Appendix K
Regulating Works Project History

Early Navigation Improvements

Small settlements of colonists along the Middle Mississippi River (between the confluences of the Ohio River and the Missouri River (MMR)) had existed as early as the late 17th century, but rarely consisted of more than a few hundred settlers. Even St. Louis, which would become the largest of these MMR towns, held just over 1,000 people at the end of the 18th century. After the United States completed the Louisiana Purchase in 1803, the nation's territory nearly doubled in size, and the western portion of the Mississippi River Basin, which stretched north to the Mississippi headwaters in Minnesota and west to the Rocky Mountains, was now open for settlement. Moreover, the entire upper Mississippi River Valley, with its abundant reserve of natural resources, was now linked with the burgeoning commercial hub of New Orleans. Recognizing this potential, settlers rushed westward, hastened along by Federal land grants. Businessmen and commercial speculators recognized the potential, too, and soon farms, small towns, and budding businesses and industries dotted the valley.[1]

The invention of the steamboat further facilitated the growth of the region. Prior to the steamboat, residents of the upper Mississippi River Valley transported goods ranging from fur pelts, logs, ore, wheat, rice, corn, salt, axel grease, whiskey and cured meats on small vessels such as keelboats, flatboats, rafts, canoes, hollowed-out logs, and numerous other inefficient modes of transportation. The first steamboat made its debut on the western rivers in 1812, when the *New Orleans* arrived in its namesake city. On the lower Mississippi, steamboat traffic flourished, but above the mouth of the Ohio River, the draft of these early boats was still too deep and their engines underpowered for the upper Mississippi. It was not until 1817 that the first steamboat, the *Zebulon M. Pike*, arrived at the St. Louis Harbor. Still, it would take another 30 years before the MMR experienced the Golden Age of Steamboat transportation. The arrival of the steamboat did, however, highlight the need for river improvements. The shallow draft keelboats, flatboats and rafts simply did not necessitate major navigation improvements, but the arrival of steamboats, with their deeper drafts, did.[2]

The arrival of the steamboat also helped to accelerate economic and population growth in the region. When the *Pike* arrived, there were virtually no settlements along the river above St. Louis, yet by 1850, there were more than 100 towns. By the time Missouri was admitted to statehood in 1821, the population of St. Louis had grown to nearly 10,000. The commercial success of the city fostered the growth of manufacturing industries, followed by further population growth. By the time the Golden Age of the Steamboat arrived in 1850, the population had grown to nearly 80,000 and doubled again by the end of the decade. The growth of St. Louis

[1] Lee Sandlin, *Wicked River: The Mississippi When It Last Ran Wild* (New York: Pantheon Books, 2010), 3-21.
[2] Ronald D. Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers* (USACE Water Resources Support Center, National Waterways Study, 1983), 13-43.

was indicative of the growth of the entire upper Mississippi River valley, and the navigability of the river was vital to the economic and commercial success of the region.[3]

Even with the arrival of the steamboat, navigating the MMR was often a perilous endeavor. The wild fluctuation of river stages led to the formation of sandbars, caving banks and uprooted trees that clogged the channel. The river also contained rapids and falls, and high water currents that impeded safe navigation. During periods of low flow, navigation was not even possible on large sections of the MMR. Because of these obstructions, the average life of a steamboat was not more than a few years. Shoals caused vessels to become stuck; violent eddies ran vessels ashore; and low flows brought navigation to a halt altogether. With the rapid growth of communities that depended on the river for their economic livelihood, the need to ensure a more dependable navigation channel on the MMR became more pressing. At the national level, the emergence of steamboats led to a heated debate between state and federal governments over who had the right to regulate interstate commerce. The Supreme Court, in the landmark case of *Gibbons v. Ogden* in 1824, found that the Commerce Clause of the Constitution granted Congress the power to regulate interstate commerce, including the regulation of United States navigable waters for the purpose of commerce. This decision opened the way for the federal government to take on an active role in promoting navigation improvements and made possible the subsequent Rivers and Harbors Acts.[4]

Even before the landmark decision of the Supreme Court, Congress had authorized the Board of Engineers for Rivers and Harbors to conduct the first survey of the Mississippi River for the purpose of improving the river for navigation. Completed in 1821, the report recommended the continual removal of snags and the use of dikes to manage currents. The report also recommended experimenting with dikes to remove sandbars. Based on the recommendations of the report and the subsequent Supreme Court decision, on May 24, 1824 Congress passed the first Rivers and Harbors Act, which included authorization "to improve navigation of the Mississippi River from the mouth of the Missouri River to New Orleans" and authorized the President of the United States (carried out by the U.S. Army Corps of Engineers (the Corps)) "to take prompt and effectual measures for the removal of all trees which may be fixed in the bed of said river" and to remove any trees that "are found upon sand-bars, upon the points of islands, or near the bank of the river" and "at the lowest stage of the water, endanger the safety of navigating said rivers."[5]

Between 1824 and 1836, Congress appropriated just under $160,000 for navigation improvements for the Mississippi between the Missouri and Ohio rivers, the bulk of which improvements consisted of removing snags from the river and any trees that threatened to fall into the river due to erosion of the bankline. Henry Shreve, whom the Secretary of War had appointed Superintendent of Western River Improvements in 1828, developed a design for a

[3] *Ibid*.
[4] Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers*, pp. 13-43.
[5] U.S. Congress, House, *Report on the Act to Improve the Navigation of the Ohio and Mississippi Rivers*, H. Rep. 18-75 (18th Cong., 1st Session); U.S. Congress, House, *Message Concerning the Ohio and Mississippi Rivers*, H. Doc. 17-35 (17th Cong., 2nd Session), 4-14; Rivers and Harbors Act of May 24, 1824, 4 Stat. 32, 33.

"snagboat" that could remove the obstructions from the river. By the early 1830s, Shreve had almost completely cleared the existing snags from the MMR.[6]

Still, even with the menacing threat of snags removed, other more chronic threats (e.g. sandbars, rapids and falls, violent eddies, low flows, etc.) still plagued navigation. Removal of such impediments would require permanent improvements. The first such improvement occurred at St. Louis Harbor, where by the 1830s the river was shifting its current to the Illinois side and threatening to land-lock the budding city and its port. After examining the harbor, General Charles Gratiot, Chief of Engineers, suggested constructing a wing dam from the Illinois shore to the head of Bloody Island to force the current into the bar forming in front of the harbor. Gratiot asked a young Lieutenant named Robert E. Lee to carry out his plan. Lee arrived in St. Louis in 1837 and began surveying the harbor. Later he and his successors would oversee the construction of several dikes intended to divert the current back towards the Missouri side. Yet because of budget constraints, damages caused by floods and ice, and the outbreak of the Civil War, it would take decades before engineers finally completed the St. Louis Harbor project.[7]

The board of engineers for the Office of Western River Improvements recommended a comprehensive survey of the river between St. Louis and the mouth of the Ohio River so that a general system of improvement could be developed to remove sandbars that had formed and were troublesome for navigation. In response, Congress authorized an examination and survey of the Mississippi River between the mouths of the Missouri and Ohio rivers in Section 2 of the June 10, 1872 Rivers and Harbors Act, the law being the first to define this section of the Mississippi as distinct from the rest of the river. Upon completion of the survey in 1873, the board of engineers concluded that the demands of commerce would require a low-water width at St. Louis Harbor of no more than 1,200 to 1,500 feet, accomplished through the construction of solid dikes and dams of brush and stone to close side channels and confine the low-water flow to a single channel. Revetments of brush mattresses and stone paving would then need to be constructed to hold and preserve the banks from erosion.[8]

The Birth of the Regulating Works Project

The first appropriations specifically for the permanent improvement of the Mississippi between the mouths of the Missouri and Ohio rivers were approved by the March 3, 1873 Rivers and Harbors Act. The first major improvement was undertaken just below St. Louis at Horsetail Bar, historically one of the worst impediments to navigation during low water. Between 1873 and 1880, Congress appropriated just under $1.5 million for the project, with much of the money going toward minor improvements at several detached localities. Col. James H. Simpson, the officer in charge of the improvements, lamented that due to meager appropriations, "the improvement will occupy at least a century." In 1875, Simpson proposed a plan of permanent improvement that involved contracting the river to a width of about 2,500 feet by means of dikes

[6] Damon Manders and Brian Rentfro, *Engineers Far from Ordinary: The U.S. Army Corps of Engineers in St. Louis* (St. Louis: USACE-MVS, 2011), 30-38.
[7] Fredrick J. Dobney, *River Engineers on the Middle Mississippi* (Washington, D.C.: GPO, 1978), 17-34; U.S. Congress, House, *Harbor of St. Louis*, H.Doc. 25-298 (25th Congress, 2nd Session).
[8] *Annual Report of the Chief of Engineers*, 1873-1875.

and the closure of side channels. These improvements would limit the river to a single channel during low water, thereby using the natural energy of the river to scour the bed. Simpson's plan was also the first to recommend an eight-foot channel between St. Louis and the mouth of the Ohio River and a six-foot channel between St. Louis and the mouth of the Illinois River.[9]

In 1880 Maj. Oswald Ernst replaced Simpson as the officer in charge of overseeing the improvement of the MMR and voiced the same concerns Simpson had, namely, that at the rate appropriations were being authorized, the project would take over a century to complete. The stretch of river between the mouths of the Missouri and Ohio rivers had become the most commercially important section of the upper Mississippi, yet the channel had deteriorated substantially by 1880 due to the significant increase in the average width of the river because of the erosion of riverbanks and the degradation of the riverbed caused by changes in the watershed. By 1880 the width of the river at bankfull stage ranged from 4,000 to 7,000 feet, with an average width of 5,300 feet, more than 2,000 feet wider than in 1820. Low-water channel widths ranged from between as little as 125 feet to 3,600 feet, with depths ranging from 3.5 to 7 feet. These conditions made navigation of this commercially vital section of river at best extremely difficult and at worst brought commercial navigation to a complete halt. The Mississippi River Commission had recently completed reports on improving navigation on the Mississippi above the Missouri and below the Ohio, and by 1881 had completed a similar report on the MMR. The commission's report simply recommended the plan Simpson had developed in 1875, which consisted of using permanent improvements to contract the river to an average width of 2,500 feet between the dike ends, to be aided by dredging, if necessary; closing sloughs and side channels to direct flows into a single channel during low water; removing rock within the navigation channel; and stabilizing and protecting banks. By doing this, it was believed that an eight-foot channel could be maintained between St. Louis and the mouth of the Ohio River and a six-foot channel between the mouth of the Illinois River and St. Louis. The 1881 plan was similar to the plan adopted in 1872, with the major modification being the replacement of solid dikes and dams with permeable ones.[10]

The work over the next two decades was carried out primarily between St. Louis and approximately 70 miles below the city, with the general project scheme being to methodically extend construction downstream rather than make isolated improvements at far-flung locations. By 1890, the project was consistently maintaining an eight-foot depth from St. Louis to approximately 30 miles downstream at Lucas Crossing. Dredging and temporary works (e.g. moveable dikes, dams and revetment) for maintaining the navigation channel were approved in the Rivers and Harbors Act dated June 3, 1896, which authorized appropriations to be "expended in the construction of suitable dredge boats, portable jetties, and other suitable appliances, and in the maintenance and operation of the same, with the view of ultimately obtaining and maintaining a navigable channel for St. Louis to Cairo not less than 250 feet in width and nine feet in depth at all periods of the year except when navigation of the river is closed by ice." Although the act did not authorize the construction of permanent improvements, also called

[9] *Annual Report of the Chief of Engineers,* 1875-1877.
[10] 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 Congress, 1st session); *Annual Report of the Chief of Engineers,* 1875.

regulating works, to obtain and maintain a nine-foot channel, temporary works, including dredging, were now authorized to achieve such a depth. The shift towards temporary means to maintain the authorized navigation channel reflects the impatience of Congress with a long-term investment that could take decades or even more than a century to complete.[11]

The Dredging Only Experiment and the Decline of New Construction

In the Rivers and Harbors Act dated June 13, 1902, the project continued its shift towards greater reliance on dredging. In addition to authorizing appropriations for contracts to continue to carry on the systematic improvement of the MMR, the act authorized the temporary removal of one or more dredges in use below Cairo and under control of the Mississippi River Commission for use on the MMR. Section 3 of the act established the Board of Engineers for Rivers and Harbors, which the House Committee on Rivers and Harbors immediately tasked with putting together a report on whether dredging or any other means of maintaining the authorized channel could be employed at less cost than the existing project. The report, which the board submitted to the committee on November 12, 1903, recommended that the project continue to use regulating works to maintain the authorized channel dimensions, but suggested that it was reasonably probable that such a channel could be maintained at a lesser cost through the use of dredging alone. In order to determine if it was practicable to maintain the channel through dredging alone, the board recommended extensive dredging and very limited work on permanent improvements. After a trial period in which data could be obtained on the efficacy and cost of extensive dredging, the board would reevaluate the project and make a determination of the best means to maintain the authorized channel. The lone dissenter of this plan was the St. Louis District Engineer, Maj. Edward Burr, who argued that although dredging was necessary and should be continued, it should be relegated to an auxiliary role to supplement the permanent improvement through regulated works, which were so far superior to dredging in maintaining a low-water channel that they should be pursued even if the cost is greater. Nonetheless, Congress authorized the board's recommendations in the Rivers and Harbors Act dated March 3, 1905. However, construction and maintenance of existing works was not brought to a complete halt, as Congress, by Joint Resolution dated June 29, 1906, authorized the Secretary of War, "in his discretion, to expend any portion of the balance now remaining…for the repair or completion of improvements already underway or for the construction of other works in accordance with general plans already made or approved."[12]

Congress reaffirmed its commitment to dredging with the Rivers and Harbors Act dated March 2, 1907, which provided for the sums appropriated to "be expended in the operation and maintenance of the dredging plant already constructed and authorized for improvement, and in temporary expedients of channel regulation connected with such operation, and in the maintenance and repair of the permanent works already constructed, except that such portion of the authorized annual expenditure as shall not be necessary for the accomplishment of the above-named purposes may be expended in the construction of permanent works of channel

[11] *Annual Report of the Chief of Engineers*, 1882-1903.
[12] U.S. Cong., *Report of the Board of Engineers for Rivers and Harbors Submitted November 12, 1903*, H. Doc. 168, (58th Cong. 2d Sess.).

regulation." In other words, appropriations were to be used first for dredging and whatever funds remained could be applied to the construction of permanent improvements.

The dredging experiment was of limited success, increasing the minimum channel depth from six feet to eight feet by 1907. However, the conditions of the MMR varied greatly from those below the mouth of the Ohio, where dredging had been highly successful. The Ohio River flows reduce the concentration of sediment in the lower Mississippi, making dredging more practicable. Moreover, low flows below the Ohio were less severe. On the MMR, the more frequent and extreme occurrence of low flows combined with the high concentration of sediment contributed by the Missouri River produced conditions that were not practicable for maintaining a navigable channel through dredging alone. It could be done, no doubt, but numerous dredges would be required and would need to remain in constant use to remove the continuously accumulating sediment. If permanent improvements were completed, much of this sediment would not accumulate at all and dredging could be limited to a few troublesome areas. Because the dredging experiment was not achieving the desired results, Congress authorized a special board of five engineers to evaluate what depth would be most practicable for maintaining a low-water navigation channel by means of permanent improvements. The same report also included an evaluation of the feasibility and practicability of a 14-foot channel from the Great Lakes to the mouth of the Mississippi. The board determined that an eight-foot channel would be sufficient for the MMR given the current amount of commerce, and such a depth would be best obtained and maintained through the construction of permanent improvements, with dredging being used as a supplement to permanent improvements. Congressed authorized the board's recommendations in the Rivers and Harbors Act dated June 25, 1910, which restored the 1881 MMR navigation channel project to be obtained and maintained through bank stabilization, the construction of regulating works, rock removal, and aided by dredging, if necessary, with a view of completing new works in 12 years at an estimated cost of $21 million additional new construction (commonly referred to as the Regulating Works Project).[13]

Despite continued economic growth in the region, commercial navigation began a steady decline in the last decade of the nineteenth century, a decline that continued until 1920. The decline was due to two factors: 1) the continued expansion of rail transportation; and 2) the lack of a reliable navigation channel for waterborne commerce. Between 1904 and 1919, the annual tonnage ranged from between 470,093 tons to 191,965 tons, whereas annual tonnage was consistently over 1 million annually prior to 1898, with annual tonnage surpassing 2 million six times. U.S. entrance into World War I further decreased tonnage because there were simply not enough men to load and man the vessels. The nation's capacity for producing goods continued to increase, but its ability to effectively ship these goods to markets was inhibited by an inadequate inland waterways system. Between 1911 and 1918, Congress appropriated just $3.8 million total to cover construction of new regulating works, maintenance of existing works, and dredging. Such a paucity of funds was not even enough to cover the cost of repairing existing works, much less fund the construction of new permanent improvements. The 1910 Act may have reasserted the 1881 project's commitment to permanent improvements, but construction of new works

[13] 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 a View to Obtaining a Channel 14 feet Deep and of Suitable Width*, H.D. 50 (61st Cong., 1st Sess.); Rivers and Harbors Act of June 25, 1910, Pub. L. No. 61-262, 36 Stat. 630.

remained stagnant. In total, the project lost nearly two decades of construction on permanent improvements and many of the existing works had fallen into disrepair.[14]

By the 1920s, Congress's appreciation for waterborne commerce began to grow. World War I had placed great pressure on the nation's transportation systems and exposed the inadequacy of railroads and the infant trucking industry for meeting commercial demands. Moreover, the opening of the Panama Canal in 1914 opened the eyes of people in the Midwest to the need for a healthy river transportation system, as the canal boosted commerce along the east and west coasts at the expense of Mississippi River commerce. To help stimulate a revival of commercial navigation between St. Louis and New Orleans, Congress created a federal barge line (the Mississippi-Warrior River line) and spent more than $8 million on equipment to restore "the Mississippi to the status of a great freight-carrying waterway." Consequently, commerce increased dramatically at St. Louis, with its value rising from $22.6 million in 1919 to $47.4 million in 1921. Nonetheless, although interest in waterborne commerce had revived, interest in funding the improvements necessary to sustain this commercial growth had not revived. Throughout most of the 1920s, appropriations for permanent improvements on the MMR were almost non-existent, meaning most of the work done consisted of maintenance on existing regulating works and very little construction of new ones.[15]

Birth of the Modern Project

Even though funding for the construction of new regulating works was sparse, many in Congress began to recognize the national importance of waterborne commerce on the MMR. When navigation improvements for the MMR were first authorized, most of the beneficiaries were small farmers and businessmen. By the 1920s, many of the small yeoman farmers had been replaced 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 nine-foot navigation channel above the mouth of the Ohio. 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 Mississippi River between the mouth of the Ohio River and St. Louis. The report, submitted to Congress in December of 1926, cited "interruptions to the work of contraction, due to reliance upon dredging, [and] meager appropriations"–between 1910 and 1925, only $2,592,920 had been appropriated for new work–as the reason why just one-third of the necessary works had been completed. St. Louis District Engineer, Maj. John Gotwals, explained that the nature of the bed of the 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." He stated that "[a]t many of the crossings where continuous dredging was necessary in the past the regulating works have provided an adequate channel

[14] Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers*, 75-94; *Annual Report of the Chief of Engineers*, 1910-1920; Dobney, *River Engineers on the Middle Mississippi*, 65-77.
[15] *Ibid*.; *Annual Report of the Chief of Engineers*, 1921.

where no dredging is now necessary. 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." Unsurprisingly, 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. He further recommended 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." The division engineer, the board of engineers for rivers and harbors, and the chief of engineers all concurred on Maj. Gotwals recommendations for how the project was to be carried out moving forward with a modification in the project's authorized dimensions. However, Maj. Gotwals estimated that funding to complete the project would total $31 million with only $6.1 million appropriated to date for new work. The division engineer concurred, and the board of engineers for rivers and harbors also concurred with the estimate, but the board noted that not all of this funding may be needed:

> It is not improbable, however, that the project may be completed with less than this expenditure if adequate funds are made available as needed. . . . The nature of the problem is such, due to uncertainties of flow and the natural instability of the river, that it is believed advisable to use as the estimated cost, $31,000,000. Particular emphasis is given to the necessity of providing funds in such amounts and at such times as needed.

The chief of engineers thought it unwise to authorize an increase in funding until the need for such increase was ripe, and thus did not recommend a change to the overall estimated cost for completion of the Project. Congress approved the recommendations of the Chief of Engineers, modifying the Regulating Works Project to provide for a nine-foot deep, 300-foot-wide channel, with additional width in bends, between the mouth of the Ohio River and the northern boundary of the city of St. Louis in the Rivers and Harbors Act dated January 21, 1927 with no noted change in the estimated project cost of $21 million.[16]

While Congress was busy reviewing the report on the proposed nine-foot navigation channel between St. Louis and the mouth of the Ohio River, the St. Louis District (the District) was studying the feasibility of a nine-foot channel between St. Louis and Grafton, Illinois, where the Illinois River enters the Mississippi. Congress had already authorized a nine-foot channel on the Illinois River from Grafton to Utica, Illinois, in the same act that authorized the nine-foot channel on the MMR below St. Louis, so expanding the nine-foot channel all the way to the mouth of the Illinois River was a logical conclusion. Congress had also recently requested a study of a nine-foot channel on the Mississippi River above Grafton and an expansion of the nine-foot project on the Illinois River all the way to the headwaters of that river, which was authorized in 1930. Accordingly, the report on the feasibility and advisability of a nine-foot-deep, 200-foot-wide channel from St. Louis to Grafton–which stretch of river includes the section of the Regulating Works Project between St. Louis and the mouth of the Missouri River–

[16] U.S. Cong., *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*, H. Doc. No. 9 (69th Cong., Second Sess.); Rivers and Harbors Act of Jan. 21, 1927, Pub. L. No. 69-560, 44 Stat. 1010.

recommended this modification to the project, which Congress authorized in the Rivers and Harbors Act dated July 3, 1930 along with additional appropriations for new work estimated in the amount of $1.5 million.[17] As of 1931, $21.1 million had been expended on new work since 1910, and the Chief of Engineers Annual Report for 1931 provided a new estimate of overall cost for new work at $35,650,000, noting that the project was considered 61% complete.

Congress's ultimate vision in the authorization of multiple projects to obtain a nine-foot channel over the entire course of the Mississippi and Illinois rivers was to create an inland waterway connecting Lake Michigan with the mouth of the Mississippi at New Orleans. With its central location connecting the Illinois River and the upper and lower portions of the Mississippi, the MMR was the critical lynchpin for the Mississippi River basin navigation system. While the nation was gripped in the throes of the Great Depression, one of the few sectors that thrived was civil works construction. In an attempt to reinvigorate the economy and create jobs, Congress authorized massive appropriations for public works projects through the Public Works Administration, Works Progress Administration and the Emergency Relief Appropriations Act, all of which included generous funding for the construction of permanent navigation improvements for the Regulating Works Project. Moreover, because of the low cost of labor during the Great Depression, the work could be completed for less. From 1931-1944 approximately $27 million was appropriated for construction and O&M of the Regulating Works Project, with approximately $18 million of that being for new work. In the 1933 Chief of Engineers Annual Report it was stated that $25 million had been expended for new work with an estimated cost of $6.4 million to complete the project, increasing the overall estimate of new work for completion to $43 million. In 1944 the Chief of Engineers Annual Report indicated that $37.2 million had been expended overall and that the project was considered 86% complete with another $5 million required for completion. [18]

In addition to the influx of appropriations during the 1930s, the need to accelerate construction was elucidated by the extreme droughts of the decade. Between 1930 and 1940, the MMR saw severe low water in 1930-1934, 1937 and 1940, the later year producing a record low of -6.2 on the St. Louis gage, which still stands as the record low. The positive consequence of the low flows was that they provided engineers the opportunity to analyze the efficacy of the regulating works. By 1934, engineering analysis had revealed that the river would require additional contraction to 1,800 feet in order to maintain the authorized channel, which increased the total estimate to complete the Regulating Works Project to $43 million. In addition to new construction being necessary to further contract the channel, a good number of existing works had deteriorated–this was especially true of timber pile dikes–or had been completely destroyed by ice and floods, or were only partially completed. Much of the work completed during the early stages of the project was very experimental in nature, that is to say, because river engineers lacked the model studies and technologies of later generations, often the only way for river

[17] Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers*, 75-94; 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.).
[18] *Annual Report of the Chief of Engineers*, 1930-1944; USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works* (St. Louis: MVS, April 1976); Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers*, 75-94; Dobney, *River Engineers on the Middle Mississippi*, 89-102 .

engineers to know what methods and designs were most effective was to observe the reaction of the river to regulating works and then modify them as necessary. Consequently, few dike fields were ever truly complete because if engineering analysis revealed that the river required further contraction or a different design to maintain the authorized channel, existing dikes would need to be modified or extended. As a result, the project evolved over the decades, always seeking the same end of maintaining the authorized navigation channel through the construction of regulating works and revetment to minimize costly dredging, but adjusting the implementation of regulating works to most effectively maintain the channel.[19]

Addressing Chain of Rocks and Adjusting Implementation of the Project Plan

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, even though the MMR was in the midst of an extreme low-water period, in 1934 the District was able to adjust the project low-water flow from 40,000 cfs to 54,000 cfs due to the expected planned releases from the soon to be completed Fort Peck Dam on the Missouri River. 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 at an estimated cost of $10,290,000.[20]

[19] *Ibid*.

[20] *Annual Report of the Chief of Engineers*, 1930-1954; 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); and USACE-MVS, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154* (St. Louis: MVS, May 1971).

As indicated above, 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 existing 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. In the Chief of Engineers Annual Report for 1958, the total estimated cost for all new work for the Project since 1910 (including the Chain of Rocks Canal and Locks No. 27) was $102,828,000 with the Project being considered 82% complete.[21]

Use of Stone Dikes and Increased Channel Contraction

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 in an estimated construction amount of $5,810,000. 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 both the 1881 Plan and 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

[21] Dobney, *River Engineers on the Middle Mississippi*, 89-122; *Annual Report of the Chief of Engineers*, 1930-1958.

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. The Chief of Engineers Annual Report in 1964 explained that the total cost of new work for the Regulating Works Project was now $112,253,000 ($64.9 million total for regulating works, $4,353,000 for the low water dam at Chain of Rocks, and $43 million to complete the work at Chain of Rocks Canal and Locks 27) with $86.5 million total appropriated, noting the Project was considered 87% complete. [22]

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.[23]

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 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

[22] Dobney, *River Engineers on the Middle Mississippi*, 89-122; *Annual Report of the Chief of Engineers*, 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).
[23] *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

permanent navigation improvements for a particularly treacherous 13-mile reach known as Devil's Island, model studies of which began at WES in 1969.[24]

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 40,000 cfs. In other words, the contraction produced a deeper channel than was required. The study concluded that using a 54,000 cfs 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. Between 1960 and 1974 while the timber pile dikes were being replaced with stone, the total estimated cost for new construction rose gradually up to $81 million for regulating works features as of 1973, considering the project to be 81% complete. With the results of the prototype study in 1974, this figure increased to $142 million for completion of the regulating works portion of the overall project, and the Project was now considered only 48% complete. 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 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. Based upon these further analyses, as of 1977 the total estimated cost of new work was $154.6 million, and the Project was considered 77% complete.[25]

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 and/or avoid or minimize 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

[24] *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*.
[25] *Ibid*.; *Annual Report of the Chief of Engineers*, 1967-1978; 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).

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 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.[26]

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.[27]

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 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.[28]

During the process of preparing the above, it was determined that without specific authority for fish and wildlife management the District was limited in what it could do within the

[26] USACE-MVS, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works*; Manders and Rentfro, *Engineers Far from Ordinary: The U.S. Army Corps of Engineers in St. Louis*, 124-133, 355-369.

[27] USACE-WES, *Study Plan for an 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)

[28] 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).

Regulating Works Project funding to achieve any meaningful results, and the District was coordinating with USFWS and state resource agencies to prepare a Post-Authorization Change Report to add this purpose to the Project. In March of 1976 as the EIS was being completed for approval, USFWS notified the District that they could not provide the necessary benefit data needed for completing the Post-Authorization Change Report due to philosophical differences of opinion as to the propriety of assigning benefits to the measures, the lack of manpower to accomplish this task, and finally, due to their long-held opinion that mitigation lands are justified for the Project. USFWS presented the District with a proposal to attempt to accomplish some of the environmental benefits pursuant to mitigation studies under the Fish & Wildlife Coordination Act (FWCA). When the Environmental River Engineering Program was first established in the early 1970's, the District had dismissed this possibility because the Regulating Works Project was 82% complete when the FWCA was enacted in 1958, so by the terms of the act it was not applicable to the Regulating Works Project (pursuant to the FWCA it was not applicable to Projects that were more than 60% complete when enacted). As discussed above, because of the shift from pile dikes to stone dikes as well as the increase in linear feet of dike and revetment work pursuant to the Prototype Study during the 1960's and early 1970's, the total estimated costs to complete construction of the Regulating Works Project increased in the mid-70's, reducing the estimated percentage completion below 60% to 48% in the 1973 Chief of Engineers Annual Report. The District inquired to the Division and Headquarters offices with a memorandum laying out the facts and asking for a determination on USFWS's proposal. The Division office concluded, and Headquarters concurred, that the change in price levels and increased work requirement did not make the project now applicable to the FWCA. Since the FWCA was not applicable to the Project in 1958, the Act does not provide for subsequent inclusion or exclusion based upon these types of changes. Further, while not mentioned in the memorandums, with the decrease in Project completion in 1973, the Project went back up to being more than 60% complete in 1976 once final plans from the prototype study were refined. After this guidance was received, the District continued to pursue a PAC, but by 1979 the District noted that this process had been slow since the 1976 FWCA guidance and that the District, USFWS, and state resource agencies had shifted focus on trying to establish the PAC through the pending GREAT River Study Efforts, specifically the GREAT III portion (described below).[29]

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

[29] USACE Memorandum executed by Col. Thorwald R. Peterson, District Engineer, St. Louis District, subject: Fish and Wildlife Coordination – Mississippi River between the Ohio and Missouri Rivers – Regulating Works, 5 April 1976 (The following attached: USACE Memorandum executed by Maj. Gen. F.P. Koisch, Division Engineer, Lower Mississippi Valley Division, subject: Fish and Wildlife Coordination – Mississippi River between the Ohio and Missouri Rivers – Regulating Works, 28 May 1976 and USACE Memorandum executed by LTC J.P. Campbell, Asst. Director of Civil Works Environmental Programs, subject: Fish and Wildlife Coordination – Mississippi River between the Ohio and Missouri Rivers – Regulating Works, 31 August 1976); and USACE Memorandum executed by Arthur L. Johnson, Acting Chief, Engineering Division, for the District Engineer, St. Louis District, subject: Fish and Wildlife Mitigation, 9 January 1979 (Fact Sheet and Clarification Data enclosed); *Annual Report of the Chief of Engineers* 1958 and 1973-77.

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 District's portion referred to as GREAT II, and St. Louis District's portion referred to as GREAT III). The first recommendation of GREAT III was that a program be initiated to modify, design, and evaluate regulating works structures to benefit aquatic resources in the MMR.[30]

In 1978 the Inland Waterways Authorization Act (PL 95-502) authorized the UMRBC in cooperation with multiple Federal, state, and local officials to prepare a Comprehensive Master Plan for Management of the Upper Mississippi River System (Master Plan). This was a large scale study of the Upper Mississippi River System defined by the study authorization as those river reaches containing commercial navigation channels on the Mississippi River main stem north of Cairo, Illinois; the Minnesota River, Minnesota; the Black River, Wisconsin; Saint Croix River, Minnesota and Wisconsin; Illinois River and Waterway, Illinois; and Kaskaskia River, Illinois (UMRS). The Master Plan was submitted to Congress in December 1981 with an accompanying EIS. Congress initiated this study as a result of disagreement with the District's request to expand Lock and Dam 26, following a lawsuit for such expansion by conservation organizations and the railroad industry. The Congressional compromise was that no further navigation expansion activities could take place until this Master Plan providing information on the environmental, economic, and recreational status of the UMRS was completed.[31]

Environmental Authority Programs

In WRDA 1986, § 1103 (33 USC § 652), Congress passed the Upper Mississippi River Management Act of 1986, recognizing the UMRS 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. 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 providing a broad authorization of everything recommended in the Master 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 of the system to be carried out by the Corps, in consultation with the USFWS and the respective states. Projects carried out under this authority require a cost-share sponsor pursuant to Section 906(e) of WRDA 1986. See the following website for details on the success of this program along with all supporting documentation for this program: http://www.mvr.usace.army.mil/Missions/Environmental-Protection-and-Restoration/Upper-Mississippi-River-Restoration/About-Us/. As of 2017, there

[30] 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.
[31] *See* http://www.umrba.org/masterplan.htm for a history of the Master Plan as well as a link to the document.

has not yet been a completed UMRR project in the MMR, but in recent years, efforts have been made to develop more UMRR projects in the MMR. Currently, the District is working on the following:

- Crains Island Habitat Rehabilitation & Enhancement Project, Randolph County, IL, RM 103.5-105.5; Sponsor: USFWS. Feasibility study underway for the restoration of 553 acres of forest, wetland, and side channel habitat for fish & wildlife. The feasibility study is currently in District Quality Control review moving towards completing the study during 2017. Once approved, the District would have the ability to start engineering design with a potential construction award in 2018.
- Harlow Island Habitat Rehabilitation & Enhancement Project, Jefferson County, MO, RM 140.5-144; Sponsor: USFWS. Feasibility study underway for the restoration of 1225 acres of forest, wetland, and back water habitat for fish & wildlife. Once the Crains Island study makes it through all reviews and with receipt of funding, this feasibility study will begin progressing. The study is estimated to be complete in 2018, engineering design in 2019, and construction in 2020.
- Oakwood Bottoms Habitat Rehabilitation & Enhancement Project, Jackson County, IL, RM 73-84; Sponsor: U.S. Forest Service. Feasibility study underway for the restoration of 13,500 acres of forest and wetland habitat for fish & wildlife. Study estimated to be completed in 2020, engineering design in 2021, and construction in 2022.
- Wilkinson Island Habitat Rehabilitation & Enhancement Project, Perry County, MO & Jackson County, IL, RM 88.5-90; Sponsor: USFWS. Feasibility study underway for the restoration of 2700 acres of forest, wetland, and back water habitat for fish & wildlife. The feasibility study is lagging the Harlow Island project, once Harlow Island makes it through all reviews, Wilkinson will start making progress (pending funding availability). Study estimated to be completed in 2019, engineering design 2020, and construction in 2021.
- Horseshoe Lake Habitat Rehabilitation & Enhancement Project, Alexander County, IL, RM 34-38; Sponsor: IDNR. Potential restoration of forest and wetland in beginning stages of development.
- Schenimann Chute Habitat Rehabilitation & Enhancement Project, Cape Girardeau County, MO; Sponsor: MDC. Potential restoration of side channel in beginning stages of development (this was formerly a NESP project that is now being considered under UMRR due to lack of funding for NESP).

Congress also authorized in Section 1103 of WRDA 1986 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 authority for the Navigation and Ecosystem Sustainability Program (NESP) (described below).[32]

Also in WRDA 1986, § 906 (33 USC § 2283), 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 on funding and land acquisition, to implement mitigation measures for those projects already completed or currently under construction as of the passing of WRDA 1986. However, due to funding limitations and the Corps' ability to do environmental work for completed projects under other environmental restoration and completed project modification authorities, the Corps has not applied Section 906(b) to completed projects.[33] The funding for mitigation is to be allocated from the project's purposes and cost-shared according to the project's authorization.

Another environmental authority granted by Congress in WRDA 1986 was Section 1135 (33 USC § 2309a), which provided the authority to study and implement the modification of structures and operations of projects already constructed if feasible and consistent with authorized project purposes to improve the quality of the environment. Any modification under this authority, requires a cost share of 25%.

Congress also expanded the Corps' general environmental authority in WRDA 1990 and WRDA 1992 by providing as policy 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 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, § 1103, 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 and were to be carried out concurrently. However, funding for NESP has not been provided in recent years, and it is currently not expected to be funded. The work done under NESP in the MMR with the funding received to date includes the following:

- Herculaneum Wing Dike Alteration RM 155-151. Project evaluated modifying dikes and placement of innovative river training structures for the purpose of creating secondary channels and improving habitat diversity within the existing

[32] *See also*, H. Conf. Rpt. 99-1013; S. Rpt. 99-126; and H. Rpt. 99-251 for additional details on this legislation.
[33] *See* Engineering Regulation 1105-2-100, App. C and Engineering Pamphlet 1165-2-1.

channel. Tentatively selected project included creation of a series of chevron dikes, dike notching, dike removal, and dike shortening. Project had completed public review prior to suspension of the NESP Program

- Buffalo Chute Side Channel Restoration, RM 26-24. Project called for the notching of two dikes within Buffalo Chute, the placement of two small stub dikes near the lower end of the chute, and placement of woody structure within the chute. Project purpose was to improve side channel connectivity with the main channel, to allow seasonal fisheries access to overwintering habitat and improve overall habitat diversity within the chute. Project was preparing for public review at the point of suspension of the NESP Program.
- Schenimann Chute Side Channel Restoration, RM 62-57. Project goals were to increase connectivity with the main channel during low flows, improve depths within the side channel, and increase duration of seasonal flows within the side channel. Project had started planning under previous programs and was restarting project planning under NESP when program was suspended. Project now in consideration under UMRR as well as other programs.

None of the legislation since 1976 modified the Regulating Works Project specifically or provided a PAC to the project as described in the EIS so that Project construction funding could be used to restore, enhance, and protect fish and wildlife. There was direct Congressional authorization in Section 5099 of WRDA 2007. However, there were two major issues with this legislation for it to provide the authority to use Regulating Works construction funding for ecosystem restoration and enhancement projects. First of all, the final legislation changed the words "construction" in preliminary versions to "operation and maintenance" – thus implying that only operation and maintenance funding on the Project could be used for these activities rather than construction funding. Further, Corps implementation guidance stated that this authority already exists for the MMR pursuant to the UMRR Program and NESP, and it indicated that these Programs should be utilized for such projects rather than as part of the Regulating Works Project. Further, the Corps implementation guidance indicated that Congress would need to appropriate specific funding under the Regulating Works Project to utilize funding for these projects and at that time additional implementation guidance would be provided. It is expected due to the Corps' authority for ecosystem restoration projects provided in WRDA 1986 as well as Corps policy for its ecosystem restoration authority, any future guidance for projects specifically funded under WRDA 2007, § 5099 would require a project cost share sponsor (See 33 USC §§ 2213(c)(7) and (e)). This expectation was further confirmed with implementation guidance received on November 4, 2015 for the Water Resources Reform and Development Act of 2014 (WRRDA 2014), § 4002(b). This recent legislation authorized that in accordance with the project for navigation under the authorities for the Regulating Works Project, the Corps may study improvements to navigation and aquatic ecosystem restoration in the MMR. The Corps was authorized to carry out projects identified in such study in accordance with the criteria under the Corps' existing continuing authorities for aquatic ecosystem restoration (33 USC § 2330), project modification for the environment (33 USC § 2309a (WRDA 1986, §1135 described above)), small navigation projects (33 USC § 577), or control of aquatic plant growths (33 USC § 610a). If an identified project does not meet the criteria for these authorities, then the project should be forwarded to Congress in the annual report required in Section 7001 of WRRDA 2014.

The implementation guidance provided for WRRDA 2014, § 4002(b) indicated that specific appropriations would be required (as opposed to using Regulating Works Project construction funding) and that the study for aquatic ecosystem restoration was to be cost-shared 50%. Further, the guidance indicated that any identified project from such study meeting the criteria of other authorizations should be converted to that authorization and follow the same process for funding, planning, and implementation for such existing program, which all of these for environmental purposes require a cost-share sponsor.

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 28). 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 (for both new construction and operation and maintenance), as well as the discretion to mitigate for any adverse impacts caused by the Project through avoidance, minimization, and if necessary, compensation for new construction work.

Therefore, elaborating on the process started in the 1970's and working in close consultation with USFWS and state resource agencies, District river engineers began designing various environmentally friendly river engineering structures in an effort to increase habitat diversity and the ecological health of the river by avoiding and minimizing the Project's impacts, all while meeting the authorized navigation mission of the project. These design adjustments 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 modifications to river training structure designs, which provided a less costly, yet still scientific, approach of analyzing flow and sedimentation movement with placement, modification, and removal of structures.. In 1995, the District established the Applied River Engineering Center to conduct applied river engineering in an office laboratory environment. The center coordinates with local and environmental interests, such as the Missouri Department of Conservation, the Illinois Department of Natural Resources, and the USFWS, in the design, development, and implementation of structures to be constructed as well as operation and maintenance on existing structures. This includes removing or notching structures in an area where new structures are being placed to increase flow into side channels or re-establish habitat lost from those structures, avoiding certain areas identified by the agencies as important fish and wildlife habitat, and testing multiple designs, configurations, and placement of structures to alleviate the dredging problem while also not impacting side channels and other desirable fish and wildlife habitat identified by the agencies. The District's efforts have resulted in the construction of numerous environmentally modified regulating works as well as modification or removal of existing structures, including notched dike and notched closure structures, off-bank revetment, chevrons, hard/round points, W-dikes, and diverter dikes.

In 1992 the Corps established the Avoid & Minimize Program to reduce possible environmental impacts of increased navigation traffic on the Mississippi River due to construction of a second lock at Melvin Price Locks and Dam as a result of the publication of

Design Memorandum No. 24, "Avoid and Minimize Measures, Melvin Price Locks and Dam, Upper Mississippi River – Missouri and Illinois" (Design Memorandum). The Design Memorandum was developed as a commitment made in the 1988 Record of Decision attached to the Melvin Price Locks and Dam EIS for the Second Lock. From the Design Memorandum, the following measures for implementation were recommended:

Number	Measure
A-3	Designate locks approach waiting areas – provide on-bank anchor points or mooring buoys
A-10	Reduce open water dredge disposal – create recreation beaches
A-11	Reduce open water dredge material disposal – create wetlands
A-13	Place dredge material in the thalweg.
A-16.	Continue dike configuration studies (i.e., notched dikes, chevron dikes and bullnose dikes)
A-17	Place off-bank revetment on islands
A-19	Monitor bendway weirs
B-8	Study reduction of tow waiting time

Because the increased navigation traffic was expected in both the MMR and in the Upper Mississippi River within the District, the Avoid & Minimize Program was applied to both projects. To date there have been seven areas in the MMR that have altered or constructed river training structures to meet the measures identified in the Design Memorandum (Cliff Cave-Kimmswick RM 162; Union Point/Wilson Landing RM 75; Jones Chute RM 96-95; Unnamed Island adjacent to Jefferson Barracks Chute RM 166; Santa Fe Chute RM 39.5-35; Marquette Chute RM 51; and Owl Creek RM 85.9-84).

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 USFWS 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 USFWS's recommendations provided in the Biological Opinion. Therefore, the District continued coordination with the USFWS 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 and reducing costly dredging, 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 environmental purposes to restore habitat for the pallid sturgeon and least tern in the MMR using the operation and maintenance funding received for Biological Opinion compliance. 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.

As part of the overall evaluation and analysis for the SEIS, recent data and information show that these structures and the modification or removal of existing structures are performing as intended to avoid and minimize adverse environmental impacts for the construction of regulating works.[34] These avoidance and minimization measures, along with the other environmental projects completed in the MMR with Regulating Works Project operation and maintenance funding under the Biological Opinion and the Avoid and Minimize Program, have resulted in the MMR not being in the dire environmental state predicted in the 1976 EIS.

Today's Regulating Works Project

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 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 would be modified to maintain greater habitat diversity to avoid and minimize impacts while the lengthening was taking place. In addition to all of this, there were still numerous sections of river that required the construction of new dike fields and revetment to meet the Project purpose. Further, additional rock removal requirements were identified following the drought in 1988-89. By the end of the 1980's, the estimated cost of total project construction had increased to nearly $200 million with the Project being estimated at 77% complete.[35]

Addressing Troublesome MMR Bends

Bendway Weirs. 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

[34] Manders and Rentfro, *Engineers Far from Ordinary*, 124-133, 355-369; USACE-MVS, *Environmental River Engineering on the Mississippi* (St. Louis: MVS, 1995).
[35] *Annual Report of the Chief of Engineers*, 1989.

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 (such as flanking), decreasing accidents and delays. Further, the bendway weirs reduced the need for costly dredging in these areas. After the successful implementation of bendway weirs in Dogtooth Bend, the design methods were further refined and the structures were constructed in many different bends within the MMR. In each instance, the weirs reduced or eliminated dredging in the bends and reduced transit times, accidents, and delays. 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.[36] From the late 1990's until 2009, the estimated total construction cost of the overall Project was around $270 million.[37]

Potential Channel Cutoff Issues. Another issue that arose in the MMR was severe erosion near bends, having the potential to form a channel cutoff from the bend, thus potentially 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. In the future, continued maintenance will be needed on the tree screens, so they don't become overgrown or die off. Also, large amounts of woody debris have deposited in the Thompson Bend area during high flow events, limiting tree screen growth. Ways of reducing woody debris concentration will also need to be investigated for the long-term re-establishment in this area.[38]

During the winter flood of 2015/2016 the Len Small Levee overtopped and eventually failed. Due to the proximity of the levee to the river bankline and the fact that there was not a competent riparian corridor, 1,000 feet of bankline was lost and a large scour hole formed landside of the levee. This posed a significant issue to the MMR navigation channel because if the bankline was not repaired, a channel cutoff could potentially form, shortening the river by 13.5 miles and inducing a headcut through the system. Repairs to the bankline were completed in early spring of 2016, and a contract was awarded to stabilize the highest priority locations along the scour hole to reduce the overall advancement of the scour hole. During the design process and working with natural resource agencies and landowners, the District implemented avoid and minimize measures to ensure that there were minimal impacts to the environment during the repairs. Additionally, the District wanted to use the natural river processes to stabilize the scour hole by letting it naturally silt in and allow for the re-establishment of native plants for increased roughness, decreasing the ability for a channel cutoff to form at a later time. This methodology was successful post-1993 flood at a breach just upstream of this most recent

[36] *Ibid*. at 126-128.
[37] *Annual Report of the Chief of Engineers*, 1990-2008.
[38] *See* USACE, Dry Bayou-Thompson Bend Report, St. Louis District (May 2013) found at http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx.

bankline failure. Currently, there are proposals for the levee to be replaced; however, if the levee is not replaced, additional measures to protect the navigation channel may become necessary.[39]

Droughts and Rock Removal

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. A significant amount of work had been completed since that low-water period five decades prior, so the drought offered one of the first major tests of the modern project. With the aid of dredging, the District was able to maintain the authorized navigation channel throughout much of the drought. However, remaining multiple rock outcrops from previous rock removal efforts in the 1920's, 1960's and 1980's were discovered protruding from the riverbed at Thebes, Grand Tower, Grays Point, Commerce and Counterfeit Rock, forcing the Coast Guard to limit the drafts of vessels to less than nine feet. [40] 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 the removal of approximately 200,000 cubic yards of the rock material that significantly impacted the navigation channel between 1988 and 1990.

In 2006, District river engineers began using multi-beam technology to survey Thebes and for the first time were able to make an accurate assessment of how much rock was there, where it was, and just how far it extended from the riverbed. The survey found approximately 6,700 cubic yards of material, much of which consisted of Ordovician aged limestones in the form of boulders and pinnacles. Recognizing that the remaining rock formations could produce potential problems for navigation in the future, the District began seeking funding to remove the rock. Because of budget constraints and lack of interest by stakeholders, no funds were available. Although a rock removal project was essentially placed on the back burner for the time being, District river engineers were able to use the recently-acquired data to prepare a plan for when funds became available and also for when the next low water event should strike. Therefore, drought contingency planning for removal of the rock pinnacles actually began as early as 2006. Between 2006 and 2012, the District continued to collect data and identify exact locations of the pinnacles and remaining boulders. The pinnacles stretched from bank-to-bank, but it would be inefficient to remove any rock that did not actually obstruct the navigation channel. So the District coordinated with the navigation industry and the Coast Guard to prioritize work locations based on impact to navigation industry to ensure earliest work provided the most benefit. With the navigation channel at Thebes defined, river engineers were able to evaluate each individual obstruction within the channel and determine its elevation and the approximate river stage at which the pinnacle would pose a threat. They were then able to coordinate with water control managers to develop a model that would allow the rock removal team and water

[39] See Environmental Assessment with FONSI, Regulating Works Project, Dogtooth Bend Phase 6, RM 34-33 LDB, MMR (2016), found at http://www.mvs.usace.army.mil/Portals/54/docs/pm/Reports/EA/RegWorksDogtoothBendPhase6FINALEABASIGNEDFONSI%20FINALPACKET20July2016.pdf?ver=2016-08-01-110955-103.

[40] 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).

control managers to know the specific stages at which each pinnacle would impact the authorized navigation channel and also which pinnacles posed the most immediate threat to navigation. When the drought resulted in extremely low river stages years later, this critical data was essential for the timely removal of the pinnacles.

After Congress passed the American Recovery and Reinvestment Act in 2009, the district had hoped that it could use funds from the stimulus package to remove the pinnacles. The district did receive $5 million for the rock removal, but this was far less than the $20 to $30 million required for a blasting and drilling project. The limited funds forced the district to try experimental methods, such as using a grinder on the pinnacles, but these efforts had little success. Further, this additional work increased the Project completion cost to a total of $350 million in 2009.

The district continued to ask for funds all the way up until the summer of 2012, but it was not until the drought conditions threatened to close the navigation channel in the Winter of 2012/2013 that funding was made available for the immediate removal by terminating an existing dike and revetment contract for convenience and shifting lower priority efforts to the critical rock removal effort. This funded the Urgent and Compelling (Phase I) effort of rock removal, which provided minimal authorized navigation channel dimensions. The Urgent and Compelling contract was completed in February of 2013. Factoring in the impacts of a prolonged low water period and all of the unknowns associated with climate change, the District moved forward with rock removal Phase 2, a follow up to the Urgent and Compelling contract. This removal effort was designed to continue gaining additional width required for a 15 barge tow configuration during low river stages. The Phase II contract was awarded in August 2013 and fully funded in October 2014. Due to the need for specific river stages for this work, the rock removal under this contract is still pending.[41]

LWRP Evaluation and Adjustment

As discussed above, the Project was authorized to provide a nine foot channel at low water. In the 1926 Chief's Report, this was identified as being 40,000 cfs, but this was adjusted in the early 1930's to 54,000 cfs due to the expected increase of flows once the Missouri River reservoirs were completed. During the drought of 2012-13, the issue of the Project's authority and what is considered low water to base the nine feet of depth requirement was researched and determined to be the 40,000 cfs identified in the 1926 Chief's Report.

The low water reference plane, commonly abbreviated as 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 miles 200 to 0. Applying LWRP to survey data allows for the determination of necessary dredging locations based on water surface and bed bathymetry in typical low water years, but it is not set at the Project's authority. LWRP is based

[41] 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; *Annual Report of the Chief of Engineers*, 2009.

on a statistical analysis of 97% exceedance discharge (a discharge that is lower than 97% of flows) at key gages and water surface profiles taken at typical low flow conditions. LWRP is used on most normal years to determine dredging levels and is used as the design guide for all river training structure design. In the event of a severe low water year, dredging depths can be set at the authorized low water depth which corresponds to a flow of 40,000 cfs.

The LWRP can change over time with varying considerations due to the dynamic nature of the Mississippi River. Just because the Project is authorized to provide a channel at a specific depth does not mean throughout the years that the identified point still makes technical and economic sense. Therefore, the District began re-evaluating the Regulating Works Project LWRP in accordance with the memo by the MVD Engineering Chief from 1974. The only variance from the procedure in that memo was to utilize data since 1967 rather than 1954 because that was the date that all of the Missouri River reservoirs were put into operation. In 2014 the District revised LWRP to account for locations where the existing LWRP was known to be incorrect based upon inconsistencies in the data at low water, to incorporate more accurate and up to date data collected with better technology, and to be compliant with ER 1110-2-8160 upon St. Louis's vertical datum conversion. Upon the revision, LWRP at St. Louis changed 0.3 ft from -3.5 ft and 54,000 cfs to -3.2 ft and 66,800 cfs (97% exceedance discharge). The largest changes from the prior LWRP at gage locations were at Locks 27 (a lowering of LWRP by 3.8 ft) and at Price Landing (a raising of LWRP by 1.7 ft).[42]

Addressing Public Concerns about Flood Risk

In the 1930's following extreme high water events, the Corps and the U.S. Geological Survey (USGS) initiated studies when data showed a major increase from prior years' data in the river stage (or height/depth) when a specific water discharge (or flow rate) was moving through the MMR. In 1933 the responsibility of monitoring river stage and discharge was transferred from the Corps to the USGS. The studies focused on the accuracy of the standard equipment and method of observation used by the two agencies. In 1952, the results of the studies found that the discharge measurements by the Corps generally exceeded USGS measurements by slightly more than 10% at high stages. The conclusion was 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" used by the Corps.[43] In 1962 another comprehensive analysis of this data was completed by the USGS, which found that the change in stage for higher flows was due to the construction and raising of levees between 1935 and 1951 along the MMR and that river training structures had a negligible effect on the increase in flood heights similar to natural factors that were found to affect stages for the same discharge (water temperature, rapid rise of the flood wave, amount of flow from the Upper Mississippi River, and amount of bed material carried by the Missouri River).[44]

[42] USACE memorandum from David Busse, St. Louis District Chief of Engineering and Construction Division, subject: "2014 Revision of the Low Water Reference Plane (LWRP) for the Middle Mississippi River," (23 Oct 2014).
[43] Ressegieu, F.E., *Comparative Discharge Measurements, Mississippi River by USGS and Corps of Engineers*, St. Louis District, U.S. Army Corps of Engineers (1952).
[44] Monroe, R.H., *Stability, Stage-Discharge Curve*, St. Louis, MO, USGS, unpublished data (1962).

In the mid-70's after the flood of 1973, two researchers (one from Colorado State University and one from Saint Louis University) published papers claiming that river training structures had caused an increase in flooding in the MMR.[45] District engineers from the Hydrologic Engineering Section and the River Stabilization Branch, as well as researchers from the University of Missouri – Rolla (nka Missouri University of Science & Technology), reviewed, evaluated, and wrote responses to these papers explaining that they contained flaws in the source data, methodology and analysis, noting that the use of the Corps' early discharge data was not appropriate due to its inaccuracy.[46] Analysis using numerical and physical modeling completed by the District in the mid-80's and 90's provided additional confirmation of the earlier Corps and USGS research that the early discharge data collected by the Corps in the MMR was inaccurate and that using this data will result in incorrect conclusions.[47]

Beginning in 2000, researchers from Southern Illinois University (Department of Geology, Department of Geography, and Environmental Resource and Policy Program) and Washington University (Environmental Studies Program and Department of Earth and Planetary Sciences) began publishing a series of papers and presentations on their studies concluding that river training structures have increased flood heights in the MMR. The District reviewed this initial research and realized that these studies had made the same errors as prior studies by using the early discharge data collected by the Corps that was inaccurate, along with errors in their analysis methods and other technical inaccuracies. However, the media began publishing news stories with the conclusions reached by these researchers from regionally local universities, and the public began questioning the District's continued construction of river training structures. The District attempted to explain the research that had already been completed on this issue, explaining the data and methods used in the recent studies had already been reviewed and found not to be accurate based upon the research that had already went into this issue by the Corps and USGS.

Therefore, in an effort to show impartiality and that the District was taking the claims seriously, the District funded four studies to be completed by the USGS, two universities (University of Iowa (IIHR – Hydroscience and Engineering) and Missouri University of Science

[45] Belt, C.B, "The 1973 Flood and Man's Constriction of the Mississippi River," *Science*, 189: 681-684, 1975; and Stevens, M.A., Simons, D.B., & Schumm, S.A., "Man-Induced Changes of Middle Mississippi River," *Journal of the Waterways Harbors and Coastal Engineering Division*, 119-133 (1975).

[46] Dyhouse, G.R., "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), 277-79 (1976); Stevens, G.T., "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), 280 (1976); Strauser, C.N. and N.C. Long, "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), 281-82 (1976); and Westphal, J.A. and P.R. Munger, "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), 283-84 (1976).

[47] *See* Dyhouse, G.R., "Effects of Federal Levees and Reservoirs on 1993 Flood Stages in St. Louis," National Research Council, Transportation Research Board, Washington, DC, Record No. 1483, p. 7 (1995); and Dyhouse, GR 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 Society of Civil Engineers Hydraulics Division, New York, 73-78 (1985).

and Technology (Department of Mathematics and Statistics)), and a private engineering consulting organization (The Biedenharn Group). The District conducted a large scale hydraulic modeling study at the University of Illinois to evaluate the impact of river training structures in a mobile bed. The District also conducted additional studies and analysis on the issue, analyzing the studies making the assertions. Further the District conducted a hydrodynamic study utilizing an Adaptive Hydraulics model of a site-specific Regulating Works Project work area in 2013-15 when concerns were raised by local residents about the effects of flood heights from the potential construction. All of these studies further refuted the assertion that river training structures increase flood heights and/or pointed out technical or scientific errors on the studies that made this assertion.[48]

Also during this time period additional research, analysis, and studies were being completed around the world on the issue of what impact river training structures have on river stages. In the Netherlands a program called Room for the River was formed to analyze multiple issues with their river systems. As part of this, a professor of Civil Engineering and Geosciences, Section of Hydraulic Engineering, at Delft University completed an analysis on the Dutch River Waal and concluded that the more submerged river training structures are the less effect they have on river stages. However, even with this determination, the researcher further clarified that even if all the dikes in that particular system were lowered, the maximum possible water level reduction at flood levels was 2.4 inches.[49] Further confirming this finding,

[48] USACE, "Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River," St. Louis District (2016) (see also the EA for Grand Tower Phase 5 (June 2016) at http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx; Brauer, E.J., and Duncan, D.L., "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*, 140(11) (2014); Brauer, E.J., "The Effect of Dikes on Water Surfaces in a Mobile Bed," MS Thesis, University of Illinois, Urbana-Champaign (2013); Brauer, E.J., "The Effect of Dikes on Water Surfaces in a Mobile Bed," MS Thesis, University of Illinois, Urbana-Champaign (2013); Watson, C.C., R.R. Holmes, D.S. Biedenharn, The Biedenharn Group, "Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri," *J. Hydraulic Engineering*, 139:1062-1070 (2013); Watson, C.C., D.S. Biedenharn, C.R. Thorne, The Biedenharn Group, "Analysis of the Impacts of Dikes on Flood Stages in the Middle Mississippi River," *J. Hydraulic Engineering*, 139:1071-1078 (2013); Brauer, E.J., "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, CRC Press (Sept. 5-7, 2012); Piotrowski, J.A., Young, N.C., Weber, L.J., University of Iowa, IIHR-Hydroscience and Engineering, "Supplemental Investigation 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 (2012); Watson, C.C., and Biedenharn, D.S., The Biedenharn Group, "Specific gage analysis of stage trends on the Middle Mississippi River," Report to U.S. Army Corps of Engineers, St. Louis District (2010); Brauer, E.J., "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, p156-163 (Sept. 6-9, 2009); Huizinga, R.J., "Examination of measurement and historic daily data for several gaging stations on the Middle Mississippi River, 1861-2008," U.S. Geological Survey Scientific Investigations Report 2009-5232, 60p. (2009) (Also available at http://pubs.usgs.gov/sir/2009/5232/); and Samaranayake, V.A., Missouri University of Science and Technology, "The statistical review of three papers on specific gage analysis," Report to U.S. Army Corps of Engineers, St. Louis District (2009).

[49] Yossef, M.F.M., *Morphodynamics of Rivers with Groynes*, Delft University Press, Delft (2005) (note that "groynes" is the term used in other parts of the world for dikes or river training structures).

PIANC's[50] Environmental Commission established an international working group of seven experts[51] on inland navigation, flood management, planning and communication, riverine ecology, and related disciplines to investigate and quantify possible relationships between waterway development and maintenance measures for navigation and flood management. The report prepared by this working group concluded that dikes can be designed to avoid high water impacts by having a top elevation below mean high water. Further, the report explains that although dikes may increase hydraulic resistance, the erosion of the low water bed may compensate for the water level upset entirely.[52] The river training structures in the MMR have always been constructed below mean high water, and the very purpose of the river training structures in the MMR is to scour the river bed to reduce dredging. Therefore, the river training structures for the Regulating Works Project are already designed so they do not have an impact on stages.

While the above studies and analyses were being completed, the researchers at Southern Illinois University and Washington University were building on their faulty analysis by doing additional studies, analyses, and presentations to further prove that river training structures increase flood heights and to respond to the studies and analyses that questioned their original findings.[53] The District reviewed these additional studies and findings, but there were still issues

[50] Per PIANC's website, they are a non-political and non-profit organization that brings together the best international experts on technical, economic and environmental issues pertaining to waterborne transport infrastructures. http://www.pianc.org/aboutpianc.php.

[51] Working Group Members: Ir. Hendrik Havinga, Ministry of Transport, Public Works and Water Management, Amhem, the Netherlands; Dr. J. Craig Fischenich, Civil Engineer, USACE Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS, USA; Dr. Juergen Stamm, Federal Waterways Engineering and Research Institute, Karlsruhe, Germany; Ir. Geert Roovers, Oranjewoud Consultants and Engineers, Oosterhout, the Netherlands; John D. Clarkson, Chief, Structural Section, Huntington District, USACE, Huntington, WV, USA; Capt. Lieven Geerinck, Navigation Programme Manager, Mekong River Commission, Phnom Penh, Cambodia; and Claude Demience, Ministry of Equipment and Transport, Liege, Belgium.

[52] PIANC, Sustainable Waterways within the Context of Navigation and Flood Management," Envi-Com Report nº 107-2009 (2009).

[53] *See* Criss, R. E., "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 (2016), found at http://en.earth-science.net; Criss, R. E., & Luo, M., "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 (2016) found at http://en.earth-science.net; Huthoff, F., N. Pinter, J.W.F. Remo, "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 (2013); Heine, R.A., Pinter, N., "Levee effects upon flood levels: an empirical assessment," *Hydrological Processes*, 26, 3225-3240. DOI: 10.1002/hyp.8261 (2012); Pinter, N., J. Dierauer, and J.W.F. Remo, "Flood-loss modeling for assessing impacts of flood-frequency adjustment, Middle Mississippi River, USA," *Hydrologic Processes*, doi:10.1002/hyp.9321 (2012); Pinter, N., "Historical discharge measurements on the Middle Mississippi River, USA: No basis for 'changing history,'" *Hydrological Processes*, 24: 1088-1093 (2010); Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, "Cumulative impacts of river engineering, Mississippi and Lower Missouri Rivers," *River Research and Applications*, 26: 546-571 (2010); Criss, R.E., "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 (2009); Pinter, N., "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 (2009); Remo, J.W.F., N. Pinter, and R.A. Heine, "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

with the scientific analysis and data used. The District reached out to the researchers at SIU by requesting the model, data, or any other supporting materials with respect to one of their studies in order for the District to further verify model results and gain a full understanding of the physical processes driving the concluded increase in flood stage. However, the SIU researchers denied the District's request for this information.[54] Therefore, since the District has questioned the model and data used and has not been able to fully evaluate the most recent studies, the District has not found sufficient evidence warranting additional costly studies to attempt to disprove these studies.

Further, a lawsuit was filed in the Southern District of Illinois by various non-governmental conservation organizations against the Corps, challenging three site-specific EAs. The river training structure increasing flood heights assertion was a key issue of this litigation to show imminent harm to the plaintiffs in their request that the court stop all action while the lawsuit was pending. Declarations by Dr. Pinter of SIU and Edward Brauer, hydraulic engineer, of the District were filed within this litigation laying out the research and studies on both sides of the issue. In an order denying the plaintiffs' motion for preliminary injunction, the court found

> [T]hat Plaintiffs have not shown conclusively that flood levels have increased as a result of river training structures and that the structures have a detrimental impact on public safety. The Court finds that Plaintiffs cannot show imminent harm. The Court has reviewed the declaration of Dr. Pinter filed by Plaintiffs in support of their request for

flood stages," *Journal of Hydrology*, 376: 403–416 (2009); Criss, R.E., and W.E. Vinston, "Public Safety and Faulty Flood Statistics," *Environmental Health Perspectives*, 116: A516 (2008); Jemberie, A.A., N. Pinter, and J.W.F. Remo, "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 (2008); Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.S. Ickes, "Flood trends and river engineering on the Mississippi River system," *Geophysical Research Letters*, 35, L23404, doi: 10.1029/2008GL035987 (2008); Remo, J.W.F., N. Pinter, B. Ickes, and R. Heine, "New databases reveal 200 years of change on the Mississippi River System," *Eos*, 89(14): 134-135 (2008); Remo, J.W.F., and N. Pinter, "Retro-modeling of the Middle Mississippi River," *Journal of Hydrology*, doi: 10.1016/j.hydrol.2007.02.008 (2007); Remo, J.W.F, and Pinter, N., "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 (2007); Ehlmann, B.L., and R.E. Criss, "Enhanced stage and stage variability on the lower Missouri River benchmarked by Lewis and Clark," *Geology*, 34: 977-980 (2006); Pinter, N., R.R. van der Ploeg, P. Schweigert, and G. Hoefer, "Flood Magnification on the River Rhine," *Hydrological Processes*, 20: 147-164 (2006); Pinter, N., B.S. Ickes, J.H. Wlosinski, and R.R. van der Ploeg, "Trends in flood stages: Contrasting trends in flooding on the Mississippi and Rhine river systems," *Journal of Hydrology*, 331: 554-566 (2006); Pinter, N., "Policy Forum: One step forward, two steps back on U.S. floodplains," *Science*, 308: 207-208 (2005); Pinter, N., and R.A. Heine, "Hydrodynamic and morphodynamic response to river engineering documented by fixed-discharge analysis, Lower Missouri River, USA," *Journal of Hydrology*, 302: 70-91 (2005); and Pinter, N., K. Miller, J.H. Wlosinski, and R.R. van der Ploeg, "Recurrent shoaling and dredging on the Middle and Upper Mississippi River, USA," *Journal of Hydrology*, 290: 275-296 (2004); Pinter, N., and R. Thomas, "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 (2003).

[54] See Letter from Col. O'Hara, Commander, St. Louis District, USACE, to Pinter and Remo, SIU, Dept. of Geology, (10 Sept. 09); Letter from Pinter and Remo, SIU, Dept. of Geology to Col. O'Hara, Commander, St. Louis District, USACE (16 Sept. 09); and Letter from Col. O'Hara, Commander, St. Louis District, USACE, to Pinter and Remo, SIU, Dept. of Geology, (6 Oct. 09).

> injunctive relief and has reviewed the declaration of Edward Brauer filed by the Corps in support of its opposition. The Court finds that Dr. Pinter's statements do not show that the risk of flooding from the three potential work sites at issue is actual or imminent.

While the order was preliminary and the lawsuit was eventually dismissed by stipulation of the parties, the court's findings reflected that the District had not been arbitrary or capricious in its analysis and conclusions on the assertions that river training structures increase flood heights.[55]

Recent Environmental Compliance Work for the Regulating Works Project

Even with all of the additional studies concluding that river training structures do not increase flood heights and studies questioning the data and methods used by those researchers concluding that they do increase flood heights, the media continued to publish these findings and the public was still skeptical and concerned. Therefore, in response to this publicity, Congressman Jerry Costello of Illinois, requested that the Government Accountability Office conduct a review of the MVS policies and procedures associated with the use of river training structures. The review included MVS's compliance with the environmental laws and regulations in conjunction with the MMR Regulating Works Project. In December 2011, the GAO produced a report from its review and provided the following recommendations in its report:

1. To ensure compliance with NEPA:
    a. Prepare an EA to determine if the MMR's 1976 EIS should be supplemented due to significant new circumstances or information;
    b. Develop and present in the EA an approach to ensure that site-specific impacts are assessed, as appropriate, for new river training structures in the MMR; and
    c. Review and revise as needed MVS procedures to determine whether existing NEPA documents need to be supplemented;
2. To ensure compliance with the Clean Water Act (CWA), obtain CWA § 404 permit-equivalents and § 401 state water quality certification for new river training structures in the MMR; and
3. To help resolve concerns over river training structures' effects on river stages during periods of high flow, conduct physical or numerical modeling.[56]

In response to the GAO's recommendations, Assistant Secretary of the Army (Civil Works), Ms. Jo-Ellen Darcy, responded that USACE believes the MMR project is in compliance with NEPA and the CWA, but stated the following in response to each of the GAO's recommendations:

[55] *See National Wildlife Federation, et al. v. USACE*, Case No. 14-590, SD IL (2014); specifically the following document numbers: 56 (Stipulation for Dismissal without Prejudice); 50 (Memorandum and Order Denying Preliminary Injunction); 27 (Reply Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction); 21-1 (Declaration of Edward J. Brauer, P.E. for Defendants' Opposition to Plaintiffs' Motion for Preliminary Injunction); and 14-2 (Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction) (all of these can be found at http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx).

[56] USGAO, "Mississippi River: Actions are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures," Government Printing Office, Washington, DC, GAO-12-41 (2012).

1. USACE will voluntarily perform an EA of river training structures for the MMR navigation project;
2. As part of the new EA, USACE will include an approach that ensures the pre-construction assessment of site-specific impacts of new river training structures in the MMR;
3. USACE will review and revise MVS procedures for implementing NEPA, as needed, to ensure that existing Corps regulations and policies are properly followed and documented;
4. As part of the new EA, USACE will perform all CWA assessments and obtain any certifications required by law and regulation; and
5. USACE is aware that some researchers outside the agency do not agree with extensive research performed by the Corps, other federal agencies, and academic institutions over the past 75 years, which has concluded that river training structures do not have an effect on flood heights. USACE has reviewed the outside research and does not believe that there is sufficient evidence to warrant costly and time-consuming large-scale numerical or physical modeling efforts at this time. The Corps will continue its ongoing efforts to monitor and analyze the effects of river training structures on flood heights, and undertake physical and/or numerical modeling if there is a need to do so and sufficient funding is available.[57]

Upon issuance of the final GAO Report, the District began taking action in accordance with Ms. Darcy's response to the report. Two Project Delivery Teams (PDTs) were formed: one to begin working on the EA of new river training structures specifically and one to take a hard look at the MMR 1976 EIS, which included all aspects of the Regulating Works Project, in order to determine if a supplement was needed.

The District had taken a hard look at the 1976 EIS in the 1990's when the District began constructing bendway weirs and altering designs to avoid and minimize impacts, but these minor design changes were determined to not be a substantial change to the Project that warranted a supplement. This current hard look along with conducting extensive analysis and discussion resulted in the District concluding that while there has still not been a substantial change to the Regulating Works Project, the entire MMR 1976 EIS should be supplemented due to the vast amount of new circumstances and information that did not exist in 1976 and had not been considered through NEPA procedures or documentation since 1976 for most of the MMR Regulating Works Project.[58] A Notice of Intent to supplement was published in the Federal Register in December 2013, and the District began supplementing the 1976 EIS, which is expected to be completed in 2017.

[57] Found in letters from Ms. Jo-Ellen Darcy, Asst. Sec. of the Army (Civil Works), to Ms. Anu Mittal, Director, Natural Resources and Environment, U.S. Government Accountability Office dated November 17, 2011 (comments on Draft Report, GAO-12-41, included in the GAO Report) and March 6, 2012 (comments on Final Report, GAO 12-41)

[58] USACE, Review of the 1976 EIS, Mississippi River between the Ohio and Missouri Rivers Regulating Works, St. Louis District (11 June 12) (Tiered site-specific EAs had been prepared for rock removal in 1983, 1988, 2006, 2009, and 2013 and the major rehabilitation of Locks 27 in 2002).

Success of the Regulating Works Project to Reduce Dredging

Since the completion of the Prototype Study, the District has continually monitored the Regulating Works Project to ensure that any new work is reducing dredging as intended for the Project purpose as well as to confirm that the environmental benefits and avoidance and minimization measures being taken as part of the Project are effective. A review of the two recent low water dredging seasons provides a good 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 ft. 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. Further, 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.[59]

Pursuant to this Congressional mandate and along with monitoring of bank erosion issues and potential channel cutoffs, 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 cost-effective minimum in the MMR. The current estimate for overall Project completion cost for the regulating works portion is $375 million at an estimate of 84% complete as of 2016.

[59] Gordon and Rodgers, "Drought, Low Water, and Dredging of the Middle Mississippi River in 2012."