4.3 INFRASTRUCTURE

4.3.1 Introduction

As described in Section 4.2, commercial dredging activity on the LOMR can contribute to ongoing changes in the elevation of the river bed and changes in the water surface elevations during periods of low and high flows. River bed degradation and associated water level changes can undermine the foundations of infrastructure facilities, affect the operation of water intake structures, expose pipelines and other submerged infrastructure, and cause slumping or undermining of revetments that could threaten the integrity of nearby levees. Infrastructure also can be affected by aggradation.

During the scoping process for this EIS, the USACE received a number of comments related to the potential adverse effects on infrastructure caused by river bed degradation and changes in water surface elevations. Commentors stated that river bed lowering increases the potential for scour effects, poses a threat to the stability of existing bridge foundations, and requires expensive countermeasures to mitigate the potential threat to bridges (Heckman pers. comm.). Water suppliers and electric utilities commented that declining low water levels from ongoing dredging has compromised the performance of water intakes that provide cooling and process water to several electric generating stations (Heidtbrink pers. Comm.). This has required expensive modifications to intake structures, premature pump wear, and damage that threaten the reliability of electric generation at the affected plants. Finally, some water suppliers were concerned that dredging near public water supply collector wells located along and under the river could decrease the yield of wells by introducing fine material and reducing the permeability of the aquifer, and could increase the risk of microbial contamination by reducing the effectiveness of river bed filtration (Orth pers. comm.).

The potential impacts of river bed degradation also affects some tributary rivers and streams joining the LOMR, resulting in bed lowering in the tributaries, erosion, bank failures, and accompanying damages to infrastructure (USACE 2009). Tributary degradation occurs as low-flow water surface elevations on the mainstem drop because tributaries adjust to the new base level by eroding their beds to match the new base elevation (Kondolf 1994, NOAA 2003), a process referred to as headcutting.

As described in the Affected Environment Section 3.5, the following six categories of infrastructure may be affected by the direct or indirect effects of commercial dredging of sand and gravel. Impacts to these same six categories were evaluated in this section:

- Water intake facilities;
- Water supply wells;
- Levees;
- BSNP structures (i.e., dikes and revetments);
- Bridge, pipeline and cable crossings; and
- Wharf and dock facilities.

The following sections describe the approach used to assess potential impacts; summarize key comments received during the scoping period; and describe the potential effects on infrastructure from implementation of the Proposed Action and the alternatives. The description of impacts is presented by river segment where appropriate.

4.3.2 Assessment Methods

The results of the geomorphology analysis, together with information from infrastructure owner/operators and their websites, were used to assess how existing infrastructure facilities on the LOMR could be affected by commercial dredging operations. The potential impacts on infrastructure were determined by assessing whether the changes in river bed elevations and changes in low-flow and high-flow water surface elevations identified in the geomorphology analysis were likely to adversely affect existing infrastructure.

The geomorphology analysis described the estimated changes in average river bed elevations and low-flow and high-flow water surface elevations using the following three categories:

- Slight change (less than approximately 2 feet);
- Moderate change (approximately 2–4 feet); and
- Substantial change (greater than approximately 4 feet).

Changes in high-flow water surface elevations were characterized as likely to increase or likely to decrease for the Proposed Action and the alternatives. Effects on infrastructure were considered adverse if estimated changes in river bed elevations and changes in low-flow and high-flow water surface elevations could:

- Damage infrastructure facilities or structures;
- Increase operation and maintenance costs;
- Undermine the foundations of dikes, revetments, or levees;
- Expose bridge piers, pile foundations, buried pipelines, or underwater cables; or
- Reduce the quantity or quality of water withdrawn from horizontal collector wells used for public water supply.

The severity or magnitude of these effects was assumed to be proportional to the number of people that could be affected, the value of property and investment potentially at risk, and the costs required to counter or prevent these effects from occurring. Potential adverse effects were assessed for both short-term (i.e., approximately 5 years) and long-term (approximately 5–20 years) periods consistent with the geomorphology analysis.

A number of restrictions on dredging operations from previous dredging permits have been assumed to apply to each alternative. These restrictions would help to protect existing infrastructure from the potential adverse effects of commercial dredging operations and include the following:

- Dredging will not occur within 500 feet of any levee centerline, pipeline, or submerged utility crossing, bridge pier, or abutment; nor within 200 feet of any dike, revetment, or other structure built or authorized by the U.S. Government; nor within 100 feet of any normal bank line or island, without special authorization.
- Dredging will not occur in a zone extending 4,000 feet upstream and 500 feet downstream from any municipal drinking water intake structure located along either bank of the river.
- Dredging will not occur in a zone extending 1,000 feet upstream and 1,000 feet downstream from any municipal drinking water horizontal collector well located along either bank of the river.
- Dredging will not occur in a zone extending 500 feet upstream and 500 feet downstream from any water intake structure other than those used for municipal drinking water.

The potential impacts on infrastructure that is located on tributaries to the LOMR also was considered, but the assessment was limited by the lack of data for tributaries. The likelihood that tributary degradation would increase under an alternative was based on the change in low-flow water surface elevations on the mainstem LOMR occurring near the tributary, as estimated in the geomorphology analysis. In general, low-flow water surface elevations would need to decrease a “moderate” or

"substantial" amount before tributary headcutting would occur and existing infrastructure would be affected.

The potential for impacts related to river bed degradation on infrastructure located in areas of alternate sources of supply that might be subject to increased dredging activity under some of the alternatives is not included in this impact analysis. Limits incorporated into existing dredging permits for the Kansas and Mississippi Rivers include conditions and restrictions that would reduce the likelihood of increased dredging in these rivers causing substantial impacts on infrastructure. In the Kansas River, there are limits on the amount of allowable river bed degradation. If degradation exceeds those limits, dredging must cease. According to the USACE, river bed degradation in the Mississippi River has not been reported to be an issue to date (USACE 2003).

Floodplain open-pit mines and instream mining could result in increased traffic on nearby roads and bridges and minor impacts on infrastructure in some areas, including the need for additional maintenance. These impacts are considered in Section 4.4.

4.3.3 Proposed Action

The Proposed Action would permit approximately 11,615,000 tons of commercial dredging from the five segments of the LOMR. This would increase the amount of material dredged in each segment, with the greatest increases occurring in the St. Joseph and St. Charles segments.

4.3.3.1 Changes in River Bed Elevations and Low-Flow and High-Flow Water Surface Elevations

Table 4.2-7 summarizes the changes in river bed elevations and low-flow and high-flow water surface elevations under the Proposed Action for each river segment.

Based on the estimated levels of river bed degradation and changes in low-flow and high-flow water surface elevations, the segments most likely to experience conditions that could adversely affect infrastructure under the Proposed Action include the St. Joseph segment between RM 445 and RM 455, the Kansas City segment over its entire length, the Jefferson City segment between RM 140 and RM 150, and the St. Charles segment between RM 0 and RM 50. Changes in the Waverly segment under the Proposed Action are not expected to adversely affect most categories of infrastructure. All of the segments are expected to experience increased high-flow water surface elevations in the long term.

4.3.3.2 Impacts to Water Intake Facilities

The existing water intake facilities primarily provide water for public water systems and cooling and process water for power generation facilities. According to the USACE, river bed degradation and a decline in low-flow river stages on the LOMR has caused increased pumping costs and pump requirements for water intakes along the degrading reaches. Considerable funds have been spent to modify existing intakes to continue operations under 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. Interruption of cooling and process water supplies to power plants could cause expensive shutdowns for electric utilities (USACE 2009).

At some facilities, short-term water losses from intake facilities can be made up by alternate well sources. In many cases, however, modifications of existing intakes have neared their practical limits. Future modifications would require major upgrades or new facilities to access low-flow water surface elevations. In the short term, the needs for dependable water supply likely would be accommodated with increased operational costs and short-term fixes (USACE 2009).

Major investments in new water intake facilities, or major modifications to existing facilities, can be expected in the long term if ongoing degradation trends persist. In some instances, these investment costs may be passed on to users in the form of higher rates. Electric utilities required to make major modifications to existing water intake facilities, or to construct new facilities, in order to obtain adequate cooling and process water during low-flow periods would incur costs that would be passed on to ratepayers (USACE 2009).

A more detailed description of potential impacts to water intake facilities under the Proposed Action for each segment is presented below.

St. Joseph Segment

The geomorphology analysis estimates that the area between RM 455 and RM 445 in the St. Joseph segment could experience nearly 2 feet of river bed degradation and a corresponding 2-foot decline in low-flow water levels over the next 5 years under the Proposed Action. These amounts increase to 4 feet or more over the next 20 years. High-flow surface water levels between RM 455 and RM 445 also are expected to increase in the long term; however, operation of water intake facilities is not usually adversely affected by temporary periods of high-flow water surface elevations.

Only one water intake facility is located between RM 455 and RM 445 in the St. Joseph segment – the intake for the 100-MW Aquila Lake Road Power Station operated by KCP&L at RM 445.9. KCP&L has expressed concerns about the effect of ongoing river bed degradation on cooling and process water intake infrastructure for several of their power plants on the Missouri River, including the Aquila Lake Road Power Station (Heidtbrink pers. comm.). Similar levels of river bed degradation and reductions in low-flow water elevations have required installation of new circulating water pumps and modifications of the intake facility at the company's Hawthorn Station (RM 358.8). KCP&L also has installed supplemental submersible pumps at the Aquila Lake Road Power Station over the past 5 years to address ongoing low-flow water conditions. It is not known whether the improvements made at the Aquila Lake Road Power Station are sufficient to counter the river bed degradation and declining low-flow water levels expected to occur over the next 20 years.

Typical costs for new water pumps can range from $1 to $3 million, while costs to modify or replace existing intake structures can exceed $10 million (Armstrong, Schrempp, Kartmann pers. comm.).

Other intake facilities in the St. Joseph segment outside of the reach between RM 455 and RM 445, including the Iatan Power Plant and several water supply intake facilities, are not expected to experience levels of river bed degradation or reductions in low-flow water levels (in the short term or the long term under the Proposed Action) that would cause a notable adverse effect on system performance or long-term operation and maintenance costs.

Kansas City Segment

The geomorphology analysis estimates that the entire Kansas City segment from RM 391 to RM 357 could experience between 2 and 4 feet of river bed degradation in the next 5 years, and as much as 4 or more feet of river bed degradation over the next 20 years under the Proposed Action. Low-flow water levels between RM 391 and RM 357 are expected to decline up to 4 feet in the next 5 years, and more than 4 feet over the next 20 years. High-flow surface water elevations between RM 391 and RM 357 also are expected to increase in the long term. The water intake facilities listed in Table 4.3-1 could be subject to the effects of river bed degradation and reductions in low-flow water elevations under the Proposed Action.

Four of these intake facilities provide cooling and process water to four major power plants, including the Nearman Bottoms, Quindaro, and Hawthorn power plants and the Trigen-Kansas City facility that provides heating and cooling to buildings in downtown Kansas City.

Table 4.3-1 Water Intake Facilities in the Kansas City Segment Potentially at Risk under the Proposed Action

Facility Name[a]	River Mile
Johnson Co. Water District No. 1 (WaterOne)	380.0
Nearman Bottoms Power Plant (KCBPU)	378.7
Mid-Continent Asphalt & Paving	378.4
Kansas City, KS Water Co. (KCBPU)	373.5
Kansas City, KS Power & Light (KCBPU)	373.4
Kansas City, Missouri Water Department	371.0
Kansas City Power and Light, Co. (KCP&L Co.)	365.8
KCP&L Co.	358.2

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

Low river levels can contribute to premature pump wear, damage, and reliability issues (Heidtbrink pers. comm.). Kansas City, Kansas, has already spent $22.6 million on a cooling tower and emergency pumps to retrofit two power generating facilities in response to declining low-flow water levels. Additional river bed degradation in the long term possible under the Proposed Action likely would require additional pumps and further intake modifications, including possible replacement of existing intake facilities in their entirety (USACE 2009).

Three of the potentially affected intake facilities in the Kansas City segment provide drinking water to nearly 1 million residents in the Kansas City metropolitan area. Declining low-flow water levels already have required the Kansas City, Missouri Water Department to make five modifications to its intake facilities at a cost of more than $6 million (Bremser pers. comm.). Continuing degradation in this segment poses a serious risk to the Department's ability to meet its customers water needs (Bremser pers. comm.).

In 2004, Water One completed installation of emergency low-level pumping units at their Missouri River intake (RM 380) at a cost of approximately $2.5 million (Armstrong pers. comm.). Continuing river bed degradation possible under the Proposed Action has the potential to require major modification and possibly total replacement of these intake facilities in the long term. The company has requested that the no dredging buffer zone for intakes be increased to 1 mile upstream and 1 mile downstream of these facilities (Armstrong pers. comm.).

Waverly Segment

The geomorphology analysis estimates that the amount of river bed degradation and decline in low-flow water elevations in the Waverly segment (RM 357 to RM 250) would be relatively unchanged in the next 5 years, and less than 2 feet over the next 20 years under the Proposed Action. This amount of change would be unlikely to affect existing water intake facilities; therefore, no adverse effects are expected in this segment under the Proposed Action. High-flow surface water elevations in the Waverly segment are expected to increase in the long term but without notable consequence to water intake facilities.

Jefferson City Segment

The geomorphology analysis estimates that the area between RM 150 and RM 140 in the Jefferson City segment could experience between 2 and 4 feet of river bed degradation over the next 5 years under the Proposed Action, and more than 4 feet of river bed degradation over the next 20 years. Low-flow water levels between RM 150 and RM 140 are not expected to change much over the next 5 years (less than 2 feet) under the Proposed Action; over the next 20 years, however, low-flow water levels could decline by as much as 4 feet under the Proposed Action. High-flow surface water elevations between RM 150 and RM 140 are expected to increase in the long term under the Proposed Action, but no adverse effects on water intake facilities are anticipated.

The only water intake facility in the Jefferson City segment potentially at risk for damage or decreased operational performance is the intake facility located at RM 144 operated by Missouri American Water Company. This intake has a capacity of 4,875 gpm and provides drinking water to the community of Jefferson City. Ongoing river bed degradation and reductions in low-flow water levels over the next 20 years under the Proposed Action could require the company to install additional pumps, modify intake structures, and possibly replace the existing intake facility to ensure adequate water supplies. These types of improvements can range from $1 to $3 million for new water pumps can and exceed $10 million to modify or replace existing intake structures, which likely would result in increased utility rates for current and future customers in this community of approximately 40,000 residents.

Other intake facilities in the Jefferson City segment located outside of the reach between RM 150 and RM 140, including the Glasgow Waterworks and the Boonville Water Company, are not expected to experience levels of river bed degradation or reductions in low-flow water levels (in the short term or the long term) that would result in a notable adverse effect on system performance or long-term operation and maintenance costs.

St. Charles Segment

The geomorphology analysis estimates that the area between RM 50 and RM 0 in the St. Charles segment could experience between 2 and 4 feet of river bed degradation over the next 5 years under the Proposed Action, and more than 4 feet of river bed degradation over the next 20 years. Low-flow water levels between RM 50 and RM 0 are expected to decline between 2 and 4 feet over the next 5 years under the Proposed Action, and more than 4 feet over the next 20 years. High-flow surface water levels between RM 50 and RM 0 also are expected to decrease in the short term but increase in the long term under the Proposed Action; however, these types of facilities are not usually adversely affected by temporary periods of high-flow surface water elevations.

The water intake facilities listed in Table 4.3-2 could be subject to the effects of river bed degradation and reductions in low-flow water elevations under the Proposed Action.

Table 4.3-2 Water Intake Facilities in the St. Charles Segment Potentially at Risk under the Proposed Action

Facility Name[a]	River Mile
City of St. Louis Waterworks	37.0
St. Louis County Waterworks	36.3
St. Louis County Waterworks	36.2
St. Charles Waterworks	29.0
St. Louis County Waterworks	20.5
St. Louis County Water Dept.	20.2

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

These six water intake facilities provide drinking water to more than 1 million people, including business and industry within the greater St. Louis metropolitan area. Ongoing river bed degradation and reductions in low-flow water levels between RM 50 and RM 0 over the next 20 years could require the municipalities and water companies operating these facilities to install supplemental water pumps, modify existing intake structures, and possibly replace the entire intake facilities to ensure adequate water supplies. While costs for new water pumps typically range from $1 to $3 million and costs to modify or replace existing intake structures exceed $10 million, the cost to modify the City of St. Louis Water Division intake structure at RM 37.0 is estimated to cost between $25 to $35 million because the

existing intake is an integral part of the pumping station (Skouby, pers. Comm.). These additional costs would result in increased utility rates for current and future customers.

Three intake facilities located in the St. Charles segment upriver from RM 50 supply cooling and process water to three major power plants, including the Labadie Power Plant at RM 57.7, the Callaway Power Plant RM 115.4, and the Chamois Power Plant at RM 117.0. These power plants generate over 3,600 MW of electricity and supply customers across central and eastern Missouri. Because the levels of river bed degradation and reduction in low-flow water elevations near these intake facilities are expected to be less than approximately 2 feet over the next 20 years, the available supply of cooling and process water to these major power plants is not expected to be adversely affected.

4.3.3.3 Impacts to Water Supply Wells

The primary concern related to the potential effect of river bed degradation on water supply wells is the possibility that dredging could affect the production capacity of the wells and diminish the levels of natural river filtration. According to engineers familiar with these processes, the depressions that are developed as the river bed materials are removed are filled by finer-grained deposits of silt and clay. These deposits reduce the permeability of the river and aquifer, and reduce the amount of water that can be pumped by the collector wells. Additionally, the deposited fine-grained materials can lead to oxygen reduction in the aquifer. These conditions can result in poorer quality water being pumped by the wells. Dredging operations also can accelerate degradation of the river bed. This leads to lower water levels in the river (and aquifer) and less available drawdown and therefore reduced yields (Stowe pers. comm.). In addition, river bank filtration relies on the river bed material to reduce turbidity, pathogens, bacteria, and viruses. Reduction of the river bed through dredging increases the possibility that these contaminants can pass through the river to the treatment plant and reduce the quality of water (Orth pers. comm.).

A more detailed description of potential impacts to water supply wells under the Proposed Action for each segment is presented below.

St. Joseph Segment

The Missouri American Water Company operates a collector well and seven vertical wells along the Missouri River near the City of St. Joseph. The primary source of water for the company's 30,000 customers is a horizontal collector well located at RM 454.75. Increased dredging activity near this well under the Proposed Action could pose a short-term and long-term threat to its ongoing operation. The company has expressed concern that ongoing dredging in the area could reduce the permeability of the

aquifer, and in turn, the output of the well. The company is also concerned that continued river bed degradation could reduce river bed filtration that the company relies on to reduce turbidity, pathogens, bacteria, and viruses in the withdrawn water. The company has recommended that a no-dredge zone be created 2,000 feet upstream and 2,000 feet downstream from the well at RM 454.75 to reduce the potential for adverse impacts on their existing system (Fuerman pers. comm.).

Kansas City Segment

The Kansas City Board of Public Utilities operates two horizontal collector wells at approximately RM 379 that are capable of producing more than 80 million gallons of source water per day. These wells are the only water source for the Nearman Water Treatment Plant, which serves over 145,000 residents in Kansas City, Kansas and Wyandotte County. The utility has concerns that ongoing dredging activity in this area could adversely affect the water quality and quantity of water available from these two high-yielding collector wells. Within the next 2 years, these two wells will become the utility's sole source for water for over 180,000 customers. The company initially recommended that a no-dredge zone be established from a point approximately 2,000 feet upriver from the intake for the Nearman Power Plant at RM 378.7 and extending downriver for approximately 1 mile to a point 2,000 feet below the second collector well at approximately RM 379.1 (Uden pers. comm.). The company is currently requesting that the no-dredge zone be increased to 1 mile upstream and downstream to ensure the continued protection of the Board's collector wells (Stewart pers. comm.).

WaterOne operates a horizontal collector well at approximately RM 385.5 capable of producing 30 million gallons per day. The well includes approximately twelve 250-foot long radial collectors, several of which are located approximately 50 feet below the river bed (Schrempp pers. comm. [d]). For the same reasons described above, the company has requested that the no-dredge zone for wells be increased to 1 mile upstream and 1 mile downstream of these facilities (Armstrong pers. comm.).

Waverly

The City of Independence, Missouri operates a horizontal collector well at approximately RM 353.5. This well produces 6,940 gallons per minute which accounts for a significant percentage of the water provided to the City's customers. The City has stated its concern that dredging could negatively impact this collector well by reducing the permeability of the aquifer and that reduced levels of bed material could provide less filtration for the water entering the well. The City is currently requesting that a no-dredge zone be created 2,000 feet upstream and 2,000 feet downstream from its well to reduce possible impacts from dredging (Kelly. pers. comm.).

Jefferson City and St. Charles Segments

No horizontal wells were identified in the Jefferson City or St. Charles segments.

4.3.3.4 Impacts to Levees

River bed degradation can set in motion a chain of events that includes bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee foundation failure, and potentially, catastrophic levee failure. In addition, vegetation encroachment along river banks and sand bars can trap sediment, creating land in the stream channel. This reduces the channel area available to convey high flows which causes increased high-flow water surface elevations and increased flood stages (USACE 2009).

River bed degradation and increased high-flow water surface elevations can adversely affect levees that provide critical flood protection. In addition to the 20 miles of federal levees protecting the Kansas City metropolitan area, another 130 miles of federal levees along the mainstem of the Missouri River protect areas between Rulo, Nebraska and St. Louis, Missouri. These levees protect a good portion of the City of St. Joseph, a number of small towns, and large amounts of rural area (USACE 2009). Approximately 360 miles of smaller non-federal levees also line the mainstem of the Missouri River and its major tributaries, protecting thousands of acres of farmland and small towns (USACE 2010a). A widespread degradation pattern could threaten many of these areas.

River bed degradation is a growing concern at many locations along the Missouri River mainstem. Of particular concern are areas where levees are founded on existing revetments or very close to unprotected slopes. Many of the levees and floodwalls in the Kansas City area are founded on revetment-protected slopes. Although the impacts have not been fully evaluated and inventoried, an investigation by the USACE in the Kansas City area indicates that the toes of some revetments supporting critical levee structures have eroded due to degraded channel conditions. The study noted that the condition of eroded revetments in this area poses a significant risk for failure of the levee system (USACE 2009).

During a major flood event, sloughing or a series of successive bank failures could cause partial, or sudden and total, failure of the affected levee segment (USACE 2009). Evidence that eroded areas can result from normal to moderate flows in these areas suggests that a major flood event could pose high risks of severe erosion and the potential for levee failure. During a large flood event, the erosion would not be visible or easily monitored; and response after levee failure would be difficult (USACE 2009). Even if a levee has not been weakened by river bed degradation, increased high-flow water

surface elevations related to channel narrowing could decrease the level of flood protection provided by that levee.

A more detailed description of potential impacts to levees under the Proposed Action for each segment is presented below.

St. Joseph Segment

The geomorphology analysis estimates that the area between RM 455 and RM 445 in the St. Joseph segment could experience river bed degradation levels of approximately 2 feet over the next 5 years under the Proposed Action, and up to 4 feet or more over the next 20 years. As a result, high-flow water surface elevations between RM 455 and RM 445 also are expected to increase in the long term under the Proposed Action. Three federal levee units between RM 455 and RM 445 could potentially be at risk from adverse effects caused by river bed degradation and increased water surface elevations during high flows (Table 4.3-3). No non-federal levees or major tributaries were identified between RM 455 and RM 445.

Levee Unit L-476 extends 7 miles along the left descending bank of the Missouri River. Most of the levee is upstream from the City of St. Joseph, and only an approximately 1-mile segment of the levee (at the downstream end) could potentially be at risk to adverse effects from river bed degradation and increased water surface elevations during high flows. Levee Unit R-471-460 extends nearly 15 miles along the right descending bank of the river and Levee Unit L-455 extends approximately 8 miles along the left bank of the river, through the heart of the City of St. Joseph. These levees protect nearly 27,000 acres of urban and industrial land, over 5,600 residents, and approximately $2.3 billion in investment value on both the Kansas and Missouri sides of the river (USACE 2010a).

Table 4.3-3 Federal Levees in the St. Joseph Segment Potentially at Risk under the Proposed Action

Unit Name[a]	River Miles
Levee Unit L-476	461.0–454.0
Levee Unit R-471-460	456.5–441.8
Levee Unit L-455	445.6–437.6

[a] R and L refer to right and left descending banks, respectively. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

The Elwood-Gladden Drainage District in Kansas is currently sponsoring a $33-million project to raise the height of Levee Unit R-460-471 by an average of 3 feet, including some minor corresponding modifications to Levee Unit L-455. These improvements are proposed to restore the original reliability and performance of the system that was overtopped and failed in the 1993 flood, causing over $65 million in damages in the protected area in Kansas (Roberts 2010).

Levee Unit L-455, between RM 444 and RM 446.5, appears to be particularly vulnerable to future river bed degradation and increased high-flow water levels under the Proposed Action. In this area, the levee is constructed on top of revetment on the outside bend of the river. Over the next 20 years, this area could be subject to substantial river bed degradation that could cause material underlying the revetment to be removed, thereby potentially putting both the revetment and levee at risk of future failure, particularly during periods of high-flow water levels. This risk would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety. Typical costs for revetment repair are discussed in Section 4.3.4.5.

Other federal and non-federal levees in the St. Joseph segment located outside of the reach between RM 455 and RM 445 would not be expected to experience levels of river bed degradation or increases in high-flow water levels (in the short term or the long term under the Proposed Action) that would result in a notable adverse effect on existing levels of protection or long-term operation and maintenance costs. This includes the approximately 32 miles of non-federal levees protecting over 55,000 acres of primarily agricultural uses along the LOMR and major tributaries.

Kansas City Segment

The geomorphology analysis estimates that the entire Kansas City segment from RM 391 to RM 357 could experience river bed degradation levels between 2 and 4 feet over the next 5 years under the Proposed Action, and up to 4 feet or more over the next 20 years. Low-flow water surface elevations are expected to decline by as much as 4 feet over the next 5 years under the Proposed Action, and possibly more than 4 feet over the next 20 years. High-flow surface water elevations in the Kansas City segment are expected to increase in the long term under the Proposed Action, posing a continuing threat to flood protection infrastructure.

Table 4.3-4 lists the federal levee units in the Kansas City segment, including major tributaries, potentially at risk from adverse effects caused by river bed degradation and increased water surface elevations. The reliability of federally constructed levees, particularly those founded upon revetment-

protected slopes, could potentially be at risk in the short-term and the long term under the Proposed Action. In some areas, the potential for catastrophic failure may be a possibility.

Table 4.3-4 Federal Levees in the Kansas City Segment Potentially at Risk under the Proposed Action

Unit Name	River Miles
Levee Unit L-385[a]	372.1-375.9
Levee Unit Fairfax-Jersey	374.0–367.5
Levee Unit North Kansas City	370.5–363.5
Levee Unit Central Industrial District	367.4–365.7
Levee Unit East Bottoms	365.7–357.5
Levee Unit Birmingham	360.3–354.0
Levee Unit Armourdale	Kansas River 2.1–6.5
Levee Unit Argentine	Kansas River 4.5–9.5

[a] L refers to left descending bank. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

Levees on major tributaries to the Missouri River could also be at risk of river bed degradation under the Proposed Action because of headcuts. In addition, the Armourdale and Argentine Levee Units along the Kansas River could be susceptible to river bed degradation and increasing high-flow water levels in areas where material has been or could be eroded from the toes of levee slopes.

Most of the non-federal levees in the Kansas City segment are located upriver or downriver from Kansas City along the mainstem of the LOMR and its major tributaries; they protect primarily agricultural areas. Approximately 10 miles of non-federal levee protect over 5,200 acres of primarily agriculture land north of Kansas City. These levees typically range between 6 and 16 feet in height and can vary with respect to maintenance standards and levels of protection.

While not all levees within the Kansas City segment have been surveyed, the USACE has identified several levees within the segment that appear vulnerable to the effects of continued river bed degradation (USACE 2009). These include the North Kansas City Levee Unit at approximately RM 370, the Fairfax-Jersey Creek Levee Unit at approximately RM 368, and the East Bottoms Levee Unit at approximately RM 366. All three of these levees are located immediately adjacent to, or

integrated with, revetment sections of the BSNP. Altogether, more than 10 miles of federal levees in the Kansas City segment are located adjacent to, or integrated with, BSNP revetments.

At-risk revetments and levees are particularly vulnerable during flood events, which can result in rapid, short-term river bed degradation. This is particularly troublesome because inspection and repair of revetment failures are extremely hampered during flood events. Extreme events, such as the 1993 flood, present an increased risk to all of the levees and floodwalls located along revetments in the Kansas City reach. Levees could become increasingly at risk as river bed degradation exceeds the performance capabilities of the existing revetments. Without effective countermeasures, there would be an increased long-term risk of levee/floodwall failure (USACE 2009).

Flood events may lower the river bed by several feet in the short term. This can cause levee and floodwall instability in reaches where the structures are near river 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. These systems were tested under extreme flow conditions in 1993 and performed successfully. Since 1993, the river bed has degraded approximately 5 feet, as measured at the Kansas City USGS gage, adding uncertainty to future performance. This amount of river bed degradation leaves no assurance that the floodwalls will perform successfully during an equivalent event in the future.

The USACE Kansas City District has responded to this concern by requesting $19 million from Congress to take corrective actions at the Fairfax-Jersey Creek Levee Unit and the North Kansas City Levee Unit. The funding request cited the findings of a 2006 USACE study (Kansas City's [Seven Levees] Phase I Feasibility Study) 2006), which determined that original design and construction deficiencies exist at sites on both levee units. The funding request also stated that, currently, both levee units pose a high probability of failure for the design flood event and that the USACE desires to be proactive by taking the necessary corrective actions before the next high-water event. Both units are in the Planning, Engineering & Design phase for their respective projects and hope to advance toward construction soon. The total cost to correct the deficiencies, as currently estimated by the USACE Kansas City District, is $9 million for the Fairfax-Jersey Creek Floodwall Improvements and $10 million for the North Kansas City Underseepage Improvements (Roberts 2010, USACE 2010b).

The severity or magnitude of these potential adverse effects can be put in perspective by identifying the number of people, number of jobs, and total investment potentially at risk from failure of levees in this segment. For example, the North Kansas City Levee Unit protects nearly 1,100 residential units, 4,900

residents, approximately 500 businesses, and 26,700 jobs. Major facilities protected by the levee unit include the Charles B. Wheeler Downtown Airport; BNSF and Norfolk Southern railroad yards; and numerous retail sector small businesses, warehouses, and industrial sites. The levee unit's estimated protected investment is almost $3.5 billion, based on October 2008 prices (USACE 2009).

The Fairfax-Jersey Levee Unit protects approximately 350 businesses and facilities, a total estimated investment of almost $3.5 billion, and a workforce of more than 11,100 people. Protected businesses include a General Motors assembly plant and other large commercial, industrial, and public facilities such as Owens-Corning, Weyerhauser, and Certainteed (USACE 2009).

The East Bottoms Levee Unit protects approximately 750 businesses and homes, with a total estimated value of approximately $5.4 billion. The industrial structure includes manufacturing, transportation, and major warehouse storage, as well as retail businesses. The area includes major facilities, including a KCP&L power plant; a water treatment plant; a Sears distribution center; the Isle of Capri Casino; and facilities operated by Cargill, General Mills, and Bayer Corporation. More than 3,200 residents live in the area, and more than 20,100 people are employed in East Bottoms businesses (USACE 2009).

Altogether, the Kansas City's Levees (Fairfax-Jersey Creek, North Kansas City, Central Industrial District, East Bottoms, Birmingham, Armourdale, and Argentine Levee Units) and Levee Unit 385 protect 154,566 acres of commercial, industrial and residential land use; a population of over 23,000; and an investment value of over $19 billion.

Non-federal levees outside the Kansas City metropolitan area, depending on their location, could experience river bed degradation levels of 4 feet or more and reductions in low-flow water elevations by more than 4 feet over the next 20 years under the Proposed Action. These conditions could subject non-federal levees to increased bank erosion, levee damage, and potentially, levee failure. Countering these effects likely would result in increased annual maintenance costs for the various levee associations, drainage districts, and conservation districts that sponsor the non-federal levees.

Waverly Segment

In the Waverly segment, there is one federal levee (Levee Unit R-351) that extends approximately 10 miles along the right bank of the river between the towns of Atherton and Sibley, Missouri (RM 350 to RM 339.7), protecting approximately 8,861 acres of rural agricultural land and approximately $15 million in investment (USACE 2010b). Non-federal levees are far more common in this segment, with approximately 130 miles of non-federal levees protect over 362,000 acres of primarily agricultural

lands. Because the Waverly segment is not expected to experience notable amounts of river bed degradation or increases in high-flow water elevations over the next 20 years under the Proposed Action, no adverse effects to these levees are anticipated.

Jefferson City Segment

The geomorphology analysis estimates that the area between RM 150 and RM 140 in the Jefferson City segment could experience between 2 and 4 feet of river bed degradation over the next 5 years and more than 4 feet of river bed degradation over the next 20 years under the Proposed Action. As a result, high-flow water surface elevations in this area are expected to increase in the long term.

No federal levee units are located between RM 150 and RM 140. Five non-federal levee units extend approximately 13.7 miles along the river in this area, which includes several tributaries. These levees typically range between 6 and 16 feet in height and protect over 12,000 acres of primarily agricultural land.

In the long term under the Proposed Action, these non-federal levees could experience increased bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee foundation failure, and potentially, levee failure. Vegetation encroachment and reduction in channel area also could result in further increases in high-flow water surface elevations and increased flood stages (USACE 2009). During a major flood event, sloughing or a series of successive bank failures could cause partial, or sudden and total, failure of an affected levee segment (USACE 2009). These risks would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety of the levee systems.

Other federal and non-federal levees in the Jefferson City segment located outside of the reach between RM 150 and RM 140 (including federal Levee Units L-246 and L-234/Chariton between the towns of Brunswick and Glasgow, Missouri) would not be expected to experience levels of river bed degradation or increases in high-flow water levels (in the short term or the long term under the Proposed Action) that would cause a notable adverse effect on existing levels of protection or long-term operation and maintenance costs.

St. Charles Segment

The geomorphology analysis estimates that the area between RM 50 and RM 0 in the St. Charles segment could experience between 2 and 4 feet of river bed degradation over the next 5 years and more than 4 feet of river bed degradation over the next 20 years under the Proposed Action. High-flow

water levels between RM 50 and RM 0 are expected to decrease in the short term but increase in the long term.

No federal levee units are located between RM 50 and RM 0. There are, however, an undetermined number of non-federal levees along portions of the river and along several tributaries. Although detailed information was not available for these levees, they appear to protect primarily agricultural areas. At least three non-federal levees protect urban areas below RM 45 (USACE 2004).

These levees could experience increased bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee foundation failure, and potentially, levee failure in the short term and the long term under the Proposed Action. During a major flood event, sloughing or a series of successive bank failures could cause partial, or sudden and total, failure of the affected levee segment (USACE 2009). These risks would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety of the levee systems.

Levees outside of the reach between RM 50 and RM 0 in the St. Charles segment would not be expected to experience levels of river bed degradation or increases in high-flow water levels (in either the short or the long term under the Proposed Action) to a degree that would cause a notable adverse effect on existing levels of protection or current operation and maintenance costs.

4.3.3.5 Impacts to Bank Stabilization and Navigation Project Structures

Continuing river bed degradation and individual flood events require ongoing maintenance of BSNP structures. The USACE maintenance program for dikes focuses on maintaining the dikes at their minimum design elevations measured against the CRP. If the channel degrades and navigation season flows cannot be maintained, the dikes must be altered to maintain the design water surface elevations in a given river segment (USACE 2009).

In many cases, the dikes self-adjust to the appropriate design height by losing material from the top of the structure to erosion as the water surface elevation drops. If the rate of river bed degradation exceeds the rate of normal erosion of the tops of the structures, it becomes necessary to mechanically remove the top few feet of each structure. Additional maintenance includes reestablishing the riverward ends of structures, repairing portions of structures that have eroded more quickly than the natural erosion rate, and repairing segments of structures that have settled or sustained flood damage. Because dikes are not likely to fail completely in a short amount of time, regular maintenance and repair are usually sufficient to maintain their function (Chapman pers. comm.).

Unlike dikes, which are somewhat self-adjusting, revetments that are made from rocks placed on the river bank extending down to the river bed cannot adjust to river bed degradation. When the river bed elevation degrades, it leaves the revetment toe exposed and hanging. Eventually, the revetment will collapse and slide into the river, exposing the upper portion of the river bank. This requires backfilling the eroded bank behind the line of the original revetment and then replacing stone to protect the reestablished bank line. This situation can be extremely serious if a levee, floodwall, road, or other structure is immediately adjacent to the revetment (Chapman pers. comm.).

Revetments tend to fail in sudden discrete events. If failure occurs during or before a severe flood event, it could allow the river to migrate into a bank. If the revetment is close enough to a levee or floodwall, or if the bank is allowed to erode away in a severe flood event until it reaches a levee or floodwall, it could undermine the levee or floodwall and cause it to fail. Failure would allow whatever is protected by the levee or floodwall to be flooded, and the river could start flowing through that weakness and erode a new channel (Chapman pers. comm.).

The USACE maintenance program for revetments focuses on reinforcement of the toe of the revetments. The stability of a revetment depends on the toe that is supported on the bed of the river. As the river degrades, the bed of the river drops from underneath the revetment and can reduce the factor of safety of the revetment or cause outright failure. To bring the revetment back to the original factor of safety, it is necessary to add rock to the toe. It is estimated that 5,000 tons per mile of revetment per foot of river bed degradation are required to maintain the original factor of safety. Some of this tonnage reflects the difficulty of placing rock underwater in swift current. The normal contract price for placed rock is $30 per ton (Chapman pers. comm.).

The potential effects of river bed degradation and changes in low-flow and high-flow water surface elevations on BSNP structures within each segment under the Proposed Action are described below.

St. Joseph Segment

Estimated river bed degradation levels under the Proposed Action of approximately 2 feet over the next 5 years and 4 feet or more over the next 20 years could adversely affect approximately 60 dikes and approximately 8 miles of rock revetment in the area between RM 455 and RM 445. This includes a 2.5-mile segment of revetment between RM 444 and RM 446.5 that is integrated into the foundation of Levee Unit L-455.

Because the rate of river bed degradation between RM 455 and RM 445 under the Proposed Action likely would exceed the rate at which erosion can remove material from the top of the dikes, mechanical removal of as much as 4 feet or more material from the top of existing dikes within the segment may be required over the next 20 years under the Proposed Action.

Over the next 20 years under the Proposed Action, the segment of revetment between RM 444 and RM 446.5 could be subject to substantial river bed degradation that could cause material underlying the revetment to be removed, thereby putting both the revetment and levee at potential risk of future failure, particularly during periods of high-flow water levels. This risk would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety. Assuming 5,000 tons of rock per mile of revetment per foot of river bed degradation, the estimated cost to reinforce the toes of 8 miles of revetment in this segment would be approximately $4.8 million.

BSNP structures in the St. Joseph segment located outside of the reach between RM 455 and RM 445 would be unlikely to experience levels of river bed degradation (in the short term or the long term under the Proposed Action) that would result in a notable adverse effect on the overall performance or operation and maintenance costs of these facilities.

Kansas City Segment

Degradation levels between 2 and 4 feet over the next 5 years and up to 4 feet or more over the next 20 years throughout the Kansas City segment under the Proposed Action pose risks to nearly 150 dikes and approximately 42 miles of rock revetments. More than 10 miles of these revetments are integrated into the foundations of critical levee units, including the North Kansas City levee, the Fairfax-Jersey Creek levee and the East Bottoms levee. The USACE has identified these levees as particularly vulnerable to the effects of river bed degradation and revetment failure, especially during periods of high-flow water levels (USACE 2009). As in other segments, this risk would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety.

The estimated cost to reinforce the toes of 42 miles of revetment in this segment would be approximately $6 million. Because of the high rates of river bed degradation in the Kansas City segment, mechanical removal of material from the top of existing dikes may be required in the long term. In 2004, the USACE spent approximately $400,000 to remove 30,000 cubic yards of rock from the tops of structures (an average of approximately 2 feet) in the Kansas City reach. In 2009, the USACE spent an additional $336,000 in the Kansas City reach to remove 24,000 cubic yards of rock

from the top of structures (another approximately 2 feet). This occurred over approximately 20 river miles, from RM 360 to RM 380 (Chapman pers. comm.)

Waverly Segment

The USACE maintains approximately 558 wooden pile and rock rip-rap dikes and approximately 127 miles of rock revetments along the navigation channel in the Waverly segment as part of the BSNP. Because this segment is not expected to experience notable amounts of river bed degradation or changes in low-flow or high-flow water elevations in the short term or the long term under the Proposed Action, no adverse effects to these BSNP structures are anticipated.

Jefferson City Segment

Estimated river bed degradation levels under the Proposed Action of between 2 and 4 feet over the next 5 years and more than 4 feet of river bed degradation over the next 20 years could adversely affect approximately 70 dikes and approximately 3 miles of rock revetment in the area between RM 150 and RM 140 in the Jefferson City segment.

Over the next 20 years under the Proposed Action, the area between RM 150 and RM 140 could be subject to substantial river bed degradation that could cause material underlying the revetments to be removed. This could put the revetments at potential risk of future failure, particularly during periods of high-flow water levels. This risk would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety.

The estimated cost to reinforce the toes of 3 miles of revetment in the Jefferson City segment is approximately $1.8 million. Because the rate of erosion between RM 150 and RM 140 likely would exceed the rate of river bed degradation under the Proposed Action, mechanical removal of material from the top of the existing dike is not expected to be required in the long term.

BSNP structures in the Jefferson City segment located outside of the reach between RM 150 and RM 140 would be unlikely to experience levels of river bed degradation (in the short term or the long term under the Proposed Action) that would result in a notable adverse effect on the performance or operation and maintenance costs of these facilities.

St. Charles Segment

Estimated river bed degradation levels of between 2 and 4 feet over the next 5 years and more than 4 feet over the next 20 years in the area between RM 50 and RM 0 in the St. Charles segment could adversely affect more than 320 dikes and over 20 miles of rock revetment under the Proposed Action.

Over the next 20 years, the area between RM 50 and RM 0 could be subject to substantial river bed degradation under the Proposed Action that could potentially put revetments at risk, particularly during periods of high-flow water elevations, due to removal of material from underneath the revetments. This risk would need to be countered with regular inspections, maintenance, and repairs to maintain the required factor of safety.

The estimated cost to reinforce the toes of 20 miles of revetment in the St. Charles segment is approximately $12 million. Because the rate of erosion in the area between RM 50 and RM 0 likely would exceed the rate of river bed degradation under the Proposed Action, mechanical removal of material from the top of the existing dike is not expected to be required in the long term.

BSNP structures in the St. Charles segment located outside of the reach between RM 150 and RM 140 would be unlikely to experience levels of river bed degradation (in the short term or the long term under the Proposed Action) that would result in a notable adverse effect on the performance or operation and maintenance costs of these facilities.

4.3.3.6 Impacts to Bridge, Pipeline, and Cable Crossings

River bed degradation can increase the risk to bridge, pipeline and cable crossing infrastructure by removing material from around bridge pylons or piers and by reducing the amount of cover needed to protect subsurface pipelines and cable crossings. Also, because the river bottom throughout most of the LOMR is composed primarily of sand, it can change dramatically during and following high-flow events. During high-flow events, bridge pier footings, bridge abutments, and pipelines can become exposed by the scour potential associated with greater channel velocity.

The potential effects of river bed degradation and changes in low-flow and high-flow water surface elevations on bridge, pipeline, and cable crossings within each segment under the Proposed Action are described below.

St. Joseph Segment

The river bed between RM 455 and RM 445 in the St. Joseph segment is expected to experience nearly 2 feet of river bed degradation and a corresponding 2-foot decline in low-flow water levels over the next 5 years under the Proposed Action. These amounts are expected to increase to 4 feet or more over the next 20 years. High-flow surface water elevations between RM 455 and RM 445 also are expected to increase in the long term under the Proposed Action.

The St. Joseph Highway Bridge at RM 447.9 and the Union Pacific Railroad Bridge at RM 448.2 are the only two bridges located in this area of substantial future river bed degradation and potential scour. According to the MoDOT, scour has been observed at the western end of the St. Joseph Highway Bridge, and countermeasures (i.e., dumping rock around the footings) have been implemented on the Kansas side. In addition, the USACE has rebuilt a dike near the bridge to help manage flows near the bridge (Stotlemeyer pers. comm.). The typical costs to remediate scour and river bed degradation problems can range between $1 and $2 million per bridge (Heckman pers. comm.).

Because the highway bridges along this segment have been built with deep foundations, are regularly inspected, and are reinforced against scour as necessary, the moderate to substantial river bed degradation and reduction in low-flow water surface elevations expected near the St. Joseph Highway Bridge under the Proposed Action are not expected to noticeably increase the risk of structural damage to the bridge.

Two pipelines crossings were identified near or between RM 455 and RM 445. These include a natural gas pipeline crossing at RM 455.5 and a water supply pipeline crossing at RM 450.4. No issues related to river bed degradation at these crossing locations have been reported. Because most pipelines crossing the Missouri River are installed at depths that would avoid the possibility of exposure under a range of changing bed conditions, the levels of river bed degradation expected at these crossing locations under the Proposed Action (4 feet or more over the next 20 years) are not be expected to pose a substantial risk to these pipelines.

All other identified highway and railroad bridges and pipelines within the St. Joseph segment are located outside of the reach between RM 455 and RM 440. These facilities would be unlikely to experience adverse effects from river bed degradation or scour (in the short term or the long term under the Proposed Action) to a degree that would threaten the soundness or security, or the long-term operation and maintenance costs, of these facilities.

Kansas City Segment

The entire Kansas City segment from RM 391 to RM 357 could experience river bed degradation levels between 2 and 4 feet over the next 5 years and up to 4 feet or more over the next 20 years under the Proposed Action. The expected trends in low-flow water surface elevations are similar, decreasing up to 4 feet over the next 5 years and more than 4 feet over the next 20 years. High-flow water surface elevations also are expected to increase in the Kansas City segment in the long term under the Proposed Action.

Table 4.3-5 lists the bridge crossings in the Kansas City segment that would be subject to the anticipated levels of river bed degradation and changes in water surface elevations under the Proposed Action. These bridges are critical links in the Kansas City transportation system. In 2009, the combined AADT on the Fairfax Highway Bridges (US 69), the Wolcott Highway Bridges (Interstate 435), the Kansas City Highway Bridge (Interstate 635), the Paseo Bridge (Interstate 29 and 35), and the Interstate 435 Bridge was over 242,000 vehicles (MoDOT 2009). This represents a substantial portion of the overall freeway traffic volume in the Kansas City area. The three railroad bridges provide important connections to major distribution centers and intermodal rail yards, as well as critical river crossings.

Most of these bridges are founded on either deep-drilled shafts that extend 60–85 feet below the river bed or on concrete spread footings up to 30 feet deep. These construction methods, combined with implementation of aggressive scour countermeasures by the MoDOT and the KDOT, greatly reduce the likelihood that ongoing river bed degradation would cause structural damage to these bridges in the short term or the long term under the Proposed Action.

Table 4.3-6 lists the pipeline and cable crossings in the Kansas City segment that could potentially be at risk from continued river bed degradation under the Proposed Action. Most of this infrastructure is concentrated in the urbanized areas approximately 10 miles upriver and downriver from the heart of Kansas City. Over 10 individual pipelines that transport natural gas, liquid petroleum, water, and wastewater are located in this area, as well as a telecommunication line.

Table 4.3-5 Bridge Crossings in the Kansas City Segment Potentially at Risk under the Proposed Action

Crossing Name (Route Number)	River Mile
Wolcott Highway Bridges (Interstate 435)	383.3
Kansas City Highway Bridge (Interstate 635)	374.1
Fairfax Highway Bridges (US 69)	372.6
Broadway Avenue Bridge	366.2
Hannibal Railroad Bridge	366.1
A.S.B. Railroad Bridge	365.6
Heart of America Bridge (Route 9)	365.5
Paseo Bridge (Interstate 29 and 35)	364.8
Chouteau Highway (Route 269)	362.3
Interstate 435 Bridge	360.3
Harry S. Truman Railroad Bridge	359.3

Table 4.3-6 Pipeline and Cable Crossings in the Kansas City Segment Potentially at Risk under the Proposed Action

Crossing Name	Utility Type	River Mile
Williams Natural Gas	Pipeline	375.2
AT&T	Cable	374.0
Williams Brothers	Pipeline	374.0
Skelley Pipeline	Pipeline	373.9
Williams Brothers	Pipeline(s)	372.5
Williams Brothers	Pipeline	369.5
Kansas City, MO Water	Tunnel	366.1
Kansas City, MO Sewer	Pipeline(s)	361.2
American Oil	Pipeline	356.5

According to an inspection report completed in February 1999, several pipelines in this area were exposed and sensitive to changes in river bed elevations (West Consultants 1999). The current status of these pipelines was not able to be verified. However, the fact that pipeline exposure has occurred in

the past 11 years within the Kansas City segment suggests that other pipelines installed at similar depths in this area may be subject to adverse effects from ongoing river bed degradation.

Waverly Segment

Four vehicle bridges and one railroad line cross the Missouri River in the Waverly segment. The vehicle bridges are operated and maintained by the MoDOT and provide cross-river connections for US 291, Route 224, US 65, and Route 41. The combined traffic volume of these four bridges is 32,768 AADT. The railroad bridge is owned and operated by the BNSF. Multiple pipelines also cross the Missouri River in the Waverly segment.

Because the Waverly segment is not expected to experience notable amounts of river bed degradation or changes in low-flow or high-flow water elevations over the next 20 years under the Proposed Action, no adverse effects to these bridges and pipelines are anticipated. Any observed problems related to river bed degradation or scour at the four highway bridges would be addressed through implementation of scour countermeasures by the MoDOT.

Jefferson City Segment

The river bed in the area between RM 150 and RM 140 in the Jefferson City segment is expected to experience between 2 and 4 feet of river bed degradation over the next 5 years and more than 4 feet of river bed degradation over the next 20 years under the Proposed Action. Low-flow water levels in the area between RM 150 and RM 140 are not expected to change much over the next 5 years (less than 2 feet) under the Proposed Action; over the next 20 years, however, low-flow water levels could decline by as much as 4 feet. High-flow water levels in the area between RM 150 and RM 140 also are expected to increase in the long term under the Proposed Action.

Only one bridge, the Jefferson City Highway Bridge (US 63 and US 54), located at RM 143.0 would be subject to substantial long-term river bed degradation under the Proposed Action. This bridge carries approximately 29,832 AADT between Jefferson City and the communities of Cedar City and North Jefferson, Missouri. One municipal sewer pipeline and one submerged cable crossing operated by Missouri River Light and Power also cross the Missouri River between RM 150 and RM 140 at RM 143.5 and RM 143.8, respectively. Although the MoDOT has reported that the Jefferson City Highway Bridge is currently being monitored for scour problems (Stotlemeyer pers. comm.), no problems at the pipelines or cable crossings have been reported.

Because the highway bridges along this segment have been built with deep foundations, are regularly inspected, and are reinforced against scour as necessary, the moderate to substantial river bed degradation and moderate decline in low-flow water surface elevations near the Jefferson City Highway Bridge are not expected to noticeably increase the risk of structural damage to the bridge under the Proposed Action.

All other identified highway and railroad bridge, pipeline, and cable crossings located in the Jefferson City segment are located outside of the reach between RM 150 and RM 140. These facilities would be unlikely to experience adverse effects from river bed degradation or scour (in the short term or the long term under the Proposed Action) to a degree that would threaten the soundness or security, or the long-term operation and maintenance costs, of these facilities.

St. Charles Segment

The river bed in the area between RM 50 and RM 0 in the St. Charles segment is expected to experience between 2 and 4 feet of river bed degradation over the next 5 years and more than 4 feet of river bed degradation over the next 20 years under the Proposed Action. Low-flow water levels in the area between RM 50 and RM 0 are expected to decline between 2 and 4 feet over the next 5 years and more than 4 feet over the next 20 years under the Proposed Action. High-flow water levels in this area are expected to decrease in the short term but increase in the long term.

Table 4.3-7 lists the bridge crossings in the St. Charles segment that would be subject to these anticipated levels of river bed degradation and changes in water surface elevations. These bridges provide critical connections for commutes and freight traveling between St. Louis and St. Charles and other parts of the metropolitan area. In 2009, the combined traffic volume on these bridges was nearly 315,000 AADT (MoDOT 2009). The two railroad bridges also provide important connections between St. Louis and St. Charles. No information was available on the condition of the railroad bridges.

Because the highway bridges in the St. Charles segment have deep foundations secured to competent material, are regularly inspected, and are reinforced against scour as necessary, the moderate to substantial river bed degradation and moderate decline in low-flow water surface elevations between RM 50 and RM 0 are not expected to noticeably increase the risk of structural damage to these bridges.

Table 4.3-8 lists the pipeline and cable crossings in the St. Charles segment that could potentially be at risk from continued river bed degradation under the Proposed Action. Five pipelines transporting water, natural gas, and liquid petroleum are located in this area, as well as two telecommunication lines. No

problems have been reported at these pipeline and cable crossings. Because most pipelines and submerged cables are likely installed at depths that would avoid the possibility of exposure under a range of changing river bed conditions, the levels of river bed degradation expected at these crossing locations (4 feet or more over the next 20 years under the Proposed Action) are not be expected to pose a substantial risk to these pipelines or cable crossings.

Table 4.3-7 Bridge Crossings in the St. Charles Segment Potentially at Risk under the Proposed Action

Crossing Name (Route Number)	River Mile
Bellefontaine Highway (US 67)	8.1
Burlington Northern Inc. Railroad	8.2
Proposed New Highway (MO 115)	27.0
Norfolk and Southern Railroad	27.1
St. Charles Highway (MO 115)	28.2
Interstate 70 and US 40	29.6
Weldon Springs Highway (US 40 and 61)	43.9

Table 4.3-8 Pipeline and Cable Crossings in the St. Charles Segment Potentially at Risk under the Proposed Action

Crossing Name	Utility Type	River Mile
Laclede Gas Co.	Pipeline	8.0
Union Electric Co.	Cable	19.6
AT&T	Cable	26.5
St. Peters Water	Pipeline	34.5
Shell	Pipeline	44.2
Shell	Pipeline	44.5
Explorer	Pipeline	54.4

All other identified highway and railroad bridge, pipeline, and cable crossings located in the St. Charles segment are located outside of the reach between RM 50 and RM 0. These facilities would be unlikely to experience adverse effects from river bed degradation or scour (in the short term or the long term

under the Proposed Action) to a degree that would threaten the soundness or security, or the long-term operation and maintenance costs, of these facilities.

4.3.3.7 Impacts to Wharf and Dock Facilities

All Segments

There are 154 wharves, docks, boat ramps, and other shoreline loading facilities along the LOMR in the Project area. These facilities can be adversely affected if changes in water surface elevation or channel characteristics damage or affect the manner in which the facilities typically are used.

Many old wharves and terminals are located along the river. Many of them were used to ship grain, petroleum, chemicals, and other products up and down the river. Most of these facilities are no longer in use (Chapman pers. comm.). Some loading facilities have been abandoned because of inaccessibility to loading and mooring capabilities that was caused by lowering of the water surface on the Missouri River (USACE 2009). Currently, only a handful of terminals are operating. Most commercial products that were shipped by barge in the past are now likely being shipped by truck or rail.

It is possible that some terminals have adapted to the river bed degradation without notifying the USACE. A likely adjustment would be using a mooring barge between the terminal and the barge being offloaded. It is likely that if an unused terminal in a degraded reach was reopened, it would be necessary to remove rock in front of the terminal to make it usable again. The USACE would work with terminal operators if there was an access problem by performing hydrographic surveys and perhaps removing rock in front of the terminal to provide barges with more draft (Chapman pers. comm.).

Most of the existing boat ramps in the Project area are new or have been completely renovated over the last 10 years. This trend was not due to river bed degradation but more to factors such as the Lewis and Clark Bicentennial, adequate State funds, and renewed interest in river recreation. The USACE has worked closely with the designers of the new/renovated boat ramps to ensure that they extend deep enough to allow for some amount of river bed degradation. Some ramps were extended over the last 10 years to make them more usable during the severe drought that occurred during the mid-2000s (Chapman pers. comm.).

Boat ramps with known problems that are likely due to river bed degradation include:

- City of Leavenworth ramp (extended in winter 2008/2009);
- City of Parkville ramp (usable only during high water elevations);
- Kansas City Missouri Riverfront Park ramp (extended when it was reopened in 2005); and
- City of Saint Charles ramp (usable only during high water elevations). (Chapman pers. comm.)

The potential effect of river bed degradation on boat ramps would be loss of access by recreational boaters and sportsmen to an affected reach of the river. Loss of access also could affect access by emergency personnel and work crews affiliated with the USACE, USGS, USFWS, and MDC work crews (Chapman pers. comm.).

4.3.4 No Action Alternative

Under the No Action Alternative, no commercial dredging would occur in any segment. Because no commercial dredging would occur, no impacts on infrastructure related to dredging would occur in any segment.

4.3.4.1 Projected Changes in River Bed Elevations and Low-Flow Water Levels

Once commercial dredging has been discontinued, the river bed would respond and change in response to influxes of bed material load in the absence of dredging. Aggradation likely would occur in areas where concentrated dredging occurred historically. Table 4.2-7 summarizes the changes in river bed elevations, and changes in low-flow and high-flow water surface elevations expected to occur in each segment under the No Action Alternative.

4.3.4.2 Impacts to Water Intake Facilities

All Segments

Under the No Action Alternative, the potential adverse effects from river bed degradation and declining low-flow water levels on water intake facilities on the LOMR that provide water for public water systems and cooling and process water for power generation plants would not occur. Water losses from intake facilities would not need to be replaced by other sources, such as wells. Major investments in new water intake facilities, or major modifications to existing facilities, would not be required. In some cases, depending on the location, maintenance costs could be affected by the need to remove

sediment buildup around intake structures. In most areas, however, existing or modified BSNP structures could effectively control sediment buildup.

4.3.4.3 Impacts to Water Supply Wells

St. Joseph, Kansas City, and Waverly Segments

Under the No Action Alternative, the potential adverse effects of river bed degradation on horizontal water supply wells in the St. Joseph, Kansas City, and Waverly segments would not occur. The permeability of the underlying aquifer would not be reduced, and existing river bed filtration would not be affected.

4.3.4.4 Impacts to Levees

All Segments

With the elimination of commercial dredging under the No Action Alternative, the processes of river bed degradation and aggradation would be controlled primarily by the USACE as part of the BSNP. The USACE would continue to maintain BSNP structures and implement countermeasures to control bank erosion, scour, and any other natural or human-related processes that could pose a threat to existing levees.

4.3.4.5 Impacts to Bank Stabilization and Navigation Project Structures

All Segments

As described above, under the No Action Alternative, the processes of river bed degradation and aggradation would be controlled to a large degree by the USACE as part of the BSNP. The USACE would continue to maintain the system of dikes by reestablishing the riverward ends of structures, repairing portions of structures that have eroded more quickly than the natural erosion rate, and repairing segments of structures that have settled or sustained flood damage. The USACE also would continue to reinforce the toes of revetments that may have been compromised by ongoing river bed degradation or severe flood events.

4.3.4.6 Impacts to Bridge, Pipeline, and Cable Crossings

All Segments

While the risk to bridge, pipeline, and cable crossing infrastructure from dredging-related river bed degradation would not be present under the No Action Alternative, ongoing river bed degradation and scour could continue to pose a threat to existing infrastructure. Threats to bridges likely would be addressed by implementation of countermeasures such as placing gabions (large rectangular wire baskets containing rock) or dumping rock around bridge footings. Pipeline or cable crossings that might become exposed likely would be reburied or protected by other means by owners and operators.

4.3.4.7 Impacts to Wharf and Dock Facilities

All Segments

Existing wharves, docks, boat ramps, and other shoreline loading facilities in the Project area likely would experience no noticeable effect under the No Action Alternative. In some areas, such as the Kansas City segment, moderate to substantial levels of aggradation may be noticeable.

4.3.5 Alternative A

Alternative A would permit approximately 2,190,000 tons of commercial dredging in the five segments of the LOMR. This alternative would decrease the amount dredged in the Kansas City, Waverly, Jefferson City, and St. Charles segments and would increase the amount dredged in the St. Joseph segment compared to 2004–2008 levels.

4.3.5.1 Projected Changes in River Bed Elevations and Low-Flow Water Levels

Table 4.2-7 summarizes the changes in river bed elevations and changes in low-flow and high-flow water surface elevations under Alternative A by river segment. Under Alternative A, all segments could experience nearly a 2-foot increase or a 2-foot decrease in river bed elevations over the next 5 years. Over the next 20 years, two segments would experience slight degradation (St. Joseph and Jefferson City) while others would experience either slight degradation or slight aggradation. Only slight changes in low-flow and high-flow water surface elevations are expected over the short term and the long term, except the Jefferson City segment, which is expected to experience an increase in high-flow water levels in the long term.

4.3.5.2 Impacts to Water Intake Facilities

All Segments

The slight change in river bed degradation and reduction in low-flow water surface elevations expected in all segments under Alternative A would result in little to no adverse impact on existing water intake facilities over the short term or the long term. The increase in high-flow water surface elevation expected in the Jefferson City segment over the next 20 years under Alternative A would not be expected to noticeably affect the Missouri American Water Company intake facility at RM 144. In some cases, depending on location, maintenance costs could be affected by the need to remove slight sediment buildup (less than approximately 2 feet) around intake structures. In most areas, however, existing or modified BSNP structures could effectively control sediment buildup.

4.3.5.3 Impacts to Water Supply Wells

St. Joseph and Kansas City Segments

Under Alternative A, the slight amount of river bed degradation expected in the St. Joseph and Kansas City segments, over both the short term and the long term, and the slight aggradation expected in the Kansas City segment over the long term, would have no noticeable adverse effect on the one horizontal water supply well located in the St. Joseph segment, operated by the Missouri American Water Company, and the three horizontal water supply wells located in the Kansas City segment, operated by the Kansas City Board of Public Utilities and WaterOne. The expected change in river bed elevation of less than 2 feet under Alternative A would not substantially reduce the permeability of the underlying aquifer or adversely affect river bed filtration at these well locations.

Waverly

The slight change in river bed degradation and reduction in low-flow water surface elevations expected in the Waverly segment under Alternative A would result in little to no adverse impact over the short term or the long term on the City of Independence, Missouri's horizontal collector well located at approximately RM 353.5.

Jefferson City and St. Charles Segments

No horizontal collector wells were identified in the Jefferson City or St. Charles segments.

4.3.5.4 Impacts to Levees

All Segments

With the substantial reduction in commercial dredging in most segments under Alternative A, the potential risk to federal and non-federal levees from potential effects such as bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee damage and potential levee failure would generally be less than under current conditions. The only area expected to experience an increase in high-flow water surface elevations in the long term under Alternative A is the area between RM 150 and RM 140 in the Jefferson City segment. Existing levees would continue to be subject to the periodic effects of high-flow water surface elevations and the potential undermining effects of those conditions. Continued inspections, maintenance, and damage repair would be required, particularly in areas such as the St. Joseph and Kansas City segments where some levees have been constructed on top of revetments.

4.3.5.5 Impacts to Bank Stabilization and Navigation Project Structures

All Segments

The potential effects on BSNP structures under Alternative A (such as exposure of the tops of dikes due to river bed degradation rates that are more rapid than erosion rates) would be less than under current conditions. Likewise, the potential for erosion at the toe of revetments would be less. The reduced potential for these types of effects would reduce the cost to maintain and repair these structures compared to existing conditions.

4.3.5.6 Impacts to Bridge, Pipeline, and Cable Crossings

All Segments

Because these segments are not expected to experience even moderate amounts of river bed degradation or changes in low-flow water elevations over the next 20 years, none of the bridges, pipelines or cable crossing in the Project area would be expected to experience adverse effects from river bed degradation or scour (in the short term or the long term under Alternative A) to a degree that would threaten the soundness or security, or the long-term operation and maintenance costs of those facilities. Any observed problems related to river bed degradation or scour at affected highway bridges would be addressed through implementation of scour countermeasures by the MoDOT and the KDOT. Any threats to pipelines or cable crossings would be addressed by the owners and operators.

4.3.5.7 Impacts to Wharf and Dock Facilities

All Segments

Existing wharves, docks, boat ramps, and other shoreline loading facilities in the Project area likely would experience no noticeable effect under Alternative A. In some areas, a slight increase in aggradation levels may be noticeable.

4.3.6 Alternative B

Alternative B would permit 5,050,000 tons of commercial dredging in the five segments of the LOMR. This would result in a decrease in the amount dredged in the Kansas City, Jefferson City, and St. Charles segments, and an increase in the amount dredged in the St. Joseph and Waverly segments compared to 2004–2008 levels.

4.3.6.1 Projected Changes in River Bed Elevations and Low-flow Water Levels

Table 4.2-7 summarizes the changes in river bed elevations and changes in low-flow and high-flow water surface elevations under Alternative B by river segment. Under Alternative B, river bed degradation levels and reductions in low-flow water levels in most segments would be less than 2 feet over the next 5 years and no more than 4 feet over the next 20 years. The Waverly segment could experience slight levels of degradation and declining low-flow water elevations or slight levels of aggradation and increasing low-flow water elevations over the short term under Alternative B.

4.3.6.2 Impacts to Water Intake Facilities

St. Joseph, Kansas City, Jefferson City, and St. Charles Segments

River bed degradation levels of as much as 4 feet over the next 20 years in portions of these segments under Alternative B could pose a moderate long-term risk to a number of existing water intake facilities within these segments compared to existing conditions. As described for the Proposed Action, these intake facilities provide critical water supplies to local communities and electric power plants throughout the Project area, including the Aquila Lake Road, Nearman Bottoms, Quindaro, and Hawthorn power plants, which together generate over 1,100 MW of electrical power. Potentially affected intake facilities include intakes operated by several water purveyors supplying water to nearly 2 million people in the Kansas City and St. Louis metropolitan areas. Intake facilities located in all segments except the Waverly segment could require modifications or installation of additional pumps to ensure sufficient water supplies. Typical costs for new water pumps can range from $1 to $3 million, while costs to

modify or replace existing intake structures can exceed $10 million. Because the City of St. Louis Water Division intake structure at RM 37.0 is an integral part of the pumping station, the cost to modify that intake structure alone would range from $25 to $35 million (Skouby, pers. Comm.). These additional costs would result in increased utility rates for current and future customers.

Waverly Segment

The potential for slight aggradation over the next 5 years in the Waverly segment under Alternative B could require additional maintenance at some intake facilities to remove up to 2 feet of sediment buildup. In most areas, however, existing or modified BSNP structures could effectively control the potential sediment buildup. The less than 2-foot change in river bed elevation in the Waverly segment over the long term under Alternative B would be unlikely to adversely affect existing water intake facilities.

4.3.6.3 Impacts to Water Supply Wells

St. Joseph and Kansas City Segments

Under Alternative B, the potential for up to 4 feet of river bed degradation in the next 5 years near four horizontal water supply wells in these segments could present an increased risk to the permeability of the underlying aquifer and the effectiveness of river bed filtration near these wells. The Missouri American Water Company has recommended that a no-dredge zone be created 2,000 feet upstream and 2,000 feet downstream from their well in the St. Joseph segment to reduce the potential for adverse impacts on their existing system (Fuerman pers. comm.). The Kansas City Board of Public Utilities and WaterOne are currently requesting that the no-dredge zone be increased to 1 mile upstream and 1 mile downstream from their horizontal collector wells in the Kansa City segment (Armstrong. pers. comm., Stewart. pers. comm.). Implementation of such restrictions could help reduce the potential for adverse impacts on these water supply systems.

Waverly

The slight change in river bed degradation and reduction in low-flow water surface elevations expected in the Waverly segment under Alternative B would result in little to no adverse impact over the short term or the long term on the City of Independence, Missouri's horizontal collector well located at approximately RM 353.5.

Jefferson City and St. Charles Segments

No horizontal collector wells were identified in the Jefferson City or St. Charles segments.

4.3.6.4 Impacts to Levees

St. Joseph, Kansas City, Jefferson City, and St. Charles Segments

The estimated river bed degradation of up to 4 feet over the next 20 years in portions of these segments under Alternative B could pose a moderate risk to existing federal and non-federal levees in the St. Joseph, Kansas City, Jefferson City, and St. Charles segments. Potential effects such as bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee damage, and potential levee failure, would generally be greater than under current conditions. Implementation of countermeasures likely would be required to ensure the required factor of safety, including regular inspections, maintenance, and repairs. This would be particularly likely in areas such as the Kansas City segment, where a number of levees have been constructed on top of revetments. Similar countermeasures may be required for levees located along major tributaries.

Waverly Segment

The estimated level or river bed degradation and decline in low-flow water surface elevations in the Waverly segment is less than 2 feet over the next 20 years under Alternative B. These low levels of change suggest that adverse affects on existing levees would not occur.

4.3.6.5 Impacts to Bank Stabilization and Navigation Project Structures

St. Joseph, Kansas City, Jefferson City, and St. Charles Segments

As described for Alternative A, the potential effects on BSNP structures (such as exposure of the tops of dikes caused by river bed degradation rates that are more rapid than erosion rates) would generally be greater under Alternative B than under current conditions, and likely would require implementation of countermeasures to ensure the required factor of safety, including regular inspections, maintenance, and repairs. Likewise, the potential for erosion at the toe of revetments would be greater under Alternative B than under current conditions. The potential costs to reinforce or repair BSNP structures in the St. Joseph, Kansas City, Jefferson City, and St. Charles segments could be substantial. For example, assuming 5,000 tons of rock per mile of revetment per foot of river bed degradation (between 2 and 4 feet), the estimated cost to reinforce the toes of 73 miles of revetment in the St. Joseph,

Kansas City, Jefferson City, and St. Charles segments segment could range between $21.9 and $43.8 million.

Waverly Segment

The less than 2-foot change in the river bed in the Waverly segment due to river bed degradation in the long term under Alternative B would be unlikely to affect existing BSNP structures; therefore, no adverse effects are expected in this segment.

4.3.6.6 Impacts to Bridge, Pipeline, and Cable Crossings

All Segments

Because all segments are expected to experience no more than moderate levels of river bed degradation and declines in low-flow water elevations over the next 20 years, none of the bridge, pipeline, or cable crossings in the Project area would be expected to experience adverse effects from river bed degradation or scour (in the short term or the long term under Alternative B) to a degree that would threaten the soundness or security, or the long-term operation and maintenance costs, of those facilities. Any observed problems related to river bed degradation or scour at affected highway bridges would be addressed through implementation of scour countermeasures by the MoDOT and the KDOT. Any threats to pipelines or cable crossings would be addressed by the owners and operators.

4.3.6.7 Impacts to Wharf and Dock Facilities

St. Joseph, Kansas City, Jefferson City, and St. Charles Segments

The wharves, docks, boat ramps, and other shoreline loading facilities located within these segments could be adversely affected under Alternative B if the expected 2–4 feet of river bed degradation would affect the manner in which the facilities typically are used. Most of the wharves and terminal facilities in these segments are no longer in use, and the expected levels of river bed degradation under Alternative B would not substantially affect current users. River bed degradation levels are not expected to adversely affect most boat ramps because most ramps in the Project area have been constructed or renovated within the last 10 years and have been designed to accommodate changing water level conditions. A few boat ramps with existing low-water elevation problems could experience worsening conditions in the long term unless they are modified to accommodate declining water elevations. These include the City of Parkville ramp (usable only during high water) and the City of Saint Charles ramp (usable only during high water) (Chapman pers. comm.).

Waverly Segment

The less than 2-foot change in the river bed in the Waverly segment due to river bed degradation in the long term under Alternative B would be unlikely to affect existing wharves, docks, boat ramps, or other shoreline loading facilities. Therefore, no adverse effects are expected in this segment.

4.3.7 Alternative C

Alternative C would permit approximately 6,900,000 tons of commercial dredging in the five segments of the LOMR. This would be approximately the same as the average annual amount of dredging from 2004 to 2008 (existing conditions).

4.3.7.1 Projected Changes in River Bed Elevations and Low-Flow Water Levels

Table 4.2-7 summarizes the changes in river bed elevations and changes in low-flow and high-flow water surface elevations under Alternative C by river segment.

Under Alternative C, river bed degradation in all segments would be less than 2 feet in the short term. Over the next 20 years, however, river bed degradation could reach and exceed 4 feet. Changes in low-flow and high-flow water surface elevations would be similar, except in the St. Joseph and Waverly segments where changes would be slight to none.

4.3.7.2 Impacts to Water Intake Facilities

Kansas City, Jefferson City, and St. Charles Segments

River bed degradation levels of as much as 4 feet or more over the next 20 years in portions of these segments under Alternative C could pose a moderate to substantial long-term risk to a number of existing water intake facilities in the segments compared to existing conditions. As described for the Proposed Action, these intake facilities provide critical water supplies to local communities and electric power plants throughout the Project area, including the Nearman Bottoms, Quindaro, and Hawthorn power plants, which together generate over 1,000 MW of electrical power. Potentially affected intake facilities also include intakes operated by several water purveyors supplying water to nearly 2 million people in the Kansas City and St. Louis metropolitan areas. Intake facilities located in all segments, except the St. Joseph and Waverly segments, could require modifications or additional pumps to ensure sufficient water supplies under Alternative C. Typical costs for new water pumps can range from $1 to $3 million, while costs to modify or replace existing intake structures can exceed $10 million (Armstrong, Schrempp, Kartmann pers. comm.). Because the City of St. Louis Water Division intake

structure at RM 37.0 is an integral part of the pumping station, the cost to modify that intake structure alone would range from $25 to $35 million (Skouby, pers. Comm.). These additional costs would result in increased utility rates for current and future customers.

St. Joseph and Waverly Segments

The less than 2-foot change in the river bed in the St. Joseph and Waverly segments due to river bed degradation under Alternative C would be unlikely to affect existing water intake facilities. Therefore, no adverse effects on water intake facilities are expected in the St. Joseph or Waverly segment.

4.3.7.3 Impacts to Water Supply Wells

St. Joseph and Kansas City Segments

Under Alternative C, the less than 2 feet of river bed degradation at the horizontal water supply well operated by the Missouri American Water Company at RM 454.75 is not expected to notably affect the permeability of the underlying aquifer or the effectiveness of river bed filtration near that well. However, the potential for 4 feet of more of river bed degradation near the two horizontal water supply wells operated by the Kansas City Board of Public Utilities at RM 379 and the one horizontal water supply wells operated by WaterOne at approximately RM 385.5 could present an increased risk to the permeability of the underlying aquifer and the effectiveness of river bed filtration near these wells. The Kansas City Board of Public Utilities and WaterOne are currently requesting that the no-dredge zone be increased to 1 mile upstream and 1 mile downstream from their horizontal collector wells in the Kansa City segment (Armstrong. pers. comm., Stewart. pers. comm.). Implementation of such restrictions could help reduce the potential for adverse impacts on these water supply systems.

Waverly Segment

The slight change in river bed degradation and reduction in low-flow water surface elevations expected in the Waverly segment under Alternative C would result in little to no adverse impact over the short term or the long term on the City of Independence, Missouri's horizontal collector well located at approximately RM 353.5.

Jefferson City and St. Charles Segments

No horizontal collector wells were identified in the Jefferson City or St. Charles segments.

4.3.7.4 Impacts to Levees

Kansas City, Jefferson City, and St. Charles Segments

The estimated river bed degradation of up to 4 feet or more over the next 20 years in portions of the Kansas City, Jefferson City, and St. Charles segments under Alternative C could pose a substantial risk to existing federal and non-federal levees in these segments. Potential effects such as bank erosion, bank instability, bank failure, soil weakening, scour and erosion, levee damage, and potential levee failure would generally be greater under Alternative C than under current conditions. Implementation of countermeasures likely would be required to ensure the required factor of safety, including regular inspections, maintenance, and repairs. This would be particularly likely in areas such as the Kansas City segment where levees have been constructed on top of revetments. Similar countermeasures may be required for levees located along major tributaries.

St. Joseph and Waverly Segments

The less than 2-foot change in the river bed in the St. Joseph and Waverly segments due to river bed degradation under Alternative C would be unlikely to affect existing levees; therefore, no adverse effects are expected in these segments.

4.3.7.5 Impacts to Bank Stabilization and Navigation Project Structures

Kansas City, Jefferson City, and St. Charles Segments

The potential effects on BSNP structures (such as exposure of the tops of dikes due to river bed degradation rates that are more rapid than erosion rates) in the Kansas City, Jefferson City, and St. Charles segments under Alternative C would generally be greater than under existing conditions, and would likely would require the implementation of countermeasures to ensure the required factor of safety, including regular inspections, maintenance, and repairs. Likewise, the potential for erosion at the toe of revetments in these segments would be greater under Alternative C than under existing conditions. Assuming 5,000 tons of rock per mile of revetment per foot of river bed degradation (4 feet or more), the estimated cost to reinforce the toes of 65 miles of revetment in the Kansas City, Jefferson City, and St. Charles segments could exceed $39 million.

St. Joseph and Waverly Segments

The less than 2-foot change in the river bed in the St. Joseph and Waverly segments due to river bed degradation under Alternative C would be unlikely to affect existing BSNP structures. Therefore, no adverse effects to BSNP structures are expected in these segments under Alternative C.

4.3.7.6 Impacts to Bridge, Pipeline, and Cable Crossings

Kansas City, Jefferson City, and St. Charles Segments

Degradation levels and changes in low-flow water elevations in the Kansas City, Jefferson City, and St. Charles segments under Alternative C would generally be greater than under existing conditions and be similar to those described for the Proposed Action. Potential adverse effects to the same bridges and pipelines as described for the Proposed Action would be likely to occur under Alternative C.

Because the highway bridges along this segment have been built with deep foundations, are regularly inspected, and are reinforced against scour as necessary, the moderate to substantial river bed degradation and reduction in low-flow water surface elevations projected in these segments under Alternative C are not expected to noticeably increase the risk of structural damage to these bridges.

Because most pipelines crossing the Missouri River are installed at depths that would avoid the possibility of exposure under a range of changing bed conditions, the levels of river bed degradation expected at these crossing locations (4 feet or more over the next 20 years under Alternative C) are not expected to pose a substantial risk to these pipelines.

Any observed problems related to river bed degradation or scour at affected highway bridges would be addressed through implementation of scour countermeasures by the MoDOT and the KDOT. Any threats to pipelines or cable crossings would be addressed by the owners and operators.

4.3.7.7 Impacts to Wharf and Dock Facilities

Kansas City, Jefferson City, and St. Charles Segments

The wharves, docks, boat ramps, and other shoreline loading facilities located within the Kansas City, Jefferson City, and St. Charles segments could be adversely affected under Alternative C if the expected 2–4 feet or more of river bed degradation would affect the manner in which the facilities typically are used. Most of the wharves and terminal facilities in these segments are no longer in use, and the expected levels of river bed degradation under Alternative C are not likely to substantially affect

current users. Expected river bed degradation levels are not likely to adversely affect most boat ramps because most ramps in the Project area have been constructed or renovated within the last 10 years and have been designed to accommodate changing water level conditions. A few boat ramps with existing low-water elevation problems could experience worsening conditions in the long term unless they are modified to accommodate declining water elevations. These include the City of Parkville ramp (usable only during high water) and the City of Saint Charles ramp (usable only during high water) (Chapman pers. comm.).

St. Joseph and Waverly Segments

The less than 2–foot change in the river bed in the St. Joseph and Waverly segments due to river bed degradation under Alternative C would be unlikely to affect existing wharves, docks, boat ramps, or other shoreline loading facilities. Therefore, no adverse effects are expected in these segments.

4.3.8 Summary Table

Table 4.3-9 contains a summary of potential impacts on infrastructure for the Proposed Action and alternatives.

Table 4.3-9 Summary of Potential Impacts on Infrastructure

Category of Effect	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Impacts to water intake facilities and water supply wells	• Increased costs of maintenance, potentially higher utility rates, and increased risk of shutdown of intake structures in the long term in St. Joseph, Kansas City, Jefferson City, and St. Charles segments. • Potential decreases in flow rate capacity and filtration effectiveness in St. Joseph and Kansas City segments.	• No impact.	• Little to no adverse impact on existing water intake facilities. • No noticeable adverse effect on water supply wells.	• Increased costs of maintenance, potentially higher utility rates, and increased risk of shutdown of intake structures in the long term in St. Joseph, Kansas City, Jefferson City, and St. Charles segments. • Potential decreases in flow rate capacity and filtration effectiveness in St. Joseph and Kansas City segments.	• Increased costs of maintenance, potentially higher utility rates, and increased risk of shutdown of intake structures in the long term in Kansas City, Jefferson City, and St. Charles segments. • Potential decreases in flow rate capacity and filtration effectiveness in St. Joseph and Kansas City segments.
Impacts to levees and Bank Stabilization and Navigation Project (BSNP) structures	• Increased risk of levee and BSNP structure failure in St. Joseph, Kansas City, Jefferson City, and St. Charles segments.	• Decreased risk of levee and BSNP structure failure in LOMR.	• Decreased risk of levee and BSNP structure failure in LOMR; except between RM 150 and RM 140 in Jefferson City segment, where the risk would remain the same.	• Increased risk of levee and BSNP structure failure in St. Joseph, Kansas City, Jefferson City, and St. Charles segments.	• Increased risk of levee and BSNP structure failure in Kansas City, Jefferson City, and St. Charles segments.
Impacts to bridge, pipeline, and cable crossings	• Increased risk of structural damage to bridges, pipeline, and cable crossings in Kansas City segment.	• Decreased risk of structural damage to bridges, pipeline and cable crossings from dredging; risks related to degradation would remain.	• Decreased risk of structural damage to bridges, pipelines, and cable crossings.	• No impact.	• No impact.
Impacts to wharf and dock facilities	• Increased risk of damage to four boat ramps.	• No impact.	• No impact, except in certain areas where aggradation would decrease risk of boat ramp damage.	• Potential increased risk of damage to two boat ramps; no impact in Waverly segment.	• Potential increased risk of damage to two boat ramps; no impact in St. Joseph or Waverly segment.

4.3.9 References

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