

Lower Missouri River Flood Risk and Resiliency System Plan

Appendix A.1: Missouri River Past Performance Assessment



December 2025



**US Army Corps
of Engineers®**

Page intentionally left blank.

Table of Contents

Table of Contents.....	iii
List of Figures	iv
List of Tables	v
1.0 Executive Summary	1
2.0 Background and History	3
2.1 Introduction.....	3
2.2 Missouri River Levee System	5
2.2.1 Federal Levees	5
2.2.2 Non-Federal Levees	5
2.2.3 Private Levees.....	6
2.3 Historical Missouri River Flooding.....	6
2.3.1 1993 Flood Event.....	6
2.3.2 2011 Flood Event.....	8
2.3.3 2019 Flood Event.....	10
3.0 Past Performance Evaluation	15
3.1 Methodology	15
3.2 Study Reaches	15
3.2.1 Study Reach 1 - Big Sioux River to Boyer River (RM 734-635).....	17
3.2.2 Study Reach 2 - Boyer River to Platte River (RM 635-595).....	24
3.2.3 Study Reach 3 - Platte River to Nishnabotna River (RM 595-542)	31
3.2.4 Study Reach 4 - Nishnabotna River to Rulo (RM 542-498)	39
3.2.5 Study Reach 5 - Rulo, NE to St. Joseph, MO (RM 498-450).....	50
3.2.6 Study Reach 6 - St. Joseph, MO to Leavenworth, KS (RM 450-400)	57
3.2.7 Study Reach 7 - Leavenworth, KS to Napoleon, MO (RM 400-330).....	63
3.2.8 Study Reach 8 - Napoleon, MO to Boonville, MO (RM 330-200).....	73
3.2.9 Study Reach 9 - Boonville, MO to Hermann, MO (RM 200-100)	85
3.2.11 Study Reach 10 - Hermann, MO to St. Louis, MO (RM 100-0).....	99
4.0 Results, Conclusions, and Recommendations	112
4.1 Federal vs Non-Federal Levee Performance	112
4.2 Repetitive Loss Areas	112
4.3 Repair Costs.....	113
4.4 Considerations for Plan Formulation	113
5.0 Literature Cited	115
6.0 List of Acronyms and Abbreviations	116
Appendix A	1
Breach Maps.....	1

List of Figures

Figure 1:	Illustration of Levee Components and Floodwall	4
Figure 2:	Illustration Showing the Difference Between Overtopping and Breaching of a Levee	4
Figure 3:	Levee Breach at MRLS 471-460-R, Elwood, KS, 6 August 1993	8
Figure 4:	Damaged Levee along the Missouri River L-575 Levee System near Hamburg, IA (Photo taken June 2011, USACE Omaha District)	9
Figure 5:	Damaged Levee along the Platte County Drainage District No 1 Section 1 Levee System, Rushville-Sugar Lake Segment near Rushville, MO	10
Figure 6:	Levee Breach along the Missouri River L-575 Levee System near Hamburg, IA (Photo taken March 2019, USACE Omaha District).	12
Figure 7:	MRLS 246-L Levee System in Chariton County, MO was Breached at Five Locations 2019. (Photo taken June 2019, USACE Kansas City District).	13
Figure 8:	Lower Missouri River Study Reach Map.....	16
Figure 9:	Map of Reach 1	18
Figure 10:	Map of Reach 2	25
Figure 11:	Map of Reach 3	32
Figure 12:	Map of Reach 4	40
Figure 13:	July 2019 Plan to Close Breaches on Mill Creek and Big Tarkio Private Levees	49
Figure 14:	Map of Reach 5	51
Figure 15:	Map of Reach 6	58
Figure 16:	Map of Reach 7	64
Figure 17:	Map of Reach 8	74
Figure 18:	Map of Reach 9	86
Figure 19:	Route 54 Overtopping in 1993.....	98
Figure 20:	Map of Reach 10	100

List of Tables

Table 3-1: USGS Gage 06486000 Missouri River at Sioux City, IA - Peak Flows.....	19
Table 3-2: USGS Gage 06601200 Missouri River at Decatur, NE - Peak Flows.....	19
Table 3-3: Design Capacities From O&M for Study Reach 1	20
Table 3-4: Loading History for Study Reach 1	21
Table 3-5: Reference Gages and Studies for Reach 1	23
Table 3-6: USGS Gage 06610000 Missouri River at Omaha, NE - Peak Flows	26
Table 3-7: NLD Data for Reach 2	27
Table 3-8: Loading History for Study Reach 2	28
Table 3-9: Reference Gages and Studies for Reach 2	29
Table 3-10: USGS Gage 06807000 Missouri River at Nebraska City, NE - Peak Flows.....	33
Table 3-11: NLD Data for Study Reach 3	35
Table 3-12: Loading History for Study Reach 3	36
Table 3-13: Reference Gages and Studies for Reach 3	37
Table 3-14: USGS Gage 06813500 Missouri River at Rulo, NE - Peak Flows.....	41
Table 3-15: NLD Data for Study Reach 4	43
Table 3-16: Loading History for Study Reach 4	45
Table 3-17: Reference Gages and Studies for Reach 4	47
Table 3-18: USGS Gage 06813500 Missouri River at Rulo, NE - Peak Flows.....	52
Table 3-19: NLD Data for Study Reach 5	53
Table 3-20: Loading History for Study Reach 5	54
Table 3-21: USGS Gage 06818300 Missouri River at Atchison, KS - Peak Flows.....	59
Table 3-22: NLD Data for Study Reach 6	60
Table 3-23: Loading History for Study Reach 6	61
Table 3-24: USGS Gage 06818000 Missouri River at St Joseph, MO - Peak Flows	65
Table 3-25: USGS Gage 06820475 Missouri River at Leavenworth, KS - Peak Flows.....	65
Table 3-26: NLD Data for Study Reach 7	66
Table 3-27: Loading History for Study Reach 7	68
Table 3-28: USGS Gage 06894650 Missouri River at Napoleon, MO - Peak Flows	75
Table 3-29: USGS Gage 06895500 Missouri River at Waverly, MO - Peak Flows	75
Table 3-30: USGS Gage 06895700 Missouri River at Miami, MO - Peak Flows.....	75
Table 3-31: USGS Gage 06906500 Missouri River at Glasgow, MO - Peak Flows	76
Table 3-32: NLD Data for Reach 8	77
Table 3-33: Loading History for Study Reach 8	79
Table 3-34: USGS Gage 06910450 Missouri River at Jefferson City, MO - Peak Flows.....	87
Table 3-35: NLD Data for Study Reach 9	91
Table 3-36: Loading History for Study Reach 9	94
Table 3-37: USGS Gage 06934500 Missouri River at Hermann, MO - Peak Flows.....	101

Table 3-38: NLD Data for Study Reach 10 103

Table 3-39: Loading History for Study Reach 10 105

Page intentionally left blank.

1.0 EXECUTIVE SUMMARY

The Missouri River basin is the biggest of the Nation's 18 major water resource regions, embracing 513,000 square miles within the United States including all or parts of 10 states. Floods along the Missouri River occur frequently. Major floods have occurred in 1881, 1943, 1951, 1952, 1993, 2011, and 2019.

While there are six U.S. Army Corps of Engineers (USACE) mainstem dams regulating runoff from the entire upper basin, there is no regulation downstream of Gavins Point Dam in Yankton, South Dakota on the mainstem of the Missouri River. Original plans for federal levees flanking most of the river from Gavins Point Dam to the mouth with a 3,000-5,000-foot-wide floodplain never came to fruition. The lower Missouri River currently has a patchwork of taller federal levees mostly set back from the river, shorter non-federally designed and constructed levees on the riverbanks that are active in the Rehabilitation Program, and privately built and owned levees with no USACE affiliation.

Since 2010, the Missouri River basin has experienced four of the six highest volume runoff years (2010, 2011, 2018 and 2019) above Sioux City, Iowa since recordkeeping began more than 120 years ago. These high runoff years are in addition to the widespread, historic flooding that occurred in the Midwest in 1993, known as the “Great Flood of 1993” along the Mississippi and Missouri Rivers and their tributaries.

While reports have been written after individual flood events, no report has captured an overall performance history of the levee systems along the lower Missouri River. In this report the Missouri River was broken out into reaches. The flood history, levee performance, repair costs, and significant impacts are described for each reach from 1993 to 2023.

In the Omaha District area of responsibility (AOR) reaches, overtopping, breaching, or interior ponding behind the federal levees in 1993, 2011, and 2019 resulted in significant economic damages to Hamburg, IA; Council Bluffs, IA; Omaha, NE; and Offutt Air Force Base as well as repeated closures of Interstate 29. Repeated overtopping of the non-federal levees has had significant impacts throughout the lower basin in the Kansas City District AOR. The non-federal levees in the Kansas City District have sustained flood damages on multiple years between 1993 and 2023 with some reaches seeing flood damages to levees in over 10 of the last 30 years. During all major flood events, a breach on one levee system has led to cascading breaches through the tieback levees on multiple downstream systems. River levels on the Missouri can remain high for months, further complicating and delaying repairs.

The Missouri River levees provide tremendous economic benefits, but the cost of repeated flood damages is also significant. The 2019 flood is the costliest to date with levee repairs estimated to be close to \$1 Billion in Omaha and Kansas City Districts combined. The basis of this study was conducted with the purpose to provide key data

analyzing the history of the Lower Missouri levee system from a multi-facet standpoint. Patterns and insights from this report will be incorporated into the measures and reach plans for the Lower Missouri River System Plan.

2.0 BACKGROUND AND HISTORY

2.1 Introduction

The Missouri River begins at the confluence of the Jefferson and Madison Rivers near Three Forks, Montana and flows east and south 2,470 miles to the mouth where it joins the Mississippi River about 15 miles north of St Louis, MO. It is the longest river in the United States. Floods along the Missouri River occur frequently. Major floods have occurred in 1881, 1943, 1952, 1993, 2011, and 2019.

In the 1944 Flood Control Act, the Pick-Sloan Plan proposed a series of flood protection works that were designed to work together compatibly as a system in the Missouri River Basin to protect communities and agriculture from flooding. In addition to construction of Mainstream dams, the Pick-Sloan Plan also called for a 3,000 - 5,000-foot-wide floodway channel from Sioux City, IA to the mouth with 1,500 miles of federal levee construction on both sides of the river. Federal levee construction was started in 1947; however, very little of the original plan was constructed. Due to limited funding, legal battles, and cost share requirements, only about 27 percent of the recommended levees were constructed and much of the river's floodway width is significantly less than laid out in the plan. Many reaches along the Missouri River ended up with a patchwork of non-federally designed and constructed levees. These levees are typically not designed to the same heights or engineering standards as required for federal levees and are often constructed much closer to the river. Most of the non-federal levees are on or very near the bank, narrowing the floodway.

A levee is a man-made structure, usually an earthen embankment, designed and constructed to contain, control, or divert the flow of water to reduce the risk of flooding to a specified area. Levees reduce flood risk but do not eliminate it. A levee is generally designed to control a certain amount of floodwater. If a larger flood occurs, floodwaters will flow over the levee. Most flooding behind levees comes from water overtopping the levee. In addition, levees do not always perform as designed. Levees can breach prior to water reaching the top due to underseepage, through seepage, stability, erosion or component failures. Figure 1 and Figure 2 illustrate the components of a levee and floodwall as well as the difference between overtopping and breaching a levee. These illustrations were obtained from the American Society of Engineers (ASCE) 2010 pamphlet "So you live behind a levee."

Figure 1: Illustration of Levee Components and Floodwall

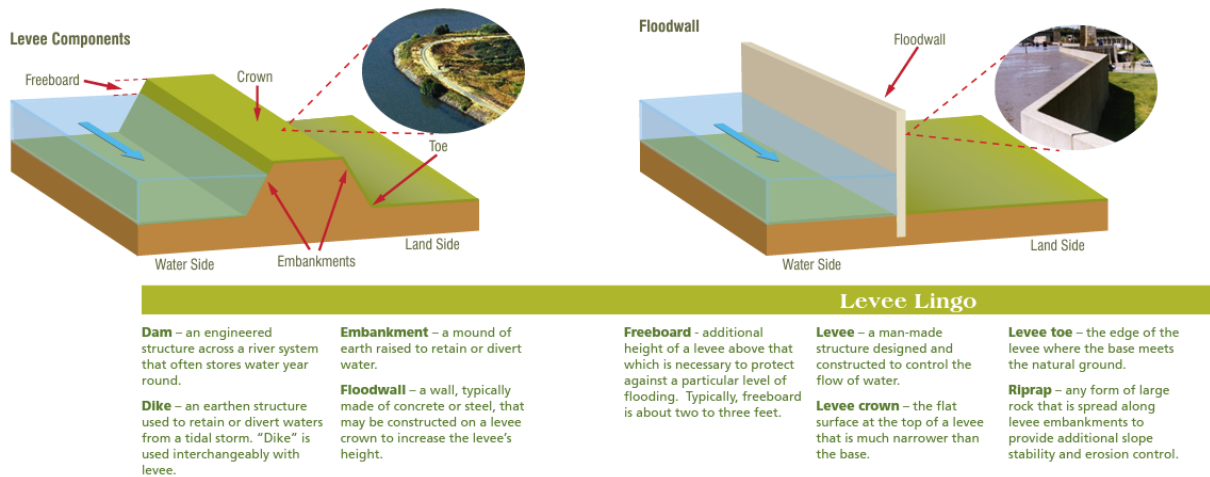
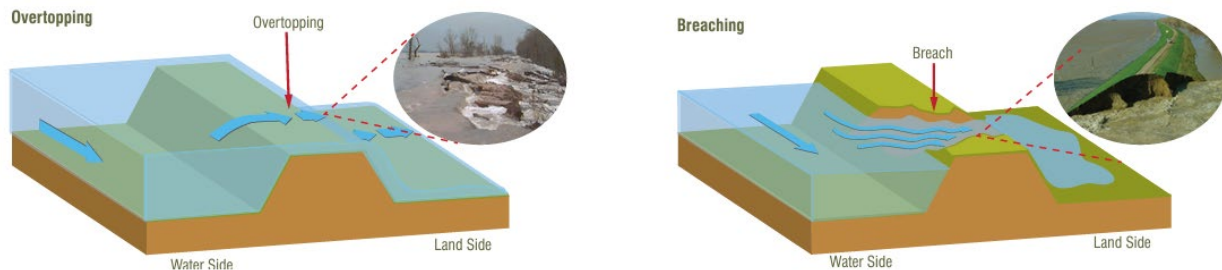


Figure 2: Illustration Showing the Difference Between Overtopping and Breaching of a Levee



Local sponsors operate and maintain all the federally constructed levees along the lower Missouri, except for the two Liberty Bend levees near Kansas City. All federal levees currently constructed are in the reach located between Omaha and Kansas City except for four units between Kansas City and Washington, Missouri (MRLS 351-R, MRLS 246-L, Lower Chariton, and New Haven) and two units downstream of Washington that are in the St Louis District’s AOR (Monarch Chesterfield and Consolidated North County). In addition to the Pick-Sloan Plan never being completed, efforts to create a Missouri River Valley Authority (MVA), similar to the Tennessee Valley Authority, have never succeeded. Unsuccessful proposals were raised to Congress in 1945, and again in 1949, to set up a government funded authority to develop and carry out comprehensive plans for flood control, navigation, and hydropower generation along the Missouri River. The idea seems to be renewed to some extent with each major flood event but has not been re-proposed in Congress.

2.2 Missouri River Levee System

There are approximately 1,200 miles of USACE levees along the Missouri River from Gavins Point Dam to the mouth. The USACE levees include federally constructed and maintained levees, federally constructed levees that local sponsors maintain, and non-federally constructed levees that are active in the USACE Public Law (P.L.) 84-99 Rehabilitation Program (hereinafter referred to as the Rehabilitation Program). There are also numerous private levees that are not tracked by USACE or the state governments. The federal levees are designed to function as a system with the mainstem and tributary reservoirs. Neither the reservoirs nor the levees alone provide the desired degree of protection, but operating to supplement each other, they provide significant flood risk reduction.

2.2.1 Federal Levees

Federal levees are levees authorized by Congress that have been designed and constructed by USACE. These levees are built following USACE engineering standards for levee design and construction. Unlike federal dams that are built to contain the maximum probable flood, levees are built to a designed flood event. Floods larger than that designed flood event will overtop the levee, usually in an uncontrolled manner. Federal levees on the Missouri River are typically designed for a 0.01 to 0.001 Annual Exceedance Probability (AEP) event. All most all federal levees are then turned over to a local taxing authority, also called a local sponsor, to operate and maintain. Through the Levee Safety Program and the Rehabilitation Program, USACE continues to engage sponsors on levee condition, risks, and expected performance. Flood damages are eligible for repair at 100 percent federal cost on federally constructed levees that are active in the Rehabilitation Program.

Federal levee projects surrounding large urban areas along the Missouri River have been constructed at Omaha, NE; Council Bluffs, IA; St. Joseph, MO; Kansas City, MO and St. Louis, MO. There are approximately 42 federal Levee units constructed on the Lower Missouri River. Thirty-six of these are in the reach between Omaha and Kansas City. Only six (MRLS 351-R, MRLS 246-L, Lower Chariton, New Haven, Monarch-Chesterfield, and Consolidated North County) are located between Kansas City and the mouth.

2.2.2 Non-Federal Levees

Local levee and drainage districts have built over 500 miles of levees, which comprise nearly 100 non-federal levee systems, along the Lower Missouri River. Most of these are active in the Rehabilitation Program and are referred to as non-federal levees. While these levees provide protection during most events, in general, most are not designed to perform during major or extreme floods. These levees are generally built to the 0.10 to 0.02 AEP events, with only a few non-federal levees built to the 0.01 AEP event. The

non-federal levees that are active in the Rehabilitation Program are required to cost share eligible post flood repairs at 20 percent of the total repair cost.

2.2.3 Private Levees

There are also numerous private levees built along the Lower Missouri River. These include levees constructed by individuals, drainage or levee districts, businesses or municipalities that do not, or are not eligible to, participate in the Rehabilitation Program. These levees are not tracked by the USACE or by the State of Missouri. Some of these have been identified and inventoried in the National Levee Database, but not all.

As part of state's recovery efforts, NeDNR, in partnership with Nebraska Emergency Management Agency (NEMA), took on an effort to inventory levees, their damage status from the 2019 flood, and their repair status. These non-USACE program levees could be a potential opportunity in future flood risk resiliency efforts but would need further evaluation beyond the scope of this study.

2.3 Historical Missouri River Flooding

2.3.1 1993 Flood Event

The Flood of 1993 on the Mississippi and Missouri Rivers was devastating throughout much of the Midwest and Great Plains regions, resulting in the death of 47 people and causing between \$15 to \$20 billion in damages. Excessive snowmelt and precipitation during March through August 1993, produced severe or record flooding in a nine-state area in the upper Mississippi and Missouri River basins. The widespread area affected by the rainstorms that caused the flood of 1993 was unique both in that it resulted in flooding on both the Mississippi and Missouri rivers within the same week, compounding the impacts of flooding. All navigation on the Mississippi River below Dubuque, IA was suspended from late June to mid-August 1993, and navigation on the Missouri River was suspended for 49 days from July 2nd to August 20th.

Gages on the Missouri River exceeded flood stage along approximately the lower 700 miles at several points throughout the year with the river reaching its crest on July 10th at Omaha, July 23rd at Nebraska City, July 26th at St. Joseph, July 27th at Kansas City, July 29th at Boonville, and July 31st at Hermann. Releases from Gavins Point Dam were reduced to 6,000 cfs in early July and did not exceed 9,000 cfs for the rest of the month, indicating the July 1993 flooding was from precipitation downstream of the mainstem reservoir system. The mainstem reservoir system served to reduce streamflow throughout the lower Missouri River during the 1993 flood. The Missouri River remained above flood stage for 43 days at St. Joseph from June 26 to August 6th (USACE, 1994). At Herman, MO the river was above flood stage for a total of approximately 120 days that year, including 54 days continuously from July 2nd to August 25th (USACE, 1994).

Federal reservoirs on the Kansas River and Osage River Basins were also in operations during the 1993 flood. The Kansas Basin reservoir system was credited with reducing peak flows on the Kansas River at De Soto, Kansas by approximately 94,000 cfs and day-average flows by approximately 51,000 cfs (Kansas City Levees H&H report, 2021). These holdouts contributed to preventing overtopping to Armourdale and CID which were loaded to 90 percent of their height with minimal freeboard remaining in several places. Whereas Osage Basin projects reduced Osage River streamflow by approximately 150,000 cfs at the peak of the flood in July. Flooding on the Kansas River peaked at 172,000 cfs at De Soto on July 27th, which occurred coincident with several reservoirs reaching record pools, and three projects, Milford, Tuttle Creek, and Perry Dams, activating spillway releases.

Within the 15,300 square mile drainage of the Osage River Basin, a total of five USACE reservoirs were in operations during the 1993 flood, the most significant being Truman Dam. A review of gate operations shows flows from Truman Dam were reduced to a maximum of 500 cfs to limit Missouri River flooding from July 1 to August 2, then flows were increased gradually to 42,000 cfs by August 16 to evacuate the flood pool. This operation is credited with reducing peak streamflow on the Lower Osage River by approximately 150,000 cfs at the peak of the July flooding. During a second storm event in September, the Osage Basin projects are credited with reducing streamflow by approximately 250,000 cfs on the lower Osage River. The computed unregulated observed peak flow in 1993 at the Hermann gage was 955,000 cfs. Combined holdouts from the mainstem Missouri River dams, Kansas River Dams, and Osage Basin dams along with smaller projects resulted a regulated peak flow of 710,000 cfs which represents a flow reduction of 245,000 cfs

The 1993 post flood report (USACE, 1994) showed that the levees and reservoir system prevented an estimated \$4.57 billion in damages at the 1993-1994 price level. In Fiscal Year 2023 dollars, that figure would be \$12.37 billion. While flooding would have been much worse without the flood risk management projects in place, flood damages were still extensive. Flooding from this event caused major highways, bridges, and rail lines to be closed for long periods. All non-federal levee systems along the Missouri River were overtopped and breached, along with nine federal levee systems in the Kansas City District alone, resulting in the most extensive levee rehabilitation effort at that time. Until then, no other natural disaster in U.S. history affected or touched so many lives for so long a duration as did the Midwest Flood of 1993 (USACE, 1994). Figure 3 shows the overtopping breach on federal levee MRLS 471-460-R near Elwood, KS.

Figure 3: Levee Breach at MRLS 471-460-R, Elwood, KS, 6 August 1993



2.3.2 2011 Flood Event

In 2011, the Missouri River Basin experienced record setting rainfall and snowmelt, resulting in the historic Missouri River flood of 2011. During the four-month period from March 1 to July 1, approximately 49-million-acre feet (MAF) of runoff poured into the system, overwhelming the floodplains and saturating, overtopping, and failing levee systems. Despite water regulation and flood fighting efforts, devastation and disruptions were massive. Flood waters forced hundreds of homeowners, farmers, and business owners to evacuate. Several Missouri River bridges as well as long stretches of interstates, highway, and roads were closed for weeks or months at a time. Approximately 250 miles of railroad tracks were in the flood areas, requiring track sections to be raised, temporary berms to be built, and damaged tracks to be repaired. Many road and rail shipments were delayed because of rerouting distribution through other states. The upper navigable portion of the Missouri River, a vital part of the transportation network, was also closed to all navigation for several months. All along the Missouri River hundreds of homes, farmsteads, and businesses were damaged or destroyed, many public and private infrastructure facilities were impacted, and nearly 1 million acres of agricultural lands were inundated and damaged.

The unprecedented volume of runoff during the spring of 2011 led to the following record releases from all six of the USACE's Mainstem dams: 65,900 cubic feet per second (cfs) at Fort Peck; 150,000 cfs at Garrison; 160,000 cfs at Oahe; 166,000 cfs at Big Bend; 166,000 cfs at Fort Randall; and 160,000 cfs at Gavins Point. Extremely high releases were sustained for several months to evacuate the flood storage from the reservoirs even after the peak of the flood had passed, which compounded flood impacts and extended the period of time before cleanup and recovery efforts could commence. Downstream tributaries added to the peak flows especially upstream of Kansas City, MO, with Nebraska City, NE reaching a peak of 229,000 cfs on July 7th, and St. Joseph, MO reaching a peak of 277,000 cfs on June 28th.

The long duration of the 2011 flood subjected both federal and non-federal levees along the Missouri River to months of hydraulic loading, resulting in seepage and erosions issues and breaches even when the levees did not overtop. All told, the event caused moderate to extensive damage to roughly 75 federal levees (and many more non-federal levees) within the basin due to overtopping, erosion, and under seepage. In addition to damages to the levees, the long duration of high flows caused significant damage to river channel training structures, such as dikes and revetments constructed to maintain the navigation channel. These high flows caused both erosion and sediment deposition at different locations along the Lower Missouri, most notably seen in the floodplains that experienced levee breaches (Figure 4 and Figure 5). New channels were scoured, and several feet of sand deposited in the same general area. Recreation areas, boat ramps and marinas, fish and wildlife habitats, and historic Tribal sites along the river channel were also impacted in many locations by the 2011 flood.

**Figure 4: Damaged Levee along the Missouri River L-575 Levee System near Hamburg, IA
(Photo taken June 2011, USACE Omaha District)**



**Figure 5: Damaged Levee along the Platte County Drainage District No 1 Section 1 Levee System, Rushville-Sugar Lake Segment near Rushville, MO
(Photo taken June 2011, USACE Kansas City District)**



2.3.3 2019 Flood Event

The 2019 flood began in March 2019 and lasted through November of that same year. Many factors contributed to the flooding: (1) a wet fall in 2018 that saturated soils and filled tributaries throughout the Missouri River Basin, (2) an extremely cold and wet winter, that resulted in deeply frozen ground, above-average snowfall, and thick river ice, (3) the “Bomb Cyclone,” which dumped rain and snow on frozen ground in Nebraska, Iowa, and South Dakota. This Bomb Cyclone included a rapid warm-up that caused snow to quickly melt over frozen, fully saturated soils, and (4) the rains of May-June that created the highest peaks downstream of the Kansas River.

Spring runoff from the “Bomb Cyclone” entered the Missouri River both upstream and downstream of Gavins Point Dam (located at Yankton, South Dakota), which is the smallest (roughly 500,000 acre-feet of total storage) and furthest downstream dam in the Missouri River Main Stem System. It is estimated that during March, April, and May, 20.8 MAF of runoff entered the Missouri River upstream of Gavins Point Dam, more than two times the average runoff. The unregulated area downstream between Gavins Point Dam and Sioux City, Iowa (including the unregulated James, Vermillion, and Big Sioux tributary rivers in eastern South Dakota) saw about 6.6 MAF of runoff during that same 3-month period, which was more than six times the average runoff. The unregulated area between Sioux City, IA and Nebraska City, NE (including the Platte and Elkhorn Rivers in Nebraska and the Floyd, Little Sioux, and Boyer Rivers in Iowa,

along with other tributaries) saw nearly 7 MAF of runoff in this 3-month period, just under the long-term annual average of 7.7 MAF.

The Missouri River Basin total runoff volume during 2019 was at near-historic levels. The runoff in the upper basin (above Sioux City) was 60.9 MAF, second all-time and just 0.1 MAF less than the 2011 record runoff of 61.0 MAF (1898-2019). The total runoff in the lower basin (Sioux City to the mouth) was 91.6 MAF, more than two times the long-term average and third all-time, exceeded only in 1973 and 1993. Total runoff in the Missouri Basin, measured at Hermon, MO, was 152.5 MAF, more than two times the long-term average and second all-time, only 0.1 MAF less than the highest runoff of record, which was observed in 1993.

Between March 13 and March 23, 2019, per preliminary analysis by the National Weather Service (<https://www.weather.gov/oax/MarchRecordFlooding2019>), over 50 gages on the Missouri River and its tributaries in the region set new stage records. Nearly all these new records were on unregulated areas of the Missouri River Basin (tributaries and the Missouri River downstream of Gavins Point Dam). For example, the U.S. Geological Survey (USGS) estimated that the Platte River peak flow at Louisville, NE, its most downstream gaging location, was a record 250,000 cfs on March 16th. The average annual peak flow at this location is approximately 50,000 cfs, and previous record post Kingsley Dam (1941) was 160,000 cfs in 1993.

This unprecedented amount of runoff resulted in the Lower Missouri River being above flood stage along much of its length for nearly nine months causing billions of dollars of damage to homes, businesses, agricultural production, infrastructure, levees, navigation structures, and recreational and natural resources across five states. Levee breaches along the Missouri River, like the one pictured below (Figure 6) on levee L-575 near Hamburg caused extensive damage to property and critical infrastructure such as Interstate-29.

As a result of the flooding, 36 federal and active non-federal levee systems were damaged or breached during the March Bomb Cyclone event in the Omaha District area of operations. Of those, 31 were active in the Rehabilitation Program and were eligible for repair assistance. In the Kansas City District, 14 active non-federal levee systems, all upstream of Kansas City, were overtopped and breached in March. All were eligible for repair assistance through the Rehabilitation Program.

**Figure 6: Levee Breach along the Missouri River L-575 Levee System near Hamburg, IA
(Photo taken March 2019, USACE Omaha District).**



In the Kansas City District, extended high upper basin runoff combined with record setting local rainfall resulted in a second peak event. The month of May included record amounts of rainfall across the Kansas River Basin where 10 to 15 inches of widespread rainfall occurred within the Kansas City District's area of responsibility (AOR). According to the Kansas State University May 2019 Kansas Climate Summary, May was recorded as the wettest May in Kansas since 1895 with a state-wide average precipitation of 10.26 inches. Fifteen to 20 inches of precipitation was also documented within the Grand River Basin in Missouri for the month of May. Beginning May 22 and extending into June, 51 levee systems were overtopped or overtopped and subsequently breached along the Grand River and Missouri River between Kansas City and Herman, MO. Fifty of those were active non-federal levees and one was federal levee MRLS 246-L shown in Figure 7. In total, 65 levees overtopped and 45 levees breached within the Kansas City District area of operations during the 2019 flood event.

Figure 7: MRLS 246-L Levee System in Chariton County, MO was Breached at Five Locations 2019. (Photo taken June 2019, USACE Kansas City District).



The 2019 flood also had a significant impact on Kansas City District reservoirs. Due to upper basin releases, several reservoirs in the Kansas River and the Osage River basins, which feed into the Missouri River, held water for extended periods of time. Nine dams reached record pool levels including Harlan County, Perry, Clinton, Long Branch, Melvern, Pomona, Hillsdale, Pomme De Terre, and Truman. In addition, Tuttle Creek and Milford, both of which had water flowing through their spillways in 1993, reached lake levels 2 feet and 7 feet, respectively, below the record levels set in 1993. Reservoir storage increased from March 2019 until the peak on June 2, 2019. On June 2nd the 18 Kansas City District reservoirs were holding 82% of their available flood control storage. This correlates to 9 million Acre Feet (MAF) of flood control storage that would otherwise have contributed to the flood on the Missouri River. All of the reservoir projects performed as designed with little performance concerns. The estimated damages prevented by the operations of the Kansas City District's dams and federal levees was \$2.01 Billion in 2019 dollars (\$2.31 Billion in 2023 dollars).

Missouri River levels downstream of Kansas City remained high throughout the summer and into winter due to the flood control releases from the Kansas City District reservoirs combined with continued upper basin releases. The flood event, which started on March

13, was declared over on December 17, making it the longest flood event on record in the Kansas City District.

Due to the extensive damage to non-federal levees in the State of Missouri, the State cost-shared up to 75 percent of the required 20 percent cost-share that is required on the non-federal levee repairs through the Rehabilitation Program. The State also cost-shared rehabilitation efforts in the St. Louis and Rock Island Districts. The State of Missouri also provided \$1.6 million for utility relocations, land acquisition, and support for land appraisals and title work as part of the L-536 setback.

3.0 PAST PERFORMANCE EVALUATION

3.1 Methodology

This report discusses the recent performance history of the levees that have been constructed along the Lower Missouri River. Levees in the Omaha District are mainly federally constructed, meaning past performance and repair efforts are better documented throughout the project's life. The Kansas City District past performance discussions below focus on events from 1993 to 2022. Their federal levees that were constructed or partially constructed during the 1951 and 1952 floods were redesigned and modified following those floods. All the non-federal levees in the Kansas City District were reconstructed and likely raised after the flood of 1993 overtopped them all. Records of performance and repair on non-federal levees prior to 1993 are scarce. Prior to the USACE developing a Levee Safety Program in 2007, there were no standards for documenting flood fighting effort and levee performance. Most records are pulled from Project Information Reports developed for repairing levees under the Rehabilitation Program.

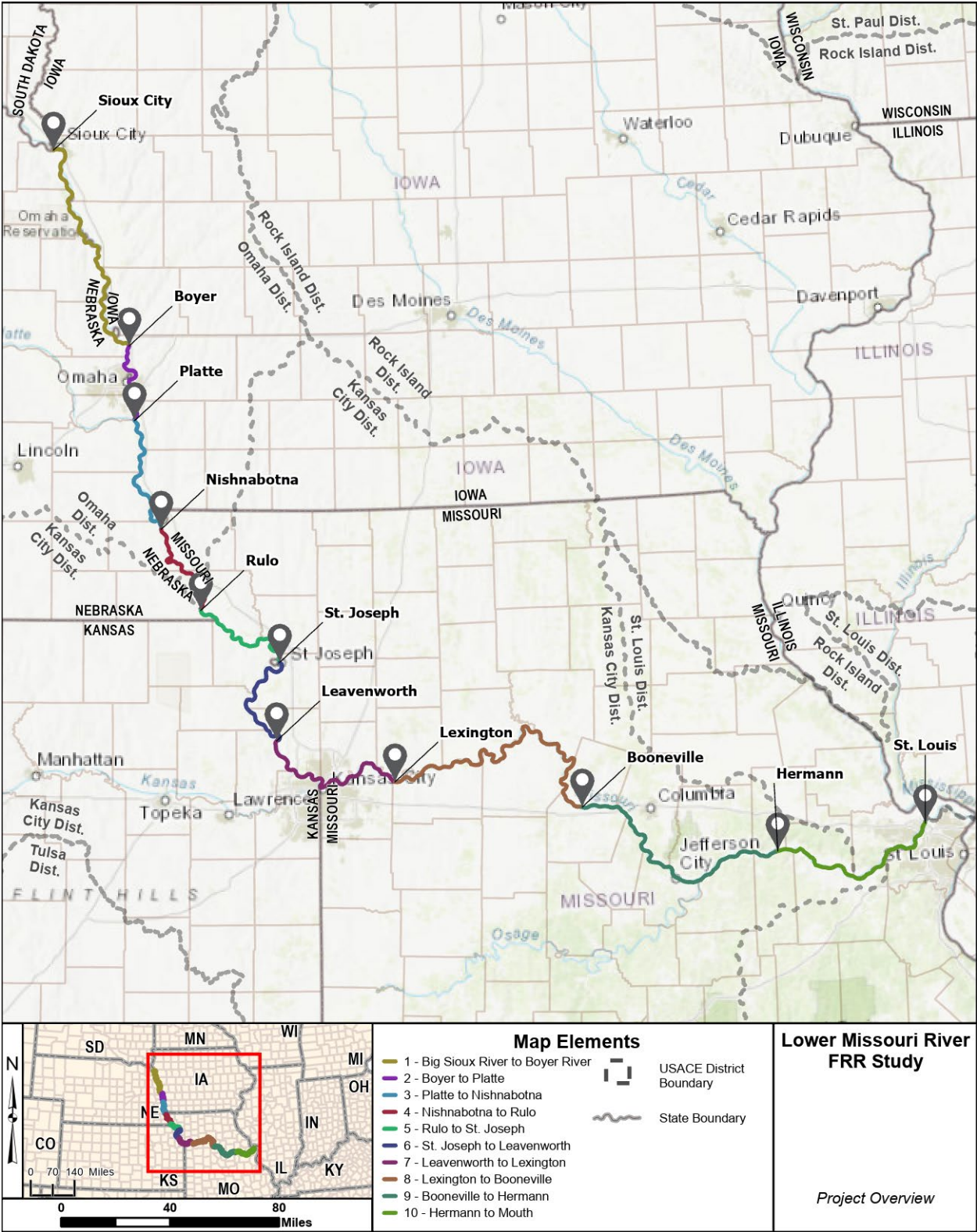
Unless otherwise stated the estimates for levee exceedance probabilities are taken from the National Levee Database. These are from the most recent levee screening level risk assessments completed sometime between 2012 and 2022. Breach locations from the 2019 flood are shown in maps in Appendix A.

The economics data for each reach is inclusive of all federal and active non-federal levees in that reach and is compiled from available data. By showing the costs of flood damage repair for the levees, we can illustrate which areas segments along the river experience greater damage during flooding events. In the Omaha District reaches, cumulative repair costs are from only the 2011 and 2019 floods. In the Kansas City District reaches cumulative repair costs are from 1993 to 2023, however there are data gaps and missing information, especially from events prior to 2011 where records are not in electronic formats. Not all repair costs on the federal levees in 1993 were found.

3.2 Study Reaches

The USACE and the four state partners of Iowa, Nebraska, Kansas, and Missouri, discussed criteria to use when selecting sites for further evaluation (using existing information and hydraulic modeling) under the "Considerations and Analysis for Flood Risk Resiliency for the Lower Missouri River (Nebraska, Iowa, Kansas, and Missouri) Section 22 Planning Assistance to States (PAS)" study scope. Agreed upon criteria included (1) frequency and extent of the flood impacts, (2) impact to infrastructure and assets, (3) duration and complexity of recovery process, and (4) regional and system benefits. This report is broken out into the same reaches used in that PAS study. Reaches 1 through 4 are within the Omaha District's AOR and reaches 5 through 10 are within the Kansas City District's AOR. Reaches are shown on Figure 8.

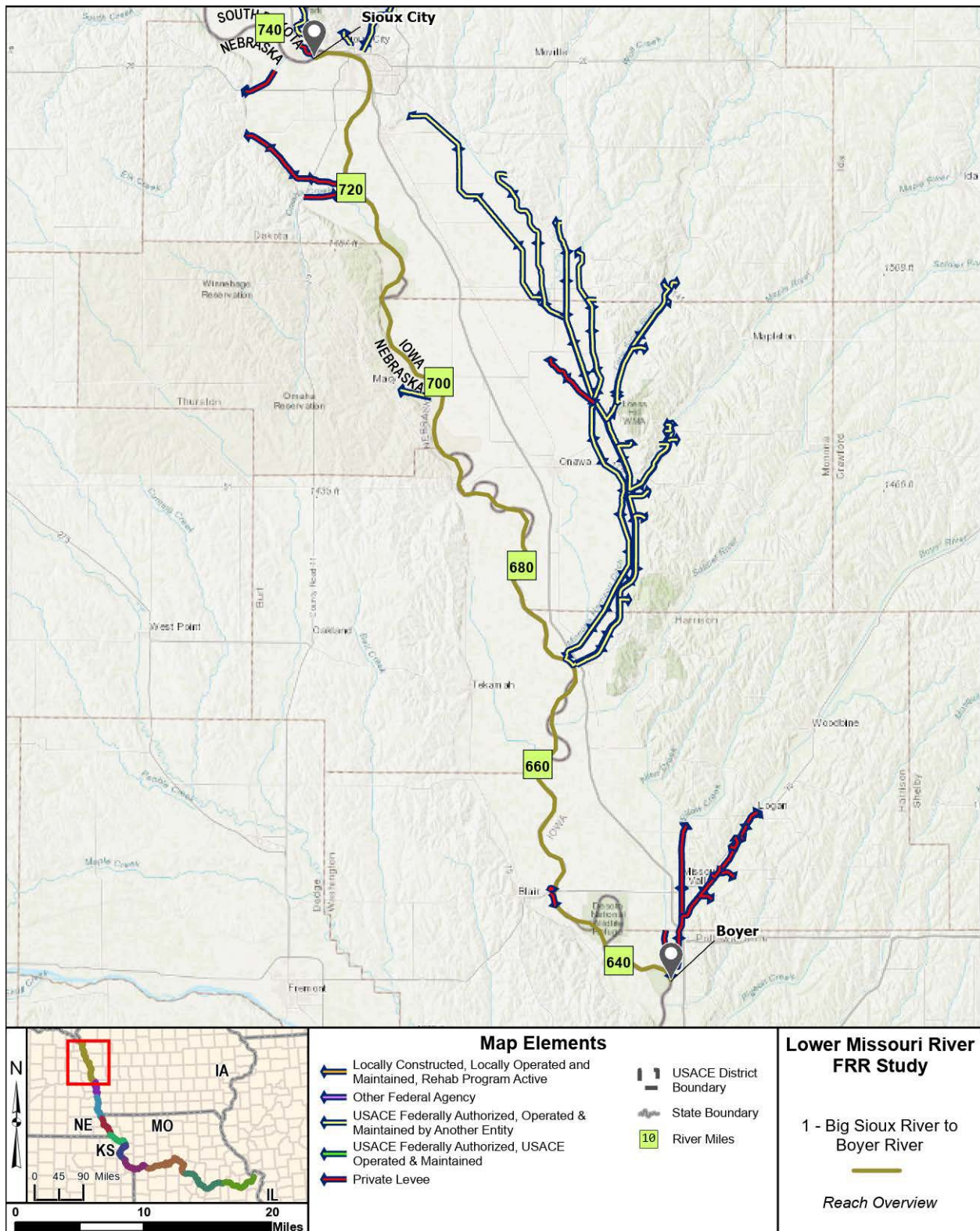
Figure 8: Lower Missouri River Study Reach Map



3.2.1 Study Reach 1 - Big Sioux River to Boyer River (RM 734-635)

The reach of the Missouri River between the Big Sioux River and the Boyer River has relatively few federal levees compared to the other reaches on the Lower Missouri River. This reach extends from Missouri River mile 734 - 635. The only federal levees near the Missouri River in this segment include those along the tributaries of Perry Creek, Floyd River, Little Sioux, and Blackbird Creek. There are no federal levees on the mainstem of the Missouri River. Figure 9 shows the extent of Reach 1.

Figure 9: Map of Reach 1



Hydraulic Characteristics

Historic peak flows have been recorded in this reach from two USGS gages: Missouri River at Sioux City, IA (USGS 06486000) and Missouri River at Decatur, NE (USGS 06601200). The peak flow and stage occurred in 1952 at the Sioux City gage, and in 2011 at the Decatur gage. The peak flows were 441,000 and 191,000 cfs, respectively. Data before 1988 is not available at the Decatur Station. Peak flows for the Sioux City gage are in Table 3-1 and peak flows for the Decatur gage are in Table 3-2.

Table 3-1: USGS Gage 06486000 Missouri River at Sioux City, IA - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (feet)
1952	441,000	44.382
1960	101,000	30.622
1967	37,100	25.032
1984	104,000	31.012
1993	72,200	27.432
1997	100,000	25.592
2007	42,100	18.682
2010	86,600	25.592
2011	192,000	35.342
2018	93,300	25.69
2019	159,000	29.78

Table 3-2: USGS Gage 06601200 Missouri River at Decatur, NE - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (feet)
1993	76,400	32.096
1997	100,000	31.896
2007	46,800	25.286
2010	80,600	31.326
2011	191,000	39.936
2018	91,900	32.18
2019	152,000	36.51

Authorized design capacities with the AEP for toe and overtopping loads are summarized in Table 3-3. Additionally, the original design capacity and top capacity are given. The original design capacities for this reach are based off the tributaries feeding into the Missouri mainstem. The loading for prior flood events is summarized in Table 3-4. Gages referenced for the levee systems are in Table 3-5.

Table 3-3: Design Capacities From O&M for Study Reach 1

Levee System	Toe AEP	Overtopping AEP	Authorized Capacity	Original Design Capacity
Perry Creek RB	0.03	0.002	0.01	16,000 cfs with no freeboard
Perry Creek LB	0.01	0.002	0.01	16,000 cfs with no freeboard
Floyd River RB	0.1	0.005	0.01	Design Discharge: 71,500 cfs Design Top Capacity: 85,000 cfs
Floyd River LB	0.1	0.005	0.01	Design Discharge: 71,500 cfs Design Top Capacity: 85,000 cfs
Blackbird Creek RB	0.33	0.01	0.02	14,000 cfs with 2ft freeboard
Blackbird Creek LB	0.33	0.01	0.02	14,000 cfs with 2ft freeboard

Table 3-4: Loading History for Study Reach 1

Levee System	Construction	1952	1984	1993	2007	2010	2011	2019
Perry Creek RB	Federal	Not Constructed	Not Constructed	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded
Perry Creek LB	Federal	Not Constructed	Not Constructed	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded
Floyd River RB	Federal	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded
Floyd River LB	Federal	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded
Blackbird Creek RB	Federal	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded
Blackbird Creek LB	Federal	Not Constructed	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded	Not Loaded

Page intentionally left blank.

Table 3-5: Reference Gages and Studies for Reach 1

Levee System	Reference Gages and Studies
Perry Creek LB/RB	38th Street gaging Station - Sioux City
Floyd River RB/LB	USGS gage at James, Iowa on the Floyd River
Blackbird Creek RB/LB	Gage from Homer, NE in the Logan-Omaha Creek Basin

Federal Levees Past Performance

The federal levees in this reach are not on the mainstem of the Missouri River. They were no performance issues noted in 2011 or 2019.

Non-Federal Levees Past Performance

There are no non-federal levees in this reach that are active in the Rehabilitation Program.

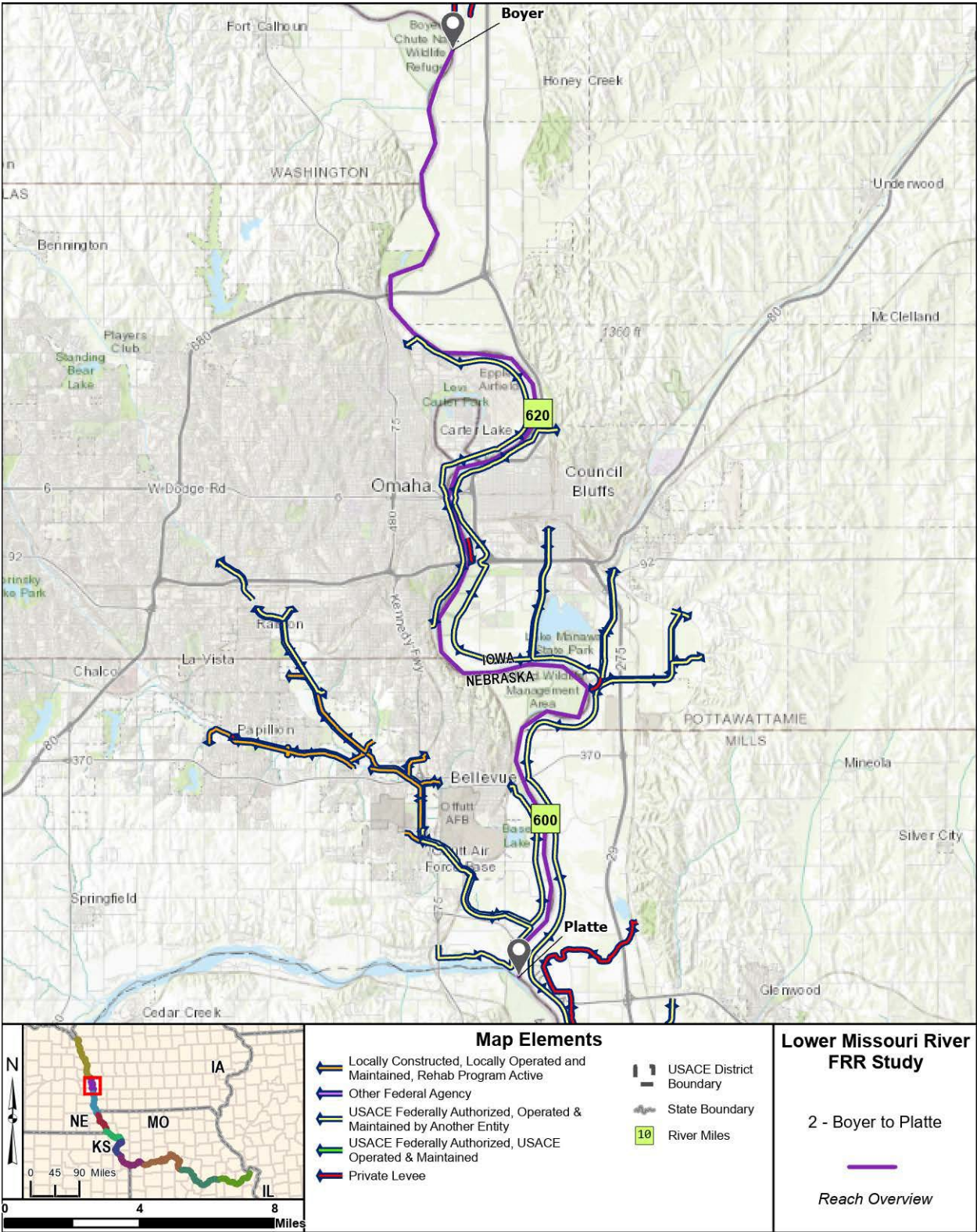
Economics

During the 2019 and 2011 flooding events, there were no active federal or non-federal levees repaired through the Rehabilitation Program.

3.2.2 Study Reach 2 - Boyer River to Platte River (RM 635-595)

The reach of the Missouri River between the Boyer River and Platte River extends from Missouri River mile 635 - 595. A map of Reach 2 is shown in Figure 10 below. This reach of the Missouri River contains more federal levees than Reach 1, and several of these levees protect significant population centers such as downtown Omaha, Nebraska and Council Bluffs, Iowa. The levees protecting these major population centers performed as designed during the 2011 and 2019 flooding events, however they were at least partially damaged and required repairs.

Figure 10: Map of Reach 2



Hydraulic Characteristics

This reach is monitored by the USGS gage 06610000 Missouri River at Omaha. The peak flow and stage occurred in 1952 with a discharge of 396,000 cfs and a stage of 39.83 ft. Additional historical floods occurred in 1960, 1967, 1984, 1993, 1997, 2007, 2010, 2011, 2018, and 2019. The peak flows and stages for these years are summarized in Table 3-6.

Table 3-6: USGS Gage 06610000 Missouri River at Omaha, NE - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	396,000	39.863
1960	120,000	26.473
1967	68,400	23.693
1984	116,000	28.683
1993	115,000	29.923
1997	110,000	26.023
2007	86,100	26.183
2010	103,000	27.263
2011	217,000	35.953
2018	114,000	28.66
2019	189,000	34.1

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-7. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-8. Gages referenced for the levee systems are in Table 3-9.

Table 3-7: NLD Data for Reach 2

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Right	Federal	618.5	4705000082	Omaha - Missouri River RB	12.2	9.8	0.0005	8375	3320
Left	Federal	614	4705000037	L-627 MO River LB & Indian Creek RB	14.9	15.1	0.001	29357	10580
Left	Federal	607	4705000036	L-624 MoRiv LB & Indian LB & Mosquito Creek RB	8.9	7.5	0.001	6305	2142
Left	Federal	606	4705000034	L-624-627-611-614 - Mosquito Cr & Upper Pony Cr	7.4	4.7	0.1	102	94
Left	Federal	598.5	4705000033	L-611-614-MoRiv LB & Upr Pony Creek LB & L1B LB	21.1	37.1	0.002	398	409
Right	Federal	598.5	4705000093	R-616-613 - MO Riv RB & Papillion Cr LB	9.7	7.0	0.005	1532	540
Right	Federal	595.5	4705000090	R-613 - Platte LB & Papillion RB & MO River RB	9.0	3.5	0.01	593	136

Table 3-8: Loading History for Study Reach 2

Levee System	Construction	1952	1984	1993	2007	2010	2011	2019
Omaha - Missouri River RB	Federal	Loaded. Did Not Breach	No Info	No Info	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
L-627 MO River LB and Indian Creek RB	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
L-624 MO River, Indian LB, Mosquito Creek RB	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
L-624-627-611-614 – Mosquito Cr & Upper Pony Cr	Federal	Not Constructed	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
L-611-614 MO River LB, Upper Pony Creek LB, L1B LB	Federal	Not Constructed	Not Constructed	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Overtopped then Breached
R-616-613 MO River RB, Papillion Creek LB	Federal	Not Constructed	Not Constructed	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Overtopped. No Breach
R-613 MO River RB, Platte LB, Papillion RB	Federal	Not Constructed	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Overtopped then Breached

Table 3-9: Reference Gages and Studies for Reach 2

Levee Systems	Reference Gages and Studies
Omaha - Missouri River RB	2003 Upper Mississippi Flow Frequency Study and USGS Gage Missouri River at Omaha
L-627 MO River LB and Indian Creek RB	2003 Upper Mississippi Flow Frequency Study
L-624 MO River, Indian LB, Mosquito Creek RB	2003 Upper Mississippi Flow Frequency Study
L-624-627-611-614 L-624-627 L-611-614	2003 Upper Mississippi Flow Frequency Study and USACE gaging station on Mosquito Creek
L-624-627	2003 Upper Mississippi Flow Frequency Study and USACE gaging station on Mosquito Creek
L-611-614 MO River LB, Upper Pony Creek LB, L1B LB	2003 Upper Mississippi Flow Frequency Study and USACE gaging station on Mosquito Creek and 2013 FIS
R-616-613 MO River RB, Papillion Creek LB	2003 Upper Mississippi Flow Frequency Study and USGS Gage Missouri River at Omaha
R-613 MO River RB, Platte LB, Papillion RB	2003 Upper Mississippi Flow Frequency Study, Papillion Creek at Fort Crook Gage, and Missouri River at Omaha

Federal Levees Past Performance

Several of the levees in this reach have experienced significant damages because of flooding on the Missouri River. The levees on the right bank reduce the flood risk for much of the Omaha area, and the levees on the left bank at Council Bluffs area reduce flooding risk within their leveed area. Damages to these levees have been repaired through the Rehabilitation Program. Levees to the south of the Omaha and Council Bluffs were more seriously damaged, in some cases resulting in flooding within the leveed areas. Notably in 2019, there was flooding at Offutt Air Force Base in Bellevue, NE that resulted in the temporary closure of several facilities on the Air Force Base.

Non-Federal Levees Past Performance

There are no active non-federal levees on the Missouri River in this reach but there are several privately owned levees, most notably to the north of the Omaha and Council Bluffs areas. Several of the levees in this reach have experienced significant damages because of flooding on the Missouri River but the USACE has no record of their performance and repair costs.

Economics

The cumulative cost for repairing the federal levees within Reach 2 is \$321,837,000 (FY2024 Dollars). The benefits provided by the federal levees in this study area reach

are notable. The Omaha – MO River RB Levee provides flood risk management for more than 3,000 buildings worth an estimated \$1.6 Billion from flooding on the Missouri River. This levee did not fail during the 2011 or 2019 flooding events; however, it was damaged and required repairs. On the opposite side of the Missouri River, L-627 MO River LB & Indian Creek RB Levee is notable as well. It provides flood risk management for more than 10,000 buildings worth an estimated \$3 Billion from flooding events on the Missouri River. This levee did not fail during the 2011 or 2019 flooding events; however, it was damaged and required repairs.

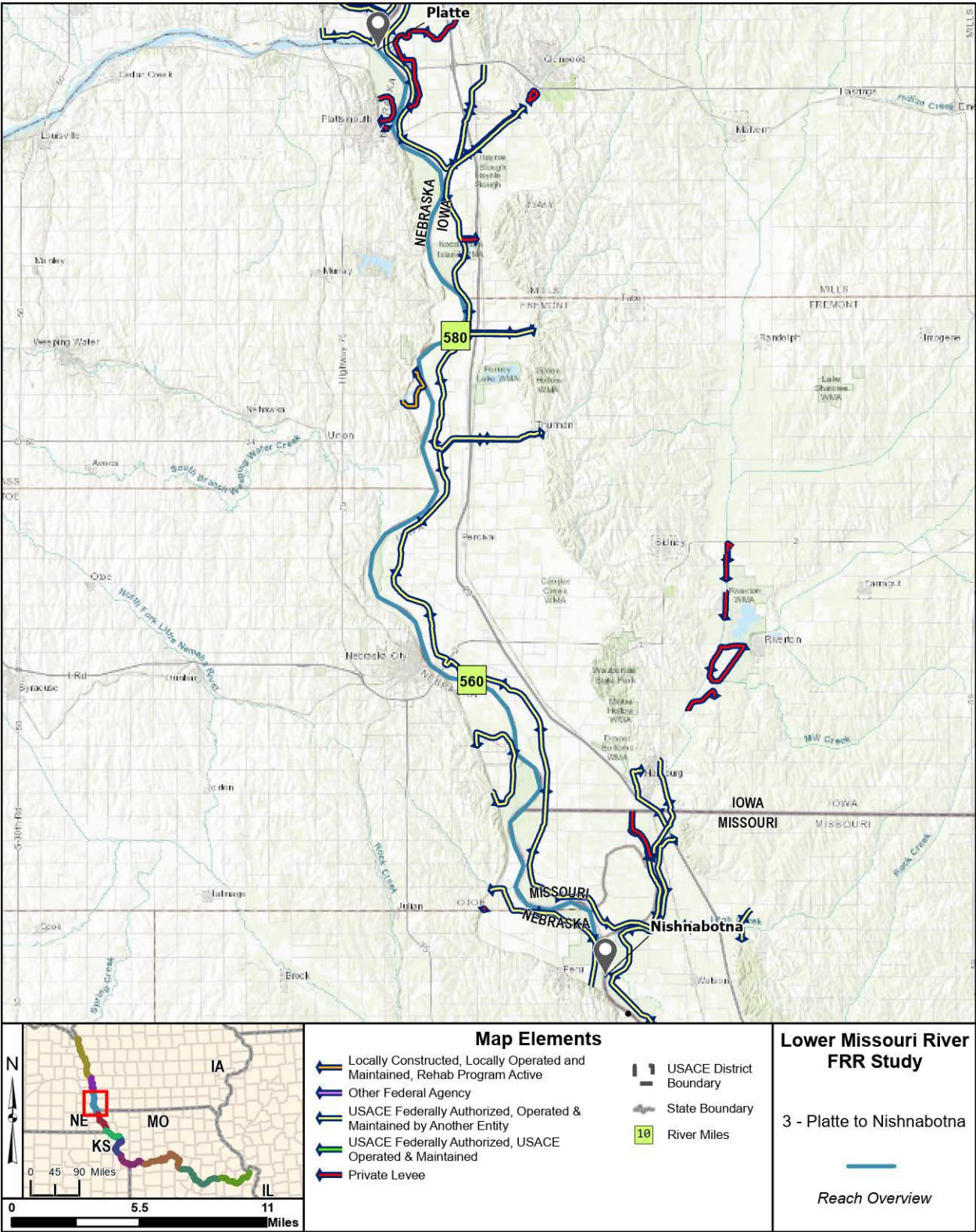
Other flooding impacts

As mentioned in Section 3.2.2.2, Offutt Air Force Base was affected by flooding behind the R-616-613 MO River RB & Papillion Creek LB Levee. Because this federal levee overtopped, the flood waters affected 137 base facilities, 1.2 million square feet of workspace and displacing 3,200 personnel. The recovery efforts resulted in an Offutt Flood Rebuild Program that has continued to work through a multiyear - multiphase plan to rebuild the facilities.

3.2.3 Study Reach 3 - Platte River to Nishnabotna River (RM 595-542)

The reach of the Missouri River between the Platte River and the Nishnabotna River extends from river mile 595 – 542. This reach experienced significant damages from both the 2019 and 2011 flooding events. The damages included scouring, overtopping, and slope failure that led to inundation of the leveed area for several federal levees. A map of Reach 3 is shown in Figure 11.

Figure 11: Map of Reach 3



Hydraulic Characteristics

This reach is monitored by the USGS gage 06807000 Missouri River at Nebraska City. The peak flow and stage occurred in 1952 with a discharge of 414,000 cfs and a stage of 23.16 ft. Additional historical floods occurred in 1960, 1967, 1984, 1993, 1997, 2007, 2010, 2011, 2018, and 2019. The peak flows and stages for these years are summarized in Table 3-10.

Table 3-10: USGS Gage 06807000 Missouri River at Nebraska City, NE - Peak Flows

Year	Peak Flow (cfs)	Peak Stage, (ft)
1952	414,000	23.164
1960	178,000	20.114
1967	166,000	23.054
1984	182,000	24.884
1993	196,000	27.294
1997	113,000	21.164
2007	122,000	21.644
2010	168,000	25.044
2011	229,000	25.344
2018	140,000	23.3
2019	342,000	30.12

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-11. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-12. Gages are referenced for the levee systems in Table 3-13.

Page intentionally left blank.

Table 3-11: NLD Data for Study Reach 3

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	Federal	588	4705000032	L-601 - Watkins Ditch RB - Watkins DD	3.3	4.3	0.002	557	302
Left	Federal	584	4705000031	L-594-601	14.5	22.3	0.05	155	119
Right	non-Federal	578	4705000121	Lake Waconda - Missouri River RB (NF)	2.5	0.6	0.005	540	206
Left	Federal	577	4705000029	L-594-575 (BW-PV-Waubonsie)	12.8	15.9	0.05	144	90
Left	Federal	559	4705000030	L-575 (BW-McKissock-Buchanan-Atchison-Hamburg)	41.8	109.8	0.05	984	916
Right	Federal	554.5	4705000095	R-573 - Missouri River RB	5.9	3.3	0.005	124	4
Right	Federal	544	4705000089	R-562 - Peru - Missouri River RB	7.5	10.6	0.01	30	14
Left	Federal	544	4705000042	L-561 - Nishnabotna LB	8.7	8.1	0.05	8	23

Table 3-12: Loading History for Study Reach 3

Levee System	Construction	1952	1984	1993	2007	2010	2011	2019
L-601 Watkins Ditch RB, Watkins DD	Federal	Not Constructed	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Overtopped. No Breach
L-594-601	Federal	Not Constructed	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Overtopped then Breached
L-594-575 BW-PV-Waubonsie	Federal	Not Constructed	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Breached x5
L-575 BW-McKissock-Buchanan-Atchison-Hamburg	Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Breached	Breached x7
R-573 MO River RB	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach
R-562 MO River RB	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (3x)	No Info	No Info	Overtopped. No Breach	Overtopped then Breached (x10)
L-561 Nishnabotna LB & High Creek RB	Federal	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach	No Info	Overtopped. No Breach

Table 3-13: Reference Gages and Studies for Reach 3

Levee System	Reference Gages and Studies
L-601 Watkins Ditch RB, Watkins DD	USGS Gage Missouri River at Nebraska City
L-594-601	USGS Gage Missouri River at Nebraska City and the 2003 Upper Mississippi Flow Frequency Study
L-594-575 BW-PV-Waubonsie	USGS Gage Missouri River at Nebraska City and the 2003 Upper Mississippi Flow Frequency Study
L-575 BW-McKissock-Buchanan-Atchison-Hamburg	Flood Frequency Analysis program and the USGS Gage above Hamburg
R-573 MO River RB	USGS Gage Missouri River at Nebraska City and the 2003 Upper Mississippi Flow Frequency Study
R-562 MO River RB	USGS Brownville gage and the 2003 Upper Mississippi Flow Frequency Study
L-561 Nishnabotna LB & High Creek RB	2010-2014 Section 22 Study on the Nish and the USGS Gage on the Nish above Hamburg

Federal Levees Past Performance

Several of the federal levees within this reach failed and inundated the leveed areas during the 2011 and 2019 flooding events. Most notably L-575 (in both Fremont County, IA and Atchison County, MO), that reduces flood risk to the town of Hamburg overtopped then breached in 2011 and breached seven times in 2019. It filled with water leading to extensive damages in the town of Hamburg and to I-29 that runs north-south through the leveed area. The other main federal levee in this reach is L-594-575 (BW-PV-Waubonsie) that provides flood risk management benefits mainly to agricultural land and Interstate I-29.

Non-Federal Levees Past Performance

There are no non-federal levees in this reach.

Economics

The cumulative cost for repairing the federal levees within Reach 3 is approximately \$598,411,000 (FY2024 Dollars). The benefits provided by the federal levees in this reach are mainly to rural areas and small towns, as well as extensive agricultural land. Key economic impacts in this area have been the detour and delay costs associated with Interstate I-29 closure. When these federal levees failed in 2011 and 2019, traffic had to be rerouted through State Highway 75 in Nebraska, which is a two-lane highway, unlike Interstate I-29 which is a four-lane highway. Thus, travelers would have to take extra time to reroute through Eastern Nebraska moving at slower speeds. These detour and delays costs led to disruptions to the National Economic Development.

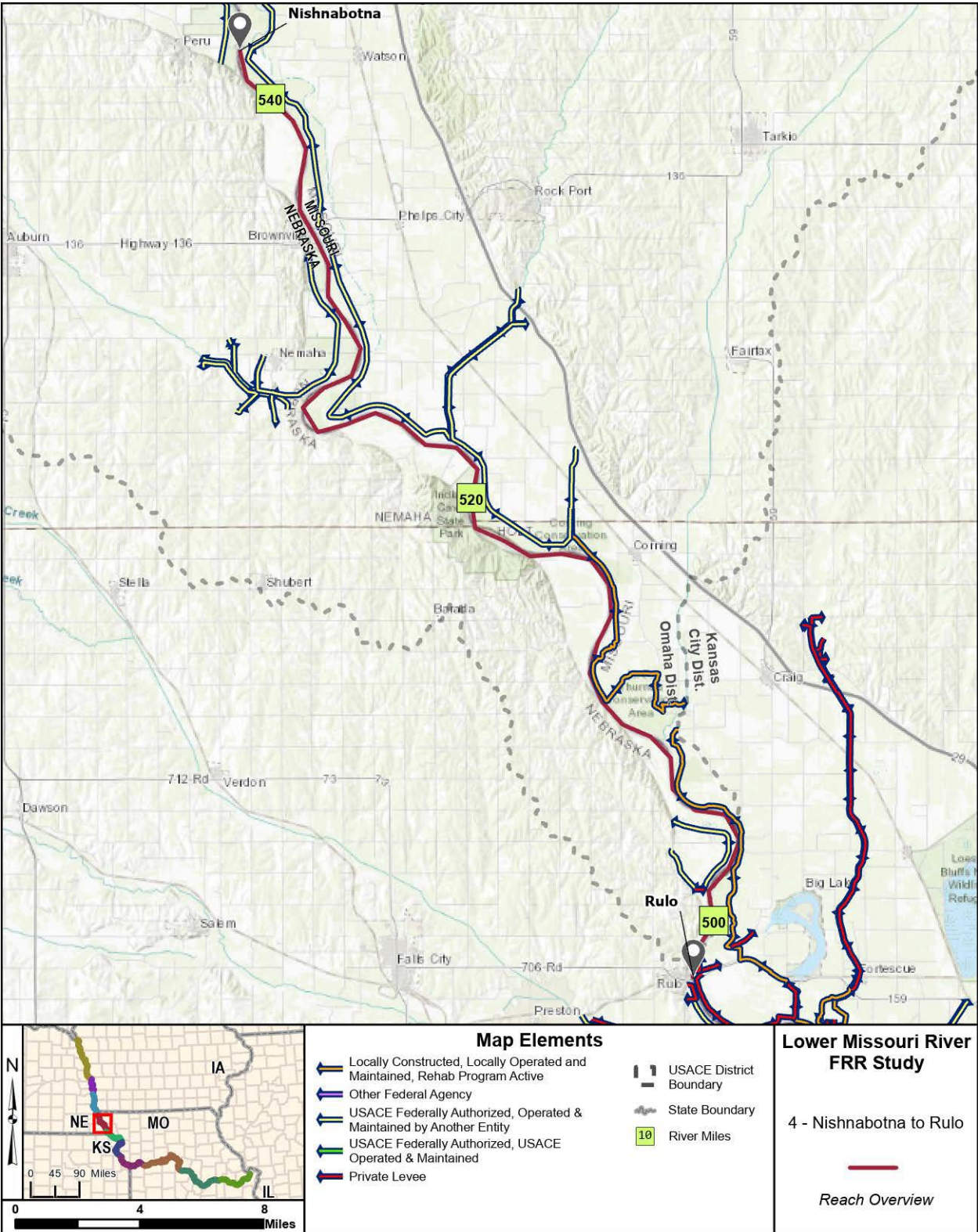
Other flooding impacts

Because of the flooding within these leveed areas and the subsequent closure of Interstate I-29, Nebraska State Highway 75 saw a significant increase in traffic. This increase in traffic lead to more wear and tear on the State Highway. Furthermore, because this is a two-lane highway and passing is permitted, there was an increased safety risk due to of higher rates of truck traffic.

3.2.4 Study Reach 4 - Nishnabotna River to Rulo (RM 542-498)

Reach 4 extends from Missouri River mile 542 to 498. From the Nishnabotna River to Rulo, Nebraska, there are only four federal levees along the main stem. A map of Reach 4 is shown in Figure 12.

Figure 12: Map of Reach 4



Hydraulic Characteristics

This reach is monitored by the USGS gage 06813500 Missouri River at Rulo, NE. The peak flow and stage occurred in 1952 with a discharge of 358,000 cfs and a stage of 24.89 ft. Additional historical floods occurred in 1960, 1967, 1984, 1993, 1997, 2007, 2010, 2011, 2018, and 2019. The peak flows and stages for these years are summarized in Table 3-14.

Table 3-14: USGS Gage 06813500 Missouri River at Rulo, NE - Peak Flows

Year	Peak Flow (cfs)	Peak Stage, (ft)
1952	358,000	24.89
1960	181,000	21.65
1967	151,000	21.7
1984	242,000	23.69
1993	307,000	24.66
1997	123,000	20.02
2007	245,000	24.38
2010	216,000	25.9
2011	328,000	26.55
2018	138,000	22.75
2019	339,000	28.12

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-15. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-16. Gages referenced for the levee systems are in Table 3-17.

Page intentionally left blank.

Table 3-15: NLD Data for Study Reach 4

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	Federal	533	4705000041	L-550-561 - Missouri River LB	31.8	61.7	0.1	313	309
Right	Federal	531.5	4705000083	R-548 - Missouri River & Little Nemaha	7.2	4.4	0.05	216	27
Right	Federal	528	4705000087	R-548 LN - Little Nemaha LB & Moores RB	2.9	0.7	0.05	0	0
Right	Federal	528	4705000088	R-548 LN - Little Nemaha LB & Happy Hollow RB	2.2	0.5	0.05	0	0
Right	Federal	528	4705000084	R-548 LN - Little Nemaha RB & Jarvis Creek LB	3.3	0.6	0.05	0	0
Right	Federal	528	4705000086	R-548 LN - Little Nemaha RB & Whiskey Run LB	1.6	0.4	0.05	2	5
Right	Federal	528	4705000085	R-548 LN - Little Nemaha RB & Whiskey Run RB	1.7	0.2	0.01	0	0
Left	Federal	519	4705000040	L-536-550 Turkey Crk LB, Rock Crk LB, Mo Riv LB, & Mill Crk RB	11.8	20.2	0.05	33	106

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	non-Federal	512	3605000226	Corning	11.4	10.9	No Data	22	20
Right	Federal	502	4705000092	R-520 - Missouri River RB	5.6	2.6	0.005	0	0
Left	non-Federal	500	3605000017	Union Township Holt County Number 10	13.8	27.2	0.1	257	482

Table 3-16: Loading History for Study Reach 4

Levee System	Construction	1952	1984	1993	2007	2010	2011	2019
L-550-561 MO River LB	Federal	Overtopped then Breached	Loaded. Did Not Breach	Breached	No info	Loaded. Did Not Breach	Overtopped then Breached	Overtopped then Breached (x4)
R-548 MO River and Little Nemaha	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped . No Breach	No info	No info	Loaded. Did Not Breach	Overtopped. No Breach
R-548 LN, Little Nemaha RB, Whiskey Run RB	Federal	No Info	Loaded. Did Not Breach	Overtopped . No Breach	No info	No info	Loaded. Did Not Breach	Overtopped. No Breach
L-536-550	Federal	Overtopped then Breached	Loaded. Did Not Breach	Overtopped . No Breach	No Info	Loaded. Did Not Breach	Overtopped. No Breach	Breach x5 and Section loss x2
R-520 MO River RB	Federal	Not constructed	Loaded. Did Not Breach	Overtopped . No Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
Corning	Non-Federal	No Info	No Info	No Info	No Info	Overtopped No Breach	Breached	Overtopped then Breached
Holt County No.10	Non-Federal	No Info	No Info	Overtopped then Breached	Overtopped then Breached (1x)	Overtopped then Breached (1x)	Overtopped then Breached (10x)	Overtopped then Breached
Union Township	Non-Federal	No Info	No Info	Overtopped . No Breach	Overtopped. No Breach	Overtopped then Breached	Overtopped then Breached (9x)	Overtopped then Breached (6x)

Page intentionally left blank

Table 3-17: Reference Gages and Studies for Reach 4

Levee System	Reference Gages and Studies
L-550-561 MO River LB	USGS Gage Missouri River at Nebraska City and the 2003 Upper Mississippi Flow Frequency Study
R-548 MO River and Little Nemaha	2003 Upper Mississippi Flow Frequency Study and Stream Gage on the Missouri River at Brownville, NE
R-548 LN, Little Nemaha RB, Whiskey Run RB	2003 Upper Mississippi Flow Frequency Study and Stream Gage on the Missouri River at Brownville, NE
L-536-550	2003 Upper Mississippi Flow Frequency Study and Stream Gage on the Missouri River at Brownville, NE 1949 Supplemental Report Unit L-550 and the USGS Gage Missouri River at Brownville
R-520	2003 Upper Mississippi Flow Frequency Study and Stream Gage on the Missouri River at Rulo

Federal Levees Past Performance

Following the floods of 2011 and 2019 there were several levee failures that lead to flooding within the leveed areas. For this study reach, the most notable failure was the federal levee L-550-561 that provides flood risk reduction for the towns of Phelps City, Langdon, and Watson, MO. The levee also reduces flood risk for Interstate I-29. Most recently during the 2019 flooding event, L-550-561 breached and the leveed area was inundated. In 2019 L-536 also breached. There were five full breaches and two partial breaches and a large-scale setback was determined to be the least cost, technically feasible rehabilitation alternative. Approximately 4.1 miles at the downstream end of L-536 levee segment was setback.

Non-Federal Levees Past Performance

There are two active non-federal levees, Corning and Union Township Holt County Number 10, located in this reach. These are both on the left bank. Corning is just north of Rulo. Union Township Holt County 10 runs through Rulo. Both systems are active in the Kansas City District's Rehabilitation Program. Their performance and repair costs are discussed with the non-federal levees in Reach 5.

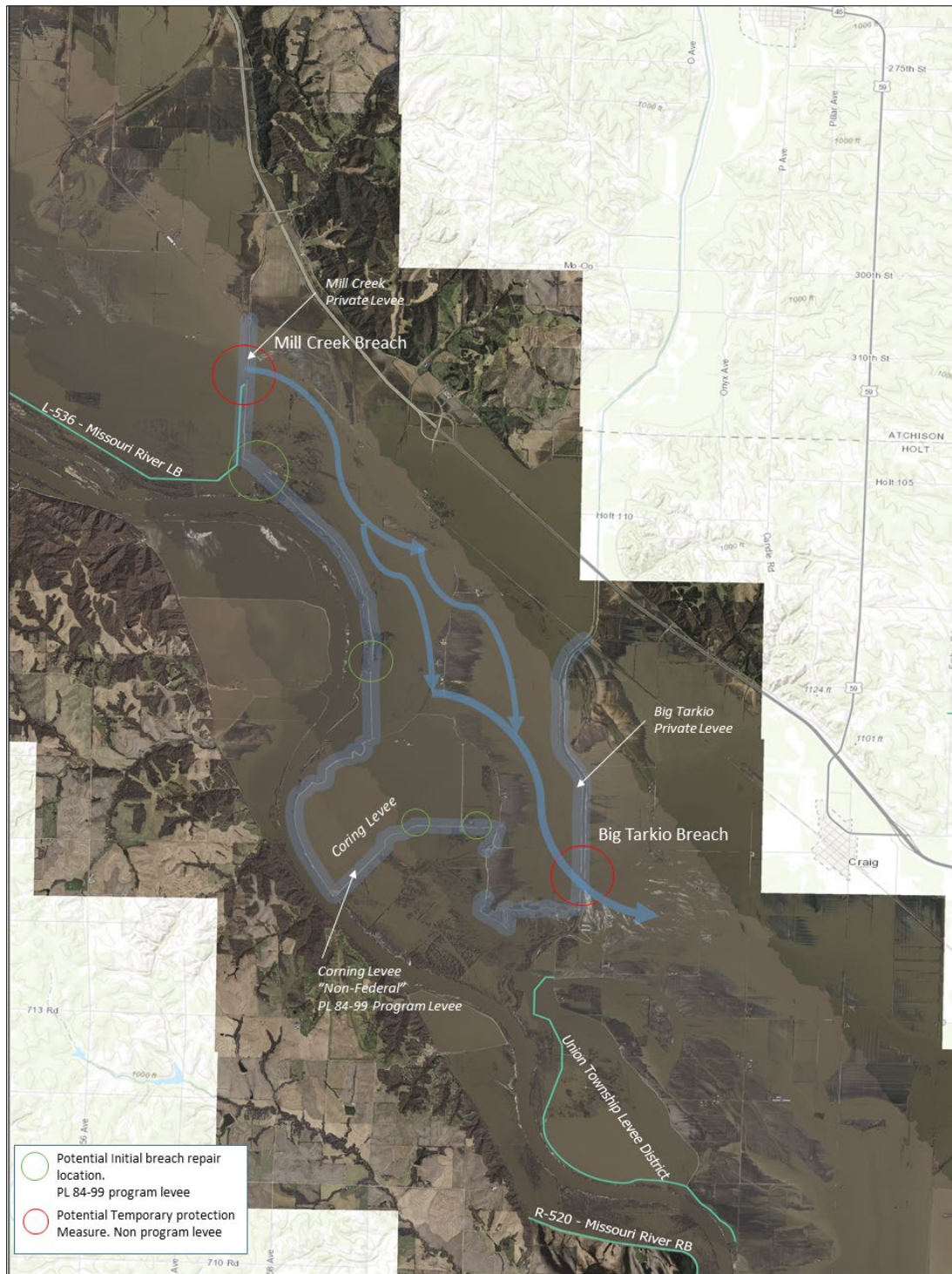
Economics

The cumulative cost for repair from the 2011 and 2019 floods is approximately \$412,908,000 (FY2024 Dollars). The most significant damages were to L-550-561, L-536 and R-520.

Other flooding impacts

The non-federal levees in this reach have a 0.02 to 0.05 AEP. Since these levees all breached from the initial March 2019 event and runoff remained high from the upper basin, breach repairs could not begin until late 2019 or 2020. In addition, the upstream and downstream breaches of the Mill Creek and Big Tarkio tiebacks on the Corning levee allowed the river to flow through much of the floodplain in Holt County throughout the majority of 2019. Figure 13 shows the rivers path through the breaches and proposed plans to close breaches in July.

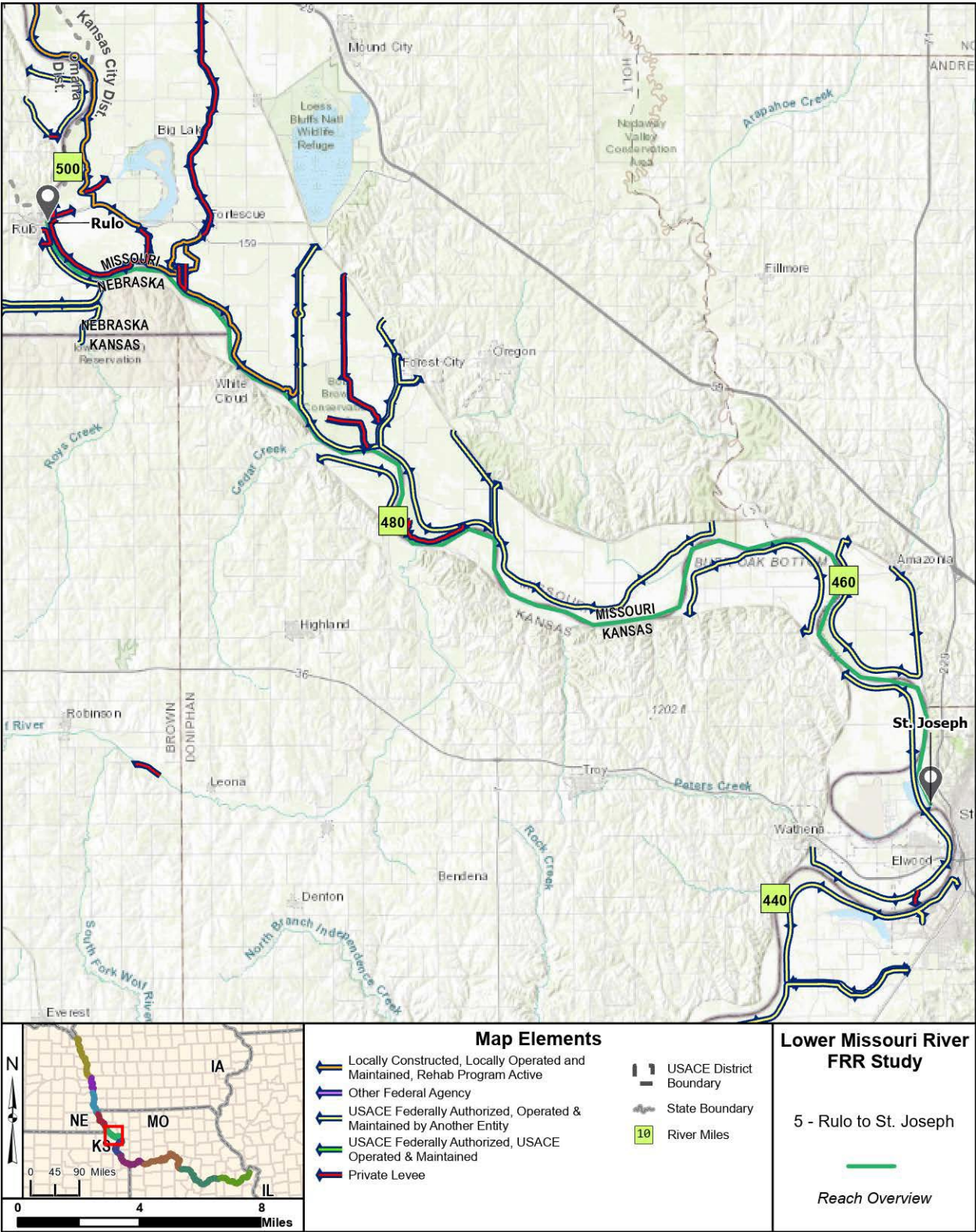
Figure 13 July 2019 Plan to Close Breaches on Mill Creek and Big Tarkio Private Levees



3.2.5 Study Reach 5 - Rulo, NE to St. Joseph, MO (RM 498-450)

This is the first reach completely within the Kansas City District's AOR. The Rulo, NE to St. Joseph, MO reach extends from Missouri River mile 498 - 450. Except for Holt County, most of this reach consists of federally constructed levees. Federal levees include Missouri River Levee Systems (MRLS) 512-513-R, 500-R, 497-L, 488-L, 482-R, 476-L, and 471-460-R as well as the Kimsey Holly federal levee segment that ties into the Canon non-federal levee. Two of these units, 512-513-R and 497-L are further broken into multiple levee systems with separate leveed areas. This reach includes three non-federal levee systems, with four total segments, that are active in the Rehabilitation Program. The non-federal levee segments are Union Township, Holt County 10, Holt County 9, and Canon. Much of the leveed areas behind these federal and non-federal levees is agricultural with scattered rural residences. The leveed area of 471-460-R includes the town of Elwood, KS, and a small portion of land that is in the State of Missouri. Rosecrans Missouri Air National Guard Base sits on the Missouri portion of land. A map of Reach 5 is shown in Figure 14.

Figure 14: Map of Reach 5



Hydraulic Characteristics

Historic peak flows have been recorded within this reach at the USGS Gage 06813500 Missouri River at Rulo, Nebraska USGS gage. The largest recorded flow was in April of 1952 with a peak flow of 358,000 cfs. Other historic peak flows events include 1993, 2007, 2010, 2011, and 2019. These peak flows are ranked by magnitude in Table 3-18. Private levees adjacent to the streamgage were built iteratively over time. The 1981 USACE floodplain report shows very small levees in this area in different locations than the current levees. The current levees were iteratively raised and/or realigned or repaired in response to floods to include 1984, 1993, 2007, 2010, 2011, and 2019. In large floods like 2019, about half of the water flows through the primary railroad and highway bridge openings between the levee and bluffs at the Rulo gage, the remainder through the overbank in the vicinity of Big Lake, MO where a second bridge opening through the railroad embankment is situated. The railroad constructed four additional smaller bridges during the 2011 flood throughout this overbank area. The private levee improvements and repairs have resulted in stages that rise over time for the same flow, however, once the levees overtop or breach, the gage rating curves show very little elevation difference between a flow of about 160,000 cfs and flows exceeding 300,000 cfs due to the very wide floodplain.

Table 3-18: USGS Gage 06813500 Missouri River at Rulo, NE - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	358,000	25.60
2019	339,000	28.12
2011	328,000	27.26
1993	307,000	25.37
2007	245,000	25.09
1984*	242,000	24.40
2010	216,000	26.61

*Event motivated private levee construction near the Rulo gage in Holt County, MO

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-19. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-20.

Table 3-19: NLD Data for Study Reach 5

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Right	Federal	496.5	3605000009	MRLS 512-513-R N	11.7	5.7	0.001	12	18
Left	non-Federal	489	3605000133	Holt County Levee District No. 9	13.5	12.4	0.02	20	49
Left	non-Federal/ Federal	484.5	3605000129	Canon Drainage District and Kimsey Holly Creek	13.7	15.5	0.02	4	44
Right	Federal	482	3605000138	MRLS 500-R	4.1	2.3	0.005	0	0
Left	Federal	483	3605000218	MRLS 497-L(1)	1.6	0.3	0.002	0	38
Left	Federal	479.5	3605000140	MRLS 497-L(2)	15.3	10.2	0.002	22	48
Left	Federal	470.5	3605000079	MRLS 488-L (Holt County District No. 7)	11.5	13.9	0.002	10	62
Right	Federal	463.5	3605000094	MRLS 482-R	8.3	7.5	0.002	7	36
Left	Federal	457.5	3605000139	MRLS 476-L	10.7	8.6	0.001	69	98
Right	Federal	449.5	3605000022	MRLS 471-460-R	13.8	20.6	0.005	2773	797

Numbers in Red have been adjusted from what is in the NLD

Table 3-20: Loading History for Study Reach 5

Levee Segment	Levee Construction	1993	2007	2010	2011	2019
Holt Co. No. 9	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (7x)	Overtopped then Breached (6x)
Canon	Non-Federal	Overtopped then Breached (10x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (7x)	Overtopped then Breached (4x)
Kimsey-Holly	Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (1x)	Reverse Overtopping.
MRLS 512-513-R N	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 500-R	Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (3x)
MRLS 497-L (1)	Federal	Loaded. Did Not Breach	Not Loaded	Not Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 497-L (2)	Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 488-L	Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS-482-R	Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS-476-L	Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS-471-460-R	Federal	Overtopped then Breached (2x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach

Federal Levees Past Performance

The federal levees in this area were all designed and constructed in the 1940s and 1950s as part of the Pick-Sloan plan. None have ever breached prior to overtopping. MRLS 512-513-R, MRLS 497-L(1) and MRLS 476-L have never overtopped whereas the others all overtopped in 1993. At St. Joseph, the river crested at the same height in 2019 as it did in 1993. In 1993, MRLS 471-460-R was overtopped and breached, flooding the town of Elwood and Rosecrans Air National Guard Base. In 2019, it held with water loading the sandbags on top of the levee that were placed during a significant sand bagging effort by the community and the Missouri Air National Guard. A USACE project to raise this levee was authorized and funded just prior to the 2019 flood, but no portions of the levee had been raised at that time.

In 2019, MRLS 500-R was the only federal levee in this reach to overtop and breach. It was not predicted to overtop based on the March 20 evening forecast, but by sunrise on March 21st it was being overtopped over a significant portion of the levee. The Kimsey Holly federal levee did have water flow over the top from reverse overtopping in 2019 due to the breach of the Canon levee segment (non-federal) that flooded the leveed area. MRLS 497-L(1), 497-L(2) and 488 were all loaded to the very top.

Although the 2011 flood did not peak as high as 2019 or 1993, its duration of several months led to significant strain on these levee systems. Large flood fighting efforts and post flood repairs were needed on most of these levees. Animal burrowing activity can increase drastically as flood waters rise. MRLS 512-513-R had water almost to the top of levee with animal burrows causing significant seepage concerns. Flood fighting efforts were successful at controlling the seepage water and preventing breach. Sandbagging efforts were successful on MRLS 497-L and 488-L in preventing under seepage failure. MRLS 497-L and 488-L both required emergency rock placement, for approximately two weeks, to prevent erosion failure. On MRLS 488-L, the scour reached within five feet of the levee crest with a 75 percent load on the levee. Significant foreshores scour in several areas was identified after the water receded. MRLS 471-460-R required emergency under seepage berms and relief wells constructed during the flood repairs to prevent failure.

Non-Federal Levees Past Performance

The non-federal levees in Reach 5 overtop much more frequently than the federally constructed levees. All the non-federal levees in this reach overtopped and breached in 2011 and 2019. In 1993 they all overtopped, however Canon and Union Township segments did not breach. The Union Township-Holt County 10 levee system also overtopped and breached on both segments in 2010. The Union Township segment overtopped without breaching in 2007 while the Holt County 10 segment had one breach that was most likely from overtopping.

The Corning non-federal levee also overtopped and breached in several locations, including on the upstream tieback on Mill Creek and the downstream tieback on the Big Tarkio. An emergency contract to fill these breaches was awarded by USACE in July and was expected to take 10 weeks. Extended high water caused additional repair delays and closure was not made until early 2020.

Economics

From 1993 to 2022, the levees in Reach 5 (including Corning and Union Township Holt County 10) have incurred repair costs resulting from flood damage of \$97,941,000 (FY2024 dollars). Of the last 30 years, seven years (1993, 2007, 2010, 2011, 2015, 2017, 2019) have seen at least one levee in Reach 5 get significantly damaged.

Other flooding impacts

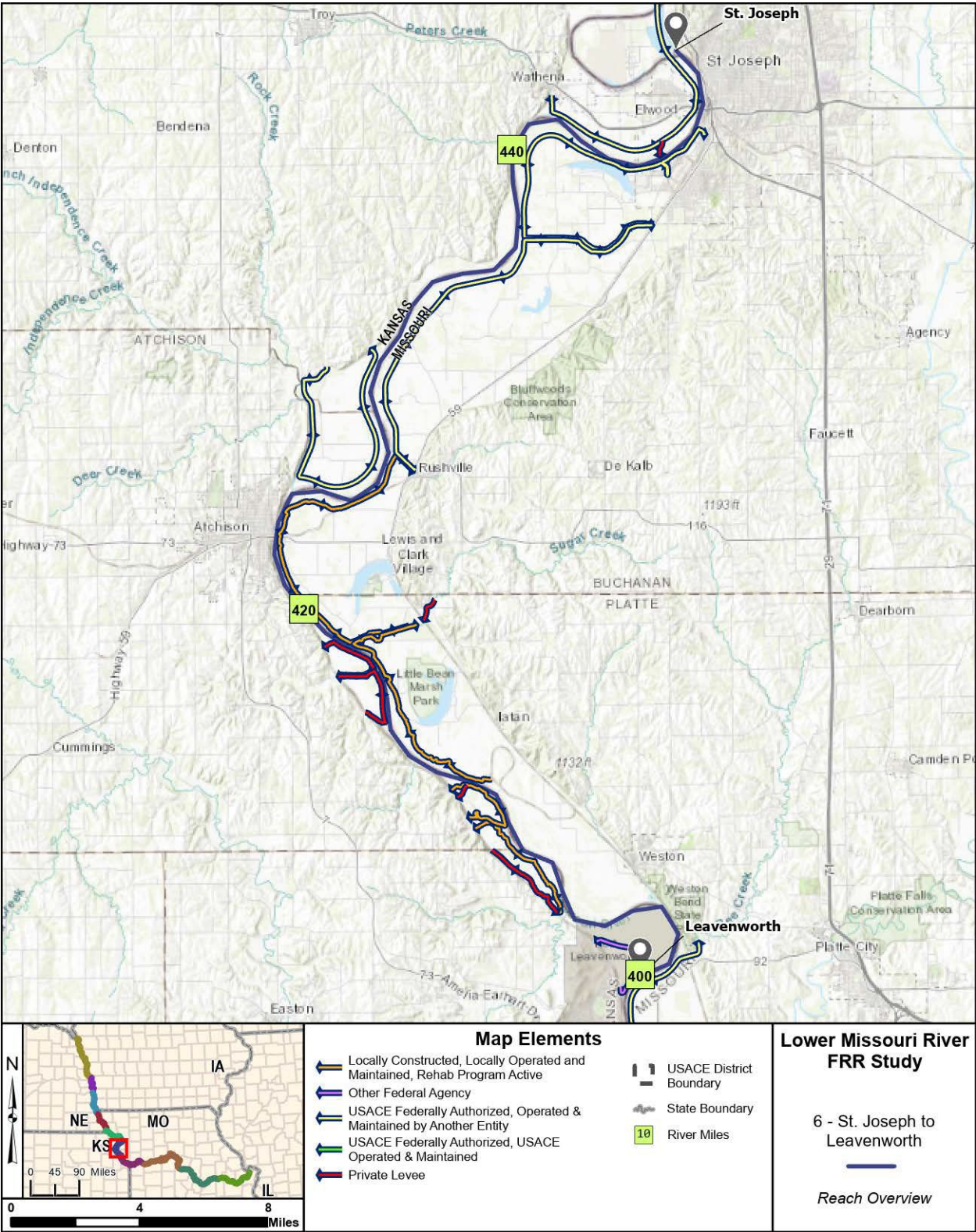
This reach is the most susceptible to flooding from the upper basin as St. Joseph acts a choke point. Downstream of St. Joseph there is more room for the river to spread out. The non-federal levees in this reach have a 0.02 to 0.05 AEP. Since these levees all breached from the initial March 2019 event and runoff remained high from the upper basin, breach repairs could not begin until late 2019 or 2020.

None of the federal levees in this reach were built with pumpstations to remove interior drainage. When river levels remain high, the leveed areas often fill with local precipitation that cannot exit the leveed area without sponsors pumping water up and over the levee with portable pumps or private pumpstations. Even when the levees perform as designed, there can still be significant flooding in the leveed area. Extended high river levels in 2011 and 2019 lead to significant pumping efforts for some sponsors and flooded leveed areas for others. As stated above, the leveed area of 471-460-R contains Rosecrans Missouri Air National Guard Base. In 1993, the base suffered millions of dollars in damages due to inundated buildings, planes and other aviation equipment.

3.2.6 Study Reach 6 - St. Joseph, MO to Leavenworth, KS (RM 450-400)

The St. Joseph, MO to Leavenworth, KS Reach extends from Missouri River mile 450 - 400. This reach includes three federal levee systems and four non-federal systems. The federal systems are MRLS-455-L, which provides flood risk management benefits to the city of St. Joseph, as well as MRLS 448-443-L and 440-R whose leveed areas are mainly agricultural. The non-federal levee systems are the Platte County Drainage District No 1 Section 1 (separated into the Rushville Sugar Lake and Platte County Section 1 segments), Platte County Section 2-Bean Lake (separated into the Platte County Section 2 and Bean Lake segments), Henry Pohl, and Grape-Bollin-Schwartz. Most of these leveed areas are agricultural, with the Platte County Drainage District No 1 Section 1 having the largest residential population. Figure 15 shows the levees in this reach.

Figure 15: Map of Reach 6



Hydraulic Characteristics

The USGS gage 06818300 Missouri River at Atchison, Kansas does not record flow, so peak historic flows are not available in this reach. Peak historic stages include 1952, 1993, 2007, 2010, 2011, and 2019. These peak stages are summarized in Table 3-21.

Table 3-21: USGS Gage 06818300 Missouri River at Atchison, KS - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	N/A	29.5
1993	N/A	31.63
2007	N/A	29.15
2010	N/A	29.83
2011	N/A	31.0
2019	N/A	31.2

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-22. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-23.

Table 3-22: NLD Data for Study Reach 6

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	Federal	442	3605000006	MRLS 455-L	15.6	12.1	0.002	1577	1463
Left	Federal	432.5	3605000024	MRLS 448-443-L	17.4	27.1	0.001	290	143
Right	Federal	427.5	3605000063	MRLS 440-R	10.6	6.9	0.001	1	0
Left	non-Federal	423	3605000010	Platte County Drainage District No. 1 Section 1	12.2	14.3	0.05	304	425
Left	non-Federal	414.5	3605000042	Platte County Section 2, Bean Lake	9.4	10.4	0.02	64	46
Right	non-Federal	411	3605000077	Henry Pohl Levee	4.0	1.1	0.05	0	0
Right	non-Federal	408	3605000102	Grape-Bollin-Schwartz Levee Association	4.7	1.7	0.05	13	7

Table 3-23: Loading History for Study Reach 6

Levee Segment	Levee Construction	1993	2007	2008	2010	2011	2019
Rushville-Sugar Lake	Non-Federal	Overtopped then Breached (3x)	Overtopped. No Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached (6x)	Overtopped then Breached (3x)
Platte County DD Section 1	Non-Federal	Overtopped then Breached (2x)	Overtopped. No Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached	Overtopped then Breached (3x)
Platte County DD Section 2	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Overtopped then Breached (1x)	Overtopped then Breached (2x)
Bean Lake	Non-Federal	Overtopped. No Breach	Overtopped. No Breach	Overtopped then Breached	Overtopped then Breached	Overtopped then Breached (10x)	Overtopped then Breached (5x)
Henry Pohl Levee	Non-Federal	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached (1x)
Grape-Bollin-Schwartz	Non-Federal	Overtopped. No Breach	Overtopped. No Breach	Loaded. Did Not Breach	No Info	Overtopped then Breached (4x)	Overtopped then Breached (3x)
MRLS-440-R	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 448-443-L	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 455-L	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach

Federal Levees Past Performance

These three federal levees were constructed in the 1950s to early 1960s. None of them have overtopped or breached. All have required post flood repair after the 1993, 2011, and 2019 floods through the Rehabilitation Program, mainly to repair under seepage issues and riverside scour. The 455-L levee required emergency under seepage repairs during the flood in 2011.

Non-Federal Levees Past Performance

In this reach, the non-federal levees have all overtopped in 1993, 2011, and 2019 with some segments overtopping in other years and all segments breaching in 2019. The Platte County Drainage District No 1 Section 1 system overtopped and breached in 1993, 2011, and 2019 on both segments. Both segments overtopped in 2007 and 2010, but current records indicate that there were no breaches. The Platte County Section 2-Bean Lake system overtopped and breached on both segments in 1993, 2011, and 2019 with the Bean Lake segment also overtopping in 2007 and overtopping and breaching in 2008. The Henry Pohl levee overtopped in 1993, 2011 and 2019, with numerous overtopping breaches in 2019. The Grape-Bollin-Schwartz system overtopped in 1993, 2007, 2011 and 2019, with numerous overtopping breach locations in 2011 and 2019.

Economics

From 1993 to 2022, the levees in Reach 6 have incurred repair costs resulting from flood damage of \$19,826,000 (FY2024 dollars). Of the last 30 years, six years (1993, 2007, 2008, 2010, 2011, 2019) have seen at least one levee in Reach 6 get significantly damaged.

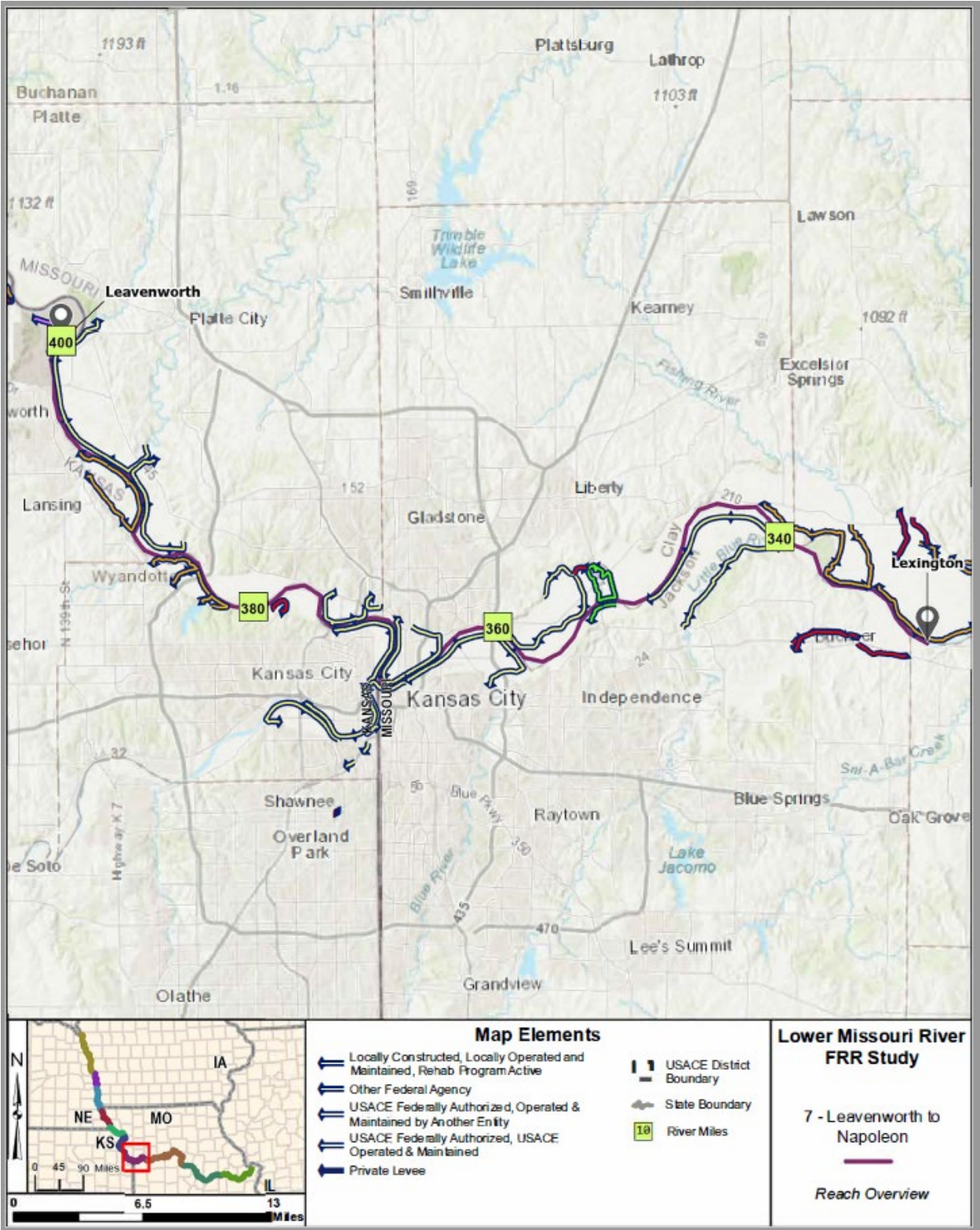
Other flooding impacts

Like the levees in the previous reach, these levees were affected by highwater levels from March through October 2019 that prevented any breach repair on non-federal levees until 2020. Because of breaches on the Rushville Sugar Lake segment, access to or from Atchison, KS across the Missouri River via the US Hwy 59 bridge was cut off for three extended periods of time from March to October 2019. An hour detour was required to cross the river St Joseph or Leavenworth during closures of US Hwy 59.

3.2.7 Study Reach 7 - Leavenworth, KS to Napoleon, MO (RM 400-330)

The Leavenworth, KS to Napoleon, MO reach extends from Missouri River mile 400 - 330. It can be further broken down to Leavenworth to Riverside, Riverside to Liberty Bend, and Liberty Bend to Napoleon. From Leavenworth, KS to Riverside, MO there are two federal levees, MRLS-408-L and MRLS-400-L, and two active non-federal levees, Kansas Department of Corrections and Wolcott. There is also a levee at Fort Leavenworth, owned and operated by the installation. From Riverside to Liberty Bend, the levees are all federally constructed and include MRLS 385-L Quindaro Bend, MRLS 385-L Riverside, Fairfax-Jersey Creek, North Kansas City, Central Industrial District (CID), East Bottoms, Birmingham, Liberty Bend Left Bank, and Liberty Bend Right Bank. From Liberty Bend to Napoleon there is one federal levee, MRLS-351-R, and five active non-federal levee systems: Egypt L&D TriCounty Ray Jack Clay; MO Valley D&L District of Ray Co MO Section 1; MO Valley D&L District of Ray Co MO Section 2; MO Valley D&L District of Ray Co MO Section 3; and Ray Lafayette Levee District No 1. The levees in this reach are shown on Figure 16.

Figure 16: Map of Reach 7



Hydraulic Characteristics

Historic peak flows have been recorded within this reach at USGS gage 06818000 Missouri River at St. Joseph. The largest recorded flow was in April of 1952 with an estimated peak flow of 397,000 cfs. Other historic peak flows events include 1993, 2007, 2010, 2011, and 2019. These peak flows are listed in Table 3-24.

Peak stages have been recorded for USGS gage 06820475 Missouri River at Leavenworth. Peak flows were not available at this gage. Table 3-25 provides a summary of the record peak stages at the Leavenworth gage, ordered chronologically.

Table 3-24: USGS Gage 06818000 Missouri River at St Joseph, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	397,000	26.82
1993	335,000	32.07
2007	183,000	25.26
2010	190,000	26.17
2011	277,000	29.97
2019	317,000	32.07

Table 3-25: USGS Gage 06820475 Missouri River at Leavenworth, KS - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1993	N/A	35.31
2007	N/A	26.82
2008	N/A	25.65
2010	N/A	25.5
2011	N/A	30.8
2019	N/A	31.31

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-26. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-27.

Table 3-26: NLD Data for Study Reach 7

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	Federal	396.5	3605000141	MRLS 408-L	12.2	15.4	0.005	222	127
Right	non-Federal	391	3605000067	Kansas Department of Corrections	9.4	4.6	0.05	1	5
Left	Federal	388	3605000025	MRLS 400-L	7.3	6.0	0.002	66	41
Right	non-Federal	385.5	3605000125	Wolcott Drainage District Section 1	4.3	1.4	0.05	1	10
Right	non-Federal	383	3605000122	Wolcott Drainage District Section 2	3.7	1.4	0.05	0	0
Right	non-Federal	381.5	3605000041	Wolcott Drainage District Section 3	2.4	0.3	0.1	0	0
Left	Federal	374	3605000221	MRLS 385-L Quindaro Bend	4.0	2.3	0.0005	1367	42
Left	Federal	372	3605000097	MRLS 385-L Riverside	1.2	0.2	0.0005	438	54
Right	Federal	371	3605000119	Fairfax-Jersey Creek	5.3	3.3	0.001	9487	200
Left	Federal	367	3605000065	North Kansas City Levee Unit	8.7	4.5	0.001	26703	1658
Right	Federal	366.5	3605000127	CID, Central Industrial District	1.8	1.5	0.001	15858	341
Right	Federal	362	3605000051	East Bottoms Unit	9.1	6.8	0.001	16539	751

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	Federal	356.5	3605000121	Birmingham Unit	10.8	7.8	0.001	1113	209
Right	Federal	345	3605000098	MRLS 351-R	16.0	12.7	0.002	245	140
Left	non-Federal	338	3605000016	Egypt L&D District Tri-County Ray Clay Jack	13.3	7.1	0.1	20	34
Left	non-Federal	330	3605000061	MO Valley D&L Dist of Ray Co. MO, Section 1	13.6	15.5	0.1	78	104
Left	non-Federal	328	3605000023	MO Valley D&L Dist of Ray Co. MO, Section 2	2.0	0.4	0.05	0	0
Left	non-Federal	327.5	3605000136	MO Valley D&L Dist of Ray Co. MO, Section 3	2.7	0.4	0.05	0	0
Left	non-Federal	320	3605000059	Ray-Lafayette Levee Dist No. 1	25.3	46.4	0.05	399	239

Numbers in Red have been adjusted from what is in the NLD

Table 3-27: Loading History for Study Reach 7

Levee Segment	Levee Construction	1993	2007	2008	2010	2011	2019
Kansas Dept. of Corrections	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (6x)	Overtopped then Breached (2x)
Wolcott Section 1	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached
Wolcott Section 2	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached	Overtopped then Breached
Wolcott Section 3	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached	Overtopped then Breached
Tri-County of Ray, Clay, Jackson, MO	Non-Federal	Overtopped then Breached	Overtopped then Breached	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached
Egypt	Non-Federal	Overtopped then Breached (3x)	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached
MO Valley D&L Dist of Ray Co. MO, Section 1	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MO Valley D&L Dist of Ray Co. MO, Section 2	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MO Valley D&L Dist of Ray Co. MO, Section 3	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
Ray-Lafayette	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach

Levee Segment	Levee Construction	1993	2007	2008	2010	2011	2019
Henrietta-Crooked Section 1	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach
MRLS 408-L	Federal	Overtopped then Breached (3x)	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 400-L	Federal	Overtopped then Breached	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach	Loaded. Did Not Breach
MRLS 385-L Quindaro Bend	Federal	Not Constructed	Not Constructed	Not Constructed	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach
MRLS 385-L Riverside	Federal	Not Constructed	Not Constructed	Not Constructed	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
Upper Fairfax-Jersey Creek	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
North Kansas City Airport	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
North Kansas City Lower	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded

Levee Segment	Levee Construction	1993	2007	2008	2010	2011	2019
CID, Missouri	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
East Bottoms	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
Birmingham	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded
MRLS 351-R, Section 1	Federal	Loaded. Did Not Breach	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Not Significantly Loaded	Loaded. Did Not Breach

Federal Levees Past Performance

Upstream of Kansas City, the L-400 and L-408 levees both overtopped in 1993 with only L-400 breaching. They performed as designed in 2011 and 2019 without major issue. In 2019, the levees were loaded to approximately 75 percent.

The federal levees within the Kansas City reach, excluding Liberty Bend levees, have performed well. Since the 1951 and 1952 floods, none of them have breached. With the exception of L-385 that was not yet constructed, all were loaded to within a few feet of the top in 1993. The federal levees in the Kansas City region are loaded less frequently than the non-federal levees or the federal levees in other reaches. They have not had a sustained large loading event since 1993. The peak loading in 2019, that only lasted a few days, was 12 feet less than the 1993 peak on the Missouri River at Kansas City gage.

The Liberty Bend levees were not specifically authorized by Congress but were part of the realignment of the Missouri River channel in the 1940s. As part of the Kansas City Levees project, the river channel east of Kansas City was widened and straightened to increase capacity through Kansas City. Existing agricultural levees were relocated as a part of that effort. These are now the Liberty Bend Cutoff Right Bank and Left Bank levees. Both levees tie into lower non-program levees that overtop frequently. Both Liberty Bend levees overtopped in 1993. In 2019, the right bank system overtopped on the non-program levee segment.

R-351 is the only federal levee east of the Kansas City metro in this reach. It has never overtopped or breached from a Missouri River flooding event. The largest loading was in 1993 with water one foot from the top of levee. It was loaded to about 12 percent of its height in 2019.

Non-Federal Levees Past Performance

Upstream of Kansas City the area, the Kansas Department of Corrections levee overtopped in 1993 without breaching and overtopped and breached in 2011 and 2019. All the Wolcott levees overtopped in 1993 and 2019. Only the Section 2 levee breached from overtopping in 1993. In 2011, Wolcott Section 2 and Section 3 overtopped and breached as well. Section 1 did not overtop but did have erosion and sod kill damages that were repaired through the Rehabilitation Program. In 2019, all three levees had overtopping and breaches. Performance data on the Leavenworth levee has not been historically tracked because it is ineligible for USACE repair assistance.

Downstream of the Kansas City metro, the Egypt L&D Tri County Ray Clay Jack levee system overtopped and breached in 1993, 2007, and 2019. MO Valley D&L District of Ray Co. MO, Section 1 overtopped and breached in 1993. Sections 2 and 3 are not on the Missouri River but are small levees on Rollins Creek. They overtopped and

breached in 1993. After the 1993 flood, the MO Valley D&L District of Ray Co. MO levees were raised about 3 to 4 feet and have not overtopped since.

Economics

In the past 30 years, the levees in Reach 7 have incurred repair costs resulting from flood damage of \$59,688,000 (FY2024 dollars). Of the last 30 years, seven years (1993, 1998, 2007, 2011, 2013, 2018, 2019) have seen at least one levee in Reach 7 get significantly damaged.

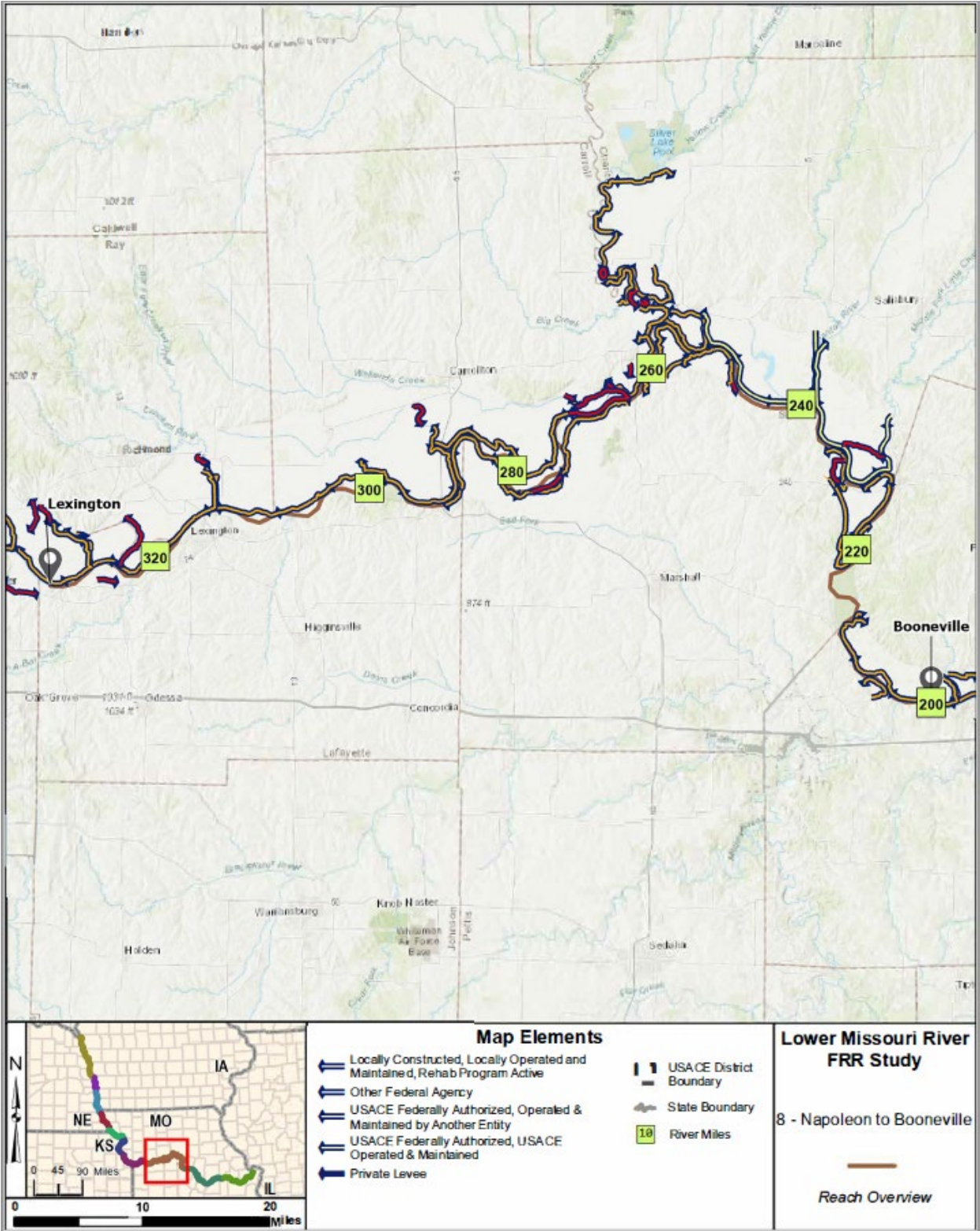
Other flooding impacts

This is a large reach with a mix of urban and agricultural levees. The levees in the Kansas City metro have a history of positive performance, however they are not often loaded. Most have not seen a significant loading since 1993. If they were to overtop or breach, the flooding damages could have major impacts to the Kansas City metro area.

3.2.8 Study Reach 8 - Napoleon, MO to Boonville, MO (RM 330-200)

The Napoleon to Boonville reach extends from Missouri River mile 330 – 200 as show in Figure 17. This reach consists of two federal levee systems and 16 non-federal levee systems that are active in the Rehabilitation Program. The federal systems are MRLS-246-L, near Brunswick, MO, and Lower Chariton. The non-federal systems include Ray-Lafayette Levee District No. 1, the Ray-Carrol Levee District, Sugartree Bottom Levee District, Wakenda Levee District, Malta Coles Saline-Lafayette Teteseau Districts, Mi-De Levee District, Miami Levee District No. 1, Brunswick Levee District, Saline County Levee District No. 2, Cambridge Levee Assn, Northeastern Saline Levee Association, West Glasgow Levee District of Saline County, Levee District Number 6 of Howard County, Howard County Drainage District No. 3 Section 1, Levee District Number 2 of Howard County, and Linneman-Weekly Levee. The levees in this reach are shown on Figure 17.

Figure 17: Map of Reach 8



Hydraulic Characteristics

Four reference gages are used in study Reach 8. The first is USGS Gage 06894650 Missouri River at Napoleon, MO. This gage has only recorded annual peak flows since 2016. Data is in Table 3-28. USGS gage 06895500 Missouri River at Waverly, MO has a full record of annual peak flows and the notable events have been recorded in Table 3-29. USGS gage 06895700 Missouri River at Miami, MO records stage only and data is located in Table 3-30. The USGS gage 06906500 Missouri River at Glasgow, Missouri gage has peak streamflow data available starting from 2000 and is shown in Table 3-31.

Table 3-28: USGS Gage 06894650 Missouri River at Napoleon, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	N/A	24.6
1993	N/A	26.7
2007	N/A	28.86
2010	N/A	25.25
2011	N/A	27.6
2019	307,000	32.07

Table 3-29: USGS Gage 06895500 Missouri River at Waverly, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	369,000	28.1
1993	633,000	31.15
2007	302,000	30.1
2010	233,000	28.47
2011	265,000	30.75
2019	3,280,001	31.92

Table 3-30: USGS Gage 06895700 Missouri River at Miami, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	N/A	26.4
1993	N/A	32.6
2007	N/A	29.48
2010	N/A	28.5
2011	N/A	28.8
2019	N/A	31.53

Table 3-31: USGS Gage 06906500 Missouri River at Glasgow, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1952	N/A	32.1
1993	N/A	39.5
2007	322,000	34.3
2010	283,000	33.91
2011	255,000	31.78
2019	367,000	37.35

Data pulled from the NLD for Federal and non-Federal levees in this reach is shown in Table 3-32. This includes NLD system name and ID, levee length, and leveed area size, as well as the overtopping AEP and people and structures at risk that were determined during the last levee risk assessment completed sometime between 2012 and 2022. The loading for prior flood events is summarized in Table 3-33.

Table 3-32: NLD Data for Reach 8

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	non-Federal	306	3605000007	The Ray-Carroll Levee District of Ray County, Missouri	21.9	21.2	0.1	627	372
Right	non-Federal	278	3605000014	Malta Coles Saline-Lafayette Teteseau Districts	39.1	38.9	0.1	98	131
Left	non-Federal	293	3605000015	Sugartree Bottom Levee District	15.4	19.1	0.1	26	330
Left	non-Federal	278	3605000001	Wakenda Levee District	21.4	51.3	0.1	304	507
Left	non-Federal	260.5	3605000089	Mi-De Levee District	8.2	6.0	0.05	0	17
Left	non-Federal	257	3605000078	Dewitt D&L District of Carroll Co., Section 1	0.7	0.1	0.2	0	0
Left	non-Federal	256	3605000043	Dewitt D&L District of Carroll Co., Section 2	5.7	3.7	0.1	7	22
Right	non-Federal	257	3605000004	Miami Levee District No. 1	12.6	7.1	0.05	2	11
Left	non-Federal	252.5	3605000144	Brunswick Levee District	9.8	5.8	0.1	0	4

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Right	non-Federal	249	3605000058	Saline County Levee District	7.1	5.7	0.2	7	5
Left	Federal	244.5	3605000046	MRLS 246-L	33.5	41.9	0.02	101	74
Left	Federal	233	3605000146	Lower Chariton	20.3	32.1	0.01	51	98
Right	non-Federal	233	3605000071	Cambridge Levee Assn., Inc. (NFP)	4.0	2.4	0.2	0	1
Right	non-Federal	228.5	3605000142	Northeastern Saline Levee Association	3.3	1.2	0.1	0	0
Right	non-Federal	222	3605000054	West Glasgow Levee District of Saline County, MO	16.8	9.6	0.1	5	20
Left	non-Federal	221	3605000033	Levee District Number 6 of Howard County	3.5	0.7	0.2	0	1
Left	non-Federal	212	3605000012	Howard County Drainage District No. 3, Section 1	1.4	0.2	0.1	0	0
Left	non-Federal	205	3605000031	Levee District Number 2 of Howard County	17.9	21.8	0.05	4	87
Right	non-Federal	205	3605000109	Linneman-Weekly Levee, Inc.	3.8	1.4	0.2	1	4

Numbers in Red have been adjusted from what is in the NLD

Table 3-33: Loading History for Study Reach 8

Levee Segment	Levee Construction	1993	1995	2001	2007	2008	2010	2011	2013	2015	2019
Ray-Carroll LD	Non-Federal	Overtopped then Breached	No Info	No Info	Overtopped then Breached	No Info	Overtopped then Breached	Breached Intentionally	No Info	No Info	Overtopped then Breached (3x)
Sugartree Bottom LD	Non-Federal	Overtopped then Breached (9x)	No Info	No Info	Overtopped then Breached (2x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
Saline-Lafayette	Non-Federal	Overtopped then Breached	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach
Coles Lake Levee	Non-Federal	Overtopped then Breached	No Info	No Info	No Info	No Info	No Info	No Info	No Info	No Info	No Info
Teteseau Bend	Non-Federal	Overtopped then Breached	No Info	No Info	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach
Wakenda Levee	Non-Federal	Overtopped then Breached (2x)	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached (2x)	No Info	Overtopped then Breached	Overtopped then Breached (1x)
Mi-De Levee	Non-Federal	Overtopped then Breached (9x)	No Info	No Info	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached (4x)

Levee Segment	Levee Construction	1993	1995	2001	2007	2008	2010	2011	2013	2015	2019
DeWitt Section 1	Non-Federal	Overtopped then Breached	No Info	No Info	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached
Dewitt Section 2	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached
Brunswick LD	Non-Federal	Overtopped then Breached (11x)	Overtopped then Breached	No Info	Overtopped then Breached	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Overtopped then Breached (3x)
Miami	Non-Federal	Overtopped then Breached (18x)	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach
Saline County	Non-Federal	Overtopped then Breached	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached (5x)
Cambridge	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached
Northeastern Saline	Non-Federal	Overtopped then Breached (15x)	Overtopped then Breached	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Cambridge	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached

Levee Segment	Levee Construction	1993	1995	2001	2007	2008	2010	2011	2013	2015	2019
Northeastern Saline	Non-Federal	Overtopped then Breached (15x)	Overtopped then Breached	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
West Glasgow	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached (3x)
Levee District Number 6 of Howard County	Non-Federal	Overtopped then Breached	Breached (3x)	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach
Howard County No. 3, Section 1	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached
Howard County No. 3, Section 2	Non-Federal	Overtopped then Breached (6x)	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach
Levee District No. 7 of Howard County, Section 4	Non-Federal	Overtopped then Breached (6x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached
Levee District Number 2 of Howard County	Non-Federal	Overtopped then Breached (22x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached (3x)

Levee Segment	Levee Construction	1993	1995	2001	2007	2008	2010	2011	2013	2015	2019
Linneman-Weekly	Non-Federal	Overtopped then Breached (2x)	Overtopped then Breached	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
MRLS 246-L	Federal	Overtopped then Breached (11x)	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached (5x)
Lower Chariton	Federal	Overtopped then Breached (2x)	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach

Federal Levees Past Performance

The two federal levees in this reach were constructed to 0.01 AEP: MRLS 246-L and Lower Chariton. MRLS 246-L overtopped and breached in 1993 and 2019. To reduce the chances of flooding the town of Brunswick, Missouri the levee district is prohibited from raising the upstream tieback section of 246-L on the Grand River. In 1993, the mainstem section of 246-L overtopped and breached filling the leveed area with water until water flowing out of the area overtopped and breached the downstream tieback of 246-L on the Chariton River. Water subsequently overtopped and breached the Chariton River upstream tieback of the Lower Chariton levee. In 2019, exit breaches were cut into 246-L once it began to overtop and therefore Lower Chariton did not overtop or breach. High water in 2021 caused additional damages to 246-L due to the 2019 repairs not being completed.

Non-Federal Levees Past Performance

In this reach, all 16 non-federal levee systems overtopped and breached in 1993. Five of them overtopped and breached again in 1995 and two in 2007. In 2019, 70 percent of them overtopped and breached. Those that did not overtop were fully loaded and sustained damages related to erosion, scour, and sod loss.

In 2011, Sugartree levee had a significant slide that required emergency repair during the flood event. The levee was eventually cut on the downstream end to allow controlled overtopping and preventing overtopping on the upstream end. Repairs made after the flood included constructing an overtopping section on the downstream end. This has worked effectively in reducing water levels and lessening damages in the leveed area.

Economics

In the past 30 years, the levees in Reach 8 have incurred repair costs resulting from flood damage of \$156,584,000 (FY2024 dollars). Of the last 30 years, 14 years (1993, 1995, 1996, 1998, 2002, 2007, 2008, 2010, 2011, 2013, 2015, 2017, 2019, 2021) have seen at least one levee in Reach 8 get significantly damaged.

Other Flooding Impacts

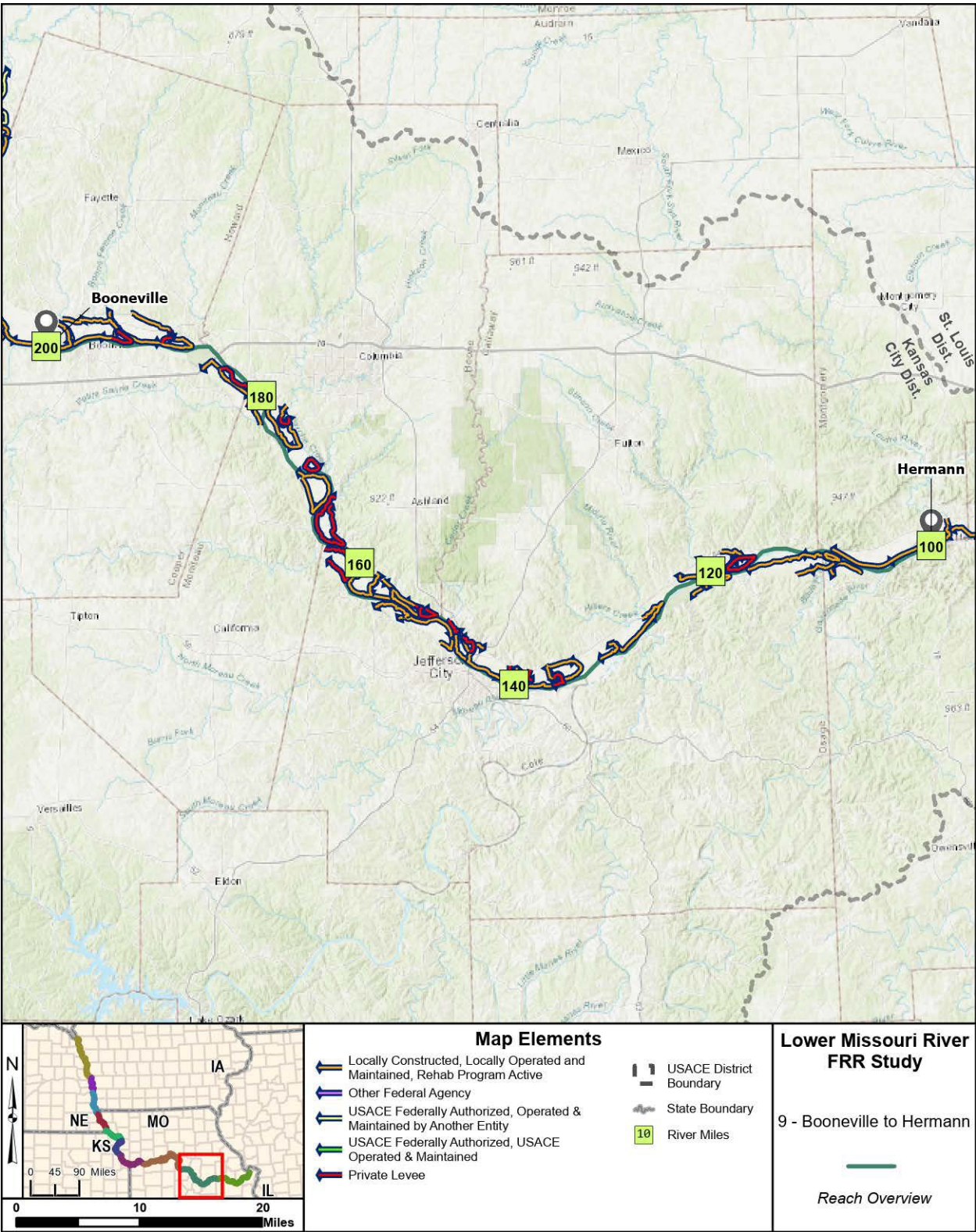
Many of the leveed areas in this reach are large and the leveed areas are mainly rural. Flooding of these areas has significant impacts to agriculture production locally and on a national level. Many of these levees are right up against the riverbank and if breached can remain flooded for weeks to months. Leveed areas are also often flooded from local precipitation combined with high river levels as the drainage to the river is all by gravity. This can impact agriculture and residences behind the levees when the levees perform without breaching.

In 1993, the closing of the Missouri River Bridge in this area due to damage to Missouri State Highway 240 caused an 80-mile detour for people who live on one side of the river but work on the other. This bridge was closed again in 2019.

3.2.9 Study Reach 9 - Boonville, MO to Hermann, MO (RM 200-100)

Reach 9, from Boonville to Hermann, does not contain any federal levees but does contain 24 non-federal levee systems that are active in the Rehabilitation Program. The non-federal systems include Howard County Levee District No. 4, Bonne Femme Levee District No. 1, Levee District No.1 of Cooper County, McBaine Levee District, Plowboy Bend Levee Association, Hartsburg Levee District Section 1, Hartsburg Levee District Section 2, Hartsburg Levee District Section 3, Prison Farm Levee, Cole Junction Levee District, Renz Levee District, Capital View Drainage District, Reveaux Drainage District, Wainwright Levee District, Jacobs Levee District, Tebbetts East Levee District, Chamois Levee District Section 1, Chamois Levee District Section 2, Mokane Levee District, Steedman Levee District, A-1 Levee Association, Diemann Levee District, Morrison Lower Bottom Levee District, and Tri-County Levee District Sec 1. A map of Reach 9 is shown in Figure 18.

Figure 18: Map of Reach 9



Hydraulic Characteristics

Flow data for USGS gage 06910450 Jefferson City, MO began being recorded in 2014. Peak stages were retrieved for 1951, 1993, 1995, 2013, and 2019 and summarized in Table 3-34.

Table 3-34: USGS Gage 06910450 Missouri River at Jefferson City, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1951	N/A	34.2
1993	N/A	38.65
1995	N/A	33.05
2013	N/A	30.83
2019	366,000	33.41

Page intentionally left blank.

Table 3-35 provides the estimated overtopping frequencies for the levees in Reach 9, pulled from the NLD. These overtopping estimates were determined during the first-round screening level risk assessment for each levee. These levee systems are all non-federally constructed so there are no authorized capacities. The loading for prior flood events is summarized in Table 3-36.

Page intentionally left blank.

Table 3-35: NLD Data for Study Reach 9

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	non-Federal	196	3605000030	Howard County Levee District No. 4	12.2	5.9	0.02	15	56
Left	non-Federal	190.5	3605000011	Bonne Femme Levee District No. 1	14.3	8.4	0.05	7	15
Left	non-Federal	181.5	3605000104	Levee District No. 1 of Cooper County	7.3	5.4	0.05	1	9
Left	non-Federal	177.5	3605000064	McBaine Levee District	10.6	3.9	0.05	4	8
Right	non-Federal	169.5	3605000128	Plowboy Bend Levee Association	8.8	3.9	0.1	0	0
Left	non-Federal	157.5	3605000000	Hartsburg Levee District, Section 1	7.3	3.2	0.1	4	26
Left	non-Federal	154.5	3605000116	Hartsburg Levee District, Section 2	5.6	2.1	0.1	134	70
Left	non-Federal	152.5	3605000076	Hartsburg Levee District, Section 3	6.5	1.2	0.2	0	0
Right	non-Federal	153.5	3605000075	Prison Farm Levee	3.8	1.6	0.1	0	0
Right	non-Federal	149	3605000145	Cole Junction Levee District	7.6	4.2	0.05	0	11
Left	non-Federal	145.5	3605000056	Renz Levee District	3.7	1.4	0.1	2	9

MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Left	non-Federal	142	3605000070	Capital View Drainage District	7.3	5.1	0.1	600	13
Left	non-Federal	138.5	3605000131	Reveaux Drainage District	6.6	3.8	0.1	0	2
Left	non-Federal	135.5	3605000130	Wainwright Levee District	5.5	2.6	0.1	0	0
Left	non-Federal	131	3605000110	Jacobs Levee District	2.5	0.7	0.2	0	1
Left	non-Federal	127.5	3605000107	Tebbetts East Levee District	8.7	3.6	0.2	11	9
Left	non-Federal	122	3605000003	Mokane Levee District	3.6	1.5	0.2	2	3
Right	non-Federal	121.5	3605000106	Chamois Levee District, Section 1	1.8	0.2	0.2	0	0
Right	non-Federal	120	3605000032	Chamois Levee District, Section 2	2.9	0.6	0.2	0	0
Left	non-Federal	119.5	3605000112	Steedman Levee District	7.4	3.7	0.1	3	18
Right	non-Federal	113	3605000035	A-1 Levee Association	11.8	7.3	0.1	30	60
Right	non-Federal	109	3605000088	Diermann Levee District	2.8	0.3	0.2	0	0
Left	non-Federal	103.5	3605000105	Tri-County Levee District, Sec 1	12.1	12	0.1	11	14

MO River Bank	System Authorization	Mid- Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
Right	non-Federal	107	3605000034	Morrison Lower Bottom Levee District	3.7	1.5	0.2	0	0

Table 3-36: Loading History for Study Reach 9

Levee Segment	Levee Construction	1993	1994	1995	1998	2001	2007	2008	2011	2013	2017	2019
Howard County No. 4	Non-Federal	Overtopped then Breached	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached
Bonne Femme	Non-Federal	Overtopped then Breached	No Info	Overtopped. No Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped. No Breach
Cooper County No. 1	Non-Federal	Overtopped then Breached	No Info	Overtopped. No Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Overtopped then Breached
McBaine	Non-Federal	Overtopped then Breached	No Info	Overtopped. No Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Plowboy Bend	Non-Federal	Overtopped then Breached	No Info	Overtopped. No Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Hartsburg Section 1	Non-Federal	Overtopped then Breached (10x)	No Info	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Hartsburg Section 2	Non-Federal	Overtopped then Breached	No Info	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Hartsburg Section 3	Non-Federal	Overtopped then Breached (4x)	No Info	Overtopped then Breached (2x)	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached

Levee Segment	Levee Construction	1993	1994	1995	1998	2001	2007	2008	2011	2013	2017	2019
Prison Farm	Non-Federal	Overtopped then Breached (5x)	No Info	Overtopped then Breached (2x)	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached
Cole Junction	Non-Federal	Overtopped then Breached (23x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Overtopped. No Breach
Renz	Non-Federal	Overtopped then Breached (11x)	No Info	Overtopped then Breached (3x)	Loaded. Did Not Breach	No Info	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached
Capital View	Non-Federal	Overtopped then Breached (13x)	No Info	Overtopped then Breached (13x)	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached (7x)
Reveaux	Non-Federal	Overtopped then Breached (9x)	No Info	Overtopped then Breached (8x)	No Info	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped then Breached (2x)
Wainwright	Non-Federal	Overtopped then Breached (7x)	No Info	Overtopped then Breached (6x)	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Jacobs	Non-Federal	Overtopped then Breached (3x)	No Info	Overtopped then Breached (4x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	No Info	Overtopped then Breached	Overtopped. No Breach	Loaded. Did Not Breach
Tebbetts East	Non-Federal	Overtopped then Breached (11x)	Loaded. Did Not Breach	Overtopped then Breached (5x)	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Intentional Breach	Overtopped. No Breach	Overtopped then Breached (1x)

Levee Segment	Levee Construction	1993	1994	1995	1998	2001	2007	2008	2011	2013	2017	2019
Chamois Section 1	Non-Federal	Overtopped. No Breach	Loaded. Did Not Breach	Overtopped. No Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach
Chamois Section 2	Non-Federal	Overtopped then Breached (2x)	Loaded. Did Not Breach	Overtopped. No Breach	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped. No Breach	Overtopped. No Breach	Loaded. Did Not Breach
Mokane	Non-Federal	Overtopped then Breached (1x)	Loaded. Did Not Breach	Overtopped then Breached (1x)	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach
Steedman	Non-Federal	Overtopped then Breached (15x)	Loaded. Did Not Breach	Overtopped then Breached (3x)	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached (1x)
A-1	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Overtopped then Breached (5x)	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach
Diermann	Non-Federal	Overtopped then Breached (2x)	Overtopped then Breached	Overtopped then Breached (1x)	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped. No Breach
Morrison Lower	Non-Federal	Overtopped then Breached (6x)	Loaded. Did Not Breach	Overtopped then Breached (4x)	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	Overtopped. No Breach	Overtopped. No Breach	Overtopped then Breached (1x)
Tri-County Levee District, Section 1	Non-Federal	Overtopped then Breached (12x)	Loaded. Did Not Breach	Overtopped then Breached (10x)	No Info	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Overtopped. No Breach	Loaded. Did Not Breach

Non-Federal Levee Past Performance

These levees have been damaged in multiple flood events. Eleven of them overtopped in 1993 and most in 1995. Several levees were damaged in 2005, 2008, 2011, 2013, 2015, and 2017. In 2019, half of the levees in this reach overtopped, all of them breached.

Economics

In the past 30 years, the levees in Reach 9 have incurred repair costs resulting from flood damage of \$60,490,000 (FY2024 dollars). Of the last 30 years, 12 years (1993, 1995, 2001, 2005, 2007, 2008, 2010, 2011, 2013, 2015, 2017, 2019) have seen at least one levee in Reach 9 get significantly damaged.

Other flooding impacts

In this reach, the Capital View Drainage District leveed area has the most development. While most of Jefferson City's population is on the right bank of the river on the bluff, there is housing, development, and the Jefferson City Municipal Airport on the left bank within the Capital View leveed area. The Capital View leveed area fills up like a bathtub when the levee overtops. Capital View levee overtopped and breached in 1993, 1995, and 2019. US Route 54 is a major route that crosses the Missouri River at Jefferson City connecting North Jefferson City, as well as Columbia, to Jefferson City and to the Lake of the Ozarks. The Lake of the Ozarks is the largest man-made non-flood control lake in the United States and draws in millions of visitors each summer. The 1993 flood overtopped US Hwy 54 causing significant damage and traffic impacts as seen in Figure 19. The lanes were raised after the 1993 flood and in 2019 water was within a few feet of requiring closure of the road.

Figure 19: Route 54 Overtopping in 1993

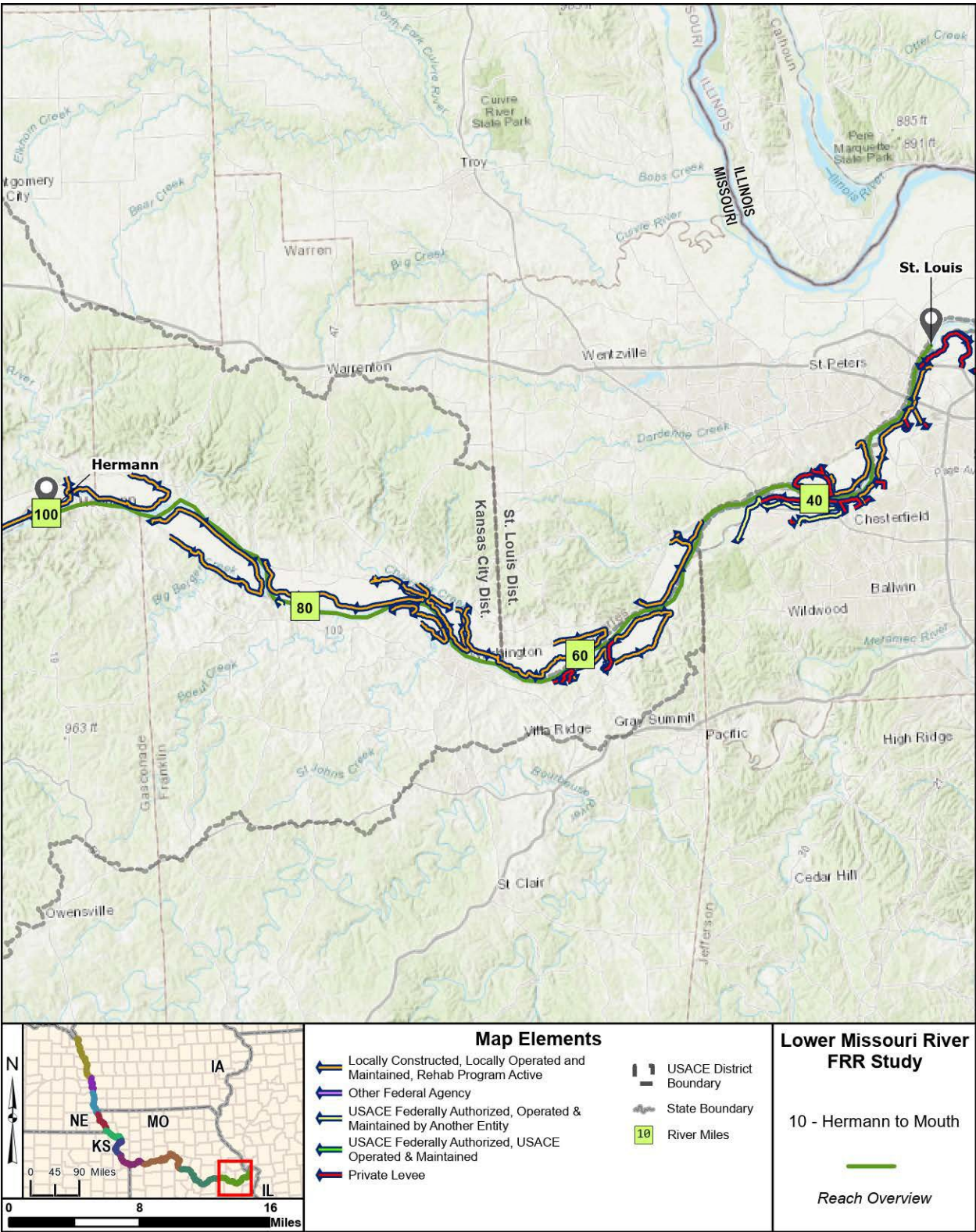


Rail traffic sees significant impacts throughout the state during large flood events. Amtrack's Missouri River Runner line typically runs twice a day between St Louis and Kansas City with stops in Jefferson City. The service was suspended multiple times in 2019 due to freight traffic moving to the Amtrack tracks because of flooded freight lines. Passengers, primarily commuters, were temporarily transported by bus.

3.2.11 Study Reach 10 - Hermann, MO to St. Louis, MO (RM 100-0)

The Reach from Hermann to St. Louis contains levees in the Kansas City District AOR and the St. Louis District AOR. Kansas City District levees include one federal levee (New Haven) and nine active non-federal levees. The Kansas City District non-federal levees are Tri-County Levee District Sec 2, Berger Levee District of Franklin County, MO Valley L.D. Sec 1, MO Valley L.D. Sec 2 (Charrette Bottom), Holtmeier Levee Association, St. Johns Bottom Levee Association, Tuque Creek, Labadie Bottoms Section 4, and St. Albans Partners/Labadie Bottoms LD Sections 5, 6. St. Louis District levees include two federal levees (Monarch Chesterfield and Consolidated North County Levee District) and nine active non-federal levees. The St. Louis District non-federal levees are Augusta Bottom and Dutzow Bottom Levee System, Darst Bottom Levee System, Missouri University Levee System, Greens Bottom Levee Sec2 System, Howard Bend Levee District System, Earth City Levee District System, Riverport Levee District System, Missouri Bottoms Levee System, and the Kuhs Levee System. The levees in this reach are shown in Figure 20.

Figure 20: Map of Reach 10



Hydraulic Characteristics

Annual peak flow data for USGS gage 06934500 Missouri River at Hermann, Missouri began being recorded in 1929. Peak stages were retrieved for 1951, 1993, 1995, 2017, and 2019 and summarized in Table 3-37.

Table 3-37: USGS Gage 06934500 Missouri River at Hermann, MO - Peak Flows

Year	Peak Flow (cfs)	Peak Stage (ft)
1951	618,000	33.33
1993	750,000	36.97
1995	579,000	36.22
2017	515,000	35.62
2019	403,000	33.52

Table 3-38 provides the estimated overtopping frequencies for the levees in Reach 9, pulled from the NLD. These overtopping estimates were determined during the first-round screening level risk assessment for each levee. These levee systems are all non-federally constructed so there are no authorized capacities. Table 3-39 includes performance history for the levees.

Page intentionally left blank.

Table 3-38: NLD Data for Study Reach 10

Reach #	MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
10	Left	non-Federal	95	3605000053	Tri-County Levee District Sec 2	9.7	8.2	0.05	3	6
10	Right	non-Federal	88	3605000151	Berger Levee District of Franklin County, MO	17.1	11.7	0.1	2	8
10	Left	non-Federal	78	3605000029	MO Valley L.D. Sec 1	15.6	13.7	0.05	102	110
10	Right	Federal	81.5	3605000117	New Haven	0.4	0.0	0.01	4	21
10	Left	non-Federal	73	3605000084	MO Valley L.D. Sec 2 (Charrette Bottom)	2.9	0.7	0.1	9	15
10	Right	non-Federal	73	3605000028	Holtmeier Levee Association, Inc.	2.2	0.4	0.2	0	0
10	Right	non-Federal	70.5	3605000111	St. Johns Bottom Levee Association, Inc.	5.2	1.3	0.2	0	0
10	Left	non-Federal	70	3605000074	Tuque Creek Levee	9.2	2.6	0.2	0	1
10	Left	non-Federal	63	5605820001	Augusta Bottom and Dutzow Bottom Levee System	17.1	11.4	0.2	60	19
10	Right	non-Federal	59.5	3605000083	Labadie Bottom Levee, Section 4	4.9	1.4	0.2	7	14
10	Right	non-Federal	56	3605000013	St. Albans/Labadie Bottoms LD, Sections 5, 6	9.5	4.9	0.2	0	3

Reach #	MO River Bank	System Authorization	Mid-Point River Mile	System ID	System Name	Levee Length (Miles)	Leveed Area (Sq Miles)	Overtopping AEP (MO River)	People at Risk	Structures at Risk
10	Left	non-Federal	52	5605810001	Darst Bottom Levee System	6.8	5.1	0.05	3	3
10	Left	non-Federal	48.5	5605830001	Missouri University Levee System	2.8	0.8	0.2	8	0
10	Right	Federal	42	5605050001	Monarch Chesterfield Levee District System	11.7	6.9	0.0002	7971	511
10	Left	non-Federal	39.5	5605860001	Greens Bottom Levee Sec1 System	1.2	0.1	No Data	0	0
10	Left	non-Federal	36.5	5605870001	Greens Bottom Levee Sec2 System	7.4	5.0	0.2	5	3
10	Right	non-Federal	33.5	5605220001	Howard Bend Levee District System	6.2	9.4	0.001	1483	132
10	Right	non-Federal	29.5	5605380001	Riverport Levee District System	2.6	0.8	0.001	5350	25
10	Right	non-Federal	28	5605120001	Earth City Levee District System	2.5	3.3	0.001	15198	215
10	Left	Federal	15.5	5605890001	Consolidated North County Levee System	37.4	55.3	0.05	1323	756
10	Right	non-Federal	24.5	5605840001	Missouri Bottoms Levee System	6.0	4.2	0.1	13	19
10	Right	non-Federal	2.5	5605660001	Columbia Bottoms Levee System	7.8	6.5	No Data	65	35
10	Left	non-Federal	2	5605670001	Kuhs Levee System	7.2	3.0	0.1	0	0

Table 3-39: Loading History for Study Reach 10

Levee Segment	Levee Construction	1993	1994	1995	2002	2008	2013	2017	2019
Tri-County LD Section 2	Non-Federal	Overtopped then Breached (8x)	Loaded. Unrepaired from 93	Overtopped then Breached (4x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Berger Levee District of Franklin County	Non-Federal	Overtopped then Breached	Loaded. Did Not Breach	Overtopped then Breached	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped then Breached (2x)	Loaded. Did Not Breach
MO Valley L.D. Sec 1	Non-Federal	Overtopped then Breached	No Info	Overtopped then Breached	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
MO Valley L.D. Sec 2 (Charrette Bottom)	Non-Federal	Overtopped. No Breach	No Info	Overtopped. No Breach	No Info	No Info	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Holtmeier Levee Association	Non-Federal	Overtopped then Breached	Overtopped. No Breach	Overtopped then Breached	No Info	No Info	Loaded. Did Not Breach	Overtopped. No Breach	Loaded. Did Not Breach
St. Johns Bottom Levee Association	Non-Federal	Overtopped then Breached	No Info	Overtopped then Breached	No Info	No Info	No Info	Overtopped then Breached	Loaded. Did Not Breach

Levee Segment	Levee Construction	1993	1994	1995	2002	2008	2013	2017	2019
Tuque Creek	Non-Federal	Overtopped then Breached	No Info	Overtopped then Breached	No Info	No Info	Loaded. Did Not Breach	Overtopped then Breached	Overtopped then Breached (1x)
Labadie Bottoms Section 4	Non-Federal	Overtopped then Breached (2x)	Overtopped. No Breach	Overtopped. No Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped. No Breach	Breached (3x) Prior to Overtopping	Breached Intentionally
St. Albans Partners	Non-Federal	Overtopped then Breached (7x)	Overtopped. No Breach	Overtopped then Breached (3x)	Overtopped No Breach	Overtopped. No Breach	Overtopped. No Breach	Overtopped then Breached	Loaded. Did Not Breach
Labadie Bottoms LD Sections 5	Non-Federal	Overtopped then Breached (4x)	Loaded. Did Not Breach	Overtopped then Breached (3x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Labadie Bottoms LD Sections 6	Non-Federal	Overtopped then Breached (1x)	Overtopped. No Breach	Overtopped. No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach
New Haven	Federal	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach	No Info	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Augusta Bottom Levee Association	Non-Federal	Overtopped then Breached (29x)	Loaded. Did Not Breach	Overtopped then Breached (8x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped then Breached (2x)	Breached (1x)
Dutzow Bottom Levee District	Non-Federal	Overtopped then Breached (8x)	Loaded. Did Not Breach	Overtopped then Breached (2x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach

Levee Segment	Levee Construction	1993	1994	1995	2002	2008	2013	2017	2019
Darst Bottom Levee System	Non-Federal	Overtopped then Breached (13x)	Loaded. Did Not Breach	Overtopped then Breached (7x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach
Missouri University Levee System	Non-Federal	Overtopped then Breached (1x)	Overtopped then Breached (1x)	Overtopped No Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped. No Breach
Monarch Chesterfield Levee District System	Federal	Overtopped then Breached (1x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach.	Loaded. Did Not Breach	Loaded. Did Not Breach
Green Bottoms Sec1 System	Non-Federal	No Info	No Info	Overtopped No Breach	No Info	No Info	Overtopped. No Breach	No Info	Overtopped. No Breach
Greens Bottom Sec2 System	Non-Federal	Overtopped then Breached (21x)	Overtopped then Breached (6x)	Overtopped then Breached (19x)	Loaded. Did Not Breach	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach
Howard Bend Levee District System	Non-Federal	Overtopped then Breached (15x)	No Info	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Riverport Levee District System	Non-Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Earth City Levee District System	Non-Federal	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach
Missouri Bottoms	Non-Federal	Overtopped then	Loaded. Did Not Breach	Overtopped then	Loaded. Did Not Breach	Loaded. Did Not Breach	Loaded. Did Not Breach	No Info	Loaded. Did Not Breach

Levee Segment	Levee Construction	1993	1994	1995	2002	2008	2013	2017	2019
Levee System		Breached (9x)		Breached (5x)					
Consolidated North County Levee System	Federal	Overtopped then Breached (51x)	Loaded. Did Not Breach	Overtopped then Breached (17x)	Loaded. Did Not Breach.	Loaded. Did Not Breach	Overtopped. No Breach	Overtopped. No Breach	Overtopped. No Breach
Kuhs Levee System	Non-Federal	Overtopped then Breached (4x)	Loaded. Did Not Breach	Overtopped then Breached (6x)	Overtopped then Breached (2x)	Overtopped then Breached (1x)	Overtopped. No Breach	Overtopped. No Breach	Overtopped then Breached (1x)
Columbia Bottoms Levee System	Non-Federal	Overtopped then Breached (18x)	No Info	Overtopped then Breached (24x)	No Info	Overtopped, No Breach	Overtopped. No Breach	No Info	Overtopped then Breached (1x)

Federal Levees Past Performance

The highest loading that the New Haven federal levee has experienced was 80 percent in 1993. Damages associated with scour, under seepage, settlement and sod kill were repaired after the flood. In 2019 it was loaded to approximately 55 percent and no significant damages were reported.

The highest loading that the Consolidated North County Levee System has experienced is over 100 percent in 1993, 1995, 2013, 2017, and 2019. Damages associated with scour, slides, under seepage, and numerous breaches were repaired after each flood.

The highest loading that the Monarch Chesterfield Levee District System was 100 percent in 1993. Damages from the flood event consisted primarily of under seepage damage and breach damage. However, after the flood of 1993, the levee system was rebuilt to the current alignment which reduces the risk of flooding to the leveed area for floods with a 50,000-year recurrence interval. The highest loading the levee has experienced in its current configuration is 31 percent. No significant damages were reported.

Non-Federal Levees

In the USACE – Kansas City District AOR eight of nine non-federal systems in this reach overtopped in 1993 and 1995. All but two breached from overtopping during both events. MO Valley L.D. Sec 2 (Charrette Bottom) overtopped only in 1993. Labadie Bottoms Section 4 overtopped during both events but only breached in 1993. It also overtopped in 2008, 2013, 2015, 2017 and 2019, breaching during three of those events. In 2019, four system overtopped and three of those breached due to overtopping. The five levees that did not overtop still had damages of erosion, under seepage, and sod kill that were repaired through the Rehabilitation Program

In the USACE - St. Louis District AOR, eleven of twelve non-federal systems in this reach overtopped in 1993 and 1995. In 1993, all levees that overtopped also breached. In 1995, all but two levees that overtopped also breached. Many non-federal levee systems in this reach have overtopped in at least four of the eight main flood events since 1993; these levee districts are Augusta Bottom Levee Association, Missouri University Levee System, Greens Bottom Sec2, Consolidated North County Levee System, Kuhs Levee System, and Columbia Bottoms Levee System. Levees that did have not overtopped or breached still had damages due to erosion, under seepage, and slides that may have been repaired through the Rehabilitation Program.

Economics

In the past 30 years, the levees in Reach 10 have incurred repair costs resulting from flood damage of \$41,103,414.73 (FY2024 dollars). Of the last 30 years, eight years

(1993, 1995, 1996, 2013, 2015, 2017, 2019, 2021) have seen at least one levee in Reach 10 get significantly damaged.

In the past 30 years, the levees in Reach 10 in the St. Louis District Area of Responsibility have incurred repair costs resulting from flood damage of \$16,213,307.34 (historic values). Of the last 30 years, at least nine years (1993, 1994, 1995, 2002, 2008, 2015, 2017, 2019, 2022) have seen at least one levee in Reach 10 get significantly damaged.

Other flooding impacts

Like Reach 9, many of these leveed areas are large. Impacts to agricultural production can be significant. The 1993 post flood report discusses impacts to the town of Hermann, which is a prominent tourist destination and wine producer in the area. In 1993, Hermann had access cut off in all directions resulting in large losses to business during the summer vacation season. Washington, MO had to deal with the closure of the Missouri State Highway 47 bridge over the Missouri River in 1993.

Crossover events are also a concern. In mid-July 1993, the Missouri River overtopped the non-federal levee on the left descending bank downstream of St. Charles, MO. Discharge measurements showed that near the crest, approximately 350,000 cubic feet per second, or 50 percent of the total flow, was flowing across St. Charles County. This flow entered the Mississippi River near Portage des Sioux, MO, approximately 18 miles upstream of the normal confluence of the two rivers. Severe damage in the form of scour and sand deposition occurred in this area.

When this crossover event occurs (Note: Crossover flow also occurred in 1986 and 1973. An event exceeding a 0.04 (1/25) AEP is required for crossover flow) between the Missouri River at St. Charles and the Mississippi River at Portage des Sioux there is an elevation differential of approximately 12 feet. Potential exists for total or partial flow capture in this crossover area. If a portion of the flow is captured, not only would navigation on the Missouri River be severely affected, but operation at Melvin Price Lock and Dam (located 13 miles downstream of Portage des Sioux and 5 miles upstream of the present confluence) would be severely impacted. While significant scour damage did occur in 1993, permanent flow capture did not result. However, the Missouri River overtopped and breached a 150-foot segment of Mainline Burlington and Northern Railroad track in the cross-over area. This track was the only source of coal supply to the Union Electric Power Plant at Portage des Sioux. A scour hole was reported at the breach and had encroached on buried pipelines which carry crude oil, natural gas, gasoline, and anhydrous ammonia.

The Levee Unit L-15 project was completed in 2004 which raised parts of the Consolidated North County Levee System (located in the crossover area) 2-4 feet to reduce the risk of flooding to the leveed area for floods with a 0.05 AEP. Since this time,

crossover flow has not been noted during flood events but could remain a concern under certain conditions.

4.0 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

4.1 Federal vs Non-Federal Levee Performance

All the study reaches saw significant damages in 2019. Most of the damages for Reaches 1 through 5 was during the March event. The May-June event had larger impacts to Reaches 6 through 10. Similarly, 1993 was a significant flood event for all the reaches, with Reaches 4 through 10 seeing most of the damage. The 2011 flood only impacted Reaches 1 through 6 and parts of Reach 7. Although river levels in 2011 were not as high as in 1993 or 2019, the length of time that the levees were loaded brought significant performance challenges.

In the USACE Kansas City District AOR, the federal levees on the Missouri River have historically performed well until they are overtopped. None have ever breached prior to overtopping and only a handful have ever overtopped. 1993 and 2019 are the only flood events since 1952 where federal levees have been overtopped. Only MRLS 500-R and MRLS 246-L overtopped both in 1993 and 2019. No federal levees overtopped in 2011.

The non-federal levees have also performed relatively well prior to overtopping, however with no national standards or state oversight in design and construction, the uncertainty in performance is higher than on the federal levees. Because most of the non-federal levees are built lower than the federal levees, they overtop and breach more frequently. They are also mainly built immediately adjacent to the riverbank, meaning they are loaded and damaged more frequently. Many non-federal levees can be significantly loaded and sustain damages to sod cover and levee slopes before water even reaches many of the federal levees. All the non-federal levees in the Kansas City District were overtopped in 1993, with most of them breaching. In 2019 65 of them overtopped with 45 of them breaching. In 2011 almost all the 14 non-federal levees between Rulo and Kansas City overtopped, with most breaching as a result. Of the last 30 years, 14 years (1993, 1995, 1996, 1998, 2002, 2007, 2008, 2010, 2011, 2013, 2015, 2017, 2019, 2021) have seen flood damages to non-federal levees active in the Rehabilitation Program. In comparison, most of the federal levees have only seen significant damages in about three of the last 30 years (1993, 2011, 2019).

4.2 Repetitive Loss Areas

The federal levees in the USACE Omaha District AOR sustained significant damages in 1993, 2011 and 2019. When the federal levees in Reach 3 breached in 2011 and 2019, Interstate I-29 had to be closed for extended periods of time resulting in economic impacts across the country.

The non-federal levees in the Kansas City District have sustained flood damages on multiple years between 1993 and 2023. In Reaches 5 through 10, there have been six years that a levee in each reach has sustained damage. Reaches 8 and 9 have seen

the highest number of flood damage years, with 14 and 12 years, respectively, causing damage to at least one levee in their reach.

Tebbetts East, Sugartree Bottom, Northeastern Saline, MRLS 246-L, Mokane, Lower Chariton, Holt County No. 10, Henrietta-Crooked Section 1, Dewitt Section 2, Brunswick, and Berger have all needed to be repaired in at least five separate instances between 1993 and 2023. MRLS 246-L has been damaged in more events than any other federal levee in the Kansas City District. It begins along the Grand River just downstream of Brunswick, MO and the levee district is prohibited from raising the levee on the Grand River tieback during high water events so that they do not induce flooding in Brunswick.

Other notable repetitive loss areas include the Capital View levee where flood damages can impact the Jefferson City Municipal Airport and as well as highway traffic on US Route 54. US Route 54 is a major route that crosses the Missouri River at Jefferson City. It connects North Jefferson City as well as Columbia to Jefferson City and to the Lake of the Ozarks. Capital View overtopped and breached in 1993, 1995 and 2019.

4.3 Repair Costs

Repair costs for the levees in the USACE Omaha District AOR (Reaches 1-4) from 2011 to the present have totaled over \$1.3 Billion in 2024 dollars. Repair costs for the levees in the USACE Kansas City District AOR (Reaches 5-10) from 1993 to present are estimated to be at least \$435 Million. This number is an underestimate as not all the repair costs from the 1993 flood could be located. These costs are only for repair of the levee projects and do not include damages and impacts to the leveed areas.

4.4 Considerations for Plan Formulation

The past performance assessment for the levees along the Missouri River will be considered for the Lower Missouri River System Plan formulation process and future recommendations. Patterns and insights from the levee past performance data will be incorporated into the measures and reach plans for the System Plan.

Historically levee breaches due to overtopping have been the most likely levee failure scenario. Because of the long duration flooding of the Missouri River, breaches can remain open for several months to over a year prior to being repaired. This impacts communities and farmers for months and years after flood events. System Plan measures that reduce the risk the overtopping will reduce damages to the areas behind the levee as well as reduce future levee repair costs. Measures that reduce the risk of levees breaching reduce damages from the flood event directly but also allow communities to return to normal much faster. Reducing the risk of breach also reduces future Rehabilitation Program levee repair costs to the levee sponsor and the public.

These benefits are not just felt locally but have ripple effects on the local, state and national economies.

5.0 LITERATURE CITED

American Society of Civil Engineers, So You Live Behind a Levee pamphlet, 2010.

National Weather Service, March 2019 Record Flooding
<https://www.weather.gov/oax/MarchRecordFlooding2019>

U.S. Army Corps of Engineers, The Great Flood of 1993 Post Flood Report, 1994.

U.S. Army Corps of Engineers, Considerations and Analysis for Flood Risk Resiliency for the Lower Missouri River (Nebraska, Kansas and Missouri) Planning Assistance to States, 2022.

6.0 LIST OF ACRONYMS AND ABBREVIATIONS

AEP	Annual Exceedance Probability
ASCE	American Society of Civil Engineers
AOR	Area of Responsibility
Cfs	cubic feet per second
CID	Central Industrial District
Ft	Feet
IA	Iowa
KS	Kansas
PAS	Planning Assistance to States
PL	Public Law
LB	Left Bank
MAF	Million Acre Feet
MRLS	Missouri River Levee System
MVA	Missouri River Valley Authority
MO	Missouri
NE	Nebraska
NEMA	Nebraska Emergency Management
NeDNR	Nebraska Department of Natural Resources
NWS	National Weather Service
RB	Right Bank
RM	River Mile
USACE	United States Army Corps of Engineers
USGS	United States Geologic Survey

Appendix A

Breach Maps