INVESTIGATION OF ROADWAY OVERTOPPING FREQUENCY ALONG RIVERTON ROAD (J46) NEAR RIVERTON, IOWA AND SIMULATION OF POTENTIAL MITIGATION ALTERNATIVES

BACKGROUND

Iowans living in Fremont County are frequently impacted by the flooding-related closure of Riverton Road (J46). This county road serves as a major east-west thoroughfare and its closure requires a significant 23-mile detour. This detour delays local emergency services and negatively impacts the regional economy.

Riverton Road crosses over the West and East Nishnabotna Rivers and is located just upstream of their confluence, as shown in Figure 1. Flooding originating from either river can force closure of the nearly 2-mile stretch of roadway within the floodplain. Satellite imagery of this area during the March 2019 flooding event is shown in Figure 2.

An initial study was completed by JEO Consulting, Inc. (JEO) in 2019 as part of the Iowa Watershed Approach's East and West Nishnabotna River Watershed and Flood Resiliency Plans (JEO Consulting Group 2019). This study developed a hydraulic model and examined potential alternatives in mitigating roadway overtopping using the 100-year flood hazard. These alternatives included:

1. Elevating the roadway above the 100-year water surface elevation
2. Increased wetland storage to attenuate flooding
3. Removal of a large private levee just downstream of Riverton Road
4. All mitigation options combined (road elevated, increased wetland storage, and levee removal)

While JEO's initial study provided valuable insights, they recommended evaluating a broader range of flood risk scenarios to optimize mitigation alternatives. In 2021, the Iowa Flood Center (IFC) continued this work in partnership with JEO, Golden Hills RC&D, and Iowa Homeland Security and Emergency Management. The purpose was to identify feasible mitigation alternatives for development of benefit cost analyses. IFC was tasked with performing hydraulic and hydrologic modeling and JEO was tasked with developing conceptual designs and benefit cost analyses.

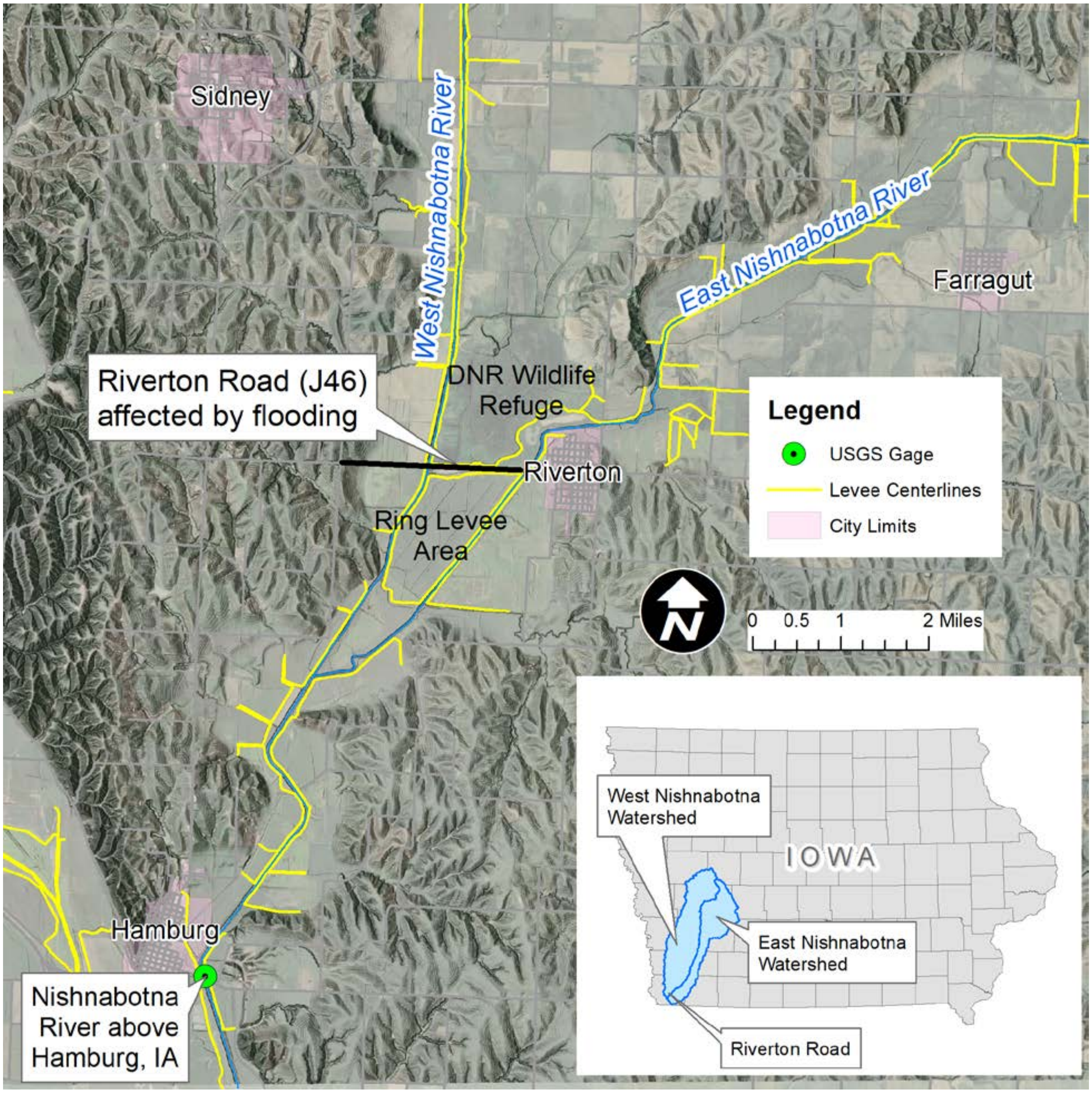


Figure 1. Riverton Road (J46) near the confluence of the West and East Nishnabotna Rivers.

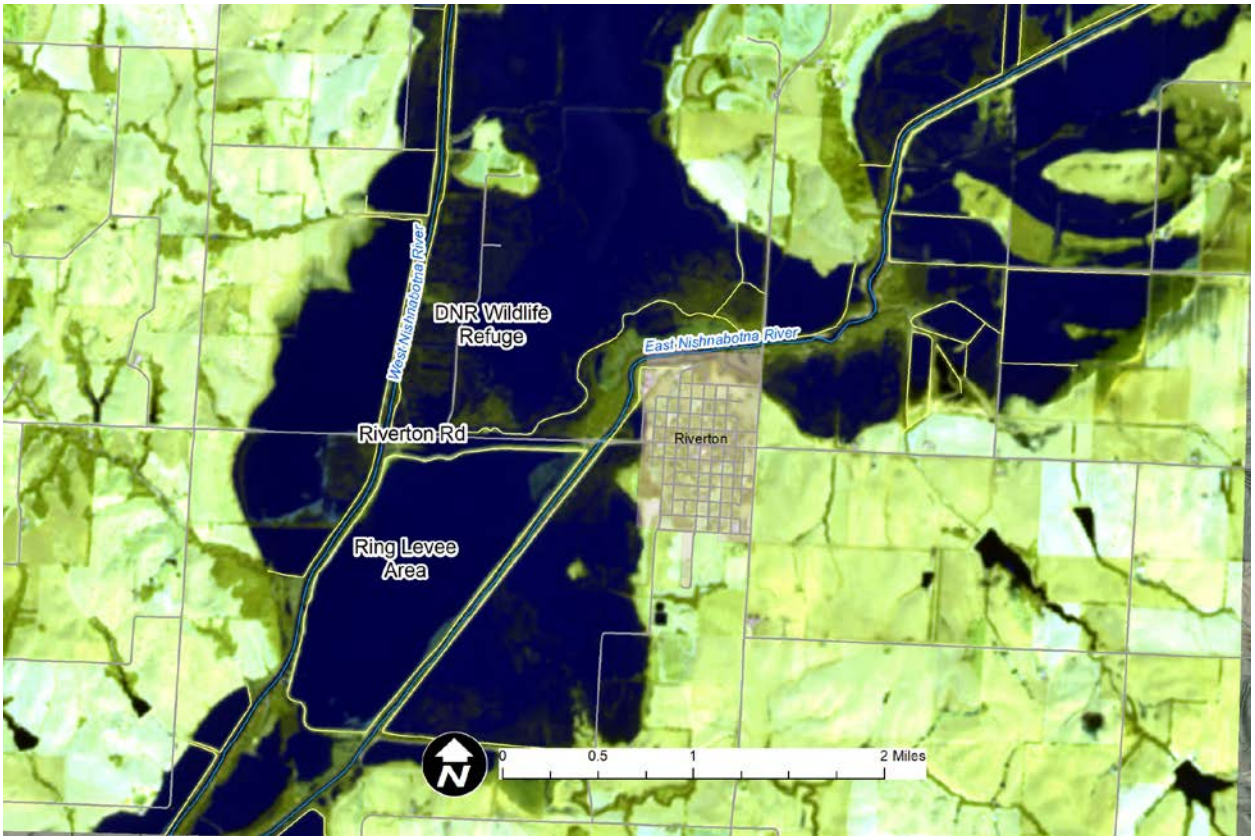


Figure 2. Riverton Road on March 21, 2019 during a major flood event using Sentinel satellite imagery.

Historic Road Closure Dates

The frequency of roadway closures is an important element in determining benefits of mitigation alternatives. Dates and durations of Riverton Road closures from 2014-2021 were provided by Fremont County Emergency Manager Mike Crecelius and are summarized by year and roadway approach direction in Table 1. The data are provided in Appendix A: Roadway Closure Dates and Durations. The west side approach was closed most frequently with 22 closures, and the east side approach was closed 16 times. Many of these closures were concurrent and correspond with the same flooding events. It is also worth noting when one side is closed the roadway is essentially closed to through traffic.

Table 1. Summary of roadway closures for west or east approach from 2014-2021.

	West Side Closures		East Side Closures	
Year	Closures	Total Duration (days)	Closures	Total Duration (days)
2014	7	17	4	6
2015	4	13	3	9
2016	2	7	2	4
2017	3	6	0	0
2018	1	3	2	3
2019	5	23	5	18
Total	22	69	16	40

Stream Flow Frequency Estimates

We estimated annual exceedance probability flows on the East, West and Nishnabotna Rivers using flow records from USGS stations at Randolph and Red Oak, Iowa, and upstream of Hamburg, Iowa. The locations of these gage stations within the watershed boundary are shown in Figure 3. At the time of analysis, these stations have annual peak discharges available for the periods shown in Table 2. We analyzed annual peak discharges using Bulletin 17C methodology (England et al. 2018) implemented in HEC-SSP 2.2 software (USACE 2019). We used a weighted skew, adopting a regional skew of -0.40 and mean square error of 0.16 from Eash et al. 2013. The resulting annual exceedance discharges for Randolph and Red Oak were adjusted to the Riverton Road area using a drainage area adjustment. The annual exceedance discharges are summarized in Table 3.

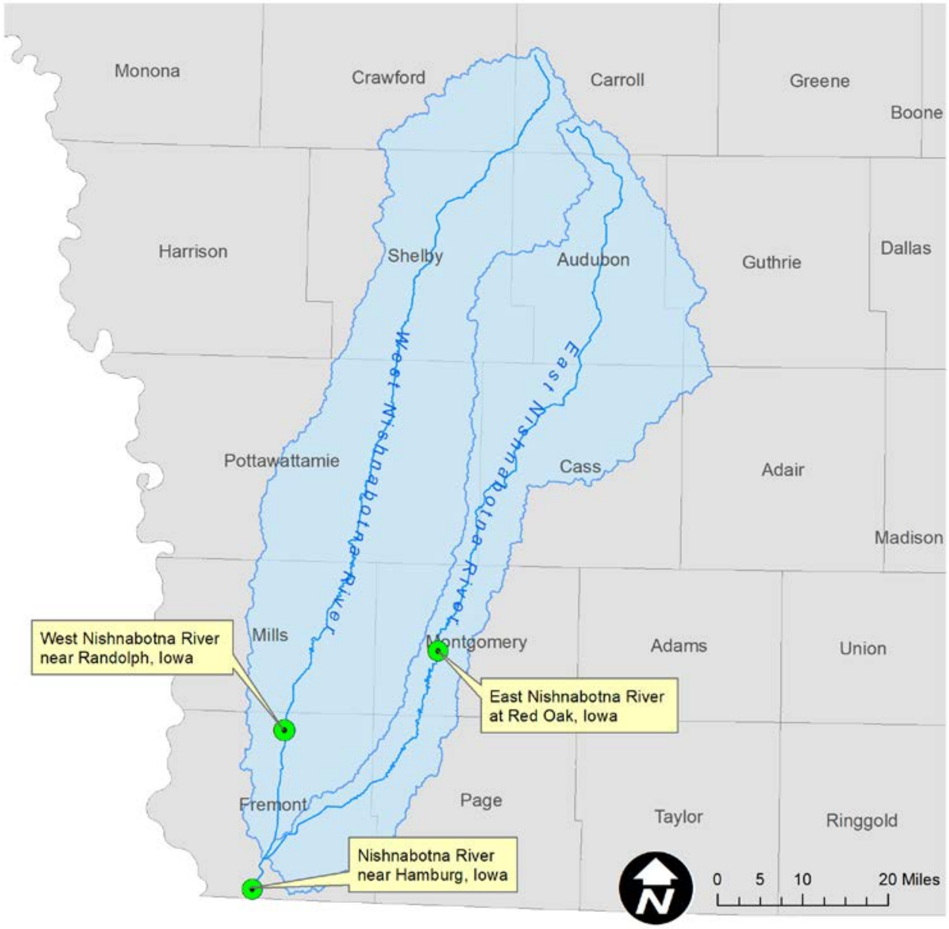


Figure 3. Watershed boundaries and USGS stream gaging locations.

Table 2. USGS stations used to estimate annual exceedance probability flows.

USGS Station	Period of Record	Missing Data
Randolph, Iowa 06808500	1949-2020	none
Red Oak, Iowa 06809500	1917-2020	1926-1935
Upstream of Hamburg, Iowa 06810000	1922-2020	1924-1928

Table 3. Estimated annual exceedance probability flows

Reach	80-pct (1.25-yr)	50-pct (2-yr)	20-pct (5-yr)	10-pct (10-yr)	4-pct (25-yr)	2-pct (50-yr)	1-pct (100-yr)
East Nishnabotna River at Riverton, IA	6,960	11,700	19,330	24,930	32,520	38,500	44,710
West Nishnabotna River at Riverton, IA	8,500	14,940	24,440	30,760	38,540	44,110	49,480
Nishnabotna River at Hamburg, IA	10,500	16,600	25,700	32,000	38,200	46,300	52,400

OBSERVATIONS

IFC Sensor Data

IFC stage sensors are located on Riverton Road's West Nishnabotna River bridge crossing and on an East Nishnabotna River bridge just upstream of Riverton Road, as shown in Figure 4. These sensors have observed stage measurements for the period of late 2016 – present. Plotting the closure dates along with observed stage measurements allows for estimation of stage thresholds that typically cause a road closure. The stage sensor observations at the West Nishnabotna sensor are shown along with known closure dates in Figure 5. The threshold that results in a closure appears to be elev. 923 feet, which is approximately the lowest elevation along the profile of Riverton Road, particularly the west approach, shown in Figure 6. The stage sensor observations at the East Nishnabotna sensor on 330th Ave are shown along with known closure dates in Figure 7. The stage threshold that results in an east closure appears to be elev. 928 feet, located approximately 1 mile upstream from Riverton Road.

Figure 4. Locations of nearby Iowa Flood Center stage sensors on the West and East Nishnabotna Rivers available in the Iowa Flood Information System (IFIS).

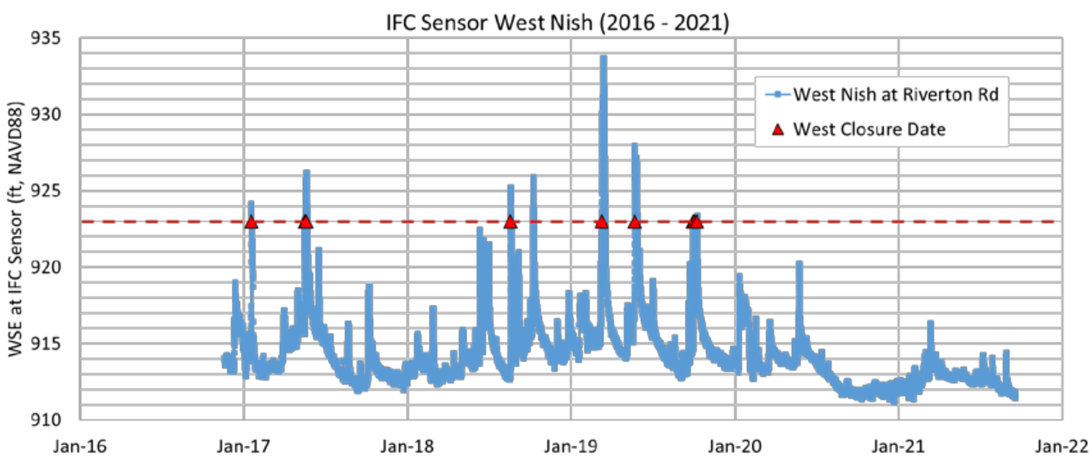
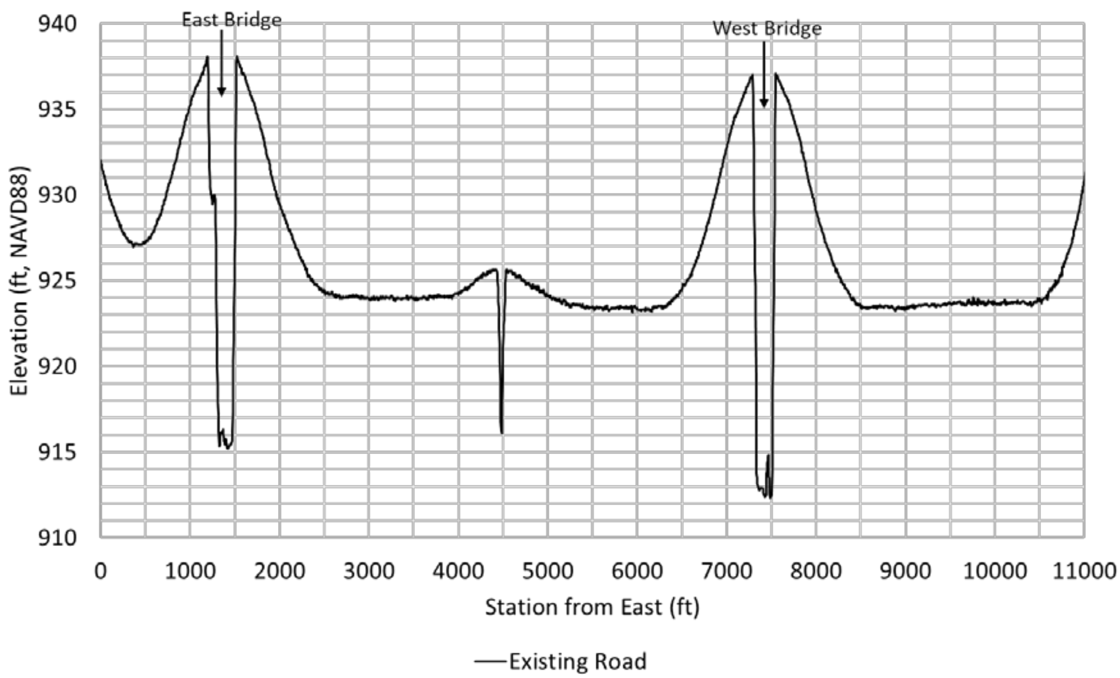


Figure 5. IFC stage sensor data at the West Nishnabotna bridge crossing from late 2016 through present, plotted with known west closure dates and estimated water surface threshold that results in a road closure.



1. Figure 6. Riverton Roadway embankment profile from LiDAR terrain data. View is from left to right looking downstream.

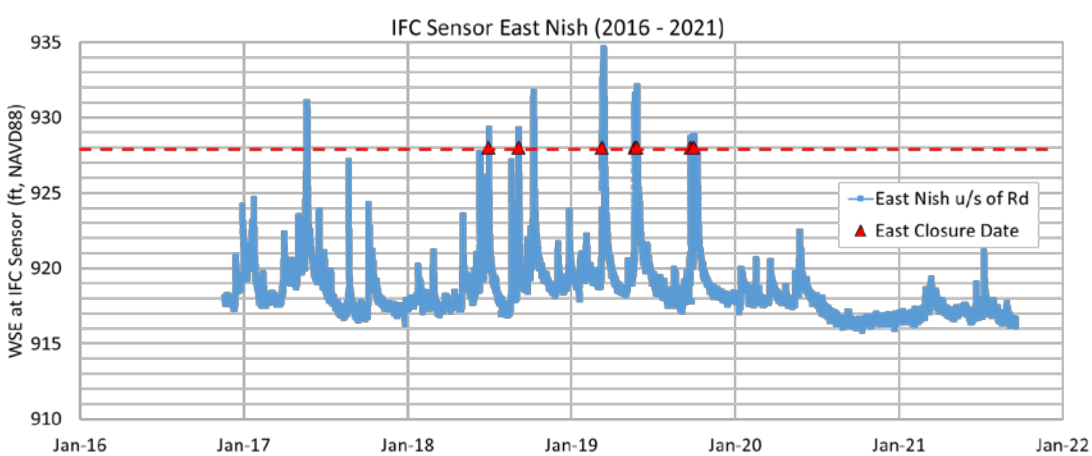


Figure 7. IFC stage sensor data at an East Nishnabotna River sensor located on 330th Ave from late 2016 through present, plotted with known east closure dates and estimated water surface threshold that results in a road closure.

United States Geological Survey (USGS) Flow Records

USGS flow records at the stream gaging stations near Riverton Road were used to estimate flows during the road closure events from 2014 – present. Hourly flow records used in this analysis were gathered for the stream gage stations located at Randolph, Red Oak and Hamburg. This analysis allows for identification of threshold flows at gage locations that typically result in Riverton Road closures. Additionally, these flows can be used to estimate the return period of the flooding events that cause closures. Estimated peak flows on the East Nishnabotna River, West Nishnabotna River and Nishnabotna River for each closure event are shown in Table 4, Table 5, and Table 6, respectively.

Table 4. Estimated peak East Nishnabotna River flows and return periods for the east side road closures. West Nishnabotna River flows and return periods at the time of the East Nishnabotna River peak flow are also provided.

East Closure Dates							
Start	**End**	**Days**	**East Nish Peak Flow (cfs)**	**Hour from Start**	**Return Period**	**West Nish Flow (cfs)**	**Return Period**
6/4/2014	6/5/2014	2	8580	18	**1.25 to 2**	20600	2 to 5
7/1/2014	7/1/2014	1	16200	20	**2 to 5**	7730	<1.25
7/5/2014	7/5/2014	1	10600	24	**1.25 to 2**	13200	1.25 to 2
9/10/2014	9/11/2014	2	18200	30	**2 to 5**	7790	<1.25
6/12/2015	6/13/2015	2	12000	24	**2 to 5**	5110	<1.25
6/15/2015	6/17/2015	3	17000	34	**2 to 5**	5750	<1.25
12/14/2015	12/17/2015	4	8170	62	**1.25 to 2**	6690	<1.25
5/10/2016	5/11/2016	2	12000	30	**2 to 5**	7710	<1.25
5/27/2016	5/28/2016	2	13600	22	**2 to 5**	4840	<1.25
7/1/2018	7/2/2018	2	9260	30	**1.25 to 2**	4340	<1.25
9/6/2018	9/6/2018	1	8350	10	**1.25 to 2**	2740	<1.25
3/11/2019	3/19/2019	9	24200	108	**5 to 10**	18700	2 to 5
5/24/2019	5/26/2019	3	6650	36	**<1.25**	3010	<1.25
5/28/2019	5/30/2019	3	10300	36	**1.25 to 2**	4690	<1.25
9/26/2019	9/26/2019	1	12100	2	**2 to 5**	2810	<1.25
10/2/2019	10/3/2019	2	8290	28	**1.25 to 2**	3350	<1.25

Table 5. Estimated peak West Nishnabotna River flows and return periods for the east side road closures. East Nishnabotna River flows and return periods at the time of the East Nishnabotna River peak flow are also provided.

West Closure Dates							
Start	End	Days	West Nish Peak Flow (cfs)	Hour from Start	Return Period	East Nish Flow (cfs)	Return Period
6/4/2014	6/5/2014	2	21900	16	**2 to 5**	8190	1.25 to 2
7/1/2014	7/2/2014	2	7760	18	**<1.25**	16000	2 to 5
7/5/2014	7/7/2014	3	16200	28	**2 to 5**	9020	1.25 to 2
8/28/2014	8/30/2014	3	12600	22	**1.25 to 2**	2790	<1.25
9/2/2014	9/2/2014	1	9360	10	**1.25 to 2**	5080	<1.25
9/10/2014	9/12/2014	3	18000	18	**2 to 5**	12000	2 to 5
10/1/2014	10/3/2014	3	9920	24	**1.25 to 2**	5030	<1.25
6/11/2015	6/13/2015	3	5220	44	**<1.25**	11300	1.25 to 2
6/15/2015	6/17/2015	3	6790	24	**<1.25**	11400	1.25 to 2
8/9/2015	8/9/2015	1	8860	12	**1.25 to 2**	645	<1.25
12/13/2015	12/18/2015	6	13800	56	**1.25 to 2**	7000	1.25 to 2
5/10/2016	5/13/2016	4	7780	32	**<1.25**	11900	2 to 5
5/26/2016	5/28/2016	3	8130	34	**<1.25**	6460	<1.25
5/17/2017	5/17/2017	1	7420	14	**<1.25**	1440	<1.25
5/20/2017	5/22/2017	3	7680	22	**<1.25**	4830	<1.25
8/20/2018	8/22/2018	3	14000	26	**1.25 to 2**	3970	<1.25
5/24/2019	5/31/2019	8	8650	16	**1.25 to 2**	4840	<1.25
10/2/2019	10/2/2019	1	4980	16	**<1.25**	3350	<1.25
10/5/2019	10/6/2019	2	5200	26	**<1.25**	3550	<1.25
10/11/2019	10/12/2019	2	6760	20	**<1.25**	6820	<1.25

Table 6. Estimated peak Nishnabotna River flows and return periods for road closures.

Closure Start (both west & east)	Peak Hour after Closure Start	Peak Q Date/time	Hamburg Maximum Flow	Return Period
6/4/2014	14	6/4/2014 14:00	23000	2 to 5
7/1/2014	20	7/1/2014 20:00	17700	2 to 5
7/5/2014	30	7/6/2014 06:00	21400	2 to 5
8/28/2014	32	8/29/2014 08:00	16800	2 to 5
9/2/2014	12	9/2/2014 12:00	15300	1.25 to 2
9/10/2014	24	9/11/2014 00:00	19300	2 to 5
10/1/2014	34	10/2/2014 10:00	18600	2 to 5
6/11/2015	50	6/13/2015 02:00	15000	1.25 to 2
6/12/2015	92	6/15/2015 20:00	16300	1.25 to 2
6/15/2015	20	6/15/2015 20:00	18700	2 to 5
8/9/2015	12	8/9/2015 12:00	16400	1.25 to 2
12/13/2015	66	12/15/2015 18:00	23700	2 to 5
5/10/2016	38	5/11/2016 14:00	21200	2 to 5
5/26/2016	38	5/27/2016 14:00	20100	2 to 5
5/27/2016	14	5/27/2016 14:00	20100	2 to 5
5/17/2017	94	5/20/2017 22:00	18000	2 to 5
5/20/2017	38	5/21/2017 14:00	19300	2 to 5
7/1/2018	32	7/2/2018 08:00	13400	1.25 to 2
8/20/2018	30	8/21/2018 06:00	14000	1.25 to 2
9/6/2018	4	9/6/2018 04:00	13100	1.25 to 2
3/16/2019	12	3/16/2019 12:00	39000	20 to 50
5/24/2019	20	5/24/2019 20:00	17800	2 to 5
5/28/2019	32	5/29/2019 08:00	18700	2 to 5
9/26/2019	6	9/26/2019 06:00	9920	<1.25
10/2/2019	24	10/3/2019 00:00	11600	1.25 to 2
10/5/2019	26	10/6/2019 02:00	10700	1.25 to 2
10/11/2019	26	10/12/2019 02:00	12500	1.25 to 2

The frequencies of each return period range that resulted in a road closure for the East Nishnabotna River, West Nishnabotna River and Nishnabotna River are plotted in Figure 8, Figure 9, and Figure 10, respectively. These summary plots indicate flood events that result in road closures are overwhelmingly less than the 5-year annual exceedance probability, with many closures occurring at an event with a return period smaller than the 2-year event.

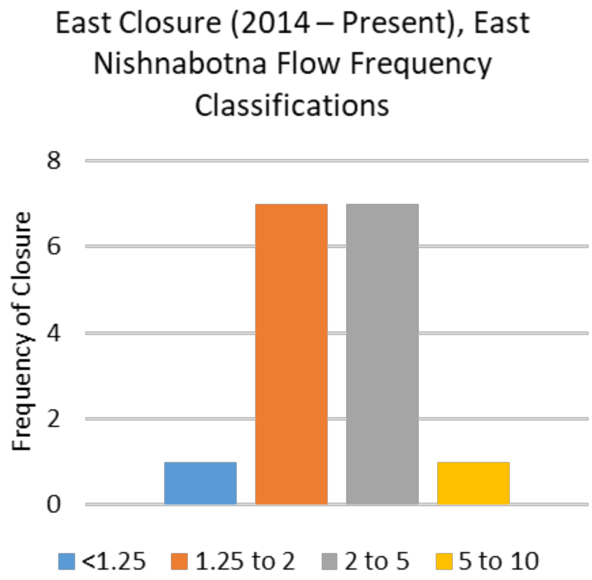


Figure 8. The frequency of each return period range that resulted in a road closure (2014-present) for the East Nishnabotna River.

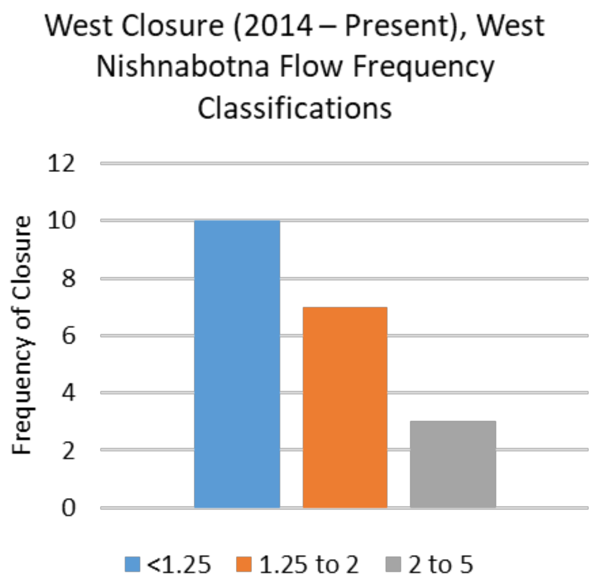


Figure 9. The frequency of each return period range that resulted in a road closure (2014-present) for the West Nishnabotna River.

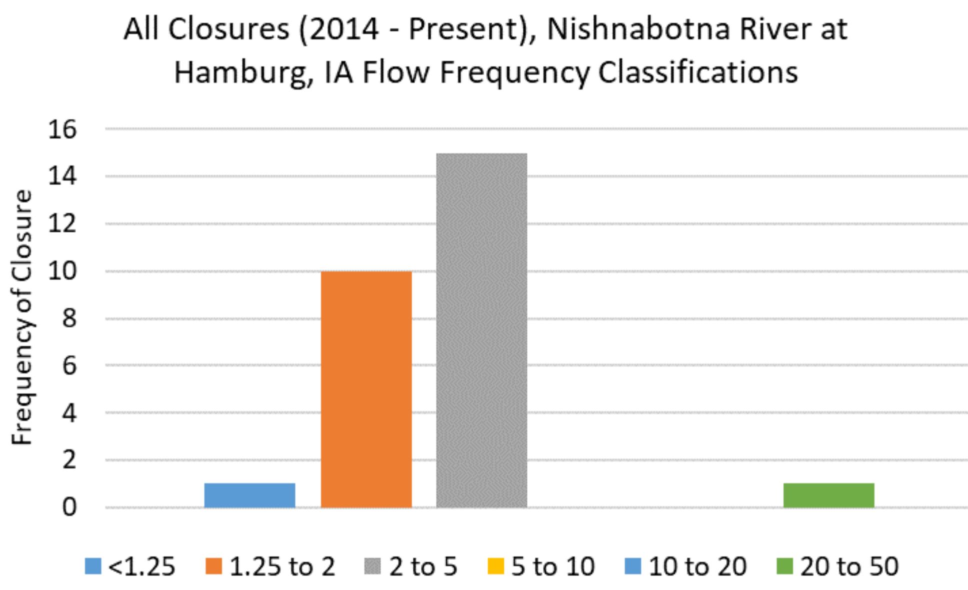


Figure 10. The frequency of each return period range that resulted in a road closure (2014-present) at the USGS stream station just upstream of Hamburg, Iowa.

Observed Flow Trends

We estimated the 1-percent annual exceedance probability (100-year) flows using Bulletin 17C statistical methods and plotted as the period of record increased at Randolph and Red Oak. A plot of the 100-year flow estimates beginning in 1960 for the West Nishnabotna River at Randolph is shown in Figure 11. A similar plot for East Nishnabotna River at Red Oak beginning in 1940 is shown in Figure 12. 100-year flow estimates at both these locations appear to have increased as their period of record increased, and larger observed annual peaks occurred. This is particularly noticeable at Red Oak with the largest events occurring in 1947, 1998 and 2007. Similar estimates were generated for the 10-percent annual exceedance probability (10-year) flows. A plot of the 10-year flow estimates beginning in 1960 for the West Nishnabotna River at Randolph is shown in Figure 13. The 10-year flow estimate for West Nishnabotna River has remained relatively stable in recent decades. A similar plot for East Nishnabotna River at Red Oak is shown in Figure 14. The 10-year flow estimate for East Nishnabotna River appears to trend sharply upward from 1940 – 1970, but the upward trend has slowed in recent decades.

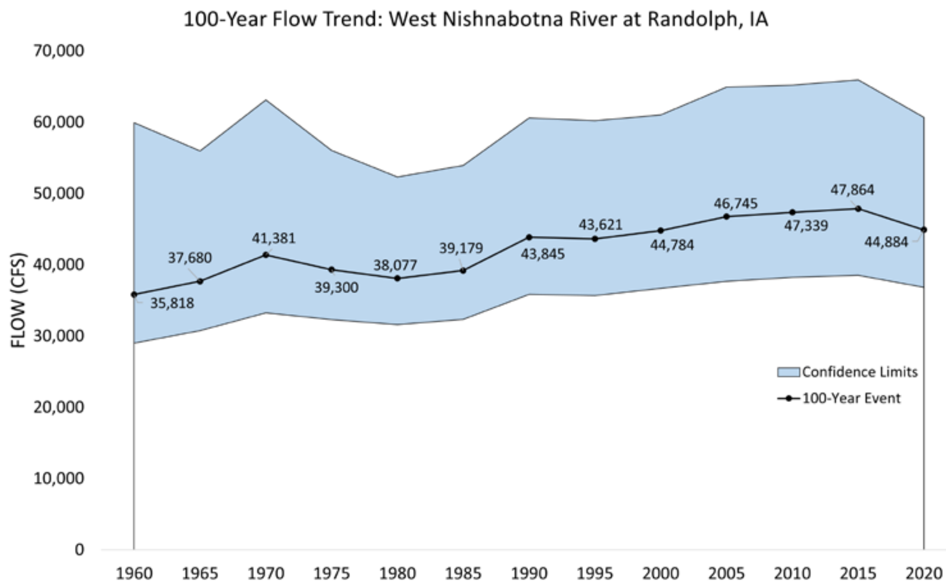


Figure 11. Estimates of the 100-year flow event on the West Nishnabotna River at Randolph, Iowa through time beginning in 1960. The 100-year flow estimate appears to trend upward since 1960 at this location.

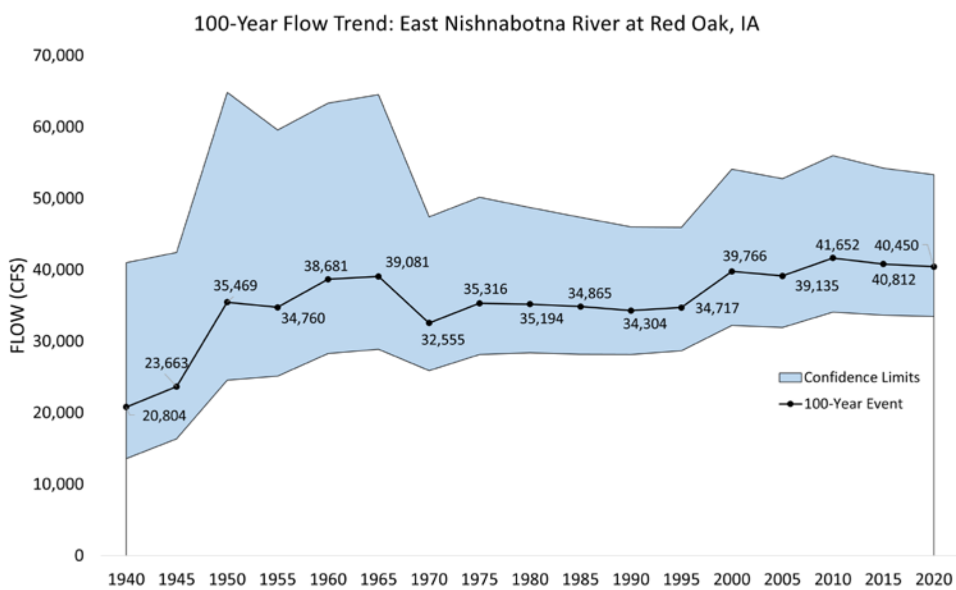


Figure 12. Estimates of the 100-year flow event on the East Nishnabotna River at Red Oak, Iowa through time beginning in 1940. The 100-year flow estimate appears to trend upward since 1940 at this location but has flattened in recent decades.

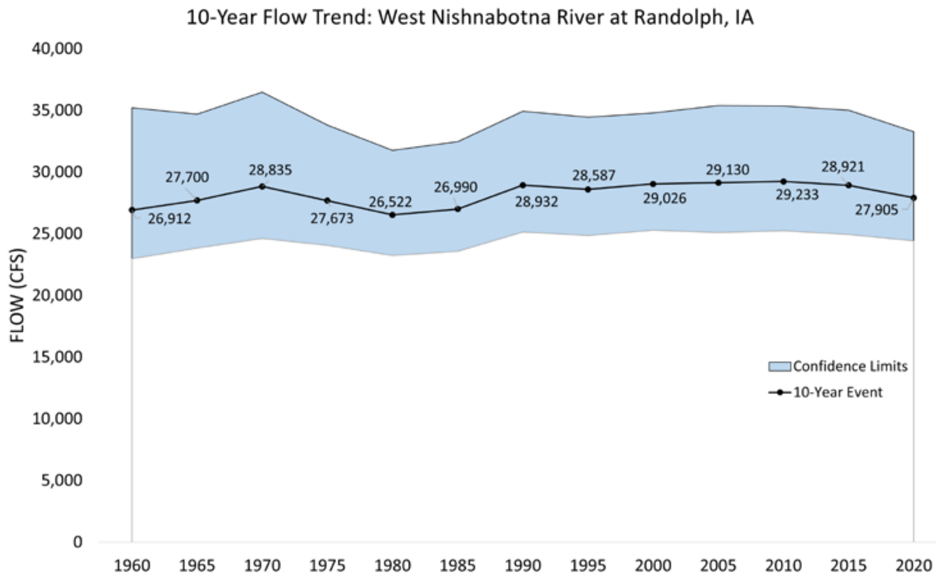


Figure 13. Estimates of the 10-year flow event on the West Nishnabotna River at Randolph, Iowa through time beginning in 1960. The 10-year flow estimate appears to have stabilized in recent decades.

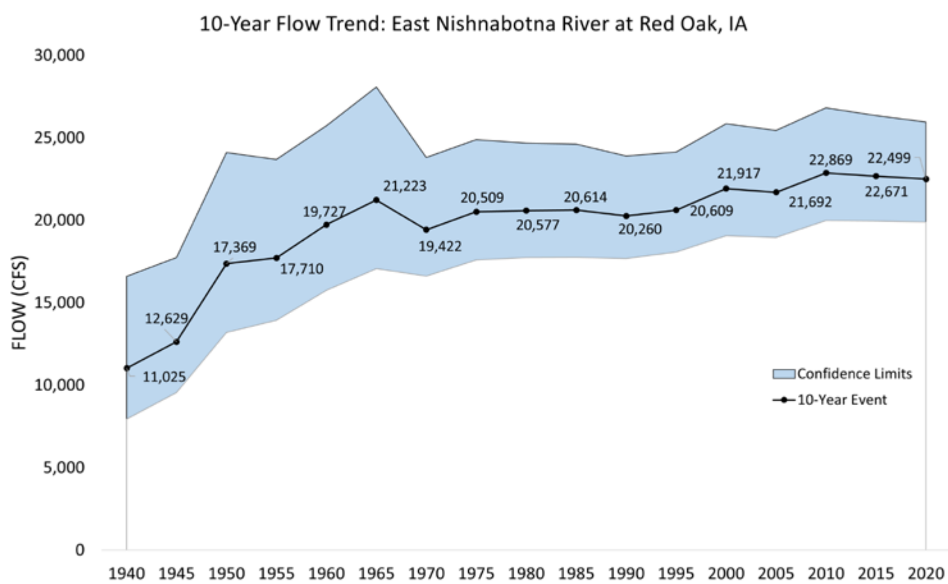


Figure 14. Estimates of the 10-year flow event on the East Nishnabotna River at Red Oak, Iowa through time beginning in 1940. The 10-year flow estimate appears to trend sharply upward from 1940 – 1970, but the upward trend has slowed in recent decades.

Using daily mean flow estimates provided by USGS, we estimated the number of days with high flow, greater than 5,000 cfs for each decade. A plot showing the number of high daily mean flows for the West Nishnabotna Rivers at Randolph is shown in Figure 15. Similar to the tread in annual exceedance estimates, days of high flow per decade for the West Nishnabotna River have remained relatively stable in recent decades. A similar plot for the East Nishnabotna River at Red Oak is shown in Figure 16. The days of high flow per decade for the East Nishnabotna River indicate an upward trend.

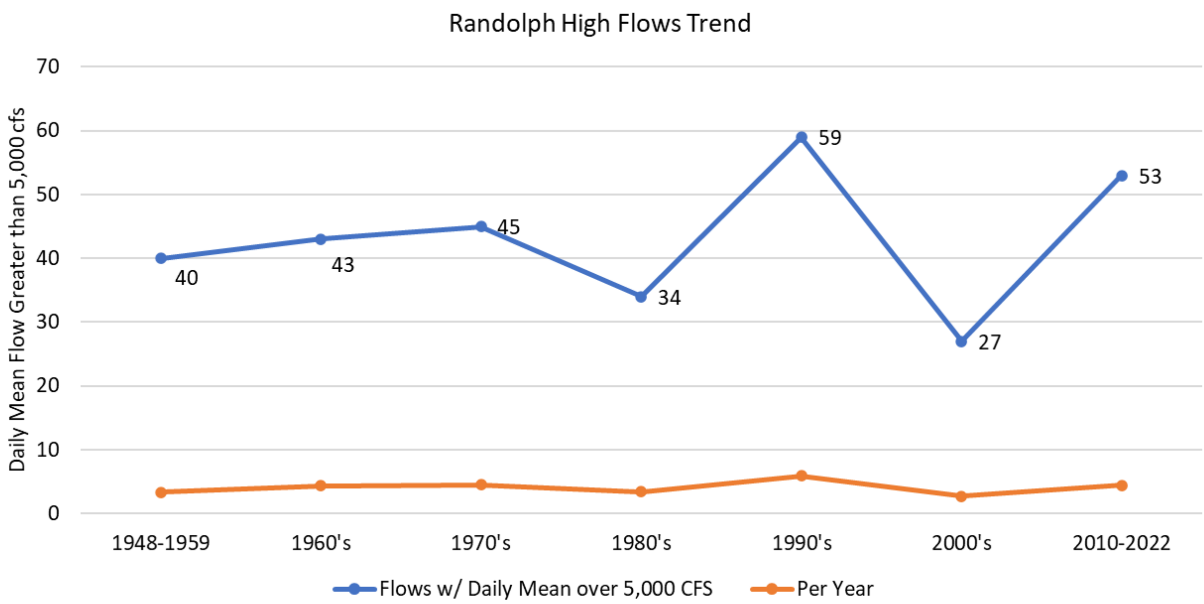


Figure 15. Number of daily mean West Nishnabotna River flow estimates at Randolph greater than 5,000 cfs for each decade.

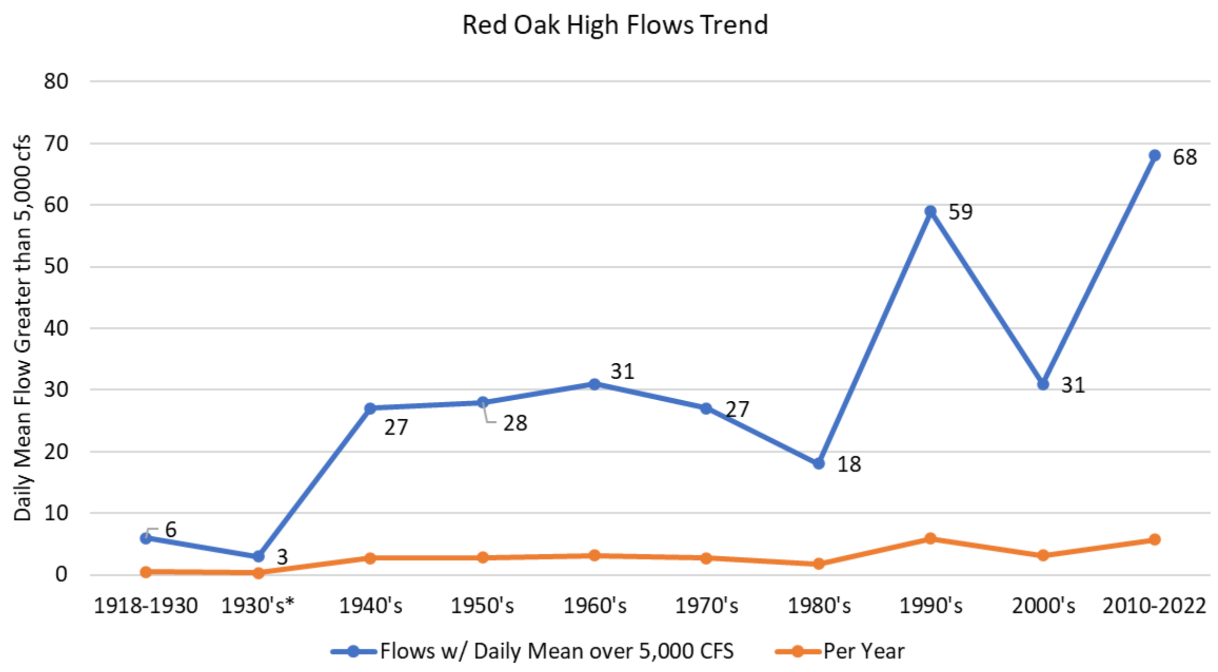


Figure 16. Number of daily mean East Nishnabotna River flow estimates at Red Oak greater than 5,000 cfs for each decade. Some data is missing in the 1930s.

Estimating Road Closures 1990 – 2013

We identified likely road closures events from 1990 – 2013 using sub-hourly flow observations at the Randolph and Red Oak USGS gaging stations. Based on the documented closure events from 2014-present, threshold flows of 7,000 cfs and 8,000 cfs were assumed on the West and East Nishnabotna Rivers at Randolph and Red Oak, respectively. A plot showing observed flows on the West Nishnabotna River at Randolph, along with potential and documented closure events are shown in Figure 17. A similar plot for the East Nishnabotna River at Red Oak is shown in Figure 18. Using these criteria, there were 41 events on the West Nishnabotna River and 45 on the East Nishnabotna River identified as possible road closure events. The average closure duration of identified potential closures was 1.5 days, which is less than the average closure duration of 2.5 to 3 days for the documented closures. In reality, it is likely identified potential closure events occurring within days of each other would amount to a single closure. Therefore, it is likely that the duration of identified potential closures would be longer, while the number of closures would decrease. The specific closure dates and durations identified in this analysis are tabulated in Appendix B.

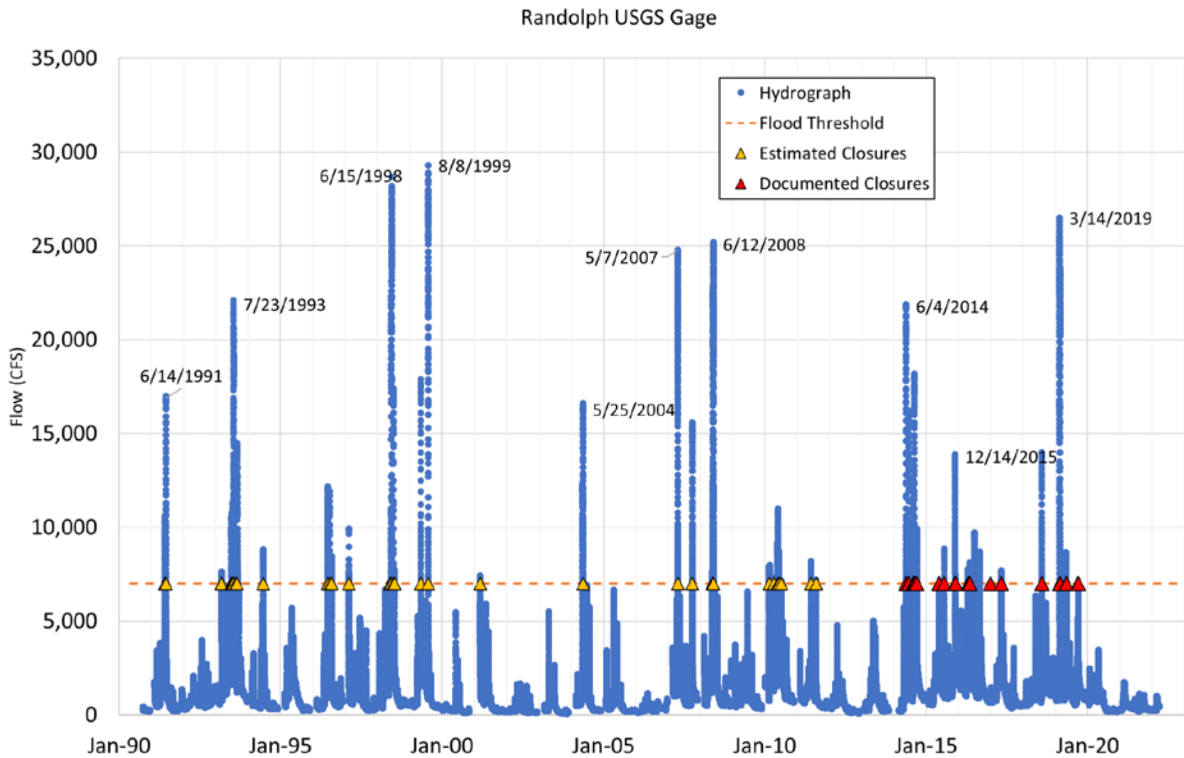


Figure 17. Flow observations on the West Nishnabotna River at Randolph, Iowa USGS gage. Possible road closure events (41) were identified for period 1990 - 2013, shown with documented closures for 2014-present.

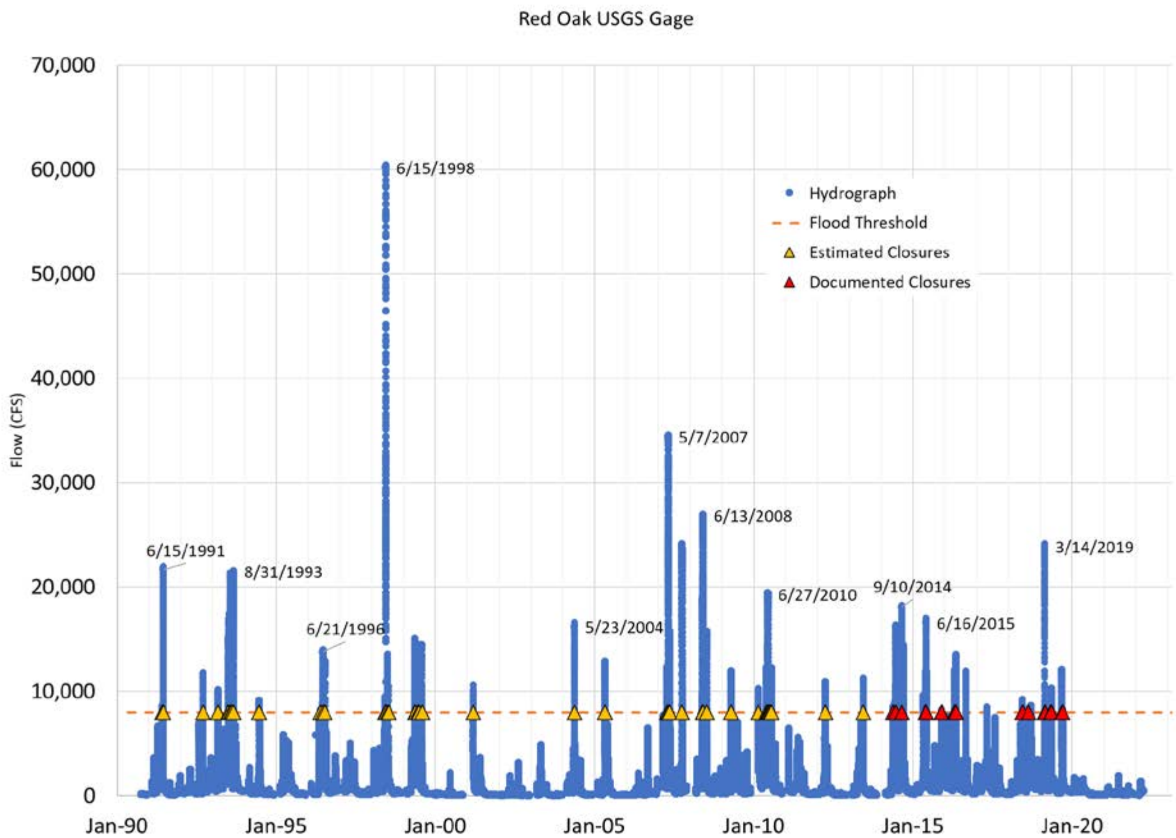


Figure 18. Flow observations on the East Nishnabotna River at Red Oak, Iowa USGS gage. Possible road closure events (45) were identified for period 1990 - 2013, shown with documented closures for 2014-present.

HYDRAULIC MODELING

IFC leveraged the hydraulic model developed by JEO for the Nishnabotna Confluence Case Study which was part of the East Nishnabotna River Watershed Management and Flood Resiliency Plan (JEO Consulting Group 2019). The model was originally developed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 5.05. The hydraulic model is capable of unsteady simulation of the two-dimensional depth-averaged shallow water equations. JEO calibrated the existing conditions model to match the FEMA Zone A flood study extent with the study area.

The mesh geometry was entirely based on 1-meter resolution Light Detection and Ranging (LiDAR) topographic data from the 2007-2009 period. An example of the mesh near Riverton Road is shown in Figure 19. Topographic break lines were used to appropriately represent high ground features like levees and roadway embankments within the study area. Bathymetric data was not collected nor incorporated into the hydraulic model. Since this effort intended to simulate flooding events more frequent than the 100-year event, IFC made small modifications to the terrain to remove LiDAR artifacts or other errors along levee centerlines and prevent premature levee overtopping. IFC modified topographic break lines to better represent the geometry at lower flows. IFC utilized the newer HEC-RAS version 6.1 to run simulations (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2022).

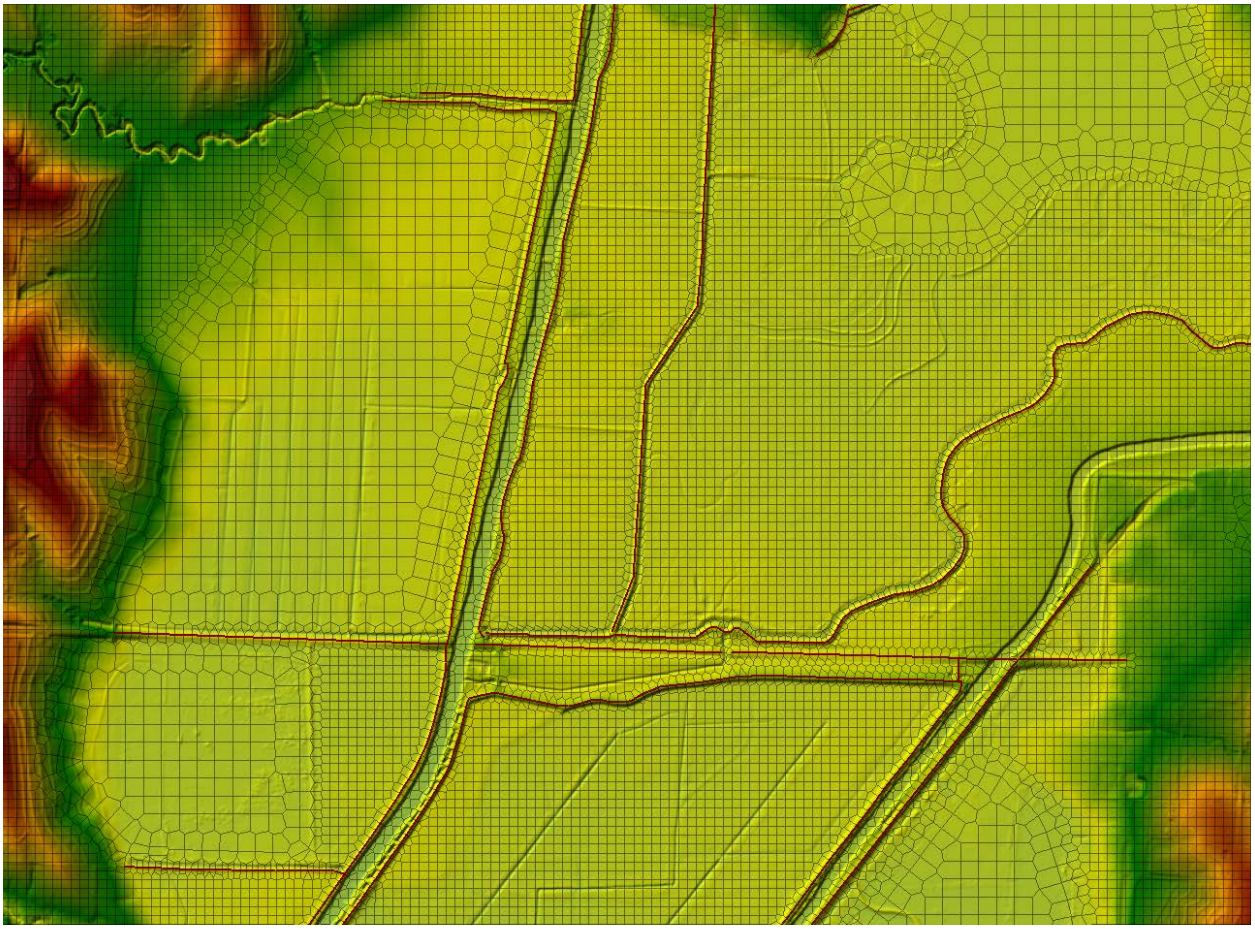


Figure 19. HEC-RAS mesh cells representing the terrain, levees and stream channels.

Simulation of Mitigation Alternatives to Prevent Overtopping

Project partners held frequent virtual meetings to collaborate on formulating and evaluating mitigation alternatives. The general approaches to formulating mitigation alternatives were to either directly raise portions of Riverton Road or to utilize levee improvements to protect the roadway.

Alternatives were investigated using a range of flood frequency flows (1.25- through 10-year) on each river to identify the impact of coincident high flows. Sixteen flow combinations used for simulation of each alternative are shown in Table 7. The inflow hydrographs were created by scaling 15-minute flow observations from the May 2007 Nishnabotna River flooding event, as observed at USGS station 06810000, upstream of Hamburg, Iowa.

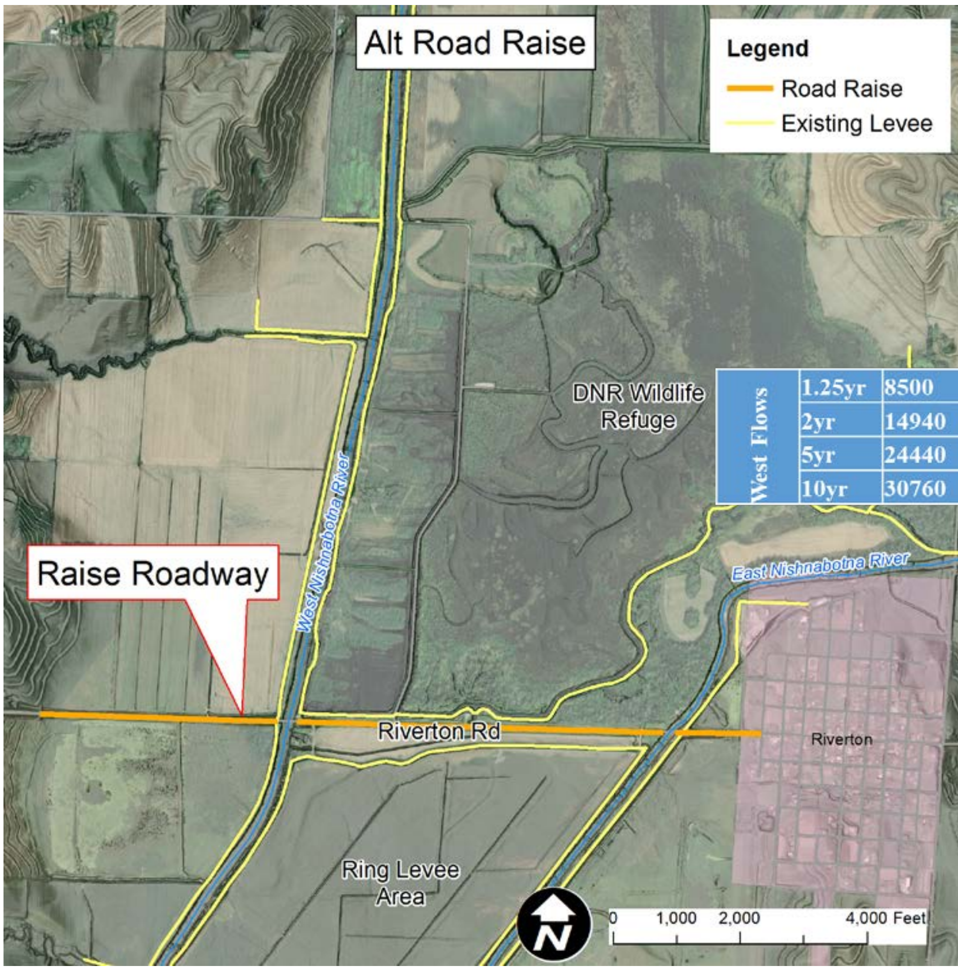
Table 7. Flood frequency flow combinations used for simulations.

Flow Combinations			East Nishnabotna River flows (cfs)			
			1.25yr	2yr	5yr	10yr
			6,960	11,700	19,330	24,930
West Nishnabotna River flows (cfs)	1.25yr	8,500	Qeast = 6960, Qwest = 8500	Qeast = 11700, Qwest = 8500	Qeast = 19330, Qwest = 8500	Qeast = 24930, Qwest = 8500
	2yr	14,940	Qeast = 6960, Qwest = 14940	Qeast = 11700, Qwest = 14940	Qeast = 19330, Qwest = 14940	Qeast = 24930, Qwest = 14940
	5yr	24,440	Qeast = 6960, Qwest = 24440	Qeast = 11700, Qwest = 24440	Qeast = 19330, Qwest = 24440	Qeast = 24930, Qwest = 24440
	10yr	30,760	Qeast = 6960, Qwest = 30760	Qeast = 11700, Qwest = 30760	Qeast = 19330, Qwest = 30760	Qeast = 24930, Qwest = 30760

Simulation results were reviewed to see if Riverton Road overtopped, and if so, where the overtopping event occurred. Tables indicating whether the alternative would have overtopped Riverton Road are included with maps and descriptions of alternatives in following sections.

Alternative – Road Raise

The most pragmatic mitigation alternative is directly raising the Riverton Road embankment. This alternative would raise much of the roadway 5-7 feet, to elevation 932 ft, elevating the lowest points of the roadway. The alignment of this improvement is shown in Figure 20. Raising to this elevation would allow existing bridges over the East and West Nishnabotna Rivers to remain. Simulated overtopping results shown in table at right.

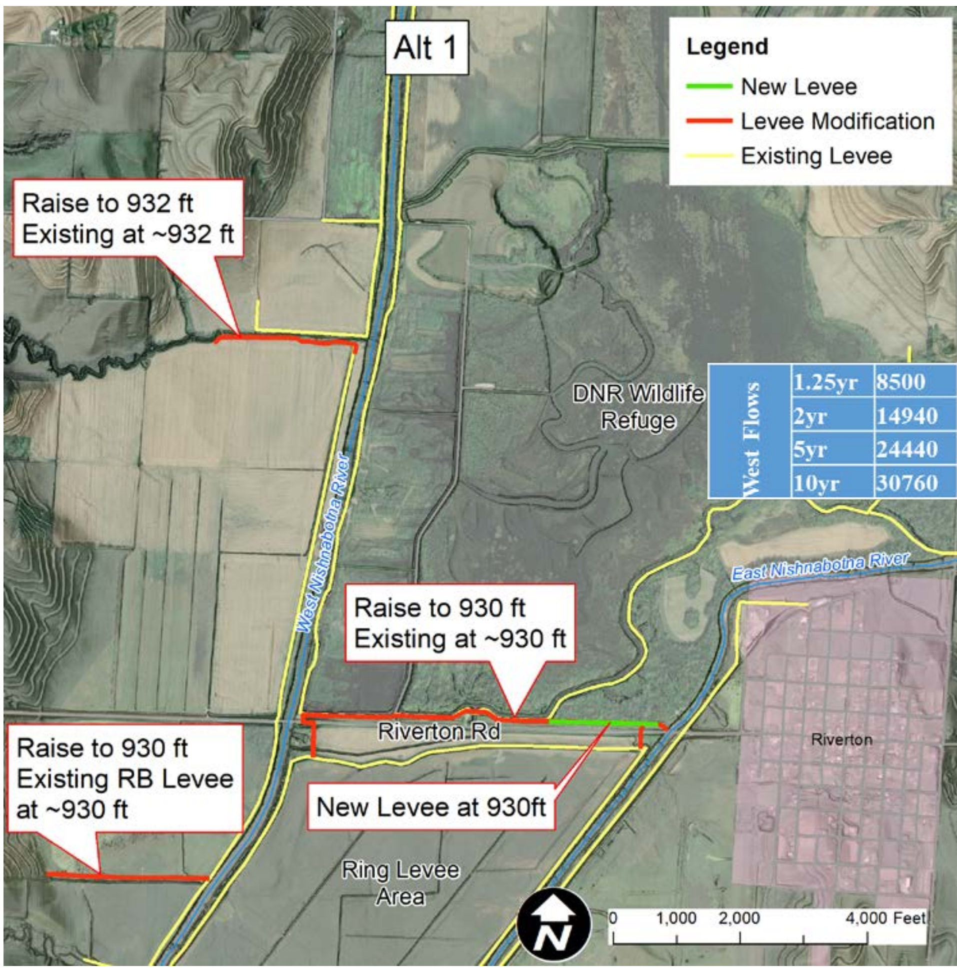


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	No
	2yr	14940	No	No	No	No
	5yr	24440	No	No	No	No
	10yr	30760	No	No	Yes	Yes

Figure 20. Alternative – Road Raise, this would raise the roadway to at least an elevation of 932 ft. Simulated overtopping results shown in table at right.

Alternative – 1

This alternative utilizes levee improvements to protect the middle portion of Riverton Road and prevent overtopping of the west portion of roadway with tributary tie-back levees, as shown in Figure 21. The new levee segments would tie into existing levee segments and the bridge abutments on the West and East Nishnabotna River bridges. Simulated overtopping results shown in table at right.

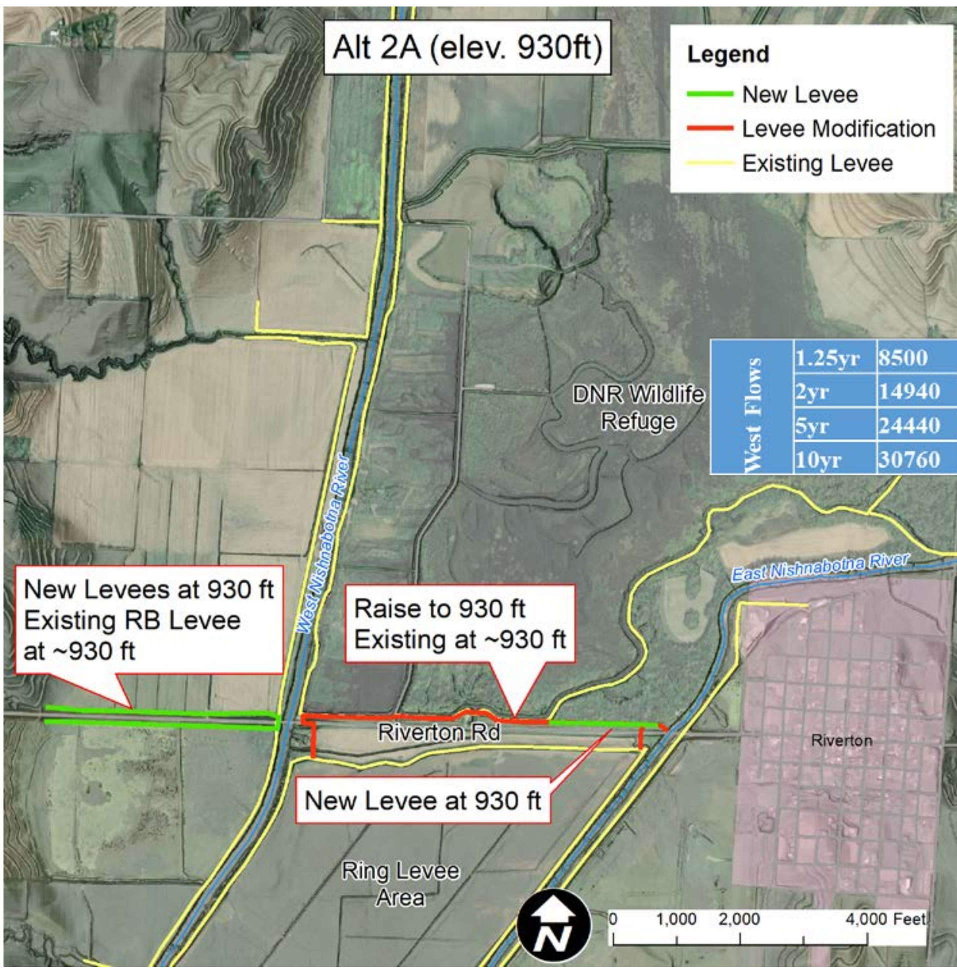


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	Yes	Yes
West Flows	2yr	14940	No	No	Yes	Yes
West Flows	5yr	24440	Yes	Yes	Yes	Yes
West Flows	10yr	30760	Yes	Yes	Yes	Yes

Figure 21. Alternative – 1, this would utilize levee improvements along tributary tie-back levees and along the roadway to prevent overtopping. Simulated overtopping results shown in table at right.

Alternative – 2A (el.930ft)

This alternative utilizes the same approach of protecting the middle portion of roadway using levee improvements. However, the western portion of roadway is protected by constructing new levees just to the north and south of the roadway, rather than tributary tie-back levees, as shown in Figure 22. Using levees along the roadway would avoid having to replace the pavement, potentially reducing costs. This alternative would require more fill material to construct these new levee segments. Simulated overtopping results shown in table at right.

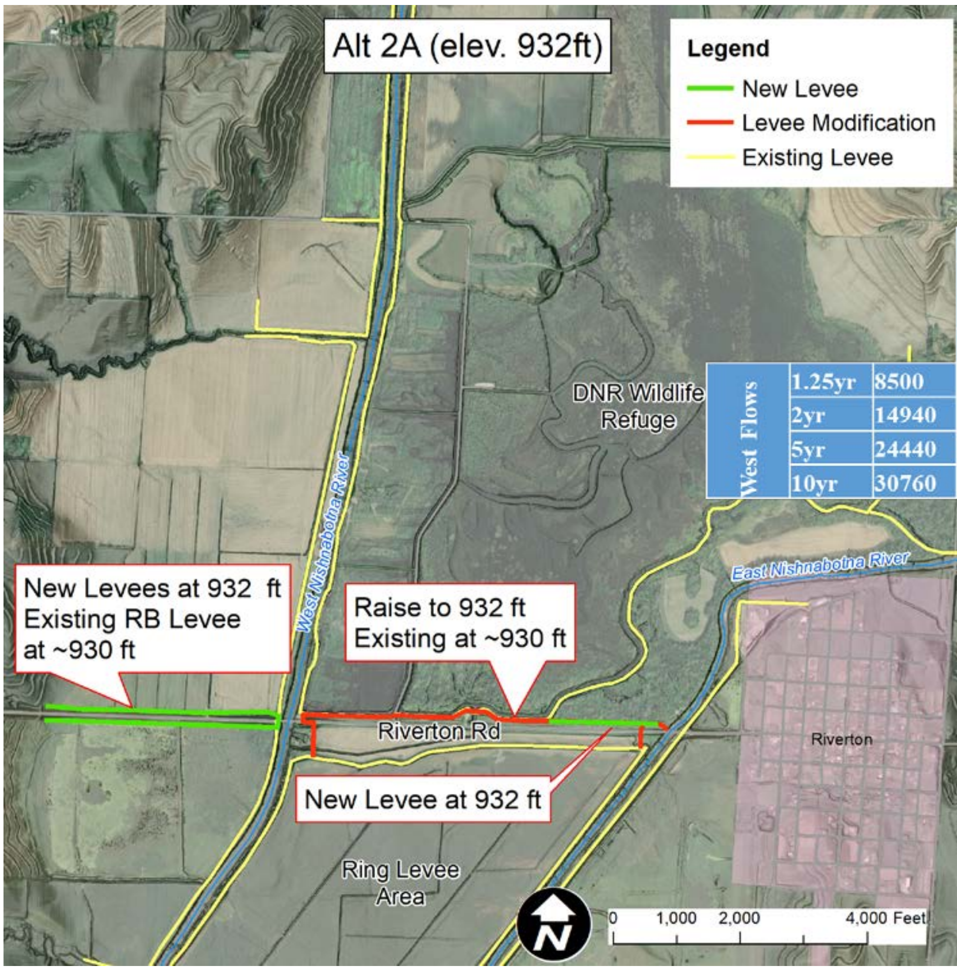


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	Yes
	2yr	14940	No	No	No	Yes
	5yr	24440	Yes	Yes	Yes	Yes
	10yr	30760	Yes	Yes	Yes	Yes

Figure 22. Alternative – 2A (el.930ft), this would utilize levee improvements to prevent overtopping along the roadway. Simulated overtopping results shown in table at right.

Alternative – 2A (el.932ft)

This alternative is the same as Alternative – 2A (el.930ft), but new levee segments and levee modifications are to el. 932ft, as shown in Figure 23. Simulated overtopping results shown in table at right.

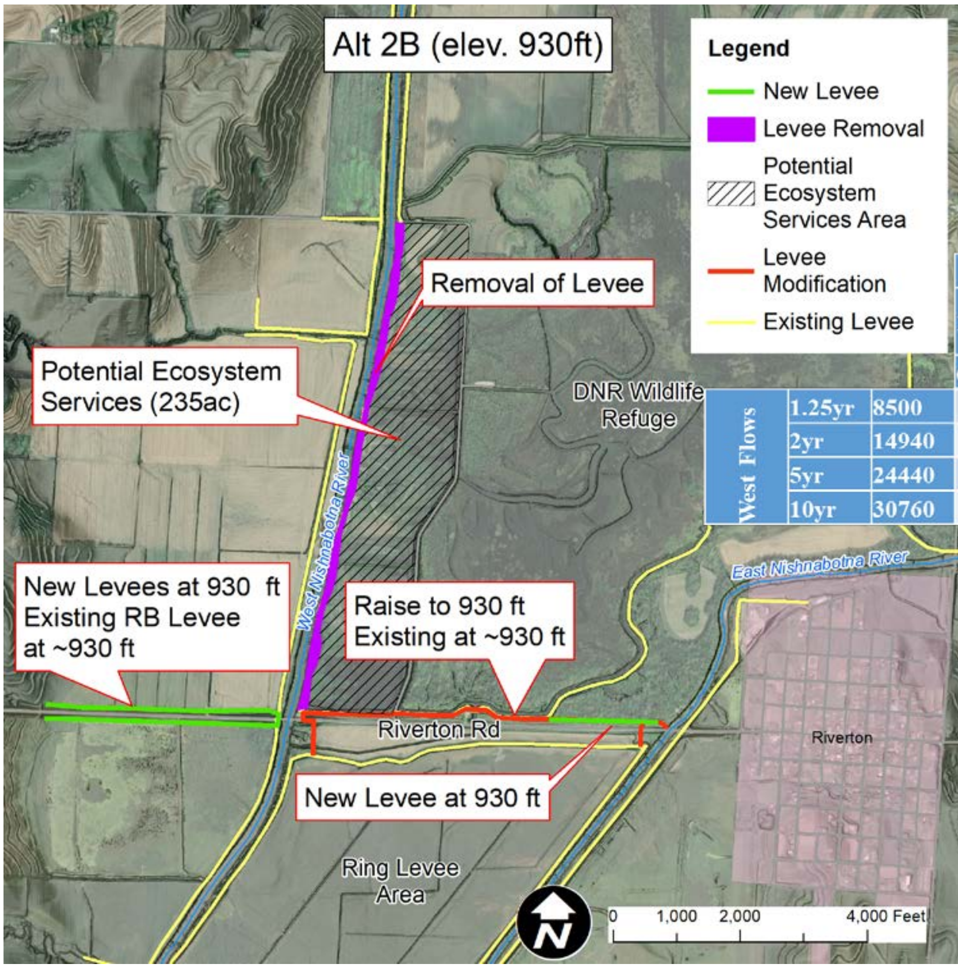


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	No
	2yr	14940	No	No	No	No
	5yr	24440	No	No	No	No
	10yr	30760	No	No	Yes	Yes

Figure 23. Alternative – 2A (el.932ft), this would utilize levee improvements to prevent overtopping along the roadway. Simulated overtopping results shown in table at right.

Alternative – 2B (el.930ft)

This alternative is the same as Alternative – 2A but would include removal of a Wildlife Management Area (WMA) spoils levee along the east descending bank of the West Nishnabotna River, as shown in Figure 24. Removal of the spoils levee is intended to create potential ecosystems services acres. Simulated overtopping results shown in table at right.

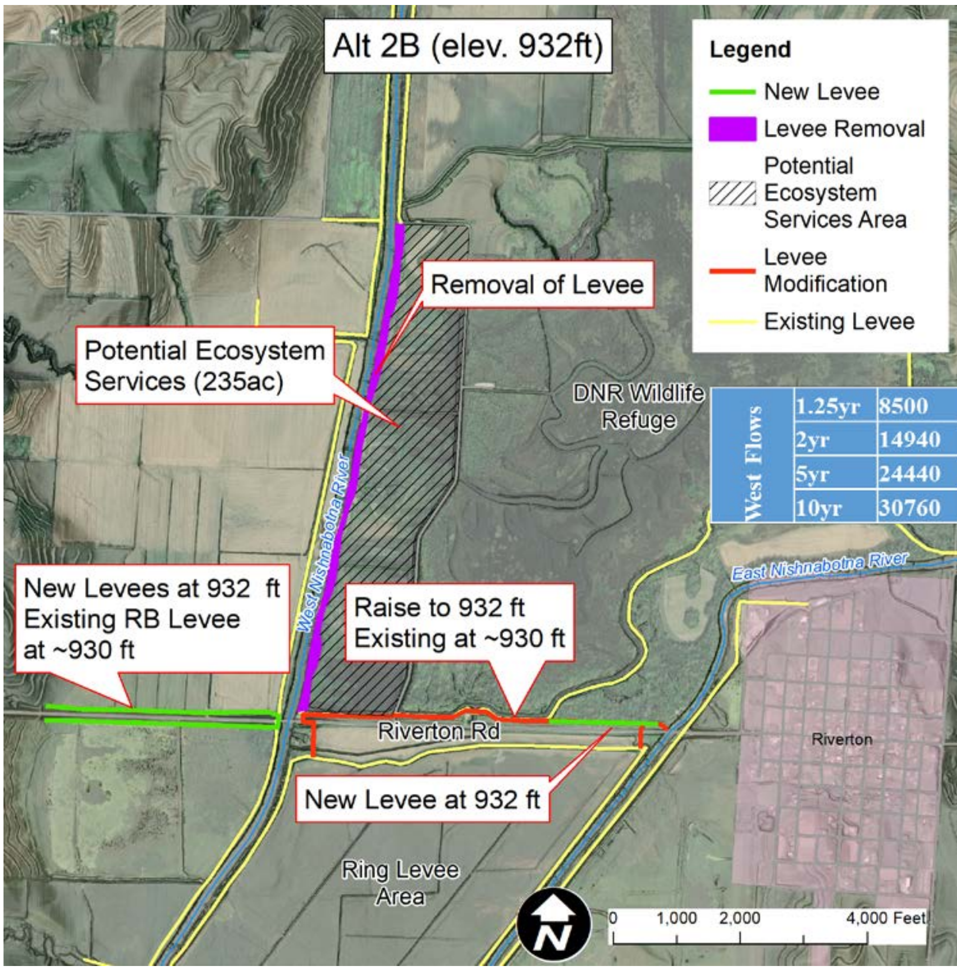


		East Flows			
		1.25yr	2yr	5yr	10yr
		6960	11700	19330	24930
West Flows 1.25yr	8500	No	No	No	No
West Flows 2yr	14940	No	No	No	Yes
West Flows 5yr	24440	No	No	Yes	Yes
West Flows 10yr	30760	Yes	Yes	Yes	Yes

Figure 24. Alternative – 2B (el.930ft), this would utilize levee improvements to prevent overtopping along the roadway and includes removal of a WMA spoils levee along West Nishnabotna River. All modifications are at a lower elev. 930 ft. Simulated overtopping results shown in table at right.

Alternative – 2B (el.932ft)

This alternative is the same as Alternative – 2B (el.930ft), but new levee segments and levee modifications are to el. 932ft, as shown in Figure 25. Simulated overtopping results shown in table at right.

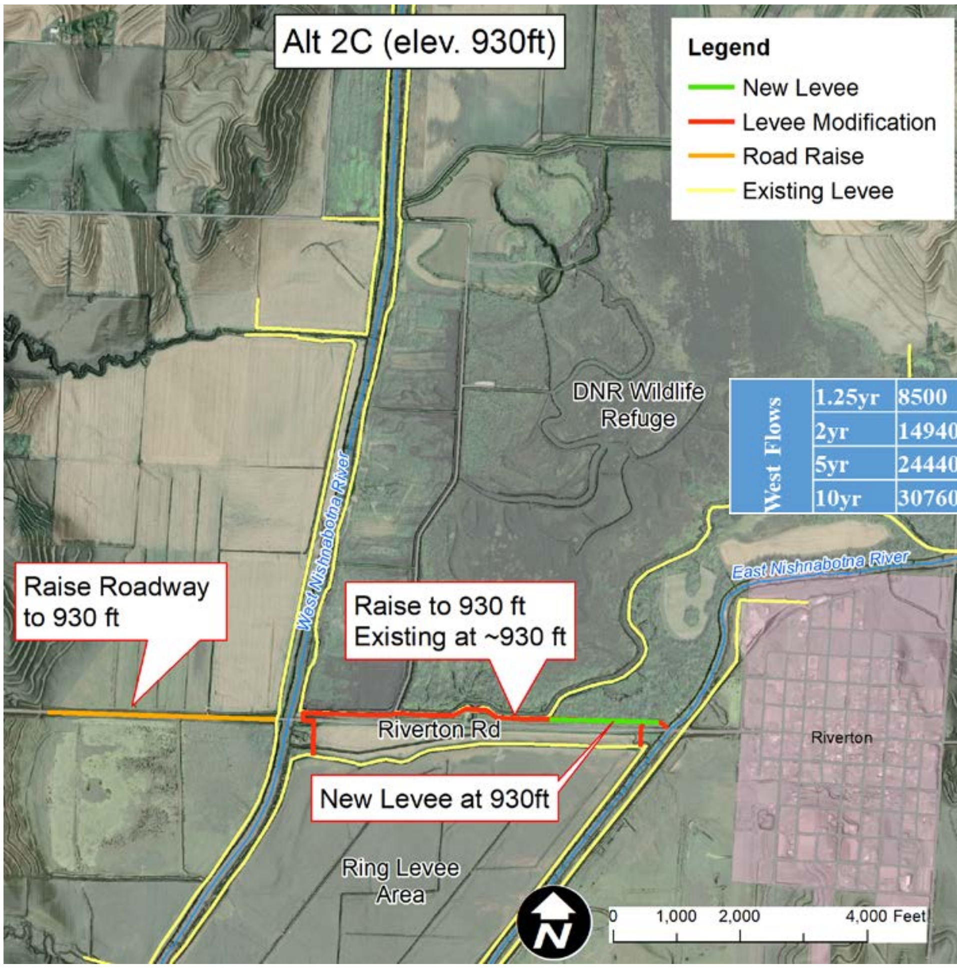


		East Flows			
		1.25yr	2yr	5yr	10yr
		6960	11700	19330	24930
West Flows	1.25yr 8500	No	No	No	No
	2yr 14940	No	No	No	No
	5yr 24440	No	No	No	No
	10yr 30760	No	No	No	Yes

Figure 25. Alternative – 2B (el.932ft), this would utilize levee improvements to prevent overtopping along the roadway and includes removal of a WMA spoils levee along West Nishnabotna River. Simulated overtopping results shown in table at right.

Alternative – 2C (el.930ft)

This alternative is the same as Alternative – 2 in protecting the middle portion of roadway using levee improvement but raises the western portion of roadway, as shown in Figure 27. This alternative would reduce the area of private land requiring easements or acquisition. Simulated overtopping results shown in table at right.

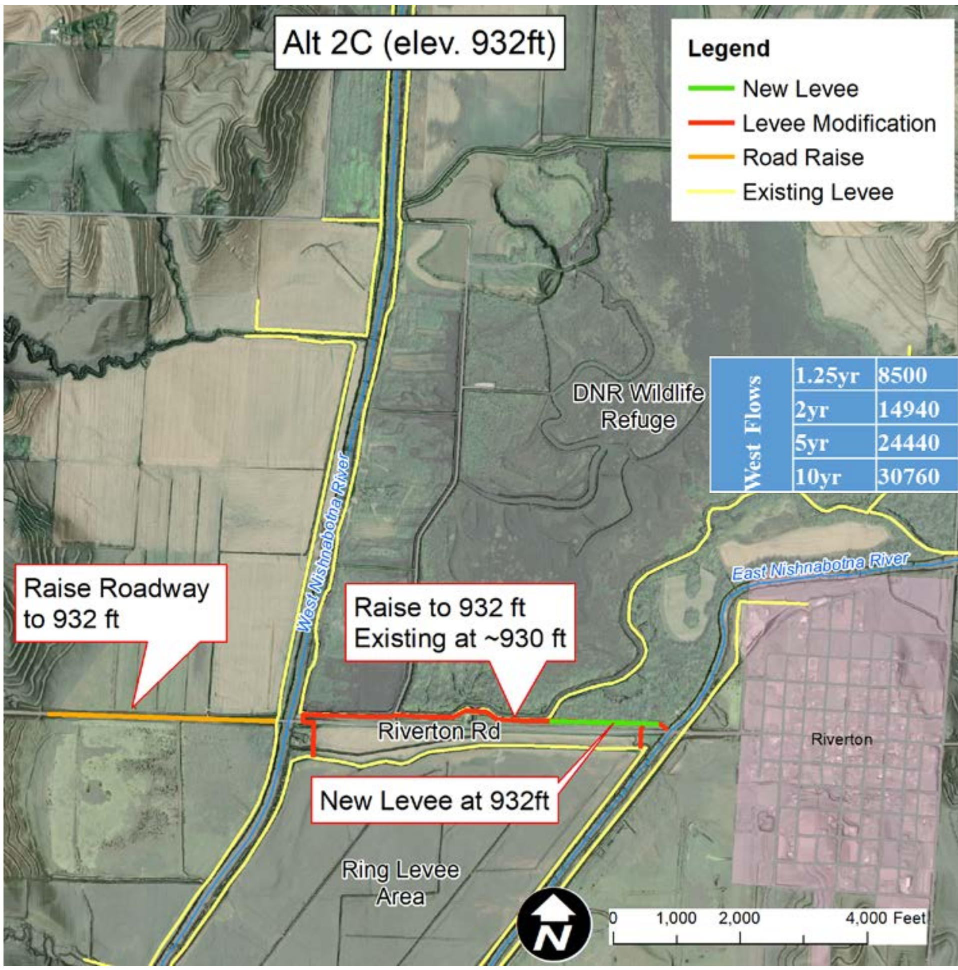


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	Yes
	2yr	14940	No	No	No	Yes
	5yr	24440	Yes	Yes	Yes	Yes
	10yr	30760	Yes	Yes	Yes	Yes

Figure 26. Alternative – 2C (el.930ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion but raises the western portion of roadway. All modifications are at a lower elev. 930 ft. Simulated overtopping results shown in table at right.

Alternative – 2C (el.932ft)

This alternative is the same as Alternative – 2C (el.930ft), except improvements are constructed to el. 932 ft rather than 930 ft, as shown in Figure 27. Simulated overtopping results shown in table at right.

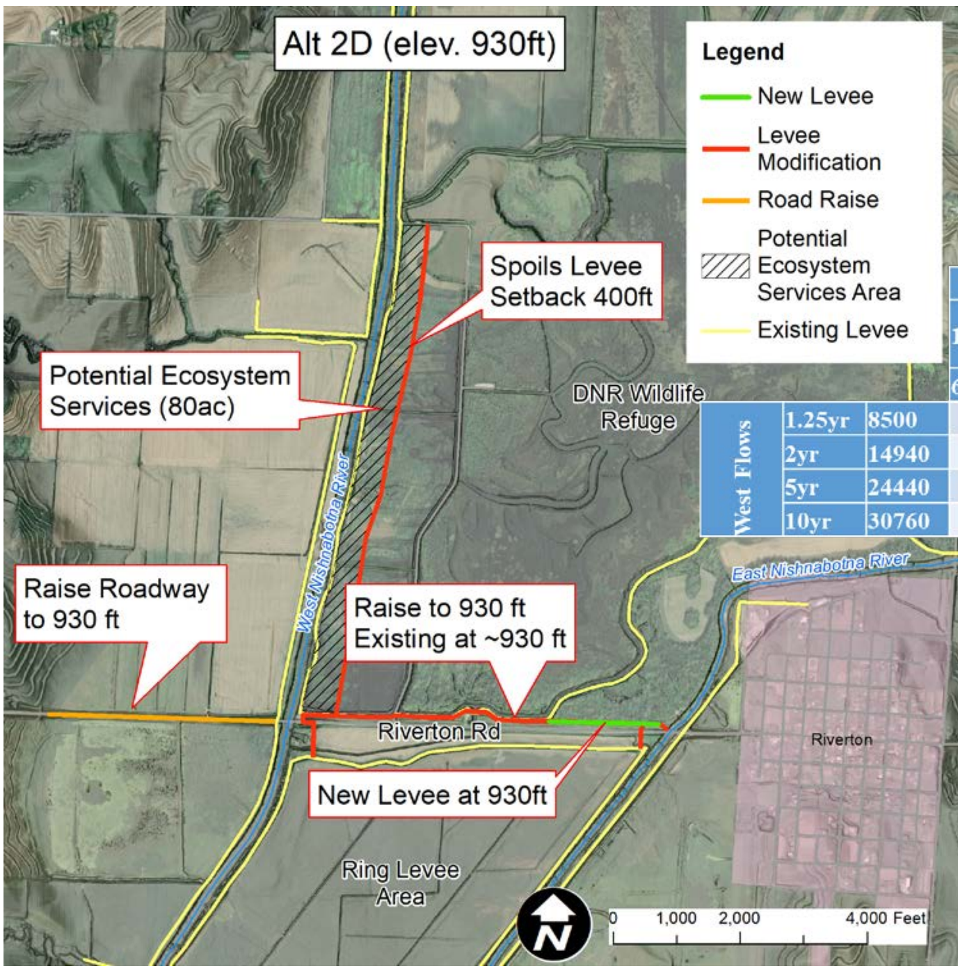


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	No
	2yr	14940	No	No	No	No
	5yr	24440	No	No	No	Yes
	10yr	30760	No	No	Yes	Yes

Figure 27. Alternative – 2C (el.932ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion but raises the western portion of roadway. Simulated overtopping results shown in table at right.

Alternative – 2D (el.930ft)

This alternative is similar to Alternative – 2C, in utilizing levee improvements and elevating the western roadway portion. Additionally, this alternative includes setback of WMA spoils levee along West Nishnabotna River approximately 400 feet to the east, as shown in Figure 28. Simulated overtopping results shown in table at right. Similar to Alternative – 2B, removal set back of the spoils levee is intended to create potential ecosystems services acres.

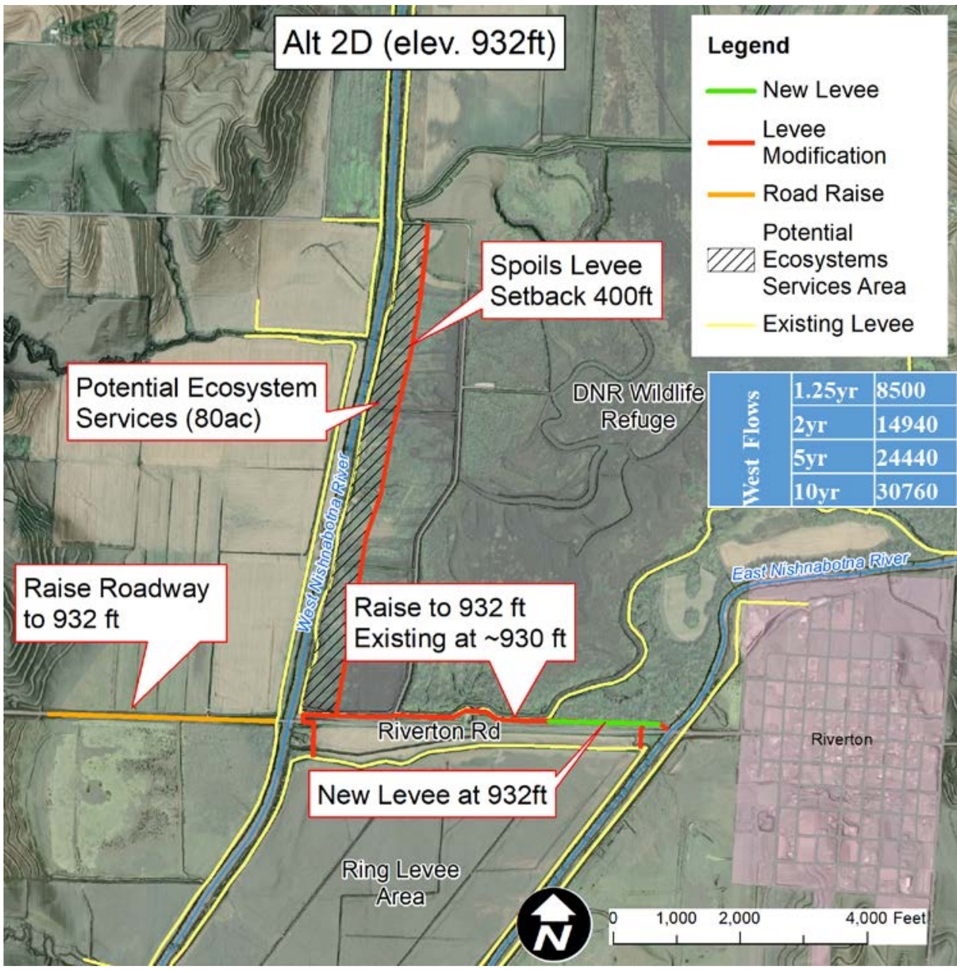


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	Yes
	2yr	14940	No	No	No	Yes
	5yr	24440	Yes	Yes	Yes	Yes
	10yr	30760	Yes	Yes	Yes	Yes

Figure 28. Alternative – 2D (el.930ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion but raises the western portion of roadway. Additionally, includes setback of WMA spoils levee along West Nishnabotna River approximately 400 feet to the east. Simulated overtopping results shown in table at right.

Alternative – 2D (el.932ft)

This alternative is the same as Alternative – 2D (el. 930ft), except improvements are constructed to elev. 932 ft rather than 930 ft, as shown in Figure 29. Simulated overtopping results shown in table at right.

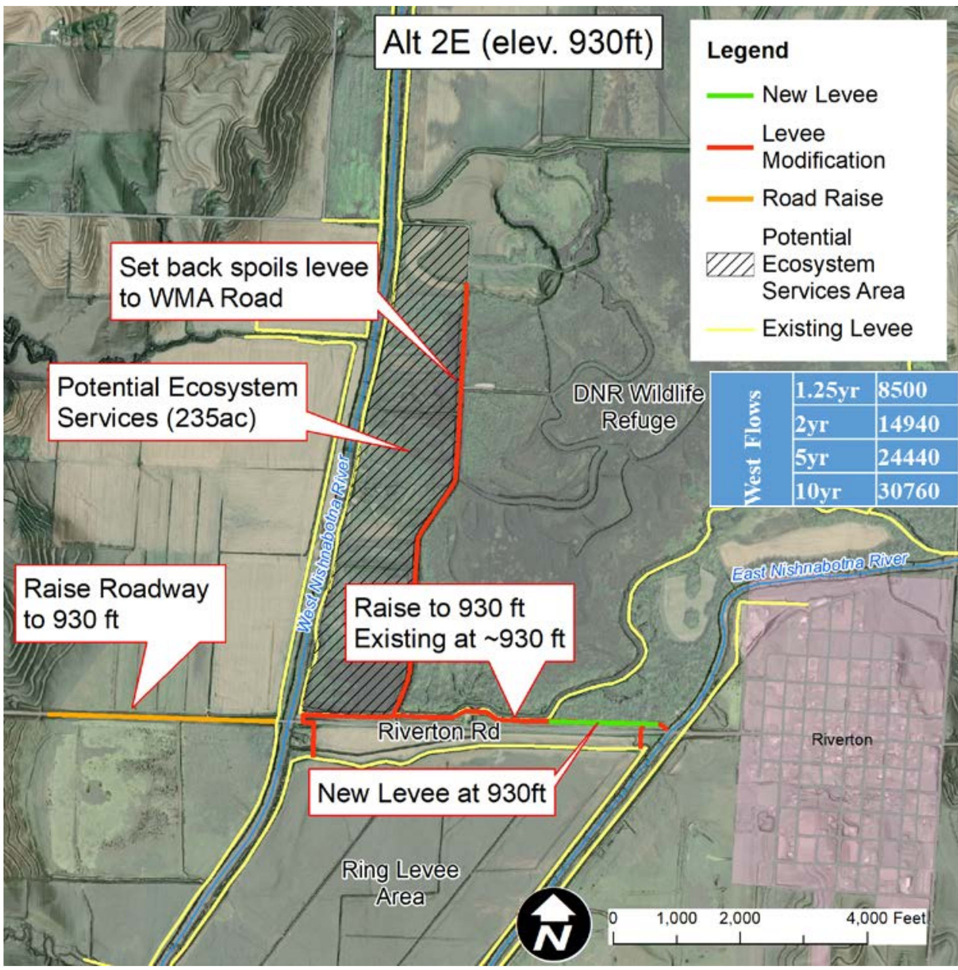


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	No
	2yr	14940	No	No	No	No
	5yr	24440	No	No	No	Yes
	10yr	30760	No	No	Yes	Yes

Figure 29. Alternative – 2D (el.932ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion but raises the western portion of roadway. Additionally, includes setback of WMA spoils levee along West Nishnabotna River approximately 400 feet to the east. Simulated overtopping results shown in table at right.

Alternative – 2E (el.930ft)

This alternative is similar to Alternative – 2D, in utilizing levee improvements and elevating the western portion of roadway. However, the WMA spoils levee along West Nishnabotna River is set back to the existing WMA road, as shown in Figure 30. Simulated overtopping results shown in table at right. Similar to Alternative – 2D, set back of the spoils levee is intended to create potential ecosystems services acres.

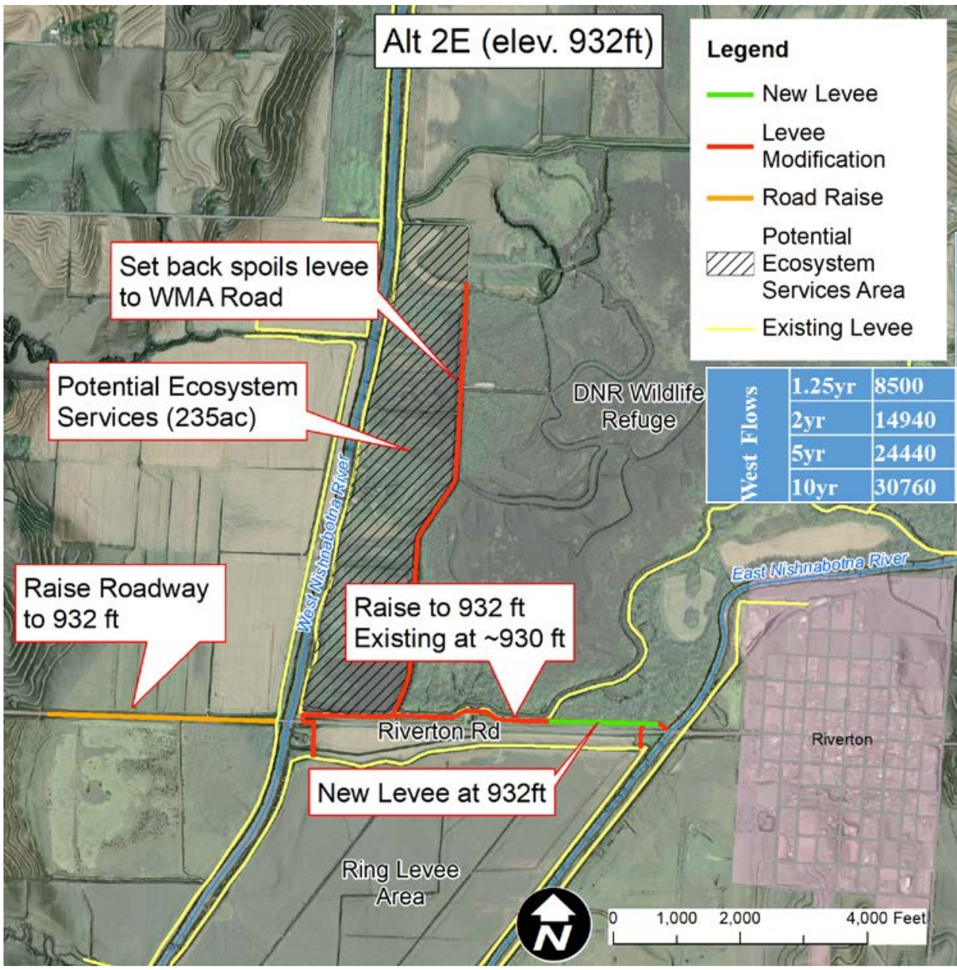


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	Yes
	2yr	14940	No	No	No	Yes
	5yr	24440	Yes	Yes	Yes	Yes
	10yr	30760	Yes	Yes	Yes	Yes

Figure 30. Alternative – 2E (el.930ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion and raises the western portion of roadway. Additionally, includes set back of the WMA spoils levee along West Nishnabotna River to the existing WMA roadway. Simulated overtopping results shown in table at right.

Alternative – 2E (el.932ft)

This alternative is the same as Alternative – 2E (el. 930ft), except improvements are constructed to elev. 932 ft rather than 930 ft, as shown in Figure 31. Simulated overtopping results shown in table at right.

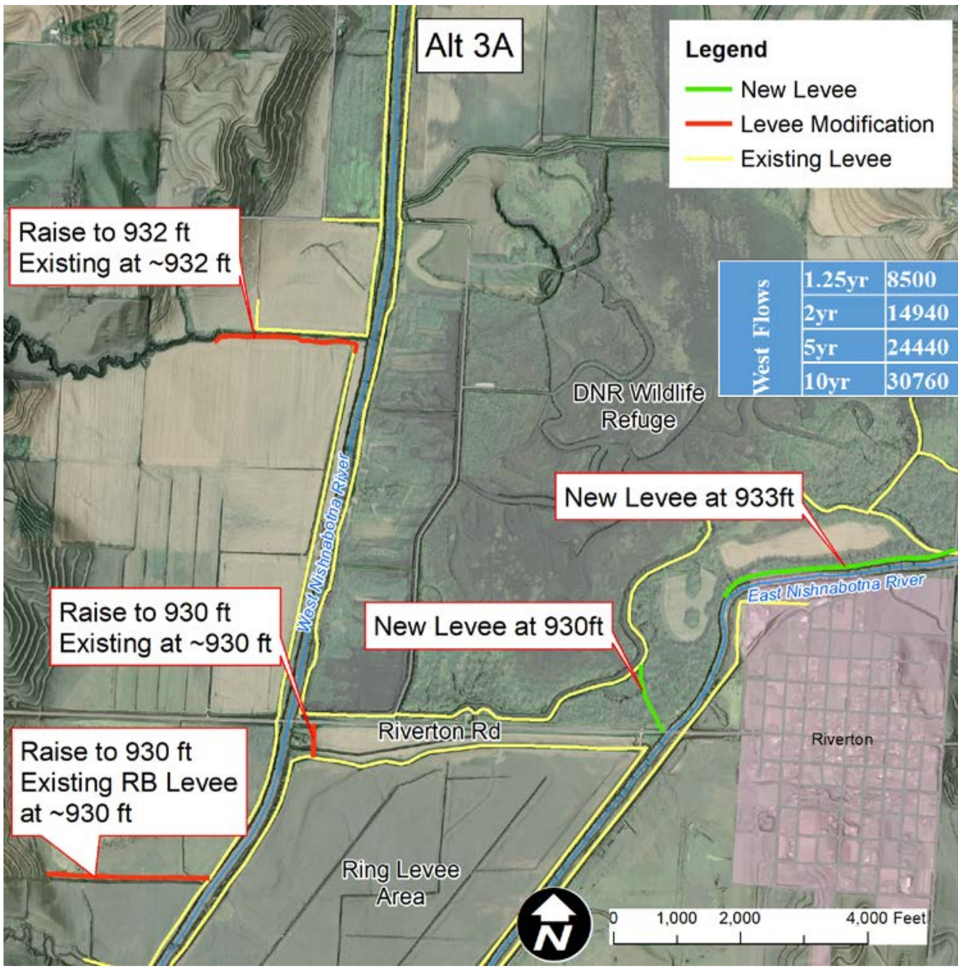


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	No	No
	2yr	14940	No	No	No	No
	5yr	24440	No	No	No	Yes
	10yr	30760	No	No	Yes	Yes

Figure 31. Alternative – 2E (el.932ft), this would utilize levee improvements to prevent overtopping along the middle roadway portion and raises the western portion of roadway. Additionally, includes set back of the WMA spoils levee along West Nishnabotna River to the existing WMA roadway. Simulated overtopping results shown in table at right.

Alternative – 3A

This alternative would utilize strategic levee improvements to prevent overtopping along the roadway, less concentrated near the middle portion of roadway, as shown in Figure 32. Simulated overtopping results shown in table at right.

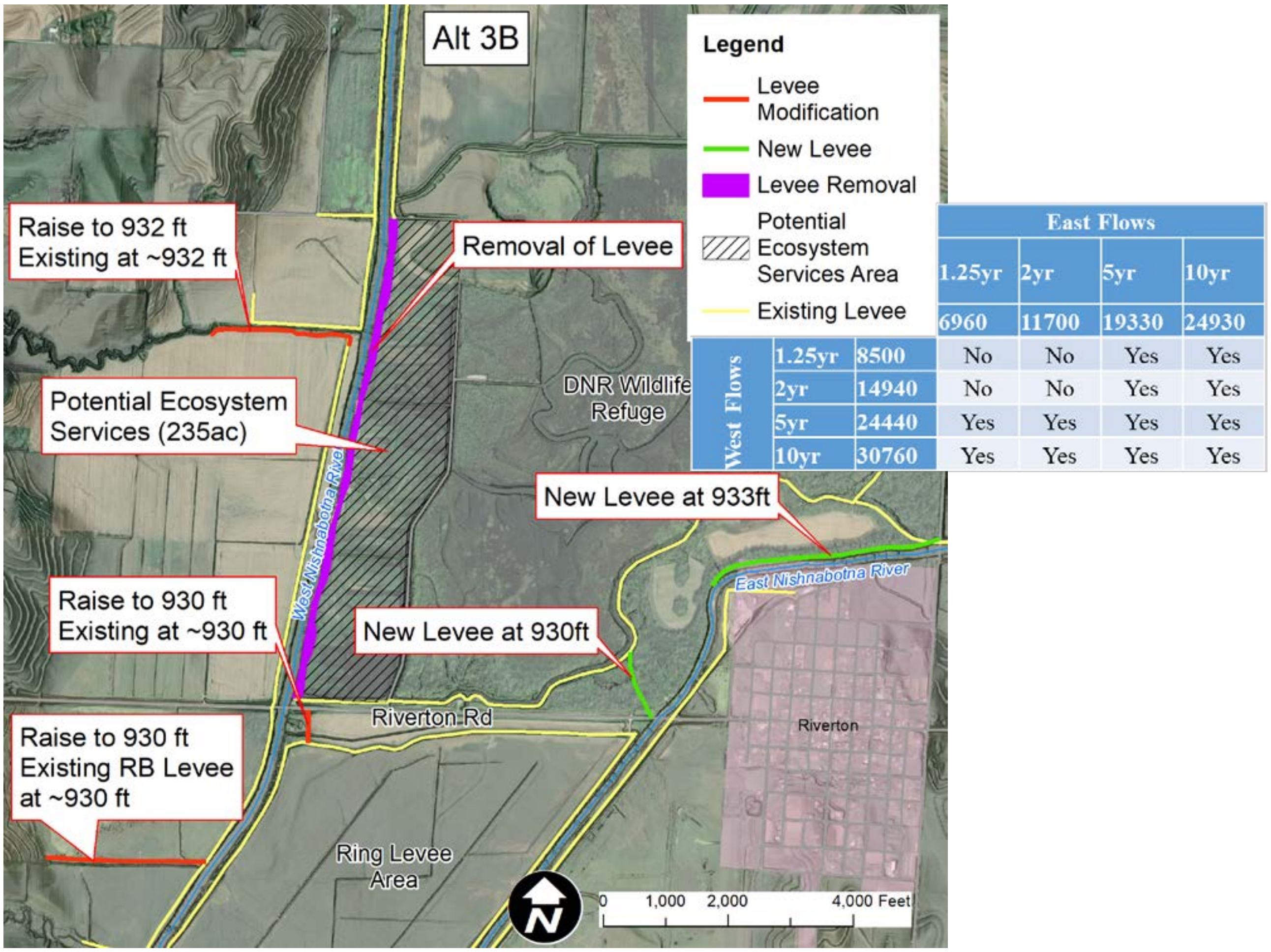


			East Flows			
			1.25yr	2yr	5yr	10yr
			6960	11700	19330	24930
West Flows	1.25yr	8500	No	No	Yes	Yes
	2yr	14940	No	No	Yes	Yes
	5yr	24440	Yes	Yes	Yes	Yes
	10yr	30760	Yes	Yes	Yes	Yes

Figure 32. Alternative – 3, this would utilize strategic levee improvements to prevent overtopping along the roadway, less concentrated near the middle portion of roadway. Simulated overtopping results shown in table at right.

Alternative – 3B

This alternative is the same as Alternative – 3A, but includes removal of a WMA spoils levee along West Nishnabotna River, as shown in Figure 33. Removal of the spoils levee is intended to create potential ecosystems services acres. Simulated overtopping results shown in table at right.



		East Flows: 1.25yr	2yr	5yr	10yr
		6960	11700	19330	24930
West Flows	1.25yr 8500	No	No	Yes	Yes
	2yr 14940	No	No	Yes	Yes
	5yr 24440	Yes	Yes	Yes	Yes
	10yr 30760	Yes	Yes	Yes	Yes

Figure 33. Alternative – 3B, this would utilize strategic levee improvements to prevent overtopping along the roadway, less concentrated near the middle portion of roadway, also includes removal of a WMA spoils levee along West Nishnabotna River. Simulated overtopping results shown in table at right.

A summary of the overtopping results is shown in Table 8. The alternatives providing the highest level of protection from overtopping were Road Raise, 2B (el. 932ft), 2C (el. 932ft), 2D (el.932ft), and 2E. Alternative 2B (el. 930ft) provided the next best level of protection for the el. 930 ft modifications. The poorest performing alternatives were Alternative 1, 3A and 3B.

Table 8. Summary of alternatives that overtopped for each flow combination.

			East Nishnabotna River flows (cfs)			
			1.25yr	2yr	5yr	10yr
			None	11,700	19,330	24,930
West Nishnabotna River flows (cfs)	None	8,500	None	None	1, 3A, 3B	1, 2A(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B
	2yr	14,940	None	None	1, 3A, 3B	1, 2A(el.930), 2B(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B
	5yr	24,440	1, 2A(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B	1, 2A(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B	1, 2A(el.930), 2B(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B	1, 2A(el.930), 2B(el.930), 2C(el.930), 2D(el.930), 2E(el.932), 2E(el.930), 3A, 3B
	10yr	30,760	1, 2A(el.930), 2B(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B	1, 2A(el.930), 2B(el.930), 2C(el.930), 2D(el.930), 2E(el.930), 3A, 3B	Road Raise 1, 2A(el.930), 2A(el.932), 2B(el.930), 2C(el.932), 2C(el.930), 2D(el.932), 2D(el.930), 2E(el.932), 2E(el.930), 3A, 3B	Road Raise 1, 2A(el.930), 2A(el.932), 2B(el.930), 2B(el.932), 2C(el.932), 2C(el.930), 2D(el.932), 2D(el.930), 2E(el.932), 2E(el.930), 3A, 3B

RESULTS SUMMARY

Simulation results were used to estimate the number of previous road closure events (2014-present) that would have been prevented for each alternative and are shown in Table 9. Overall, there are several potential mitigation alternatives that would have prevented the vast majority if not all previous road closures since 2014.

Table 9. Number of previous closures events (2014-present) prevented for all alternatives.

Alternative	% Events Prevented	# Events Prevented out of 27
Road Raise (932ft)	100%	27
Alt 1	85%	23
Alt 2A (el.930ft)	93%	25
Alt 2A (el.932ft)	100%	27
Alt 2B (el.930ft)	96%	26
Alt 2B (el.932ft)	100%	27
Alt 2C (el.930ft)	93%	25
Alt 2C (el.932ft)	100%	27
Alt 2D (el.930ft)	93%	25
Alt 2D (el.932ft)	100%	27
Alt 2E (el.930ft)	93%	25
Alt 2E (el.932ft)	100%	27
Alt 3A	77%	21
Alt 3B	77%	21

REFERENCES

(NOAA Atlas 14) Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffrey Bonnin (2013). NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA, National Weather Service, Silver Spring, MD.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Eash, D.A., Barnes, K.K., and Veilleux, A.G., 2013, Methods for estimating annual exceedance-probability discharges for streams in Iowa, based on data through water year 2010: U.S. Geological Survey Scientific Investigations Report 2013–5086, 63 p. with appendix.

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., https://doi.org/10.3133/tm4B5.

JEO Consulting Group. 2019, East and West Nishnabotna River Watershed Management and Flood Resiliency Plan. East Nishnabotna Watershed Management Coalition.

U.S. Army Corps of Engineers, Hydrologic Engineering Center. Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.1 Available online at https://www.hec.usace.army.mil/software/hec-ras/. Accessed 03/24/2022.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2019, HEC-SSP Statistical Software Package User's Manual (ver 2.2, June 2019).

APPENDIX A: ROADWAY CLOSURE DATES AND DURATIONS (2014-PRESENT)

Provided by Fremont County Emergency Manager Mike Crecelius

East Road Closure Dates (16)				West Road Closure Dates (22)		
Start	End	Days		Start	End	Days
6/4/2014	6/5/2014	2		6/4/2014	6/5/2014	2
7/1/2014	7/1/2014	1		7/1/2014	7/2/2014	2
7/5/2014	7/5/2014	1		7/5/2014	7/7/2014	3
9/10/2014	9/11/2014	2		8/28/2014	8/30/2014	3
6/12/2015	6/13/2015	2		9/2/2014	9/2/2014	1
6/15/2015	6/17/2015	3		9/10/2014	9/12/2014	3
12/14/2015	12/17/2015	4		10/1/2014	10/3/2014	3
5/10/2016	5/11/2016	2		6/11/2015	6/13/2015	3
5/27/2016	5/28/2016	2		6/15/2015	6/17/2015	3
7/1/2018	7/2/2018	2		8/9/2015	8/9/2015	1
9/6/2018	9/6/2018	1		12/13/2015	12/18/2015	6
3/11/2019	3/19/2019	9		5/10/2016	5/13/2016	4
5/24/2019	5/26/2019	3		5/26/2016	5/28/2016	3
5/28/2019	5/30/2019	3		1/17/2017	1/18/2017	2
9/26/2019	9/26/2019	1		5/17/2017	5/17/2017	1
10/2/2019	10/3/2019	2		5/20/2017	5/22/2017	3
				8/20/2018	8/22/2018	3
				3/12/2019	3/21/2019	10
				5/24/2019	5/31/2019	8
				10/2/2019	10/2/2019	1
				10/5/2019	10/6/2019	2
				10/11/2019	10/12/2019	2

Appendix B: Estimated Roadway Closure Dates and Durations (1990 -2013)

Estimated using USGS sub-hourly observations at the Randolph and Red Oak, Iowa stream gaging stations. Flow thresholds were 8,000 cfs for East Nishnabotna River at Red Oak, and 7,000 cfs for West Nishnabotna River at Randolph.

Estimated East Closure Dates (45)				Estimated West Closure Dates (41)		
Start	End	Days		Start	End	Days
6/2/1991	6/2/1991	1		6/2/1991	6/2/1991	1
6/14/1991	6/16/1991	2		6/5/1991	6/6/1991	1
9/15/1992	9/16/1992	1		6/14/1991	6/15/1991	1
3/8/1993	3/8/1993	1		3/4/1993	3/5/1993	1
6/30/1993	7/1/1993	1		3/8/1993	3/8/1993	1
7/8/1993	7/14/1993	6		6/24/1993	6/24/1993	1
7/23/1993	7/26/1993	3		6/28/1993	6/28/1993	1
8/12/1993	8/12/1993	1		7/8/1993	7/9/1993	1
8/29/1993	8/31/1993	2		7/16/1993	7/18/1993	2
6/23/1994	6/23/1994	1		7/22/1993	7/26/1993	4
5/24/1996	5/24/1996	1		8/12/1993	8/12/1993	1
6/20/1996	6/24/1996	3		8/29/1993	8/30/1993	1
7/17/1996	7/18/1996	1		6/23/1994	6/23/1994	1
6/9/1998	6/9/1998	1		6/21/1996	6/23/1996	2
6/11/1998	6/12/1998	1		6/23/1996	6/24/1996	1
6/14/1998	6/18/1998	4		7/19/1996	7/19/1996	1
7/5/1998	7/7/1998	2		8/6/1996	8/6/1996	1
7/22/1998	7/22/1998	1		2/19/1997	2/19/1997	1
5/16/1999	5/18/1999	1		5/29/1998	5/30/1998	1
5/21/1999	5/25/1999	4		6/11/1998	6/12/1998	1
6/23/1999	6/23/1999	1		6/14/1998	6/17/1998	3
7/6/1999	7/6/1999	1		7/5/1998	7/6/1998	1
7/9/1999	7/10/1999	1		7/22/1998	7/22/1998	1
8/7/1999	8/7/1999	1		5/17/1999	5/17/1999	1
3/15/2001	3/15/2001	1		8/7/1999	8/9/1999	2
5/23/2004	5/25/2004	2		3/15/2001	3/15/2001	1
5/12/2005	5/13/2005	1		5/23/2004	5/26/2004	3

4/25/2007	4/26/2007	1
5/6/2007	5/8/2007	2
5/24/2007	5/25/2007	1
10/14/2007	10/16/2007	2
6/3/2008	6/5/2008	2
6/8/2008	6/9/2008	1
6/11/2008	6/13/2008	2
7/24/2008	7/25/2008	1
4/27/2009	4/27/2009	1
3/10/2010	3/12/2010	2
6/11/2010	6/14/2010	4
6/22/2010	6/24/2010	2
6/27/2010	6/28/2010	1
7/4/2010	7/5/2010	1
7/19/2010	7/20/2010	1
8/4/2010	8/4/2010	1
4/15/2012	4/15/2012	1
6/24/2013	6/25/2013	1

5/6/2007	5/9/2007	4
10/14/2007	10/15/2007	1
5/30/2008	5/30/2008	1
6/5/2008	6/6/2008	2
6/8/2008	6/10/2008	2
6/11/2008	6/14/2008	2
3/11/2010	3/13/2010	2
4/30/2010	4/30/2010	1
6/12/2010	6/14/2010	3
6/23/2010	6/24/2010	1
6/27/2010	6/28/2010	1
7/20/2010	7/20/2010	1
6/27/2011	6/27/2011	1
8/22/2011	8/22/2011	1