ERDC/EL SR-21-8

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Engineering With Nature®

Water Level Management for Enhanced Fish and Wildlife Habitat Production in Upper Mississippi River Navigation Pools

An Engineering with Nature® Review of Practice

Charles Theiling, Benjamin McGuire, Gretchen Benjamin, Dave Busse, Jon Hendrickson, Kevin Kenow, Kevin Landwehr, Tim Schlagenhaft, and Mary Stefanski

September 2021

Water Level Management for Enhanced Fish and Wildlife Habitat Production in Upper Mississippi River Navigation Pools

An Engineering with Nature® Review of Practice

Charles Theiling, PhD

US Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Benjamin McGuire

US Army Engineer Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63103

Gretchen Benjamin

The Nature Conservancy
Great Rivers Partnership
La Crosse, WI 54601

Dave Busse

US Army Engineer Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63103

Jon Hendrickson

US Army Engineer Corps of Engineers
St. Paul District
180 Fifth Street East
St. Paul, MN 55025-1638

Kevin Kenow

US Geological Survey
Upper Midwest Environmental Sciences Ctr
2630 Fanta Reed Road
La Crosse, WI 54603

Kevin Landwehr

US Army Engineer Corps of Engineers
Rock Island District
PO Box 2004
Rock Island, IL 61204

Tim Schlagenhaft

Audubon (retired)
Lake City, MN 55066

Mary Stefanski

US Fish and Wildlife Service
51 East 4th Street #100
Winona, MN 55987

Final report

Prepared for Dredging Operations Technical Support Program (DOTS)
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Under Funding Account Code U4359734; AMSCO Code 086000

Abstract

There is a long history of fish and wildlife management associated with Upper Mississippi River navigation dams owned and operated by the US Army Corps of Engineers (USACE). Many operational changes have been made to improve aquatic habitat, with recent emphasis on pool-scale drawdowns to enhance wetland benefits without affecting navigation or other uses. This special report describes projects successfully incorporating Engineering With Nature® principles in a review of the physical setting and historical fish and wildlife habitat management efforts using Upper Mississippi River System navigation dams. We reviewed 80 years of adaptation and lessons learned about how to integrate navigation operations and wildlife management. Several experiments have revealed the capacity to produce thousands of hectares of emergent and submersed aquatic plants, restoring much-needed riparian habitat for a variety of aquatic, wetland, and avian species.

Contents

Figures and Tables

Figures

Tables

Preface

This review of practice was conducted for the US Army Engineer Research and Development Center (ERDC) Engineering With Nature® (EWN) initiative (www.engineeringwithnature.org). Dr. Todd Bridges was the Program Manager of the Dredging Operations and Environmental Research (DOER) Program and EWN National Lead. This report was funded by the Dredging Operations Technical Support (DOTS) program under Funding Account Code U4359734; AMSCO Code 086000. Dr. Burton Suedel was the Program Manager.

This review was completed by the Ecological Resources Branch (ERB) of the Ecosystem Evaluation and Engineering Division (EEE) of the ERDC–Environmental Laboratory (ERDC-EL). At the time of publication Dr. Lynn Escalon was Acting Branch Chief, ERB, Mr. Mark Farr was Chief, EEE. The Deputy Director of ERDC-EL was Dr. Brandon Lafferty, and the Director was Dr. Edmond J. Russo.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director of ERDC.

1 Introduction

1.1 Background

Upper Mississippi River System (UMRS) navigation dams and locks (Figure 1) were approved in the 1927 River and Harbors Act[1], designed soon after, and constructed during the 1930s. They follow a similar design, but each structure is unique, with individual operating rules (WEST 2000; Wlosinski and Hill 1995). The locks and dams maintain water depths suitable for navigation during low-flow periods by maintaining a minimum water surface elevation through gate adjustments. Nearly all dams periodically operate in an open-river condition by lifting gates out of the water or lowering them to the bottom, as is the case on several Illinois River dams, during high river flows. At moderate river flows water levels at the dams may drop in response to gate openings, a condition called “drawdown”. The frequency of open-river conditions differs at each dam, which changes the amount of time that water-level drawdowns can be performed through gate operation. Recreational boating, municipal and industrial infrastructure, and the design of lock chambers limit the amount of drawdown possible during low-flow conditions. The window of opportunity to incorporate drawdowns occurs between low-flow conditions and high flow, open-river conditions.

Following construction through the 1950s, gates on most Mississippi River dams were lifted to let ice pass during winter. Lentic fish that flourished in the expanded impoundments became trapped when the pool levels were dropped, so fisheries managers stepped in to protect the valuable fishery. There was a period of “fish rescues,” when huge seines would be used to corral fish in isolated pools. These fish would be transported to suitable habitat or contributed to fish-stocking programs around the country. Natural resource managers in the five UMRS states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin) formed the Upper Mississippi River Conservation Committee (UMRCC) in 1943 to advocate for fisheries and aquatic habitat, and they have been instrumental in the management of the river. River teams formed in each Upper Mississippi River US Army Corps of Engineers (USACE) district (that is, St. Paul, Rock Island, and

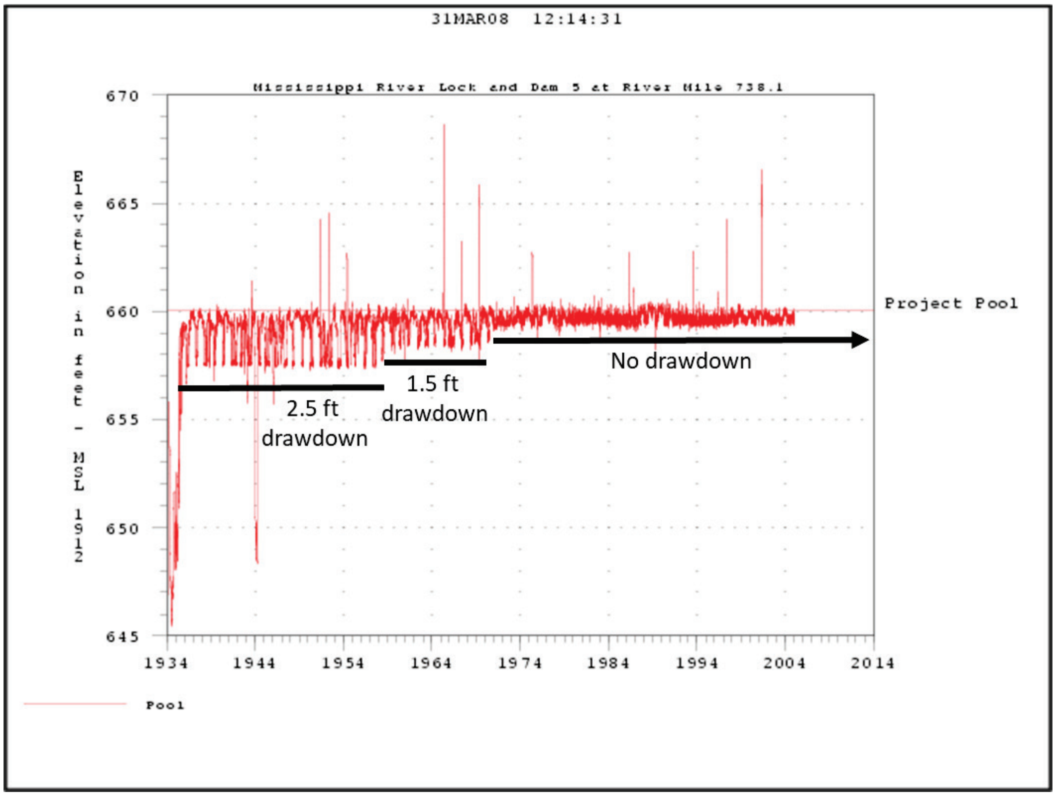
1. Act of January 21, 1927, Pub. L. No. 69-560, 44 Stat. 1010 (1927). https://www.loc.gov/law/help/statutes-at-large/69th-congress/session-2/c69s2ch47.pdf.

St. Louis Districts) to coordinate natural resource management, advocating for reduced drawdowns in the 1960s and no drawdowns since 1972. Figure 2 demonstrates historical changes in minimum pool stage regulations these groups were able to effect for Lock and Dam 5 operations.

Figure 1. Upper Mississippi River (UMR) Navigation System in St. Paul, Rock Island, and St. Louis US Army Corps of Engineer districts.

In addition to fish entrapment concerns, sedimentation and "pool aging" (Lubinski 1999, 16–8) effects on aquatic habitat emerged as important issues in the 1970s. Fisheries managers emphasized loss of depth in backwater lakes where game fish overwintered. They requested in a 1996 Problem Appraisal Report that USACE manage winter water levels on the high side of the operating band to maximize water depth in backwater lakes. USACE also investigated policy and operational constraints on increasing water levels.

Figure 2. UMR Lock and Dam 5 pool stage illustrates changes in operational drawdowns over time.



UMRS water level management (WLM) prior to 1994 consisted of maintaining overwintering fish habitat in connected backwaters and water management in isolated wetlands for moist soil plant food resources for migratory waterfowl. There were single-species management conflicts (that is, fish versus waterfowl) regarding backwater lake management and connectivity (UMRCC 2009) on the lower pools and Illinois River until the UMRCC encouraged a broader view of ecosystem management as defined by Grumbine (1984) during water management planning workshops held in 1994.

The USACE Upper Mississippi River Restoration Program (UMRS) Long Term Resource Monitoring Program (LTRMP) began investigating dam operating procedures and practices in the early 1990s as some of its initial ecological status and trends investigations (Wlosinski and Hill 1995). Following UMRCC ecosystem management workshops in 1994, increased appreciation for drawdown potential and plans translated to the launch of an experimental phase of WLM in the three UMRS USACE districts, discussed in detail below. Pool-scale WLM to mimic natural growing season conditions (that is, reduced water levels to expose river edge and mudflats to reinvigorate the seedbank) was first accomplished by the St. Louis District as “environmental pool management” (EPM) (that is, operating water levels for environmental benefits within authorized operating limits) and in Rock Island and St. Paul Districts as pool-scale drawdowns (that is, lowering water levels below authorized operating limits). Pool-scale experimentation provided evidence necessary for larger-scale program integration of water level management in the Navigation and Ecosystem Sustainability Program (NESP). The Upper Mississippi River–Illinois Waterway (UMR-IWW) System Navigation Feasibility Study (USACE 2004) studied the potential costs for advanced dredging and environmental benefits of WLM in nine navigation pools with the highest potential for successful drawdowns (Table 1; Landwehr et al. 2004). The NESP authorized funding for advanced dredging required to support drawdowns and many other restoration projects. It became apparent during experimentation and planning that in addition to substantial environmental benefits, significant implementation costs, human impacts, and potential negative effects on nontarget organisms like freshwater mussels can also occur.

Although these studies were implemented before Engineering With Nature® (EWN) was established, planners considered the economic, social, and environmental benefits collectively prior to making WLM recommendations. Current WLM embraces EWN principles, including

> using science and engineering to produce operational efficiencies; using natural processes to maximize benefit; increasing the value provided by projects to include social, environmental, and economic benefits; [and] using collaborative processes to organize, engage, and focus interests, stakeholders, and partners. (USACE 2018, 5)

Table 1. Summary of costs and benefits (acres exposed for wetland establishment) associated with navigation pool environmental drawdowns in St. Paul and Rock Island Districts (1 ha = 2.47 ac).[1] (Source: USACE 2004).

Pool	Drawdown magnitude (feet)	Success rate (%)	Acres exposed	Dredging required (yd^3)	Dredging cost	Cost per acre
5	1	95	1,200	135,811	$643,175	$585
	2	81	2,200	287,236	$1,365,093	$620
7	1	98	1,206	0	$0	$0
	2	74	2,331	215,000	$1,280,000	$549
8	1	74	1,300	2,000	$88,000	$68
	2	50	3,090	120,253	$475,000	$154
9	1	71	4,571	0	$0	$0
	2	57	6,932	75,000	$375,000	$54
11	1	91	399	0	$0	$0
	2	86	883	49,368	$399,400	$452
13	1	86	1,560	35,200	$316,800	$203
	2	86	2,822	131,032	$1,021,093	$362
16	1	55	157	13,200	$118,800	$757
	2	55	307	75,636	$601,121	$1,955
18	1	50	484	26,400	$237,600	$491
	2	50	761	133,848	$816,230	$1,385
19	1	100	790	4,400	$39,600	$50
	2	100	1,627	50,380	$363,900	$248

1.2 Objectives

There is a long history of fish and wildlife management associated with Upper Mississippi River (UMR) navigation dams. Many operational changes have been made to improve aquatic habitat, with recent emphasis on pool-scale drawdowns to enhance wetland benefits without affecting navigation or other uses. In this special report, we review the physical setting and historical fish and wildlife habitat management efforts with emphasis on recent drawdown experiments that have been successfully implementing EWN principles.

1. For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf. For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 345–7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

1.3 Approach

We prepared this review of practice to disseminate innovations in USACE project operations for environmental benefit using the EWN platform for communicating sustainable design and operational approaches. The UMR is an example of a region with many large USACE projects that affect multiple aspects of watershed, river, and floodplain management. A Congressional designation for the UMR system as a *Nationally Significant* waterway and ecosystem is unique and implies the inherent connections in the complex social-ecological system. The social-ecological connections going back to the Clean Water Act[1] implementation through recent navigation, floodway, and environmental restoration planning also helped expand natural resource management coordination among agencies and programs through increased communication.

Traditionally, environmental benefits were associated with USACE ecosystem restoration projects, and environmental impacts were associated with navigation and flood-risk management projects. EWN, however, provides a platform to share beneficial practices that produce a broader range of ecosystem goods and services (EGS) associated with economic, social, and environmental benefits. Natural resource managers in three USACE districts within the UMR have partnered with fish and wildlife management agencies since the inception of the UMR-IWW navigation system nearly 80 years ago to avoid and minimize environmental impacts. The shared understanding that emerged from collaborative planning and implementation of multiple navigation and environmental restoration projects led to new understanding of UMR operational and policy constraints that could be optimized to achieve multiple benefits. The problems, lessons learned, and opportunities discussed herein apply not only across the large UMR area of operation but to USACE impoundments in other river systems.

1. Federal Water Pollution Control Act of 1948, 33 USC. § 1251 et seq. (2018). https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf.

2 Water Level Management (WLM) Experiments

2.1 St. Louis District

2.1.1 Initial experiments

St. Louis District was the first to implement WLM experiments, which evolved into the current EPM for Pool 24, 25, and 26. EPM is successful in St. Louis District because the dam and water management design includes drawdowns as routine operational events and accommodates frequent gate manipulations as conditions change. Each Pool is drawn down 3.5–6.5 ft (1 – 2 m) (Table 2) during moderate discharge and then filled again or allowed to flood depending on discharge. These operational conditions were adapted for environmental benefits in 1994 and have been in operation ever since. Several studies have documented the environmental benefits of these operations (Wlosinski et al. 2000; Garvey et al. 2003; Flinn et al. 2005; Flinn et al. 2008), and the district managed public perception by coordinating with the barge industry and marina owners affected by WLM operations.

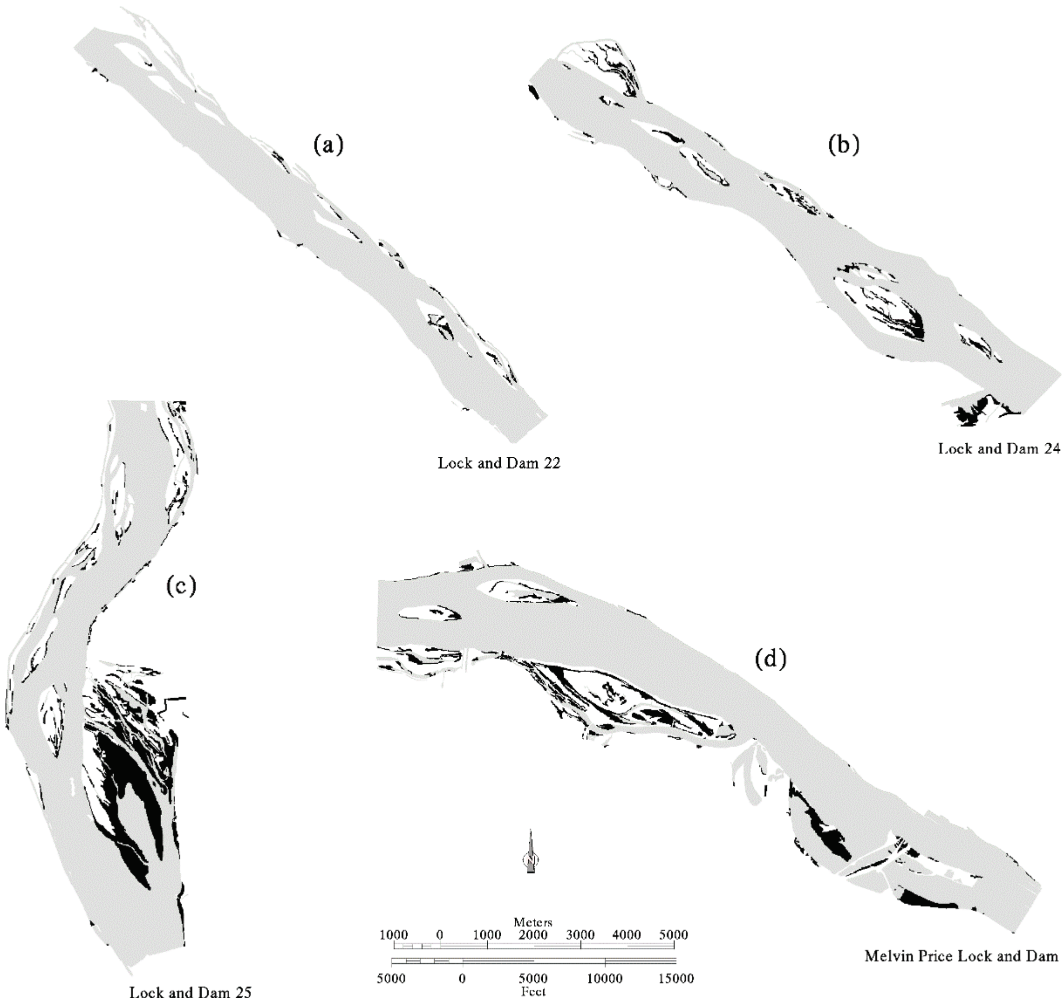
Table 2. Operation elevations (feet above sea level) at dams 24, 25, and 26.

Pool	Maximum regulated pool	Maximum drawdown	EPM elevations
Pool 24	449.0	445.5	448.0–448.5
Pool 25	434.0	429.7	432.0
Pool 26	419.0	412.5	417.0

Experimental drawdowns were conducted in Pool 24 and 25 from mid-June through July during both in 1995 and 1996 (Wlosinski et al. 2000). Water levels were held 1–3 ft lower than maximum regulated pool elevation and raised gradually to avoid rapid inundation that would kill emergent aquatic plants. Emergent plant sampling confirmed seven genera colonizing mud flats in 1995 and five in 1996, which included valuable waterfowl foods like pigweed (*Amaranthus* spp.), chufa (*Cyperus* spp.), wild millet (*Echinochloa* spp.), rice cutgrass (*Leersia* spp.), sprangle top (*Leptochloa* spp.), smartweed (*Polygonum* spp.), and foxtail (*Setaria* spp.). Plants germinated and grew to 7–10 in, which allowed them to survive when water levels were slowly raised. Spatial assessments indicated production of 880 ac of moist soil plants in Pool 25 and 225 ac in

Pool 24, compared to only 51 ac in Pool 22, which was not drawn down (Figure 3). Minnow seining conducted by the Illinois Department of Natural Resources indicated no significant change to fish communities (Wlosinski et al. 2000).

Figure 3. Areas vegetated during drawdowns on UMR Pools 24, 25, and 26 and Pool 22, which is not drawn down (black shaded areas represent new vegetation colonization due to the drawdown (Source: Wlosinski et al. 2000, 12).



Macroinvertebrate and zooplankton response to EPM was investigated in Pool 25 during 1999–2000 (Flinn et al. 2005) because they are regarded as important food resources for both fish and waterfowl. Opportunities for EPM varied with discharge; high discharge in June and July 2000 prevented a drawdown. Moist soil vegetation was abundant following the drawdown in 1999, leaving remnant stubble in spring 2000; it was absent because of flooding in 2000, and it was moderately abundant in 2001. Macroinvertebrates sampled in 2000 and 2001 were most abundant in areas with successful vegetation response. Oligochete abundance was higher among vegetated plots in comparison to non-vegetated plots, which accounted for most change. Zooplankton were not abundant in any samples.

Flinn et al (2008) investigated differences in substrate, organic matter, macroinvertebrate abundance, and fish communities along a longitudinal gradient in Pool 25 during 2001–2003. Hinge-point water management results in midpool reaches that are more stable than other parts of the pool that experience drawdowns and flooding. Benthic organic matter was stable at midpool but variable in the lower pool depending on vegetation response to drawdowns. Smaller, fast-reproducing species (for example, *Berosus* sp.) were common in the variable lower pool, and larger, longer-lived species (for example, *Hexagenia* sp.) occurred in the midpool reach. Fish communities were dominated by cyprinids, with limnophilic species in the lower pool and rheophilic species in midpool, which is consistent with findings in Pool 26 (Theiling, Maher, and Sparks 1996).

2.1.2 Recent environmental pool management (EPM) opportunities

Prolonged high-flow conditions upstream of Pool 26 in 2014 necessitated an 86-day drawdown near the lower portion of the operating band (USGS 2019, 25). This atypical condition produced a higher diversity of both annual and perennial aquatic vegetation, such as broadleaf arrowhead (*Sagittaria latifolia*) and American lotus (*Nelumbo lutea*) (McGuire 2016, 6-7). These unique conditions demonstrate the possibility of regenerating a mix of annual and perennial aquatic vegetation through extended drawdowns.

After 2014, St. Louis District implemented an experimental operating procedure to extend the drawdown period from the typical 30–45 days to 90+ days for four consecutive years. As has been the case for the last 20+ years, this experimental procedure was still within the normal pool operating band (see Table 2).

In 2016, St. Louis District used USACE Sustainable Rivers Program funding to monitor the benefits of long-term drawdowns (McGuire 2016). Moderate to high discharge supported a 1 ft drawdown of 224 days and a 2 ft drawdown over 110 days. Emergent aquatic plant community colonization in the drawdown area included 27 species in Pool 24, 17 in Pool 25, and 14 in Pool 26. Vegetation growth was robust in the early growing season (Figure 4) and continued through most of the growing season to maturity. These benefits have been repeated in all but four of the last 25 years (Table 3); thus, EPM operations represent an efficient wetland management tool.

Figure 4. Vegetation growth on exposed mudflats caused by a 1–5 ft drawdown from March to June 2016 in Pool 24, UMR. The person is moving along an elevation gradient to illustrate the vegetation height difference achieved on substrate exposed for longer periods of time. The shortest vegetation occurs where deeper substrates were exposed, flooded, and exposed again in response to changes in river flow (top panels). The tallest vegetation occurs on areas <2 ft below normal pool, which were exposed the entire period (bottom panels) (Photos credit: Ben McGuire).

Table 3. Upper Mississippi River System (UMRS) navigation pool water-level management (WLM) implementation by year (shaded boxes). Pools 24, 25, and Mel Price achieve success within routine pool operational ranges (EPM); others are deviations from routine operations.

	Pool 5	Pool 6	Pool 8	Pool 13	Pool 24	Pool 25	Mel price pool
1994					WLM	WLM	WLM
1995					WLM	WLM	WLM
1996					WLM	WLM	WLM
1997					WLM	WLM	WLM
1998				WLM	WLM	WLM	WLM
1999					WLM	WLM	WLM
2000					WLM	WLM	WLM
2001			WLM		WLM	WLM	WLM
2002			WLM		WLM	WLM	WLM
2003					WLM	WLM	WLM
2004					WLM	WLM	WLM
2005	WLM				WLM	WLM	WLM
2006	WLM				WLM	WLM	WLM
2007					WLM	WLM	WLM
2008							
2009					WLM	WLM	WLM
2010		WLM					
2011					WLM	WLM	WLM
2012					WLM	WLM	WLM
2013							WLM
2014							WLM
2015					WLM	WLM	WLM
2016					WLM	WLM	WLM
2017					WLM	WLM	WLM
2018					WLM	WLM	WLM

St. Louis District identified WLM opportunities to improve environmental outcomes within their authorized operating band (see Table 2) and without additional dredging. They undertook a purposeful experimental approach to minimize social and economic effects while monitoring and documenting environmental benefits. Success with EPM was documented at the outset in the 1990s and again more recently (McGuire 2016) as plant diversity and abundance increased in response to hydrologic conditions, creating more opportunities for longer, deeper drawdowns. EPM implements EWN principles by using science and hydrologic engineering to increase environmental sustainability within routine operations;

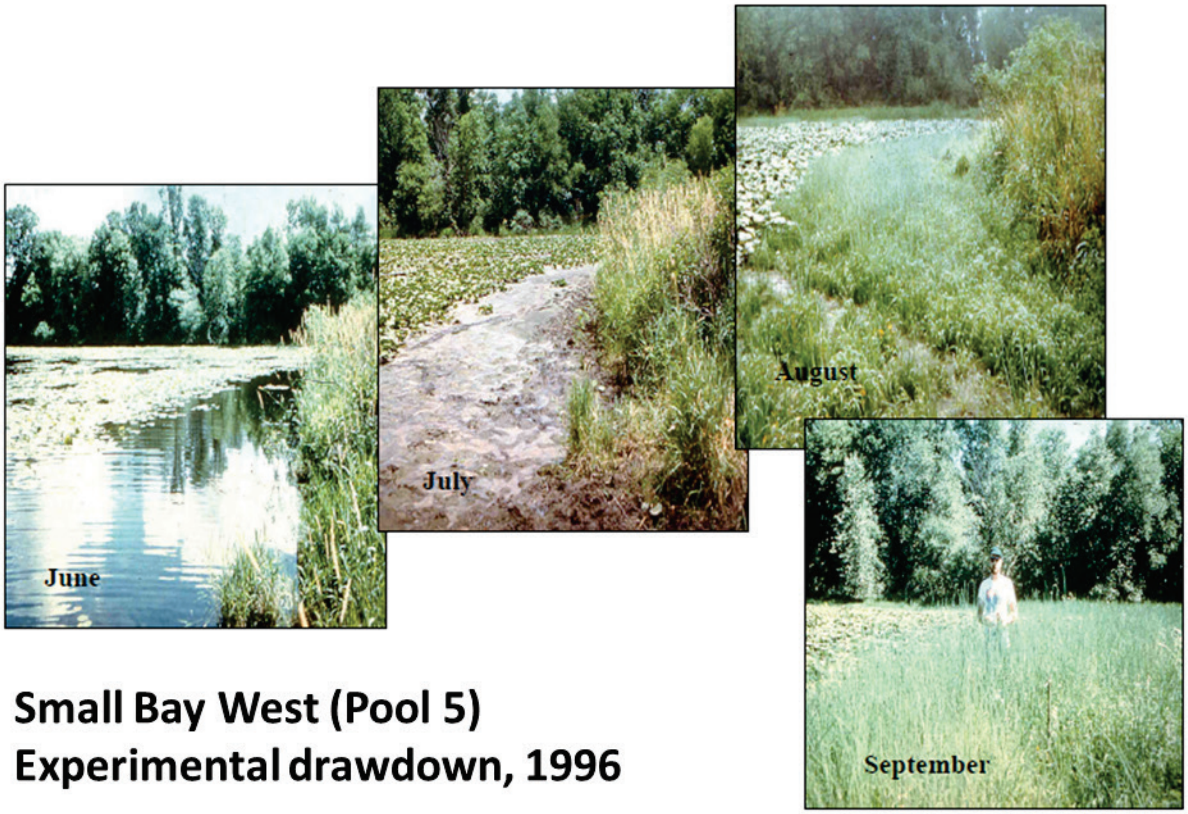
considering natural hydrologic cycles (that is, natural processes) in navigation system and ecosystem operations; by increasing social and environmental benefits beyond routine operations; and collaborating with partners to implement, monitor, and communicate outcomes.

2.2 St. Paul District

2.2.1 Small-scale (backwater lake) drawdowns

The Water Level Management Task Force (WLMTF), a technical advisory group to St. Paul District, was formed in 1995 to help coordinate drawdown experiments (Kenow et al. 2016). Their initial water-level drawdown experiments included implementing small-scale drawdowns on small, isolated backwater lakes in Pools 5 and 9 during 1996 through 1999 (Kenow et al. 2016; for example, Figure 5). Quantifying sediment and plant response through monitoring supported further planning for pool-scale drawdowns, which required significant interagency collaboration to build broad support for the action. Public opinion and recreational impacts were as important as potential navigation operation and safety. Many complex policy questions raised by the WLMTF were satisfactorily resolved by the small-scale drawdowns, so larger experiments were implemented in Pool 8 during 2001–2002.

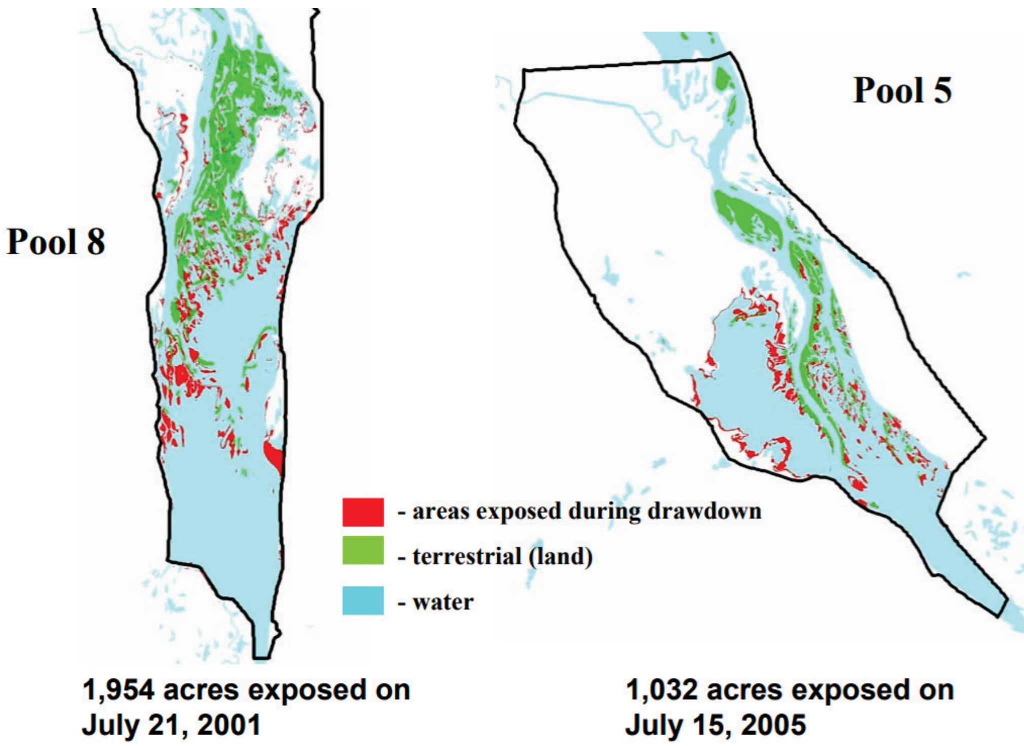
Figure 5. Pool 5 experimental backwater drawdowns in 1996. The sequence of photographs (left to right) through time from June to September 1996 shows the positive plant response to the planned drawdown (USACE 2007, 2).



2.2.2 Pool 8 drawdown

St. Paul District also manages navigation pools using hinge-point control, but the operating plans have smaller drawdowns of between 0.5 and 1 ft and less flexibility in the range of water surface elevations that can be maintained for a given flow condition (±0.2 ft). The configuration of St. Paul District pools provides for large expanses of exposed substrate with a 1.5 ft drawdown, given appropriate river discharge. A pool-scale Pool 8 drawdown implemented from 2000 to 2001 was monitored by the interagency WLMTF, and results were reported frequently in UMRCC, river team meetings, and in the technical literature (Kenow et al. 2016). The region contains abundant biodiversity, with approximately 50 different plant species observed on areas exposed during the drawdown (Figure 6). During the second consecutive year of drawdown, the plant community shifted from one dominated by annuals to one dominated by perennials. Arrowhead (*Sagittaria* spp.) tuber production increased 16-fold during the two years (Kenow et al. 2003, 53). There were no documented fish kills, no negative effects on fish populations, and an increase in forage species. However, freshwater mussels had higher than anticipated mortality, which led to significant monitoring in subsequent drawdowns (beyond regulated stages). Shorebird abundance doubled, and waterfowl response was positive. Tundra swan response was exceptional, but increased diving ducks were coincidental with other continental factors. Other responses included sediment compaction and better water quality (Nissen 2014, 70). The WLMTF did an outstanding job communicating results to management agencies, affected businesses, and the public to maintain support for the sustainable management action (Kenow et al. 2016).

Figure 6. UMR Pool 8 and Pool 5 drawdown response (USACE 2007, 3).



2.2.3 Pool 5 drawdown

A pool-scale drawdown was implemented in Pool 5 during 2005 (Figure 6). This drawdown showed positive environmental responses similar to Pool 8, but mussel mortality monitoring quantified negative impacts (Nissen 2014, 50). Mussel survival in the drawdown zone was 72%, compared to 100% in a control site. Survival was higher in deeper areas and on slopes, and thick-shelled species survived better than thin-shelled species. The impacts and desire to continue drawdowns prompted formal, pool-wide mussel population impact studies to document WLM benefits for the UMR-IWW System Navigation Feasibility Study (Newton, Zigler, and Gray 2015). Mussel population studies were conducted post hoc in Pool 5 and in advance of Pool 6 and Pool 18 drawdowns to consider impacts on endangered species.

2.2.4 Pool 6 drawdown

The Pool 6 drawdown in 2010 was implemented to further demonstrate drawdown potential. It provided another opportunity to assess impacts to freshwater mussels in a rigorous mussel distribution and mortality study that tracked individual animals during 2009 (baseline) and 2010 (impact) monitoring. Results detected 11% mortality in Pool 6 during the drawdown, compared to 5% in a non-drawdown year. Mussel movement increased in response to drawdowns, and their behavior was considered consistent with each species biology. Thick-shelled mussels burrowed, and thin-shelled mussels moved laterally with no apparent directionality of movement toward water (Newton et al. 2015).

2.2.5 Advanced dredging

In both Pools 8 and 5, a significant amount of additional dredging was required so that commercial navigation could continue during an environmental drawdown. Pool 8 advanced dredging required 210,000 yd^3, compared to a typical long-term average of 75,000 yd^3. However, following the increased dredging activity at the initiation of the drawdown, Pool 8 required less dredging for two years after the drawdown. Routine dredging returned the third year following the drawdown (Nissen 2014, 18). The cost of this additional dredging and identifying a funding source are challenges that must be addressed before water-level drawdowns can continue in St. Paul District.

2.2.6 Coordination and monitoring

St. Paul District anticipated challenges implementing drawdowns that required deviations from traditional operation, so they implemented a technical, policy, and social coordination process leading to pool-wide drawdowns. They anticipated navigation impacts that required additional dredging and reduced boat access to backwaters and marinas that required public education. They did not anticipate impacts to nontarget species, but these negative effects became an important concern after the first pool-scale experiment. Drawdowns were evaluated in two backwaters and three pool-scale drawdowns over a decade.

WLM implements EWN principles in many ways, first by using environmental science and hydrologic engineering to adapt navigation system operations for enhanced environmental benefits. Regulating rules at many UMR dams can be optimized to use natural flood cycles to support managed drawdowns that promote emergent aquatic vegetation. WLM practices increase environmental and social benefits beyond routine operations for no or low costs relative to the substantial EGS benefits derived. WLM requires substantial partnership and communication because the approach affects thousands of shoreline acres for long river reaches. Some WLM locations are rural. Some are highly populated, but all create short-term impacts on public access and long-term benefits from improved habitat and recreation opportunities. Extensive environmental monitoring was conducted to quantify and communicate the impacts and benefits to natural resource managers and the public. Implementing EWN principles for WLM has created support to transfer the approach to other USACE projects. The USACE Sustainable Rivers Program, which supports reservoir adaptive management, has adopted WLM to make USACE lakes a greater consideration in watershed management.

2.3 Rock Island District

Drawdowns in Rock Island District pools are typically not as feasible within ordinary operating limits because most are operated at dam-point control, which offers less flexibility; however, Pools 16 and 20 do have hinge-point control (Landwehr et al. 2004).

Analyses completed by Rock Island District Hydrology and Hydraulics Branch indicated a drawdown could be implemented for discharge between 50,000 to 110,000 ft^3/s in Pool 13, so there was reasonable confidence it could be successful. An experimental drawdown of Pool 13 was implemented in 1998, with a goal for a 1 ft drawdown during the June 15 to August 15 period. Moderate discharge supported the drawdown only through July 15, but photos document vegetation colonization on exposed mudflats (Figure 7). The Pool 13 drawdown was not closely monitored and gained negative public perception in the local area. Fisherman and bait dealers complained about poor recreational access to Illinois Department of Natural Resource staff, and biologists documented fish kills in isolated lakes and wetlands. Illinois management agencies have not embraced the practice in the region because of fewer opportunities and uncertain success relative to existing conditions, but a new project is being proposed to implement EWN principles on another Pool 13 drawdown experiment.

Drawdowns in Rock Island District have not been a management priority since 1998, but there was substantial planning in 2006 for a Pool 18 drawdown under the Navigation and Ecosystem Sustainability Program. The program was not funded, and the Pool 18 drawdown has not been implemented. A full feasibility study evaluated alternatives, costs, and benefits, with substantial emphasis on freshwater mussel impacts. There was a positive recommendation for Pool 18 drawdowns but some concern about the probability for success under changing hydrologic regimes. Statistical analysis of USACE daily discharge records for a 30-year period indicated a 30-day drawdown could be accomplished on average, once every three years (Landwehr et al. 2004). Because of concerns that climate-related hydrologic change would reduce drawdown success, for this report we reviewed two-decade steps and found the probability for success decreases through time (Table 4). Non-stationarity associated with climate-related increases in river discharge can reduce the probability for drawdown success in some reaches but increase it in others, like Pools 24, 25, and 26. A system-wide re-evaluation of WLM opportunities is currently in progress.

Table 4. Probability for the correct moderate range of river discharge to support a 2 ft, pool-scale drawdown in UMR Pool 18 for four 20-year time steps.

	1940–1960	1960–1980	1980–2000	1990-2009
Drawdown period	Years w/ drawdown opportunity (%)*	Years w/ drawdown opportunity (%)*	Years w/ drawdown opportunity (%)*	Years w/ drawdown opportunity (%)*
30-day	100	100	95	95
45-day	100	95	95	90
60-day	100	90	86	70
90-day	0	0	0	0

*Drawdown opportunity for the period July 10–September 30.

Figure 7. Vegetation response to WLM in Pool 13, UMRS (Source: USACE–Rock Island District).

3 Planning and Policy Considerations

The WLMTF of the River Resources Forum (RRF) also conducted an evaluation of WLM as a restoration tool (Nissen 2014). The WLMTF was established in 1995 as a technical advisory group to the RRF, which supports interagency coordination on river-related issues (Kenow et al. 2016). Representatives included four federal agencies and three state departments of transportation and natural resources. Input was sought from the public, nongovernmental organizations, and navigation and recreation industries. The WLMTF provided an effective forum to address issues related to WLM, and while participating organizations could vote, the task force usually reached consensus on management decisions (Kenow et al 2016).

In addition to the experimental drawdowns coordinated by the WLMTF we describe above, the planning and policy review activities they undertook are also noteworthy. WLM can prove contentious, with needs for navigation, recreation, environment, and other social factors, so the WLMTF wanted to remain inclusive and open. The group used significant partner engagement to select sites, develop alternative plans, select a preferred alternative, apply for waivers to change water control, and implement and monitor the drawdown (Figure 7). A project report described the planning, implementation, and monitoring results in great detail for the local audience (Nissen 2014), and the science staff documented the ecological response in the scientific literature (Kenow et al. 2016).

The UMR-IWW System Navigation Feasibility Study (USACE 2004) included an environmental sustainability component that considered system-wide opportunities for WLM (Landwehr et al. 2004). UMR river natural resource coordination teams were consulted on a range of considerations identified by the WLMTF. Each district team implemented their review of WLM opportunities slightly differently than the others for their river reaches, and results were compiled into system-wide recommendations for WLM opportunities (Landwehr et al. 2004):

- growing season drawdowns—Pools 5, 7, 8, 9, 11, 13, 16, 18, 24, 25, and 26
- modifying dam operation from hinge-point to dam-point control—Pools 16, 24, 25, and 26

- modifying distribution of flow across dams—as needed for fish passage–attracting flows;
- minimizing short-term fluctuations—Illinois Waterway.

The latest engagement on WLM was coordinated by the Upper Mississippi River Basin Association (UMRBA), who held a workshop in April 2017 to motivate progress towards implementing projects. Interagency participation from all USACE UMR districts resulted in broadly supported recommendations (UMRBA 2017):

1. Employ WLM opportunistically.
2. Perform a cost-benefit analysis to determine merit.
3. Address various policy and program implementation issues.
4. Implement drawdowns in Pools 13 and 18.
5. Seek and secure necessary funding.
6. Gain a better understanding of how hydrology and hydraulics affect river management.

The UMRBA initiated a planning assistance to states agreement with St. Paul District in 2018 to explore opportunities for more routine, systemic WLM implementation. Progress toward WLM implementation continues to be pursued in all parts of the river system.

Figure 8. Process flow chart for planning and implementation of pool-scale drawdowns on the UMR (adapted from Kenow et al. 2016, 301).

Input or activity	Process
• Factors regulating pool water surface elevation • Extent of aquatic area benefit • Dredging to support commercial and recreational boating • Hydrologic limitations • Ability to conduct comprehensive monitoring • Socioeconomic factors • Public input	Pool Selection
• Develop alternatives: depth and duration under regime flows • Evaluate alternatives: consider hydrology sediment transport, channel maintenance requirements, impact on commercial and recreational facilities, likelihood of ecologically effective drawdown.	Drawdown Plan Development For Selected Pool
• Solicit public input • Selection based on ecological need, logistics of implementation, and public acceptance	Plan Selection
• USACE planning document/environmental assessment • Request to deviate from approved reservoir plan	Modify Reservoir Operating Plan
• Channel surveys and advanced dredging • Recreational access dredging • Monitoring by partner agencies: water quality, sediment, recreational use, cultural resources, biological response • Public information campaign	Implement Drawdown

4 Discussion

UMRS WLM was implemented years before the EWN approach was formalized, but UMR planners and scientists implemented similar principles very well and documented their experience for others to learn from. Each UMR USACE district implemented drawdown experiments differently because of their unique physical setting and agency-public constituency, but they all used environmental science and hydrologic flow frequency analysis to optimize water management strategies to achieve increased wetland habitat benefits. The approach simulates low-flow conditions of natural flood-drought cycles that promote a variety of wetland functions. Operating procedures at some dams were adapted to extend routine operational drawdowns for longer periods during the growing season. Deviations from routine operations, advanced dredging to maintain navigation, and significant coordination were required at other sites. The drawdowns were implemented after considering the potential social, economic, and environmental benefits, which were monitored to document outcomes.

Social and economic impacts and benefits are closely related. The commercial navigation system is the primary UMRS purpose, and it must be maintained within authorized standards. Navigation has significant positive economic cost benefits (USACE 2004), but other social effects and environmental impacts of altered hydrology are evident and well documented (USGS 1999). Pool-scale drawdowns were recommended in 1994 to counteract impoundment effects on riverine wetlands. The case studies described here document that drawdowns can have positive environmental benefits for no cost in some places. Cost for dredging to maintain commercial navigation may be required in some places, but drawdown costs were comparable to other ecosystem restoration measures (USACE 2004). Drawdowns are cost effective because they influence large areas and improve wetland habitat that benefits many species over thousands of acres. The principle to use a science-based collaborative process to organize and focus interests, stakeholders, and partners was an important component of drawdown planning and implementation. The UMR system wide WLM assessments (Landwehr et al. 2004) substantiated the economic, social, and environmental benefits leading to an authorization for widespread drawdown implementation (USACE 2004).

Recreation can be temporarily affected by midsummer drawdowns that limits access. The navigation channel depth is always maintained, but backwater lakes, side channels, and marinas may become inaccessible because of water-level reductions. Environmental planners were proactive, seeking sponsors to support recreational access dredging to maintain Pool 8 marina operations. Recreational users, like fishers and hunters, were educated through communication and outreach and ultimately came to appreciate that temporary impacts on access would help restore and maintain healthy ecosystems over longer periods of time.

Risk to freshwater mussels was the highest concern of implementing drawdowns after unexpected strandings during early UMR pool-wide drawdown experiments. Monitoring methods were developed and implemented to document the potential impacts in subsequent drawdown planning. Such impacts are not a factor for EPM, which occurs within routine operating bands where mussel abundance is low. Many aquatic and riparian species must be considered when planning WLM for enhancing wetland benefits.

Impacts from hydrologic alteration are common in USACE water resource projects, but as demonstrated herein, some impacts can be overcome or minimized. As noted in the case studies above, experienced planning teams can facilitate WLM decision-making with available data and tools to view operational constraints on a project-specific basis. Experience from UMR WLM can be applied in other regions with an EWN planning approach that ensures coordination and communication to facilitate technology transfer.

5 Conclusions

Our review demonstrates that UMR WLM operations produce multiple environmental, social, and economic benefits consistent with EWN principles. We analyzed over 80 years of water management operational practices, with an emphasis on the intentional alteration of USACE water project operations to achieve multiple-use benefits. The UMR region has a long history of developing large, integrated, water infrastructure plans within institutional stovepipes that were traditional barriers to information dissemination. However, recognizing the inherent physical, hydraulic, and ecological interdependencies of UMR social, economic, and environmental systems through ecosystem management planning in 1994 drove increased emphasis on collaborative planning on the UMR. WLM was an outcome in which environmental scientists and river engineers collaborated on navigation and ecosystem restoration mission integration for increased UMRS benefits.

After reviewing experiences with WLM in three distinctly different regions of the UMRS, we determined that there is a high level of success and significant stakeholder support for the practice. Some of the challenges ahead for expanding these practices on the UMR and elsewhere include cost (for example, planning, increased annual dredging, monitoring); risk to nontarget species (for example, mussels); risk to other river uses (for example, recreation); desire from managers; and authority to deviate from conventional water management protocols.

The challenges for WLM implementation can be overcome, because it can often be implemented with little cost where no dredging is required. There are engineering constraints on all projects, but the practice is widely transferable to reservoirs, where slight changes to water management can create significant wetland benefits. When compared to the cost of other restoration projects, WLM with advanced dredging can be cost effective because it affects large areas and has moderate cost per are. Risk to nontarget species is not an issue where routine operations include drawdowns; rather, it is an issue when lowering water levels below typical stages. The risk can be minimized with slow changes in water levels and rescue operations. Risk to other users must be considered, but primary project purposes, like navigation or flood-risk management, must be maintained during WLM implementation. Other uses like recreation or habitat management might be interrupted, so there must be adequate communication to help users adapt to temporary changes. Communication and education about EWN approaches typically garners strong support for the potential beneficial outcomes. Support from river users and stakeholders can drive more interest in EWN approaches that might motivate other river managers to ask for deviations from routine operations. Evidence of successful WLM and sound engineering analysis for new projects will provide information to support alternative water management requests.

References

Flinn, M. B., M. R. Whiles, S. R. Adams, and J. E. Garvey. 2005. "Macroinvertebrate and zooplankton response to emergent plant production in upper Mississippi River floodplain wetlands." *Archive for Hydrobiology* 162:187-210

Flinn, M. B., S. R. Adams, M. R. Whiles, and J. E. Garvey. 2008. "Biological response to contrasting hydrology in backwaters of upper Mississippi River Pool 25." *Environmental Management* 41:468-486.

Garvey, J. E, B. D. Dugger, M. R. Whiles, S. R. Adams, M. B. Flinn, B. M. Burr, and R. J. Sheehan. 2003. Responses of fished, waterbirds, invertebrates, vegetation, and water quality to environmental pool management: Mississippi River Pool 25. Fisheries and Illinois Aquaculture Center, Southern Illinois University, Carbondale, Illinois contract report to US Army Corps of Engineers, St. Louis District.

Grumbine, R. E. 1984. "What is ecosystem management?" *Conservation Biology* 8:27-38.

Kenow, K. P., G. L. Benjamin, T. Schlagenhaft, R. A. Nissen, M Stefanski, G. J. Wege, S. A. Jutila, and T. J. Newton. 2016. "Process, Policy, and Implementation of pool-wide drawdowns on the upper Mississippi River: A promising approach for ecological restoration of large impounded rivers." *River Research and Applications* 32:295-308.

Kenow, K. P., J. E. Lyon, R. K. Hines, and L. R. Robinson. 2003. Vegetation response to a demonstration drawdown on Pool 8 of the Upper Mississippi River. P. 53 in *Proceedings of the 34th Annual Meeting of the Mississippi River Research Consortium*, 24-25 April, 2003, LaCrosse, WI. http://m-r-r-c.org/Proceedings/2003_MRRC_proceedings.pdf.

Landwehr, K. J., C. H. Theiling, T. R. Gambucci, D. R. Busse, J. M. Stemler, and D. B. Wilcox. 2004. Water level management opportunities for ecosystem restoration on the upper Mississippi River and Illinois Waterway. Upper Mississippi River – Illinois Waterway Navigation Feasibility Study Environmental Report 53. Report prepared for the US Army Corps of Engineers. http://www2.mvr.usace.army.mil/UMRS/NESP/Documents/ENVReport53.pdf

Lubinski, K. S. 1999. "Floodplain River Ecology and the Concept of River Ecological Health." In *Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long-Term Resource Monitoring Program*. Report Number LTRMP 99-T001., La Crosse, Wisconsin: United States Geological Survey.

McGuire, B. 2016. Environmental pool management 2016 summary report. US Army Corps of Engineers, St. Louis District, St. Louis, Missouri.

Newton, T. J., S. J. Zigler, and B. R. Gray. 2015. "Mortality, movement, and behavior of native mussels during a planned water-level drawdown in the Upper Mississippi River." *Freshwater Biology* 60:1–15.

Nissen, R. A., editor 2014. Habitat enhancement using water level management on the Upper Mississippi River. Water Level Management Task Force-River Resources Forum, 87.

Theiling, C. H., R. J. Maher, and R. E. Sparks. 1996. “Effects of variable annual hydrology on a river regulated for navigation: Pool 26, Upper Mississippi River System.” *Journal of Freshwater Ecology* 11:101–114.

Upper Mississippi River Basin Association (UMRBA). 2017. Upper Mississippi River Basin Association Water Level Management Workshop [proceedings]. Grand River Center, 4-5 April 2017, Dubuque, IA. Upper Mississippi River Basin Association, St. Paul, MN. 69 pp. https://umrba.org/sites/default/files/documents/umrba-wlm-workshop4-2017.pdf

USACE (United States Army Corps of Engineers). 2004. Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study. US Army Corps of Engineers, Rock Island district, Rock Island, IL. 705 pp.

USACE. 2007. *Summary of Results of the Pool 5 and Pool 8 Drawdowns on the Upper Mississippi River*. River Resources Forum Water Level Management Task Force Report. https://www.mvp.usace.army.mil/Portals/57/docs/Navigation/River%20Resource%20Forum/Summary%20of%20Results%20-%20Pools%205%20&%208%20DDs.pdf

USACE. 2018. *Engineering With Nature Strategic Plan 2018–2023:Expanding Implementation*. Vicksburg, MS: US Army Engineer Research and Development Center. https://ewn.el.erdc.dren.mil/pub/EWN-StrategicPlan2018-2023FINAL.pdf.

USGS (United States Geological Survey). 1999. Ecological Status and Trends of the Upper Mississippi River System 1998: a report of the Long Term Resource Monitoring Program. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. LTRMP 99-T001. 236 pp.

USGS. 2019. Enhancing Restoration and Advancing the Knowledge of the Upper Mississippi River. Science in Support of Restoration and Management FY19 SOW. Upper Mississippi River Restoration Program, US Geological Survey, La Crosse, WI. 86 pp. https://www.umesc.usgs.gov/ltrmp/documents/fy19_science_support1aug2019.pdf

UMRCC (Upper Mississippi River Conservation Committee). 2009. Habitat Connectivity White Paper. UMRCC, US Fish and Wildlife Service, Marion, Illinois https://docs.wixstatic.com/ugd/d70a05_f0de7e60309c43599986705b44ee1c6d.pdf

WEST Consultants, 2000. Upper Mississippi River and Illinois Waterway cumulative effects study, Volume 1 and Volume 2. Environmental Report #40 for the Upper Mississippi River – Illinois Waterway System Navigation Study. US Army Corps of Engineers, Rock Island District, Rock Island, Illinois.

Wlosinski, J. H., and L. Hill. 1995. Analysis of water level management on the upper Mississippi River (1980-1990). Regulated River Research and Management 11:239-248.

Wlosinski J. H., J. T. Rogala, T. W. Owens, K. L. Dalrymple, D. Busse, C. N. Strauser, and E. Atwood. 2000. Response of vegetation and fish during an experimental drawdown in three pools, Upper Mississippi River. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, August 2000. LTRMP 2000-T001. 18 pp. + Appendixes A – B

Acronyms and Abbreviations

DOER	Dredging Operations and Environmental Research
DOTS	Dredging Operations Technical Support
EGS	Ecosystem Goods and Services
EL	Environmental Laboratory
EPM	Environmental Pool Management
ERDC	Engineer Research and Development Center
EWN	Engineering with Nature®
IWW	Illinois Waterway
LTRMP	Long Term Resource Monitoring Program
NESP	Navigation and Ecosystem Sustainability
RRF	River Resources Forum
UMR	Upper Mississippi River
UMRBA	Upper Mississippi River Basin Association
UMRCC	Upper Mississippi River Conservation Committee
UMRS	Upper Mississippi River System
USACE	US Army Corps of Engineers
WLM	Water level management
WLMTF	Water Level Management Task Force

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
September 2021	Special Report	

4. TITLE AND SUBTITLE

Water Level Management for Enhanced Fish and Wildlife Habitat Production in Upper Mississippi River Navigation Pools: An Engineering with Nature® Review of Practice

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Charles Theiling, Benjamin McGuire, Gretchen Benjamin, Dave Busse, Jon Hendrickson, Kevin Kenow, Kevin Landwehr, Tim Schlagenhaft, and Mary Stefanski

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

See next page.

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/EL SR-21-8

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Dredging Operations Technical Support Program
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

10. SPONSOR/MONITOR'S ACRONYM(S)

DOTS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

Funding Account Code U4359734; AMSCO Code 086000.

14. ABSTRACT

There is a long history of fish and wildlife management associated with Upper Mississippi River navigation dams owned and operated by the US Army Corps of Engineers (USACE). Many operational changes have been made to improve aquatic habitat, with recent emphasis on pool-scale drawdowns to enhance wetland benefits without affecting navigation or other uses. This special report describes projects successfully incorporating Engineering With Nature® principles in a review of the physical setting and historical fish and wildlife habitat management efforts using Upper Mississippi River System navigation dams. We reviewed 80 years of adaptation and lessons learned about how to integrate navigation operations and wildlife management. Several experiments have revealed the capacity to produce thousands of hectares of emergent and submersed aquatic plants, restoring much-needed riparian habitat for a variety of aquatic, wetland, and avian species.

15. SUBJECT TERMS

Mississippi River—Water levels
Fishes—Habitat—Effect of water levels on
Environmental management
Wildlife—Habitat-Effect of water levels on
Restoration ecology

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	39	

US Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

US Army Engineer Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63103

The Nature Conservancy
Great Rivers Partnership
La Crosse, WI 54601

US Army Engineer Corps of Engineers
St. Paul District
180 Fifth Street East
St. Paul, MN 55025-1638

US Geological Survey
Upper Midwest Environmental Sciences Ctr
2630 Fanta Reed Road
La Crosse, WI 54603

US Army Engineer Corps of Engineers
Rock Island District
PO Box 2004
Rock Island, IL 61204

Audubon (retired)
Lake City, MN 55066

US Fish and Wildlife Service
51 East 4th Street #100
Winona, MN 55987