US Army Corps
of Engineers
Kansas City District

Missouri River

MISSOURI RIVER
BED DEGRADATION
RECONNAISSANCE STUDY

Section 905(b)
(Water Resources Development Act of 1986)
Analysis

FINAL

PN 124302
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Missouri River Bed Degradation Reconnaissance Study
Section 905(b) (Water Resources Development Act of 1986) Analysis

1.0 Study Authority

The Missouri River Bed Degradation Reconnaissance Study is being carried out under the U.S. Army Corps of Engineers' General Investigations Program. The study was authorized by Section 216 of Public Law 91-611, Flood Control Act of 1970, which reads:

> The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significant changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest.

The Energy and Water Development Appropriations Act of 2008 included appropriation of general investigation funds for the Missouri River Bed Degradation Reconnaissance Study.

2.0 Study Purpose

The primary objective of the Missouri River Bed Degradation Reconnaissance Study is to evaluate the potential for federal interest in implementing solutions to water resources problems and opportunities related to bed degradation within the lower 498 miles of the Missouri River. If federal interest is demonstrated, the reconnaissance phase will include development of a project management plan (PMP) and negotiation of a feasibility cost share agreement (FCSA) with non-federal partners for the next phase of study—a feasibility study.

The feasibility study would address bed degradation (i.e., lowering of the riverbed) and its effects on the short- and long-term stability of the federal flood risk management (FRM) systems within the lower 498 miles of the Missouri River. The feasibility study's purpose would be to ensure continued flood protection for areas currently protected by those systems. In addition, the feasibility study would address the effects of degradation on the long-term stability and sustainability of the navigation system by determining whether or not structural or operating changes might minimize or eliminate impacts of degradation on the system. The feasibility study would consider approaches to help maintain or enhance the viability of federally constructed ecosystem projects such as constructed wetlands and shallow water habitat. In addition, the feasibility study would address the potential for protection of local infrastructure.

Existing information was utilized for the analysis in this report to qualitatively define the federal interest, to the extent possible. Existing or readily available data (e.g., historical reports, U.S. Geological Survey [USGS] gage data, hydrographic surveys, aerial photography, stakeholder-provided information, and relevant information from previous studies) were used as the basis for conducting preliminary analyses and evaluations. Where information was not available, suitable assumptions were made based on standard environmental, economic, and engineering practices. The Missouri River Bed Degradation Reconnaissance Study is consistent with Army policies for determination of costs, benefits, and environmental impacts of identified potential project alternatives.

The Missouri River Bed Degradation Reconnaissance Study is being conducted in coordination with a broad array of stakeholders and agencies to assess the level of interest and support from non-federal entities in cost-sharing, feasibility-phase studies, and future project construction.

3.0 Location of Study, Non-Federal Sponsor, and Congressional Districts

The study area is located on the lower Missouri River, from River Mile (RM) 498 at Rulo, Nebraska, to the mouth, located north of St. Louis, Missouri. The Missouri River bisects a two-state area. Major cities affected in Missouri are St. Joseph, Kansas City, and Jefferson City. In Kansas, Kansas City and smaller communities adjacent to the Missouri River are affected. The study area also includes tributary rivers and streams where direct influence or effects between the tributary and the Missouri River are evident. Maps of the study area are included in Appendix A.

The Missouri River has exhibited degradation and scour of the riverbed to varying degrees throughout the study area. There is a good deal of variation in current impacts. In recent years, the rate of bed degradation has increased. This is especially true within the Kansas City reach (RM 350 to RM 400), where communities have and are currently incurring costs for repairs and/or upgrades to infrastructure. A growing concern is the significant threat to critical infrastructure along the river (e.g., the Kansas Citys [*sic*] Metropolitan Levee System, water supply intake structures, and utility intake structures) and smaller infrastructure on the tributaries where head cuts and bank erosion are occurring.

(**Note**: The Kansas Citys Metropolitan Levee System is also known as the Kansas Cities Seven Levees System and the Kansas Cities Flood Protection System. The spelling of "Citys" in the levee system's name comes from title used in the system's congressional authorization.)

Non-federal sponsorship for the feasibility phase of the study is under discussion with a number of potential sponsors. Currently, a potential lead sponsor has been identified.

The study area is within the jurisdiction of the following congressional districts:

Kansas District 3, U.S. Rep. Dennis Moore
Missouri District 4, U.S. Rep. Ike Skelton
Missouri District 5, U.S. Rep. Emanuel Cleaver, II
Missouri District 6, U.S. Rep. Sam Graves
Missouri District 9, U.S. Rep. Blaine Luetkemeyer

The following U.S. senators represent the study area:

U.S. Sen. Sam Brownback, Kansas
U.S. Sen. Pat Roberts, Kansas
U.S. Sen. Kit Bond, Missouri
U.S. Sen. Claire McCaskill, Missouri

4.0 Existing Projects

As mentioned above, the reconnaissance study's purpose is to determine if there is a federal interest in participation in a feasibility study. To make this determination, the reconnaissance study has identified and reviewed the following federal projects for current and potential future impacts.

4.1 Missouri River Bank Stabilization and Navigation Project

The Missouri River Bank Stabilization and Navigation Project (BSNP) was first authorized by the Rivers and Harbors Act of 1912 and subsequent authorizations in 1925, 1927, and 1945. The existing BSNP spans 732.3 miles of the Missouri River, from Sioux City, Iowa, to the mouth, located near St. Louis, Missouri. The existing BSNP maintains a channel that is 9 feet deep and 300 feet wide. Features of the BSNP consist mainly of rock revetments and dikes that restrict lateral movement of the river channel and maintain a self-scouring navigation channel. The BSNP was built over a period of 50 years, with the final features being constructed in the early 1980s. Adjustments are made occasionally to these features to maintain the navigation channel at the authorized depth. The BSNP is a federally operated and maintained project.

Construction of the BSNP has highly altered the lower Missouri River by channelizing the river into a single main channel. In its natural state, the lower Missouri River channel occupied roughly 300,000 acres and consisted of numerous islands, channels, chutes, sandbars, and backwater habitats that supported a wide diversity of animals and plants. A U.S. Army Corps of Engineers (USACE) fish and wildlife mitigation feasibility study and environmental impact statement (EIS) in 1981 (USACE, 1981) estimated that as a result of the BSNP, the lower Missouri River channel would be reduced to an area of approximately 112,000 acres by 2003. No follow-on studies have been conducted to confirm or verify any of the estimates from the 1981 USACE study.

Prior to the BSNP, the Missouri River was very dynamic, constantly changing from one flood event to another (USACE, 1981; U.S. Fish and Wildlife Service [USFWS], 1980). It is estimated that channelization of the lower Missouri River impacted the system by causing the loss of over a half-million acres of terrestrial and aquatic habitat. As a result, only minor fragments remain of this once vast, diverse, and unique ecological resource.

Before the BSNP was built, the Missouri River meandered across a part of the flood plain known as the meander belt. Channel migrations of up to 3,000 feet occurred in response to meander cutoffs, ice jams, debris jams, and sediment deposition. Because the abandoned channel could take 40 years to fill to the elevation of the flood plain, the river's natural, unrestrained meandering created a highly dynamic environment. The BSNP has altered or eliminated much of the driving mechanisms that created that rich flood plain ecosystem.

In 1981, the USACE estimated that the meander belt consisted of an area of approximately 606,000 acres adjacent to the river's natural channel, of which an estimated 354,000 acres would be lost by 2003 (USACE, 1981). The meander belt consisted of successional wetlands, various types of herbaceous and woody habitats, and limited agricultural areas. An estimated 522,000 acres of aquatic and terrestrial habitat was projected to have been eliminated from the natural river channel and meander belt by 2003 (USACE, 1981).

The BSNP's greatest impact to wildlife populations on the Missouri River has been a general reduction in wildlife numbers resulting from changes to the flood plain ecosystem, specifically in the quantity and quality of habitat. Many mammals, reptiles, amphibians, songbirds, and waterfowl utilized the various habitats in and along the Missouri River before construction of the BSNP. The USACE estimated total losses attributable to the construction of the BSNP to be more than 654,800 individuals of key terrestrial wildlife species, as well as more than 15 million pounds of fish that could have been supported at any one time by the pre-BSNP lower Missouri River ecosystem (USACE, 1981). Prior to construction of the BSNP, the lower Missouri River contained a large and diverse fish population. The most obvious impact to the fishery is a general reduction in the number and poundage of fish. This reduction is a direct result of the area of surface water lost on the river and the variety of critical aquatic habitats lost due to channelization (USACE, 1981).

Impacts on habitat and fish and wildlife populations associated with the BSNP also affect opportunities for human use of the lower Missouri River. In 1981, the USACE projected that as many as 772,000 days of recreation would be lost annually by the year 2003 due to the reduction of habitat and fish and wildlife populations (USACE, 1981).

4.1.1 Missouri River Recovery Program

A fish and wildlife mitigation program was authorized for the BSNP in the Water Resources Development Act (WRDA) of 1986, based on the 1981 USACE feasibility study and EIS. The WRDA authorization allowed the USACE to purchase and/or develop

48,100 acres of fish and wildlife habitat on the lower Missouri River. This program was reauthorized and expanded in the 1999 WRDA, increasing the total land acquisition/habitat development acreage to 166,750 acres.

In 2000, as required by the Endangered Species Act, the USACE completed formal consultation with the USFWS for protection of the pallid sturgeon, a federally listed endangered fish species native to the Missouri River, at several USACE projects. Among the USACE projects affected by the pallid sturgeon consultation was the operation and maintenance of the BSNP.

That same year, the USFWS completed a biological opinion (BiOp) on the USACE projects affected by the pallid sturgeon consultation (USFWS, 2000). This BiOp concluded that these USACE projects jeopardized the continued existence of the pallid sturgeon and issued the USACE a reasonable and prudent alternative (RPA) for implementation. The RPA requires future operation and maintenance of the BSNP to result in "no-net-loss of existing shallow water habitat" and requires the USACE to restore 7,530 acres of shallow water habitat (from 12,035 to 19,565 acres). The BSNP fish and wildlife mitigation program (now known as the Missouri River Recovery Program) is the main USACE project being used to comply with the RPA to recover the endangered pallid sturgeon.

4.2 Federal flood risk management systems

There are a number of channel improvements, levees, and floodwalls within the Kansas City reach that comprise the Kansas Citys Metropolitan Levee System. The features of these FRM systems were constructed starting in the 1950s, with improvements and modifications occurring through the present day to provide flood protection for Kansas City and several surrounding communities. The Kansas Citys Metropolitan Levee System covers a two-state and multi-community area with multiple levee districts and supporting agencies.

Numerous FRM systems exist along the Missouri River to provide protection for other communities; the most notable of these systems is in St. Joseph, Missouri. These federal FRM systems are operated and maintained by public entities as sanctioned by the statutes of their respective states. In some cases, there are shared boundaries between the FRM systems' structures and the features of the BSNP. Maintenance responsibilities in these instances have been generally defined by the sloping reference plane called the Construction Reference Plane (CRP). Public entities have responsibility for maintenance at elevations above a horizontal plane established at 13 feet above the CRP; however, there is some overlap with federal maintenance activities. Locations of the FRM system levees are illustrated in Figure A-1, located in Appendix A.

5.0 Prior Reports

The Missouri River Bed Degradation Reconnaissance Study reviewed and analyzed numerous historic reports and an extensive amount of existing data. Key references are listed below:

1. Simons, Li, and Associates, "Analysis of Channel Degradation and Bank Erosion in the Lower Kansas River," USACE, Missouri River Division (MRD), Kansas City District (KCD), MRD Sediment Series No. 35, 1984.

Summary: This report evaluates impacts of the operations of federal reservoirs located in the Kansas River Basin on the Kansas River. This report addresses sand and gravel dredging from the Kansas River and the impact of this dredging on the river. In general, this report presents the morphology of the Kansas River. This report provides information that was used in the current effort to evaluate the Kansas River's impact on bed degradation in the Missouri River.

2. USACE, "Potamology Investigation Missouri River, Rulo, Nebraska to Mouth," USACE, MRD, KCD, MRD Sediment Series No. 22, 1980.

Summary: This report presents historical data on the Missouri River from the mouth to RM 498.4 for the years 1880 to 1978. This report reviews historical data to determine major physical impacts that occurred during that period. The report documents stream length changes over time. In so doing, river cutoffs and their impacts are discussed. This report was valuable to the current study by providing documentation of the short-term response of the river to St. Joseph, Liberty, and Jackass Bends.

3. West Consultants, Inc., "Final Report Missouri River Levee Unit L385 Sediment Analysis," USACE, KCD, May 1999.

Summary: This report was produced for the KCD to present an analysis of dredging for construction of Missouri River Levee System (MRLS) Unit L-385. The report quantifies how dredging from the Missouri River to provide construction fill for MRLS Unit L-385 would impact the behavior and morphology of the river system in the vicinity of the dredging. Information from this report was important because it provided conclusions linking dredging activities in the Kansas City area to streambed degradation.

4. Stark, Mellema, and Thomas, "Missouri River Levee Unit L-385 Dredging Impact Study, Final Report," USACE, KCD, April 2000.

Summary: This is a follow-up report to the May 1999 report by West Consultants, Inc. Stark, Mellema, and Thomas primarily added the results of sediment computer modeling of the proposed dredging using HEC-6T. This report was beneficial to the current effort by presenting the likely outcomes of dredging in the Kansas City area.

5. USACE, “Investigation of Channel Degradation 2001 Update,” USACE, Omaha District, December 2001.

Summary: This report documents the ongoing degradation of the Missouri River channel immediately downstream of the main stem dams. This report updates the status of the channel based on survey data and discusses trends. This report supports the current study by providing insight to the limits of the degradation caused by the main stem dams. This information help support the conclusion that main stem dams have a minimal impact on channel degradation in the Kansas City area.

6. USACE, “Missouri River Fish and Wildlife Mitigation Iowa, Nebraska, Kansas, and Missouri Final Feasibility Report and Final Environmental Impact Statement,” USACE, MRD, May 1981.

Summary: This report documented the adverse impacts to fish and wildlife habitat that resulted from the construction and operation of the BSNP. This report recommended construction of a fish and wildlife mitigation project.

7. USFWS, “Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System,” USFWS, Region 3 and 6, November 2000.

Summary: This BiOp concluded that the USACE projects jeopardized the continued existence of the pallid sturgeon. The USFWS issued the USACE an RPA for implementation. In addition to other requirements, this RPA requires future operation and maintenance of the BSNP to result in “no-net-loss of existing shallow water habitat” and requires the USACE to restore 7,530 acres of shallow water habitat (from 12,035 to 19,565 acres).

8. USFWS, “2003 Amendment to the 2000 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System,” USFWS, Region 3 and 6, May 2003.

Summary: This BiOp concurred with a USACE proposal to accelerate construction of shallow water habitat.

9. USACE, “Characterization of the Suspended-Sediment Regime and Bed-Material Gradation of the Mississippi River Basin,” Report 1, Volume 1, Appendix B, “Characterization of the Suspended-Sediment Regime and Bed-Material Gradation of the Missouri River Basin,” U.S. Army Engineer Waterways Experiment Station, August 1981.

Summary: This report contains a study of suspended sediment of the Mississippi River Basin. Appendix B contains a characterization of the suspended-sediment and bed-

material gradation for the Missouri River Basin. The study assessed long-term trends in suspended sediment through the Missouri River main stem following the construction of the major dam construction, channelization, and changes in land-use practices.

10. USFWS, Missouri River Stabilization and Navigation Project, Sioux City, Iowa to Mouth Detailed Fish and Wildlife Coordination Act Report, 1980 (USFWS Division of Ecological Services, Kansas City Area Office, North Kansas City, Missouri).

Summary: This report documented the adverse impacts to fish and wildlife that resulted from the construction, operation, and maintenance of the BSNP. This report discussed future fish and wildlife habitat needs and made recommendations for mitigation.

6.0 Geography of the Lower Missouri River Basin

The discussion in this section provides context for the general setting of the study area. Geography can be described as either physical or cultural; initially, this report describes the physical characteristics of the lower Missouri River watershed in the context of the riverbed degradation problem. Rivers are drains of their watersheds, representing primarily two aspects: rainfall and the geology of the river basin.

Figure A-2, Appendix A depicts the average annual precipitation across the entire Missouri River Basin. Because the initial amount of any rain event will infiltrate into the ground, the drier areas of the watershed, located above Omaha, will have a disproportionately lower amount of rainfall runoff. The higher rainfall areas below Omaha will overwhelm the infiltration capability of the soil more often and produce higher rainfall runoff yields. Just from rainfall patterns alone, the characteristics of the lower Missouri River below Sioux City, Iowa, are very different from the upper watershed managed by the six main stem dams on the upper Missouri River.

The six main stem dams in Montana, North Dakota, and South Dakota are designed primarily to capture the annual spring snowmelt event. From a storage point of view, the upper Missouri River is one of the most heavily regulated rivers in the world. The river's outstanding storage capability allows the USACE to reduce flood risks and eliminate summertime extreme low flows on the lower Missouri River. In addition, these dams provide a large hydroelectric capability and are tremendous recreational assets. However, by the time the Missouri River reaches Kansas City it has taken on characteristics more dominated by the rain zone in the lower Missouri River watershed, which has annual precipitation rates of more than 30 inches per year.

The rainfall pattern in the upper Missouri River watershed is dominated by the Rocky Mountains, which block the flow of moisture from the Pacific Ocean. The lower Missouri River watershed is dominated by its proximity of the Gulf of Mexico. The variability in rainfall in the upper watershed is more dominated by drought, while the variability in the lower watershed is more dominated by tropical storms and hurricane remnants. During the past decade, the lower watershed has been significantly affected by seven years of

drought flows on the Missouri River. This effect is important and can be explained by first considering the link between rainfall and geology.

Figure A-3, Appendix A shows the surface geology of the Missouri River Basin. Only the characteristics of the lower 700 miles of the Missouri River watershed will be discussed in this section of the report. In general, the surface map represents three important geologic features:

1. At the lowest position in the basin and exposed on many valley walls are bedrock formations consisting of limestone and shale deposited in shallow seas eons ago.

2. More recently, several waves of glaciers deposited glacial till on top of this bedrock. The presence of these glaciers moved the alignment of many rivers including the Missouri River.

3. Following the Wisconsin glacial event, vast areas of unforested glacial till and open lake bottoms from drained glacial lakes were exposed to high winds. The pulverized rock dust and lake sediment blew from as far as Siberia across the rugged western areas of North America. When the calm interior of the continent was encountered, these fines settled out of the air as silty loess.

Figure A-4, Appendix A shows the typical depositional pattern of eolian loess in the middle of North America. These wind-blown deposits can be seen on the surface of the watershed on Figure A-4 in northern Missouri and western Iowa. The tributaries to the Missouri River cut valleys in this loess exposing the underlying glacial till, with the deepest channels exposing bedrock. The consequence of this surface exposure of glacial till and loess can be seen on Figures A-5 and A-6 in Appendix A. Figure A-5 gives an indication of fine sediment concentrations in water samples across America. From the concentration of sediment in the water, the areas of Iowa, Nebraska, Kansas, and northern Missouri produce some of the muddiest runoff in all of North America. Consequently, the nickname “Muddy Mo” is appropriate for the Missouri River. Figure A-6 illustrates the actual yield of materials from the watershed when these sediment concentrations are multiplied by rainfall runoff and snowmelt.

The yield of sediment materials from the watershed is important for the maintenance of the Missouri River channel and flood plain. The finest sediment will be deposited in backwater areas of the river and during floods across the flood plain. Coarse silt and fine sands build channel banks. Sand of all sizes will build point bars along the river. Sand and gravel are important on the channel bottom in areas where hardpans or bedrock are not exposed. The availability of these different size fractions is a function of local watershed rainfall and the local geology of each tributary to the Missouri River. Although the concentration of fine sediments is greater in central Kansas, the lower amount of rainfall in that area produces the same sediment yield as southern Missouri (i.e., southern Missouri has lower fine sediment concentrations than central Kansas; however, its higher rainfall produces an equal sediment yield). However, southern Missouri is dominated by the Osage River Basin, which has 92 percent of its watershed behind large reservoir

dams. These dams capture the Osage River's sediment yield, which has a noticeable effect on the Missouri River bed degradation problem below Jefferson City.

The presence of water supply and flood control dams in the Kansas, Osage, Platte, Blue, and Chariton watersheds is a cultural feature of the lower Missouri River Basin. Only a few of these dams are a direct consequence of local urban development (see Figure A-7, Appendix A). Many of the water supply dams in the Kansas River Basin were constructed for the purpose of irrigating farmland. The primary design of these dams is to change the timing and rate of water supply in their watersheds for various cultural purposes (i.e., farming and forestry). These dams are effective sediment traps that reduce sediment delivery to the Missouri River.

The cultural practices of farming and forestry will increase sediment delivery and change the rates and timing of watershed runoff and baseflow. Although farming and forestry are important locally, it is hard to judge their basin-wide impacts. Farming is the primary motivator for levees that have been constructed along the Missouri River and its tributaries. These farm levees can affect local channel flows and limit sediment deposition during shallow flood events. Urban levees are responsible for a very small percentage of the total length of the Missouri River; however, the cultural and economic significance of these levees vastly exceeds their small footprint in the overall Missouri River flood plain.

Like farm levees, urban levees have local effects on flow and sediment deposition. However, the basic consequence of urban areas is the rate of economic expansion, development, and population growth on the utilization of construction materials. Although crushed, angular limestone from quarries is a superior building material than rounded river gravel; no building material is superior to river sand. Therefore, in urban areas the demand on river sand may have significant local effects. The active urban areas along the lower Missouri River are St. Louis, St. Charles, Jefferson City, Columbia, Kansas City, and St. Joseph. A fundamental problem with urban areas is that urban development is independent of, and therefore does not tract well, with droughts or floods. The delivery of sediment from tributaries is vastly reduced during droughts; likewise, the rate of sediment transport down the Missouri River channel is lowered. As a consequence of large, flood-producing weather cycles, there is a disconnection between the natural supply of river sand and the cultural demand for this building material.

7.0 Review of Existing Information—Causes of Degradation

To formulate realistic alternatives to address the Missouri River bed degradation problem, it is critical to conduct an accurate assessment of the problem's causes. There are multiple facets to the causes of the riverbed's degradation; the influences of each facet vary both spatially and temporally. This section discusses the identified causes, how the causes relate to one another, and each cause's role in the observed degradation.

7.1 Dikes and structures

History. During the period of stream data record, the Missouri River has been changed by both natural phenomena and construction work on the BSNP. The BSNP includes river construction work such as dikes, revetments, and cutoffs to stabilize the riverbanks and improve the channel for navigation. The BSNP was authorized by Congress under the River and Harbor Act of 1912 to provide a 6-foot-deep, 200-foot-wide channel from Kansas City, Missouri, to the mouth of the Missouri River. In 1927, Congress authorized an extension of the project to Sioux City, Iowa.

In 1945, the existing project from Sioux City to the mouth of the Missouri River was modified by Congress to provide a navigation channel of 9 feet in depth and not less than 300 feet wide. This modification to the project was to be accomplished by constructing dikes and revetments (to shape the waterway and stabilize the banks), cutoffs (to eliminate sharp and protracted horseshoe bends), and chute closure dikes (to close minor and diverted channels); removing snags; and dredging where necessary. Prior to work on the 1912 project, nearly all construction activities on the Missouri River were done to protect bridges, railroads, highways, and waterworks from erosion.

About 15 percent of the dikes on the Missouri River were built prior to 1930 (see Figure 1, below). A majority of the dikes built prior to 1930 were built in 1923 and 1929. However, 30 percent of the revetments built prior to 1930 were intended to stabilize the banks. Very few dikes were extended prior to 1930. After 1930, a large number of pile dikes were built to shape the river into a designed course. A major portion of Missouri River construction was done between 1930 and 1940. Although few dikes were built between 1930 and 1940, the dikes built during that time frame were relatively long (2,000 to 3,000 feet). Consequently, the major amount of channel constricting took place during the 1930s.

Between 1940 and 1950, especially during World War II, construction of new structures was nearly eliminated (all construction completed in this period was done during the late 1940s). A large number of dikes and dike extensions were built after 1950, although they were much shorter in length than those built during the 1930s. By 1950, the Missouri River had reached the refinement stage; many dikes and revetments were built from the accretion deposits that formed during the development of the river’s designed course.

After 1960, dike sills (low-elevation dikes) were introduced, accounting for a large amount of dike extensions from 1960 to date. L-head, stone-fill revetment construction was also introduced after 1960, accounting for a large amount of revetment construction since that time.

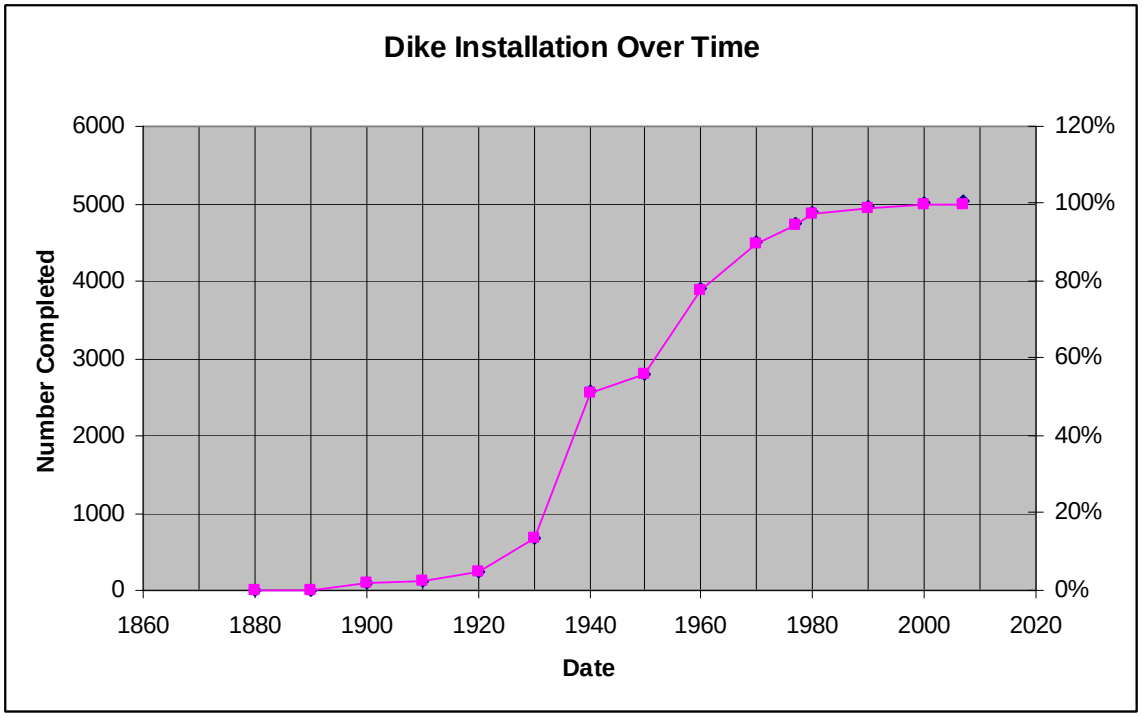


Figure 1. Timeline for installation of Missouri River dikes

The heights of all dikes and revetments are referenced to the CRP. Prior to 1973, the CRP was established at an elevation approximately equal to the low-water stage. In 1973, the CRP was revised to an elevation approximately equal to the normal navigation stage. This provided a direct relationship between the full-service navigation flows and the elevations to which the structures were built.

By 1960, the river channel had been essentially stabilized into one channel. As a result, the design height of new structures was lowered from previous design criteria. The new structures were designed to an optimum elevation that allows the river stage to exceed the top of the structures for a certain percentage of time during the navigation season. This practice allows the structures to adequately maintain the navigation channel at a minimum height, which has less effect on flood heights and causes fewer adverse environmental effects. These structures are also more economical to build.

Modifications. It is notable that modification of the dikes by extension dramatically increased from 1940 through the 1980s. This practice enhanced the river's ability to maintain the low-flow channel once the channel eroded or was excavated. Modification by extension and addition of dikes in the Kansas City reach continued intermittently until 1989.

In recent years, dikes have been modified by notching and lowering primarily associated with the Missouri River Recovery Program. These modifications have provided some localized relaxation to the constrictive impacts of the dike system.

Maintenance. In general, the maintenance program is focused on maintaining the dikes to at least their design elevations (based on the CRP) to maintain a navigable channel.

Near-bank deposition. The dike and revetment system creates low-velocity regions near the banks that are conducive to deposition during and on the falling side of flood events. The dike system provides scouring velocities in the channel simultaneously to deposition on the banks. Once the deposition areas become vegetated, they provide additional constrictions that tend to incise the low-flow channel.

Overall impacts of dikes/revetments on degradation. The dikes and revetments were designed primarily to maintain an open, navigable channel during times of low flow. This channel is achieved by restricting and confining flow in a manner that causes flow velocities during times of low flow to be greater than they would be under natural conditions. This practice causes sediments that ordinarily would be deposited under certain discharges to be moved downstream.

When dikes and revetments are present in sufficient numbers to maintain the low-flow channel depth, the material removed from that reach of the stream results in a lowering of the streambed. The dike or revetment functions effectively to maintain the lower bed configuration. If the constriction provided by the dikes or revetments is relaxed, material that is carried through the constriction is allowed to deposit to a level consistent with the dikes or revetments at the new location.

In reaches where material extraction results in a lower streambed, the streambed does not readily recover. This lack of recovery is consistent with the self-scouring design and function of the dikes/revetments.

The Kansas City reach of the Missouri River has required additional dikes and the accompanying flow restrictions. This requirement is primarily due to the confluence of the Kansas River at Kansas City. The confluence of a stream results in more complex and varied deposition and erosion conditions. These conditions are partly due to a variety of backwater conditions. Also, the inflowing sediment load varies with inflow from the Kansas River independent of the flow in the Missouri River. This set of river conditions has resulted in the installation of a very constrictive dike system to maintain a navigation channel. The construction of that dike system has resulted in a reach of river that is very efficient at “cleaning” and maintaining the low-flow channel.

7.2 Major flood events

Major flood events in the Kansas City reach of the Missouri River result in short-term bed scour that recovers to levels nearly consistent with a long-term trend of bed degradation. The long-term bed degradation trend evaluated at the Kansas City USGS gage location is approximately one foot or less per year. However, the degradation rate can be several feet in a single flood event. This short-term deviation from the long-term degradation trend for individual flood events can be shown by analyzing stage, flow, and average bed elevations. It is also noteworthy that in some cases, even though the riverbed

recovers most of the loss within a couple of years following the flood event, the riverbed fails to make a full recovery. This is evident in Kansas City for major floods and some lesser floods. Based on these observations and historical data, it can be concluded that major flood events play a significant role in the riverbed degradation process in the Kansas City reach of the Missouri River.

The residual impact of floods on riverbed degradation is also evident in the St. Joseph and Waverly, Missouri, reaches of the river. The temporary shifts that occur in the average bed elevation, both during and following flood events, are evident for the 1951, 1952, and 1993 floods. However, this phenomenon is not clearly evident at other USGS gage locations along the lower 500 miles of the Missouri River.

Residual shifts resulting from high-flow events, including the 1987 and 1993 floods, are easily observed using data taken at the Kansas City reach. For the 1993 flood, substantial (~8 feet) short-term (less than 2 years) erosion occurred and a significant (~2 feet) long-term bed shift resulted. Unique to the 1993 flood is that after partial recovery, the long-term degradation rate in the Kansas City reach increased. A shift also accompanied the 2007 flood. However, the data since the 2007 flood is not of adequate duration to determine if the 2007 flood resulted in a long-term shift.

In summary, flood events contribute to riverbed degradation having both short- and long-term impacts on the Missouri River's low-flow stream channel.

7.3 Missouri River and tributaries dam construction

Main stem dams. All six dams on the Missouri River (main stem dams) were completed and brought into service between 1940 and 1964, with the most downstream dam (Gavins Point Dam) becoming operational in 1955. Figure A-7 in Appendix A shows the locations of these dams. The most downstream dam is approximately 450 miles upstream of Kansas City, Missouri. Degradation downstream of these dams because of sediment trapped in the upstream reservoirs has been well documented over the years (USACE, 2001). Sediment trapping occurs in the reservoirs when flow velocities drop as a stream enters the quiet waters of the reservoirs. All but the smallest of sediments settle to the bottom and are trapped upstream of the dam. Degradation downstream of a dam occurs as a result of clear water released from the reservoir scouring the channel to reestablish the sediment load characteristics of the stream prior to construction of the dam.

Table 1. Missouri River main stem dams			
Most Downstream Reservoir	**River Miles Above the Mouth of the Missouri River**	**Name of Dam**	**First Year of Operation**
	1771.5	Fort Peck Dam	1940
	1389.9	Garrison Dam	1955
	1072.3	Oahe Dam	1962
	987.4	Big Bend Dam	1964
	880.0	Fort Randall Dam	1953
X	811.1	Gavins Point Dam	1955

Evaluations of USGS gage data and other data collected by the USACE indicate that the degradation caused by main stem lakes has not extended downstream to Rulo, Nebraska. In fact, the data show a trend of deposition in the vicinity of Rulo, Nebraska.

Low-flow profiles taken downstream of Rulo, Nebraska, in 1990 and 2005 were compared for differences in riverbed elevation. The differences provide evidence of changes in streambed elevations. These profiles were adjusted, based on USGS stage and flow measurements, to common discharges for comparison. These low-flow profiles provided an indirect evaluation of the channel geometry. Although indirect, the results indicate changes in the low-flow channel and hence the degradation/deposition along the reach. This analysis indicated no long-term trend of lowering of the average bed elevation at Rulo, Nebraska, between 1990 and 2005.

The low-flow water surface at Nebraska City, Nebraska, is clearly stable or rising with time. By contrast, Omaha, Nebraska, shows a slight drop in stage at low flows and Sioux City, Iowa, shows a steep, downward trend for all discharges. Data taken at the USGS gaging locations indicate that degradation associated with main stem dam construction extends through Omaha, Nebraska, but ends upstream of Rulo, Nebraska. It is therefore concluded that degradation trends in the lower 498 miles of the Missouri River are not a result of the capture of sediment caused by the construction of the main stem reservoirs. It has been more than 50 years since the closure of the last main stem dam (Gavins Point Dam) at RM 811.1. No evidence was found to indicate degradation impacts have reached RM 498.1. Therefore, the blocking of sediment transport by dams upstream is not currently impacting riverbed degradation at or downstream of Rulo, Nebraska.

Kansas River Basin dams. Six USACE reservoirs and one Bureau of Reclamation reservoir control a major portion of the flow from Kansas River tributaries. All other reservoirs in the Kansas River Basin are upstream of these reservoirs; therefore, these reservoirs are not significant in terms of sediment control to the Kansas River. These reservoirs have and continue to trap sediment and release sediment-depleted water downstream. The proximity of these reservoirs to the Kansas River is such that degradation downstream of these structures has impacted the Kansas River channel geometry (Simons, Li, and Associates, 1984). Sediment loads carried by the Kansas River have been reduced by the reservoirs. The extent that bed, bank, and tributary erosion downstream of the reservoirs have overcome this depletion is not fully addressed;

however, this erosion does tend to reestablish some sediment load in the lower Kansas River.

Tables 2 and 3 list the closure dates for the Kansas River Basin dams along with other pertinent information.

Table 2. USACE reservoirs on Kansas River tributaries

Most Downstream Reservoir for Each Tributary	Reservoir	Date of Closure	Tributary Location
X	Kanopolis	1946	Smoky Hill
	Harlan County	1951	Republican
X	Tuttle Creek	1959	Big Blue
X	Wilson	1963	Saline
X	Milford	1964	Republican
X	Perry	1966	Delaware
X	Clinton	1975	Wakarusa

Table 3. Bureau of Reclamation reservoirs on Kansas River tributaries

Most Downstream Reservoir	Reservoir	Date of Closure	Tributary Location
	Harry Strunk	1949	Republican
	Bonny	1950	Republican
	Cedar Bluff	1950	Smoky Hill
	Enders	1950	Upper Republican
	Swanson	1953	Upper Republican
	Kirwin	1955	Solomon
	Webster	1956	Solomon
	Lovewell	1957	Republican
	Hugh Butler	1961	Republican
	Norton	1964	Republican
X	Glen Elder	1967	Solomon

Osage River Basin dams. Bagnell Dam is a privately owned hydropower structure that was completed in April of 1931. The construction of Bagnell Dam traps nearly 100 percent of the sediment carried by the Osage River upstream of its location. It is reasonable to conclude that this sediment trapping changed the Osage River's contribution of sediment to the Missouri River. This study has not quantified those impacts to the Missouri River.

Other tributary dam construction. Smithville Lake, although close to Kansas City, Missouri, controls such a small quantity of inflow compared to the Missouri River flow that it is assumed inconsequential in the riverbed degradation discussion. Rathbun Dam

and Long Branch Dam have small drainage areas, far removed from the Missouri River, and are assumed to have no substantial impact on Missouri River bed dynamics.

Conclusions. Although the construction of main stem dams has impacted streambed degradation and sediment deposition some distance downstream of the dams, the impacts as noted above have not been shown to be a substantial cause of the riverbed degradation downstream of Rulo, Nebraska. Tributary dams have not been evaluated to the level necessary to assess their impact on the Missouri River.

7.4 Flow modification by regulation

As mentioned above, flows along the Missouri River have been altered by the operation of the six main stem dams and several tributary dams. The historical mean annual flows for USGS gaging locations along the lower Missouri River were analyzed and flow duration curves for selected time windows were compared. The most upstream gaging station is at Rulo, Nebraska; the most downstream station is at Hermann, Missouri. Gaging locations are illustrated on Figure A-8 in Appendix A.

Flow duration curves show that flows have been modified over the years in large part by the regulation provided by reservoir construction and operation. These flow duration curves show a substantial increase in discharge for flows that are exceeded more than 10 percent of the time (indicating that flow during non-flood events has increased); this shift has taken place since 1946. The flow that is exceeded 75 percent of the time (i.e., the flow in the river will be greater than the particular flow 276 days out of a year) has approximately doubled between the 1920s and the year 2000; the bulk of this change occurred after the 1947 to 1964 time period.

The flow that is exceeded 75 percent of the time during the navigation season (April through December) is used to establish the CRP. The CRP is represented at all points along the river by the river stage (elevation) concurrent with the flow that is exceeded 75 percent of the time. The CRP is used as a reference for designing, constructing, and maintaining the dikes. The flows associated with the navigation season have substantially increased over the years with flow regulation by the upstream reservoirs. Greater upstream regulation has caused flows to be systematically increased during navigation season in support of barge traffic. Therefore, the physical characteristics and the function of the dikes have been impacted by the flow duration shifts. In the Kansas City reach of the Missouri River, the increases in low-flow duration and the impact of those increases on the CRP has been more than offset by low-flow stage trends. This scenario has resulted in dikes that are above the CRP-based design/maintenance criteria. The total impact of duration shifts on degradation of the channel has not been quantified.

Qualitatively, some observations are useful in understanding the impacts of these flow changes. Generally, in reaches where the bed is stable and the CRP has risen, the dikes have increased in height due to maintenance based on CRP criteria. Where degradation is most prevalent and CRP elevations are more than offset by dropping flow elevations, the dikes in general evolve to elevation well above the CRP criteria. In these instances, the

dikes confine the flows a greater percentage of the time than that of the original design. This extra confinement results in velocities that prevent deposition and encourage bed erosion.

The flood control capacity of the reservoir systems by design reduces the peak flow for flood events. As noted earlier, flood events directly impact bed degradation. The data in the Kansas City reach of the Missouri River illustrates that the larger the flood, the greater the resulting degradation of the bed. Thus, by reducing the magnitude of the flood events, regulation tends to lessen the short- and long-term degradation issues associated with floods.

Conclusions. Flow regulation has a two-fold impact. One impact is to change the CRP and resulting design and maintenance criteria elevations. This impact tends to degrade the channel or maintain a lower channel bottom once degradation has occurred by other causes. The other impact of flow regulation is to lessen the severity of degradation caused by flood events. The combined effects of these impacts have not been quantified in this study.

7.5 River cutoffs

Three major stream bend cutoffs have taken place between the Kansas City river gage (RM 366.1) and the Waverly river gage (RM 293.4). This shortening of the river took place between RMs 324 and 352 from 1915 to 1957. A cutoff upstream of Kansas City near St. Joseph, Missouri, also occurred during the same time frame. Table 4, below, includes details on the cutoffs.

The total cutoff mileage between Kansas City and Waverly, Missouri, is 16.4 miles, half of which occurred since 1950. These cutoffs should be viewed as actions that worked in concert with the construction of the BSNP because the BSNP tends to lock the river banks in place, thereby limiting the way the river can respond to cutoff.

According to “Potamology Investigation Missouri River, Rulo, Nebraska to Mouth,” 1980, MRD Sediment Series No. 22, the Liberty Bend cutoff resulted in degradation extending 8.3 miles upstream within seven years and deposition that extended 21.3 miles downstream. The same investigation indicated that the St. Joseph cutoff resulted in degradation extending 8.5 miles upstream within four years and deposition that extended 20 miles downstream.

Table 4. Cutoff locations and extents

Name of cutoff	Pre-cutoff slope feet/mile	~ River Mile	Miles cut off	Date of cutoff
Napoleon Bend	-	324	~8.2	1915
Liberty Bend	.77	352	~3.6	1950
Jackass Bend	-	337	~4.6	1957
St. Joseph	.75	450	~6.2	1956

Potential erosion upstream of cutoffs. Rivers develop meanders to minimize the rate of energy expended as the water moves downstream. The meander lengthens the water's travel distance, which reduces the river slope and the velocity, thus reducing the rate of energy expenditure and the water's erosion potential. The degree of meandering depends on the overall slope of the flood plain and gradation of the flood plain material. The occurrence of natural cutoffs is delayed by the presence of forest on the flood plain, which increases the tendency for looping meanders to develop.

Meanders translate downstream with time. If the flood plain is entirely homogeneous and the slope is uniform, the meander waves would be uniform in size and shape. However, an actual flood plain is heterogeneous, with numerous hard points that block the translation of the meanders. Meanders move and become more distorted around hard points. A cutoff channel is a connection at a narrow region in the bend. The steep gradient along the cutoff reach rejuvenates the river; the river forms new meanders to return to an equilibrium slope.

The new, rejuvenated river is shorter than its predecessor. This can be seen by comparing river stationing (mileages) before and after the cutoff. The slope of the river increases considerably through the new channel.

To return to the equilibrium slope, the river must erode any overburden of sediment. Immediately after the cutoff, a head cut starts moving upstream. The head cut generates sediment, which clogs the downstream channel, forcing the river to cut into its banks and generate a new meander downstream. Over years, the river will work to return to the slope prior to cutoff.

If the river channel is locked in place, prohibiting a new meander to form, the river still works to return to the equilibrium slope. To return to that slope the river must move the entire overburden of upstream sediment. Conceptually, this overburden could extend all the way to the headwaters of the river. Of course, the river cannot remove this overburden all the way up into its headwaters. Instead, another type of equilibrium with a greater slope and velocity is established, making the riverbed coarser and more resistant to erosion.

This total slope correction would result in a maximum degradation roughly equal to change in slope over the length of the cutoff multiplied by the length of the cutoff. That maximum degradation is not likely to be reached in a stream with bed material that has armoring capabilities. The slope will likely be re-established somewhat steeper than the original slope after fine material has been eroded from the upper layer of the streambed. A variety of things can alter or lessen the renewed stability, including large flood events and dredging activities. These activities either overpower or destroy the bed material that provides the new stability. The maximum total slope correction would result in a maximum degradation roughly equal to change in slope over the length of the cutoff multiplied by the length of the cutoff. Between Kansas City and Waverly, that maximum would be approximately 14 feet total for the four cutoffs using data from Table 4.

The Missouri River is substantially locked in place by dikes and revetments and is subject to the stream response noted previously. The likely response to the stream would be the sorting of the bed material and degradation of the streambed for a reach upstream of the cutoffs. The dike and revetment system was being implemented concurrent and subsequent to the cutoffs. According to the 1980 USACE report "Potamology Investigation Missouri River," the river from St. Charles, Missouri, to St. Joseph, Missouri, was becoming steeper. This, in the context of the dike and revetment construction, is not surprising in light of the flow-duration discussions above. The Missouri River at Nebraska's Platte River confluence is no longer competent to move all of the sediment delivered into the main channel. The Missouri River is steepening below this confluence by aggredation.

The full extent of the impact the cutoffs have on stabilizing the streambed at a steeper slope has not been quantified. A detailed study of the time history of the channel's geometry up and downstream of the historic cutoffs is necessary to identify more than a maximum potential for degradation resulting from the cutoffs.

Conclusions. Cutoffs have contributed to degradation in certain reaches of the Missouri River. These reaches have been altered in character by the construction of dikes and revetments; in some instances, these alterations have constrained the river and placed additional stresses for degradation of the streambed.

7.6 Dredging

Sand and gravel extraction dredging is prevalent in selected reaches of the lower 498 miles of the Missouri River and on the lower Kansas River. Commercial dredging is conducted under federal permits issued by the USACE regulatory program. An EIS is currently being conducted for commercial dredging on the lower Missouri River as a requirement in the permit process.

Based on stream hydrographic surveys, USGS measurements, analyses of river gage data, and dredging records, a clear correlation exists between dredging reaches of the Missouri River and riverbed degradation below RM 498. However, the data is not conclusive as to the details cause-and-effect relationship between dredging and riverbed degradation. The contribution of dredging to riverbed the degradation will be explored with additional analyses in future studies. This section represents the results of data analyses to date.

Current data shows that substantial dredging is taking place in the reaches of the lower Missouri River that are experiencing the greatest amount of degradation. The quantities of dredged material removed over time are substantial, when compared to the volume changes in the streambed. Comprehensive analyses of streambed surveys are not currently available to make direct comparison of volumes of dredged material removed and degradation volumes. However, such evaluations of existing and data obtained in the future would be useful.

Even though a complete mass balance has not been done for the Missouri River and may not be attainable because of the inherent complexities, the following analysis provides a conceptual understanding of the potential magnitude of impact of dredging: Dredged materials removed in between RMs 353 and 378 from 1990 to 2005 represent a volume of in-situ material roughly equivalent to a change of bed elevation over the same reach of about 9 feet. If this is spread over the reach of degradation between RM 290 and RM 440, the equivalent bed change is between 1–2 feet.

To keep this in perspective one needs to consider that some areas downstream of the Kansas City reach have experienced deposition over the same period. This deposition is potentially a result of displacement of material from the Kansas City reach. The analysis of the combined impact of dredging and other potential causes compared to the mass balance of bed material movement is necessary to assess the specific contribution of dredging to the degradation problem.

Analyses of low-water profile data and dredging records along the reach from Rulo, Nebraska, to the Mississippi River reveal a strong correlation between dredging extraction quantities and change in low-water profiles between 1990 and 2005. This is graphically represented in Figure 2, below.

Further analysis was performed of stage changes at the USGS gages and dredging in the vicinity of those gages for the time period 2000 to 2005. A strong correlation was discovered between the drop in stage for a given low flow and the dredging quantity extracted during the same time period. This strongly suggests a correlation between dredging activities and degrading stream reaches along the lower 498 miles of the Missouri River.

Because both of these approaches indicate the greatest bed degradation is in the Kansas City reach of the Missouri River and the greatest dredge extraction quantities were taken from that reach, further analyses specific to the Kansas City reach were performed. The average bed elevations, derived from data from flow measurements used to support the USGS Kansas City stream gage, were evaluated with respect to degradation rates since 1974. Time periods with similar rates of degradation were selected. Total degradation over that time frame was compared to tons of material dredged during the same period. These analyses also showed a clear correlation between increasing dredging and increasing degradation.

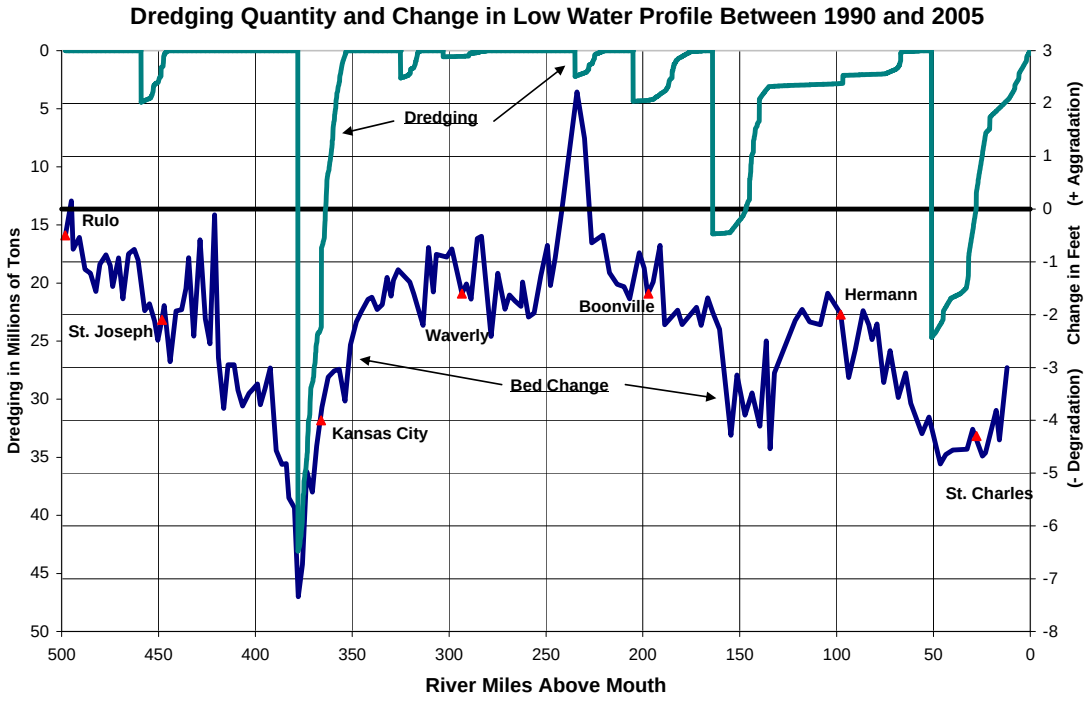


Figure 2. Dredging quantities and change in low-water profiles, 1990 to 2005

As noted previously, the rate of bed degradation in the Kansas City reach of the Missouri River has substantially increased since the mid-1990s. It should be noted that dredging take from the Kansas City reach has more that doubled in that same time period. The increase in dredging take is evident from Figure 3, below.

Earlier studies of the Kansas City reach of the Missouri River have identified dredging as a cause of degradation (West Consultants, Inc., 1999; and Stark, Mellema, and Thomas, April 2000). The West Consultants document specifically identified annual extraction rates well below the current extraction rate that would result in riverbed degradation.

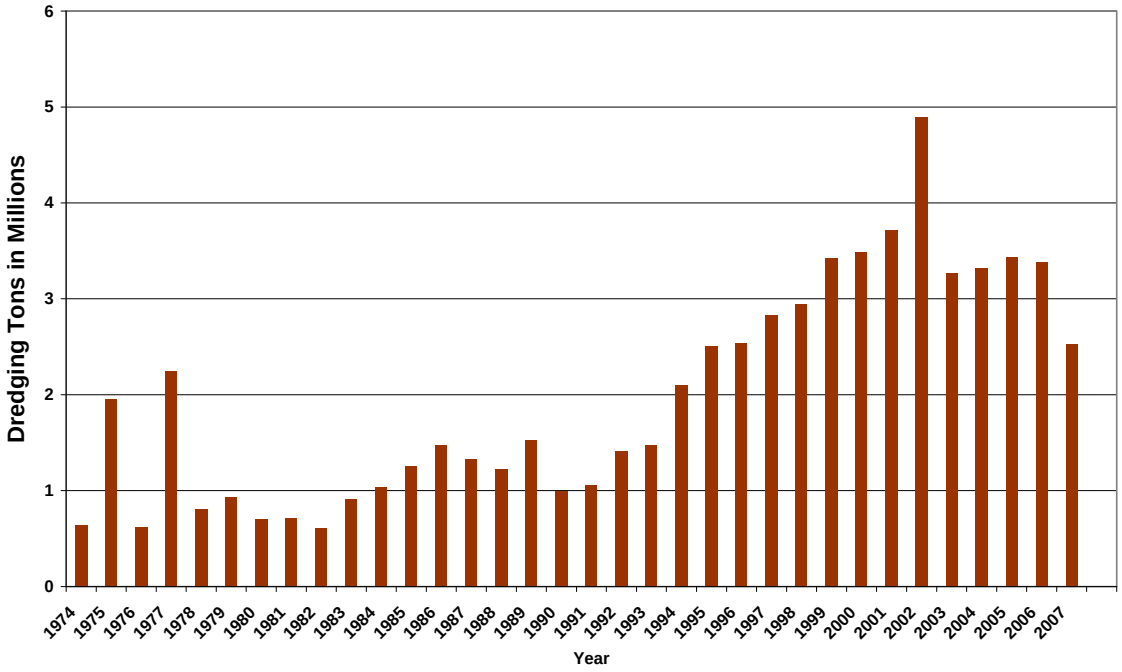


Figure 3. Dredging take from the Kansas City reach of the Missouri River

Sand and gravel dredging on the Kansas River. Studies of the historical impacts of sand and gravel mining on the lower Kansas River and its impact on the stream have been completed (Simons, Li, and Associates, 1984). The dredging quantities taken from the lower Kansas River should be evaluated in regard to their potential impact on degradation of the Missouri River channel.

Conclusions. The analyses to date show a strong correlation between the locations, time frames, and quantities of dredging in the lower Missouri River and degradation of the Missouri River channel.

7.7 Summary of degradation causes

The aforementioned causes of riverbed degradation all have individual impacts on the degradation problem in the Kansas City reach and other reaches of the Missouri River. However, the causes of riverbed degradation all are interrelated and cumulatively shape the problem. The challenge is to understand all the components of the problem in context and how they interact in order to formulate alternative solutions.

The BSNP has been reshaping the Missouri River since construction began more than a century ago. With the objective of maintaining a stable navigable channel, river structures have been constructed and maintained that inhibit sediment deposition in the low-flow channel. All causes of riverbed degradation must be understood against the backdrop of a developing and ultimately fully functional BSNP. In general terms, the BSNP narrowed, deepened, and steepened the river channel for low-flow conditions. As structures were

put in place they caused a gradual evolution of the river. With the completion of the BSNP in the 1980s, the river began to seek long-term stability.

This long-term stability was occasionally interrupted by flood events. During and in the months following these flood events the low-flow channel was substantially lowered. Following each flood event the low-flow channel returned to stability with a net loss in bed elevation. This lack of full recovery can be attributed in part to the effectiveness of the BSNP in inhibiting deposition in the navigation channel. The 1993 flood resulted in about 8 feet of short-term degradation, with a net of about 2 feet of long-term degradation after recovery.

The influence of channel shortening between the Kansas City and Waverly reaches of the Missouri River prior to the completion of the BSNP provided an instability in the river that potentially, in conjunction with the features of the BSNP, encouraged a limited erosion trend upstream of the cutoffs. By the 1980s, Kansas City gage data showed signs of channel stability only interrupted by flood events.

In the same time frame as the completion of the BSNP, commercial dredging extraction in the Kansas City reach averaged about 1 million tons per year. Between 1990 and 1999, the dredging take was in excess of 3 million tons per year and remained at that level through 2006. Between 2007 and 2008, the take dropped to between 2 and 3 million tons.

Subsequent to the completion of the BSNP and concurrent with the tripling of the annual dredging take from the river, the bed elevation in the Kansas City reach (based on USGS measurements at the Kansas City gage) has consistently degraded. Since 1995, the average bed elevation has degraded approximately 4 feet.

In summary, riverbed degradation in the Kansas City reach and other reaches of the lower 498 miles of the Missouri River is the result of a combination of causes. Over time, shifts between degradation causes and an interaction between those causes have varied. Data collected over the last 15 years suggest that increased dredging take, working in concert with the BSNP, has become the dominant cause of degradation.

8.0 Plan Formulation

The Water Resources Council's Principles and Guidelines provide six planning steps for federal water resources planning efforts leading to plans recommended for authorization. The following are the council's six planning steps:

1. Specify problems and opportunities.
2. Inventory and forecast conditions.
3. Formulate alternative plans.
4. Evaluate effects of alternative plans.
5. Compare alternative plans.
6. Select recommended plan.

Of the six planning steps above, reconnaissance studies emphasize step 1 (specify problems and opportunities) and step 2 (inventory and forecast of conditions). Initial formulation and evaluation of alternative plans is done in the reconnaissance phase. It is anticipated that the information will be refined in future iterations of the planning steps during the feasibility phase.

Public concerns. Formulation of the preliminary plan for this phase of study was conducted in an open manner; public meetings were held with stakeholders to both seek and share information. The causes of riverbed degradation and the existing conditions were described to the extent possible and water resources problems, as well as opportunities to address those problems, were identified. Three public meetings were held in separate geographic locations (St. Joseph, Kansas City, and Jefferson City) along the Missouri River. In addition, several meetings were held with stakeholders who have responsibility for managing various public infrastructures. Discussions were held with potential non-federal sponsors to determine their interest in participating in feasibility phase investigations.

A wide range of public concerns were identified prior to and during the process of conducting the reconnaissance study:

1. Water supply intakes for water supply entities and public utilities have been lowered by degradation of the Missouri River channel. The potential exists for these structures to require total replacement with continued bed lowering. An example is Kansas City, Missouri, where low flows have forced the city to spend more than $4 million to extend water intakes and drinking water pumps to reach lower river levels. The city of Kansas City, Kansas, has spent $22.6 million on a cooling tower and emergency pumps to retrofit two electrical generating facilities. Additional problems are anticipated with further degradation; future degradation may require replacement of intake structures in their entirety at much greater cost.

2. Erosion of foundation materials caused by bed degradation threatens bank stability, affecting the primary levee system along the Missouri River in Kansas City, water intakes, and drainage outfall structures. Although the impacts have not been fully evaluated and inventoried, a review of existing hydrographic data indicates that the toes of revetments supporting critical levee structures have eroded due to the degraded channel conditions. The condition of the eroded revetments poses a significant risk for failure of the levee system. During a major flood event, sloughing or a series of successive bank failures could result in partial or sudden and total failure of the affected levee segment. The evidence of the eroded areas resulting from normal to moderate flows indicates that a major flood event would pose high risks of severe erosion and the probability of levee system failure. Many of the levees and floodwalls are founded on the revetment-protected slopes. Similarly, drainage outfalls are built into the revetment-protected slopes. If the slopes supporting these outfall structures fail, the outfall structures would be impacted. During a large flood event the erosion would not be

visible or easily monitored; a response after a levee section failure would be difficult.

3. Head cuts are occurring on several of the tributaries. These head cuts are affecting bank stability, causing scour and exposure of bridge piers, and causing potential loss of habitat as banks of tributary streams erode. An example is a bridge at Line Creek, located near RM 385 in the Kansas City reach. In this location, a traffic bridge located just upstream of the tributary mouth was shut down temporarily for safety concerns while temporary measures were implemented to ensure the bridge's safety. This incident occurred in FY 2009 and is an indication of the active nature of the riverbed degradation and its impacts. The head cut on this tributary has now migrated to the point that a railroad bridge further upstream is also at risk. Habitat on tributary streams is potentially affected by the sloughing of banks that occurs as head cuts migrate. As this occurs, trees and vegetation along the slopes are lost and may not be reestablished. In both urban and rural areas, these vegetated areas are important habitat resources.

4. Bridges and utility crossings located on the main stem and/or tributaries in close proximity to degrading reaches of the river may be impacted. These include state and local bridges, railroad bridges, and numerous public and commercial pipeline crossings. An important consideration for bridges is an understanding of how riverbed degradation may affect the bridge abutments. A full inventory and identification of these potentially impacted features has not been completed. However, a number of stakeholders, such as the Kansas Department of Transportation and Missouri Department of Transportation, have expressed interest in providing information for an inventory and assessment of bridge or roadway features during the feasibility phase.

5. Environmental impacts of riverbed degradation include potential loss of shallow water habitat due to the lowering of surface water levels. Some shallow water habitat has been constructed as a part of the Missouri River Recovery Program. In addition, managed wetlands constructed in the early 1990s by the Missouri Department of Conservation could be adversely impacted by the lowering of the riverbed, resulting in lower groundwater levels. Some of the wetland habitat acreage is recharged seasonally by shallow groundwater that is influenced by surface water elevations in the river. Lowering surface water elevations may impact these important groundwater connections to the wetland habitat resource. Modeling may be necessary to fully quantify the severity of this potential future impact.

6. Analysis conducted using existing data shows a correlation between commercial dredging activities and the riverbed degradation. The commercial dredging community has expressed concern that riverbed degradation is also attributable to other causes and has indicated their view that these causes should also be fully examined.

7. Bank erosion is resulting in loss of land. This is a concern expressed by stakeholders with farming interests located downstream of Kansas City. These stakeholders are concerned that any potential changes to the management and operations of the BSNP would result in additional bank erosion.

8. There is concern that upstream dams, both on the main stem and tributaries, are trapping sediment and causing a lack of sediment on the lower Missouri River.

9. Utility companies are concerned about water quality and how changes to the management and operations of the BSNP might affect their ability to meet permit requirements.

10. Barge operators said some loading facilities have been abandoned because of inaccessibility to loading and mooring capabilities caused by lowering of the water surface on the Missouri River.

8.1 Forecasting future conditions

One must rely heavily on past and current behavior when attempting to forecast future conditions in a system as complex and uncertain as the Missouri River. The predicted short- and long-term impacts are merely extrapolations of past and current data and assumptions of similar behavior in the future. The near-term (5–10 years) assessment of potential impacts is considered reasonable and reliable; however, the confidence in accurate prediction of potential impacts is significantly reduced beyond the 10-year window.

Many of the causes of riverbed degradation are transient in nature. Flood events have been linked to both to immediate lowering of the streambed and altering the longer-term trend. Dredging rates and impacts on degradation are governed by a variety of drivers, including regulatory restrictions and market demand. Modification and maintenance dikes and revetments are driven by changing needs for project implementation, such as shallow water habitat under the Missouri River Recovery Program. In addition, regular maintenance activities are determined to some degree by funding levels, causing a focus on the most-needed activities. Therefore, a lack of comprehensive maintenance capabilities may impact the rate and magnitude of degradation and sediment availability.

Inherent in the following discussions is that bed degradation is assumed to continue at its present rate for the next 10 years. Also inherent in the discussion are the assumptions that the rate of degradation will begin to slow from 10 years in the future forward and reach a quasi-stable configuration in the Kansas City reach in the next 50 years. It is not necessarily assumed that all reaches of the lower Missouri River will reach that state in the next 50 years. It is quite likely that as the Kansas City reach of the river stabilizes other reaches will become more active.

8.1.1 Near-term without project conditions

Bank stabilization failure. The existing bank stabilization features constructed as part of the BSNP will be stressed by the continued riverbed degradation in the near term (less than 10 years). Field data, although sparse at this time, indicate a launching of revetment stone into the degrading channel. The continued effectiveness of this process is dependent on the quantity of stone placed during original construction. As this stone is used up by the degradation process, revetment and degradation failures will occur. Over the short term, these failures will likely begin to occur with highest incidence in the Kansas City reach of the Missouri River simply because the magnitude of degradation is greatest in that reach of the river. The result of those sporadic failures will be an increase in maintenance and repair costs. In some instances, these failures may negatively impact navigation for short periods of time.

Levee failure during flood events. Flood events have the short-term impact of lowering the streambed by several feet. This can cause levee and floodwall instability in reaches where the structures are near stream banks stabilized by revetments. In the Kansas City reach, some levees and floodwalls are placed in these locations, most notably along the right descending bank of the Missouri River near the confluence of the Kansas River. This study has not reliably quantified the risk of failure of these levees and floodwalls based on riverbed degradation. These systems were tested under extreme flow conditions in 1993 and performed successfully. Since 1993, the streambed has degraded about 5 feet, as measured at the Kansas City USGS gage, adding uncertainty to future performance. Therefore, this amount of degradation leaves no assurance that the floodwalls will perform successfully during an equivalent event in the future.

What is clear from the data is that flood events result in rapid, short-term riverbed degradation. This is particularly troublesome because inspection and repair of revetment failures are extremely hampered during flood events. In the short term, extreme events such as the 1993 flood present an increased risk to the levees and floodwalls along the revetments in the Kansas City reach.

Expenditures to modify intakes. Streambed degradation has led to a corresponding drop in low-flow river stages. This situation has caused increased pumping costs and pump requirements for water intake systems along the degrading reaches. These intake systems primarily support water supply and power generation. Considerable funds have been spent to modify existing intakes to continue operations at the current river conditions. On several occasions during winter low-flow periods water levels at intakes have reached critical levels, nearly taking water supply intakes out of operation.

Water supplies on the Missouri River face potential disruptions; for short periods, water losses from intakes will be made up by alternate well sources. Interruption of cooling water supplies will result in expensive shutdowns for electrical utilities.

In many cases, modifications of existing intakes on the Missouri River have neared their practical limits. Future modification, given current degradation trends, will require major

upgrades or new facilities to access low flows. In the near term (less than 10 years), the needs will likely be accommodated with only increased operational costs and short-term fixes.

Increased releases from upstream dams. In the interim period between implementing additional modifications to the water intakes, there will be a continued or increased need for releases from upstream dams to meet the demand for water supply under low-flow water conditions.

Tributary and drainage structure degradation. In the short term, drainage structures at levees and other locations will continue to require repair and high levels of maintenance. In the case of levee systems, the structures must remain operational to provide interior management. Failure of these levee systems would likely cause flood damages inside the protected area.

Both large and small tributaries are experiencing erosion, bank failures, and the accompanying damages to land and infrastructure. This will require investment of funds to construct mitigating measures.

Reduction in commercial dredging production (permit restrictions). In the short term, limits have been placed on commercial dredging permits to lessen the impact of dredging on degradation in certain reaches of the river. A number of individual permits for commercial dredging have been issued on various reaches of the river. These dredging permits are being evaluated collectively under a single EIS, the Missouri River Commercial Dredging EIS, which is currently underway.

8.1.2 Potential long-term impacts without project conditions

Continued fish and wildlife habitat degradation. Bed degradation can worsen channelization's adverse biologic impacts and reduce the river's ability to produce and support aquatic species. Bed degradation and the resulting lowering of the water surface can impact the system in many ways, including lowering the adjacent groundwater elevation, increasing bank erosion, and head cutting of adjacent drainages. These physical impacts can de-water existing shallow water habitat along the channel border, de-water adjacent flood plain wetlands and other adjacent water resources, increase maintenance costs for existing bank stabilization, increase pumping costs for adjacent well fields and water intakes, and block fish migration up adjacent drainages.

Bed degradation can worsen channelization's adverse biologic impacts by concentrating the flows in the constructed trapezoidal channel and reducing the amount of shallow water habitat available for: (1) primary production of plankton and invertebrates and (2) fish spawning and nursery areas. This situation reduces the river's ability to produce and support aquatic species. Continued riverbed degradation may affect the long-term stability and functioning of habitat restored by the Missouri River Recovery Program. Future studies are needed to quantify these impacts.

Major modifications to water intakes. Major investments in new or dramatically upgraded water intake facilities can be expected in the long term without project conditions. It is anticipated that these investments will increase water costs to users.

Reduced electricity production. Likewise, electric utilities that rely on river water for cooling generating plants will be required to construct major water intake features to obtain cooling water during low-flow periods.

Possible elimination of in-channel commercial dredging. The long-term viability of commercial dredging in the river channel is very much dependent on the outcome of the EIS currently in preparation. Commercial dredging permits on the lower Missouri River are set to expire in December of 2009, pending the completion of the EIS.

Utility crossings damaged. Data has not been analyzed as part of this study to identify the threat to Missouri River utility crossings. However, it is assumed that some level of threat exists over the long term.

Tributary and drainage structure degradation. It is anticipated that tributary erosion will persist long after bed degradation is stabilized on the Missouri River, as head cuts and flow profiles adjust over the length of the tributary. This will result in a variety of utility and road crossing modifications far into the future.

Bridge abutments and piers. Missouri River bridge crossings will need to be re-evaluated in light of the degradation/erosion around piers and abutments. New or replacement bridges will be designed and constructed to reflect the long-term without project conditions. It is anticipated that riverbed degradation will increase the cost of maintaining and building bridge crossings.

Navigation. Riverbed degradation will continue to expose or make more threatening submerged river structures such as remnants of bridge piers where bridges have been removed. Major failures of revetments will potentially interrupt navigation.

Levee failure during flood events. Levee systems will become increasingly at risk as degradation exceeds the performance capabilities of the existing revetments. Without project conditions, there is an increased long-term risk of levee/floodwall failure.

8.2 Specify problems and opportunities

The water resources problem addressed by this reconnaissance study is riverbed degradation and its direct impacts on other water resources. Riverbed degradation impacts numerous resources, including federally constructed infrastructure, non-federal infrastructure, and ecological resources. There are concerns with impacts to federally constructed infrastructures such as levees and floodwalls as well as impacts to the cost of maintenance of the BSNP features that support navigation. As noted in the discussion of public concerns, there is a wide range of public infrastructures that are impacted by riverbed degradation. Detrimental impacts to the ecosystem and habitat resources on both

(1) the main stem of the Missouri River and (2) tributaries (where head cuts occur) are of concern. There are numerous problems resulting from bed degradation in the Missouri River; opportunities to address those problems are outlined in Table 5.

Table 5. Missouri River bed degradation problems and opportunities

PROBLEMS	OPPORTUNITIES
Increased maintenance costs associated with bed degradation for adjustments to BSNP features to maintain the navigation channel.	Reduce the need for future adjustments to the BSNP features.
Increased risk of levee system failure. The reliability of the federally constructed levee systems located along the Missouri River, where the system features are founded upon revetment-protected slopes, is threatened; catastrophic failure could occur during a large flood event. Some federally constructed levees systems on the tributaries may also be at increased risk at their confluence with the Missouri River because of head cuts that cause undermining of those features.	Reduce the risk of levee system failure of the federally constructed levee systems located on the Missouri River and tributary confluences.
Increased demand for water releases from upstream federal dams to meet water supply needs at Kansas City during low-flow conditions. Riverbed degradation has lowered river stages below design elevations for water supply intake structures.	Reduce the need for supplemental releases from upstream dams during periods of low-flow conditions and to maintain historic river stages upon which the water supply intake infrastructure was designed.
Public infrastructure is being damaged because of degradation of the lower Missouri River channel. Although the damage is not fully inventoried, it is most notable in the Kansas City reach. Pipeline crossings, water intakes, bridge abutments, and other infrastructure on the main stem will continue to be impacted by bed degradation.	Reduce or eliminate impacts of bed degradation to public infrastructure along the main stem of the lower Missouri River channel.
Bed degradation is damaging to aquatic and riparian habitat in and along the lower Missouri River, including shallow water habitat and wetlands. These habitat areas consist of remnants of natural habitat and restored habitat constructed under the Missouri River Recovery Program.	Protect or restore natural and constructed shallow water habitat and wetlands along degrading reaches of the lower Missouri River.
Missouri River bed degradation is the primary cause of head cutting on tributaries with confluences in degrading channel reaches. The eroding tributary channels will damage infrastructure (e.g., bridge abutments, pipeline crossings, and levee structures located on the tributaries).	Reduce the impacts of tributary erosion caused by head cutting related to Missouri River bed degradation.
Head cutting impacts important environmental habitat (e.g., bank-stabilizing riparian habitat) as head cuts migrate upstream from the confluence of the affected tributaries and the Missouri River.	Reduce damage to ecological resources caused by head cutting related to Missouri River bed degradation. Minimize damage to ecological resources.

8.3 National objectives

The national or federal objective of water resources and related land resources planning is to contribute to national economic development (NED) in a manner consistent with protecting the nation's environment, pursuant to national environmental statues, applicable executive orders, and other federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are direct net benefits that accrue in the planning area and the rest of the nation.

The USACE has added a second national objective for national ecosystem restoration (NER) in response to legislation and administration policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the output of ecosystem goods and services value to human society.

8.4 Planning objectives

The national objectives of NED and NER are general statements. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for formulating alternative solutions.

The planning objectives for the Missouri River bed degradation studies are as follows:

1. Reduce risk of catastrophic failure of the urban federal FRM systems to reduce the risk of loss of life.

2. Reduce risk of catastrophic failure of the urban federal FRM system to minimize flood damages.

3. Provide reduction of the growing public safety threat posed by potential undermining of urban levees/floodwalls.

4. Minimize further degradation to reduce economic or environmental impacts.

5. Restore degraded reaches of the Missouri River to reduce economic or environmental impacts.

6. Reduce the threat and impact to the sustainability of the natural ecosystem and the ecosystem restoration provided by the Missouri River Recovery Program.

7. Reduce risk of impacts to the BSNP system's reliability and operating costs.

8. Reduce economic damage caused by impacts on water intakes and other structures.

9. Reduce economic damage caused by head cuts on tributaries.

10. Reduce environmental damage caused by head cuts on tributaries.

8.5 Planning constraints

Planning constraints are temporary or permanent limits imposed on the scope of the planning process and choice of solutions. Planning constraints include ecological, economic, engineering, legal, and administrative constraints. Some planning constraints are states of nature; others are based on the design of built structures. Legislation or rule-making impose other planning constraints. Human-imposed constraints can be changed. Planning constraints identified in this study include the following:

1. The planning process must be consistent with all applicable federal, state, and local laws, regulations, and policy.

2. Navigation and FRM will be maintained.

3. The ecological and environmental considerations are extensive; impacts to endangered species and the Missouri River Recovery Project will be important considerations in screening alternative solutions.

8.6 Measures and alternatives

During the reconnaissance phase, potential measures were identified and assessed at a relatively low level of detail, with a focus on screening the measures for their potential to achieve study objectives. The study team evaluated the likelihood that more detailed plans could be formulated that would demonstrate a federal interest. In plan formulation, the no-action measures are analyzed and used to form a baseline on which to compare impacts of the action measures. The no-action alternative is a key component of the National Environmental Policy Act (NEPA) documentation. The initial measures or alternatives considered, with a brief assessment of how well each would meet the planning objectives, are as follows:

1. No action. This includes inventorying and forecasting without project conditions, forming the baseline on which to analyze impacts of the other measures. This is a key component of NEPA and plan formulation for comparison of alternatives.

2. Dike modifications associated with degrading reaches. This includes lowering dike sill elevations, shortening dikes, notching dikes, removing some dikes, redesigning or reconfiguring some dikes, as well as continuing to maintain the navigation channel. This alternative will be difficult to implement as a stand-alone alternative.

3. Channel widening using levee setbacks. This alternative has not been fully evaluated; however, it could be implemented in conjunction with the dike modifications described above. In some reaches, the channel geometry is such that the levees and floodwalls are in close proximity to the river. Further evaluation of the potential for use of levee setbacks needs to be addressed in future studies.

4. Eliminate navigation and redesign dike system to stabilize degradation (adaptive). Two options were identified: (1) allow continued dredging or (2) eliminate dredging. This alternative does not comply with the planning constraint of maintaining a navigation channel.

5. Establish sustainable dredging levels. This alternative could include reduction of dredging, elimination of dredging in certain reaches (adaptive), or modification of dredging techniques. This alternative would have the objective of eliminating the contribution dredging activities make to riverbed degradation. It could impose restrictions on dredging techniques, limit depths of extraction, restrict dredging in some reaches, and/or allow dredging of the foreshore areas between dikes. Dredging in the Missouri River is regulated under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act and is currently permitted. However, the KCD is currently preparing the Missouri River Commercial Dredging EIS concerning the applications to renew the dredging permits. A strategy to limit the impact of dredging on bed degradation will be developed in that EIS and implemented in the permit decision.

6. Strengthen existing revetments in critical reaches of the Missouri River. This alternative would meet the planning objective of reduction of risk to public safety and potentially reduce the economic damages caused by flooding and the subsequent operations and maintenance for repair of bank failures. This alternative is primarily aimed at eliminating the potential for levee and floodwall failures due to bank toe erosion. The public safety concerns are linked to the failure of the structures and the resulting flooding. If failures occur, forcing repair of levees or floodwalls, the resulting operation and maintenance costs would be substantial. The revetment would be reinforced by the addition of stone to the toe of the existing revetment and repairing weakened areas. Definition of the critical reaches will be required based on surveys and inspections of the revetments adjacent to levees and floodwalls. This, as a stand alone measure, does not address the long-term planning objective of minimizing future riverbed degradation.

7. Construct stability structures for levee outfall facilities. This measure would meet the planning objective of reduction of risk to public safety and potentially reduce the economic damages due to flooding. However, because this measure does not minimize future riverbed degradation, it is not comprehensive.

8. Construct grade control structures on tributaries. This measure would address short-term impacts caused by head cuts on the tributaries. Depending on the type of structure, there may be ecological and habitat implications with the implementation of these measures. Implementing these measures does not minimize long-term riverbed degradation.

9. Provide sediment nourishment by constructing shallow water habitat features and using overbank excavations to widen the channel. Sediment transport and the

effects of introducing sediment are not well enough understood to fully quantify their effect on riverbed degradation. However, these measures may be beneficial in some reaches of the river. In general, opportunities for this activity are limited within the most degraded reaches of the Missouri River; therefore, this measure may help but may not meet the long-term planning objectives.

10. Re-establish bends where cutoffs have occurred downstream. This alternative is unlikely due to changed land use subsequent to the cutoffs occurring and the planning constraint of maintaining a navigation channel.

11. Construct new utility and bridge crossings as they become endangered. This alternative is not likely for bridge crossings on the main stem of the Missouri River; however, it may be required on tributaries if streambed degradation on the tributaries continues and short-term stabilization measures fail over the long term.

12. Add grade control structures in the Kansas City reach of the Missouri River. Grade control structures can take several forms. One example would be to engineer rock cascade structures in a manner that the rock, which is placed on the channel bed, will not be mobilized during floods. This measure has the potential to meet the planning objective of minimizing economic impacts to navigation and FRM systems by either stabilizing the riverbed in the most highly degraded reach and/or reversing the degradation within this reach.

13. Increase releases from upstream dams to maintain water level during low-flow periods. This alternative would provide relief to water intake operators; however, it would not solve problems for erosion-susceptible infrastructure or address the long-term threats to the levee system.

14. Construct a series of navigation locks and dams. This alternative is not anticipated as a cost-effective solution; however, it would substantially meet several planning objectives. The locks would provide an ability to assure consistency for water intake stages, trap sediment for dredging, improve reliability of navigation, and provide upstream water savings.

15. A future sediment bypass at Gavins Point Dam, located upstream of the study area is in early stages of study. If deemed feasible, such a bypass might provide additional sediment load for the lower Missouri River. However, because this study is in the very early stages, it is not considered a likely alternative for implementation in the foreseeable future.

16. Establish chutes upstream of the most degrading reaches of the Missouri River. This measure has received very little examination during the reconnaissance phase; however, it is mentioned here as a potential measure that could slow riverbed degradation and restore habitat.

9.0 Preliminary Screening

For preliminary screening, the combination of measures described below has been identified as having the highest potential for implementation.

One alternative is to establish sustainable dredging practices on the Missouri River, relax constriction of dike fields in certain reaches, strengthen bank revetment in critical areas, monitor and stabilize tributaries head cuts, and provide projections of maximum scour depths for infrastructure planning with monitoring (adaptive). It is anticipated that the EIS for commercial dredging that is currently underway will provide information regarding sustainable dredging practices.

This alternative combines many of the previously described measures in an effort to take a balanced approach and address the bed degradation problem comprehensively. To address the long-term degradation problem, dredging quantities and locations must be managed in concert with sustainability. A sustainable dredging extraction rate will need to be implemented in conjunction with all the other components of this alternative. This alternative may meet planning objectives for both short- and long-term stabilization of the affected reaches of the Missouri River.

To arrest further degradation during flood events and create flow conditions conducive to bed recovery in reaches with the greatest amount of degradation, the dike and revetment system will require careful refinement. This refinement must both maintain a navigation channel and not have a negative impact on FRM systems. The more difficult task will be maintaining a navigation channel. Too much relaxation of the dike and revetment system would result in sediment accumulation in the navigation channel to the detriment of navigation. This refinement would be approached incrementally with careful monitoring.

Critical areas will require additional revetment to assure bank stability in the short term during the river's acclimation to a new set of conditions and bed fluctuations during major flood events.

Delays in implementing this or other alternatives will result in additional tributary and drainage outfall erosion problems. These erosion problems will require monitoring; the actions required will reflect existing problems, as well as problems that will develop prior to full implementation of this alternative.

Studies, monitoring, data collection, and analyses will be required to make reliable projections of the maximum scour likely to occur with this alternative in place. Although some recovery of the streambed is anticipated in the long term, it is likely that scour will continue for some time at some locations until full implementation of this alternative is achieved and the system has responded.

It is noted that a second alternative, specific to the Kansas City reach of the Missouri River, also has a high potential for implementation. The Kansas City reach-specific alternative would include a similar combination of measures as described in the first

alternative; however, this alternative would focus on addressing the degradation through the Kansas City reach with the following additional measures:

- Using stone weirs in conjunction with existing dikes.
- Maintaining navigation channel depth at minimum navigation flows.
- Establishing sustainable extraction dredging practices through the Kansas City reach (determinations of sustainable dredging practices are anticipated to be made through the completion the ongoing EIS).
- Maintaining flood flow capacity by notching dikes.

9.1 Economic evaluation

The preliminary screening indicates a number of measures that would have an impact on, and in part meet, the planning objectives. Complete environmental and socioeconomic screening is beyond the scope of an initial appraisal, which is founded primarily on existing information rather than new analysis. Much of the present analysis is qualitative, although we have included quantification to the extent possible. Ultimately, the economic justification of any federal project addressing riverbed degradation will depend on estimating the magnitude of annualized economic losses and benefits. Existing information on Missouri River bed degradation issues is abundant in some respects; however, the probabilistic technical engineering analysis required to support annualized economic impacts must await a much more detailed study. At present, we simply lack the quantitative engineering estimates that would allow for calculation of even an approximate range of benefit-cost ratios. Therefore, this analysis does not attempt any direct benefit-cost analysis of alternatives addressing riverbed degradation. However, it is clear that there are a number of significant economic impacts associated with riverbed degradation. In this analysis, we discuss existing information that will suggest the magnitude of potential economic losses under existing conditions, as well as the potential scale of benefits that might be derived from project alternatives.

9.1.1 Levees

One obvious potential consequence of riverbed degradation is the undermining of federal levees that are critical to protecting cities from major floods. Degradation, by eroding the riverbank, sets in motion a chain of events that includes progressive bank instability and failure, failure of the levee foundation, soil weakening, and catastrophic scouring and erosion, culminating in levee failure. Degradation is a significant and growing concern at many locations along the Missouri River main stem in the KCD. In addition to the Kansas Citys Metropolitan Levee System, there are 15 MRLS units along the Missouri River main stem between Rulo, Nebraska, and St. Louis. These levees protect large portions of the cities of St. Joseph, Missouri; Kansas City, Kansas; and Kansas City, Missouri, along with large rural areas. A widespread degradation pattern could threaten many of these areas. Basic demographic data, including population, for all counties bordering the Missouri River main stem in Missouri and Kansas is summarized in the table in Figure A-9 in Appendix A.

While primarily utilizing existing information to investigate the potential federal interest in participation in a feasibility study, it may be sufficient to focus on the Kansas City reach of the Missouri River. In addition to the physical evidence of riverbed degradation at various sites in the Kansas City reach, an extensive and up-to-date economic database of properties protected by the federal levees is also available from the Kansas Citys Metropolitan Levee System feasibility study that is currently in progress. This economic database allows for a certain amount of quantification of the potential economic consequences of levee failure at Kansas City, Kansas, and Kansas City, Missouri.

Three of the seven federal levee units in the Kansas Citys Metropolitan Levee System have been appraised for this analysis: East Bottoms, Fairfax, and North Kansas City. Each of these units is known to be threatened by significant degradation.

North Kansas City. The North Kansas City levee unit protects a left bank area across the Missouri River from downtown Kansas City, Missouri. The protected area, which is essentially the city of North Kansas City, Missouri, includes nearly 1,100 residential units—home to almost 4,900 residents—and almost 500 businesses and facilities, including Kansas City's Charles B. Wheeler Downtown Airport. The Burlington Northern Santa Fe and Norfolk Southern railroad yards are also protected, as are a significant retail sector, numerous small businesses, warehouses, and industrial sites. About 26,700 people work in North Kansas City. The levee unit's estimated protected investment is almost $3.5 billion, based on October 2008 prices. The existing condition of the riverbed at RM 370.1, near the Charles B. Wheeler Downtown Airport, is estimated to have dropped 24 feet, resulting in loss of rockfill toe protection at one storm sewer outlet. An additional drop of 10 feet in the riverbed's future condition is currently assumed, raising the already significant danger of levee undermining.

Fairfax. The Fairfax levee unit protects a right bank industrial area in Kansas City, Kansas. The protected area includes about 350 businesses and facilities with a total estimated investment of almost $3.5 billion. A General Motors assembly plant anchors the area, which also includes large commercial, industrial, and public facilities such as Owens-Corning, Weyerhauser, and Certainteed. The area has no residents; however, the area's workforce exceeds 11,100 people. Analysis of the existing riverbed condition at RM 367.8 has indicated that a drop of 20 feet in the riverbed already has occurred and is threatening a slide in the riverside bank. An additional drop of 10 feet in the riverbed's future condition is currently assumed, raising the already significant danger of levee undermining. Approximately 40 years ago, the loss of a section of sheet pile wall from the Fairfax levee unit was attributed to degradation. This is significant because the current area of concern is immediately upstream of the previous failure section. The Kansas Citys Metropolitan Levee System feasibility study conservatively assumed 5 feet of degradation, and the estimated reliability losses were significant.

East Bottoms. The East Bottoms levee unit protects a right bank industrial area of Kansas City, Missouri. The protected area contains about 750 businesses and homes with a total estimated value of about $5.4 billion. The industrial structure includes manufacturing, transportation, and major warehouse storage, as well as retail businesses.

Among the approximately 500 companies and facilities in the area include a Kansas City Power and Light plant, a water treatment plant, a Sears distribution center, Cargill, the Isle of Capri Casino, General Mills, and Bayer Corporation. Approximately 250 residential units also are protected. More than 3,200 residents live in the area, and more than 20,100 people are employed in East Bottoms businesses. At RM 364.5, a 15-foot drop in the riverbed already has occurred. An additional drop of 10 feet in the riverbed's future condition is currently assumed, raising the already significant danger of levee undermining. This would greatly increase the probability of a slide undermining the East Bottoms floodwall.

Degradation would eventually undermine these three federal levee units of the Kansas Citys Metropolitan Levee System. It is anticipated that a levee failure in this context would result in major destruction in the short term and continuing catastrophic economic impacts in the long term:

- **Loss of life.** More than 8,000 people reside in these three areas; more than 57,000 people work in these levee units' protected areas. The serious public safety concerns inherent in any major flood event would be exacerbated in this case by the unseen character of erosion and scour beneath the surface of the river, which could result in little or no warning time in advance of levee failure. Significant loss of life would be probable.

- **Single-event damages.** Just in these three areas, a portion of the federally-protected Kansas City flood plain, the occurrence of major floods resulting from levee undermining potentially would threaten $12.4 billion in investment, based on October 2008 prices. Damages in a major flood event probably would exceed $7.6 billion.

- **Levee reconstruction costs.** These three levee units would be severely damaged in a major flood event and would require major repairs. A current cost estimate for rebuilding these three levee units is not available; however, based on repair costs being developed for the Kansas Citys Metropolitan Levee System feasibility study and previously for the MRLS L-385 unit, it can be assumed that costs would be at least $75 million per unit.

- **Annual flood damage reduction benefits lost.** In addition to the single-event damages, the long-term annual benefits provided by these three levee units would be lost until completion of reconstruction. Together, the three levee units account for annual benefits of $625 million over a 50-year period of analysis, according to the economic analysis done for the Kansas Citys Metropolitan Levee System feasibility study.

- **Regional economic development effects.** Many businesses, including leading regional companies, would suffer income losses from flood-related operational interruptions, eventually resulting in closing or relocation. The jobs of

thousands of people would be threatened by business closings or relocations out of the region.

- **Other social effects.** In addition to responding to the danger of loss of life, addressing streambed degradation would contribute to maintaining the viability of Kansas City, Missouri, and Kansas City, Kansas, as cities. These cities would be gravely damaged by the loss of long-term FRM provided by the federal levees. The cities' central industrial districts, many of the largest regional businesses, and many neighborhoods would be left to decline. In addition, socioeconomically disadvantaged groups are disproportionately represented in most of the leveed areas. A project that alleviated degradation enough to prevent the undermining of the levees would contribute to maintaining the cohesion of these neighborhoods and businesses.

- **Environmental quality effects.** Degradation could result in a number of environmentally destructive effects, of which the most important might be the threat to shallow water habitat in the Kansas City reach, including habitat restored under the Missouri River Recovery Program. A project addressing riverbed degradation would protect this habitat, which is important to native river fish such as the endangered pallid sturgeon. Such a project also might be beneficial from an aesthetic standpoint, because the erosion associated with degradation results in an unsightly landscape at many locations.

Once again, it should be emphasized that this focus on urban FRM in Kansas City is intended only as one example of economic impacts throughout the study area. Other federal FRM projects between Rulo, Nebraska, and St. Louis also may be threatened by similar problems. A total population of more than 2.2 million people resides in counties bordering the Missouri River between Rulo, Nebraska, and St. Louis; approximately half of this population is outside the immediate Kansas City area.

9.1.2 Infrastructure impacts

In addition to federal levees, other types of infrastructure threatened by riverbed degradation include bridges, water intakes, and utility crossings.

Bridges. Within the Kansas City District, there are 25 highway bridges and nine railroad bridges crossing either the Missouri River or tributaries near the confluence with the Missouri River. Bridges over rivers are held up by pylons that extend deep into the ground, using the stability of the earth to strengthen foundational support. Degradation erodes the riverbed, exposing pylons and diminishing support for the bridge, with obvious consequences for the risk of bridge failure. The total number of Missouri River bridges currently threatened by riverbed degradation is not known, but several currently show obvious effects of erosion from degradation. Replacement costs for Missouri River bridges vary greatly, but a two-lane bridge with pedestrian lane and safety barrier currently in construction on Route 19 at Hermann, Missouri, on the Missouri River is estimated to cost $33 million. A project addressing riverbed degradation could accrue

significant benefits from preventing the need for bridge replacement (or, in some cases, from replacing bridges prior to their normal replacement schedule).

Utilities. One source of project benefits—likely a major source—would be cost savings from reducing or preventing the need for low-flow responses, such as retrofitting by water and power plants. There are 11 water supply plant intakes on the Missouri River within the Kansas City District, serving an estimated 2.25 million people. There are also 11 power plant intakes. These power plants have a gross generating capacity of 6,046 megawatts.

At Kansas City, Missouri, low flows have forced the city to spend more than $4 million to extend water intakes and drinking water pumps to reach lower river levels. Jefferson City, Missouri, is facing the same problem and has applied for a permit to lower its intake pipes. At Kansas City, Kansas, the city has spent $22.6 million on a cooling tower and emergency pumps to retrofit two electrical generating facilities, The Wyandotte County Board of Public Utilities has estimated that low-flow costs are responsible for a total economic loss (including capital, operations and maintenance, and purchased power) of more than $35 million. (**Note:** Not all of the low-flow costs stem from degradation; in some cases, drought has also contributed. At this time, we do not have the data necessary to delineate costs from each source.) New projects that are on the near-term planning horizon are expected to incur low-water intake costs of $63.2 million, and low-water infrastructure is expected to cost another $286.1 million. If the retrofitting is insufficient to avoid a regional blackout—a possibility that utility officials consider increasingly realistic—costs would exceed $1 billion.

In addition, there are at least 38 pipelines, cables, or power lines crossing the Missouri River between Rulo, Nebraska, and St. Louis (28 petroleum pipelines, 4 water and sewer pipelines, 3 power lines, and 3 telephone cables). Degradation-related impacts on the pipelines are unquantified at this time, but project benefits presumably would include averting potential disruptions in energy and communications to Missouri River basin communities served by this infrastructure.

Navigation. Degradation brings submerged obstructions into play, creating dangerous obstacles for barges and potentially shutting down barge traffic. There are 64 docks and terminals on the Missouri River between Rulo, Nebraska, and St. Louis. Commercial tonnage chiefly consists of agricultural products such as corn and wheat, petroleum products, chemicals, and cement, as well as sand and gravel. Potential benefits of addressing riverbed degradation would include savings from preventing or reducing navigation delays. A season-long shutdown of Missouri River navigation would entail estimated losses of $128 million, according to the Food and Agriculture Policy Research Institute at the University of Missouri-Columbia.

9.1.3 Project Costs

Several measures were identified and screened for this report. Preliminary cost estimates were not completed for all possible alternatives. However, one comprehensive alternative

combines several measures into a plan that likely would be one of the focal points of a feasibility study. This alternative contained the following measures and preliminary cost estimates:

- Relaxation of dike restrictions ($120 million over 400 miles of river)
- Revetment strengthening ($20 million)
- Monitoring and stabilizing tributary head cuts ($20 million)
- Additional monitoring, data collection, and analysis ($10.5 million)

Based on these preliminary estimates, the total cost of this alternative would be $170.5 million. These costs are for a project addressing the entire Missouri River main stem within Kansas City District, not just the Kansas City reach. Assuming the current federal interest rate of 4.625 percent and a 10-year project implementation period, the annualized cost would be about $27 million.

The massive potential losses in the Kansas City reach, which have been described above, include $625 million in annual benefits that would be lost following a major flood event due to degradation. This figure does not consider many other sources of potential benefits, including property damage behind the levees, levee reconstruction costs, potential benefits from other units in the system that may also be affected by degradation, costs to replace bridges and retool water intakes for municipal water supply and power plants, or benefits from other reaches of the Missouri River. Although it is impossible to calculate benefits at this time, it certainly appears that a project with an annual cost of $27 million would be likely to attain economic justification in a future feasibility study.

10.0 Federal Interest

Ensuring a navigation channel and FRM are outputs with high budget priority. Navigation and FRM would be the primary outputs of the alternatives to be evaluated in the feasibility phase; therefore, there is a strong federal interest in conducting the feasibility study. There is also a federal interest in other related outputs of the alternatives, including habitat restoration that could be enhanced under the existing authority for the Missouri River Recovery Program. Based on preliminary screening of alternative, potential project alternatives appear to exist that would be consistent with Army policies, costs, benefits, and environmental impacts. This is based on the screening-level assessment that indicates there are potentially feasible measures for implementation, the screening-level cost estimates, and current economic data.

11.0 Preliminary Financial Analysis

A number of sponsors have co-signed a letter of intent. These sponsors are working on agreements for provision of funds for the feasibility project. The sponsoring entity for the study phase of the feasibility project may be a regional planning agency, the Mid-

America Regional Council (MARC). The MARC has indicated an interest in serving as the sponsor for the project and would serve at the request of the local affected governments and agencies. This potential sponsor has provided a letter of intent, co-signed by multiple affected governments and agencies. In addition to the MARC letter, a number of other letters have been received indicating intent to serve in the sponsor role. These include both letters of intent and letters of support for the project moving forward. Copies of these letters are included in Appendix B. Stakeholders are meeting regularly to encourage additional participation by regional stakeholders, developing a plan for providing funds to support the project, and participating in a scheduled series of discussions for the feasibility scope development with the KCD.

12.0 Assumptions and Exceptions

Feasibility phase assumptions. Riverbed degradation has many physical consequences that potentially pose severe economic impacts on the affected communities and the transportation community in general. The lowering of water levels has already adversely affected the water intakes at power plants and water supply systems. Docking facilities reportedly have been abandoned because barges can no longer be moored. The undercutting of revetment toes has initiated four recent slumping failures (documented in April and May of 2009) at RM 380. Analysis of this type of toe slumping failure indicates that a repeat of the 1993 flood situation could cause a cascade of slumps to cause failures of floodwalls and levees in the Kansas City area with the existing level of riverbed degradation. Tributaries are following the Missouri River downward, posing significant failure threats to bridges, levees, and utility pipelines. The degradation problem has already had significant economic effect on industry and communities along the Missouri River.

The feasibility study would address riverbed degradation and its effects on both the short- and long-term stability of federal FRM systems. The study's purpose would be to ensure continued flood protection for areas currently protected by the FRM systems. In addition, the feasibility study would address the effects of degradation on the long-term stability and sustainability of the navigation system by determining whether or not structural or operating changes to the navigation system might minimize or eliminate impacts of degradation on the system. The feasibility study would consider approaches to help maintain or enhance the viability of federally constructed ecosystem projects such as constructed wetlands and shallow water habitat, and the potential for ecosystem benefits as a result of implementation of measures to address the degradation. In addition, the study would address the potential for protection of local infrastructure.

The following critical assumptions will provide a basis for the feasibility study:

1. A project management plan and feasibility cost-sharing agreement (FCSA) will be executed with the priorities and schedule determined in consultation with the non-federal sponsor and stakeholders.

2. Primary planning constraints consist of maintaining the navigation channel and FRM systems.

3. More comprehensive understanding is needed of sediment load and transport and the ability to forecast future conditions.

4. Better understanding is needed of how the interaction of tributaries impacts riverbed degradation.

5. Quantified hydrologic effects of land use—such as urbanization on sediment transport/load—need to be better understood.

6. Data developed for the EIS for commercial dredging will be important in determining the outcomes of the feasibility study. Economic data, environmental data, and data supporting sustainable levels of commercial dredging will be the key outputs of the EIS, which would be utilized in the feasibility study.

Policy exceptions and streamlining initiatives. No policy exceptions or streamlining initiatives are noted.

Other approvals required. Approval by Headquarters, USACE and the Assistant Secretary of Army for Civil Works will be needed for approval of a non-standard FCSA. The FCSA would be a non-standard agreement in this instance because the proposed non-federal sponsor, the MARC, is a non-profit agency. The Water Resources Development Act of 2007 allows non-profit entities to serve as local sponsor with the consent of the local affected governments. The MARC serves as a regional environmental and water resources planning agency. Degradation impacts affect many of the agencies involved in the MARC's current regional planning activities. Support for the MARC serving as the non-federal sponsor is highlighted by many of the stakeholders in their letters of intent.

13.0 Feasibility Phase Milestones

The feasibility phase milestones are outlined below. This schedule is dependent upon federal appropriation of funds and the availability of sponsor cost-share funding.

Table 6. Feasibility phase milestones

Key events	Milestone
Initiate study	Jan 2010
Public workshop/scoping	Jun 2010
Feasibility scoping meeting	Jun 2011
Alternative formulation briefing	May 2012
Draft feasibility report	Aug 2012
Final public meeting	Aug 2012
Draft report to USACE, Northwestern Division	Sep 2012
District Engineer's public notice	Oct 2012
Civil Works Review Board	Nov 2012
Chief's report	Dec 2012

14.0 Views of Other Resource Agencies

Due to funding and time constraints, limited and informal coordination has been conducted with other resource agencies. Public meetings were attended by some of the resource agencies; these agencies, which are primarily state resource agencies, are attending ongoing meetings to discuss scope development. The MARC and stakeholders are currently participating in discussions and opportunities for partnering; interested agencies are being encouraged to participate. As with the contributing stakeholder group, the interested resource agency participants are still in formative process.

Appendix A

Figures


Kansas City District
Federal Levees
Figure A-1
N
Argentine Unit
Armourdale Unit
CID Kansas
CID Missouri
East Bottoms Unit
Fairfax-Jersey Creek
Kimsey Holly Creek
L 385
L 400
L 408
L 448-443
L 455
L 476
L 488
L 497
R 351
R 440
R 471-460
R 482
R 500
R 512-513
North Kansas City Airport Unit
North Kansas City Lower Unit
Riverside-Quindaro Bend
Falls City
Richardson
Holt
Kimsey Holly Creek
L 497
R 512-513
Andrew
Gentry
Savannah
R 500
L 488
R 482
L 476
Hiawatha
De Kalb
Daviess
Brown
R 471-460
Doniphan
St. Joseph
Cameron
L 455
Buchanan
L 448-443
R 440
Caldwell
Atchison
Clinton
Atchison
Jackson
Smithville Lake
Jefferson
Kearney
Excelsior Springs
Platte
Leavenworth
L 408
Smithville
Ray
Clay
Richmond
Perry Lake
L 400
Kansas City
R 351
Shawnee
Leavenworth
L 385
Riverside
North KC
Jackson
Fairfax-Jersey Creek
Topeka
Tonganoxie
Wyandotte
CID KS
East Bottoms
Buckner
Lafayette
Argentine
CID MO
Johnson
Armourdale
0
5
10
20
Miles

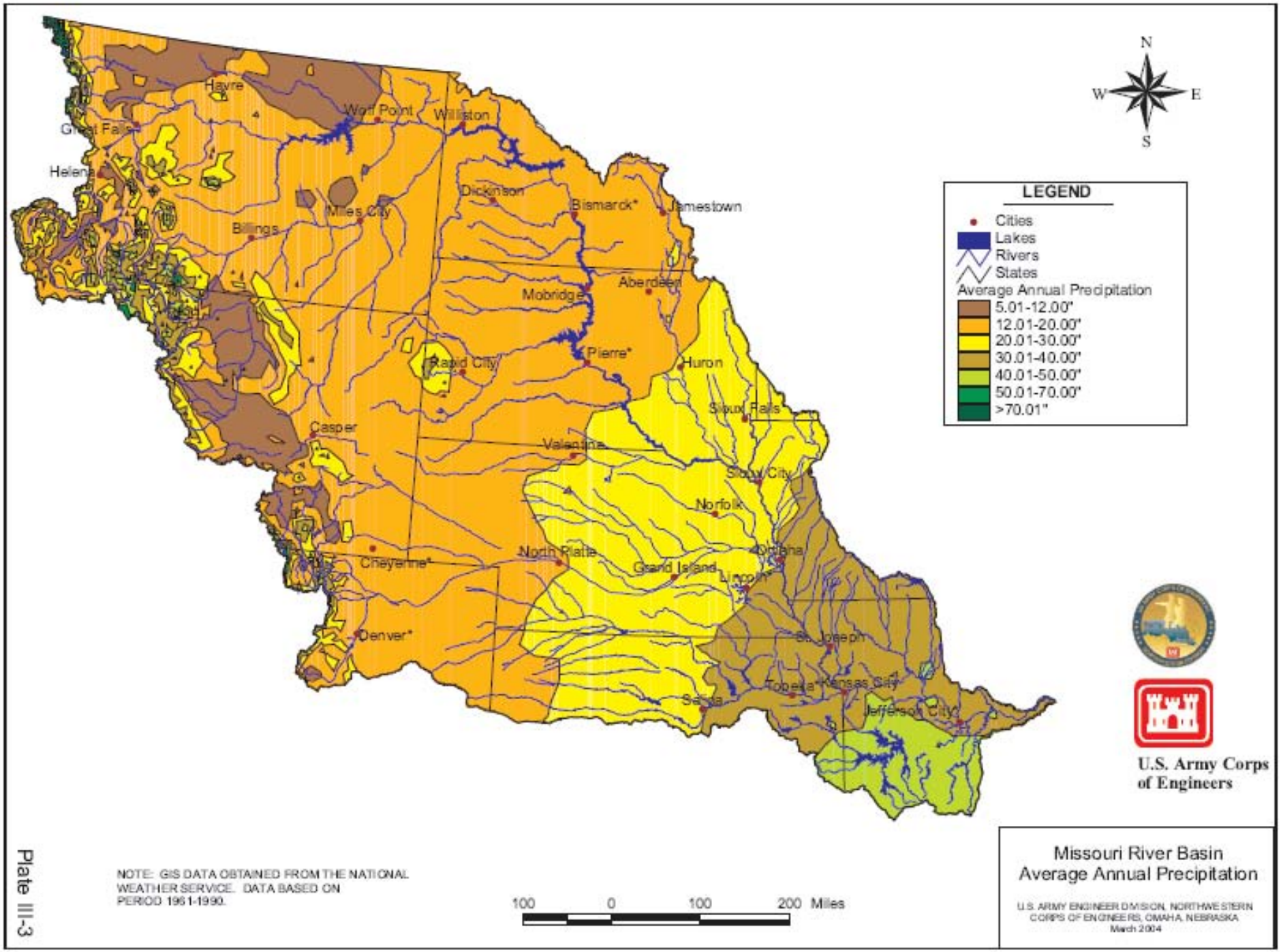
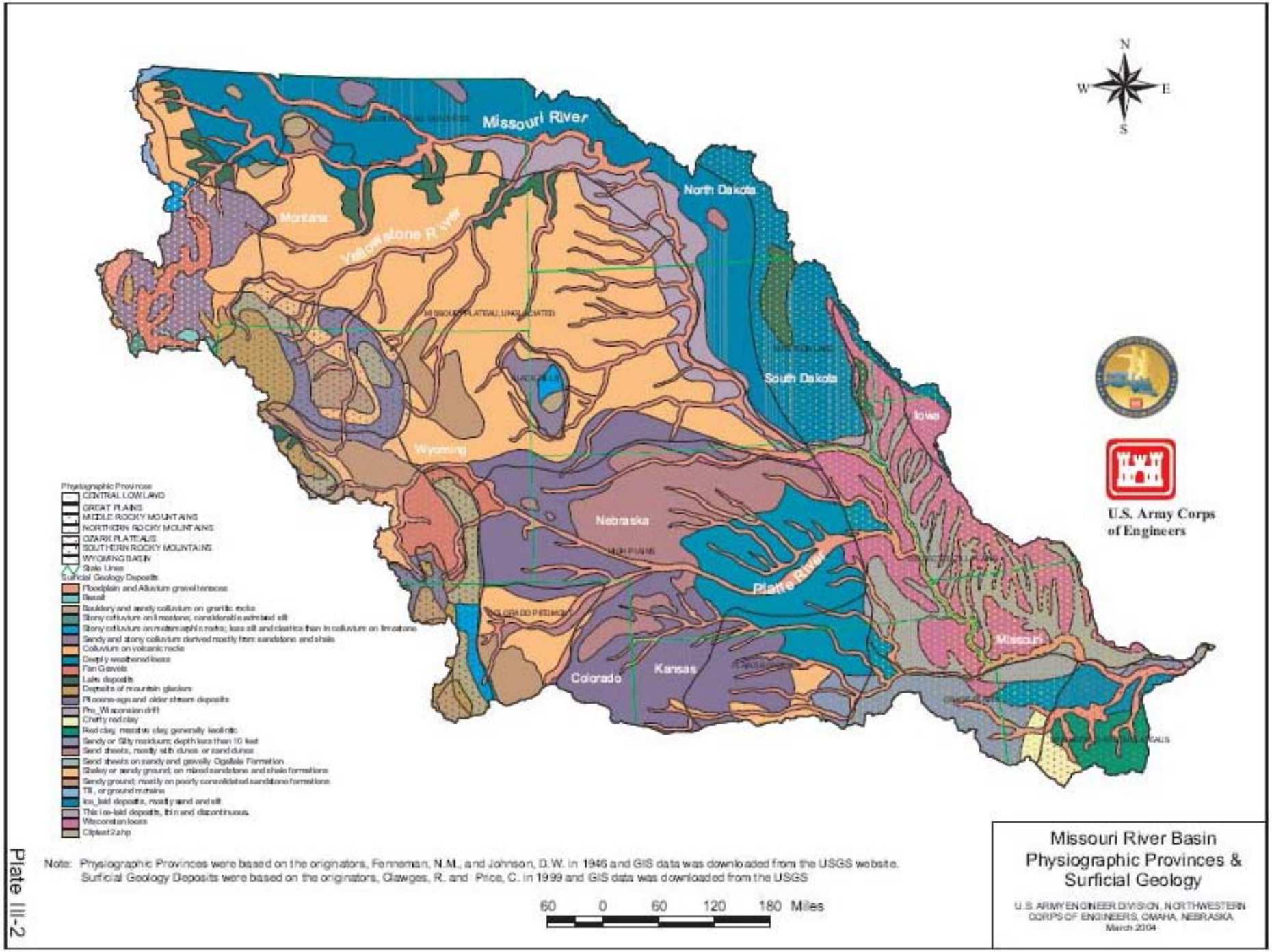

N
W
E
S
LEGEND
Cities
Lakes
Rivers
States
Average Annual Precipitation
5.01-12.00"
12.01-20.00"
20.01-30.00"
30.01-40.00"
40.01-50.00"
50.01-70.00"
>70.01"
Havre
Wolf Point
Williston
Great Falls
Helena
Dickinson
Bismarck*
Jamestown
Miles City
Billings
Aberdeen
Mobridge
Pierre*
Rapid City
Huron
Sioux Falls
Casper
Valentine
Sioux City
Norfolk
North Platte
Omaha
Cheyenne*
Grand Island
Lincoln*
Denver*
St. Joseph
Topeka*
Kansas City
Salina
Jefferson City
U.S. Army Corps of Engineers
NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.
100 0 100 200 Miles
Missouri River Basin
Average Annual Precipitation
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004
Plate III-3

Figure A-2



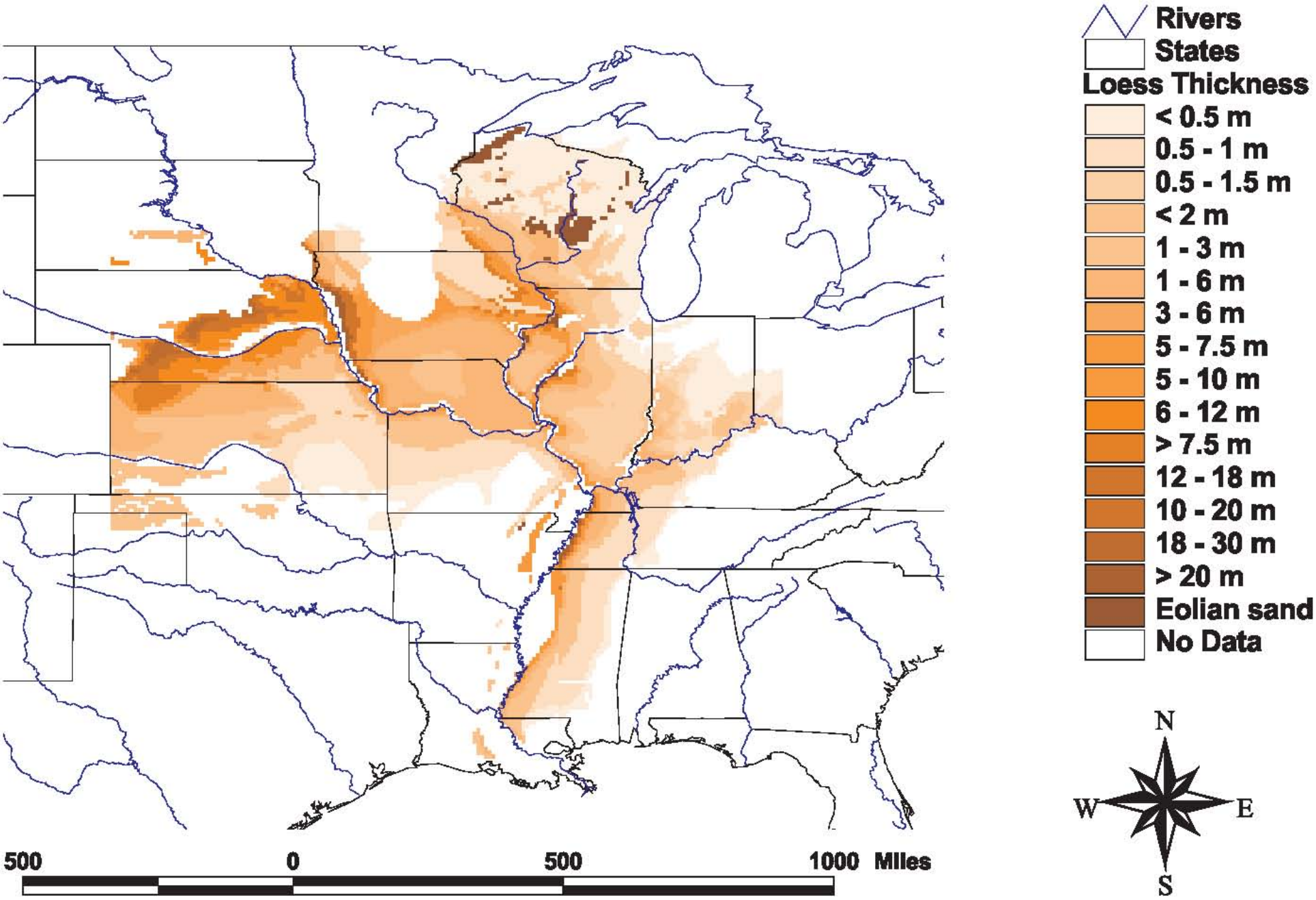
Note: Physiographic Provinces were based on the originators, Fenneman, N.M., and Johnson, D.W. in 1946 and GIS data was downloaded from the USGS website. Surficial Geology Deposits were based on the originators, Clawges, R. and Price, C. in 1999 and GIS data was downloaded from the USGS

Missouri River Basin
Physiographic Provinces &
Surficial Geology

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

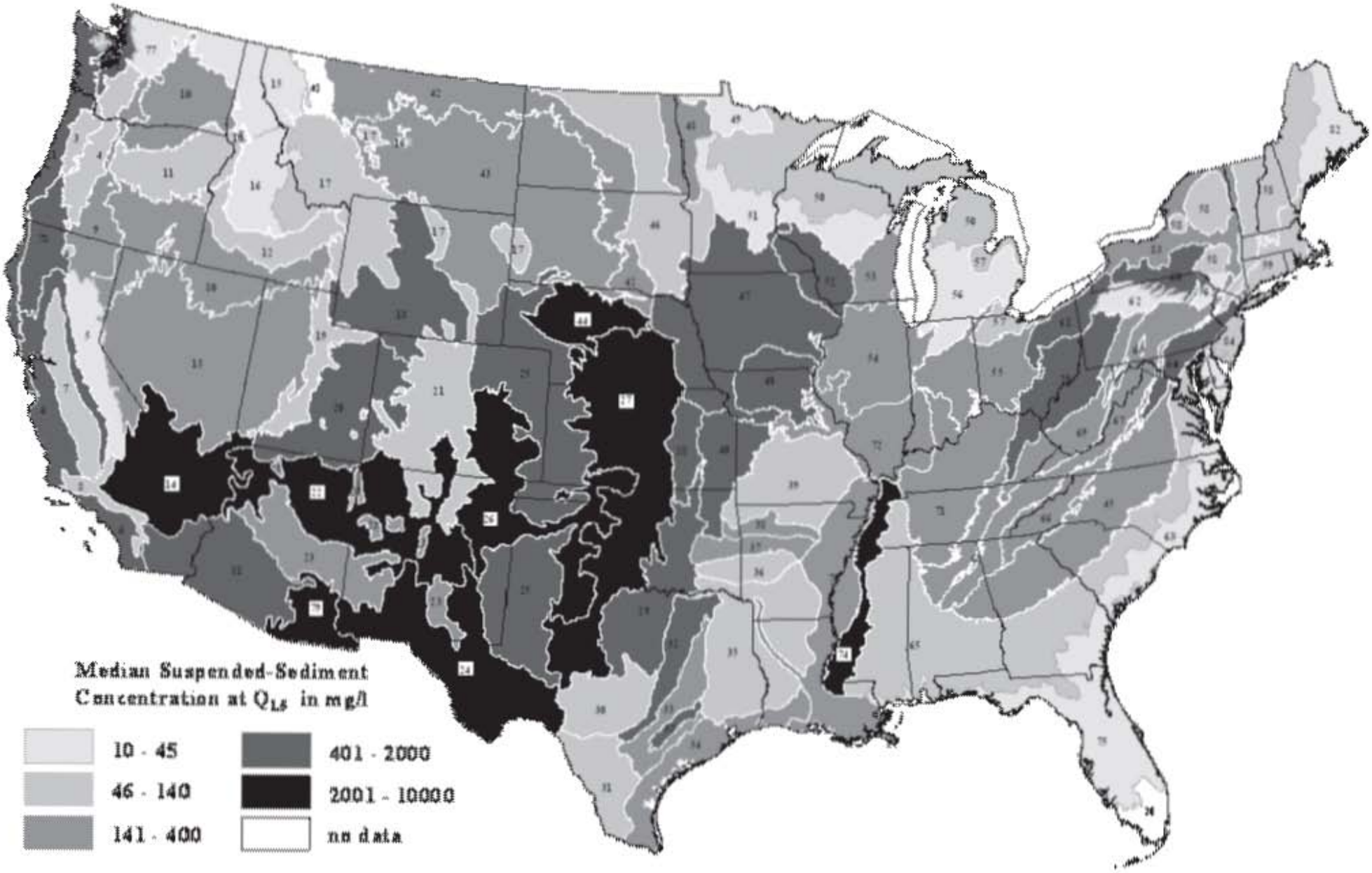
Plate III-2

Figure A-3

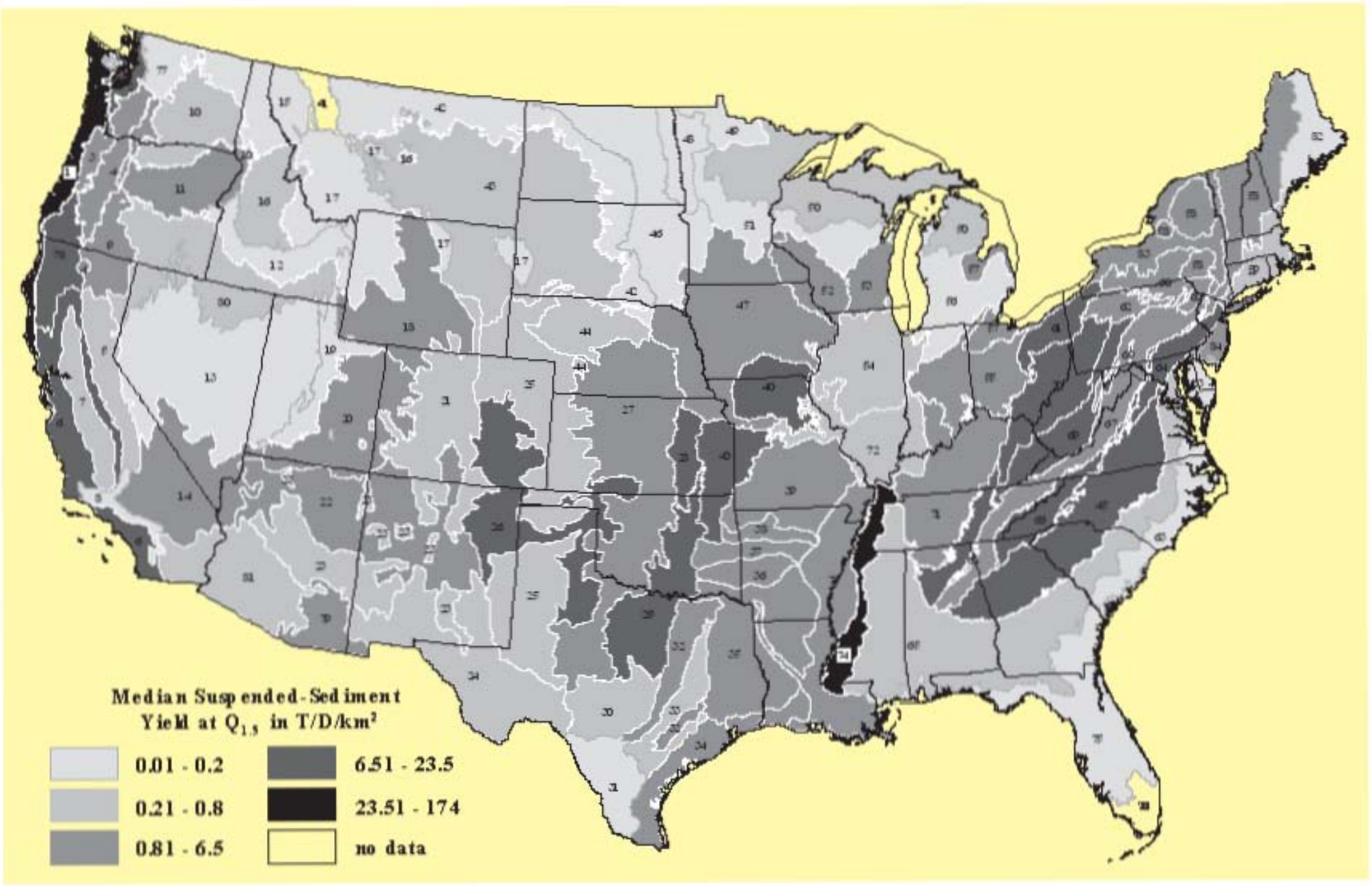


Modified from Lutenegger (1987)

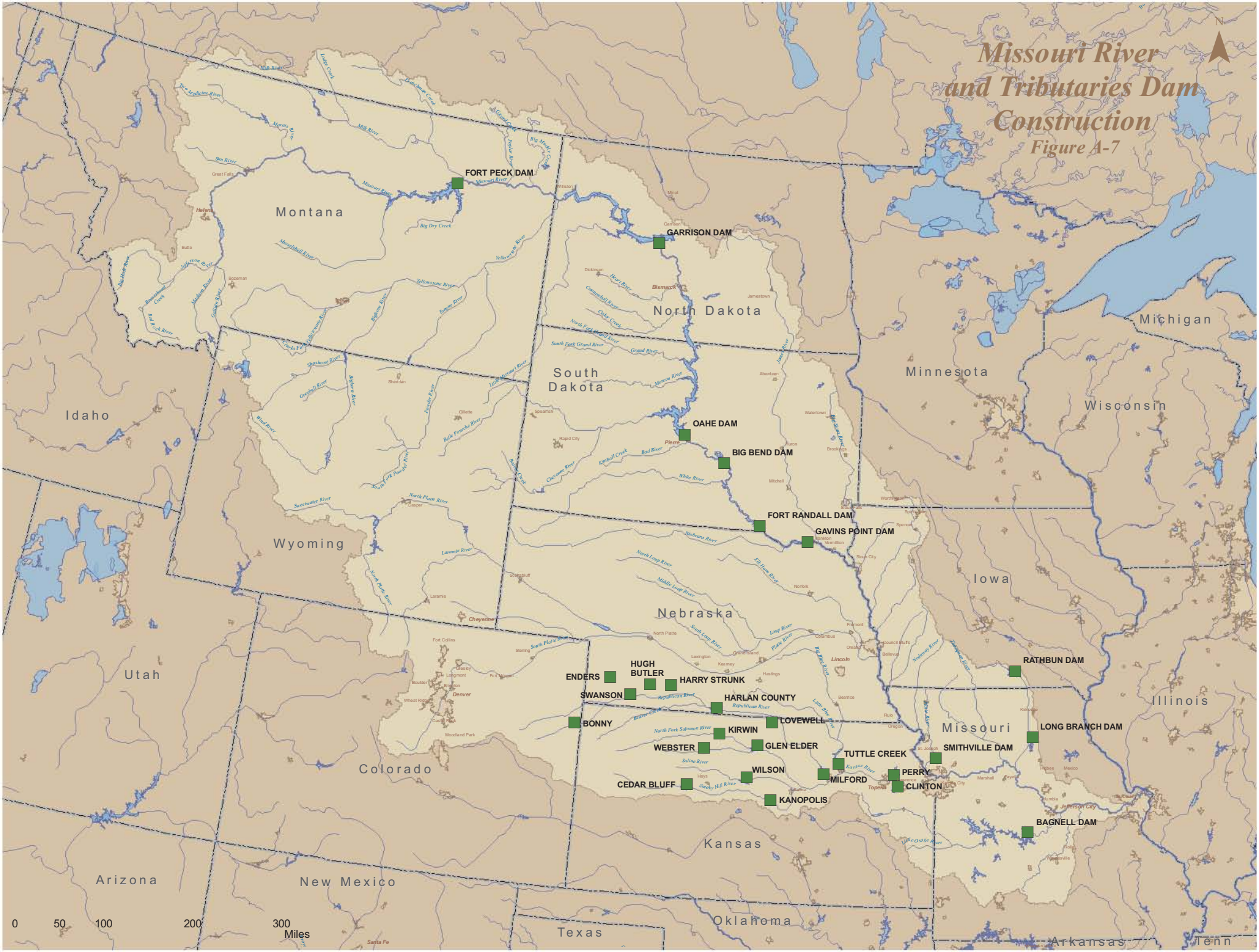
Figure A-4



USDA-ARS National Sedimentation Laboratory, Oxford, MS
Andrew Simon, PhD.
Figure A-5



USDA-ARS National Sedimentation Laboratory, Oxford, MS
Andrew Simon, PhD.
Figure A-6


Missouri River
and Tributaries Dam
Construction
Figure A-7
FORT PECK DAM
GARRISON DAM
OAHE DAM
BIG BEND DAM
FORT RANDALL DAM
GAVINS POINT DAM
ENDERS
HUGH BUTLER
HARRY STRUNK
SWANSON
HARLAN COUNTY
BONNY
LOVEWELL
KIRWIN
WEBSTER
GLEN ELDER
TUTTLE CREEK
SMITHVILLE DAM
WILSON
PERRY
MILFORD
CEDAR BLUFF
CLINTON
KANOPOLIS
RATHBUN DAM
LONG BRANCH DAM
BAGNELL DAM
Montana
North Dakota
South Dakota
Minnesota
Michigan
Wisconsin
Idaho
Wyoming
Nebraska
Iowa
Illinois
Missouri
Utah
Colorado
Kansas
Arizona
New Mexico
Oklahoma
Texas
Arkansas
0 50 100 200 300
Miles


USGS Gauge Locations
Figure A-8
N
500
Rulo
475
Savannah
450
St. Joseph
425
400
Perry Lake
Leavenworth
375
350
325
300
275
250
225
200
175
150
125
100
Hermann
Lawrence
Clinton Lake
Kansas City
Hillsdale
Lee's Summit
Pleasant Hill
Odessa
Higginsville
Marshall
Fayette
Boonville
Columbia
Fulton
Jefferson City
Warrensburg
Sedalia
Knob Noster
Harrisonville
Louisburg
Windsor
Clinton
Eldon
Garnett
Butler
Harry S. Truman
Lake of the Ozarks
Maryville
Bethany
Trenton
Chillicothe
Cameron
Brookfield
Silver
Smithville Lake
Smithville
Excelsior Springs
Cut-Off Lake
Kirksville
Longbranch
Macon
Thomas Hill Reservoir
Moberly
Mexico
Vandalia
Bowling Green
Hannibal
Quincy
Keokuk
Nodaway River
Platte River
Grand River
Thompson River
Chariton River
Mississippi River
Marais Des Cygnes
Osage River
Gasconade River
0 5 10 20 30
Miles

Socioeconomic characteristics of first-tier Missouri River counties

First-tier = counties bordering Missouri River main stem

	Population (2008, Census Bureau)	Population growth since 1990 (Census Bureau)	Per capita personal income (2007, Bureau of Economic Analysis)	Unemployment rate (2008, Bureau of Labor Statistics)	Poverty rate (2007, Census Bureau)	High school diploma or more (2000, Census Bureau)
U.S.	**304,059,724**	**22.2%**	**$36,714**	**4.6%**	**13.0%**	**80.4%**
MISSOURI	**5,911,605**	**15.5%**	**$33,964**	**6.1%**	**13.3%**	**81.3%**
Andrew	16,923	15.7%	$33,641	4.6%	8.4%	84.7%
Atchison	6,031	-19.1%	$28,052	5.1%	15.2%	81.5%
Boone	154,365	37.4%	$32,884	4.3%	16.0%	89.2%
Buchanan	89,408	7.6%	$28,997	5.1%	15.2%	81.5%
Callaway	43,464	32.5%	$25,041	5.3%	12.4%	78.9%
Carroll	9,756	-9.2%	$26,470	7.1%	16.0%	79.1%
Chariton	7,740	-15.9%	$27,795	6.3%	13.5%	79.6%
Clay	215,707	40.6%	$35,220	5.1%	7.1%	88.7%
Cole	74,313	16.9%	$36,223	4.4%	10.9%	85.3%
Cooper	17,535	18.2%	$25,900	5.7%	12.7%	80.3%
Franklin	100,898	25.2%	$32,407	7.5%	9.5%	77.7%
Gasconade	15,261	9.0%	$27,554	7.7%	11.4%	74.0%
Holt	4,905	-18.7%	$26,542	5.0%	14.6%	81.9%
Howard	9,918	3.0%	$29,211	5.8%	6.0%	81.3%
Jackson	668,417	5.6%	$36,402	6.9%	15.0%	83.4%
Lafayette	32,913	5.8%	$31,823	6.0%	13.1%	79.9%
Moniteau	15,121	23.0%	$26,032	5.4%	13.2%	77.6%
Montgomery	11,804	4.0%	$27,104	7.2%	14.8%	71.1%
Osage	13,465	12.0%	$29,344	6.1%	10.2%	75.2%
Platte	85,896	48.4%	$40,149	4.7%	6.2%	91.8%
Ray	23,445	6.7%	$30,907	6.3%	9.0%	79.2%
Saline	22,505	-4.3%	$28,871	5.5%	17.1%	74.0%
St. Charles	349,407	64.2%	$36,711	5.4%	4.6%	89.1%
Warren	31,214	59.8%	$30,448	7.5%	9.7%	79.5%
KANSAS	**2,802,134**	**13.1%**	**$36,525**	**4.4%**	**11.2%**	**86.0%**
Atchison	16,481	-2.7%	$27,515	4.4%	14.3%	84.7%
Doniphan	7,753	-4.7%	$26,131	5.2%	12.4%	80.2%
Leavenworth	74,267	15.4%	$31,097	5.4%	8.2%	86.5%
Wyandotte	154,287	-4.8%	$25,963	7.7%	19.5%	74.0%

Figure A-9 Socioeconomic characteristics of first-tier Missouri River counties

Appendix B

Sponsor Letters of Intent and Letters of Support

Holliday
SAND AND GRAVEL COMPANY
9660 LEGLER ROAD
PH: (913) 492-5920 LENEXA, KS 66219-1291 FAX (913) 438-0200

5/8/09

District Engineer
U.S. Army District, Kansas City
601 E 12th Street
Kansas City, Missouri

Re: Letter of Intent - Missouri River Degradation

Dear Sir:

This letter serves as a notice of intent by Holliday Sand & Gravel Company ("Holliday") to work with the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problems in the Kansas City region.

Degradation of the bed of the Missouri River could cause instability to river banks and could undermine utility, transportation and other structures on the Missouri River and its tributaries, particularly in the Kansas City reach of the river. Bed degradation has also significantly impacted river intakes for the Kansas City region's major water suppliers and electric utilities. The Corps is completing a reconnaissance study of the river bed degradation issues, which will support the importance of addressing these serious issues.

The Corps has indicated that solutions to the degradation problem could be pursued through a feasibility study of the degradation issues in the Kansas City reach, with 50 percent of study costs funded by the Corps and 50 percent of the study costs funded by non-federal (local) sponsors. It is anticipated that the non-federal cost would be borne by a number of local entities with interest in identifying solutions to address the Missouri River bed degradation. We also understand that the scope, cost and schedule for the feasibility study will be determined through the development of a mutually acceptable Project Management Plan. The scope, costs and schedule identified in the Project Management Plan would then be used to guide the feasibility study efforts, as referenced by the formal Feasibility Cost Sharing Agreement to be signed by the Corps and the local sponsor(s).

Accordingly, please accept this letter as Holliday's expression of intent to proceed with the development of a Project Management Plan that we hope will lead to a local sponsor or sponsors entering into a Feasibility Cost Sharing Agreement with the Corps. We anticipate that the Feasibility Cost Sharing Agreement may produce recommendations that may be appropriate for cost sharing, and others that are appropriate to be fully funded by the federal government. It is our expectation that implementation of such recommendations would move forward expeditiously, so as to avoid further degradation and

associated costs. This letter is an expression of interest only, and shall not constitute or be construed as a contractual, financial or other obligation on the part of Holliday.

Holliday is also interested in working with the Mid-America Regional Council, which could serve as the local sponsor for the feasibility study, on behalf of those organizations willing to provide resources for the cost share portion of the study. MARC is an association of local governments serving the bi-state Kansas City region and has assisted the region by serving as a project sponsor on transportation and other regional projects. The MARC Board of Directors, composed of 33 local elected officials from across the region, has authorized MARC to offer to serve as local sponsor if desired by local stakeholders. MARC has the personnel capacity to serve as a project sponsor if requested to do so by local stakeholders.

Holliday appreciates the serious impacts that bed degradation of the Missouri River presents to the government and private entities in this region. We look forward to a successful partnering effort as we proceed with this project.

Sincerely,
Holliday Sand & Gravel Company

M. L. Odell

Mike Odell
Vice President

Encl.

Kansas City,
Board of Public Utilities 540 MINNESOTA AVENUE • KANSAS CITY, KANSAS 66101 • (913) 573-9000

May 8, 2009

District Engineer
U.S. Army District, Kansas City
601 E 12th Street
Kansas City, Missouri

Re: Letter of Intent - Missouri River Degradation

Dear Sir:

This letter serves as a notice of intent by the Kansas City Board of Public Utilities (BPU) to work with the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problems in the Kansas City region.

Degradation of the bed of the Missouri River has caused instability to river banks and has undermined utility, transportation and other structures on the Missouri River and its tributaries, particularly in the Kansas City reach of the river. Bed degradation has also significantly impacted river intakes for the Kansas City region's major water suppliers and electric utilities. The Corps is completing a reconnaissance study of the river bed degradation issues, which will support the importance of addressing these serious issues.

The Corps has indicated that solutions to the degradation problem could be pursued through a feasibility study of the degradation issues in the Kansas City reach, with 50 percent of study costs funded by the Corps and 50 percent of the study costs funded by non-federal (local) sponsors. It is anticipated that the non-federal cost would be borne by a number of local entities with interest in identifying solutions to address the Missouri River bed degradation. We also understand that the scope, cost and schedule for the feasibility study will be determined through the development of a mutually acceptable Project Management Plan. The scope, costs and schedule identified in the Project Management Plan would then used to guide the feasibility study efforts, as referenced by the formal Feasibility Cost Sharing Agreement to be signed by the Corps and the local sponsor(s).

Accordingly, please accept this letter as BPU's expression of intent to proceed with the development of a Project Management Plan that we hope will lead to a local sponsor or sponsors entering into a Feasibility Cost Sharing Agreement with the Corps. We anticipate that the Feasibility Cost Sharing Agreement may produce recommendations that may be appropriate for cost sharing, and others that are appropriate to be fully funded by the federal government. It is our expectation that implementation of such recommendations would move forward expeditiously, so as to avoid further degradation and associated costs. This letter is an expression of interest only, and shall not constitute or be construed as a contractual, financial or other obligation on the part of BPU.

BPU is also interested in working with the Mid-America Regional Council, which could serve as the local sponsor for the feasibility study, on behalf of those organizations willing to provide resources for the cost share portion of the study. MARC is an association of local governments serving the bi-state Kansas City region and has assisted the region by serving as a project sponsor on transportation and other regional projects. The MARC Board of

Directors, composed of 33 local elected officials from across the region, has authorized MARC to offer to serve as local sponsor if desired by local stakeholders. MARC has the personnel capacity to serve as a project sponsor if requested to do so by local stakeholders.

BPU appreciates the serious impacts that bed degradation of the Missouri River presents to the government and private entities in this region. We look forward to a successful partnering effort as we proceed with this project.

Sincerely,

James Epp by

James Epp
Manager Water Operations & Acting Chief Administrative Officer

May 8, 2009

District Engineer
U.S. Army District, Kansas City
601 E 12th Street
Kansas City, Missouri

Re: Letter of Support for Missouri River Degradation Feasibility Study

Dear Sir:

This letter serves as a letter of support by Kansas City Power & Light Company of the importance for the U.S. Army Corps of Engineers to complete a feasibility study to address the Missouri River bed degradation problems in the Kansas City region. Kansas City Power & Light Company operates four electric generating stations on the Missouri River that draw water from the Missouri River for once-through cooling.

Degradation of the bed of the Missouri River has caused instability to river banks and has undermined utility, transportation and other structures on the Missouri River and its tributaries, particularly in the Kansas City reach of the river. Bed degradation has also significantly impacted river intakes for the Kansas City region's major water suppliers and electric utilities. The Corps is completing a reconnaissance study of the river bed degradation issues, which will support the importance of addressing these serious issues. The Corps has indicated that solutions to the degradation problem could be pursued through a feasibility study of the degradation issues in the Kansas City reach.

Kansas City Power & Light Company will work with the Mid-America Regional Council, which could serve as the local sponsor for the feasibility study, on behalf of impacted organizations; although, we are unable to provide resources for the cost share portion of the study at this time. MARC is an association of local governments serving the bi-state Kansas City region and has assisted the region by serving as a project sponsor on transportation and other regional projects. The MARC Board of Directors, composed of 33 local elected officials from across the region, has authorized MARC to offer to serve as local sponsor if desired by local stakeholders. MARC has the personnel capacity to serve as a project sponsor if requested to do so by local stakeholders.

Kansas City Power & Light Company appreciates the serious impacts that bed degradation of the Missouri River presents to the government and local utilities like us in this region. We look forward to a successful partnering effort as this project moves forward.

Sincerely,

Scott Heidtbrink
Senior Vice-President - Supply

KANSAS
NATURAL RESOURCE SUB-CABINET

Mark Parkinson, Governor
J. Michael Hayden, Chair

May 7, 2009

Colonel Roger A. Wilson, Jr., District Commander
U.S. Army Corps of Engineers, Kansas City District
601 E 12th Street
Kansas City, Missouri 64106

Re: Missouri River Degradation

Dear Col. Wilson:

The purpose of this letter is to share our concern about bed degradation of the Missouri and Kansas rivers. The problems associated with degradation of the riverbed should be of mutual concern to the State of Kansas and the Corps of Engineers, and we are willing to work with the COE to explore possible solutions. Bed degradation of the portion of the Missouri River adjacent to Kansas and the lower Kansas River is a growing problem that has been of concern to the State for some time and has been made a priority issue in the Kansas Water Plan. The Water Plan is an ongoing effort to identify and address priority water resource issues throughout the State.

Degradation of the Missouri River bed raises a variety of concerns, some of which are well documented. Instability of the riverbanks, undermined infrastructure such as utility and transportation structures and impacts to intakes for public water supplies, utilities and industry. We do understand the Corps is conducting a reconnaissance study of Missouri River bed degradation in the lower 498 river miles, from Rulo, Nebraska to the mouth of the river at St. Louis, Missouri. That should help to illustrate the importance of addressing these serious issues. Similarly degradation of the Kansas River bed has also caused the same types of problems. We request that the Corps include the Kansas River in the reconnaissance study and degradation study – at least the lower reach from the WaterOne weir in Johnson County to the confluence with the Missouri River.

The Corps has indicated that solutions to the degradation problem could be pursued through a feasibility study of the degradation issues in the Kansas City reach, with half of the study costs funded by the Corps and the other half of the study costs funded by non-federal sponsors. It is anticipated that non-federal costs would be shared by a number of local entities with interest in identifying solutions to the Missouri River bed degradation. We also understand the scope, cost and schedule for the feasibility study will be determined through the development of a mutually acceptable project management plan.

We look forward to working with you on this important effort and would welcome an opportunity to visit with you and your staff in the near future. As one step in the process we

Natural Resource Sub-Cabinet
1020 S Kansas Ave., Suite 200, Topeka, KS 66611-1327
(785)296-2281 · Fax: (785)296-6953

would like to invite you to attend a meeting of the Natural Resource Cabinet Team so we can discuss this study and how we may be of assistance.

Sincerely,

J. Michael Hayden
Kansas Secretary of Wildlife & Parks
Chair, Kansas Natural Resources Cabinet Team

c: Mid-America Regional Council
Kansas Department of Transportation

The Kansas Natural Resources Cabinet Team is composed of agency heads from the Departments of Agriculture, Animal Health, Health & Environment, Wildlife & Parks, Kansas Corporation Commission, State Conservation Commission, and Kansas Water Office.

600 Broadway, Suite 200
Kansas City, Missouri 64105-1659

816/474-4240
816/421-7758 FAX
www.marc.org

MARC
Mid-America Regional Council

May 8, 2009

Colonel Roger A. Wilson, Jr.
District Commander
U.S. Army Corps of Engineers, Northwestern Division
Kansas City District
601 E 12th Street
Kansas City, Missouri

Re: Letter of Intent - Missouri River Degradation

Dear Sir:

This letter will serve as a notice of intent by the Mid-America Regional Council (MARC), the City of Kansas City, Missouri, Platte County, Missouri, the Fairfax Drainage District of Wyandotte County, and the North Kansas City Levee District, to work with the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problem in the Kansas City region. Other interested stakeholders may be communicating their intent to work with the Corps on this matter in a separate communication(s).

Degradation of the bed of the Missouri River has caused instability to river banks and has undermined utility, transportation and other structures on the Missouri River and its tributaries, particularly in the Kansas City reach of the river. Bed degradation has also significantly impacted river intakes for the Kansas City region's major water suppliers and electric utilities. The Corps is completing a reconnaissance study of the river bed degradation issues, which will support the importance of addressing these serious issues.

The Corps has indicated that solutions to the degradation problem could be pursued through a feasibility study of the degradation issues in the Kansas City reach, with 50 percent of study costs funded by the Corps and 50 percent of the study costs funded by non-federal (local) sponsors. It is anticipated that the non-federal cost would be borne by a number of local entities with interest in identifying solutions to address the Missouri River bed degradation. We also understand that the scope, cost and schedule for the feasibility study will be determined through the development of a mutually acceptable Project Management Plan. The scope, costs and schedule identified in the Project Management Plan would then used to guide the feasibility study efforts, as referenced by the formal Feasibility Cost Sharing Agreement to be signed by the Corps and the local sponsor(s).

Accordingly, please accept this letter as an expression of intent by the undersigned to proceed with the development of a Project Management Plan that we hope will lead to a local sponsor or sponsors entering into a Feasibility Cost Sharing Agreement with the Corps. We anticipate that the Feasibility Cost Sharing Agreement may produce recommendations that may be appropriate for cost sharing, and others that are appropriate to be fully funded by the federal government. It is our expectation that implementation of such recommendations would move forward expeditiously, so as to avoid further degradation and associated costs. This letter is an expression of interest only, and shall not constitute or be construed as a contractual, financial or other obligation on the part of MARC or any of the undersigned.

MARC is an association of local governments serving the bi-state Kansas City region and has assisted the region by serving as a project sponsor on transportation and other regional projects. The MARC Board of Directors, composed of 33 local elected officials from across the region, has authorized MARC to offer to serve as local sponsor if desired by local stakeholders. MARC has the personnel capacity to serve as a project sponsor if requested to do so by local stakeholders.

MARC and the undersigned entities appreciate the serious impacts that bed degradation of the Missouri River presents to the governments and private entities in this region. We look forward to a successful partnering effort as we proceed with this project.

Sincerely,

David Warm
Mid-America Regional Council

Additional entity signature pages attached.

The signature below confirms the intent of the City of Kansas City, Missouri to work with MARC and the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problem in the Kansas City area.

The City of Kansas City, Missouri

By: _____
Bernardo Garcia
Director, Water Services Department

The signature below confirms the intent of Platte County, Missouri to work with MARC and the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problem in the Kansas City area.

Platte County, Missouri

By: Betty Knight
Betty Knight
Presiding Commissioner
Platte County, Missouri

The signature below confirms the intent of the Fairfax Drainage District of Wyandotte County, Kansas to work with MARC and the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problem in the Kansas City area.

Fairfax Drainage District of Wyandotte County, Kansas

By: Kevin S. Brown

Kevin S. Brown, P.E.
President

The signature below confirms the intent of the North Kansas City Levee District to work with MARC and the U.S. Army Corps of Engineers on the next stage of study to address the Missouri River bed degradation problem in the Kansas City area.

North Kansas City Levee District

By: _____
Richard M. Lanning, Jr., SHOR
President, Board of Supervisors

MISSOURI
AMERICAN WATER

Terry L. Gloriod
President
terry.gloriod@amwater.com

727 Craig Road
St. Louis, MO 63141

www.amwater.com

P 314.996.2304
F 314.432.7824
C 314.882.1207

May 4, 2009

District Engineer
U.S. Army District, Kansas City
601 E. 12th Street
Kansas City, MO 64106

RE: Missouri River Degradation – Kansas City Area

Dear Sir:

The Kansas City District Office of the U.S. Army Corps of Engineers is completing a reconnaissance study of the river bed degradation issues occurring in the lower 498 miles of the Missouri River. The Corps has indicated its desire to pursue a feasibility study of the degradation issues. It is our understanding that attempting to pursue a feasibility study with the federal government supporting the full cost of the study could result in considerable delay of the study.

Based on the information obtained to date, Missouri American Water is interested in pursuing initial negotiations with the Corps on the scope of a feasibility study that is funded on a cost-share basis. Missouri American Water may be willing to participate as a non-federal sponsor in a cost-share approach to the feasibility study, with the cost of the study allocated by agreement between the Corps and all participating non-federal sponsors. The non-federal cost-share may be provided in cash or in-kind services.

This letter is an expression of interest only, and shall not constitute or be construed as a contractual, financial or other obligation on the part of all or any of the parties that are signatories hereto.

Missouri American Water appreciates the serious impacts that bed degradation of the Missouri River presents to both government and private entities in this region. As we understand, degradation of the bed of the Missouri River has caused instability to river banks and has undermined utility, transportation and other structures on the Missouri River and its tributaries. It is our hope that these issues can be further studied and addressed in a way that is of significant benefit to impacted parties.

Very truly yours,

Terry L. Gloriod
President

Cc: Frank Kartmann, Bob Fuerman, Steve Murray

Missouri Department of Transportation

MoDOT

Elizabeth A. Wright, District Engineer

District 4 – Kansas City Area
600 NE Colbern Road
Lee's Summit, MO 64086
(816) 622-6500
Fax (816) 622-6323
Toll free 1-888 ASK MoDOT
(1-888-ASK-6636)
www.modot.mo.gov

April 29, 2009

Colonel Roger A. Wilson, Jr.
District Commander
U.S. Army Corps of Engineers, Northwestern Division
Kansas City District
601 E. 12th Street, Room 700
Kansas City, MO 64106

Re: Letter of Intent- Missouri River Degradation- Kansas City Area

Dear Colonel Wilson:

Degradation of the bed of the Missouri River has caused instability to riverbanks and has undermined utility, transportation and other structures on the Missouri River and its tributaries.

The Degradation has the potential to significantly impact Missouri Department of Transportation's bridge and drainage structures. The Kansas City District Office of the U.S. Army Corps of Engineers is completing a reconnaissance study of the riverbed degradation issues occurring in the lower 498 miles of the Missouri River. The Corps has indicated its desire to pursue a feasibility study of degradation issues. It is our understanding that attempting to pursue a feasibility study with the Federal Government supporting the full cost of the study could result in considerable delay of the study.

Based on the information obtained to date, MoDOT is interested in pursuing initial negotiations with the Corps on the scope of a feasibility study that is funded on a cost-share basis. MoDOT may be willing to participate as a non-federal sponsor in a cost-share approach to the feasibility study, with the cost of the study allocated by agreement between the Corps and all participating non- Federal sponsors. The non-federal cost-share may be provided in cash or in-kind services.

MoDOT is also interested in working with the Mid-America Regional Council (MARC), which would act as the local sponsor for the feasibility study, on behalf of those organizations willing to provide resources for the cost-share portion of the study. MARC is an association of local governments serving the bi-state Kansas City region and has assisted local governments by serving as a project sponsor on transportation and other regional projects. MARC has the capacity to serve as a project sponsor if requested to do so by local stakeholders.

This letter is an expression of interest only, and shall not constitute or should not be construed as a contractual, financial or other obligation on the part of all or any of the parties that are signatories hereto.

MoDOT appreciates the serious impacts the bed degradation of the Missouri River presents to both government and private entities in this region. It is our hope that these issues can be further studied and addressed in a way that is of significant benefit to impacted parties.

Respectfully,

Elizabeth A. Wright, P.E.
District Engineer

Copies: Dave Nichols – MoDOT
Dennis Heckman – MoDOT
Kathy Harvey – MoDOT
Tom Schrempp – WaterOne
Darci Meese – WaterOne
Ginevera Moore – MARC

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
Missouri Water Science Center
1400 Independence Road
Rolla, Missouri 65401

May 1, 2009

District Engineer
U.S. Army District, Kansas City
601 E 12th Street
Kansas City, Missouri

Dear Sir:

This letter will service as acknowledgment by the U.S. Geological Survey, Missouri Water Science Center of the importance to the area of the U.S. Army Corps of Engineers sponsored study to address the Missouri River bed degradation problem in the Kansas City region and along the entire Lower Missouri River.

Degradation of the bed of the Missouri River has caused instability to river banks and undermined utility, transportation and other structures on the Missouri River and its tributaries, particularly in the Kansas City reach of the river. Bed degradation has also significantly impacted river intakes for the Kansas City region's major water suppliers and electric utilities. One result of bed degradation is a long-term decline in river stages. Groundwater levels in the alluvial aquifer are strongly influenced by changes in river stage - especially long-term changes. A lowered water table may increase pumping costs for water-supply wells, degrade water quality by reducing the thickness of saturated alluvial deposits between the Missouri River bed and lateral screens of water-supply collector wells, decrease well yields, and cause substantially drier hydroperiods that can affect the biological integrity of Missouri River riparian wetlands. The Corps is completing a reconnaissance study of the river bed degradation issues, which will support the importance of addressing these serious issues.

Respectfully

Michael E. Slifer
Director
U. S. Geological Survey
Missouri Water Science Center

WaterOne
Water District No. 1 of Johnson County

Setting the Standard for Utility Excellence

May 5, 2009

District Engineer
U.S. Army District, Kansas City
601 E. 12th Street
Kansas City, MO

Re: Missouri River Degradation- Kansas City Area

Dear Sir:

This letter serves as a notice of intent by WaterOne to work with the U.S. Army Corps of Engineers in the next stage of study to address the Missouri River bed degradation problems in the Kansas City region.

Degradation of the bed of the Missouri River has caused instability to river banks and has undermined utility, transportation and other structures on the Missouri River and its tributaries. The degradation has also significantly impacted WaterOne's river intakes as well as intakes operated by other water suppliers and electric utilities. The Kansas City District Office of the U.S. Army Corps of Engineers is completing a reconnaissance study of the river bed degradation issues occurring in the lower 498 miles of the Missouri River. The Corps has indicated its desire to pursue a feasibility study of the degradation issues.

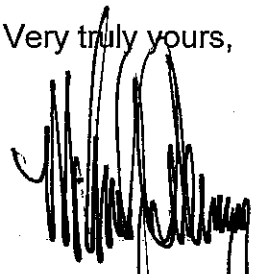
Based on the information obtained to date, WaterOne is interested in pursuing initial negotiations with the Corps on the scope of a feasibility study that is funded on a cost-share basis. WaterOne may be willing to participate as a non-federal sponsor in a cost-share approach to the feasibility study, with the cost of the study allocated by agreement between the Corps and all participating non-federal sponsors. The non-federal cost-share may be provided in cash or in-kind services.

WaterOne is also interested in working with the Mid-America Regional Council (MARC), which would act as the local sponsor for the feasibility study, on behalf of those organizations willing to provide resources for the cost-share portion of the study. MARC is an association of local governments serving the bi-state Kansas City region and has assisted local governments by serving as a project sponsor on transportation and other regional projects. MARC has the capacity to serve as a project sponsor if requested to do so by local stakeholders.

This letter is an expression of interest only, and shall not constitute or be construed as a contractual, financial or other obligation on the part of all or any of the parties that are signatories hereto.

WaterOne appreciates the serious impacts that bed degradation of the Missouri River presents to both government and private entities in this region. It is our hope that these issues can be further studied and addressed in a way that is of significant benefit to impacted parties.

Very truly yours,



Michael J. Armstrong
General Manager

MJA/jb

cc: WaterOne Board
Tom Schrempp
Mid-America Regional Council (MARC)