Appendix J

Structural Analysis of Independent Structures

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Appendix A – Chapter 3

Structural Analysis of Independent Structures

A structural examination of bridges, water intakes, Federal and Non-federal Floodwalls, Gatewells, Pumping Plant and Closure Structures within Flood Control Systems, and Outlet Pipes and Structures

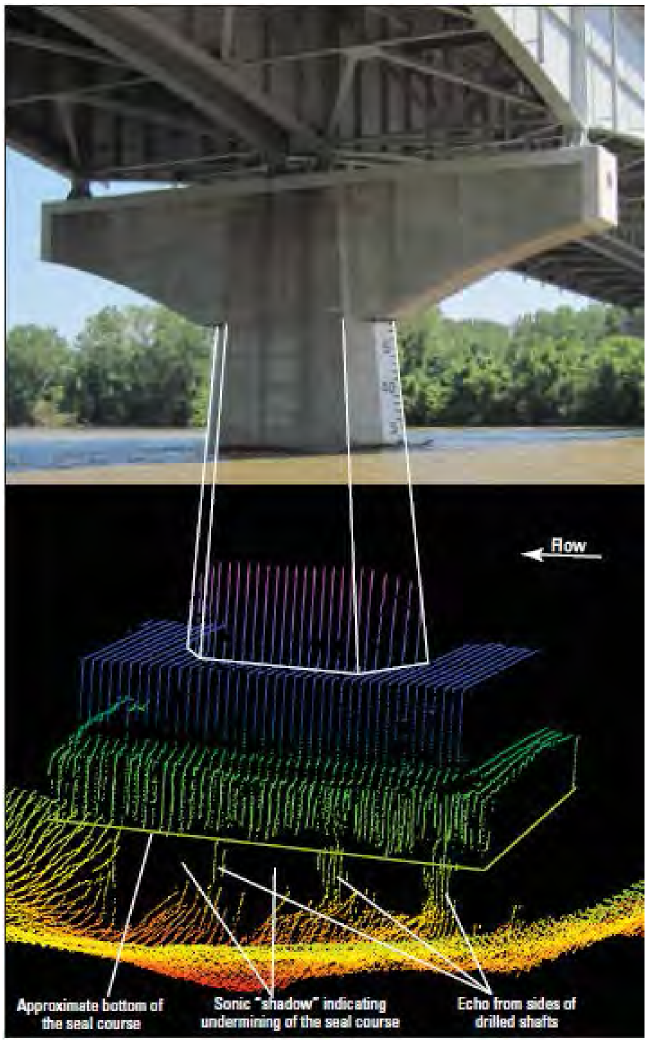

Illustration of existing bridge pier scour and bed degradation. This was taken from 2011 USGS bathymetric survey.

November 06, 2013
U.S. Army Corps of Engineers
Kansas City District

Design Branch
Structural Engineering Section

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3. Structural Analysis of Independent Structures

For the Missouri River Degradation Feasibility Study, the structural design section has been tasked with examining the impacts of river degradation on the structural infrastructure along the Missouri River between Rulo, Nebraska and the mouth of the Missouri River. The structural design section has been asked to provide reliability assessments, as well as critical levels of degradation that could trigger the owners to spend money beyond the general operations and maintenance that would be expected with no degradation. These costs would include repairs or structure replacement due to degradation.

In addition to the Missouri River, the study also includes the tributaries to the Missouri River in the study reach. It is expected that degradation of the Missouri River bed elevation will cause corresponding head cutting on the tributaries to the river. This tributary bed lowering will move upstream along the tributaries at varying rates based on the amount of main stem degradation, tributary bed material properties and the flow in each tributary. The river hydraulics section is working to better estimate the existing and anticipated tributary head cutting for individual tributaries; however, based on existing research, the initial estimate that was used by the structural design section was a maximum upstream impact on any tributary would be four miles upstream along the tributary bed length. These potential impacts would include damage and increased maintenance needs on structures along the tributaries.

3.1 Assumptions and Identified Risks

The structural analysis associated with this feasibility study has required many assumptions. Many of the individual assumptions are discussed in the following sections of this chapter. In order to meet the SMART Planning intent and guidelines, engineering analysis is limited during the feasibility phase of a project to those tasks absolutely necessary to reach the desired goal of a selected alternative.

The scope of the project does not include advanced engineering analysis or site investigation of river conditions or structural strength or stability of the structures discussed in the following sections of this chapter. Existing available information about the current condition of infrastructure and the Missouri River and its tributaries was relied upon to establish a baseline existing condition. This required flexibility in setting varying beginning dates for existing conditions, which the hydraulic sediment transport model was able to support. Basic, conservative assumptions were made regarding the structural stability and strength of the infrastructure that was investigated. Without individual detailed structural analysis, critical elevations with regard to degradation were established primarily relying on geometry and existing information provided by the infrastructure owners.

The scope of which structures were analyzed was also limited based on a limited scope, budget and schedule according to the engineering judgment of which structures would most likely be impacted by degradation and by which structures, if impacted, would have the most monetary impact on the study. It was established early in the study that the structural analysis of existing infrastructure would be used exclusively for the determination of avoided future maintenance, repair and replacement costs which would ultimately be used as potential benefits when evaluating alternatives. The results of the limited structural investigation and analysis are not meant to be definitive statements about the exact elevation at which any individual structure will require repair or fail. Instead the estimates can assist in establishing how much benefit a potential alternative might have in avoiding future maintenance, repair or replacement costs to infrastructure that would have otherwise been required exclusively to Missouri River bed degradation.

The assumptions that are outlined above and in the remainder of this chapter carry with them some inherent risks and uncertainties. The project development team (PDT) has worked diligently to identify, document and communicate the major risks that the assumptions carry as the project has moved forward. A risk register was created and has been updated throughout the process that summarizes the major risks that the PDT has identified.

The major risks that come with the assumptions that were made during the structural analysis of the infrastructure are the risks that the avoided future costs/potential benefits are either overestimated or underestimated because of the limited scope and detail of the investigation and analysis performed for each individual piece and category of infrastructure. Without expensive and extensive individual analysis it is impossible to pinpoint a critical elevation at which a structure will fail due to degradation. Conservative assumptions that were made regarding critical elevations, could ultimately lead to a high estimate of potential benefits of reducing future degradation.

Little information is known about the existing condition of many of the structures on the tributaries. Almost no information is available on the current condition or geological makeup of nearly all of these individual tributaries. This made establishing an existing condition very difficult and establishing probable future condition of these tributaries almost impossible. Because of this, it was decided that the impacts to the tributaries would be identified qualitatively, rather than quantitatively. This carries a large risk of underestimating the potential benefits that these structures could provide in the evaluation of an alternative that prevents future impacts on the tributaries that would have otherwise occurred as a result of continued bed degradation of the Missouri River.

3.2 PED Considerations

Considerations should be made during any future PED phase of this project as to the limited scope and accuracy of the investigation and results presented during the feasibility phase of this project. Repairing individual structures at a certain degradation level was not considered as a possible measure to be included in the selected alternative. Instead the scope of the structural analysis was only to assist in identifying potential benefits that might result from an alternative that is implemented to reduce river bed degradation.

3.3 Design Criteria

No specific design criteria were available in analyzing structures for river degradation. The independent structures that were analyzed as a part of this study were not analyzed as possible measures to be included in a selected alternative, but only as a means of estimating potential benefits that might be gained by implementing a selected alternative.

Engineering judgment based on available information, experience and multiple conversations with the owners of many of the structures was used to establish the process used to identify critical degradation elevations for each piece and type of structure.

3.4 Existing Conditions of Independent Structures

The first step in this structural investigation was to identify all structures that might be impacted by degradation of the bed of the Missouri River and to establish existing baseline conditions for these identified structures so that future with and without project conditions could be compared to this baseline condition.

3.4.1 Bridges

3.4.1.1 General

Roadway, railroad and pedestrian bridges that cross a river or stream can be greatly impacted by changing riverbed elevations, depending on their designs. The design and construction of bridges vary greatly depending on the era of construction, length of spans and location of bedrock beneath the riverbed. The main impact of river degradation on bridge structures is the effect of the lowering bed elevation on any intermediate piers located in the main river channel. A few intermediate piers on some tributaries may be founded on shallow foundations. If this is the case, a lowering of the river bed would result in bearing failure once the bed elevation drops enough to allow material to escape from beneath the pier footing.

Most intermediate piers are founded on deep foundations, deriving their bearing capacity from either skin friction between piles or drilled shafts and soil or end bearing on rock. Both general types of foundations can be compromised by degradation of the river bed. With lowering bed elevations, friction type foundations can lose friction interaction with the soil near the top of the foundation, leading directly to reduced bearing capacity of the pier. Additionally, both friction type and end bearing type piers can be impacted by lowering bed elevations with the exposure of drilled shafts and piles that support a footing below the main bridge pier. As the bed elevation decreases, the footing is exposed, followed by the piles or shafts themselves. These piles and shafts were designed as braced members. As more of their length is exposed, their unbraced lengths are increased. At some point, the unbraced length becomes large enough that the members can buckle, if not properly braced.

A secondary impact of river degradation on bridge structures can be the potential widening of the main channel. This could cause additional piers to be exposed to river flow that were not originally designed to be located in the main channel. These piers may be more susceptible to local scour leading to other issues similar to those described above relating to exposed deep foundation members. On smaller tributaries, the bridge abutments may be located inside, or within a few feet of, the existing main channel river bank. A deepening of these tributaries will lead to steepening of the existing river bank slopes and loss of river bank material that protects these abutments. These end spans may be founded on shallow or deep foundations. Both types of foundations would experience problems and failures similar to those described above for main channel piers.

Another factor with regard to piers in the river channel is localized pier and contraction scour. Some assumed or measured value of scour has to be added to the general river degradation amounts based on past performance of bridge piers in the river for accurate analysis of the structures. Where it has been made available, underwater inspection data or bathymetric survey data was used to determine these values. Where it is not available, engineering judgment will be used to take some scour depth into consideration. The actual depth of scour can change greatly from one time to another depending on varying river conditions.

To this point in the study, an accurate count of the bridges located in the reach from River Mile 329.0 to 453.7 has been obtained. 16 highway, 6 railroad bridges and 4 pedestrian bridges on the Missouri River and approximately 90 highway and 50 railroad bridges on the major tributaries within four tributary river miles of the main stem have been identified. These bridges and a quick reference of the information that is currently available to the PDT for each can be found in Table 2 below.

Due to the large study area and large number of structures included in this area, the PDT decided to focus on the areas that have exhibited the most degradation to date and those areas projected by preliminary runs of the sediment transport model to experience the most severe degradation during the project study duration. The study area was narrowed to the area from River Mile 352.7 to 453.7. This reduces the number of bridges to 16 highway and 5 railroad bridges on the Missouri River, and approximately 88 highway, 42 railroad bridges and 4 pedestrian bridges on the major tributaries within four tributary river miles of the main stem. The owners of all of these bridges on the Missouri River, all of the railroad bridges and nearly all of the highway bridges on the tributaries have been identified. Detailed information on most of the Missouri Department of Transportation (MoDOT) and Kansas Department of Transportation (KDOT) owned bridges of interest has been obtained. The Kansas Water Office (KWO) has provided information on the highway bridges on the Kansas tributaries. They were able to provide some detailed information on the Kansas Department of Transportation (KDOT) bridges, and some basic information on the county and city-owned structures. The PDT has been in contact with the Burlington Northern Santa Fe Railroad (BNSF) and the Union Pacific Railroad (UP) regarding their structures. A process has been established to securely review their bridge information and have requested bridge structure and condition information from them, as well. BNSF and UP have provided most of the requested information that is available to them on their structures.

Existing conditions of the Missouri River bed at most of the bridge locations have been established from several sources. These sources include average riverbed cross sections from 2007-2009 data provided by the River Hydraulics section (HR), two reports prepared by USGS, *Bathymetric Surveys at Highway Bridges Crossing the Missouri River in Kansas City, Missouri, using a Multibeam Echo Sounder, 2010* and *Bathymetric and Velocimetric Surveys at Highway Bridges Crossing the Missouri River in Missouri during Summer Flooding, July-August 2011*, and data from various underwater inspections of the river piers of many of the Missouri River bridges. The dates of the underwater inspections vary based on the inspection schedule for the individual bridges.

Following the SMART Planning principles, only the information gathering and analysis necessary to make reasonable planning decisions will be executed. The PDT determined that at this time, the cost and time that it would take to gather the necessary information to perform even a cursory investigation of the tributary bridges is not justified for making the selection of a reasonable alternative. If necessary, as the study progresses, drawings, existing bridge and stream bed conditions, projections of head cut travel and other information would have to be gathered to make any determination on whether Missouri River bed degradation has impacted these structures or at what elevation the mainstem degradation would have an impact on their substructures.

“Critical elevations” of the substructures have been determined for each of the Missouri River structures, based on the available construction plans and input from the existing MoDOT scour action plans. No detailed analysis was performed on these structures, but the critical elevations for structures with no scour action plans were taken as the bottom of footings or seal courses, changes in the caisson dimensions or design river bed elevations on older straight vertical concrete caissons. These values are all conservative, and generally these structures are not expected to fail when the degradation and scour reaches these levels; however, a detailed individual substructure analysis would need to be done on each structure to determine more accurately what level of degradation would impact the stability of these structures. This analysis would include determining the controlling load cases on the substructure and analyzing the piers to find what unbraced length they can withstand. The complicated and varying structure types of several of the Missouri River bridges will make determining these loads a time-consuming process. The unknown material properties and reinforcing in some of the older structures will make analysis of those structures difficult, as well. For those structures for which MoDOT has already created a scour action plan, the elevation identified in that plan will trigger notification of their bridge office. These critical elevations are the elevations at which it is expected that repair costs will be incurred.

The PDT has had extended conversations with bridge engineers at MoDOT, BNSF and UP regarding their observations regarding scour, degradation and head cutting at their structures and their approaches to evaluation and remediation of at-risk structures. This information has been vital to using engineering judgment to determine reliability of the structures with relation to degradation as well as predicting possible future maintenance and repair methods and costs that might be required due to degradation of the Missouri River.

After reviewing the existing conditions data, there are no bridges that currently require enhanced maintenance or repairs due to bed degradation at the present time.

3.4.1.2 Critical Elevation Example

Below is a summary of information gathered and critical elevation determination for piers 5 and 6 of the Heart of America Bridge carrying Missouri Highway 9 over the Missouri River at river mile 365.5.

Initially, the pier type, geometry, bottom of cap and seal course elevations, and bottom of pile elevations were gathered from the as-built plans provided by MoDOT, as shown in Figure 1 and Figure 2 below.

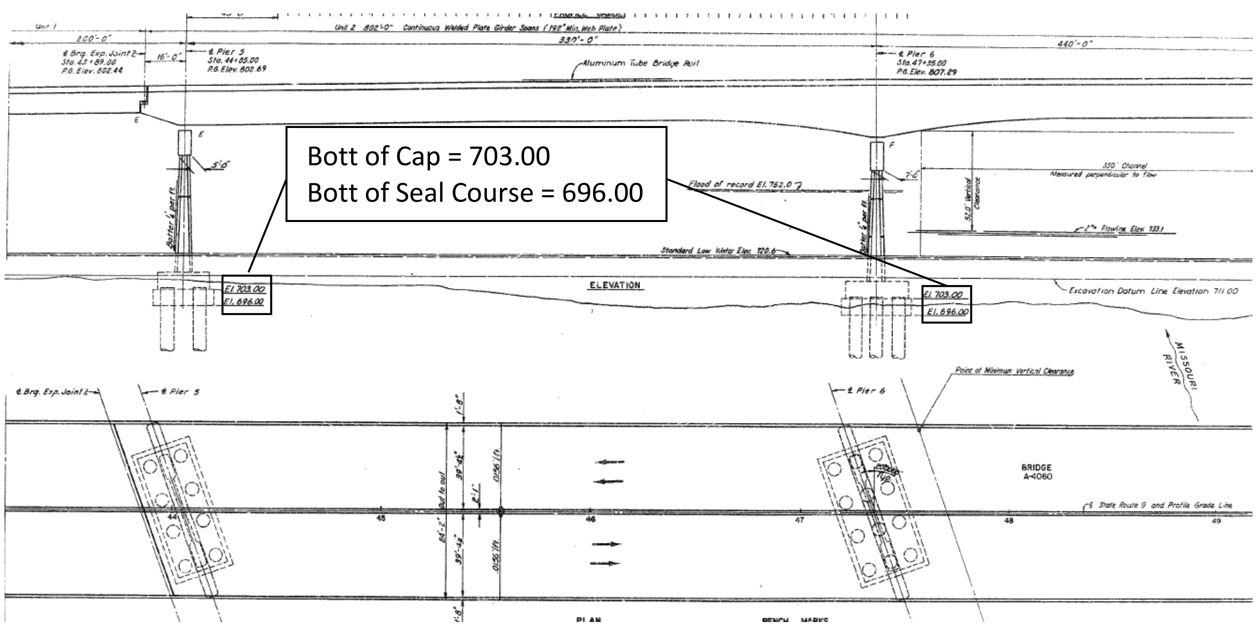

Figure 1 - As-Built Substructure Plans, MO Hwy 9 Bridge

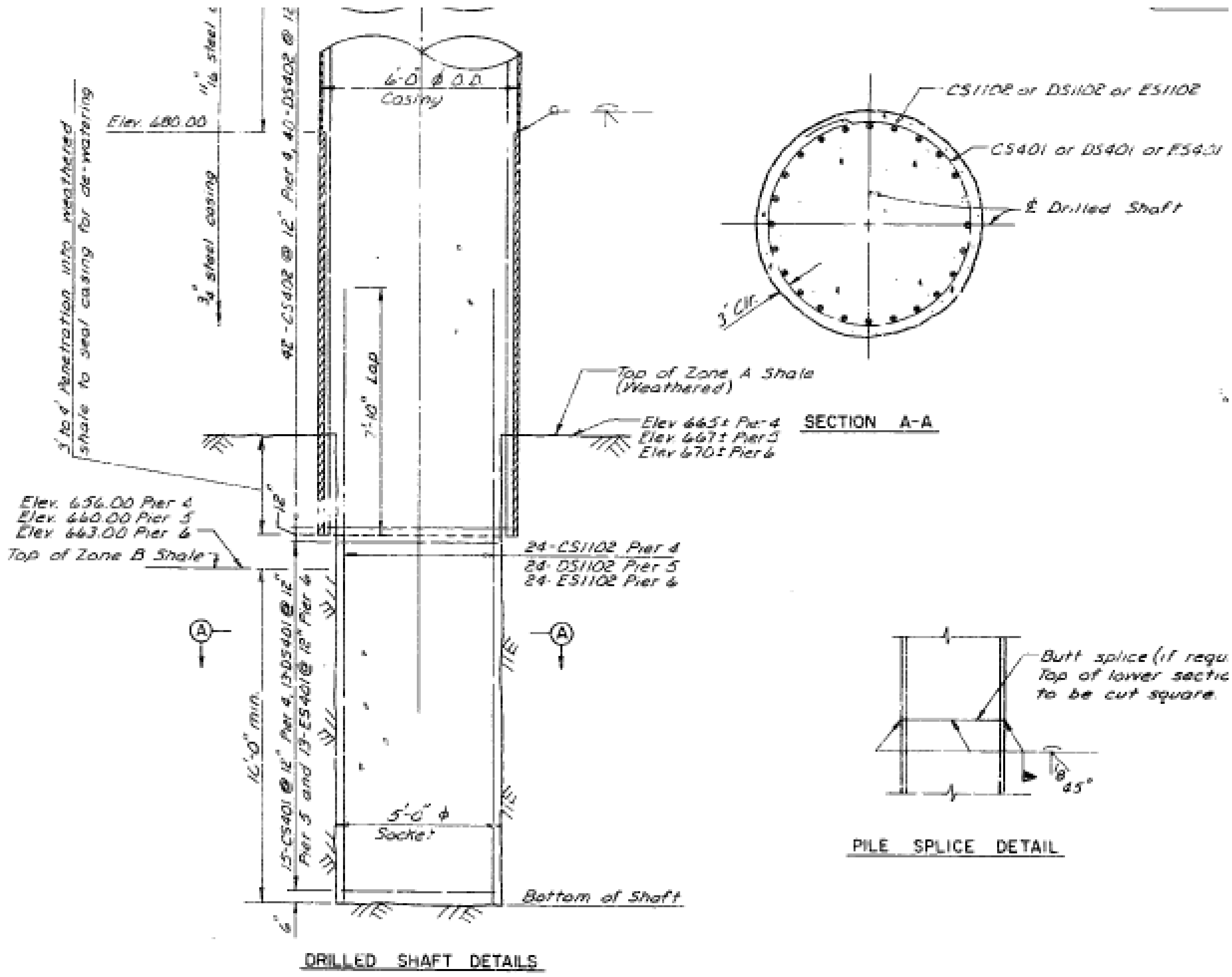

Figure 2 - Drilled Shaft Details, MO Hwy 9 Bridge

Next the “current” riverbed elevations at the piers were gathered from the latest underwater diving inspection, as shown in Figure 3, when available, and or the USGS Bathymetric Survey Report, as shown in Figure 4.

The bed width was estimated from river survey information provided by the River Hydraulics Section (ED-HR). The survey information was an average of surveys taken in 2007, 2008 and 2009.

The critical elevation for this bridge was based on information provided by MoDOT, as shown in Figure 5. However, when no such scour action plan was available from the owner, the elevation at the bottom of the seal course would have been selected, since no accurate calculations as to the acceptable exposed unbraced length of the drilled shafts was available, and these types of analysis are outside the scope of the feasibility report. Comparing the current river bed elevation to the critical bed elevation resulted in the critical change in elevation that will then be compared to the estimated change over the study period from the sediment transport model.

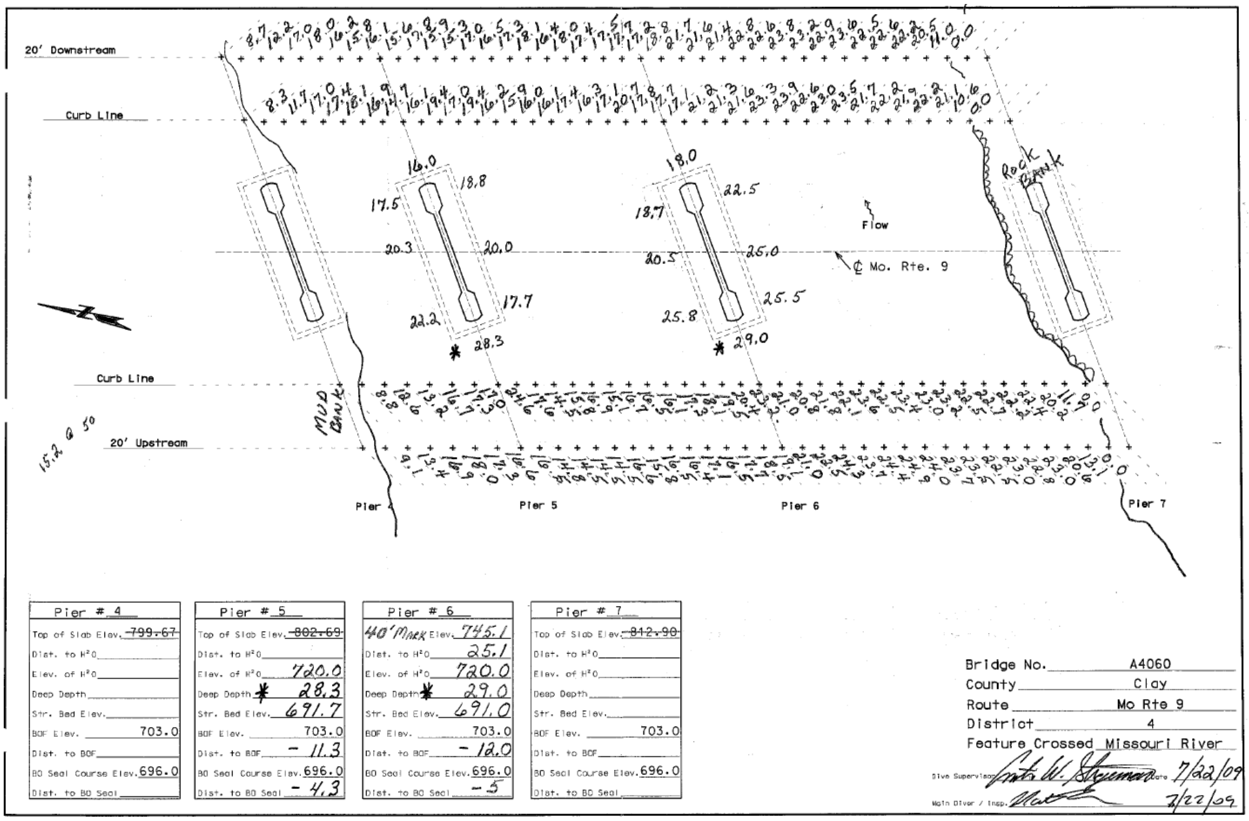

Figure 3 - 2009 Underwater Bridge Inspection Results, MO Hwy 9 Bridge

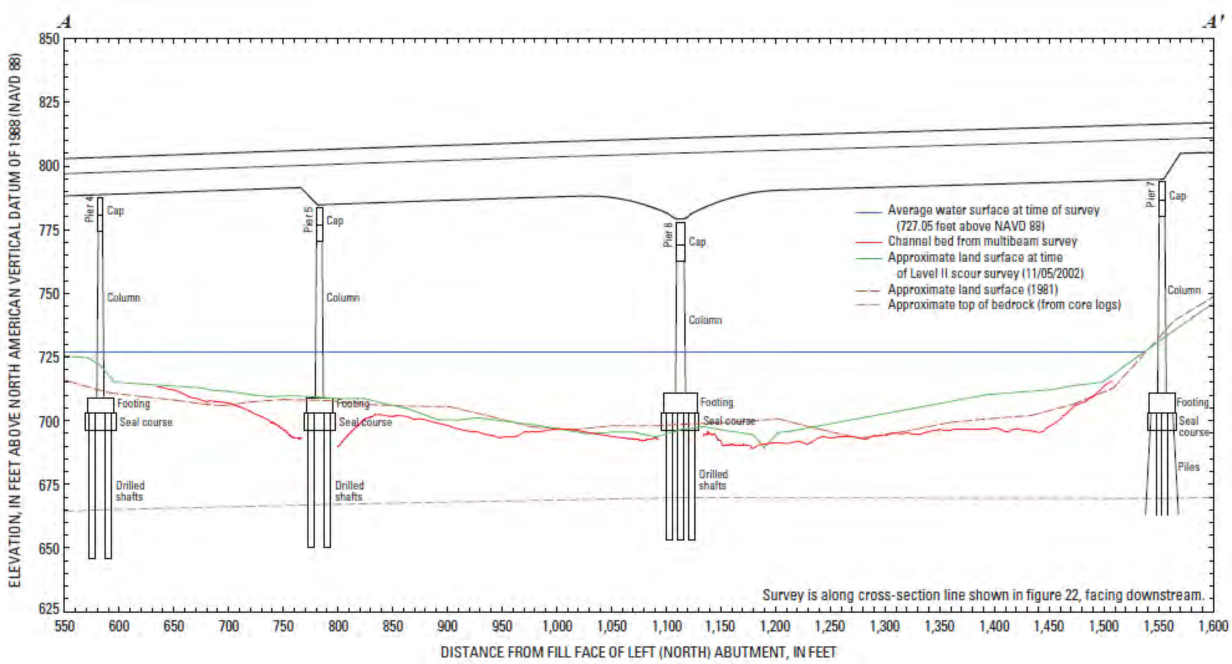

Figure 4 - USGS Batymetric Survey 2010, MO Hwy 9 Bridge

Local Name	Route	Comment	Foundation Type	Recommendations
Heart of America	MO 9	Seals Undermined	Pier no. 5, Concrete footing and seal course on 8- 6ft. diameter drilled shafts with 10 ft. deep rock sockets; Pier no. 6, Concrete footing and seal course on 12- 6 ft. diameter drilled shafts with 10 ft. deep rock sockets. 3-4 ft of weathered shale above rock socket.	No conclusive information for scour found in design computations. Based on engineering judgment, comfortable with scour up to 19 ft. below the seal course at pier no. 5 (Elev. 677.0) and 17 ft. below the seal course at pier no. 6 (Elev. 679.0). This equates to approximately 107 ft. and 99 ft. below the top of the beam cap, respectively. No gauge marks could be found on the plans for pier no. 5. At pier no. 6, this is approximately 66 ft. below the vertical clearance gage "40" mark. Once scour reaches this level contact Bridge Division. Contact HNTB to see if they can provide original design computations. If they cannot, recommend hiring a consultant to perform a structural analysis of the pier to determine the allowable scour depth and/or design countermeasures.

Figure 5 - MoDOT Scour Documentation for USACE NWK, MO Hwy 9 Bridge

3.4.2 Water Intake Structures

Although, water intakes are considered dependent infrastructure, the actual structure and foundation of these intakes are also independent infrastructure. These structures can fail if the normal water level drops below the minimum acceptable elevation, but they can also fail if the structure itself becomes unstable. The foundations for these structures will be similar to bridge foundations, either shallow spread footings or deep foundations bearing in soil or on rock. At some level of degradation, these structures would become structurally unstable and fail. Water One has gathered some limited information on the water intake structures located in the Kansas City Reach. The screening process for these was based on foundation type, similar to the process used for bridges.

During determination of degradation thresholds, it was determined that not much information was available on the structural support of these structures. Based on input from the intake owners and information that was provided to the team in a questionnaire that was filled out by the intake owners, it was also determined that the structures are most likely supported on deep foundations and are not overly susceptible to structural problems related to degradation. They are much more likely to be controlled by the water surface elevation limitations at low flows. Based on limited investigation and engineering judgment, the PDT determined that further structural analysis was not warranted on these structures for existing or future conditions.

3.4.3 Federal Floodwalls and Non-Federal Floodwalls

Typical critical sections of floodwalls for all sections of the Kansas Citys levees have been identified in previous projects. These sections have been used for categorization of the wall types for this study. It is assumed that there are no floodwalls outside the Kansas Citys levees, so non-federal floodwalls were not considered. There are 34 unique sections of wall. Floodwalls could be impacted by degradation if degradation leads to unstable channel banks and loss of foreshore material in front of the floodwalls. This loss of material could lead to floodwall instability and possible floodwall rotation. This failure mode was considered by the geotechnical team on this project. The loss of foreshore could also cause a shortened seepage path and elevated uplift pressures on structures that are not threatened by loss of stability. This could cause the structures to fail by trying to shift upward or rotate during large flood events.

Floodwalls were divided into structures that retain soil and those that do not. These two groups were further divided into types of wall construction. The major types are walls on deep pile foundations, T – walls on spread footings and I-walls. Degradation thresholds were examined for each of these types of foundations. With limited time and budget for analysis, these walls were assigned conservative thresholds based on geometry, observation and past calculations.

The 34 wall sections have been grouped into types and the critical section of each type of wall has been determined. Based on 2010 periodic inspections for all sections of the Kansas Citys levees, no significant river side foreshore loss has occurred near the floodwalls; therefore, all floodwall sections are considered reliable for existing conditions, with regard to degradation.

3.4.4 Gatewell, Pumping Plant and Closure Structures within Flood Control Systems

Gatewell closure structures and pumping plants located within flood control systems could be impacted by degradation due to foreshore loss along the river bank. The loss of foreshore could cause loss of stability and catastrophic failure as the foundation fails. The loss of foreshore could also cause a shortened seepage path and elevated uplift pressures on structures that are not threatened by loss of stability. This could cause the structures to fail by trying to shift upward and out of the ground during large flood events. Closure structures such as stoplog and sandbag gaps could experience reduced stability and possible failure due to foreshore loss, as well.

Due to the limited scope of structural investigations and analysis during this study, it is assumed that all gatewells, pumping plants and other closure structures in the levee units will remain viable unless the surrounding levee units are predicted to fail due to loss of stability. All or nearly all of these structures are located close to the centerline of the levee system of which they are a part. The chances of a structure failing due to loss of stability without the surrounding levee failing due to loss of stability are small. Although this is true, there remains a possibility that a structure could fail before the levee fails and allow a flood to breach the levee. Only more detailed information gathering and analysis of these structures would allow a more reliable estimation of these potential failures due to degradation.

3.4.5 Outlet Pipes and Outfall Structures

There are numerous interior drainage structures that have pipes and culverts that run through various flood controls systems and outlet to the Missouri River. These pipes and outlet structures will be some of the first structures impacted by river bed degradation due to their close proximity to the river banks. Bed degradation which could lead to loss of bank stability would leave these structures undermined and their foundations exposed. This would cause a loss of stability and possible failure of the structures. However, due to the limited scope of structural investigations and analysis and the relatively small cost of individual pipe and outlet structure replacements as well as the remaining high probability of the flood control system to remain intact through other means of closure, these structures will not be analyzed individually. The known structures will be assumed to fail due to loss of stability when the surrounding levee units are predicted to fail due to loss of stability.

Although the pipes and outlet structures will likely fail prior to levee failure, only more detailed information gathering and analysis of these structures would allow a more reliable estimation of these potential failures due to degradation. There is some information in the 2010 periodic inspections of the Kansas Citys levees that documents current problems of scour and degradation around outlet structures, but it is not assumed that this is a comprehensive list of current conditions for these types of structures.

Due to the relatively small cost associated with most of these repairs, no information has been gathered on outlet structures and pipes for this study. Following the SMART Planning principles, only the information gathering and analysis necessary to make reasonable planning decisions will be executed. The PDT determined that at this time, the outlet structure information and projected repair costs are not necessary to make a reasonable alternative selection.

3.5 Future without Project Conditions

After the existing conditions were established and the sediment transport model was able to provide some preliminary estimates of future without project conditions of the Missouri River, the structures identified during the Existing Conditions phase were evaluated to identify any structures that would be impacted by the future degradation of the Missouri River bed.

3.5.1 Bridges

Critical elevations were established during the existing conditions investigation and analysis for the Missouri River bridge crossings. These elevations were reviewed and refined based on additional information and conversations with bridge owners. The critical elevations were provided to the economists so that they could determine if and when during the study duration each structure will require a monetary investment due exclusively to bed degradation of the river.

As discussed in the Existing Conditions section above, the critical elevations were established based on MoDOT's scour action plans that define when action should be taken to address scour at particular piers that were of concern to MoDOT based on bridge design, construction type and previous inspections. For the bridges that do not have a scour action plan, elevations were conservatively selected based on engineering judgment and primarily the geometry and type of piers that are in the Missouri River. These conservative elevations resulted in an indication that the Missouri River bed has already dropped below the critical elevation at four bridges shown in Table 1 below. These piers all have solid concrete, caisson-type foundations that have not shown any signs of distress or serious concern from their owners. The actual critical elevations are most likely much lower than indicated by the selected elevations; however, in the absence of a scour action plan, additional information, and time for analysis, there is no quick or easy way to determine those elevations. The given elevations were selected based on a change in pier geometry and original bed elevations.

The assumption was made that as degradation continues, local pier and contraction scour will continue to drop at a constant rate with the bed degradation. For example if there is 11' of local scour immediately surrounding a given pier, it was assumed that if the overall Missouri River bed in that area is projected to drop by 21 feet, the elevation surrounding a given pier will also drop a corresponding 21 additional feet past the current depth at the bottom of the scour hole. See Figure 6 for a visual depiction of this example. The orange line shows the future bed degradation, including continued scour below the surrounding the bed elevation. This assumption may be more accurate for some bridges than others, but without detailed scour analysis of each structure, this was the most logical assumption to make. The values and bridge example in Figure 6 are hypothetical and do not necessarily represent actual scour or degradation values at any specific bridge.

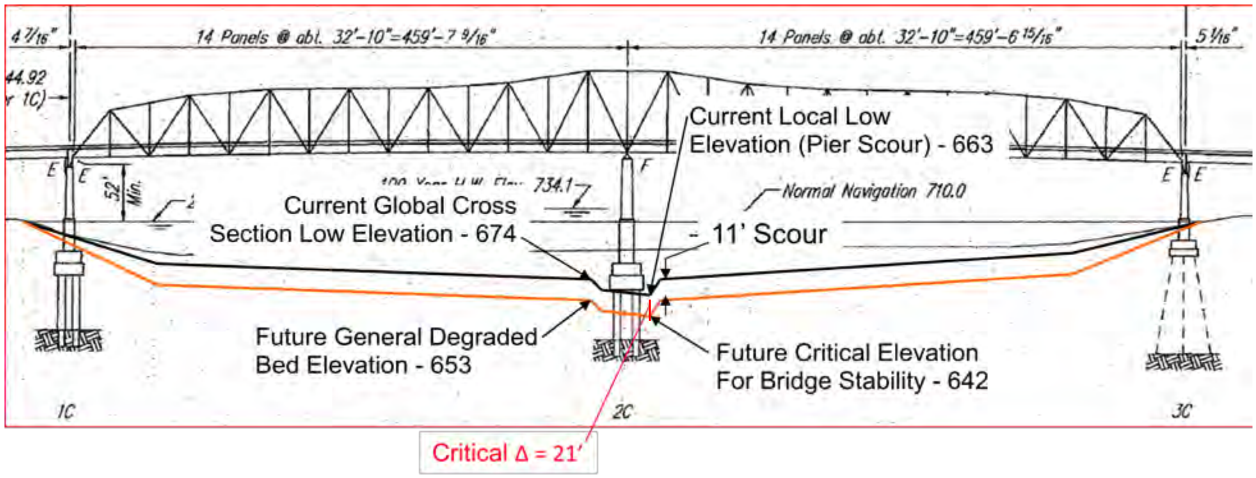

Figure 6 - Scour and Degradation Diagram

Potential repairs were considered for strengthening and stabilizing the bridge piers if the bed did reach the critical elevation for action by the bridge owner. Based on discussions with bridge owners and an existing repair of a railroad bridge pier on the Kansas River just upstream of the confluence with the Missouri River, a proposed solution was identified for all bridge piers. See Figure 7 for details of the existing repair. Sheet pile would be driven down to rock and then extended up to within a few feet of the normal low water line around the entire pier and braced to the pier. Concrete would then be tremied underwater and would fill the shell created by the sheet piles. This would provide stiffening of the pier to provide more strength and stability to compensate for the unbraced length of the pier created by the lower bed elevation. This repair was coordinated with the cost estimating section.

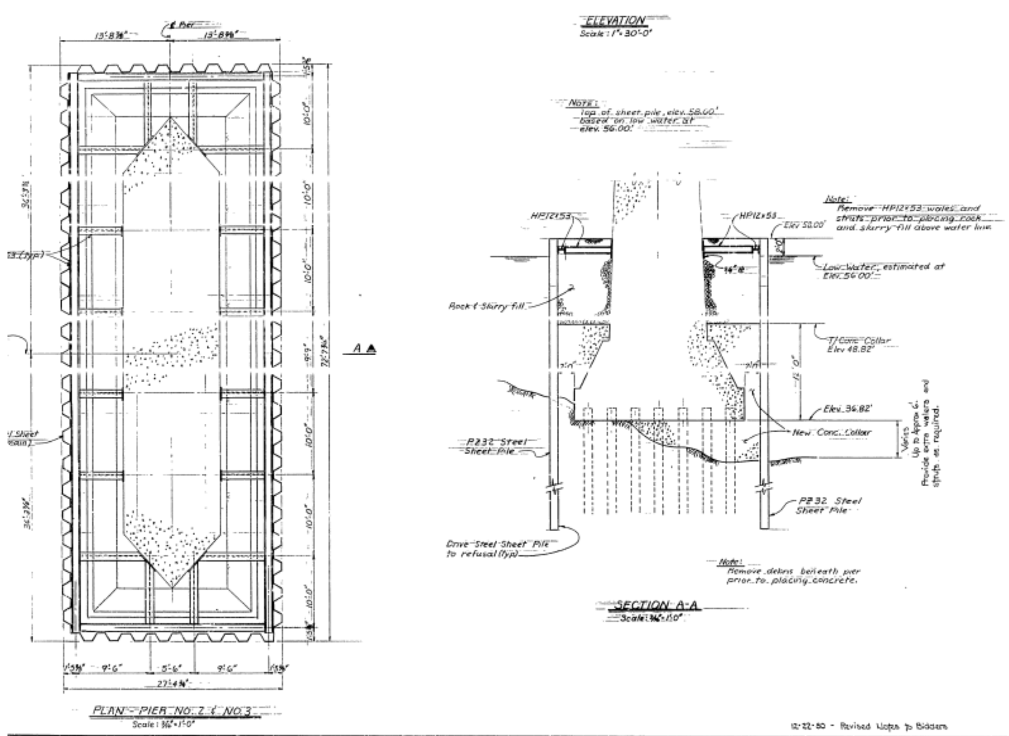

Figure 7 - Existing Kansas River Bridge Pier Repair

The results of the determination of the critical elevation for bed degradation are shown in Table 1 below. As discussed in Section 3.4.1, tributary bridges have not been investigated to determine critical elevations and are not included in this information.

Table 1 - Bridge Pier Current and Critical Bed Elevations for Missouri River Bridges

River Mile	Bridge	Pier No.	Critical Elevation	"Current" Riverbed Elev at Structure	Date Bed Elev was Collected	Bed Width (ft)	Critical Change (ft)
352.7	Liberty Bend (Old) Hwy 291/I-470	5	643	665.9	15-Jun-10	645	22.9
352.7	Liberty Bend (New) Hwy 291/I-470	2C	624	663	15-Jun-10	645	39
359.4	Harry S Truman Drawbridge RR Bridge		No Info	-	-	-	-
360.3	I-435 (Randolph)	7	666	685.68	9-Jun-09	660	19.68
362.3	Chouteau Trfwy	2	bedrock	690.5	12-Aug-10	625	No Critical Change
364.8	Christopher Bond I-29/35	Pylon	bedrock	699.5	-	629	No Critical Change
365.5	Heart of America Hwy 9	5	677	691.7	22-Jul-09	570	14.7
365.5	Heart of America Hwy 9	6	679	691	22-Jul-09	570	12
365.6	ASB RR Bridge	4	700.7	694	2008 Dec	500	-6.7
366.1	Hannibal Drawbridge RR Bridge	4	697	685	2010 Mar	515	-12
366.2	Broadway	2	672	678.4	22-Jul-09	535	6.4
372.6	Fairfax Hwy 69/169 S (Old)	7	655	684.3	10-Jun-09	625	29.3
372.6	Fairfax Hwy 69/169 N (New)	9	662	690.8	10-Jun-09	620	28.8
374.1	I-635 (Riverside)	3	666	700.16	10-Jun-09	550	34.2
383.3	I-435	9	701	717.5	25-Sep-10	725	16.5
397.6	Leavenworth Hwy 92	2	719	721.6	29-Sep-10	840	2.6
422.5	Hwy 59 (new bridge)	-	bedrock	-	-	-	No Critical Change
422.5	Railroad	-	No Info	-	-	-	-
447.9	Hwy 36	8	789	788.5	29-Apr-13	760	-0.5
447.9	Hwy 36	9	774	769.8	29-Apr-13	760	-4.2
447.9	Hwy 36	10	758	768.2	29-Apr-13	760	10.2
448.2	Railroad	-	No Info	772.4	29-Apr-13	-	-

3.5.2 Federal Floodwalls

Based on geotechnical and hydraulic predictions for the degradation of the Missouri River, it has been determined that the local stability of the floodwalls will not be affected due to Missouri River degradation. Figure 8 shows a typical sketch of the assumed and projected conditions of the Missouri River. The black lines are the assumed current conditions and the red lines show the typical assumed future conditions of the river bed and bank. It is assumed that there will be a 1:1.5 degradation of the slope. This assumed degradation will affect the global stability of the wall, which can be found in the geotechnical section of the report, but by inspection of the cross sections and through discussions with the PDT, there are no floodwalls close enough to the river bank for the new degraded slope to affect the local stability of the floodwall based on the limited scope of analysis that is being performed for this study. This conclusion is based on the assumption that local stability of the wall is not greatly impacted until the floodwall foundation becomes exposed. Effects from shortened seepage paths and changed uplift forces were not considered because that would require more accurate existing cross sections at the location of each floodwall and detailed structural analysis that is beyond the scope of this project.

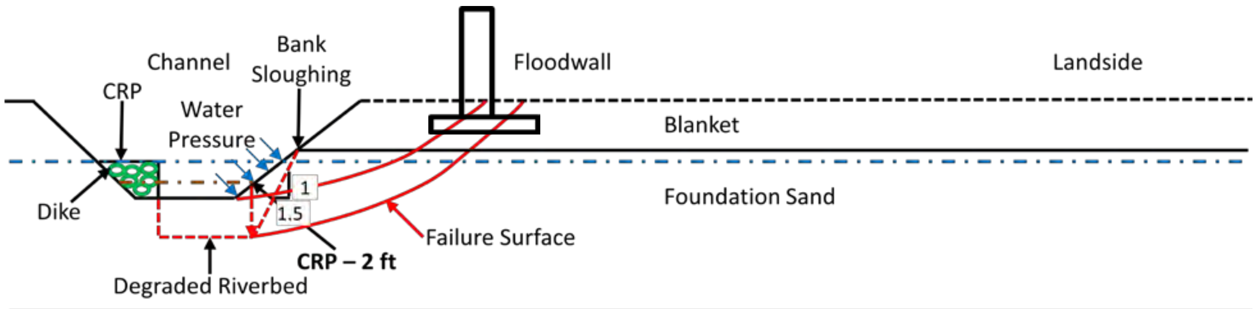

Figure 8 - Foreshore Stability of Typical Levee Floodwall Section

3.5.3 Summary

Structures along the Missouri River were analyzed to determine the river bed elevation at each structure which would cause the owner to expend funds to implement repairs. This information was used to inform the economic analysis. It should be understood that no “future” project was identified for this report. The analyses were developed to a level sufficient to evaluate alternatives, but may require additional effort for other future applications.

Table 2 - Summary Inventory of Bridges, River Miles 329.0-453.7

River Mile	Waterway Crossed	Route Carried	Owner	Structure Inventory and Appraisal Sheet (SI&A)	As-Built Drawings	Current River Bed Elevations
329.0	Hicklin Branch	Hwy 224	MoDOT	N	N	N
329.0	Hicklin Branch	Railroad	UP	N	Y	N
330.6	Fire Prairie Creek	Hwy 24	MoDOT	N	N	N
330.6	Fire Prairie Creek	CR H	Unknown	N	N	N
330.6	Fire Prairie Creek	Railroad	UP	N	Y	N
334.1	Fishing River	Railroad	BNSF	N	N	N
334.1	Fishing River	Railroad	BNSF	N	N	N
334.1	Fishing River	Hwy 210	MoDOT	N	N	N
334.1	Fishing River	CR 376	Unknown	N	N	N
336.2	Missouri River	Railroad	BNSF	N	N	N
339.5	Little Blue River	Railroad	BNSF	N	N	N
339.5	Little Blue River	Atherton Sibley Rd	Unknown	N	N	N
345.1	Rose Branch	Railroad	Unknown	N	N	N
345.1	Rose Branch	Railroad	Unknown	N	N	N
345.1	Rose Branch	Old Hwy 210	Unknown	N	N	N
345.6	Dry Creek	Hwy 210	MoDOT	N	N	N
345.6	Dry Creek	Railroad	Unknown	N	N	N
345.6	Dry Creek	Old Hwy 210	Unknown	N	N	N
345.6	Dry Creek	Scott Ave	Unknown	N	N	N
345.6	Dry Creek	84th St	Unknown	N	N	N
347.3	Rush Creek	Hwy 210	MoDOT	N	N	N
347.3	Rush Creek	Railroad	Unknown	N	N	N
347.3	Rush Creek	Old Hwy 210	Unknown	N	N	N
347.3	Rush Creek	Old Hwy 210	Unknown	N	N	N
350.6	Mill Creek	Railroad	BNSF	N	N	N
350.6	Mill Creek	Hwy 291	MoDOT	Y	Y	N
350.6	Mill Creek	Courtney Atherton Rd	Unknown	N	N	N
351.8	Shoal Creek	Railroad	CP	N	N	N
351.8	Shoal Creek	Hwy 210	MoDOT	N	N	N
351.8	Shoal Creek	Hwy 291	MoDOT	Y	Y	N
352.7	Missouri River	Hwy 291/I-470	MoDOT	Y	Y	Y
356.7	Sugar Creek	Railroad	BNSF	N	N	N

356.9	Rock Creek	Kentucky Rd	KCMO?	N	N	N
356.9	Rock Creek	Railroad	KCT	N	N	N
356.9	Rock Creek	Hwy 24	MoDOT	Y	Y	N
356.9	Rock Creek	Railroad	Unknown	N	N	N
356.9	Rock Creek	Wilson Rd	Unknown	N	N	N
River Mile	**Waterway Crossed**	**Route Carried**	**Owner**	**SI&A**	**As-Built Drawing s**	**Current River Bed Elevation s**
356.9	Rock Creek	Park Rd ???	Unknown	N	N	N
356.9	Rock Creek	Park Rd ???	Unknown	N	N	N
356.9	Rock Creek	Railroad	UP	N	Y	N
356.9	Rock Creek	Railroad	UP	N	Y	N
358.0	Blue River	Railroad	KCS	N	N	N
358.0	Blue River	Railroad	KCT	N	N	N
358.0	Blue River	I-435	MoDOT	Y	Y	N
358.0	Blue River	Access Rd?	Unknown	N	N	N
358.0	Blue River	Railroad	UP	N	Y	N
359.4	Missouri River	Railroad	Unknown	N	N	N
360.3	Missouri River	I-435	MoDOT	Y	Y	Y
361.3	Buckeye Creek	Railroad	BNSF	N	Y	N
361.3	Buckeye Creek	Birmingham Rd	KCMO?	N	N	N
362.3	Missouri River	Chouteau Tfwy	MoDOT	Y	Y	Y
362.6	Rock Creek	Railroad	BNSF	N	Y	N
362.6	Rock Creek	Riverboat Dr	KCMO?	N	N	N
362.6	Rock Creek	Hwy 210	MoDOT	N	Y	N
364.8	Missouri River	I-29/35	MoDOT	Y	Y	Y
365.5	Missouri River	Hwy 9	MoDOT	Y	Y	Y
365.6	Missouri River	Railroad	BNSF	N	Y	Y
366.1	Missouri River	Railroad	BNSF	N	Y	Y
366.2	Missouri River	Broadway Ave	MoDOT	Y	Y	Y
367.5	Kansas River	Railroad	KC Southern	N	Y	N
367.5	Kansas River	Railroad	KCT	N	Y	N
367.5	Kansas River	I-70	KDOT	Y	Y	Y
367.5	Kansas River	I-670	KDOT	Y	Y	N
367.5	Kansas River	18th St/Hwy 69	KDOT	Y	Y	Y
367.5	Kansas River	Kansas Ave/Hwy 32	KDOT	Y	Y	N
367.5	Kansas River	I-635	KDOT	Y	Y	N
367.5	Kansas River	Turner Diagonal/Hwy 32	KDOT	Y	Y	N
367.5	Kansas River	James St	UG	N	N	N

367.5	Kansas River	Central Ave Viaduct	UG	N	Y	N
367.5	Kansas River	23rd St Tfwy	UG	N	N	N
367.5	Kansas River	7th St Tfwy	UG	N	Y	N
367.5	Kansas River	12th St	UG	N	Y	N
367.5	Kansas River	Pedestrian Rd?	Unknown	N	Y	N
367.5	Kansas River	Railroad	UP	N	N	N
River Mile	**Waterway Crossed**	**Route Carried**	**Owner**	**SI&A**	**As-Built Drawings**	**Current River Bed Elevations**
367.5	Kansas River	Railroad	UP	N	Y	N
367.5	Kansas River	Railroad	UP	N	Y	N
372.2	Line Creek	Railroad	BNSF	N	Y	N
372.2	Line Creek	Argosy Pkwy	KCMO?	N	N	N
372.2	Line Creek	Tullison Rd	KCMO?	N	N	N
372.2	Line Creek	Cliff View Dr	KCMO?	N	N	N
372.2	Line Creek	Hwy 9	MoDOT	N	N	N
372.2	Line Creek	I-29	MoDOT	N	N	N
372.2	Line Creek	Unknown Rd	Unknown	N	N	N
372.2	Line Creek	Hwy A	Unknown	N	N	N
372.2	Line Creek	Vivion Rd	Unknown	N	N	N
372.6	Missouri River	Hwy 69/169	MoDOT	Y	Y	Y
374.1	Missouri River	I-635	MoDOT	Y	Y	Y
374.8	Eddy Creek	Railroad	UP	N	N	N
375.9	Burlington Creek	Railroad	BNSF	N	Y	N
375.9	Burlington Creek	Pedestrian Rd	KCMO?	N	N	N
375.9	Burlington Creek	Intercon Dr	KCMO?	N	N	N
375.9	Burlington Creek	Hwy 9	MoDOT	Y	Y	N
377.4	Rush Creek	Railroad	BNSF	N	Y	N
377.4	Rush Creek	Pedestrian Rd	Parkville	N	N	N
377.4	Rush Creek	Main St	Parkville	N	N	N
377.4	Rush Creek	Rush Creek Rd	Parkville	N	N	N
382.8	Connor Creek	Lake Dam	Unknown	N	N	N
382.8	Connor Creek	Railroad	UP	N	N	N
382.9	Brush Creek	Railroad	BNSF	N	Y	N
382.9	Brush Creek	Hwy 45	MoDOT	N	N	N
382.9	Brush Creek	River Rd	Parkville	N	N	N

382.9	Brush Creek	Unknown Rd	Parkville	N	N	N
383.3	Missouri River	I-435	MoDOT	Y	Y	Y
384.9	Ellis Branch	Railroad	BNSF	N	Y	N
386.3	Island Creek	Hwy 5	KDOT	Y	Y	N
386.3	Island Creek	115th St	UG	Y	N	N
386.3	Island Creek	Polfer Rd	UG	Y	N	N
386.3	Island Creek	Railroad	UP	N	N	N
387.8	Little Snell Creek	Hwy 5	KDOT	Y	Y	N
387.8	Little Snell Creek	Driveway	Unknown	N	N	N
387.8	Little Snell Creek	Railroad	UP	N	N	N
River Mile	**Waterway Crossed**	**Route Carried**	**Owner**	**SI&A**	**As-Built Drawings**	**Current River Bed Elevations**
388.1	Sevenmile Creek	Unknown Rd	Unknown	N	N	N
388.1	Sevenmile Creek	Railroad	UP	N	N	N
391.2	Platte River	Railroad	BNSF	N	Y	N
391.2	Platte River	Hwy 45	MoDOT	N	N	N
395.6	Fivemile Creek	2nd St	Leavenworth	Y	N	N
395.6	Fivemile Creek	Marion St	Leavenworth	Y	N	N
395.6	Fivemile Creek	Railroad	UP	N	N	N
396.6	Threemile Creek	Hwy 73	KDOT	Y	Y	N
396.6	Threemile Creek	Pedestrian Rd	Leavenworth	N	N	N
396.6	Threemile Creek	2nd St	Leavenworth	Y	N	N
396.6	Threemile Creek	3rd St	Leavenworth	Y	N	N
396.6	Threemile Creek	5th St	Leavenworth	Y	N	N
396.6	Threemile Creek	6th St	Leavenworth	Y	N	N
396.6	Threemile Creek	7th St	Leavenworth	Y	N	N
396.6	Threemile Creek	Broadway St	Leavenworth	Y	N	N
396.6	Threemile Creek	Cherokee St	Leavenworth	Y	N	N

396.6	Threemile Creek	Shawnee St	Leavenworth	Y	N	N
396.6	Threemile Creek	10th St	Leavenworth	Y	N	N
396.6	Threemile Creek	Osage St	Leavenworth	Y	N	N
396.6	Threemile Creek	Railroad	UP	N	N	N
397.6	Missouri River	Hwy 92	KDOT	Y	Y	N
398.0	Corral Creek	Sherman Ave	Unknown	N	N	N
398.0	Corral Creek	Railroad	UP	N	N	N
401.3	Bee Creek	Railroad	BNSF	N	N	N
401.3	Bee Creek	Hwy 45	MoDOT	Y	Y	N
401.3	Bee Creek	Bluff Rd	Platte County	N	N	N
403.3	Bear Creek	Railroad	BNSF	N	N	N
403.3	Bear Creek	Harpst Rd	Unknown	N	N	N
406.3	Salt Creek	Coffin Rd	Unknown	N	N	N
406.3	Salt Creek	Railroad	UP	N	N	N
413.8	Little Walnut Creek	226th St	Unknown	N	N	N
413.8	Little Walnut Creek	Railroad	UP	N	N	N
414.8	Owl Creek	Railroad	UP	N	N	N
414.8	Owl Creek	Railroad	UP	N	N	N
417.0	Walnut Creek	Railroad	BNSF	N	N	N

River Mile	**Waterway Crossed**	**Route Carried**	**Owner**	**SI&A**	**As-Built Drawings**	**Current River Bed Elevations**
417.0	Walnut Creek	River Rd	Unknown	N	N	N
417.0	Walnut Creek	Old Hwy 73	Unknown	N	N	N
418.2	Sugar Creek	Railroad	BNSF	N	N	N
418.2	Sugar Creek	Hwy 45	MoDOT	N	N	N
418.2	Sugar Creek	River Rd	Unknown	N	N	N
418.2	Sugar Creek	Stanton Rd	Unknown	N	N	N
420.9	Whiskey Creek	Railroad	UP	N	N	N
420.9	Whiskey Creek	Railroad	UP	N	N	N
422.5	Missouri River	Hwy 59	MoDOT	Y	Y	N
422.5	Missouri River	Railroad	UP	N	Y	N
424.0	Independence Creek	River Rd	Unknown	N	N	N
428.0	Lost Creek	Railroad	BNSF	N	N	N

428.0	Lost Creek	Hwy 59	MoDOT	N	N	N
428.0	Lost Creek	Hwy 116	MoDOT	N	N	N
428.0	Lost Creek	Hwy 116	MoDOT	N	N	N
428.0	Lost Creek	CR 249	Unknown	N	N	N
428.0	Lost Creek	3rd St	Unknown	N	N	N
433.5	Brush Creek	Monument Rd	Unknown	N	N	N
433.5	Brush Creek	Ottumwa Rd	Unknown	N	N	N
437.3	Contrary Creek	51st Rd	Unknown	N	N	N
437.3	Contrary Creek	46th Rd	Unknown	N	N	N
440.1	Walnut Creek	Sheridan Rd	Unknown	N	N	N
440.1	Walnut Creek	Monument Rd	Unknown	N	N	N
440.1	Walnut Creek	Port William Rd	Unknown	N	N	N
441.7	Peters Creek	Monument Rd	Unknown	N	N	N
447.9	Missouri River	Hwy 36	MoDOT	Y	Y	N
448.2	Missouri River	Railroad	UP	N	Y	N
453.7	Mace Creek	Local Road	Unknown	N	N	N