in elevation of the disposal area will vary greatly from site to site but will generally be greater than if traditional rigid pipe were used.

Rock. Placement of stone associated with dike, weir, and revetment construction and maintenance will cause an immediate change in elevation over the aerial extent of the structure from the pre-construction condition to the design elevation of the structure. Design elevations of structures will vary from site to site based on local conditions and the intended purpose of the structures. Typical structure designs can be found at Plate 14.

In addition to the change in elevation in the footprint of the structure, dikes and weirs will also likely cause permanent changes in elevation of adjacent areas. Structures typically cause varying patterns of scour and deposition in the immediate vicinity of the area of placement and are designed to induce scour in the adjacent navigation channel. The degree of elevation changes both in the area of placement and the adjacent navigation channel will vary based on local conditions and the configuration of each structure.

(3) Migration of Fill.

Dredged Material. Dredged material placement sites generally return to their pre-placement elevation over time, with fill gradually eroding and migrating downstream. How quickly this occurs is largely dependent on the configuration of the river channel at the placement site and river stages subsequent to placement.

Rock. Rock fill material used in construction and maintenance of dikes, weirs, and revetment is intended to be very stable and resistant to the erosive forces of the river. Nonetheless, some erosion of stone does occur, particularly during high flow events and winter ice conditions.

(4) Changes to Environmental Quality and Value.

Dredged Material. The dredged material placed in disposal areas is of similar composition to the existing material and is, therefore, anticipated to be of equivalent environmental quality and value.

Rock. The rock fill material used in construction of dikes, weirs, and revetment is expected to provide improved substrate for colonization by a wide variety of macroinvertebrates. The environmental quality and value of the substrate is anticipated to be of equal or greater value in relation to the existing material.

The changes in elevation of adjacent areas associated with placement of rock structures, in combination with the changes in current patterns discussed in Section II.B.(1) below, are anticipated to have an adverse effect on some segments of the MMR fish community. This adverse effect and proposed mitigation measures are discussed further in Section II.E.(3) below.

(5) Actions to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas.

B. Water Circulation, Fluctuation, and Salinity Determinations.

(1) Alteration of Current Patterns and Water Circulation.

Dredged Material. Some minor changes in current patterns are expected at placement sites due to changes in elevation. These changes are expected to gradually subside as the disposal site elevations return to normal over time.

Rock. Dikes and weirs are specifically designed to alter current and sedimentation patterns to improve the depth and/or alignment of the navigation channel. Dike placement alters current patterns in main channel border areas downstream by creating diverse areas of slack water, eddies, and current breaks, particularly at river stages when structures are not overtopped. The exact pattern of circulation depends on the type of dike constructed and the location within the river channel. Dike placement also alters current patterns in the adjacent navigation channel. Velocities in the navigation channel initially increase in response to dike placement, resulting in channel deepening. Velocities gradually return to pre-construction levels as the channel deepens.

Weirs are placed on outside river bends to shift current patterns away from the outside bend, thereby controlling excessive channel deepening, reducing adjacent riverbank erosion on the outside bendway, and shifting the navigation channel toward the center of the river. This results in a wider, more evenly distributed current pattern across the bend, and, consequently, a safer navigation channel.

Revetment has little impact on current patterns and water circulation.

(2) Interference with Water Level Fluctuation.

Analysis of river stage data over time from gages on the MMR indicates that there appears to be a trend of decreasing river stages at lower flows on the MMR. This is likely caused by a combination of river training structures deepening the channel and a decrease in the sediment load entering the MMR from upstream tributaries. Based on current projections, decreases in stage of 0.13 to 0.88 feet can be anticipated at St. Louis across the range of non-flood flows (less than 425,000 cfs). Stages at Chester are anticipated to decrease 0.08 to 0.30 feet only at flows between 75,000 and 150,000 cfs and are anticipated to increase at all other flows. It is not possible to differentiate what portion of this effect is attributable to river training structure construction versus a reduction in sediment load from tributaries.

(3) Salinity Gradient Alteration. No effect.

(4) Cumulative Effects on Water Quality.
  a. Salinity. No effect.
  b. Clarity. See suspended particulate / turbidity determinations below.
  c. Color. No effect.
  d. Water Chemistry and Dissolved Gasses. Limestone material used for construction and maintenance of structures could potentially affect local water chemistry (e.g., alkalinity, hardness, and pH). However, given the prevalence of limestone in the watershed geology and the quick dissipation of any associated fine materials in the water column, the impact is expected to be negligible.
  e. Temperature. No effect.
  f. Nutrients. No effect.

(5) Changes to Environmental Quality and Value.

The changes in current patterns associated with placement of rock structures, in combination with the changes in elevation discussed in Section II.A.(2) above, are anticipated to have an adverse effect on some segments of the MMR fish community. This adverse effect and proposed mitigation measures are discussed further in Section II.E.(3) below.

(6) Actions Taken to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas.

C. Suspended Particulate / Turbidity Determinations.

(1) Alteration of Suspended Particulate Type and Concentration.

Disposal of dredged material is likely to result in increased turbidity in the immediate vicinity of the placement area and for a short distance downstream. However, given the general lack of fine-grained sediments in dredged material, the similarity of dredged material to placement area material, and the degree of natural variability in MMR turbidity, this effect is expected to be short-term and minor.

Construction and maintenance of dikes, weirs, and revetment is likely to result in a slight increase in turbidity in the vicinity of construction activities. However, given the degree of natural variability in MMR turbidity, this effect is expected to minor.

Dikes and weirs are designed to change current and sedimentation patterns and would, therefore, cause some minor temporary changes in the suspended sediment concentration in the immediate vicinity of placement locations as the river bed adjusts to the altered flow patterns. When compared to the typical sediment load in the MMR, this increase in suspended sediment concentration from all future river training structure construction and maintenance is expected to be negligible.

Revetment is designed to reduce bankline erosion and would, therefore, reduce suspended sediment concentration in the immediate vicinity of placement locations indefinitely. When compared to the typical sediment load in the MMR, this reduction in suspended sediment associated with reduced bankline erosion from all future revetment construction is considered negligible.

(2) Particulate Plumes Associated with Discharge.

Discharge of dredged material is expected to result in some degree of particulate plume in the vicinity of the placement area. The degree of increase in turbidity is directly related to the proportion of fine-grained sediment in the material to be dredged (Herbich and Brahme 1991). Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. Given that the vast majority of dredged material is sand and not fine-grained material that would stay in suspension longer, the impact would be localized and would dissipate quickly. Turbidity plumes from dredging operations in the Upper Mississippi River are generally undetectable one-half mile downstream from the dredging location (WEST 2000). The Corps' St. Paul District monitored dredging operations in the main channel of the Mississippi River in the 1970s (Anderson et al. 1981a; Anderson et al. 1981b) and found that dredging operations had only minor, localized effects on turbidity. The Corps' Kansas City District monitored dredging operations on the Lower Missouri River in the 1980s (USACE 1990) and found that the plume from dredging operations returned to background levels within approximately 1,300 feet.

Construction and maintenance of dikes, weirs, and revetment is likely to result in minor particulate plumes in the immediate vicinity of construction activities. However, this effect is expected to be minor given its highly localized nature and the natural variability in background turbidity levels on the MMR.

(3) State Water Quality Standards. No violations of state water quality standards are anticipated. The District obtains Clean Water Act Section 401 Water Quality Certification for all dredging and river training structure construction activities on the MMR as required.

(4) Changes to Environmental Quality and Value. No effect.

(5) Actions to Minimize Impacts. No actions to minimize impacts necessary.

D. Contaminant Determinations.

As a requirement associated with Clean Water Act Section 401 Water Quality Certification, the District is required to conduct grain size analysis on all dredge locations to ensure that less than 20 percent of the material is silt and clay. Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. If any samples contain more than 20 percent silt and clay, further chemical testing is required to analyze for potential contaminants. In addition, all potential river training structure placement sites are screened to facilitate early identification of potential hazardous, toxic, and radioactive waste in accordance with USACE regulations (ER 1165-2-132 and ER 200-2-3). Accordingly, no adverse effects from contaminants are anticipated.

E. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. No effect.

(2) Effects on Benthos.

Dredged Material. Due to the shifting nature of main channel sediments and the lack of fine organic particulate matter, main channel disposal areas generally provide poor habitat for macroinvertebrate colonization. Nonetheless, these areas do typically hold low densities of benthic macroinvertebrates that are likely lost through burying at the disposal site. Losses of benthic macroinvertebrates at main channel border disposal sites are likely much greater due to greater densities of organisms. Based on the current average annual dredge quantity of approximately 4 million cubic yards, approximately 550 acres of habitat are impacted by dredged material disposal each year. Given the naturally dynamic nature of the largely main channel areas impacted by dredged material disposal, the low densities of macroinvertebrates found in these habitats, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, adverse effects to benthic macroinvertebrates associated with dredging are anticipated to be minor. These adverse effects are expected to decrease gradually as chronic dredging locations are addressed through construction of new river training structures.

Rock. Placement of stone for dike, weir, and revetment construction and maintenance likely eliminates those benthic organisms utilizing the habitat and largely precludes future re-colonization. However, the rock used for river training structure construction generally provides habitat that results in greater densities of macroinvertebrates than the native sediments it replaces. Future construction of river training structures is expected to increase benthic macroinvertebrate numbers.

(3) Effects on Nekton.

Dredged Material. Placement of dredged material in main channel and main channel border areas likely temporarily causes avoidance of the areas by fish due to disturbance. This effect is short-term with dredge placement areas being usable by fish soon after completion of dredging. The floating flexible dredge pipe is specifically used to improve habitat diversity of dredge placement sites. Based on the current average annual dredge quantity of approximately 4 million cubic yards, approximately 550 acres of habitat are impacted by dredged material disposal each year, which represents approximately 2 percent of the riverine habitat in the MMR. This is expected to decrease to approximately 2.4 million cubic yards and 330 acres of habitat over the course of the remaining period of construction. Adverse effects to the MMR fish community from dredged material placement is anticipated to be minor.

Rock. Direct impacts from placement of rock for dike, weir, and revetment construction and maintenance activities on the MMR fish community are expected to be minor as fish likely avoid sites during construction. Placement of river training structures is expected to indirectly benefit the MMR fish community by increasing habitat diversity and by increasing the amount of shallow low velocity main channel border habitat which is generally regarded as important habitat to a large segment of the fish community. However, along with these benefits, there are adverse effects to fish that are anticipated with future construction of river training structures. Three-dimensional modeling conducted by the District indicates that construction of river training structures generally results in a decrease in shallow to moderate depth, moderate to high velocity habitat which is important habitat to some MMR fluvial specialists, or species that are found almost exclusively in flowing water throughout their life cycles. This habitat is characteristic of MMR unstructured main channel border areas. Based on the amount of remaining construction anticipated, it is estimated that river training structure construction could affect another 1,100 acres[1] of unstructured main channel border habitat. This represents approximately 8% of the remaining unstructured main channel border habitat in the MMR. This conversion is expected to have a significant adverse

[1] The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation needs will not be known until a main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

effect on the MMR fish community and the District has concluded that this warrants compensatory mitigation.

Compensatory Mitigation. In order to compensate for the projected adverse effects of future river training structure placement, potential mitigation measures may include, but are not limited to, wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities.. Removal, shortening, notching, etc. of existing obsolete river training structures would facilitate the replacement of lost function with an equivalent amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the Middle Mississippi River reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel. Detailed mitigation planning will be handled on a site by site basis and will be covered in site-specific Environmental Assessments and associated 404(b)(1) analyses.

(4) Effects on the Aquatic Food Web. No effects on the aquatic food web, beyond those effects on the constituent organisms delineated above, are anticipated.

(5) Effects on Special Aquatic Sites.
   a. Sanctuaries and refuges. No effect.
   b. Wetlands. No effect.
   c. Mud Flats. No effect.
   d. Vegetated shallows. No effect.
   e. Coral reefs. No effect.
   f. Riffle and pool complexes. No effect.

(6) Effects on Threatened and Endangered Species.

In 1999 the Corps prepared a Tier I Biological Assessment for the Operation and Maintenance of the Upper Mississippi River Navigation Project within the St. Paul, Rock Island, and St. Louis Districts to determine the impacts of operation and maintenance of the 9-foot navigation channel on threatened and endangered species. Subsequently, the U.S. Fish and Wildlife Service prepared a Biological Opinion on the O&M of the 9-foot navigation channel. In their Biological Opinion, the Service concluded that continued operation and maintenance of the 9-foot navigation channel

- would jeopardize the continued existence of the pallid sturgeon (*Scaphirhynchus albus*),
- would not jeopardize the continued existence of the least tern (*Sterna antillarum*), but would result in incidental take,
- would likely adversely affect the Indiana bat (*Myotis sodalis*), but impacts would be offset by management actions or would be negligible and would not rise to the level of incidental take, and

- would adversely affect the decurrent false aster (*Boltonia decurrens*), but would not jeopardize its continued existence.

Based on these determinations, the Service recommended appropriate actions for the Corps to take in order to avoid impacts to pallid sturgeon and least terns. The Corps initiated implementation of these actions subsequent to the issuance of the Biological Opinion and currently continues to implement them. Implementation of the recommendations of the Biological Opinion is coordinated extensively and continually with the Service and other natural resource agencies. Implementation of the District's Biological Opinion Program is expected to continue until such time as the species are considered recovered or it is determined that the District's actions are no longer jeopardizing the species or resulting in incidental take.

In addition to the species covered by the 2000 Biological Opinion, nine new species have been listed for counties in the Project Area since that time (see Table 2 below). The District has concluded that the Project may affect but is not likely to adversely affect the Northern long-eared bat and will have no effect on the remaining species.

Table 2. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion.

Species	Federal Status
Red knot (*calidris canutus rufa*)	Threatened – listed in 2015
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013
Scaleshell mussel (*Leptodon leptodon*)	Endangered – listed in 2001
Sheepnose mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012
Snuffbox mussel (*Epioblasma triquetra*)	Endangered – listed in 2012
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012
Grotto sculpin (*Cottus specus*)	Endangered – listed in 2013
Northern long-eared bat (*Myotis septentrionalis*)	Threatened – listed in 2015
Eastern massasauga (*Sistrurus catenatus*)	Candidate species

(7) Effects on Other Wildlife. No effect.

(8) Actions to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas. Compensatory mitigation will be implemented as necessary to offset adverse effects to the MMR fish community based on ongoing site-specific analysis of impacts.

F. Proposed Disposal Site Determinations.

Discussions pertaining to turbidity and suspended particulates are covered under Section II.C above. Discussions pertaining to contaminants are covered under Section II.D above. Implementation of the proposed project will have no significant adverse effects on municipal or private water supplies; recreational or commercial fisheries; water related recreation or aesthetics; parks; national monuments; or other similar preserves. Any adverse effects not covered by compensatory mitigation measures will be minor and of short-term duration.

G. Determination of Cumulative Effects on the Aquatic Ecosystem.

No significant adverse cumulative effects are anticipated beyond those outlined in Section II.E.(3) above.

H. Determination of Secondary Effects on the Aquatic Ecosystem.

No significant adverse secondary effects are anticipated beyond those outlined in Section II.E.(3) above.

III. FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE

A. Adaptation of Section 404(b)(1) Guidelines. No significant adaptations of the guidelines were made relative to this evaluation.

B. Alternatives. No practicable alternatives to the proposed discharges could be identified that would have less adverse effect on the aquatic ecosystem.

C. Compliance with State Water Quality Standards. Chemical constituents of the materials released during disposal operations are not expected to exceed Missouri or Illinois Water Quality Standards. The District obtains Clean Water Act Section 401 Water Quality Certification for all dredging and river training structure construction activities on the MMR as required.

D. Compliance with Endangered Species Act. The proposed action is compliant with the Endangered Species Act of 1973, as amended.

E. Evaluation of Extent of Degradation of the Waters of the United States. The proposed dredging and placement activities would not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing. The proposed activities would not adversely affect plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic life and other wildlife would not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability and on recreational, aesthetic, and economic values would not occur.

F. Appropriate and Practicable Steps Taken to Minimize Potential Adverse Impacts of the Discharge on the Aquatic Ecosystem. All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas. Compensatory mitigation will be implemented as necessary to offset adverse effects to the MMR fish community. Accordingly, the project as proposed is specified as complying with the requirements of these guidelines.

Date: ______________________________ ______________________________

Literature Cited

Anderson, D.D., R.J. Whiting, and B. Jackson. 1981a. An assessment of water quality impacts of maintenance dredging on the Upper Mississippi River in 1978. US Army Engineer District, St. Paul, MN.

Anderson, D., R. Whiting, and J. Nosek. 1981b. An assessment of water quality impacts of maintenance dredging on the Upper Mississippi River in 1979. US Army Engineer District, St. Paul, MN.

Herbich, J. B. and S. B. Brahme. 1991. Literature review and technical evaluation of sediment resuspension during dredging. Contract Report HL-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

USACE (U.S. Army Corps of Engineers). 1990. Final Regulatory Report and Environmental Impact Statement: Commercial Dredging Activities on the Kansas River, Kansas. January 1990.

WEST Consultants, Inc. 2000. Upper Mississippi River and Illinois Waterway Navigation Feasibility Study – Cumulative Effects Study, Volumes 1-2. Prepared by WEST Consultants, Inc. for the U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois.

PLATES

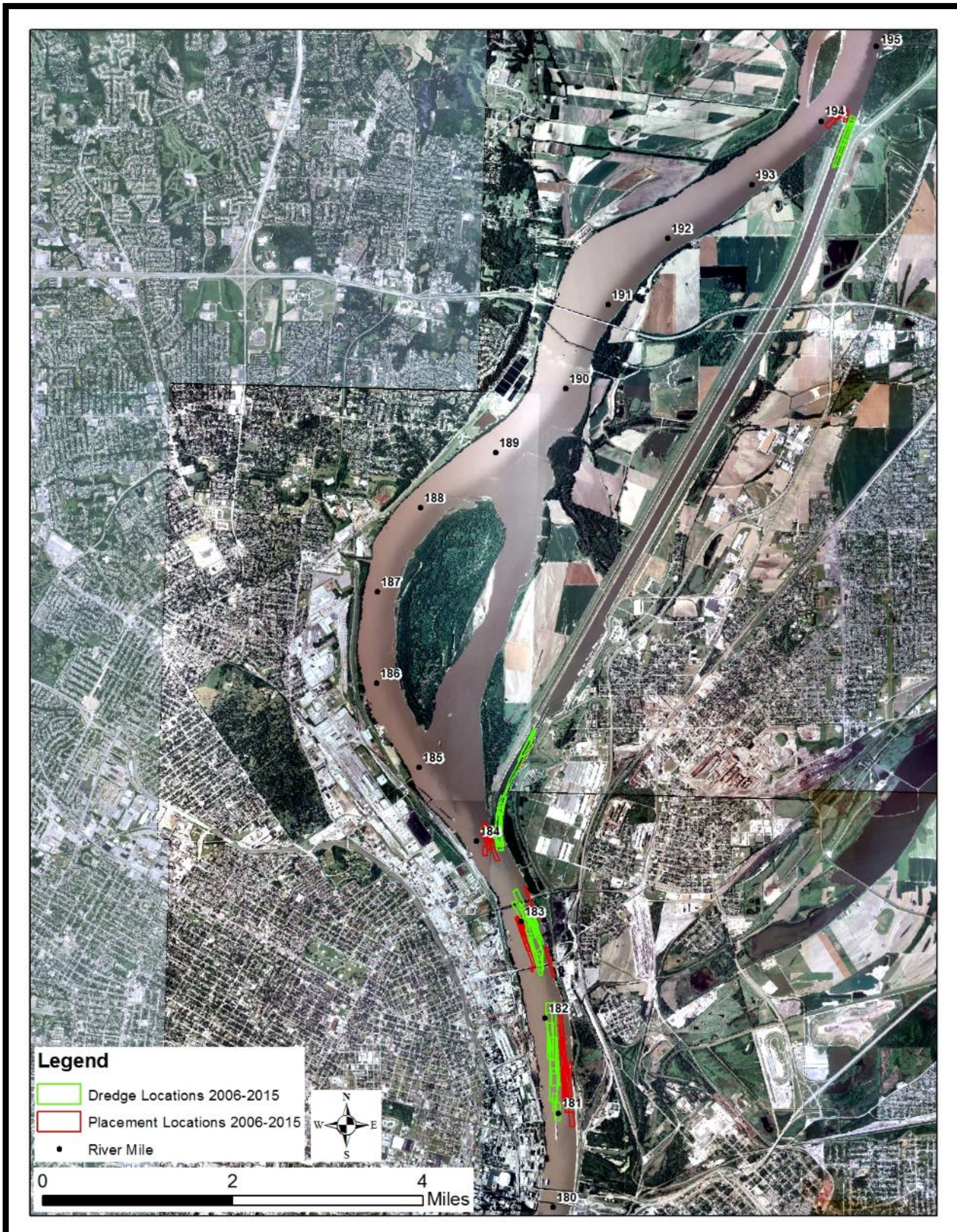


Plate 1. MMR dredge and placement locations, 2006 to 2015, river miles 195 to 180

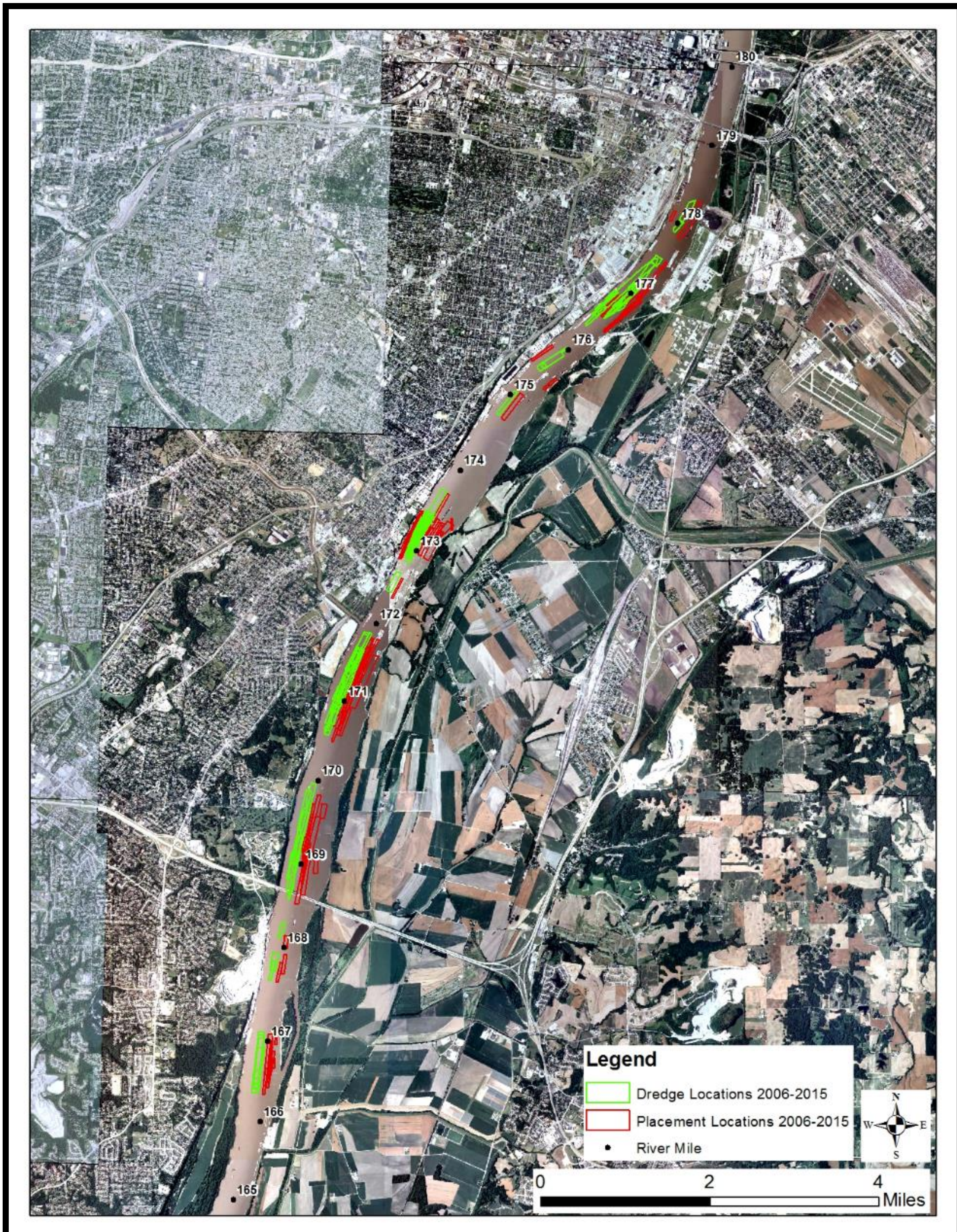


Plate 2. MMR dredge and placement locations, 2006 to 2015, river miles 180 to 165.

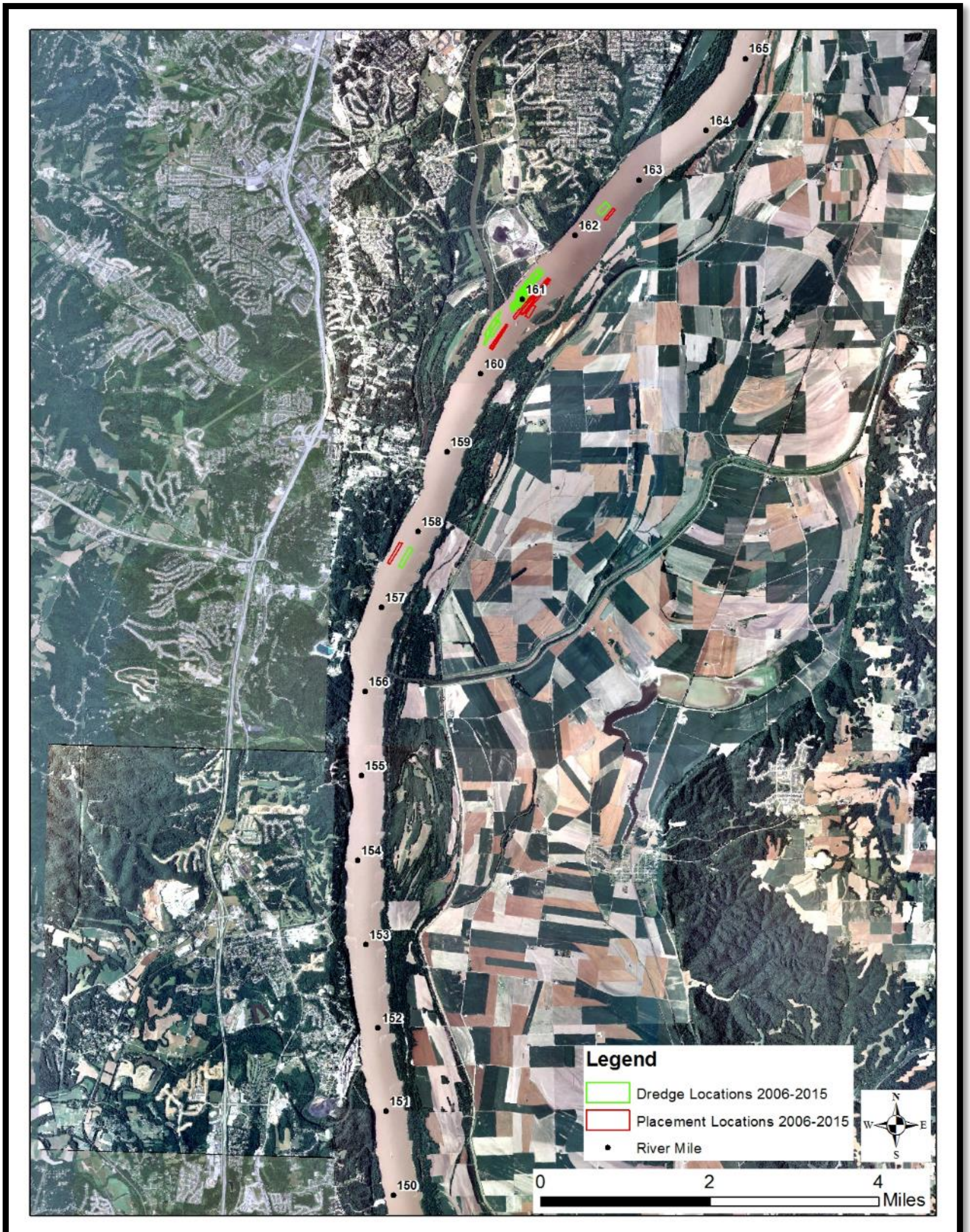


Plate 3. MMR dredge and placement locations, 2006 to 2015, river miles 165 to 150.

Plate 4. MMR dredge and placement locations, 2006 to 2015, river miles 150 to 135.

Plate 5. MMR dredge and placement locations, 2006 to 2015, river miles 135 to 120.

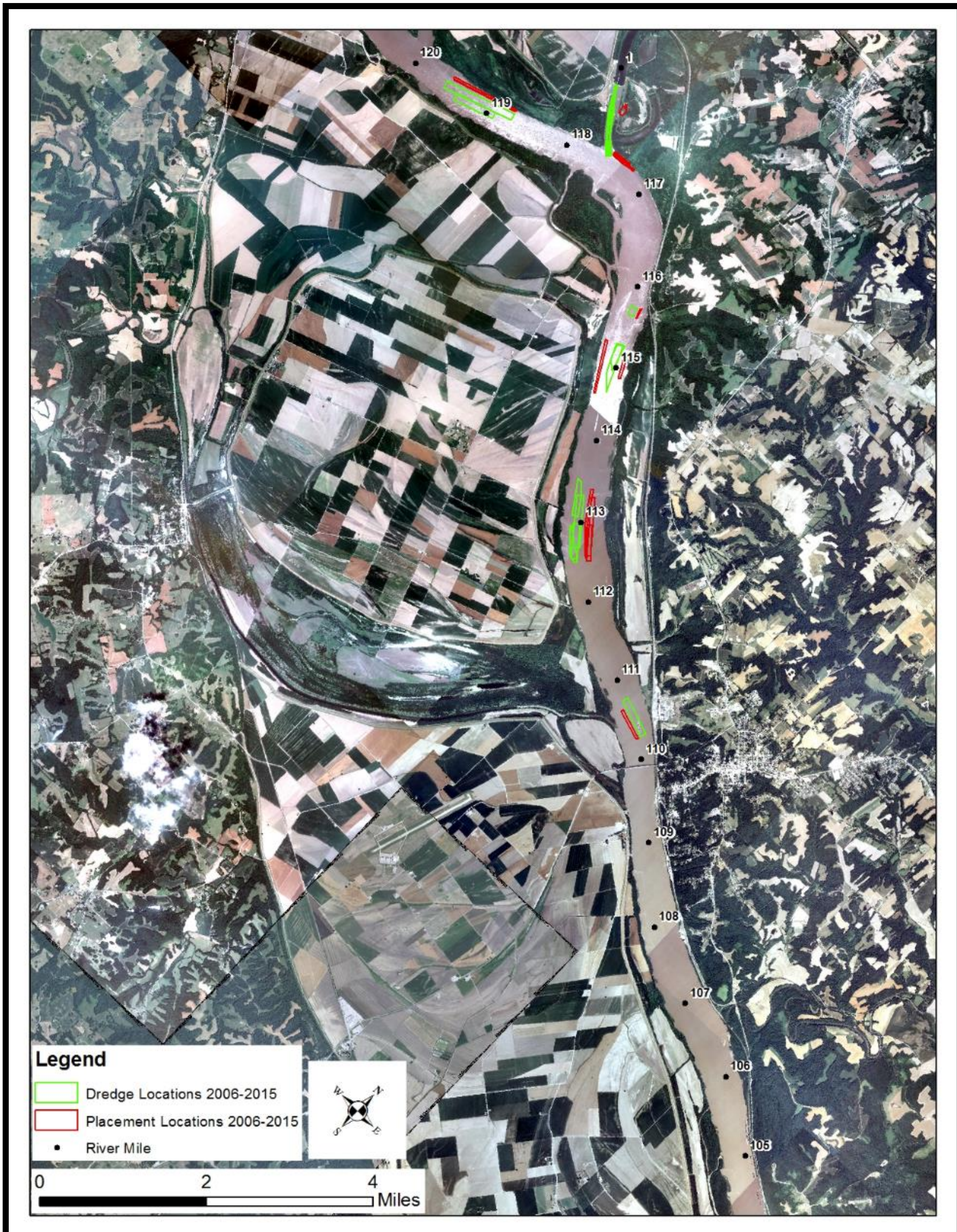


Plate 6. MMR dredge and placement locations, 2006 to 2015, river miles 120 to 105.

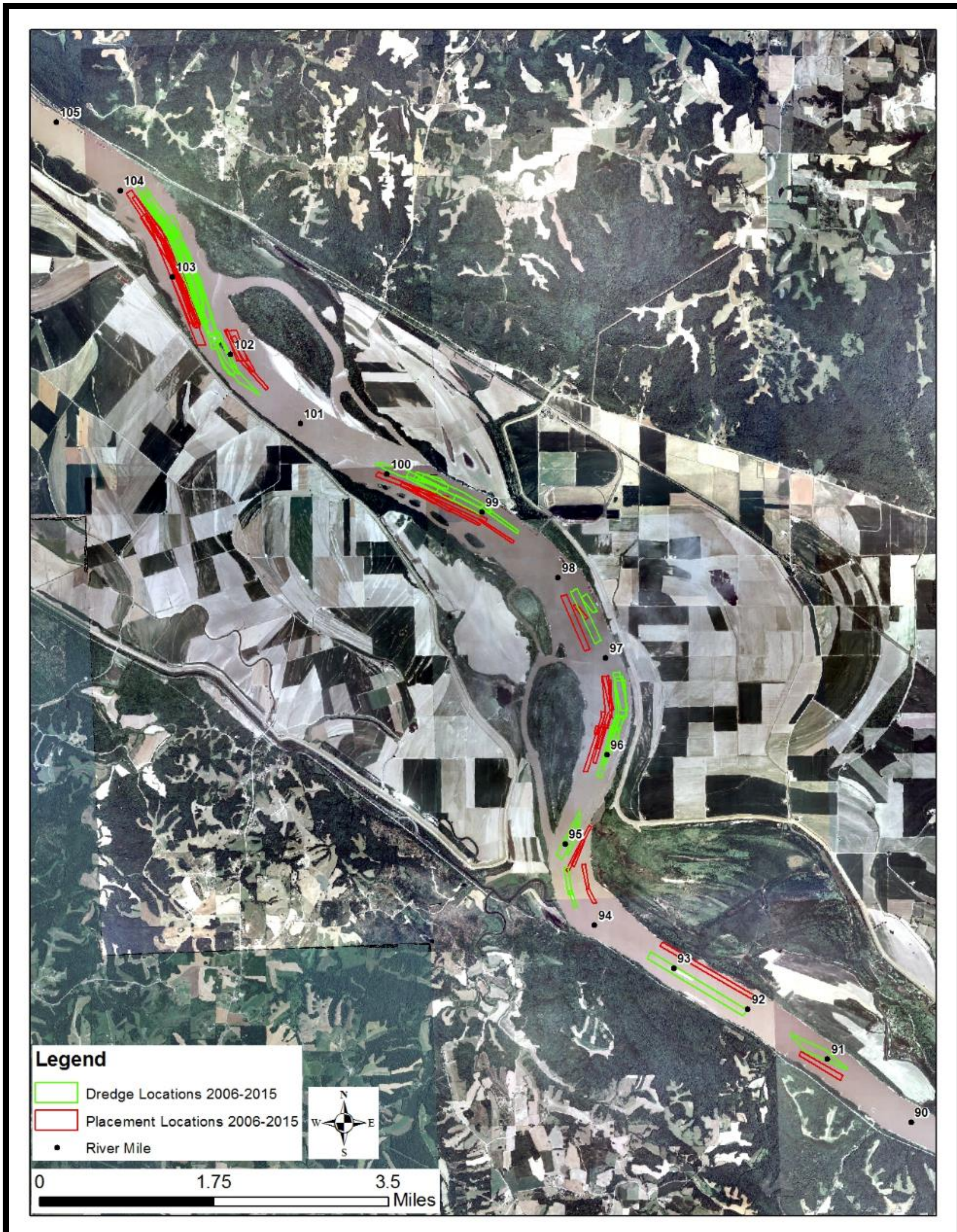


Plate 7. MMR dredge and placement locations, 2006 to 2015, river miles 105 to 90.

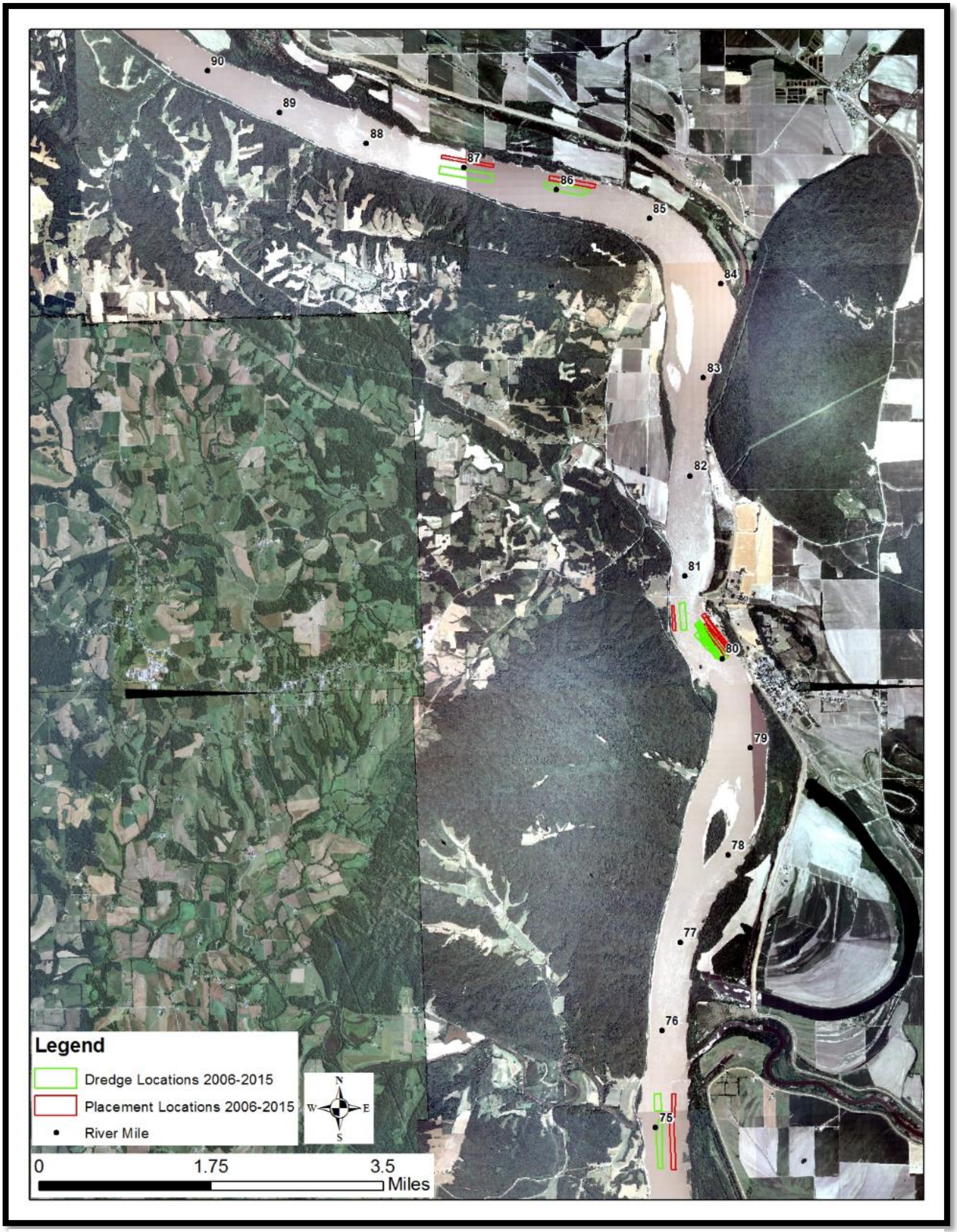


Plate 8. MMR dredge and placement locations, 2006 to 2015, river miles 90 to 75.

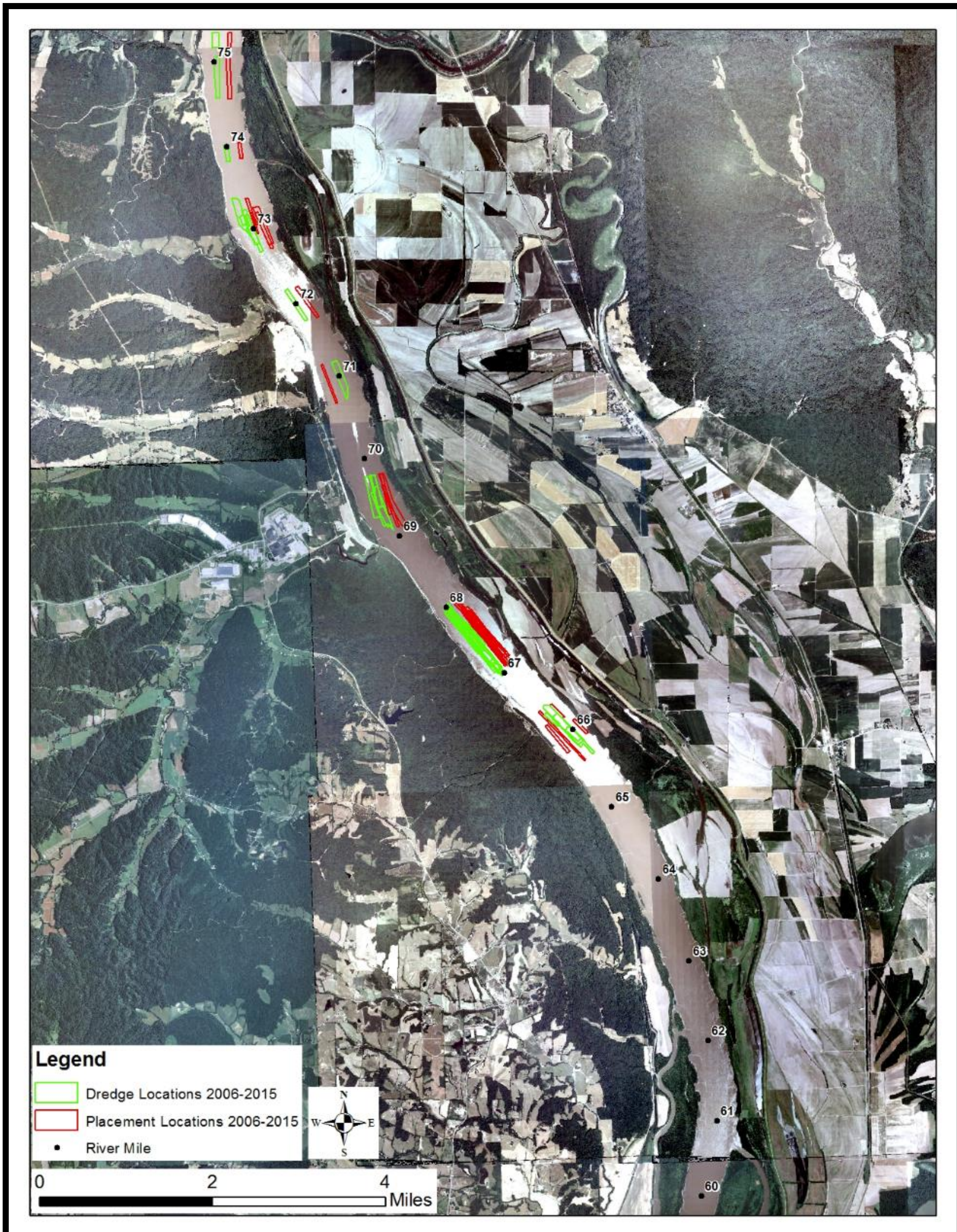


Plate 9. MMR dredge and placement locations, 2006 to 2015, river miles 75 to 60.

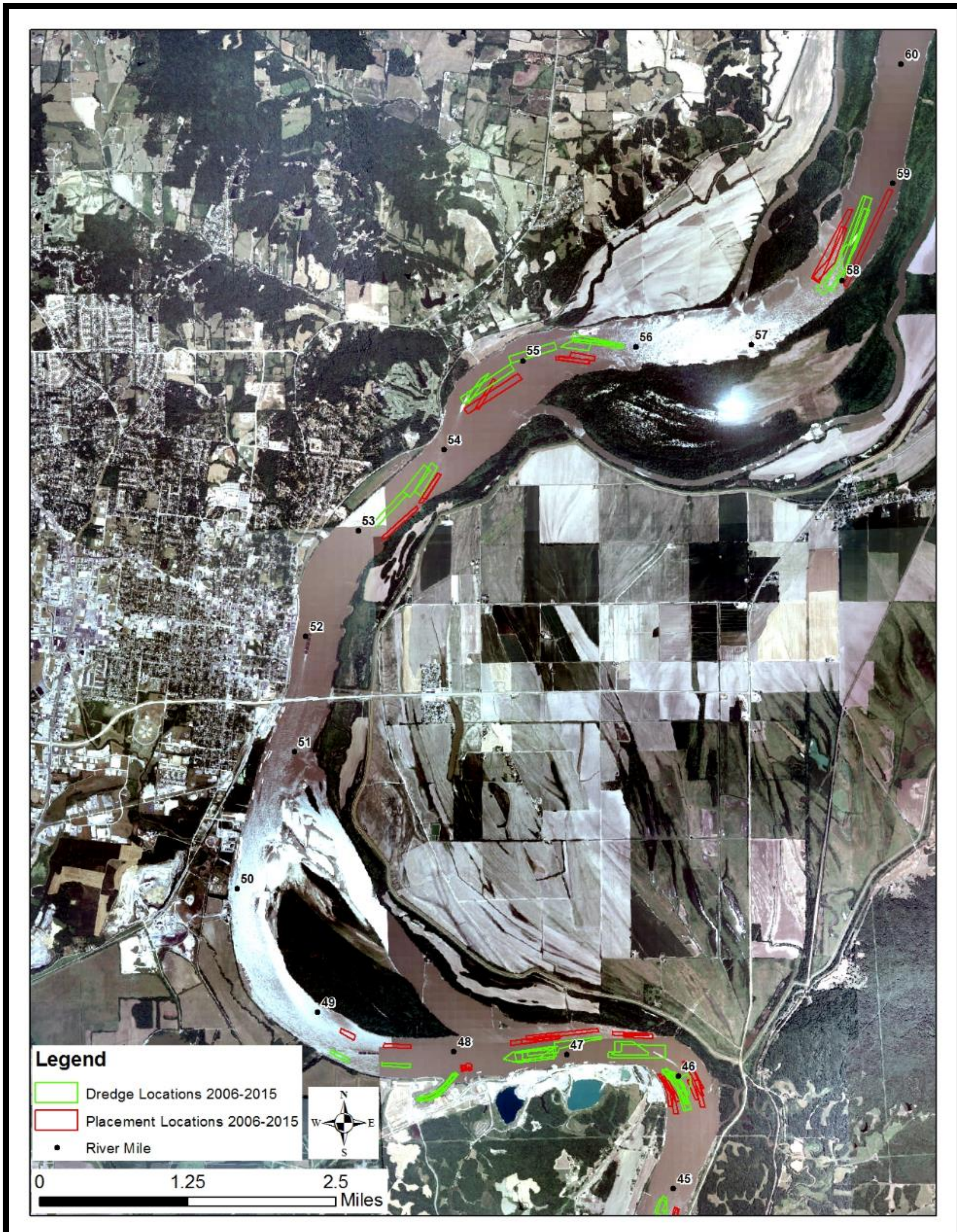


Plate 10. MMR dredge and placement locations, 2006 to 2015, river miles 60 to 45.

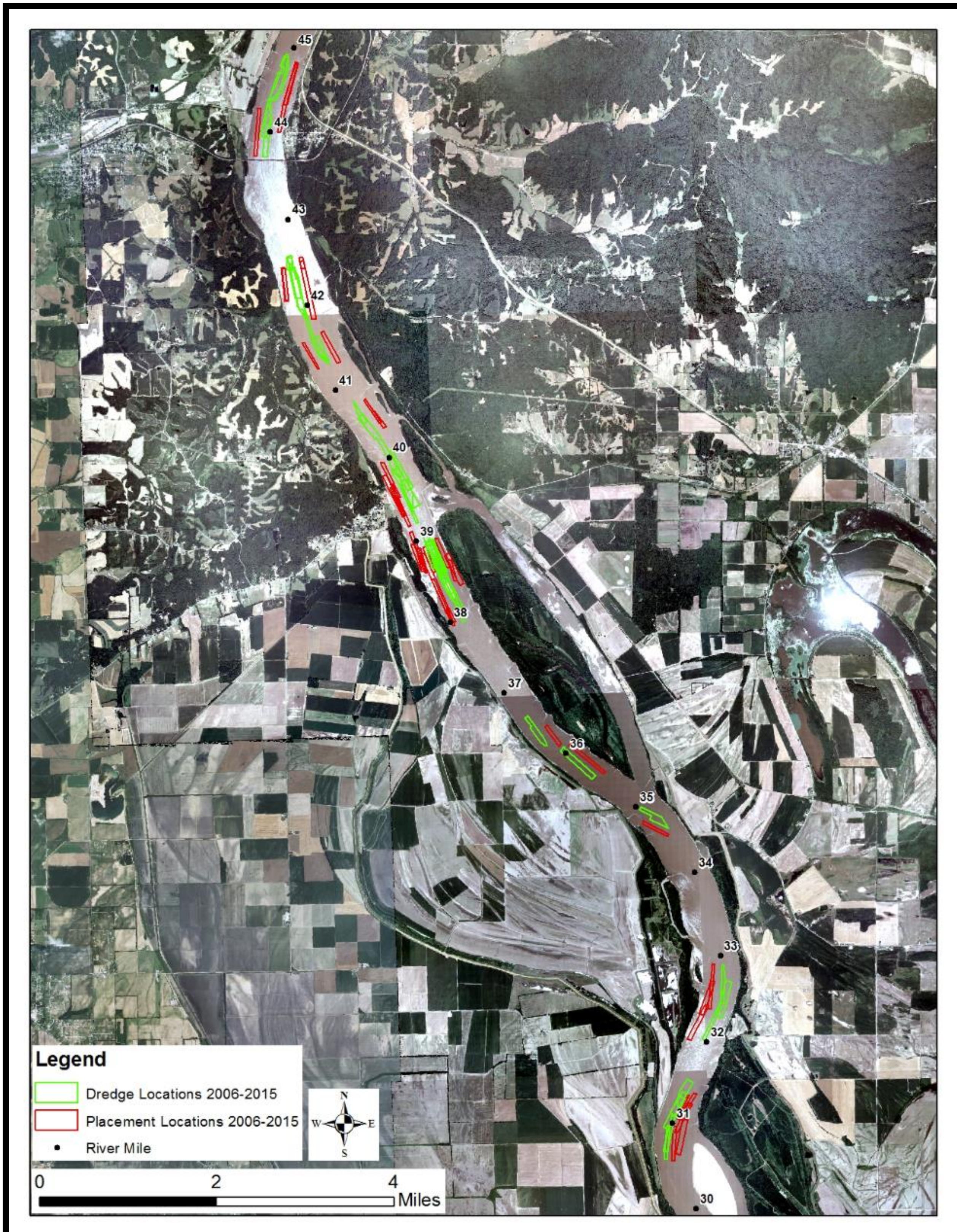


Plate 11. MMR dredge and placement locations, 2006 to 2015, river miles 45 to 30.

Plate 12. MMR dredge and placement locations, 2006 to 2015, river miles 30 to 15.

Plate 13. MMR dredge and placement locations, 2006 to 2015, river miles 15 to 0.

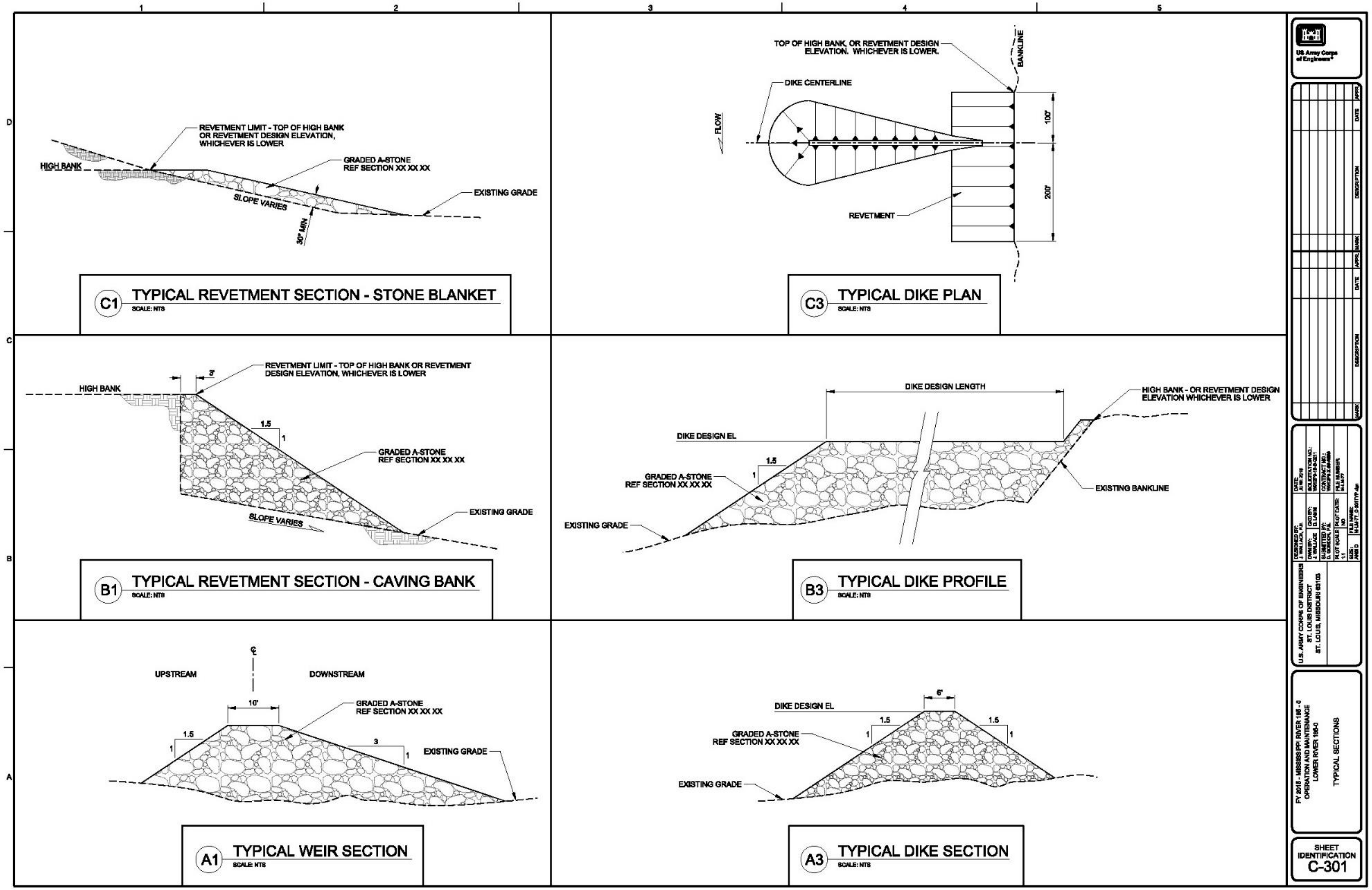


Plate 14. Typical structure sections.

Appendix E: Agency and Tribal Government Coordination

(to be provided in Final SEIS)

Appendix F: Determination of National Register Eligibility

Determination of National Register Eligibility (DOE) Study
Middle Mississippi River Regulating Works Project
Missouri and Illinois

(Agreement No. W912P9-13-D-0502, Delivery Order No. 0010)

prepared for

U.S. Army Corps of Engineers,
St. Louis District

prepared by

Commonwealth Heritage Group, Inc.
West Chester, Pennsylvania

January 2016

DETERMINATION OF NATIONAL REGISTER ELIGIBILITY (DOE) STUDY

MIDDLE MISSISSIPPI RIVER REGULATING WORKS PROJECT MISSOURI AND ILLINOIS

Agreement No. W912P9-13-D-0502
Delivery Order No. 0010

prepared for

U.S. Army Corps of Engineers, St. Louis District
1222 Spruce Street, Room 4.207
St. Louis, MO 63101-2833

prepared by

Greg W. Rainka
Brian Rentfro (USACE Contractor)

Commonwealth Heritage Group, Inc.
535 North Church Street
West Chester, PA 19380-2303

January 2016

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers, St. Louis District (USACE), in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), prepared a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River (MMR) Regulating Works Project (Project). The purpose of the DOE was to assess the historic and engineering significance of the Project and its associated built features. The DOE includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. Key sources included USACE annual reports; authorizing legislation concerning the MMR; and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also consulted, along with the MMR features catalog, providing location data from 1881 to the present for dikes constructed as part of the Project.

The study indicates that the Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR is demonstrated to be immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. However, to be eligible for the National Register, a property must also possess integrity, i.e., the ability of a property to convey significance. With most, if not all, of its associated structures post-dating the period of significance (1881-1965), the Project is unable to convey its considerable national significance. Therefore, due to a loss of integrity, the Project is recommended *not eligible* for the National Register.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District (USACE), in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), contracted with Commonwealth Heritage Group, Inc. (Commonwealth) to prepare a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River (MMR) Regulating Works Project (Project). The MMR is defined as the 190-mile section of the Mississippi River between its confluence with the Missouri River above St. Louis, Missouri, and its confluence with the Ohio River at Cairo, Illinois (Figures 3.1 and 3.2). This DOE is intended to support the preparation of a Supplemental Environmental Impact Statement (SEIS) for the Project by the USACE. The original Environmental Impact Statement (EIS) was prepared in April 1976.

The purpose of this DOE is to assess the historic and engineering significance of the Project and its associated built features. Historically, the objective of the Project has been to ensure a safe and dependable navigation channel through bank stabilization and sediment management. Continuous implementation of the Project has been achieved primarily through dredging and the construction and calculated placement of river-training structures, namely dikes and revetments, along the length of the MMR. This DOE includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. As an ever-evolving system composed of many adaptable, functionally-related built features, the Project was evaluated for the National Register as a district.

2.0 METHODOLOGY

Commonwealth conducted extensive historical research to gain a comprehensive understanding of the Project and prepare an appropriate historic context for assessing its National Register eligibility. Various primary and secondary resources were utilized in conjunction with USACE staff having expert knowledge of the Project. Specifically, development of the historic context was a joint effort between Commonwealth and Brian Rentfro, a USACE contractor who co-authored *Engineers Far From Ordinary: The U.S. Army Corps of Engineers in St. Louis.*[1] Key sources included USACE annual reports, authorizing legislation concerning the MMR, and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also provided by the USACE, along with a features catalog with location data from 1881 to the present for dikes constructed on the MMR as part of the Project. A field examination was not included in the scope of work for this DOE study, so the features catalog helped Commonwealth staff to visualize the distribution of the river-training structures, quantify changes to the MMR over time, and determine overall integrity of the Project.

This DOE was prepared in accordance with guidance provided by the National Park Service (NPS) on evaluating and documenting the eligibility of historic properties, specifically *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation* and *The Components of a Historic Context.*[2] These publications formed the basis for analyzing the applicability of the National Register evaluation criteria to the Project and identifying the physical characteristics of the Project and its associated built features that are needed to convey historic and/or engineering significance.

[1] Damon Manders and Brian Rentfro, *Engineers Far From Ordinary: The U.S. Army Corps of Engineers in St. Louis* (St. Louis: USACE, 2011).

[2] National Park Service, *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation* (Washington, D.C.: U.S. Department of the Interior, NPS, 1991); Barbara Wyatt, *The Components of a Historic Context* (National Register White Paper Series, 2009), accessed August 13, 2015, http://nps.gov/nr/publications/policy.htm.

3.0 HISTORICAL OVERVIEW

3.1 THE MISSISSIPPI RIVER

The Mississippi River begins near Lake Itasca in northern Minnesota and meanders south for approximately 2,320 miles. The river either passes through or borders Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana. The Mississippi River Watershed covers more than 1,245,000 square miles and drains 41 percent of the continental United States, including all or parts of 31 states and two Canadian provinces. The most significant tributaries of the Mississippi River are the Illinois, Missouri, Ohio, Arkansas, and Red rivers.

The Mississippi River can be divided into three sections. The Upper Mississippi River (UMR) stretches from the river's source at Lake Itasca in Minnesota to the confluence of the Mississippi and the Missouri rivers just above (north of) St. Louis, Missouri. The MMR is an approximately 190-mile section of river that extends from the mouth of the Missouri River to the mouth of the Ohio River. The section from the mouth of the Ohio River to where the Mississippi flows into the Gulf of Mexico is known as the Lower Mississippi River (LMR).

Congress has authorized the USACE to maintain a minimum navigation channel depth and width for the entire Mississippi River. Each section of the river is unique and presents its own set of challenges for engineers attempting to maintain the channel. On the UMR, flows are relatively low when the river is in its free-flowing, natural state without dams. The sediment load carried by the UMR is also much lower than on the MMR and LMR. Consequently, the construction of river regulating works (various types of dikes and bank stabilization structures) and channel contraction are not an effective means of maintaining the navigation channel. The USACE originally attempted to maintain a navigable channel on the UMR through the construction of regulating works and channel contraction, but ultimately this method proved ineffective. By 1940 the UMR had been canalized through the construction of locks and dams.

Flows on the MMR are much more substantial due to its merging with the Illinois and Missouri rivers. In addition, the sediment load in the MMR is much higher than on the UMR because the Missouri River transports a large amount of material. As a result, the MMR requires no locks or dams, and engineers can maintain the authorized navigation channel through the construction of regulating works to contract the channel, stabilization of riverbanks to prevent meandering and collapsing riverbanks, and dredging (the Project). The regulating works slow the flow of the river near dike fields, thereby causing sediment to be deposited and new riverbanks to be built up. This creates a narrower river that allows the energy of the river's flow to be directed into the navigation channel. The natural energy of the river scours the riverbed and flushes much of the sediment out of the channel, pushing it downstream.

On the LMR, regulating works are used less extensively because flows are typically substantial enough, and dredging alone can be used as the primary means of maintaining the authorized navigation channel.

The Mississippi River and its commercially navigable tributaries cut through the largest piece of contiguous farmland in the world. A great majority of America's prime agricultural lands lie within about 120 miles of a navigable river. Farmers and industries in the nation's interior depend on river transportation to move their goods to national and global markets. Because of this extensive river commerce, numerous cities and ports have been established along the Mississippi

River and they depend, or have depended in the past, on this commerce for their economic livelihood.[3]

The most important port of the Mississippi River system is the Port of South Louisiana, which stretches 54 miles along the Mississippi River between Baton Rouge and New Orleans. It is the largest tonnage port district in the Western Hemisphere and one of the largest in the world. The majority of agricultural products in the Midwest pass through the UMR and MMR and their tributaries on their way to the Port of South Louisiana. This port possesses global significance, as approximately 60 percent of product reaching it is exported.[4]

The MMR is especially important because it is the linchpin of the river system. Commercial vessels carrying bulk goods from the upper and lower Mississippi, Illinois, Missouri, and Ohio rivers often must traverse the MMR in order to reach their destinations. Should the MMR close or become a less safe and reliable navigable waterway, commerce and industry on both a national global scale would suffer greatly. For commercial navigation to thrive, each part of the system must function as designed. On the MMR commercial navigation needs are met by the Project, through the construction of regulating works and channel contraction.

3.2 EARLIEST SURVEY AND NAVIGATION IMPROVEMENTS

Europeans began establishing permanent settlements along the Mississippi River as early as 1716. Two years later, New Orleans was founded and the city became the capital of the region known as the Louisiana Territory. The city's growth occurred in large part because of its position near the mouth of the Mississippi River, as goods from the lower Mississippi valley and its tributaries were sent downriver to New Orleans. Because the river was the primary means of shipping goods from the Mississippi valley, most of the earliest settlements along the river were trading posts where goods from the interior could be shipped to New Orleans.[5]

The purchase of the Louisiana Territory by the United States from France in 1803 opened up the fertile lands west of the Mississippi River for settlement. Just sixteen years earlier Congress had passed the Northwest Ordinance, which established the Northwest Territory and allowed for the settlement of lands northwest of the Ohio River and east of the UMR. Thus, in a span of less than two decades, the nation had expanded to include nearly all the lands in the Mississippi River watershed.

In the early 1800s the vast majority of land in the upper Mississippi valley was still raw and uncultivated wilderness. When Thomas Jefferson authorized the Louisiana Purchase, he envisioned these western lands as a place where settlers could cultivate the land and establish small farms. It was in these lands, Jefferson believed, that the future greatness of America lay. Many Americans shared his vision and ventured westward. By 1840 around 40 percent of the nation's population lived west of the Appalachian Mountains. But for these settlers to get their goods from the Midwest's interior to markets, a dependable form of transportation was needed.[6]

---

[3] Stratfor, Inc., *The Geopolitics of the United States, Part 1: The Inevitable Empire* (Austin, Texas: Stratfor, Inc., 2012).

[4] Stratfor, *The Geopolitics of the United States*; Port of South Louisiana, "Overview of the Port," accessed July 10, 2015, http://www.portsl.com/overview.htm.

[5] Fredrick J. Dobney, *River Engineers on the Middle Mississippi* (Washington, D.C.: GPO, 1978), 1-15.

[6] Stephen Ambrose, *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West* (New York: Simon and Schuster, 1996), 68-79; Ronald D. Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers* (USACE Water Resources Support Center, National Waterways Study, 1983), 13-18.

Before the invention of the steamboat, river commerce mostly consisted of floating timber logs downstream or transporting furs and minerals (mostly lead) downstream via flatboat (Figure 3.3). The introduction of the steamboat completely transformed the course of history for the Mississippi River and the Midwest. The first steamboat to arrive in St. Louis was the *Zebulon Pike* in 1817. Within a decade river traffic was bustling around St. Louis and other towns such as St. Genevieve, Cape Girardeau, and New Madrid, Missouri (Figure 3.4). This increase in river commerce facilitated population growth in these towns, especially in St. Louis, where the population rose from around 925 in 1800 to nearly 5,000 in 1830, over 16,000 in 1840, nearly 78,000 in 1850, and just over 160,000 by 1860. During this same period, annual steamboat arrivals at St. Louis grew from 3 to over 3,600. By the 1850s St. Louis was the largest city west of Pittsburgh and would continue to grow at a torrid pace until the 1870s.[7]

Westward expansion and the arrival of the steamboat in 1817 necessitated survey of the MMR, which was first completed the same year. Settlement occurred along the river prior to this, so the survey did not represent the river in a completely "natural" state, but it was the earliest accurate survey and thus a close approximation to the "natural" river. At that time, the average width of the river was 3,358 feet. The river also included numerous chutes and side channels, fords and shallows, islands, snags, and numerous other obstructions to navigation. The Federal Government showed interest in removing these obstructions, as was indicated by the 1821 report of the Board of Engineers for Rivers and Harbors, which recommended the removal of snags, but it was not yet decided if the government had the constitutional authority to approve or fund such improvements.[8]

Commercial river navigation was a major challenge with the UMR and MMR in their "natural" state. If St. Louis was to continue to grow and if Midwest farmers were going to be able to ship their harvests to markets, then a dependable form of transportation was needed. At that time, transporting by river was by far the most practical means of moving goods from the nation's interior, but improvements were required to make the rivers dependably safe and navigable. While it was undecided if the Federal Government had the constitutional authority to fund river improvements, a landmark case *Gibbons v. Ogden* (1824) served as precedent. With this decision the U.S. Supreme Court ruled that the Federal Government had the power to regulate interstate commerce and river navigation "so far as that navigation may be in any manner connected with commerce." This gave Congress the legal authority to fund river improvements that promoted commercial navigation.[9]

The 1824 General Survey Act authorized the president to employ civil engineers and officers of the USACE to make surveys, plans, and estimates for "routes of such roads and canals as he may deem of national importance." The Act also, for the first time, provided for internal improvements on a national scale, including the first Rivers and Harbors Act, also passed in 1824. The Rivers and Harbors Act gave the USACE responsibility for improvement of internal waterways and contained the first appropriation for the improvement of the Mississippi River. The Rivers and Harbors Act of 1826 combined the authorities of the two 1824 Acts into a single Act that gave the USACE responsibility for surveys and projects, in turn setting the stage for river

[7] Dobney, 17-37; Tweet, 13-25; Charles E. Landon, "Technological Progress in Transportation on the Mississippi River System," *The Journal of Business* 33, no. 1 (1960): 43-62.

[8] E. J. Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River* (St. Louis: USACE, 2013); *U.S. Congress, Report of the Board of Engineers on the Ohio and Mississippi Rivers*, House Doc. No. 35 (17th Cong. 2d sess.).

[9] *Thomas Gibbons vs. Aaron Ogden*. 22 U.S. 9 Wheat. 1 (1824).

engineering projects for the next two centuries. The USACE would carry out surveys and studies and make recommendations, while Congress would be responsible for approving and funding improvement projects. Once approved and funded, the USACE would oversee construction.[10]

The first improvements on the MMR consisted of removing snags (Figure 3.5). In 1828 the Secretary of War appointed Henry Shreve to the post of Superintendent of Western Rivers and asked him to carry out the task. Shreve constructed the first steam snagboat, the *Heliopolis*, in 1828 and by 1830 he had cleared the worst snag obstructions from the Mississippi River between St. Louis and New Orleans.[11]

The next task was to improve the St. Louis Harbor (Figure 3.6). Thanks to the removal of snags from the MMR and the arrival of the steamboat, river commerce was increasing dramatically at St. Louis, and the population was increasing accordingly. When the snag removal project first began in 1828, less than 300 steamboats arrived at the Port of St. Louis, but by 1838 this total increased to approximately 1,600. This trade made St. Louis the most important commercial city on the MMR and an essential port through which the goods from the Midwest's interior passed. The MMR, however, was naturally beginning to meander to the east, a serious threat to the city that would leave it landlocked if not corrected. The City lacked the financial means and engineering knowledge to do so, so City officials looked to the Federal Government for aid.[12]

In 1836 General Charles Gratiot, the Chief of Engineers of the USACE, proposed building a wing dam and a dike opposite St. Louis near Bloody Island to force the current back west toward the sandbar. He appointed a young Lieutenant name Robert E. Lee to carry out the effort. Although Lee would begin the work in 1837, it would take decades to complete, but it eventually saved the vital St. Louis Harbor. It also represented the first attempt to construct river regulating works to permanently improve a section of the MMR.[13] However, owing to the expansion of railroads, the growth of Chicago, and the Civil War, it was not until 1872 that Congress appropriated funds for additional permanent river navigation improvements on the MMR. Permanent improvements of the entire MMR were not authorized until 1881.[14]

The country's network of railroads began expanding west toward the Mississippi River during the 1850s, but there were few railroads that reached into western Iowa and the Dakotas prior to the 1870s (Figure 3.7). Most of the railroads that were constructed east of the Mississippi terminated at Chicago. Moreover, the completion of the Illinois-Michigan Canal in 1848 connected the Illinois River to Lake Michigan at Chicago. These two developments allowed goods from the eastern portion of the upper Mississippi valley and the Illinois River valley to be shipped to New York via Chicago instead of to New Orleans via St. Louis. Thus began the rise of Chicago as the commercial rival of St. Louis.[15]

[10] Damon Manders and Brian Rentfro, 16-23.

[11] Dobney, 17-34; Tweet, 13-25.

[12] Dobney, 17-34; Tweet, 13-25; U.S. Congress, *Harbor of St. Louis*, House Doc. 25-298 (25th Cong., 2d sess.).

[13] Dobney, 17-34; Tweet, 13-25; U.S. Congress, *Harbor of St. Louis*, House Doc. 25-298 (25th Cong., 2d sess.).

[14] Dobney, 39-62; U.S. Congress, *Letter from the Secretary of War Transmitting a Progress Report of the Mississippi River Commission, dated November 25, 1881*, Senate Executive Doc. No. 10 (47th Cong., 1st sess.). This is the report on which the original 1881 navigation project on the middle Mississippi River is based. Hereafter cited as Senate Executive Doc. No. 10.

[15] Frank Haigh Dixon, *A Traffic History of the Mississippi River System* (Washington, D.C.: GPO, 1909); James H. Lemly, "The Mississippi River: St. Louis' Friend or Foe?" *The Business History Review* 39, no. 1 (1965): 7-15; Lewis F. Thomas, "Decline of St. Louis as Midwest Metropolis," *Economic Geography* 25, no. 2 (1949): 118-127.

St. Louis and the MMR still dominated commerce in the Midwest because the railroads had not expanded sufficiently into the Missouri River basin and the western portion of the upper Mississippi valley, but the Civil War severed the LMR from the MMR and the commerce that ran through it. Many of the steamboats once used for commerce were now used to support the war effort and were badly damaged or sunk. On July 1, 1862, Congress further facilitated the growth of Chicago and rail transportation by chartering the Union Pacific Railroad. When construction of the railroad was completed in 1869, it connected the Pacific Coast to Council Bluffs, Iowa. Railroads began expanding rapidly southwest from Chicago and redirecting much of the Missouri River valley commerce, which otherwise would have passed through St. Louis and the MMR. During the 1870s and 1880s the Illinois Central Railroad began expanding into the south with a rail line near the eastern banks of the Mississippi River that terminated at New Orleans.[16]

The impact of railroad expansion on St. Louis and Chicago is clearly shown by the population growth of each city. In 1860 St. Louis had a population of 160,773 and Chicago 112,172, but by 1890 the population of Chicago was 1,099,850 and St. Louis had just 451,770 residents. The annual commercial tonnage on the MMR declined along with the population, peaking in 1869 at 2,243,499 tons, the same year that the Union Pacific Railroad was completed. By 1890 the annual tonnage was just 1,299,679. The annual tonnage declined to an average of around 500,000 by the first decade of the twentieth century, and it further declined to an average of less than 300,000 in the decade that followed.[17]

The decline of river commerce was as much due to unreliable and un-navigable waterways as it was to the expansion of railroads. Navigation of the Mississippi River and its tributaries above the Ohio River was often difficult if not impossible for long periods of time, either because of ice or low water. Even when there was sufficient flow in the channel, the rivers had shoals and other obstructions that grounded, delayed, or damaged vessels (Figure 3.8). A large part of the problem was that the MMR's channel was growing wider. In 1817 the river had an average width of 3,358 feet, but by 1881 the average width had increased to 3,743 feet, leading to a shallower channel that made navigation increasingly more dangerous and challenging. In contrast, the railroads were expanding and becoming more and more dependable. The rivers had the potential to be dependable, but ensuring this would require years of effort and significant financial investment.[18]

Many in Congress showed little support for river projects because they were believed to produce only local benefits or were considered pork barrel appropriations. The other problem was that there was not sufficient river commerce to justify the investment of large sums in projects. The supporters of river improvements argued that if a dependable channel could be obtained and maintained, then river commerce would return, but this was merely speculation. Moreover, because the Mississippi River and its tributaries act as a system, for improvements to be effective, they needed to be system-wide. It would matter little if the UMR, for example, was improved and saw an increase in river commerce if vessels could not pass through the MMR and reach New Orleans. Similarly, navigation improvements on the MMR would only provide a full return on investment if river commerce was also increased on the UMR and elsewhere.[19]

[16] Dixon; Lemly, 7-15, Thomas, 118-127.

[17] Dixon; Lemly, 7-15, Thomas, 118-127; Dobney, 39-63; Tweet, 21-41.

[18] Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River*; Edward J. Brauer et al., *Geomorphology Study of the Middle Mississippi River* (St. Louis: USACE, 2005).

[19] John O. Anfinson, *The River We Have Wrought: A History of the Upper Mississippi River* (Minneapolis: University of Minnesota Press, 2003), 29-80.

Following the Civil War, river navigation supporters held conventions in St. Louis in 1867, 1872, and 1873; in New Orleans in 1869 and 1876; in St. Paul in 1875 and 1877; and in Prairie du Chien in 1868, to discuss how to increase river commerce and to pressure Congress to expand the work of the USACE. They believed that railroads were becoming monopolies and charging exploitative rates, and that the best way to lower rail rates was to increase competition by promoting river commerce. The farmers and navigation supporters argued that the Midwest was the nation's granary, and an affordable and efficient means of transportation was needed to transport the product of the fertile lands to markets. In 1864 the Midwest produced more than one-quarter of the value of all crops in the nation, including nearly one-half of all wheat and corn, one-quarter of all livestock, and between one-third and one-half of the country's leading food staples. For navigation boosters, this was a national, not a regional, issue.[20]

Congress responded by passing the Rivers and Harbors Act of 1866, which signaled the beginning of permanent navigation improvements on the UMR (Figure 3.9). The act appropriated $400,000 for channel improvements and surveys north of St. Louis. For the improvement of the MMR, Congress authorized $100,000 in the 1872 Rivers and Harbors Act. The USACE was to expend these funds on the improvement of the MMR just between the mouths of the Missouri and Meramec rivers.[21]

These projects were hardly enough to maintain the dependable navigation channel required for river commerce to compete with railroads. At that time, the MMR was divided by numerous islands and bars, which distributed large portions of the flow through chutes, sloughs, and secondary channels to the detriment of navigation. At many locations, the width of the river was one to one-and-one-half miles wide and the maximum usable channel depth was only three-and-one-half to four feet. If a dependable navigation channel was going to be obtained and maintained, a comprehensive river improvement project on a considerably larger scale would be necessary. By the 1870s the USACE recognized this and began planning for such a project.[22]

In 1873 the USACE established a permanent engineering office in St. Louis to oversee the improvement of the MMR. Under the leadership of Col. James Simpson, the St. Louis District Engineer, the district spent the next seven years studying the MMR to determine the best means to maintain a dependable navigation channel, which he recommended should be at least eight-feet-deep between St. Louis and the mouth of the Ohio River. To accomplish this, he recommended a policy of permanent river improvement structures based on the principle that the river itself should be used to do the work of channel maintenance wherever possible. In other words, the channel should be contracted through the construction of dikes and the stabilization of riverbanks so that the energy of the river would be directed into the main channel to scour the riverbed and reduce the accumulation of sediment and the need for dredging.[23]

In 1879 Congress established the Mississippi River Commission, with its headquarters in St. Louis, to oversee the implementation of plans for flood control and navigation improvements on the Mississippi River. The commander of the USACE Mississippi Valley Division, which included all the engineering districts in the Mississippi River valley, would serve as the commission's president, and the USACE became responsible for implementing the commission's

[20] Anfinson, 53-80; Tweet, 47-53.

[21] Anfinson, 53-80.

[22] USACE, *Annual Report of the Chief of Engineers* (1921), 1197. All subsequent references to Annual Reports refer specifically to those sections of the reports covering the section of the Mississippi River between the mouths of the Missouri and Ohio rivers.

[23] Dobney, 48-56; Manders and Rentfro, 47-59.

plans. The creation of the commission represented the first federal attempt to develop a coordinated plan for the development of the Mississippi River.[24]

In 1881 the commission adopted the plan proposed by Col. Simpson and included it in a report to Congress, which Congress then used as the basis for its authorization of the Project. The master plan recommended making "the improvement continuous, working downstream from St. Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet." The objective of the contraction was to maintain a minimum navigation channel depth of eight feet during low water. This plan was based on the premise, observed by Captain O.H. Ernst – the St. Louis District Engineer – and Col. Simpson before him, that all of the construction was intended to use the energy of the river "simply to restore what once existed and to do it in such a way that the restoration shall be permanent."[25]

The authorization of the projects for permanent navigation improvements on the UMR and MMR must also be understood within the context of the economic and political developments of the 1870s. Between 1873 and 1879 the United States was in the midst of a major economic depression. Midwest farmers were especially impacted by the depression because their profit margins were so slim. Often times the cost of transporting goods determined whether or not farmers made a profit. The expansion of the railroads had initially benefitted farmers west of the Mississippi River, but with the decline of river commerce, railroads began raising their rates. Farmers complained of a railroad monopoly and exploitative shipping rates. These complaints eventually led to what became known as the Granger Movement, which consisted of a union of farmers who came together to promote navigation improvements and oppose the railroad industry. They believed that the railroads needed to be regulated to keep rates low, and the best means to regulate rail rates naturally was through promoting commercial river navigation to provide more competition.[26]

Minnesota Senator William Windom, who was the chairman of the Senate Select Committee on Transportation to the Seaboard, shared many of the sentiments of the Granger Movement, especially the idea that river navigation improvements could be used to combat high rail rates. Windom's committee presented a report to the Senate in 1874 that recommended navigation improvements as a means to control rail rates. The report also recommended navigation improvements as a means to increase the export of grain between New Orleans and British ports so that the United States could challenge Russia and Europe for the British grain trade and develop its trade in Central and South America.[27]

In the Rivers and Harbors Act of 1878, Congress authorized a four-and-one-half foot navigation channel on the UMR. Although these improvements were not on the MMR, they nonetheless impacted its future development because any goods originating in the upper Mississippi valley had to traverse the MMR on their way to New Orleans. Thus the fate of the UMR and MMR were, and would continue to be, closely linked to one another.[28]

---

[24] Charles A. Camillo and Matthew T. Pearcy, *Upon Their Shoulders: A History of the Mississippi River Commission from its Inception Through the Advent of the Modern Mississippi River and Tributaries Project* (Vicksburg, Miss.: Mississippi River Commission, 2004), 25-35.

[25] USACE, *Annual Report of the Chief of Engineers* (1975), 471-495; Senate Executive Doc. No. 10.

[26] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

[27] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

[28] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

3.3 FIRST DECADES OF THE MMR PROJECT (1881-1910)

The general plan of the Project was to methodically build river training structures downstream from St. Louis rather than piecemeal at various locations. The river training structures consisted primarily of permeable wooden pile dikes and jetties, which slowed the flow in-between the structures and caused sediment to accumulate, thereby forming new banks and contracting the river. With the distance between riverbanks decreased, the river's energy would be directed into the navigation channel, in turn scouring the riverbed and reducing sedimentation and the need for dredging. The riverbanks were stabilized through the construction of hurdles and willow weave mattresses. Lastly, river training structures were constructed to close side channels so that the majority of the river's flow would remain in the navigation channel.[29]

At first, the greatest impediment to the Project was the lack of appropriations from Congress. At the end of his tenure as district engineer, Col. Simpson lamented that based on the rate of appropriations, the project would take a century to complete. The other major impediment was that the early pile dikes were not very durable and were often damaged or destroyed because of floods or because of ice, vessels, or debris crashing into them. Much of the earliest work consisted of as much repairing of damaged dikes as construction of new dikes.[30]

The first two decades of the project saw construction at Horsetail Bar, Sawyer Bend, Rush Tower, Cahokia Chute, Arsenal, Fort Chartres, Turkey, Liberty, Devil's, Dickey, Widow Beard's, Carroll's Island, Twin Hollows, Jim Smith's, Kaskaskia and Hat islands; Herculaneum and St. Genevieve, Mo, Platin Rock, Fish Bend, and Jones's Point. Nearly all of the improvements between 1881 and 1900 occurred no more than 80 miles downriver of St. Louis. By 1890 the St. Louis District reported that an eight-foot channel was being consistently maintained from St. Louis to Lucas Crossing, 30 miles downstream. By 1900 the USACE had constructed over 350,000 linear feet of dikes and 300,000 linear feet of revetment on the MMR.[31]

By the end of the century engineers were starting to consider other means of maintaining the authorized channel. In the Rivers and Harbors Act of 1896 Congress authorized the USACE to use dredges and temporary regulating works to maintain the channel. Consequently, nearly all work stopped on permanent navigation improvements, and for over a decade the USACE experimented with maintaining the authorized navigation channel through dredging.[32]

The Rivers and Harbors Act of 1902 established the Board of Engineers for Rivers and Harbors to compile a report on whether or not dredging was a more effective and cost efficient means of maintaining the navigation channel. The board determined that dredging could be more cost efficient, but to be certain, nearly all work on river training structures would have to cease and dredging would have to be used almost exclusively. Once enough data were gathered on the

[29] Senate Executive Doc. No. 10; USACE, *Annual Report of the Chief of Engineers*, 1881 to 1896, sections covering the Mississippi River between the mouths of the Missouri and Ohio rivers.

[30] USACE, *Annual Report of the Chief of Engineers* (1879), 1032.

[31] Brauer et al., *Geomorphology Study of the Middle Mississippi River*; USACE, *Annual Report of the Chief of Engineers*, 1881 to 1900, 1921.

[32] River and Harbor Act of 1896, (29 Stat. 202), passed June 3, 1896; U.S. Congress, *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a View to Obtaining a Channel 14 Feet Deep and of Suitable Width*, House Doc. No. 50 (61st Cong., 1st sess.).

efficacy of dredging, the board would make its final recommendation. The Rivers and Harbors acts of 1905 and 1907 reaffirmed the commitment to dredging.[33]

By 1910 the dredging experiment had run its course, and after an evaluation of the use of dredging exclusively, the board determined that the authorized channel could best be maintained through the construction of river training works, with dredging used as a supplement. Congress authorized the board's recommendations in the Rivers and Harbors Act of 1910, thereby restoring the original 1881 Project. The Act also authorized the construction of new permanent river training structures.[34]

3.4 THE DECLINE OF RIVER NAVIGATION (1910-1925)

Even though the 1910 River and Harbors Act restored the Project, actual construction of regulating works depended on Congress's willingness to authorize appropriations. Between 1911 and 1924 Congress appropriated just over $8 million for the Project. However, these funds had to cover not only the construction of new regulating works, but also the maintenance and repair of existing works and dredging costs. Consequently, only about 60 percent of funds were applied to the construction of new regulating works. The remaining 40 percent went mostly to the repair and maintenance of existing works, many of which were deteriorating so quickly that more old dikes were lost each year than there were new dikes constructed. In fact, between 1881 and 1924, almost as much money had been expended on maintenance and repair as had been expended on the construction of new regulating works. The 1921 Annual Report of the Chief of Engineers estimated that 40 percent of dikes constructed before 1910 had already been destroyed. The report also stated that between 1914 and 1921, funds were insufficient to even cover the repair of seasonal damages. The USACE estimated that between 1881 and 1921, 403,116 linear feet of dikes had been constructed, but 188,131 linear feet of dikes had been lost due to damage or deterioration.[35]

To continue the project Congress needed to appropriate funds, but the dramatic decline in river commerce did not justify the investment. When Congress first authorized the project, traffic on the MMR was just over 2 million tons annually. By the turn of the century, the total had fallen to around 800,000 tons. Between 1900 and 1910, the MMR averaged just 500,000 tons annually, and in 1910 just 191,965 tons traversed this stretch of river. Between 1911 and 1921 the average annual tonnage declined to just 200,000. It was not until the late 1920s and 1930s that commercial river traffic finally began to return to the MMR in considerable numbers.[36]

3.5 NATIONAL DEVELOPMENTS IMPACTING RIVER NAVIGATION

The population, economy, and agricultural production of the Midwest had continued to grow even though river commerce was in decline. Expanding railroads now controlled most of commercial transportation. Between 1900 and 1930, however, several developments occurred that increased commercial traffic on the Mississippi River and heightened the significance of the Project.

[33] U.S. Congress, *Report of the Board of Engineers for Rivers and Harbors Submitted November 12, 1903*, House Doc. No. 168 (58th Cong. 2d sess.).

[34] U.S. Congress, *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a View to Obtaining a Channel 14 Feet Deep and of Suitable Width*, House Doc. No. 50 (61st Cong., 1st sess.).

[35] USACE, *Annual Report of the Chief of Engineers*, 1910 to 1924.

[36] Tweet, Appendix A.

The first of these was the Panama Canal Project, which the United States had taken over in 1904 (Figure 3.10). When completed in 1914, the canal would provide a cheap means of transporting Midwest goods to the West Coast by water. However, to get the goods from the UMR and MMR to New Orleans, significant river improvements were needed. Politicians, farmers, and business interests in the region understood this and formed the Upper Mississippi River Improvement Association (UMRIA) to lobby for a six-foot channel for the UMR. In a 1905 speech the UMRIA president said that "the building of the Panama Canal makes the improvement of the Mississippi and Ohio rivers imperative, as the natural trend of commerce will then be along these highways to the Gulf and thence to and from the markets of the world." Even Chicago, he noted, sought to tie itself to the canal through the Mississippi River. Not only did Midwesterners need the canal, the canal needed goods from the Mississippi and Ohio rivers to be successful. Col. John L. Vance, president of the Ohio River Improvement Association, predicted that with the canal completed, "the products of the Ohio and Mississippi Valleys will control the markets of the world."[37]

The other reason why farmers and commercial interests called for navigation improvements was the same reason they called for them in the 1870s and 1880s: to lower rail rates and promote competition. Moreover, the rail shortage of 1906-1907 exposed the inadequacy of the railroads to support the growing transportation needs of the Midwest economy. Building enough railroads to support the commercial needs of the Midwest and West would take decades and billions of dollars. Instead of expanding railroads, river commerce boosters called for navigation improvements and a deeper channel on the UMR. Many congressmen still did not support navigation improvements, believing they were merely pork barrel appropriations that produced only local benefits, but Midwestern congressmen continued to show strong support for navigation improvements. More importantly, Teddy Roosevelt's administration was a strong supporter of water resource projects. This support was enough for Congress to authorize a six-foot channel in the Rivers and Harbors Act of 1907. However, the six-foot channel authorization had no impact on commercial river traffic, which did not begin to rebound until the late 1920s.[38]

Another development that led to increased funding for navigation improvements was the rise of the corporate farmer. When navigation improvements for the MMR were first authorized in the nineteenth century, most of the beneficiaries were small farmers and businessmen. By the 1920s many of the small yeoman farmers had been supplanted by large plantations, and the smaller farms that still existed had banded together to form corporate bodies. Consequently, a powerful farm lobby emerged. The influence of the farm lobby combined with the growing influence of commercial barge lines were enough to pique congressional interest in a possible a nine-foot navigation channel above the mouth of the Ohio River.[39]

3.6 BIRTH OF THE MODERN MMR PROJECT (1924-1927)

In 1924 the House Committee on Rivers and Harbors requested that the Board of Engineers for Rivers and Harbors study the feasibility and advisability of obtaining and maintaining a nine-foot-deep and 300-foot wide channel on the MMR. The report, submitted to Congress in December of 1926, cited "interruptions to the work of contraction, due to reliance upon dredging, [and] meager appropriations" as the reason why just one-third of the necessary works had been completed (between 1910 and 1925, only $2,592,920 had been appropriated for new work). USACE St. Louis District Engineer Maj. John Gotwals explained that the nature of the bed of the

[37] Anfinson, 130-144.
[38] Anfinson, 130-144.
[39] Anfinson, 125-144, 175-195.

river is such that maintaining a navigable depth is especially difficult in stretches only partially improved or not improved at all. Without sufficient permanent improvements, navigation could only be maintained by dredging and “it is impracticable to maintain a dredging fleet sufficient in number of dredges to safeguard the required depth at each bar.” Maj. Gotwals recommended the modification of the Project to maintain a nine-foot-deep, 300-foot-wide channel, and insisted that continued contraction of the river through regulating works and revetment was essential to achieve this end. Congress approved the recommendations of the report, modifying the Project to provide for a nine-foot-deep, 300-foot-wide channel on the MMR in the Rivers and Harbors Act of 1927.[40]

3.7 NAVIGATION IMPROVEMENTS ON INTERRELATED RIVERS

The authorization of a nine-foot channel on the MMR was just the first in a series of navigation improvement authorizations between 1927 and 1930 that would completely transform the entire Mississippi River navigation system and dramatically increase the importance of the MMR and the Project. In 1927 Congress approved a nine-foot channel for a portion of the Illinois River and expanded the nine-foot channel authorization to include the entire river in 1930. Construction of the Illinois River nine-foot channel project was completed by the mid-1930s. The impact of the project is exemplified by the increase in commercial traffic between 1940 and 1975. In 1940 the annual tonnage on the Illinois River was 3.745 million; in 1950 it rose to 13.7 million; in 1960 it rose to 22.8 million; and by 1975, it was 43.6 million. The significance of this increase in relation to the MMR is that Chicago and New Orleans are linked via the MMR, as it connects the LMR and Illinois River. Thus, without a navigable channel on the MMR, which is maintained by the Project, the inland navigation channel between Chicago and New Orleans would be severed, as well as the link between the Great Lakes and the Gulf of Mexico.[41]

Congress also authorized the study of a nine-foot channel project for the UMR in 1927 and in 1930 approved a project for canalizing the UMR through the construction of 26 locks and dams. By the end of 1940 the USACE had completed the nine-foot channel project, and for the first time, farmers, businessmen, and the barge industry had a dependable navigation channel that would allow river commerce to compete with rail transport. As a result, commercial traffic dramatically increased on the UMR between 1940 and 1975. In 1940, 3.5 million tons passed through the UMR; by 1950, the total was over 11 million; by 1960 it was 27.3 million; and by 1975, it was over 63 million. The significance of the UMR nine-foot channel project in relation to the MMR is obvious, as the MMR served to connect the goods from the UMR to the ports on the LMR. This is exemplified by the fact that the increase in commerce on the MMR occurred in tandem with that on the UMR.[42]

Authorization of river navigation improvements of course meant nothing without appropriations for construction. The Great Depression, combined with the Franklin Roosevelt administration’s philosophy on Federal spending and civil works projects, ensured congressional support in the form of massive civil works appropriations that allowed the UMR and Illinois River to be transformed in a little over a decade (Figure 3.11). These improvements also impacted the

[40] U.S. Congress, *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Made on Mississippi River Between the Mouth of the Ohio River and the Northern Boundary of the City of St. Louis*, House Doc. No. 9 (69th Cong., 2d sess.); U.S. Cong., *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Submitted on Illinois and Mississippi Rivers*, House Committee on Rivers and Harbors, House Committee Doc. 12 (70th Cong., 1st sess.).

[41] Tweet, 64-74 and Appendix B.

[42] Tweet, 75-95.

Project, as it made little sense to make such massive investments in the other sections of the river system without also investing in the critical linchpin where all of these rivers converged.

3.8 THE GOLDEN AGE OF REGULATING WORKS CONSTRUCTION (1926-1950)

The period from 1926 until around 1950 was the golden age of construction for the Project for several reasons. First, there was a large amount of money available for construction during the period due to the Great Depression and the Roosevelt Administration's investment in public works projects. Secondly, the authorization of other navigation projects on the UMR and Illinois River made a dependable navigation channel on the MMR a necessity. Lastly, in the early 1930s engineers completed a study of the original regulating works design plan and concluded that the project design should be modified to contract the river to 1,800 feet instead of 2,500 feet, as initially recommended in 1881.[43]

Between 1926 and 1950 Congress appropriated approximately $68 million for the Project, around 75 percent of which was used for the construction of new regulating works; the remainder was put toward the repair and maintenance of existing structures. As a point of reference, Congress had appropriated around $24 million for the Project over the previous 45 years, and nearly half of that was used for repair and maintenance.[44]

Between 1926 and 1950, the USACE oversaw construction of around 633,000 linear feet of dikes on the MMR. The types of dikes constructed remained mostly the same as they had been since the start of the Project: permeable wooden pile dikes. Although all of these dikes were categorized as new construction, what equated to "new construction" was very broad and varied depending on the needs of a particular section of river. In some cases new work consisted of building an entirely new single dike or dike field, but often the work consisted of extending an existing dike or dike field, slightly modifying it in some way, or replacing a dike or dike field that was completely destroyed. Other new work consisted of building a new dike to contract or close a side channel. None of the dike designs or methods of construction was particularly unique but was rather in line with the standard river engineering techniques and structures used at that time.[45]

The Project also included bank stabilization. The USACE still used the same method to stabilize banks that it had since the beginning of the Project, which was to place wooden willow weave and brush mattresses along sections of the riverbank that were susceptible to erosion and caving, and also along the new riverbanks built up by the sediment accumulated in dike fields. However, by the 1940s, and especially by the 1950s, hand-placed stone revetment, which was much more durable, began to be used for bank revetment. Neither the use of brush mattresses nor stone revetment was unique in respect to river engineering methods used at that time but was the standard means to stabilize banks.[46]

Between 1928 and 1956 the Project had successfully contracted the average planform width of the river (which extends from tree line to tree line and includes all channels, side channels, sandbars and islands) from 4,662 feet to 3,502 feet. When the Project first began, the average

[43] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154* (St. Louis: USACE, May 1971).

[44] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.

[45] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.

[46] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.

planform width was 6,085 feet. Much of the work that occurred between 1881 and 1927 had focused on eliminating side channels and sandbars and thus had a dramatic effect on the planform width of the river. However, the main channel is what commercial vessels use for navigation, a simple fact that is critical to understanding the impact of dike and revetment construction. At the beginning of the Project the average main channel width was 3,743 feet. By 1928, through the construction of dikes and revetment, engineers had contracted the channel to 3,160 feet. By 1956 the average width of the main channel was 2,667 feet. The closure of side channels had directed more flow into the main channel, and the contraction of the main channel directed the energy of this flow into the riverbed so that it could scour the bed and reduce sedimentation. The result was a deeper, more dependable navigation channel.[47]

The successful contraction of the MMR allowed for year-round commercial navigation by the 1940s. Prior to this, a nine-foot channel was only possible for around two-thirds of the year at best, and between December and February the river was closed completely. By the 1940s the investment in river navigation improvements was beginning to pay dividends. In 1927 just 1.1 million tons passed through the MMR, but by 1945 this total increased to 4.5 million tons. By 1950 it reached 11.5 million tons. Most of this tonnage originated on the UMR, with lesser amounts coming from the Missouri and Illinois rivers. The majority of the tonnage passing through the MMR was bound for the LMR for exportation to global markets.[48]

The golden age of construction for the Project was also the period when St. Louis saw its population grow to over 800,000, peaking at 856,796 in 1950.[49]

3.9 MMR PROJECT MODIFICATIONS (1950-1970)

The 1950s saw nearly a complete halt to construction of dikes and revetment on the MMR. During the decade only 10,000 linear feet of dikes were constructed, and between 1953 and 1956 specifically, only one new dike and no new revetment were constructed. The reason for the decline was the Korean War and later the conservative fiscal policies of the Eisenhower Administration. Even when Congress began appropriating funds for the Project again in 1957, the amount was meager at less than $200,000 per year. Because of heavy ice flows in the winters of 1950-1951, 1957-1958, and 1962-1963, and because of floods in 1951, many regulating works were destroyed or damaged. Consequently, most of what little money Congress appropriated went to maintenance and repair of existing structures.[50]

In the 1960s appropriations began to return to the levels that had existed in the 1940s. Because of the high cost of timber pile dikes and the meager appropriations of the 1950s, engineers began looking for a way to reduce the cost of dike construction. By the late 1950s they began experimenting with stone dikes because of the abundance of stone in the region. The St. Louis District was the first USACE district in the country to experiment with the use of stone dikes. The dikes performed the same function as pile dikes, but they were more durable and had greater longevity. This had been one of the major problems with the pile dikes: they simply were not durable enough and limited the efficacy of the project.[51]

[47] Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River.*
[48] USACE, *Annual Report of the Chief of Engineers*, 1927-1950; Dobney, 113-122.
[49] "Historical Census Browser," University of Virginia Library, Retrieved June 22, 2015.
[50] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.
[51] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.

The other reason for converting to stone dikes was the completion of the Missouri River reservoir system, which reduced sediment flow in the Missouri River and, in turn, reduced the sediment load on the MMR. The reduction of sediment in the MMR made timber pile dikes less effective because they depended on sediment deposition. Impermeable stone dikes depended less on sediment deposition than pile dikes, so it made engineering sense to convert to them.[52]

At first the district used stones to construct new dikes or to repair existing dikes, but by the early 1960s, the district began building only stone dikes and replacing existing dikes with stone dikes. By 1965, 25 percent of pile dikes had already been converted to stone-fill dikes, and this trend of converting timber dikes to stone dikes continued in the decades that followed.[53]

Prior to the conversion to stone dikes, the methods of constructing dikes had been largely unchanged since the Project began in 1881. The only changes in the project prior to the 1960s had been in respect to how many dikes needed to be constructed and how much the river needed to be contracted to maintain the nine-foot channel.[54]

In 1966 the district began a study to determine whether the Project criteria needed to be revised in order to assure a dependable nine-foot channel. Severe droughts between 1963 and 1965 exposed the inadequacy of the project for maintaining the navigation channel during extreme low-water conditions. Engineers had hoped that converting pile dikes to stone dikes and contracting the river to 1,800 feet would be enough to maintain the authorized channel and the river would not require further contraction, but this was not the case. The study evaluated whether the river needed to be further contracted through the extension of existing dikes and construction of new dikes.[55]

Engineers studied a prototype reach of the river between River Mile 55 and 68, the Devil's Island reach, which was one of the most difficult stretches of river to maintain. The study used stone dikes to contract the river to 1,200 feet between 1967 and 1969. The study revealed that contraction to 1,200 feet produced a deeper channel than was required at low-water. The study concluded that a contraction to 1,500 feet would be sufficient to maintain the navigation channel. Further experiments were conducted at the Waterways Experiment Station, which confirmed the district's conclusions. St. Louis District river engineers adopted the 1,500 foot contraction plan in 1974, and all future work on the Project followed this plan.[56]

3.10 REBIRTH OF RIVER COMMERCE ON THE MISSISSIPPI RIVER (1950-1970)

After peaking in 1950, the population of St. Louis began to decline in the 1950s and has continued this decline until the present day. In 1960 the population declined to 750,026, and in 1970 it was 622,236. Much of the loss of population was due to economic stagnation, residential

[52] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.

[53] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963; USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*.

[54] USACE, *Annual Report of the Chief of Engineers*, 1950-1963; USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*.

[55] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154;* USACE, *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4)* (St. Louis: MVS, June 1977).

[56] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154;* USACE, *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4)* (St. Louis: MVS, June 1977).

deterioration, and suburbanization. Not a single new office building was constructed between 1930 and the late 1950s, and unemployment reached 71,800 people by 1958. Many people fled the city to live in the suburbs, leading to a decline in the city's population but a rise in the population of the county and metro area, a trend common to many of the country's major metropolitan areas.[57]

One of the few exceptions for St. Louis's dismal economy during this period was the growth of river commerce at the Port of St. Louis, which increased from 2,259,894 tons in 1947 to 7,408,279 in 1956, over 9 million in 1960, and 10.4 million in 1970. Traffic at the port had increased so much that the port limits had to be expanded in 1972, and with the expanded port limits, tonnage increased to 21.7 million by 1974, making it by far the busiest port above Baton Rouge.[58] This reflected an overall increase in the use of inland waterways in general during the period. In 1950, 11.5 million tons passed through the MMR; by 1960 the total increased to 30 million tons; by 1970 it was 58.3 million tons; and by 1975 the total was 71.6 million tons. The increase in traffic on the MMR was largely due to increased traffic on the UMR, which saw its annual tonnage increase from 11 million in 1950 to 27.4 million in 1960 and 54 million in 1970. The Illinois River also saw substantial increases in annual tonnage, rising from 11 million tons in 1950 to 34.3 million in 1970. Tonnage also increased on the Missouri River, but not as substantially as on the other rivers in the system. Taken together, this increased tonnage dramatically increased the regional and national importance of the MMR and the Project. By 1974, 193.4 million tons were carried between New Orleans and the Gulf of Mexico, over a third of which passed through the MMR. The systematic improvement of the Mississippi River and its tributaries had allowed the Port of South New Orleans to become the busiest port in the Western Hemisphere and a vital part of the nation's economy.[59]

3.11 THE MMR PROJECT FROM 1970 TO PRESENT

Since 1970 Project construction activities have largely been limited to maintenance and repair, replacing existing pile dikes with stone dikes, and extending existing dikes and dike fields to further contract the channel in troublesome areas prone to sedimentation. About two-thirds of the Project's dikes had been converted to stone by 1976. The remaining one-third remained timber pile dikes, many of which were in a state of disrepair and needed to be replaced with stone dikes. The Project has also included extensive work to remove natural rock formations that protrude from the riverbed and impede navigation. Engineers also developed new innovative regulating works such as chevron dikes, L-dikes, wing dikes, and bendway weirs, but construction of these did not begin until the 1980s and 1990s.[60]

The major development in the modern period was the passing of the National Environmental Policy Act and the formation of the Environmental Protection Agency. Environmental laws required the district to coordinate with local, state, and federal environmental agencies to assess the environmental impact of projects and to modify regulating works to create greater habitat diversity and limit their environmental impact. In the 1970s the St. Louis District began

[57] Dobney, 113.

[58] Dobney, 113.; Mississippi River Commission, *Mississippi River Navigation* (Vicksburg, Miss.: Mississippi River Commission, 1975), 17.

[59] Tweet, 75-98; Mississippi River Commission, 17; Port of South Louisiana; Stratfor, Inc., *The Geopolitics of the United States*.

[60] USACE, *Environmental River Engineering on the Mississippi* (St. Louis: USACE, 1995); U.S. Government Accountability Office, *Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures*, GAO-12-41 (Washington, D.C.: GPO, 2012), 6-10.

experimenting with new designs and modifications for regulating works. Many of the modifications were minor, such as placing notches in dikes to allow flow to pass through them, thereby creating side channels and greater habitat diversity. Some dikes were lowered; others used stone of various sizes; some revetments were placed off the riverbanks to allow channels between the banks and revetment. The purpose of these modifications was to allow for a greater diversity of habitats, which would thereby allow for a greater diversity of riverine ecology, while at the same time allowing the project to perform its intended purpose of maintaining the congressionally authorized navigation channel.[61]

[61] USACE, *Environmental River Engineering on the Mississippi* (St. Louis: USACE, 1995); U.S. Government Accountability Office, *Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures*, GAO-12-41 (Washington, D.C.: GPO, 2012), 6-10; USACE, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works* (St. Louis: USACE, April 1976).

4.0 DESCRIPTION OF RESOURCES

4.1 THE MMR PROJECT

The MMR is defined as the 190-mile section of the Mississippi River between its confluence with the Missouri River at St. Louis, Missouri, and its confluence with the Ohio River at Cairo, Illinois. It is a relatively small reach of river compared to the UMR and LMR, yet serves as the hub of a vast interconnected inland waterway system. In its natural, pre-Project state, the MMR was obstructed by countless snags and split into separate channels or chutes in many places. The river was also progressively widening, which was consequently decreasing the depth of the navigation channel.

The Project, as initially authorized in the 1881 Rivers and Harbors Act, called for the construction of bankline revetments and permeable dikes to contract the river to a uniform width of 2,500 feet between dike ends and develop and maintain an eight-feet-deep and 200-feet-wide low-water navigation channel. The purpose of the Project—to provide a safe and dependable navigation channel on the MMR—has not changed since 1881, though the specifications were modified in 1927 and 1930 due to increased river traffic and a demand for deeper draft vessels. Since that time the Project has been authorized to maintain a nine-feet-deep and 300-feet-wide navigation channel. To do so, the width of the MMR between dike ends was reduced to 1,800 feet, then further to 1,500 feet in the 1970s.

The USACE has ensured adequate navigation depth and width through bank stabilization and sediment management, which has been achieved by the use of river training structures (dikes), revetments, and dredging. This has allowed for "open river" navigation on the MMR, as opposed to the UMR, for example, with its comprehensively engineered system of locks and dams. As a result, the MMR maintains a comparatively more natural appearance.

Since its inception, the Project has involved constructing new dikes and extending, modifying, or replacing existing dikes to maintain the authorized navigation channel. There are currently more than one thousand structures on the MMR and, in general, similar structures have been used since the nineteenth century. The specific types of river training structures associated with the Project are discussed in detail below.

4.2 ASSOCIATED BUILT FEATURES

There are two main types of river training structures on the MMR: redirective and resistive. Redirective structures, as the name implies, direct a river's flow into the main channel to use the river's energy to enhance and maintain the navigation channel. A resistive structure acts to maintain the system by preventing bank erosion and channel migration.

Redirective structures are usually a series of dikes that extend from the riverbank. The major function of dikes for navigation projects is to concentrate the river's energy into a single channel, control the location and increase the depth of the channel, and prevent the accumulation of sediment to reduce the need for dredging. Redirective structures are also used in environmental applications to create more environmental diversity by change flow velocity and scour patterns.

Resistive structures, also known as revetment, are used to prevent bank erosion and channel migration on the outside of a river bend and to establish or maintain a desired channel alignment.

Revetment historically consisted of brush and timber mattresses, but since the 1940s has primarily been constructed of stone.

4.2.1 Dikes

Dikes are structures placed in a river to redirect the river's energy to provide a variety of effects, such as preventing erosion and protecting structures along the bank; realigning a reach of river; constricting the channel and scouring the riverbed to increase depth; cutting off side channels and chutes; reducing sedimentation and the need for dredging; and creating environmental habitat.

4.2.1.1 Dike Types

The most common type of dike is a ***spur dike***, also called a ***wing dam*** or ***jetty*** (Figure 4.1). This type of dike typically extends perpendicularly from the riverbank toward the main river channel, or it extends across a side channel or chute to act as a dam to close the side channel and concentrate the river's flow into a single channel. This is the most common type of dike and has been constructed on the MMR since the nineteenth century. Other less-common types of dikes come in a variety of shapes and configurations, but they still perform the same basic function.

A ***rootless dike*** is one that is offset from the river bank, meaning the structure starts some distance off the bank. The typical offset distance is 100 feet or more. The rootless section provides environmental diversity by altering flow and sediment transportation. Many times, multiple dikes are left rootless and positioned in a line to create a secondary channel for environmental enhancement. Construction of these structures did not begin until after 1970.

L-head dikes, also called ***trail dikes***, extend from the riverbank like a spur dike but also have a section at the dike end that extends downstream (Figure 4.2). The L-head section spreads the energy of the flow over a larger area and can be used to increase the spacing between dikes, to reduce scour on the stream end of the dike, or to extend the effects of the dike system further downstream. The L-head also tends to block the movement of sediment behind the dike by reducing the formation of eddies downstream. This type of dike did not become common on the MMR until after 1970.

Closure dikes are built in side channels, or chutes, to reduce or eliminate the flow through these secondary channels, thereby allowing more flow to be concentrated in the main channel (Figure 4.3). Spur dikes divert sediment into the side channel and closure dikes reduce the velocity of the flow in the side channel, leading to increased sediment deposition and potentially the eventual closure of the side channel or a reduction in its size. Closure dikes have been constructed on the MMR since the nineteenth century.

Side channels are not used for navigation, but are valuable environmental areas. Traditionally these side channels were closed with rock structures to divert the flow into the main channel. While improving navigation, this process tends to fill the side channels with sediment and convert aquatic habitat to terrestrial habitat. Notching a closure structure can prevent the side channels from filling with sedimentation. ***Notched closure dikes*** form areas of deep water and shallow water, creating a diversity of habitat and attracting different species of fish. Construction of these structures did not begin until after 1970.

A ***bendway weir*** is a low-level, fully submerged rock structure that is positioned from the outside bankline of a river bend and angled upstream toward the flow (Figure 4.4). These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging. The first bendway weirs were constructed on the MMR in 1989.

Chevrons are dike structures designed with a blunt-nosed, arch shape (Figure 4.5). They are constructed parallel to flow and like regular dikes utilize the energy of the river to redistribute flow and sediment. They are usually placed adjacent to the river bank to allow flow separation and create both channel deepening, side channel development, and middle bar formation. Chevrons were first constructed on the MMR in 2001.

Hard points are very short rock dikes that are used to stabilize side channel river banks (Figure 4.6). These navigation structures extend from the riverbank into the river and do not cause a significant buildup of sediment. Their contribution to habitat improvement is the creation of scour holes under the hard points. These deep plunge holes attract catfish that flourish in this environment. Hard points were first constructed after 1970.

Notched dikes are simply dikes with notches added (Figure 4.7). The notches allow the river to move in and out between them, thus creating a greater diversity of river habitats while still allowing the dike to perform its primary function of directing flow into the main channel for navigation. River engineers first began experimenting with notched dikes in the late 1960s and they became much more prevalent on the MMR after the 1970s. In some cases, new dikes were designed with notches, and in other cases, notches were added to existing dikes.

Multiple roundpoints structures (MRSs) are alternating rows of rock mounds within the footprint of a typical dike (Figure 4.8). They are used like a dike to maintain the navigation channel and to create flow and bathymetric diversity within a dike field. The main benefit of these structures is to create diverse flow and scour patterns for aquatic improvement. MRSs were not constructed on the MMR until after the 1970s. Currently, there is only one MRS field on the MMR.

W-dikes are dikes that have four legs and are shaped like the letter “W,” with the apex of two legs facing upstream. Flows are directed toward the apexes, forming two scour holes and one depositional bar downstream. The tips of the W-dikes behave like traditional dike structures, constricting the channel and increasing sediment transport through an area. The landward side of a W-dike can be attached to the bankline. Construction on these structures did not begin until after 1970.

Dike extensions are used when a dike is not performing adequately and additional channel constriction is needed. The extension may incorporate a gap between the existing structure and new construction, which performs like a notch and can provide a dynamic system for environmental enhancement.

4.2.1.2 Dike Design and Construction

While most dikes are very similar in their basic design, there are numerous variations. Dike design can vary by type of material, length, crest height and width, slope, angle, and spacing.

Stone and timber are the two most common materials in the construction of dikes. Prior to the 1960s, timber piles were constructed almost exclusively on the MMR, but in the late 1950s, engineers began experimenting with stone dikes. By the early 1960s all new dikes were built with stone, and timber pile dikes were being replaced with stone dikes. About two-thirds of the Project's dikes were converted to stone by 1976.

Timber pile dikes were constructed by driving timber piles vertically into the riverbed and then filling the area between the vertical piles with material, usually brush, and placing a horizontal spreader between the vertical piles (Figure 4.9). Stone was then placed on the shore end of the dike. To construct a stone dike, stone is placed onto a barge and dumped into the river. The construction is carried out in accordance with design specifics, such as length, angle, width, height, slope, etc.

Prior to the late 1960s all dikes constructed were spur dikes. But in the 1990s and 2000s, new structures such as bendway weirs, MRSs, chevron, and L-dikes (see Section 4.2.1.1 above) have been constructed. In the 1970s engineers began modifying the design of structures for environmental purposes. Some of the stone dikes built in the 1960s were later modified, usually through adding notches or an L-head or other extension.

The length of dikes is determined by the desired contraction width of a specific section of river. If engineers determine that a particular section of river needs to be contracted to a specific width to maintain the congressionally authorized navigation channel, then they will design dikes of the necessary length to contract the river to this width. Engineers may also extend the length of existing dikes if this is deemed necessary to further contract the river to provide for a dependable navigation channel. Typically, dikes will initially be constructed to a specific length and then engineers will gather data and observe the response of the river. Once the river has responded to the dikes, engineers will gather these data to determine if any design modifications are necessary.

When the Project first began in 1881, dikes were constructed to such a length as to contract the river to an average width of 2,500 feet. Since that time, engineers have observed the response of the river to the construction of dikes and have determined that the river required further contraction in order to maintain the navigation channel. In the 1930s engineers developed design guidelines that advised contraction of the MMR to 1,800 feet between dike ends, and in the late 1960s, engineers modified the guidelines to a width of 1,500 feet. Since the 1970s engineers have designed dikes to be of such a length as to contract the river to an average width of 1,500 feet. Extension of existing dikes was sometimes necessary.

The height or top elevation of dikes is normally associated with the reference plane associated with the Project (Figure 4.10). The elevation of dikes relative to the water surface can have an important bearing on the structures' performance, their impact on the stream, and their impact on the areas within the dike field. On open river portions of the Mississippi River the top elevation of dikes typically varies from about 10 to 18 feet above the Low Water Reference Plane.

The width of the crest of a stone dike is generally determined by the method of construction, but with a minimum design width of 5 feet. Dikes constructed from a barge usually have a crest width of 6 to 10 feet, while those constructed by truck have a crest width of 10 to 14 feet to accommodate movement of the truck/backhoes and other equipment on the dike structure. In river reaches susceptible to ice flows, dikes with crest widths of less than 6 feet may have their top portion sheared off as the ice moves downstream. One other method for determining dike crest width is to design the dikes based on the size of stone used and the height of the dike. In this case the crest width is allowed to vary so long as the minimum width of 5 feet is maintained.

Summarizing, there is some variation in the crest widths used for dikes, but virtually all dikes fit within the range of 5 to 20 feet with the majority of dikes constructed with a crest width of 5 to 10 feet.

Dike angling and spacing vary based on the needs of a particular stretch of river. The angle of a dike is an important factor in determining where and how much scour occurs at the stream end of the dike and the location of the channel that develops adjacent to the dike. Historically, dikes have been constructed normal to the adjacent bank line or angled slightly downstream.

4.2.2 Revetment

Revetment includes resistive structures placed on or near a river bank, usually on the outside of a river bend and on banks around new structures. They are primarily used to prevent bank erosion and channel migration and to establish or maintain a desired channel alignment.

4.2.2.1 Revetment Types

The majority of stone revetment consists of a layer of non-uniform size stone, or rip rap, laid on a sloping river bank. ***Traditional stone revetment*** has been the most common type of revetment on the MMR since the 1930s (Figure 4.11).

Willow/board mattresses were the earliest and most common type of revetment used on the MMR prior to the 1930s when cheap stone became available (Figures 4.12 and 4.13). Board mattresses consist of wooden boards woven together; similarly, willow mattresses consist of willow brush woven together or formed together using wire. The mattresses are then placed along the riverbank to prevent erosion. They continue to be employed in combination, such as stone above the flow line and mattress below.

Off-bankline revetment is revetment built slightly off the riverbank and sometimes notched to allow for flow to pass between the riverbank and the revetment, thereby allowing for a greater diversity of habitats (Figure 4.14). This modified type of revetment was not constructed on the MMR until after 1970.

4.2.2.2 Revetment Design and Construction

On the MMR, revetment must consist of a minimum of a 30-inch rock blanket of “A” stone (a well-graded stone with a maximum size of 5,000 pounds) on the existing bank grade. Stone is placed in such a way as to meet the necessary bank grade. Stones are typically block-like and angular. Since the 1970s, engineers have used stones of non-uniform size to allow for a greater diversity of habitats. Prior to the 1930s, willow weave mattresses were the more common type of revetment. These are constructed by weaving together willow brush and/or timber and placing the mattresses along the river bank at the appropriate grade. During the early decades of the Project, mattresses were used to protect the portion of the banks below the low–water stage, and stone was used to protect the portion of the banks above the low-water stage. The design and construction of both stone revetment and willow weave mattresses were standard for the time and had been widely used on other rivers.

Off-bankline revetment is constructed by placing stone on a barge and dropping the stone into the river just off the bankline to form a long, dike-like structure between the riverbank and the revetment. These structures were not first constructed until after the 1970s. Much of the earliest revetment remains in place on the MMR.

5.0 EVALUATION OF SIGNIFICANCE

5.1 APPLICABILITY OF NATIONAL REGISTER CRITERIA

Four criteria are used to evaluate the eligibility of properties (buildings, structures, objects, sites, and districts) for the National Register. To be eligible, a property must be associated with significant historic events or trends (*Criterion A*) or the lives of significant persons (*Criterion B*), possess significant design or construction value (*Criterion C*), or yield information important in history or prehistory (*Criterion D*). Below are summaries of how each criterion may be applied to the Project and its associated built features.

5.1.1 Criterion A: Event

To be eligible for the National Register under *Criterion A* a property must be significantly associated with a specific event, pattern of events, or trend important to history. River navigation projects are inherently important, especially those concerning principal navigable waterways, such as the Mississippi River. The need for safe and dependable navigation channels is immense and widespread, and since 1824 almost every Congress has passed one or more Rivers and Harbors acts to authorize the maintenance and improvement of the nation's rivers and harbors for the benefit of navigation.[62] Navigation projects on the Mississippi River, specifically, have played a critical role in the nation's economy. Commercial navigation on the largest river system in the United States has opened the country's agriculturally-rich interior to global markets and has had a profound impact on growth and development in the region.

A river navigation project may be found eligible for the National Register under *Criterion A: History* if it has a demonstrably important association with historically significant events or trends. Mere coexistence or speculative association would not equate to National Register eligibility under this criterion. For example, a specific project may be eligible if it represents the first successful attempt to construct regulating works to permanently improve a section of river for navigation purposes. Conversely, a project that successfully maintained a navigation channel as designed but otherwise had no momentous historical influence on river commerce and possessed no other associations would not be eligible.

5.1.2 Criterion B: Person

For eligibility under *Criterion B* a property must be closely associated with a significant person and illustrate that person's important achievements and/or his or her productive life better than any other extant property. River navigation projects would rarely be found eligible under this criterion, primarily because an association with a prominent engineer or other significant individual would apply more to *Criterion C*, discussed below. These projects also generally represent the work of many people, rather than specific individuals. A project could be eligible under *Criterion B* if it best represents a person's significant contributions to river engineering and navigation history.

---

[62] American Public Works Association, *History of Public Works in the United States, 1776-1976* (Chicago: American Public Works Association, 1976), 30-31.

5.1.3 Criterion C: Design/Construction

Properties eligible for the National Register under *Criterion C* are notable for their design and/or construction qualities. They may embody distinctive characteristics of a type, period, or method of construction; exemplify the work of a master; possess high artistic merit; or represent a significant unified entity (a district) whose component resources lack individual distinction. A river navigation project or any one of its individual structural elements may have unique engineering values, represent a specific navigation improvement, or illustrate trends in engineering as a design innovation. These projects may also be noteworthy for the way they were adapted over time to continuously meet their objectives. In any case, it must be demonstrated that the project or individual engineering resource is important within its engineering context.

It is unlikely that a river navigation project, as a whole, would be eligible under *Criterion C* as the work of a master, since these types of undertakings are typically conceived and executed by numerous people across many disciplines and as the result of various factors. Certainly, an individual component of a designed river system, such as a lock and dam, could be a good example of a single important engineer’s work. To be eligible for its artistic value, a project or any one of its engineering features must express an aesthetic ideal or particular design concept more fully than other examples of its type.

5.1.4 Criterion D: Information Potential

Properties that have yielded, or are likely to yield, important information regarding history may be eligible for the National Register under *Criterion D*. This criterion most often applies to archaeological sites, as they can serve as principal sources of data. Information regarding the history of extant aboveground resources, on the other hand, is generally well documented or obtainable from other sources. For a river navigation project to be eligible under *Criterion D*, it must possess significant research value. For example, early built features of a project that have been buried by sediment may be able to provide important information regarding river engineering practices that is otherwise not known or available, such as the modification of dike placement and construction methods in reaction to previously unencountered site conditions. Projects with an especially long history with gaps in its historical record certainly have the potential to supply new insights. Once the research potential of a property has been realized, it is no longer eligible for the National Register under *Criterion D*.

5.2 NATIONAL REGISTER ELIGIBILITY OF THE MMR PROJECT

River navigation projects are undertaken to fulfill a specific navigational need and generally involve the design and implementation of various engineering works intended to work together to achieve desired outcomes. This is exemplified by the Project, an enterprise of the USACE representing more than 130 years of river engineering dedicated to maintaining a safe and dependable navigation channel on the MMR. Specifically, the Project has primarily involved the use of river training structures to sustain its singular goal. Although there are more than a thousand of these structures, the Project is a unified entity reflecting one principal activity (see Feature Catalogue Maps). As a result, it is most appropriate to evaluate the Project for National Register eligibility as a district.

Unlike the navigation channel project on the UMR, which consists of a system of individually distinctive locks and dams, the built features on the MMR are undistinguished and do not act as focal points. Similar structures have been constructed as part of the Project since the nineteenth century, and they are not unique to this river system. The types of dikes and revetment that have been used are common river-training structures, employ relatively simple engineering principles and construction methods, and were built in large numbers. There is no indication that any have the potential to possess exceptional design qualities or important historical associations on their own. Consequently, none of the Project's structures was evaluated individually for National Register eligibility.

5.2.1 Criterion A: Event

The Project represents a long-standing, concentrated effort by the USACE to ensure a safe and dependable navigational channel on the MMR, a vital section of the nation's largest river system. The significance of the Project from its outset in 1881 is undeniable. No river has influenced the development and expansion of the United States more than the Mississippi River, and the Mississippi River could not have attained its current place in history without the sustained navigability of the MMR.

The Project is directly associated with defining periods in the country's agricultural, commercial, engineering, industrial, and transportation histories, and maintaining the navigation channel on the MMR has certainly contributed to the furtherance of these themes. The Project was a reaction to the decline of river commerce in the Midwest caused by rapid railroad expansion and the Mississippi River's unreliability and sometimes completely un-navigable conditions. The navigational improvements on the MMR helped to combat the exploitative shipping rates of the railroads that were hampering the agricultural industry and the country's ability to compete in the global trade market. In addition, the Project essentially marked the beginning of the USACE's St. Louis District and has since remained one of the agency's primary missions.

The significance of the Project was heightened in the twentieth century. After the opening of the Panama Canal in 1914, the most efficient shipping route between the East and Midwest regions of the United States and Asia was by water. The safe and dependable transportation of goods down the Mississippi River was critical to the success of the canal and the country gaining a global foothold. The Project is also associated with the "Golden Age" of the USACE, when the agency achieved its greatest influence and completed its greatest volume of work. Substantial navigational improvements were made to the MMR during that period, roughly defined as 1930 to 1950, and annual tonnage on the river increased exponentially.

Given its vast historical impact and its continued importance on a national scale, the Project possesses significance under *Criterion A*. The period of significance is 1881, the year the Project was first congressionally authorized, to 1965, the National Register's 50-year threshold. Any structures built prior to 1966 should be considered as contributing resources of the district.

5.2.2 Criterion B: Person

The Project is associated with notable people, such as engineers Col. James Simpson and O.H. Ernst, but ultimately represents the work of many over the course of more than 130 years. It does not appear that any individuals achieved historical significance specifically through their contributions to the Project. As a result, the Project is recommended not eligible for the National Register under *Criterion B*.

5.2.3 Criterion C: Design/Construction

The Project is a functioning, ever- evolving engineered system that is embodied by the physical form and properties of the MMR and the various river-training structures constructed, reconstructed, modified, and upgraded by the USACE since 1881. It does not necessarily represent a specific type of river-engineering project, method of obtaining and maintaining a navigation channel, or period of construction. Rather, it has been an ongoing, dynamic process that has been directed by shifting riverine conditions, changes in economics and attitudes, and modern technological advancements. The Project does not possess distinctive characteristics with unique engineering values or that could be considered design innovations. The various dikes and revetment used on the MMR are typical examples of their respective types and are not distinctly interrelated within the context of river engineering. Also, the need for constant engineering on the MMR to continuously meet the objectives of the Project does not represent a significant achievement. In essence, similar structures have been used since the Project's inception, and additions and modifications to the Project have been made for maintenance purposes or simply because newer, better ways have been found to achieve comparable results. Without any discernible significant design or construction value, the Project is recommended not eligible for the National Register under *Criterion C*.

5.2.4 Criterion D: Information Potential

It does not appear that the Project is a likely source of information important to history. Research indicated that the Project, and permanent navigation improvements on the MMR in general, is well documented through USACE annual reports, historic maps and design drawings, and construction records. Remnants of early timber pile dikes constructed as part of the Project are presumably present in the MMR, buried by sediment, but such archaeological material would provide little research value considering what is already known regarding construction methods and materials of the time. There are no other apparent important research questions that only in depth study and analysis of the Project would answer. The Project is, therefore, recommended not eligible for the National Register under *Criterion D*.

5.3 INTEGRITY

In addition to eligibility under one or more evaluation criteria, a property must also possess integrity, or the ability to convey its significance. There are seven aspects of integrity to consider—*location, design, setting, materials, workmanship, feeling, and association*—and a property must retain at least several, and usually most, of these qualities. The evaluation of integrity for a river navigation project essentially consists of determining if it retains the identity for which it is significant.

Arguably, the Project retains integrity with regard to five of the aspects of integrity. Since its initial authorization in 1881 the objective of the Project has been the same—to ensure a safe and dependable navigation channel on the 190-mile reach of the Mississippi River known as the MMR (*location*). The navigation channel was obtained and has been maintained for over 130 years through bank stabilization and sediment management measures, which have been limited to the use of dikes, revetment, and dredging (*design*). Although the appearance of the MMR has changed quite perceptibly as it has been narrowed over time, its position within its environment and its basic physical conditions as a free-flowing river with "open river" navigation have been consistent (*setting*). And the use of similar river-training structures since the nineteenth century and the sustained commercial traffic on the MMR are expressions of the Project's permanence and provide a direct link between present day and its nineteenth-century beginnings (*feeling* and *association*).

The nature of the Project requires that it continually evolve to meet its objectives and react to any changing needs. Ongoing maintenance, improvements, and upgrades have been, and will continue to be, necessary for it to uphold its purpose of maintaining a safe and dependable navigation channel on the MMR. As a result, relative to its period of significance (1881-1965), the Project fails to retain integrity with regard to the two remaining aspects of integrity, *materials* and *workmanship*. With few, if any, associated structures that date from the historic period, the Project is not a truly tangible historic resource. Continuous engineering of the Project to keep it current and functional has led to the loss of the essential physical features that would enable it to convey its historic identity and significance. In its current physical state, the Project can no longer be identified as a historic regulating works project. Without an ample number of components that contribute to its significance the Project does not possess sufficient integrity to be eligible for the National Register as a district.

5.4 CONCLUSION

National Register eligibility is dependent upon two major factors: significance and integrity. *Significance* is the ability of a property to meet one or more of the criteria for evaluation; *integrity* is the ability of a property to convey significance. This study demonstrates that the Project clearly meets the significance test, but not the integrity test. The criteria for evaluation allow that a property can be eligible if it possesses specific important associations with events that have made a significant contribution to the broad patterns of history. Documentary research indicates that since 1881 the USACE has undertaken the mission of ensuring that a safe and dependable navigation channel exists on the MMR. The Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR has been immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. However, the study also demonstrates that due to continual, but necessary, modifications of various river training structures, the Project no longer retains integrity of materials and workmanship from its period of significance (1881-1965). With most, if not all, of its associated structures post-dating 1965, the Project is unable to convey its considerable national significance. Therefore, the project is recommended *not eligible* for the National Register.

6.0 BIBLIOGRAPHY

Alexander, J.S., Wilson, R.C., and Green, W.R. *U.S. Geological Survey Circular 1375: A Brief History and Summary of the Effects of River Engineering and Dams on the Mississippi River System and Delta*. Reston, Va.: U.S. Geological Survey, 2012.

Ambrose, Stephen. *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West*. Simon and Schuster: New York, 1996.

American Public Works Association. *History of Public Works in the United States, 1776-1976*. Chicago: American Public Works Association, 1976.

Anfinson, John O. *The River We Have Wrought: A History of the Upper Mississippi River*. Minneapolis: University of Minnesota Press, 2003.

Ballou, W.H. "Improvement of the Mississippi River." *Science* 1, no. 19 (1880): 232-233.

Baumel, C. Phillip and Jerry Van Der Kamp. *Past and Future Grain Traffic on the Missouri River*. Minneapolis: Institute for Agriculture and Trade Policy, 2003.

Belt, Jr., C.B. "The 1973 Flood and Man's Constriction of the Mississippi River." *Science* 189, no. 4204 (1975): 681-684.

Brauer, Edward J., David R. Busse, Claude Strauser, Robert D. Davinroy, David C. Gordon, Jasen L. Brown, Jared E. Myers, Aron M. Rhoads, Dawn Lamm. *Geomorphology Study of the Middle Mississippi River*. St. Louis: USACE, 2005.

Brauer, E.J, R.D. Davinroy, L. Briggs, and D. Fisher. *Supplement to Geomorphology Study of the Middle Mississippi River*. St. Louis: USACE, 2013.

Brauer, E.J. "The Effect of River Training Structures on Flood Heights on the Middle Mississippi River." in *River Flow 2012*, 1245-1252. London: Taylor & Francis Group, 2012.

Brown, D. Clayton. *Western Tributaries of the Mississippi*. USACE Water Resources Support Center, National Waterways Study, 1983.

Brown, Robert Marshall. "The Mississippi River as a Trade Route." *Bulletin of the American Geographical Society* 38, no. 6 (1906): 349-354.

Camillo, Charles A. and Matthew T. Pearcy. *Upon Their Shoulders: A History of the Mississippi River Commission from its Inception Through the Advent of the Modern Mississippi River and Tributaries Project*. Vicksburg, Miss.: Mississippi River Commission, 2004.

Dixon, Frank Haigh. *A Traffic History of the Mississippi River System*. Washington, D.C.: GPO, 1909.

Dobney, Fredrick J. *River Engineers on the Middle Mississippi*. Washington, D.C.: GPO, 1978.

Haupt, Lewis M. "The Mississippi River Problem." *Proceedings of the American Philosophical Society* 43, no. 175 (1904): 71-96.

Hill, Forest G. *Roads, Rails and Waterways: The Army Engineers and Early Transportation.* Norman, Okla.: University of Oklahoma Press, 1957.

Landon, Charles E. “Technological Progress in Transportation on the Mississippi River System.” *The Journal of Business* 33, no. 1 (1960): 43-62.

Lee, Robert E. and Montgomery C. Meigs. "No. 3 Map of the Harbor of St. Louis, Mississippi River," submitted to the U.S. Army Corps of Engineers Chief Engineer, October 1837. Accessed September 17, 2015. http://statehistoricalsocietyofmissouri.org/cdm/ref/collection/Maps/id/8.

Lemly, James H. “The Mississippi River: St. Louis’ Friend or Foe?” *The Business History Review* 39, no. 1 (1965): 7-15.

Lippincott, Isaac. “History of River Improvement.” *Journal of Political Economy* 22 (1914): 630-660.

Manders, Damon and Brian Rentfro. *Engineers Far From Ordinary: The U.S. Army Corps of Engineers in St. Louis*. St. Louis: USACE, 2011.

Mississippi River Commission. *Mississippi River Navigation*. Vicksburg, Miss.: Mississippi River Commission, 1975.

Mississippi River Corridor Study Commission. *Mississippi River Corridor Study,* vol. 2. Washington, D.C.: GPO, 1996.

National Park Service. *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation.* Washington, D.C.: U.S. Department of the Interior, NPS, 1991.

Paullin, Charles O. and John K. Wright. *Atlas of the Historical Geography of the United States*. Washington, D.C.: Carnegie Institute of Washington and the American Geographic Society of New York, 1932.

Port of South Louisiana. “Overview of the Port.” Accessed July 10, 2015. http://www.portsl.com/overview.htm.

Schumm, Stanley A. *River Variability and Complexity*. New York: Cambridge University Press, 2005.

Shallot, Todd. *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers*. Austin, Tex.: University of Texas Press, 1994.

Stevens, Michael A., Daryl B. Simons, and Stanley A. Schumm. “Man-Induced Changes of Middle Mississippi River.” *Journal of the Waterways, Harbors, and Coastal Division* 101, no. 2 (1975): 119-133.

Stratfor, Inc. *The Geopolitics of the United States, Part 1: The Inevitable Empire*. Austin, Texas: Stratfor, Inc., 2012.

Task Committee of the Waterways Committee of the Coasts, Oceans, Ports, and Rivers Institute. *Inland Navigation Channel Training Works*. American Society of Civil Engineers, 2013.

Thomas, B.F. and David Alexander Watt. *The Improvement of Rivers*. 2nd ed. New York: John Wiley & Sons, Inc., 1918.

Thomas Gibbons vs. Aaron Ogden. 22 U.S. 9 Wheat. 1 (1824).

Thomas, Lewis F. "Decline of St. Louis as Midwest Metropolis." *Economic Geography* 25, no. 2 (1949): 118-127.

Tweet, Ronald D. *History of Transportation on the Upper Mississippi and Illinois Rivers*. USACE Water Resources Support Center, National Waterways Study, 1983.

U.S. Army Corps of Engineers. *Annual Report of the Chief of Engineers*, 1872-2012.

———. *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works*. St. Louis: USACE, April 1976.

———. *Environmental River Engineering on the Mississippi*. St. Louis: USACE, 1995.

———. *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4).* St. Louis: USACE, June 1977.

———. *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*. St. Louis: USACE, May 1971.

U.S. Congress. *Harbor of St. Louis*, House Doc. No. 25-298. 25th Cong., 2d sess.

———. *Letter from the Secretary of War Transmitting a Progress Report of the Mississippi River Commission, dated November 25, 1881*. Senate Executive Doc. No. 10. 47th Cong., 1st sess.

———. *Message Concerning the Ohio and Mississippi Rivers.* House Doc. No. 17-35. 17th Cong., 2d sess.

———. *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a View to Obtaining a Channel 14 Feet Deep and of Suitable Width.* House Doc. No. 50. 61st Cong., 1st sess.

———. *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a view a View to Obtaining a Channel 14 feet Deep and of Suitable Width*. House Doc. No. 50. 61st Cong., 1st sess.

———. *Report of the Board of Engineers for Rivers and Harbors Submitted November 12, 1903*. House Doc. No. 168. 58th Cong., 2d sess.

———. *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Made on Mississippi River Between the Mouth of the Ohio River and the Northern Boundary of the City of St. Louis.* House Doc. No. 9. 69th Cong., 2d sess.

———. *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Submitted on Illinois and Mississippi Rivers.* House Committee on Rivers and Harbors. House Committee Doc. No. 12. 70th Cong., 1st sess.

———. *Report of the Board of Engineers on the Ohio and Mississippi Rivers*. House Doc. No. 35. 17th Cong., 2d sess.

———. *Report of the Select Committee on Transportation Routes to the Seaboard*. Senate Report No. 307, Part I. 43d Cong., 1st sess.

———. *Report on the Act to Improve the Navigation of the Ohio and Mississippi Rivers*, House Report 18-75. 18th Cong., 1st sess.

———. *Report on the Mississippi River between Ohio River and Mouth of Missouri River*. House Doc. No. 231. 76th Cong., 1st Sess.

U.S. Government Accountability Office. *Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures.* GAO-12-41. Washington, D.C.: GPO, 2012.

University of Virginia Library. "Historical Census Browser." Accessed June 22, 2015. http://mapserver.lib.virginia.edu.

Way, R.B. "Mississippi Improvements and Traffic Prospects." *Annals of the American Academy of Political and Social Science*. Vol. 31. American Waterways (Jan., 1908), pp. 146-163.

Wyatt, Barbara. "The Components of a Historic Context." National Register White Paper Series, 2009. Accessed August 13, 2015. http://www.nps.gov/nr/publications/policy.htm.

FIGURES

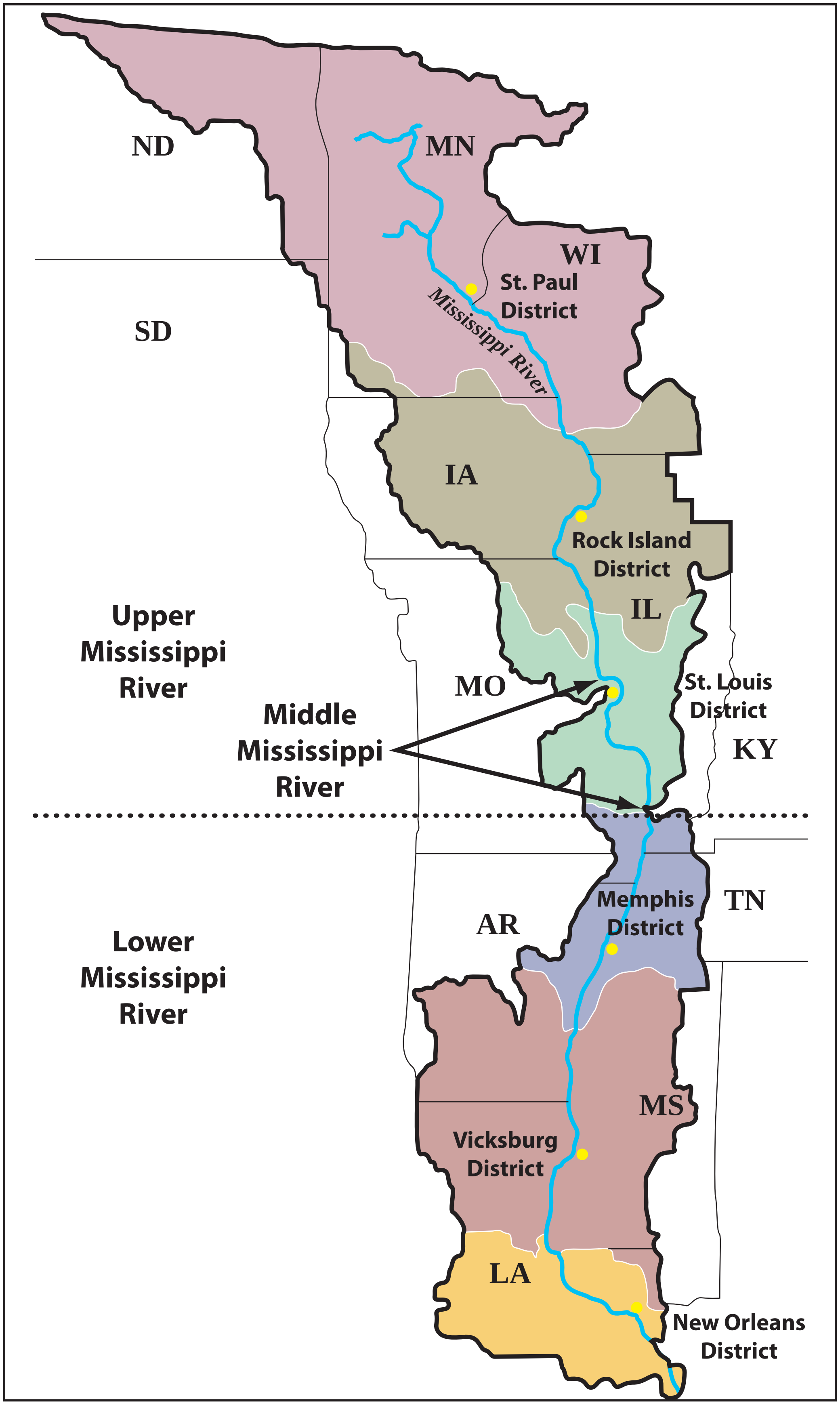


Figure 3.1. The Three Sections of the Mississippi River (USACE).

Figure 3.2. The Middle Mississippi River (Google Earth).

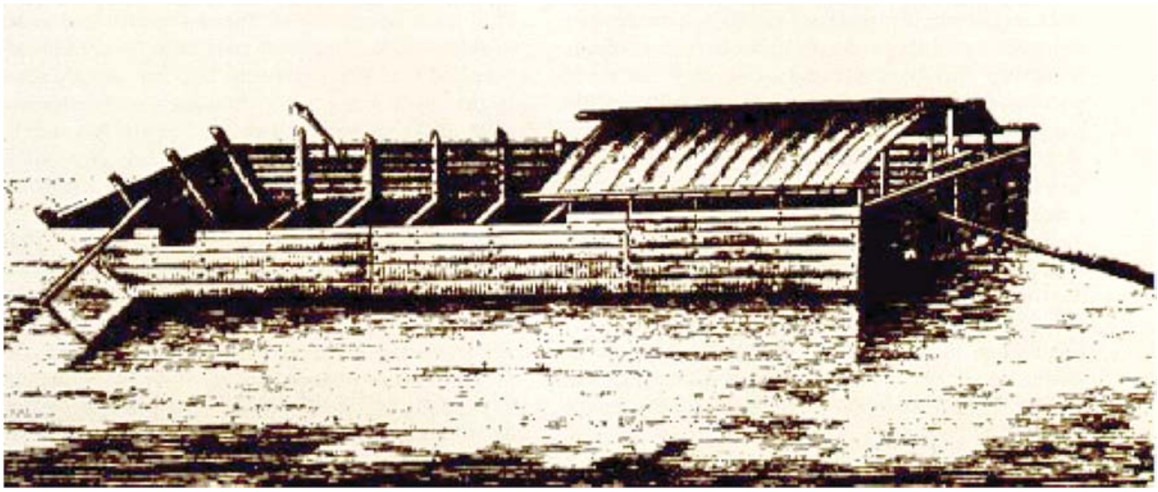


Figure 3.3. A Flatboat (Dobney, 21).

Figure 3.4. Steamboats on the Mississippi River (Manders and Rentfro, 33).

Figure 3.5. The Removal of Snags on the Middle Mississippi River via Snagboat (Manders and Rentfro, 33).

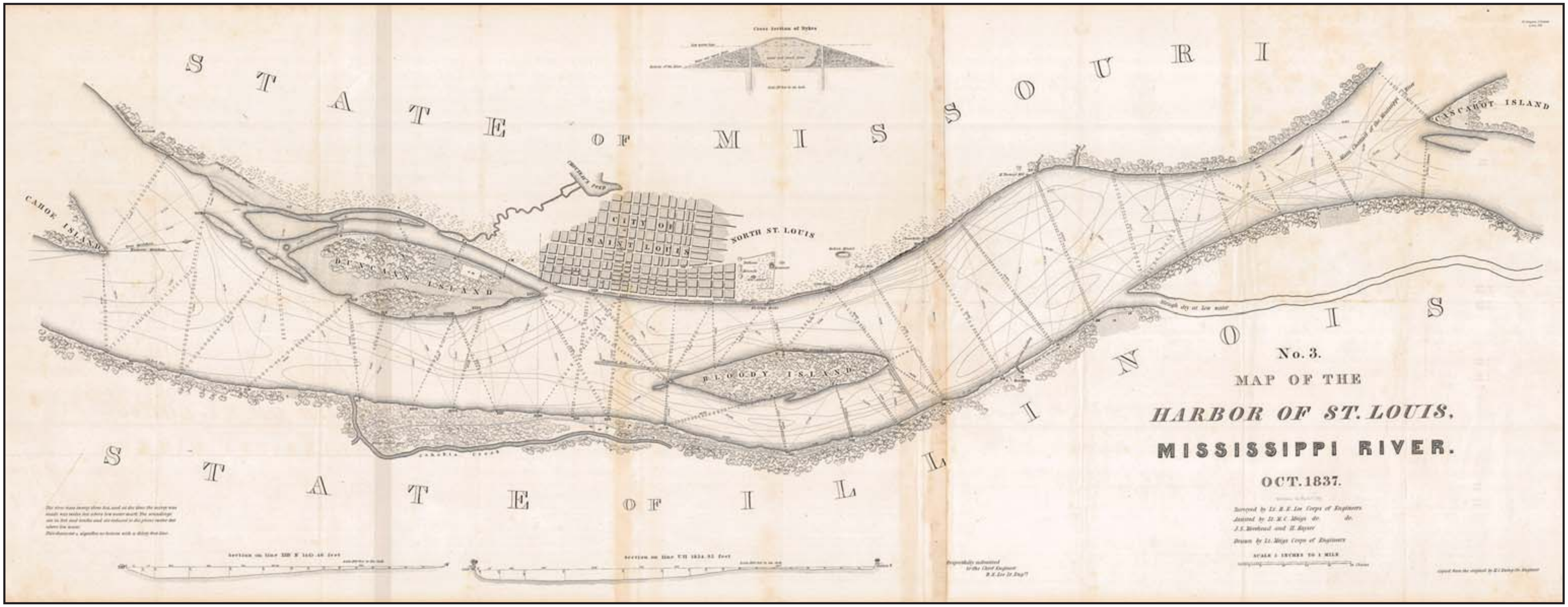


Figure 3.6. The St. Louis Harbor Project (Lee and Meigs).

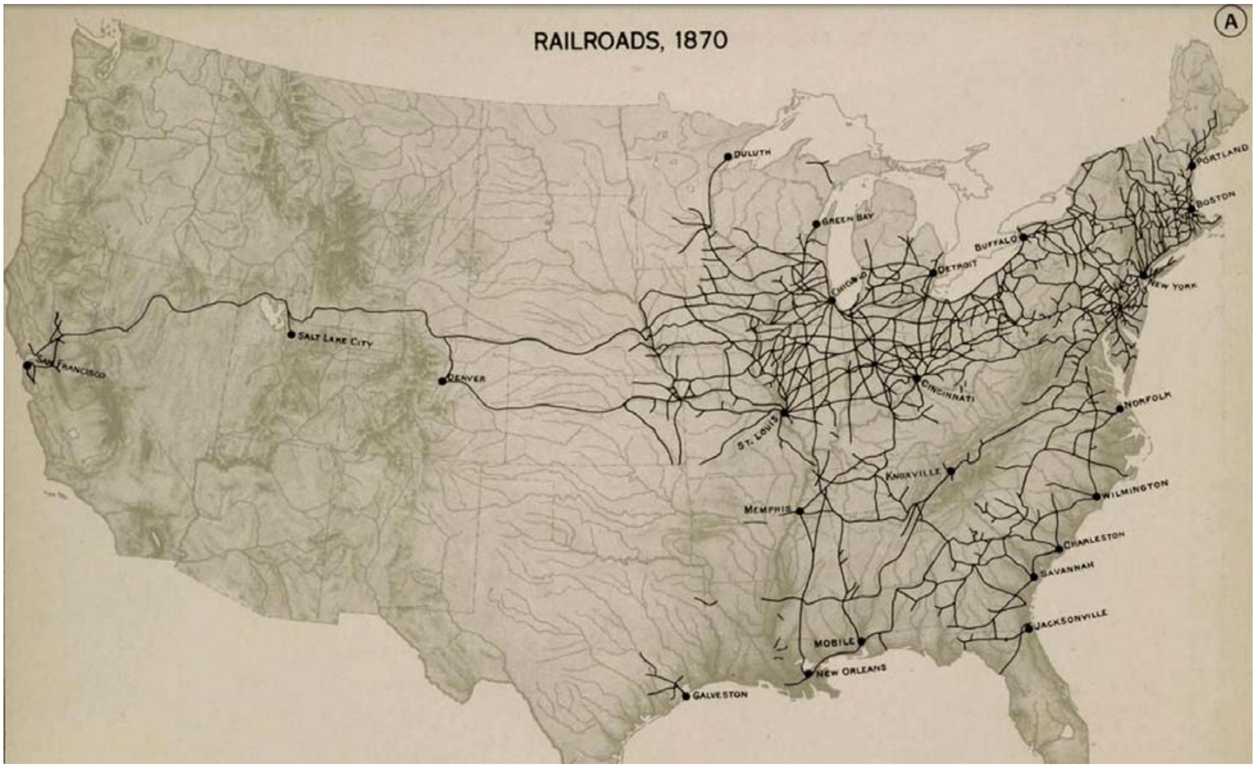


Figure 3.7. Railroads in the United States in 1870 (Paullin and Wright, 140).

Figure 3.8. Shipwreck on the Middle Mississippi River (Manders and Rentfro, 106).

Figure 3.9. Dredging on the Middle Mississippi River (Manders and Rentfro, 67).

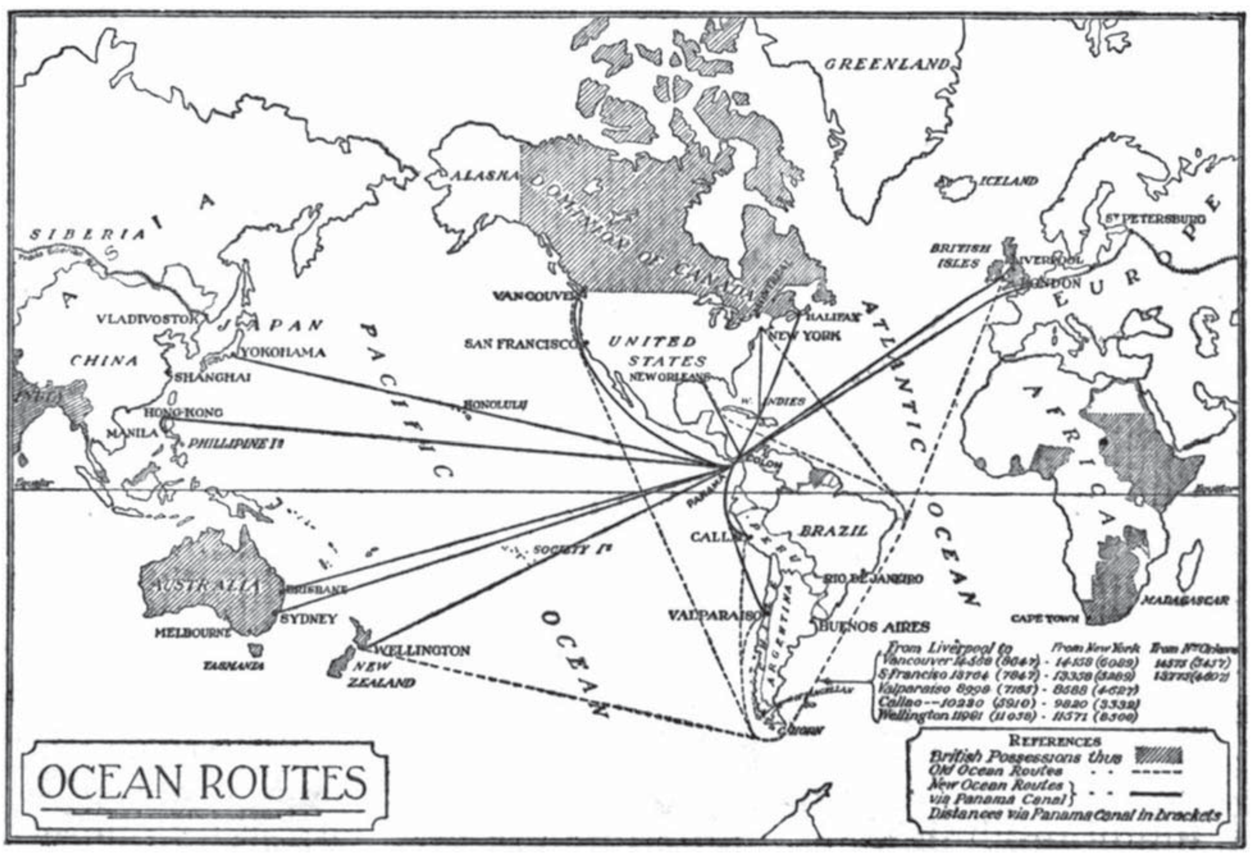


Figure 3.10. The Panama Canal (Mills, 245).

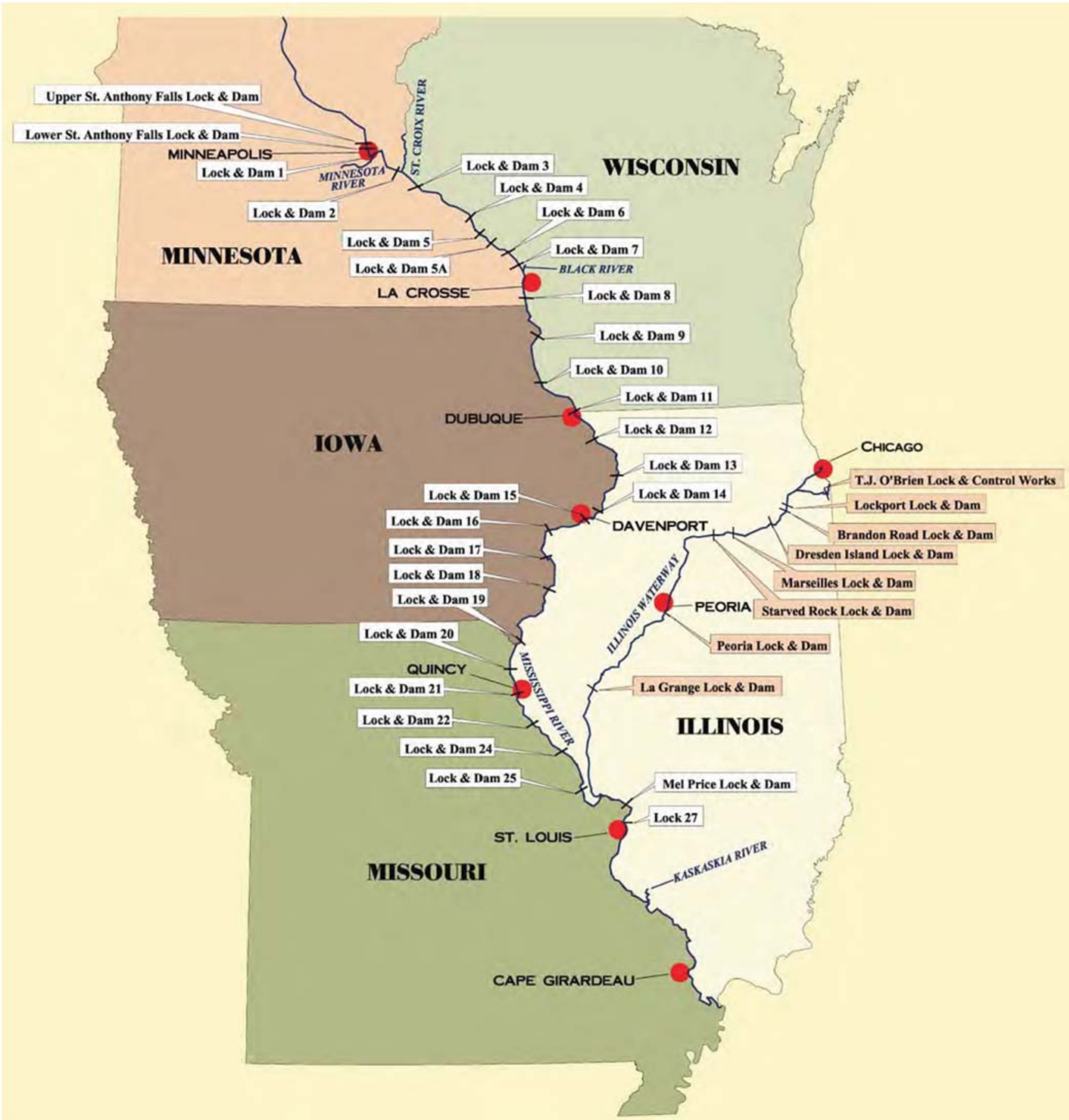


Figure 3.11. The Upper Mississippi River and Illinois River Locks and Dams (Manders and Rentfro, 93).

Figure 4.1. Spur Dike/Wing Dam Field (USACE).

Figure 4.2. L-Head Dike (USACE).

Figure 4.3. Closure Dike (USACE).

Figure 4.4. Artist's Conception of Bendway Weirs (USACE).

Figure 4.5. Chevrons (USACE).

Figure 4.6. Hard Points (USACE).

Figure 4.7. Notched Dikes (USACE, top; U.S. Fish and Wildlife Service, bottom).

Figure 4.8. Multiple Roundpoint Structures (USACE).

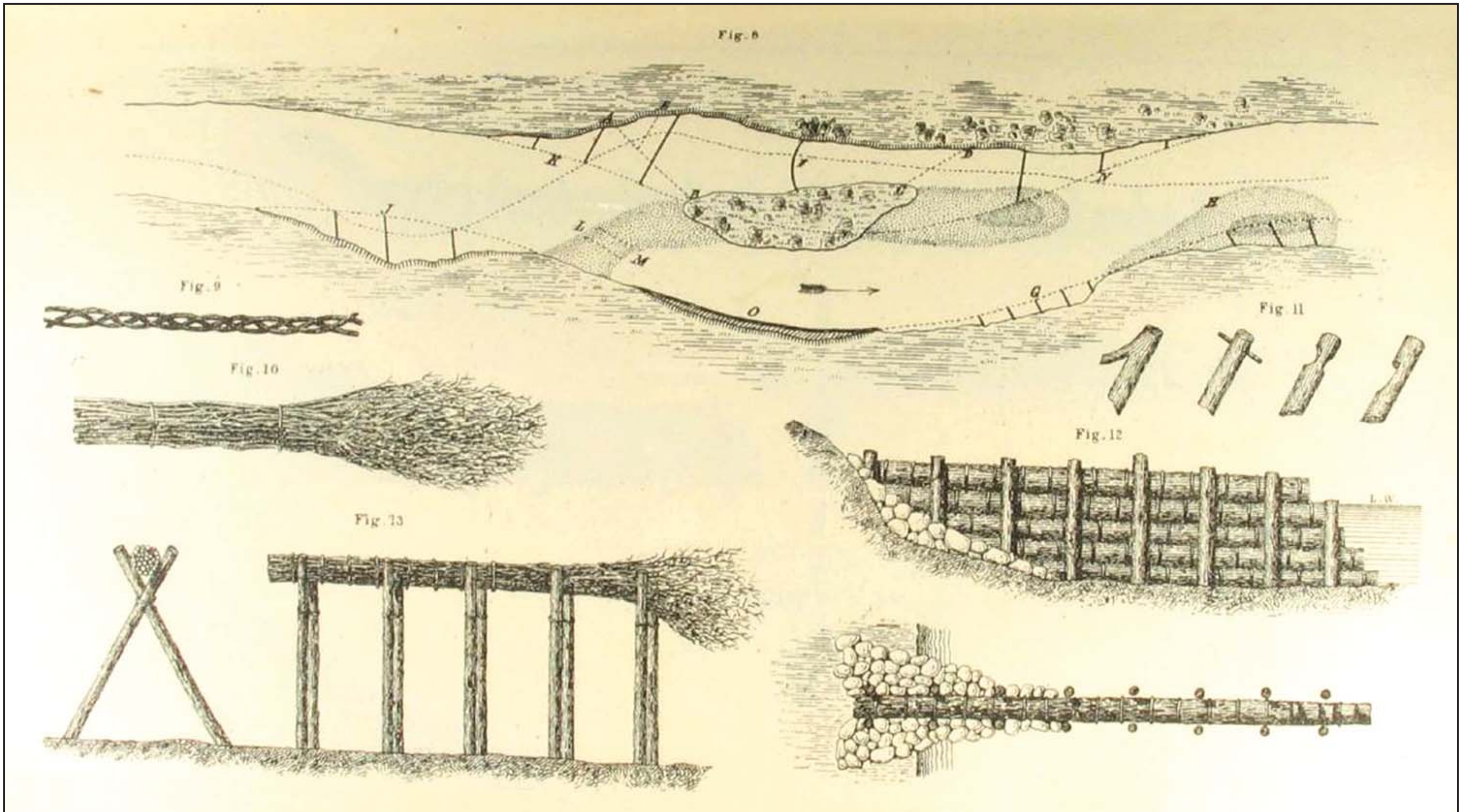


Figure 4.9. Illustrations of Early Timber Pile Dikes (USACE, *Annual Report* [1875], follows 466).

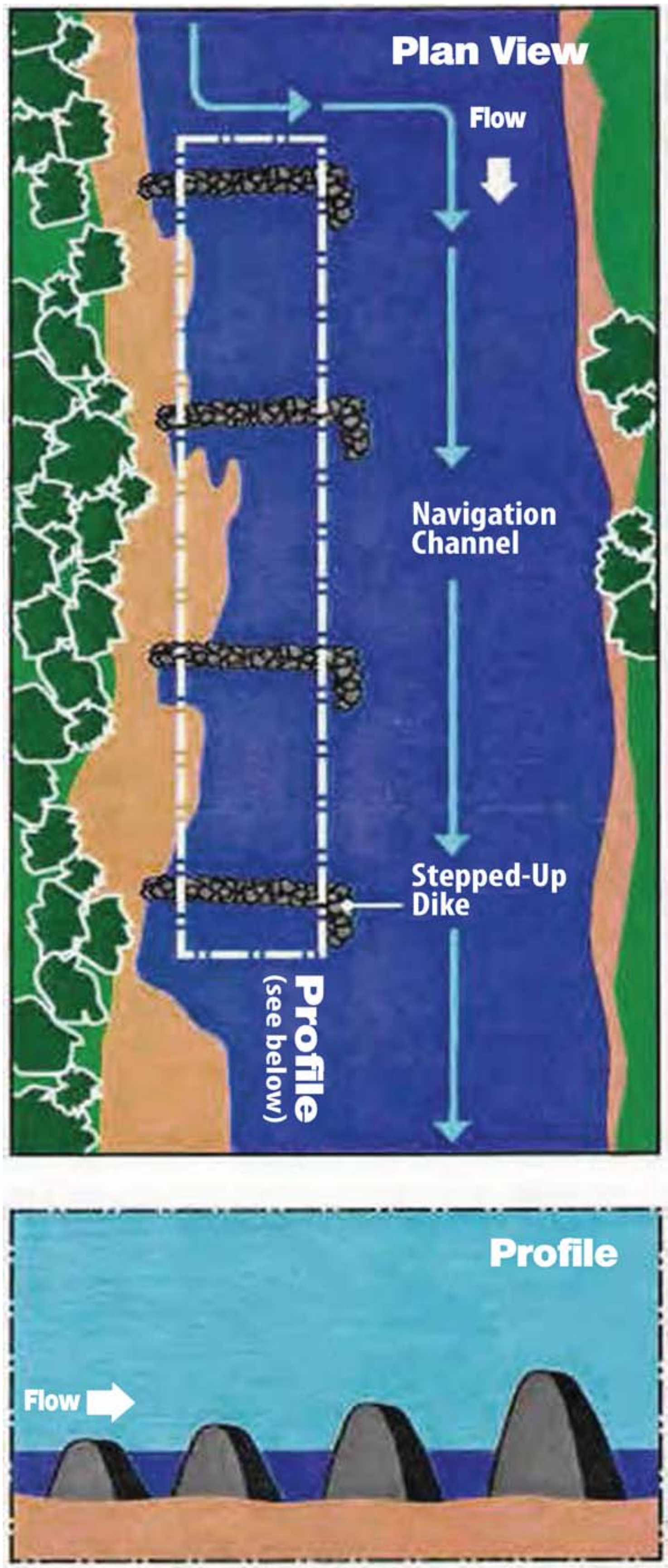


Figure 4.10. Artist's Conception of a Stepped-up Dike Field (USACE).

Figure 4.11. Stone Revetment (USACE).

Figure 4.12. Board Mattress (USACE).

Figure 4.13. Timber Mattress (USACE).

Figure 4.14. Off-Bankline Revetment (USACE).

Supplement to Appendix F

<u>Regulating Works Project History</u>

Purpose

This document supplements the Determination of National Register Eligibility Study Middle Mississippi River Regulating Works Project Missouri and Illinois (the DOE) prepared by Commonwealth Heritage Group, Inc., January 2016. The DOE provides a detailed early historical context of the authority and implementation of the Middle Mississippi River (MMR) Regulating Works Project for the purpose of determining the eligibility of the construction of regulating works portion of the overall Project for listing on the National Register. This supplement was prepared by the U.S. Army Corps of Engineers (the Corps), St. Louis District (the District), to provide further information and history on the Regulating Works Project with respect to early changes to the implementation of the Regulating Works Project, the Chain of Rocks Canal and Low Water Dam portions of the Regulating Works Project, and additional details on the history and implementation of the Regulating Works Project since the 1960's.

Adjusting the Implementation of the Project Plan and Addressing Chain of Rocks

Even though the 1930s had been the driest period the Midwest had experienced since the Regulating Works Project began, low water on the MMR had not been unduly obstructive to normal navigation traffic, which, at the time, only occurred mid-February to mid-December. In fact, in 1934 the District was able to adjust the project low-water flow from 40,000cfs to 54,000cfs even though the MMR was in the midst of an extreme low-water period. Prior to 1940, the river was closed to navigation between mid-December and mid-February each year because the channel was simply too shallow during these typically low-water months. But by the early 1940s, due to the construction of permanent navigation improvements as well as the use of steel-hulled boats, the navigation season was extended year-round, except for when the river was closed by ice. Nonetheless, one section of river remained an impediment to navigation during low flows, and this was at Chain of Rocks. To address this issue, in 1938 the House Committee on Rivers and Harbors requested a review of the Regulating Works Project with a view to determining whether a modification to the existing project was necessary. The lowering of the riverbed below Chain of Rocks had led to increased slope, high flow velocity and the more frequent exposure of rock bars in the section of river between St. Louis and Locks and Dam No. 26. Because of the exposed rock ledges along the riverbed, depths at low water reached as low as 5 feet, essentially shutting down navigation through the reach and severing Illinois River commerce from the middle and lower Mississippi. The Board of Engineers for Rivers and Harbors, having reviewed the District's recommendations, proposed the construction of a lateral canal with navigation locks that would allow vessels to bypass this treacherous stretch. Congress authorized modifying the Regulating Works Project to include the construction of the Chain of Rocks Canal along with Locks No. 27 in the Rivers and Harbors Act dated March 2, 1945. Construction of these features of the Regulating Works Project was completed in 1953.[1]

[1] *Annual Report of the Chief of Engineers*, 1930-1939; USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works* (St. Louis: MVS, April 1976); Ronald D. Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers* (USACE Water Resources Support Center, National Waterways Study, 1983), 75-94; Fredrick J. Dobney, *River Engineers on the Middle Mississippi* (Washington, D.C.: GPO, 1978), 89-102; U.S. Cong., *Report on the Mississippi River Between Ohio River and Mouth of Missouri River*, House Doc. 231 (76th Congress, 1st Session). Besides the construction of numerous regulating works, the completion of Fort Peck Reservoir on the Missouri River allowed the District to adjust its project flow, as it was believed that a more dependable flow from the Missouri River, which flows into the Mississippi just above St. Louis, would provide a supplement to Mississippi flows during low water periods.

During the 1930s and 1940s, support for the construction of permanent navigation improvements on the MMR increased substantially. Excluding appropriations for the Chain of Rocks Canal and Locks 27, between 1930 and 1945 Congress appropriated more funds for the construction and maintenance of regulating works than it had over the previous 50 years. As a result, the District was able to construct over 750 dikes, totaling over 400,000 linear feet, and 224 revetments totaling approximately 276,000 linear feet. However, major floods in 1943, 1945 and 1951 and heavy ice flows in 1950 and 1951 critically damaged many of the regulating works. Although the last two decades had seen a dramatic increase in appropriations for the project, many of the regulating works constructed in the first two decades of the project were now reaching the end of their life cycle. Timber pile dikes had deteriorated to such a degree that some were completely destroyed by the high flows and ice. New and more durable permanent improvements were needed, but funding, once again, began to diminish. Between 1930 and 1950, Congress had appropriated approximately $47 million for the construction of new regulating works, for operations and maintenance of existing works, and for the construction of Chain of Rocks Canal and Locks No. 27 (averaging approximately $2.4 million per year). Yet between 1953 and 1958, Congress appropriated just $1.6 million to cover operations and maintenance as well as construction of new regulating works (averaging approximately $300,000 per year). Consequently, the 1950s saw Regulating Works construction in the District come to a complete halt, with budget cuts being so severe that the District had to reduce its workforce. Moreover, heavy ice flows damaged regulating works again in 1957 and 1958, and because of insufficient funding and the deteriorated state of the older regulating works, damages and deterioration were occurring faster than appropriations came to make repairs.[2]

[2] Dobney, *River Engineers on the Middle Mississippi*, 89-122; *Annual Report of the Chief of Engineers*, 1930-1958.

By the late 1950s, Congressional support and appropriations for the Regulating Works Project began to increase again. In the Rivers and Harbors Act dated July 3, 1958, Congress authorized the construction of a fixed-crest rock-fill dam (Dam No. 27) 900 feet below Chain of Rocks Bridge. The dam was designed to provide additional water depth at the lower gate sills of Lock No. 26 so that vessels with a nine-foot draft could navigate the lock during low water. Congress also authorized appropriations for the District to begin repairing or replacing deteriorated structures, as well as to begin constructing new regulating works for the first time in nearly a decade. Yet by the 1960s, District river engineers had determined that the existing plan for river contraction was insufficient for maintaining the authorized navigation channel during low water without the use of extensive and costly dredging. River engineers recognized that dredging would always be an ancillary part of the project as was noted in the 1926 Chief's Report, but the regularization of the river was intended to reduce reliance on dredging to a minimum, and thus far the existing plan had failed to accomplish this. Engineers supposed that one possible reason why the existing plan had not produced the desired results was that the timber pile dikes were not as effective as hoped. They postulated that the reason for this was that the construction of the Missouri River reservoirs had potentially reduced the sediment concentration and the size of the sediment particles in the Mississippi below the mouth of the Missouri River. If this were the case, permeable pile dikes, which relied on this sediment for deposition when velocities slowed down, would not be as effective as impermeable stone dikes. The deteriorated state of many of the timber pile dikes, which were once again severely damaged by heavy ice flows in 1963 and 1964, further contributed to their inefficacy. In 1960, the District discontinued the use of timber pile dikes and began replacing existing pile dikes with stone dikes, which provided for more efficient structures in that the life cycle of the stone dikes far exceeded that of the pile dikes.[3]

By 1965, approximately 25 percent of the timber pile dikes had been replaced with stone dikes, but a severe low-water period between 1963 and 1965 ultimately proved that merely replacing the deteriorated dikes would not be enough and a reevaluation of the existing plan of river contraction would be necessary. The same plan of contracting the MMR to a width of 1,800 feet had been in place since the nine-foot navigation channel was first authorized by the 1927 Rivers and Harbors Act. The plan had produced a more dependable channel, no doubt, but extensive dredging was still required at low flows. In the past, the District had not been required to maintain the authorized navigation channel from mid-December to mid-February, when the lowest flows typically occurred. But the growth of commercial navigation on the MMR and the confidence the navigation industry now had in the dependability of the channel–all of which was only possible because of the navigation improvements of the previous decades–led to the decision that USACE had an obligation to maintain the authorized navigation channel year-round.[4]

District river engineers postulated that the river would need to be contracted to a width of around 1,200 feet between the banks if a dependable nine-foot channel was to be maintained year-round with minimal dredging. In the summer of 1967, District river engineers began studying a 15-mile prototype section of the MMR between river miles 140 and 154 in order to

[3] Dobney, *River Engineers on the Middle Mississippi*, 89-122; *Annual Report of the Chief of Engineers* ARs 1958-1964; USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works*; USACE-MVS, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154* (St. Louis: MVS, May 1971).
[4] *Annual Report of the Chief of Engineers*, 1965; USACE-MVS, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*; Dobney, *River Engineers on the Middle Mississippi*, 89-122

analyze and verify the preliminary design assumptions (i.e. that the river would need to be contracted to 1,200 feet). Still, it would take years before enough data would be available to verify the efficacy of the design features used in the prototype reach. Throughout the rest of the MMR, plans were underway to improve some of the most troublesome locations on the river. In 1968, the District established the River Stabilization Branch specifically to design engineering works for the development and maintenance of the Regulating Works Project. The branch was to work in cooperation with the Waterways Experiment Station (WES) to conduct model studies for some of the most difficult reaches of the MMR. The branch's first major project was to design permanent navigation improvements for a particularly treacherous 13-mile reach known as Devil's Island, model studies of which began at WES in 1969.[5]

Construction of the prototype reach was completed by 1969 and observations over the next two years revealed that a contraction to a 1,200-foot width would develop a channel exceeding nine feet at a project flow of 40,000cfs. In other words, the contraction produced a deeper channel than was required. The study concluded that using a 54,000cfs project flow and a contraction to 1,500 feet would most likely achieve a dependable nine-foot channel at the least project cost. Model tests conducted at WES indicated that the plan recommended in the prototype study would generally maintain the authorized channel dimensions with some additional contraction required in troublesome areas. The District adopted the recommended 1,500-foot channel contraction in 1974. Still, river engineers needed to conduct a study comparing various 1,500-foot contraction plans before adopting a specific plan. In 1977, the District completed a potamological study that evaluated various contraction plans and numerous

[5] *Annual Report of the Chief of Engineers*, 1967-1969; USACE-MVS, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*; USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works*.

hydrographic surveys completed over the previous decade. Based on the recommendations of the study, the District adopted a plan of beginning contraction upstream and gradually working downstream.[6]

Permanent Navigation Improvements in the NEPA Era

As the District was carrying out navigation improvements along the prototype reach and Devil's Island, Congress passed the National Environmental Policy Act in 1969 (NEPA). With the passage of NEPA, the District would need to begin the process of evaluating the Regulating Works Project to ensure that it was in compliance with NEPA and the subsequent regulations. To coordinate with environmental agencies and ensure that environmental values were considered in the design and construction of regulating works and any adverse impacts were avoided and minimized, the District established the Environmental River Engineering Program. The District began sending all of its planned construction projects to conservation agencies for review and comment, and then held periodic coordination meetings with these agencies to discuss the planned construction. The environmental representatives would then offer their input on the plan and make suggestions as to how it might be altered to provide environmental benefits or decrease negative impacts. River engineers would then test the design modification either through model tests at WES or on the river itself. A joint committee would then review all proposed contract work for the purpose of implementing environmental considerations prior to the preparation of finalized plans and specifications. The Environmental River Engineering Program then ensured that the proposed environmental modifications were incorporated into the design and construction of the structures. Engineers and environmental specialists could then observe the

[6] *Ibid*.; Annual Report of the Chief of Engineers, 1967-1971; USACE-MVS, *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4)* (St. Louis: MVS, June 1977).

impacts of these modifications and collect data that could be analyzed to determine the impact of the modifications on navigation and the environment. These early modifications included placing small notches in dikes, lowering dikes, and modifying chute closures to create greater habitat diversity.[7]

In the spring of 1972, the District completed a study plan for an environmental analysis and assessment of the Regulating Works Project. The study plan was based on separate studies completed by WES, the District, the Missouri and Illinois departments of conservation, Southern Illinois University and Colorado State University. Based on these individual studies, the District completed an environmental inventory and assessment of the project and included this information in a study plan summarizing the conclusions and recommendation of each of these studies.[8]

The study plan served to provide a reference source for the preparation of the Regulating Works Project Environmental Impact Statement (EIS). The EIS, which the District completed in 1976, concluded that although the Regulating Works Project was essential for maintaining the authorized navigation channel, the project, as practiced up to that time, did have a negative environmental impact. The impacts considered most detrimental were the loss of side channels and the contraction of the river, both of which had decreased habitat diversity and produced a narrower and deeper river. Because at the time there was no environmental authority, general or specific to the Regulating Works Project, the 1976 EIS Statement of Findings stated that in order

[7] USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works*; Damon Manders and Brian Rentfro, *Engineers Far from Ordinary: The U.S. Army Corps of Engineers in St. Louis* (St. Louis: USACE-MVS, 2011), 124-133, 355-369.

[8] USACE-WES, *Study Plan for and Environmental Inventory and Assessment of the Mississippi River 9-foot Channel Project Between St. Louis, Missouri, and Cairo, Illinois* (Vicksburg: Waterways Experiment Station, November 1973)

to avoid or minimize these impacts, the District Engineer had forwarded for consideration by Congress a framework to initiate a comprehensive river management plan to provide an authorized means for funding and incorporating the total river and related land resource requirements into the presently authorized nine-foot navigation project. It also stated that in addition to this, the District Engineer would continue to pursue the development of a post-authorization change (PAC) of the Regulating Works Project to add fish and wildlife as an authorized project purpose, to the extent that it was either acted upon separately or completely integrated into the aforementioned river management plan.[9] A memorandum and fact sheet from 1979 indicates that there were disagreements between the U.S. Fish & Wildlife Service (FWS) and the Corps on the development of the PAC, and the fact sheet concluded that the District would proceed to accomplish the PAC through the GREAT III study effort (described below).[10]

The Water Resources and Development Act (WRDA) of 1976, § 117, authorized the Corps, in cooperation with state and federal agencies, to investigate and study through the Upper Mississippi River Basin Commission (UMRBC) the development of a river system management plan in the format of the "Great River Study" for the Mississippi River from the mouth of the Ohio River to the head of navigation at Minneapolis. The District completed its portion of the study and submitted its recommendations to the Board of Engineers for Rivers and Harbors in 1982 to subsequently be submitted to Congress (commonly called the Great River Resource Management Study (GRRM) –St. Paul District's portion referred to as GREAT I, Rock Island

[9] USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works.* (The proposed PAC described in the EIS would authorize the dredging of side channel areas; placement of dredged material in accordance with planned fish and wildlife management programs; maintenance and construction of pile dikes to enhance fish habitat; notching and/or lowering dikes, if considered feasible and desirable; and altering stone dikes which provide access to islands. *Id*. at 234).
[10] USACE Memorandum executed by Arthur L. Johnson, Acting Chief, Engineering Division, St. Louis District, subject: Fish and Wildlife Mitigation, 9 January 1979.

District's portion referred to as GREAT II, and St. Louis District's portion referred to as GREAT III).[11] In 1978, the Inland Waterways Authorization Act authorized the UMRBC to prepare a Comprehensive Master Plan for Management of the Upper Mississippi River System (Master Plan), which was submitted to Congress on January 1, 1982.[12]

In WRDA 1986, § 1103, Congress passed the Upper Mississippi River Management Act of 1986, recognizing the Upper Mississippi River system as a nationally significant ecosystem and a nationally significant commercial navigation system, stating that the system shall be administered and regulated in recognition of its several purposes. In this section, Congress defined the Upper Mississippi River system as the commercially navigable portions of the Mississippi River north of Cairo, Illinois; Minnesota River, Minnesota; Black River, Wisconsin; St. Croix River, Minnesota and Wisconsin; Illinois River and Waterway, Illinois; and Kaskaskia River, Illinois) (UMRS). Referencing both the UMRBC Master Plan and the GRRM studies, Congress approved the Master Plan as a guide for future water policy, but specifically provided that Congress was not authorizing any recommendations in the plan. Congress did, however, authorize in this section what is today known as the Upper Mississippi River Restoration – Environmental Management Program (commonly called today UMRR, but previously commonly called EMP), which authorized, as identified in the Master Plan, a new program, separate from the navigation channel projects, for the evaluation and construction of measures for fish and wildlife habitat rehabilitation and enhancement; implementation of a long-term resource monitoring program; and implementation of a computerized inventory and analysis system to be carried out by the Corps, in consultation with the FWS and the respective states.

[11] GREAT III, Great River Resource Management Study – 14028, Mississippi River (Saverton, Missouri to Cairo, Illinois) Final Report, Lower Mississippi Valley Division, St. Louis District, September 1982.
[12] *Ibid*.

Congress also authorized in this section the construction of the second lock at locks and dam 26, now known as Mel Price Locks and Dam; recreation programs and disposal of dredge materials all as recommended in the Master Plan and the GRRM studies; and continued evaluation of increases in lock capacity and monitoring of traffic movements, including the need for river rehabilitation and environmental enhancement in conjunction with these evaluations, which eventually led to the development of NESP (described below).[13]

Also in WRDA 1986, § 906, Congress authorized the Corps to mitigate for damages to fish and wildlife from water resources projects. Section 906(a) made mitigation for these damages mandatory for newly authorized projects or projects already authorized but construction had not yet started as of the passing of WRDA 1986. Section 906(b) gave the Corps the discretion, with certain limitations, to implement mitigation measures for those projects already completed or currently under construction as of the passing of WRDA 1986; although due to funding limitations and the Corps' other environmental restoration and complete project modification authorities, the Corps has only applied Section 906(b) to projects under construction and not to completed projects.[14]

Congress also expanded the Corps' general environmental authority in WRDA 1990 and WRDA 1992 by providing that environmental protection shall be included as one of the primary missions of the Corps in planning, designing, constructing, operating and maintaining water resources projects (WRDA 1990, § 306); authority for environmental dredging when necessary to meet the requirements of the Federal Water Pollution Control Act or as a cost-shared project if requested by a non-Federal sponsor (WRDA 1990, § 312); and authority to carry out

[13] *See also*, H. Conf. Rpt. 99-1013; S. Rpt. 99-126; and H. Rpt. 99-251 for additional details on this legislation.
[14] *See* Engineering Regulation 1105-2-100, App. C and Engineering Pamphlet 1165-2-1.

environmental projects with beneficial uses of dredge material, subject to cost-share with a non-Federal sponsor (WRDA 1992, § 204).

In WRDA 2007, Title VIII, stemming from the evaluation authority granted in WRDA 1986, Congress authorized the Corps to develop ecosystem restoration projects within the upper Mississippi (River Miles 0.0-854, including the MMR) and parts of Illinois (River Miles 0.0-327) waterways in conjunction with projects also authorized in the same section for the improvement of navigation features. All of the projects authorized by this legislation are commonly called the Navigation and Ecosystem Sustainability Program (NESP), which was designed to promote navigation efficiency and ecological restoration. However, to date no NESP projects have been constructed within the MMR, and Congress has not recently funded any aspect of NESP.

Although none of the legislation since 1976 modified the Regulating Works Project specifically or provided a PAC to the project as referenced in the EIS, Congress did authorize projects and programs separate from the already authorized navigation projects that accomplish the same items that the EIS PAC envisioned (see footnote 9). Further, by providing the discretionary authority to mitigate for damages to fish and wildlife for projects under construction and additional environmental policy considerations provided by Congress, the District then had the authority to make environmental considerations an essential part of the planning process and implementation of the Regulating Works Project, as well as the discretion to mitigate for any adverse impacts caused by projects under construction through avoidance, minimization, and if necessary, compensation.

Therefore, District river engineers began developing numerous environmental river engineering structures in an effort to increase habitat diversity and the ecological health of the river, all while meeting the authorized navigation mission of the project. Based on the input of biologists and ecologists from environmental and conservation agencies, engineers experimented with designing modifications to regulating works and using various-sized stones in the structures. These experimental modifications were originally tested on the river itself or by using large-scale models at WES laboratories. However, in the 1990s, the District developed Hydraulic Sediment Response Models (also known as HSR or Micro-Models) to test new regulating works or modifications to existing designs. In 1995, the District established the Applied River Engineering Center to conduct applied river engineering in an office laboratory environment. The center cooperates with local and environmental interests, such as the Missouri Department of Conservation, the Illinois Department of Natural Resources, and the FWS, in the development of river regulating works. The District's efforts have resulted in the construction of numerous environmentally modified regulating works, including notched dike and notched closure structures, off-bank revetment, chevrons, hard/round points, and W-dikes. All of these structures help create greater habitat diversity than traditional river engineering structures and avoid and minimize any adverse environmental impacts for the construction of regulating works.[15] See Section 4.2.1.1 of the DOE portion of this Appendix for more information on the types of river training structures used in the MMR.

Today's Regulating Works Project and New Problems Solved

Because of the need for environmental modifications to regulating works and also because of the adoption of the 1,500-foot contraction plan, the amount of work required to

[15] Manders and Rentfro, *Engineers Far from Ordinary*, 124-133, 355-369; USACE-MVS, *Environmental River Engineering on the Mississippi* (St. Louis: MVS, 1995).

complete the Regulating Works Project increased significantly by the late 1970s. Of the 800 dikes constructed as of 1976, 300 were still timber pile dikes that needed to be replaced by stone dikes. Those 500 dikes that had already been converted to stone would also need to be extended at least another 300 feet in order to contract the river to 1,500 feet. Also, many of these structures needed to be modified to maintain greater habitat diversity. In addition to all of this, there were still numerous sections of river that required the construction of new dike fields and revetment. Damages from major floods in 1993 and 1995 destroyed or severely damaged many of the deteriorated dikes. These floods also exposed deficiencies with the Chain of Rocks Canal. Following the floods, the District prepared a design deficiency report on the canal, which recommended additional berms, relief wells, and a pump station to correct the issues at the canal. Corps Headquarters approved the improvements and work on them began in 1999.[16]

Another issue that arose in the MMR was severe erosion near bends, having the potential to form a channel cutoff from the bend, thus losing the navigation channel for years. This issue was identified at Dry Bayou-Thompson's Bend in the 1980's. District engineers attempted various solutions including traditional stone revetment, but after little success and setbacks from the floods of 1993 and 1995, the concept of a tree screen or riparian corridor was developed. This acted as a buffer strip of fast-growing, water-resistant hardwoods planted between the riverbank and the flood plain to prevent erosion. This work required obtaining real estate interests in the land above the ordinary high water mark, but the work proved to be successful for avoiding a navigation channel cutoff, as well as being environmentally friendly. To date due to the number of sharp bends in the MMR, the District continues to monitor the potential for

[16] *Annual Report of the Chief of Engineers*, 1996, 1999-2009.

navigation channel cutoffs and take appropriate action to prevent this potentially catastrophic event from happening.

Also to address the bends in the meandering MMR, the District, working with WES, began developing bendway weirs in the late 1980s. Before the development and implementation of bendway weirs, engineers would revet the outer riverbank in bends to address erosion issues that threatened the availability of the navigation channel. However, this tended to redirect the river’s energy away from the bank and into the riverbed, scouring an excessively deep channel and resulting in sediment accumulation on the inside of the bend, narrowing the channel. The deeper, narrower channel in the bends was extremely complex and difficult for tows to navigate, which resulted in substantial navigation delays and thus burdened the overall economy associated with inland waterway navigation. Therefore, in addition to placing revetment on the bank to prevent erosion in the bends, the Corps was also spending a large amount of money annually to dredge bends to attempt to keep the channel from narrowing. Bendway weirs were designed similar to traditional dike structures but at a lower elevation (submerged even at low water) and angled upstream from the outside bank of a river bend. Bendway weirs were designed to redistribute flow to greatly reduce sediment accumulation as well as widen the river to create a safer and more navigable channel in the treacherous bends in the MMR. The initial construction of bendway weirs at Dogtooth Bend in the MMR produced quick and effective results, widening the channel by more than 200 feet within two months after the weirs were constructed. Within five months after construction of the bendway weirs, navigation traffic could navigate Dogtooth Bend without having to take extreme, complex measures, decreasing accidents and delays. Further, the bendway weirs reduced the need for costly dredging in these areas. Therefore, the development of bendway weirs resulted in a huge economic benefit to the nation, and the District and its personnel were widely recognized for this innovation.[17]

In the late 1990's and in accordance with the Endangered Species Act, the Corps prepared a biological assessment for the operation and maintenance of the nine foot navigation channel projects on the UMRS, and the FWS issued a Biological Opinion from that assessment. Pertinent to the Regulating Works Project, the Biological Opinion resulted in a jeopardy determination for the pallid sturgeon and an incidental take statement for the least tern. The Biological Opinion provided reasonable and prudent measures and alternatives and terms and conditions to offset the adverse impacts to the pallid sturgeon and to minimize the impacts of incidental take on the least tern. The Corps agreed, with certain caveats, to implement the FWS's recommendations provided in the Biological Opinion. Therefore, the District continued coordination with the FWS on the design and alternative screening process for new construction of river training structures and revetment for the primary purpose of obtaining and maintaining the navigation channel, but now with an additional focus on pallid sturgeon and least tern habitat. Additionally, as part of the Biological Opinion reasonable and prudent measures, the District began constructing new river training structures and revetment and/or modifying existing structures for primarily environmental purposes to restore habitat for the pallid sturgeon and least tern in the MMR.

Droughts have been the other major challenge to the modern Regulating Works Project. Between 1988 and 1989, the MMR was plagued by its lowest flows since the severe droughts of the 1930s and early 1940s. Much work had been completed since that low-water period five

[17] *Id*. at 126-128.

decades prior, so the drought offered one of the first major tests of the mature project. With the aid of dredging, the District was able to maintain the authorized navigation channel throughout much of the drought. However, rock pinnacles protruding from the riverbed at Thebes, Grand Tower, Grays Point, Commerce and Counterfeit Rock forced the Coast Guard to limit the drafts of vessels to less than nine feet. [18] In response to the 1988/1989 drought and pursuant to the Regulating Works Project's authority, the District embarked on aggressive river engineering development, design, and construction of regulating works to reduce the channel maintenance dredging as well as removed a substantial amount of the rock material that significantly impacted the navigation channel in 1988 and 1989.

By the early 2000s, due to technological advancements such as side-sonar and multi-beam survey equipment, the District identified precisely the quantity and location of rock material remaining that impeded the navigation channel in the MMR at low water. The District attempted to have the material removed, but the contractor's attempts to remove the rock by grinding the material was not successful. Funding for a more efficient method of rock removal was not available. When another major drought struck in 2012, the pinnacles once again became a threat to navigation. The only areas that posed a threat during the event were at Thebes and Grand Tower, Illinois, where rock pinnacles still remained. During the 2012 low water event, funding was made available to remove enough of the material to ensure the authorized navigation channel was maintained.

[18] USACE-MVS, *After Action Report of 1988* (St. Louis: MVS, Oct. 1988); USACE, *Surviving the Drought 1988: The Corps of Engineers Response to Drought Conditions* (Fort Belvoir: USACEHQ, July 1989).

A review of these two recent low water dredging seasons provides a quantitative look at the reduction of dredging as a result of the Regulating Works Project. During the 1988-89 dredge seasons, the river gage at St. Louis dropped below zero for 94 days in 1988 and 112 days in 1989. During this time, the Corps dredged approximately 19 million cubic yards of material each year to keep the channel open down to a stage of -4 ft on the St. Louis Gage. In December of 1989, 22 groundings occurred over just one weekend, which caused the Coast Guard to essentially close the entire MMR until conditions improved. However, during the 2012 dredge season, the St. Louis Gage dropped below zero for 160 days. During this time the Corps dredged approximately 9.3 million cubic yards of material to keep the channel open to a stage of -7 on the St. Louis Gage while water surfaces dropped as low as -4.6 ft on the St. Louis Gage. Even though the river stayed below zero on the St. Louis Gage for much longer and the channel was maintained to a greater depth than in 1988 and 1989, there were no groundings or unplanned closures within the marked navigation channel. The 2012 dredge season showed over a 50% reduction in dredge quantities versus the 1988 dredge season, demonstrating that the original plan authorized by Congress to construct regulating works in order to reduce dredging was working.[19]

Pursuant to this Congressional mandate and along with monitoring of bank erosion issues, the District continues to monitor sites where excessive dredging occurs and studies the areas to determine if the construction or modification of regulating works will reduce dredging in the area to ultimately reduce dredging to a feasible minimum in the MMR.

---

[19] David C. Gordon and Michael T. Rodgers, "Drought, Low Water, and Dredging of the Middle Mississippi River in 2012," presented at the Proceedings of the Joint Federal Interagency Conference 2015, 5th Federal Interagency Hydrologic Modeling Conference and 10th Federal Interagency Sedimentation Conference, *Sustainable Water Resources in a Changing Environment*, Reno, NV, April 19-23, 2015.

Appendix G: Distribution List

The following individuals and organizations received e-mail notification of the Public Notice:

Adrian, D
Alexander County Highway Department
Amato, Joel
Andria, Kathy
Atwood, Butch
Baldera, Patrick
Banner Press
Barnes, Robert
Bax, Stacia
Beardslee, Thomas
Bellville, Colette
Beres, Audrey
Berland, Paul
Boaz, Tracy
Boehm, Gerry
Brescia, Chris
Brinkman, Elliot
Brown, Doyle
Buan, Steve
Buffalo, Jonathan
Burlingame, Chuck
Caito, J
Campbell-Allison, Jennifer
Caneff, Denny
Carney, Doug
Ceorst MVS External Stakeholder
Chicago Commodities
Chief John Red
City of Portage des Sioux
Clements, Mark
Clover-Hill, Shelly
Coder, Justin
Congressman Clay
Congressman Graves
Corker, Ashley
Crowley, S
Cruse, Lester
Curran, Michael
Davis, Dave
Deel, Judith
Dewey, Dave

Diedrichsen, Mike
District Director Senator Blunt
Docks
Dodd, Harold
Dorothy, Olivia
Dotts, Glenn
Dougherty, Mark
Duncan, Cecil
Ebey, Mike
Elmestad, Gary
Enos, Tim
Escudero, Marisa
Fabrizio, Christi
Favilla, Christine
Foster, Bill
Fretz, Eileen
Fung, Jenny
Genz, Greg
Glenn, S
Goode, Peter
Great Lakes Dredge & Dock
Grider, Nathan
Hall, Mike
Hammond, Cheryl
Hanke Terminals
Hanneman, M
Hansens Harbor
Harding, Scott
Held, Eric
Henleben, Ed
Henry, Donovan
Heroff, Bernard
Herschler, Mike
Herzog, Dave
Hilburn, Craig
HMT Bell South
Hoppies Marine
Howard, Chuck
Hubertz, Elizabeth
Hughes, Shannon
Hunt, Henry
Hussell, B
IL SHPO

Jamison, Larry
JBS Chief
Jefferson Port Authority
Jochim, Christine
Johnson, Frank
Knowles, Kim
Knuth, Dave
Kowal, Kathy
Kovarovics, Scott
Kristen, John
Lange, James
Larson, Robert
Lauer, Steve
Lavalle, Tricia; Senator Blunt
Leary, Alan
Lipeles, Maxie
Logicplus
Louis Marine
Malone, Pat
Manders, Jon
Mangan, Matthew
Mannion, Clare
Mauer, Paul
McPeek, Kraig
MDNR
Medina, Santita
Melgin, Wendy
Menees, Bob
Middleton, Joeana; Senator McCaskill
Miller, Jeff
Miller, Kenneth
Miller, M
Missouri Corn Growers Association
Morgan, Justin
Morrison, Bruce
Muench, Lynn
Muir, T
Nash-Mayberry, Jamie
Nelson, Lee
Niquette, Charles
Novak, Ron
O'Carroll, J
Paurus, Tim

Pehler, Kent
Peper, Sarah
Pinter, Nicholas
Popplewell, Mickey
Porter, Jason
Reitz, Paul
Roark, Bev
Rowe, Kelly
Salveter, Amy
Samet, Melissa
Sauer, Randy
Schranz, Joseph Standing Bear
Schulte, Rose
SEMO Port
Senator Blunt's Office
Shepard, Larry
Shoulberg, J
Skrukrud, Cindy
Slay, Glen
Smith, David
Southern Illinois Transfer
Spoth, Robert
Stahlman, Bill
Staten, Shane
Sternburg, Janet
Stout, Robert
Strole, Todd
SUMR Waterways
Taylor, Susan
Teah, Philip
Todd, Brian
Tow Inc
Tyson, J
Urban, David
U.S. Salt
USEPA Region 5
USEPA Region 7
Walker, Brad
Welge, Owen
Werner, Paul
Westlake, Ken
Wilmsmeyer, Dennis
Winship, Jaci

York Bridge Co.
Zupan, T

The following individuals received a hard copy mailing of the Public Notice:

Bighorse, Scott
Blankenship, Tina
Bradley, Russell
Campbell, Leon
Congressman Bost
Congressman Luetkemeyer
Congressman Smith
Damptz, Amanda
Governor Nixon
Governor Rauner
Keo, Nellie
Knupp, Virgil
Korando, David
Houghton, Fay
Houston, Elena
Mezo, Braden
Schranz, Joseph Standing Bear
Senator Durbin
Senator Kirk
Shepard, Ron
Spurlock, Jessica
Taflinger, Jim
Verble, Kenneth
Verble-Whitaker, LaRae