Appendix O

Economic Analysis

This page is intentionally left blank.

Economic Analysis – Appendix O

Missouri River Bed Degradation Technical Report

Table of Contents

1 Introduction

Bed degradation of the Missouri River has historically impaired the operation and performance of important municipal and private structures, such as bridges, weirs, and water supply intakes. In response to the effects of historical bed degradation, local infrastructure owners and operators have relocated, repaired, and reconstructed infrastructure on the Missouri and Kansas Rivers. Based on interviews with local stakeholders, the costs of these remedial actions are known to total more than $100 million since 1990, and this cost would likely be higher if smaller actions taken on tributaries and actions by smaller alluvial well operators were investigated.

Projected future degradation will cause additional impacts to infrastructure operations and performance. For some structures, actions consistent with historical levels of effort to repair or restore infrastructure performance will not be sufficient to address future degradation. Far greater actions, such as construction of alternative power plant cooling systems, will be required due to projected future degradation. In current dollars, the cost of these actions is estimated to be more than $269 million during the study period (2018 – 2068).

Arresting or substantially slowing bed degradation can defer to sometime farther in the future, or avoid altogether, the costs of repairing, restoring, or replacing infrastructure. These avoided costs are the National Economic Development (NED) benefits of alternative plans to reduce bed degradation.

An economic model was developed to estimate the economic damages associated with varying levels of bed degradation. This model has been approved by Headquarters USACE for one-time use. Note that the model used for this analysis would require substantial modifications to be used in future analyses. If this model is used in the future, new inquiries to the infrastructure owners would be required in conjunction with the most up-to-date Missouri River survey data.

2 Historical Effects of Bed Degradation

Historical bed degradation has affected the structural integrity and operational effectiveness of important infrastructure along the Missouri River and its tributaries since at least the 1990's, based on interviews with local infrastructure operators. The two major effects of historical bed degradation have been falling water levels and exposure of foundation structures. Examples of the effects of historical bed degradation are discussed below. Although not all costs of historical responses to bed degradation have been identified, more than $45 million in capital construction costs and $55 million in increased operating costs have been incurred by the major utilities since the 1990's due to bed degradation. Additional actions taken by stakeholders, for which cost information is not available, includes bridge repairs, utility crossing repairs, increased energy consumption for water supply production from groundwater wells, and bank stabilization on tributaries.

Table 1: Summary of Major Structures Historically Affected by Bed Degradation

Structure	Stakeholder	Action taken
Local road bridge	KCMO Highway Dept.	Repaired bridge foundation
Highway Bridge	MODOT	Increased design criteria for bridge construction
Water Supply Intakes	Water One	Supplemental pump installed
Water Supply Intakes	KCMO Water Services Dept.	Supplemental pump installed
Water Supply Intakes	KCMO Water Services Dept.	Supplemental pump installed
Water Supply Intakes	Leavenworth Water	Supplemental pump installed
Cooling Water Intakes	KCBPU - Quinadaro	Supplemental pump installed
Cooling Water Intakes	KCBPU – Nearman Creek	Supplemental pump installed
Cooling Water Intakes	KCBPU – Nearman Creek	Cooling tower constructed
Flood Control Structures	Levee Districts & USACE	Levee and floodwall reconstructed
BSNP* Structures	USACE	Repaired and modified

*Bank Stabilization and Navigation Project

2.1 Decreasing Water Surface Elevation

As the bed of the Missouri River has degraded over time, any given flow volume achieves a lower water surface elevation. In other words, historical bed degradation has caused a reduction in water levels over time[1]. Low water levels are especially prevalent during winter months when scheduled flows from Gavins Point Dam are at their lowest levels and ice jams can further exacerbate low water level conditions. Falling water levels affect water intakes, which are designed to operate across a fixed range of water levels. In order to maintain flow through the intakes during period of low water levels, water suppliers and power utilities have augmented their intakes with auxiliary pumps which reach farther into the river and pump water into the fixed water intake. In some instances these auxiliary pumps have been further extended (shaft extension) or moved farther into the river channel "chasing" low water levels as they have receded over the years. In 2003, one power plant on the Missouri River constructed a cooling tower for use during low flows (typically two months in the winter) because the auxiliary intake pumps installed in 1999 were not able to provide sufficient cooling water to the fixed intakes.

Falling water levels in the Missouri River also affect water levels in hydraulically connected unconfined aquifers, which are comprised of sediments with high hydraulic conductivity. Water suppliers have documented decreased well production due to reduced aquifer water levels during low flows in the Missouri River.

Because of this hydrologic connection between the Missouri River and the adjacent alluvial aquifer, decreases in river stage as a result of bed degradation result in a lowering of the elevation of the groundwater surface in the adjacent alluvial aquifer. The lowering of the water

[1] Note that the drop in water levels has the largest impact when flows are low. During high flow events bed degradation has less effect on water levels and does not contribute to flood risk management in a substantial way.

table effectively drains water from oxbow lakes and wetlands in the floodplain (NRC, 2002). The 1978 FEIS on the continuing construction and maintenance of the bank stabilization and navigation project (BSNP) states, "*degradation of the river bed in the upper reach of the project area also drains, isolates, or significantly lowers water levels of the chutes and sloughs which adjoin the river, significantly diminishing their overall value, ecologically, to the river's aquatic ecosystem*." (USACE, 1979).

2.2 Exposure of Foundation Structures

During the process of historical bed degradation (1987 – 2011), the loss of material has exposed the foundations of bridges and other structures in the Missouri River and its tributaries. The Missouri Department of Transportation periodically performs a bathymetric assessment of its bridges to ensure that its bridges' structural integrity is not compromised by increased foundation exposure. The new Christopher S. Bond Bridge (opened in 2013) was designed specifically to withstand future bed degradation. A local roadway bridge over Line Creek, which is a small tributary to the Missouri River, had pile caps undercut and exposed due to bed degradation. The bridge foundation was repaired with sheet pile and concrete.

The foundation and/or protective toe of floodwalls and levees have also been affected by bed degradation. At Jersey Creek, a small tributary to the Missouri River, the structural integrity of the sheet pile wall, which protects the Fairfax levee foreshore (a unit of the Kansas Citys, Missouri and Kansas Flood Control Project) was compromised by undermining caused by historical bed degradation. Repairs to the wall are underway. In 2004, a rock jetty on the Kansas River, which directed water towards a water utility intake, collapsed due to undermining and increased head differential caused by bed degradation. In 2010, the rock jetty was replaced by a concrete cell weir, which has stopped the upstream migration of bed degradation.

3 Infrastructure at Risk from Future Bed Degradation

Infrastructure at risk from future bed degradation was identified through interviews and site inspections with local utilities, assessments of bridge design and as-built drawings, and modeling of levee and floodwall structures. Preliminary without-project condition bed degradation modeling was used to inform the identification of infrastructure potentially at risk from future bed degradation. Revised bed degradation modeling was used in the determination of the without-project condition and in the detailed evaluation of alternatives.

Note that the economic model is designed to estimate damages and benefits (avoided costs) under various levels of dredging and structural alternatives. The model does not attempt to identify an optimal level of dredging or economically justify any level of dredging. In addition, the damages identified below are for major types of infrastructure that are projected to be impacted by bed degradation, although not necessarily an exhaustive list of potentially impacted infrastructure. The major infrastructure, which are included in the economic evaluation, were selected because they are presumed to represent the largest component of potential damages and are therefore deemed to provide sufficient information to support Federal decision making.

3.1 Local Utility Companies

Interviews and site inspections were conducted with:

- Kansas City Board of Public Utilities;
- Kansas City Power and Light (interview only);
- Kansas City Missouri Water Services Department;
- Water District 1 of Johnson County, Kansas (Water One);
- City of Saint Joseph;
- City of Atchison; and
- Leavenworth Water Department.

Interviews and site inspections conducted with the local power and water utility companies indicate that the utility companies have each historically taken action to address historical bed degradation and are each planning future action in response to future bed degradation. Most of the historical actions taken in response to past bed degradation will be insufficient to address conditions of future degradation. For example, the use of supplemental pumps to deliver raw water to power plant and water supply intakes was a feasible solution for historical levels of bed degradation, but as the river bed degrades further supplemental pumps must encroach farther into the existing navigation channel, becoming less productive and less reliable because they would be more at risk from ice and floating debris. In addition, supplemental pump productivity is typically less than the productivity of a fully operable intake; therefore, power and water supply output is typically reduced when supplemental pumps are being used. Further bed degradation also increases the amount of time that supplemental pumps are required, which for some utilities would create an unacceptable impact on output.

Building a new intake, which would be repositioned to operate under lower water levels, is an option available to some facilities. For other facilities, building a new intake is not a feasible option. For facilities which continued use of supplemental pumps and new intakes are not feasible, alternative water sources are being sought, including alluvial wells and horizontal collectors. The development of new wells to replace or supplement existing Missouri River intakes requires large capital expenditures, long planning lead times (for engineering design, permitting, financing, and construction), and may require real estate purchases.

Additionally, recirculating cooling systems are being considered as replacements for existing river-dependent once-through cooling systems. Obtaining the required permits and approvals for construction of a recirculating system for existing power plants, which would use a cooling tower, can be difficult and cannot be considered a definite outcome. Alternatively, the power plant may be replaced with a combined-cycle (gas/steam generated power) plant, which may conceivably use a dry cooling system, which does not require a recirculating cooling tower.

The economic model evaluates damages under the assumption that capital costs are incurred in the same year that the critical elevation is achieved. If additional maintenance costs are also incurred as a component of damages those additional maintenance costs are also incurred in the same year that the critical elevation is achieved and continue to be incurred each year throughout the remainder of the planning horizon. A sensitivity analysis looks at the effects of advancing construction costs, which is described further in Section 8: Advancing capital expenditures

3.2 Bridges

The as-built drawings for bridges spanning the Missouri River from Liberty, Missouri to Leavenworth, Kansas were assessed by the U.S. Army Corps of Engineers (USACE) Kansas City District for information pertaining to the type of foundation (caisson, footing on shafts, footing on piles, etc.), number of piers, and the riverbed elevation at the time of construction. This information was used to develop a critical bed elevation, which if reached by bed degradation would trigger corrective action by the bridge owner. Eight bridges spanning the Missouri River were identified as potentially requiring future corrective action due to future bed degradation. It is assumed that the corrective action would take place well in advance of any compromise of the bridge's structural integrity.

The economic model evaluates bridge damages in the same manner as described for local utility companies in section 3.1.

3.3 Flood Damage Risk Reduction Structures

The bed degradation effect on local flood damage risk reduction structures, including flood walls and levees, was assessed by the USACE Kansas City District under alternative conditions of bed degradation. The assessment was conducted using probabilistic modeling, which projected flood damage risk reduction structure performance during flood events by evaluating the effects of bed degradation on underseepage, landside slope stability, and riverside slope stability. The assessment of impacts to structure performance was also conducted during non-flood events by evaluating the effects of bed degradation on riverside slope stability. The analysis identified three levee locations (Fairfax-Jersey Creek Wharf, Fairfax-Jersey Creek Levee, and East Bottoms) which will potentially require future corrective action due to future bed degradation.

The economic model evaluates flood risk reduction structure damages in the same manner as described for local utility companies in section 3.1.

3.4 BSNP Structures

BSNP structures such as dikes, sills, and revetments are designed, constructed, and maintained to specific elevations relative to the Construction Reference Plane (CRP). The CRP is based on average daily flows during the navigation season from April 1 to December 1. The plane is based on United States Geological Survey (USGS) stage gages and observed surface water profiles. As such, changes in the average surface water profile imply a change in the CRP, thereby necessitating a change in BSNP structure elevations. The CRP is periodically adjusted to reflect locally changed conditions. Since the 1990's the CRP has been falling in response to bed degradation. The decreasing CRP requires that BSNP structures be modified in order to be compliant with the current CRP. Future degradation would require more frequent and potentially larger scale adjustments to BSNP structures.

Damages to BSNP structures are evaluated in two-foot increments. Costs for BSNP modifications due to bed degradation were calculated and applied for two feet, four feet, and six feet of degradation in the Base Case, Less Degradation, and 3-year advance costs model runs. Costs for BSNP modifications were calculated at eight feet of degradation in the More Degradation scenario, which is further explained in Section 6.0 Economic Evaluation of Alternatives. ..

3.5 Shallow Water Habitat

In order to maintain shallow water habitat under conditions of continued bed degradation USACE may need to reconfigure existing “chutes”, which may no longer be inundated or which may experience reduced durations of inundation due to bed degradation. Damages to chutes are evaluated for three feet of degradation and for six feet of degradation.

3.6 Tributaries

Degradation on a mainstem river induces degradation on tributaries (Germanaski and Rutter 1988). Recently, degradation on the Missouri River at RM 372.2 contributed to degradation of Line Creek, a tributary to the Missouri River, damaging the adjacent Federal levee, L-385, and threatening Missouri Highway 9 Bridge. The solution included a rock grade control structure plus levee repairs at a cost of approximately $1.6 million. Approximately 118 tributaries with potential for degradation damage enter the Missouri River from RM 293 to 498, the modeled reach of the Missouri River Bed Degradation Technical Report (Degradation Report). Analyzing the infrastructure impacts for each tributary is impractical due to the large geographic extents and insufficient physical and infrastructure data. Rather than analyze infrastructure damage on tributaries, the Missouri River Bed Degradation Feasibility Study assumes that if a sufficient amount of bed degradation occurs on the Missouri River, then grade control will be built on the adjacent tributary to prevent damage.

Tributary damages are evaluated in two foot increments. Costs of tributary grade control structures we developed for and applied in the model for two feet of degradation and four feet of degradation. Note that at four feet of degradation, the costs of additional shoreline protection is also included in the damages evaluation. This underestimates the degradation damages on tributaries because (1) the actual tributary damages likely exceed the cost of the grade control, and (2) the costs of additional grade control structures required when degradation exceeds six feet (in the FWOP base case) and when degradation exceeds eight feet (in the more degradation scenario) have not been included.

Table 2: Summary of Major Structures at Risk from Projected Future Bed Degradation

Structure	Projected Future Problem	Projected Future Action
Highway Bridges	Reduced bridge pier foundation integrity	Proactive repairs to bridge pier foundation
Water Supply Intakes	Water surface elevation below operable level of intakes and supplemental equipment	Construct new intake; access alternative water source
Cooling Water Intakes	Water surface elevation below operable level of intakes and supplemental equipment	Install supplemental pumping equipment; construct new intake; use recirculating system with cooling towers
Flood Damage Risk Reduction Structures	Increased underseepage and reduced slope stability	Proactive repairs to restore foundation integrity
BSNP Structures	Reduced structural integrity of bank revetments	Proactive repairs to restore bank protection
Shallow Water Habitat	Reduced inundation of shallow water habitat "chutes"	Reconfigure chutes to restore shallow water habitat
Tributaries	Induced degradation on adjacent tributary	Construct grade control structure on the tributary

4 Potential Future Without-Project Infrastructure Costs Due To Bed Degradation

Confidential information concerning potential future responses to continuing bed degradation, including potential plans and their costs, was gathered from local utilities and municipalities. This confidential information includes potential future actions which may be taken in the near-term and other actions which are long-term. The scheduling of these actions will be determined by the perceived extent of future degradation at each facility. High flow events in the near-term with associated bed degradation would likely cause a facility operator to initiate plans that would otherwise be scheduled farther into the future. Similarly, high flow events in the near term with associated bed degradation may cause a larger, more expansive response from a facility operator than would be executed under conditions of more gradual bed degradation.

For the base-case economic scenario, which is based on the average bed degradation projections from the bed degradation model, the entire infrastructure re-construction or repair cost is entered into the model in the year that the critical bed elevation is achieved. However, municipalities and utilities are averse to risks, which may impact the provision of fundamental services such as water and power. Responses to perceived future bed degradation would likely be proactive so that service provision continues with minimal disruption. It would likely be years between planning, construction, and operation of a large, capital intensive response to bed degradation, such as development of an alternative water source or switching to a recirculating cooling system. It would not be unreasonable to assume that a facility operator may begin the planning process five years prior to the critical level of bed degradation being achieved and begin construction three years prior to the projected year of service disruption. This assumption has been confirmed in our interviews to date. Incorporating this long lead time into the planning process, the facility operator can ensure that the new structure will be in operation prior to the failure of the existing structure. The economic model may be adjusted to account for a longer lead time. This adjustment was used as a sensitivity analysis for the base case scenario. The analysis, which included a three-year lead time to account for construction being performed in advance of service disruptions, is in Section 8.

In order to maintain the confidentially under which potential future plans and projected future costs were disclosed, the potential future costs of plans to address the effects of future bed degradation are grouped into categories (Table 3). Potential future costs for municipal infrastructure include capital construction costs and annual additions to operations and maintenance costs. Note that not all costs identified in Table 3 are projected to be incurred during the 50-year planning horizon because the projected degradation at some facilities is not sufficient to achieve the critical elevation for that structure.

Table 3: Potential Future Major Infrastructure Costs Due to Bed Degradation ($FY17)

Structure Type – Capital Costs	
Auxiliary Intake Equipment	$23,400,000
New Intake Construction	$244,800,000
Alternative Water Supply Sources	$135,600,000
Alternative Cooling Systems	$342,600,000
Bridge Repairs	$20,800,000
Levees and Floodwalls	18,300,000
Total Capital Costs	**$785,500,000**
Operations and Maintenance Costs	
Increased annual O&M costs - utilities	$29,000,000
Total increased annual O&M costs	**$29,000,000**

River bed degradation adversely affects the BSNP in two ways; river training structures become perched above their design elevation, and outside bend revetments become undermined resulting in an over-steepened slope along the face of the revetment. The cost of revetment reinforcement is estimated to be $320,000 per river mile per foot of degradation. The cost of lowering river training structures is estimated to be $25,000 per river mile per foot of degradation[2]. The economic model applies a total cost of $695,000 (FY17 dollars) for each two-foot increment of bed degradation. For example at two-feet of degradation a cost of $695,000 is applied to modify

[2] Appendix H - Analysis of the Cost of Degradation of the Bed of the Missouri River to the Missouri River Bank Stabilization and Navigation Project (BSNP)

the structure. At four-feet of degradation a cost of $695,000 is applied to modify the structure and so on.

Side channel chutes have been constructed as a part of the Missouri River Recovery Program (MRRP) effort to restore Shallow Water Habitat (SWH) to avoid jeopardy of the endangered Pallid Sturgeon. Because these SWH chutes were built to target specific flow and depth criteria, river bed degradation has the potential to adversely affect the function of chutes in the vicinity of main channel degradation. For this analysis, all chutes within the Kansas City District above River Mile 290 are considered to be potentially impacted by bed degradation. This includes the following chutes:

- Dalbey Bottoms Chute C; RM 415.0-415.9;
- Dalbey Bottoms Chute B; RM 416.0-418.0;
- Dalbey Bottoms Chute A; RM 418.0-419.3;
- Benedictine Bottoms Independence Creek Chute; RM 424.1-424.6;
- Benedictine Bottoms Chute; RM 425.6-427.5; and
- Worthwine Island Chute; RM 456.9-458.9

If bed degradation, and a corresponding drop in water stage, occurs in the vicinity of the chutes, it will be necessary to lower the control structures in order to maintain the design flow relationships and biological access.

With a current thickness already at the minimum of five feet, the control structures in Worthwine Chute cannot be lowered without removing the existing rock and trenching in a new control structure at the proper elevation and updated dimensions, including greater thickness of ten feet and greater length parallel to flow of 60 feet. However, the control structures in the other chutes could be lowered up to five feet before reaching the minimum thickness and needing to be replaced.

If bed degradation in the main channel of the river results in a corresponding drop of the water surface in the chutes, the flow control structures for the six chutes located in the area of degradation concern would need to be modified to maintain the designed function of the chutes. Likely trigger points for modification of control structures would occur when the degradation near the chute reaches three feet and again at six feet. At each of the two trigger points, the control structures in each of the five affected chutes would need to undergo either modification of the structure elevation or an entire rebuild of the structure.

Costs per chute for elevation modification at the three-foot trigger point range from approximately $29,000 to approximately $59,000, with the exception of the Worthwine Chute which requires more extensive modifications at a cost of $843,000. Costs per chute for full rebuild of the control structure at the six-foot trigger point range from approximately $325,000 to approximately $650,000, with the exception of the Worthwine Chute which requires less extensive modifications at a cost of $88,000. Detailed information regarding costs is located in Appendix K-Analysis of Costs of Degradation to Shallow Water Habitat.

Tributaries were identified along the Missouri River in the Degradation Study Reach, River Mile 293-498 using aerial photography. Elevation data from representative cross-sections of the tributaries were extracted from 10-meter LiDAR data collected in 2013. This analysis only includes structures to protect against future degradation, not current headcuts which may have been induced by past Missouri River degradation. Construction of a grade control structure is only included for tributaries with associated Missouri River degradation projected to be two feet or more from 2015 to 2065. At two-feet of degradation costs for grade control structure construction range from a low of $42,000 to a high of $462,000. At four feet of degradation a new grade control structure would be combined with bank protection. The costs at four feet of degradation range from $480,000 to $2,100,000. Detailed information regarding costs is located in Appendix L-Cost Estimate to Construct Rock Grade Control Structures on Tributaries.

5 Avoided Costs

The Principles and Guidelines[3] identifies the Federal objective of water and related land resources planning as the contribution to national economic development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are defined as "increases in the net value of the national output of goods and services, expressed in monetary units"[4]. Increases in net value can occur when a project increases output values greater than input costs, or alternatively, increases in net value can occur when a project reduces input costs while maintaining output values.

The major outputs of concern, related to Missouri River bed degradation, include power generation, municipal and industrial water supply, highway transportation, flood damage risk reduction, bank stabilization, and navigation. The future provision of these outputs will not be reduced by projected future bed degradation because of the national and local importance of these fundamental outputs. The 2.4 million people residing within the Kansas City Metropolitan Statistical Area[5] will continue to receive power, water, transportation, and flood damage risk reduction services regardless of bed degradation because there exist specific entities which were chartered to provide these specific services, such as utility companies, levee districts, and state departments of transportation. Additionally, USACE is mandated by Congress to maintain the authorized project purposes of the BSNP and to maintain habitat for the Pallid Sturgeon.

---

[3] Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, U.S. Water Resources Council, March 10, 1983.
[4] Ibid., Chapter 1, Section II (b).
[5] https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk accessed 13Mar17

Although projected future bed degradation will not affect the provision of these fundamental outputs, the costs of providing these outputs will be substantially affected by projected future bed degradation. Alternative plans, which reduce the future cost of providing these outputs, would contribute to NED by increasing the net value of these outputs. The future costs avoided by alternative plans are the NED benefits of those plans. These avoided costs will be compared to plan implementation costs in the evaluation of alternative plans. Note that not all of the projected future costs due to bed degradation presented in Table 3 above will necessarily be avoided by alternative plans

5.1 Projected Future Costs under Without-Project Conditions

Under without-project conditions, the base-case bed degradation model indicates that federal costs to maintain the BSNP and fish and wildlife habitat will increase by $82.9 million dollars in present value over the 50-year planning time period. The costs to municipal water and electric utilities will increase by $34.6 million in present value and the cost to maintain tributary structures will increase by $21.4 million in present value over the 50-year planning time period. In total, over the 50-year planning time period, the present value of additional costs due to bed degradation are estimated to be $139 million, with an average annual cost of $5.3 million (evaluated using the FY17-discount rate of 2.875%).

Table 4: Projected future costs to existing infrastructure that may occur over the next 50 years if bed degradation is allowed to continue. Values were calculated over 50 years using the FY17 2.875% discount rate.

	Present Value	**Average Annual Value**
Federal Projects		
BSNP	$82,200,000	$3,120,000
Fish and Wildlife Habitat	$760,000	$30,000
Subtotal	**$82,960,000**	**$3,150,000**
Non-Federal		
Utilities	$34,580,000	$1,310,000
Tributaries	$21,400,000	$810,000
Subtotal	**$55,980,000**	**$2,120,000**
Total	**$138,940,000**	**$5,270,000**

Reducing or avoiding these projected future costs would contribute to NED. The future costs avoided by alternative plans are the NED benefits of those plans. These avoided costs will be compared to plan implementation costs in the evaluation of alternative plans.

6 Economic Evaluation of Alternatives

The primary economic criterion for the evaluation of alternatives is the net benefit of the alternative. The net benefit is calculated as the difference between the damages avoided by the alternative and the cost of implementing the alternative. The damages avoided are the avoided future costs of providing future power generation, municipal and industrial water supply, highway transportation, flood damage risk reduction, bank stabilization, navigation, and Pallid Sturgeon habitat.

Alternative 1A is the without-project condition, which includes the continuation of permitted levels of dredging and no actions taken to reduce bed degradation. Alternative 1B includes no structural action but reduces commercial sand and gravel dredging in the St. Joseph, Kansas City, and Waverly reaches of the river. Alternative 1C includes no structural action but eliminates commercial sand and gravel dredging from the St. Joseph, Kansas City, and Waverly reaches of the river. The economic evaluation of alternatives shows that the project with the greatest net benefits is Alternative 1C. Alternative 1B provides a very similar level of net benefits to Alternative 1C.

There are two different structural alternatives that were evaluated in combination with reduced and eliminated dredging. Alternative 4 incorporates BSNP modifications and Alternative 5 proposes building a series of grade control structures. Alternative 4A (continuation of permitted dredging levels) does not provide positive net benefits, alternative 4B (reducing dredging) and 4C (eliminating dredging) (from the St. Joseph, Kansas City, and Waverly reaches) provide only nominal positive net benefits compared to the non-structural alternatives. Residual damages under Alternative 4A are greater than the without-project condition damages because this alternative shifts the degradation toward reaches of the river where higher value impacts occur. None of the alternatives evaluated under Alternative 5 provide positive net benefits. Implementing a reduction or elimination of commercial dredging from the focused study area is not within the Section 216 authority. As there is no alternative with positive net benefits at the permitted level of dredging, the economic evaluation indicates that there is no Federal interest in a structural solution to the problem.

Tables 5 through 7 present the results of the base case economic evaluation. Tables 8 through 13 present the results of the Less Degradation and More Degradation sensitivity analyses. Note that values in the tables have been influenced by rounding and may not sum exactly for all entries.

Table 5: Base Case Alternative 1: No Structural Action

All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 1A: 2015 Permitted Dredging	Alt 1B: Reduced Dredging	Alt 1C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$5,270,000	$2,200,000	$2,170,000
Damages Avoided (Benefits)	$0	$3,080,000	$3,100,000
Alternative Implementation Cost	$0	$0	$0
Net Benefits		$3,080,000	$3,100,000

Table 6: Base Case Alternative 4: BSNP Modifications
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 4A: 2015 Permitted Dredging	Alt 4B: Reduced Dredging	Alt 4C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$5,420,000	$2,360,000	$2,310,000
Damages Avoided (Benefits)	($150,000)	$2,920,000	$2,960,000
Alternative Implementation Cost	$2,840,000	$2,840,000	$2,840,000
Benefit/Cost Ratio	-0.1	1.0	1.0
Net Benefits	($2,990,000)	$80,000	$120,000

Table 7: Base Case Alternative 5: Grade Control Structures
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 5A: 2015 Permitted Dredging	Alt 5B: Reduced Dredging	Alt 5C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$2,140,000	$880,000	$840,000
Damages Avoided (Benefits)	$3,130,000	$4,400,000	$4,430,000
Alternative Implementation Cost	$12,780,000	$11,750,000	$11,750,000
Benefit/Cost Ratio	0.2	0.4	0.4
Net Benefits	($9,650,000)	($7,350,000)	($7,320,000)

The economic evaluation of alternatives was conducted for the base case, i.e., the most likely future scenario, and for two alternative scenarios as sensitivity analyses: more degradation and less degradation than projected for the base case. As with the base case, there is no alternative with positive net benefits at the permitted level of dredging, therefore even under the sensitivity analysis scenarios, the economic evaluation does not support Federal interest in a structural solution to the problem. In the less degradation scenario none of the structural alternatives provide positive net benefits. In the more degradation scenario, none of the structural scenarios provide more net benefits than the non-structural alternative with reduced or eliminated commercial sand and gravel dredging.

Table 8: Less Degradation Scenario Alternative 1: No Structural Action
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 1A: 2015 Permitted Dredging	Alt 1B: Reduced Dredging	Alt 1C: Eliminated Dredging
FWOP Damages	$3,100,000	$3,100,000	$3,100,000
Residual Damages	$3,100,000	$1,660,000	$1,660,000
Damages Avoided (Benefits)	$0	$1,450,000	$1,450,000
Alternative Implementation Cost	$0	$0	$0
Net Benefits		$1,450,000	$1,450,000

Table 9: Less Degradation Scenario Alternative 4: BSNP Modifications
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 4A: 2015 Permitted Dredging	Alt 4B: Reduced Dredging	Alt 4C: Eliminated Dredging
FWOP Damages	$3,100,000	$3,100,000	$3,100,000
Residual Damages	$3,180,000*	$1,880,000	$1,880,000
Damages Avoided (Benefits)	($80,000)	$1,220,000	$1,220,000
Alternative Implementation Cost	$2,840,000	$2,840,000	$2,840,000
Benefit/Cost Ratio	0.0	0.4	0.4
Net Benefits	($2,920,000)	($1,620,000)	($1,620,000)

*Under Alternative 4A, the damages avoided (benefits) are negative because this alternative shifts the degradation toward reaches of the river where higher value impacts occur.

Table 10: Less Degradation Scenario Alternative 5: Grade Control Structures
All values are in FY17 dollars discounted over 50 years at the FY17 discount rate (2.875%)

Average Annual Economic Results	Alt 5A: 2015 Permitted Dredging	Alt 5B: Reduced Dredging	Alt 5C: Eliminated Dredging
FWOP Damages	$3,100,000	$3,100,000	$3,100,000
Residual Damages	$1,070,000	$410,000	$410,000
Damages Avoided (Benefits)	$2,040,000	$2,690,000	$2,690,000
Alternative Implementation Cost	$12,780,000	$11,750,000	$11,750,000
Benefit/Cost Ratio	0.2	0.2	0.2
Net Benefits	($10,740,000)	($9,060,000)	($9,060,000)

In the less degradation scenarios, the results displayed in Tables 8 - 10 show that none of the structural alternatives (BSNP modifications and grade control) provide positive net benefits. This includes alternatives B and C, which reduce or eliminate commercial sand and gravel dredging in the St. Joseph, Kansas City, and Waverly reaches.

Table 11: More Degradation Scenario Alternative 1: No Structural Action
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 1A: 2015 Permitted Dredging	Alt 1B: Reduced Dredging	Alt 1C: Eliminated Dredging
FWOP Damages	$7,750,000	$7,750,000	$7,750,000
Residual Damages	$7,750,000	$2,920,000	$2,960,000
Damages Avoided (Benefits)	$0	$4,840,000	$4,800,000
Alternative Implementation Cost	$0	$0	$0
Net Benefits		$4,840,000	$4,800,000

Table 12: More Degradation Scenario Alternative 4: BSNP Modifications
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 4A: 2015 Permitted Dredging	Alt 4B: Reduced Dredging	Alt 4C: Eliminated Dredging
FWOP Damages	$7,750,000	$7,750,000	$7,750,000
Residual Damages	$9,350,000*	$3,370,000	$3,350,000
Damages Avoided (Benefits)	($1,600,000)	$4,380,000	$4,410,000
Alternative Implementation Cost	$2,840,000	$2,840,000	$2,840,000
Benefit/Cost Ratio	-0.6	1.5	1.6
Net Benefits	($4,440,000)	$1,540,000	$1,570,000

*Under Alternative 4A, the damages avoided (benefits) are negative because this alternative shifts the degradation toward reaches of the river where higher value impacts occur.

Table 13: More Degradation Scenario Alternative 5: Grade Control Structures
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 5A: 2015 Permitted Dredging	Alt 5B: Reduced Dredging	Alt 5C: Eliminated Dredging
FWOP Damages	$7,750,000	$7,750,000	$7,750,000
Residual Damages	$6,090,000	$1,800,000	$1,790,000
Damages Avoided (Benefits)	$1,670,000	$5,950,000	$5,960,000
Alternative Implementation Cost	$12,780,000	$11,750,000	$11,750,000
Benefit/Cost Ratio	0.1	0.5	0.5
Net Benefits	($11,110,000)	($5,800,000)	($5,790,000)

In the more degradation scenarios, the results displayed in Tables 11 – 13 show that none of the structural alternatives provide more positive net benefits than the non-structural alternative (Alternative 1), which reduces or eliminates the extraction of commercial sand and gravel from the St. Joseph, Kansas City, and Waverly reaches. Non-structural alternatives 1B (reduced dredging) and 1C (eliminated dredging) have net benefits of $4,840,000 and $4,800,000 respectively. Alternative 4B (BSNP modification with reduced dredging) and Alternative 4C (BSNP modifications with eliminated dredging) have net benefits of $1,540,000 and $1,570,000 respectively.

7 Regional Economic Development

The RED account registers changes in the distribution of regional economic activity that results from each alternative plan. Regional income and regional employment are the metrics that typically constitute the RED account. The RED analysis focuses on the local impact of reducing or eliminating commercial dredging from the St. Joseph and/or Kansas City reach of the Missouri River (dredging is permitted between river miles 498 and 250). Note that the primary economic evaluation criterion is (changes to NED) based on a national perspective without differentiation of which sector of the economy or which region of the country benefits from the alternative. The RED analysis, on the other hand, is necessarily a local analysis of shifts in employment and income.

In addition to an evaluation of the completeness, effectiveness and efficiency of the alternatives plans, evaluations of potential impacts to RED were conducted to help determine acceptability. Because the study did not recommend an alternative plan for implementation under the Section 216 study authority, these items were not evaluated to the level of detail that is typical for a feasibility study. Only a cursory RED analysis was performed for this study.

For alternatives with reduced and eliminated commercial dredging on the river, it is assumed that the reduction in the quantity of material dredged from the river would be replaced with an equivalent quality and quantity of material from a floodplain pit mine. Investigation into pit mine operation indicate that material excavated from a local floodplain pit mine is tested in accordance with industry standards as is material mined from the river. Materials from both sources meet the industry standard for common applications such as concrete and asphalt production. Numerous floodplain pit mines currently operate in the area and the undelivered price of material is similar from floodplain and river sources.

Publicly available information regarding detailed industry operation information as well as information regarding distances from pit mine and dredged material stockpiles were used in this evaluation. Information about pricing for sand and gravel from floodplain pit mines and sand and gravel mining on the river was gathered from regional price quotes. No new direct operational information from industry operators providing commercially available sand and gravel was obtained.

There are numerous concrete and asphalt plants located throughout the Kansas City metropolitan area. Material is trucked from stockpiles near the material source to the various concrete and asphalt production facilities. The specific location(s) where sand and gravel would be stockpiled from either in-river operations or open pit operations is unknown, but is assumed to be within the Kansas City metropolitan area. Likewise, the exact locations of various users are also unknown but are also assumed to be within the Kansas City metropolitan area. Regardless of where the stockpiles are located, they are likely to be closer to some users and further away from other users. Therefore, given the impossibility of projecting exact future locations, it can reasonably be assumed that there is no appreciable overall change in total distance traveled to deliver sand and gravel from either floodplain or river sources.

Changes in employment resulting from replacing river dredging operations to pit mining operations are projected to be marginal. Both operations require skilled machinery operators, although different skills would be required for the different operations. For example, dredge operators would be replaced by earth moving equipment operators. The number of employees for each operation is relatively small. A dredge, for example, may have a crew of 8 to 12 workers, and typically only a single dredge is working on the river in the Kansas City reach at a time. Although through the full modeled reach from St. Joseph to Waverly, there may be up to three dredges active at a given time.

Overall, the RED effects of reducing or eliminating commercial dredging from this reach of the Missouri River would be marginal and any employment and income losses would be largely offset by employment and income gains to pit mining operations.

RED impacts that would include a boost to the local economy based on project implementation (construction of a new project) was not considered since there was not a structural plan recommended.

8 Sensitivity Analysis: Advanced Capital Costs

For the base-case economic scenario, the entire infrastructure repair or reconstruction cost is entered into the model in the year that the critical bed elevation is achieved. However, municipalities and utilities are averse to risks, which may impact the provision of fundamental services such as water and power. Responses to perceived future bed degradation would likely be proactive so that service provision continues with minimal disruption. It would likely be years between planning, construction, and operation of a large, capital intensive response to bed degradation, such as development of an alternative water source or switching to a recirculating cooling system. It would not be unreasonable to assume that a facility operator may begin the planning process three to five years prior to the critical level of bed degradation being achieved. This assumption has been confirmed in interviews. Incorporating this long lead time into the planning process, the facility operator can ensure that the new structure will be in operation prior to the failure of the existing structure. A sensitivity analysis (Tables 14-16) was performed in which the economic model was adjusted to account for a three year lead time. In the sensitivity analysis the capital costs are incurred three years prior to the year that the critical bed elevation is achieved.

Table 14: Sensitivity: Capital Expenditures 3 Years in Advance
Alternative 1: No Structural Action
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 1A: 2015 Permitted Dredging	Alt 1B: Reduced Dredging	Alt 1C: Eliminated Dredging
FWOP Damages	$5,830,000	$5,830,000	$5,830,000
Residual Damages	$5,830,000	$2,390,000	$2,370,000
Damages Avoided (Benefits)	$0	$3,440,000	$3,460,000
Alternative Implementation Cost	$0	$0	$0
Net Benefits		$3,440,000	$3,460,000

Table 15: Sensitivity: Capital Expenditures 3 Years in Advance
Alternative 4: BSNP Modifications
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 4A: 2015 Permitted Dredging	Alt 4B: Reduced Dredging	Alt 4C: Eliminated Dredging
FWOP Damages	$5,830,000	$5,830,000	$5,830,000
Residual Damages	$5,990,000*	$2,560,000	$2,520,000
Damages Avoided (Benefits)	($170,000)	$3,260,000	$3,310,000
Alternative Implementation Cost	$2,840,000	$2,840,000	$2,840,000
Benefit/Cost Ratio	-0.1	1.1	1.2
Net Benefits	($3,010,000)	$420,000	$470,000

*Under Alternative 4A, the damages avoided (benefits) are negative because this alternative shifts the degradation toward reaches of the river where higher value impacts occur.

Table 16: Sensitivity: Capital Expenditures 3 Years in Advance
Alternative 5: Grade Control Structures
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 5A: 2015 Permitted Dredging	Alt 5B: Reduced Dredging	Alt 5C: Eliminated Dredging
FWOP Damages	$5,830,000	$5,830,000	$5,830,000
Residual Damages	$2,330,000	$950,000	$920,000
Damages Avoided (Benefits)	$3,500,000	$4,870,000	$4,910,000
Alternative Implementation Cost	$12,780,000	$11,750,000	$11,750,000
Benefit/Cost Ratio	0.3	0.4	0.4
Net Benefits	($9,280,000)	($6,880,000)	($6,840,000)

The sensitivity analysis increases the without project condition damages and increases net benefits of all alternatives (Table 17). However, including lead time into the model does not alter the overall efficiency or inefficiency of any of the alternatives. Increasing the lead time to five years prior to achieving the critical elevation continues the pattern of increasing damages.

Table 17: Comparison of Advanced Expenditure Sensitivity Net Benefits
to Base Case Net Benefits

Alternative	Base Case	3-Year Advance Expenditure
1A	$0	$0
1B	$3,080,000	$3,440,000
1C	$3,100,000	$3,460,000
4A	($2,990,000)	($3,010,000)
4B	$80,000	$420,000
4C	$120,000	$470,000
5A	($9,650,000)	($9,280,000)
5B	($7,350,000)	($6,880,000)
5C	($7,320,000)	($6,840,000)

9 Sensitivity Analysis: Land-Based Production Costs

As a sensitivity analysis, an NED economic evaluation using the base case level of degradation was conducted that includes assumptions concerning the costs of switching from a river dredging operation to a pit-mining operation.

For reduced commercial dredging alternatives it was assumed that 100 acres of land needs to be purchased for one floodplain pit mine in St. Joseph. Cost assumptions include:

- Land value is estimated at $15,000/acre;
- $3,000,000 will be needed for permitting (EIS document); and
- $500,000 for reclamation of the land.

For eliminated commercial dredging alternatives it was assumed that 400 acres of land needs to be purchased for four (4) floodplain pit mines, one would open in the St. Joseph area, two floodplain pit mines that would open in the Kansas City area and one floodplain pit mine that would open in the Waverly area. Cost assumptions include:

- Land value is estimated at $15,000/acre;
- $3,000,000 for permitting each site (EIS document); and
- $500,000 for reclamation of the land at each site.

Note that values in the tables have been influenced by rounding and may not sum exactly for all entries

Table 18: Pit Mine Costs Sensitivity Analysis Alternative 1: No Structural Action
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 1A: 2015 Permitted Dredging	Alt 1B: Reduced Dredging	Alt 1C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$5,270,000	$2,200,000	$2,170,000
Damages Avoided (Benefits)	$0	$3,080,000	$3,100,000
Alternative Implementation Cost	$0	$190,000	$760,000
Net Benefits		$2,890,000	$2,340,000

Table 19: Pit Mine Costs Sensitivity Analysis Alternative 4: BSNP Modifications
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 4A: 2015 Permitted Dredging	Alt 4B: Reduced Dredging	Alt 4C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$5,420,000*	$2,360,000	$2,310,000
Damages Avoided (Benefits)	($150,000)	$2,920,000	$2,960,000
Alternative Implementation Cost	$2,840,000	$3,030,000	$3,600,000
Benefit/Cost Ratio	-0.1	1.0	0.8
Net Benefits	($2,990,000)	($110,000)	($640,000)

*Under Alternative 4A, the damages avoided (benefits) are negative because this alternative shifts the degradation toward reaches of the river where higher value impacts occur.

Table 20: Pit Mine Costs Sensitivity Analysis Alternative 5: Grade Control Structures
All values are average annual values in FY17 dollars amortized over 50 years at the FY17-discount rate (2.875%)

Average Annual Economic Results	Alt 5A: 2015 Permitted Dredging	Alt 5B: Reduced Dredging	Alt 5C: Eliminated Dredging
FWOP Damages	$5,270,000	$5,270,000	$5,270,000
Residual Damages	$2,140,000	$880,000	$840,000
Damages Avoided (Benefits)	$3,130,000	$4,400,000	$4,430,000
Alternative Implementation Cost	$12,780,000	$11,940,000	$12,510,000
Benefit/Cost Ratio	0.2	0.4	0.4
Net Benefits	($9,650,000)	($7,540,000)	($8,080,000)