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FOREST RIVER RCPP WATERSHED PLAN

Environmental Scoping Report

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Prepared on Behalf of:
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TABLE OF CONTENTS

LIST OF TABLES

EXHIBITS

APPENDICES

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1 INTRODUCTION AND BACKGROUND

The Walsh County Water Resource District (WCWRD) has been working to complete a Watershed Plan for the Forest River Watershed through the Natural Resource Conservation Service's (NRCS) Regional Conservation Partnership Program (RCPP). This plan included efforts to implement flood prevention and flood damage reduction measures along the Forest River near the towns of Forest River and Minto, North Dakota (**Exhibit 1 – Project Location Map**). The WCWRD entered into a cooperative agreement with the NRCS to complete the watershed plan. Under this agreement, the WCWRD is leading the planning effort as the Sponsoring Local Organization (SLO) while the NRCS is providing a significant portion of the funding as well as technical support. The WCWRD also provided local guidance during plan development.

The WCWRD and its planning team initially identified a Purpose and Need Statement for the plan and then developed a set of potential alternatives that would address the goals attached to this Purpose and Need Statement. After analyzing these alternatives, a preferred alternative was selected by the WCWRD and the planning team (**Appendix A – Screening of Alternatives for Detailed Review**). The preferred alternative for this project was presented in the *Screening of Alternatives Report* as the Ardoch Coulee Bypass and Forest River Site FR3-AR. The Ardoch Coulee Bypass is a diversion channel that will bypass a portion of the river flows around the communities of Forest River and Minto, North Dakota. Site FR3-AR is an off-channel impoundment site designed to store floodwaters diverted from the Forest River mainstem with the use of the Ardoch Coulee Bypass and a small area contributing runoff to Ardoch Coulee in the Forest River Watershed.

After initial public engagement and discussion on the preferred alternative, the WCWRD elected not to proceed with further design and evaluation of the preferred alternative. The purpose of this watershed planning report is to document the planning work that has been completed so that the effort can potentially be resumed in the future. The WCWRD's decision to cease planning for the Forest River Watershed RCPP planning effort occurred prior to all the necessary field work being completed for the analysis of the preferred alternative. Therefore, this report was completed with the limited field survey data collected previously as described in the **Appendix B – Ardoch Coulee Bypass and Forest River Site FR3 – AR Concept Design Report** and **Appendix C – Existing Conditions Hydrology and Hydraulics Report**). Geologic investigations and geotechnical analyses were not completed for this report. Additional field exploration will be necessary if project planning continues beyond the extent described in the Concept Design Report.

This Watershed Planning Report describes the data collected up to this point, the preliminary analysis of this data, as well as potential environmental concerns and mitigation efforts associated with the preferred alternative. The main body of this report focuses primarily on the environmental aspects of the planning effort, while the reports included in the appendices focus on the planning process, alternative analyses, and preliminary design efforts associated with the planning effort.

2 PURPOSE AND NEED FOR ACTION

The project is needed in order to protect human welfare and safety, public transportation infrastructure, and cropland from reoccurring flood damages. The project will reduce or prevent floodwater damages by reducing runoff, erosion, and sediment and reduce frequency, depth, or velocity of flooding in the project area.

The purpose of the proposed action is to implement flood prevention and flood damage reduction measures to:

1. Reduce flood damages for up to a 10-year rainfall event on cropland.
2. Increase flood resiliency for up to a 10-year event on public and private infrastructure within the communities that reside along the Forest River. (Primary)
3. Increase flood resiliency for the communities of Minto and Forest River, ND, during a 100-year flood event. (Primary)
4. Maintain or reduce flood flows downstream of Lake Ardoch. (Primary)
5. Improve soil health and water quality throughout the watershed. (Secondary)

To achieve the goals outlined in the Purpose and Need Statement, various steps were taken to screen potential alternatives (**Appendix A – Screening of Alternatives for Detailed Review**), to develop a detailed concept design of the preferred alternative (See **Appendix B – Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report**), and to model existing conditions (**Appendix C – Existing Conditions Hydrology and Hydraulics Report**).

3 PROJECT ALTERNATIVES

Preliminary development of alternatives focused on narrowing the range of alternatives by reviewing and analyzing the technical and practical considerations to evaluate the potential of each to meet project objectives from the Purpose and Need Statement. Alternatives were first analyzed based on wide-ranging flood reduction strategies such as reducing runoff volume, increasing conveyance capacity, and increasing temporary flood storage in the watershed. After the initial screening based on technical considerations, more detailed alternatives were analyzed. The detailed evaluation included a no-action alternative, setback levees along the Forest River, multiple storage sites in the watershed, and a bypass channel to divert flood flows. Through this analysis, alternatives were either eliminated or carried forward based on how each performed with respect to the goals outlined in the Purpose and Need Statement. For more information on the screening of alternatives for the Forest River Watershed Plan refer to **Appendix A**, which contains the *Screening of Alternatives for Detailed Review*.

4 RESOURCE INFORMATION

The Forest River is in northeast North Dakota and is a tributary to the Red River of the North. The contributing watershed area to the Forest River is 884 square miles. This report describes the potential environmental concerns associated with the preferred alternative within two ranges: (1) the Area of Interest (AOI), and (2) the construction corridor (CC). The AOI covers the extent to which the activities associated with this project may affect environmental resources. The CC covers the extent in which the project activities may have direct impacts to environmental resources during and after construction of the bypass channel and **Exhibit 2 – Area of Interest and Construction Corridor Map**.

4.1 PREFERRED ALTERNATIVE

The preferred alternative for this project consists of a bypass channel that carries flood flows from the Forest River mainstem to Ardoch Coulee. A storage site located downstream of the bypass on Ardoch Coulee is also part of the preferred alternative. The storage site will accommodate increased discharges created by the bypass channel. The bypass is referred to as the Ardoch Coulee Bypass, and the storage site is referred to as Site FR3-AR.

4.1.1 SITE CHARACTERISTICS

The Ardoch Coulee Bypass would divert flows south out of the Forest River in Section 1 of Strabane Township, Grand Forks County, and then east along the north side of 35th Ave NE for approximately 2.5 miles, where it would outlet into an existing swale that flows into Ardoch Coulee near the half-section line of Section 4 of Johnstown Township, Grand Forks County. The total drainage area upstream of the inlet to the Ardoch Coulee Bypass is 378 square miles. A structure across the Forest River near the bypass inlet would be constructed to divert flows out of the Forest River into the bypass channel. Additionally, a structure at the inlet of the Ardoch Coulee Bypass would be implemented to control the amount of flow diverted for the larger runoff events. The bypass channel would remain dry during periods of low flow. Five crossings will be constructed along the bypass channel at a private driveway, 32nd St NE, 31st St NE, Grand Forks County Road 2, and a Northern Plains Railroad line.

Site FR3-AR is an off-channel impoundment site located in the Ardoch Coulee Watershed. The proposed site consists of a constructed earthen embankment located approximately 0.50 miles south of the Walsh/Grand Forks county line in Section 3 of Johnstown Township, Grand Forks County. The location of the embankment was chosen to maximize the amount of storage for a site on Ardoch Coulee. The structure would consist of a 5-foot diameter low-flow pipe that would allow local flow from the Ardoch Coulee Watershed to flow through the site without creating a permanent pool. A riser tower with a weir length of 60 feet would be implemented with the purpose of maximizing the storage in the site for a four-day, 10-year rainfall event. The drainage area contributing directly to the site (from the Ardoch Coulee Watershed) is approximately 9.9 square miles. For more detailed information on the layout of the site and the site performance with respect to hydrologic and hydraulic analysis, refer to **Appendix B**, which contains the *Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report*.

4.1.2 LANDFORMS AND TOPOGRAPHY

The AOI is located within the Red River Valley, which was formerly the lakebed of Glacial Lake Agassiz (USEPA, 2020). The surrounding area is extremely flat with an average gradient of 6 inches per mile descending from west to east, but there are areas of gently rolling slopes along the eastern and western boundaries of the valley. Due to the low gradient and poorly defined floodplain, this region has a high proportion of depressional wetlands and few meandering streams, including the Forest River, Ardoch Coulee, and several other unnamed streams. Lake Ardoch is located within the AOI northwest of the town of Ardoch. The Red River Valley region covers the entire eastern edge of North Dakota and is bounded on the west by the Beach Ridge and Sand Deltas, which extend south from the Pembina Escarpment.

The topography and landforms within the AOI and CC consist of flat agricultural fields, with some depressional wetlands and streams (**Exhibit 3 – LiDAR Map**). The Ardoch Coulee extends into the CC from the northeast and meanders southeast before terminating. The Forest River also flows through the northeast corner of the CC.

4.1.3 LAND USE

Land use is predominantly cultivated agricultural over the entire AOI and within the CC (**Exhibit 4 - Land Use Map**, USGS 2020). Other land use within the AOI includes the communities of Forest River and Minto, rural residential properties, commercial properties, pastures, and natural areas including forests, rivers, and lakes.

4.1.4 STATE LANDS, FEDERAL LANDS, AND CONSERVATION EASEMENTS

There are no conservation easements within the CC. The Ardoch National Wildlife Refuge encompasses Lake Ardoch and is located at the eastern border of the AOI (**Exhibit 5 - Federal and State Lands Map,** ND GIS Hub 2020) There are also several temporary Wetlands Reserve Program easements held by the NRCS near Ardoch National Wildlife Refuge. There are no other state or federal lands within the AOI or CC.

4.1.5 SOILS

Dominant soils for the AOI and CC are shown in **Table 1** and **Table 2**. These tables also include data pertaining to sections 3.1.4.1 and 3.1.4.2

4.1.5.1 SOIL UNITS, SURFACE TEXTURES, AND DRAINAGE CLASS

Throughout the AOI, there are 71 different mapped units (**Exhibit 6 – Soil Survey Map**, USDA-NRCS 2020). The dominant soils within this region are formed in glaciolacustrine deposits and have silty loam, silty clay, and silty clay loam surface textures. The drainage classes of dominant soils within the AOI and CC range from “very poorly drained” to “excessively drained”.

4.1.5.2 EROSION: K-FACTOR

The K-factor is used as a measure of the relative susceptibility of a soil to erosion under flooding conditions (US Department of Agriculture RUSLE Development Team, 2001). These values range from 0.20 to 0.64, where higher ratings indicate a higher susceptibility to erosion. High-silt soils are the most erodible (compared to other textures high in clay or sand). The AOI and CC are dominated by silt loams which typically have moderate K values ranging from 0.25 to 0.45.

The K values within the AOI and CC range from 0.02 to 0.49 (**Tables 1** and **2**, USDA-NRCS 2020). Dominant soils within the AOI have K values ranging from 0.17 to 0.43, and dominant soils within the CC have K values ranging from 0.02 to 0.32.

Table 1. Soil survey data for the AOI (USDA-NRCS 2020).

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI	Surface Texture	Drainage Class	K-factor
I518A	Overly silt loam, 0 to 2 percent slopes	1,083.10	2.30%	Silt loam	Moderately well drained	0.43
I201A	Glyndon silt loam, 0 to 2 percent slopes	5,196.40	10.90%	Silt loam	Somewhat poorly drained	0.32
I383A	Overly silty clay loam, 0 to 2 percent slopes	3,404.50	7.20%	Silty clay loam	Moderately well drained	0.32
I119A	Bearden silty clay loam, 0 to 2 percent slopes	4,234.50	8.90%	Silty clay loam	Somewhat poorly drained	0.28
I531A	Overly silty clay loam, 0 to 1 percent slopes, fans	3,398.90	7.10%	Silty clay loam	Moderately well drained	0.28
I329A	Fairdale silt loam, 0 to 2 percent slopes, occasionally flooded	3,286.60	6.90%	Silt loam	Moderately well drained	0.28
I601A	Bearden silty clay loam, moderately saline, 0 to 2 percent slopes	1,387.10	2.90%	Silty clay loam	Somewhat poorly drained	0.28
I176A	Ojata silty clay loam, 0 to 1 percent slopes	1,169.30	2.50%	Silty clay loam	Poorly drained	0.28
I479B	Fairdale-Fluvaquents, channeled complex, 0 to 6 percent slopes, frequently flooded	1,109.60	2.30%	Silt loam	Moderately well drained	0.28
I130A	Hegne-Fargo silty clays, 0 to 1 percent slopes	3,246.40	6.80%	Silty clay	Poorly drained	0.24
I534A	Overly silty clay, 0 to 2 percent slopes	1,238.60	2.60%	Silty clay	Moderately well drained	0.24
I229A	Fargo silty clay, 0 to 1 percent slopes	3,963.70	8.30%	Silty clay	Poorly drained	0.17
I537A	Overly silty clay, 0 to 1 percent slopes, fans	2,059.30	4.30%	Silty clay	Moderately well drained	0.17
I527A	Bearden silty clay, 0 to 2 percent slopes	1,085.40	2.20%	Silty clay	Somewhat poorly drained	0.17

Table 2. Soil survey data for CC. (USDA-NRCS 2020).

Map unit symbol	Map unit name	Acres in CC	Percent of CC	Surface Texture	Drainage Class	K-Factor
I201A	Glyndon silt loam, 0 to 2 percent slopes	3,340.90	41.20%	Silt loam	Somewhat poorly drained	0.32
I468A	Divide loam, 0 to 2 percent slopes	633.80	7.80%	Loam	Somewhat poorly drained	0.20
I490A	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	519.70	6.40%	Silt loam	Somewhat poorly drained	0.32
I594A	LaDelle silt loam, 0 to 2 percent slopes, occasionally flooded	426.60	5.30%	Silt loam	Moderately well drained	0.32
I202A	Gardena silt loam, 0 to 2 percent slopes	391.90	4.80%	Silt loam	Moderately well drained	0.37
I119A	Bearden silty clay loam, 0 to 2 percent slopes	374.70	4.60%	Silty clay loam	Somewhat poorly drained	0.28
I356A	Ulen fine sandy loam, 0 to 2 percent slopes	255.10	3.10%	Fine sandy loam	Somewhat poorly drained	0.15
I383A	Overly silty clay loam, 0 to 2 percent slopes	218.20	2.70%	Silty clay loam	Moderately well drained	0.32

4.1.6 AGRICULTURAL PRODUCTIVITY

4.1.6.1 PRIME FARMLAND

Protection for important farmland, rangeland, and forest land is established in the Farmland Protection Policy Act (USDA 2020). Federal agencies are to consider actions that could reduce adverse effects on farmland and ensure that federal programs, to the extent practicable, are compatible with state, local government, and private programs.

Within the AOI, approximately 64.30% (30,697 acres) of the project area is classified as “prime farmland” (USDA-NRCS 2020). Of the remaining areas, 2.50% (1,139 acres) is considered “farmland of statewide importance”; 17.80% (8,549 acres) is considered “prime farmland if drained”; and 13.00% (6,068 acres) is considered “not prime farmland” (**Exhibit 7 – Prime Farmland Map**).

Approximately 74.90% of the CC is classified as “prime farmland” (6,092 acres). Of the remaining areas, 6.30% (519 acres) is considered “farmland of statewide importance”; 12.70% (1,023 acres) is considered “prime farmland if drained”; and 6.00% (275 acres) is considered “not prime farmland” (**Exhibit 7**).

4.1.7 WATERS

Waters in the area consist of wetlands and a network of streams. Some of these waters may be protected to varying degrees under the Clean Water Act and other legislation. When federal funding is used for construction and improvement projects, Executive Order 11990 requires federal agencies to preserve, enhance, or minimize degradation and losses to wetlands. NRCS policy for implementing the executive order can be found at 190-GM, Part 410, Subpart B, Section 410.26. The Clean Water Act Section 404 requires permitting from the US Army Corps of Engineers for activities that impact wetlands and Other Waters of the US. The NRCS floodplain management policy reviews activities in wetlands that occur within the 50-year floodplain (190-GM Section 510.25). Rivers, in addition to regulation under the US Army Corps of Engineers, may fall under the National Wild and Scenic Rivers Act of 1968 (Public Law 90-542).

The National Wetland Inventory (NWI, USFWS 2020a) provides a detailed survey and additional information about wetlands and other water bodies throughout the United States. Many waters within the AOI and CC are identified by the NWI and are shown in **Exhibit 8 – National Wetland Inventory Map**.

The AOI and CC are located, geographically, within the Prairie Pothole Region (PPR). Wetlands within the Red River Valley are not typically considered potholes due to differing geologic formation processes. The topography within the PPR was formed by the retreat of the Wisconsinan Glacier, which left behind uneven deposits of glacial till. This resulted in a high concentration of small depressions, also known as potholes, which receive hydrology mainly from snowmelt and groundwater recharge. Wetlands within the Red River Valley are formed in what was previously the lakebed of Glacial Lake Agassiz. Although the area is extensively drained for agricultural purposes, the flat topography and high clay content in soils of the Red River Valley contribute to retention of floodwaters and formation of wetlands where there are undulations in the landscape.

4.1.7.1 RIVERS AND STREAMS

The Red River of the North is a navigable river and by definition the Forest River and tributaries would be considered Waters of the US and under the jurisdiction of the US Army Corps of Engineers. Neither the Forest River nor its tributaries are included in the list of rivers designated as Wild and Scenic Rivers (USFWS 2020b)

There were two streams identified during the offsite review of aquatic resources within the CC (See **Appendix D – Offsite Wetland Delineation Report**). The Forest River flows northeast through the northeast corner of the CC. The Ardoch Coulee begins within the CC and flows northeast outside of the CC toward Lake Ardoch.

4.1.7.2 WETLANDS AND OPEN WATER

The NWI maps several wetlands within the project area (US Fish and Wildlife Service, 2018) (**Exhibit 8 – National Wetland Inventory Map**). There are a variety of wetland types within the project area that have been mapped by the NWI including palustrine, emergent, temporary flooded/seasonally flooded (PEMA/C); palustrine, aquatic bed, semi-permanently flooded (PABF); riverine, intermittent, streambed, seasonally flooded (R4SBC); and palustrine, forested, temporarily flooded/seasonally flooded (PFOA/C) (Cowardin et al. 1979).

A total of 150 wetlands (220.05 acres) were identified during the offsite review of aquatic resources within the project area (**Appendix D – Offsite Wetland Delineation Report**). Of these, the most frequent wetland types are freshwater emergent and riverine wetlands.

4.1.8 VEGETATION COVER AND WILDLIFE HABITATS

4.1.8.1 ECOREGIONS

The AOI is in the Lake Manitoba and Lake Agassiz Plains Level III Ecoregion, which covers the entire eastern boarder of North Dakota and extends into western Minnesota (See **Exhibit 9 – Ecoregion Map,** USEPA 2020). Topography in this region was defined approximately 10,000 years ago when the retreating glaciers were blocked by large ice sheets, which formed many glacial lakes, with Glacial Lake Agassiz forming the current-day topography of the Red River Valley and Pembina Escarpment.

The CC is in the Glacial Lake Agassiz Basin Ecoregion. Most of this ecoregion is covered by deep loamy soils, and the topography is very flat with an average gradient of about 6 inches per mile. The watershed is generally characterized by very low slopes and a poorly defined floodplain for the Red River of the North.

The AOI spans the following Level IV Ecoregions: Glacial Lake Agassiz Basin, Sand Deltas and Beach Ridges, and Saline Area.

The AOI extends west of the CC into the Beach Ridges and Sand Deltas and Saline Area Ecoregions. This ecoregion intersects the flat topography of the Lake Agassiz Plain Ecoregion and consists of sandy and gravelly soil.

The Saline Area Ecoregion is northeast of the CC. Soils within the Saline Area Ecoregion are formed in glacial till and lacustrine sediments which allow artesian groundwater to flow to the surface. The topography in this ecoregion is similarly flat compared to the Lake Agassiz Plain Ecoregion.

4.1.8.2 PLANT COMMUNITIES

Historic tallgrass prairie plant communities within the AOI and CC have been mostly replaced by cultivated agriculture which dominates the plant communities in the region. Other plant communities include pasture/hay, forests, and wetlands.

4.1.9 FISH AND WILDLIFE

4.1.9.1 GENERAL FISH AND WILDLIFE

A large variety of animals potentially occupy the AOI and CC. These include the taxonomic groups of birds, mammals, fish, reptiles, amphibians, and various invertebrates. Fish species found in the Forest River include typical communities of warm water streams and many species found in the connected waters of the Red River of the North drainage area; however, there are currently no direct fish passages between the Red River of the North and the Forest River upstream from Lake Ardoch.

4.1.9.2 THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) directs federal agencies to conserve endangered and threatened species (USFWS 2020c). The whooping crane (*Grus americana*) is listed as endangered, and the northern long-eared bat (*Myotis septentrionalis*) is listed as threatened (**Table 3**).

The USFWS online Information Planning and Conservation System (IPaC) program shows no designated critical habitat in the CC.

Table 3: North Dakota threatened and endangered species with potential to occur in the AOI and/or CC. (USFWS 2020c).

Latin name	Common name	Status	Potential to occur
Grus americana	whooping crane	endangered	potential territory, but not within core migration route. There is final designated critical habitat for this species. These birds may migrate through North Dakota but avoid human populations.
Myotis septentrionalis	northern long-eared bat	threatened	potential territory, key breeding habitat in summer. No critical habitat has been designated for this species in North Dakota. Bats use trees, particularly if they are part of a forest corridor, for roosting and breeding.

4.1.9.3 SPECIES ASSOCIATED WITH CONSERVATION PRIORITY IN NORTH DAKOTA

The North Dakota Game and Fish Department oversees the State Wildlife Action Plan (SWAP), which includes strategies for fish and wildlife conservation (ND Game and Fish 2015). The SWAP lists animal species that are targeted for conservation priority and described critical habitat throughout the state of North Dakota. The species on that list that may occur in the watershed areas include a variety of mammals, birds, fish, and reptiles/amphibians. Important habitats listed in the SWAP that may occur in the AOI or CC include tallgrass prairie, eastern Drift Plains mixed grass prairie, tame grassland, deciduous forest, wetlands, rivers and riparian forests.

4.2 RESOURCE CONCERNS

4.2.1 POTENTIAL EFFECTS AND RESOURCE AVOIDANCE MEASURES

4.2.1.1 LANDFORMS AND TOPOGRAPHY

Outside of the CC, there will be no significant or long-term impact to landforms or topography within the AOI. The project activities taking place within the CC will include excavation of the bypass channel and construction of the impoundment site. These project features will permanently alter the topography within the CC.

4.2.1.2 LAND USE

Minor changes to land use within the AOI may result from this project. Reduced flooding along the Forest River and surrounding areas will increase the availability of land for other uses. Within the CC, some agricultural land will be converted for the construction of the bypass channel and the impoundment site. Downstream on the Ardoch Coulee may occasionally experience higher flows that could temporarily impact land use in some areas, but impacts related to changes in land use along the Ardoch Coulee will be mitigated through the permitting and regulatory approval processes.

4.2.1.3 STATE LANDS, FEDERAL LANDS, AND CONSERVATION EASEMENTS

There are no anticipated impacts to existing conservation easements, federal lands, or state lands within the AOI. There are no conservation easements or state/federal lands within the CC.

4.2.1.4 SOILS

Soils may be impacted by altered flows and flooding patterns along the Forest River and Ardoch Coulee. The AOI typically experiences overland flooding at some point during most years. Reduced flooding in the surrounding areas will likely result in maintained quality of the existing soils and less sediment/erosion in areas that have previously experienced issues with flooding.

Soils within the CC will be temporarily disturbed during the construction of the bypass channel and impoundment site. These areas will likely experience frequent inundation, and soils will likely change over time when these conditions persist. Outside of the bypass channel and impoundment site, impacts to soils are not anticipated within the CC.

4.2.1.5 AGRICULTURAL PRODUCTIVITY

The reduced frequency and duration of inundation in areas within the AOI that previously experienced flooding will result in fewer planting delays and increased agricultural productivity. It has also been shown that short-term floods can significantly impact soil quality in agricultural settings (De-Campos et al. 2009).

The project activities within the CC will result in slightly decreased agricultural productivity due to the conversion of some agricultural land for the construction of the bypass channel and impoundment site, but at least a portion of this loss in productivity will be offset by improved agricultural drainage within the CC.

4.2.1.6 WATERS

Waters will be impacted by this project in several ways. The AOI will experience altered flows in the Forest River and Ardoch Coulee. This may result in changes in the water quality, and there may be fewer temporarily ponded wetlands that have developed in areas where frequent flooding had previously occurred. The construction of the bypass channel and impoundment site will likely result in the filling of some wetland areas. Preliminary estimates show approximately 5.44 acres of impacts to waters within the CC. However, wetlands may redevelop in the channel and/or the impoundment site, and any outstanding impacts to waters will be mitigated according to regulatory (USACE) standards.

4.2.1.7 VEGETATION COVER AND WILDLIFE HABITATS

There will be changes to the types of vegetation cover within the AOI and CC. However, there will be no significant or long-term impacts related to vegetation cover are anticipated for the AOI and the CC. There are no critical or regulated wildlife habitats within the AOI or CC. Some wetland habitats may be altered due to reduced flooding (lack of hydrology) and some wetland habitats may be destroyed during the construction of the bypass channel and impoundment site. Impacts to wetlands will be mitigated according to regulatory (USACE) standards.

4.2.1.8 FISH AND WILDLIFE

Fish and wildlife populations may be impacted by reduced flooding along the Forest River. Habitats along the river will experience less flooding and therefore will persist for longer periods of time. Reduced flooding along the river may result in increased habitation of some wildlife populations. Wildlife that are dependent on temporary habitats created by flooding conditions (i.e. temporarily flooded/ponded wetlands) may have reduced viability within the AOI.

Fish and wildlife within the CC may increase after the construction of the bypass channel and the impoundment site. These may provide suitable habitat for some wetland/aquatic wildlife species and other species that currently inhabit the CC.

4.2.2 REQUIRED CONSULTATION AND PERMITS

Potential required consultations are listed in **Table 4**. Permit requirements will also be established through completion of the Watershed Planning effort.

Table 4: Potential Required Consultations

Resource Concern/Regulation	Consulting Entity
Water Quality	ND Department of Environmental Quality
Downstream Water Quantity	ND State Water Commission
Prime Farmland	US Department of Agriculture
Endangered and Threatened Species	US Fish and Wildlife Service, North Dakota Game and Fish Department
Waters of the United States, Including Wetlands	US Army Corps of Engineers

4.2.3 NEPA DOCUMENTATION REQUIRED

It is anticipated that the preferred alternative will require an Environmental Assessment (EA) only. If the impacts cannot be reasonably overcome, an Environmental Impact Statement (EIS) may be necessary.

5 CONCLUSION AND CLOSE-OUT STATEMENT

During the RCPP planning process, the project team consisted of local landowners, local agency staff, and state and federal agency staff. Prior to further analysis of the alternatives selected for further analysis, the project team determined that the problems and resource concerns in the watershed did not warrant continued planning at this time.

The project team accomplished the following items during the planning process:

1. Held an agency scoping meeting to get feedback from agencies on their watershed concerns.
2. Held a public scoping meeting to get feedback and priority resource concerns from the public within the watershed.
3. Developed a Purpose and Need Statement, which was review and commented on by NRCS and approved as a draft.
4. Reviewed and updated existing conditions in the watershed through extensive preliminary hydraulic and hydrologic modeling efforts. Calibrated hydraulic and hydrologic models based on historical rainfall events and USGS gage analysis. Reviewed results for synthetic rainfall events. Submitted detailed report on Forest River Watershed existing conditions hydrology and hydraulics.
5. Reviewed and narrowed flood damage reduction strategy categories that could address issues noted in the Purpose and Need Statement. There were 20 general flood damage reduction strategies reviewed. The project team eliminated 16 of the strategies and carried four strategies forward to build possible alternatives around. Developed alternatives for one remaining strategy was carried forward. As the alternatives were developed, extensive preliminary hydraulic and hydrologic watershed models were created for the Forest River Watershed. This model information is still available for the SLO for future needs.
6. Held numerous meetings to review and analyze potential alternatives. They narrowed the complete list of alternatives down to six alternatives. The project team also reviewed various combinations of alternatives.
7. Adopted one alternative that the project team felt was worthy of pursuing in greater detail. Analyzed results from the alternative and met with local landowners who would be impacted by the project. Presented results to local landowners and members of the communities of Minto and Forest River, ND, during public meetings.
8. Discussed the preferred alternative and felt the opposition to the project outweighed the support and did not warrant further pursuit at this time. The main concern was the lack of support from landowners who would benefit from the implementation of the project and the apparent resistance from landowners who would be impacted by construction of the proposed site (some agricultural land would need to be taken out of production to build the project). At that point, the watershed planning process was suspended.

The SLO has all the planning information developed and reviewed by the project team. The SLO believes this information will be valuable in the future if the existing conditions or priorities change. Should existing conditions or priorities change, the SLO has some viable alternatives that could be reviewed and possibly implemented. The SLO also has the watershed models to use as tools for future analysis of the existing viable alternatives or new alternatives. Additionally, the models may also be used to assist the SLO in targeting key areas to focus efforts in flood reduction within the watershed, which is the general goal for the planning effort.

6 REFERENCES

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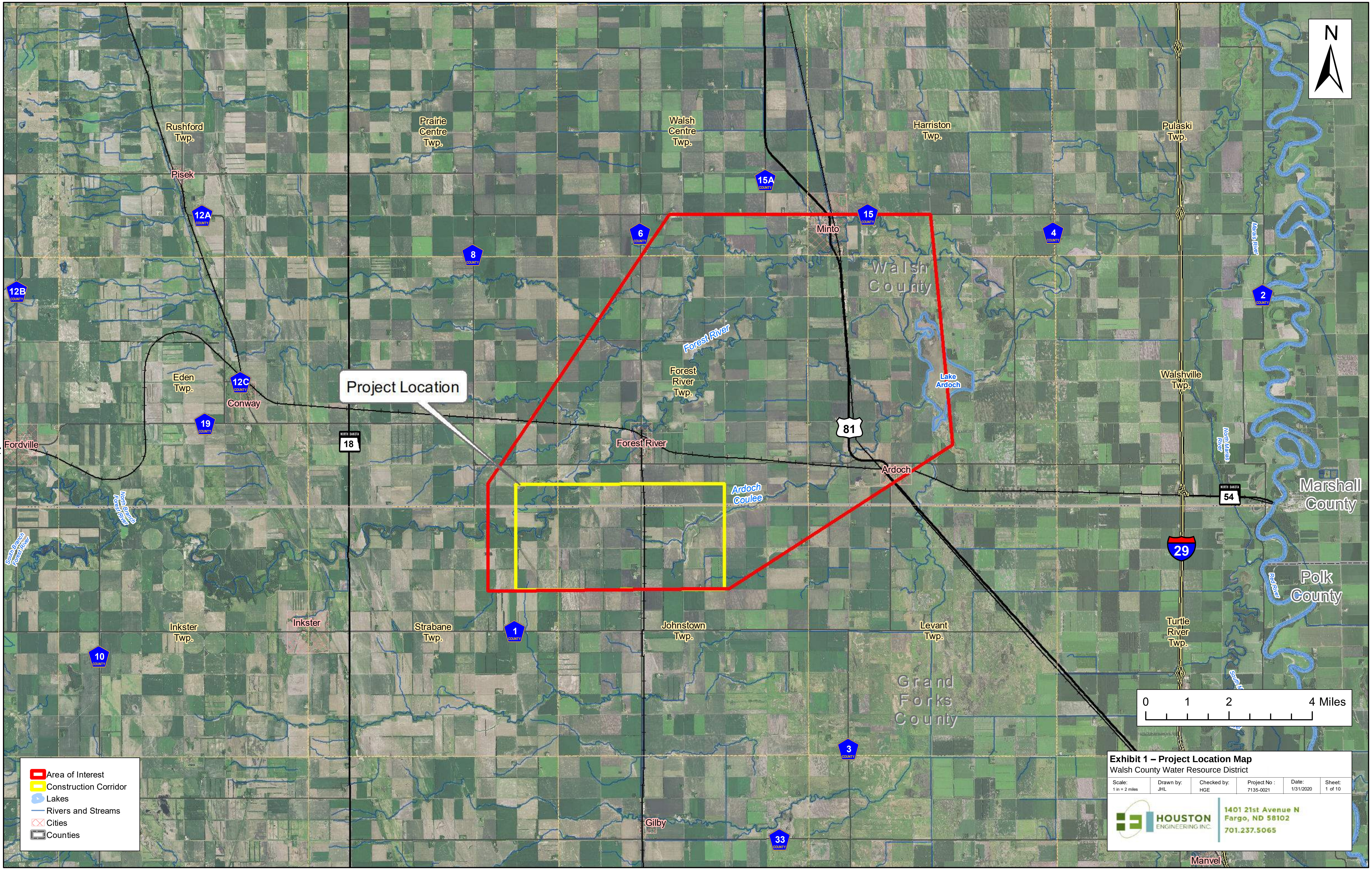
EXHIBIT 1

PROJECT LOCATION MAP



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AREA OF INTEREST AND CONSTRUCTION CORRIDOR MAP

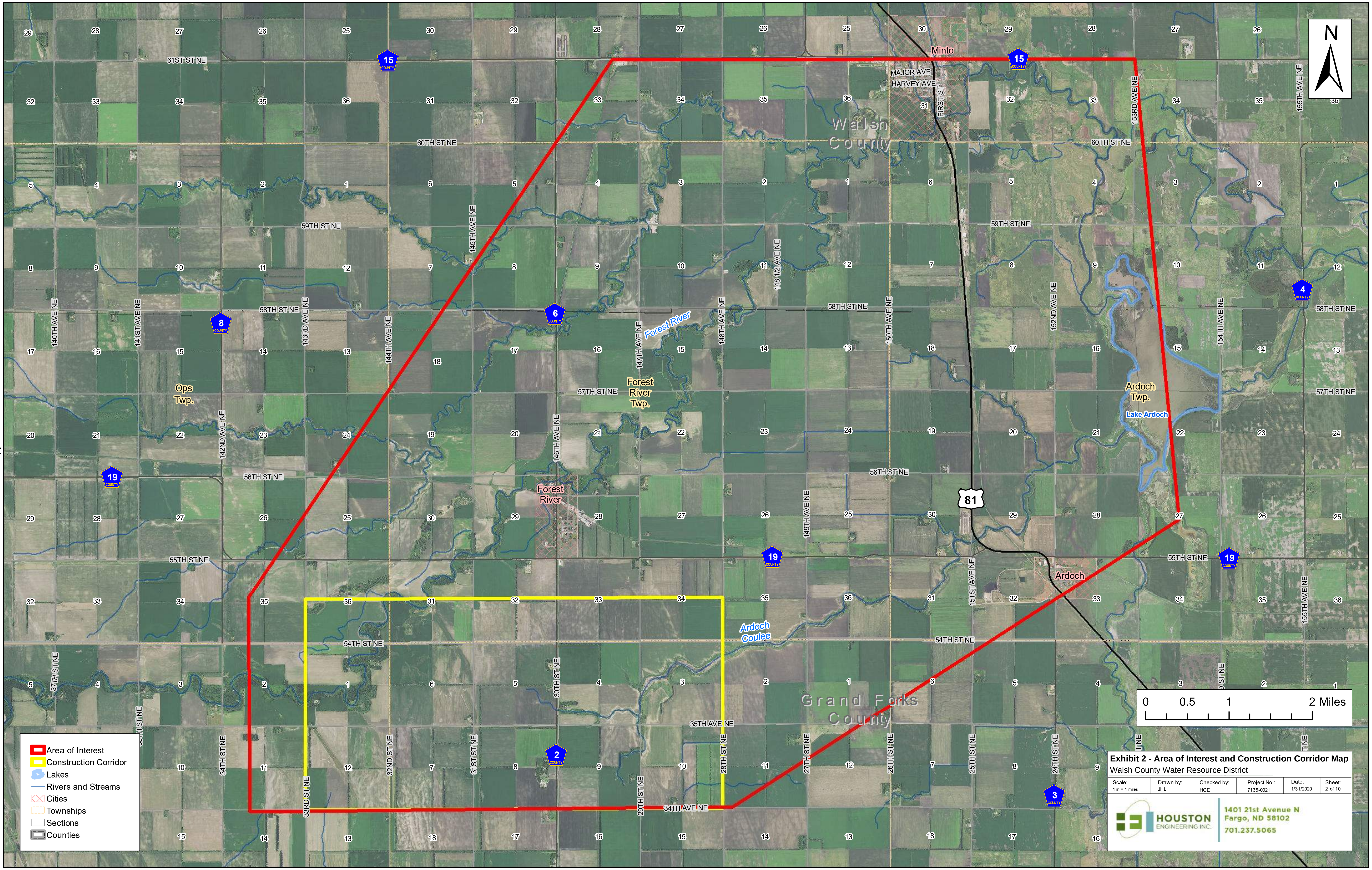

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EXHIBIT 3

LiDAR MAP

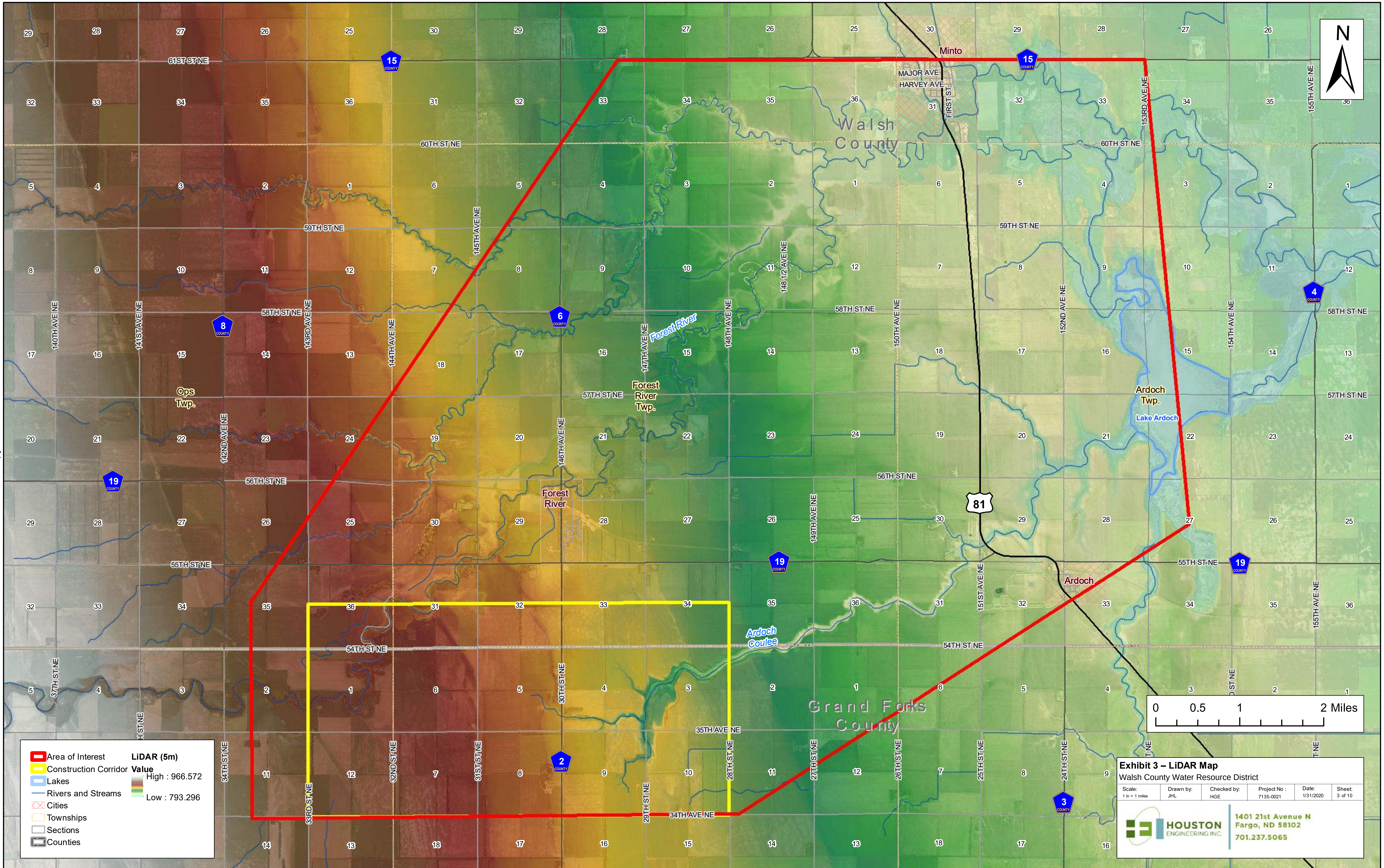

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EXHIBIT 4

LAND USE MAP

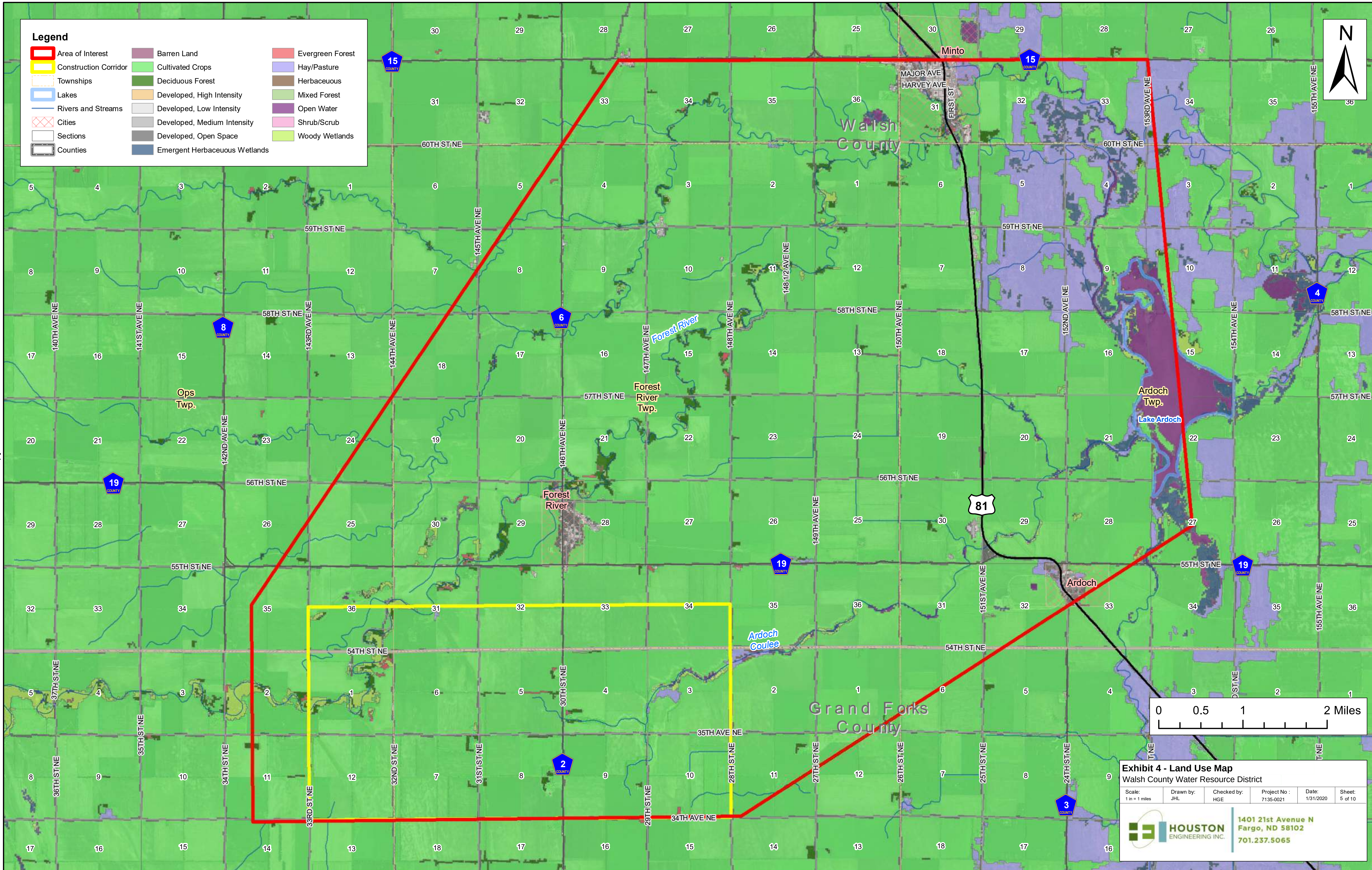

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EXHIBIT 5

FEDERAL AND STATE LANDS MAP

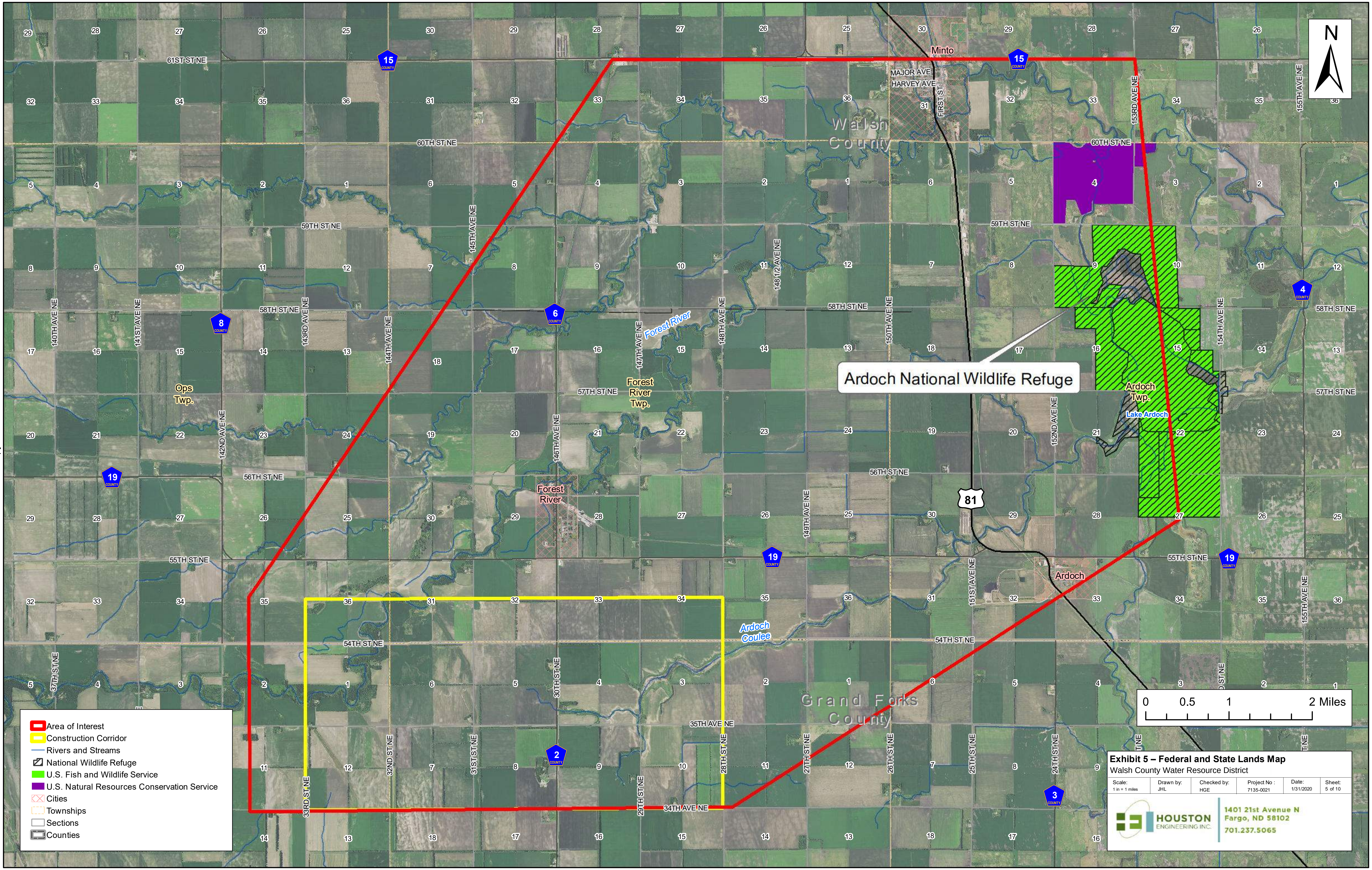

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EXHIBIT 6

SOIL SURVEY MAP

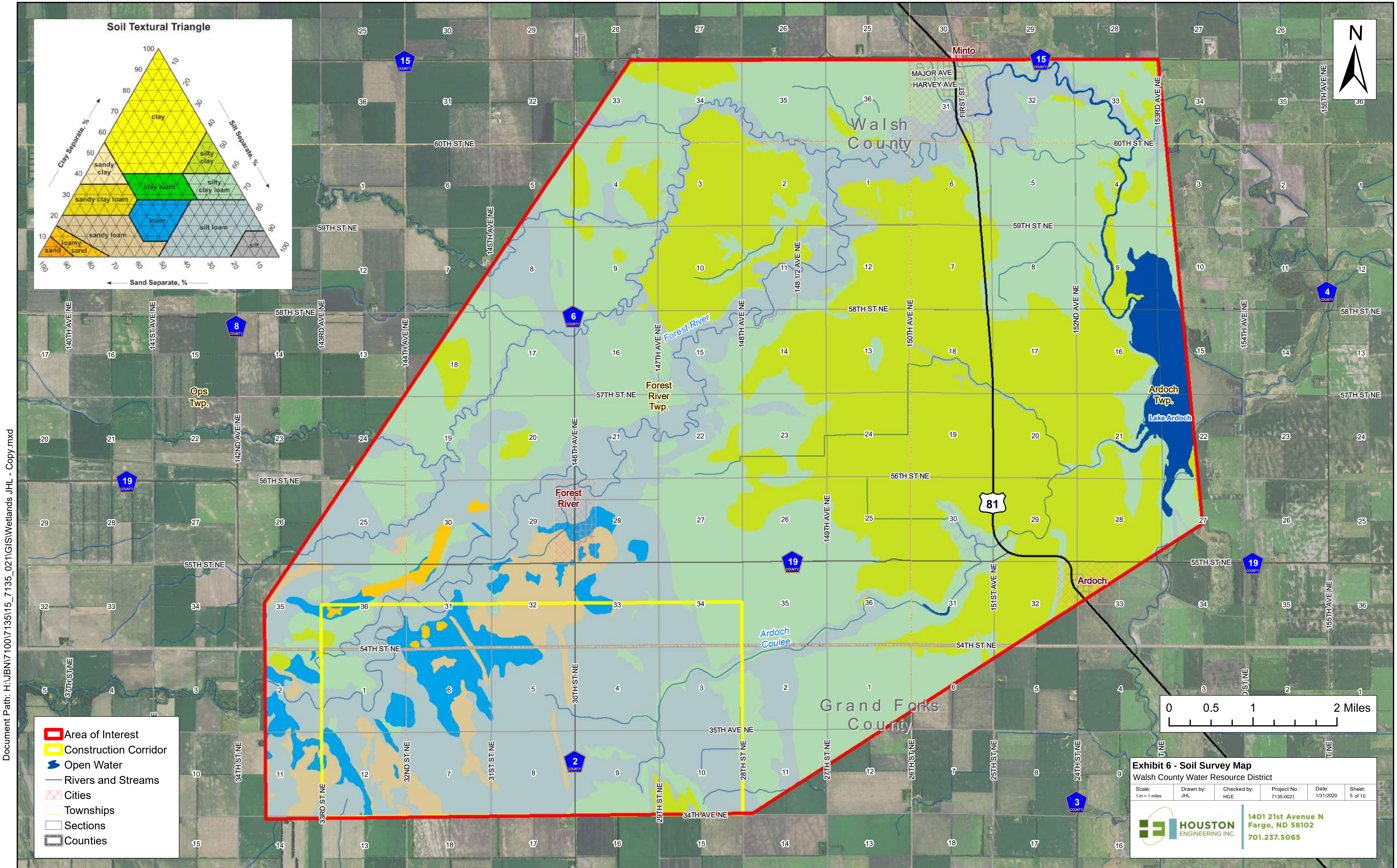
Soil Textural Triangle
clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
loam
silt loam
sandy loam
loamy sand
sand
silt
Clay Separate, %
Silt Separate, %
Sand Separate, %
N
Walsh County
Grand Forks County
Minto
Forest River
Ardoch
Forest River Twp.
Ardoch Twp.
Ops Twp.
Forest River
Lake Ardoch
Ardoch Coulee
MAJOR AVE
HARVEY AVE
FIRST ST
60TH ST NE
59TH ST NE
58TH ST NE
57TH ST NE
56TH ST NE
55TH ST NE
54TH ST NE
35TH AVE NE
34TH AVE NE
140TH AVE NE
141ST AVE NE
142ND AVE NE
143RD AVE NE
144TH AVE NE
145TH AVE NE
146TH AVE NE
147TH AVE NE
148TH AVE NE
148 1/2 AVE NE
149TH AVE NE
150TH AVE NE
151ST AVE NE
152ND AVE NE
153RD AVE NE
154TH AVE NE
155TH AVE NE
37TH ST NE
34TH ST NE
33RD ST NE
32ND ST NE
31ST ST NE
30TH ST NE
29TH ST NE
28TH ST NE
27TH ST NE
26TH ST NE
25TH ST NE
24TH ST NE
Area of Interest
Construction Corridor
Open Water
Rivers and Streams
Cities
Townships
Sections
Counties
0 0.5 1 2 Miles
Exhibit 6 - Soil Survey Map
Walsh County Water Resource District
Scale: 1 in = 1 miles
Drawn by: JHL
Checked by: HGE
Project No : 7135-0021
Date: 1/31/2020
Sheet: 5 of 10
HOUSTON ENGINEERING INC.
1401 21st Avenue N
Fargo, ND 58102
701.237.5065
Document Path: H:\JBN\7100\7135\15_7135_0021\GIS\Wetlands JHL - Copy.mxd

EXHIBIT 7

PRIME FARMLAND MAP

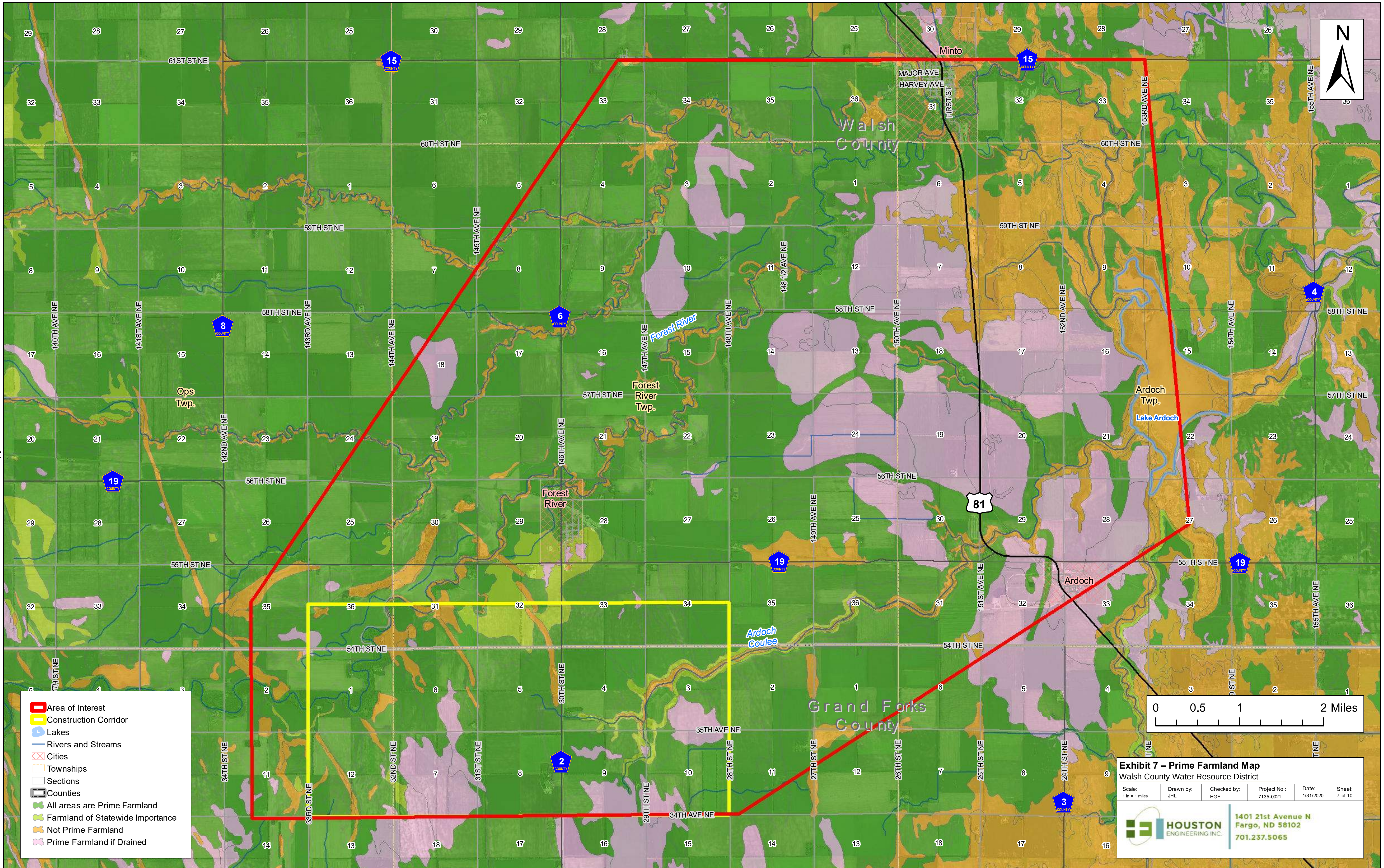

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EXHIBIT 8

NATIONAL WETLAND INVENTORY MAP

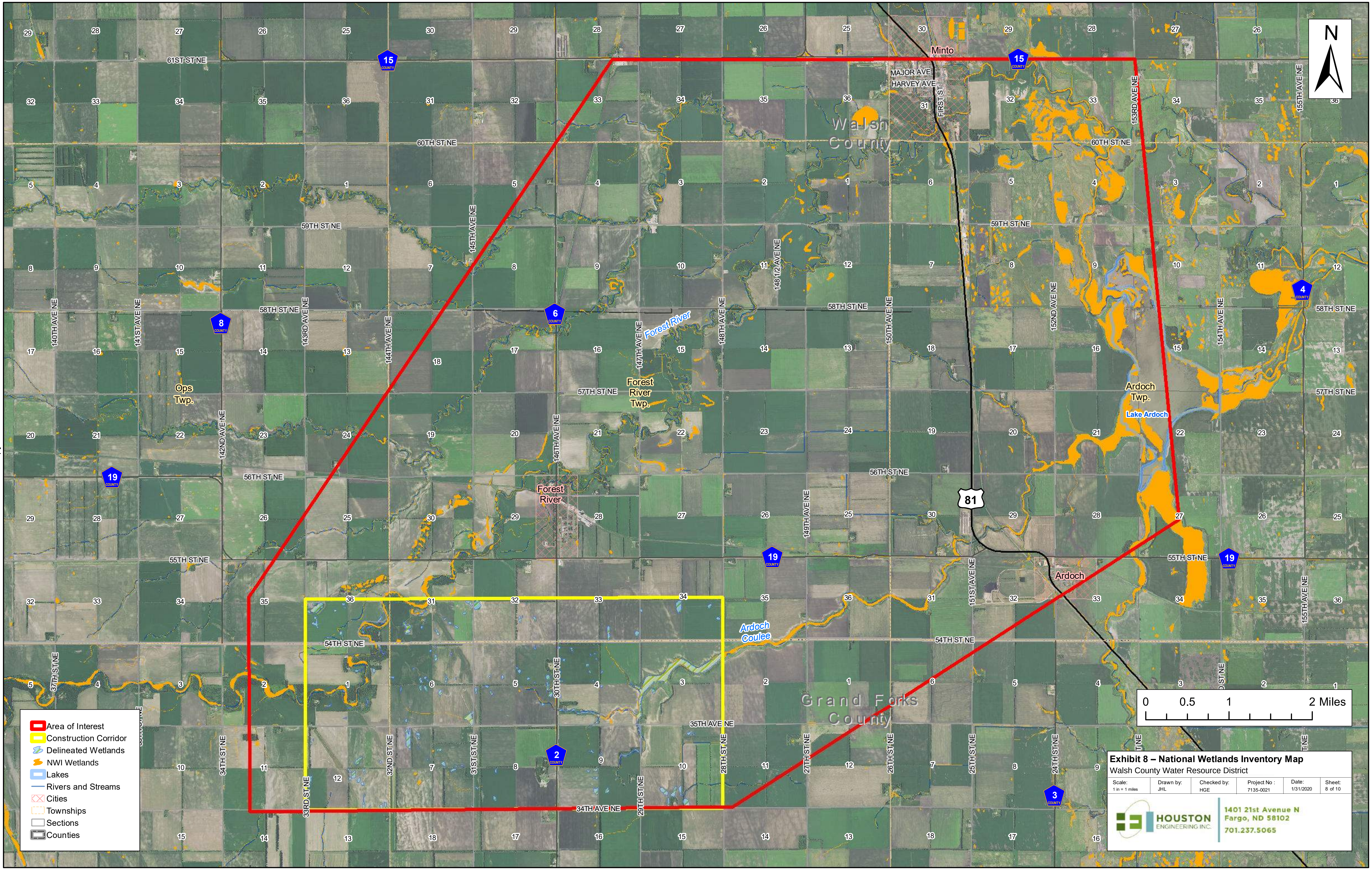

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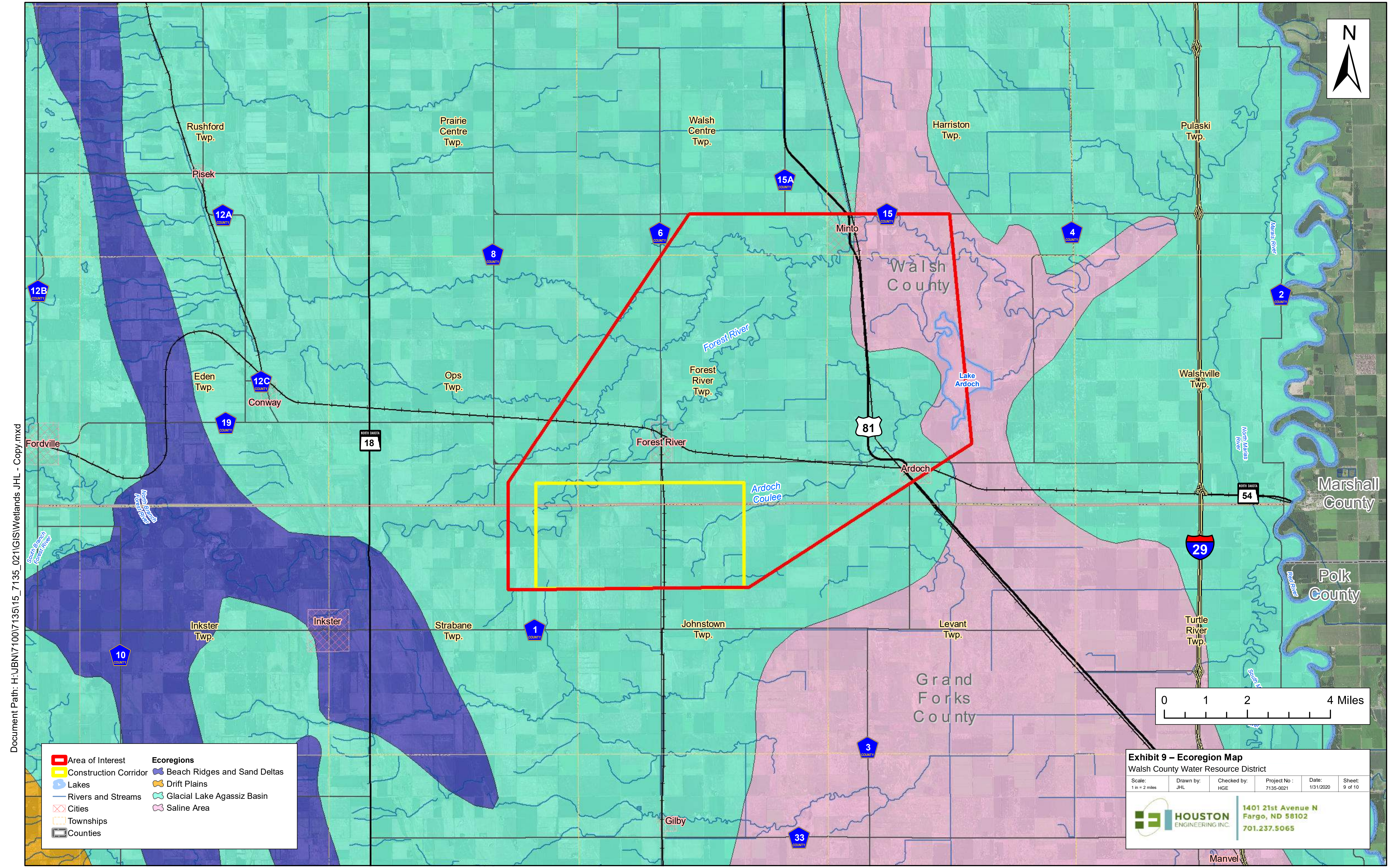
EXHIBIT 9

ECOREGION MAP



Rushford Twp.
Prairie Centre Twp.
Walsh Centre Twp.
Harriston Twp.
Pulaski Twp.
Pisek
Minto
Walsh County
Forest River
Forest River Twp.
Lake Ardoch
Eden Twp.
Conway
Ops Twp.
Walshville Twp.
Fordville
Forest River
Ardoch
Ardoch Coulee
Marshall County
Polk County
Inkster Twp.
Inkster
Strabane Twp.
Johnstown Twp.
Levant Twp.
Turtle River Twp.
Grand Forks County
Gilby
Manvel
0 1 2 4 Miles
N
Area of Interest
Construction Corridor
Lakes
Rivers and Streams
Cities
Townships
Counties
Ecoregions
Beach Ridges and Sand Deltas
Drift Plains
Glacial Lake Agassiz Basin
Saline Area
Exhibit 9 – Ecoregion Map
Walsh County Water Resource District
Scale: 1 in = 2 miles
Drawn by: JHL
Checked by: HGE
Project No : 7135-0021
Date: 1/31/2020
Sheet: 9 of 10
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APPENDIX A

SCREENING OF ALTERNATIVES FOR DETAILED REVIEW

Fargo, ND | HEI No. 7135_0021
DRAFT February 21st, 2020

Outlet of Matejcek Dam Downstream Channel – Forest River in Walsh County, North Dakota

FOREST RIVER RCPP WATERSHED PLAN

SCREENING OF ALTERNATIVES FOR DETAILED REVIEW (DRAFT)

FOREST RIVER RCPP WATERSHED PLAN

SCREENING OF ALTERNATIVES FOR DETAILED REVIEW (DRAFT)

February 21st, 2020

Walsh County Water Resource District

In cooperation with:
Forest River Joint Water Resource District

Houston Engineering, Inc.
1401 21st Ave. N
Fargo, ND 58102
Phone # 701.237.5065

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of North Dakota.

Zachary O. Herrmann, PE
PE-8405

Paul D. LeClaire, PE
PE-28012

Date

Date

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

The Walsh County Water Resource District (WCWRD) entered into a cooperative agreement with the Natural Resource Conservation Service (NRCS) in 2015 to complete a watershed plan for the Forest River Watershed through the Regional Cooperation Partnership Program (RCPP). This will be referred to as the Forest River Watershed Plan. The WCWRD is also referred to as the Sponsoring Local Organization (SLO) for the Forest River Watershed Plan. The Forest River Joint Water Resource District (FRJWRD) also provided local guidance during plan development. The FRJWRD includes the Nelson, Grand Forks, and Walsh county water resource districts. The FRJWRD put together a local planning team to work through the planning process outlined by the NRCS and provide additional local input to the FRJWRD.

As part of the Forest River Watershed Plan, a Purpose and Need Statement was identified by the planning team and approved by the NRCS. The purpose of the proposed action is to implement flood prevention and flood damage reduction measures to:

1. Reduce flood damages for up to a 10-year rainfall event on cropland.
2. Increase flood resiliency for up to a 10-year event on public and private infrastructure within the communities that reside along the Forest River. (Primary)
3. Increase flood resiliency for the communities of Minto and Forest River, ND, during a 100-year flood event. (Primary)
4. Maintain or reduce flood flows downstream of Lake Ardoch. (Primary)
5. Improve soil health and water quality throughout the watershed. (Secondary)

To achieve the goals outlined in the Purpose and Need Statement, the planning team set out to develop and analyze potential alternatives that would address the objectives in the Purpose and Need Statement. The benefit provided by the potential alternatives was determined by comparing the alternatives to the existing condition in the Forest River Watershed. The development of existing conditions models is described in the *Forest River Watershed Plan – Existing Conditions Hydrology and Hydraulics Report* (Houston Engineering, Inc., 2019).

This report will focus on the screening of flood reduction strategies and alternatives based on technical data, practicality to implement, and their ability to satisfy the Purpose and Need Statement for the Forest River Watershed Plan. Alternatives that are deemed worthy to carry forward will be analyzed in more detail.

1.2 APPROACH

The preliminary development of alternatives focused on narrowing the range of alternatives by reviewing and analyzing technical and practical considerations to evaluate potential to meet project objectives from the Purpose and Need Statement. Strategies were first evaluated based on known causes of flooding. In some cases, a preliminary hydrologic analysis was completed to reasonably evaluate a strategy's potential to meet flood damage reduction objectives. Alternative concepts that were based on strategies that would meet the project objectives were then developed and preliminarily analyzed to further narrow the range of alternatives based on the ability to address the Purpose and Need Statement.

To assist with a comparative analysis of the alternatives, the following indicators were established as pass-fail criteria for the preliminary development of alternatives. Important locations used to assess the indicators are shown on **Figure 1**. Results from the *Existing Conditions Hydraulics and Hydrology Report* indicate that 4-day duration rainfall events are the most critical in terms of peak flow and inundation for the Forest River Watershed. Therefore, 4-day events were used to develop the objectives associated with the Purpose and Need Statement. The objectives and associated indicators are summarized as follows:

- **INDICATOR NO. 1:** Reduce cropland inundation for flood durations equal to or less than four days by 20% within the Lower Forest River Watershed during the 10-year flood event. Four days of inundation is assumed to be the maximum amount of damage that crops in the Forest River Watershed can withstand without total loss. Though some crop types in the area require less inundation time for total loss, reducing the amount of inundation that occurs on cropland from zero to four days will ensure added economic benefit for all crop types. These crop types include wheat, soybeans, corn, dry beans, potatoes, and sugar beets. A 20% reduction in cropland inundation was deemed to be a realistic expectation of the preliminary screening for alternatives.
- **INDICATOR NO. 2:** Increased flood resiliency for public and private infrastructure along the Forest River would be gained by a reduced frequency of high flow rates. The following reduction in peak flow rates were assumed to be realistic targets based on reasonable expected acre-feet reduction for alternatives from the peak of the flood hydrograph. Acre-feet reductions presented below should be considered "ideal", meaning these reductions can only be achieved if alternatives were placed in locations that exactly match the source and timing of flood flows. In practice, placement of hydrologically ideal volume reduction measures is generally limited due to the feasibility of other technical and environmental concerns.
  - **(a)** 20% on the Forest River at Walsh County Road 6 near the community of Forest River, ND. A 20% reduction of the 10-year peak flow rate would require approximately 400 acre-feet of volume reduction from the peak of the flood hydrograph.
  - **(b)** 20% on the Forest River crossing at 1st Street in Minto. A 20% reduction of the 10-year peak flow rate would require approximately 800 acre-feet of volume reduction from the peak of the flood hydrograph.
- **INDICATOR NO. 3**: Increase flood resiliency for the communities of Minto and Forest River, ND, during a 100-year flood event. The following criteria were deemed realistic expectations of the preliminary screening for alternatives.
  - **(a)** Reduce the 100-year event peak flow rate by 16% on the Forest River at the community of Forest River, ND. Reducing the 100-year peak flow rate by 16% on the Forest River would result in a with-project conditions 100-year peak flow rate approximately equivalent to the existing conditions 50-year peak flow rate.
  - **(b)** Reduce the 100-year event peak flow rate by 8% on the Forest River at the community of Minto, ND. Reducing the 100-year peak flow rate by 8% on the Forest River would result in a stage reduction at Minto of one foot.
- **INDICATOR NO. 4**: No increase in peak flow rate at the Forest River crossing with Walsh County Road 4 downstream of Lake Ardoch.

All reasonable alternatives that were identified were considered, regardless of eligibility under Public Law 83-566 or other NRCS administered funding sources. The alternatives that successfully achieve the objectives defined in the Purpose and Need Statement based on the presented indicators are proposed to be carried forward for a detailed review. It should be noted that these indicators are used as a preliminary screening tool. After the preliminary screening, the alternatives that meet the identified indicators will be analyzed in more detail and an analysis of benefits will be completed to establish the benefit/cost ratio for each alternative if the alternatives are further developed through the NRCS planning process.

2 INITIAL STRATEGY SCREENING

The initial phase of the development of alternatives was a review of a comprehensive list of strategies that represent categories of types of alternatives. The initial list of strategies was developed based on guidance from *Red River Basin Flood Damage Reduction Work Group Technical and Scientific Advisory Committee Technical Paper No. 11* (Anderson & Kean, 2004). The goal of the strategy evaluation was to narrow the scope of the preliminary alternative review through the acceptance or elimination of strategies based on limited technical evaluation and practical considerations. To aid in this review, strategies were categorized in the five generalized groups:

1. No-Action involves forecasting the watershed condition if no alternative plan is selected.
2. Reduce runoff volume involves structural and non-structural practices that result in reductions to the excess runoff volume from the water budget during a rain event.
3. Increase conveyance capacity provides additional hydraulic capacity within the watershed at known damage locations.
4. Increase temporary flood storage would provide additional flood storage within the watershed, typically through structural measures that would maximize available flood storage.
5. Protection/Avoidance are structural and non-structural practices that would reduce damage frequency for land, structures, and infrastructure.

A description of strategies that have been identified and considered within each category is provided in **Table 1**.

Table 1: Strategy Description

Category	Strategy	Description
No-Action	No-Action	The future-without-project, or No-Action, alternative is required under Public Law 83-566 Watershed Planning. Involves forecasting the watershed conditions that are expected to exist if an alternative plan is not selected.
Reduce Runoff Volume	Cropland Better Management Practices	Cropland management practices have been developed to conserve soil and water resources. These are collectively referred to as best management practices (BMPs). The most commonly used agricultural BMPs are forms of conservation tillage that leave the soil better protected by crop residues than other tillage methods. This may also increase infiltration, thereby reducing runoff. The reduction in runoff varies with the topography, amount of rain, and type of soil.
	Conversion to Grassland	Perennial grassland, including CRP, hay meadow, and well-managed pasture, can produce less rainstorm runoff than cultivated cropland.
	Conversion to Forest	Forestland can produce less rainstorm runoff than cultivated cropland. The effects on snow accumulation and spring snowmelt runoff from forestland have not been well documented.

Category	Strategy	Description
	Aquifer Storage	The recharging of underground aquifers can potentially provide storage capacity when combined with a passive infiltration system and a surface storage site. Using underground aquifers to store runoff is dependent on the location and availability of the aquifer within the watershed.
	Other Beneficial Uses of Stored Water	Stored water can be used for domestic or industrial purposes or for stream flow augmentation during drier periods of the year to improve fish habitat and provide other instream flow benefits. Use of this water results in drawdown of a storage reservoir, providing annual removal of water from the spring flood volume.
Increase Conveyance Capacity	Channelization	Channelization projects may include enlarging or realigning natural channels or creating channels in areas of natural overland flow. Channelization projects are usually constructed to decrease localized flooding; however, the potential increase to flooding downstream of the channelization extents must be considered and mitigated for.
	Drainage	The primary purpose of agricultural drainage in the Red River Basin is to remove excess surface water and soil moisture. Depending on the type of drainage, this can allow the ground to warm up faster in the spring, provide an aerated rooting zone for crop development, and minimize drowning of crops by excess precipitation. The need for outlets for field drainage led to the development of larger collector ditch systems in many areas of the Red River Basin.
	Flood Water Diversion	Diversion projects typically remove water from a flood-prone stream, convey it safely around a known damage site, and return it to a downstream watercourse. A diversion is an alternative to channelization or protection measures, such as levees and floodwalls, when environmental impacts, cost, or other land use issues are better addressed by this measure.
	Increase Roadway Capacity	During high flows in flat topography, road crossings typically restrict conveyance more than the available channel capacity. Roadway capacities can be increased in these instances to reduce flooding caused by high headwater elevations on roadway bridges and/or culverts. While this strategy can reduce localized flooding upstream of roadways, downstream flooding must be considered and mitigated for.
Increase Temporary Flood Storage	On-Channel Dam	On-channel dams are constructed to temporarily store and attenuate peak flows downstream. The most important consideration from an overall flood control standpoint is the timing of the storage and release of attenuated peak flows. An embankment is typically constructed across a natural water course with a regulated outflow structure.
	Reduced Bridge/Culvert Capacity	Culvert sizing is a technique that can be used to control runoff rates. By appropriately sizing road and drainage system culverts throughout a subwatershed or watershed, the flow rates can be regulated to better suit downstream channel capacities. Excess water is temporarily detained upstream of culverts.

Category	Strategy	Description
	Wetland Restoration/Creation	Created or restored wetlands are basins that are implemented primarily to attain a natural resource and/or habitat objective. Wetlands developed for natural resource and/or habitat objectives can provide temporary flood storage. Temporary flood storage is considered beneficial if the topography allows for levels to be managed to provide a reasonable assurance that flood storage is available when needed without adversely impacting other objectives.
	Setback Levees	Levee systems set back from the river channel can be used to increase channel retardance, channel conveyance, and floodplain connectivity, allowing for increased storage within the river corridor. Setback levees require balancing the increased channel retardance with the increased conveyance volume from containing breakout flows. Setback levees are generally located where geotechnical stability is ensured. Setback levees require careful consideration to drainage of lands directly adjacent to the levees to ensure additional damages are not caused by a lack of an adequate outlet when high water conditions are present within the levee corridor.
	Meter Runoff	Drain tile and culvert sizing can be used to store runoff within the existing landscape by utilizing existing depressions within the watershed that consist of agricultural fields bounded by existing roads. Culverts at the outlet of the depressions are sized so that runoff is stored for a short time so that agricultural lands are not adversely impacted.
	Off-Channel Impoundment	Off-channel impoundments are constructed to temporarily store and release flood waters when downstream flooding recedes. The most important consideration from an overall flood control standpoint is the timing of the storage and release of floodwaters. Off-channel impoundments typically consist of an embankment constructed around an area adjacent to a channel with topography conducive to storing runoff. From a locally acceptable perspective, the best suited locations are typically in already flood-prone areas, where higher value crop land or pasture land is not required to be removed from production. A control structure is typically required to divert flows from the channel into the impoundment location.
	River Corridor Protection/ Restoration	Existing riparian corridors would be restored and protected to ensure proper geomorphic conditions are present. From a flood damage reduction standpoint, restoration of a degrading channel would allow for more frequent access to a vegetated floodplain to reduce downstream flow rates. Incised channels can be modified to reduce channel conveyance for increased floodplain connectivity. Setback levees are often required to contain the floodplain and to keep break out flows contained within the riparian corridor.

Category	Strategy	Description
Protection/ Avoidance	Levees	Levee systems are meant to contain the natural floodwaters and the natural floodplain and can be used to protect communities, rural farmsteads, and cropland. If a levee system encroaches on the natural floodplain, the system can result in increased flows,v and downstream flooding must be considered and mitigated for. As with setback levees, consideration for drainage of land directly adjacent to the levee is critical. In many urban settings, this results in large lift stations being installed with high capacity electrical pumps to lift water over the levee during floods.
	Flood Warning System	Flood warnings and emergency response begins with long- and short-term forecasts of flood potential and can lead to sandbagging, earthen levee construction, or other emergency protection methods and ultimately evacuation, if necessary. Available timing between flood warning issuance and actual flood conditions is critical to ensure emergency response can be coordinated.
	Floodplain Easements	Landowners would be compensated through establishment of a set-aside easement to no longer operate on flood-prone areas. (Emergency Watershed Protection Program, etc.)

2.1 TECHNICAL CONSIDERATIONS

A technical evaluation was completed to provide enough information on the potential for the various strategies to meet objectives from the Purpose and Need Statement. The technical evaluation utilized the hydrologic and hydraulic models developed for the Forest River Watershed. The development of the HEC-HMS and HEC-RAS models is documented in the *Forest River Watershed Plan Existing Conditions Hydrology and Hydraulic Report* (HEI, 2019). Multiple reporting locations were selected to evaluate model results. The reporting locations are shown on **Figure A.1** in **Appendix A** and are further summarized below.

- Forest River at North Dakota State Highway 32 – First major stream crossing downstream of Matejcek Dam near the upstream extent of the hydraulic model. Located upstream of the confluence of the Middle Branch Forest River and the North Branch Forest River.
- Forest River at 134th Ave NE – At USGS Streamgage 05084000 near Fordville, ND. Downstream of the confluence between the Middle Branch Forest River and the North Branch Forest River. Also downstream of the confluence between the Forest River mainstem and the South Branch Forest River.
- Forest River at North Dakota State Highway 18 – Forest River crossing at major highway. Crossing location is just upstream from where the Forest River transitions from a well-defined valley to a perched river system where breakout flows travel overland.
- Forest River at Walsh County Road 6 – North of the town of Forest River, ND. Downstream of large breakout that conveys flow north into an unnamed tributary. Upstream of large breakout that conveys flow east to Ardoch Coulee.
- Forest River at 1st Street Crossing – At USGS Streamgage 05085000 at Minto, ND. Located downstream of US Highway 81 and upstream of a BNSF railroad. Last major crossing before the Forest River enters Lake Ardoch.
- Forest River at Walsh County Road 4 – Downstream of Lake Ardoch. Reporting location used to ensure that the peak discharge downstream of Lake Ardoch does not increase.

- Forest River North Breakout at 148th Ave NE – A perennial stream that enters the Forest River upstream of Minto, ND. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee Breakout at US Highway 81 – A perennial stream that enters Ardoch Coulee approximately 1 mile downstream of US Highway 81. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee at US Highway 81 – Major stream crossing upstream of Lake Ardoch.

To accurately evaluate the preliminary alternatives, both the changes in peak flow and inundated acres need to be compared to existing conditions. **Table 3** provides information on peak flow and inundated acres for the different alternatives as discussed in the following sections.

2.1.1 REDUCE RUNOFF VOLUME

A sensitivity analysis was completed using the watershed hydrologic and hydraulic models to assess the maximum flood volume reduction benefits that could be attained by converting cropland to perennial vegetation. While not all strategies that categorically fit under the *Reduce Runoff Volume* category are focused on cropland conversion to perennial vegetation, this review assumed that other strategies within the category would perform hydrologically equivalently to perennial vegetation at the optimum design. For this analysis, cropland refers to lands with National Land Cover Database (NLCD) Land Use Codes of pasture/hay (81) and cultivated crops (82) (Homer, et al., 2015). While conversion of all the cropland within the watershed may not be practical to implement, it provides a baseline of the highest potential flood volume reduction in the watershed using these practices. In total, there are 683 square miles (77% of the total area) of cropland within the Forest River Watershed. The scenarios evaluated for this analysis included cropland conversion in two regions of the Forest River Watershed, which are shown on **Figure 2.1.1** and are described as follows;

- Cropland west of North Dakota State Highway 18 would be converted to perennial vegetation, with the remaining watershed left as the existing condition.
- Cropland within the Forest River Watershed upstream of Lake Ardoch would be converted to perennial vegetation, with the remaining watershed left as the existing condition.

While conversion from cropland to perennial vegetation would represent the maximum achievable hydrologic reduction to runoff volume, a more practical ability to implement would be somewhere between the results of the sensitivity analysis and the existing conditions.

NRCS curve number values were adjusted in the hydrologic model to assume that all cropland within the three regions discussed would be converted to perennial vegetation based on guidance from *TR-55 Urban Hydrology for Small Watersheds* (NRCS, 1986). **Table 2** below summarizes the existing and modified NRCS curve numbers that were used for this analysis.

Table 2: NRCS 24 Hour Curve Number Modifications for Perennial Vegetation Analysis

NLCD Land Use Code	Condition	Hydrologic Soil Type A	B	C	D	A/D	B/D	C/D
Pasture/Hay (81)	*Existing*	49	69	79	84	84	84	84
	Perennial Vegetation	30	58	78	78	78	78	78
Cultivated Crops (82)	*Existing*	61	71	78	81	61	71	78
	Perennial Vegetation	30	58	78	78	30	58	78

The hydrologic and hydraulic models for the Forest River Watershed were used to compute reduced volume flood hydrographs that would result from cropland conversion. Using NRCS curve number methods to calculate the rainfall/runoff volume relationship results in a higher percentage of rainfall converted to runoff as the rainfall depth increases. The analysis indicates that there will be significant reductions to peak flow near the communities of Forest River and Minto, ND. The peak flow is reduced by more than 30% at the Forest River crossing with Walsh County Road 6, and more than 40% at the Forest River crossing at 1st Street in Minto, ND for the 10-year event. Peak flow reductions of 20% to 30% were evaluated during the 100-year event at those same locations. At the Forest River crossing with Walsh County Road 4, the peak flow is reduced by 47% for a 10-year rainfall event with all cropland upstream of Lake Ardoch converted to perennial vegetation. **Table 3** shows peak flow reductions at all reporting locations and changes to inundated acres for the two scenarios. Hydrographs showing preliminary modeling results for the 10- and 100-year events are available in **Appendix A.2**.

2.1.2 INCREASE CONVEYANCE CAPACITY

Increased structural hydraulic capacity within the watershed would result in a reduced travel time for flood waters and reduced access to natural flood plain areas. To estimate the effects of increased structural conveyance capacity within the Forest River Watershed, existing bridge and culvert crossings on the channel between ND Highway 18 and Lake Ardoch were approximately doubled in available flow area and analyzed using the hydraulic model. An additional simulation was completed with bridge and culvert crossing sizes increased on the Forest River mainstem as well as the structures in Ardoch Coulee, the perennial stream north of the Forest River mainstem, and throughout the floodplain of the Lower Forest River Watershed. **Figure 2.1.2** shows the structures that were increased in size on the Forest River mainstem and all other bridges/culverts increased in the watershed. This analysis indicated that peak flood flow rates at Walsh County Road 4, downstream of Lake Ardoch, increased by 0.2% during the 10-year event and 1.2% during the 100-year event with bridges and culverts only increased along the Forest River mainstem. The increase in flood flow rates at Walsh County Road 4 with bridges and culverts increased throughout the Lower Forest River Watershed was approximately 2.6% during the 10-year event and 0.9% during the 100-year event. Refer to **Table 3** for changes in peak flow at all reporting locations and changes to inundated acres for these scenarios. Hydrographs showing preliminary modeling results are available in **Appendix A.3**.

2.1.3 INCREASE TEMPORARY FLOOD STORAGE

As indicated from public comments and preliminary hydraulic model simulations, much of the flooding that occurs within the Forest River Watershed occurs in the Lower Forest River Watershed (shown in **Figure**

1). Areas in the Upper Forest River Watershed are characterized with numerous wetlands and moderate to steep slopes. The steeper slopes cause runoff to accumulate rapidly in the Upper Forest River Watershed. In the lower portion of the Forest River Watershed, the topography flattens and causes expansive flooding when the capacity of the Forest River channel is exceeded. The floodplain is still mostly channelized at the crossing of the Forest River with North Dakota State Highway 18. The area west (upstream) of North Dakota State Highway 18 accounts for approximately 71.3% of the drainage area to Minto, ND, and 45% of the area contributing to the Forest River crossing with Walsh County Road 4 downstream of Lake Ardoch. The area upstream of North Dakota State Highway 18 can be subdivided into three unique drainage areas: the area above Matejcek Dam; the area between Matejcek Dam and Fordville, ND; and the area between Fordville, ND, and North Dakota State Highway 18. These areas are shown on **Figure 2.1.3a**.

The hydrologic and hydraulic models were used to estimate the runoff volume from the three drainage areas in the upper portion of the watershed by incrementally removing the runoff volume from each of the areas. The three different simulations are described further below:

- <u>Retention Upstream of Matejcek</u>: runoff volume from drainage area upstream of Matejcek Dam removed.
- <u>Retention Upstream of Fordville</u>: runoff volume from the drainage area upstream of Fordville, ND, removed. This includes all drainage area upstream of Matejcek Dam; the drainage area for the Middle Branch Forest River from Matejcek Dam to Fordville, ND; and all drainage area from the North Branch Forest River.
- <u>Retention Upstream of ND Highway 18</u>: runoff volume from the drainage area upstream of North Dakota State Highway 18 removed. This includes all drainage area upstream of Fordville, ND, plus the drainage area along the Forest River from Fordville, ND, to North Dakota State Highway 18 and the drainage area from the South Branch Forest River.

The results detailing the peak discharge and cropland inundations for the different regions are shown in **Table 3** for all reporting locations. Discharge hydrographs showing preliminary modeling results are available in **Appendix A.4**. This analysis shows the timing and impact of various areas in the Forest River Watershed at locations critical to the Purpose and Need Statement and provides information about which areas should be targeted for potential retention structures. For example, the 10-year discharge hydrograph for the Forest River crossing at 1st Street in Minto, ND, shows that the volume contributing to the peak flow is largely coming from areas upstream of Fordville, ND, which includes the North Branch and South Branch Forest River. Peak flows for the 10-year event are reduced by 48% for the Forest River crossing at 1st Street when all area upstream of Fordville, ND, is removed from the hydrologic model. Peak flow reductions of 12% to 13% are obtained downstream of Lake Ardoch during a 10-year event when all area upstream of Fordville area is removed.

Further analysis on temporary flood storage within the watershed was done specifically for wetland restoration. The National Wetlands Inventory (NWI) dataset was used to apply the methods described in USGS Open File Report 2007-1159 (Gleason, Tangen, Laubhan, Kermes, & Euliss Jr., 2007). This report provides a method to estimate potential surficial flood storage volumes for drained wetland basins in the Prairie Pothole Region, which includes the Forest River Watershed, based on wetland acreages. Wetland acreages are used with empirical equations to get an estimated flood storage. Drained wetland basins are described as NWI wetlands indicated as drained or partially drained. Within the Forest River Watershed, there are approximately 2,502 acres of NWI wetlands attributed as being drained or partially drained. Using methods from the USGS Open File Report 2007-1159, the potentially available flood storage within each individual NWI drained based was calculated. In total, this resulted in approximately 4,166 acre-feet of available surficial flood storage. The locations of the NWI drained basins within the watershed are presented in **Figure 2.1.3b**. Each of the NWI drained basins were overlaid with the subbasins from the hydrologic model, and an adjustment was made to NRCS curve numbers to reflect the change in volume based on the calculated available surficial flood storage. The hydrologic and hydraulic models were run using the adjusted NRCS curve number values to estimate flow reductions when compared to the existing conditions. It should be noted that while the NWI dataset may not be considered a comprehensive source for all landscape areas representing potential restorable wetlands, it was assumed to be appropriate for depressional basins that facilitate flood storage through changes in water depth within the wetland basin.

Vegetative restoration of other wetlands that may not lend themselves to providing significant surficial storage were also analyzed. Reestablishment of perennial vegetation in areas that contain hydric soils was reviewed and analyzed with the hydrologic and hydraulic models. The two scenarios considered in this analysis are as follows:

- Conversion of lands containing hydric soils with a hydric rating greater than or equal to 50. As indicated by the SSURGO soil database, areas with a hydric rating greater than or equal to 50 in the Forest River Watershed make up approximately 121 square miles of the total 884 square mile drainage area, or 13.7%.
- Conversion of lands containing hydric soils with a hydric rating of 100. Areas with a 100% hydric rating in the Forest River Watershed make up approximately 16 square miles of the total 884 square mile drainage area, or 1.8%.

NRCS curve number values for areas indicated as hydric soils under each scenario were adjusted to reflect runoff volume reductions as indicated in Table 5-2 in the North Dakota Hydrology Manual (USDA, SCS). These adjusted NRCS curve numbers were then input into the hydrologic and hydraulic model and used to estimate changes in peak flow and inundation acres.

The most significant peak flow and inundation reductions occur when land with hydric ratings greater than 50 are converted to wetlands. A peak flow reduction of 26% is obtained during the 10-year event at the Forest River crossing with 1st Street in Minto, ND, for wetland conversion in lands with a hydric rating greater than 50. During that same event and at that same location, NWI wetland restoration and restoration of lands with a hydric rating of 100 had peak flow reductions of 1.4% and 0.8%, respectively. Refer to **Table 3** for changes in peak flow and inundated acres for the scenarios described. A map showing partially drained or ditched wetlands based on the NWI dataset and areas with hydric soils in the Forest River Watershed is presented in **Figure 2.1.3b**. Hydrographs showing preliminary modeling results with wetland conversion based on hydric soil data are available in **Appendix A.5**.

2.1.4 TEMPORARY PROTECTION

Flood timing was reviewed from the existing conditions hydrologic and hydraulic models to assess the potential for advanced warning systems and installation of temporary protection. Measures could be established by local emergency management officials to better inform residents of impending flood risk. When comparing the peak intensity of rainfall with the peak flow at Minto, ND, an approximate 3-day lag is observed for a 10-year 4-day rainfall event.

Table 3: Peak Flow and Inundation Changes for Technical Consideration Alternatives 2.1.1-2.1.4

Scenario	Existing Conditions	Reduce Runoff Volume		Increase Conveyance Capacity		Increase Temporary Flood Storage					
		Cropland Conversion Upstream of ND Highway 18	Cropland Conversion Upstream of Lake Ardoch	Along Forest River	Along Forest River, Ardoch Coulee, and the floodplain	Retention Upstream of Matejcek	Retention Upstream of Fordville	Retention Upstream of ND Highway 18	Wetland Restoration - NWI	Wetland Restoration - Hydric Soils Rating ≥ 50	Wetland Restoration - Hydric Soils Rating=100
Recurrence Interval and Location	*Peak Flow - 10 Year, cfs (% Change)*										
10-yr at Forest River at ND Highway 32	421 -	248 (-41.1%)	248 (-41.1%)	421 (0.0%)	421 (0.0%)	407 (-3.3%)	117 (-72.2%)	117 (-72.2%)	413 (-1.9%)	313 (-25.7%)	421 (0.0%)
10-yr at Forest River at 134th Avenue NE	2,762 -	1,274 (-53.9%)	1,274 (-53.9%)	2,763 (0.0%)	2,763 (0.0%)	2,711 (-1.8%)	342 (-87.6%)	132 (-95.2%)	2,724 (-1.4%)	2,128 (-23.0%)	2,762 (0.0%)
10-yr at Forest River at ND Highway 18	2,841 -	1,333 (-53.1%)	1,333 (-53.1%)	2,843 (0.1%)	2,843 (0.1%)	2,793 (-1.7%)	495 (-82.6%)	130 (-95.4%)	2,804 (-1.3%)	2,202 (-22.5%)	2,841 (0.0%)
10-yr at Forest River at Walsh County Road 6	1,316 -	908 (-31.0%)	844 (-35.9%)	1,320 (0.3%)	1,436 (9.1%)	1,262 (-4.1%)	509 (-61.3%)	280 (-78.7%)	1,263 (-4.0%)	1,137 (-13.6%)	1,316 (0.0%)
10-yr at Forest River at 1st Street Crossing	2,905 -	1,696 (-41.6%)	1,294 (-55.5%)	2,915 (0.3%)	2,863 (-1.4%)	2,845 (-2.1%)	1,498 (-48.4%)	1,362 (-53.1%)	2,865 (-1.4%)	2,159 (-25.7%)	2,882 (-0.8%)
10-yr at Forest River at Walsh County Road 4	4,173 -	3,659 (-12.3%)	2,213 (-47.0%)	4,181 (0.2%)	4,283 (2.6%)	4,127 (-1.1%)	3,667 (-12.1%)	3,636 (-12.9%)	4,114 (-1.4%)	2,784 (-33.3%)	3,984 (-4.5%)
10-yr at Forest River North Breakout at 148th Avenue NE	1,835 -	1,008 (-45.1%)	676 (-63.2%)	1,849 (0.8%)	1,727 (-5.9%)	1,756 (-4.3%)	912 (-50.3%)	905 (-50.7%)	1,758 (-4.2%)	1,300 (-29.2%)	1,823 (-0.7%)
10-yr at Ardoch Coulee Breakout at US Highway 81	390 -	227 (-41.8%)	232 (-40.5%)	390 (0.0%)	482 (23.6%)	380 (-2.6%)	119 (-69.5%)	119 (-69.5%)	387 (-0.8%)	334 (-14.4%)	381 (-2.3%)
10-yr at Ardoch Coulee at US Highway 81	375 -	375 (0.0%)	187 (-50.1%)	375 (0.0%)	369 (-1.6%)	375 (0.0%)	375 (0.0%)	375 (0.0%)	374 (-0.3%)	289 (-22.9%)	364 (-2.9%)

Duration (Hours)	*Inundated Acres - 10 Year (% Change)* Existing Conditions: Cropland	Existing Conditions: Total	Cropland Conversion Upstream of ND Highway 18: Cropland	Total	Cropland Conversion Upstream of Lake Ardoch: Cropland	Total	Along Forest River: Cropland	Total	Along Forest River, Ardoch Coulee, and the floodplain: Cropland	Total	Retention Upstream of Matejcek: Cropland	Total	Retention Upstream of Fordville: Cropland	Total	Retention Upstream of ND Highway 18: Cropland	Total	Wetland Restoration - NWI: Cropland	Total	Wetland Restoration - Hydric Soils Rating ≥ 50: Cropland	Total	Wetland Restoration - Hydric Soils Rating=100: Cropland	Total
0-24	1,103 -	1,574 -	388 (-64.8%)	567 (-64.0%)	415 (-62.4%)	597 (-62.1%)	1,101 (-0.2%)	1,570 (-0.2%)	1,164 (5.5%)	1,641 (4.3%)	1,185 (7.4%)	1,705 (8.3%)	240 (-78.2%)	345 (-78.1%)	214 (-80.6%)	308 (-80.4%)	1,085 (-1.6%)	1,551 (-1.4%)	921 (-16.5%)	1,295 (-17.7%)	1,091 (-1.1%)	1,566 (-0.5%)
24-48	1,006 -	1,354 -	577 (-42.6%)	782 (-42.3%)	555 (-44.8%)	761 (-43.8%)	1,010 (0.4%)	1,359 (0.4%)	1,031 (2.6%)	1,379 (1.9%)	1,049 (4.4%)	1,436 (6.1%)	446 (-55.7%)	597 (-55.9%)	394 (-60.8%)	524 (-61.3%)	997 (-0.9%)	1,345 (-0.7%)	925 (-8.1%)	1,270 (-6.2%)	1,031 (2.5%)	1,389 (2.6%)
48-72	854 -	1,171 -	762 (-10.8%)	994 (-15.1%)	552 (-35.3%)	746 (-36.3%)	862 (0.9%)	1,180 (0.8%)	918 (7.5%)	1,240 (5.9%)	1,034 (21.0%)	1,403 (19.8%)	518 (-39.4%)	702 (-40.1%)	473 (-44.7%)	653 (-44.3%)	849 (-0.6%)	1,163 (-0.7%)	864 (1.2%)	1,175 (0.3%)	868 (1.6%)	1,188 (1.5%)
72-96	817 -	1,050 -	555 (-32.1%)	752 (-28.4%)	339 (-58.6%)	497 (-52.7%)	813 (-0.5%)	1,046 (-0.4%)	775 (-5.2%)	1,011 (-3.7%)	845 (3.3%)	1,094 (4.2%)	475 (-41.9%)	678 (-35.4%)	477 (-41.6%)	683 (-35.0%)	817 (-0.1%)	1,049 (-0.1%)	639 (-21.8%)	847 (-19.4%)	776 (-5.0%)	1,006 (-4.2%)
96-120	588 -	785 -	566 (-3.9%)	802 (2.2%)	396 (-32.8%)	595 (-24.2%)	590 (0.3%)	787 (0.2%)	551 (-6.3%)	747 (-4.8%)	612 (3.9%)	852 (8.5%)	364 (-38.1%)	551 (-29.8%)	349 (-40.7%)	557 (-29.0%)	577 (-1.9%)	773 (-1.5%)	466 (-20.8%)	686 (-12.6%)	591 (0.5%)	789 (0.5%)
>120	3,770 -	7,185 -	3,084 (-18.2%)	6,216 (-13.5%)	2,679 (-28.9%)	5,606 (-22.0%)	3,765 (-0.1%)	7,178 (-0.1%)	3,684 (-2.3%)	7,069 (-1.6%)	3,284 (-12.9%)	6,444 (-10.3%)	2,393 (-36.5%)	5,133 (-28.6%)	2,075 (-45.0%)	4,592 (-36.1%)	3,730 (-1.1%)	7,129 (-0.8%)	2,969 (-21.2%)	6,015 (-16.3%)	3,671 (-2.6%)	7,050 (-1.9%)
TOTAL	8,138 -	13,118 -	5,932 (-27.1%)	10,112 (-22.9%)	4,935 (-39.4%)	8,801 (-32.9%)	8,141 (0.0%)	13,120 (0.0%)	8,125 (-0.2%)	13,088 (-0.2%)	8,008 (-1.6%)	12,934 (-1.4%)	4,436 (-45.5%)	8,006 (-39.0%)	3,982 (-51.1%)	7,317 (-44.2%)	8,054 (-1.0%)	13,009 (-0.8%)	6,784 (-16.6%)	11,287 (-14.0%)	8,029 (-1.3%)	12,988 (-1.0%)

Recurrence Interval and Location	*Peak Flow - 100Year, cfs (% Change)* Existing Conditions	Cropland Conversion Upstream of ND Highway 18	Cropland Conversion Upstream of Lake Ardoch	Along Forest River	Along Forest River, Ardoch Coulee, and the floodplain	Retention Upstream of Matejcek	Retention Upstream of Fordville	Retention Upstream of ND Highway 18	Wetland Restoration - NWI	Wetland Restoration - Hydric Soils Rating ≥ 50	Wetland Restoration - Hydric Soils Rating=100
100-yr at Forest River at ND Highway 32	1,934 -	831 (-57.0%)	831 (-57.0%)	1,933 (-0.1%)	1,933 (-0.1%)	1,181 (-38.9%)	117 (-94.0%)	117 (-94.0%)	1,791 (-7.4%)	1,007 (-47.9%)	1,934 (0.0%)
100-yr at Forest River at 134th Avenue NE	8,541 -	5,176 (-39.4%)	5,177 (-39.4%)	8,647 (1.2%)	8,616 (0.9%)	8,459 (-1.0%)	811 (-90.5%)	132 (-98.5%)	8,446 (-1.1%)	7,184 (-15.9%)	8,542 (0.0%)
100-yr at Forest River at ND Highway 18	8,677 -	5,292 (-39.0%)	5,295 (-39.0%)	8,821 (1.7%)	8,780 (1.2%)	8,601 (-0.9%)	1,252 (-85.6%)	130 (-98.5%)	8,594 (-1.0%)	7,344 (-15.4%)	8,677 (0.0%)
100-yr at Forest River at Walsh County Road 6	2,090 -	1,482 (-29.1%)	1,508 (-27.8%)	2,106 (0.8%)	2,255 (7.9%)	2,031 (-2.8%)	920 (-56.0%)	517 (-75.3%)	2,031 (-2.8%)	1,840 (-12.0%)	2,085 (-0.2%)
100-yr at Forest River at 1st Street Crossing	7,453 -	5,857 (-21.4%)	5,268 (-29.3%)	7,615 (2.2%)	7,315 (-1.9%)	7,412 (-0.6%)	3,857 (-48.2%)	3,833 (-48.6%)	7,421 (-0.4%)	6,544 (-12.2%)	7,604 (2.0%)
100-yr at Forest River at Walsh County Road 4	11,541 -	10,343 (-10.4%)	7,807 (-32.4%)	11,682 (1.2%)	11,642 (0.9%)	11,509 (-0.3%)	10,358 (-10.3%)	10,318 (-10.6%)	11,465 (-0.7%)	9,102 (-21.1%)	11,327 (-1.9%)
100-yr at Forest River North Breakout at 148th Avenue NE	5,146 -	4,184 (-18.7%)	3,637 (-29.3%)	5,167 (0.4%)	5,125 (-0.4%)	5,122 (-0.5%)	2,651 (-48.5%)	2,633 (-48.8%)	5,108 (-0.7%)	4,518 (-12.2%)	5,132 (-0.3%)
100-yr at Ardoch Coulee Breakout at US Highway 81	604 -	492 (-18.5%)	474 (-21.5%)	603 (-0.2%)	761 (26.0%)	595 (-1.5%)	290 (-52.0%)	289 (-52.2%)	602 (-0.3%)	541 (-10.4%)	597 (-1.2%)
100-yr at Ardoch Coulee at US Highway 81	967 -	968 (0.1%)	695 (-28.1%)	966 (-0.1%)	959 (-0.8%)	967 (0.0%)	967 (0.0%)	967 (0.0%)	967 (0.0%)	821 (-15.1%)	939 (-2.9%)

2.2 PRACTICAL CONSIDERATIONS

The practicality of each strategy was also assessed to determine if there is a reasonable ability for the local sponsor to successfully finance, implement, and maintain the project.

2.2.1 LOCAL FINANCING AND ACCEPTANCE

The WCWRD has the authority to operate under certain provisions of North Dakota Century Code (NDCC) Chapter 61, which allows for project-specific taxing authority through the formulation of an assessment district to finance project installation, operation and maintenance, and rehabilitation. Under NDCC Chapter 61, establishment of an assessment district requires that a vote be conducted, with votes cast based on the monetary value of benefits/damages received from the proposed project. In order to ensure successful financing of all (or any required match for state and/or federal funding), alternatives need to have local support and acceptance to establish the required local taxing authority.

2.2.2 ENVIRONMENTAL CONCERNS

The ability to successfully address regulatory concerns was considered during the strategy evaluation. While the planning effort will be used to identify potential impacts and work to minimize impacts, if certain strategies were likely to lead to significant environmental issues, they were eliminated from further consideration.

2.2.3 ABILITY TO IMPLEMENT

The ability of strategies to be implemented in a reasonable timeframe was considered to ensure that outcomes from the planning effort can efficiently be implemented after permitting is completed and financing is in place. The primary considerations were the SLO's ability to secure land rights, assurances of participation for any required voluntary programs, and potential issues with current local/state laws and zoning ordinances.

2.3 OUTCOMES

Table 4 provides a list of strategies within each category and rationale for strategies included/excluded from further review.

Table 4: Strategy Review

Category	Strategy	Determination	Rationale
No-Action	No-Action	Carry Forward	• Required; based on public comment and the SLO's desire to pursue solutions for flood damages, this alternative is not locally preferred. • Several dams in the upper Forest River Watershed have met or exceeded their expected design life.

Category	Strategy	Determination	Rationale
Reduce Runoff Volume	Cropland Better Management Practices	Eliminate	• Alternative considered undesirable for local landowners. • While not practical as an individual alternative, this concept can be a component of other alternative enhancements.
	Conversion to Grassland	Eliminate	• Converting prime farmland to grassland is considered undesirable for local landowners.
	Conversion to Forest	Eliminate	• Converting prime farmland to forest is considered undesirable for local landowners. • Implementation of conversion to Forest would take considerable amount of time, and the alternative would not be effective for several years.
	Aquifer Storage	Eliminate	• Fordville Aquifer does not show evidence of being depleted based on USGS groundwater data (USGS, 2019) • Site Number 481841097490301 156-056-22DDD was used to assess the current groundwater levels at the Fordville Aquifer. • Based on current groundwater levels, the amount of available storage in the aquifer is likely limited. • The ability of the SLO to successfully implement in a reasonable timeframe is limited.
	Other Beneficial Uses of Stored Water	Eliminate	• Would provide minimal impact to the goals outlined by the Purpose and Need Statement. • While not likely practical as an individual alternative, this concept can be a component of other alternative enhancements.
Increase Conveyance Capacity	Channelization	Eliminate	• Channelization throughout the watershed would not be practical because shorter flow paths produce larger flow rates downstream of the planning watershed.
	Drainage	Eliminate	• Increased drainage off farm fields would cause increased peak flow and inundation in downstream areas.

Category	Strategy	Determination	Rationale
	Flood Water Diversion	Carry Forward	• A flood water diversion was previously proposed for the Forest River Watershed in prior planning efforts. The capacity available in Ardoch Coulee is favorable for this scenario. • Additional measures would be needed to mitigate any increased downstream flow rates.
	Increase Roadway Capacity	Eliminate	• Increasing conveyance capacity could be used in localized areas to reduce agricultural damages by removal of cropland floodplain; however, model results (Section 2.1.2) showed that increasing conveyance capacity would increase flow rates downstream of the planning watershed.
Increase Temporary Flood Storage	On-Channel Dam	Carry Forward	• A site near the Forest River Hutterite Colony was identified in early scoping. • No other on-channel impoundments were investigated due to a high likelihood of significant impacts to existing riparian areas. Impacts include likely loss of habitat, water quality concerns, and creation of aquatic life barriers. Other sites were considered in prior studies but eliminated due to these concerns.
	Reduced Bridge/Culvert Capacity	Eliminate	• ND Century Code provide Stream Crossing Standards that do not allow culvert sizes to be reduced.

Category	Strategy	Determination	Rationale
	Wetland Restoration/ Creation	Eliminate	• Wetland restoration in the upper watershed has been identified as a potential alternative based on comments from the interagency planning team. • The ability of the SLO to successfully implement in a reasonable timeframe and maintain sufficient locations is limited, given land rights are typically secured through a voluntary easement program. • Preliminary analysis using NWI wetlands and USGS Open File Report 2007-1159 (2007) indicated minimal reductions to peak flood flows and inundation in problem areas (see **Table 3**). • Preliminary hydric soil data and Table 5-2 from the ND Hydrology Manual (USDA, SCS) indicated flow reduction potential for damage areas and at the outlet downstream of Lake Ardoch; however, it is not considered practical for the SLO to successfully implement sufficient acres to attain the objectives in the Purpose and Need Statement. • While not practical as an individual alternative, wetland restoration/creation can be a component of other alternative enhancements.
	Setback Levees	Carry Forward	• Levees would be used to contain breakout flows and provide floodplain storage along the Forest River. • Measures may be needed to mitigate flow rate increases because of elimination of breakout flows.
	Meter Runoff	Eliminate	• The ability of the SLO to successfully implement in a reasonable timeframe is limited. • Concept was adopted to reduce flooding along the Red River but would cause an increase to agricultural damages within the Forest River Watershed.
	Off-Channel Impoundment	Carry Forward	• Storage would be used to attenuate peak flow rates associated with flood damages. • Model results show that attenuated flood volume would reduce the peak discharge near the communities of Minto and Forest River, ND. • Model results also show that flood water storage would be most effective if storage sites were located in the North Branch Forest River Watershed or in the Forest River Watershed below North Dakota State Highway 18.

Category	Strategy	Determination	Rationale
	River Corridor Restoration/ Protection	Eliminate	• Need for restoration not apparent in upper portion of the watershed. • Increased access to floodplain in the lower portion of the watershed may reduce peak flows where agricultural flood damages are primarily occurring. • SLO has indicated that the ability to implement in a timely manner is not practical. • Lack of local acceptance would have a high probability of an inability to general and local funding requirement as discussed in Section 2.2.
Protection/ Avoidance	Levees	Eliminate	• Levees for the community of Forest River would not meet all objectives outlined in the Purpose and Need Statement but could be included when combined with other alternatives. • Levees for the community of Minto are not practical due to proximity of structures and building sites to the Forest River. • Ring levees around farmsteads were not considered for an individual alternative because they would not adequately address the objectives in the Purpose and Need Statement.
	Flood Warning System	Eliminate	• Not practical for the Forest River. During the 10-year event, there is an approximate 3-day lag between the peak rainfall intensity and the peak inflow to Minto, ND. This is not sufficient time to implement temporary measures to meet objectives defined in the Purpose and Need Statement.
	Floodplain Easements	Eliminate	• Floodplain easements would be required on the areas with inundation longer than 24-hours for the 10-year, 4-day event to meet the objectives defined in the Purpose and Need Statement. • Ability of the SLO to implement in a timely manner is limited.

From the initial strategy evaluation, the following strategies were selected to move forward with preliminary alternative identification:

- No-Action
- Flood Water Diversion (Increase conveyance capacity)
- On-Channel Impoundment (Increase temporary flood storage)
- Off-Channel Impoundment (Increase temporary flood storage)
- Set-back Levees (Increase temporary flood storage)

3 PRELIMINARY ALTERNATIVES

The strategies identified in Section 2 were used to preliminarily identify a range of alternatives. These alternatives were then analyzed to determine their potential to attain the objectives from the Purpose and Need Statement. The following provides a brief description of each alternative considered.

3.1 ALTERNATIVE IDENTIFICATION AND ANALYSIS

Alternatives were identified through resource assessment of the watershed. Information primarily utilized for this phase of alternative investigation consisted of the existing conditions hydrologic and hydraulic model, available topographic field survey data, LiDAR topographic data, and other readily available geospatial information. The following sections provide a brief description of each alternative that was preliminarily analyzed. A watershed map illustrating the location(s) of alternative components is available in **Figure 3.1**.

3.1.1 ALTERNATIVE 1 – NO-ACTION

The No-Action alternative is required to be considered based on the NRCS *National Watershed Program Manual* (2015). There are eight existing flood control dams within the Forest River Watershed, which were constructed between 1962 and 1978. As of 2020, six of the eight dams have exceeded their original design life of 50 years. Future efforts would likely maintain some or all eight of the dams. The existing dams currently control runoff from 207 square miles (23% of the total area) in the Forest River Watershed. The existing dams and drainage areas controlled by the existing dams are shown on **Figure 3.1.1**. The No-Action alternative was simulated by removing all eight of the dams in the Forest River Watershed. Results for the No-Action condition would likely be between the existing condition and the simulated condition with all dams decommissioned.

The hydrologic and hydraulic models for the Forest River were used to estimate the increases in peak flow rates due to the decommissioning of the dams. **Table 5** details the peak flow and cropland inundation values with all eight dams in the Forest River Watershed decommissioned. **Table 6** shows the changes to cropland inundation in the Lower Forest River Watershed (necessary for Indicator 1). Hydrographs showing preliminary modeling results are available in **Appendix B.2**.

3.1.2 ALTERNATIVE 2 – SETBACK LEVEES

The setback levee alignments used for this analysis are displayed on **Figure 3.1.2**. The purpose of the proposed setback levees is to allow more flood water volume to travel within the river corridor and not allow breakout flows to leave the river corridor for up to a 4-day, 10-year rainfall event. Flows larger than the 4-day, 10-year rainfall event would overtop the levees at appropriate locations and travel overland. The routes of levee alignments were chosen to balance the amount of additional floodplain necessary to allow a 4-day, 10-year rainfall event to pass through the river corridor while minimizing the amount of agricultural land that would need to be included within the river corridor. Peak discharge and cropland inundation are detailed in **Table 5** for all reporting locations. Reduction to cropland inundation in the Lower Forest River Watershed is shown in **Table 6**. Hydrographs at various reporting locations are available in **Appendix B.2**.

3.1.3 ALTERNATIVE 3 – SITE FR1-M

Forest River Impoundment Site FR1-M is a proposed on-channel dam located on the mainstem of the Forest River approximately 2 miles south and 4 miles east of Fordville, ND. The proposed embankment is located approximately 2 miles downstream of the confluence of the Middle Branch Forest River and the South Branch Forest River. The embankment is in the Northeast ¼ of Section 4, Inkster Township, Grand Forks County, and has a contributing watershed of 359.5 square miles. The dam would be constructed as an earthen embankment with an outlet structure that would attenuate flood flows greater than a 4-day, 2-year rainfall event. The structure causes less than 1 foot of head increase for the 4-day, 2-year rainfall event when compared with existing conditions. The attenuated flows would inundate riparian and vegetated floodplain habitat upstream of the embankment. Peak discharge and cropland inundation are detailed in **Table 5** for all reporting locations. Reduction to cropland inundation in the Lower Forest River Watershed is shown in **Table 6**. Hydrographs at various reporting locations are available in **Appendix B.3**. A location map of Site FR1-M is provided in **Figure 3.1.3**.

3.1.4 ALTERNATIVE 4 – SITE FR2-NB

Forest River Impoundment Site FR2-NB is an off-channel impoundment site located in the North Branch Forest River Watershed approximately 2 miles south and 3 miles east of Lankin, ND. The proposed impoundment site consists of a constructed earthen embankment in Section 5, Medford Township, and Section 32, Vernon Township, Walsh County. The embankment would utilize an existing ridge on the east side of the impoundment in order to reduce embankment heights. The embankment would be constructed across an existing tributary to the North Branch Forest River and have a total drainage area of 36.5 square miles. The site is located downstream of Kratochvil Dam and Soukup Dam. Peak discharge and cropland inundation are detailed in **Table 5** for all reporting locations. Reduction to cropland inundation in the Lower Forest River Watershed is shown in **Table 6**. Hydrographs at various reporting locations are available in **Appendix B.3**. A location map of Site FR2-NB is provided in **Figure 3.1.4**.

3.1.5 ALTERNATIVE 5 – ARDOCH COULEE BYPASS

To analyze a floodwater diversion in the Forest River Watershed, a channel routing flows from the Forest River mainstem to Ardoch Coulee and ultimately to Lake Ardoch was simulated using the hydraulic model. The purpose of this channel bypass is to mitigate flooding impacts to farmland adjacent to the Forest River and in the communities of Forest River and Minto, ND. The channel that diverts the floodwater will be referred to herein as the Ardoch Coulee Bypass. The Ardoch Coulee Bypass would divert flows south out of the Forest River in Section 1 of Strabane Township, Grand Forks County, and then east along the north side of 35th Ave NE for approximately 2.5 miles, where it would outlet into an existing swale that flows into Ardoch Coulee near the half section line of Section 4 of Johnstown Township, Grand Forks County. The total drainage area upstream of the inlet to the Ardoch Coulee Bypass is 378 square miles. The Ardoch Coulee Bypass is shown on **Figure 3.1.5**.

A structure across the Forest River near the bypass inlet would be constructed to divert flows out of the Forest River into the bypass channel. Additionally, a structure at the inlet of the Ardoch Coulee Bypass would be implemented to control the amount of flow diverted for the larger runoff events. The bypass channel would remain dry during periods of low flow. Five crossings will be constructed along the bypass channel at a private driveway, 32nd St NE, 31st St NE, Grand Forks County Road 2, and a Northern Plains Railroad line.

Peak flood flow rates at Walsh County Road 6 and at the 1st Street crossing in Minto, ND, were reduced by approximately 22% for the 4-day, 10-year event with the bypass in place. Additionally, the amount of total cropland inundation for the 4-day, 10-year event was reduced by approximately 11%. However, the peak flood flow rates at Walsh County Road 4, downstream of Lake Ardoch, increased by 4% during the 10-year event and 3% during the 100-year event with the Ardoch Coulee Bypass in place. This is an indication that the Ardoch Coulee Bypass would need to be implemented in combination with another alternative to mitigate any downstream impacts. The peak discharge and cropland inundation for Ardoch Coulee Bypass are detailed in **Table 5** for all reporting locations. Reduction to cropland inundation in the Lower Forest River Watershed is shown in **Table 6**. Hydrographs at various observation locations are available in **Appendix B.4**.

3.1.6 ALTERNATIVE 6 – SITE FR3-AR AND ARDOCH COULEE BYPASS

Forest River Impoundment Site FR3-AR is an off-channel impoundment site located in the Ardoch Coulee Watershed. The proposed site consists of a constructed earthen embankment located approximately 0.5 miles south of the Walsh/Grand Forks county line in Section 3 of Johnstown Township, Grand Forks County. The location of the embankment was chosen to maximize the amount of storage for a site on Ardoch Coulee. The structure would consist of a 4-foot diameter low-flow pipe that would allow local flow from the Ardoch Coulee Watershed to flow through the site without creating a permanent pool. A riser tower with a weir length of 80 feet would be implemented with the purpose of maximizing the storage in the site for a 4-day, 10-year rainfall event. The drainage area contributing directly to the site (from the Ardoch Coulee Watershed) is approximately 9.9 square miles.

To maximize the benefit of Site FR3-AR, the Ardoch Coulee Bypass described in Section 3.1.5 would be included for design of the storage site. If Site FR3-AR were to be used without the Ardoch Coulee Bypass, it would fail to meet peak flow reduction goals on the Forest River mainstem and would not provide benefit for cropland inundation caused by breakout flows from the Forest River. Therefore, having Site FR3-AR without the Ardoch Coulee Bypass would not sufficiently meet the goals outlined in the Purpose and Need Statement. The peak discharge and cropland inundation are detailed in **Table 5** for all reporting locations. Reduction to cropland inundation in the Lower Forest River Watershed is shown in **Table 6**. Hydrographs at various observation locations are available in **Appendix B.4**. A location map of Site FR3-AR is provided in **Figure 3.1.6**.

Table 5: Peak Flow and Inundation Changes for Identified Alternatives

Scenario	Existing Conditions	Alternative 1 No-Action	Alternative 2 Setback Levees	Alternative 3 Site FR1-M	Alternative 4 Site FR2-NB	Alternative 5 Ardoch Coulee Bypass	Alternative 6 Ardoch Coulee Bypass & Site FR3-AR
Recurrence Interval and Location	*Peak Flow - 10 Year, cfs (% Change)*						
10-yr at Forest River at ND Highway 32	421 -	789 (87.4%)	421 (0.0%)	421 (0.0%)	421 (0.0%)	421 (0.0%)	421 (0.0%)
10-yr at Forest River at 134th Avenue NE	2,762 -	3,742 (35.5%)	2,762 (0.0%)	2,762 (0.0%)	2,213 (-19.9%)	2,762 (0.0%)	2,762 (0.0%)
10-yr at Forest River at ND Highway 18	2,841 -	3,813 (34.2%)	2,840 (0.0%)	2,558 (-10.0%)	2,304 (-18.9%)	2,841 (0.0%)	2,841 (0.0%)
10-yr at Forest River at Walsh County Road 6	1,316 -	1,396 (6.1%)	2,775 (110.9%)	1,242 (-5.6%)	1,181 (-10.3%)	1,019 (-22.6%)	991 (-24.7%)
10-yr at Forest River at 1st Street Crossing	2,905 -	3,799 (30.8%)	2,540 (-12.6%)	2,858 (-1.6%)	2,536 (-12.7%)	2,274 (-21.7%)	2,309 (-20.5%)
10-yr at Forest River at Walsh County Road 4	4,173 -	4,829 (15.7%)	3,648 (-12.6%)	4,130 (-1.0%)	3,911 (-6.3%)	4,333 (3.8%)	3,930 (-5.8%)
10-yr at Forest River North Breakout at 148th Avenue NE	1,835 -	2,536 (38.2%)	905 (-50.7%)	1,684 (-8.2%)	1,539 (-16.1%)	1,415 (-22.9%)	1,441 (-21.5%)
10-yr at Ardoch Coulee Breakout at US Highway 81	390 -	409 (4.9%)	119 (-69.5%)	397 (1.8%)	359 (-7.9%)	331 (-15.1%)	335 (-14.1%)
10-yr at Ardoch Coulee at US Highway 81	375 -	375 (0.0%)	375 (0.0%)	375 (0.0%)	375 (0.0%)	990 (164.0%)	351 (-6.4%)

Duration (Hours)	Existing Conditions Cropland	Existing Conditions Total	Alt. 1 Cropland	Alt. 1 Total	Alt. 2 Cropland	Alt. 2 Total	Alt. 3 Cropland	Alt. 3 Total	Alt. 4 Cropland	Alt. 4 Total	Alt. 5 Cropland	Alt. 5 Total	Alt. 6 Cropland	Alt. 6 Total
	Inundated Acres - 10 Year (% Change)													
0-24	1,103 -	1,574 -	1,659 (50.4%)	2,306 (46.5%)	542 (-50.9%)	954 (-39.4%)	631 (-42.8%)	947 (-39.8%)	881 (-20.1%)	1,243 (-21.0%)	902 (-18.3%)	1,359 (-13.6%)	874 (-20.8%)	1,325 (-15.8%)
24-48	1,006 -	1,354 -	1,999 (98.9%)	2,690 (98.7%)	563 (-44.0%)	871 (-35.7%)	1,145 (13.9%)	1,570 (16.0%)	852 (-15.3%)	1,164 (-14.0%)	663 (-34.0%)	962 (-28.9%)	604 (-39.9%)	880 (-35.0%)
48-72	854 -	1,171 -	1,901 (122.6%)	2,576 (120.0%)	456 (-46.6%)	738 (-37.0%)	737 (-13.7%)	1,025 (-12.5%)	843 (-1.3%)	1,141 (-2.6%)	704 (-17.6%)	997 (-14.9%)	667 (-21.9%)	944 (-19.4%)
72-96	817 -	1,050 -	1,294 (58.3%)	1,747 (66.4%)	402 (-50.9%)	595 (-43.3%)	671 (-17.9%)	878 (-16.3%)	805 (-1.5%)	1,031 (-1.7%)	790 (-3.4%)	1,021 (-2.8%)	740 (-9.4%)	953 (-9.3%)
96-120	588 -	785 -	966 (64.2%)	1,303 (66.0%)	377 (-36.0%)	553 (-29.5%)	611 (3.8%)	805 (2.6%)	518 (-12.0%)	712 (-9.2%)	525 (-10.8%)	717 (-8.7%)	525 (-10.8%)	707 (-10.0%)
>120	3,770 -	7,185 -	3,637 (-3.5%)	6,866 (-4.4%)	3,517 (-6.7%)	6,977 (-2.9%)	4,263 (13.1%)	7,815 (8.8%)	3,514 (-6.8%)	6,832 (-4.9%)	3,628 (-3.8%)	7,002 (-2.5%)	3,794 (0.6%)	7,235 (0.7%)
TOTAL	8,138 -	13,118 -	11,457 (40.8%)	17,488 (33.3%)	5,856 (-28.1%)	10,688 (-18.5%)	8,059 (-1.0%)	13,040 (-0.6%)	7,412 (-8.9%)	12,124 (-7.6%)	7,212 (-11.4%)	12,058 (-8.1%)	7,204 (-11.5%)	12,043 (-8.2%)

Recurrence Interval and Location	Existing Conditions	Alternative 1 No-Action	Alternative 2 Setback Levees	Alternative 3 Site FR1-M	Alternative 4 Site FR2-NB	Alternative 5 Ardoch Coulee Bypass	Alternative 6 Ardoch Coulee Bypass & Site FR3-AR
	Peak Flow - 100 Year, cfs (% Change)						
100-yr at Forest River at ND Highway 32	1,934 -	5,525 (185.7%)	1,934 (0.0%)	1,934 (0.0%)	1,934 (0.0%)	1,934 (0.0%)	1,934 (0.0%)
100-yr at Forest River at 134th Avenue NE	8,541 -	15,499 (81.5%)	8,543 (0.0%)	8,541 (0.0%)	6,892 (-19.3%)	8,543 (0.0%)	8,552 (0.1%)
100-yr at Forest River at ND Highway 18	8,677 -	15,637 (80.2%)	8,662 (-0.2%)	4,302 (-50.4%)	7,135 (-17.8%)	8,677 (0.0%)	8,674 (0.0%)
100-yr at Forest River at Walsh County Road 6	2,090 -	3,637 (74.0%)	3,475 (66.3%)	1,441 (-31.1%)	1,818 (-13.0%)	1,696 (-18.9%)	1,708 (-18.3%)
100-yr at Forest River at 1st Street Crossing	7,453 -	12,407 (66.5%)	7,220 (-3.1%)	5,493 (-26.3%)	6,862 (-7.9%)	7,008 (-6.0%)	7,025 (-5.7%)
100-yr at Forest River at Walsh County Road 4	11,541 -	16,069 (39.2%)	10,583 (-8.3%)	10,362 (-10.2%)	10,918 (-5.4%)	11,850 (2.7%)	11,406 (-1.2%)
100-yr at Forest River North Breakout at 148th Avenue NE	5,146 -	6,295 (22.3%)	4,508 (-12.4%)	3,820 (-25.8%)	4,798 (-6.8%)	5,063 (-1.6%)	5,073 (-1.4%)
100-yr at Ardoch Coulee Breakout at US Highway 81	604 -	787 (30.3%)	492 (-18.5%)	513 (-15.1%)	555 (-8.1%)	561 (-7.1%)	560 (-7.3%)
100-yr at Ardoch Coulee at US Highway 81	967 -	984 (1.8%)	953 (-1.4%)	966 (-0.1%)	967 (0.0%)	1,393 (44.1%)	1,026 (6.1%)

Table 6: Lower Forest River Cropland Inundation Reduction

Durations (hours)	Existing Conditions	Alternative 1 No-Action	Alternative 2 Setback Levees	Alternative 3 Site FR1-M	Alternative 4 Site FR2-NB	Alternative 5 Ardoch Coulee Bypass	Alternative 6 Ardoch Coulee Bypass & Site FR3-AR
0-24	967	1,446	450	534	812	759	769
24-48	921	1,759	511	1,032	772	557	517
48-72	764	1,637	411	662	770	604	589
72-96	733	1,159	348	597	724	697	669
96-120	507	867	315	517	433	438	449
>120	2,119	1,933	1,831	2,594	1,886	1,996	2,141
0-96	3,385	6,001	1,720	2,825	3,078	2,617	2,544
% Change	-	(77.3%)	(-49.2%)	(-16.5%)	(-9.1%)	(-22.7%)	(-24.8%)

3.2 PRELIMINARY EVALUATION

The identified preliminary alternatives were evaluated using the hydrologic and hydraulic model in order to assess their potential to meet objectives from the Purpose and Need Statement. Potential benefits and disbenefits were determined for individual alternatives to develop an understanding of how the alternatives perform on an individual basis. Combinations of alternatives were not analyzed for this report but should be considered for future analysis. Available GIS data was also reviewed to estimate potential resource impacts.

Table 7 provides information on the ability of each alternative to meet objectives defined in the Purpose and Need Statement, identifies potential resource impacts, and provides the rationale to either carry forward or eliminate alternatives from further consideration. The determination to carry forward or eliminate alternatives was made by balancing the ability to address the Purpose and Need Statement with the potential for resource impacts. Alternatives evaluated in this report should be considered conceptual and are subject to revision as each of the selected alternatives are evaluated in detail.

Based on this review, the alternative that will be carried forward for a more detailed review is Alternative 6 – Ardoch Coulee Bypass and Site FR3-AR. This alternative provides the benefit associated with the Ardoch Coulee Bypass and does not have negative impacts downstream of Lake Ardoch. Storage sites located in the upper region of the watershed do not appear to have the ability to reduce flows significantly in the Lower Forest River Watershed. Based on this review, flood control directly adjacent to the damage location was required to provide adequate benefit. Alternative 6 meets all but one of the indicators described in Section 1.2. All other alternatives evaluated failed at least two of the indicators.

Table 7: Preliminary Alternative Evaluation Summary

Alternative	**INDICATOR 1: Reduce 10-year cropland inundation for flood durations equal to or less than four days by 20% within the Lower Forest River Watershed.** *(Percent Change)*	**INDICATOR 2a: Reduce the 10-year event peak flow rate by 20% at the Forest River Crossing with Walsh County Road 6 near Forest River, ND.** *(Percent Change in 10-year Peak Discharge)*	**INDICATOR 2b: Reduce the 10-year event peak flow rate by 20% at the Forest River Crossing with 1st Street in Minto, ND.** *(Percent Change in 10-year Peak Discharge)*	**INDICATOR 3a: Reduce the 100-year event peak flow rate by 16% at the Forest River Crossing with Walsh County Road 6 near Forest River, ND.** *(Percent Change in 100-year Peak Discharge)*	**INDICATOR 3b: Reduce the 100-year event peak flow rate by 8% at the Forest River Crossing with 1st Street in Minto, ND.** *(Percent Change in 100-year Peak Discharge)*	**INDICATOR 4: No increase in peak flow rate at the Forest River Crossing with Walsh County Road 4 downstream of Lake Ardoch.** *(Percent Change in 10- and 100-year Peak Discharge)*	Determination	Additional Comments
1. No Action	NO *(77.3%)*	NO *(6.1%)*	NO *(30.8%)*	NO *(74.0%)*	NO *(66.5%)*	NO *(39.2%)*	Eliminate	• Alternative does not meet any of the indicators from the Purpose and Need Statement. • Alternative is required under Public Law 83-566 Watershed Planning. • Alternative is not locally preferred.
2. Setback Levees	YES *(-49.2%)*	NO *(110.9%)*	NO *(-12.6%)*	NO *(66.3%)*	NO *(-3.1%)*	YES *(-8.3%)*	Eliminate	• Alternative does not meet indicators 2 and 3 from the Purpose and Need Statement. • Setback levees contain flows that would break out of the channel during high flow under existing conditions. • SLO has indicated that the ability to implement on the scale analyzed through the preliminary alternatives analysis is not practical.
3. Site FR1-M	NO *(-16.5%)*	NO *(-5.6%)*	NO *(-1.6%)*	YES *(-31.1%)*	YES *(-26.3%)*	YES *(-1.0%)*	Eliminate	• Alternative does not meet indicators 1 and 2 from the Purpose and Need Statement. • Alternative is less effective for higher recurrence flood events.
4. FR2-NB	NO *(-9.1%)*	NO *(-10.3%)*	NO *(-12.7%)*	NO *(-13.0%)*	NO *(-7.9%)*	YES *(-5.4%)*	Eliminate	• Alternative does not meet indicators 1 through 3 from the Purpose and Need Statement. • Though the North Branch Forest River is indicated as an area that has impacts in the lower watershed, flood storage on the scale analyzed indicates that retention in the North Branch Forest River Watershed is not a practical means to meet the objectives of the Purpose and Need Statement.
5. Ardoch Coulee Bypass	YES *(-22.7%)*	YES *(-22.6%)*	YES *(-21.7%)*	YES *(-18.9%)*	NO *(-6.0%)*	NO *(3.8%)*	Eliminate	• Alternative does not meet indicators 3b or 4 from the Purpose and Need Statement. • An increase in peak discharge downstream of Lake Ardoch is not permissible. • The Ardoch Coulee Bypass combined with storage might alleviate adverse impacts downstream.
6. Site FR3-AR and Ardoch Coulee Bypass	YES *(-24.8%)*	YES *(-24.7%)*	YES *(-20.5%)*	YES *(-18.3%)*	NO *(-5.7%)*	YES *(-1.2%)*	**Carry Forward**	• Alternative does not meet Indicator 3b from the Purpose and Need Statement. • Benefit provided during higher recurrence interval flood events is significant. • No adverse impacts downstream of Lake Ardoch.

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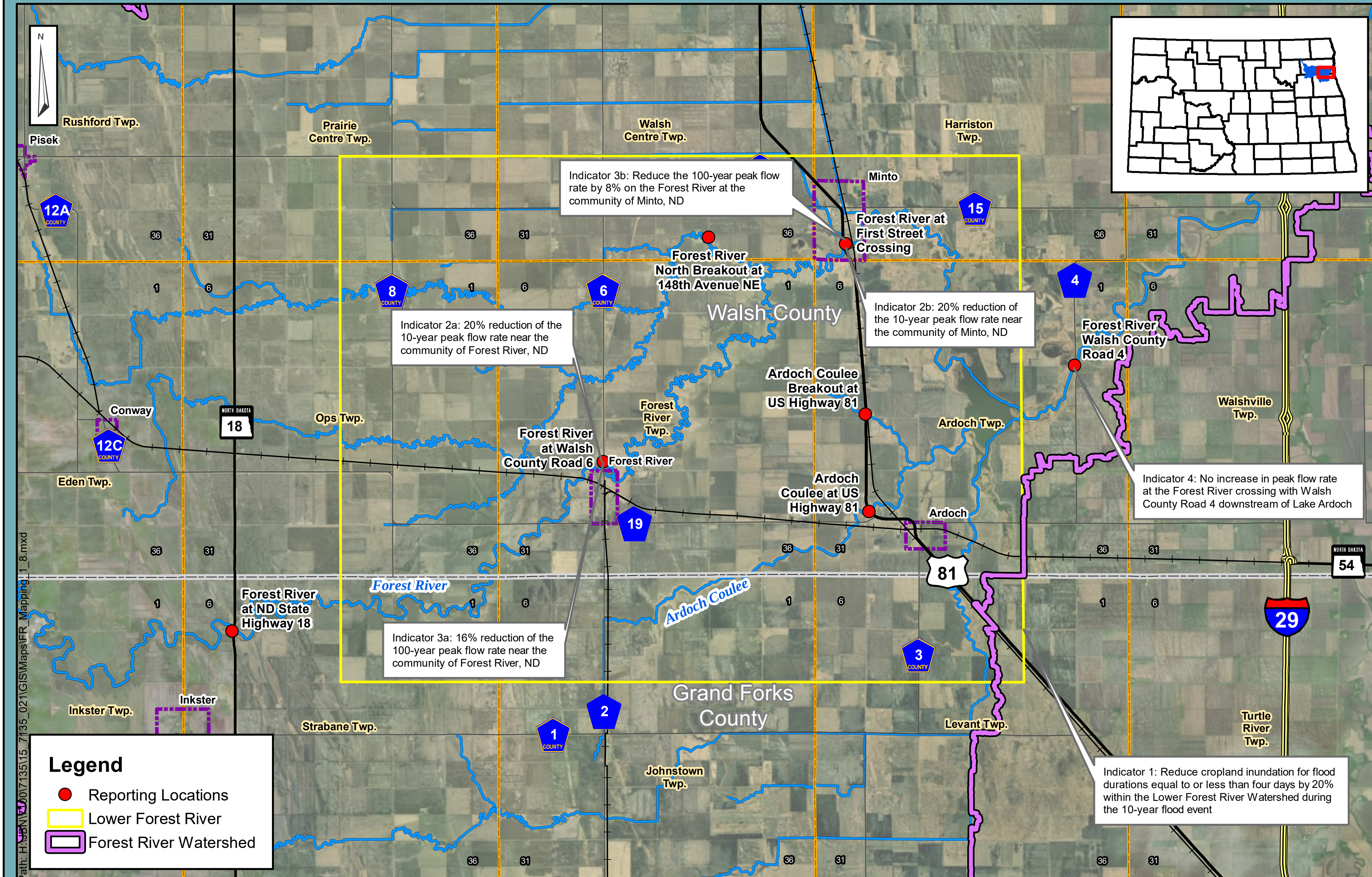
FIGURES



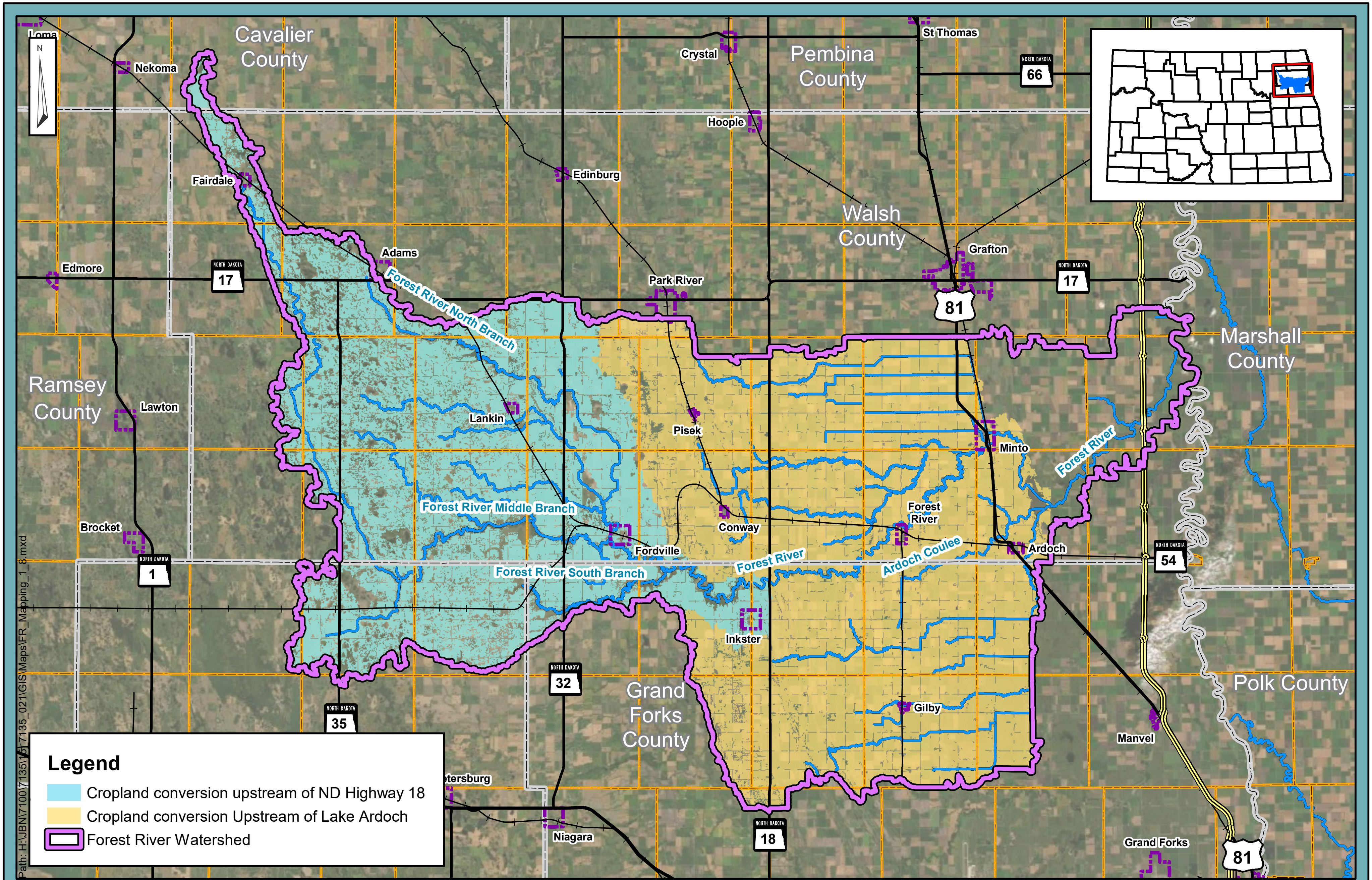
F-1

Figure 1: Project Indicator Locations

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.

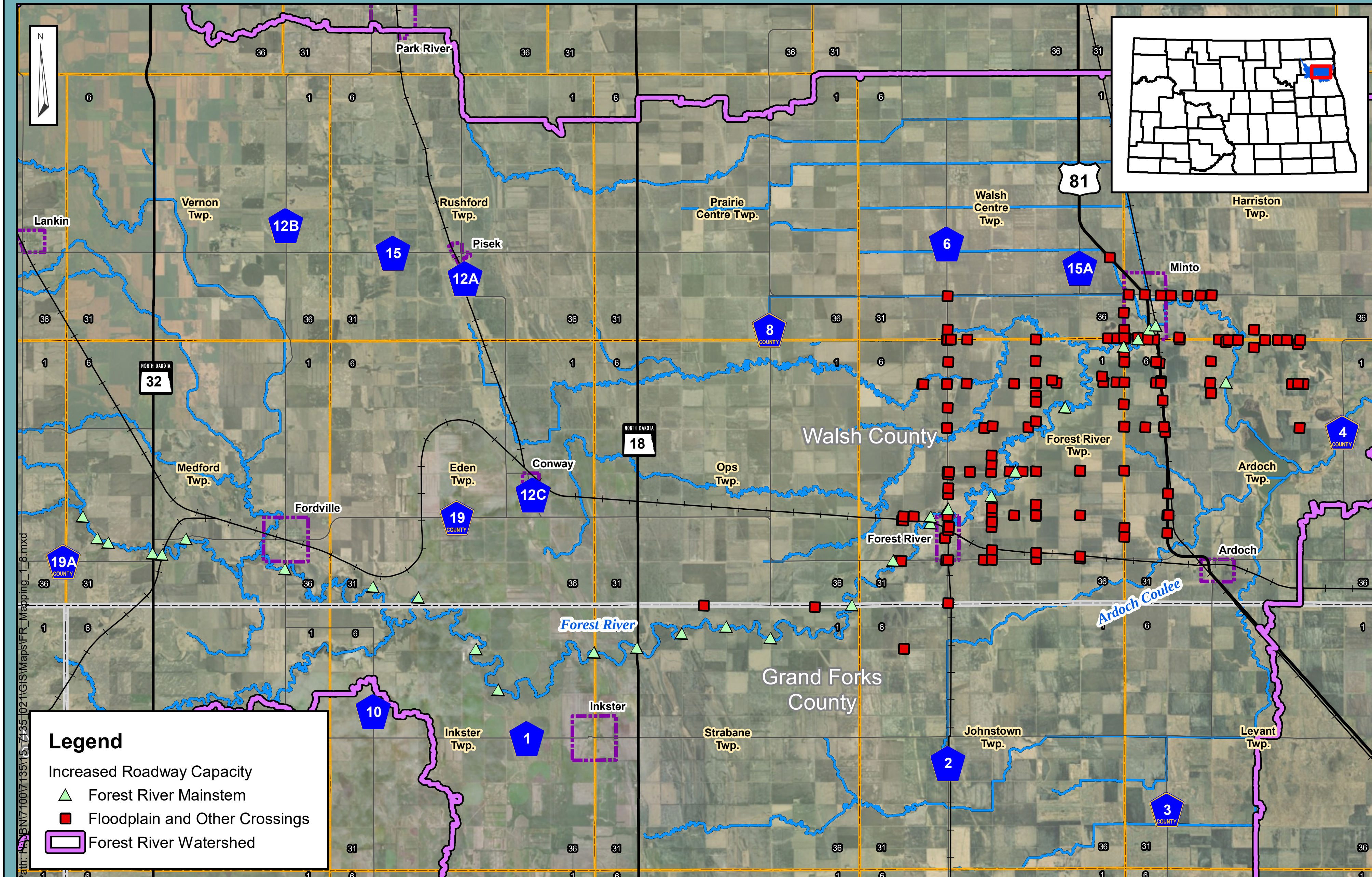


F-2.1.1

Figure 2.1.1: Reduced Runoff Volume

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

Houston Engineering Inc.



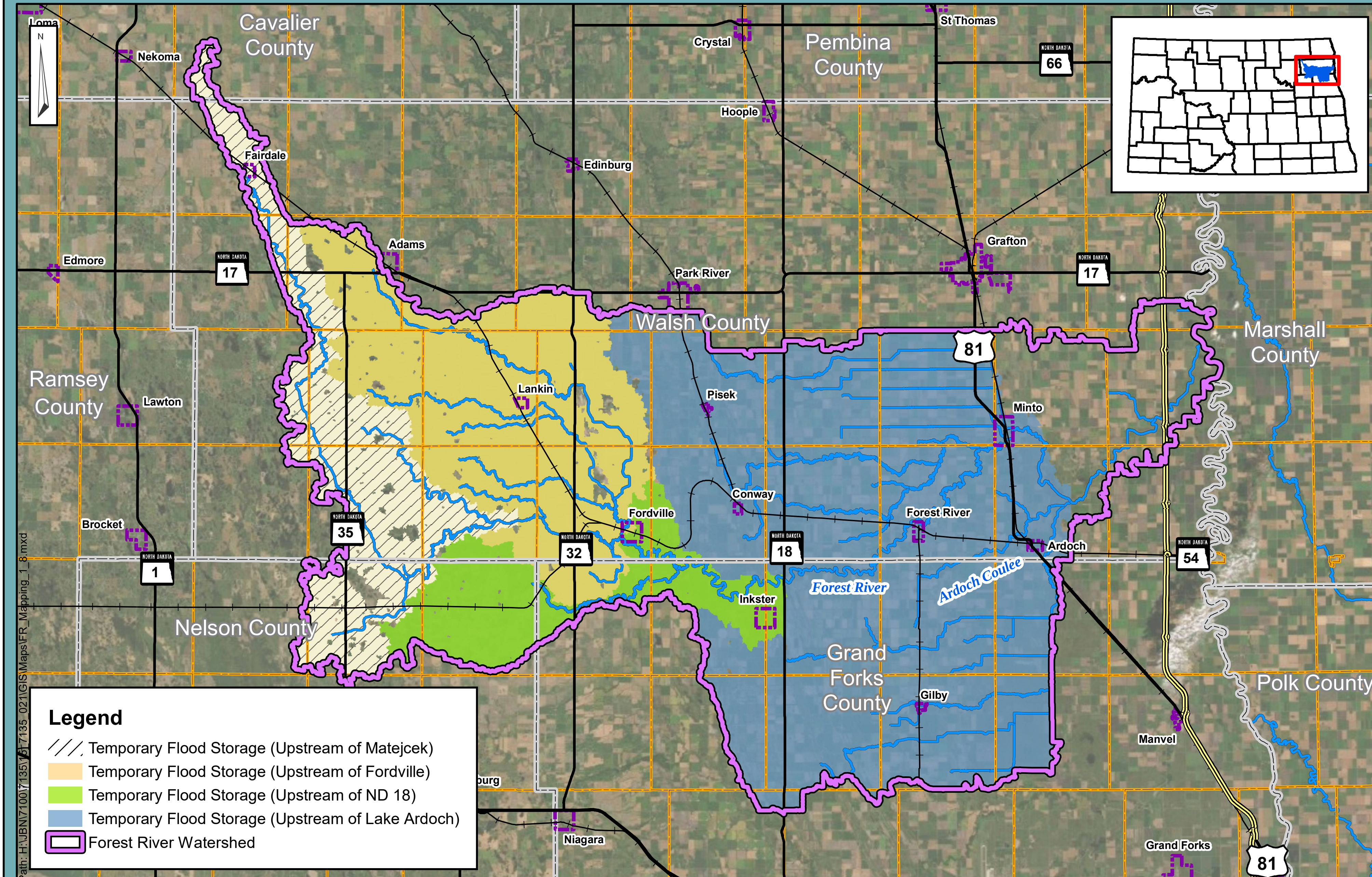
F-2.1.2

Figure 2.1.2: Increased Roadway Capacity

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 1.25 2.5 5 Miles

Houston Engineering Inc.



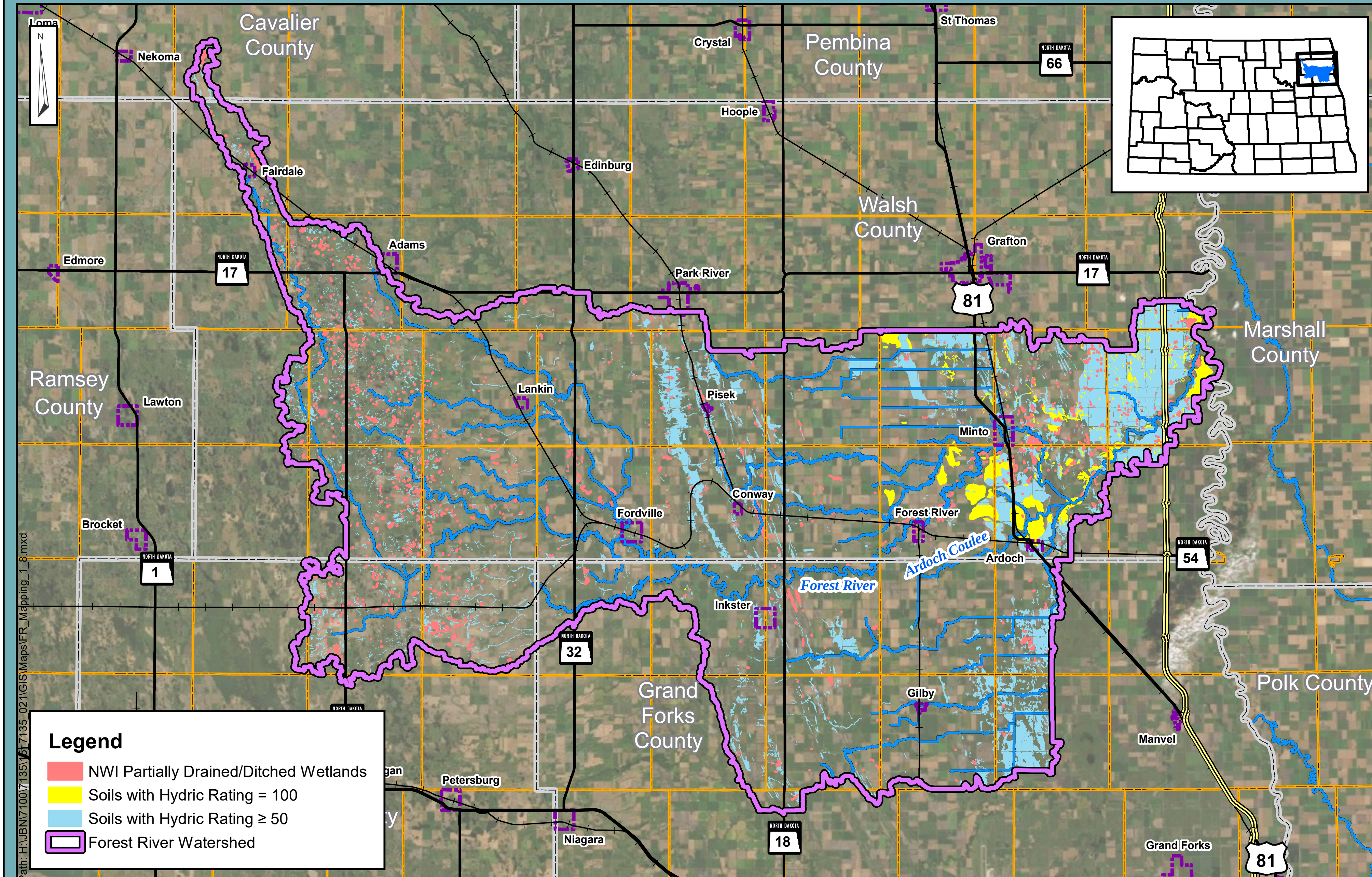
F-2.1.3a

Figure 2.1.3a: Increased Temporary Flood Storage

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 3 6 12 Miles

Houston Engineering Inc.



F-2.1.3b

Figure 2.1.3b: Wetland Restoration

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 3 6 12 Miles

Houston Engineering Inc.

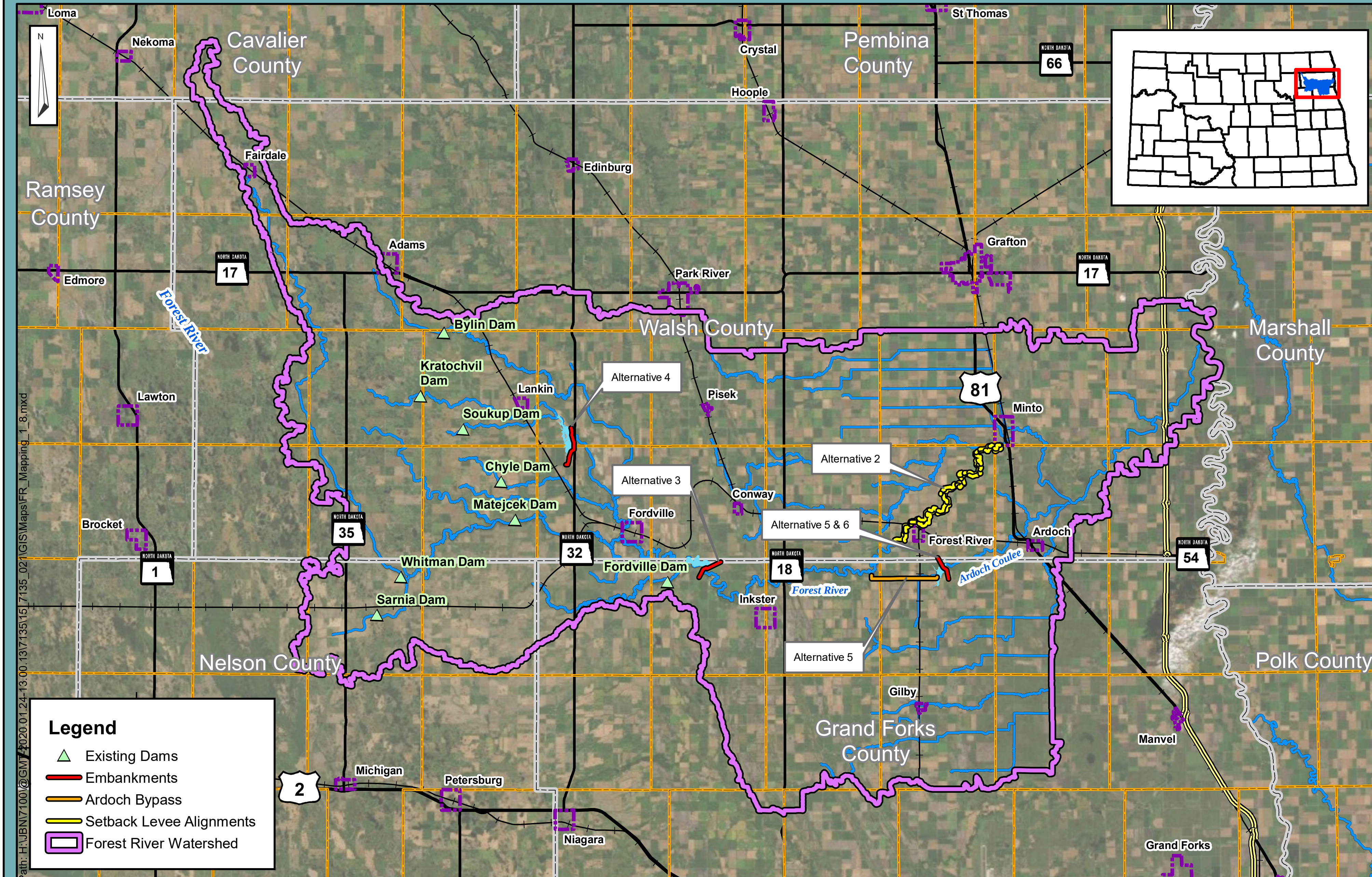
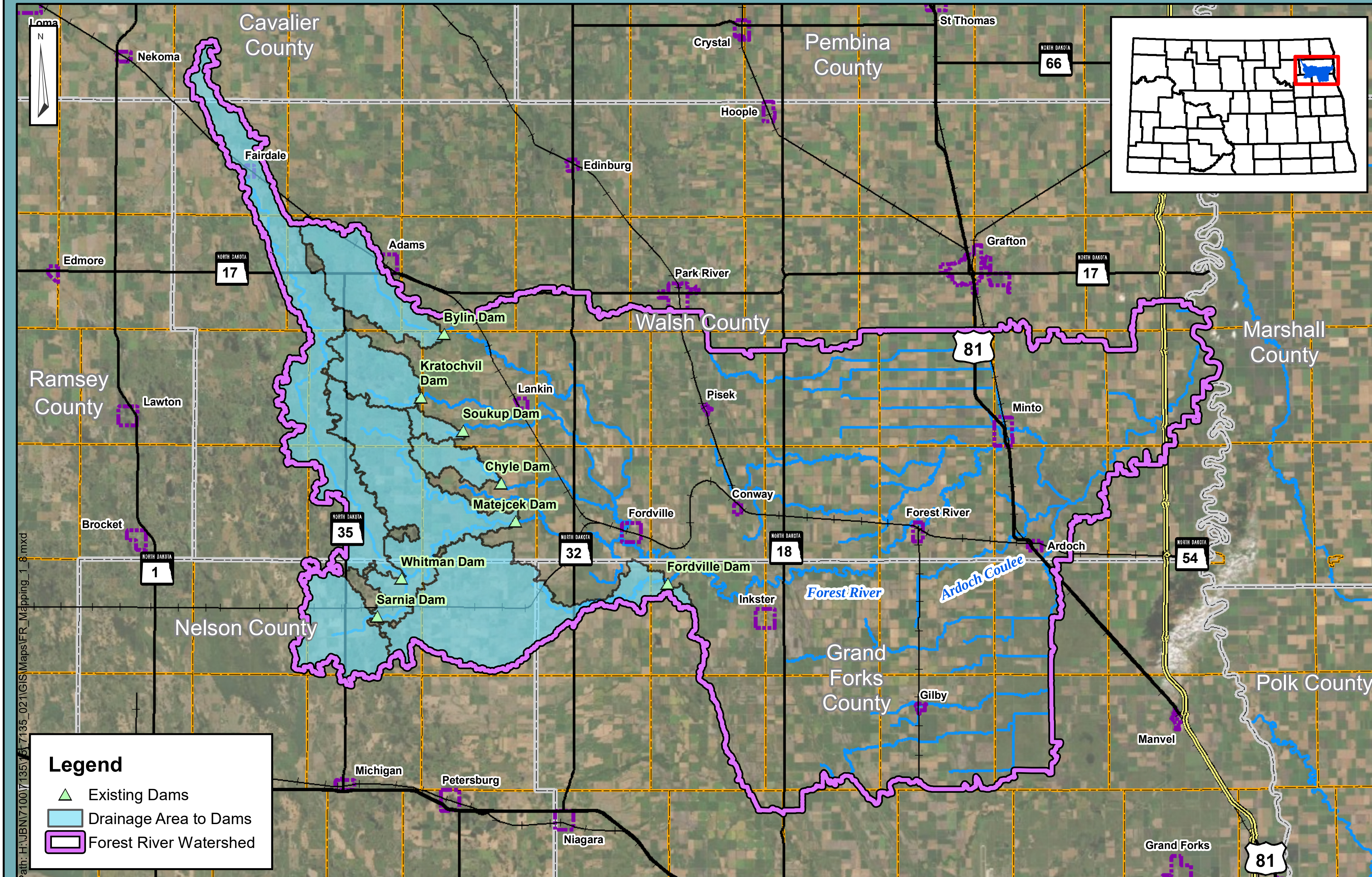


Figure 3.1: Forest River Identified Alternatives

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

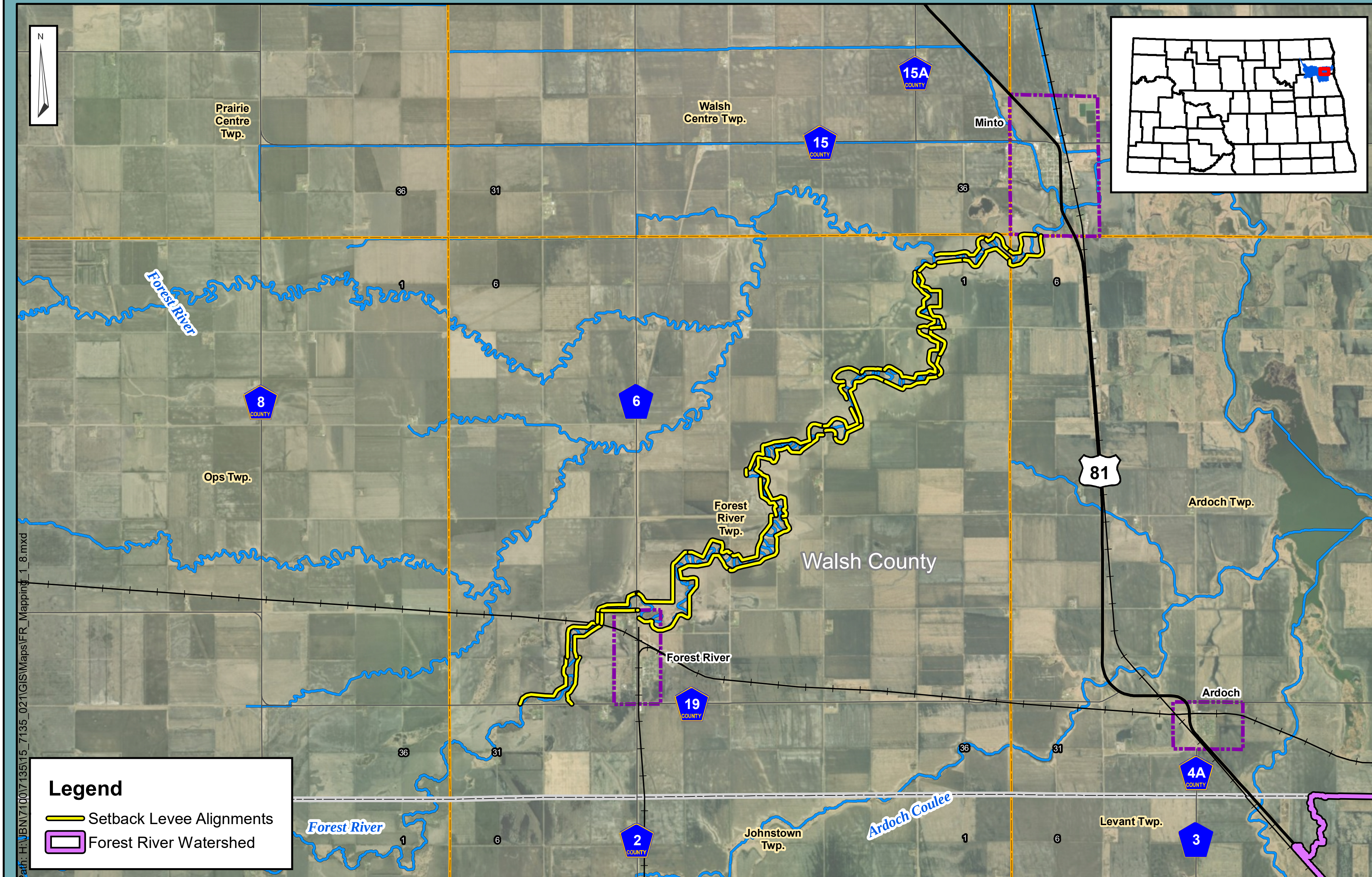


F-3.1.1

Figure 3.1.1: Alternative 1 - No Action

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

Houston Engineering Inc.



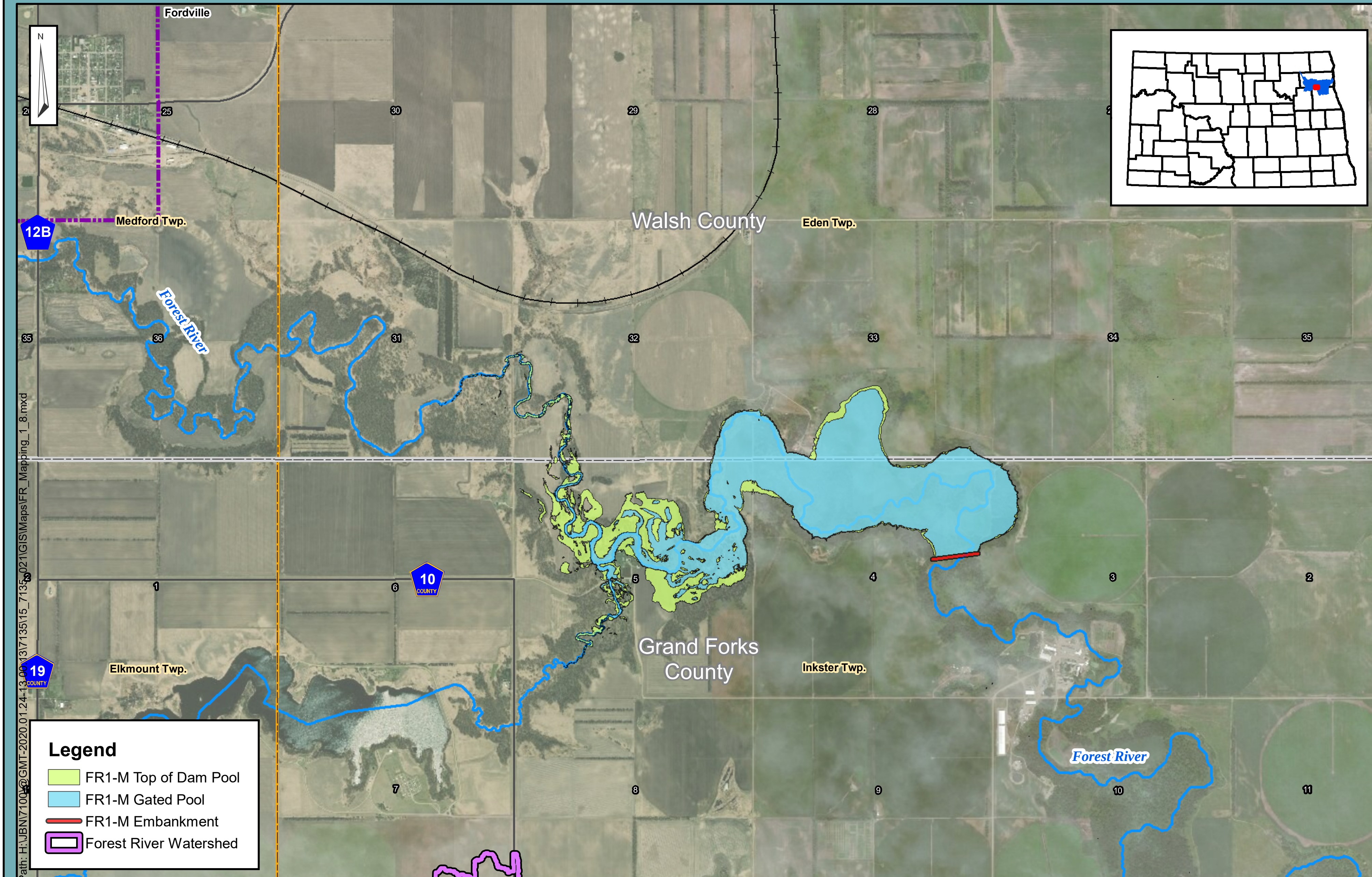
F-3.1.2

Figure 3.1.2: Alternative 2 - Setback Levees

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 0.5 1 2 Miles

Houston Engineering Inc.

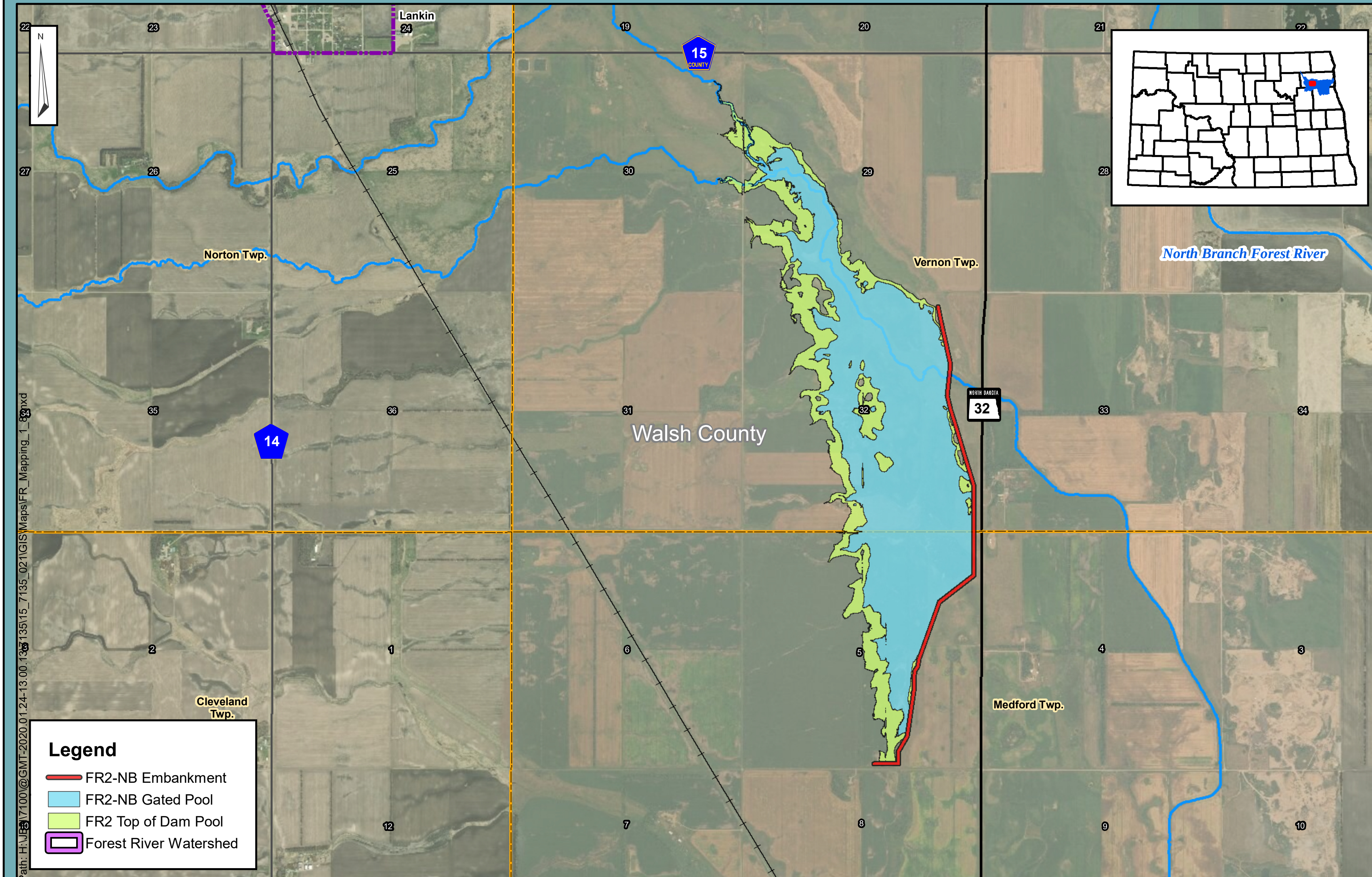


F-3.1.3

Figure 3.1.3: Alternative 3 - Site FR1-M

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

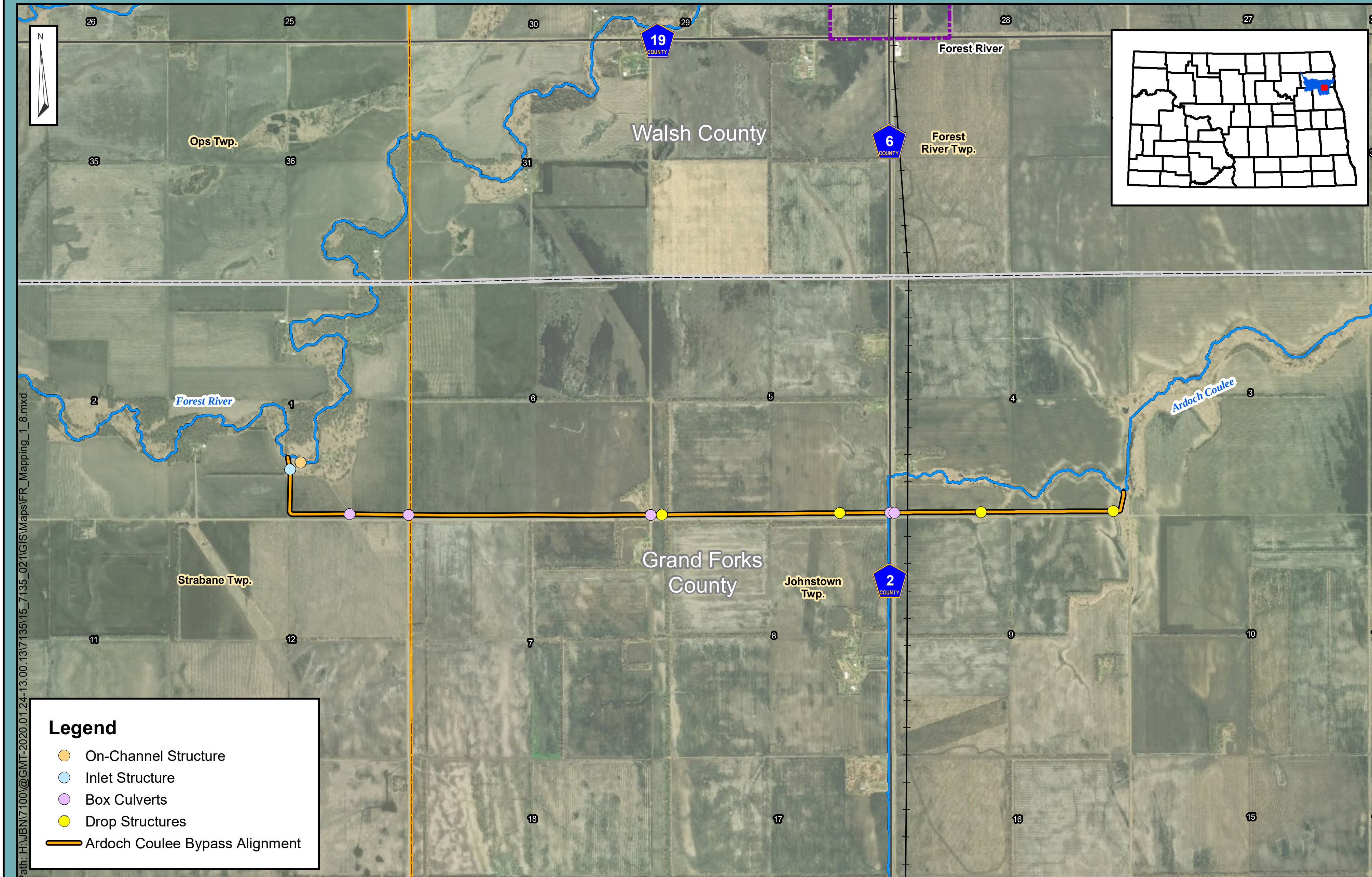
Houston Engineering Inc.



F-3.1.4

Figure 3.1.4: Alternative 4 - Site FR2-NB

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District



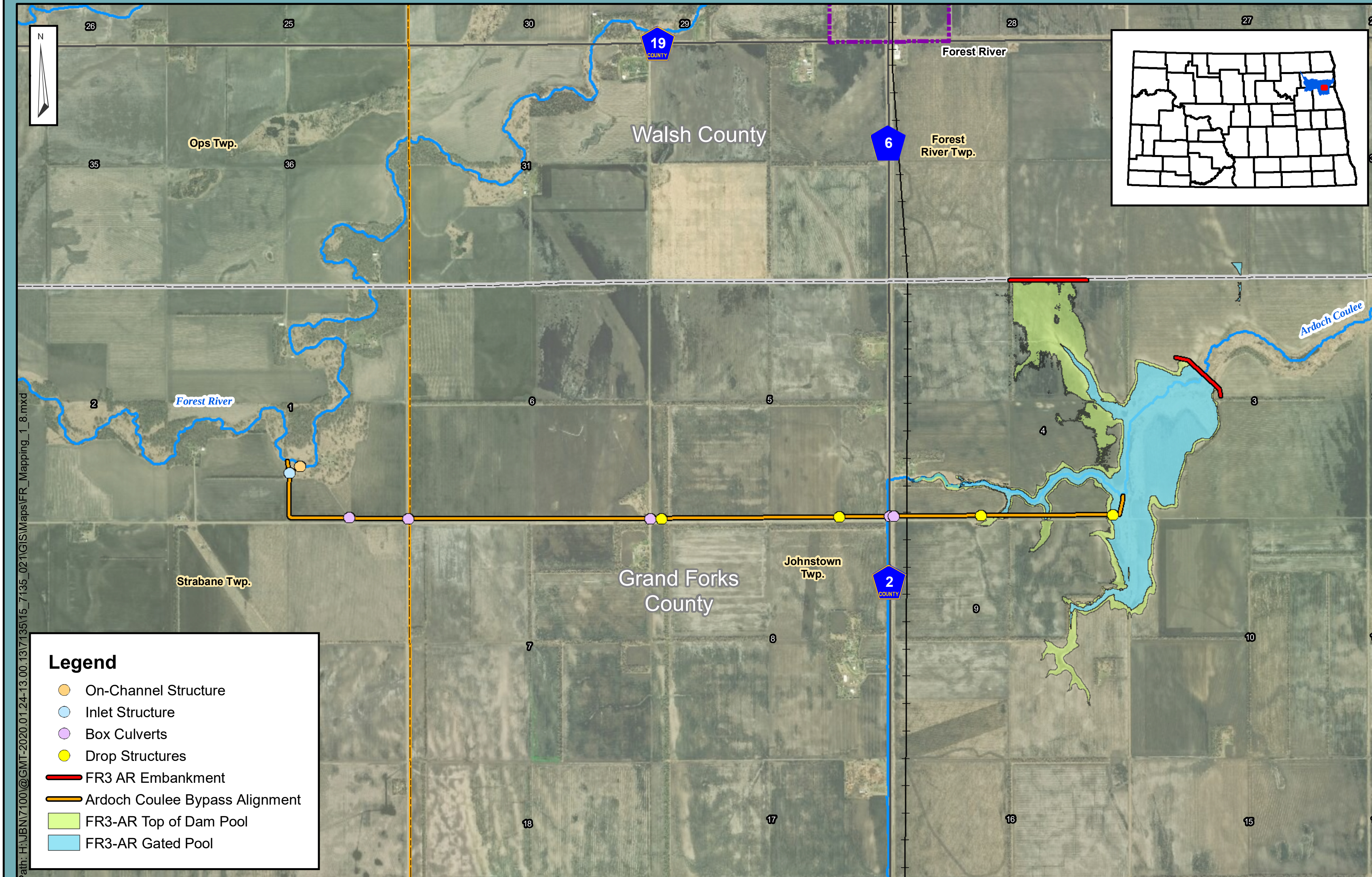
F-3.1.5

Figure 3.1.5: Alternative 5 - Ardoch Coulee Bypass

Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 0.25 0.5 1 Miles

Houston Engineering Inc.



F-3.1.6

Figure 3.1.6: Alternative 6 - Site FR3-AR and Ardoch Coulee Bypass

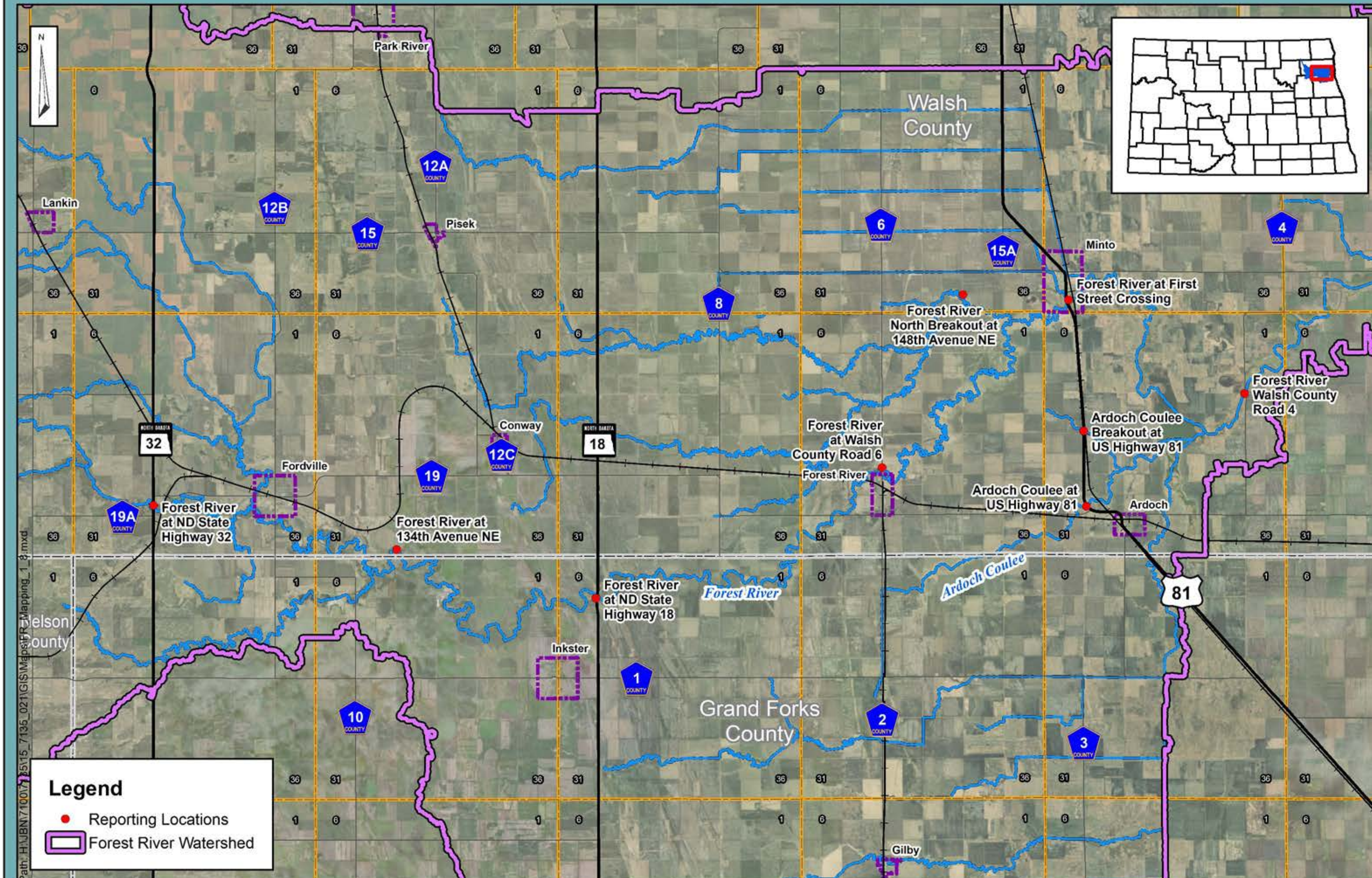
Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

0 0.25 0.5 1 Miles

Houston Engineering Inc.

APPENDIX A

Figure A.1 Technical Considerations – Reporting Locations
A.2 Reduce Runoff Volume – Hydrographs
A.3 Increase Conveyance Capacity – Hydrographs
A.4 Increase Temporary Flood Storage – Hydrographs
A.5 Wetland Restoration – Hydrographs



F-A.1

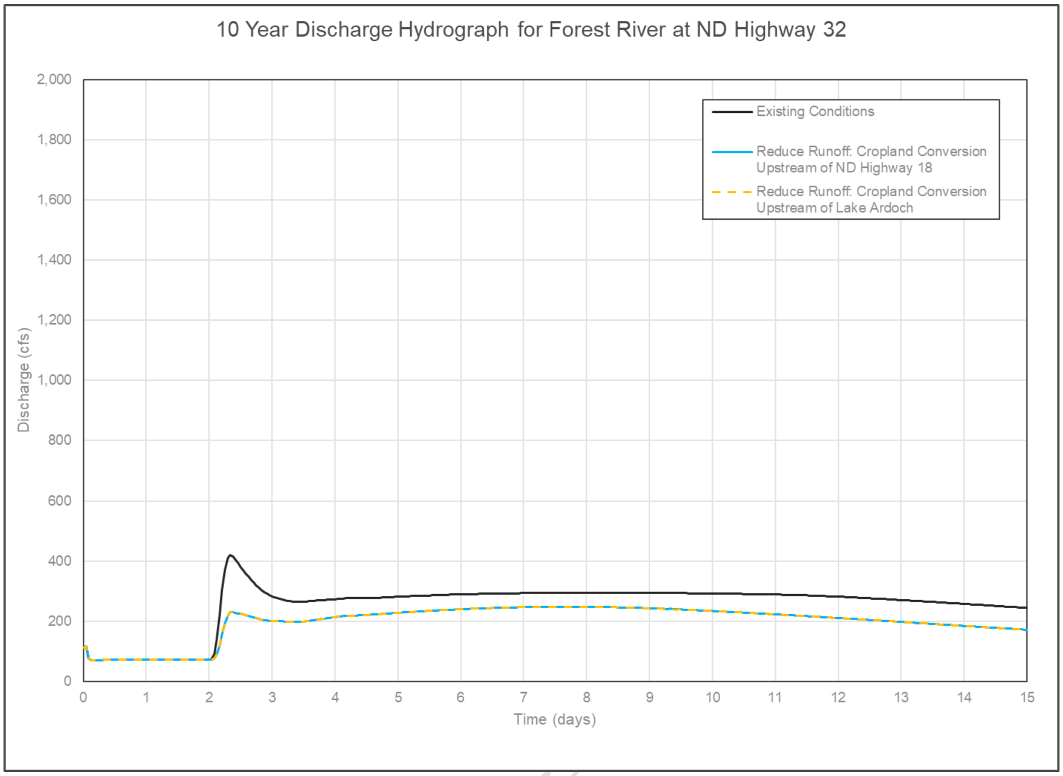
Figure A.1: Technical Considerations - Reporting Locations

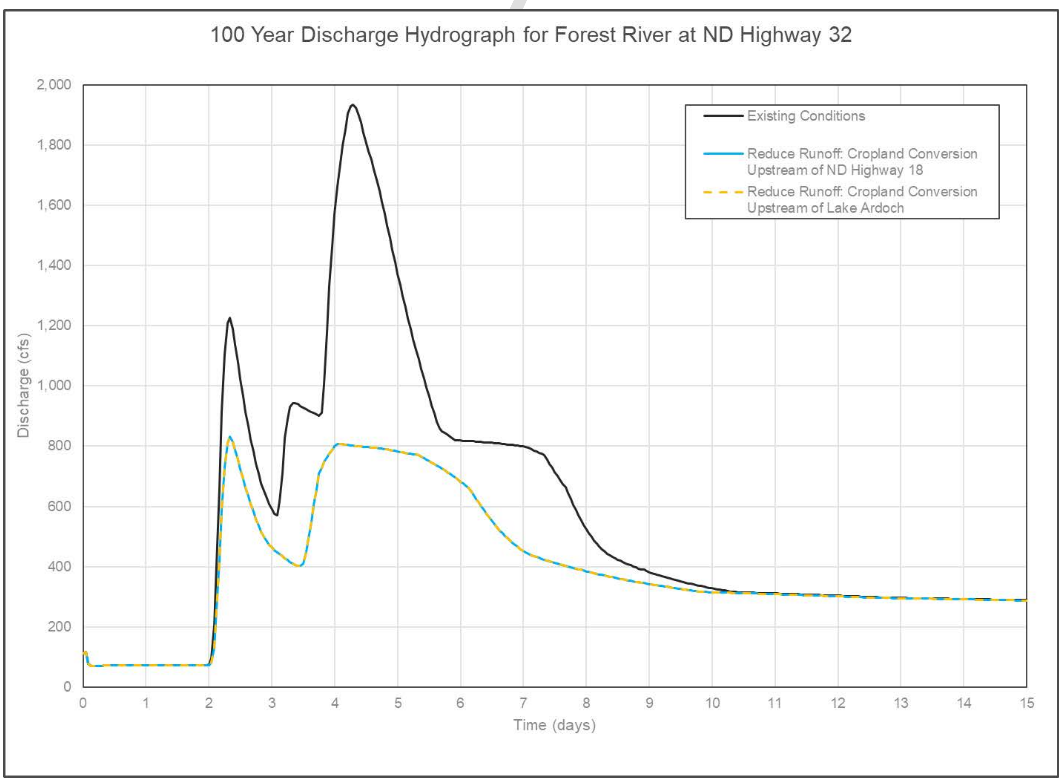
Forest River Watershed
Screening of Alternatives for Detailed Review
Walsh County Water Resource District

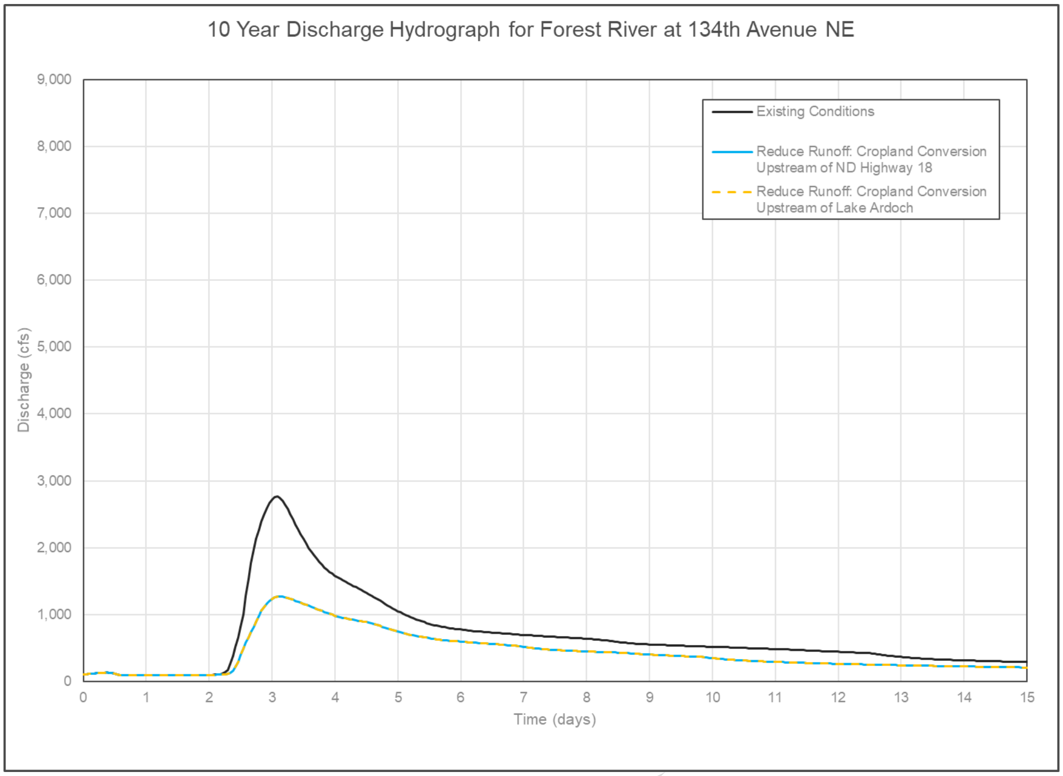
0 1.5 3 6 Miles

Houston Engineering Inc.

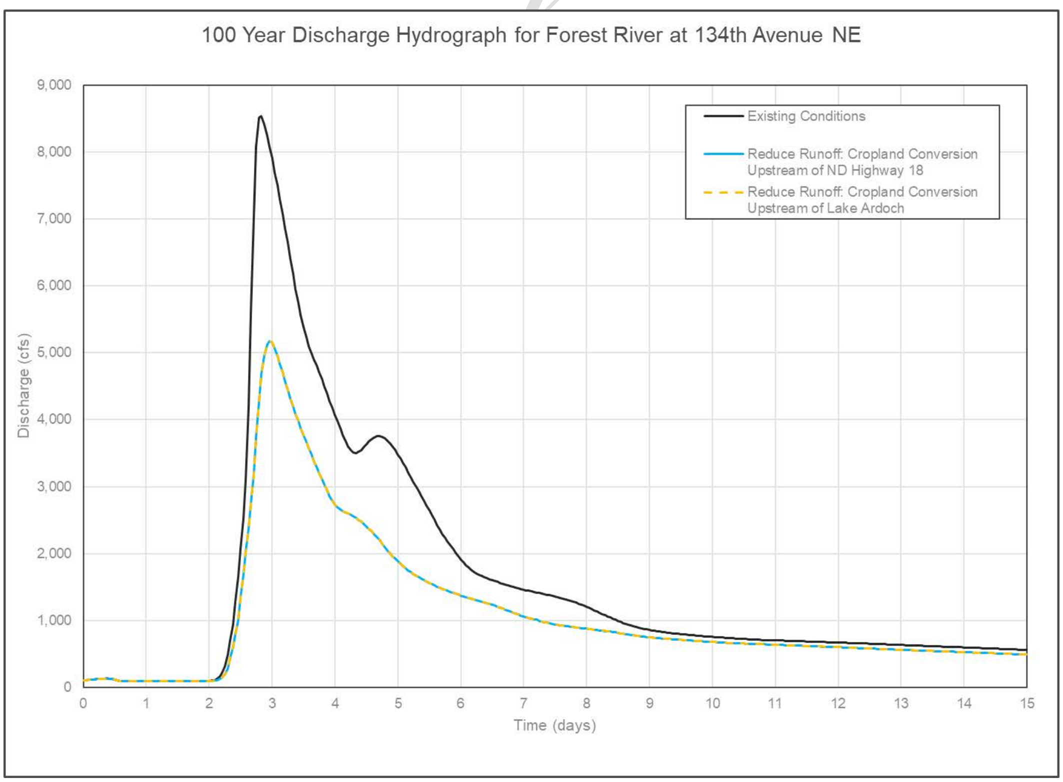
A.2 REDUCE RUNOFF VOLUME - HYDROGRAPHS



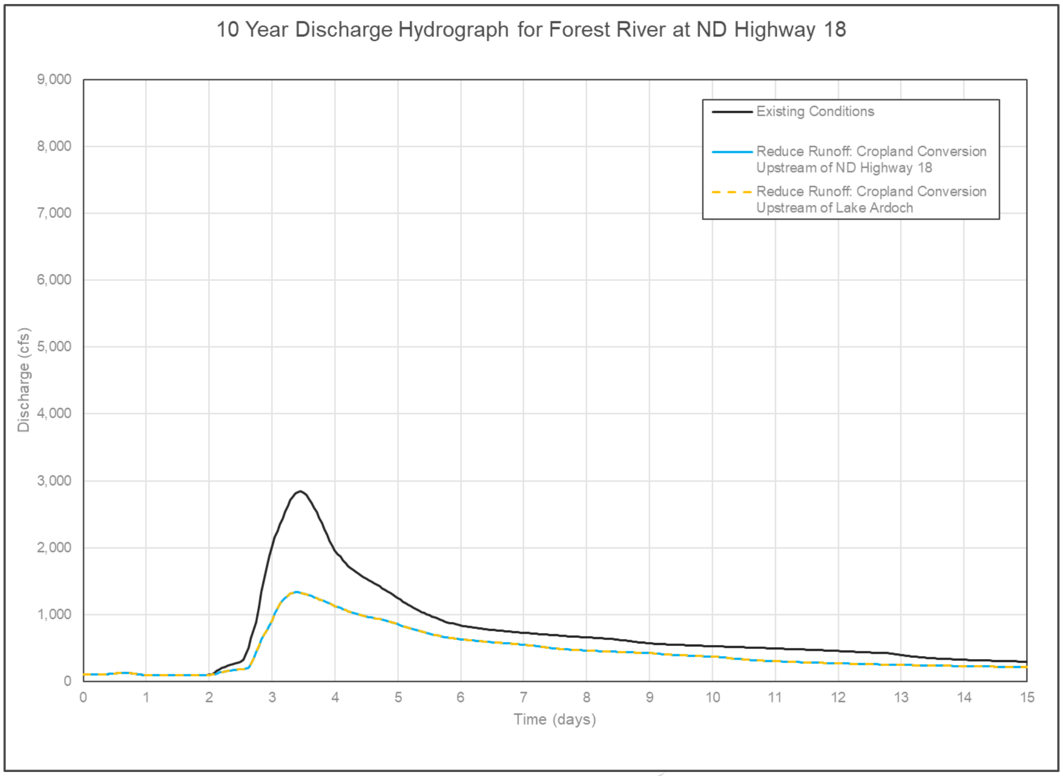


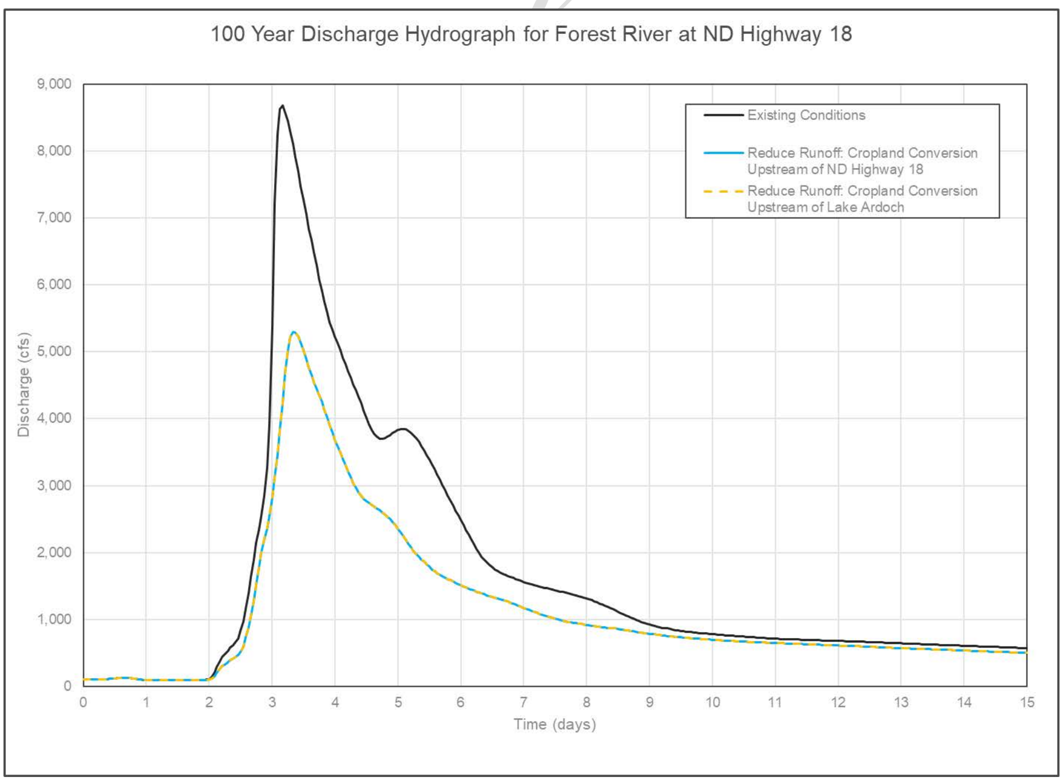


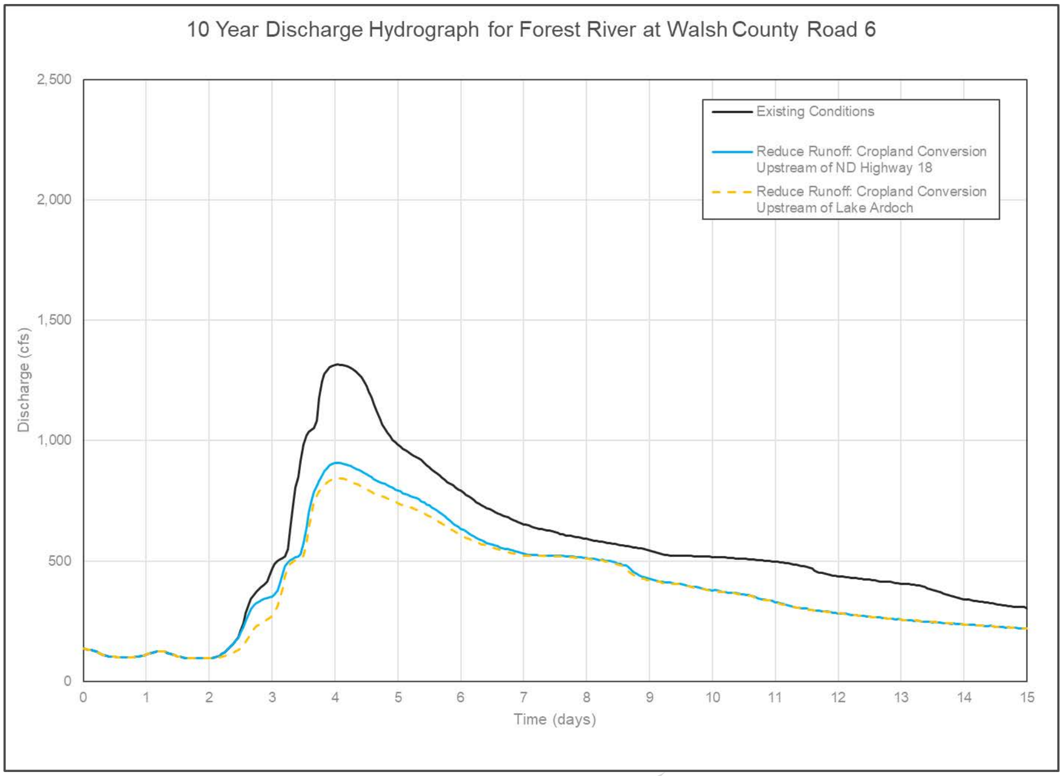
10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch

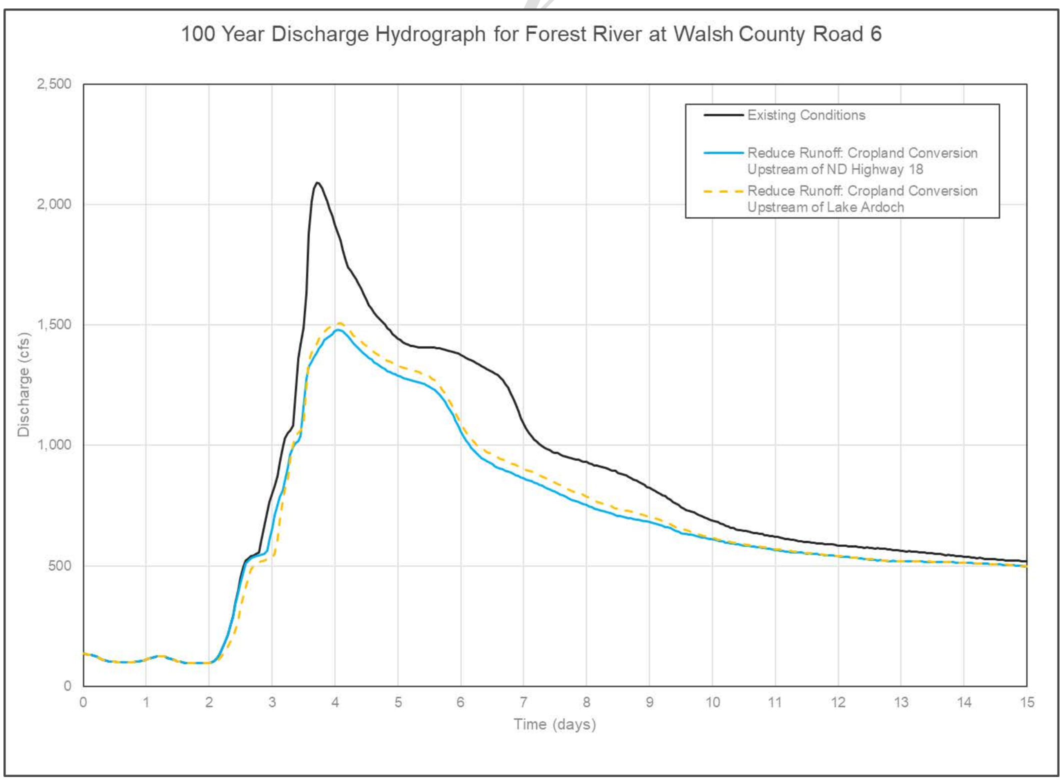


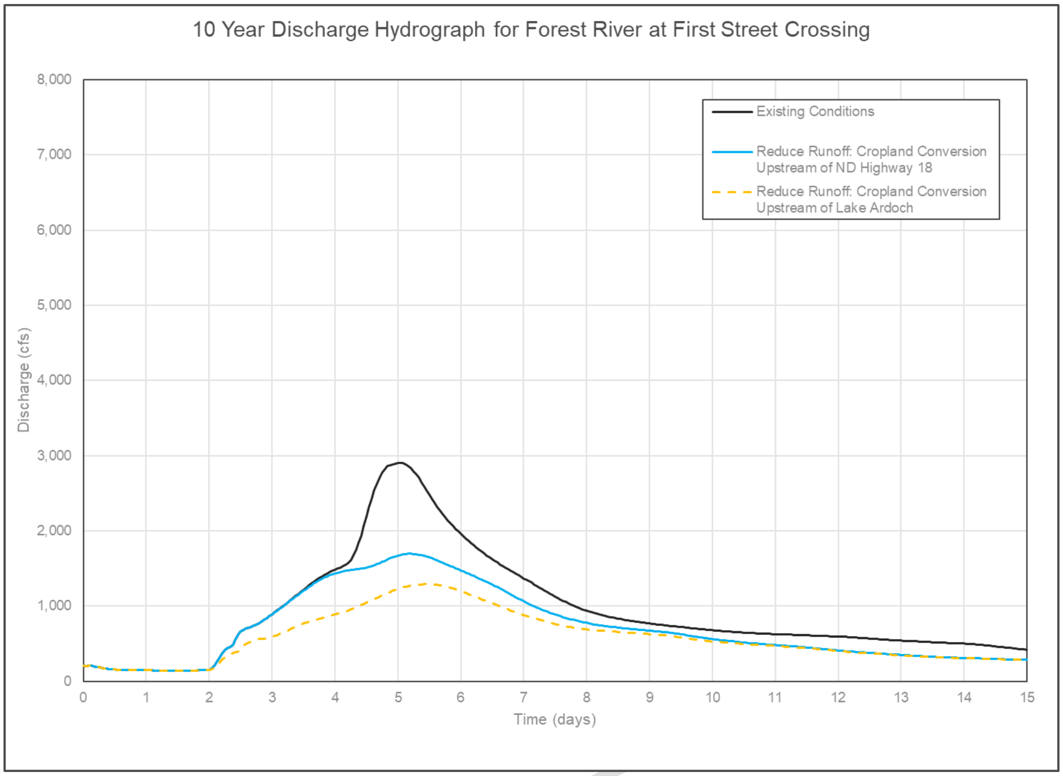
100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch

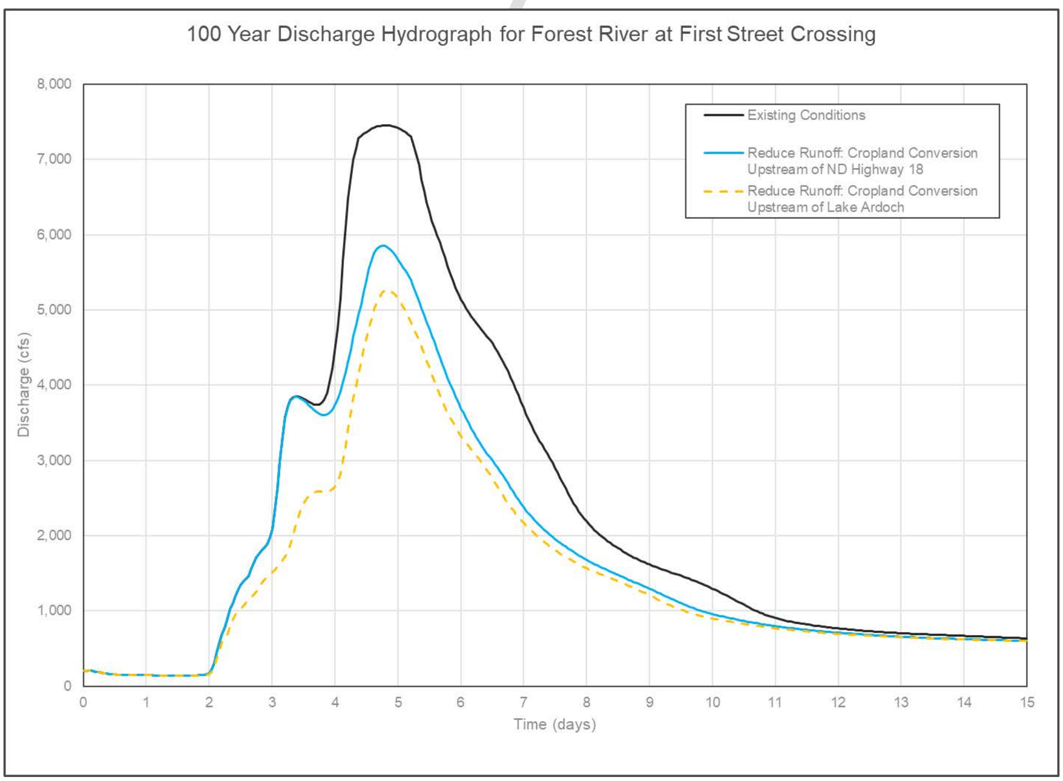

10 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

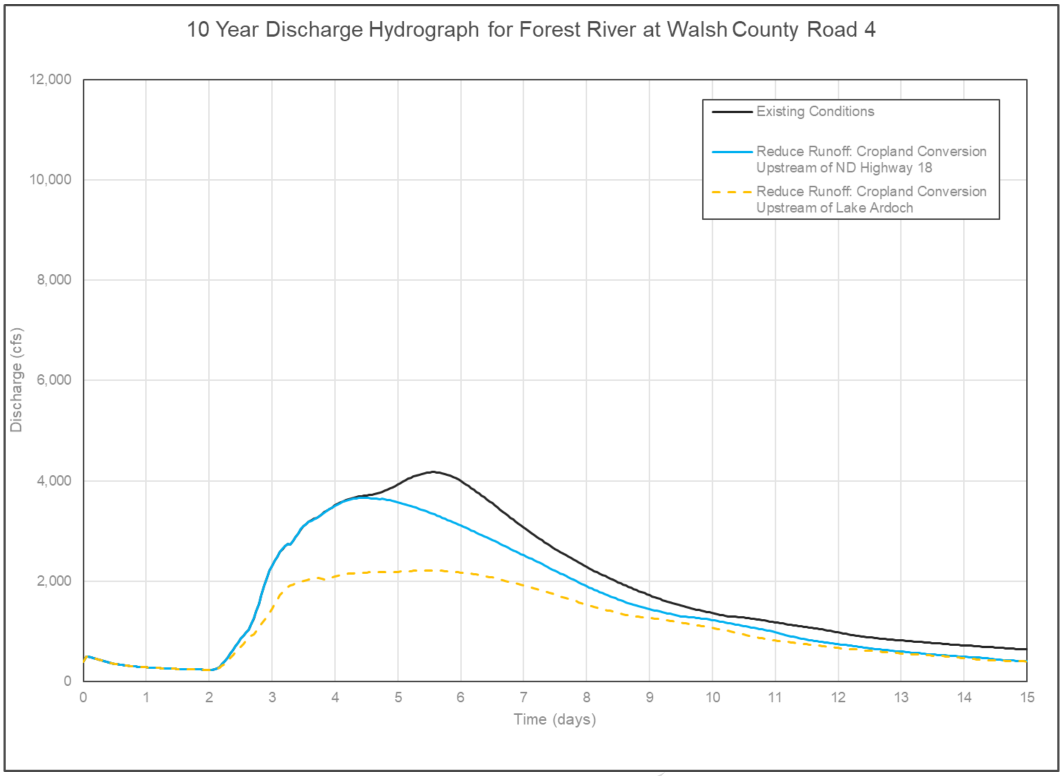

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

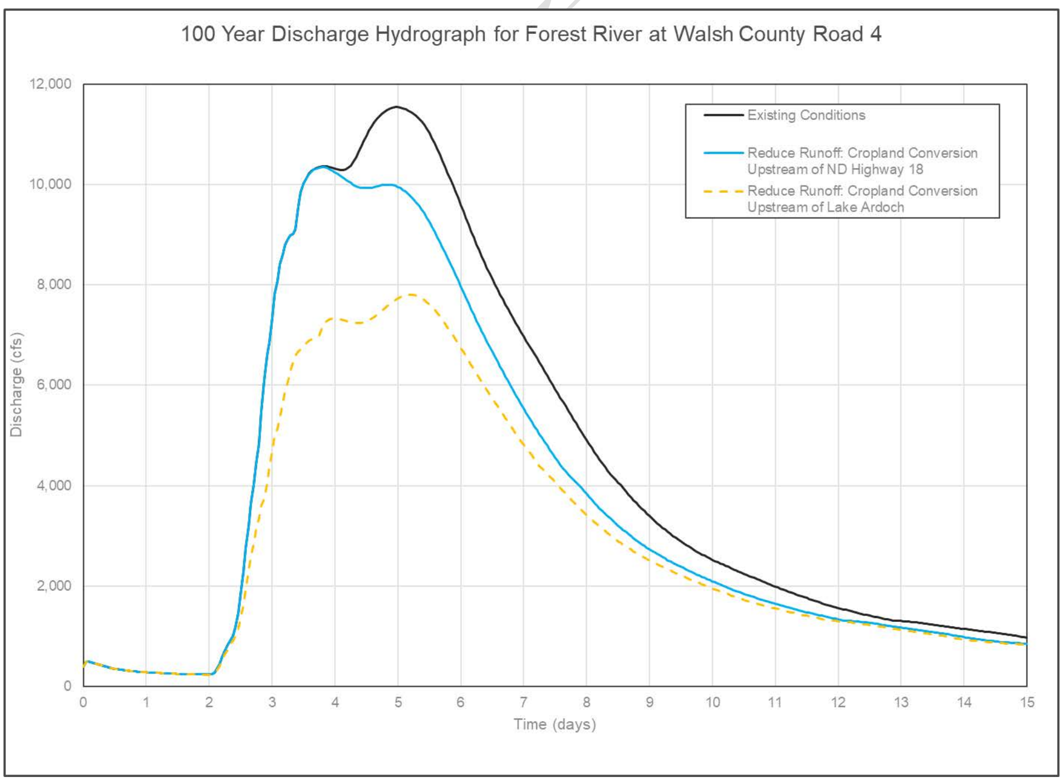

10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

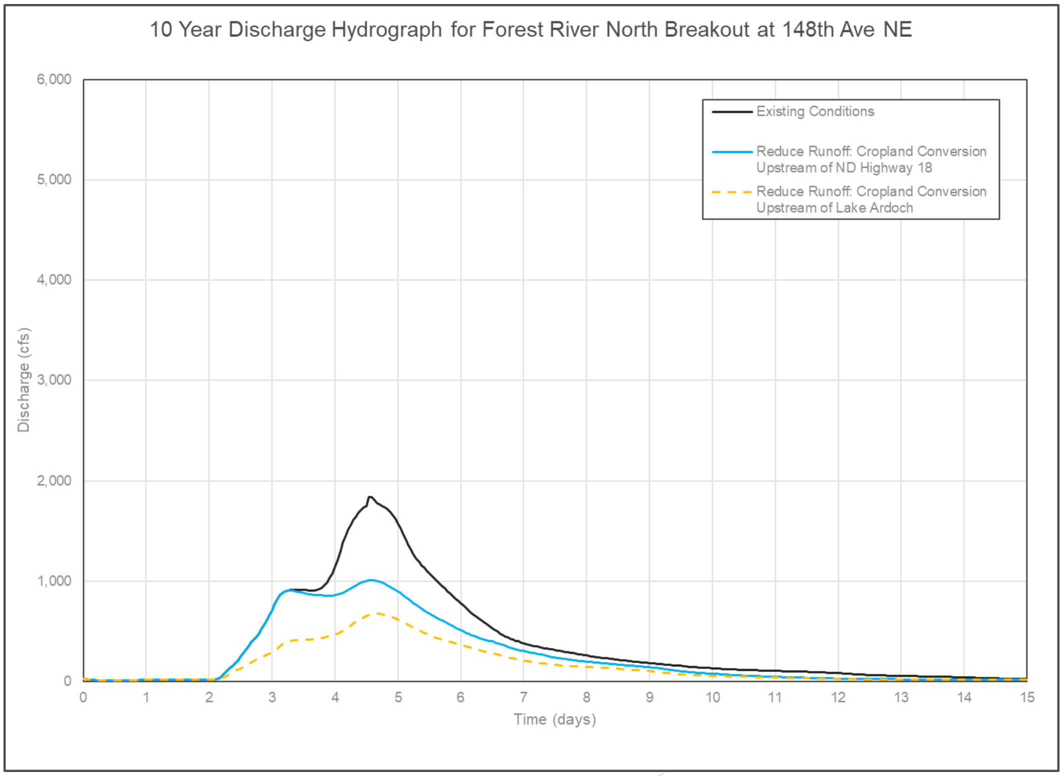

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

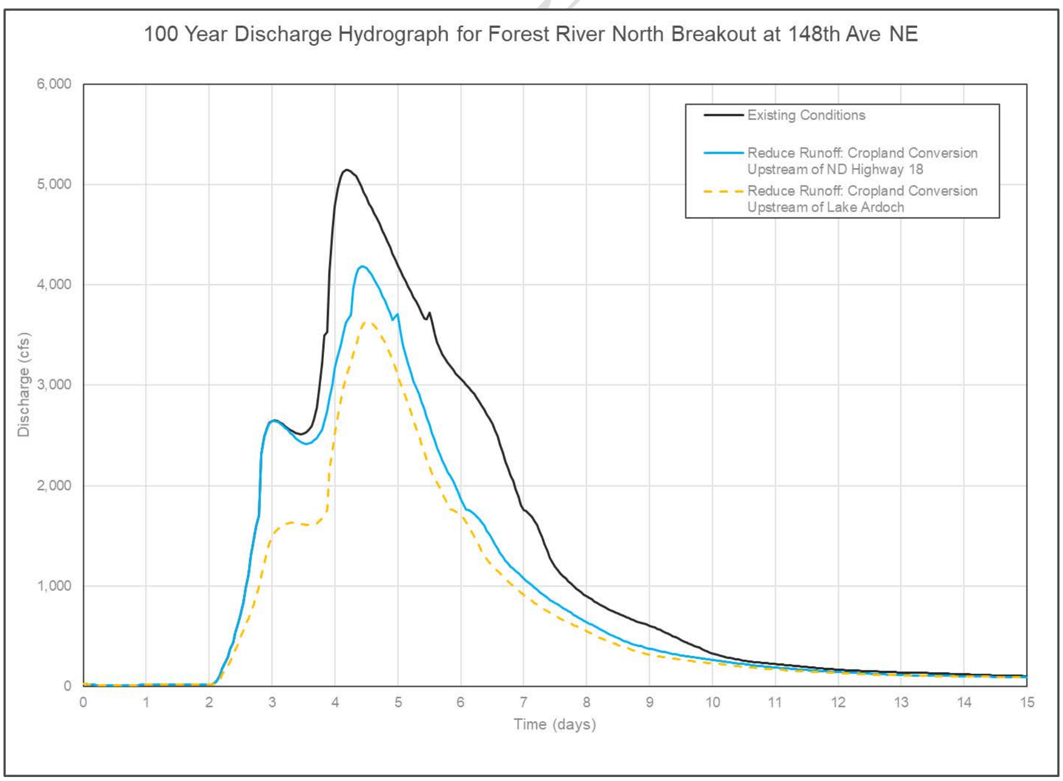

10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

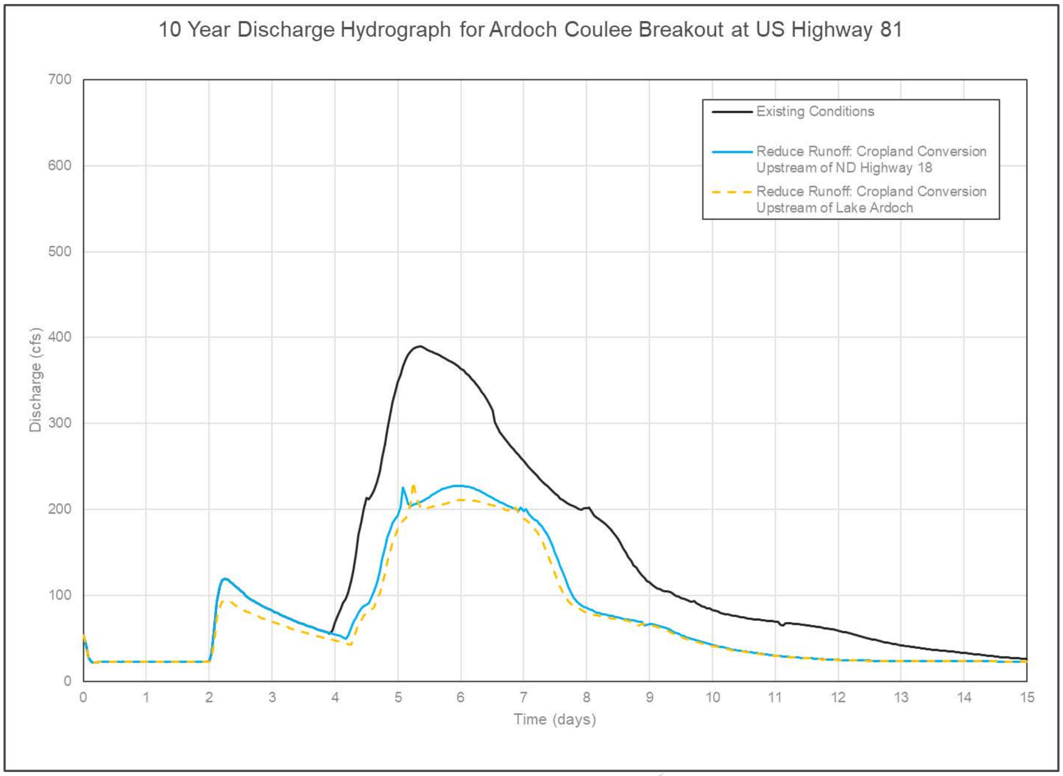

100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

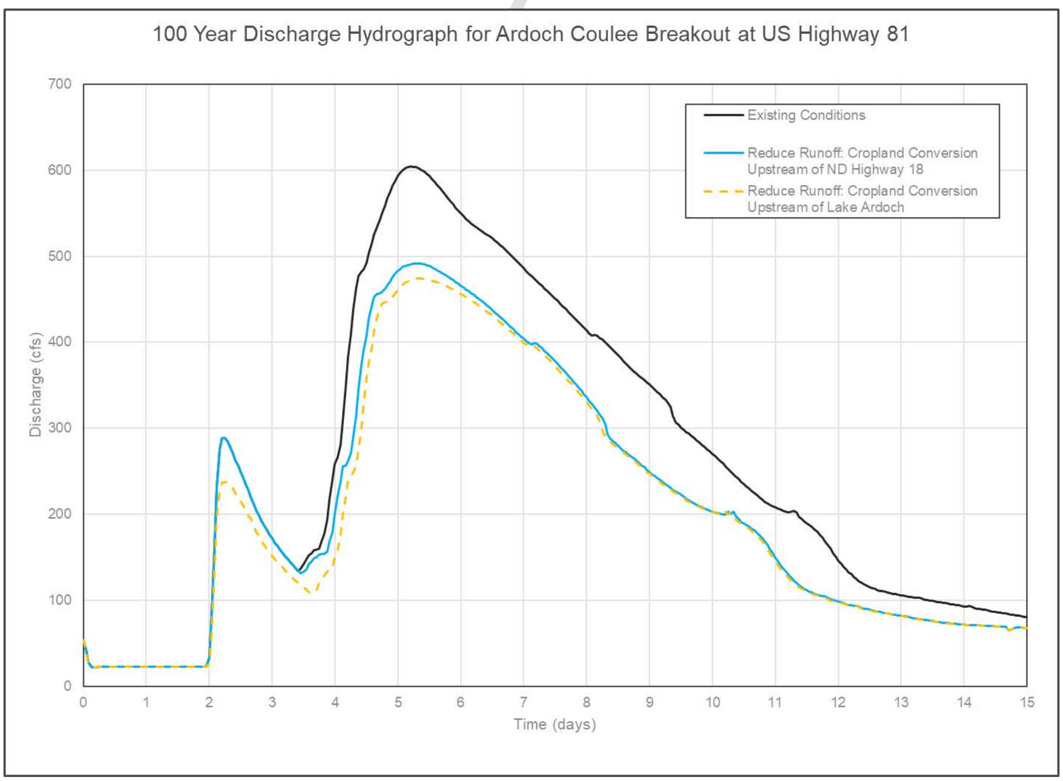

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

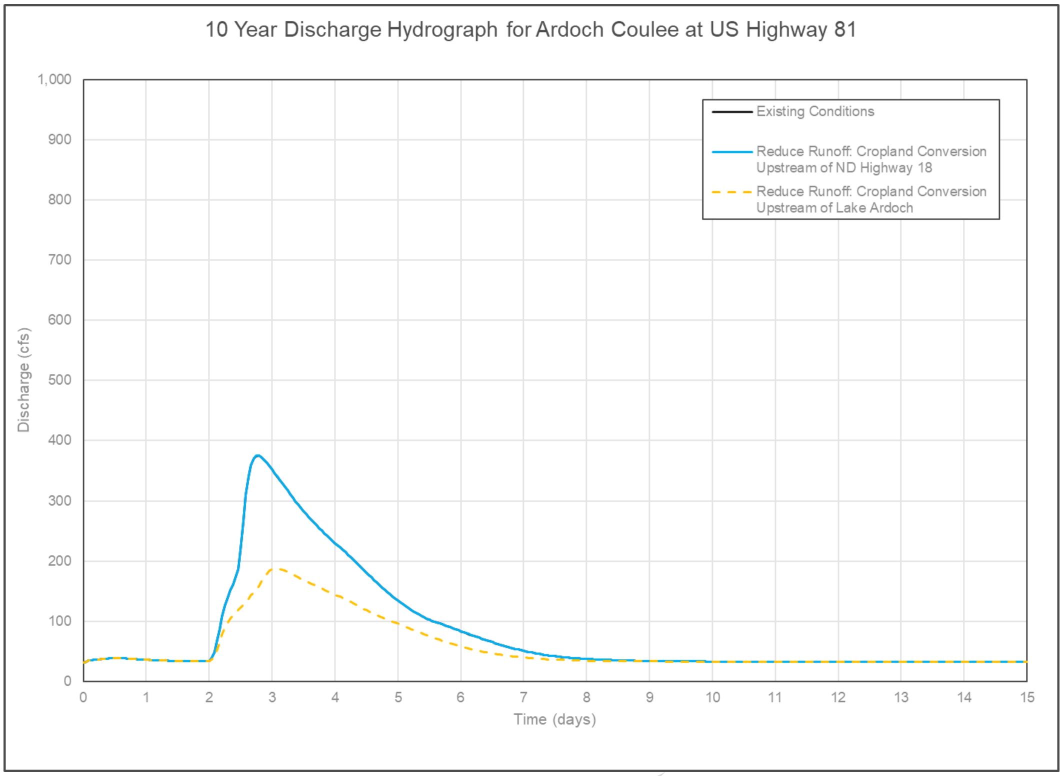

100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

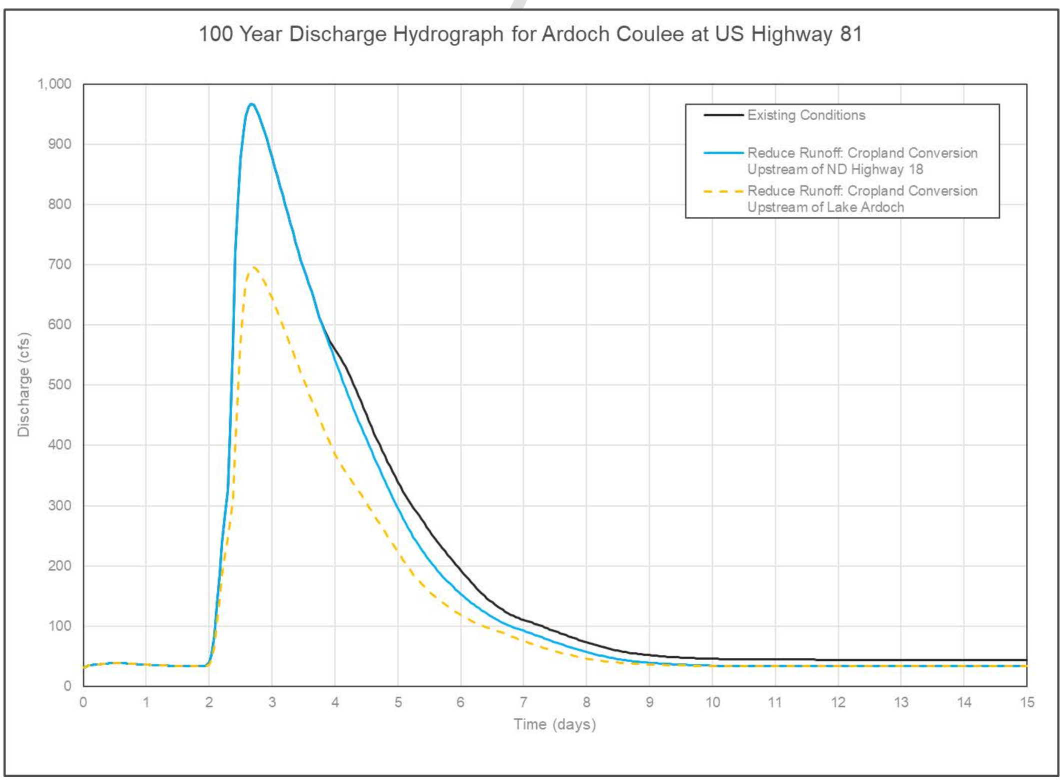


10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch

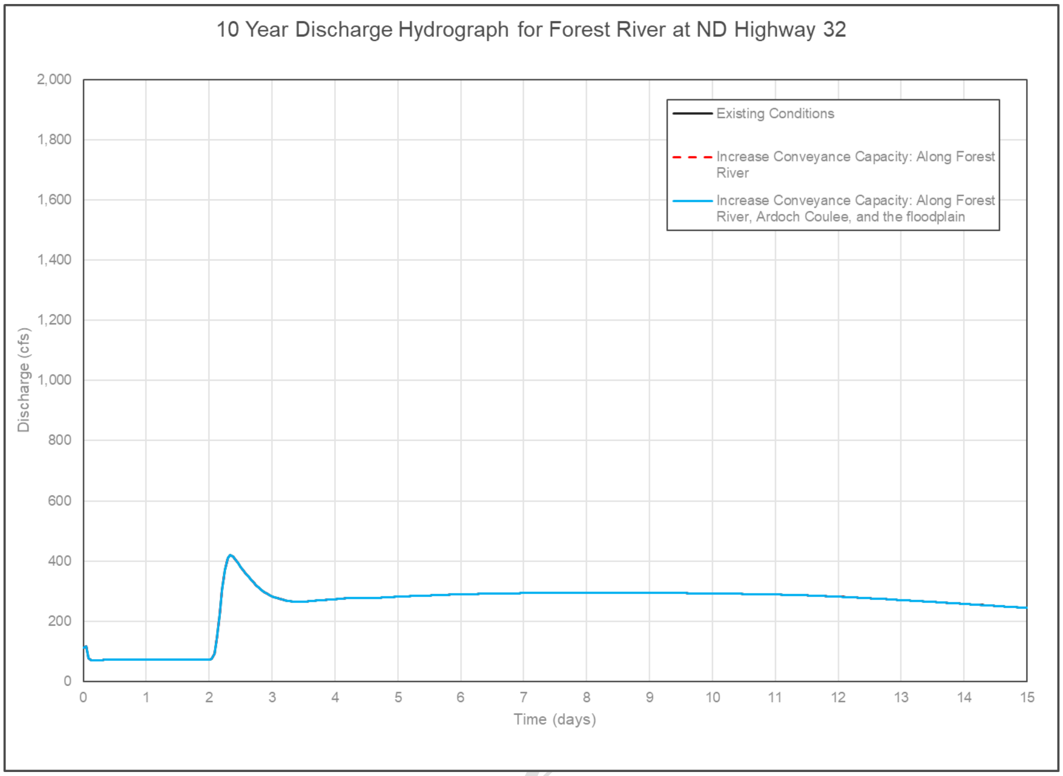


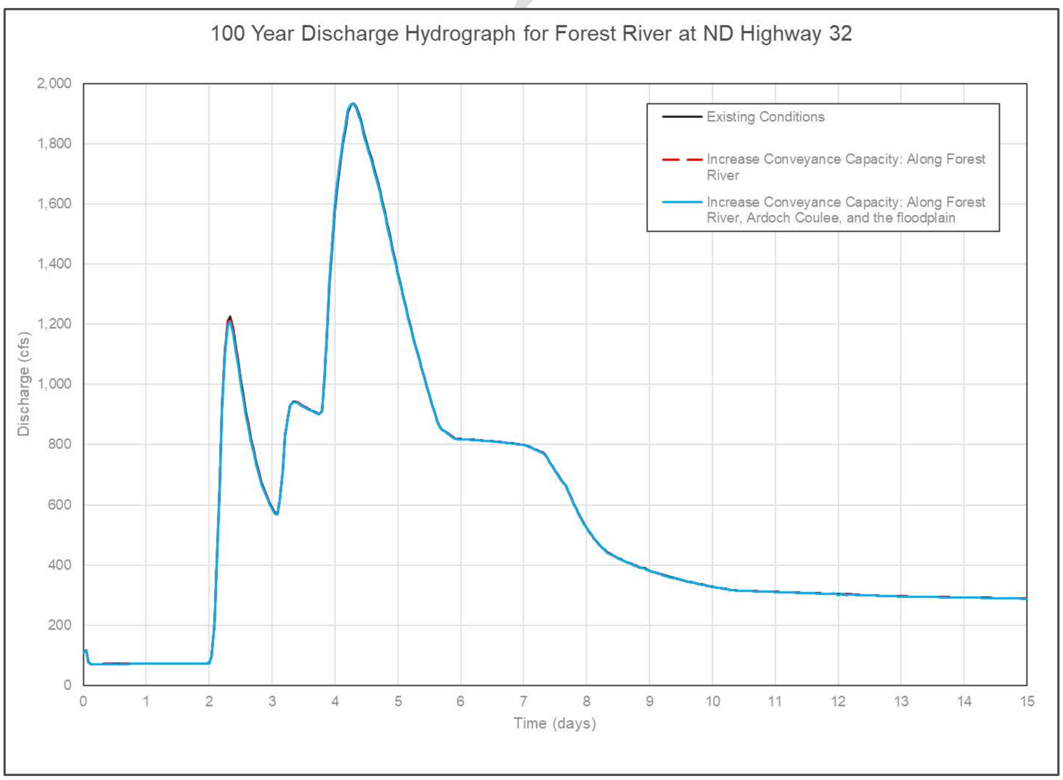
100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch

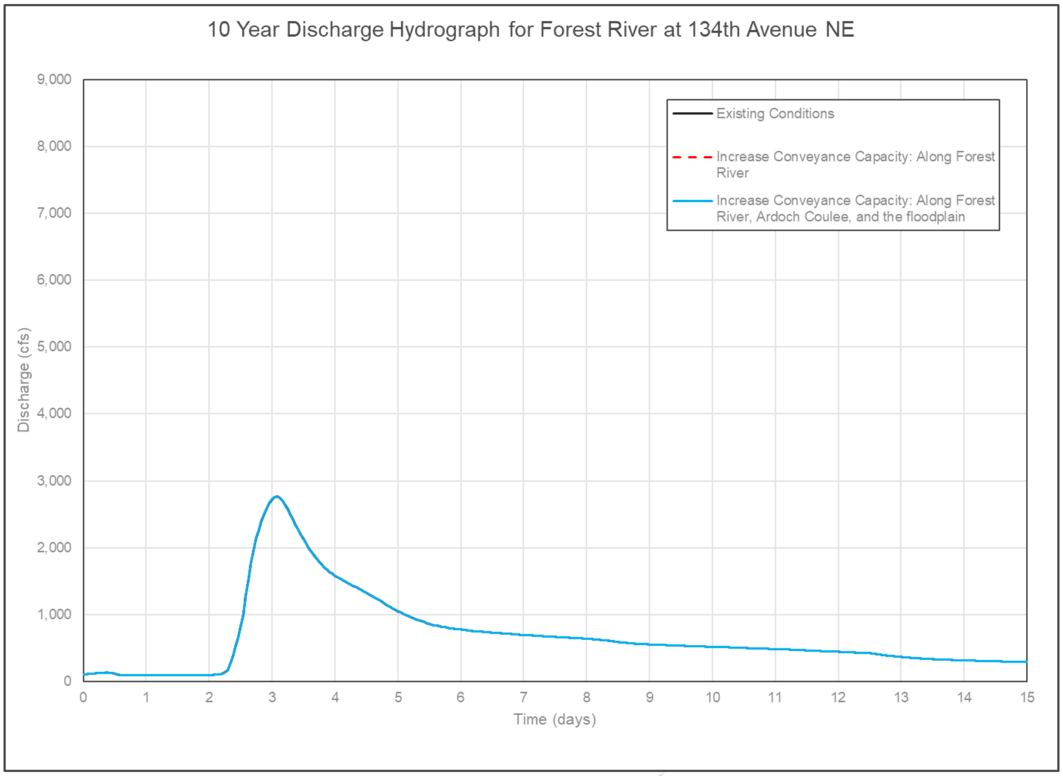

10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
1,000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

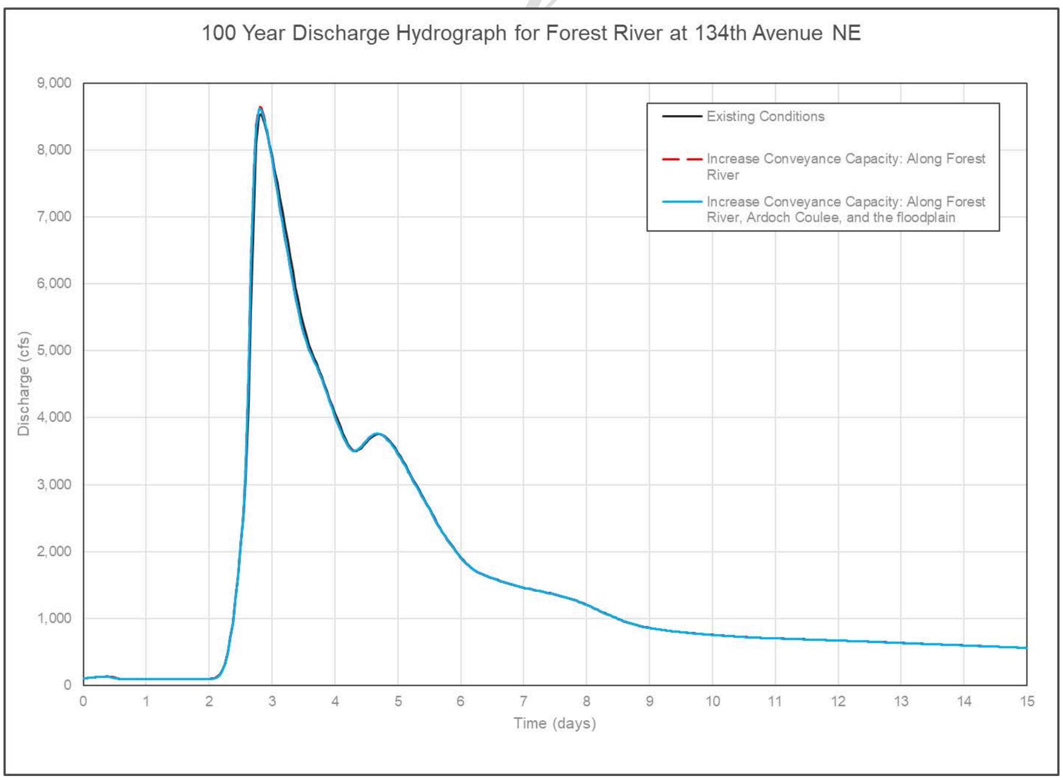

100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Reduce Runoff: Cropland Conversion Upstream of ND Highway 18
Reduce Runoff: Cropland Conversion Upstream of Lake Ardoch
1,000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

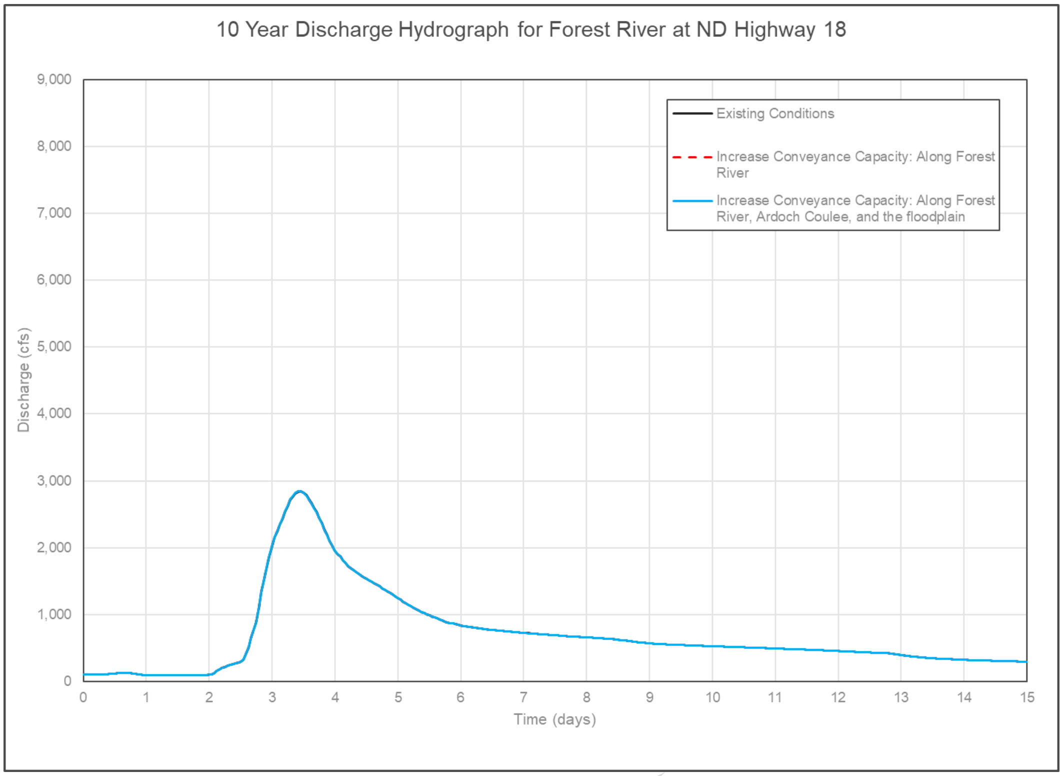
A.3 INCREASE CONVEYANCE CAPACITY - HYDROGRAPHS

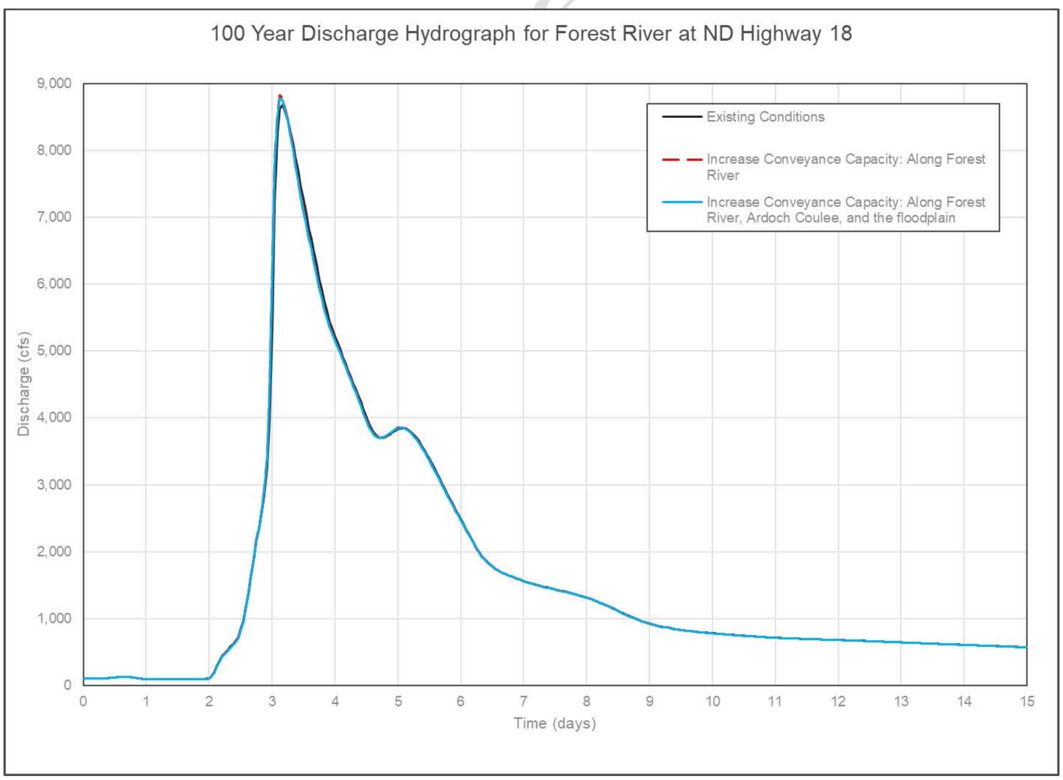


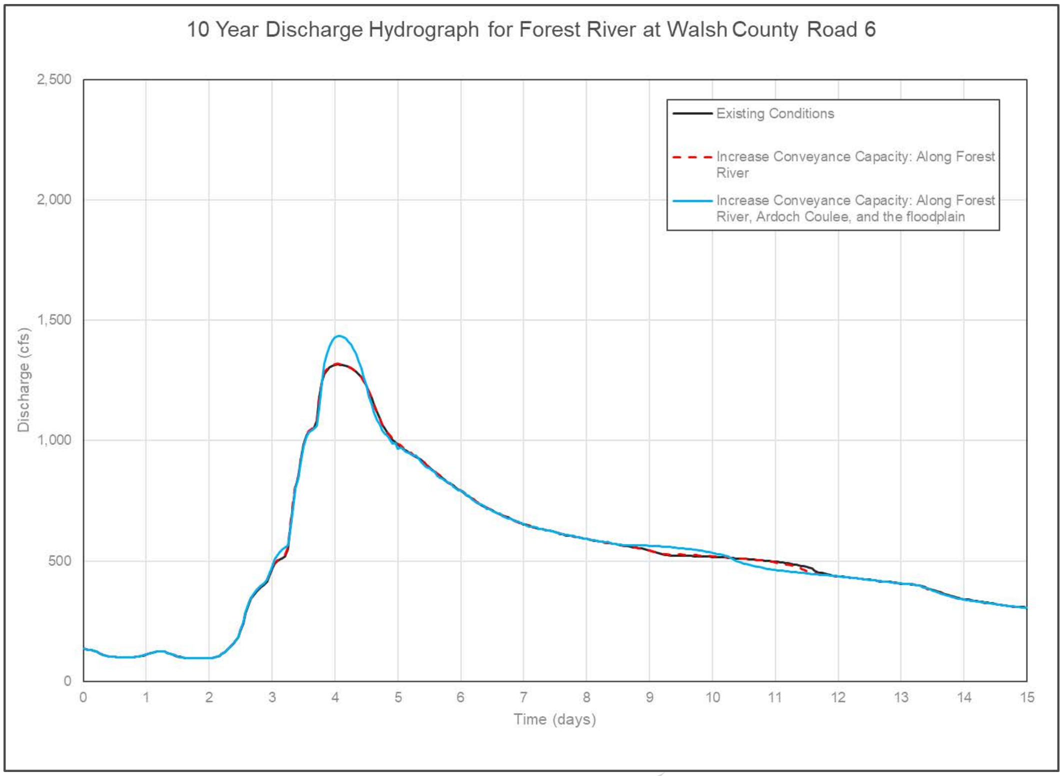



10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

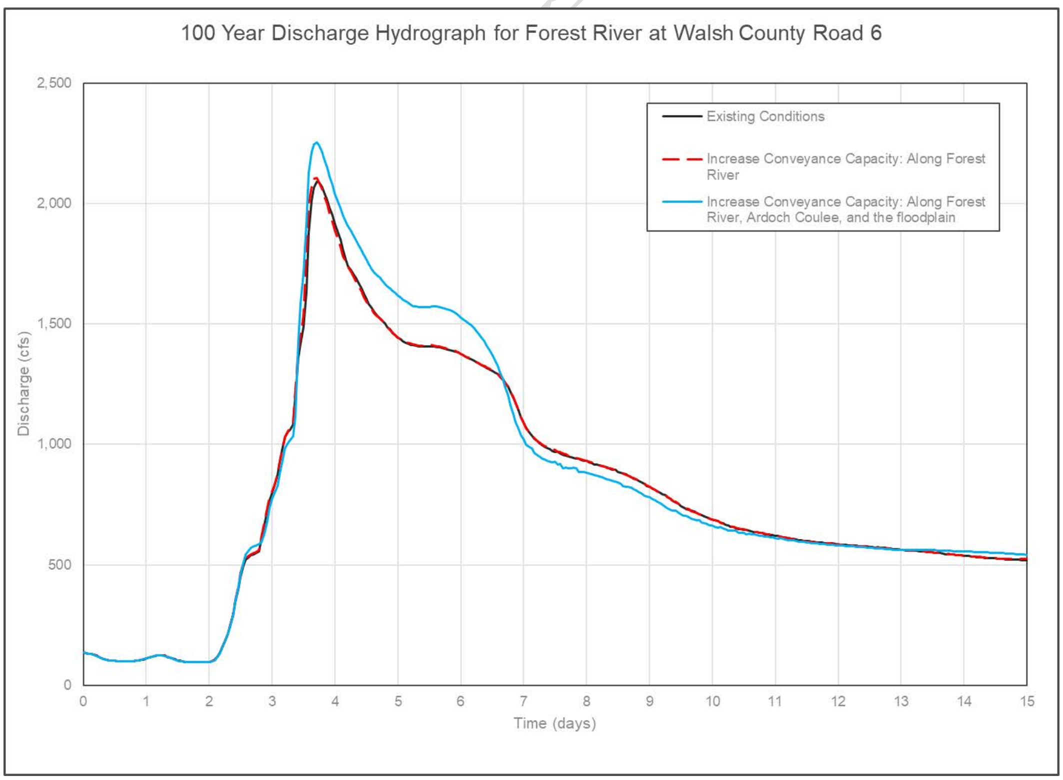

100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


10 Year Discharge Hydrograph for Forest River at ND Highway 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain

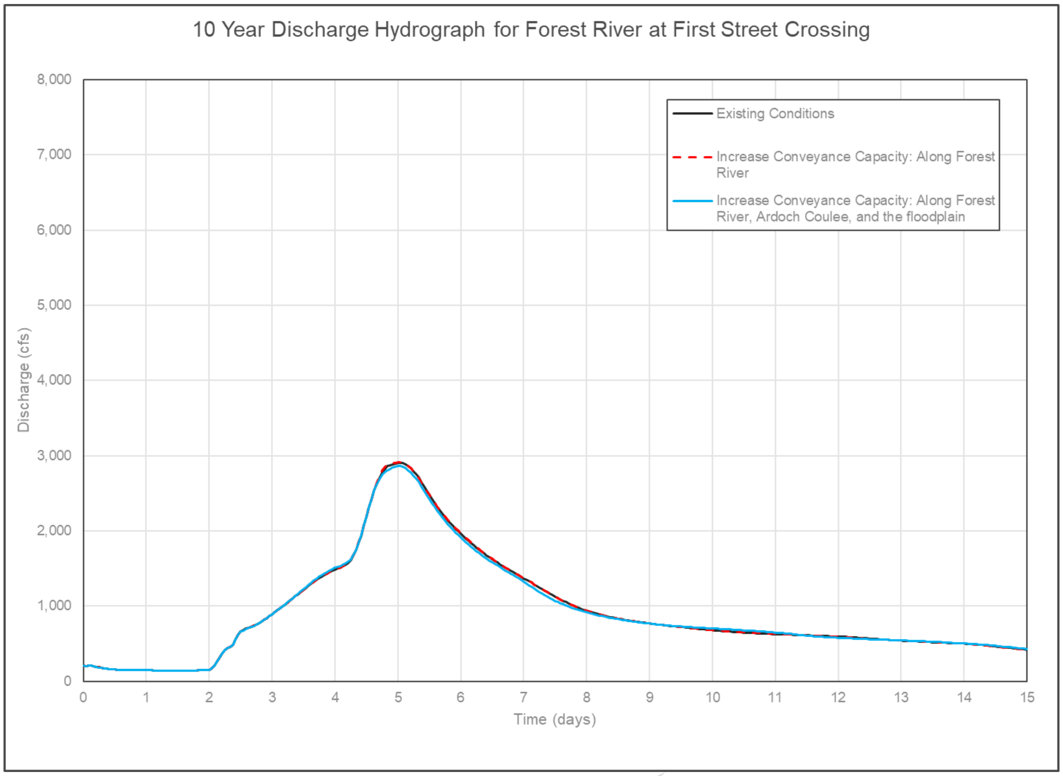

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain



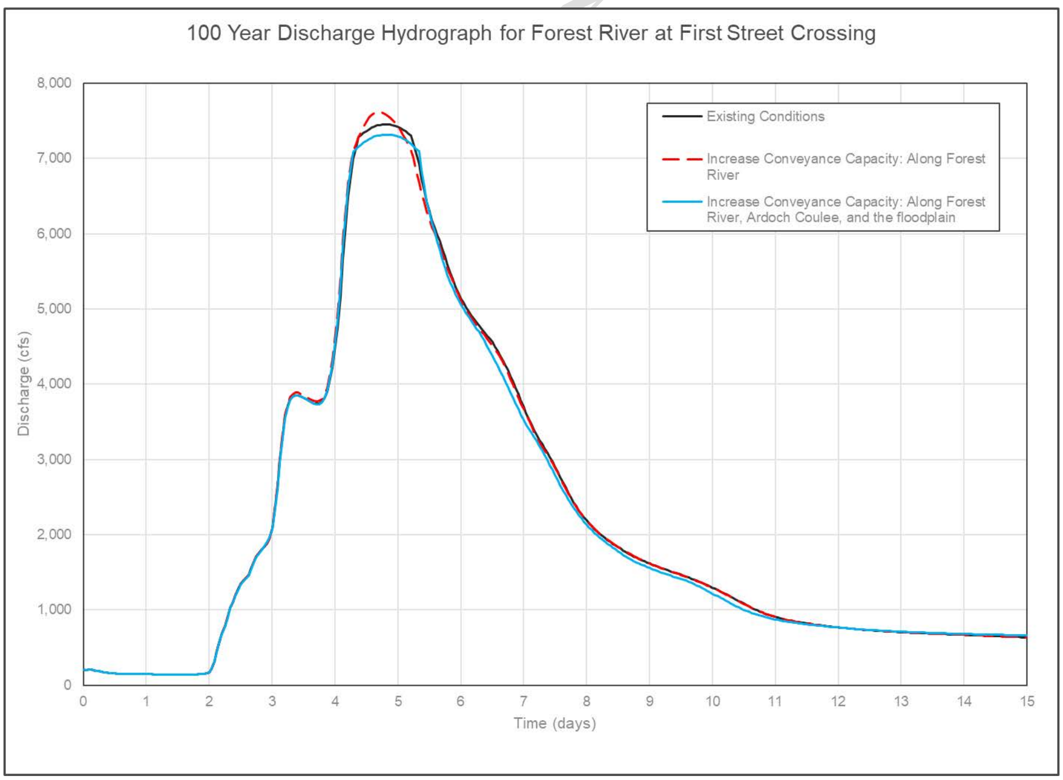
10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15



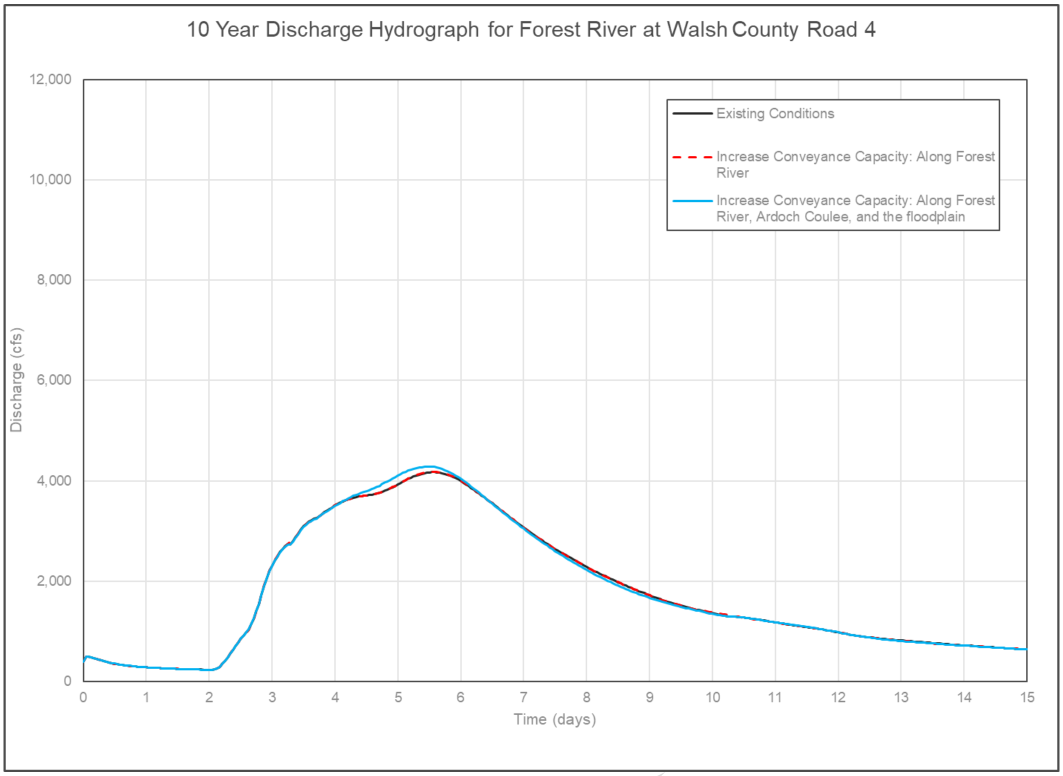
100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

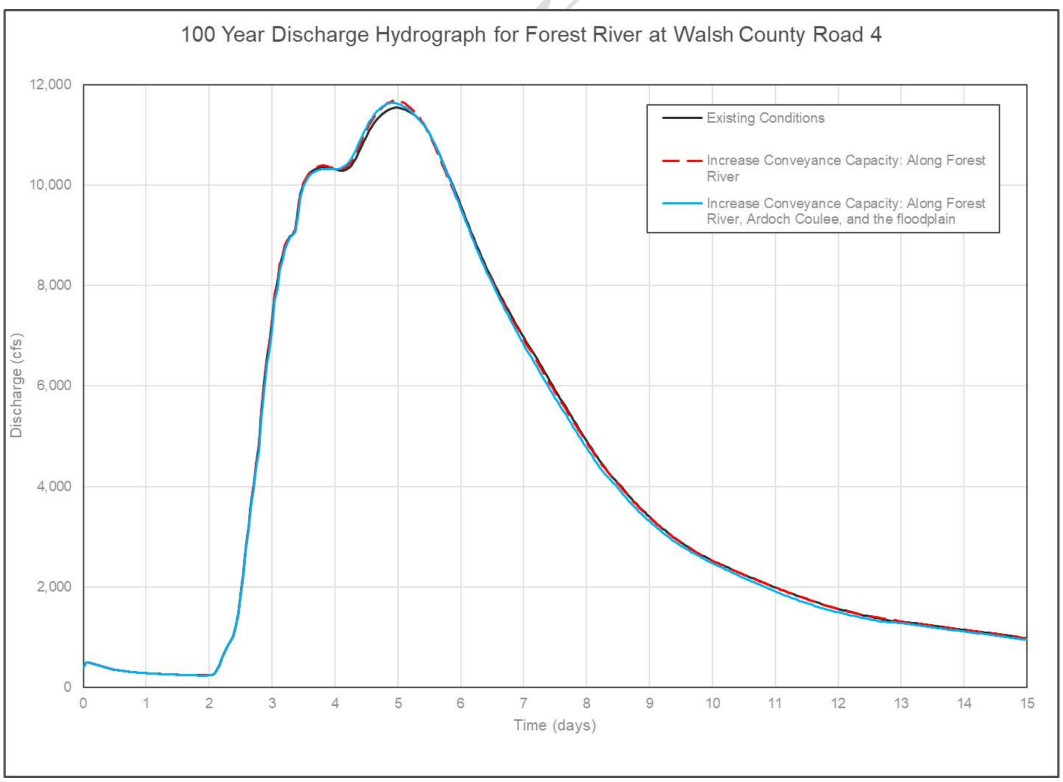


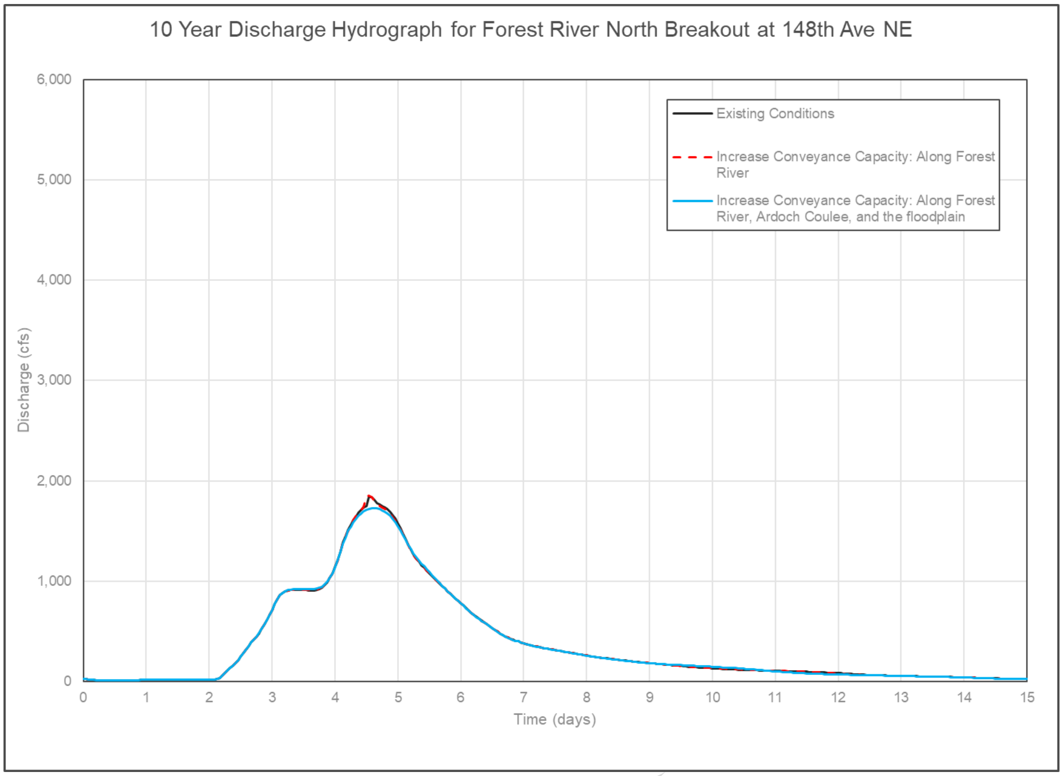
10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

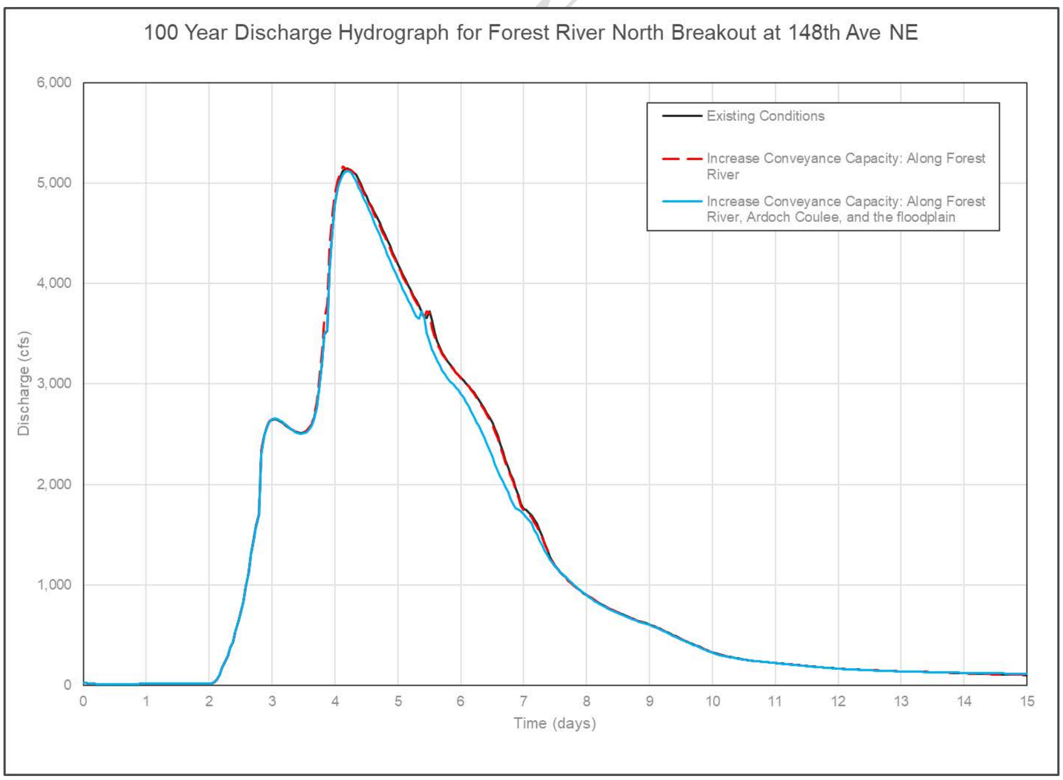


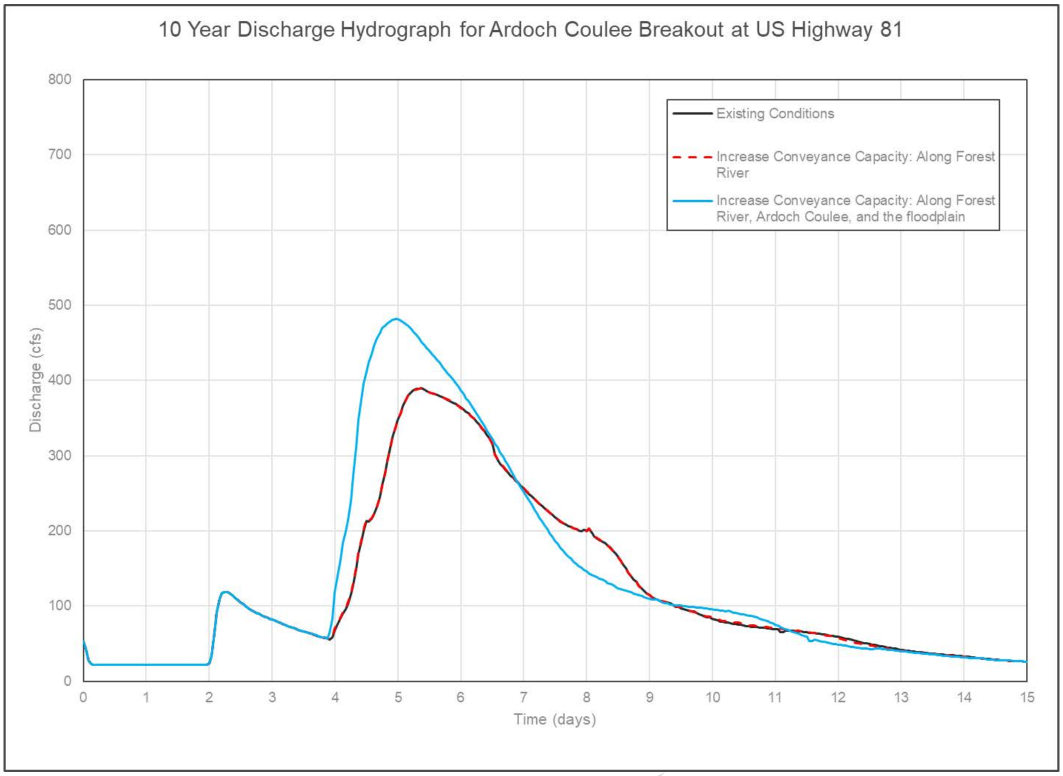
100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

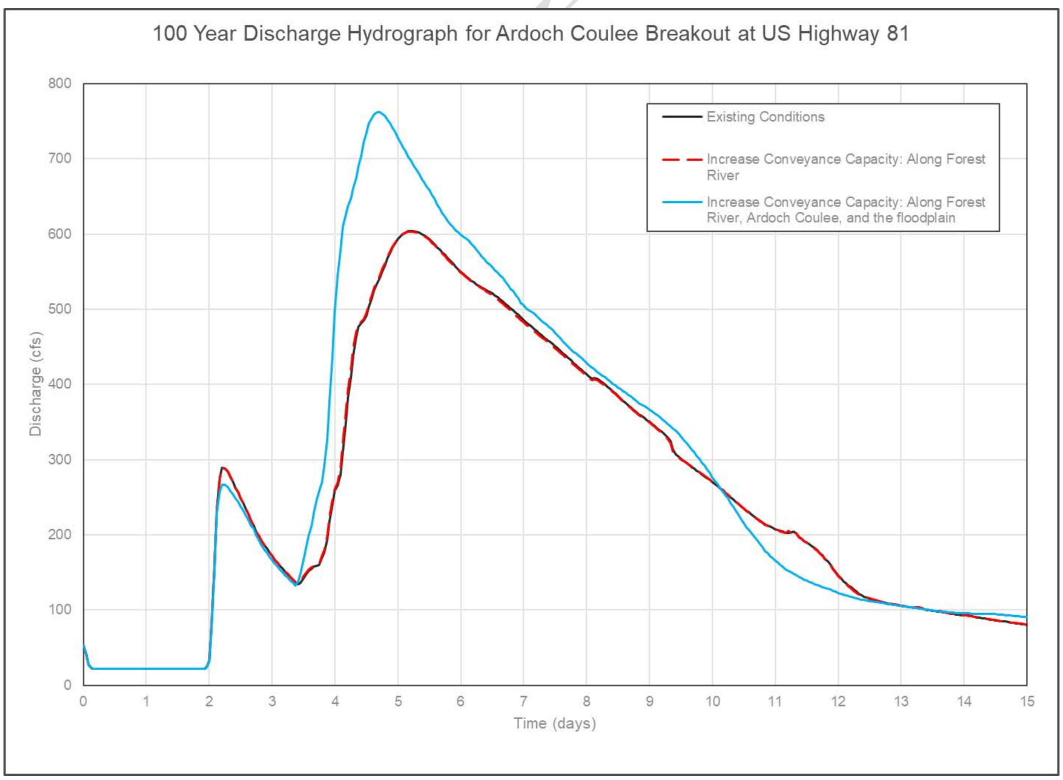

10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

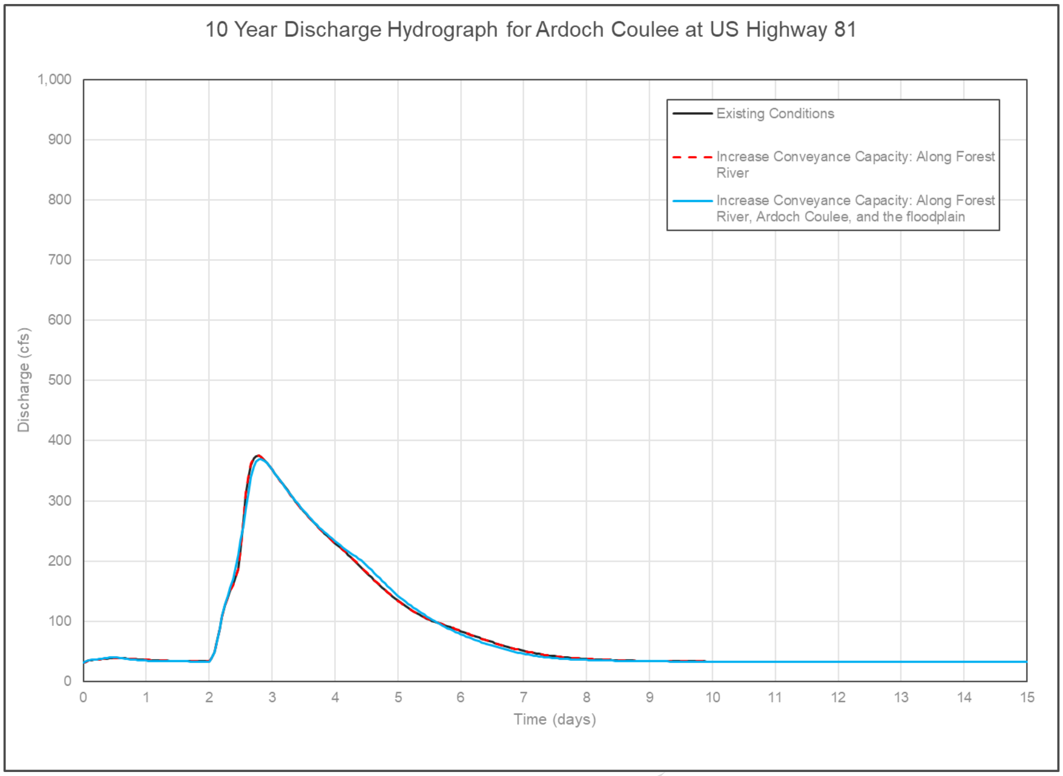

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

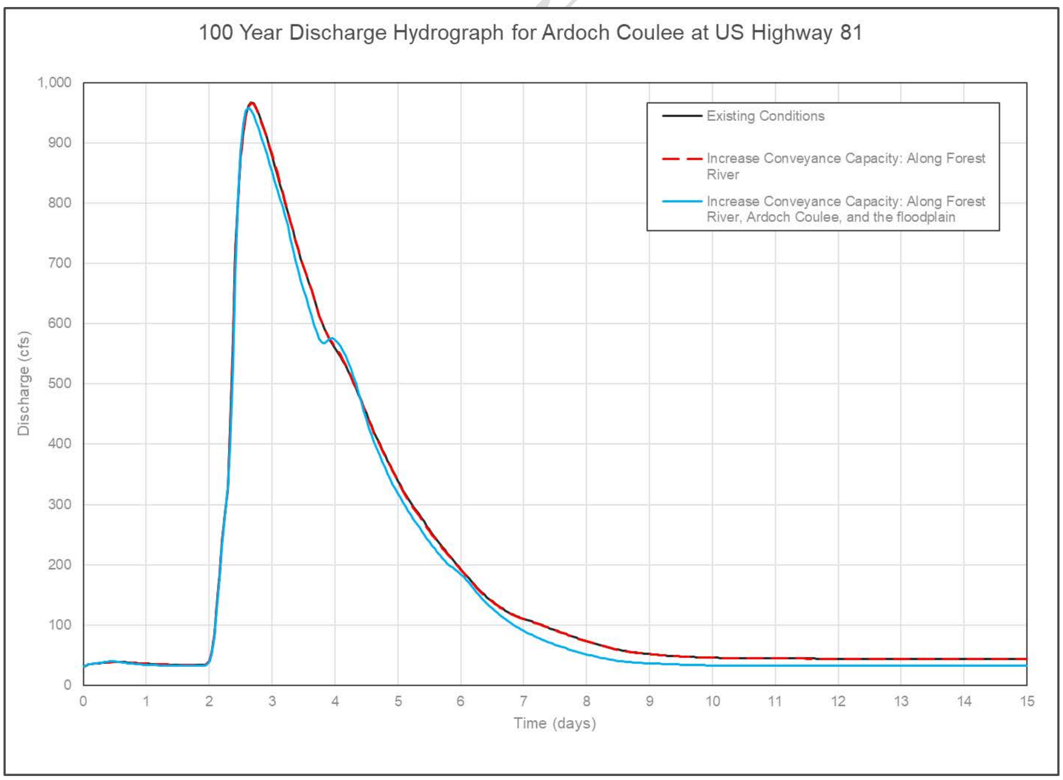

10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

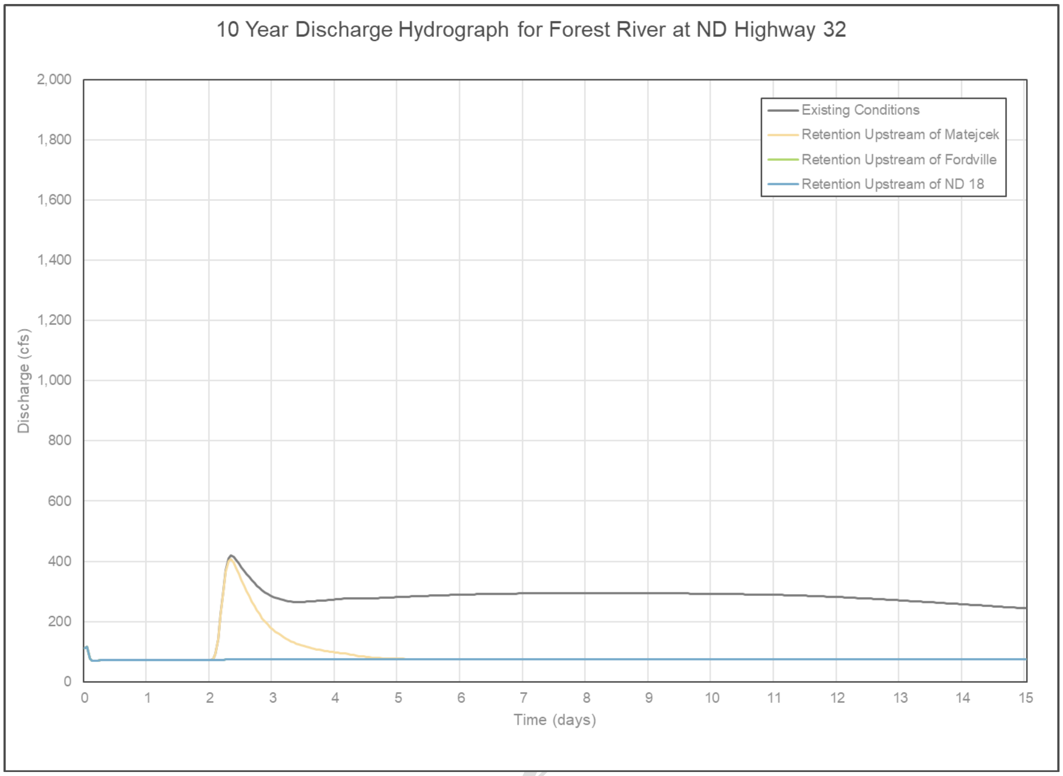

10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
0
100
200
300
400
500
600
700
800
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

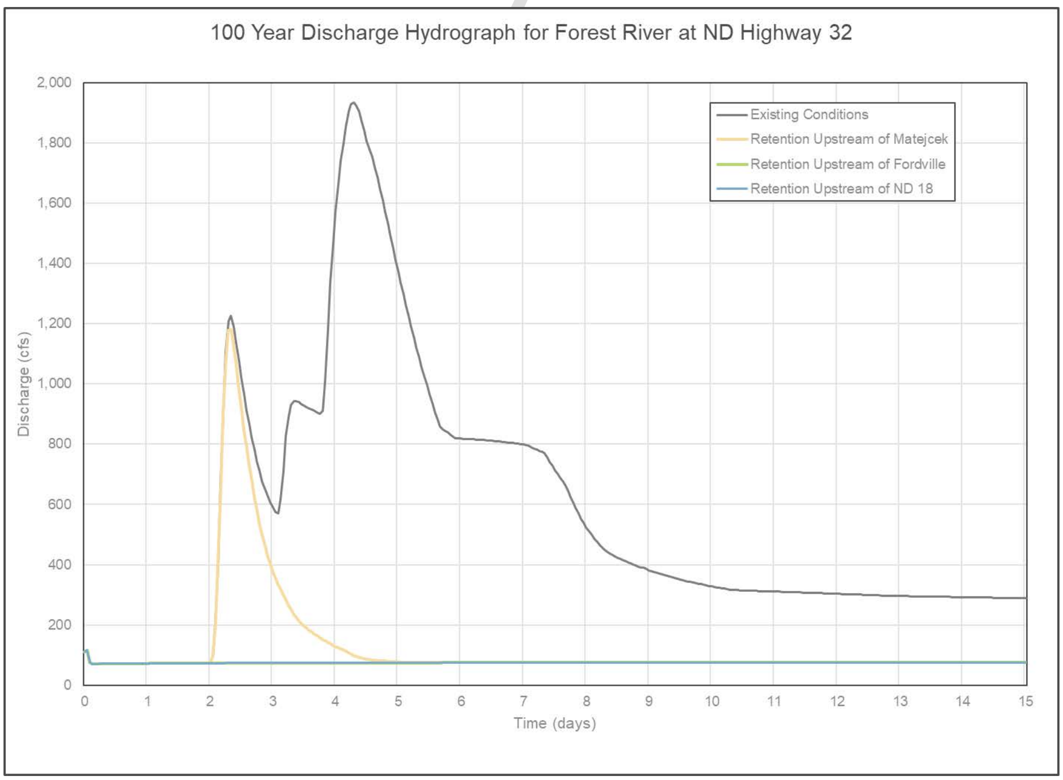

100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain
0
100
200
300
400
500
600
700
800
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

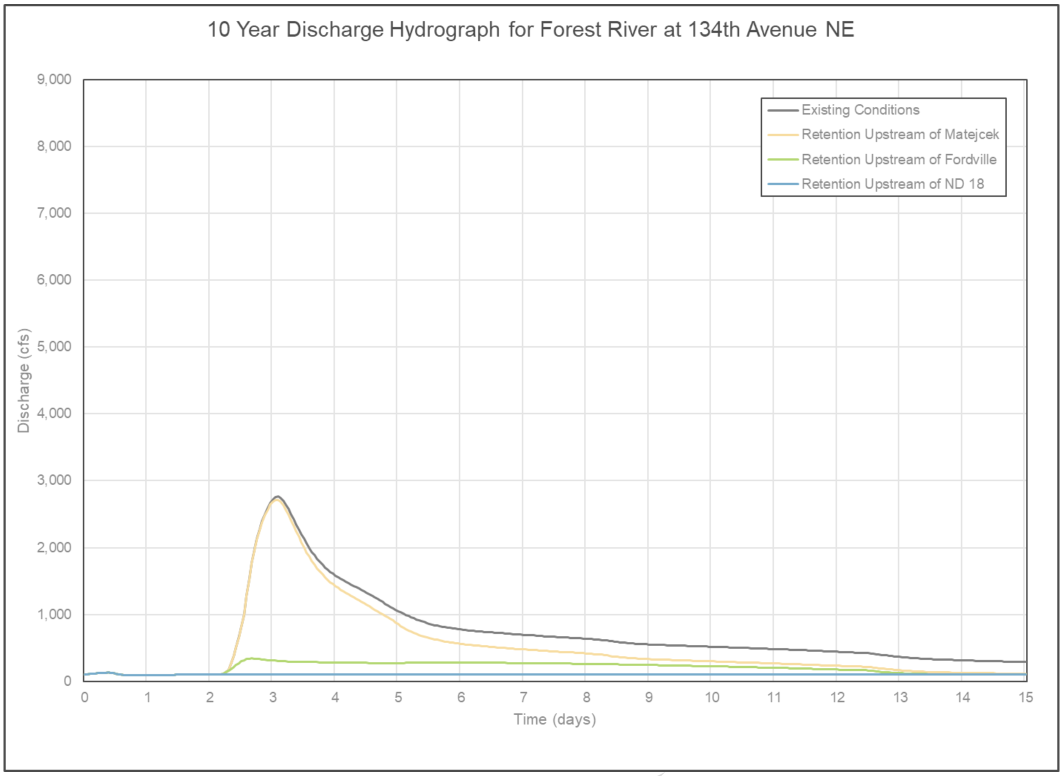

10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain


100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Increase Conveyance Capacity: Along Forest River
Increase Conveyance Capacity: Along Forest River, Ardoch Coulee, and the floodplain

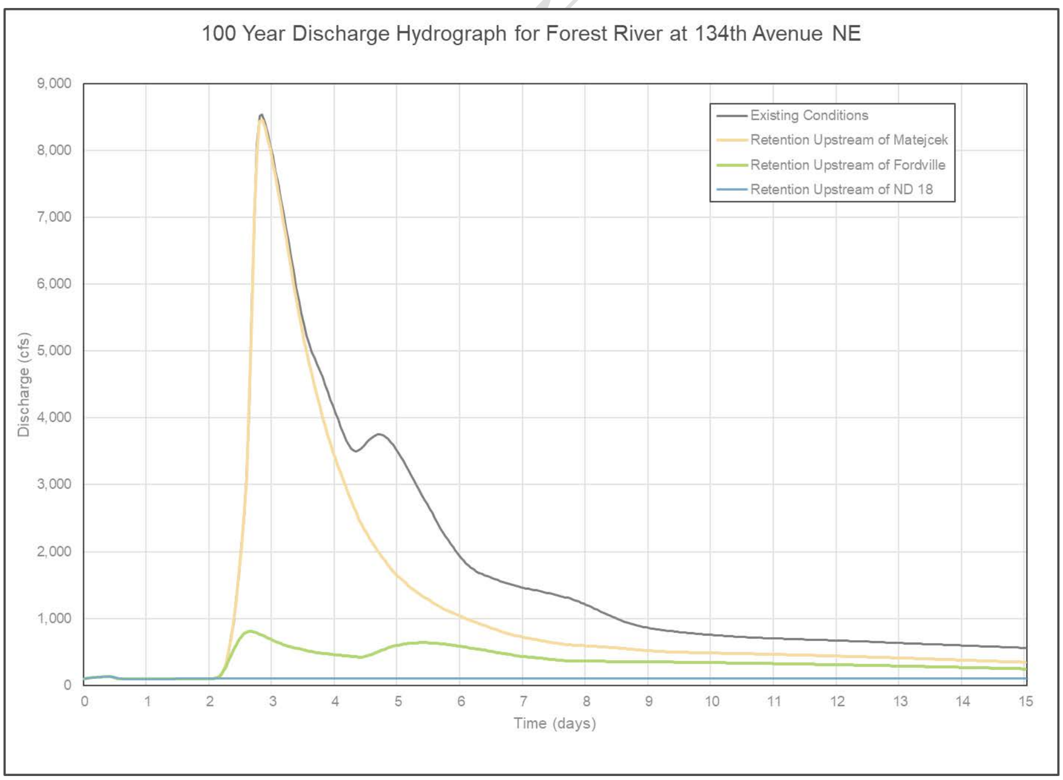
A.4 INCREASE TEMPORARY FLOOD STORAGE – HYDROGRAPHS



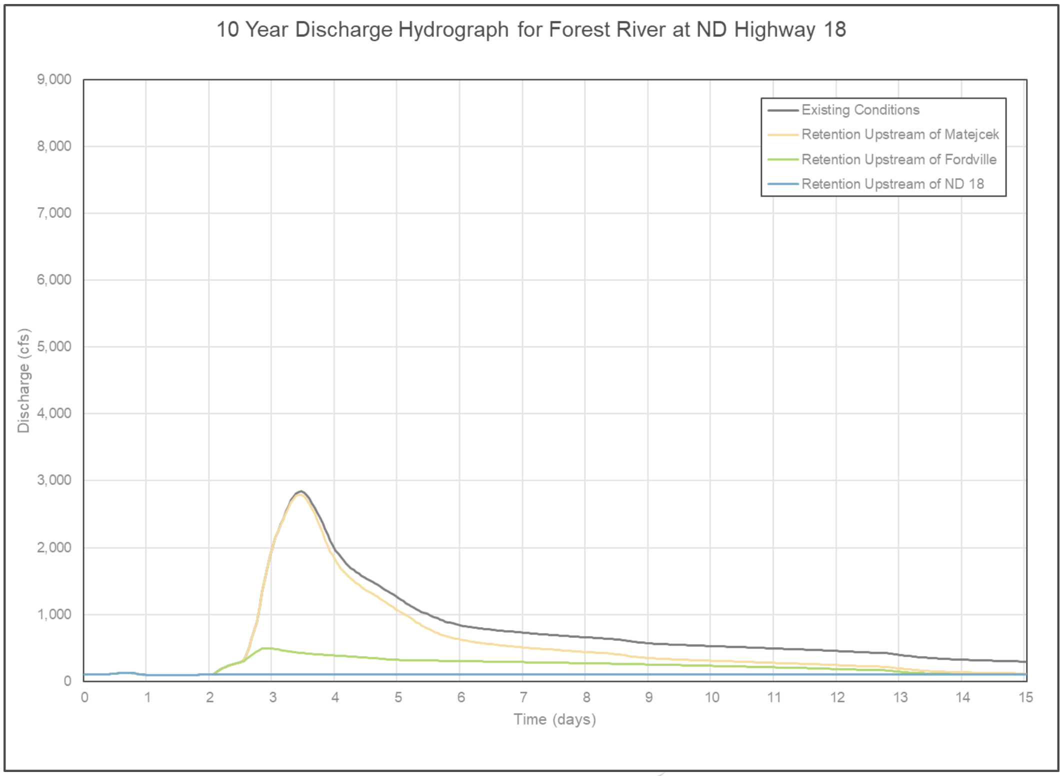


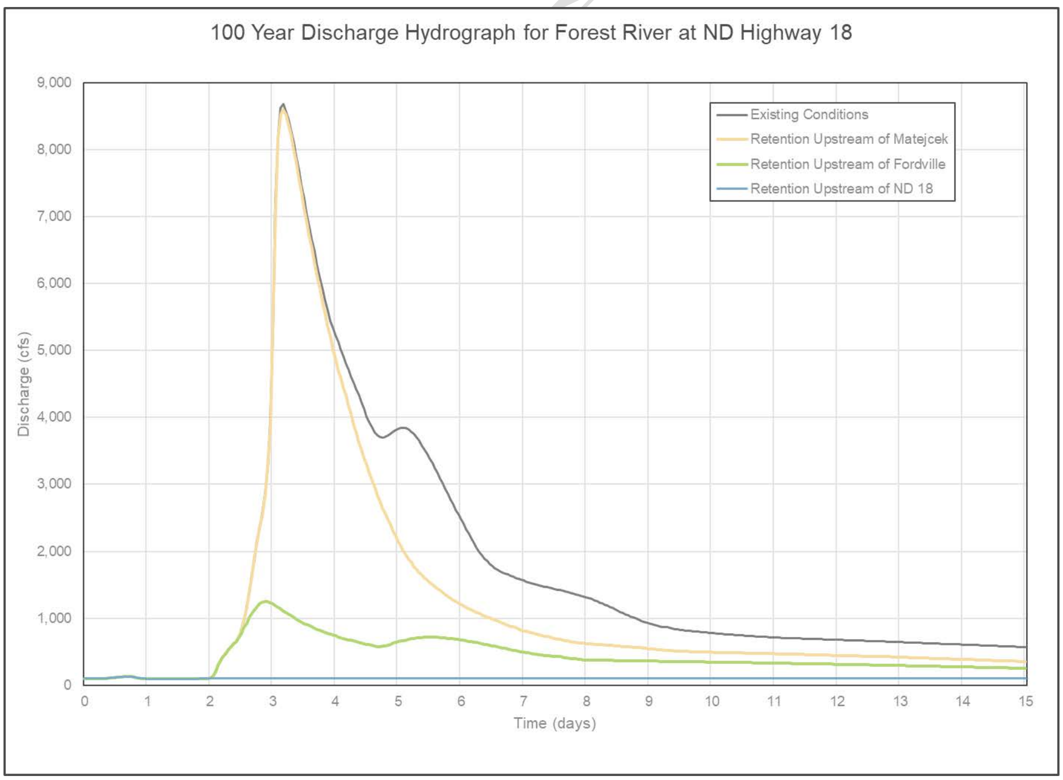


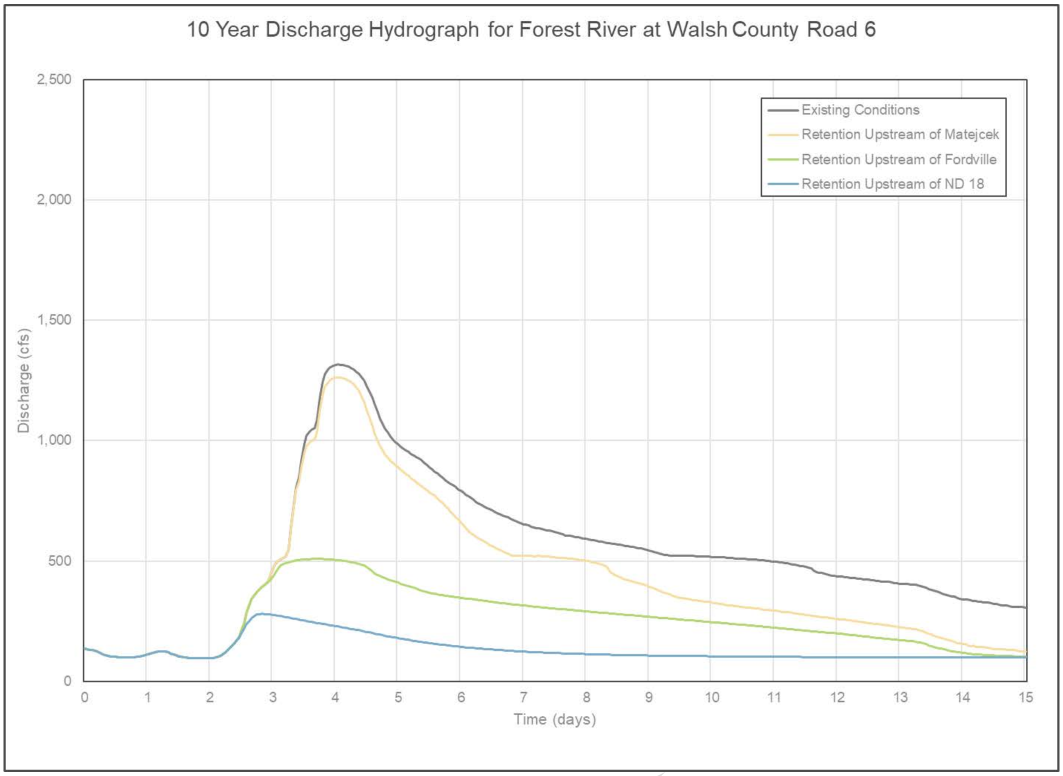
10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)

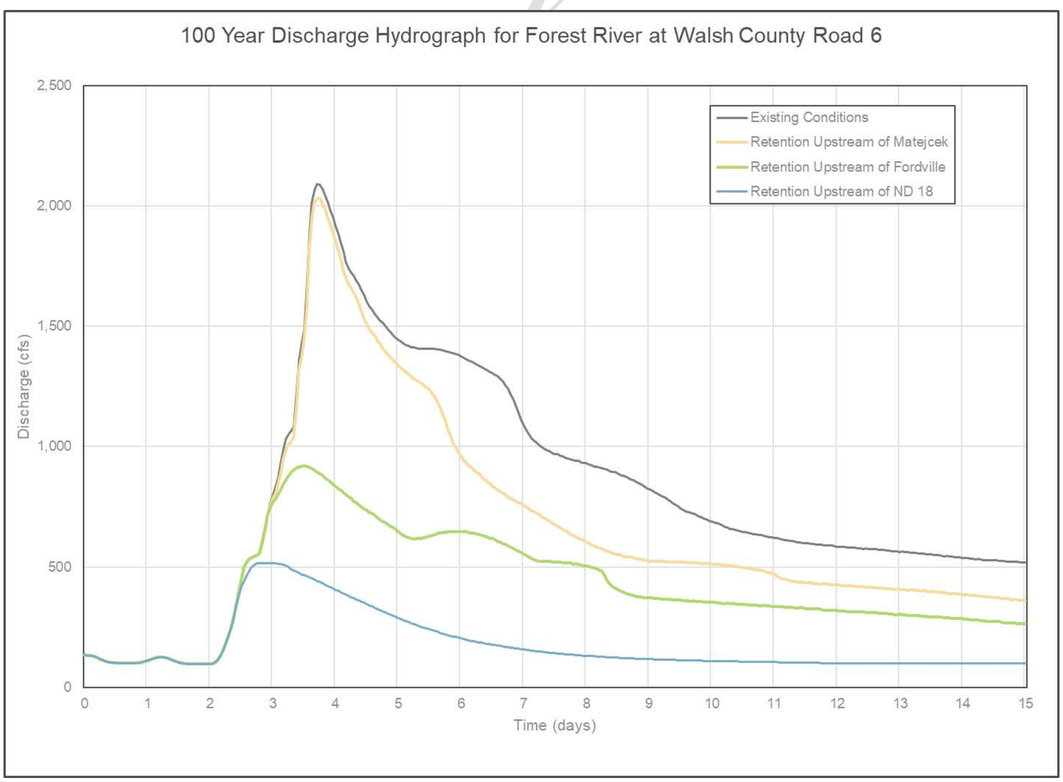


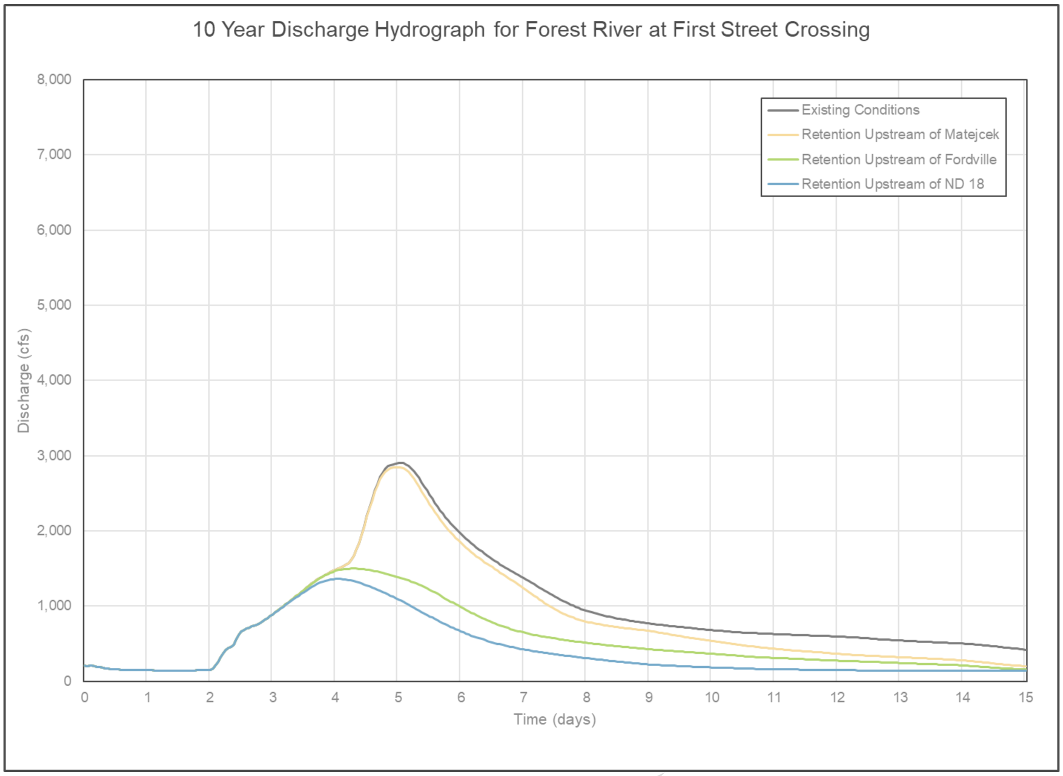
100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)

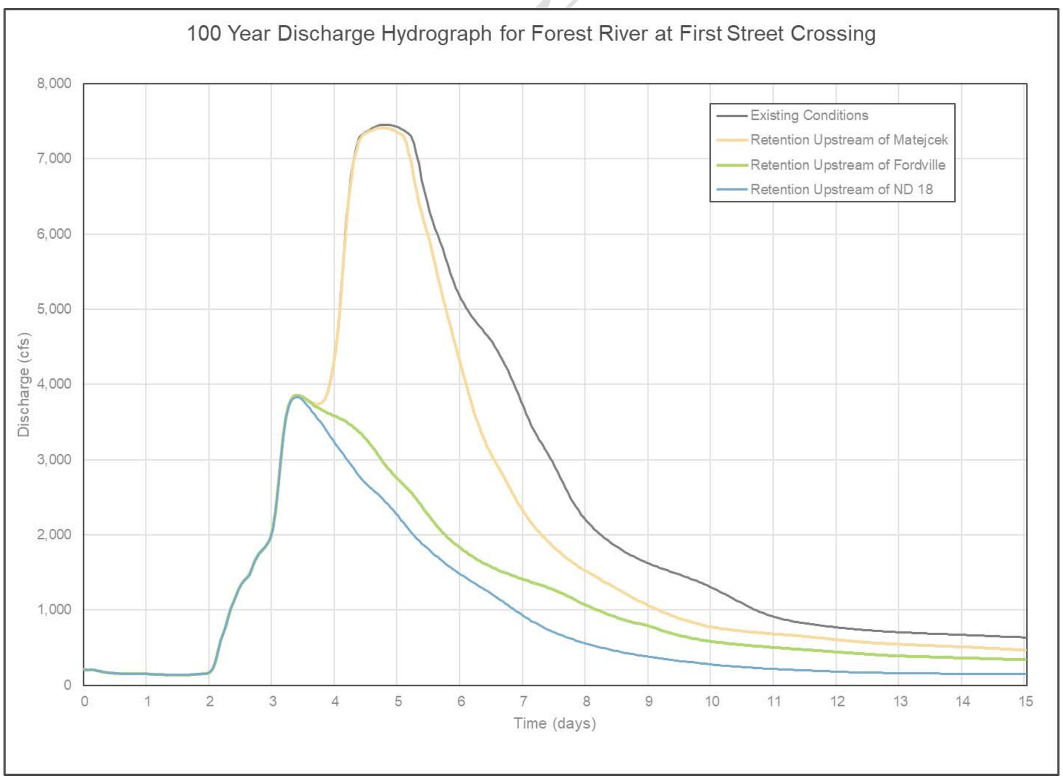

10 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

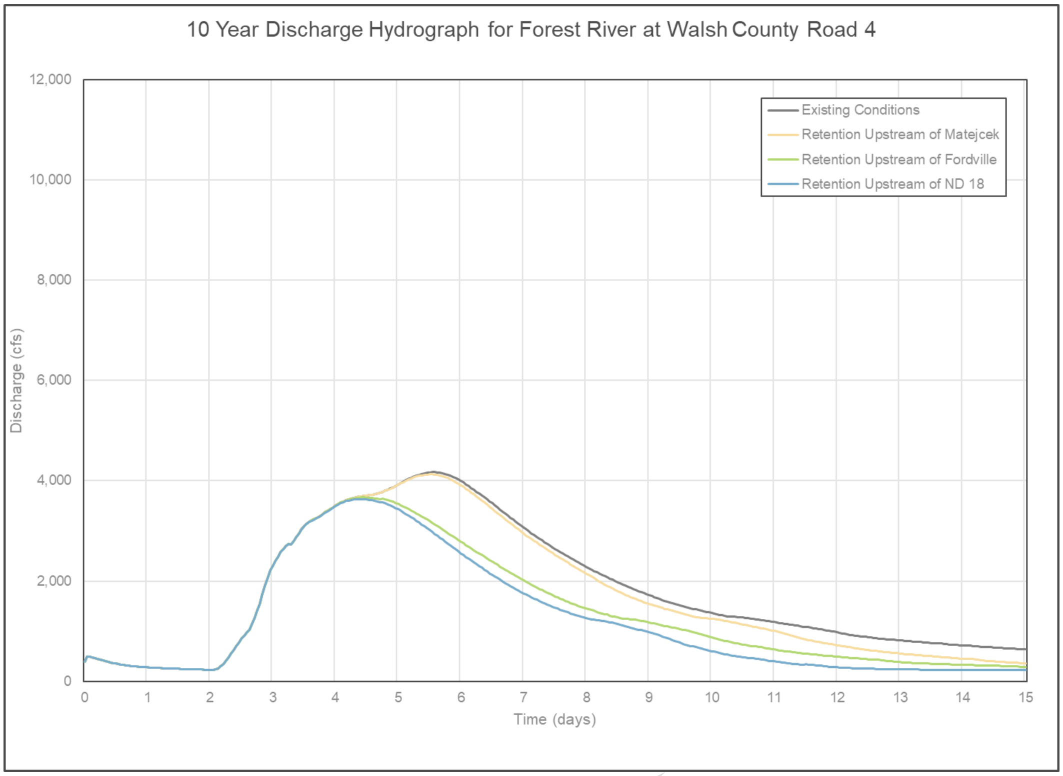

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

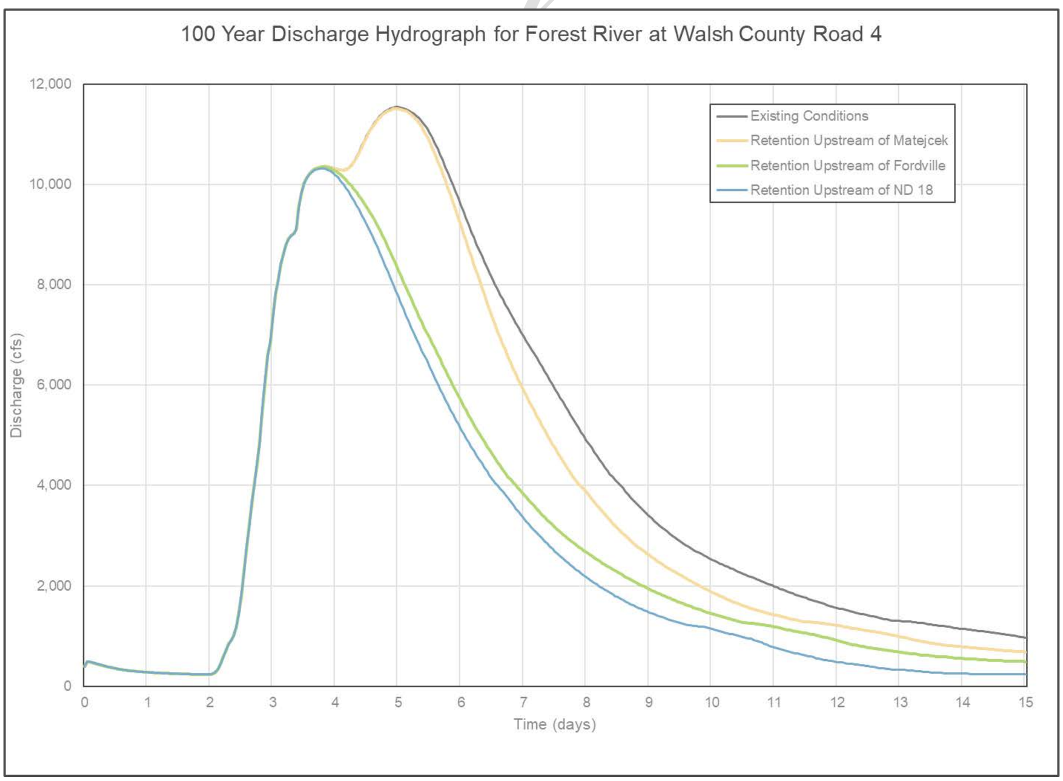

10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

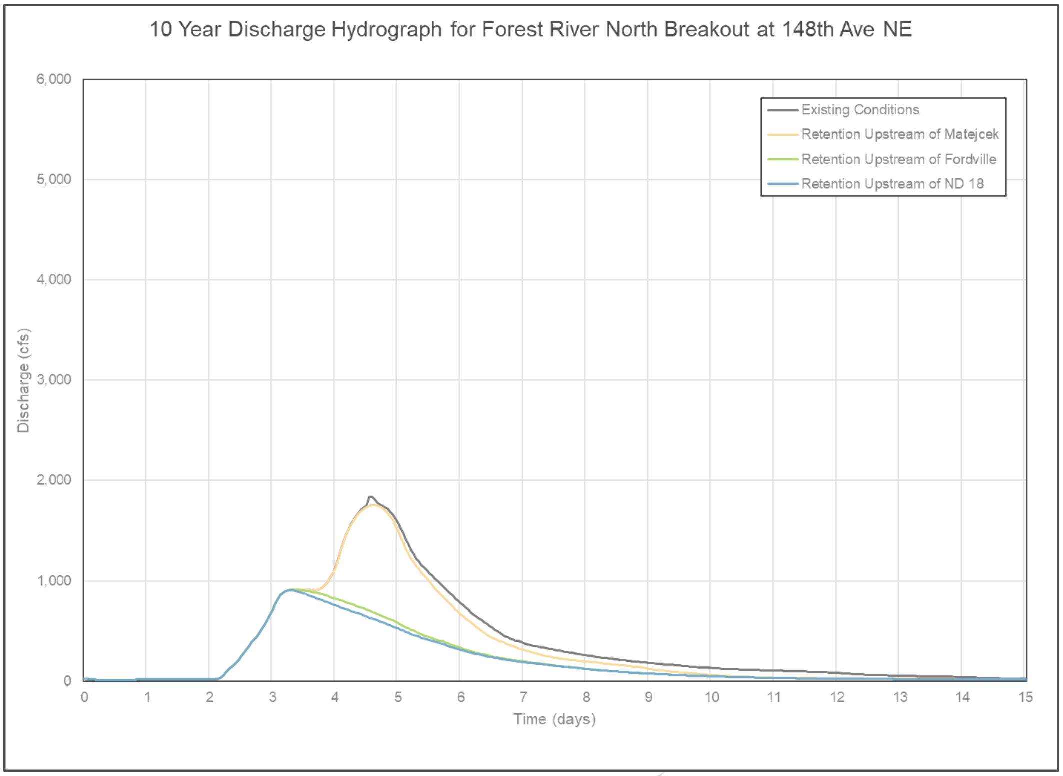

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

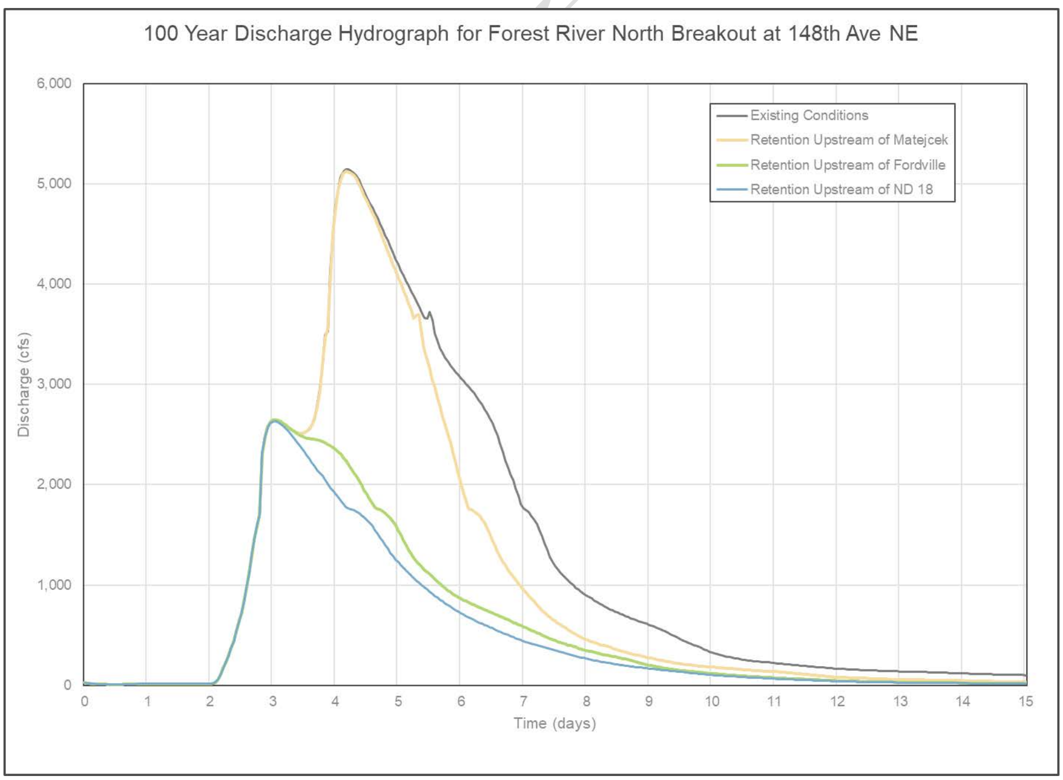

10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

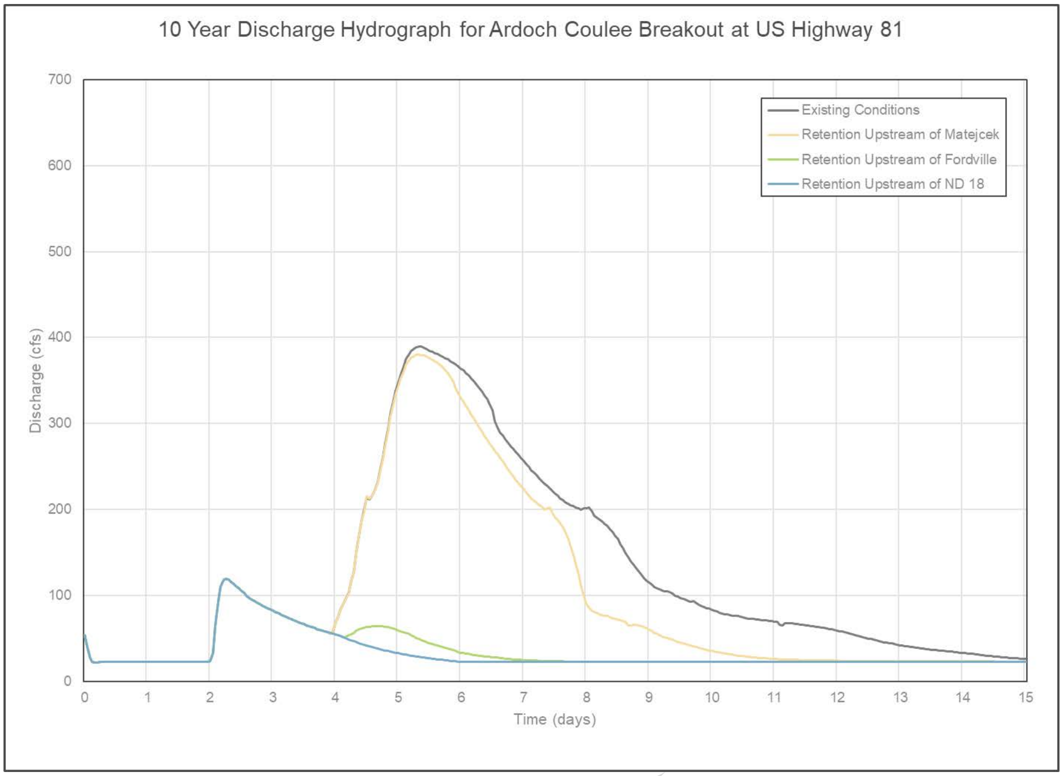

100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

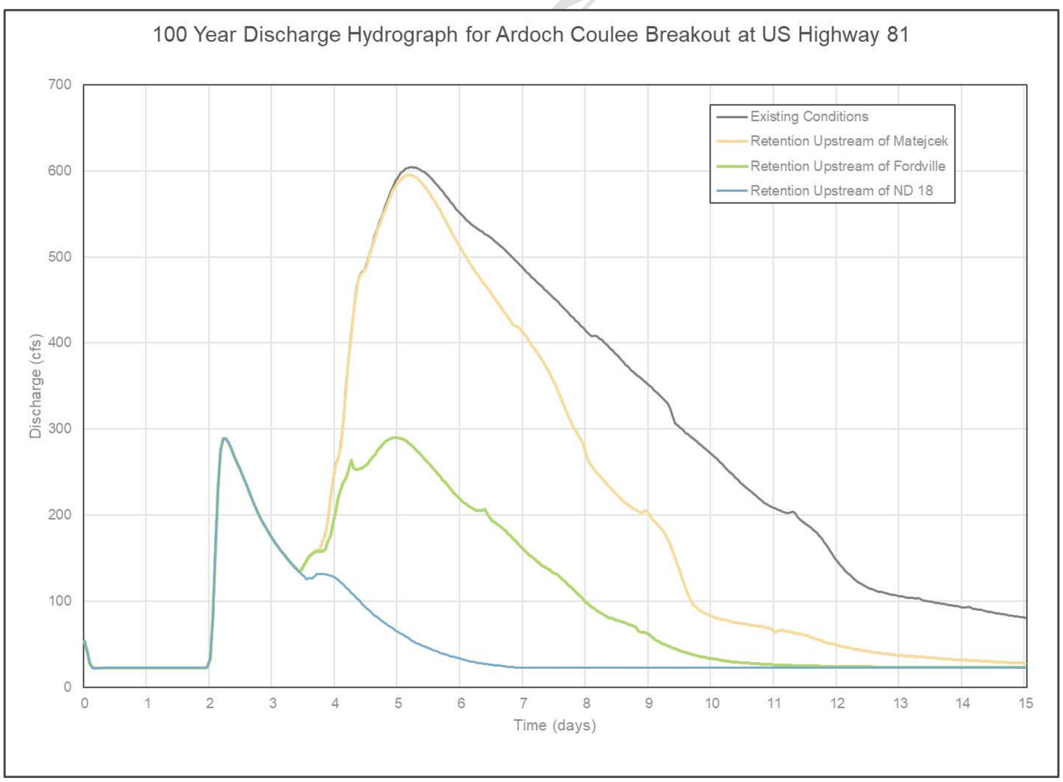

10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

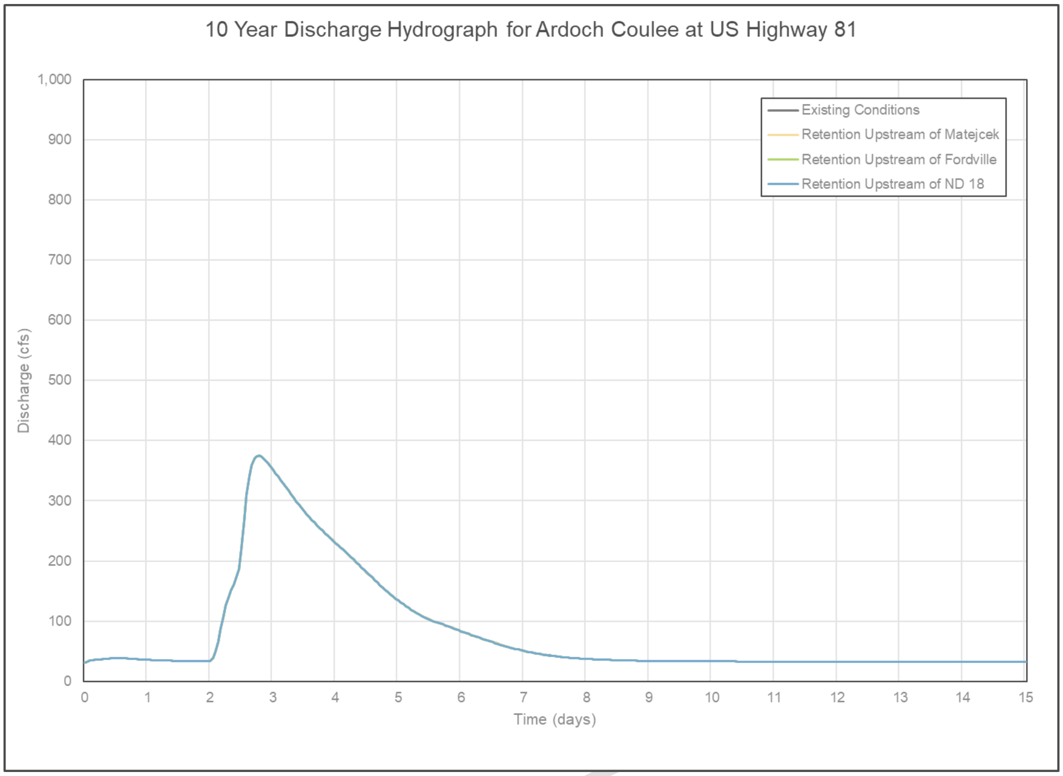

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
Time (days)
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

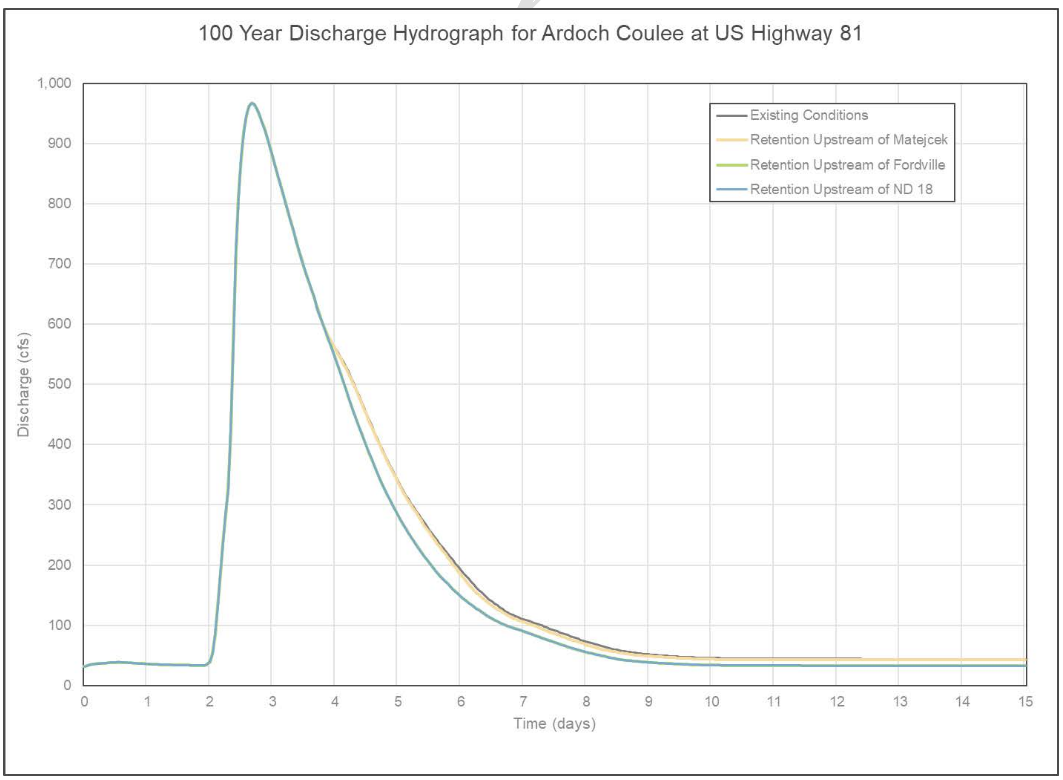

10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Discharge (cfs)
Time (days)
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Discharge (cfs)
Time (days)
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18

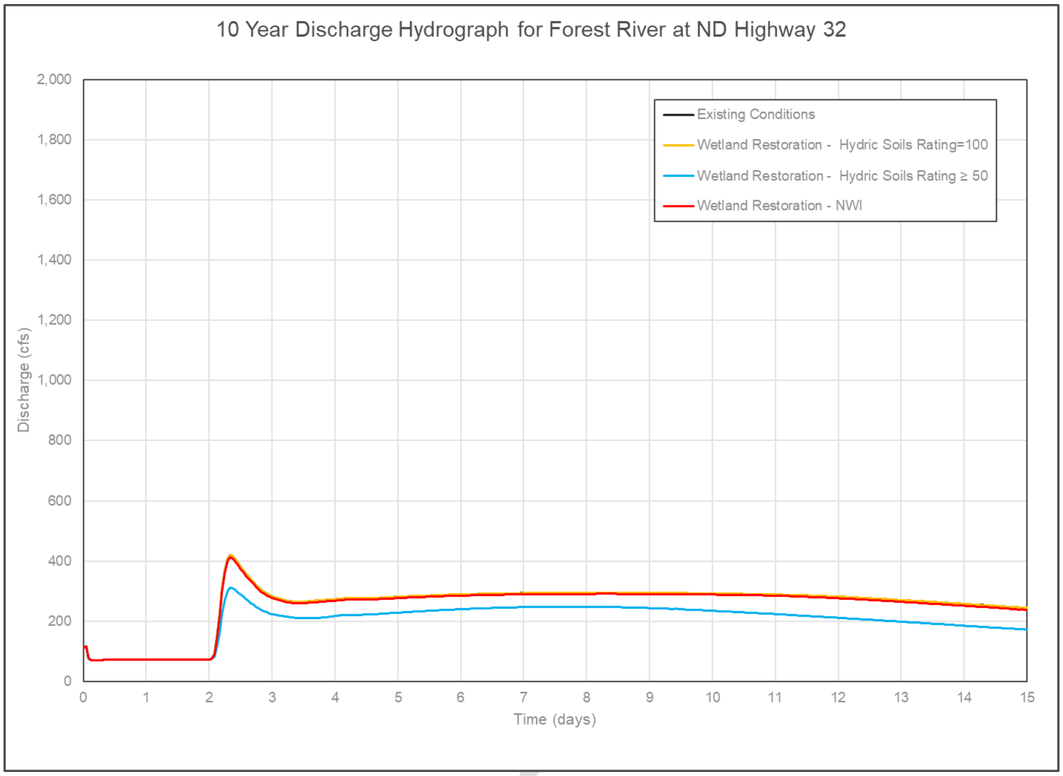

10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
0
100
200
300
400
500
600
700
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

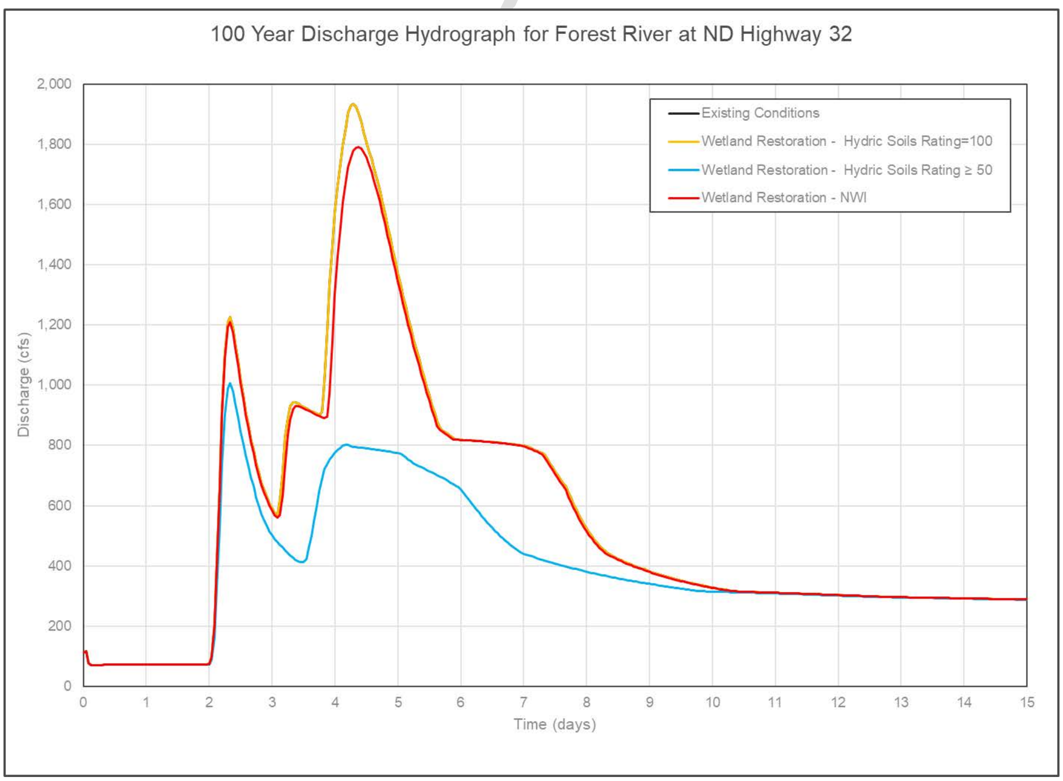

100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18
Discharge (cfs)
0
100
200
300
400
500
600
700
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

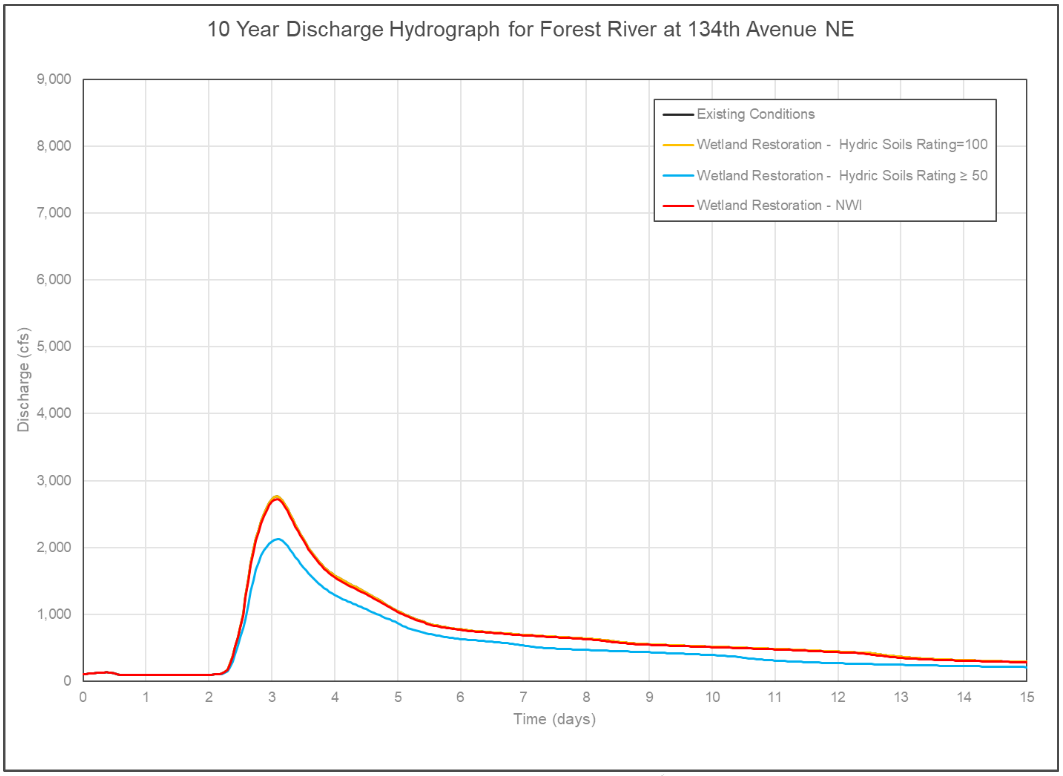

10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18

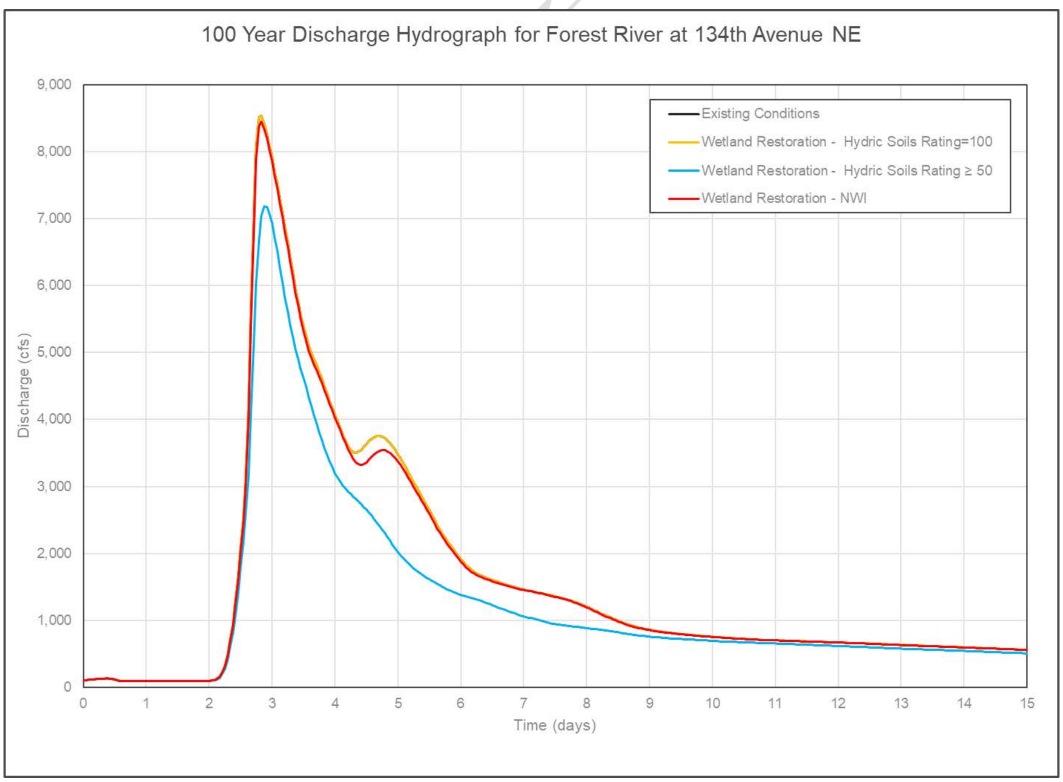

100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Retention Upstream of Matejcek
Retention Upstream of Fordville
Retention Upstream of ND 18

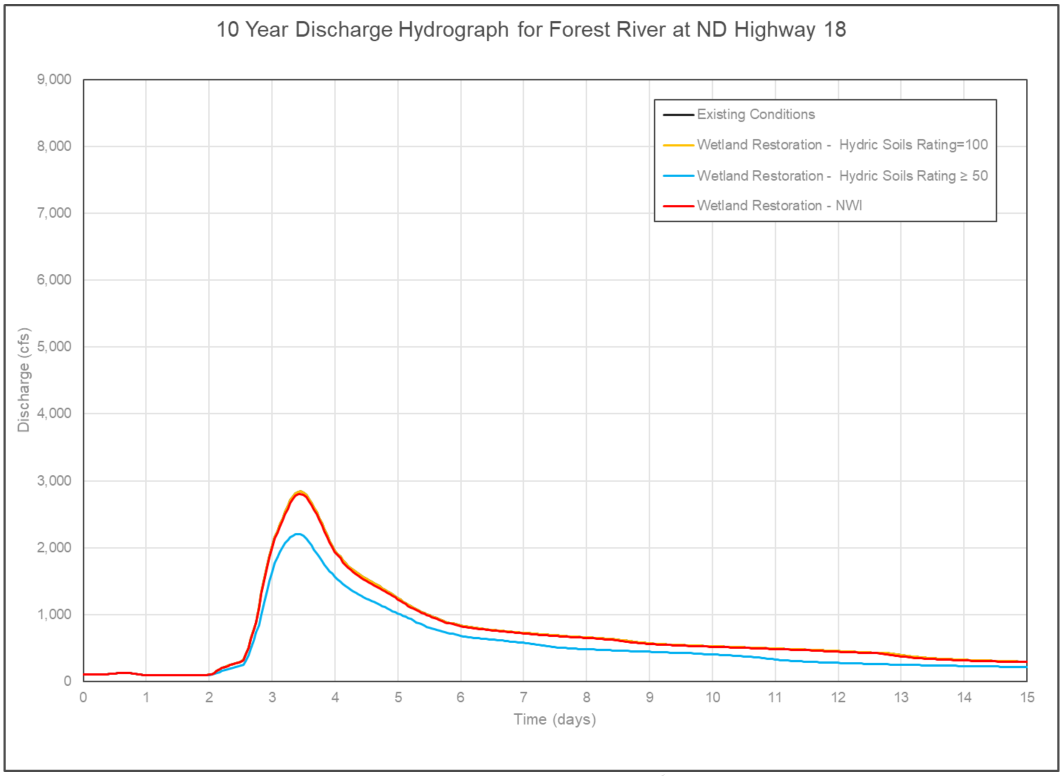
A.5 WETLAND RESTORATION – HYDROGRAPHS



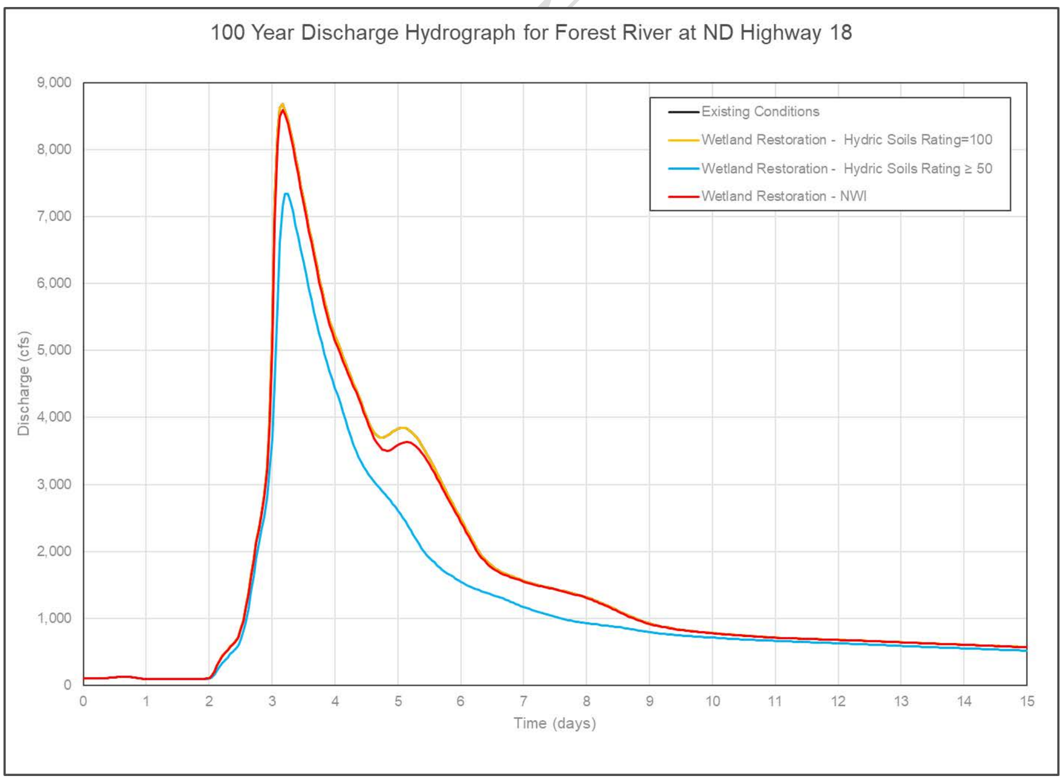



10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

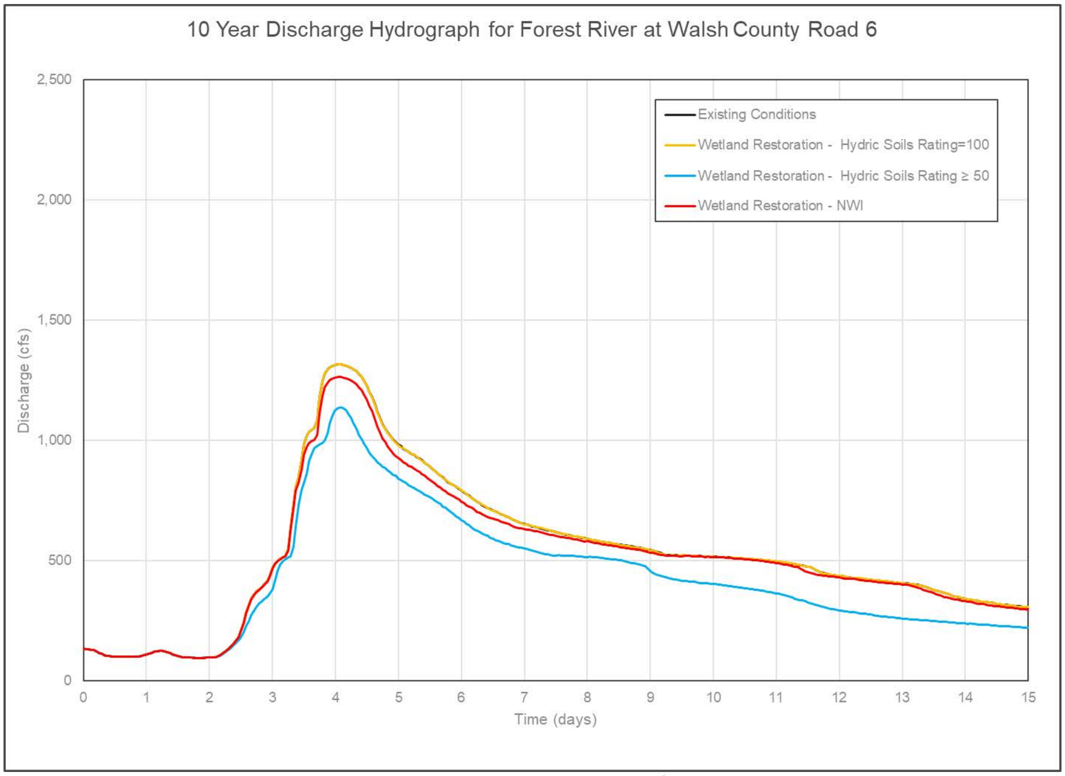

100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

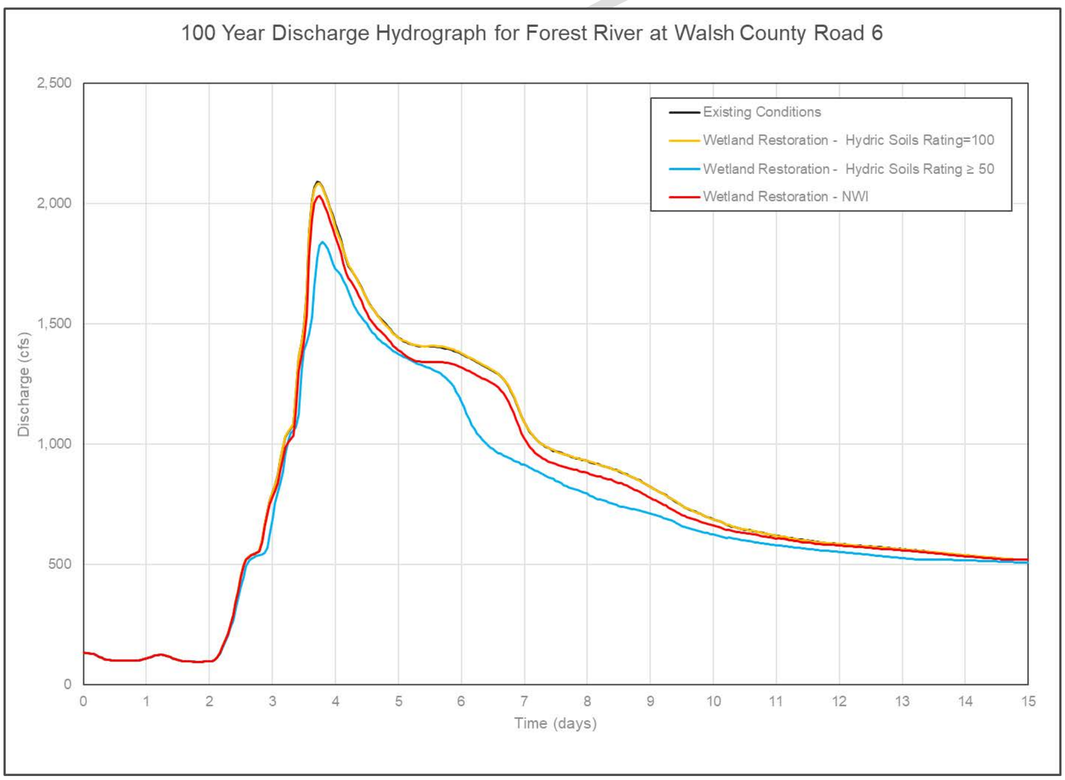


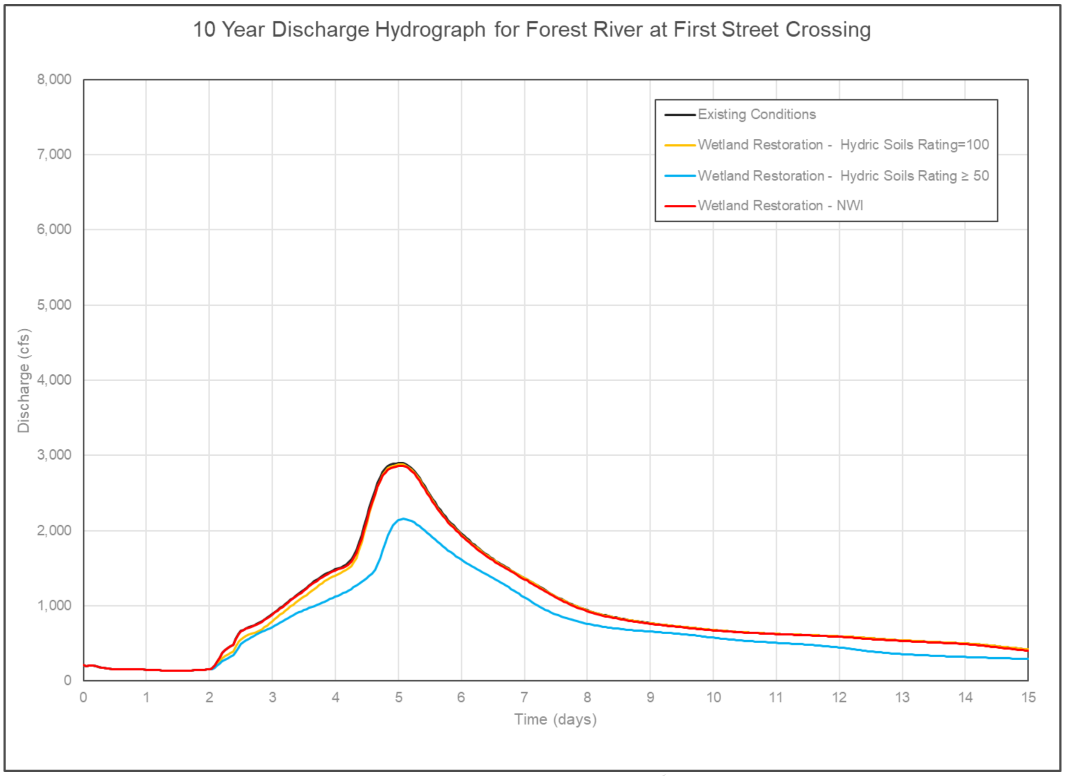
10 Year Discharge Hydrograph for Forest River at ND Highway 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI



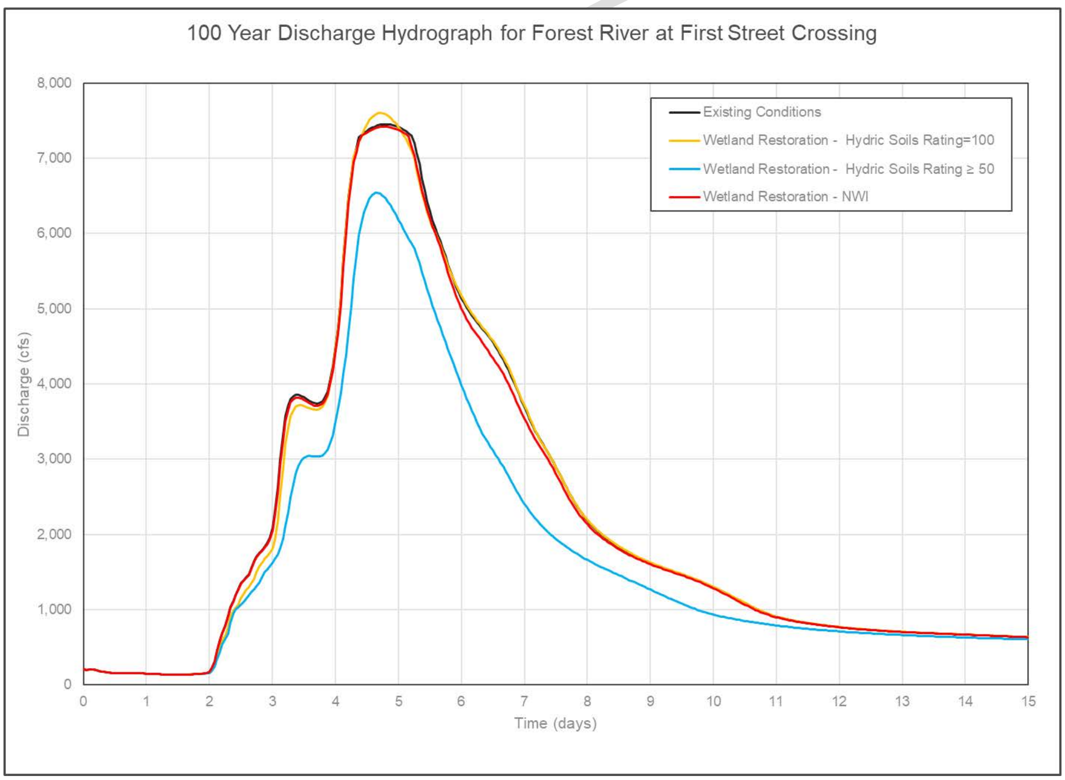
100 Year Discharge Hydrograph for Forest River at ND Highway 18
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI


10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

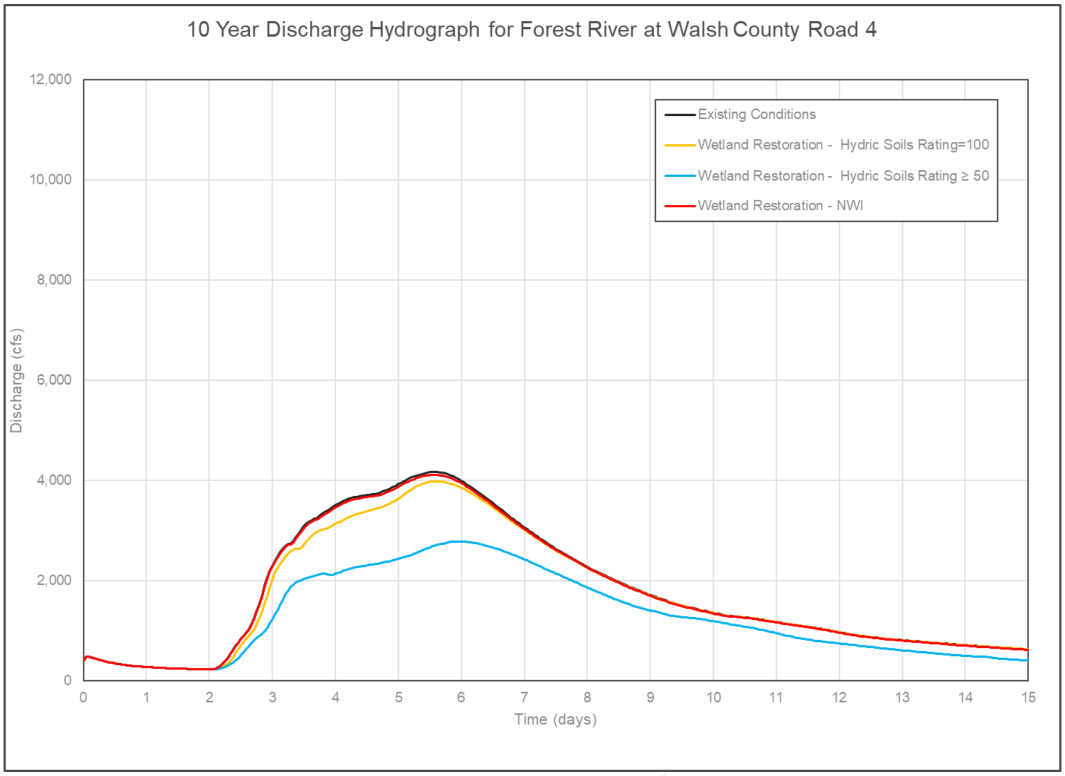

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

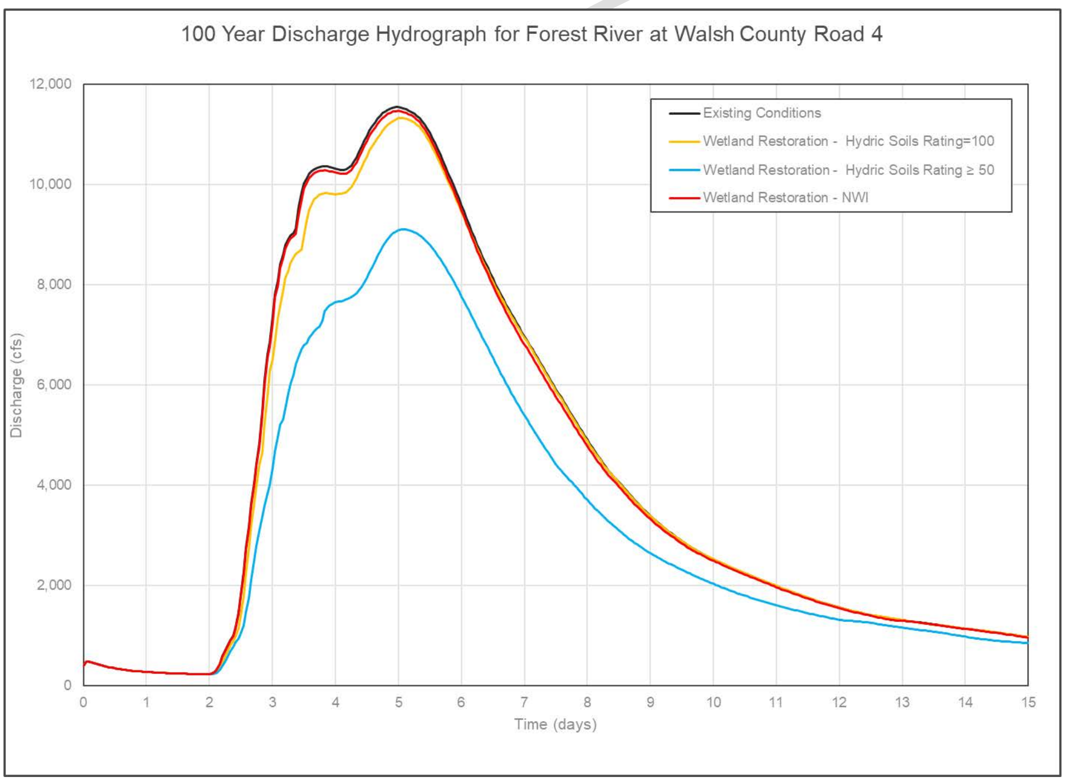


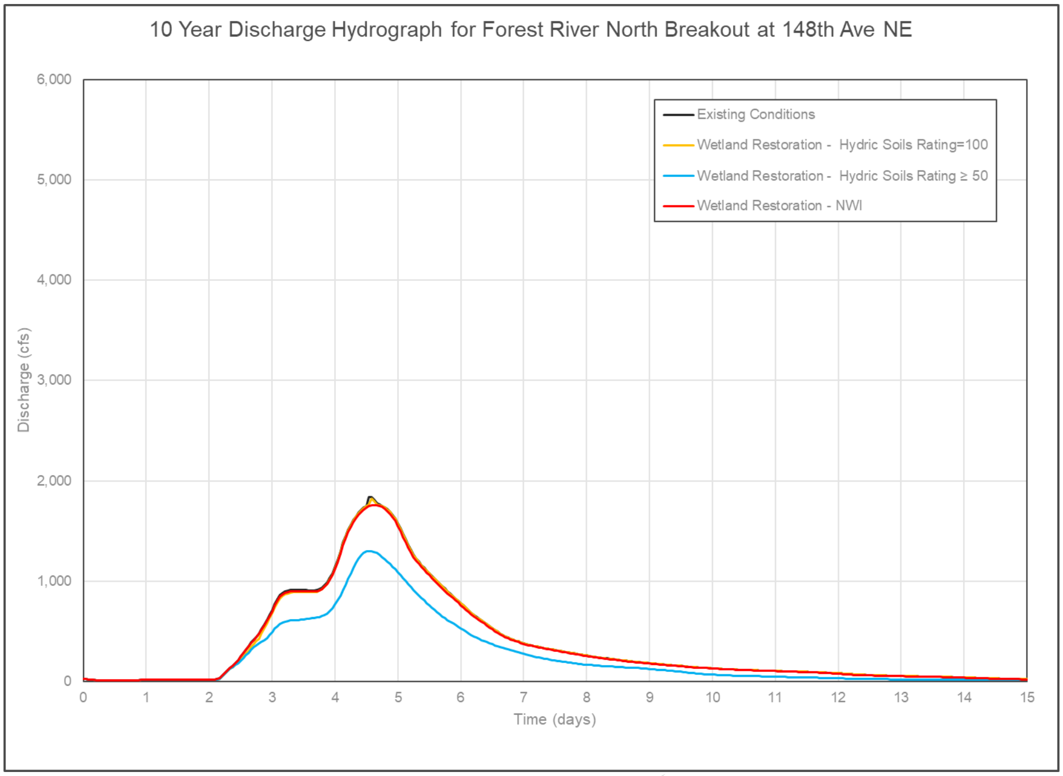
10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

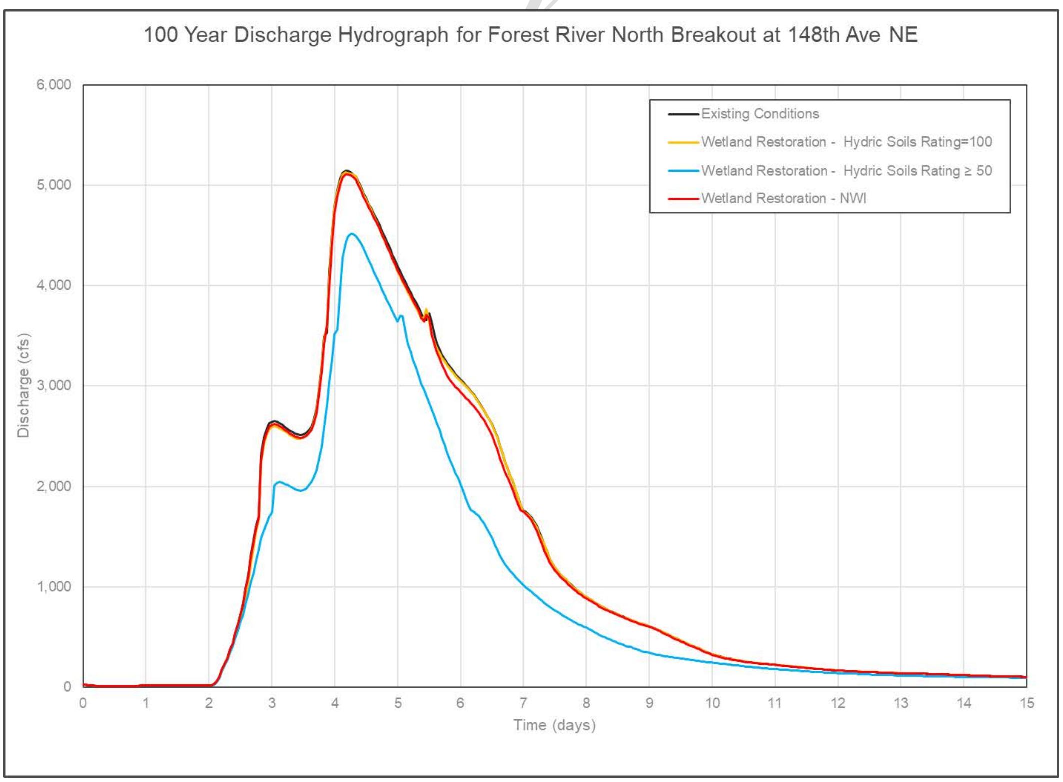


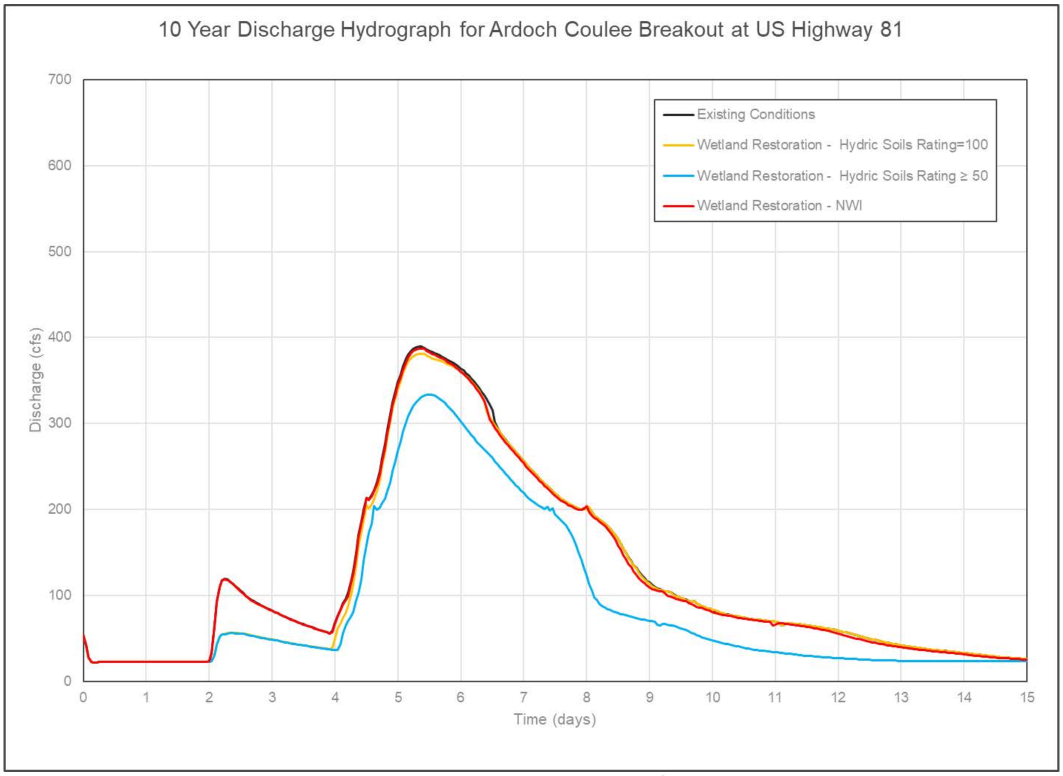
100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

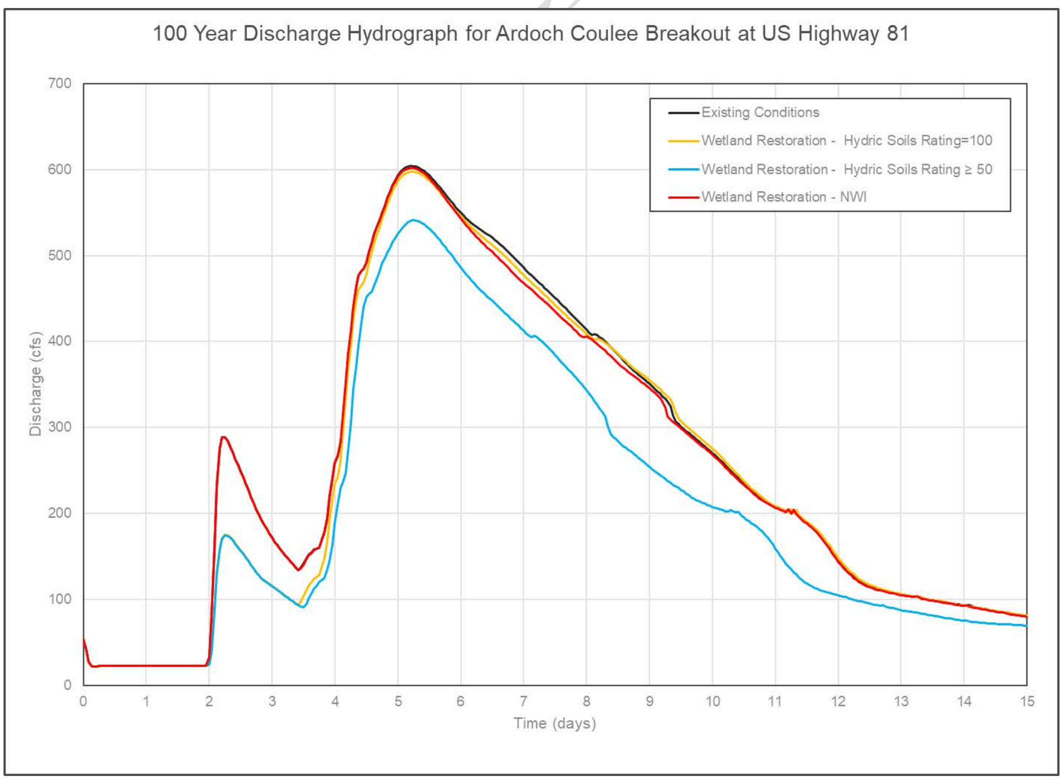

10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
2,000
4,000
6,000
8,000
10,000
12,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

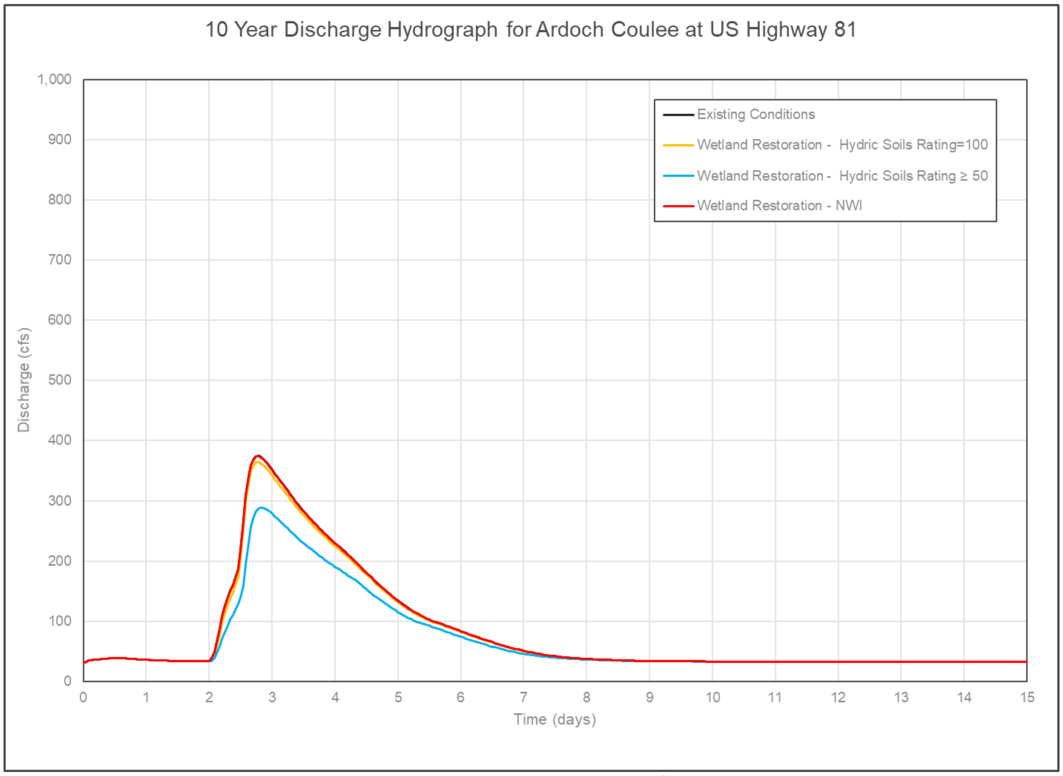

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
2,000
4,000
6,000
8,000
10,000
12,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

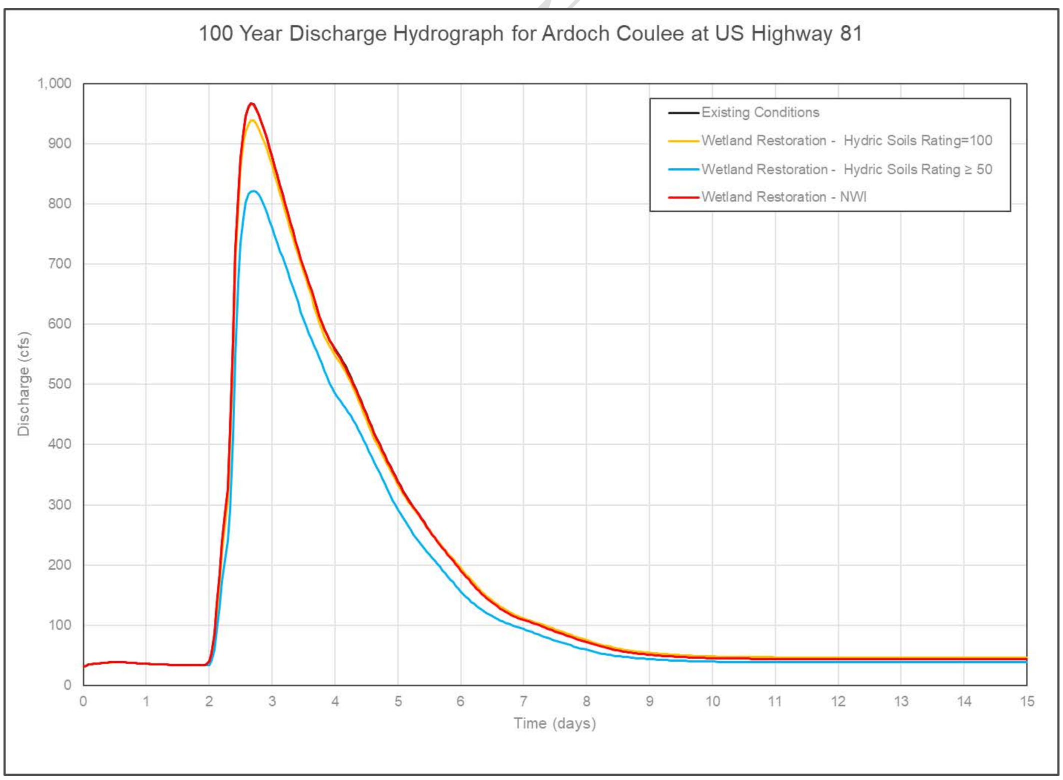

10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
1,000
2,000
3,000
4,000
5,000
6,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Discharge (cfs)
Time (days)
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
0
1,000
2,000
3,000
4,000
5,000
6,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

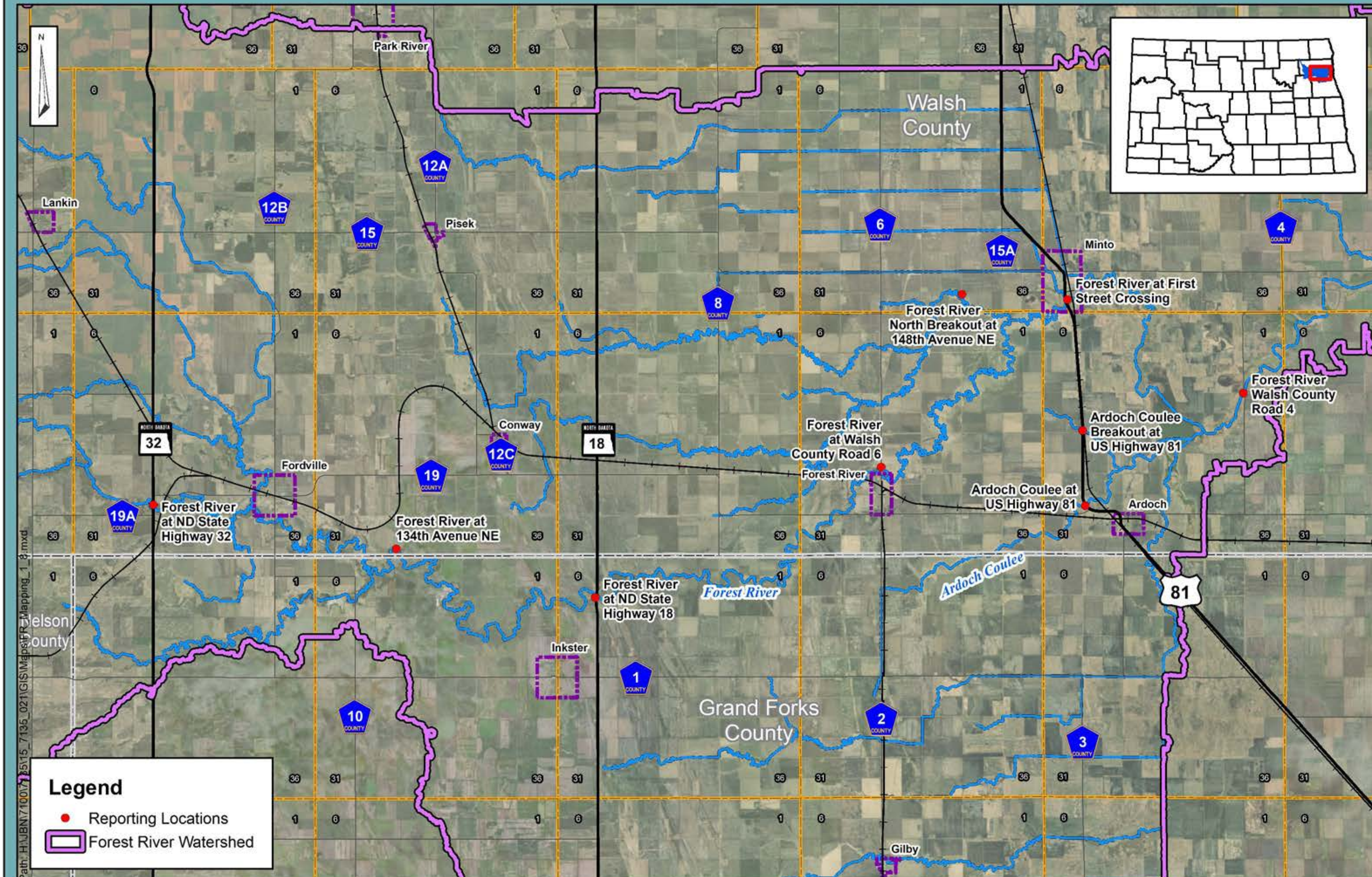

100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
800
900
1,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Existing Conditions
Wetland Restoration - Hydric Soils Rating=100
Wetland Restoration - Hydric Soils Rating ≥ 50
Wetland Restoration - NWI
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
800
900
1,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

APPENDIX B

Figure B.1: Identified Alternative Reporting Locations
B.2 Alternatives 1-2 – No-Action and Setback Levees – Hydrographs
B.3 Alternatives 3-4 – Site FR1-M and Site FR2-NB – Hydrographs
B.4 Alternatives 5-6 – Ardoch Coulee Bypass Site FR3-AR – Hydrographs



F-B.1

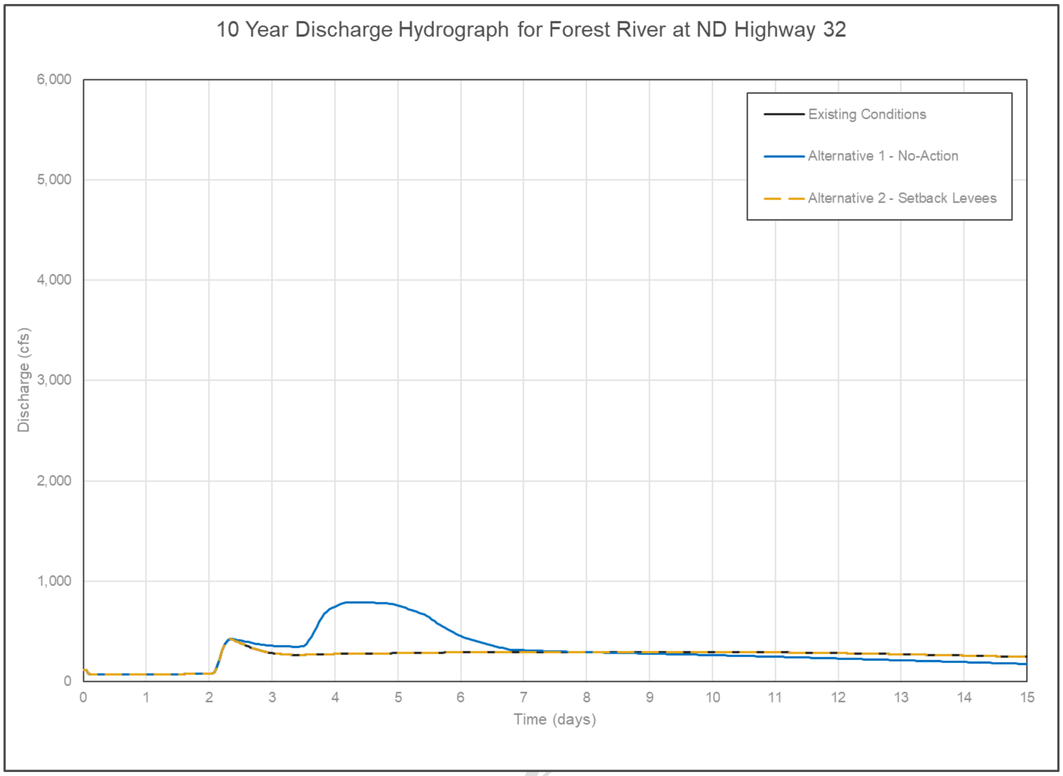
Figure B.1: Identified Alternative - Reporting Locations

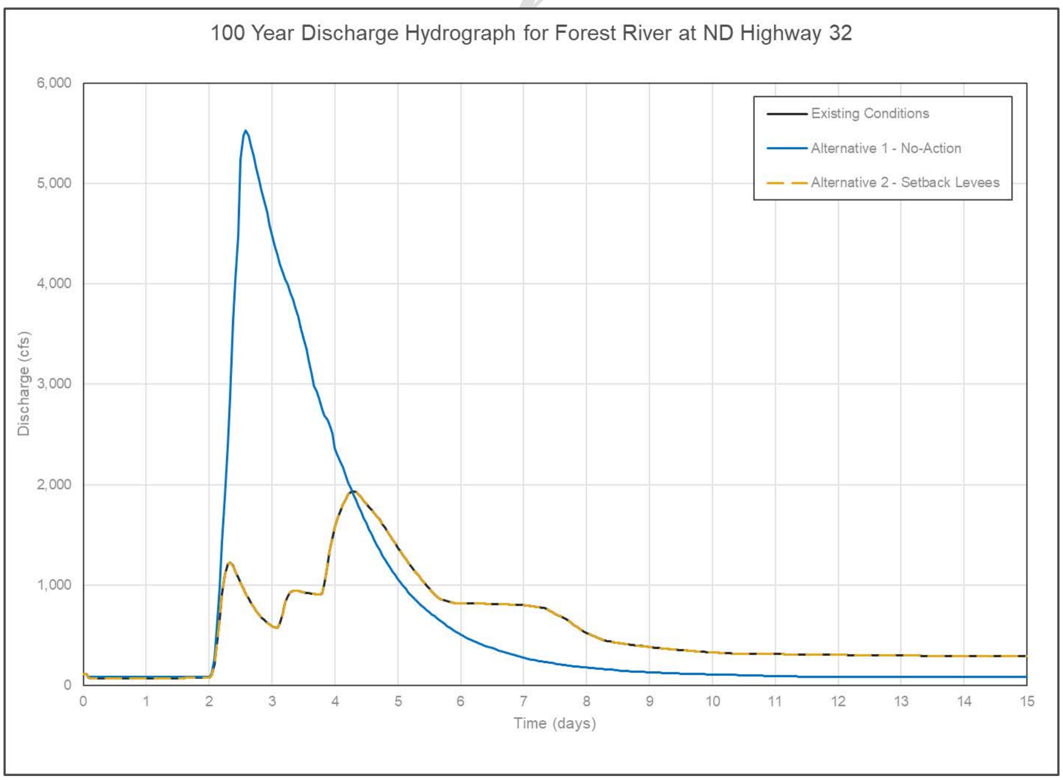
Forest River Watershed
Screening of Alternatives for Detailed Review
Forest River Joint Water Resource District

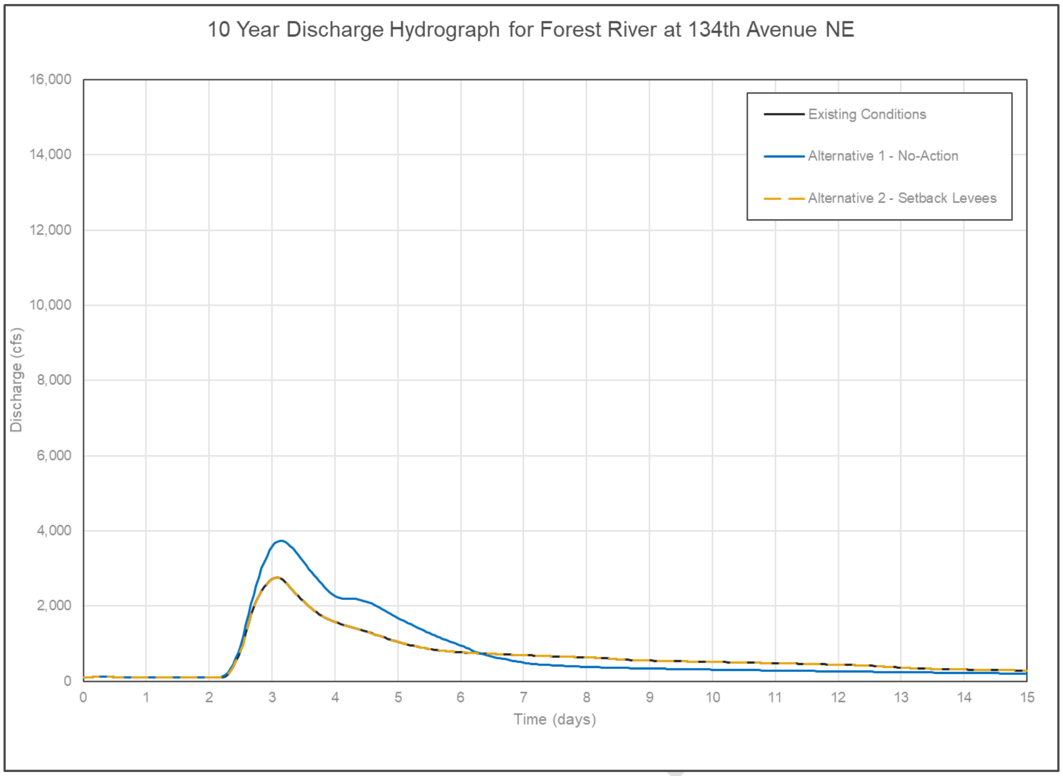
0 1.5 3 6 Miles

Houston Engineering Inc.

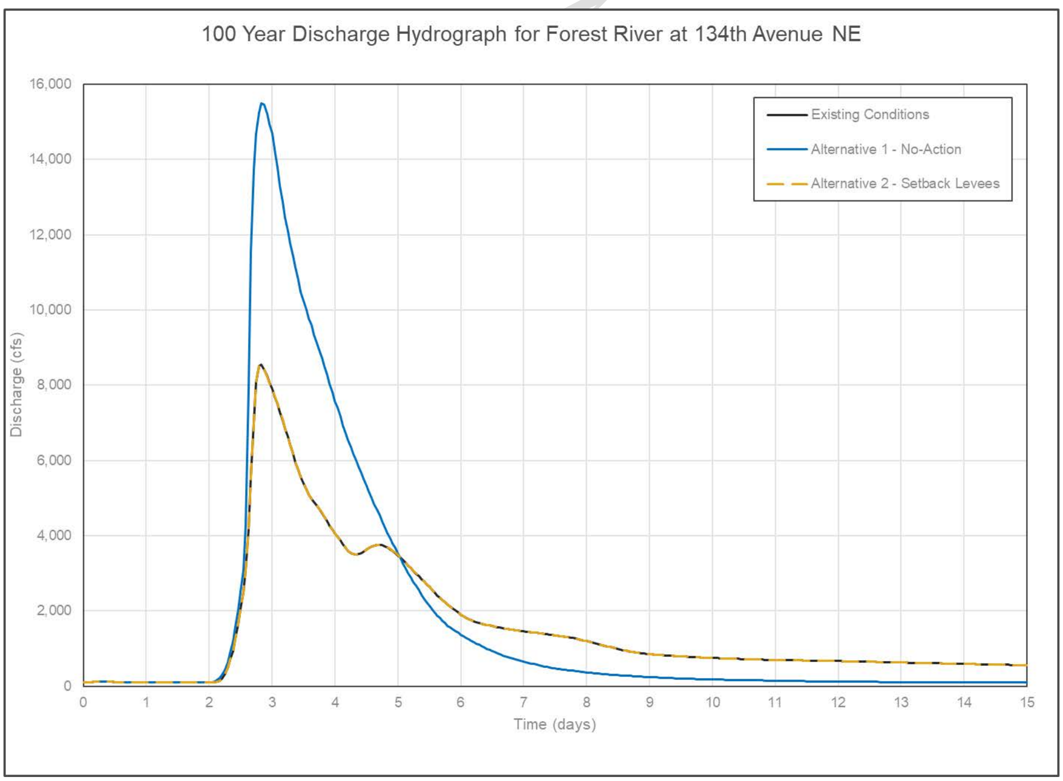
B.2 ALTERNATIVES 1-2 – NO ACTION AND SETBACK LEVEE - HYDROGRAPHS



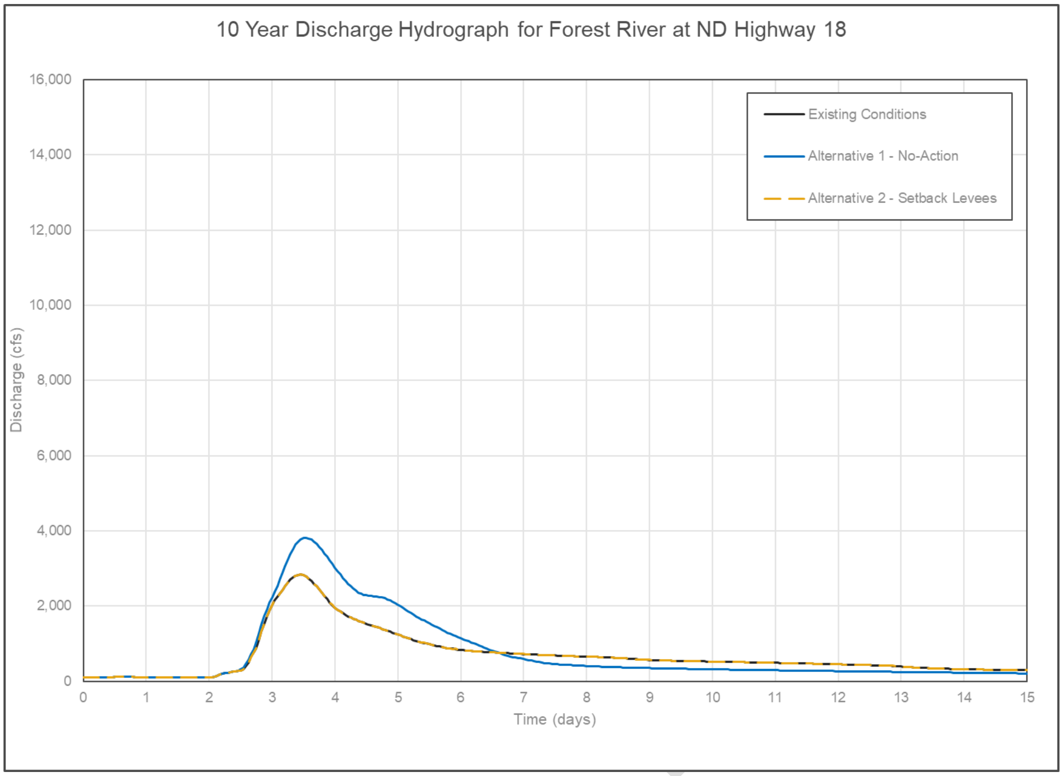


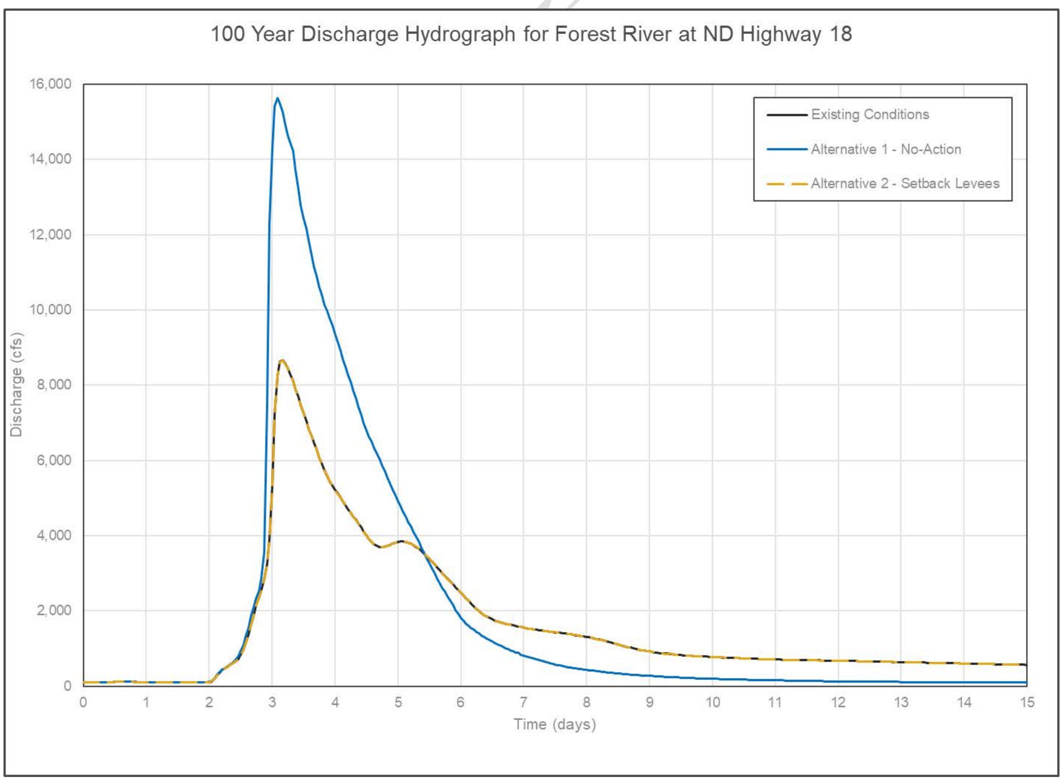


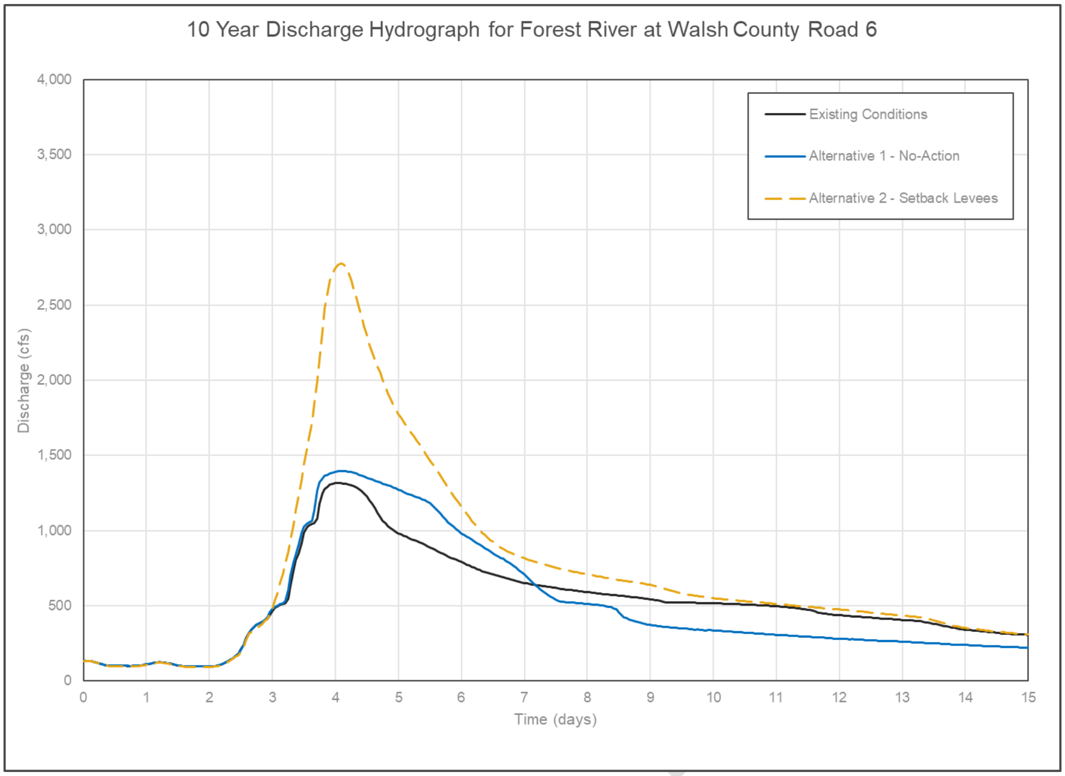
10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

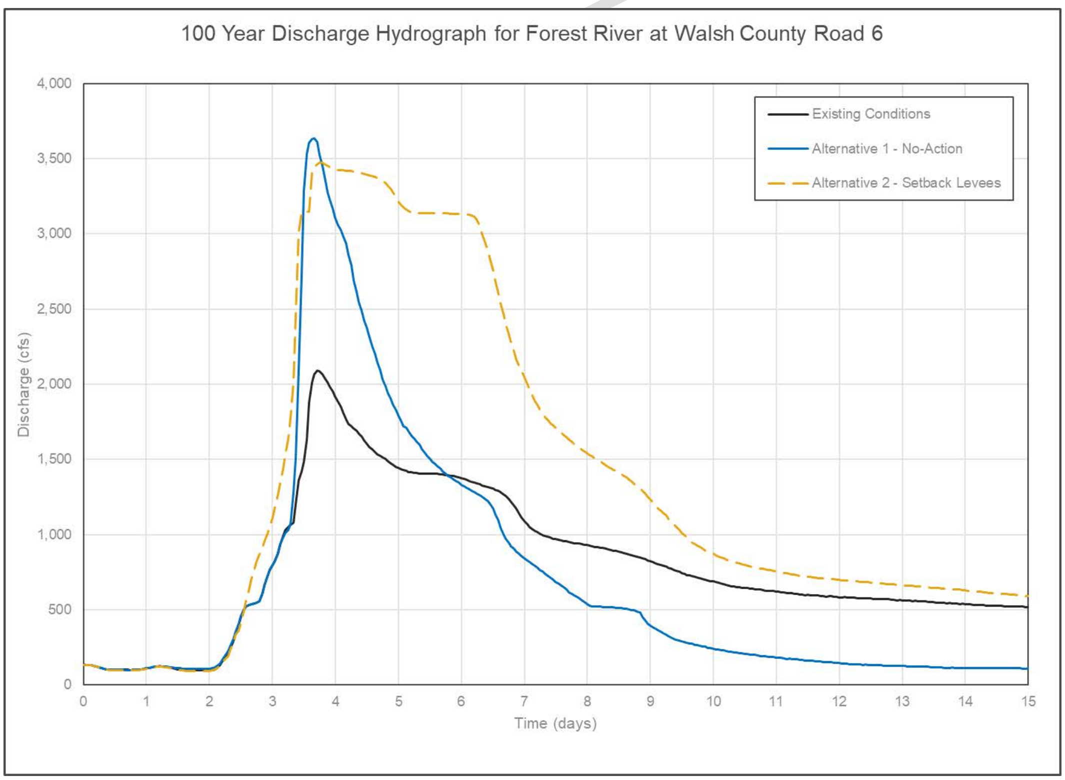


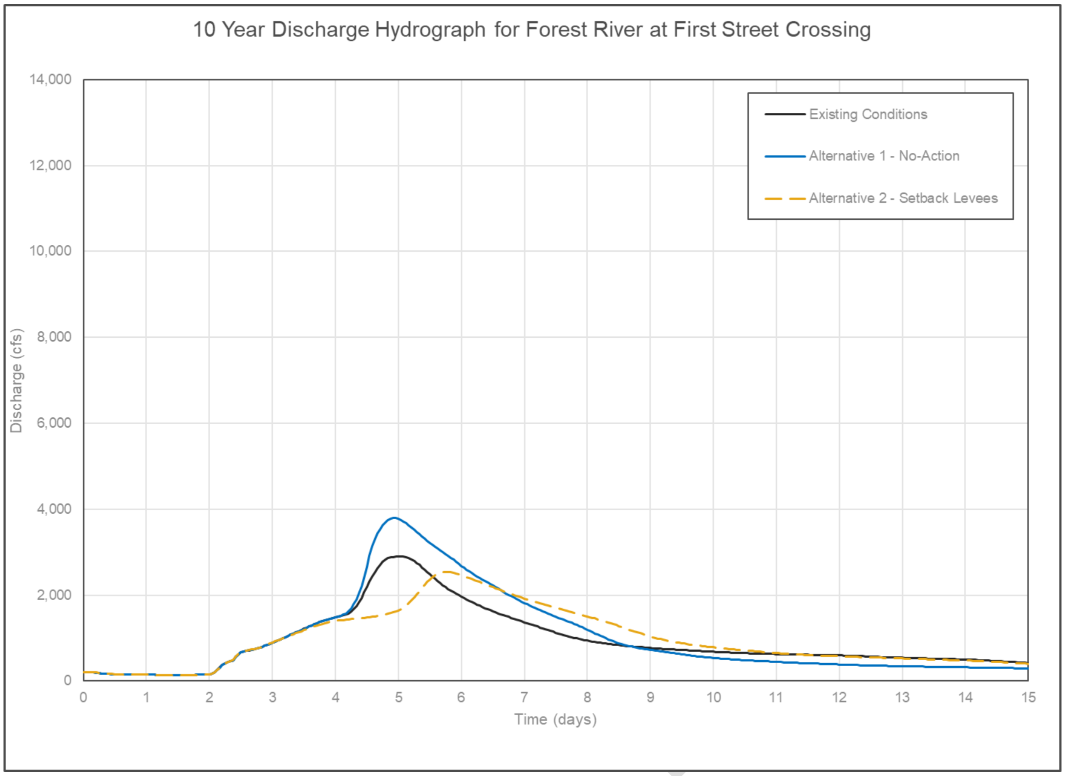
100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)


10 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
Time (days)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

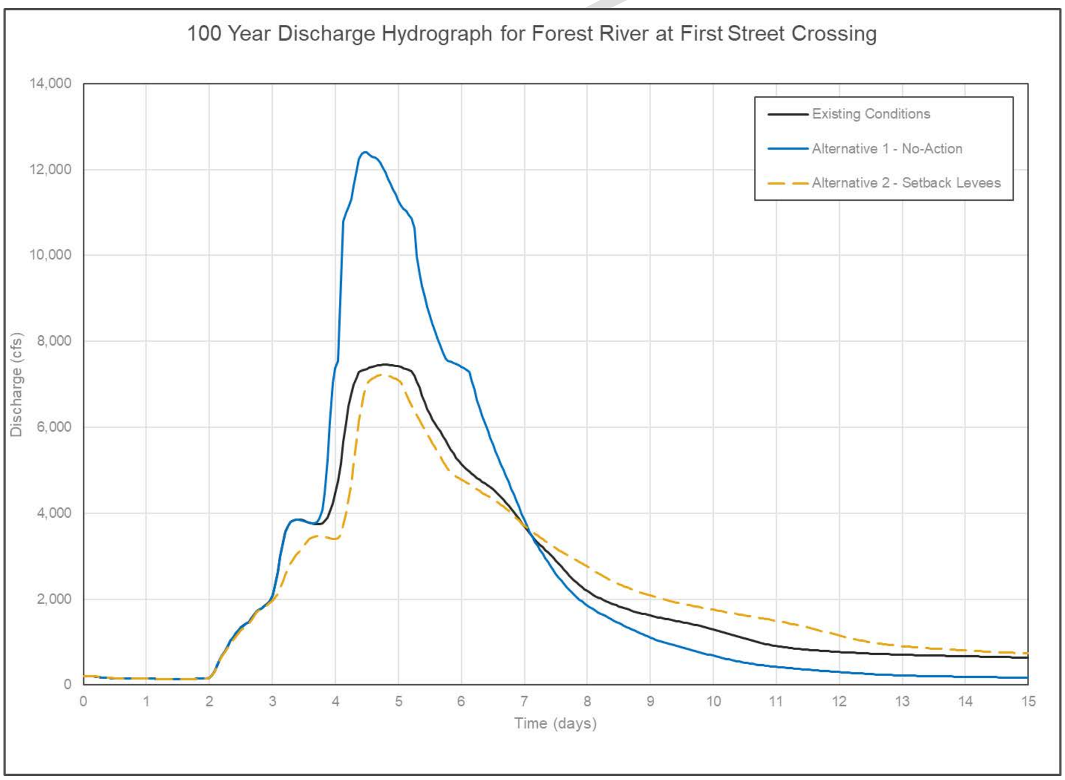

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
Time (days)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees

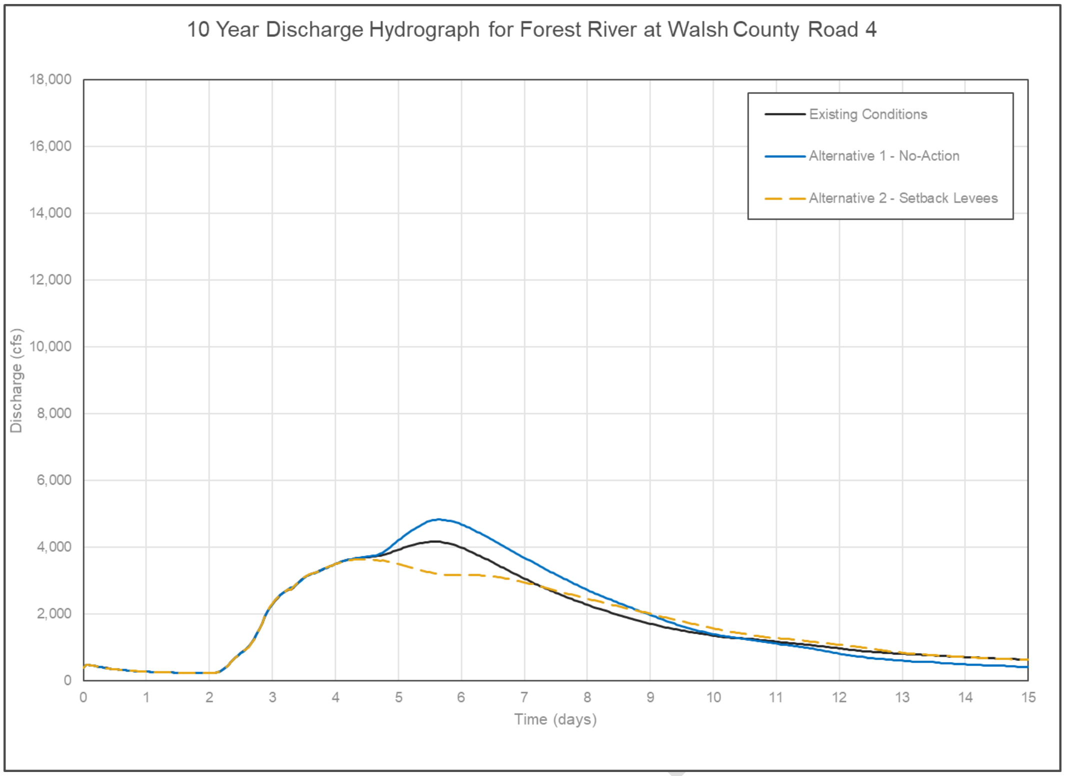

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees

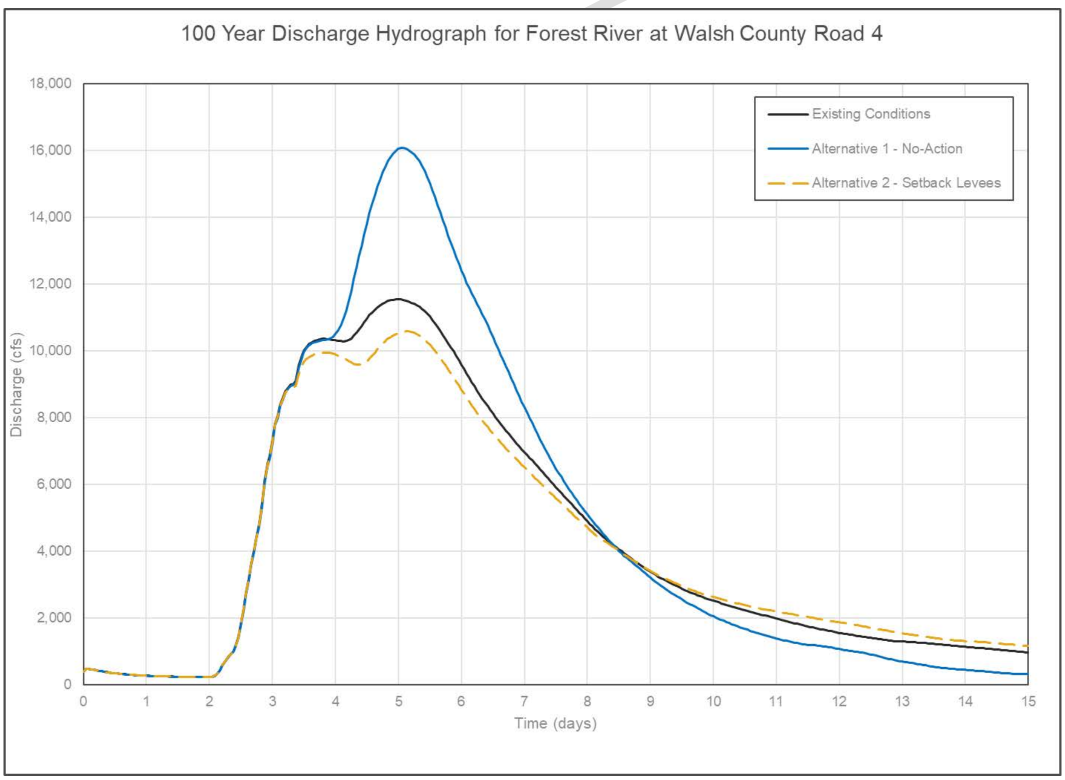


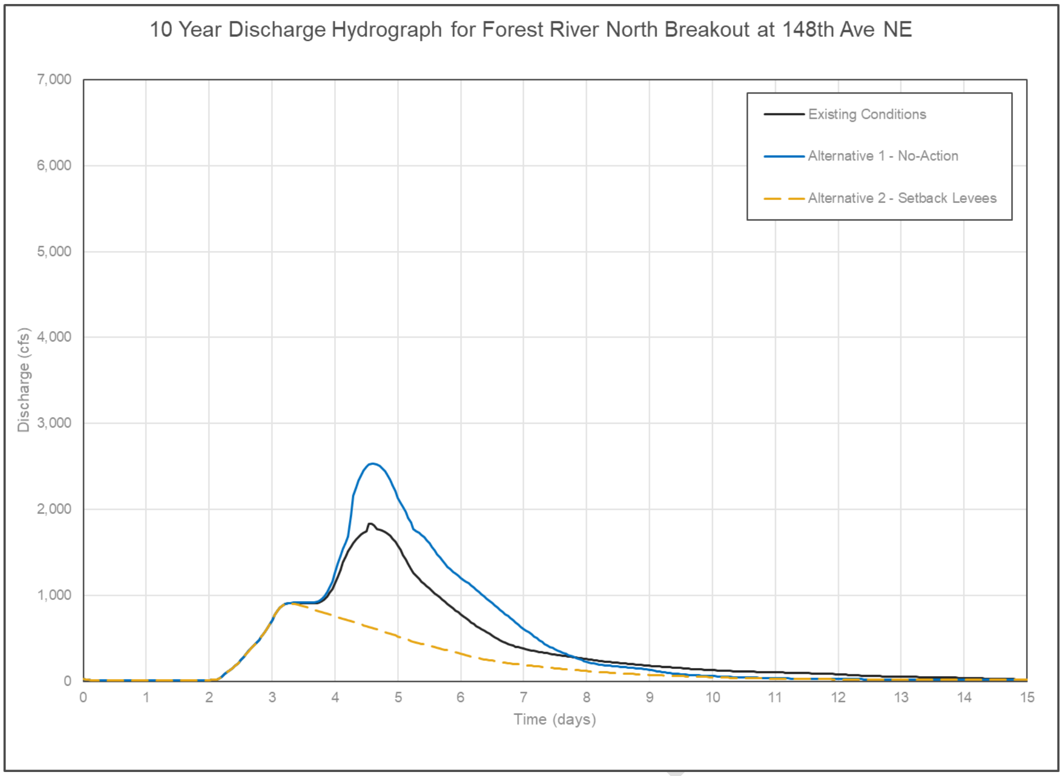
10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

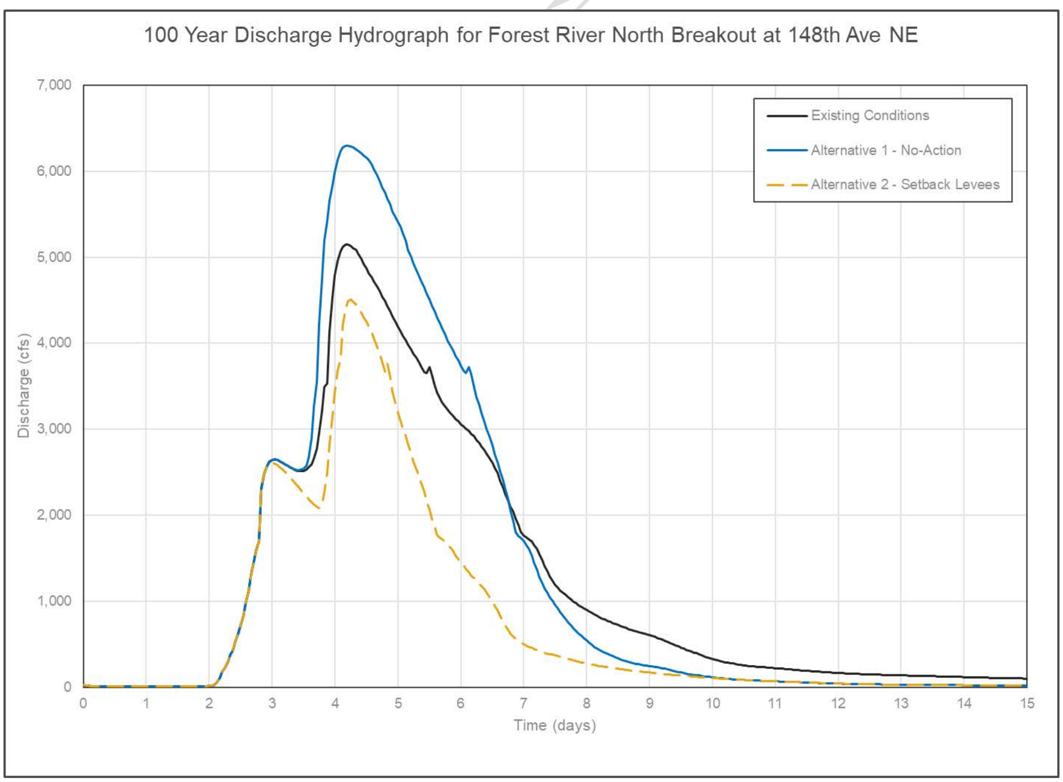


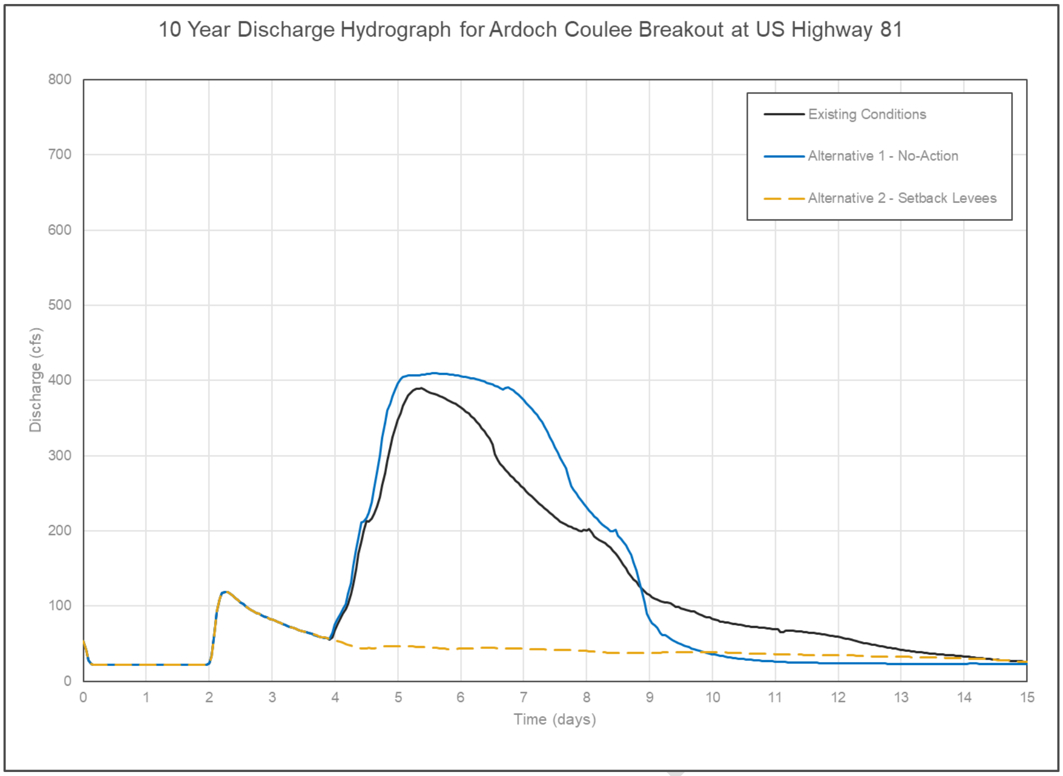
100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

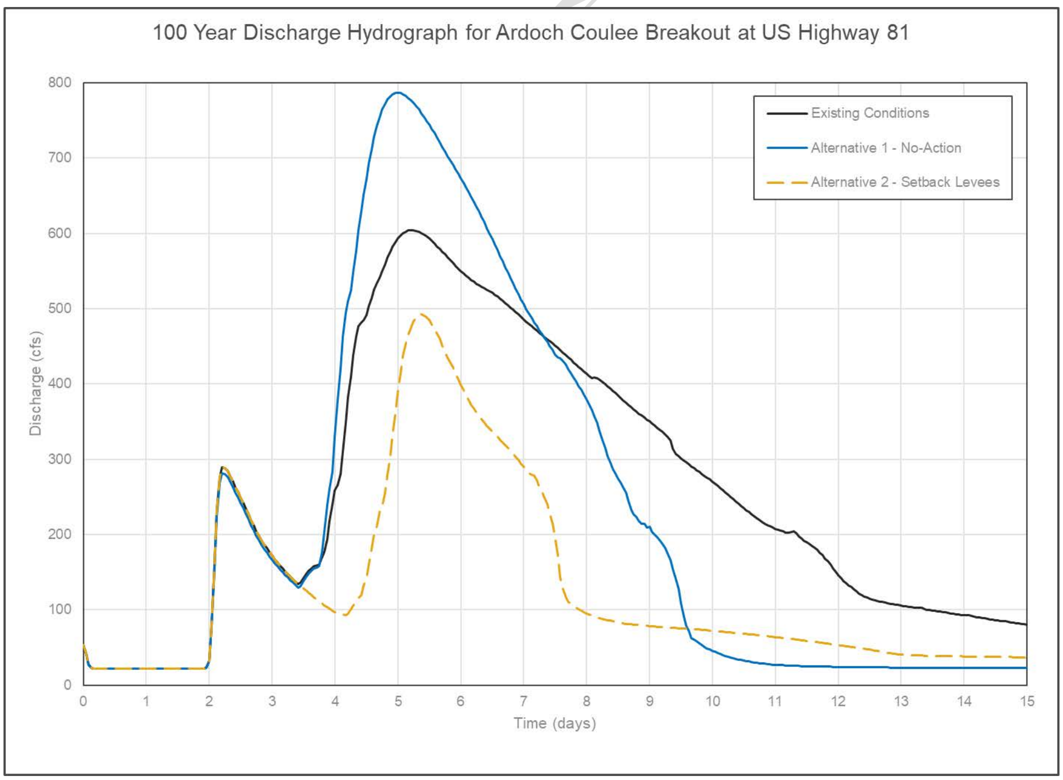

10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

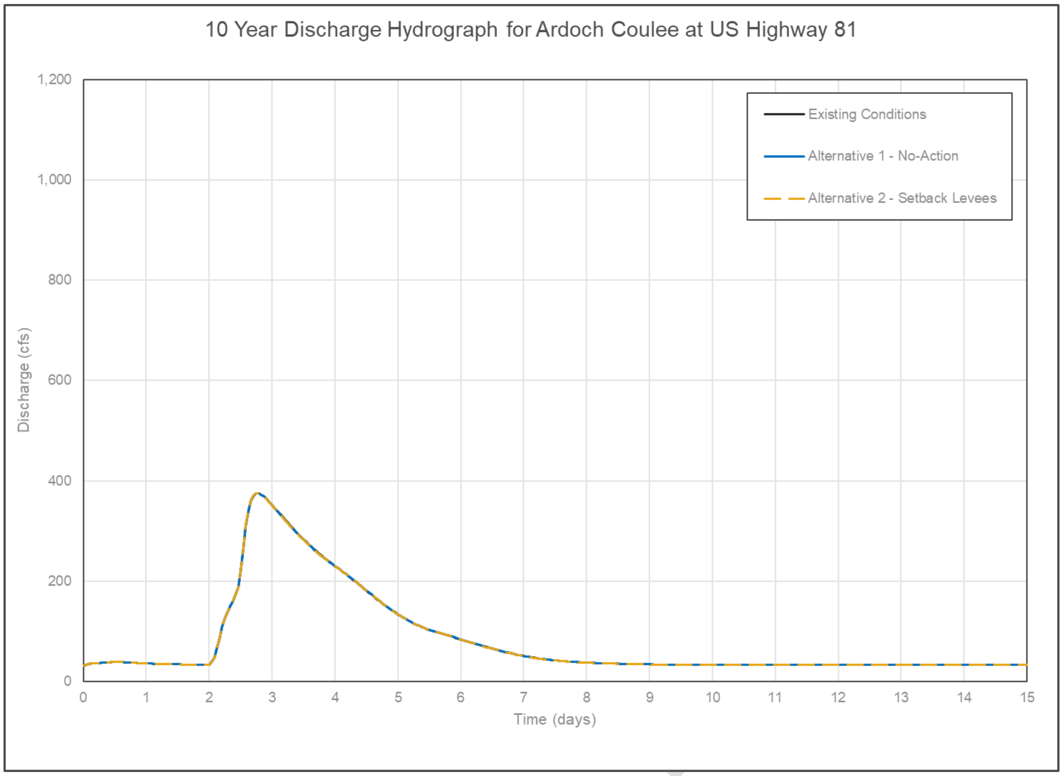

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

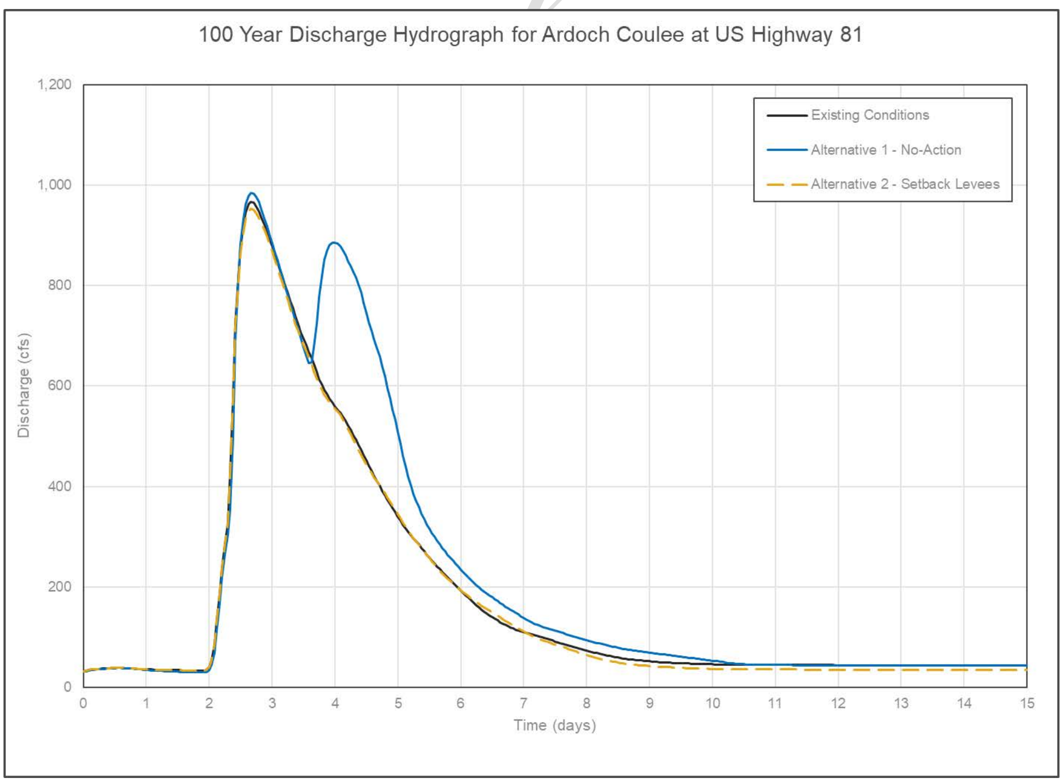

10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

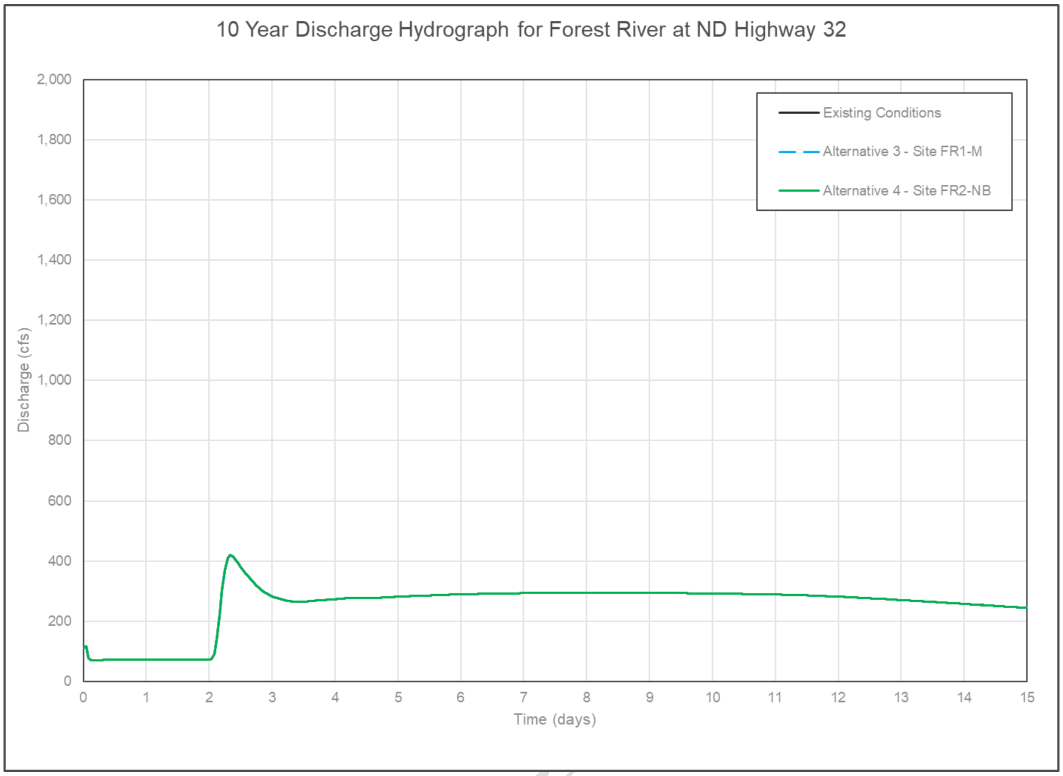

10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
0
100
200
300
400
500
600
700
800
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

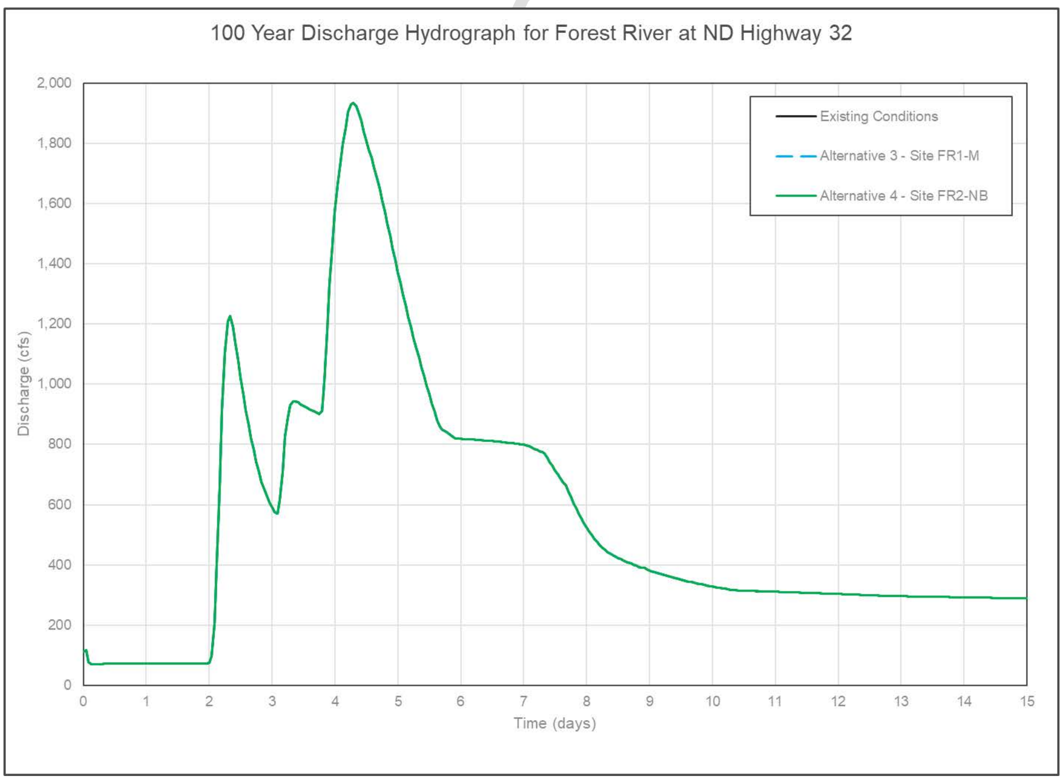

100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees
Discharge (cfs)
0
100
200
300
400
500
600
700
800
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

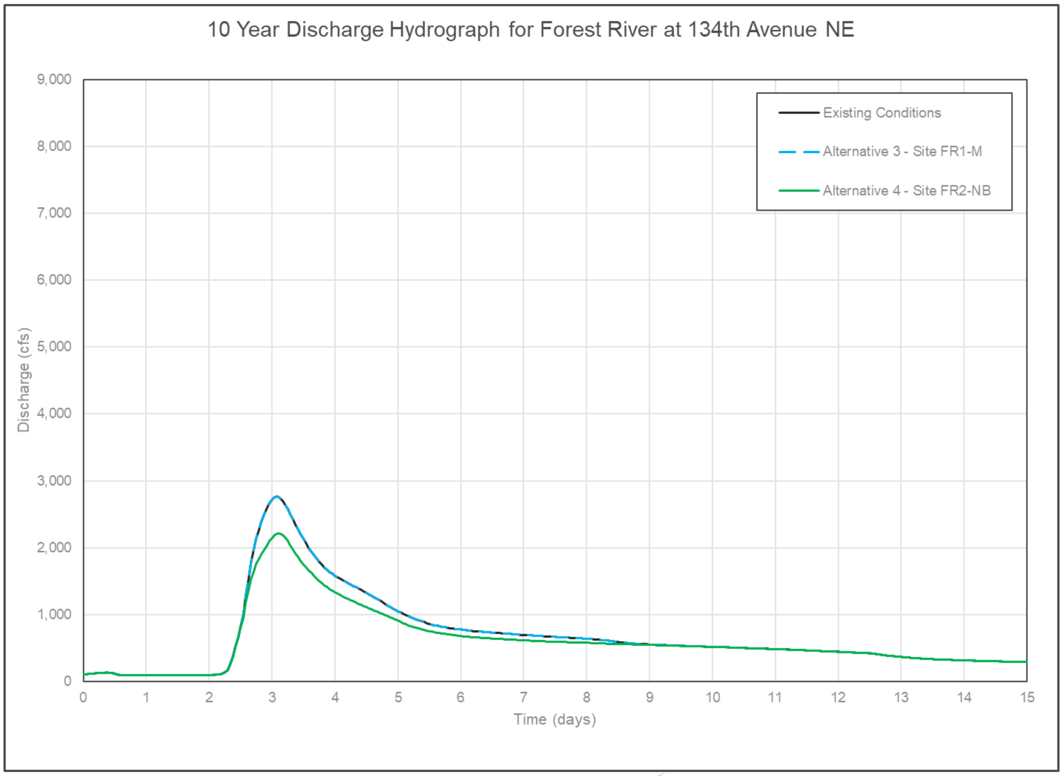

10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
0
200
400
600
800
1,000
1,200
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees

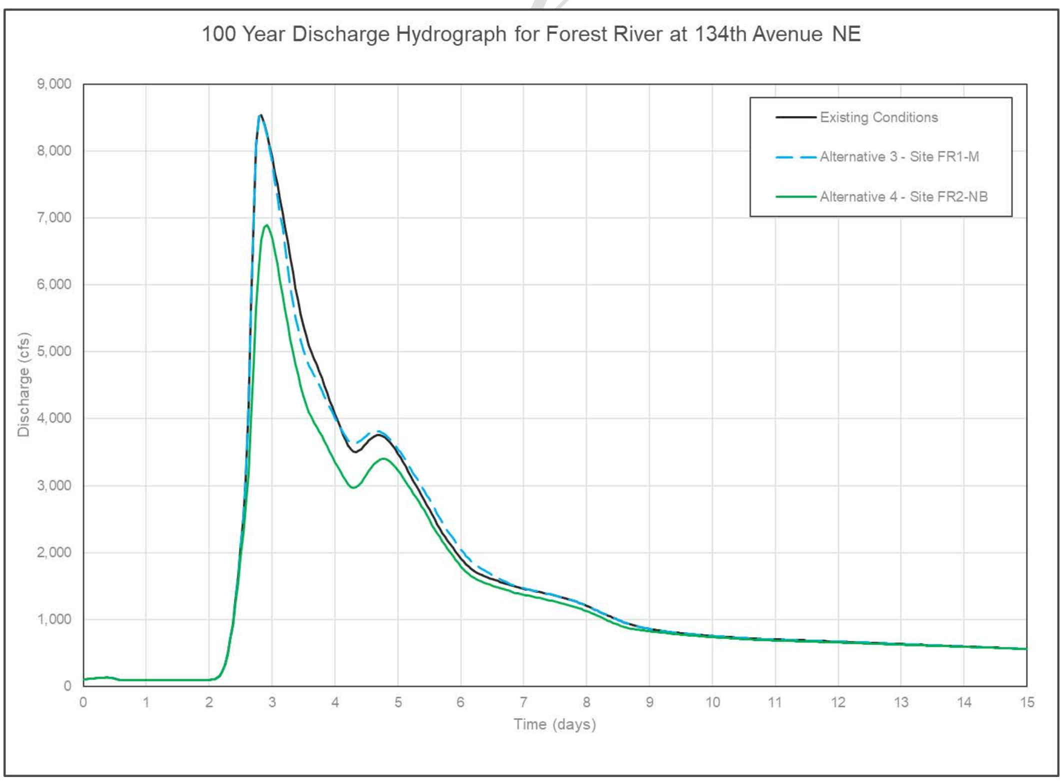

100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
0
200
400
600
800
1,000
1,200
Time (days)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Alternative 1 - No-Action
Alternative 2 - Setback Levees

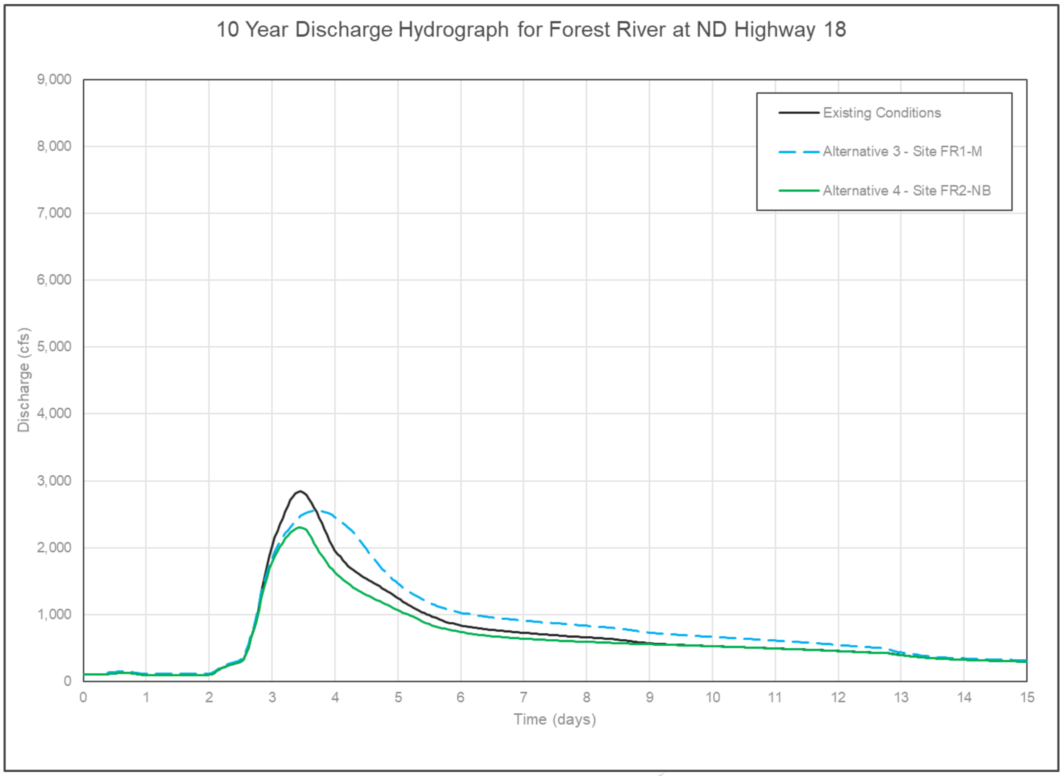
B.3 ALTERNATIVES 3-4 – SITE FR1-M AND SITE FR2-NB

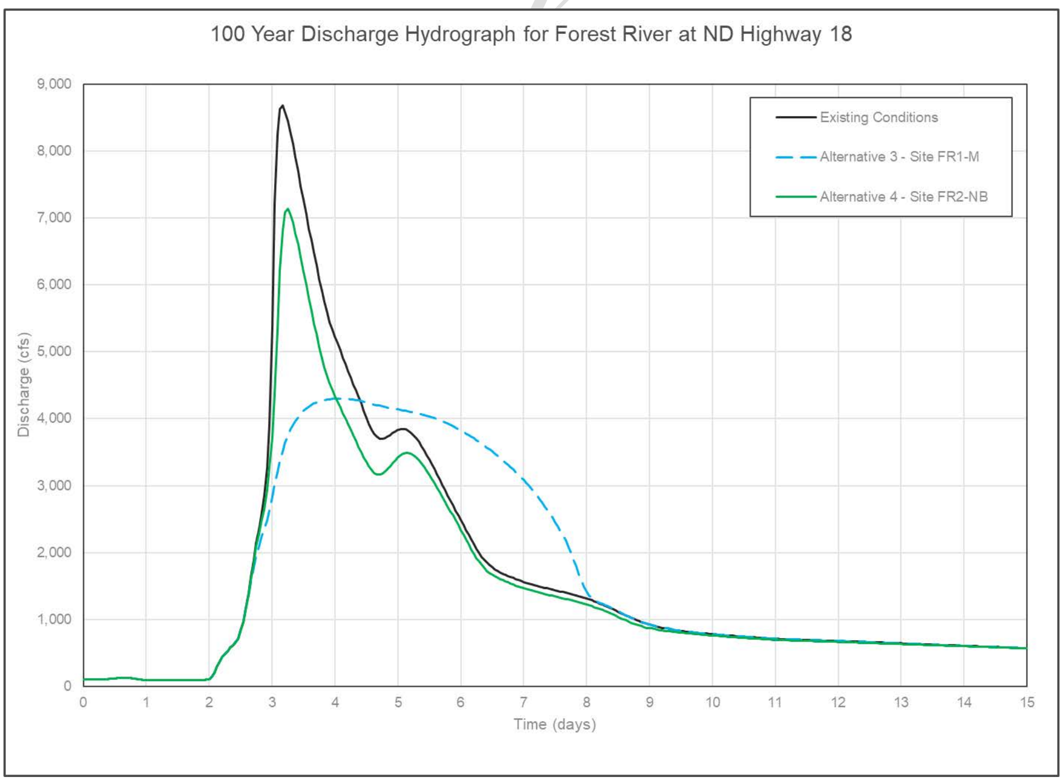


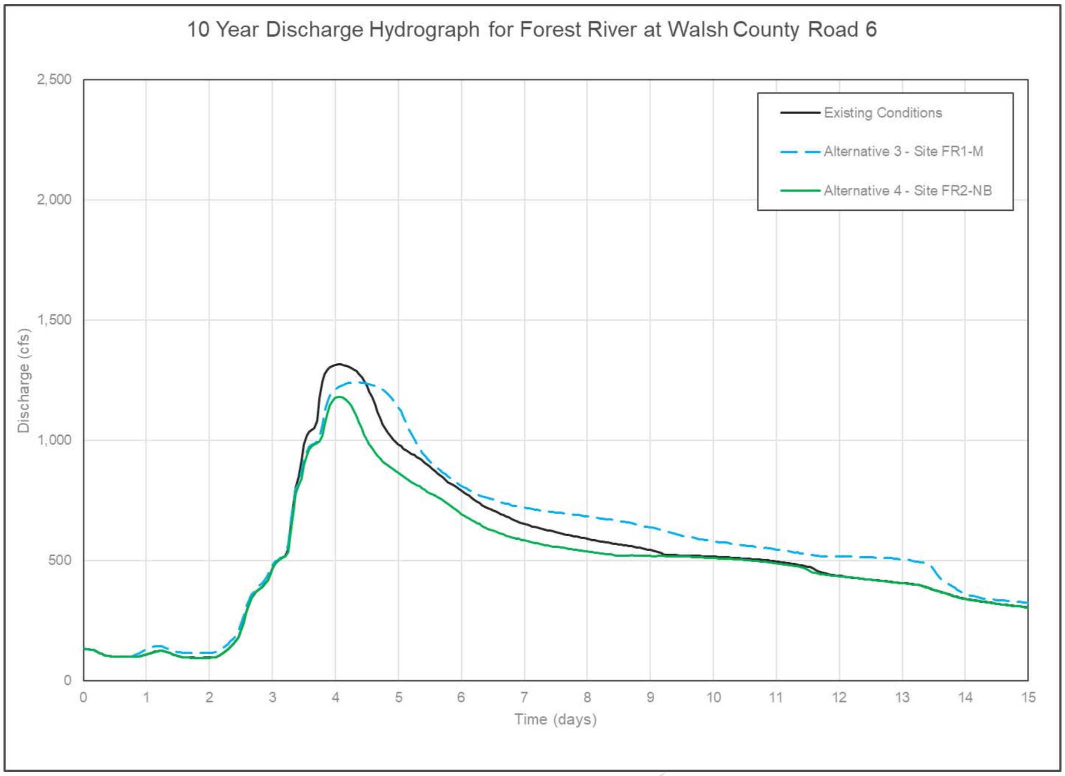


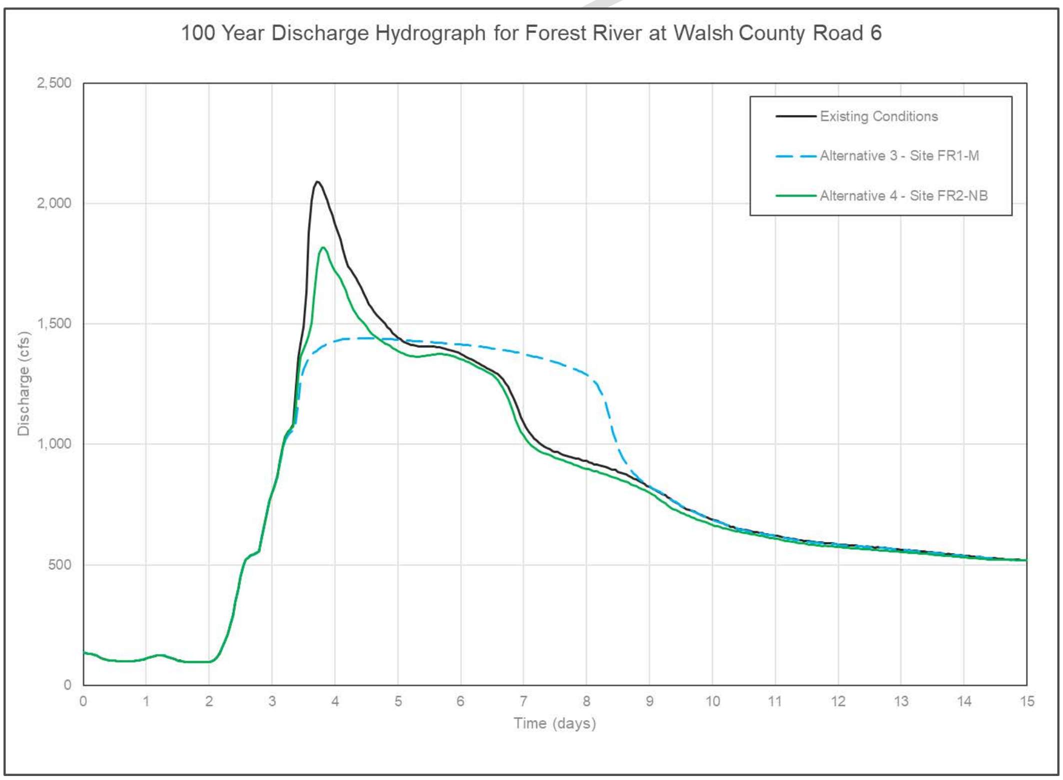

10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

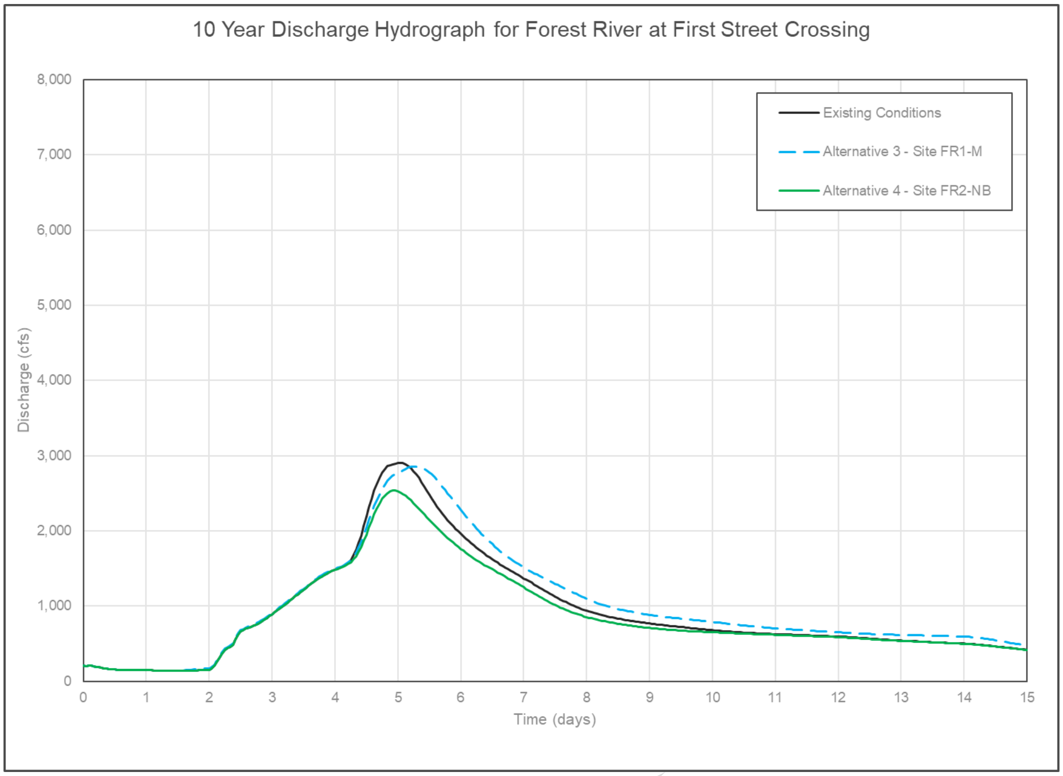

100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

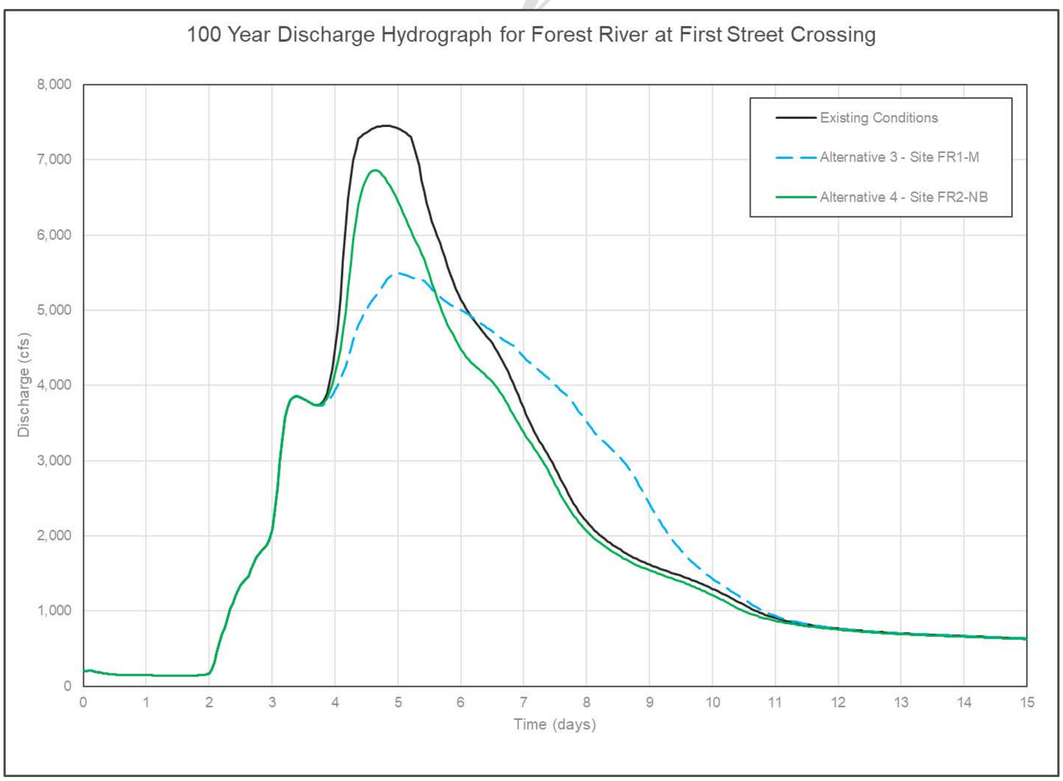

10 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)

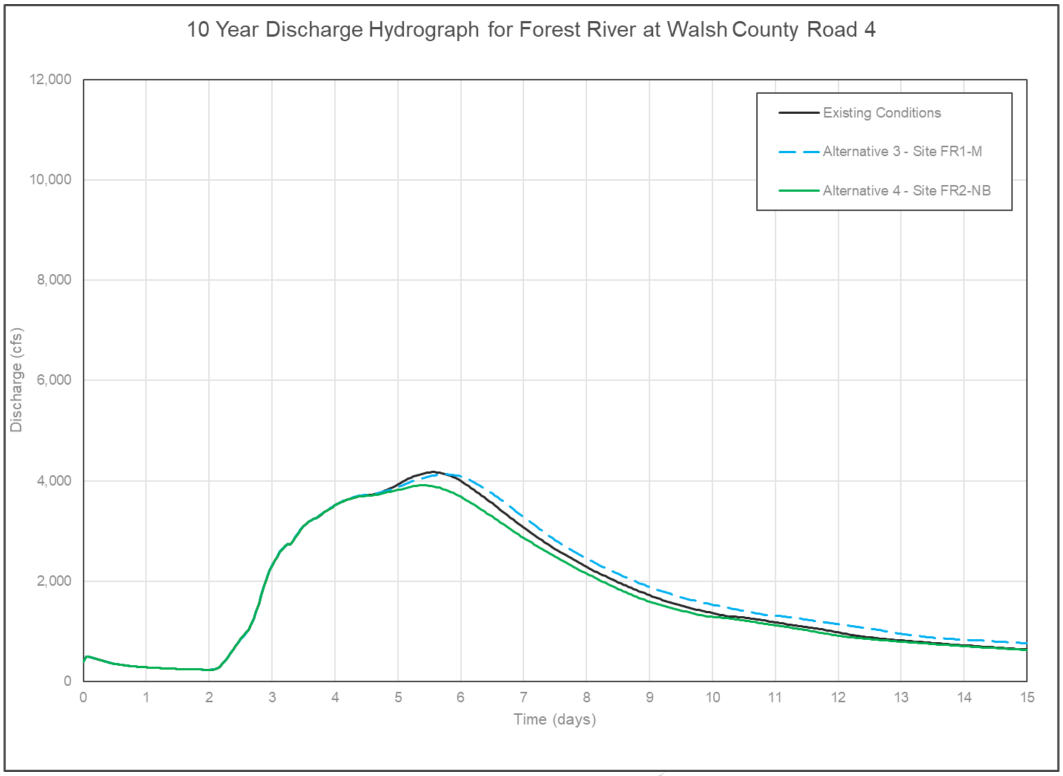

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)

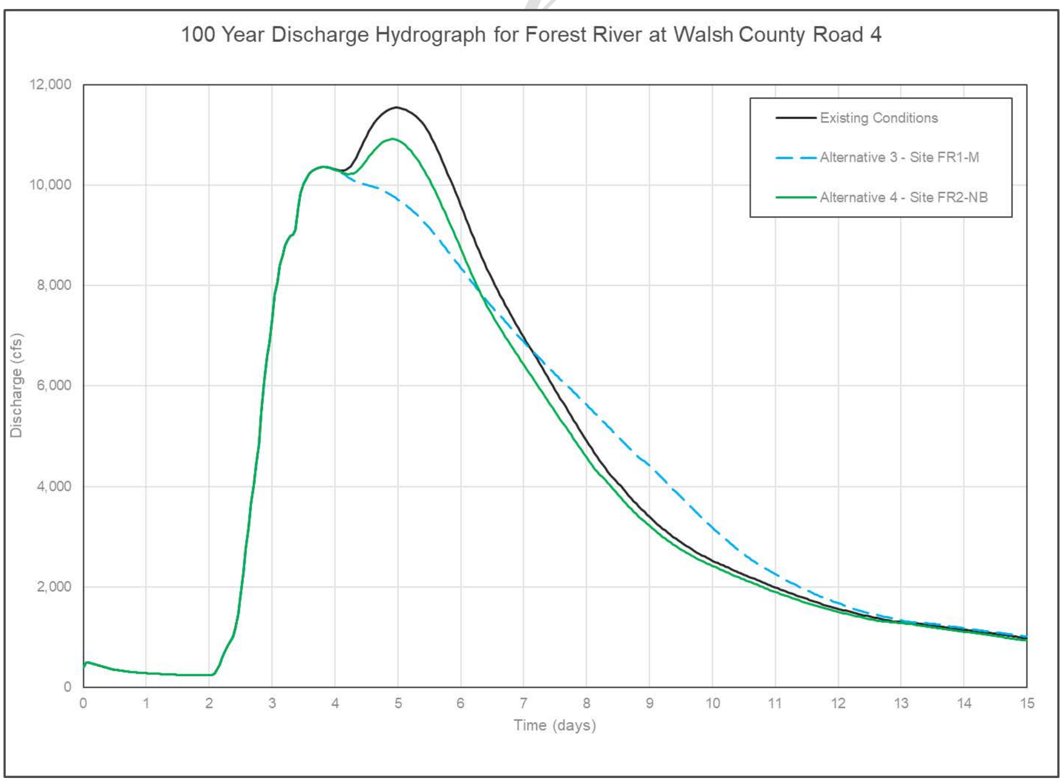

10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Discharge (cfs)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

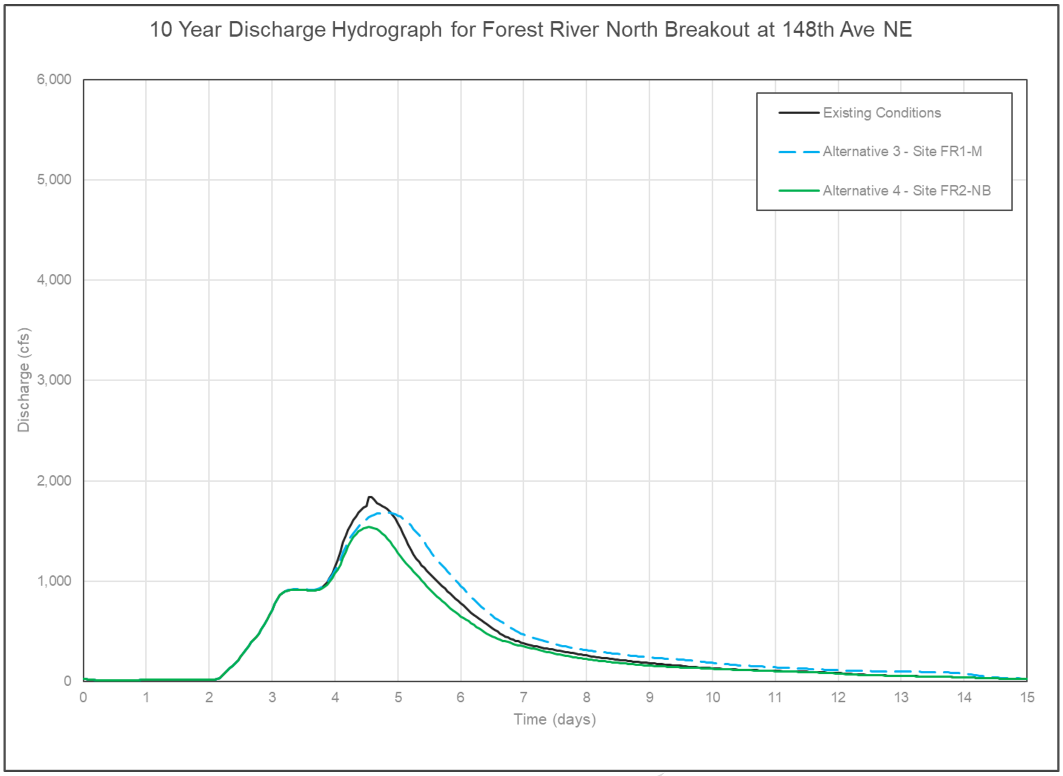

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Discharge (cfs)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

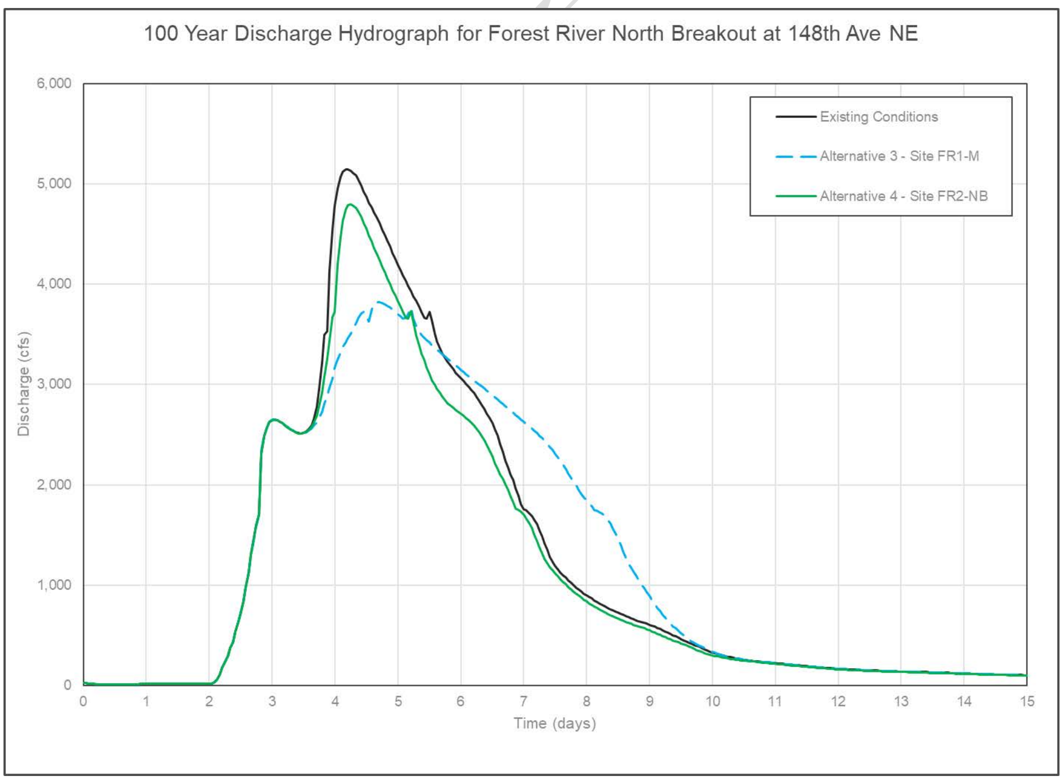

10 Year Discharge Hydrograph for Forest River at First Street Crossing
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

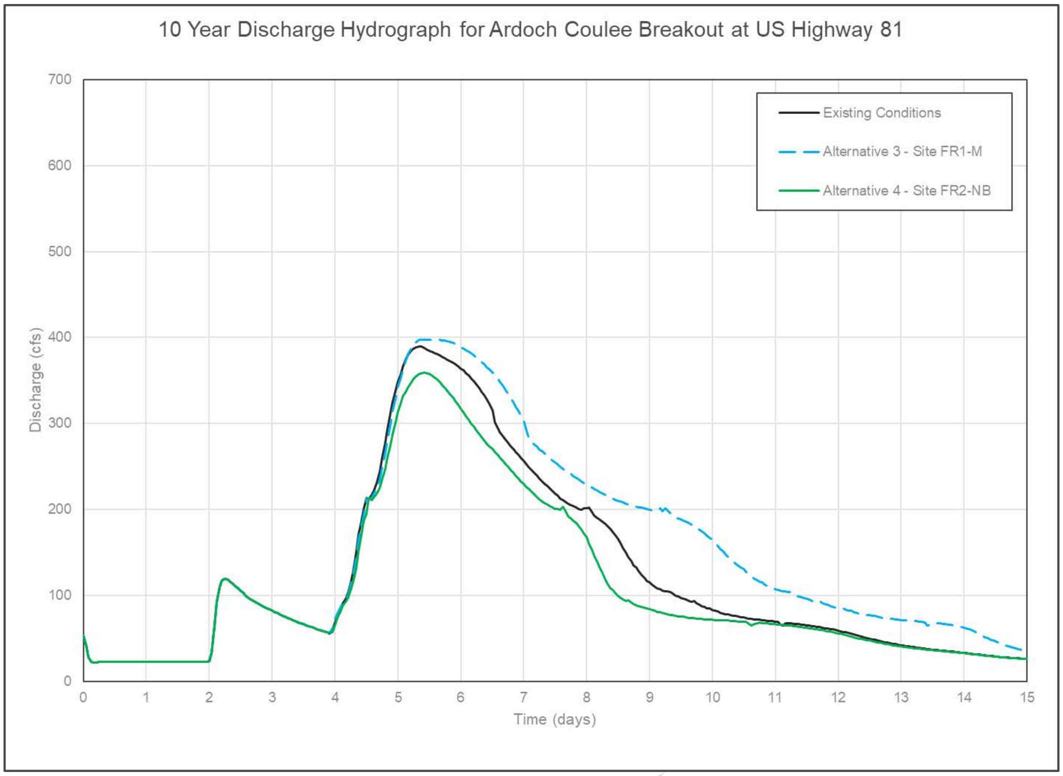

100 Year Discharge Hydrograph for Forest River at First Street Crossing
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

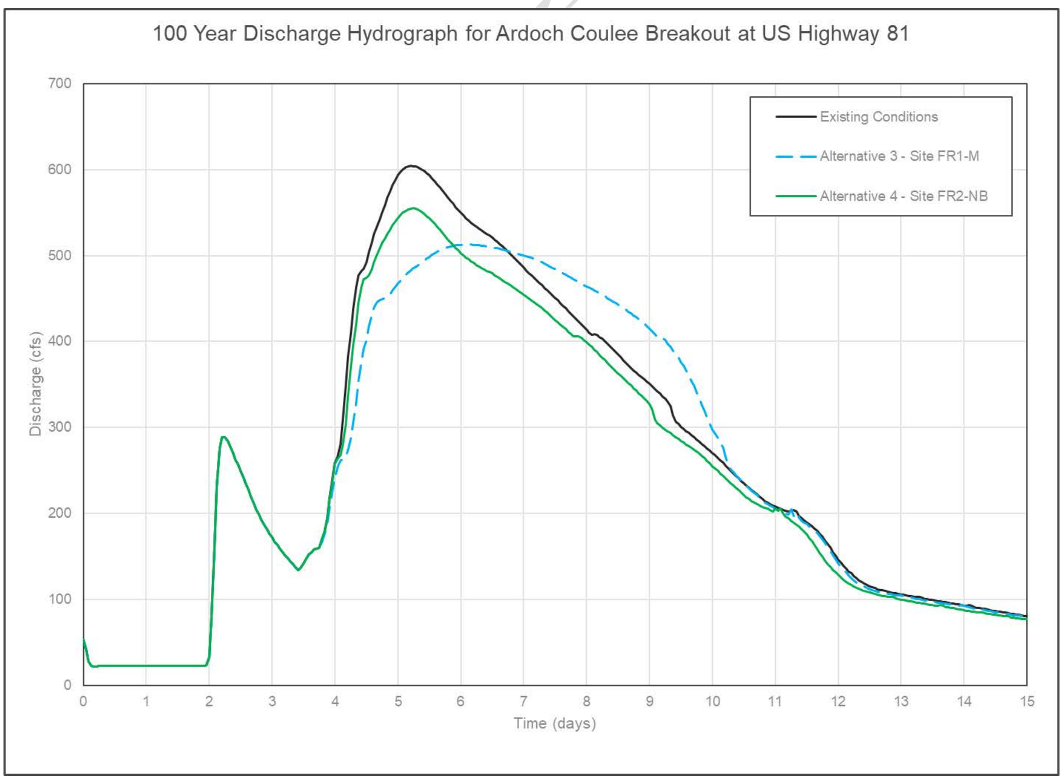

10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

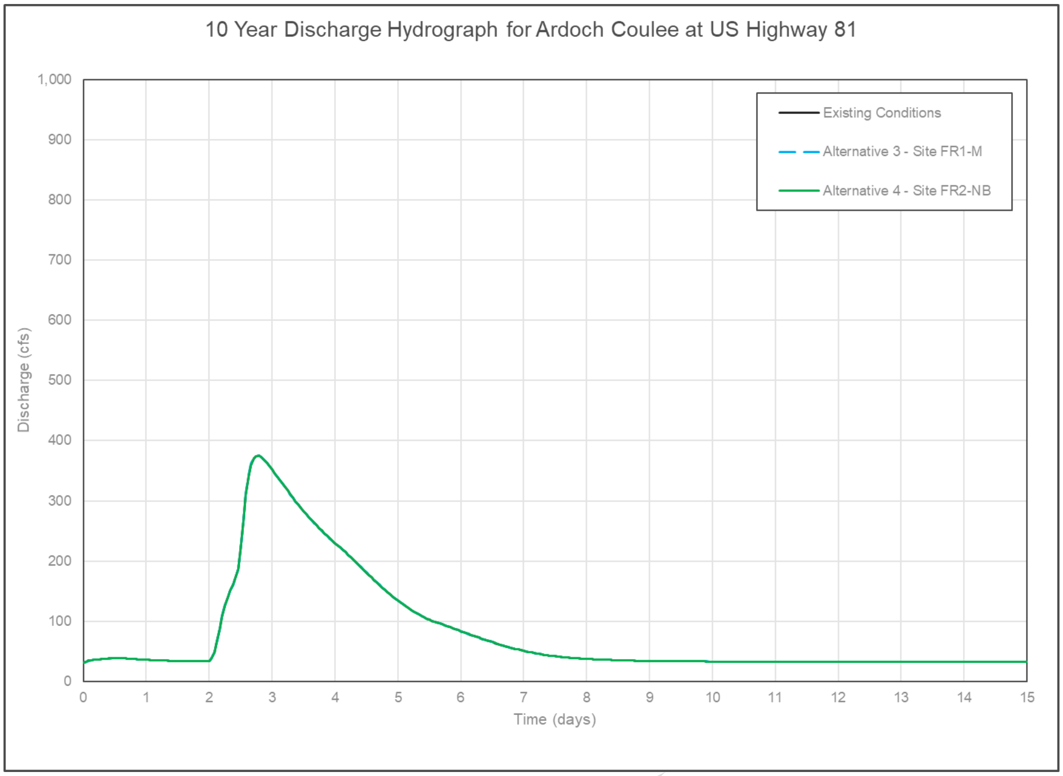

100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

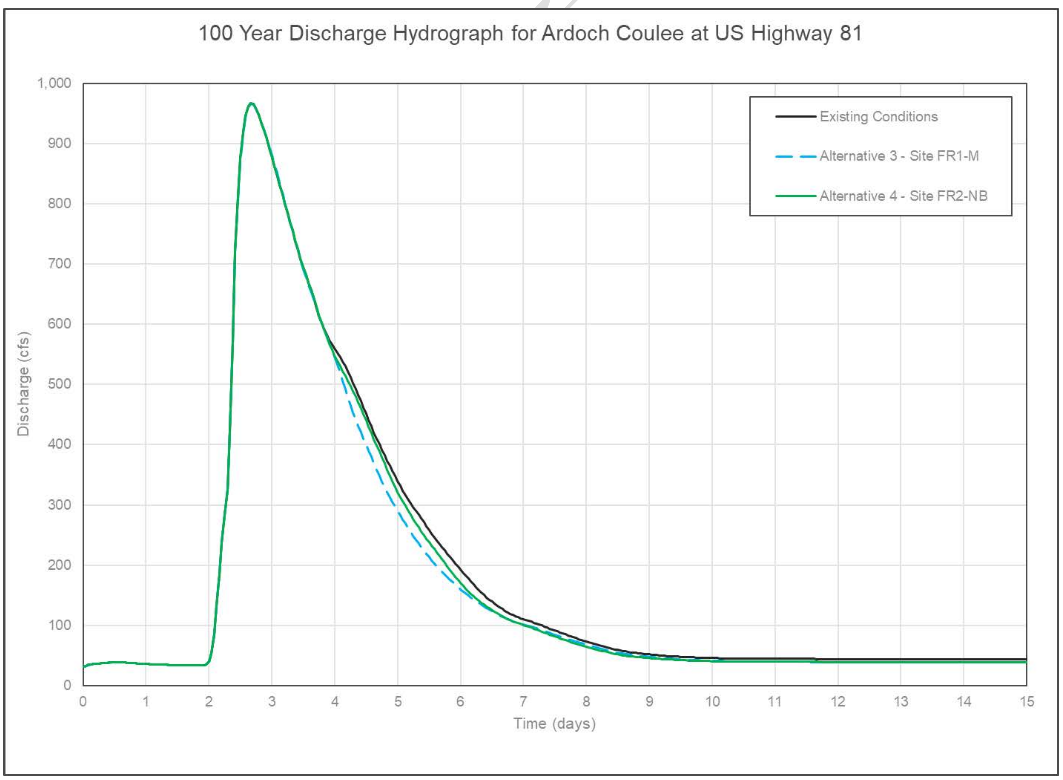

10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

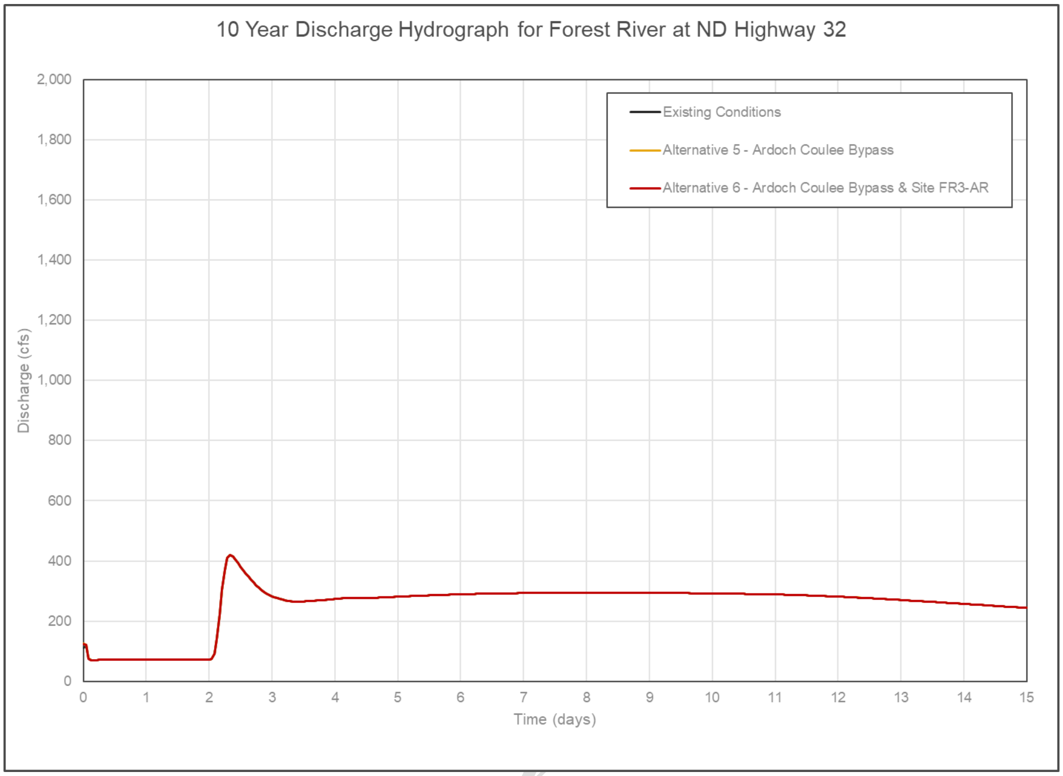

10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

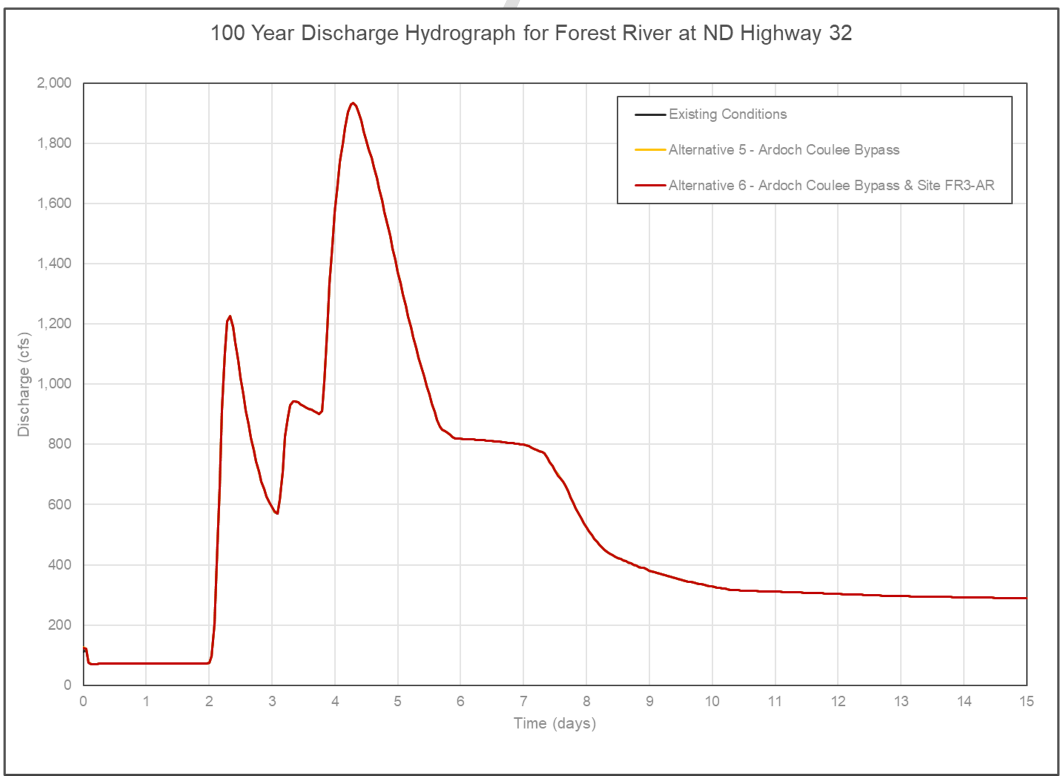

100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB
Discharge (cfs)
Time (days)
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

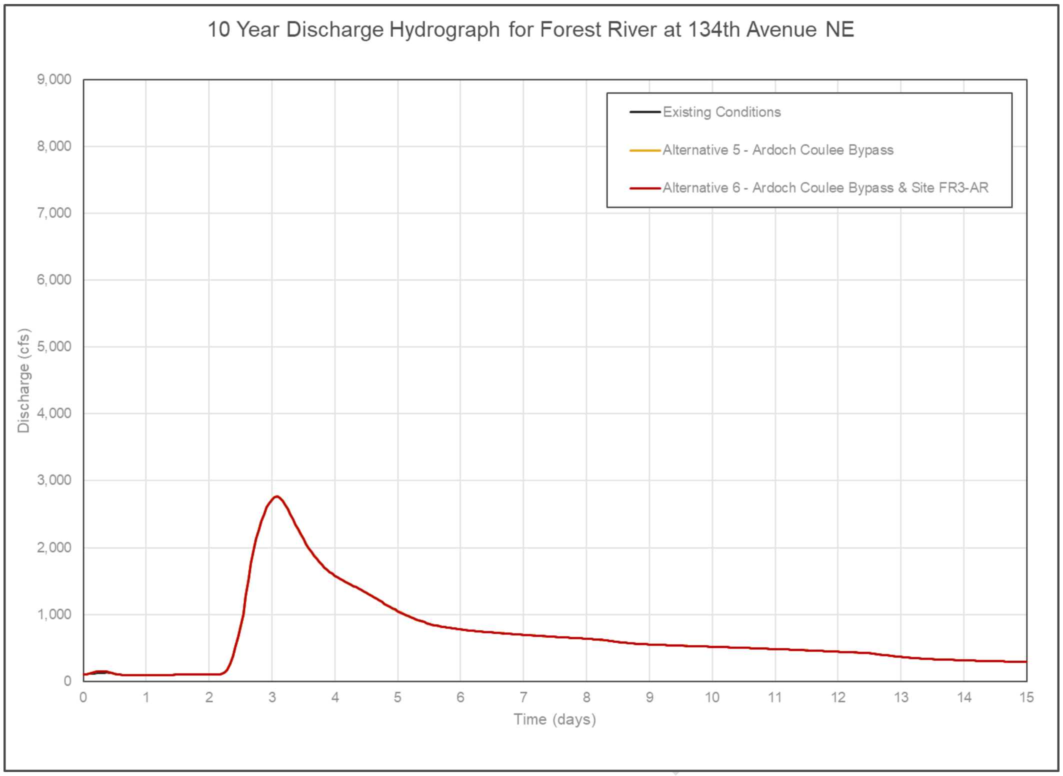

10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

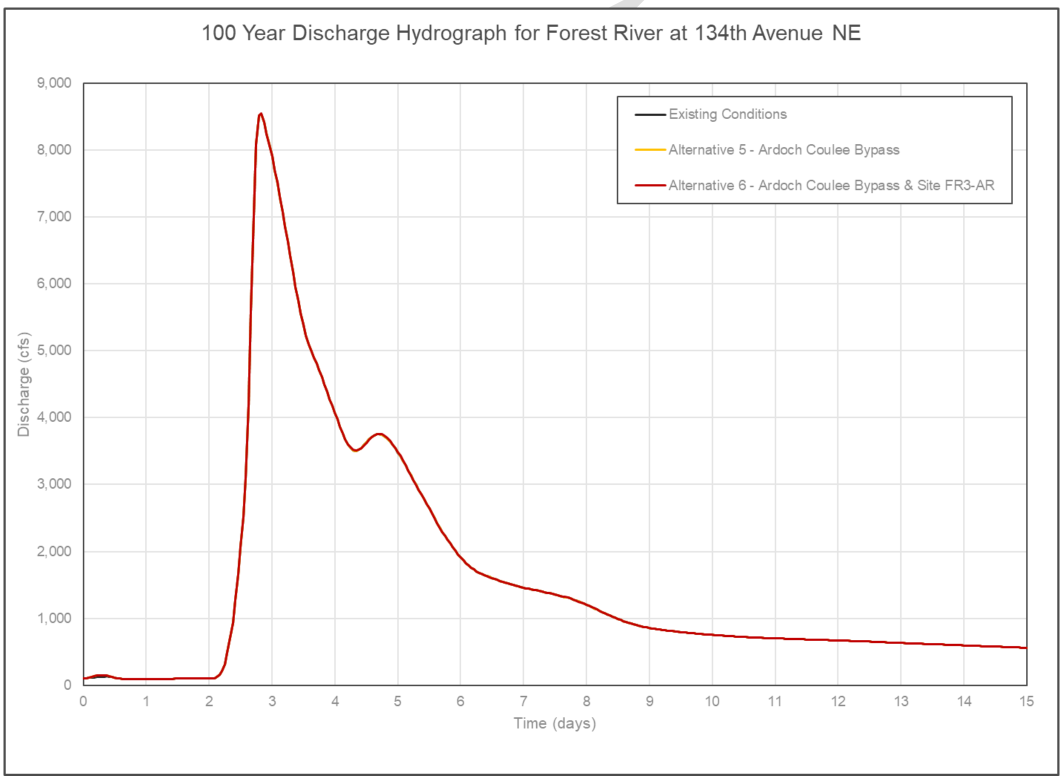

100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
Time (days)
Existing Conditions
Alternative 3 - Site FR1-M
Alternative 4 - Site FR2-NB

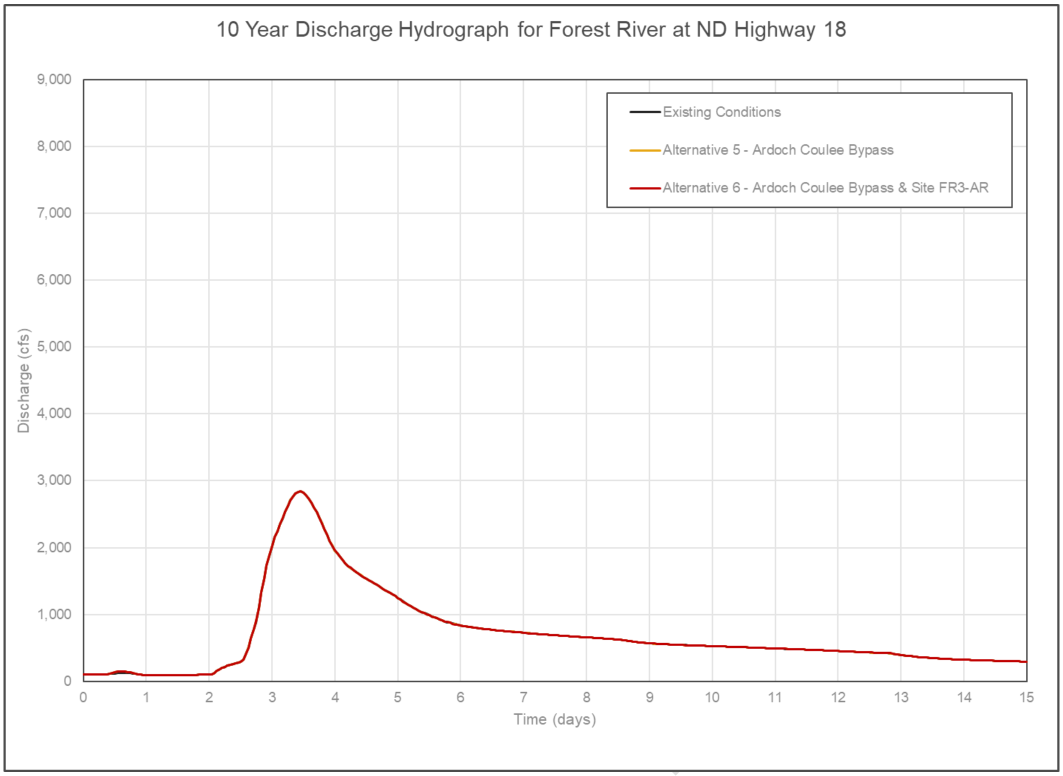
B.4 ALTERNATIVES 5-6 –ARDOCH COULEE BYPASS AND SITE FR3-AR – HYDROGRAPHS

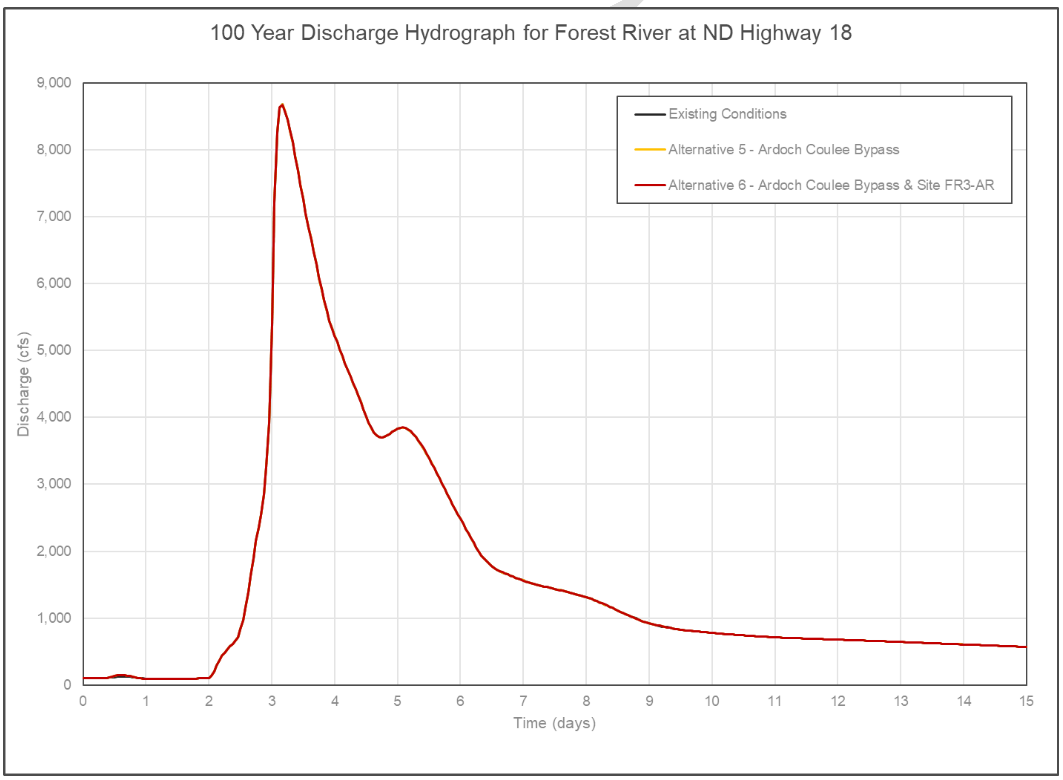


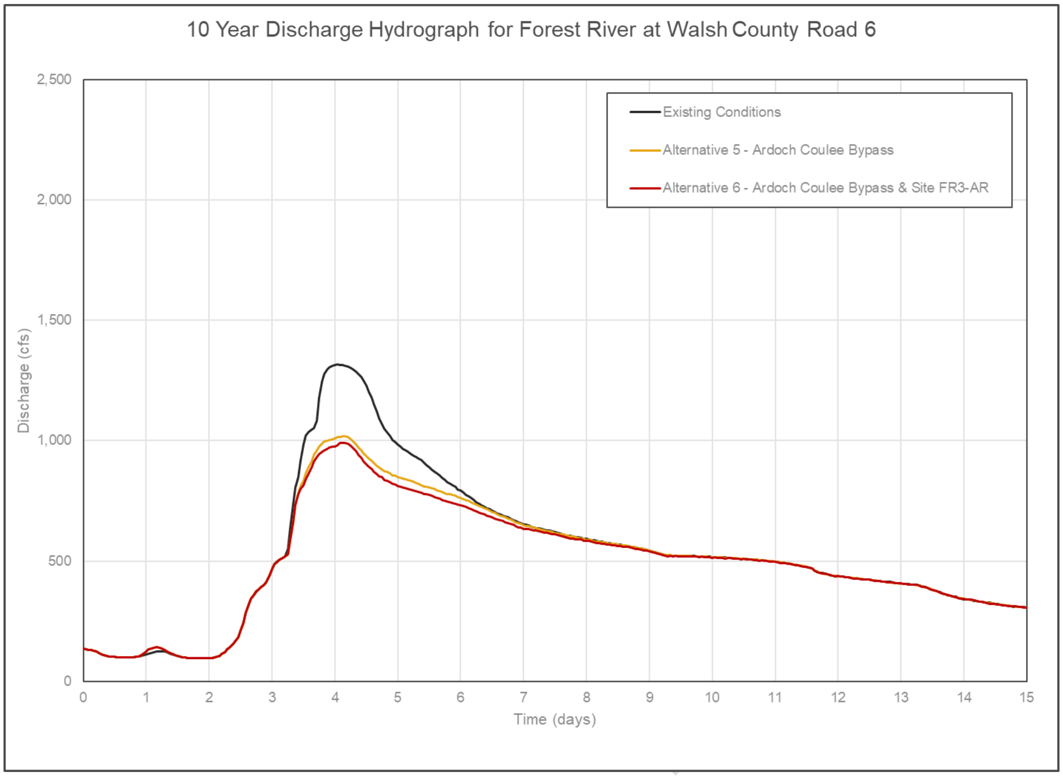


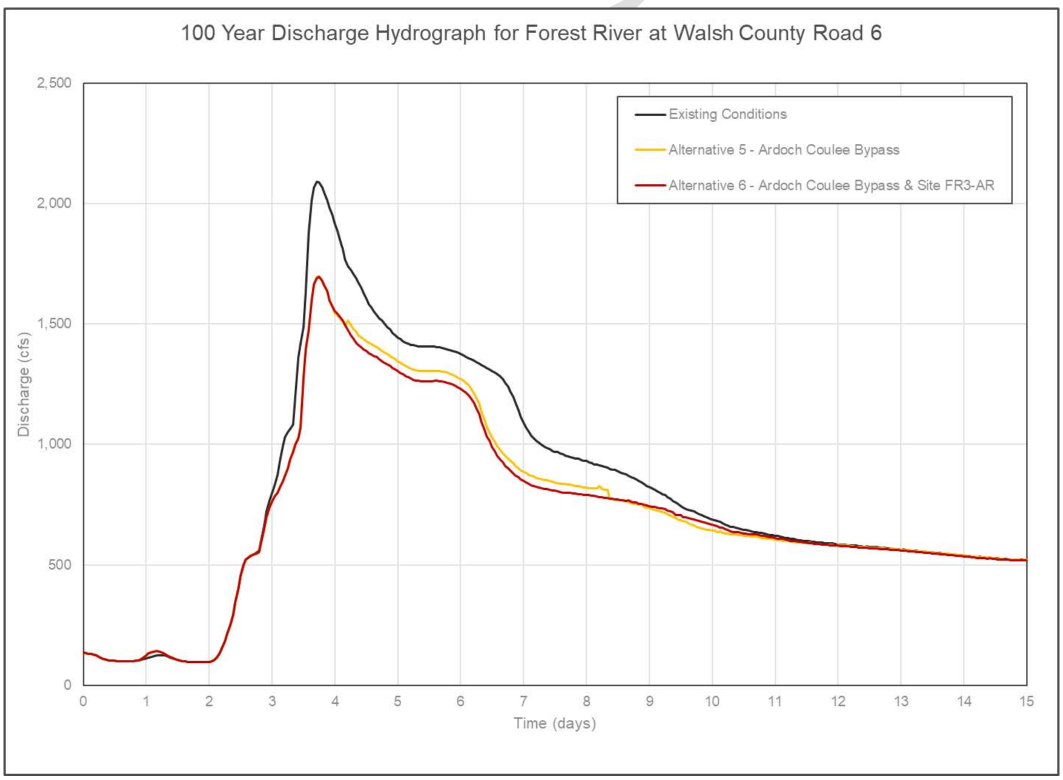

10 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)

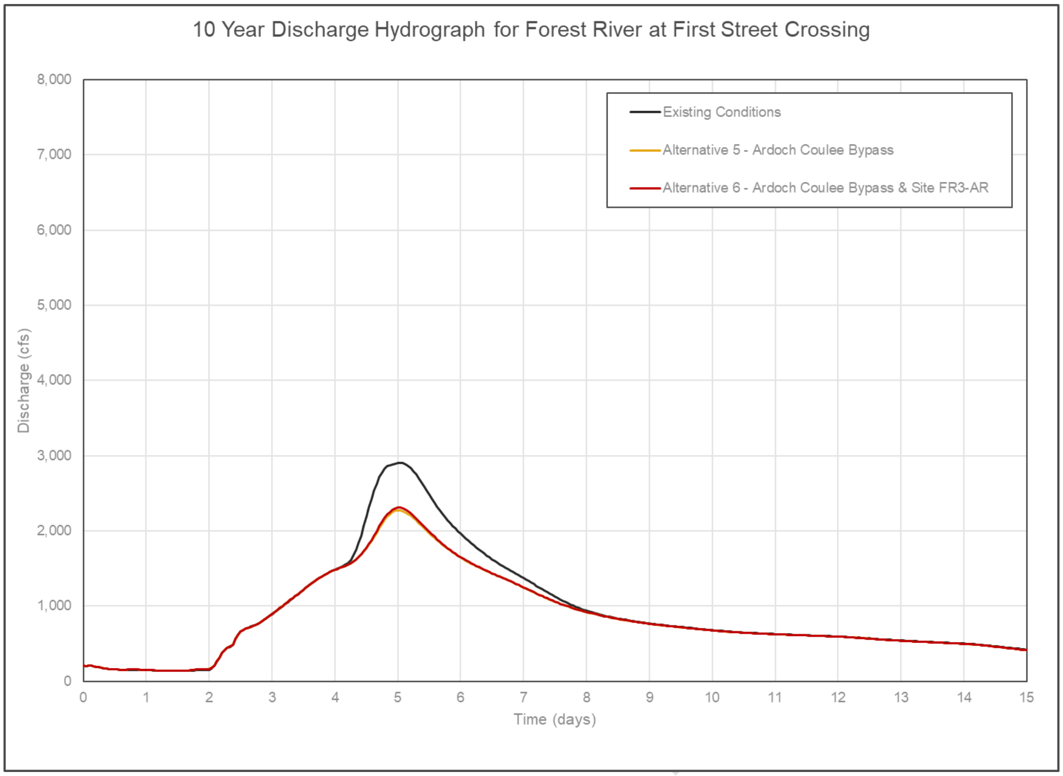

100 Year Discharge Hydrograph for Forest River at 134th Avenue NE
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)


10 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)

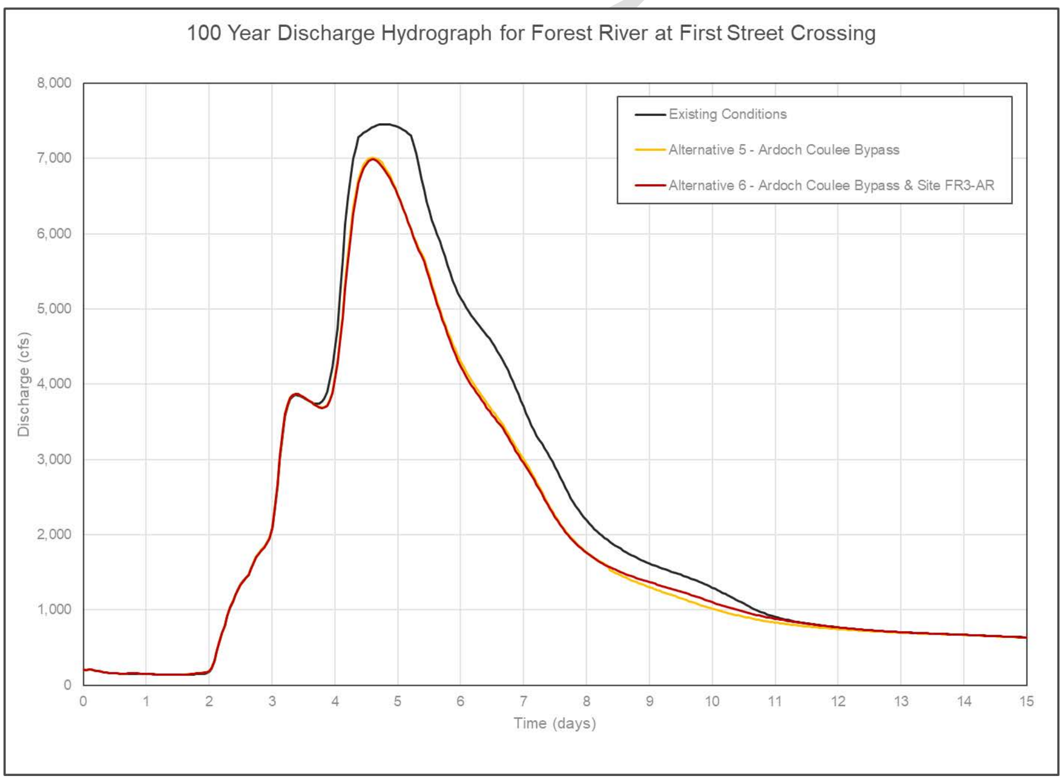

100 Year Discharge Hydrograph for Forest River at ND Highway 18
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (days)


10 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

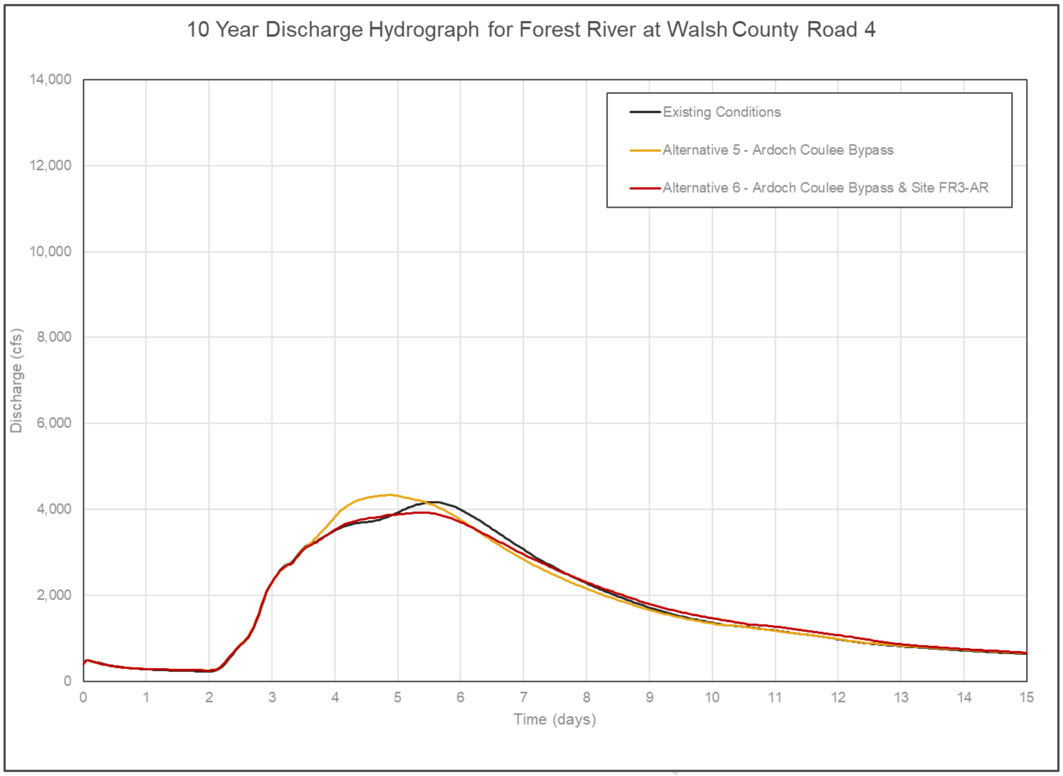

100 Year Discharge Hydrograph for Forest River at Walsh County Road 6
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15



10 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)



100 Year Discharge Hydrograph for Forest River at First Street Crossing
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (days)


10 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
0
1
2
3
4
5
6
7
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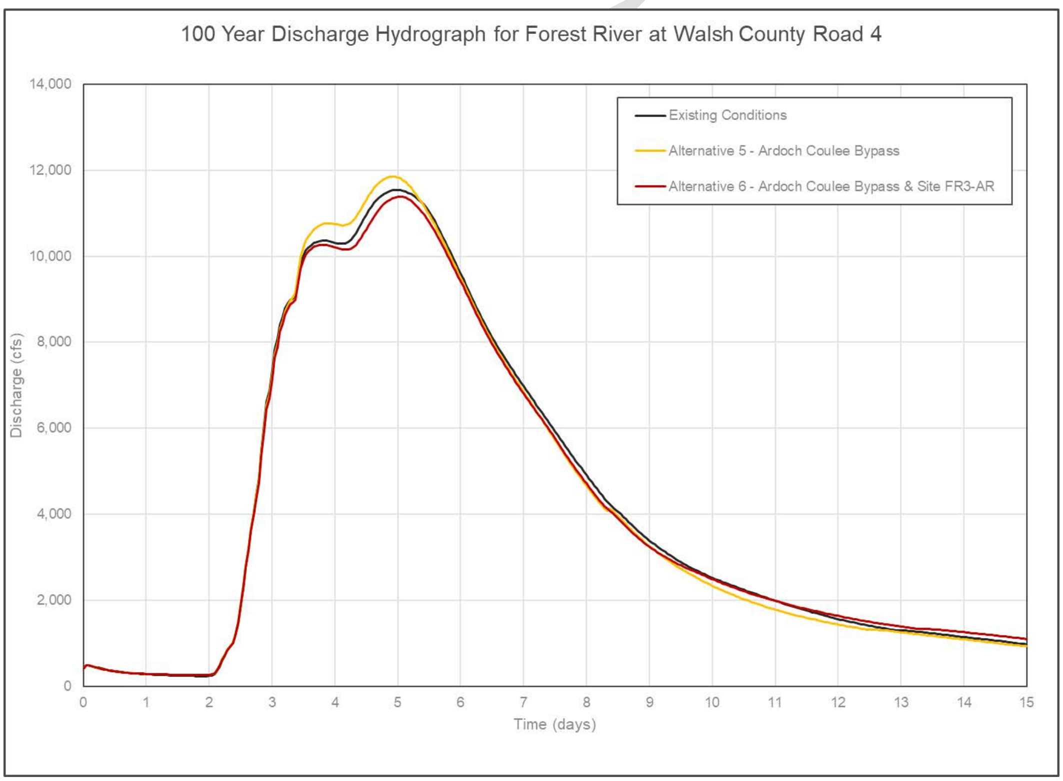
11
12
13
14
15


100 Year Discharge Hydrograph for Forest River at Walsh County Road 4
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
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1
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3
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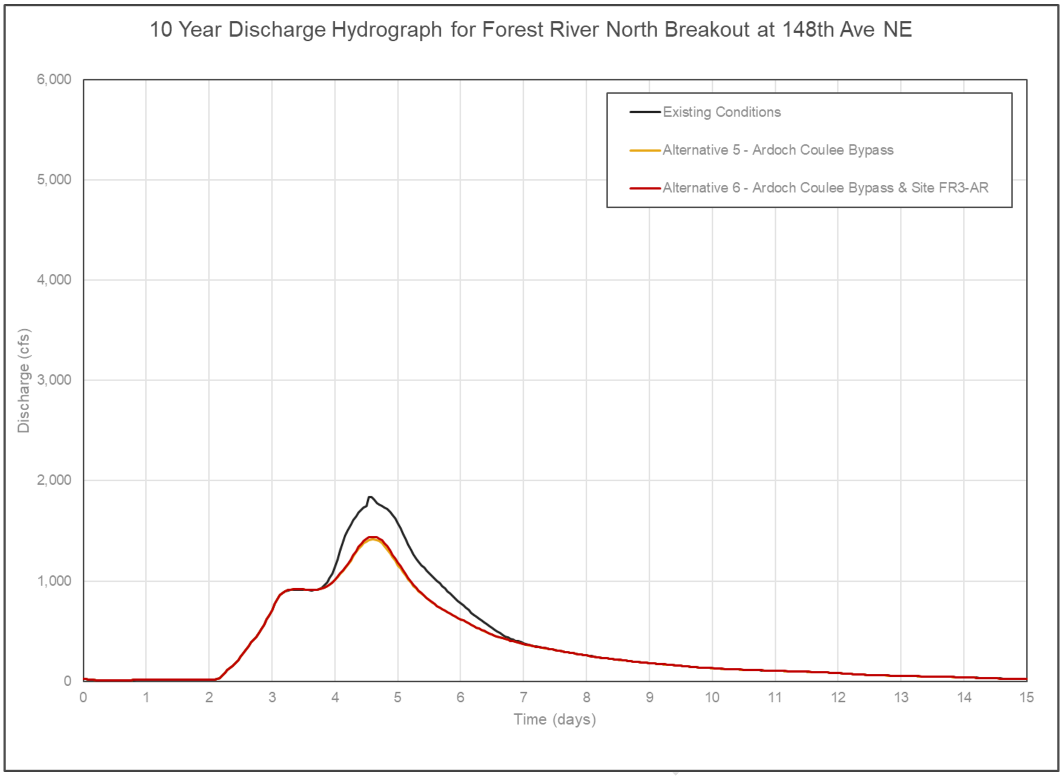
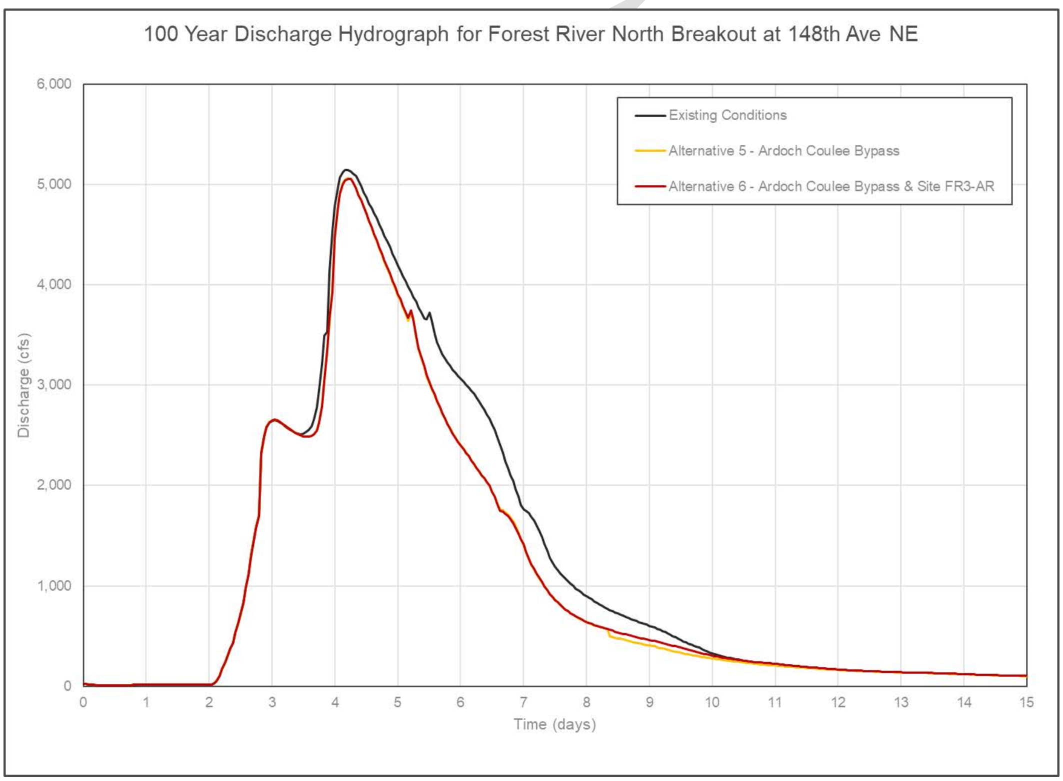
11
12
13
14
15


10 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


100 Year Discharge Hydrograph for Forest River North Breakout at 148th Ave NE
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)
6,000
5,000
4,000
3,000
2,000
1,000
0
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1
2
3
4
5
6
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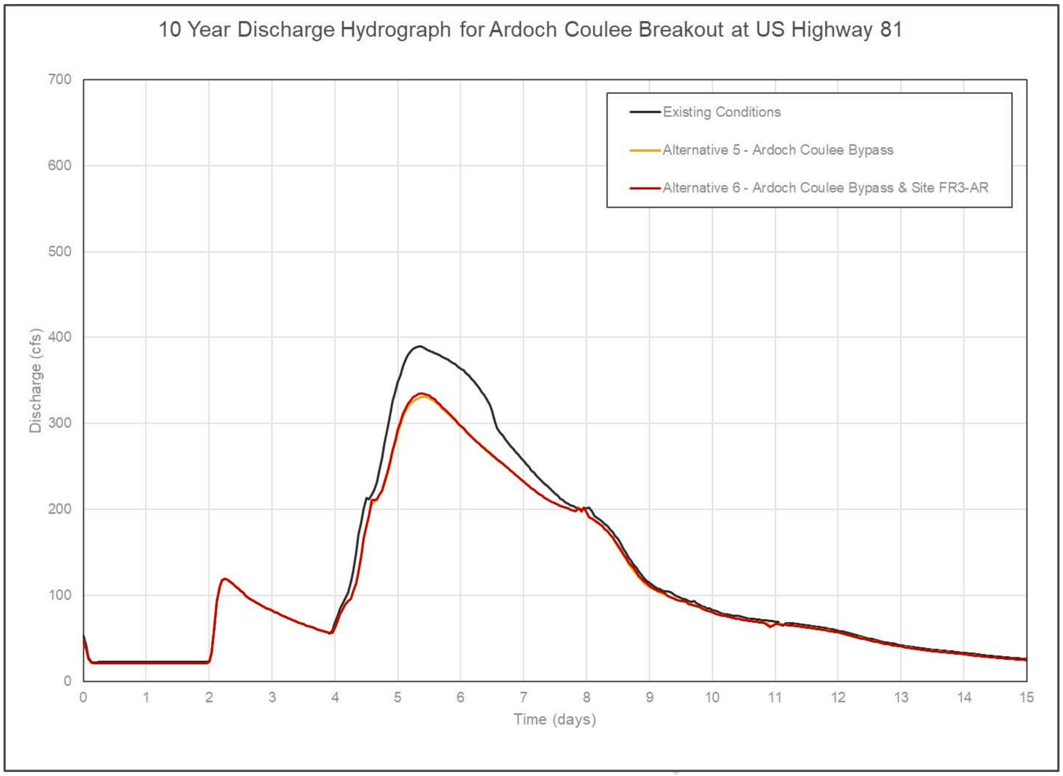
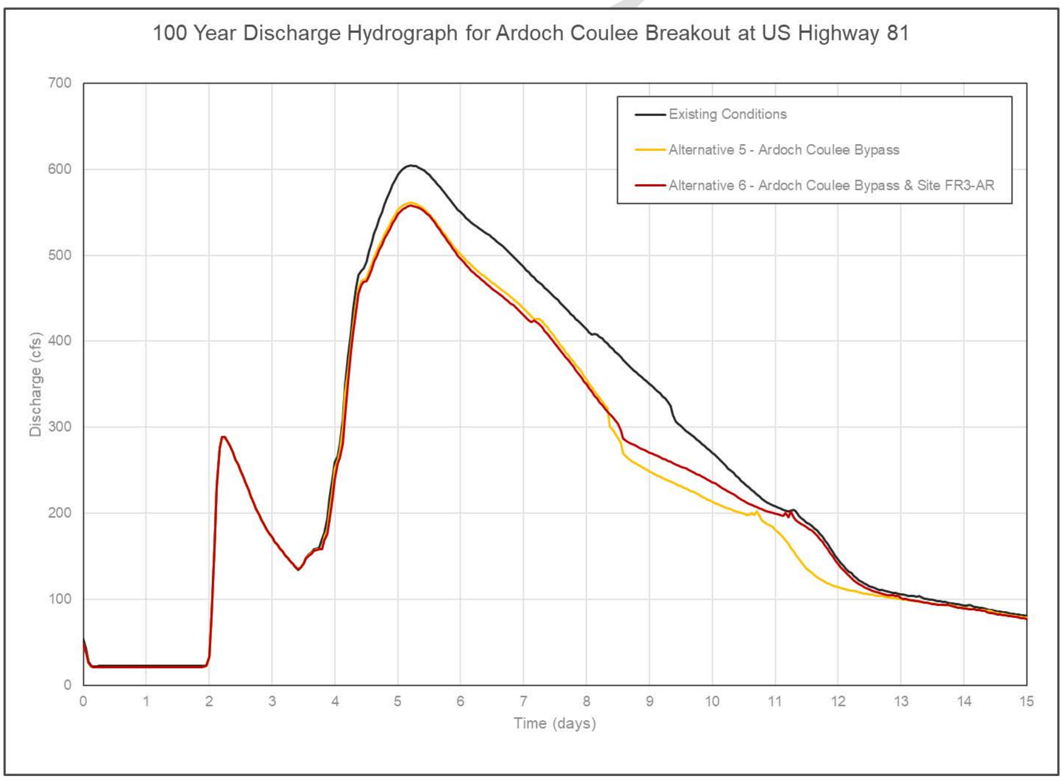
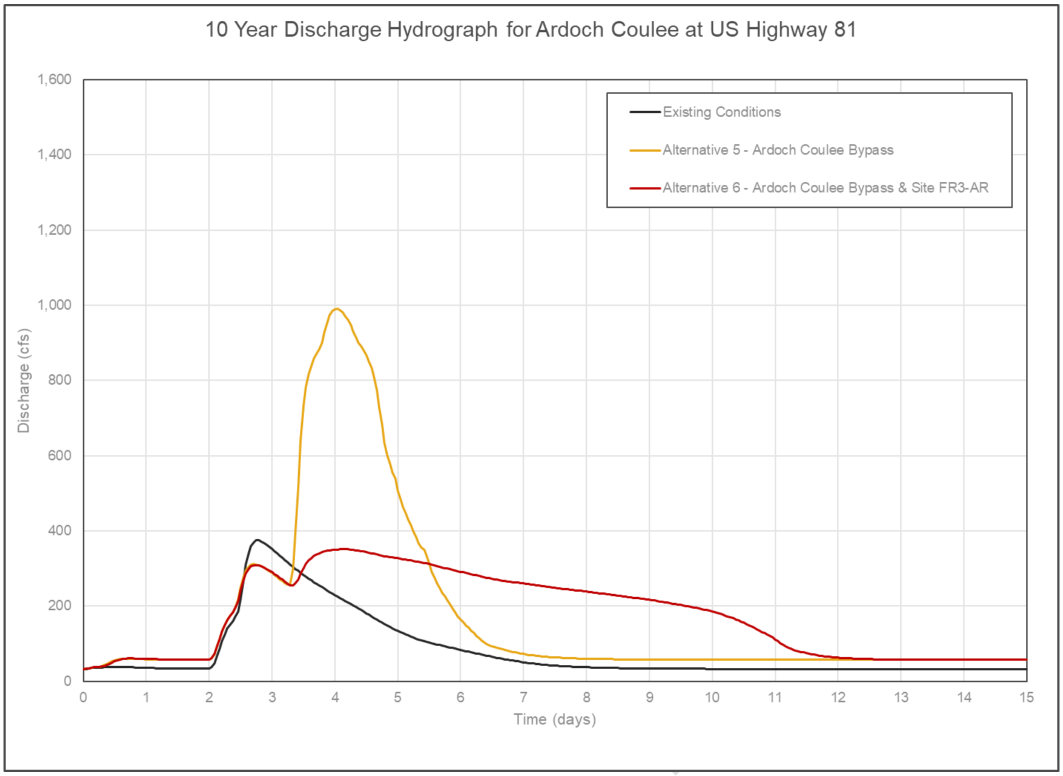
11
12
13
14
15

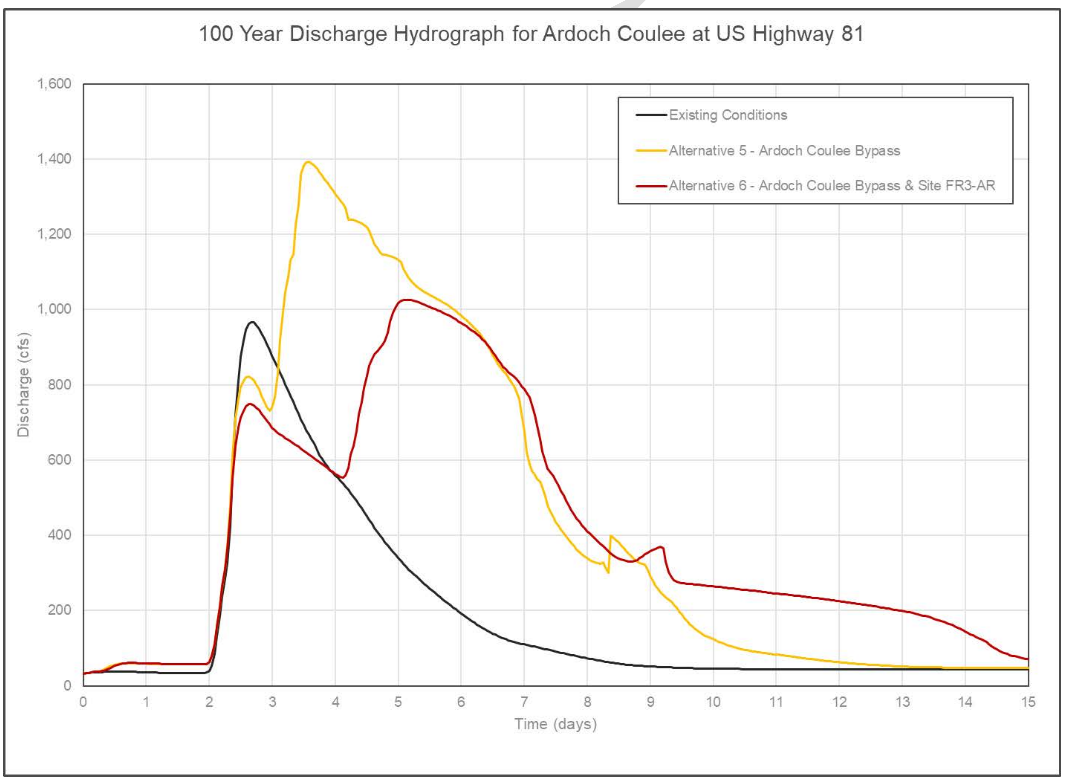


10 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)



100 Year Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR
Discharge (cfs)
Time (days)


10 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
1,600
1,400
1,200
1,000
800
600
400
200
0
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR


100 Year Discharge Hydrograph for Ardoch Coulee at US Highway 81
Discharge (cfs)
1,600
1,400
1,200
1,000
800
600
400
200
0
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Existing Conditions
Alternative 5 - Ardoch Coulee Bypass
Alternative 6 - Ardoch Coulee Bypass & Site FR3-AR

APPENDIX B

ARDOCH COULEE BYPASS AND FOREST RIVER SITE FR3-AR CONCEPT DESIGN REPORT

Fargo, ND | HEI No. 7135_0021
DRAFT February 21st, 2020

Ardoch Coulee in Grand Forks County, North Dakota

FOREST RIVER RCPP WATERSHED PLAN

ARDOCH COULEE BYPASS AND FOREST RIVER SITE FR3-AR CONCEPT DESIGN REPORT

Natural Resources Conservation Service

FOREST RIVER RCPP WATERSHED PLAN

ARDOCH COULEE BYPASS AND FOREST RIVER SITE FR3-AR CONCEPT DESIGN REPORT

February 21st, 2020
DRAFT

Walsh County Water Resource District

In cooperation with:
Forest River Joint Water Resource District

Houston Engineering, Inc.
1401 21st Ave. N
Fargo, ND 58102
Phone # 701.237.5065

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of North Dakota.

Zachary O. Herrmann, PE
PE-8405

Paul D. LeClaire, PE
PE-28012

Date

Date

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

The Walsh County Water Resource District (WCWRD) entered into a cooperative agreement with the Natural Resource Conservation Service (NRCS) in 2015 to complete a watershed plan for the Forest River Watershed through the Regional Cooperation Partnership Program (RCPP). This will be referred to as the Forest River Watershed Plan. The WCWRD is also referred to as the Sponsoring Local Organization (SLO) for the Forest River Watershed Plan. The Forest River Joint Water Resource District (FRJWRD) also provided local guidance during plan development. The FRJWRD includes the Nelson, Grand Forks, and Walsh county water resource districts. The FRJWRD put together a local planning team to work through the planning process outlined by the NRCS and provide additional local input to the FRJWRD.

As part of the Forest River Watershed Plan, a Purpose and Need Statement was identified by the planning team and approved by the NRCS. The purpose of the proposed action is to implement flood prevention and flood damage reduction measures to:

1. Reduce flood damages for up to a 10-year rainfall event on cropland.
2. Increase flood resiliency for up to a 10-year event on public and private infrastructure within the communities that reside along the Forest River. (Primary)
3. Increase flood resiliency for the communities of Minto and Forest River, ND, during a 100-year flood event. (Primary)
4. Maintain or reduce flood flows downstream of Lake Ardoch. (Primary)
5. Improve soil health and water quality throughout the watershed. (Secondary)

Previously, existing conditions modeling and screening of potential alternatives was completed to supplement the planning team's ability to make decisions to achieve the goals outlined in the Purpose and Need Statement. The development of existing conditions models is described in the *Forest River Watershed Plan – Existing Conditions Hydrology and Hydraulics Report* (Houston Engineering, Inc., 2019). Various flood reduction strategies were evaluated for the Forest River Watershed. The screening of strategies and alternatives is described in the *Forest River RCPP Watershed Plan – Screening of Alternatives for Detailed Review* (Houston Engineering, Inc., 2020). Flood reduction strategies and alternatives were screened based on technical data, practicality to implement, and their ability to satisfy the Purpose and Need Statement for the Forest River Watershed Plan.

Based on the screening of alternatives and local stakeholder input, one alternative has been identified as a potential project. The project was presented in the *Screening of Alternatives for Detailed Review* as Ardoch Coulee Bypass and Forest River Site FR3-AR. The project impoundment herein is referred to as Site FR3-AR and the project diversion as Ardoch Coulee Bypass.

Site FR3-AR is an off-channel impoundment site designed to store floodwaters diverted from the Forest River mainstem with the use of the Ardoch Coulee Bypass and a small area contributing runoff to Ardoch Coulee in the Forest River Watershed. The project location, characteristics, dam hazard classification, site design, performance, and estimated project cost are described in the following sections of this report.

Field survey to supplement the design of the proposed site was not collected due to the SLO's desire to cease planning for the Forest River Watershed Plan. Survey data collected previously and throughout this planning effort is described in Section 3 of this report and in the *Forest River Watershed Plan – Existing Conditions Hydrology and Hydraulics Report*. Similarly, geologic investigations and geotechnical analyses were not completed for this report. The intent with this report is to document the conceptual design for the preferred alternative based on the data and information available so that the project could be continued in the future if the SLO or another entity chose to do so. Additional field exploration will be necessary if project planning continues beyond the extent described herein.

1.2 VERTICAL DATUM

All elevations within this report are in reference to North American Vertical Datum of 1988 (NAVD88).

2 SITE LOCATION

The location of the impoundment site and bypass channel relative to the Forest River Watershed is shown on **Figure 2**. The direct contributing drainage area to the impoundment site is 9.9 square miles. The drainage area to the Ardoch Coulee Bypass inlet on the Forest River mainstem is 378 square miles. Both the direct contributing drainage area and the drainage area to the bypass inlet are shown on **Figure 2**. The total drainage area to the Ardoch Coulee Bypass and Site FR3-AR is 388 square miles, which accounts for approximately 44% of the 884 square mile Forest River Watershed. The western portion of the contributing area consists of mostly agricultural land above the beach ridge. As flows move easterly, they are collected in valleys and ravines along the steep slopes of the beach ridge. The beach ridge then transitions to the Lake Agassiz lake plain, which is characterized by flat slopes and predominantly agricultural land use. Descriptions of both the location of the impoundment for Site FR3-AR and the Ardoch Coulee Bypass is provided in the following sections.

2.1 IMPOUNDMENT LOCATION

Site FR3-AR is an off-channel impoundment constructed of an earthen embankment located within Section 3 of Johnstown Township, Grand Forks County, ND. The impoundment site is approximately 2 miles south and 1 mile east of Forest River, ND, and approximately 5 miles west and 1 mile south of the community of Ardoch, ND. The embankment of Site FR3-AR spans across the Ardoch Coulee valley. The land use associated with the drainage area that contributes to the impoundment within the Ardoch Coulee Watershed (direct contributing drainage area) consists of mostly agricultural land with a small amount of forested land.

2.2 BYPASS LOCATION

The upstream end of the Ardoch Coulee Bypass is in Section 1 of Strebane Township, Grand Forks County, North Dakota. The bypass channel conveys flows south for approximately 1,000 feet and then turns to convey flows east along the north side of 35th Ave NE. The bypass continues east through Section 1 of Strebane Township and Sections 6, 5, and 4 of Johnstown Township, where it enters an existing swale, which ultimately flows to Ardoch Coulee and Site FR3-AR. The Ardoch Coulee Bypass would need to cross through one private drive, two township roads, one county road, and a railroad before discharging into Ardoch Coulee. Aside from the roadway crossings, the areas impacted by the Ardoch Coulee Bypass are mostly agricultural lands.

3 FIELD SURVEY

Field survey data was collected by Houston Engineering, Inc. (HEI) beginning in 2013 as part of a planning effort that was underway prior to the Forest River Watershed Plan. Topographic field survey data was collected to aid in the development of an existing conditions hydraulic model. Data that was collected consisted of information on the river channel hydraulic structures, river channel cross sections throughout the Forest River mainstem, levee elevations and apparent breakout locations, and information on various culverts and bridges in the floodplain that convey breakout waters during large runoff events. Additional information on the field survey data can be found in the *Existing Conditions Hydrology and Hydraulics Report* (Houston Engineering, Inc., 2019).

LiDAR topographic data made available through the International Water Institute (IWI, 2008-2009) was used to supplement the field survey data. The LiDAR data was collected in 2008 and 2009.

4 SITE CHARACTERISTICS

Site FR3-AR is an off-channel impoundment with an earthen embankment. Floodwaters are diverted into the site via the Ardoch Coulee Bypass. The outlet consists of a low flow pipe, a principal spillway riser tower, and an earthen auxiliary spillway. A site map showing the Ardoch Coulee Bypass and Site FR3-AR is displayed on **Figure 4**. Preliminary site plans are shown in **Appendix A**. The following sub-sections describe the individual project components, and reference sections of the plans in **Appendix A**.

4.1 INLET COMPONENTS

There are two methods that allow floodwaters to enter the site: direct drainage to the site, which comes from local inflow, and the Ardoch Coulee Bypass inlet on the Forest River mainstem. The local inflow to the site comes from natural drainage paths and enters through existing swales and culverts.

The inlet along the Forest River mainstem consists of two structures: an on-channel structure and an inlet structure for regulating flood flows going into the Ardoch Coulee Bypass. The on-channel structure is sized so that there is minimal head increase for a 1.5-year event. A 1.5-year event is generally accepted as the bankfull discharge, which is defined as “the channel-forming or effective discharge” (Leopold, 1994). Causing minimal head increase for the 1.5-year event will help to prevent adverse impacts to the morphology of the Forest River downstream of the on-channel structure. The structure consists of two 14’ x 7’ reinforced concrete box culverts. The structure is designed to increase headwater elevations for events larger than the 1.5-year rainfall event up to the 10-year rainfall event. An overflow weir with a 350-foot bottom width and 20:1 side slopes is placed at an elevation slightly higher than the headwater elevation produced from a 10-year rainfall event. The overflow weir would be protected with rock riprap to prevent erosion during larger runoff events.

The inlet structure that regulates flood flows into the Ardoch Coulee Bypass consists of an overflow weir that is 100 feet in length that drops into a 9’ x 6’ reinforced concrete box culvert. The weir/inlet structure is activated for events larger than the 1.5-year rainfall runoff event. Runoff events smaller than the 1.5-year event will continue on the Forest River mainstem, and the Ardoch Coulee Bypass channel will only carry local inflow to the proposed impoundment site. The reinforced concrete box culvert in the structure is designed to control flows above a 10-year event. For events larger than the 10-year event, flood flows are regulated by the culvert, and more flow is directed to the overflow weir on the Forest River on-channel structure. Details for the on-channel structure and the inlet structure are shown in the C-100 series in **Appendix A**.

4.2 BYPASS CHANNEL

Flood water that passes through the inlet structure enters the Ardoch Coulee Bypass channel. The channel consists of a 16-foot channel bottom, 4:1 side slopes, and a 0.07% channel gradient. Channel benches are implemented when the depth of the channel exceeds 8 feet to increase stability in the channel. The channel is assumed to be geotechnically stable throughout this analysis based on channel design used for other projects in the area; however, additional geotechnical analysis will need to be completed to verify channel stability for future analysis. Geotechnical analysis for channel stability was not completed for this report due to the SLO's desire to cease planning for the Forest River Watershed Plan.

The channel is designed to pass the 100-year rainfall event without allowing the peak water surface elevation to exceed the adjacent field elevation. This will ensure that landowners adjacent to the bypass channel will not be adversely impacted by the project for rainfall events up to the 100-year event. As was discussed in Section 2.2, there are a total of five crossings of the bypass and roadways or railroads. The structures at the crossings are designed to pass the 100-year event without causing headwater elevations to increase above adjacent field elevations. Four of the five crossings contain double 8' x 6' reinforced concrete box culverts. The structure through the railroad crossing contains a triple 10' x 6' reinforced concrete box culvert. The structure through the bypass crossing with the railroad is larger than the other crossing structures because of its proximity to the crossing with Grand Forks County Road 2. The larger structure reduces the tailwater elevation of the crossing at Grand Forks County Road 2, which reduces the headwater upstream of the county road to an elevation below the adjacent field elevation during a 100-year event.

In addition to the five crossings, there are a total of four rock drop structures in the bypass. The rock drop structures are approximately 5 feet high. The drop structures are designed by following guidelines in *Technical Release No. 59 – Hydraulic Design of Riprap Gradient Control Structures* (Soil Conservation Service, 1976). The plans associated with the Ardoch Coulee Bypass are shown in the C-200 series in **Appendix A**.

4.3 EMBANKMENT

The embankment for Site FR3-AR is constructed across the Ardoch Coulee valley. The embankment consists of a 14-foot top width at an elevation of 860 feet with 4:1 side slopes on both the wet and dry side of the embankment. The embankment has a maximum height of approximately 24.1 feet and an average height of 15.5 feet. The NRCS document *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019) specifies that the minimum top width shall be 12 feet for a maximum embankment height of 20-24.9 feet. A top width of 14 feet was selected to ensure that the guidance in *Technical Release 210-60* was met since the maximum height of the dam is on the border of the next highest increment of embankment heights (a minimum top width of 14 feet is specified for a maximum embankment height of 25-34.9 feet).

Due to the SLO's desire to cease the planning effort for the Forest River Watershed Plan, there were no geologic investigations completed at the site, and no geotechnical analysis was done. Therefore, the materials and dimensions used for the embankment are assumed. A clay core with 1.5:1 slopes on both the wet and dry sides of the embankment is assumed for the center of the embankment with general fill placed between the core and the 4:1 side slopes. An inspection trench is assumed to be excavated below the embankment and filled with impervious clay material similar to the embankment clay core. The inspection trench is assumed to have a 5-foot bottom width, 1:1 side slopes, and a maximum depth of 6 feet. The embankment ties in to natural ground on the northwest and southeast sides of the valley. Plans for the embankment are shown in the C-300 series in **Appendix A**.

4.4 SPILLWAYS

Flows exit Site FR3-AR via the principal spillway or the auxiliary spillway. The spillways are discussed in detail in the follow sub-sections. Summary data associated with Site FR3-AR is provided in **Table 1**, which includes information on the embankment, spillways, and other general information about the proposed impoundment.

4.4.1 PRINCIPAL SPILLWAY

The principal spillway consists of a riser tower with a primary low flow inlet pipe, a secondary inlet weir, and an outlet conduit. The low flow inlet is a 48-inch reinforced concrete pipe set near the upstream channel elevation of 834.76 feet. This allows the site to be completely drawn down without the operation of a gate structure.

The secondary inlet is the weir crest of the riser tower. The riser tower is a 12’ x 28’ concrete riser. At the crest elevation, the riser is open on all sides, allowing for 80 feet of weir flow length. An anti-vortex splitter wall is located at the center of the opening. The crest of the riser tower is at an elevation of 854.7 feet. The weir crest begins to operate between a 10-year and 25-year event. During the 10-year event, only the primary low flow pipe is operating.

The outlet conduit carries flows from the riser tower, through the embankment, and outlets back into Ardoch Coulee. The outlet conduit is a 12’ x 8’ reinforced concrete box culvert. The conduit was sized to ensure the hydraulic control switches from the weir to the conduit before orifice flow can occur. With this design, orifice flow and cavitation in the riser tower should not occur. The principal spillway structure details are shown on sheet C-300 in **Appendix A.**

4.4.2 AUXILIARY SPILLWAY

Guidance from *National Engineering Handbook, Part 628 Dams, Chapter 50 Earth Spillway Design* (NRCS, 2014) was used to design the auxiliary spillway. The auxiliary spillway is an earthen spillway north of Ardoch Coulee in the northwest quarter of Section 3, Johnstown Township. The auxiliary spillway crest elevation is at 857.00 feet. The spillway will be constructed in natural ground and not on placed fill material. The spillway is a total of 200 feet long with an average exit channel slope of 4%. The spillway outlets into Ardoch Coulee downstream of the principal spillway outlet for the site. The auxiliary spillway details and layout are shown in the C-300 series in **Appendix A**.

Table 1: Site FR3-AR Summary Table

General Data		
Purpose	Flood Control	
Hazard Classification	Significant Hazard	
Drainage Area – Direct Contributing[1]	9.9 square miles	
Drainage Area – Non-Direct Contributing[2]	388 square miles	
Dam Height (Average)	15.5 feet	
Maximum Dam Height	24.1 feet	
Embankment Length	920 feet	
Embankment Top Width	14 feet	
Embankment Upstream Slope	4H:1V	
Embankment Downstream Slope	4H:1V	
Critical Elevations (NAVD88)		
Principal Spillway Low Flow Culvert Invert	834.76 feet	
Principal Spillway Riser Tower Crest	854.7 feet	
Auxiliary Spillway Crest	857 feet	
Top of Dam	860 feet	
Storage Capacities	**Volume**	**Surface Area**
Principal Spillway Riser Tower Crest	1,448 acre-feet	181 acres
Auxiliary Spillway Crest	1,890 acre-feet	205 acres
Top of Dam	2,608 acre-feet	317 acres
Other Features		
Principal Spillway Low Flow Culvert	48-inch RCP	
Principal Spillway Riser Tower Width	12 feet	
Principal Spillway Riser Tower Length	28 feet	
Principal Spillway Riser Tower Weir Crest Length	80 feet	
Principal Spillway Outlet Conduit	12 feet wide x 8 feet high RCBC	
Auxiliary Spillway Flow Width	200 feet	

[1] Drainage area coming from Ardoch Coulee Watershed

[2] Drainage area to Ardoch Coulee Bypass plus drainage area from Ardoch Coulee Watershed

4.5 STAGE-STORAGE-AREA-DISCHARGE RELATIONSHIP

A stage-storage-area relationship has been developed based on LiDAR elevation data. The stage-storage-area relationship for Site FR3-AR is shown on **Figure 4.5a**.

A stage-discharge relationship was developed for the principal and auxiliary spillways for Site FR3-AR. The relationship was verified with the hydraulic model. Both the principal spillway and auxiliary spillway stage-discharge relationships for Site FR3-AR are shown on **Figure 4.5b**.

5 DAM HAZARD CLASSIFICATION

5.1 DAM BREACH CRITERIA

Guidance for peak breach discharge criteria for hazard classification of a dam is provided in *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019). Based on this guidance, the dam failure shall be evaluated with a water surface elevation at the dam crest or the peak reservoir stage resulting from the probable maximum flood. For Site FR3-AR, the dam failure was evaluated based on the top-of-dam elevation of 860 feet. This was selected because it represents the worst-case scenario of the two water surface elevations.

TR 210-60 also provides equations to calculate the minimum peak discharge of the breach hydrograph based on volume of storage and site characteristics. Equations are provided for both a low narrow dam and a low wide dam. For FR3-AR, the minimum peak discharge of the breach hydrograph was calculated to be 26,000 cubic feet per second. The calculations to determine this discharge are shown in **Figure 5.1a**. These calculations were completed using an excel file developed by the NRCS National Water & Climate Center (NRCS WCC, 2013). (The equations were calculated by hand to ensure accuracy in a third party excel file.) The breach hydrograph is calculated based on site characteristics and is not the result of a hydrologic event.

A 1-dimensional unsteady hydraulic model was used to perform the breach analysis from Ardoch Coulee at Grand Forks County Road 2 to Lake Ardoch and from Lake Ardoch to the Forest River crossing at US Interstate 29. *TR 210-60* provides equations to calculate a theoretical breach width based on the depth of water at the time of the breach and the peak breach discharge. For Site FR3-AR, the theoretical breach width was 434 feet. The breach formation time variable within the HEC-RAS modeling software was adjusted until the peak outflow from the dam was within 1% of the calculated peak breach discharge. The Site FR3-AR simulated breach outflow hydrograph is shown in **Figure 5.1b**.

5.2 DAM BREACH RESULTS

Once the breach hydrograph was developed based on NRCS guidance, the hydrograph was routed through the hydraulic model to evaluate the downstream impacts resulting from a dam breach. The floodplain resulting from the dam breach is shown on **Figure 5.2**. The impacts and inundation shown on **Figure 5.2** are solely related to the impoundment site breach hydrograph.

Based on the inundation extents shown in **Figure 5.2**, there is one inhabitable structure that could potentially be in danger in the event of a breach. *ACER Technical Memorandum 11 – Downstream Hazard Classification Guidelines* (U.S. Bureau of Reclamation, 1988) was reviewed to determine if the inhabitable inundation at the structure in question would cause loss of life. The results show that the depth of flooding at the structure is approximately 1 foot and the velocity is approximately 0.6 feet per second. Based on the information provided in Figures 2 through 6 in *ACER Technical Memorandum 11* (U.S. Bureau of Reclamation, 1988), the depth-velocity combination at the inundated structure would fall into the "Low Danger" category, meaning that there would not be probable loss of life in this case.

5.3 DAM HAZARD CLASSIFICATION

Title 210, National Engineering Manual, Part 520 Subpart C "Dams" (NRCS, 2017) describes the hazard potential resulting from failure of dams. According to this guidance, a high hazard potential is defined as "dams where failure may cause loss of life or serious damage to homes, industrial or commercial buildings, important public utilities, main highways, or railroad," and a significant hazard potential is defined as "dams in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, or minor railroads or interrupt service of relatively important public utilities."

Currently, the North Dakota State Water Commission (SWC) is developing updated guidance for assigning hazard classification to dams in North Dakota through the Dam Safety Program. Gannett Fleming provided recommendations for hazard classification to the SWC in July 2017. In the recommendations provided to the SWC, the high hazard potential classification is defined as “dams where failure or misoperation will probably cause loss of human life” and the significant hazard potential as “dams where failure or misoperation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns.”

Based on the dam breach results presented in Section 5.2 and the hazard potential definitions provided in this section, Site FR3-AR is a classified as a significant hazard dam.

6 DAM SAFETY REQUIREMENTS

Technical Release 210-60: Earth Dams and Reservoirs (NRCS, 2019) provides guidance on the minimum spillway precipitation criteria for the three dam hazard classifications. **Table 2** presents the minimum precipitation data and precipitation depth for the design of principal and auxiliary spillways for a significant hazard dam. The design hydrographs are described in detail in the following sub-sections. The flood pools for the principal spillway riser tower elevation, auxiliary spillway crest elevation, and top of dam elevation are shown on **Figure 6**.

Table 2: Technical Release 210-60 Minimum Precipitation Data for Significant Hazard Dams

Design Event Hydrograph	Precipitation Data[1]	Depth (inches)
Principal Spillway Hydrograph	P_{50}	4.08 [2] 6.72 [3]
Auxiliary Spillway Hydrograph	P_{100} + 0.12 * (PMP - P_{100})	NA
Freeboard Hydrograph	P_{100} + 0.40* (PMP - P_{100})	12.2[4] 14.5[5]

[1] P_{50} = Precipitation for the 50-year return period; P_{100} = Precipitation for the 100-year return period; PMP = Probable Maximum Precipitation
[2] Runoff depth based on *NEH Part 630 Chapter 21*. See Section 6.1.1
[3] Rainfall depth based on *NOAA Atlas 14*. See Section 6.1.2
[4] Rainfall depth based on a 72-hour duration event for 388-square-mile drainage area that includes the area to the Ardoch Coulee Bypass inlet and drainage area from the Ardoch Coulee Watershed. See Section 6.2
[5] Rainfall depth based on a 24-hour duration event for 9.9-square-mile drainage area that includes only the drainage area from the Ardoch Coulee Watershed. See Section 6.2

6.1 PRINCIPAL SPILLWAY DESIGN

Based on *TR 210-60*, the principal spillway of a significant hazard dam must pass, at a minimum, the 50-year return period storm without activating the auxiliary spillway. Guidance dictates this storm shall have a duration of not less than 10 days. Four methods to determine runoff volume for the design of the principal spillway are presented in *National Engineering Handbook, Part 630 Hydrology, Chapter 21 Design Hydrographs* (NRCS, 2019). For the design of Site FR3-AR, two methods were used to determine the critical event: runoff volume maps and runoff curve number procedure.

6.1.1 RUNOFF VOLUME MAPS

Runoff volume maps presented in *NEH Part 630 Chapter 21* were generated for areas where runoff from snowmelt can potentially produce greater runoff volumes than rainfall events. The 10-day 100-year runoff volume for Site FR3-AR is 4.80 inches according to Figure 21-2 of *NEH Part 630 Chapter 21*. To attain the 10-day 50-year runoff volume, the 100-year value is multiplied by a ratio of 0.85 for sites in North Dakota. This results in a runoff volume of 4.08 inches for the proposed site. No areal reduction is applied to this runoff volume. Curve Numbers in the hydrologic model were modified to result in 4.08 inches of runoff.

The total runoff of 4.08 inches is the result of a 10-day runoff. Guidance from *NEH Part 630 Chapter 21* was used to develop the principal spillway mass curve, or runoff distribution curve, for the 10-day event. For Site FR3-AR, 1-hour time increments were used to develop the distribution. Using equation 21-2 from *NEH Part 630 Chapter 21*, the total runoff at any given time during the event can be calculated. These 1-hour values can then be arranged in either a decreasing order (Curve A), an increasing order (Curve B), or a critical stacking order (Curve C). The principal spillway mass curves are shown on **Figure 6.1.1a**.

The runoff volume of 4.08 inches was simulated through the hydrologic and hydraulic models using the principal spillway mass curves A, B, and C. All three curves were simulated to ensure the auxiliary spillway was not activated during any event, and the resulting stage and discharge at the outlet of Site FR3-AR are shown on **Figure 6.1.1b**. The auxiliary spillway for Site FR3-AR would not be activated during the passage of these principal spillway design events. The most critical event using these procedures is the runoff produced using mass curve B.

Quick Return Flow (QRF) is the rate of discharge that persists beyond the flood period of the principal spillway hydrograph. Based on Figure 21-4 in *NEH, Part 630, Chapter 21*, the QRF for runoff at Site FR3-AR is approximately 1.5 cubic feet per second per square mile. Because the site is designed to allow baseflow on the Forest River to pass without entering the bypass channel, QRF is only considered for the 9.9-square-mile drainage area that directly contributes to the impoundment site. This results in a QRF of approximately 15 cubic feet per second. The baseflow required to simulate the alternative in the HEC-RAS model is greater than 15 cubic feet per second. Therefore, QRF at the proposed site is being accounted for conservatively in the hydraulic model.

6.1.2 RUNOFF CURVE NUMBER PROCEDURE

The runoff curve number procedure presented in *NEH, Part 630, Chapter 21* uses climatic data and watershed characteristics to convert rainfall data into runoff volumes. The 10-day 50-year rainfall event was simulated using depths published in *NOAA Atlas 14* (NOAA, 2017). For Site FR3-AR the 10-day 50-year rainfall depth is 6.72 inches. The simulation used a nested distribution as described in the *Existing Conditions Hydrology and Hydraulics Report* (Houston Engineering, Inc., 2019). A 10-day Curve Number with an average moisture condition (AMC II) was used. The stage and discharge hydrograph from this event are shown on **Figure 6.1.2**. The figure also includes the critical event, mass Curve B, from the runoff volume maps procedure discussed in Section 6.1.1.

6.1.3 PRINCIPAL SPILLWAY ADEQUACY

Guidance from *NEH 210-60* states that the principal spillway capacity should empty at least 85% of the principal spillway hydrograph in 10 days or less. The 10-day drawdown begins when the peak water surface elevation is attained in the site during the passage of the principal spillway hydrograph. For Site FR3-AR, the critical principal spillway event resulted from the runoff volume maps mass Curve B described in Section 6.1.1. For this event, the principal spillway passes all flood water volume 10 days after the peak water surface elevation occurs. The drawdown storage volume hydrograph for Site FR3-AR is shown on **Figure 6.1.3**. Therefore, the principal spillway meets the minimum 10-day drawdown capacity.

The auxiliary spillway for Site FR3-AR would not be activated during the passage of the principal spillway design events from both Section 6.1.1 and Section 6.1.2. The principal spillway meets the 10-day drawdown requirement.

6.2 AUXILIARY SPILLWAY DESIGN

There are two critical hydrologic events that must be analyzed for the auxiliary spillway based on guidance from *NEH 210-60*. These events are the auxiliary spillway stability design hydrograph (SDH) and the freeboard hydrograph (FBH). For the purposes of this report, field investigation for geotechnical considerations was not completed. As a result, any analysis required to determine the stability and integrity of the earthen auxiliary spillway was not completed. This includes examining the auxiliary spillway stability with the use of the SDH and the auxiliary spillway integrity with the use of the FBH. Stability and integrity should be considered for future planning of the proposed site. For this analysis, only the FBH was simulated to verify that the capacity of the auxiliary spillway is adequate. The FBH involves the use of probable maximum precipitation rainfall depths to calculate the minimum design rainfall event.

For this analysis, probable maximum precipitation (PMP) depths were determined based on *Hydrometeorological Report No. 51* (NOAA, 1978), also known as *HMR-51*. PMP rainfall depths are dependent on the drainage area being analyzed. The depths for this analysis were determined based on the direct drainage area contributing to the site (9.9 square miles) and the total drainage area including the drainage area to the bypass inlet (388 square miles). PMP depths were determined by interpolating between the published values for 10-, 200-, and 1,000-square-mile drainage areas.

The minimum design event for the freeboard hydrograph (FBH) defined by *NEH 210-60* is shown in **Table 2**. The duration of the FBH was developed based on guidance from *NEH 210-60*. That guidance states that both the 6- and 24-hour storm durations shall be analyzed, and *NEH, Part 630, Chapter 21* states that a storm duration equal to or greater than the time of concentration shall be analyzed. The time of concentration to Site FR3-AR is approximately 20 hours for the drainage area that directly contributes to the site. The time of concentration for the total drainage area is several days. Due to the high time of concentration for the larger drainage area, 6-, 24-, 48-, and 72-hour duration storms were analyzed. The rainfall distribution used for the FBH simulation was an SCS Type II distribution. The SCS Type II distribution was deemed appropriate for this level of design. The rainfall hyetograph and distribution curve for the FBH is shown on **Figure 6.2a**.

The discharge hydrograph for all FBH scenarios considered for Site FR3-AR is shown on **Figure 6.2b**. Based on the figure, the peak water surface elevation within Site FR3-AR occurs during the 72-hour storm event with the drainage area to the bypass inlet and direct contributing drainage area being considered. During passage of the most critical freeboard hydrograph applied, the stage within Site FR3-AR rises to a maximum elevation of 857.49 feet, which inundates 212 acres. This results in a max depth of flow over the auxiliary spillway of 0.49 feet and a combined peak discharge of approximately 1,760 cubic feet per second. The peak discharge through the auxiliary spillway is approximately 255 cubic feet per second. The principal spillway, auxiliary spillway, combined inflow, and combined outflow hydrographs are shown on **Figure 6.2c**.

The peak water surface elevation of 857.49 feet is below the top of dam elevation of 860.0 feet; therefore, the auxiliary spillway passes the FBH without overtopping.

7 SYNTHETIC RAINFALL EVENTS AND SITE PERFORMANCE

To analyze the performance of the Ardoch Coulee Bypass and Site FR3-AR, synthetic rainfall events were simulated and routed through the hydraulic model. Synthetic rainfall events for the Forest River Watershed Plan are defined in the *Existing Conditions Hydrology and Hydraulics Report*. The events include 2-year through 100-year return periods based on NOAA Atlas 14 rainfall depths with a 4-day duration (the 4-day duration was determined to be the most critical duration for the Forest River Watershed). Runoff Curve Numbers were adjusted from a 24-hour Curve Number to a 4-day Curve Number based on guidance from *NEH, Part 630, Chapter 21* and were set to average antecedent moisture condition (AMC II). The rainfall distribution used for the synthetic events was developed using a nesting technique described in *NEH, Part 630, Chapter 4* (NRCS, 2015). This report was prepared subsequent to the *Existing Conditions Hydrology and Hydraulics Report* and the *Screening of Alternatives for Detailed Review*. The existing conditions model was modified to incorporate the Ardoch Coulee Bypass and Site FR3-AR project components. Inundated acreages were updated for this report and may not match the *Existing Conditions Hydrology and Hydraulics Report* and the *Screening of Alternatives for Detailed Review*.

Impoundment Site Performance

Floodwaters were diverted into the site for the 2-year through 100-year events. The average rainfall depth, peak pool elevation, storage volume at peak elevation, pool area at peak elevation, and peak discharge through the principal spillway for each event are shown in **Table 3**.

For 2-year through 10-year events, only the primary low flow culvert of the principal spillway riser would be activated. The principal spillway riser tower crest would be activated between the 10-year and 25-year events. The peak water surface elevation within the site for the 100-year event would be 856.75 feet, or 0.25 feet below the auxiliary spillway. Inundation within the site would range from nine acres to 202 acres for the 2-year through 100-year events. Inundation during the 2-year through 100-year events is shown on **Figure 7**.

Table 3: Ardoch Coulee Bypass and Site FR3-AR Synthetic Rainfall Event Results

Event	NOAA Atlas 14 4-Day Rainfall Depth[1] (inches)	Peak Flood Pool Elevation (feet)	Storage Volume[2] (ac-ft)	Pool Area[2] (acres)	Principal Spillway Discharge (cfs)
2-year	2.68	839.44	13	9	82
5-year	3.33	849.35	610	129	212
10-year	3.93	854.66	1441	180	255
25-year	4.83	856.33	1756	197	713
50-year	5.58	856.65	1819	201	849
100-year	6.40	856.75	1840	202	892

[1] Average rainfall depth adjusted for areal reduction based on watershed size of 884 square miles
[2] Values are in reference to the Peak Flood Pool Elevation

Changes to Peak Flows Downstream of the Impoundment Site

Multiple reporting locations were selected in the *Screening of Alternatives for Detailed Review*. These locations were selected to evaluate modeling results throughout the watershed at geographically significant locations. These locations include North Dakota state highways, township roads, cities, and near the outlet of the watershed. For this analysis, only the reporting locations in the lower region of the watershed were considered because the proposed site does not have an impact in the upper portion of the watershed. Therefore, results for reporting locations at North Dakota State Highway 32 and at 134th Ave NE are not included. The reporting locations used for this analysis are shown in **Appendix B**, **Figure B.1**, and are further summarized below. Hydrographs for the 2-year through 100-year events at the reporting locations are shown in **Appendix B**, **Figures B.2** through **B.8**. The peak discharges for the analyzed events at the reporting locations are shown in **Table 4**.

- Forest River at North Dakota State Highway 18 – Forest River crossing at major highway. Crossing location is just upstream of where the Forest River transitions from a well-defined valley to a perched river system where breakout flows travel overland. All discharge hydrographs for the proposed alternative upstream of North Dakota State Highway 18 are identical to existing conditions.
- Forest River at Walsh County Road 6 – North of the town of Forest River, ND. Downstream of large breakout that conveys flow north into an unnamed tributary. Upstream of large breakout that conveys flow east to Ardoch Coulee. First reporting location downstream of the Ardoch Coulee Bypass on the Forest River.
- Forest River at 1st Street Crossing – At USGS Streamgage 05085000 at Minto, ND. Located downstream of US Highway 81 and upstream of a BNSF railroad. Last major crossing before the Forest River enters Lake Ardoch.
- Forest River at Walsh County Road 4 – Downstream of Lake Ardoch. Reporting location showing any potential impact to area downstream of Lake Ardoch near the watershed outlet.
- Forest River North Breakout at 148th Ave NE – A perennial stream that enters the Forest River upstream of Minto, ND. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee Breakout at US Highway 81 – A perennial stream that enters Ardoch Coulee approximately 1 mile downstream of US Highway 81. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee at US Highway 81 – Major stream crossing upstream of Lake Ardoch and downstream of Site FR3-AR.

At the Forest River crossing with Walsh County Road 6, peak flow reductions range from 5.3% to 32.7% for the 2-year through 100-year events. Peak flow reductions at Walsh County Road 6 vary because of the existing breakout location upstream of the reporting location. The maximum percent reduction at Walsh County Road 6 occurs during the 10-year rainfall event at 32.7%.

Further downstream at the Forest River crossing with 1st Street in Minto, ND, peak flow reductions range from 0.7% to 26.4%. Peak flow reductions are smallest for the 2-year rainfall event and begin to increase through the 10-year rainfall event. As the rainfall event becomes less frequent than the 10-year rainfall event (25-, 50-, and 100-year rainfall events), the peak flow reduction begins to decrease. This is primarily due to the sizing of the structures at the Ardoch Coulee Bypass inlet discussed in Section 4.1. The inlet structure limits inflow to the Ardoch Coulee Bypass for flows above the 10-year rainfall event and more flow is directed into the Forest River mainstem over the on-channel weir.

Table 4: Peak Flow Changes

Location	Event	Existing Conditions	Cart Creek Site 1	% Change
Forest River at ND Highway 18	2-year	1,012	1,013	(-0.1%)
	5-year	1,850	1,850	(0.0%)
	10-year	2,841	2,841	(0.0%)
	25-year	4,714	4,712	(0.0%)
	50-year	6,568	6,567	(0.0%)
	100-year	8,677	8,674	(0.0%)
Forest River at Walsh County Road 6	2-year	773	734	(5.3%)
	5-year	973	876	(11.1%)
	10-year	1,316	991	(32.7%)
	25-year	1,452	1,361	(6.7%)
	50-year	1,670	1,460	(14.3%)
	100-year	2,090	1,708	(22.4%)
Forest River at 1st Street Crossing	2-year	1,009	1,002	(0.7%)
	5-year	1,840	1,456	(26.4%)
	10-year	2,905	2,309	(25.8%)
	25-year	4,706	3,988	(18.0%)
	50-year	6,096	5,490	(11.0%)
	100-year	7,453	7,025	(6.1%)
Forest River at Walsh County Road 4	2-year	1,605	1,611	(-0.3%)
	5-year	2,706	2,711	(-0.2%)
	10-year	4,173	3,930	(6.2%)
	25-year	6,759	6,579	(2.7%)
	50-year	8,923	8,769	(1.7%)
	100-year	11,541	11,406	(1.2%)
Forest River North Breakout at 148th Avenue NE	2-year	440	434	(1.4%)
	5-year	1,103	827	(33.5%)
	10-year	1,835	1,441	(27.4%)
	25-year	3,231	2,777	(16.4%)
	50-year	4,307	4,012	(7.3%)
	100-year	5,146	5,073	(1.4%)
Ardoch Coulee Breakout at US Highway 81	2-year	161	159	(1.1%)
	5-year	291	237	(22.7%)
	10-year	390	335	(16.3%)
	25-year	436	413	(5.5%)
	50-year	506	463	(9.5%)
	100-year	604	560	(7.8%)
Ardoch Coulee at US Highway 81	2-year	123	134	(-7.8%)
	5-year	245	289	(-15.1%)
	10-year	375	351	(6.7%)
	25-year	592	784	(-24.5%)
	50-year	768	929	(-17.3%)
	100-year	967	1,026	(-5.7%)

The results indicate that there is no increase in peak flow changes for the Forest River crossing with Walsh County Road 4 downstream of Lake Ardoch. The maximum peak flow reduction at Walsh County Road 4 is 6.2%, which occurs for the 10-year event. The peak flow reduction for the 100-year rainfall event is 1.2%. The peak flow for the Ardoch Coulee crossing with US Highway 81 increases as much as 24.5%. However, the additional flow in Ardoch Coulee does not overtop US Highway 81 and the crossing still meets North Dakota stream crossing standards detailed in the North Dakota Century Code. Similar impacts occur at other crossings downstream of the site impoundment. Additional consideration of stream crossing standards for other crossings downstream of Site FR3-AR may be necessary for future planning.

Floodplain Inundation Statistics

The inundation for the 2-year through 100-year events is shown in **Appendix B**, **Figures B.9** through **B.14**. Inundation for both existing conditions (red) and with Ardoch Coulee Bypass and Site FR3-AR (blue) are shown on the figures. The red represents lands that are no longer flooded with the project for that event. Blue represents lands that are flooded for both conditions. The figures show the maximum inundation extent that occurs during the event; however, the full benefit of the project is not based only on maximum inundation. Flood damages, especially damages to agricultural lands, are caused both by the extent of the inundation and, almost equally as important, the duration of inundation. The total inundated acres and cropland inundated acres for the analyzed events based on duration are shown in **Table 5**. Cropland acres were estimated using the National Agricultural Statistics Service (NASS) data from 2017 (USDA, 2017).

The proposed Ardoch Coulee Bypass and Site FR3-AR reduce the total inundated acres for the 2- through 100-year events by 0.5% to 8.2%, and cropland inundated acres are reduced by 1.2% to 11.5%.

Typical crops within the Forest River Watershed include wheat, soybeans, corn, dry beans, potatoes, and sugar beets. Flood inundation durations greater than four days generally represents the maximum anticipated damages, or total loss, for the crop types in the study area.

Table 6 shows total inundated acres for durations less than 4-days in the Lower Forest River Watershed, which is described in the *Screening of Alternatives for Detailed Review* (Houston Engineering, Inc., 2020). To provide benefit to agricultural lands, flood durations between zero and four days should be reduced. Zero to four days represents the time between no inundation and total crop loss inundation.

During the existing conditions 10-year event, there are 3,384 cropland acres inundated for less than four days. With the bypass and impoundment site, the same event would inundate 2,545 cropland acres for less than four days. This results in a reduction of 840 acres or 24.8%. This is a reduction in inundation of 1.3 square miles. Ardoch Coulee Bypass and Site FR3-AR reduce the cropland inundation for durations less than four days by 4.6% to 25.4% for the 2-year through 100-year events.

Table 5: Inundated Acreage for Entire Forest River Watershed

Scenario	Duration (hours)	2-year		5-year		10-year		25-year		50-year		100-year	
		Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total
Existing Conditions	0-24	299	437	701	990	1,103	1,574	1,671	2,326	2,132	2,869	2,595	3,378
	24-48	408	564	762	1,044	1,006	1,354	1,467	1,952	1,924	2,439	2,059	2,523
	48-72	314	490	739	1,001	854	1,171	1,022	1,346	1,459	1,919	1,933	2,473
	72-96	354	542	567	758	817	1,050	969	1,278	1,004	1,276	1,795	2,309
	96-120	260	444	414	609	588	785	886	1,150	1,073	1,418	1,211	1,518
	>120	2,096	4,588	3,033	6,123	3,770	7,185	5,006	8,827	6,107	10,272	7,767	12,319
	TOTAL	3,732	7,065	6,217	10,525	8,138	13,118	11,020	16,880	13,699	20,193	17,359	24,520
Ardoch Coulee Bypass and Site FR3-AR	0-24	272	407	361	585	874	1,325	1,601	2,286	2,308	3,046	2,386	3,126
	24-48	391	544	521	739	604	880	1,222	1,686	1,688	2,215	2,208	2,660
	48-72	305	483	664	902	667	944	759	1,052	1,186	1,623	1,759	2,328
	72-96	348	532	538	735	740	953	849	1,145	836	1,103	1,612	2,111
	96-120	249	421	392	582	525	707	753	986	956	1,284	1,006	1,309
	>120	2,124	4,641	3,028	6,137	3,794	7,235	4,925	8,734	5,818	9,943	7,246	11,734
	TOTAL	3,689	7,029	5,505	9,679	7,204	12,043	10,109	15,889	12,792	19,215	***16,218***	***23,268***
% Change	0-24	-9.0%	-6.9%	-48.6%	-40.9%	-20.8%	-15.8%	-4.2%	-1.7%	8.3%	6.2%	-8.0%	-7.5%
	24-48	-4.0%	-3.6%	-31.6%	-29.3%	-39.9%	-35.0%	-16.7%	-13.6%	-12.3%	-9.2%	7.2%	5.4%
	48-72	-2.9%	-1.3%	-10.1%	-10.0%	-21.9%	-19.4%	-25.7%	-21.9%	-18.7%	-15.4%	-9.0%	-5.9%
	72-96	-1.7%	-1.9%	-5.1%	-3.1%	-9.4%	-9.3%	-12.3%	-10.5%	-16.7%	-13.5%	-10.2%	-8.6%
	96-120	-4.6%	-5.2%	-5.4%	-4.4%	-10.8%	-10.0%	-15.0%	-14.3%	-10.9%	-9.4%	-16.9%	-13.7%
	>120	1.3%	1.2%	-0.1%	0.2%	0.6%	0.7%	-1.6%	-1.0%	-4.7%	-3.2%	-6.7%	-4.7%
	TOTAL	-1.2%	-0.5%	-11.4%	-8.0%	-11.5%	-8.2%	-8.3%	-5.9%	-6.6%	-4.8%	***-6.6%***	***-5.1%***

Table 6: Inundated Acreage Less than 4-Days in the Lower Forest River Watershed

Scenario	Duration	2-year		5-year		10-year		25-year		50-year		100-year	
		Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total
Existing Conditions	Less than 4-days *(0-96 Hours)*	1,250	1,659	2,575	3,219	3,384	4,163	4,284	5,086	5,499	6,339	6,651	7,557
AC Bypass and Site FR3-AR		1,193	1,595	1,900	2,401	2,545	3,178	3,580	4,346	4,998	5,823	6,279	7,143
Difference		-57	-64	-675	-819	-840	-984	-704	-739	-501	-516	-372	-414
% Change		-4.6%	-3.8%	-26.2%	-25.4%	-24.8%	-23.6%	-16.4%	-14.5%	-9.1%	-8.1%	-5.6%	-5.5%

**Inundated acres based on the Lower Forest River Watershed area described in the Screening of Alternatives for Detailed Review.*

8 OTHER CONSIDERATIONS

Additional consideration was given to non-construction elements of the proposed site, such as utility relocates, engineering, right-of-way, and permitting. Some of the additional elements considered for the detailed alternative analysis are described in more detail in the sub-sections that follow.

8.1 RIGHT OF WAY AND EASEMENTS

Right of way acquisition is required for areas impacted permanently by the construction of Ardoch Coulee Bypass and Site FR3-AR. Areas permanently impacted by site construction include the on-channel embankment extents on the Forest River mainstem, the Ardoch Coulee Bypass channel where excavation is needed, the embankment for Site FR3-AR, and the excavation for the auxiliary spillway associated with Site FR3-AR. Right of way within 33 feet of the section line along 35th Ave NE was assumed to be owned by Grand Forks County when evaluating the overall cost of the project. Temporary easements for construction of the bypass channel would also need to be purchased. The construction easements would range from 250 to 300 feet in width along the entire bypass channel.

Additional right of way acquisition is necessary for the pool area upstream of the Site FR3-AR impoundment. The assumed area to be acquired is the area that results from a water surface elevation at the auxiliary spillway elevation. The area used to obtain the right of way upstream of Site FR3-AR can be seen in **Figure 6** labeled as Auxiliary Spillway and is equal to 205 acres. A flowage easement would also be required from the auxiliary spillway pool to the top-of-dam elevation. The area used for the flowage easement can also be seen in **Figure 6** labeled as Top of Dam.

8.2 PERMITTING

Permitting for the proposed site includes coordination with various entities. The entities that will need to be consulted for the proposed site are detailed in the *Forest River RCPP Watershed Plan – Environmental Scoping Report* (Houston Engineering Inc., 2020).

9 ESTIMATED PROJECT COST

The engineer's estimated project cost is shown in **Table 7**. Quantities were based on the preliminary design and unit prices were estimated based on previous projects completed in the region. Unit prices are estimated in 2020 dollars. All preliminary plans for Ardoch Coulee Bypass and Site FR3-AR are shown in **Appendix A**. ***The total estimated project cost for Ardoch Coulee Bypass and Site FR3-AR is $11,298,250.00.***

Table 7: Ardoch Coulee Bypass and Site FR3-AR Engineer's Cost Estimate

No.	Item	Unit	Unit Price	Quantity	Total Price
ARDOCH COULEE BYPASS CHANNEL					
1	Stripping & Topsoiling (By Volume)	CY	$3.00	204,800	$614,400.00
2	Common Excavation (By Volume)	CY	$2.50	558,700	$1,396,750.00
3	Seeding and Mulching	AC	$700.00	100	$70,000.00
4	Double 8'x6' Precast RCBC	LF	$2,000.00	276	$552,000.00
5	Double 8'x6' Precast RCBC End Section	EA	$16,000.00	8	$128,000.00
6	Triple 10'x6' Precast RCBC	LF	$3,000.00	70	$210,000.00
7	Triple 10'x6' Precast RCBC End Section	EA	$35,000.00	2	$70,000.00
8	Pipe Corr Steel .064in 24in	LF	$50.00	418	$20,900.00
9	Pipe Corr Steel .064in 30in	LF	$80.00	268	$21,440.00
10	Pipe Corr Steel .064in 36in	LF	$90.00	204	$18,360.00
11	Flap Gate 24in	EA	$550.00	4	$2,200.00
12	Flap Gate 30in	EA	$650.00	3	$1,950.00
13	Flap Gate 36in	EA	$950.00	2	$1,900.00
14	Riprap ND Grade I	CY	$70.00	350	$24,500.00
15	Riprap ND Grade II	CY	$80.00	550	$44,000.00
16	Rock Drop (Riprap ND Grade III)	EA	$50,000.00	4	$200,000.00
17	Traffic Control	LS	$20,000.00	1	$20,000.00
18	Erosion Control	LS	$50,000.00	1	$50,000.00
				TOTAL	**$3,446,400.00**
Forest River On-Channel Structure					
19	Stripping & Topsoiling (By Volume)	CY	$3.00	1,200	$3,600.00
20	Dewatering and Subgrade Prep	LS	$40,000.00	1	$40,000.00
21	General Fill (By Volume)	CY	$5.00	3,300	$16,500.00
22	Seeding and Mulching	AC	$700.00	1	$700.00
23	Double 14'x7' Precast RCBC	LF	$2,400.00	66	$158,400.00
24	Double 14'x7' Precast RCBC End Section	EA	$27,000.00	2	$54,000.00
25	Riprap ND Grade I	CY	$70.00	1,620	$113,400.00
26	Riprap ND Grade II	CY	$80.00	120	$9,600.00
				TOTAL	**$396,200.00**
Ardoch Coulee Bypass Inlet Structure					
27	Dewatering and Subgrade Prep	LS	$25,000.00	1	$25,000.00
28	Structural Concrete	CY	$1,500.00	220	$330,000.00
29	Single 9'x6' Precast RCBC	LF	$1,250.00	106	$132,500.00
30	Single 9'x6' Precast RCBC End Section	EA	$11,000.00	1	$11,000.00
31	Riprap ND Grade II	CY	$80.00	1,530	$122,400.00
32	Water Control Structure	EA	$75,000.00	1	$75,000.00
33	Catwalk System	LS	$25,000.00	1	$25,000.00
				TOTAL	**$720,900.00**
SITE FR3-AR					
34	Stripping & Topsoiling (By Volume)	CY	$3.00	7,500	$22,500.00
35	Common Excavation (By Volume)	CY	$2.50	45,400	$113,500.00
36	Inspection Trench (By Volume)	CY	$15.00	2,500	$37,500.00
37	Impervious Clay Core Embankment (By Volume)	CY	$15.00	29,000	$435,000.00

No.	Item	Unit	Unit Price	Quantity	Total Price
38	Fine Aggregate Filter Drainage Diaphragm	CY	$100.00	670	$67,000.00
39	General Fill (By Volume)	CY	$5.00	26,000	$130,000.00
40	Seeding and Mulching	AC	$700.00	10	$7,000.00
41	Erosion Control	LS	$40,000.00	1	$40,000.00
				TOTAL	**$852,500.00**
Principal Spillway Structure					
42	Dewatering and Subgrade Prep	LS	$25,000.00	1	$25,000.00
43	Structural Concrete	CY	$1,500.00	240	$360,000.00
44	Pipe Conc Reinf 48in CL V	LF	$400.00	30	$12,000.00
45	End Sect Conc Reinf 48in	CY	$1,800.00	1	$1,800.00
46	Single 12'x8' Precast RCBC	LF	$1,800.00	122	$219,600.00
47	Principal Spillway Outlet	LS	$375,000.00	1	$375,000.00
48	Riprap ND Grade II	CY	$80.00	70	$5,600.00
49	Sluice Gate 48"	EA	$10,000.00	1	$10,000.00
50	Catwalk System	LS	$10,000.00	1	$10,000.00
51	Trash Rack	LS	$5,000.00	1	$5,000.00
				TOTAL	**$1,024,000.00**
				Ardoch Coulee Bypass Channel Construction Subtotal	**$4,563,500.00**
				Site FR3-AR Construction Subtotal	**$1,876,500.00**
				Construction Contingency (20%)	**$1,288,000.00**
				Total Construction Costs	**$7,728,000.00**
	Ardoch Coulee Bypass Right-of-Way Acquisition				$465,000.00
	Site FR3-AR Right-of-Way Acquisition				$825,000.00
	Site FR3-AR Flowage Easement				$57,500.00
	Construction Easement				$36,250.00
	Permitting and Wetland Mitigation Credits				$400,000.00
	Utility Relocation				$200,000.00
	Pre-Construction Engineering				$772,800.00
	Geotechnical Engineering				$300,000.00
	Construction Engineering				$463,700.00
	Legal & Administrative				$50,000.00
				Total Non-Construction Costs	**$3,570,250.00**
				Total Estimated Project Costs	**$11,298,250.00**

[1] 2020 Dollars

10 SUMMARY

As previously noted, a Purpose and Need Statement was identified at the beginning of the planning process, and the identified purpose of the proposed action is to implement flood prevention and flood damage reduction measures to:

1. Reduce flood damages for up to a 10-year rainfall event on cropland.
2. Increase flood resiliency for up to a 10-year event on public and private infrastructure within the communities that reside along the Forest River. (Primary)
3. Increase flood resiliency for the communities of Minto and Forest River, ND, during a 100-year flood event. (Primary)

4. Maintain or reduce flood flows downstream of Lake Ardoch. (Primary)
5. Improve soil health and water quality throughout the watershed. (Secondary)

During the alternative screening process, indicators were developed to establish criteria used in determining if an alternative meets the purpose. The indicators are presented in detail in the *Screening of Alternatives for Detailed Review* (Houston Engineering, Inc., 2020). The summarized indicators and the synthetic modeling results for Ardoch Coulee Bypass and Site FR3-AR are shown in **Table 8**.

Table 8: Ardoch Coulee Bypass and Site FR3-AR Purpose and Need Statement Evaluation Summary

Purpose and Need Statement Indicator	Ardoch Coulee Bypass and Site FR3-AR Results
INDICATOR 1: Reduce the 10-year cropland inundation for durations less than four days by 20% in Lower Forest River Watershed.	840 Acres 24.8% Reduction
INDICATOR 2(a): Reduce the 10-year event peak flow rate by 20% at the Forest River crossing with Walsh County Road 6 near Forest River, ND.	32.7% Reduction
INDICATOR 2(b): Reduce the 10-year event peak flow rate by 20% at the Forest River crossing with 1st Street in Minto, ND.	25.8% Reduction
INDICATOR 3(a): Reduce the 100-year event peak flow rate by 16% at the Forest River crossing with Walsh County Road 6 near Forest River, ND.	22.4% Reduction
INDICATOR 3(b): Reduce the 100-year event peak flow rate by 8% at the Forest River crossing with 1st Street in Minto, ND.	6.1% Reduction
INDICATOR 4: No increase in peak flow rate at the Forest River crossing with Walsh County Road 4 downstream of Lake Ardoch.	Reduction ranges from 0% to 6.2%

While Indicator 3(b) fails to meet the target reduction, it should not be seen as a failure for the project as a whole. The indicators were established as a way to quantitatively measure an alternative against the purpose of the project. The percentages selected for the indicators were based on preliminary modeling and were simply targets for flood reduction. Therefore, Indicator 3(b) failing to reach the target by 2.9% is acceptable.

When examining the results qualitatively against the project purpose, flood damages to cropland will be reduced for the 2-year through 100-year events by reducing the inundation to cropland for durations of less than 4 days. Flood resiliency to public and private infrastructure and to the communities of Forest River and Minto, ND, will be improved by reducing peak flows along the Forest River from the Ardoch Coulee Bypass inlet location to the confluence of the Forest River with the Red River of the North. The peak flow at the Forest River crossing with Walsh County Road 4 downstream of Lake Ardoch increases by a negligible amount for higher frequency events and reduces slightly for the lower frequency events, indicating that the site will provide some benefit during the higher frequency events at the confluence of the Forest River with the Red River of the North. With the reduced cropland flooding and reduced peak flows, soil health and water quality throughout the watershed will be improved.

11 REFERENCES

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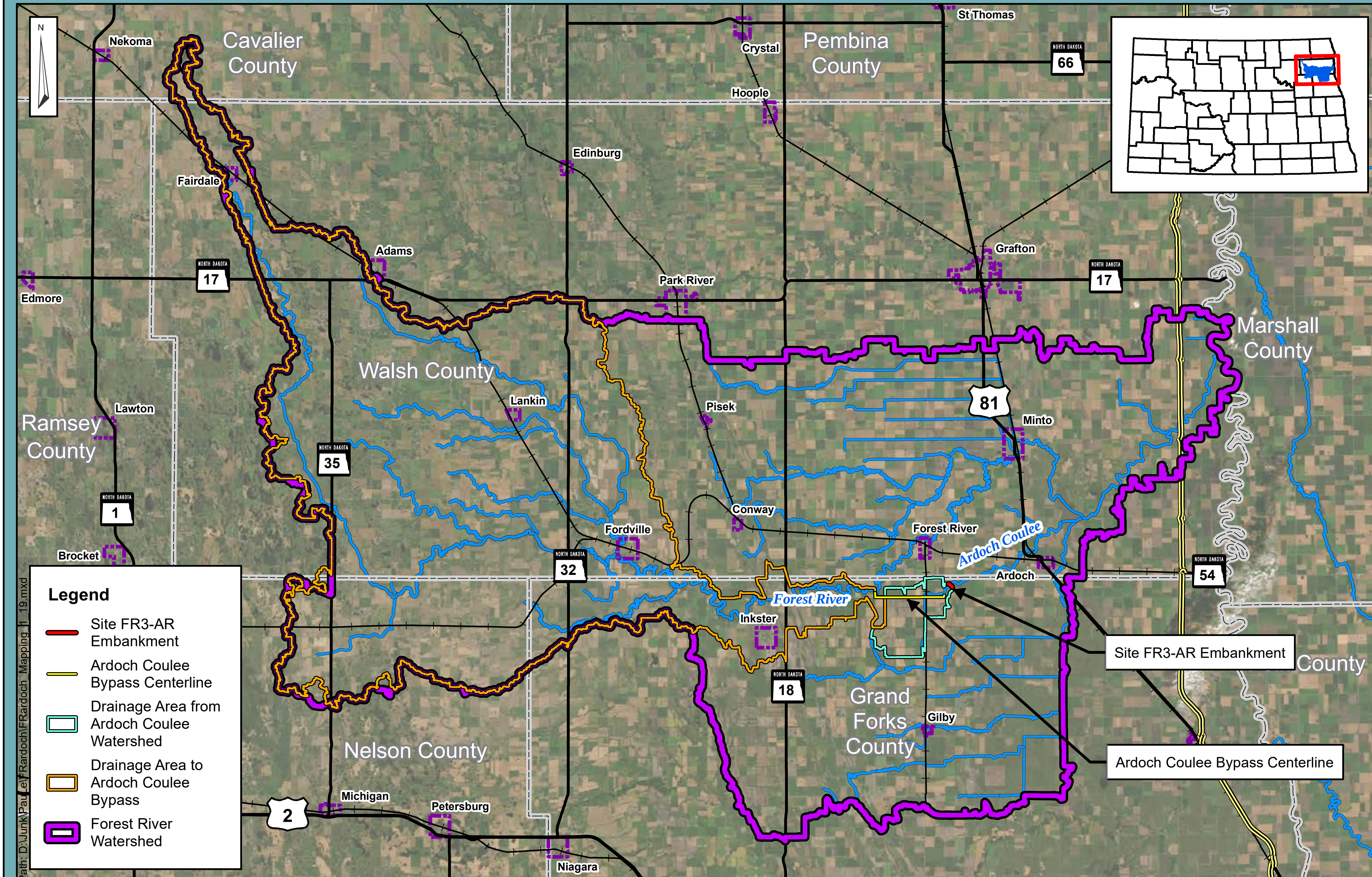
FIGURES



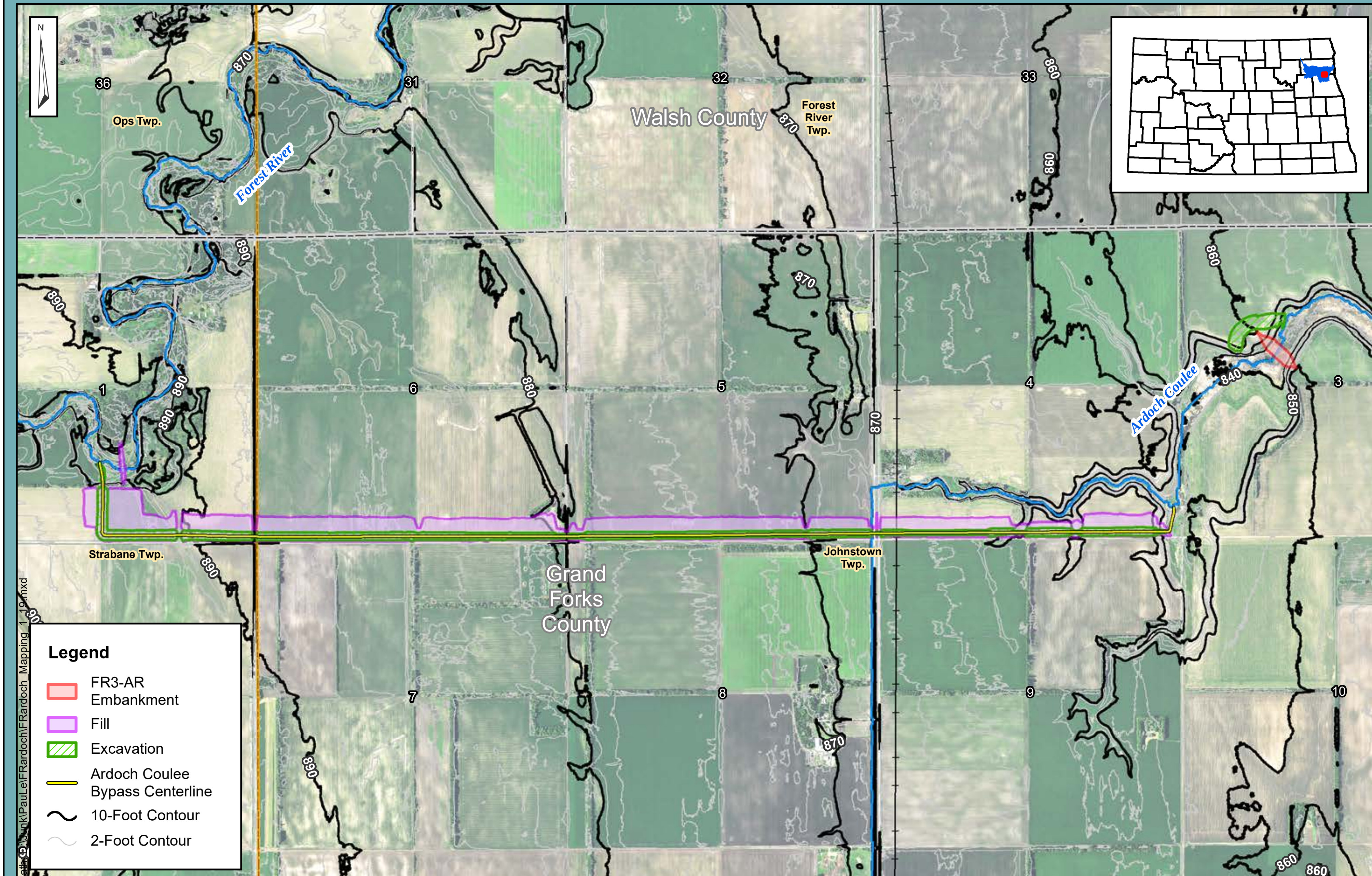
F-2

Figure 2: Ardoch Coulee Bypass and Site FR3-AR Location Map

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 2.5 5 10 Miles

Houston Engineering Inc.



F-4

Figure 4: Ardoch Coulee Bypass and Site FR3-AR Site Map

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 0.125 0.25 0.5 Miles

Houston Engineering Inc.

Figure 4.5a: *Stage-Storage-Area Relationship*

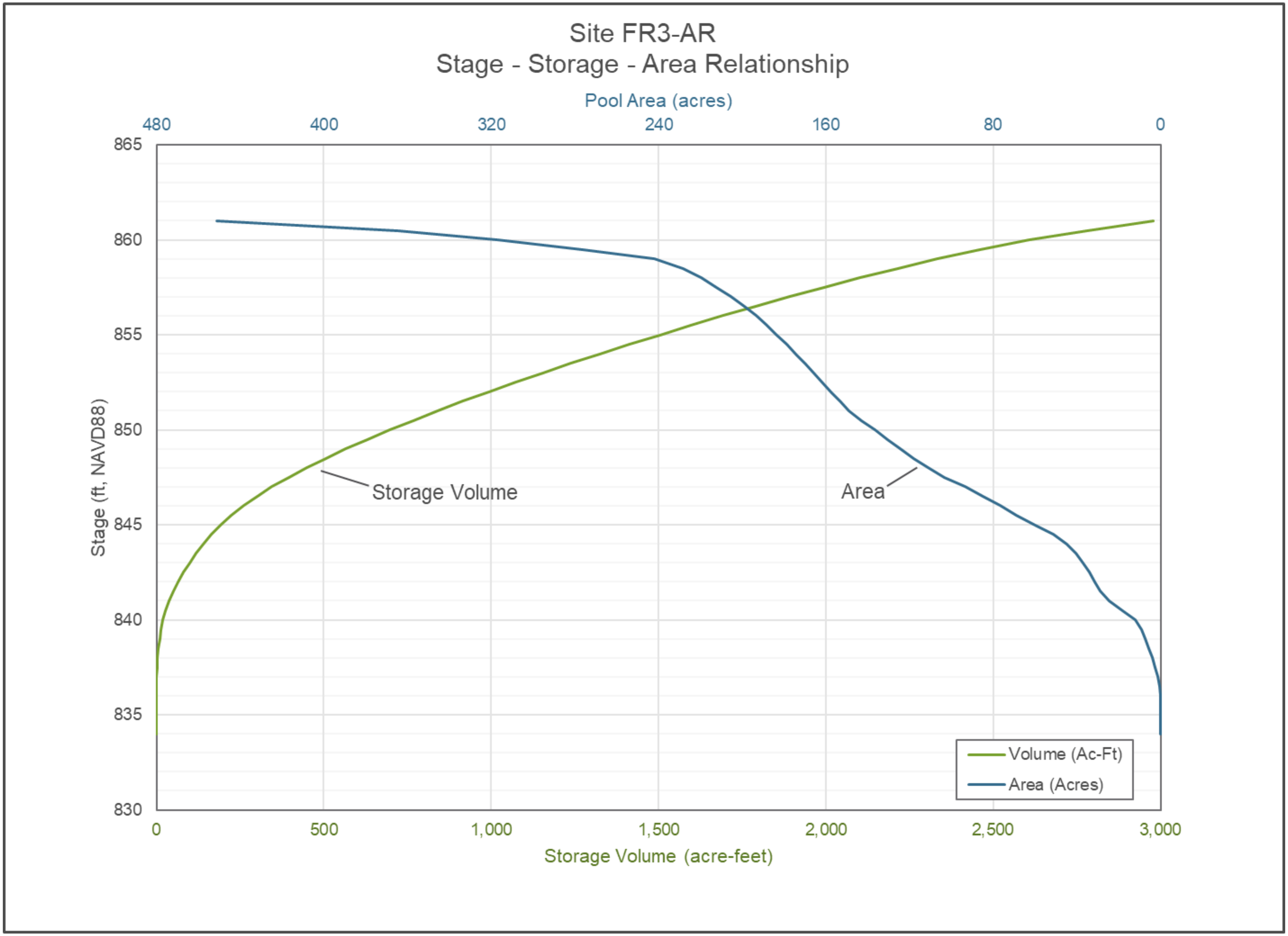


Figure 4.5b: *Stage-Discharge Relationship*

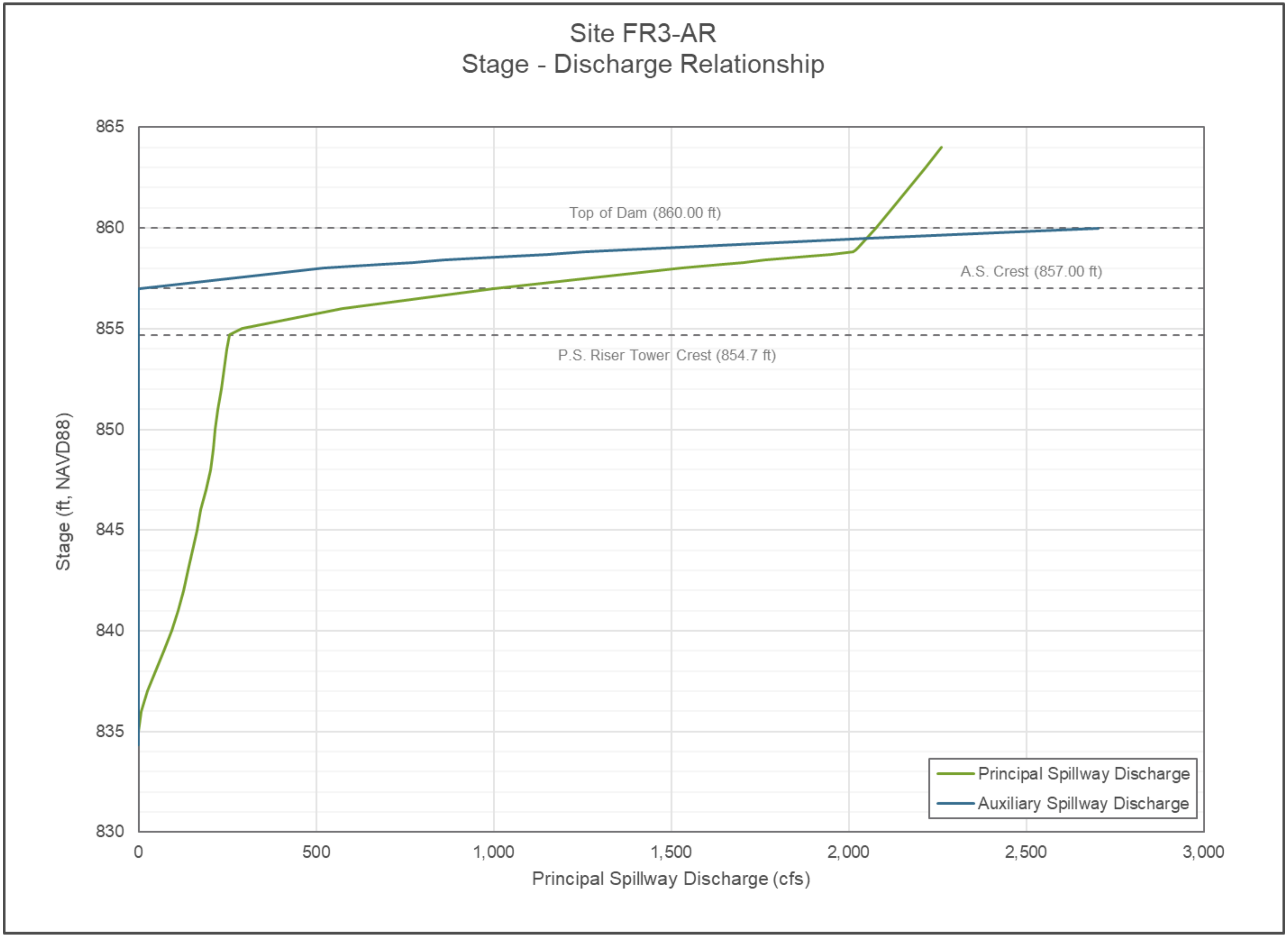


Figure 5.1a: *TR 210-60 Dam Breach Calculations*

Watershed Name:	**Forest River**	Date	**Jan 22, 2020**
Site No.	**FR3-AR**	Prepared By:	**RCG**
County, ST	Grand Forks County, ND		

Elevations						
Top of Dam	860.0	Ft msl	Top Width	16	Ft	
Water Surface@Breach	860.0	Ft msl	Upstream Slope Above Berm	4	:1	
Wave Berm	850.0	Ft msl	Upstream Slope Below Berm	4	:1	
Average Valley Floor	834.8	Ft msl	Downstream Slope Above Berm	4	:1	
Stability Berm	850.0	Ft msl	Downstream Slope Below Berm	4	:1	
Length of Dam at Breach Elev	928	Ft	Wave Berm Width	10	Ft	L
Volume of Breach	2,608	Ac-ft	Stability Berm Width	10	Ft	

Breach Discharge Computations

Hw < 103 - Low Dam

Volume of Breach (Vs)	2,608	Ac-ft	
Height Of Breach (Hw)	25	Ft	Hw
Cross Section Area CAD	2,711		
$T = 65(H^{0.35})/0.416$ - theoretical breach width	484	Ft	T

L > T - Wide Dam

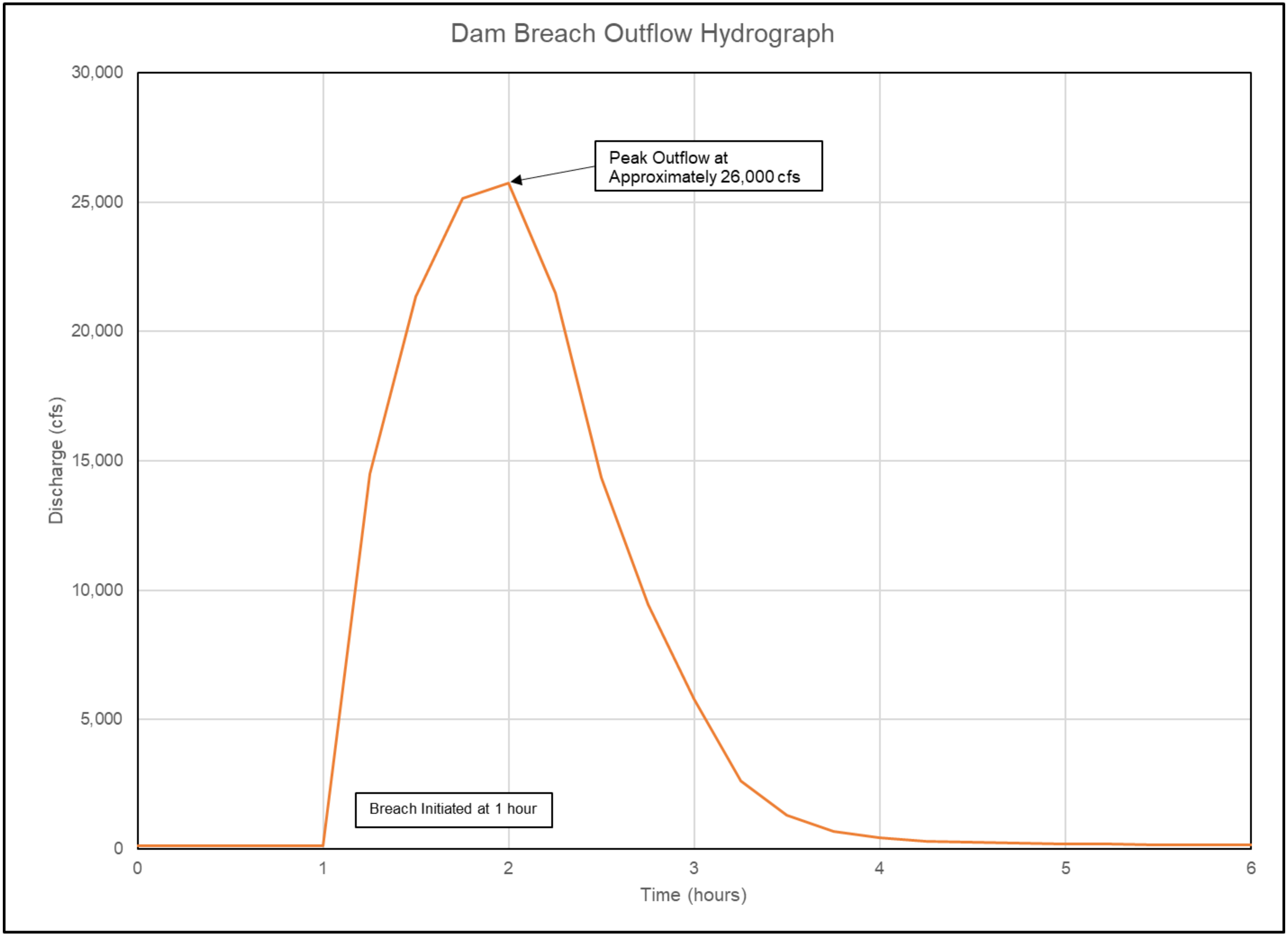
Q_{max} NOT GREATER THAN		Upper Bound Check		
$Q_{max} = 65(HW^{1.85})$	L>T Wide	25,514	cfs	UpBndWide
$Q_{max} = 0.416\ (\ L)(Hw^{1.5})$	L<T Narrow	48,953	cfs	UpBndNarrow

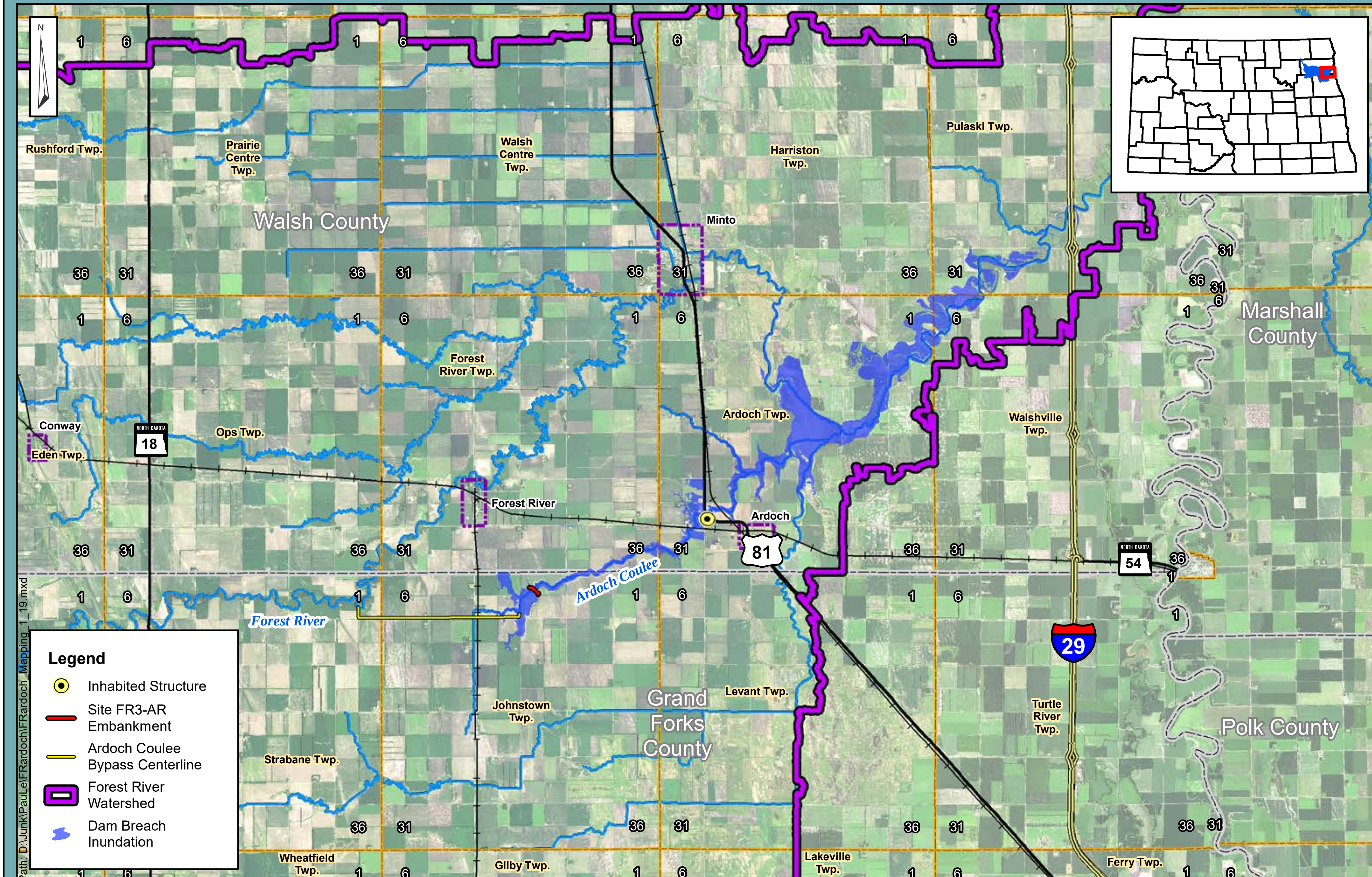
$Br = (Vs * Hw)/A$	Value	24.28		Br
$Q_{max} = 1{,}100\ (Br)^{1.35}$		81,571	cfs	

Q_{max} NOT LESS THAN	Lower Bound Check		
$Q_{max} = 3.2(Hw^{5/2})$	10,242	cfs	LowBnd

TR-60 Breach Q_{max} for Hazard Class: **26,000** cfs

Figure 5.1b: *Dam Breach Outflow Hydrograph*





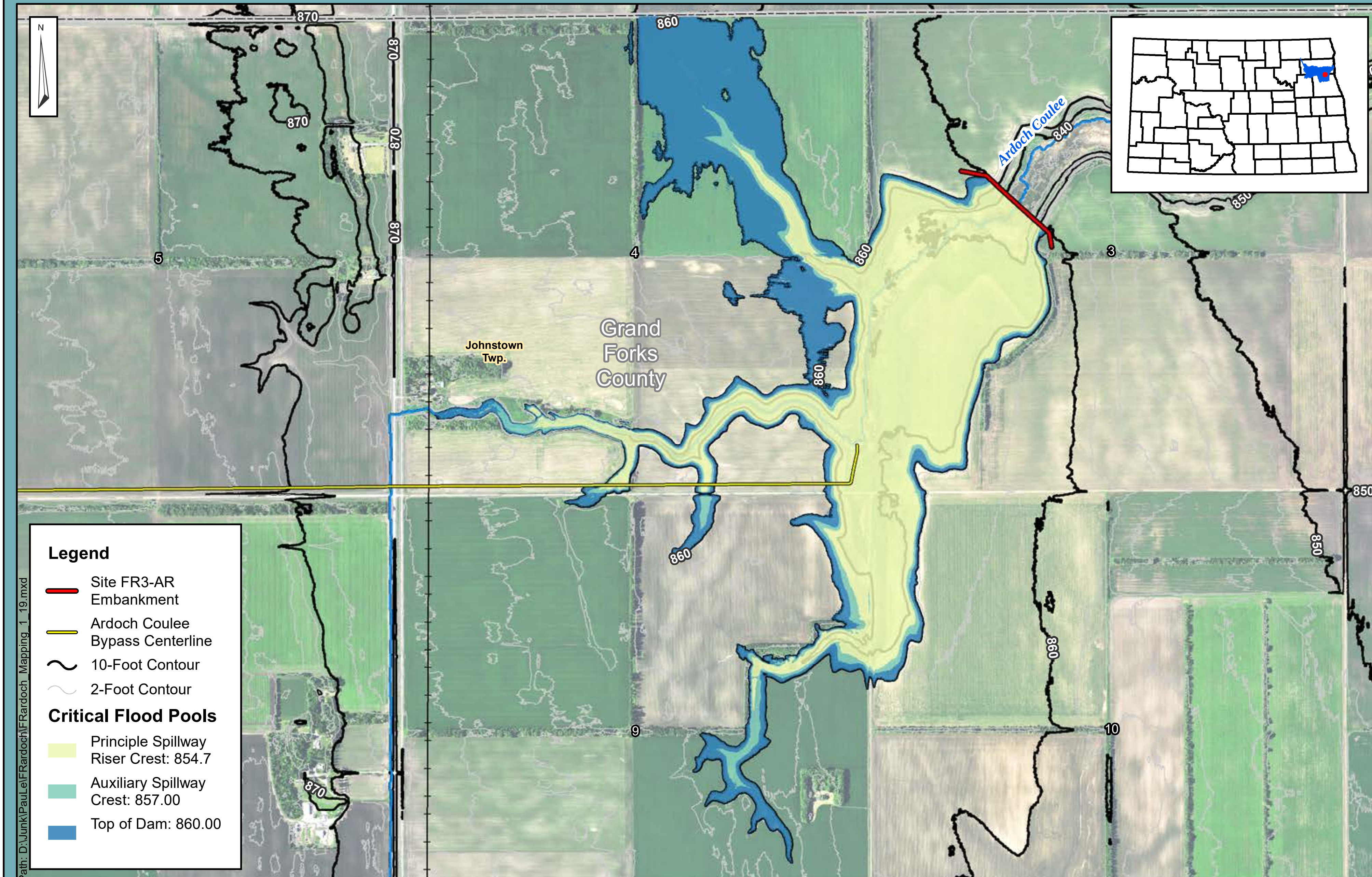
F-5.2

Figure 5.2: Dam Breach Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 1.25 2.5 5 Miles

Houston Engineering Inc.



F-6

Figure 6: Site FR3-AR Critical Flood Pools

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

Houston Engineering Inc.

Figure 6.1.1a: *Principal Spillway Mass Curves for Runoff Volume*

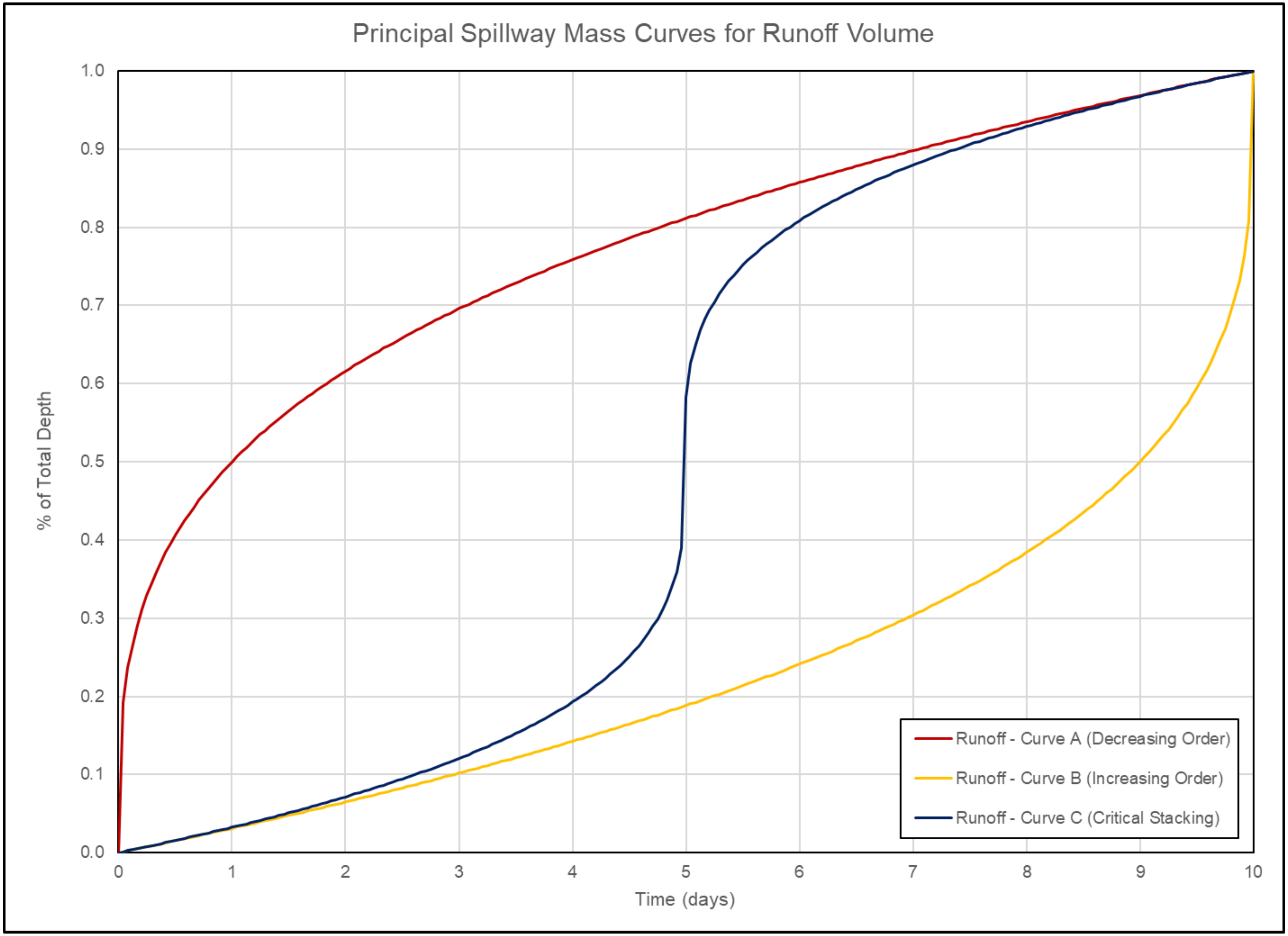


Figure 6.1.1b: Site FR3-AR Principal Spillway Runoff Volume Maps Hydrographs

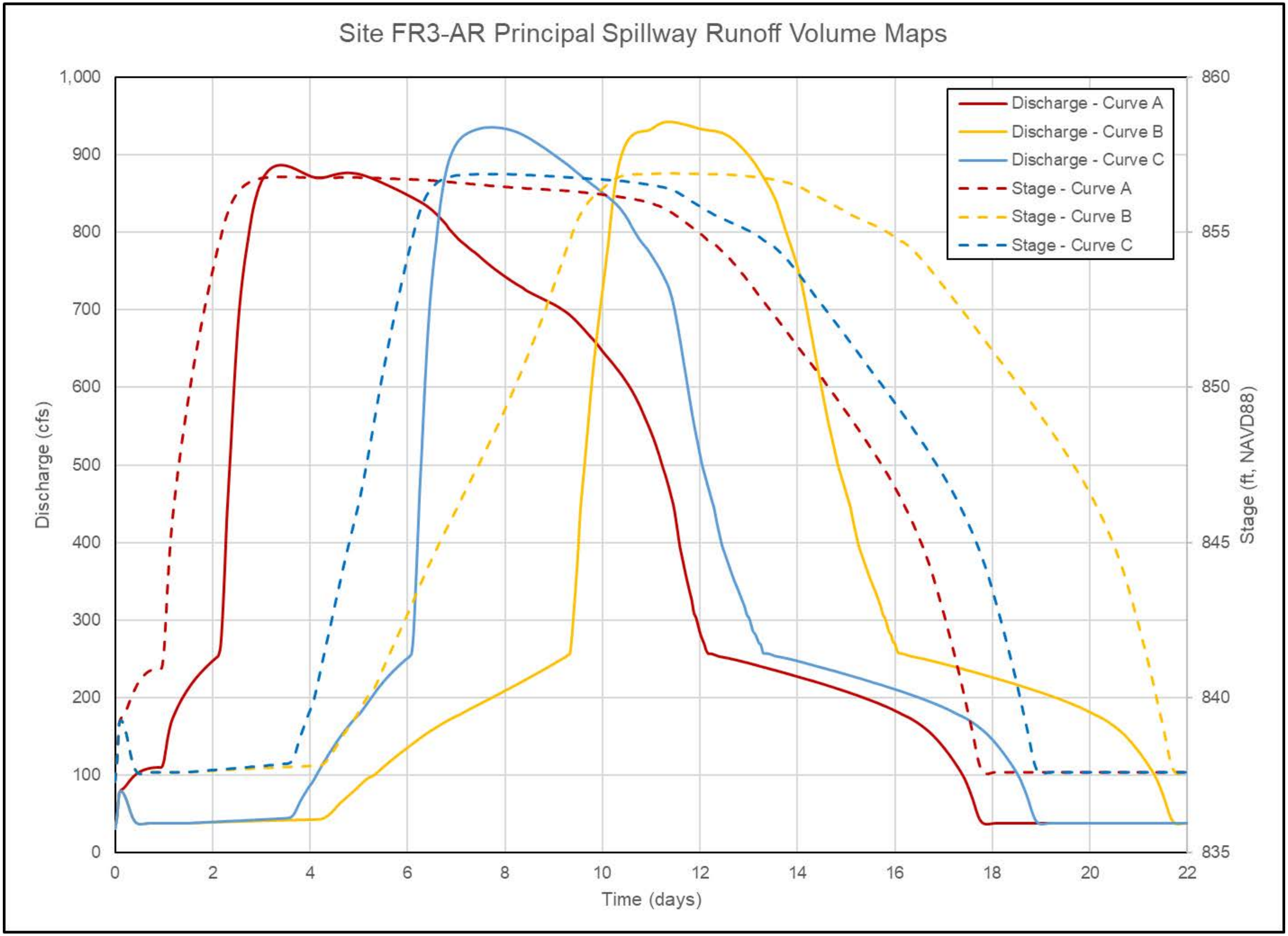


Figure 6.1.2: *Site FR3-AR Principal Spillway Runoff Curve Number Procedure Hydrographs*

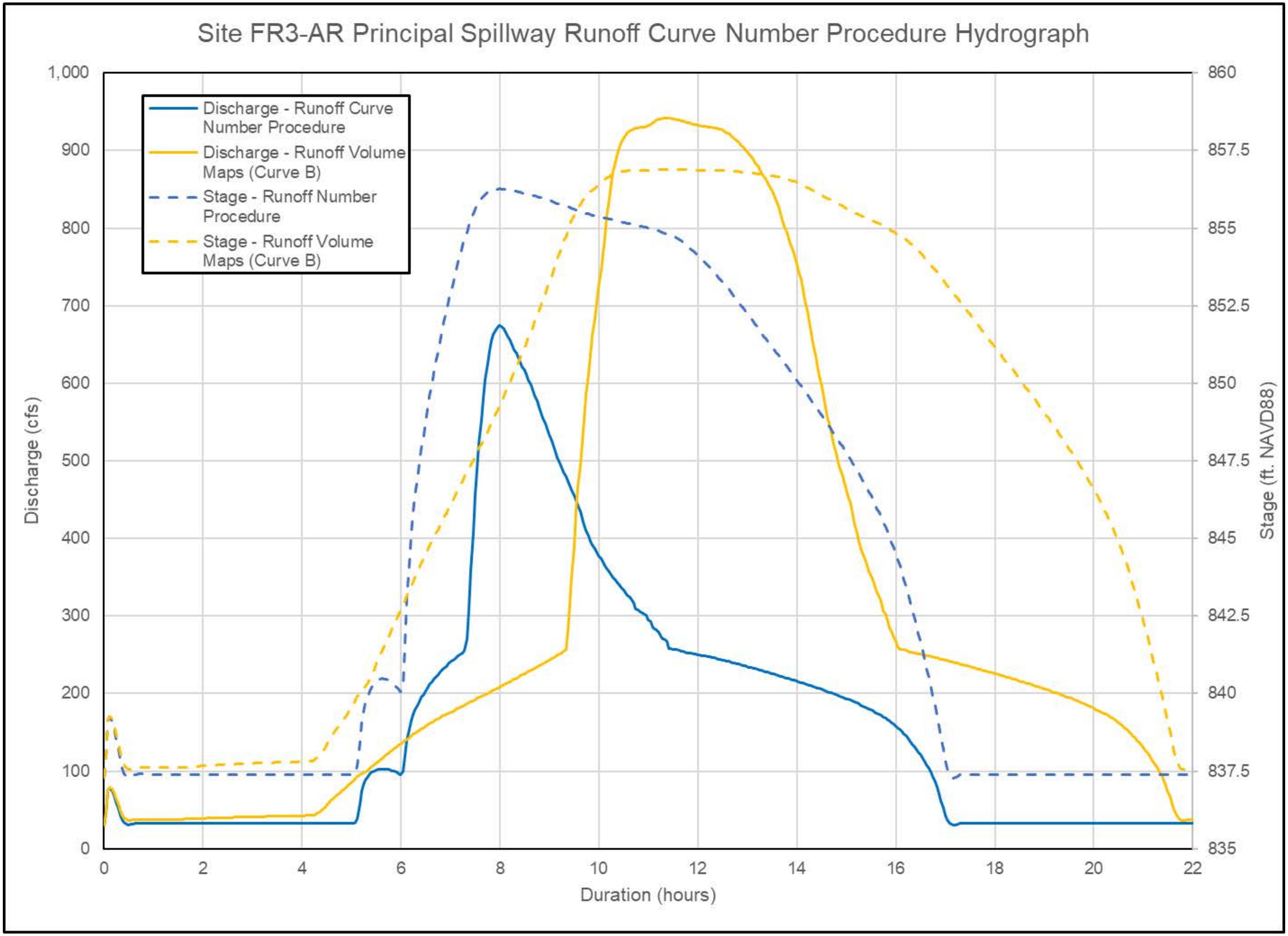


Figure 6.1.3: *Site FR3-AR Principal Spillway 10-day Drawdown*

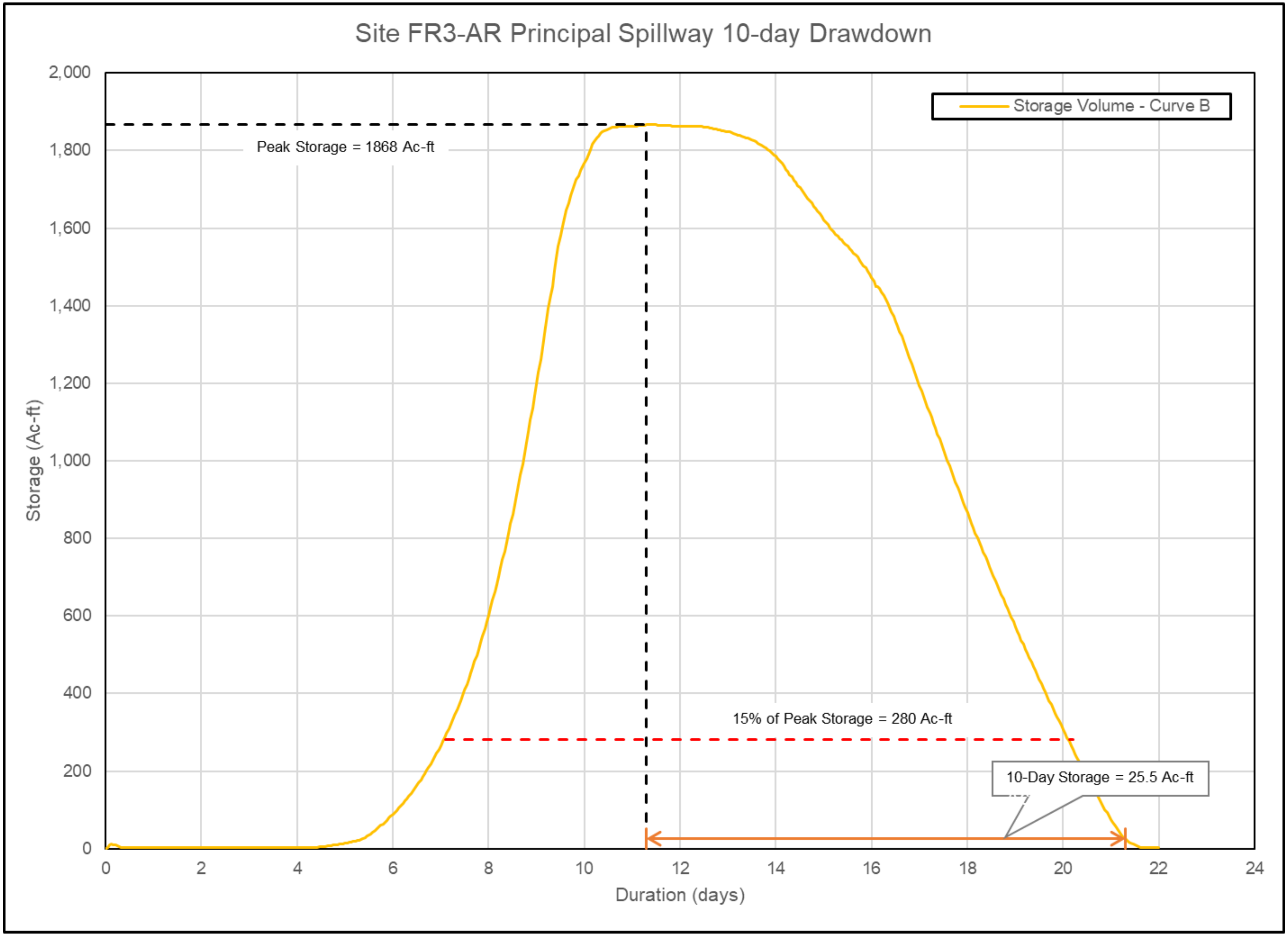


Figure 6.2a: Freeboard Hydrograph – Rainfall Hyetograph and Distribution

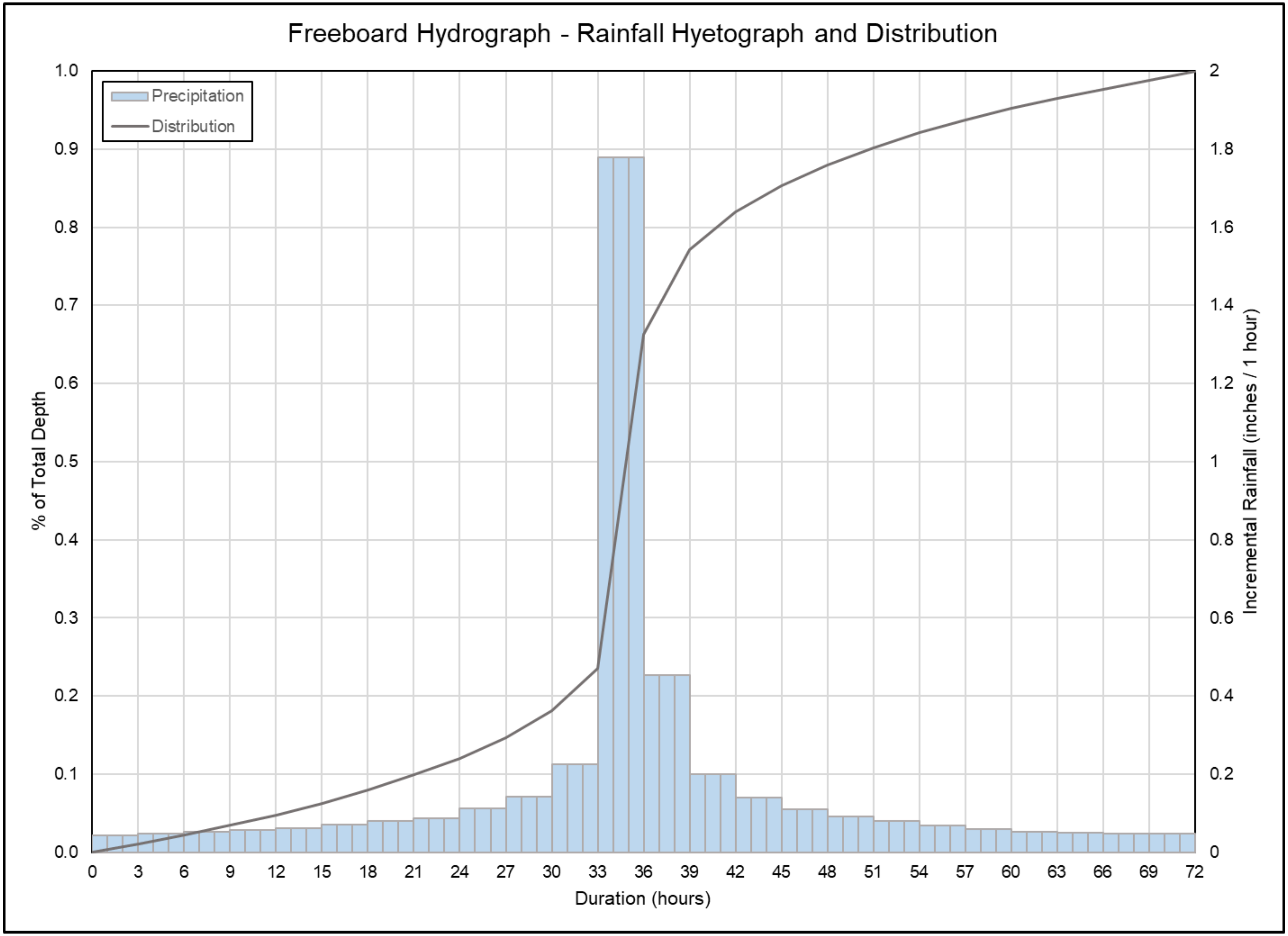


***Figure 6.2b:** Freeboard Hydrograph – Site FR3-AR Discharge Hydrograph*

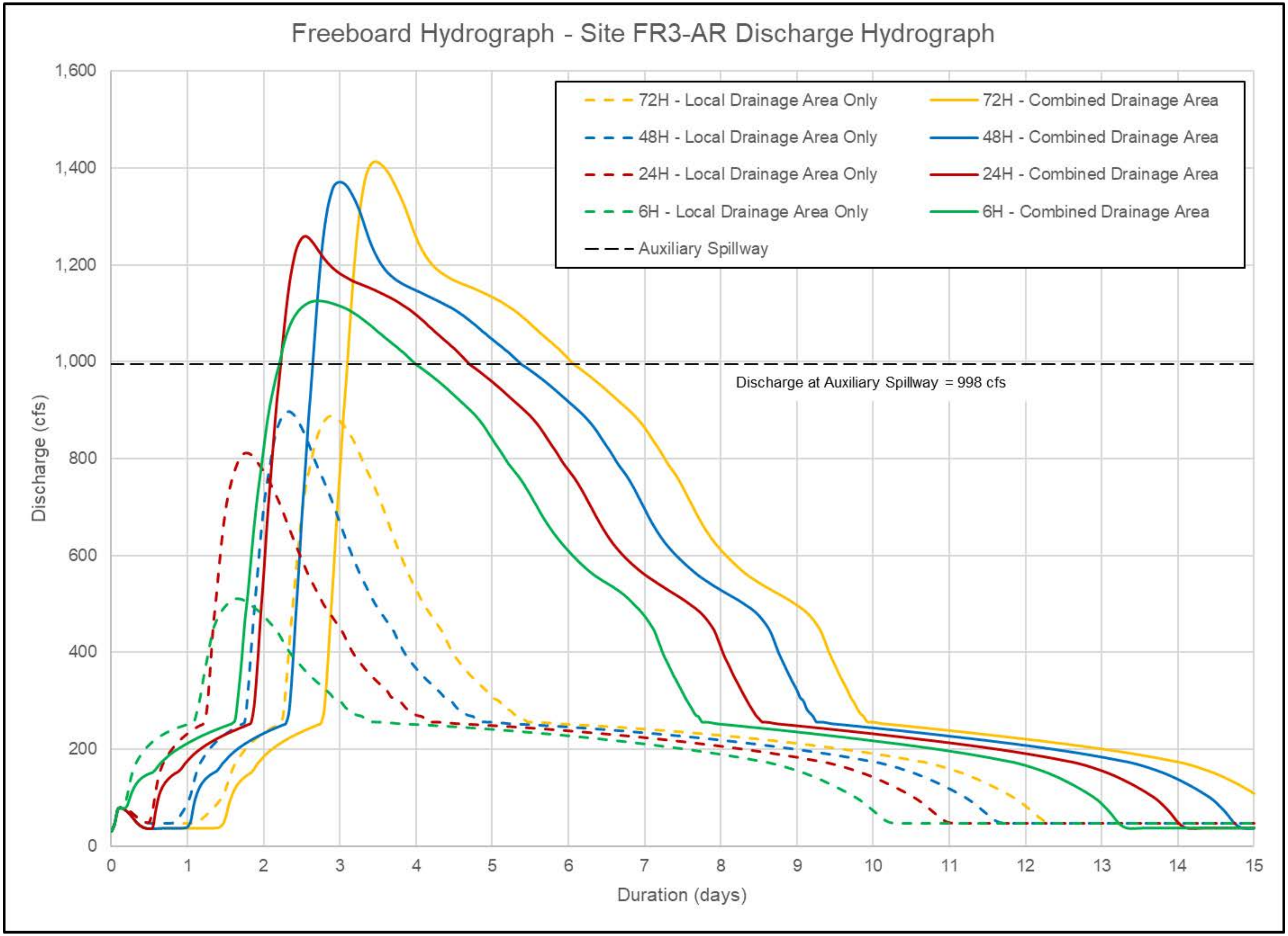
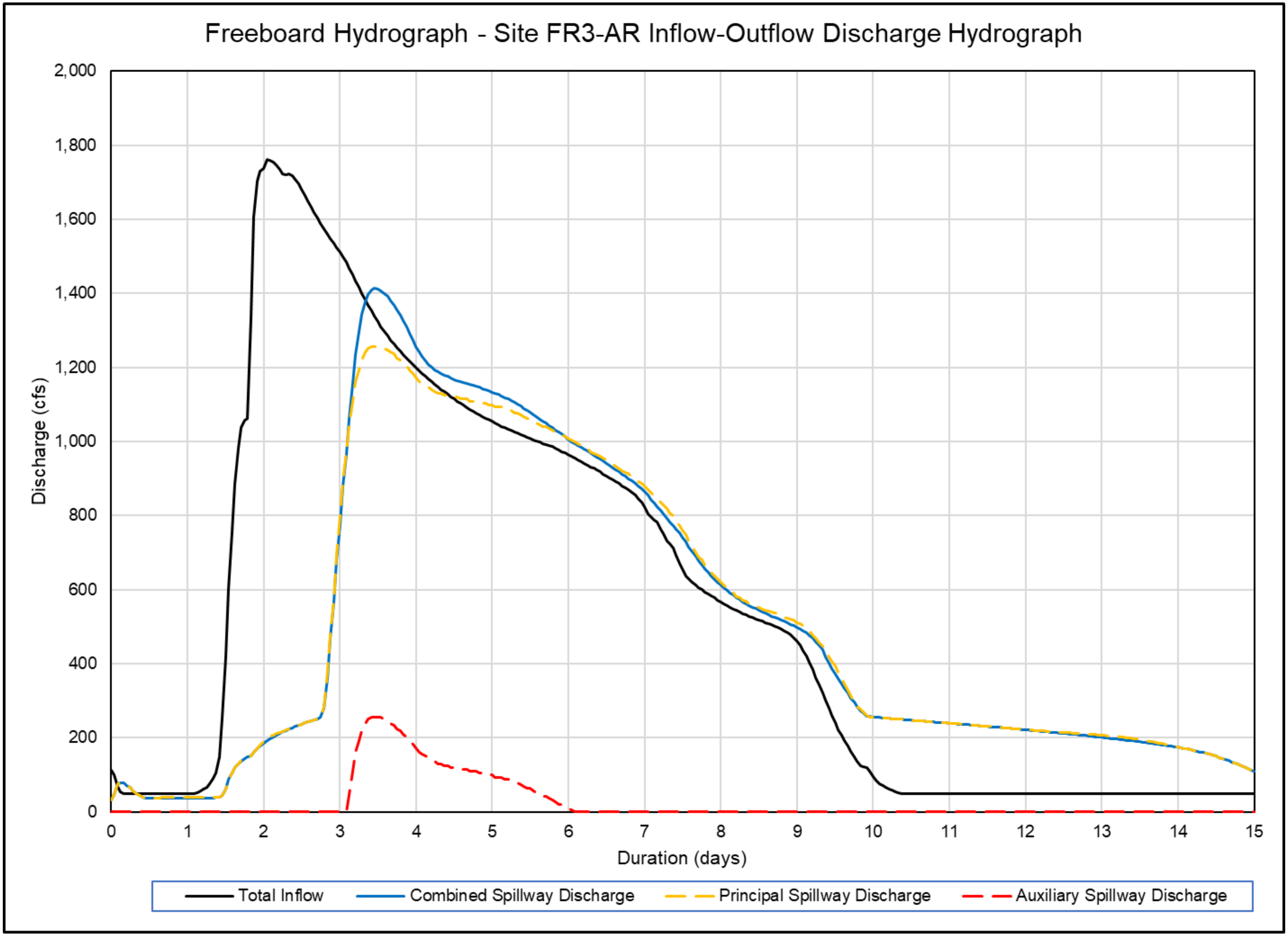
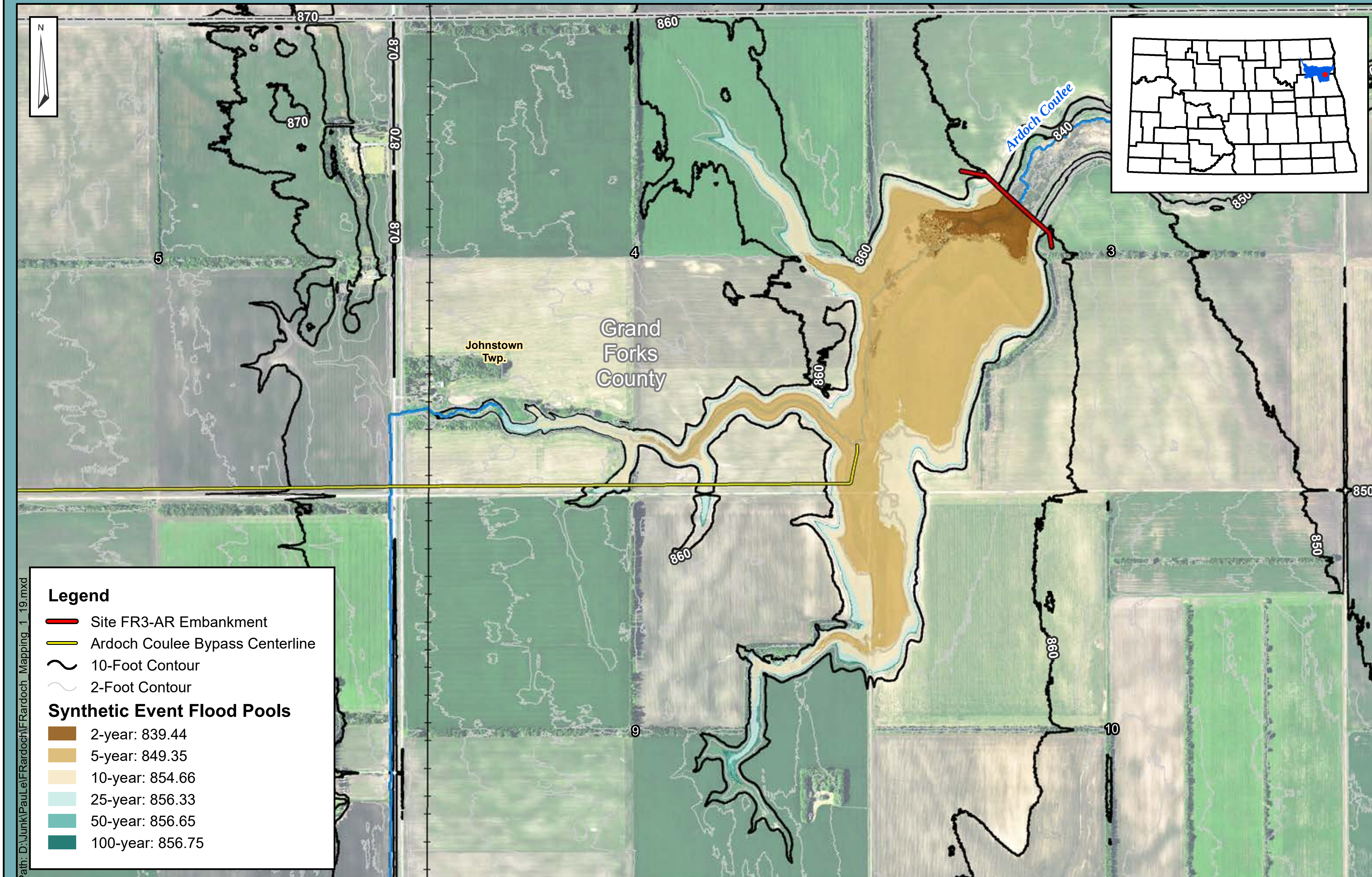


Figure 6.2c: *Freeboard Hydrograph – Site FR3-AR Inflow-Outflow Discharge Hydrograph*





F-7

Figure 7: Site FR3-AR Synthetic Event Flood Pools

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

APPENDIX A

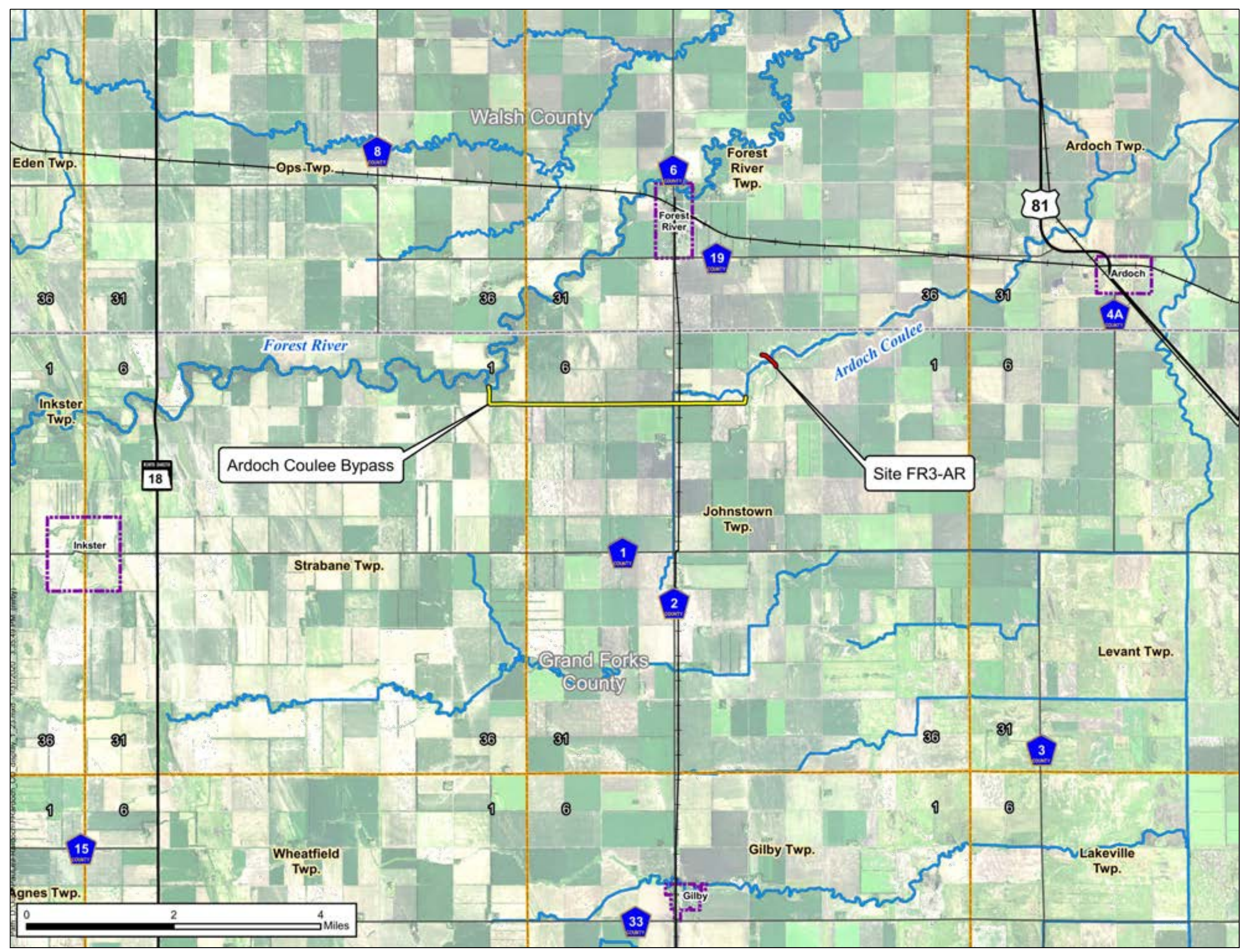
Preliminary Design Drawings

PRELIMINARY CONSTRUCTION PLANS (NOT FOR CONSTRUCTION) FOR

ARDOCH COULEE BYPASS AND SITE FR3-AR

WALSH COUNTY WATER RESOURCE DISTRICT

GRAFTON, NORTH DAKOTA
FEBRUARY, 2020

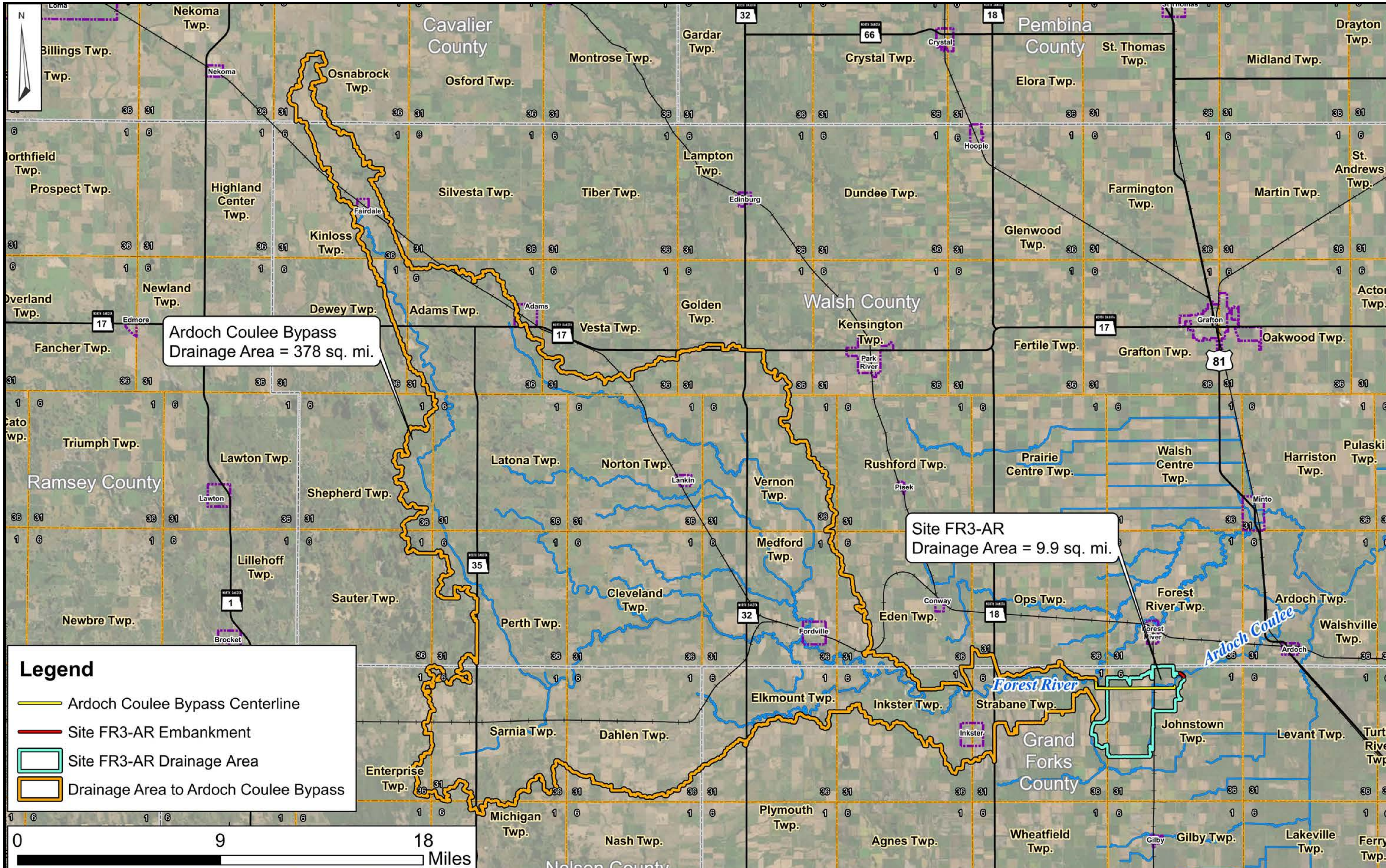


INDEX OF DRAWINGS:

This document is preliminary and not for construction or implementation purposes.

PRELIMINARY

Proj. No. 7135-021
Houston Engineering Inc.
Ph: 701.237.5065



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No.	Revision	Date	By

PRELIMINARY
Not for Construction

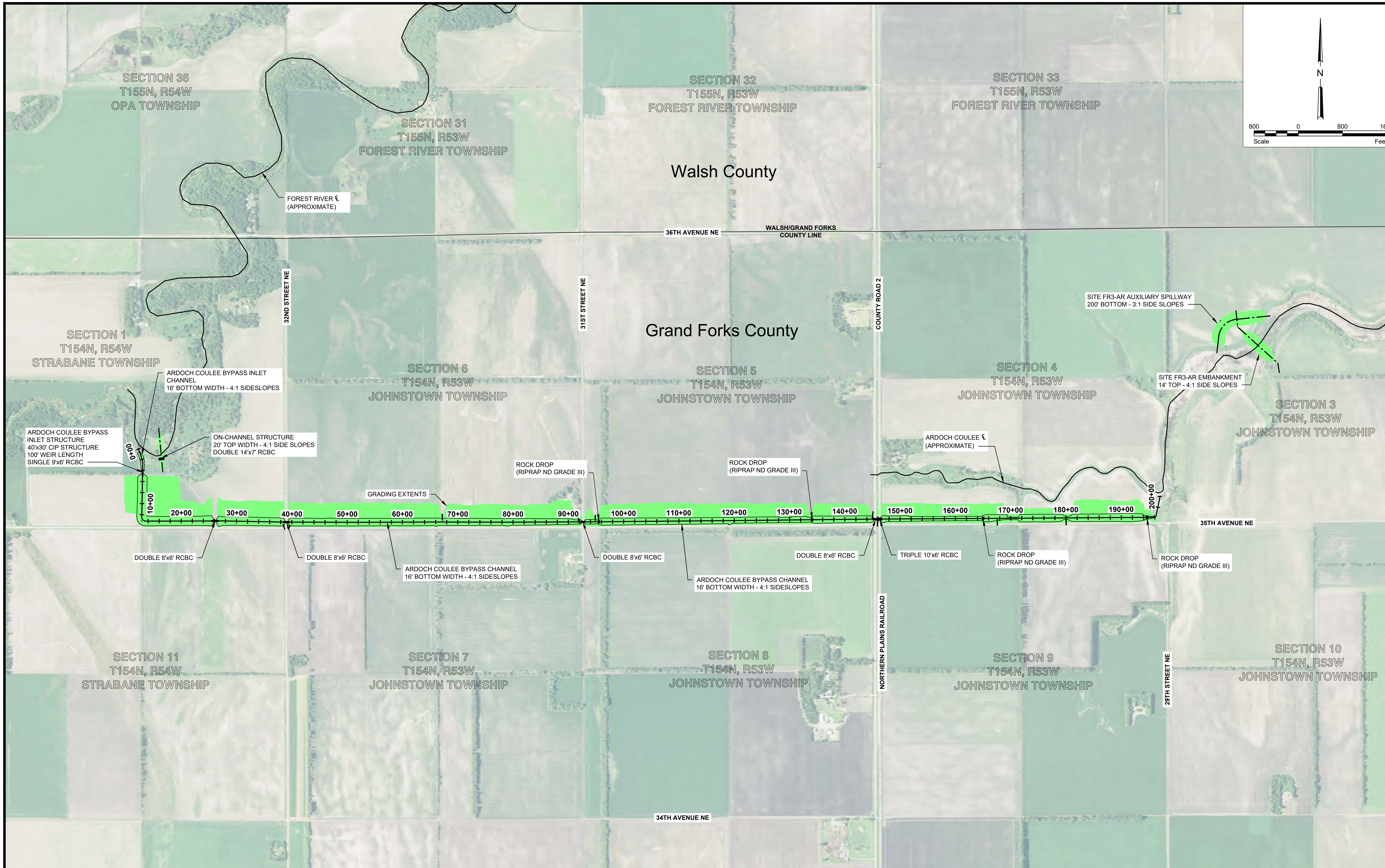
Houston Engineering Inc.
Fargo
P: 701.237.5065
F: 701.237.5101

Drawn by	Date
CAO	02-03-2020
Checked by	Scale
ZOH	AS SHOWN

ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

DRAINAGE AREA MAP
PROJECT NO. 7135-021

SHEET
G-101



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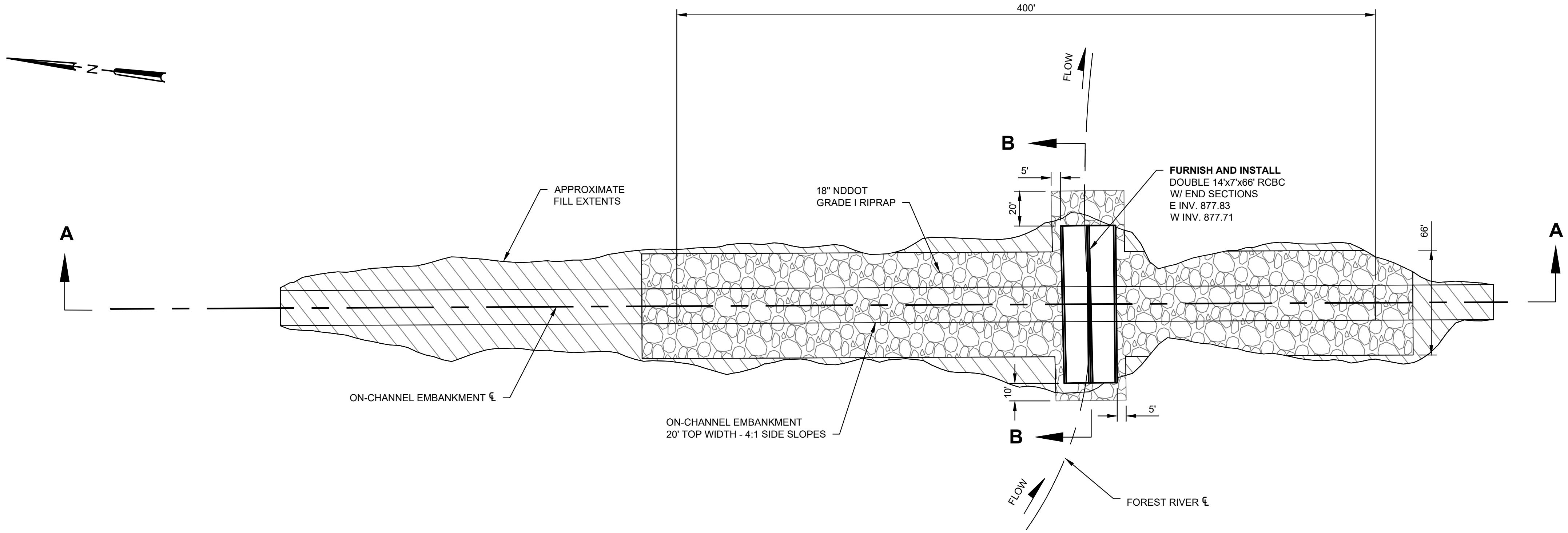
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

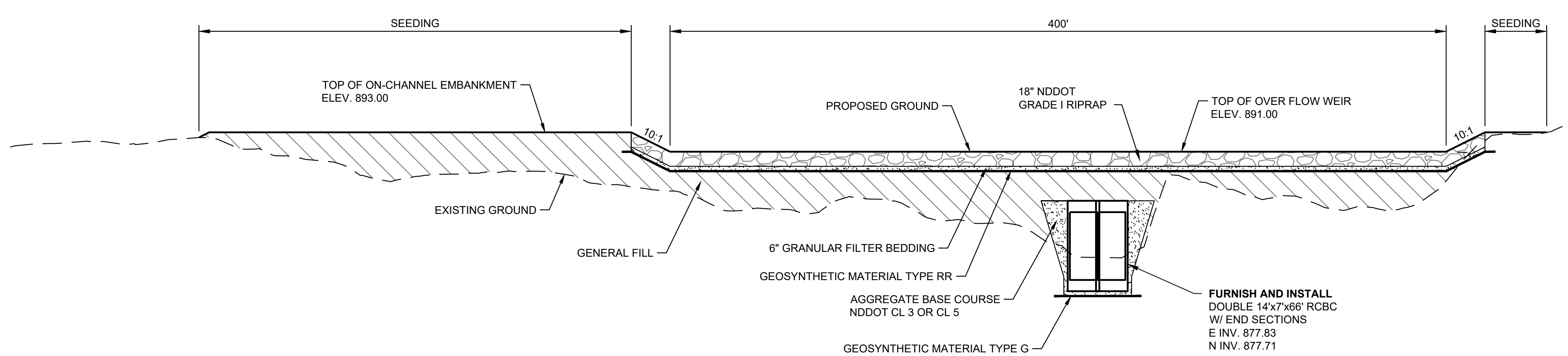
OVERALL SITE PLAN
PROJECT NO. 7135-021

SHEET G-102



PLAN VIEW

NOT TO SCALE



SECTION A-A

NOT TO SCALE

ON-CHANNEL STRUCTURE DETAIL

NOT TO SCALE

NOTES:

1. SEEDING SHALL OCCUR IN ALL DISTURBED AREAS WHERE BARE GROUND IS EXPOSED.
2. TOPSOILING SHALL OCCUR IN DISTURBED AREAS WHERE BARE GROUND IS EXPOSED EXCEPT FOR THE CHANNEL BOTTOM.

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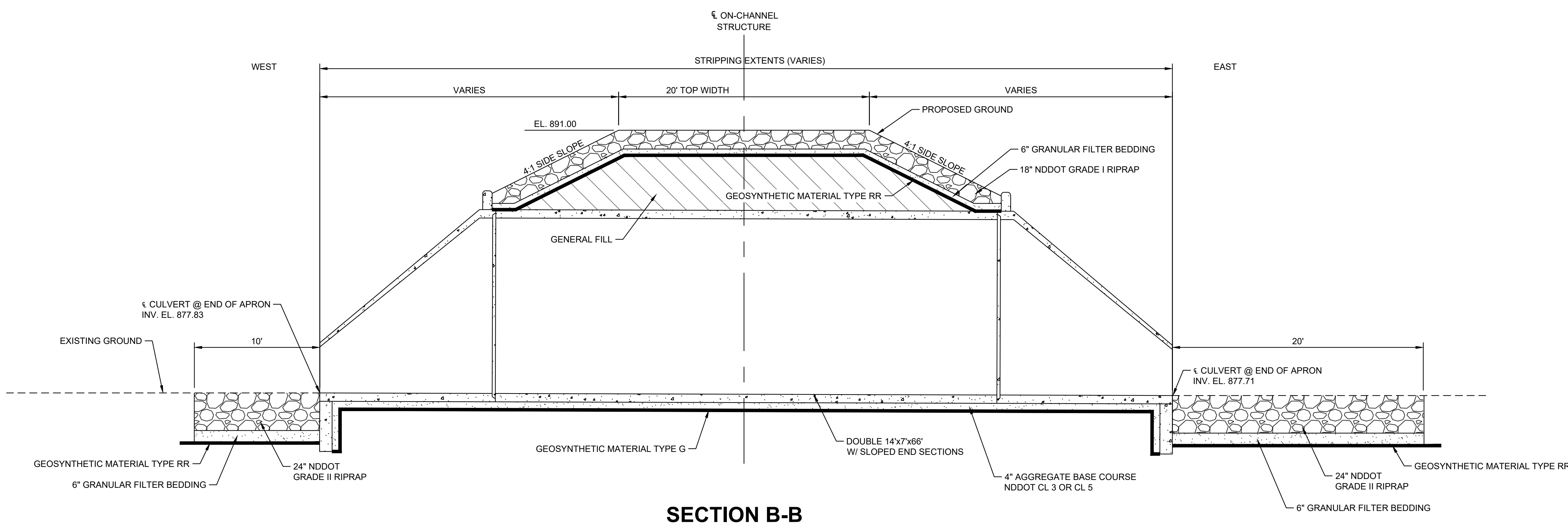
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ON-CHANNEL STRUCTURE DETAILS

PROJECT NO. 7135-021

SHEET
C-100



SECTION B-B
NOT TO SCALE

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ON-CHANNEL STRUCTURE DETAILS

PROJECT NO. 7135-021

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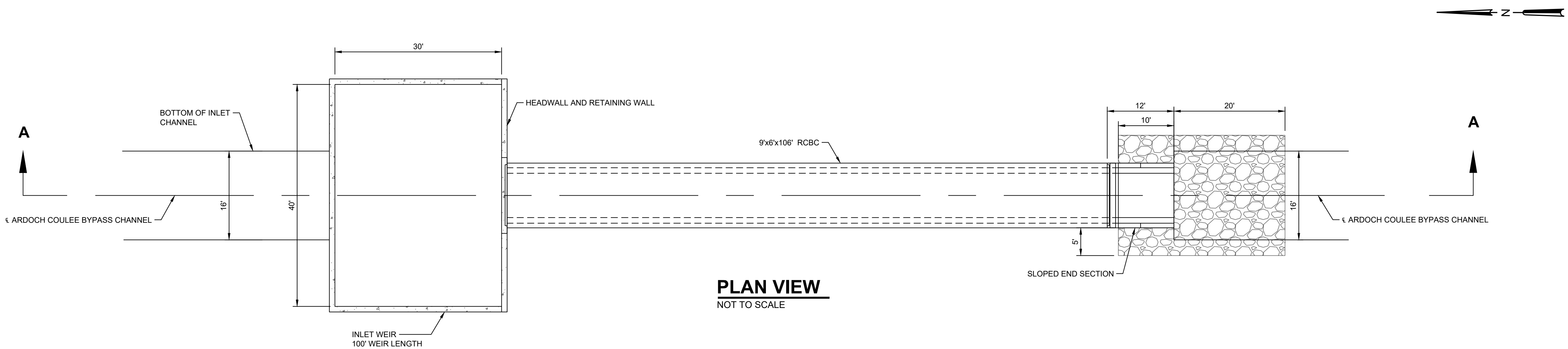
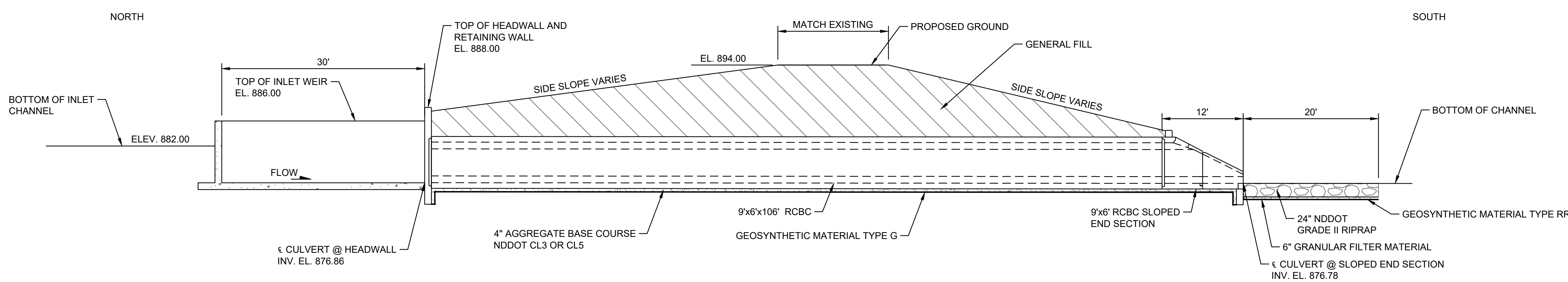
C-101



PLAN VIEW
NOT TO SCALE



SECTION A-A
NOT TO SCALE

NOTES:

1. CROSS HATCHING INDICATES AREAS WHERE FILL IS REQUIRED.

ARDOCH COULEE BYPASS INLET STRUCTURE
NOT TO SCALE

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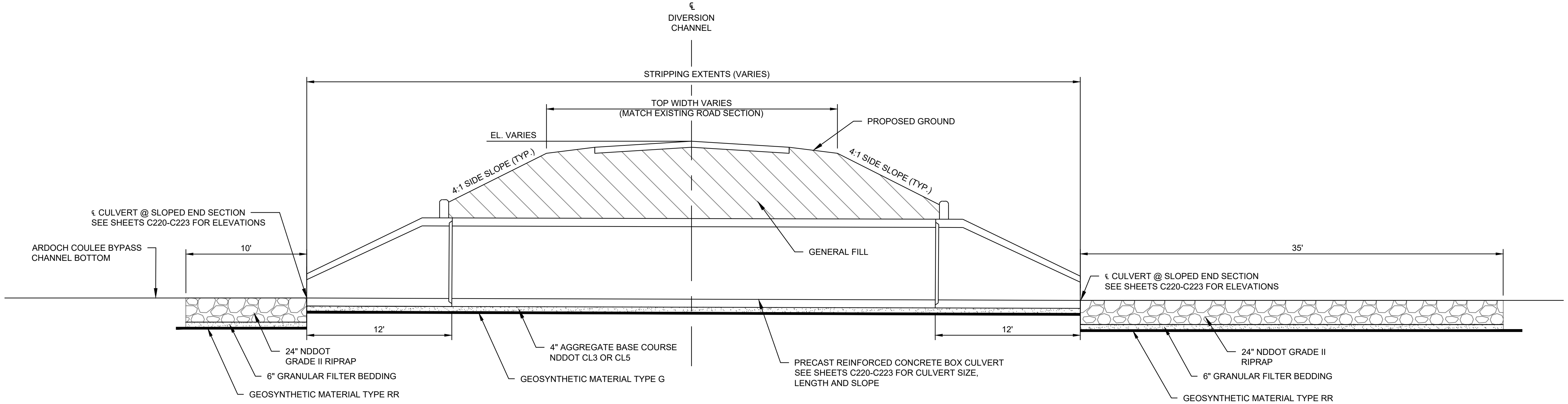
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

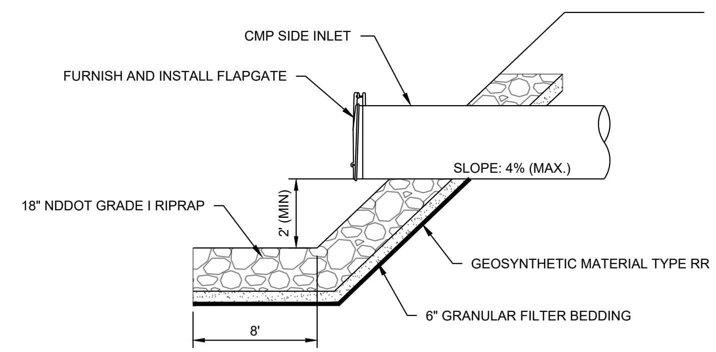
ARDOCH COULEE BYPASS CHANNEL DETAILS
PROJECT NO. 7135-021

SHEET C-200



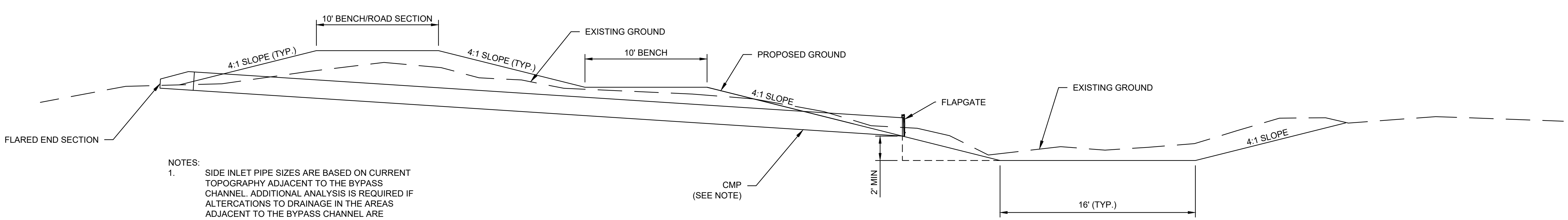
TYPICAL ARDOCH COULEE BYPASS CHANNEL BOX CULVERT SECTION

NOT TO SCALE



TYPICAL SIDE INLET PIPE OUTLET

NOT TO SCALE



NOTES:

1. SIDE INLET PIPE SIZES ARE BASED ON CURRENT TOPOGRAPHY ADJACENT TO THE BYPASS CHANNEL. ADDITIONAL ANALYSIS IS REQUIRED IF ALTERCATIONS TO DRAINAGE IN THE AREAS ADJACENT TO THE BYPASS CHANNEL ARE IMPLEMENTED.
2. SLOPE OF CMP SIDE INLET SHALL BE LIMITED TO A MAXIMUM OF 4%.

TYPICAL SIDE INLET SECTION

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

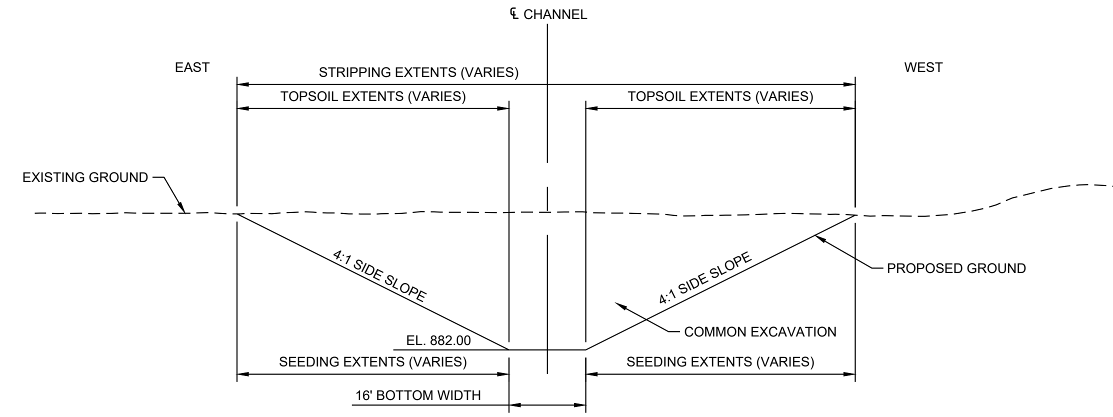
ARDOCH COULEE BYPASS CHANNEL DETAILS

PROJECT NO. 7135-021

SHEET C-201

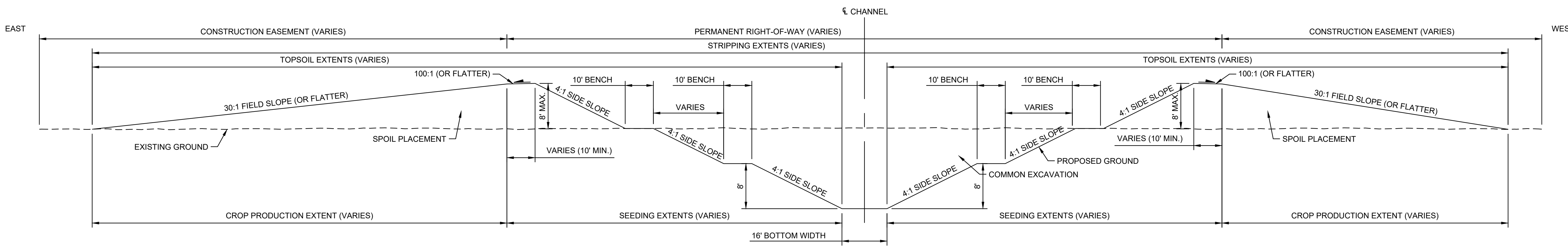
NOTES:

1. STRIPPING SHALL REMOVE ALL TOPSOIL UP TO A DEPTH OF 12" AS REQUIRED BY THE ENGINEER.
2. ADJACENT ROADS SHALL NOT BE DISTURBED. ANY DISTURBED AREAS SHALL BE RESTORED TO THE SATISFACTION OF THE ENGINEER.



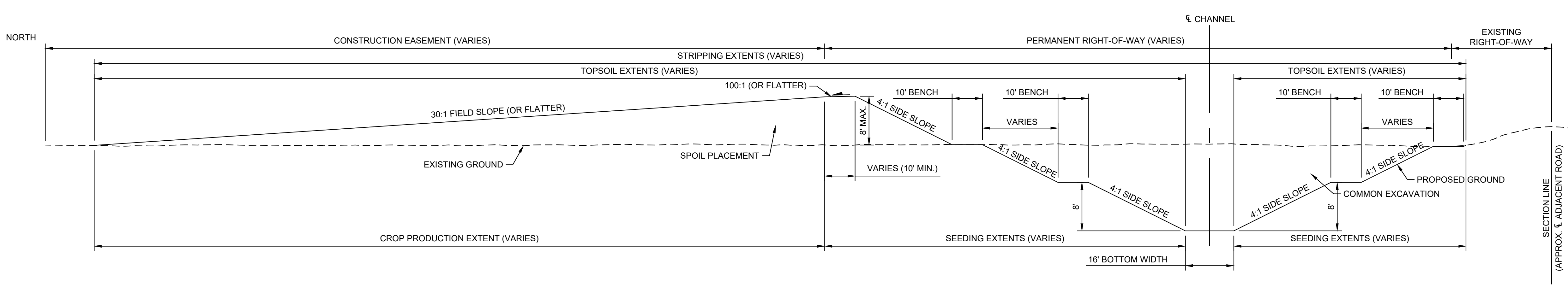
TYPICAL SECTION - ARDOCH COULEE BYPASS INLET CHANNEL (STA. 0+44 TO STA. 4+00)

NOT TO SCALE



TYPICAL SECTION - ARDOCH COULEE BYPASS CHANNEL (STA. 5+19 TO STA. 13+00)

NOT TO SCALE



TYPICAL SECTION - ARDOCH COULEE BYPASS CHANNEL (STA. 13+00 TO STA. 196+13)

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS CHANNEL TYPICAL SECTIONS

PROJECT NO. 7135-021

SHEET C-210

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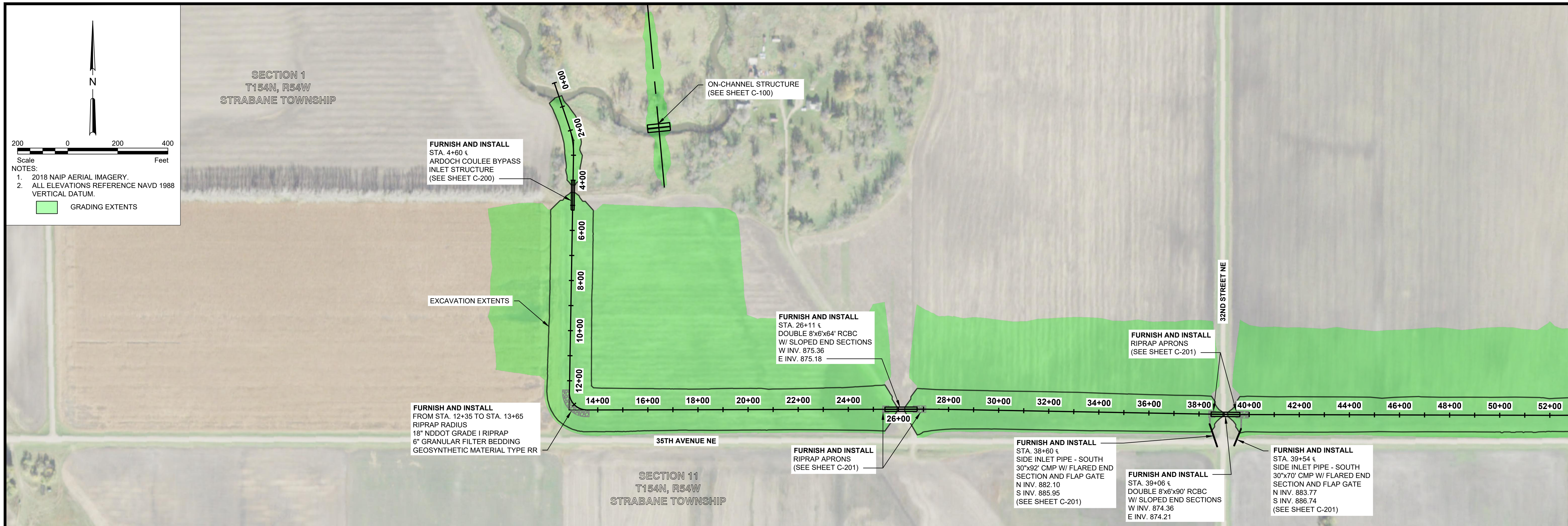

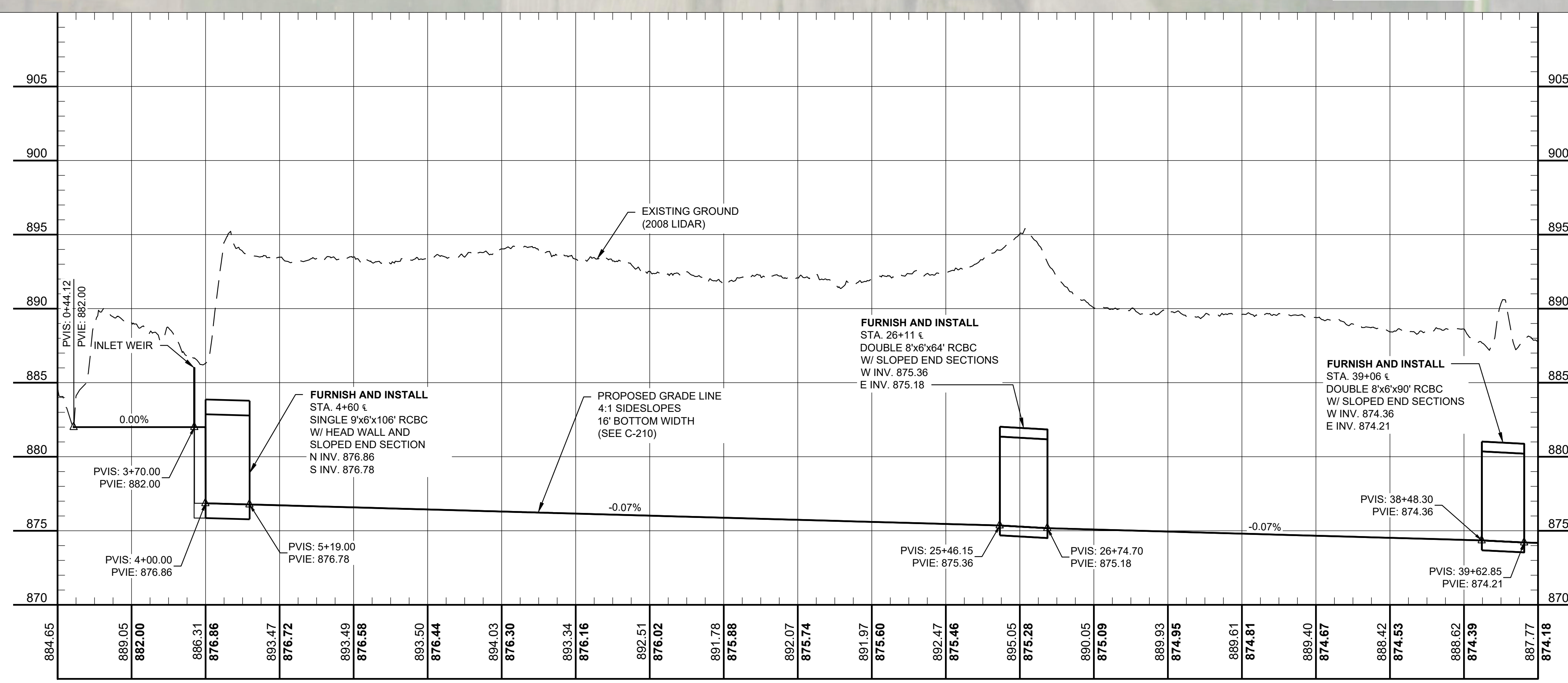

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL PLAN AND PROFILE

PROJECT NO. 7135-021

SHEET
C-220

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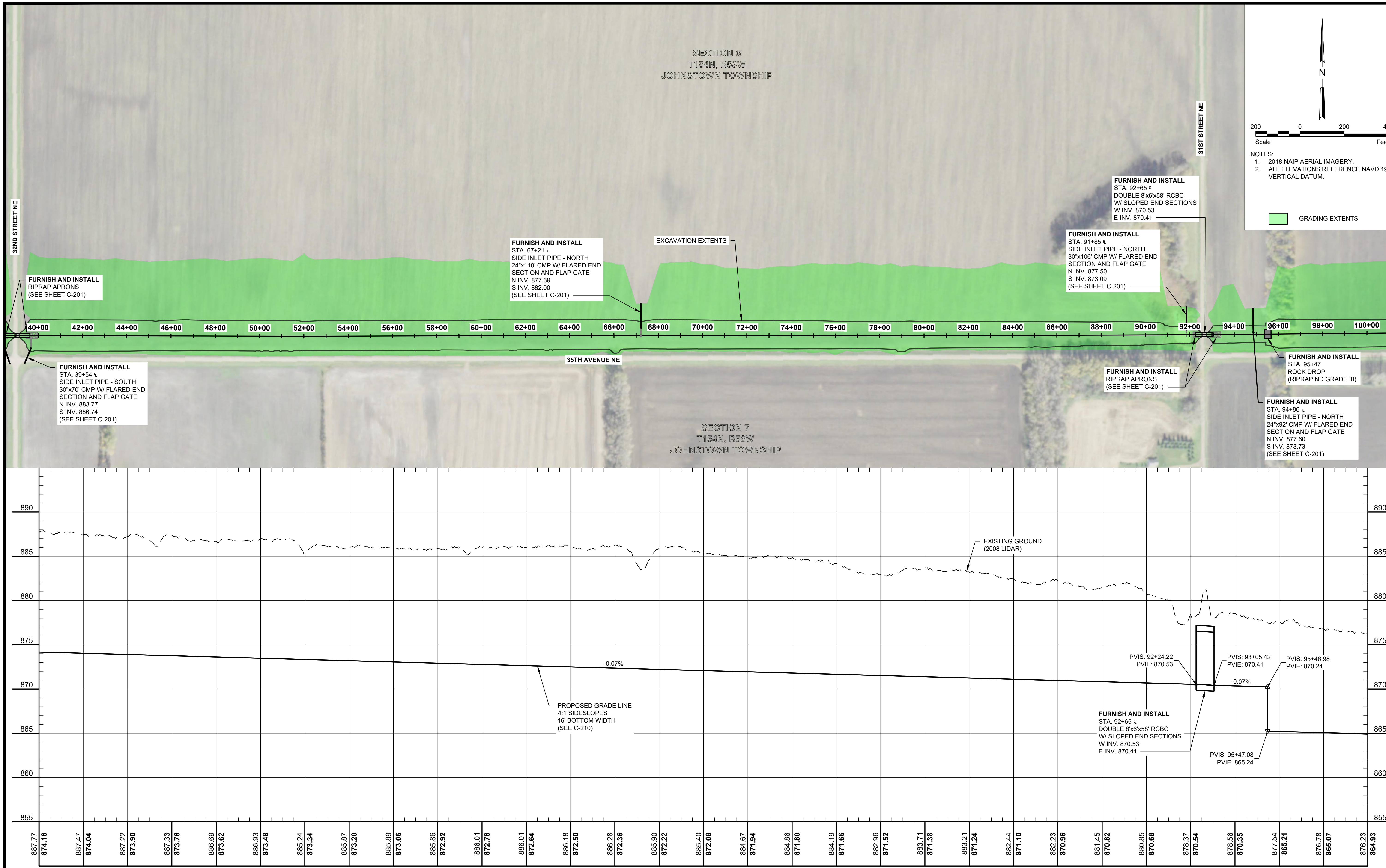

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL PLAN AND PROFILE

PROJECT NO. 7135-021

SHEET C-221

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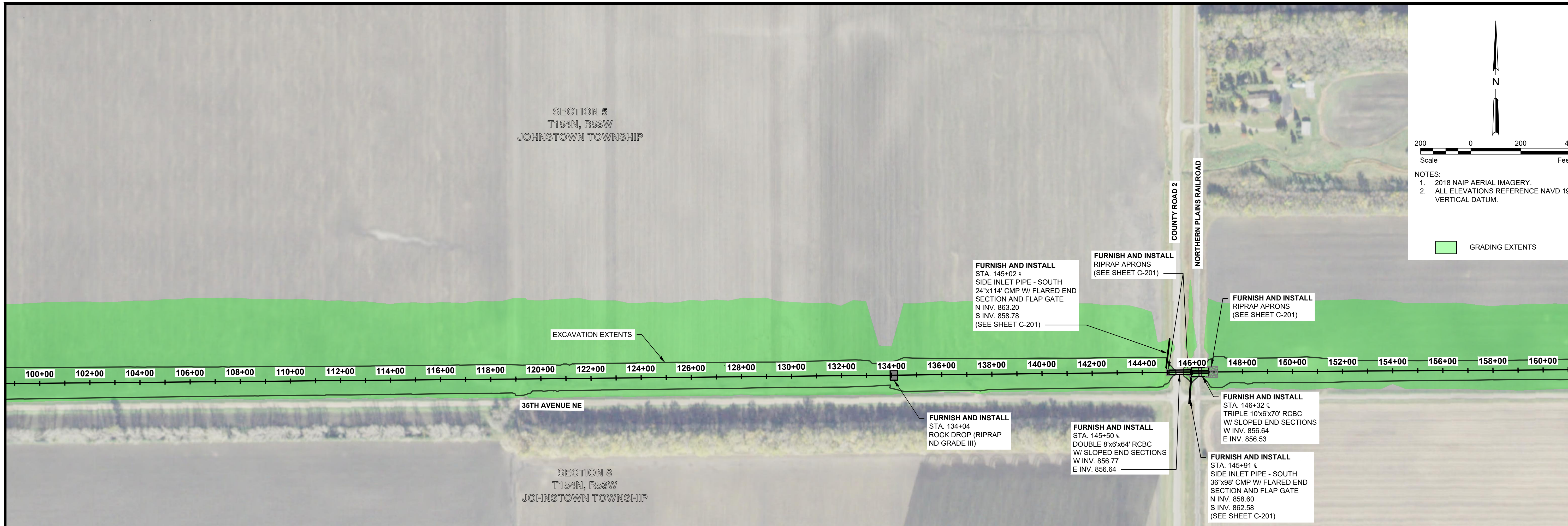

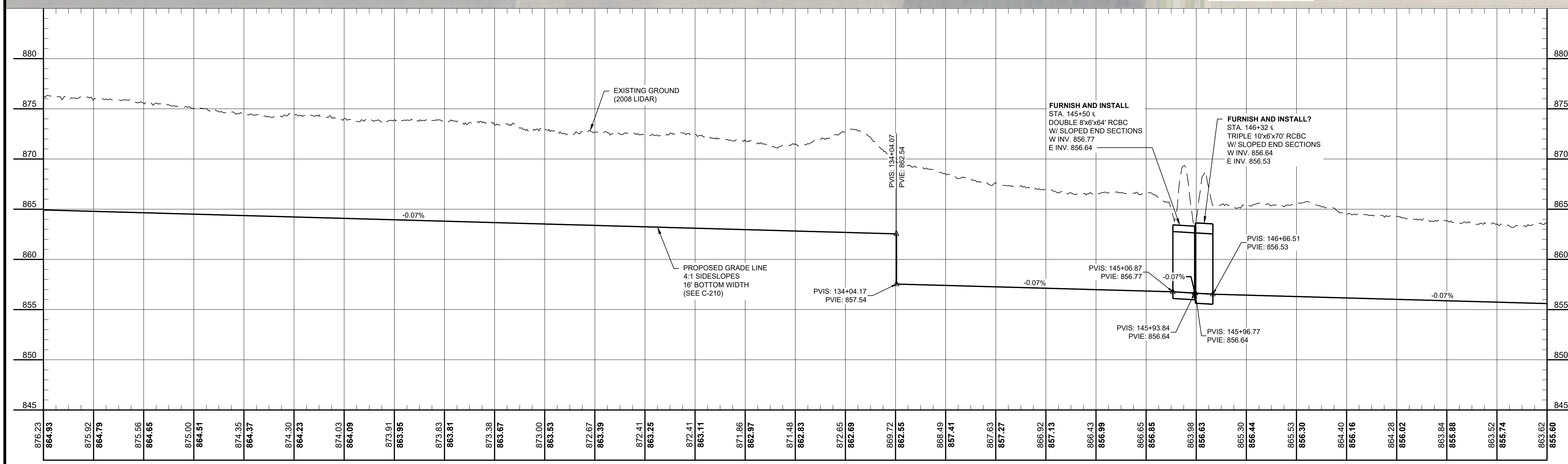

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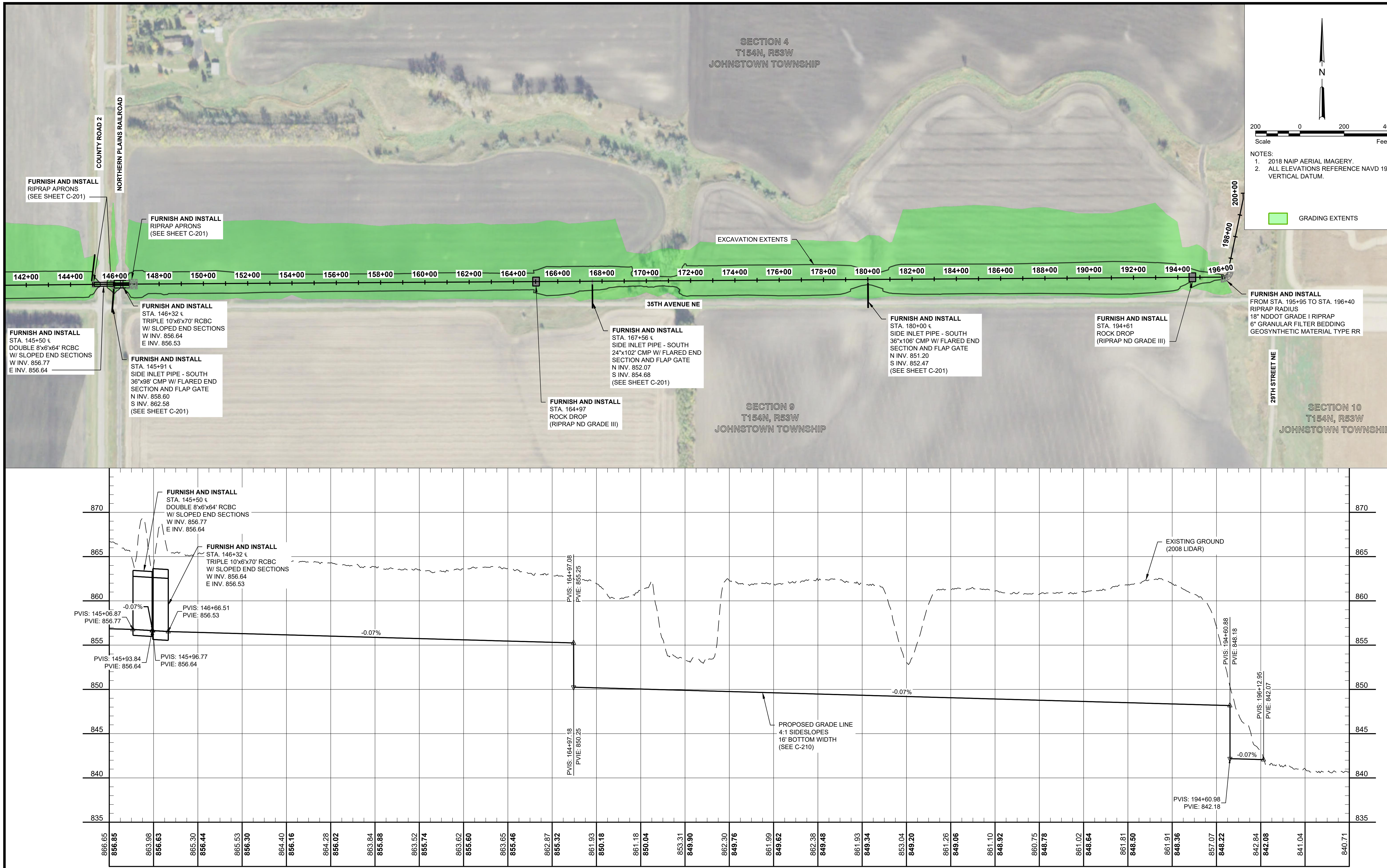
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL PLAN AND PROFILE
PROJECT NO. 7135-021

SHEET C-222



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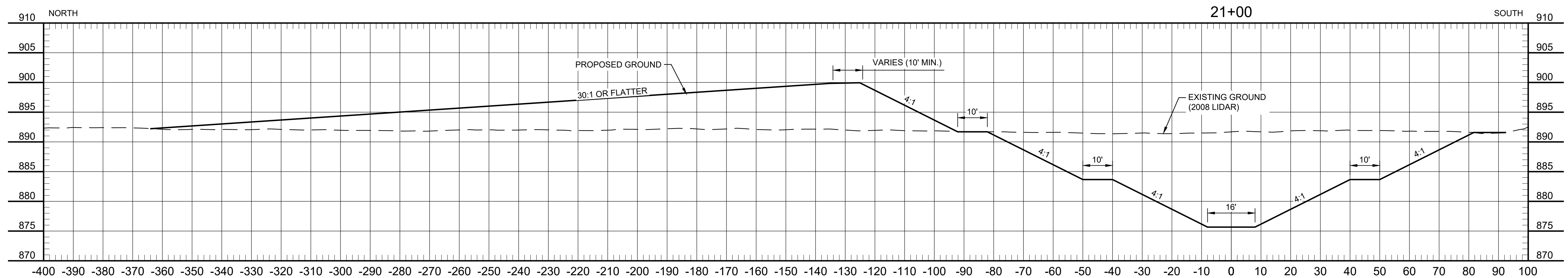
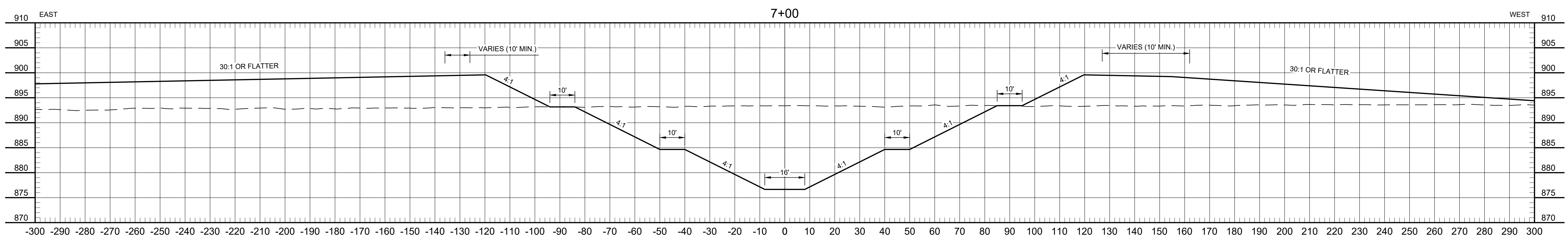
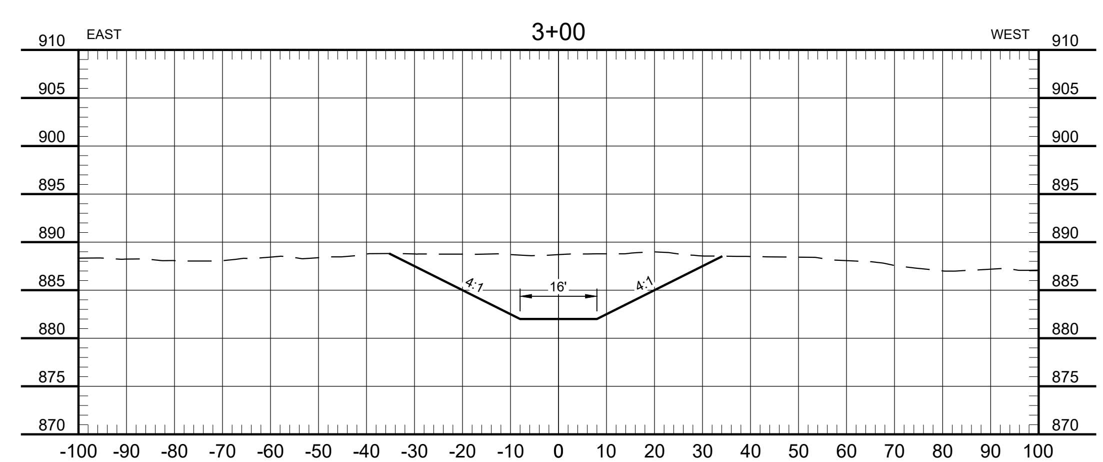
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL PLAN AND PROFILE
PROJECT NO. 7135-021

SHEET C-223







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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL SECTIONS

PROJECT NO. 7135-021

SHEET
C-230

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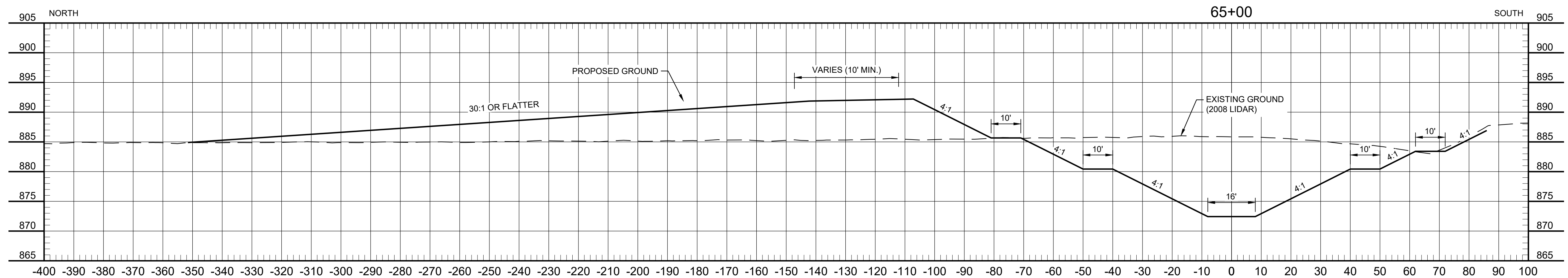

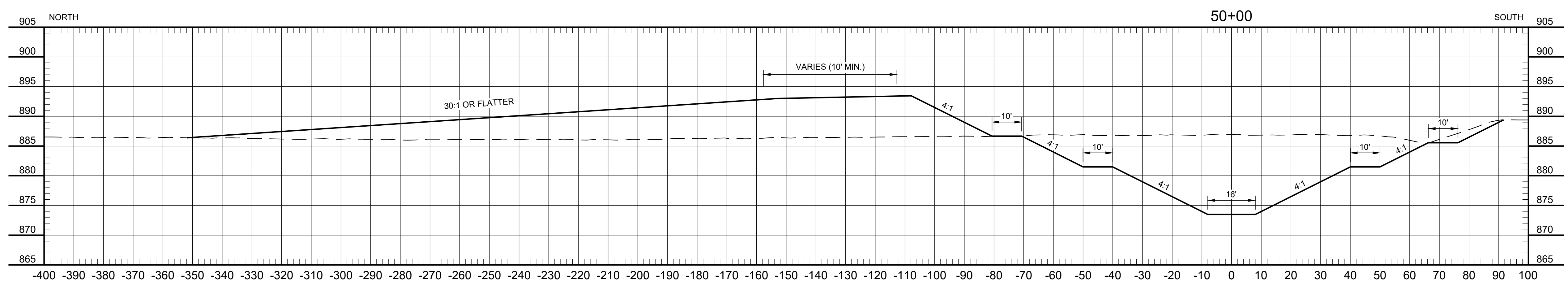

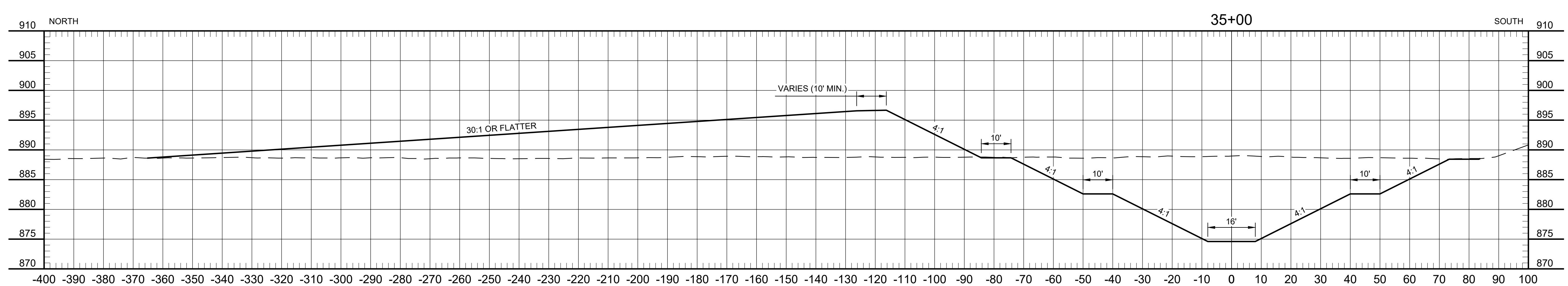

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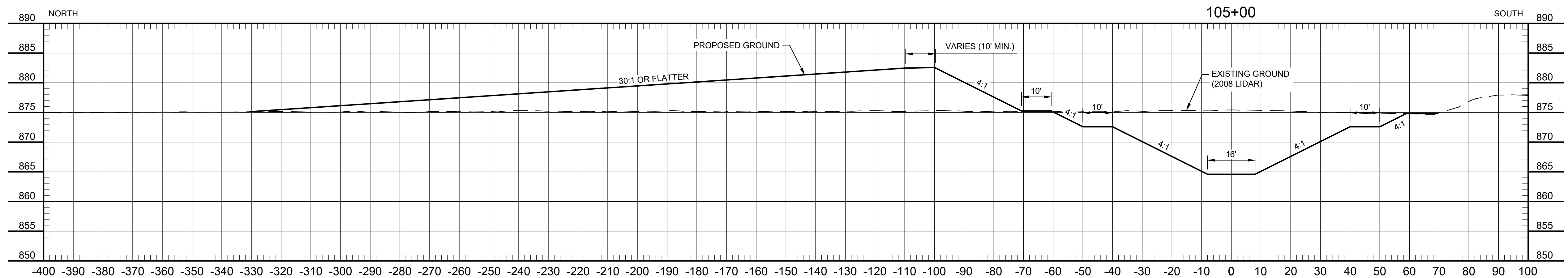
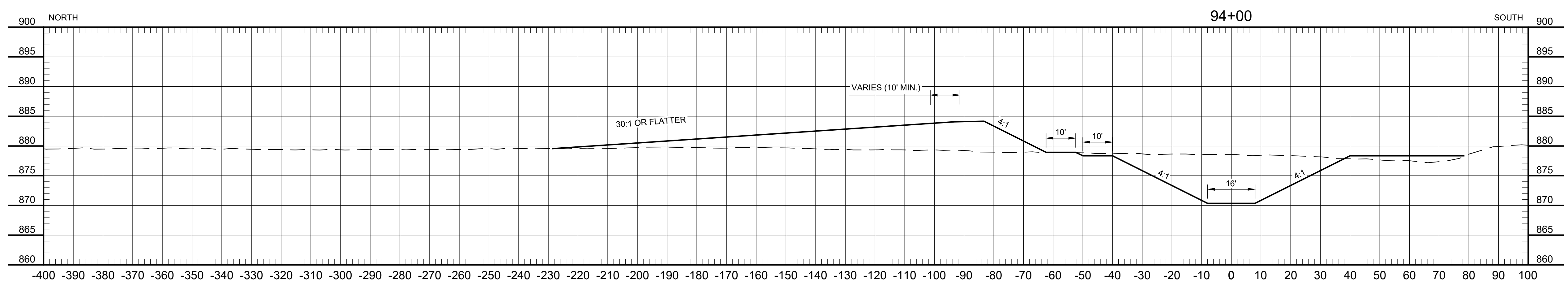
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

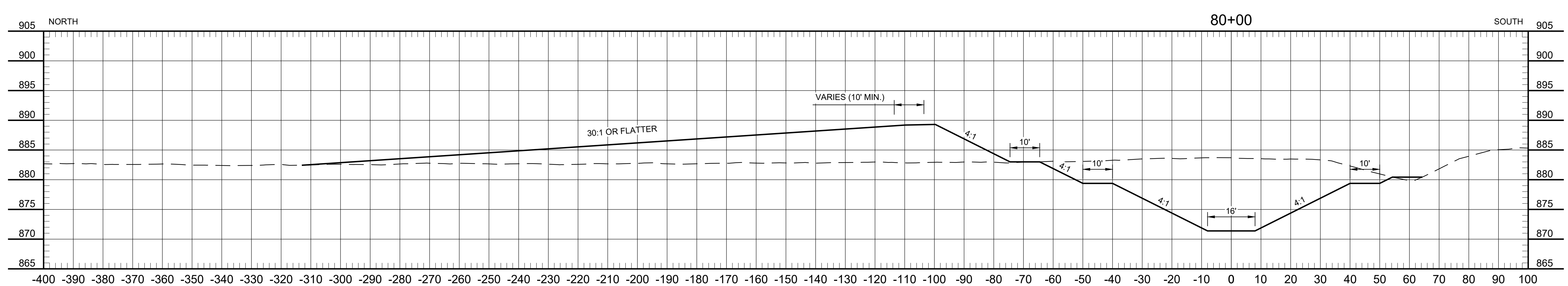
ARDOCH COULEE BYPASS
CHANNEL SECTIONS

PROJECT NO. 7135-021

SHEET
C-231







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ARDOCH COULEE BYPASS
CHANNEL SECTIONS

PROJECT NO. 7135-021

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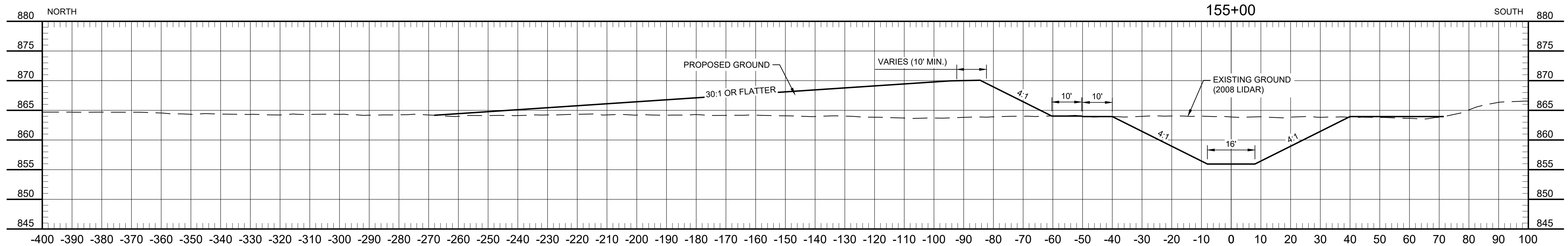

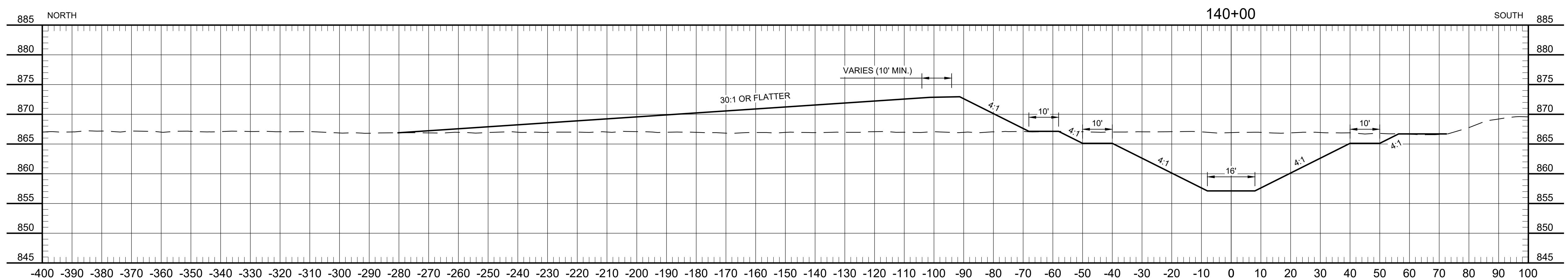

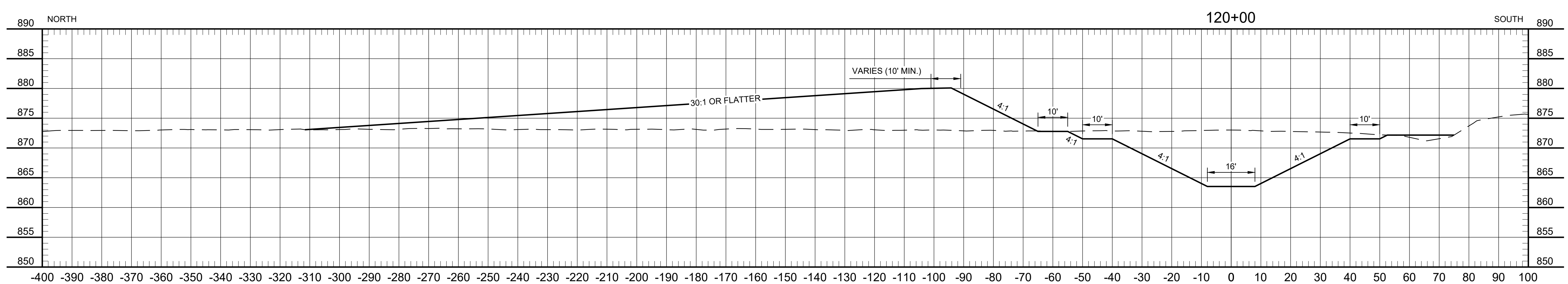

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ARDOCH COULEE BYPASS
CHANNEL SECTIONS

PROJECT NO. 7135-021

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C-233

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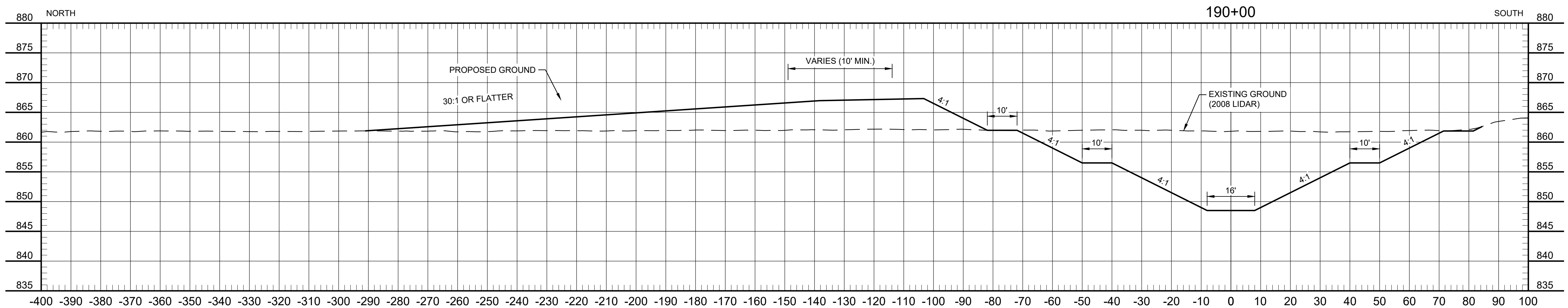

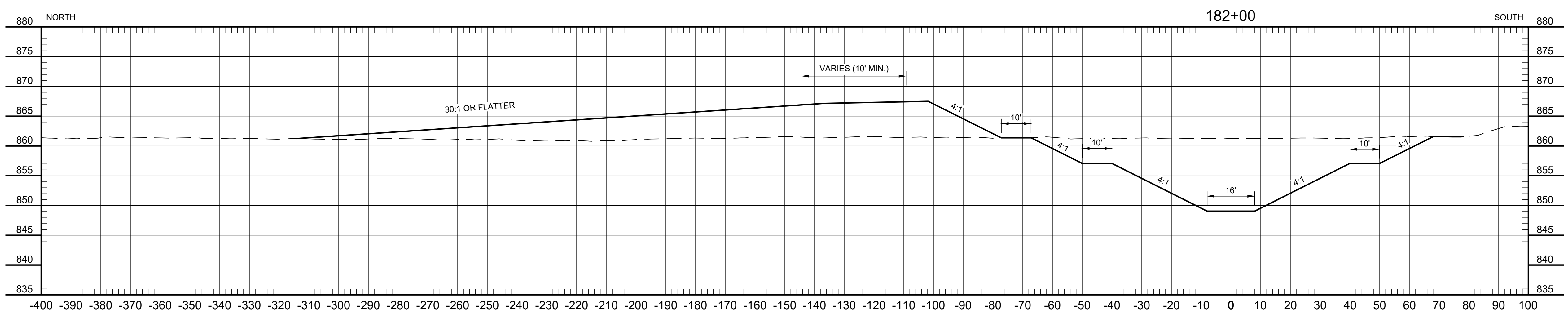

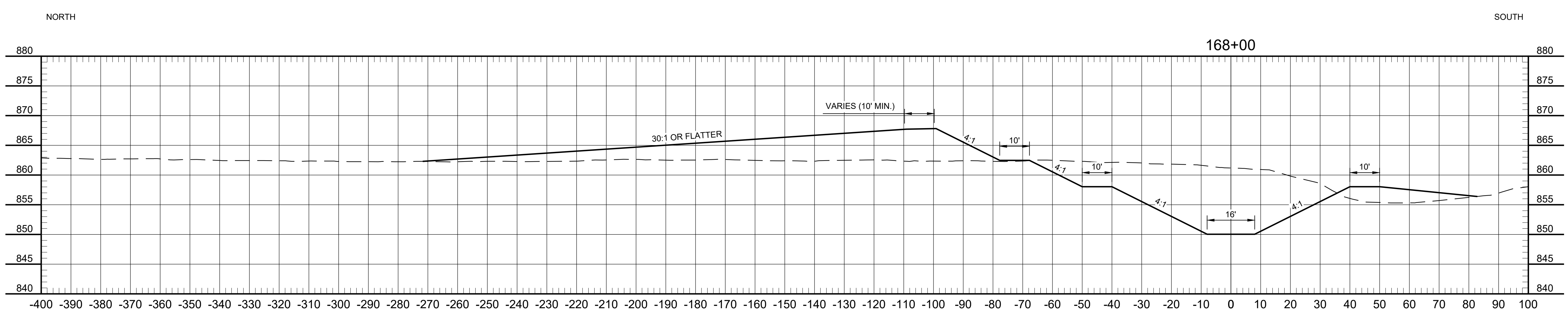

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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

ARDOCH COULEE BYPASS
CHANNEL SECTIONS

PROJECT NO. 7135-021

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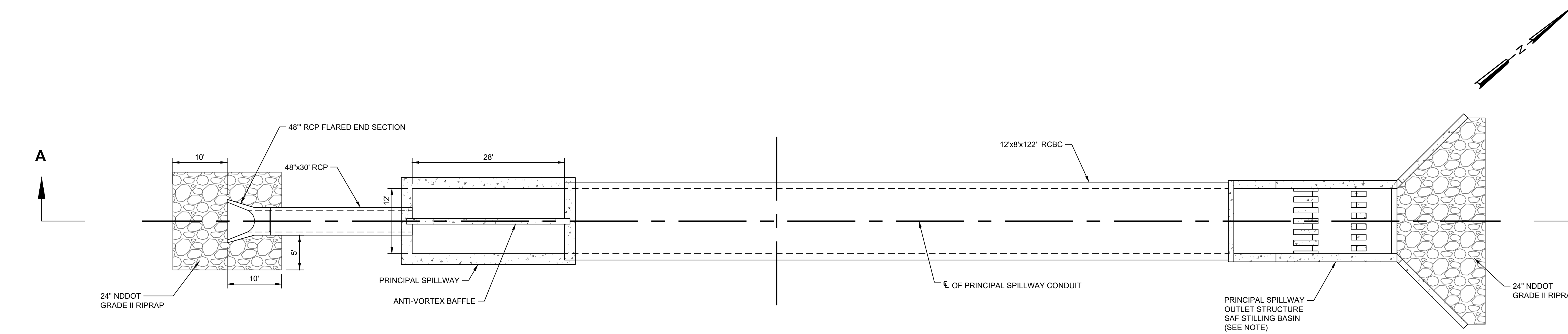

PLAN VIEW

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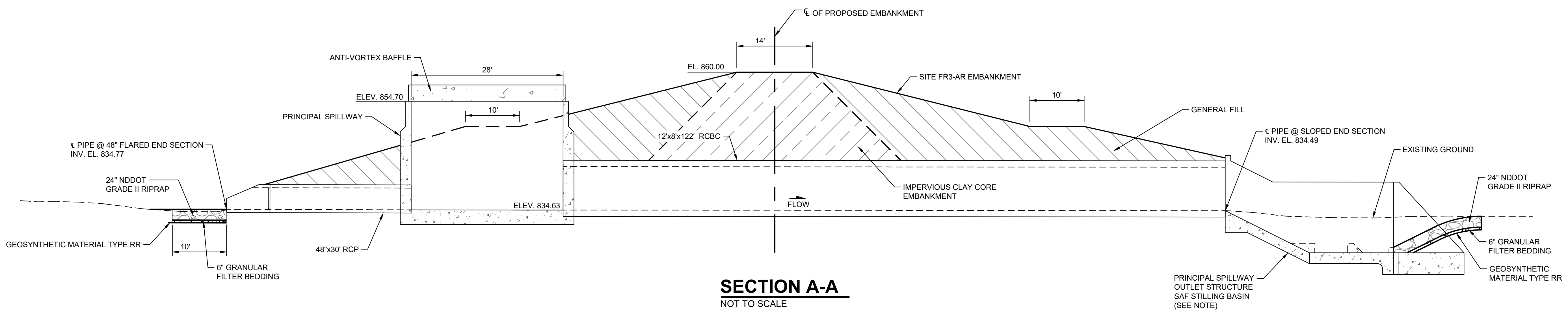

SECTION A-A

NOT TO SCALE

NOTES:

1. TRASH RACK AND LADDER SHALL BE INSTALLED WITH THE PRINCIPAL SPILLWAY STRUCTURE.
2. THE OUTLET CONDUIT FOR THE PRINCIPAL SPILLWAY STRUCTURE SHALL BE INSTALLED WITH A FILTER DIAPHRAGM BASED ON GUIDANCE FROM THE NATIONAL ENGINEERING HANDBOOK, PART 628, CHAPTER 45.
3. REFER TO HYDRAULIC ENGINEERING CIRCULAR NO. 14, CHAPTER 8 FOR SAINT ANTHONY FALLS (SAF) STILLING BASIN DESIGN GUIDANCE. THE PRINCIPAL SPILLWAY OUTLET STRUCTURE DESIGN AND DIMENSIONS DISPLAYED ARE PRELIMINARY. FURTHER ANALYSIS SHOULD BE COMPLETED FOR FINAL DESIGN OF THE SAF STILLING BASIN.

SITE FR3-AR PRINCIPAL SPILLWAY DETAIL

NOT TO SCALE

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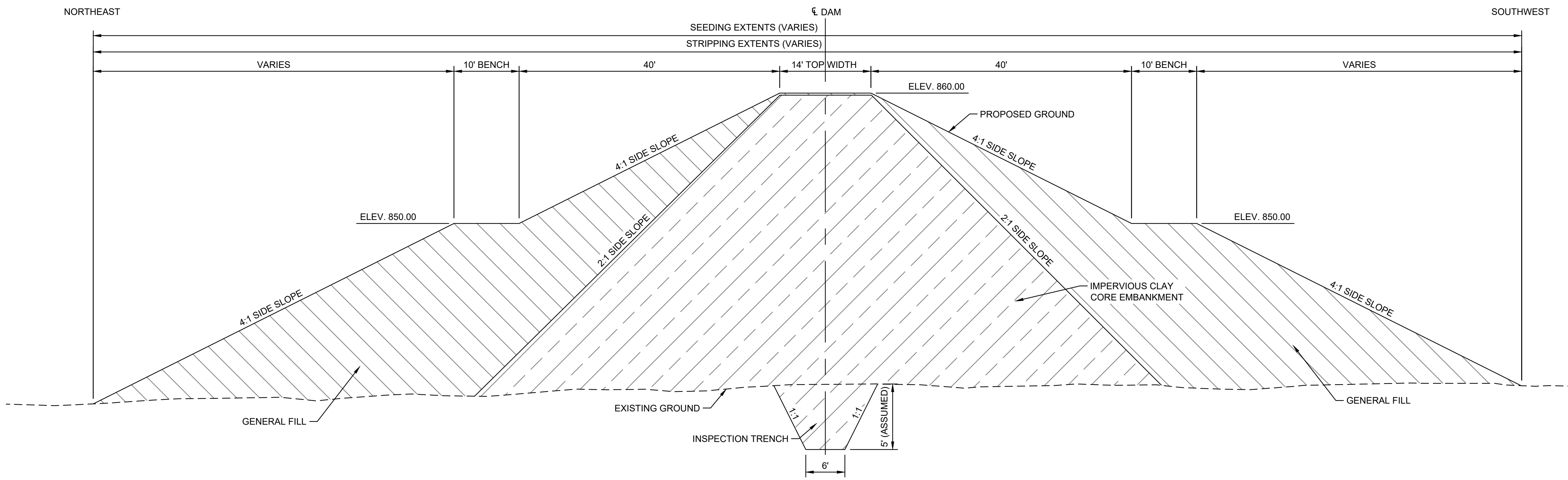
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

SITE FR3-AR DETAILS

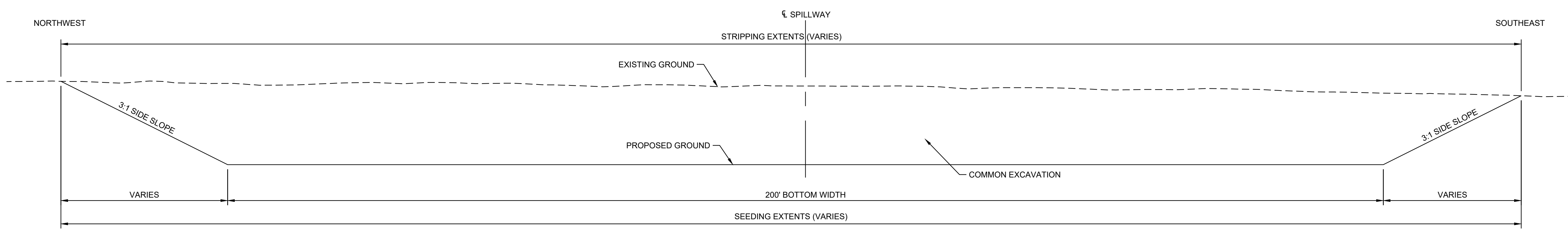
PROJECT NO. 7135-021

SHEET C-300



TYPICAL SECTION - SITE FR3-AR EMBANKMENT

NOT TO SCALE



TYPICAL SECTION - SITE FR3-AR AUXILIARY SPILLWAY

NOT TO SCALE

NOTES:

1. MATERIAL SPECIFICATIONS SHALL BE BASED ON GUIDANCE FROM THE GEOTECHNICAL REPORT.
2. CROSS SECTION OF EMBANKMENT AND DEPTH OF INSPECTION TRENCH ARE ASSUMED. GEOTECHNICAL ENGINEER SHALL EVALUATE DESIGN BEFORE CONSTRUCTION AND PROVIDE GEOTECHNICAL RECOMMENDATIONS.

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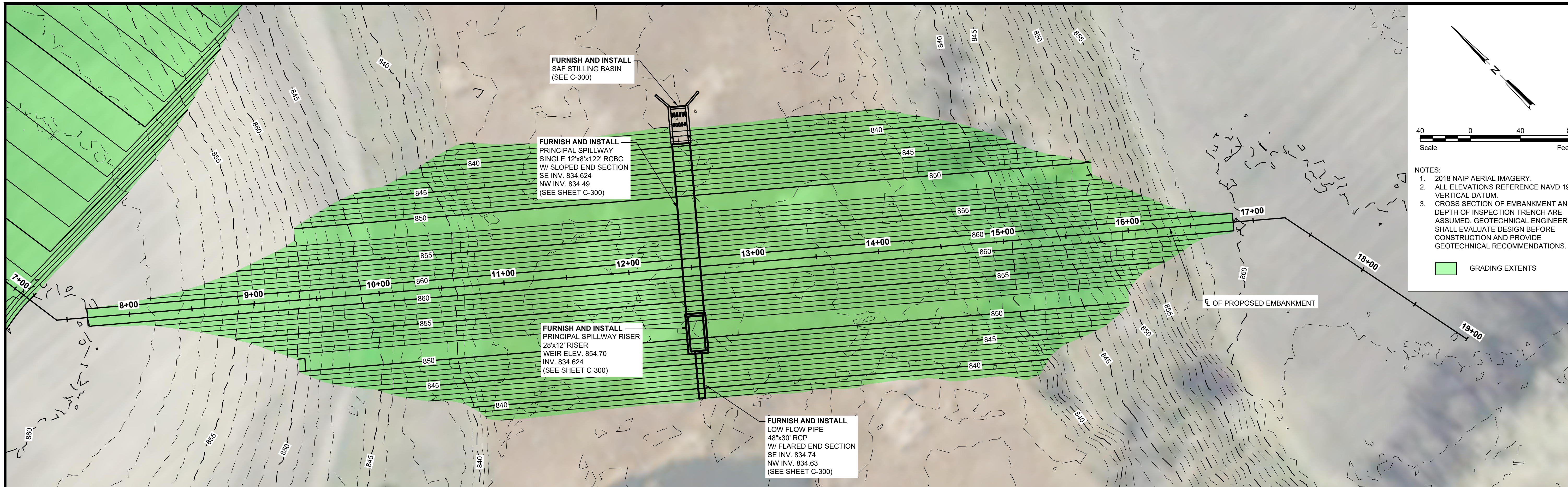

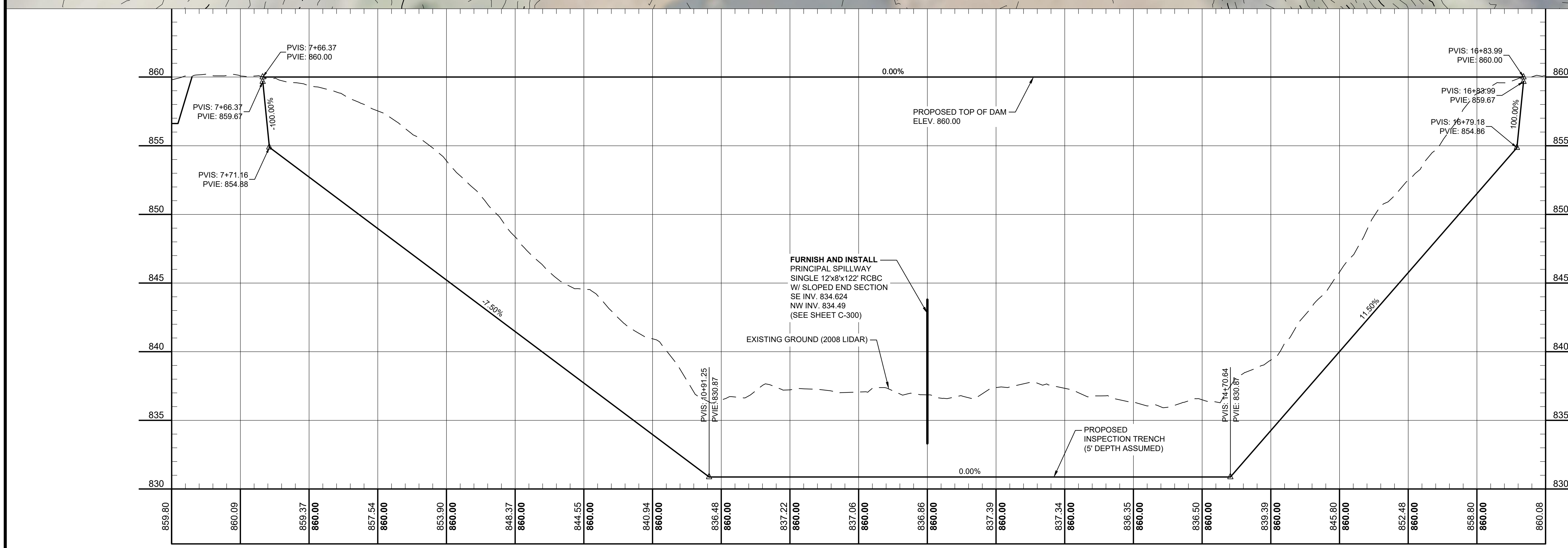

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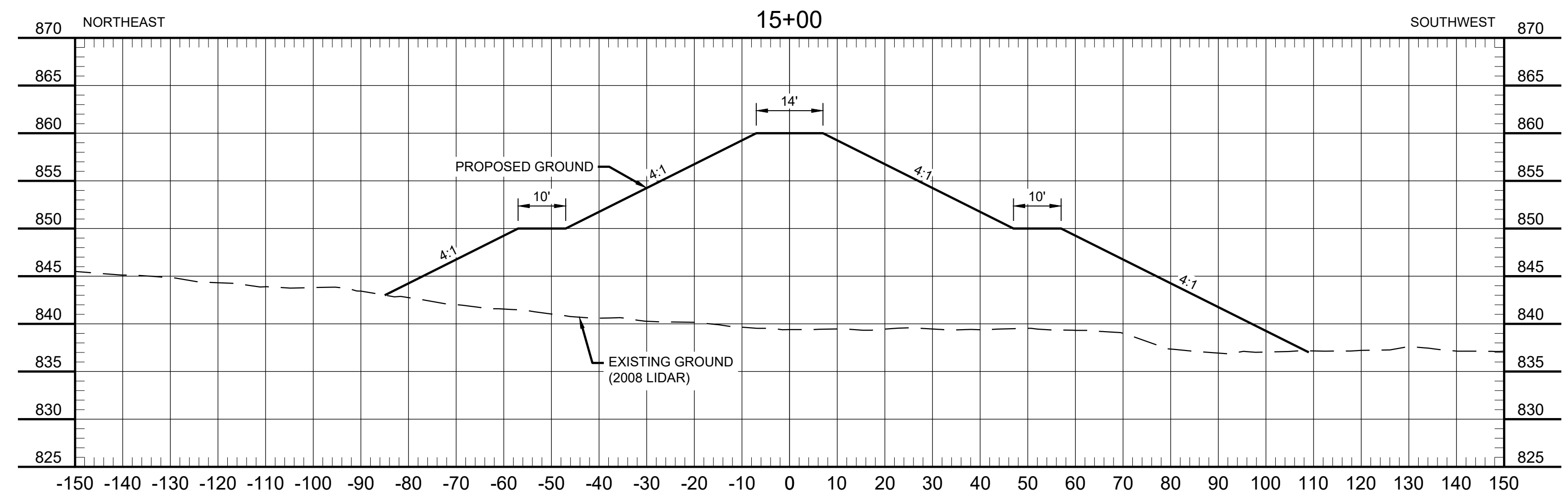
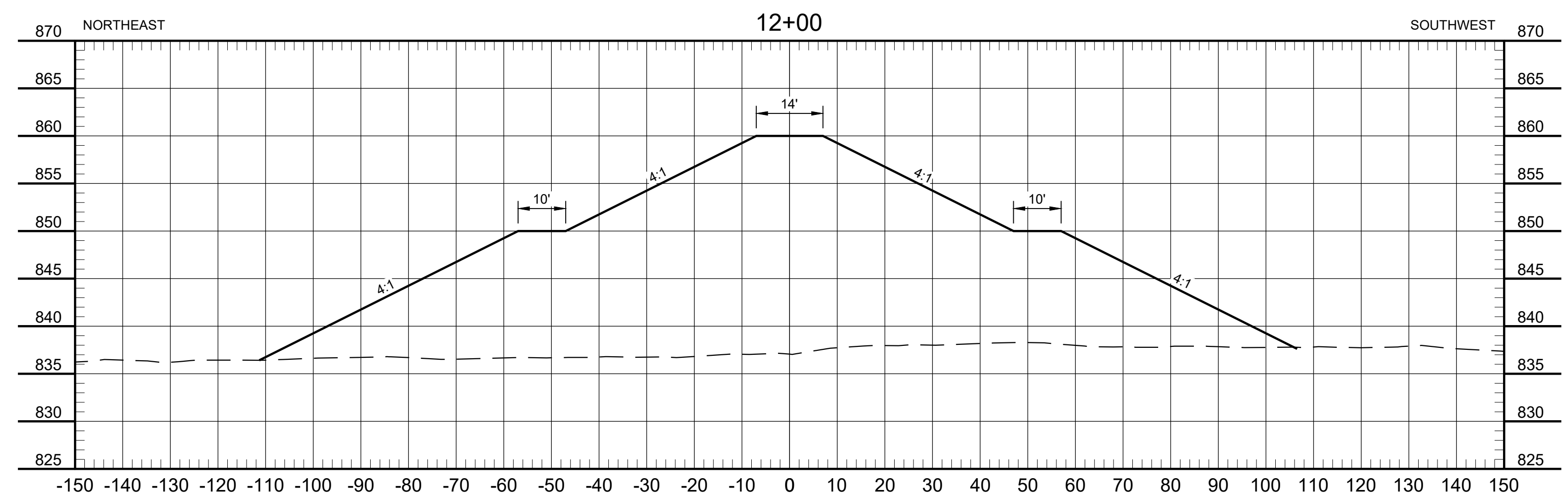
ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

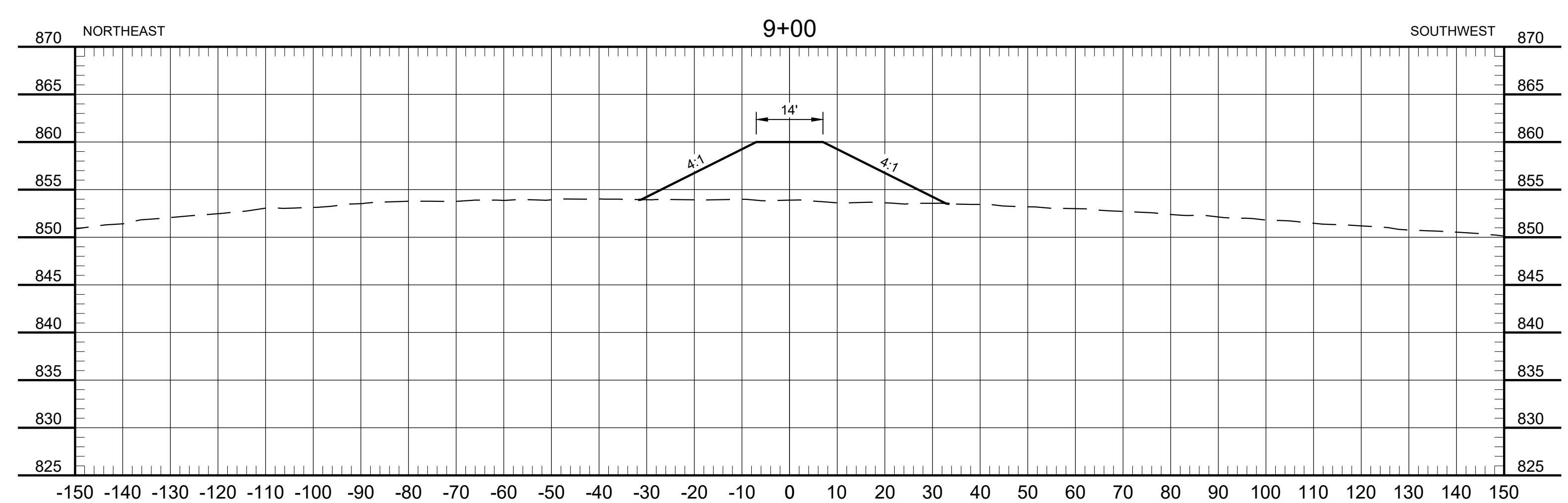
SITE FR3-AR EMBANKMENT
PLAN AND PROFILE

PROJECT NO. 7135-021

SHEET
C-320







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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

SITE FR3-AR EMBANKMENT CROSS SECTIONS

PROJECT NO. 7135-021

SHEET C-330

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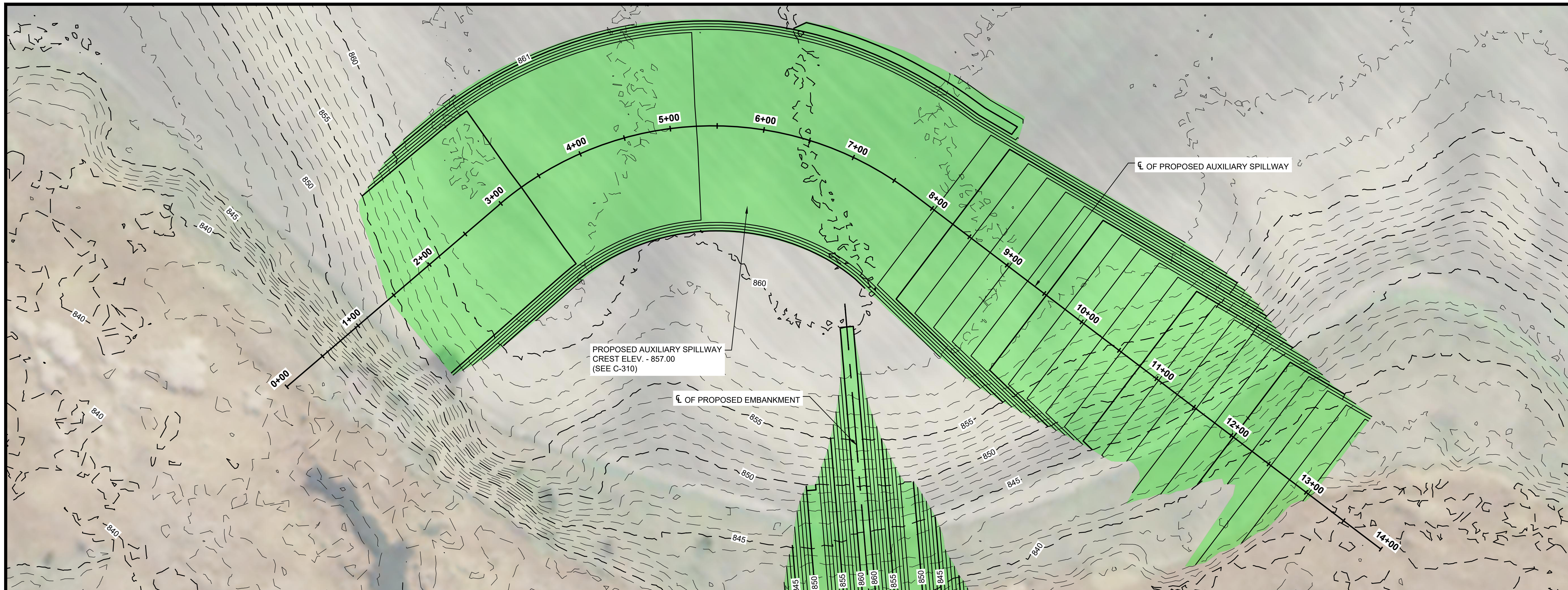

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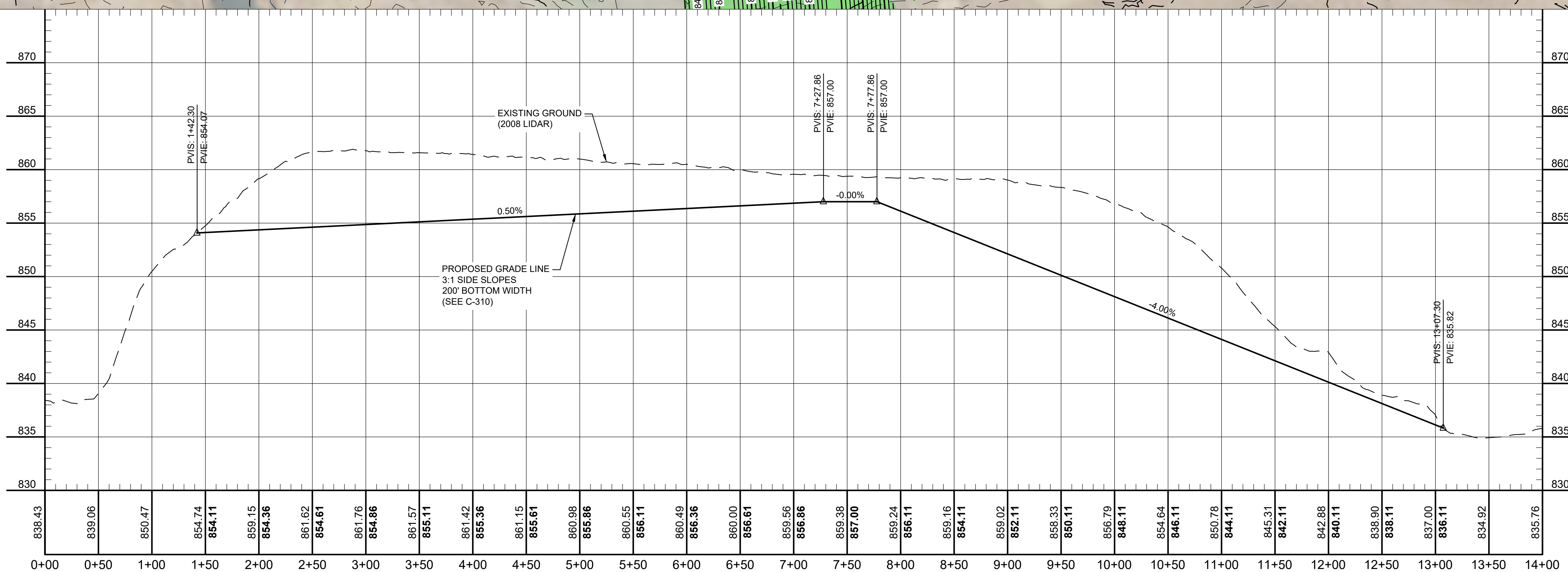
1. 2018 NAIP AERIAL IMAGERY.
2. ALL ELEVATIONS REFERENCE NAVD 1988 VERTICAL DATUM.

GRADING EXTENTS



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ARDOCH COULEE BYPASS AND SITE FR3-AR
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

SITE FR3-AR AUXILIARY SPILLWAY PLAN AND PROFILE

PROJECT NO. 7135-021

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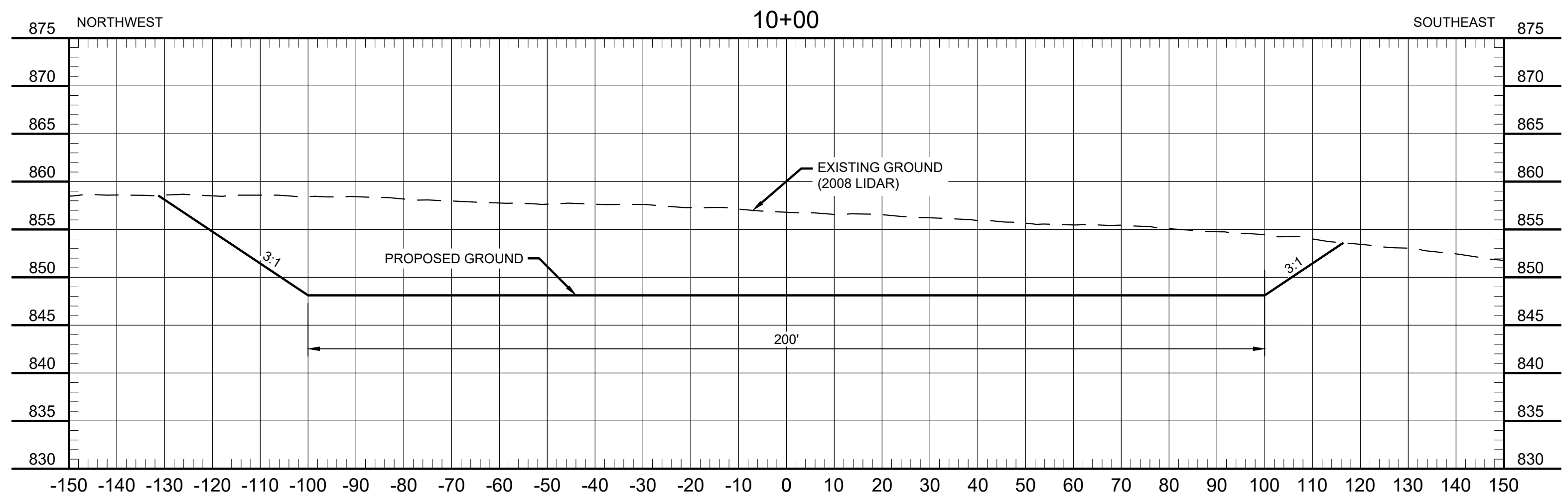

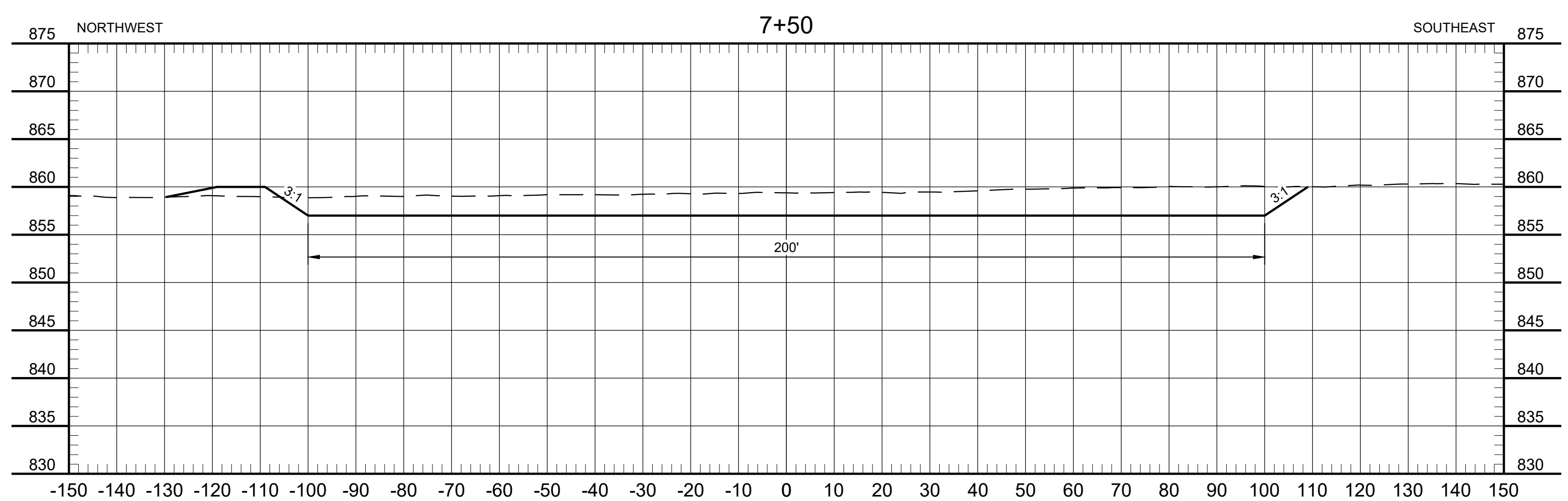

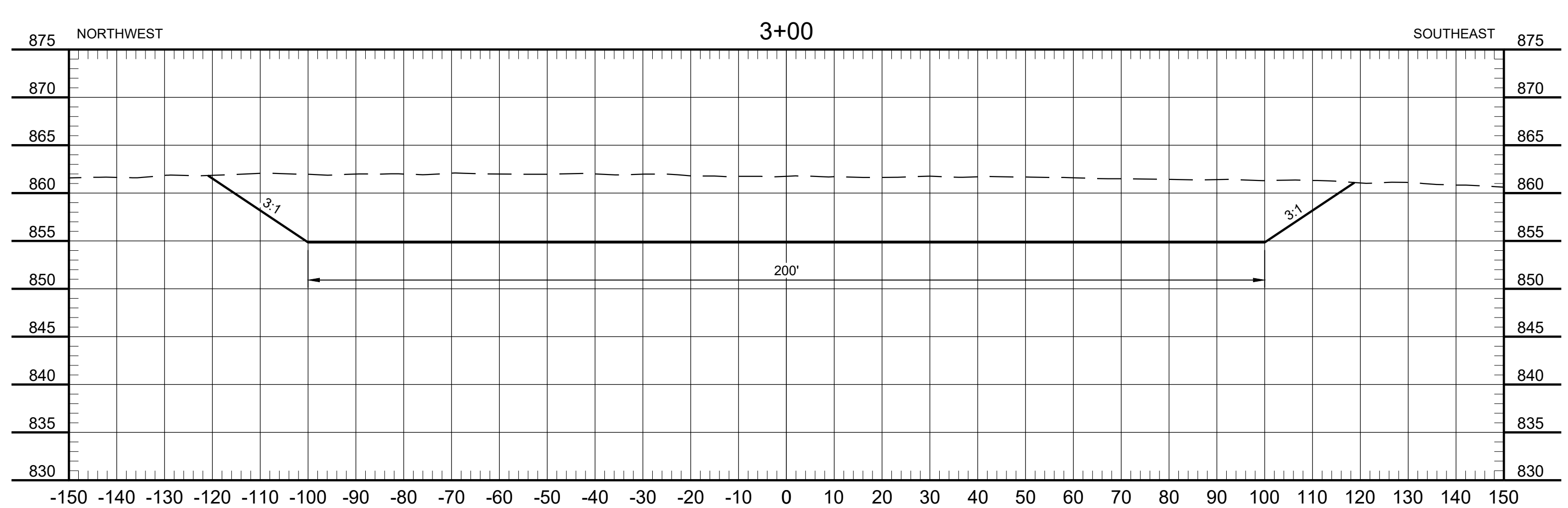

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ARDOCH COULEE BYPASS AND SITE FR3-AR
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GRAFTON, NORTH DAKOTA

SITE FR3-AR AUXILIARY SPILLWAY CROSS SECTIONS

PROJECT NO. 7135-021

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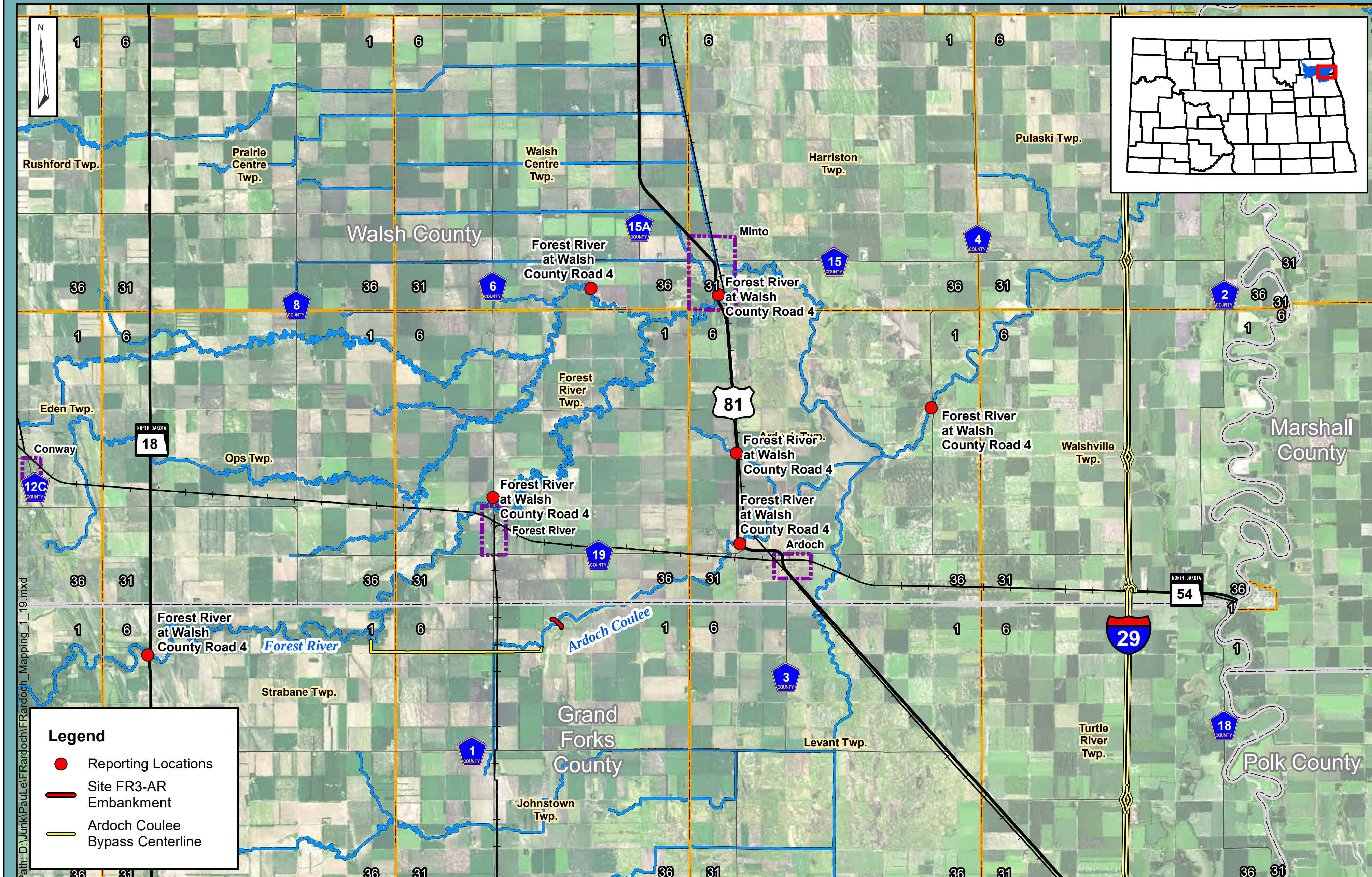
APPENDIX B

Synthetic Rainfall Events and Site Performance

APPENDIX B

Synthetic Rainfall Events and Site Performance



F-B.1

Figure B.1: Reporting Locations

Forest River Watershed

Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report

Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.

Figure B.2: Discharge Hydrograph for Forest River at ND Highway 18

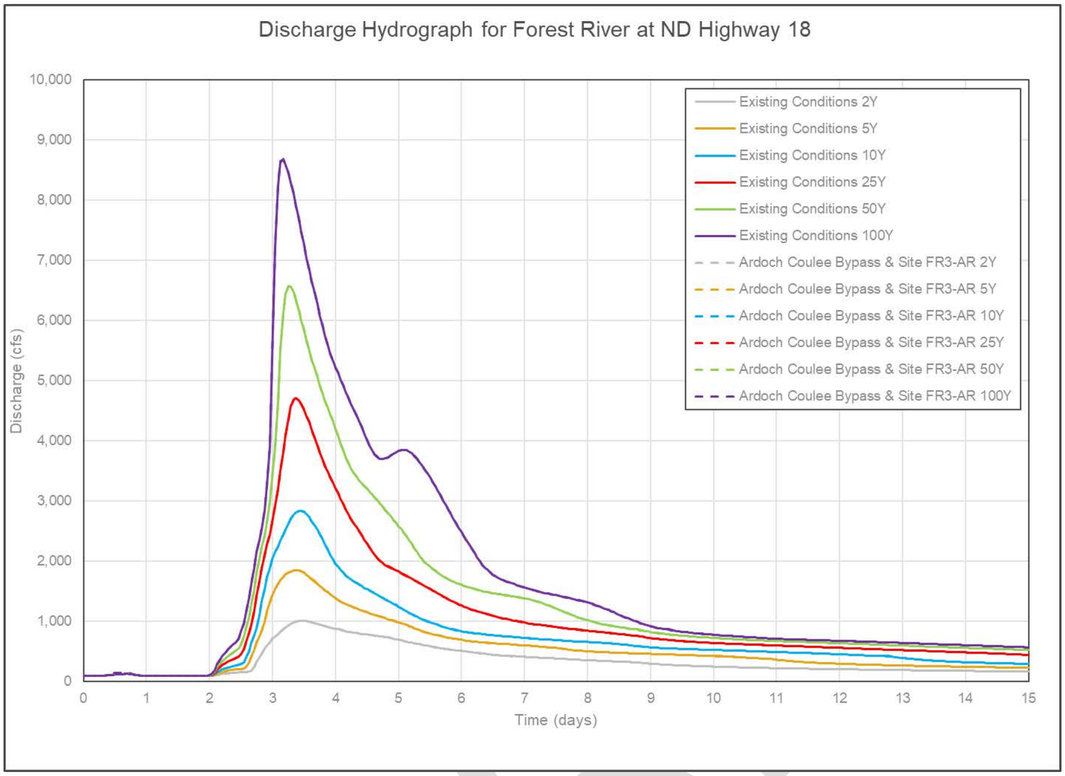


Figure B.3: Discharge Hydrograph for Forest River at Walsh County Road 6

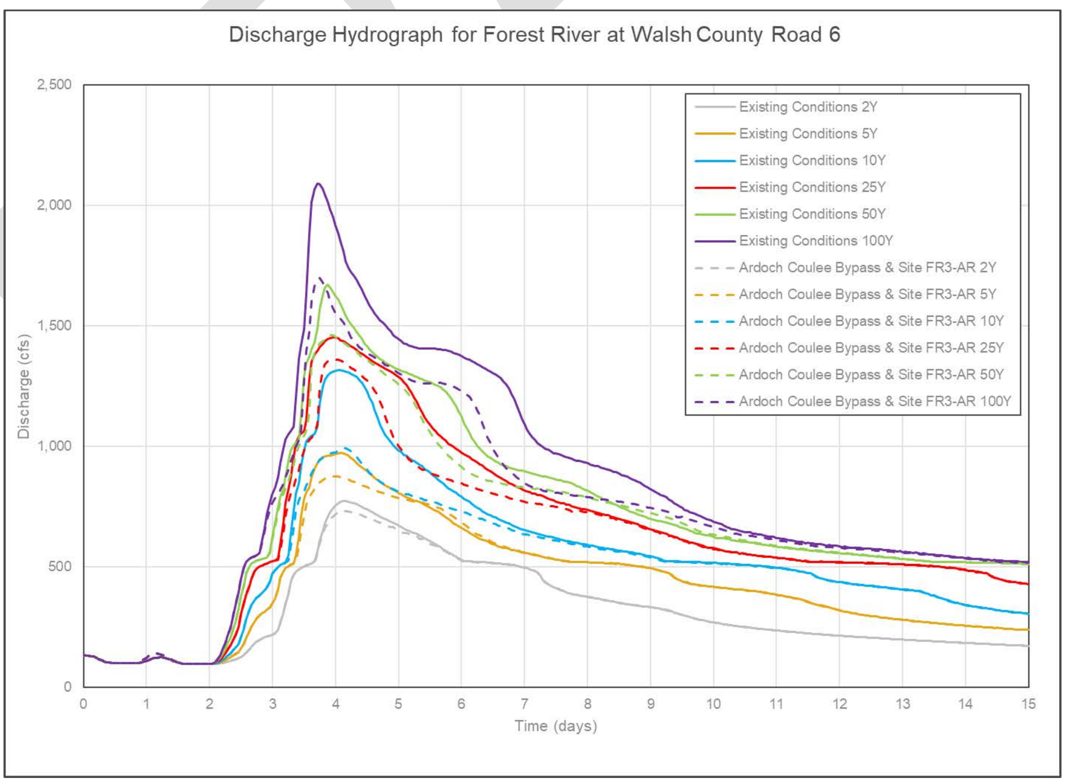


Figure B.4: *Discharge Hydrograph for Forest River at First Street Crossing*

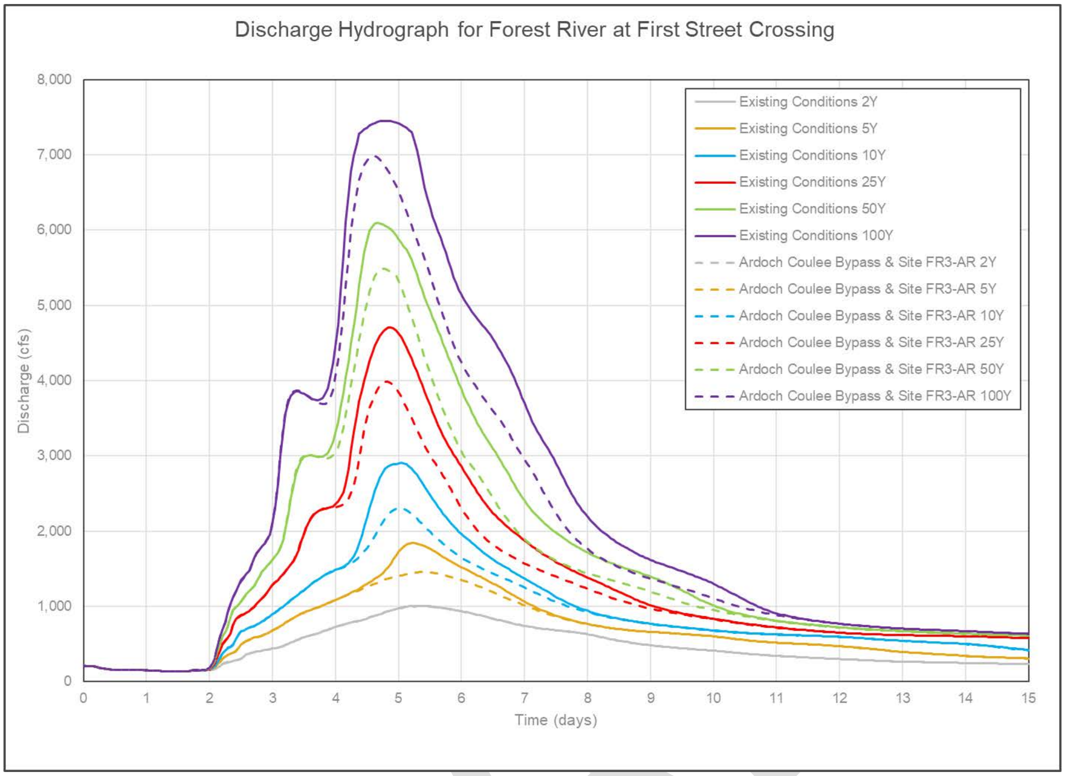


Figure B.5: *Discharge Hydrograph for Forest River at Walsh County Road 4*

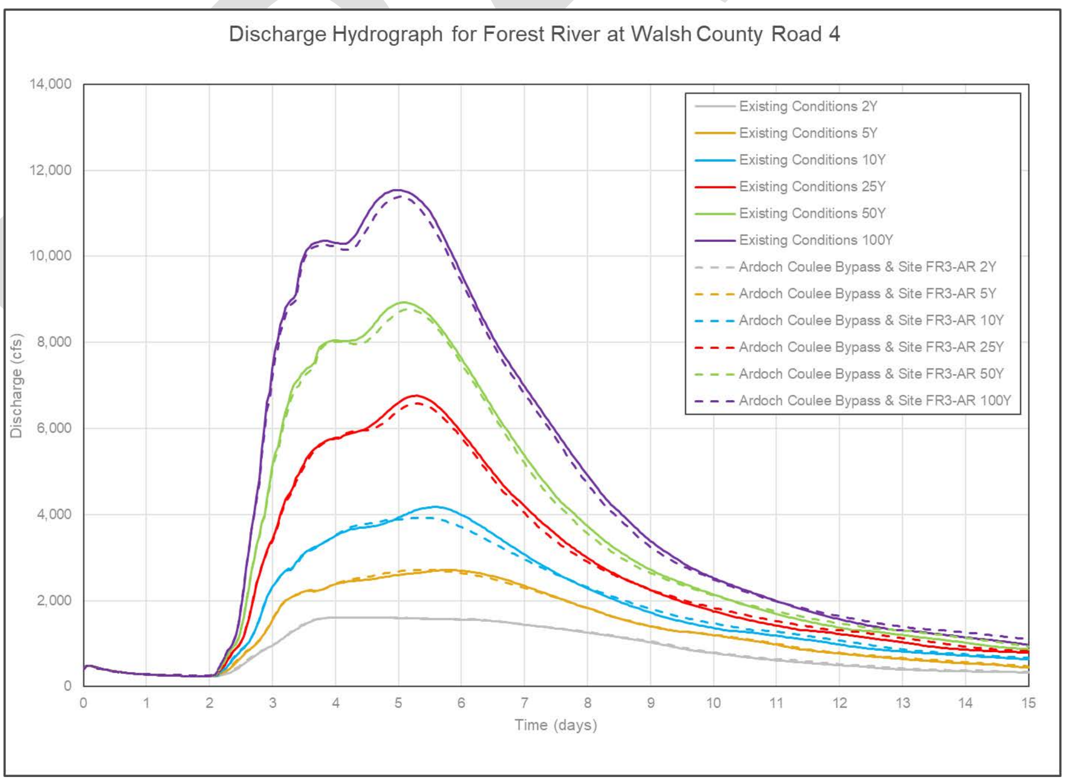


Figure B.6: *Discharge Hydrograph for Forest River North Breakout at 148th Avenue NE*

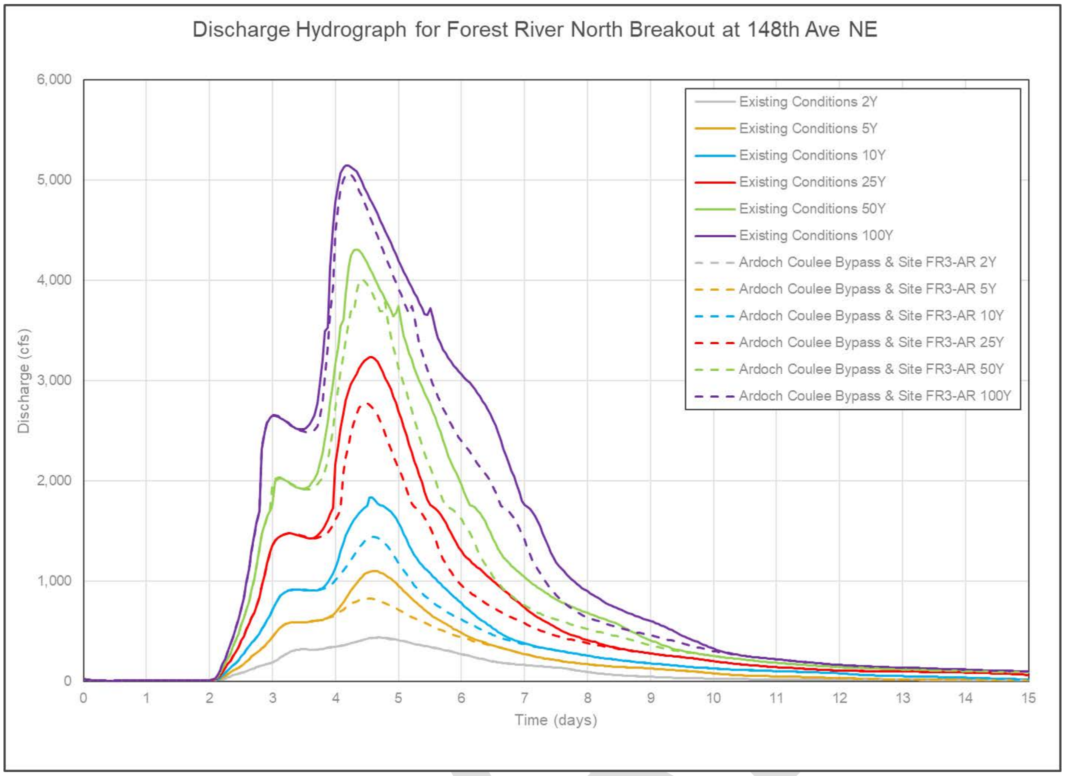


Figure B.7: *Discharge Hydrograph for Ardoch Coulee Breakout at US Highway 81*

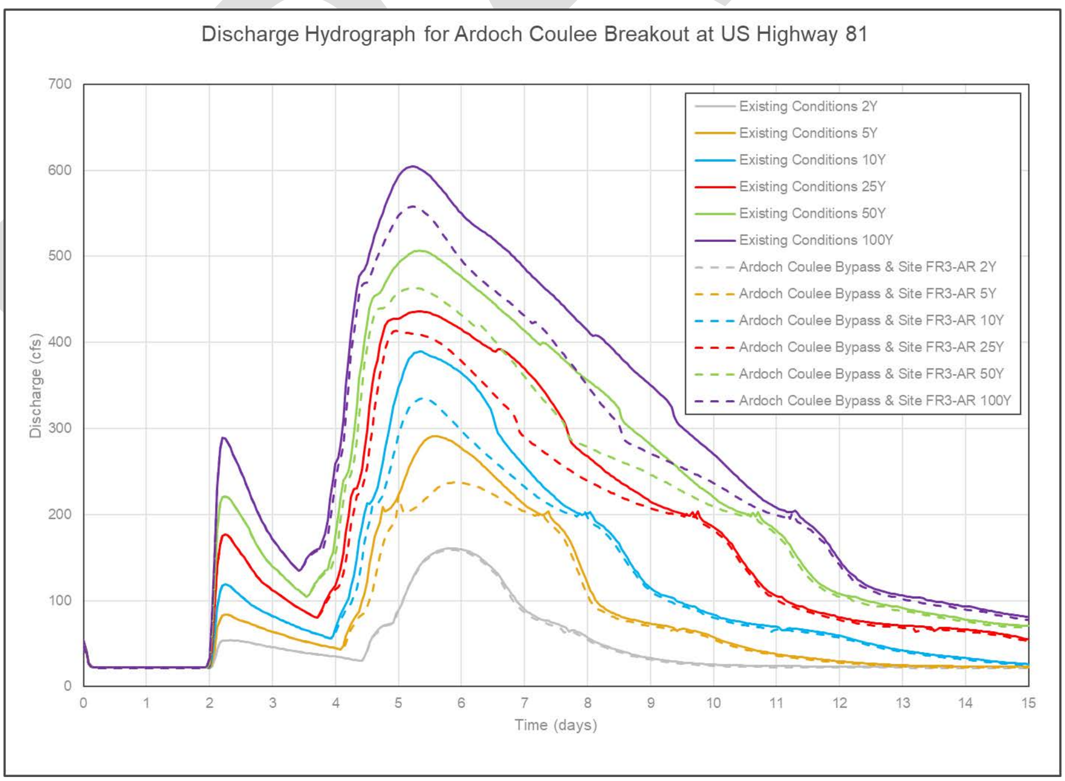
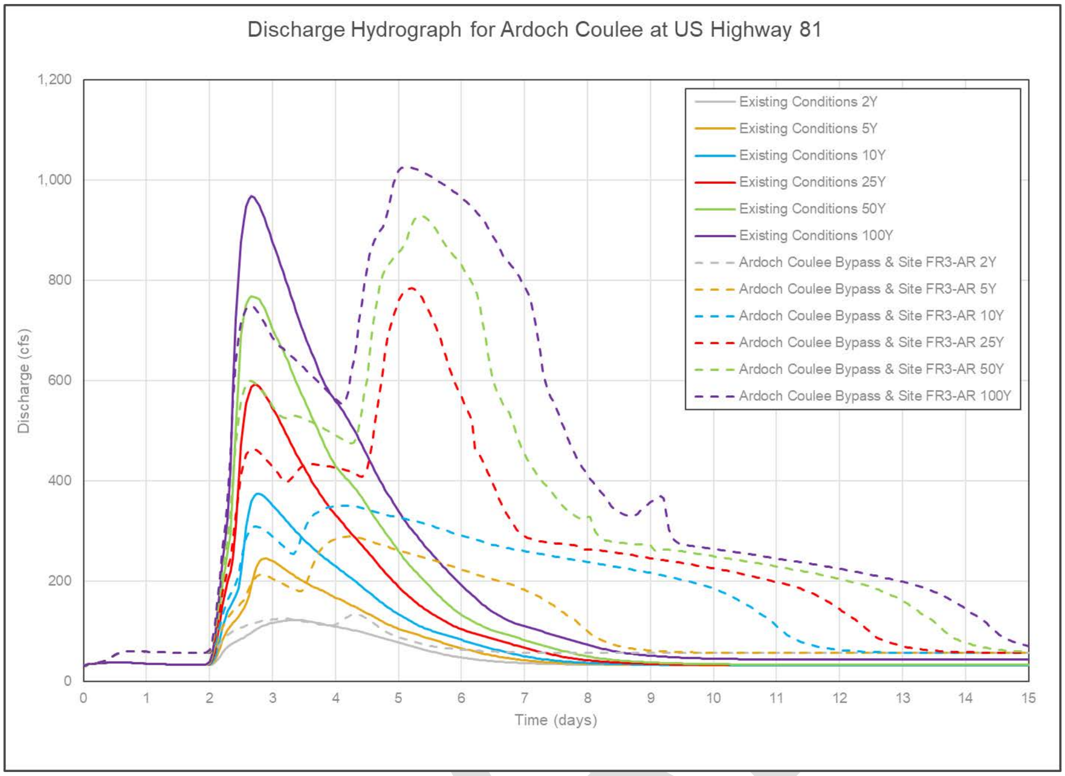
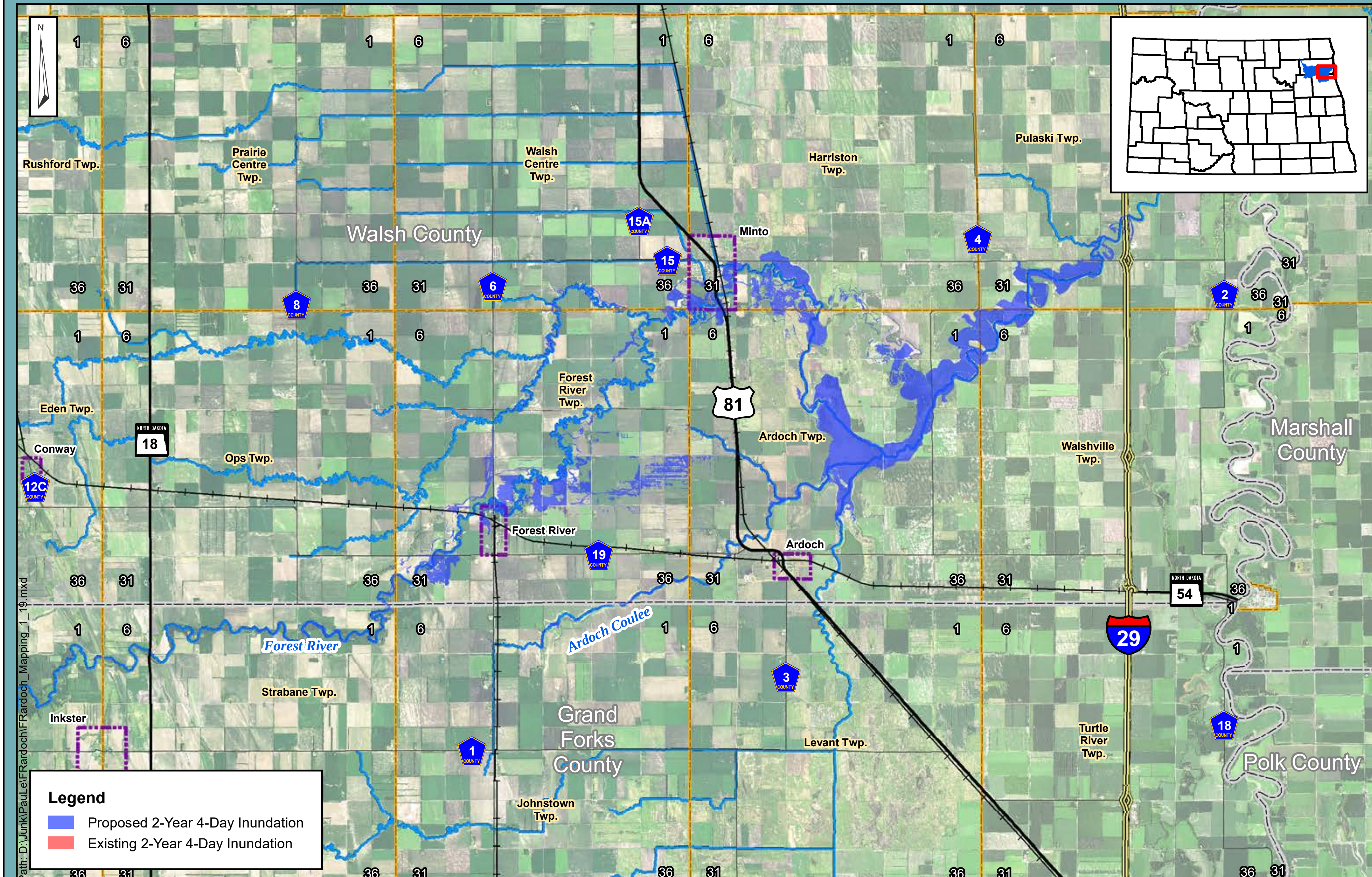


Figure B.8: *Discharge Hydrograph for Ardoch Coulee at US Highway 81*



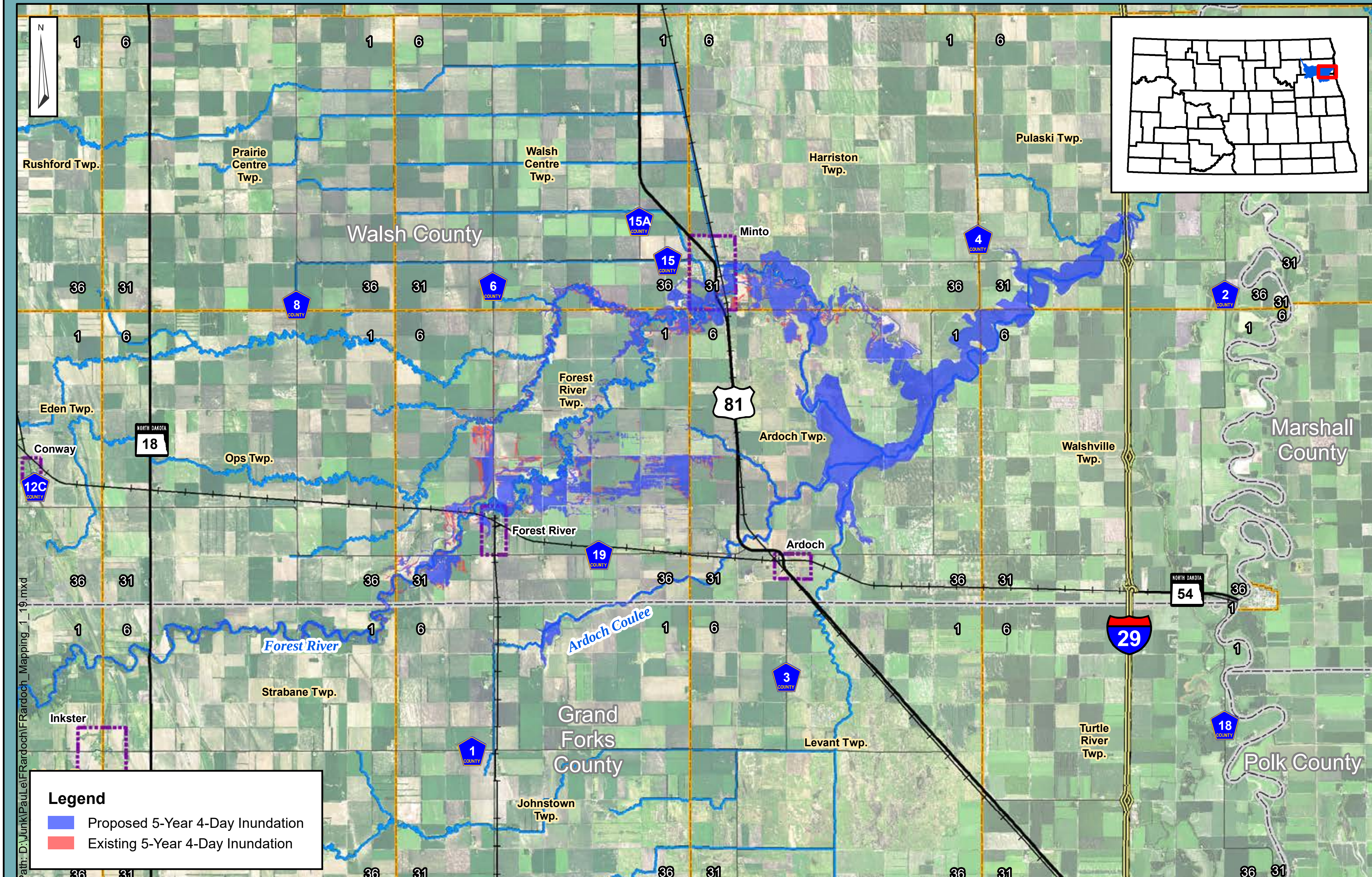


F-B.9

Figure B.9: 2-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

Houston Engineering Inc.



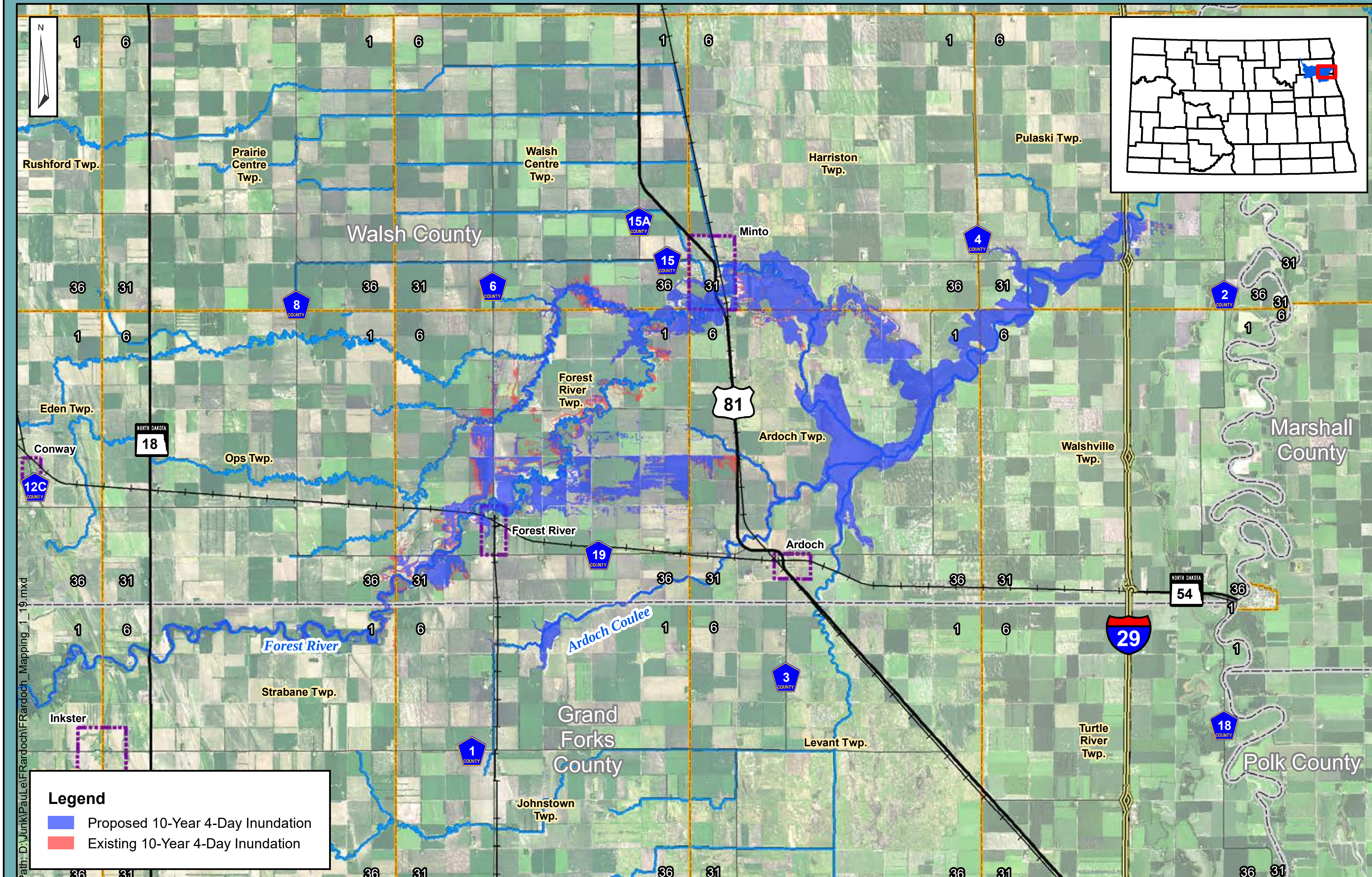
F-B.10

Figure B.10: 5-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.



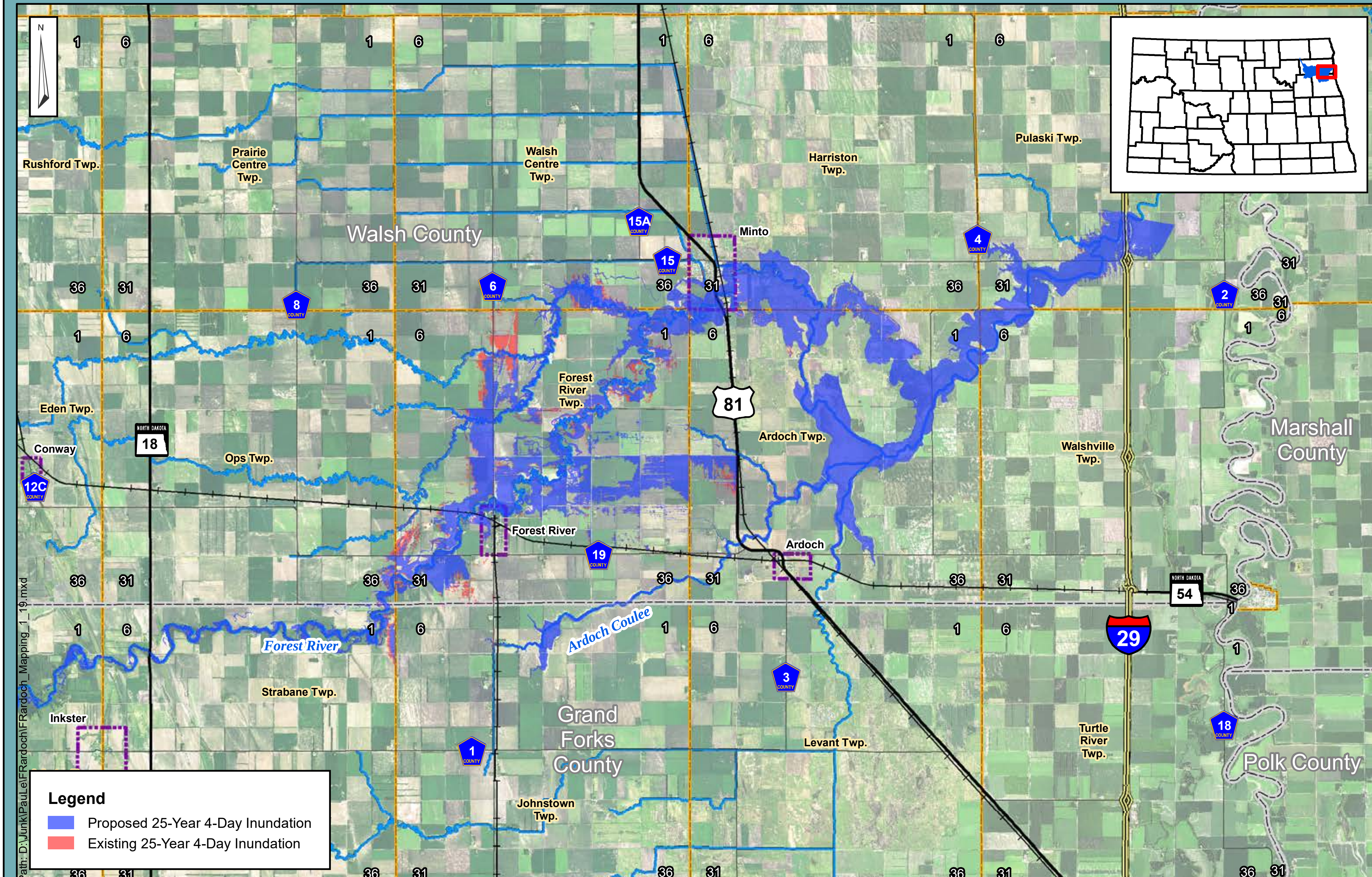
F-B.11

Figure B.11: 10-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.



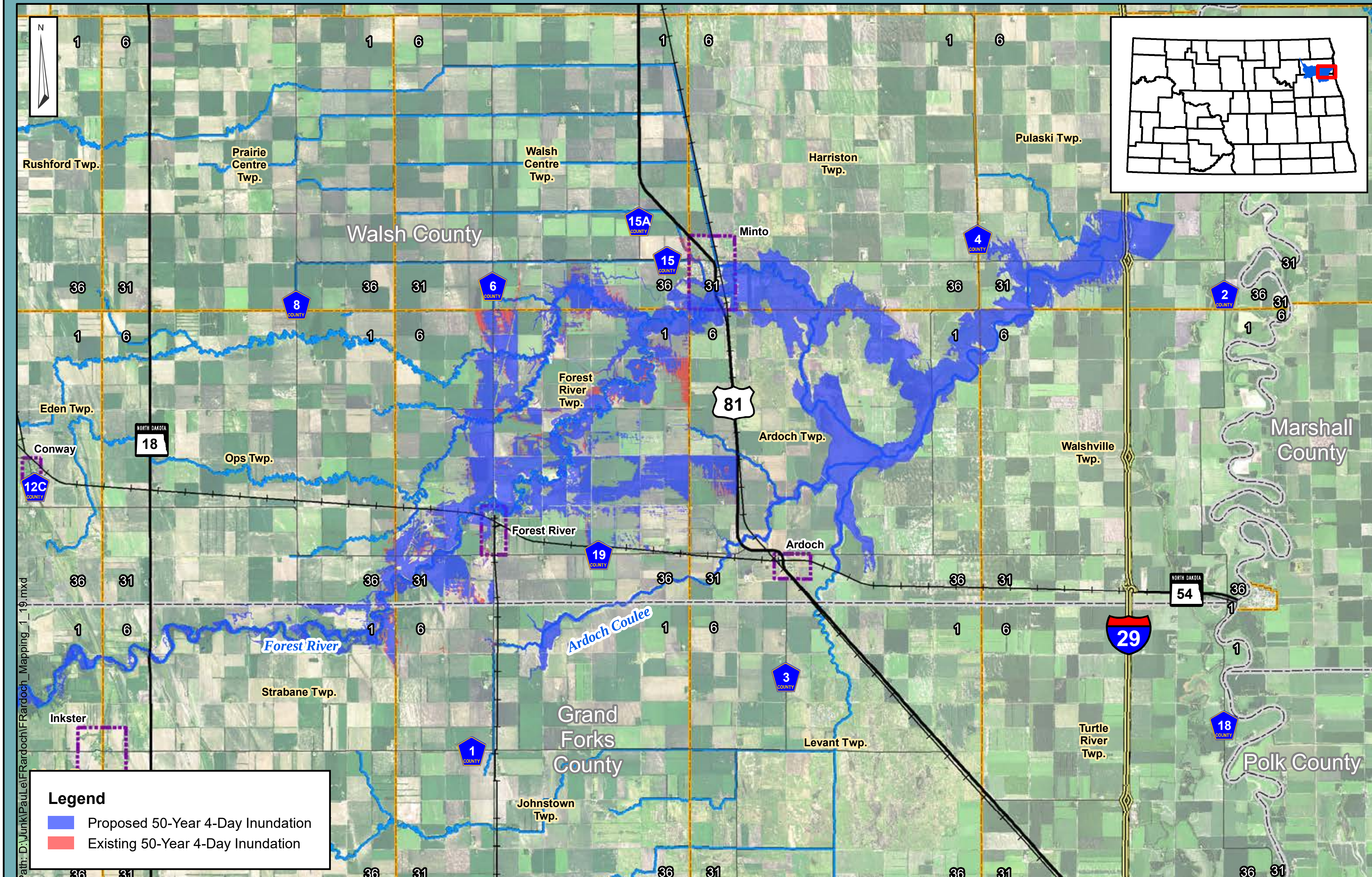
F-B.12

Figure B.12: 25-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.



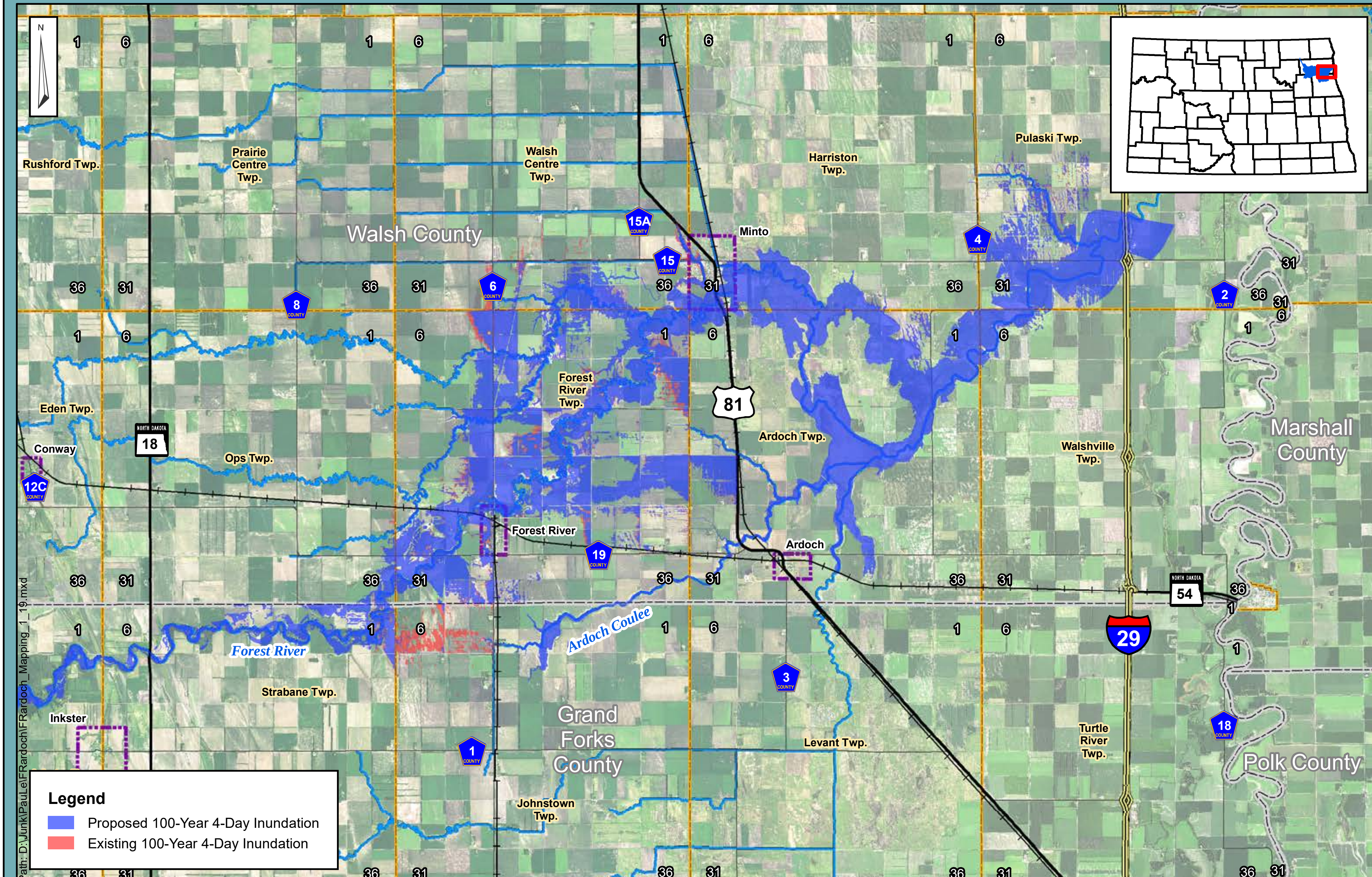
F-B.13

Figure B.13: 50-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

0 1 2 4 Miles

Houston Engineering Inc.



F-B.14

Figure B.14: 100-Year 4-Day Inundation

Forest River Watershed
Ardoch Coulee Bypass and Forest River Site FR3-AR Concept Design Report
Walsh County Water Resource District

Houston Engineering Inc.

APPENDIX C

EXISTING CONDITIONS HYDROLOGY AND HYDRAULICS REPORT

Fargo, ND | HEI No. 7135_0021
July 31st, 2019

Outlet of Matejcek Dam Downstream Channel – Forest River in Walsh County, North Dakota

FOREST RIVER WATERSHED PLAN

Existing Conditions Hydrology and Hydraulics Report

Natural Resources Conservation Service

FOREST RIVER WATERSHED PLAN

EXISTING CONDITIONS HYDROLOGY AND HYDRAULICS REPORT

July 31st, 2019

Walsh County Water Resource District

HOUSTON ENGINEERING INC.

Houston Engineering, Inc.
1401 21st Ave. N
Fargo, ND 58102
Phone # 701.237.5065

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of North Dakota.

Bret Z

Bret T. Zimmerman, PE
PE-10646

REGISTERED PROFESSIONAL ENGINEER
BRET T. ZIMMERMAN
PE-10646
DATE
NORTH DAKOTA

July 31, 2019

Date

Paul D. LeClaire, PE
PE-28012

Date

FOREST RIVER WATERSHED PLAN

EXISTING CONDITIONS HYDROLOGY AND HYDRAULICS REPORT

July 31st, 2019

Walsh County Water Resource District

Houston Engineering, Inc.
1401 21st Ave. N
Fargo, ND 58102
Phone # 701.237.5065

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of North Dakota.

Bret T. Zimmerman, PE PE-10646	Paul LeClaire Paul D. LeClaire, PE PE-28012
Date	July 31, 2019 Date

REGISTERED PROFESSIONAL ENGINEER
PAUL D. LeCLAIRE
PE-28012
DATE
NORTH DAKOTA

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

The Walsh County Water Resource District (WCWRD) entered into a Cooperative Agreement with the Natural Resource Conservation Service (NRCS) in 2015 to complete a Watershed Plan through the Regional Cooperation Partnership Program (RCPP) for the Forest River Watershed. Prior to entering into the Cooperative Agreement, locally led planning was already underway by the WCWRD. Data developed from this previous planning that is applicable to the NRCS Watershed Planning effort will be completed through the Cooperative Agreement.

The Forest River Watershed is an 896 square mile watershed and is shown on **Figure 1**. As part of the watershed planning effort, the existing conditions hydrology and hydraulics as it relates to flooding is evaluated. This report provides documentation on the development of hydrologic and hydraulic models used for the Forest River Watershed Planning effort. This includes previously developed base data and models, and the development of existing conditions models used for the Forest River Watershed Plan.

2 PREVIOUSLY DEVELOPED MODELS AND BASE DATA

Prior to 2011 several hydrology models existed for the tributary rivers of the Red River of the North, however these models were developed independently and resulted in little uniformity between each model. In 2010 the City of Fargo, ND, partnered with the United States Army Corps of Engineers (USACE) to develop a uniform set of tributary hydrology models that could be used to analyze the hydrology of the southern half of the Red River Basin (Phase I). Phase I consisted of developing a set of base input data and model development standards, development of HEC-HMS (v.3.5) models for tributaries upstream of Halstad, MN, and routing HEC-HMS outflows into an existing HEC-RAS unsteady model for the Red River. The study results were presented in the *Fargo-Moorhead Metro Basin-Wide Modeling Approach Hydrologic Modeling* report. (USACE & City of Fargo, 2011).

In 2011, the USACE along with local sponsors began work on Phase II of the Red River HEC-HMS modeling effort, which included development of standardized HEC-HMS (v.3.5) hydrology models between Halstad, MN, and the international border. The Phase II study used base input data and modeling standards developed in the Phase I study. At the completion of the Phase II study, uniform HEC-HMS models existed for the tributary subwatersheds for the United States portion of the Red River Basin (excluding the Devils Lake Basin). The study results were presented in the *Red River of the North Hydrologic Modeling – Phase 2* report (USACE, 2013). Methods developed in Phase I, and further implemented in Phase II, were aimed at developing a consistent method to analyze hydrology within the Red River Basin while still accounting for unique characteristics within each subwatershed that may influence flooding.

2.1 HEC-HMS PHASE II MODEL DEVELOPMENT

Development of the HEC-HMS model for the Forest River Watershed was completed through the *Red River of the North Hydrologic Modeling – Phase 2* effort (USACE, 2013). Section 2.1 provides a brief overview of the development of the Forest River HEC-HMS model. This model was initially used and subsequently modified as part of the Forest River RCPP Watershed Planning effort. More information on the summary information provided in this section is available in the *Red River of the North Hydrologic Modeling – Phase 2* report (USACE, 2013) and the USACE Final Report specific to the Forest River Watershed (USACE, 2012).

2.1.1 LIDAR RECONDITIONING

LiDAR topographic data made available through the International Water Institute (IWI) (IWI, 2008-2009) was used throughout the study. The "bare earth" LiDAR data does not account for any subsurface drainage (i.e. culverts). The "bare earth" LiDAR was reconditioned in order to hydrologically represent how flows move across the landscape. The reconditioning includes a technique within GIS to "burn" in culverts to the LiDAR, which artificially lowers LiDAR elevation at roadways allowing water to flow through. The hydrologically reconditioned LiDAR is then used to create derivative GIS datasets (slope, flow direction, flow accumulation, etc.).

2.1.2 DRAINAGE AREA DELINEATION

Hydrologically reconditioned LiDAR topographic data was used to delineate subbasin boundaries. During initial model development, subbasins were defined at an approximate HUC 12 size. Additional subbasin splits were added during model development based on existing project locations, locally critical areas as determined by County Water Resource Boards, critical hydrologic flood routing locations (flow splits, break-outs, etc.) and other sensitive areas (towns, known flood issues, etc.). Non-contributing drainage areas were identified through a "fill-and-spill" methodology using LiDAR data to evaluate potential for hydrologically closed basins to contain the 100-year 10-day runoff volume as defined by *TR-60: Earth Dams and Reservoirs* (NRCS, 2005). Of the 896 square mile watershed, 884 square miles are contributing, and 12 square miles are hydrologically closed basins, or non-contributing.

2.1.3 TIME OF CONCENTRATION

Travel time grids were created for each tributary subwatershed using a Travel Time Routine developed by the Minnesota Department of Natural Resources (MnDNR). The routine is implemented within a GIS environment using LiDAR topographic data, National Land Cover Data (NLCD) (Homer, et al., 2015), and derivative GIS datasets from hydrologic reconditioning. The routine assigns a Manning's N-value based on the accumulated flow and land use. Slope is then used to estimate velocity, and subsequently travel time using Manning's equation. Longest travel time per subbasin can then be derived in a consistent method across the modeling extents. The longest travel time derived from the MnDNR Travel Time Routine served as an initial time of concentration (Tc) estimate for each subbasin, with further refinements through calibration to historic flood events.

2.1.4 CLARK'S UNIT HYDROGRAPH PARAMETERS

A regional regression analysis was conducted, during the Phase II model development, to develop a consistent method for the initial estimate of the Clark's Storage Coefficient (R). The analysis considered parameters for the watersheds above gaging locations such as stream length, drainage area, percent slope, NWI wetlands and lakes, and watershed slope. This analysis resulted in a relationship between the time of concentration and the Clark's Storage Coefficient that was spatially dependent. The relationship was applied in GIS to allow the relationship to be applied to each subbasin used in the HEC-HMS model. Similar to the time of concentration, Clark's Storage Coefficients derived with this analysis served as an initial estimate for each subbasin, with further refinements through calibration to historic flood events.

2.1.5 RUNOFF CURVE NUMBER DEVELOPMENT

The NLCD (Homer, et al., 2015) data and Hydrologic Soil classifications from the Soil Survey Geographic Database (SSURGO) (NRCS, 2001) were combined to develop Red River Basin-wide 24-hour AMC II Curve Number (CN) data. Guidance from *TR-55 Urban Hydrology for Small Watersheds* (NRCS, 1986) and

Minnesota Hydrology Guide (USDA, SCS, 1976) was used to develop a conversion table to determine an appropriate 24-hour CN for a given hydrologic soil group and an NLCD land use combination. *TR-55* lists the 24-hour CN values for a range of agricultural land cover types, such as row crops and small grains. NLCD land cover data does not differentiate cropland based on row crops or small grains, instead all cultivated cropland is grouped into one category. A Technical Advisory Committee (TAC) was established during Phase I of the hydrologic model development. Through development of the Red River Basin-wide CN data, the TAC vetted synthetic CN values for the Red River Basin. The TAC determined that cultivated cropland should consist of 80% row crop and 20% small grains in good condition. Due to the relatively flat slopes predominant in the majority of the Red River Basin, a treatment type of contoured and terraced was assumed for selection of CN values from *TR-55* (NRCS, 1986). The CN conversion table used for the Red River Basin is shown in **Appendix A**. This information was applied in GIS to create a Red River Basin 24-hour AMC II CN gridded dataset.

2.1.6 REACH ROUTING

Model reaches were derived using reconditioned LiDAR data. The HEC-HMS models used two types of reach routing based on the location within the watershed.

- Muskingum Cunge routing was used along the beach ridge and upper portions of the watershed where attenuation is not as critical. Cross sections and slopes were estimated from LiDAR data.
- Modified Puls routing was used in the Lake Agassiz lake plain using the best available HEC-RAS models. If no HEC-RAS model was available, simplified HEC-RAS models were developed using LiDAR data to estimate an anticipated floodplain storage vs flow relationship.

2.1.7 CALIBRATION

A combination of Next-Generation Radar (NEXRAD) (NOAA, 1995) and existing rainfall gage data was used to compile a set of rainfall driven runoff events for calibration. Since NEXRAD isn't available prior to 1995, historic rainfall events were limited to events after 1995. Each of the Red River tributary subwatersheds were calibrated to at least two historic rainfall events. The Forest River Watershed was calibrated to three historic rainfall events. These events occurred in June of 2000, May of 2010, and June of 2009. The calibration was completed by primarily adjusting the following parameters; initial abstraction, Curve Number, Clark's Storage Coefficient, time of concentration, and baseflow. The subwatershed conditions prior to the calibration events were reviewed to determine the approximate antecedent moisture condition (AMC). The goal of model calibration was to meet the following criteria:

- Simulated total runoff volume within 10% of the observed volume.
- Simulated peak flow within 10% of the observed peak flow.
- Simulated time to peak flow within ½ day of observed time to peak flow.

2.1.8 SYNTHETIC MODEL DEVELOPMENT

Synthetic modeling parameters for the calibrated Clark's Storage Coefficients and time of concentration were averaged from the calibrated events. During calibration, Curve Number parameters were adjusted to reflect the moisture conditions within the Forest River Watershed preceding the historic rainfall events. For the synthetic events, Curve Number parameters were set to the original values determined based on soil types and land use to reflect average (AMC II) conditions within the watershed. Several synthetic modeling scenarios were developed, including 2-year through 100-year events for both the 24-hour (Hershfield, 1961) and 10-day (Miller, 1964) duration rainfall events, and a 100-year, 10-day runoff event (NRCS, 2005). For more specific information on calibration for the Forest River Watershed, refer to the USACE Final Report for the Forest River Watershed (USACE, 2012).

3 FOREST RIVER WATERSHED PLAN EXISTING CONDITIONS

The Forest River Watershed Plan is focused on the Forest River Watershed above Lake Ardoch. The Forest River Watershed above Lake Ardoch is shown on **Figure 3**. The Forest River Watershed above Lake Ardoch is an approximate 570 square mile subwatershed of the 896 square mile Forest River Watershed. Of the 570 square mile subwatershed, there are approximately 12 square miles of non-contributing drainage area. The Forest River Watershed HEC-HMS model previously developed as part of the Phase II study (USACE, 2013), discussed in Section 2 of this report, was used as a base model and modified to meet requirements for the Forest River Watershed Planning effort.

This section provides additional information on modifications that were made to the HEC-HMS hydrologic model, development of a HEC-RAS unsteady hydraulic model, calibration of the hydrologic and hydraulic model, and development of synthetic rainfall event simulations.

3.1 HYDROLOGIC (HEC-HMS) MODEL

Modifications were made to the Forest River HEC-HMS model to add detail within the Forest River Watershed. The hydrologic model was completed as necessary to generate inflow hydrographs for the HEC-RAS hydraulic model that was developed for a portion of the Forest River Watershed. These hydrologic model modifications are discussed in the following subsections.

3.1.1 SUBBASIN BOUNDARY MODIFICATIONS

The HEC-HMS model used in the Forest River Watershed Planning effort is primarily used to generate inflow hydrographs for the HEC-RAS unsteady state flow model that is discussed in Section 3.2. Subbasins were split and re-delineated to add detail in areas such as hydraulic routing storage locations, road crossings, and other critical hydraulic locations. A comparison of the initially developed subbasins and the re-delineated subbasins for the Forest River Watershed Plan is shown on **Figure 3.1.1**. These modifications resulted in 69 subbasins within the study area compared to 28 subbasins from the Phase II study. The re-delineated subbasins were reduced in size from an average of 20.4 square miles from the Phase II study to an average of 8.3 square miles for the Forest River Watershed Plan.

3.1.2 RUNOFF CURVE NUMBER

Initial runoff Curve Numbers for the re-delineated subbasins were estimated by overlaying the Curve Number gridded GIS datasets described in Section 2.1.5 with the modified subbasins. 24-hour AMC II Curve Numbers values for the modified subbasin are displayed in **Figure 3.1.2**. The values range from 68 to 84 throughout the watershed.

3.1.3 INITIAL UNIT HYDROGRAPH PARAMETERS

Initial unit hydrograph parameters were estimated for the time of concentration (Tc) and Clark's Storage Coefficient (R) using the same methodology used for the Phase II study discussed in Sections 2.1.3 and 2.1.4 of this report, respectively. R/Tc ratios provide a method to normalize unit hydrograph parameters that have been used previously within the Red River Basin. Generally, the more available subbasin flood storage (for example, lakes and wetlands) for runoff originating in a subbasin, the higher the R/Tc ratio. As illustrated in in **Figure 3.1.3**, R/Tc values generally increase in the western portion of the Forest River Watershed, where more depressional areas in the landscape provide flood storage. Further downstream, where most landscape is flat and drained for agricultural production, the R/Tc ratio reduces.

3.1.4 REACH ROUTING

With additional subbasin delineations in the Forest River Watershed, additional reaches were required in the model. For the Forest River Watershed Plan, routing of the Forest River mainstem from Matejcek Dam to the Forest River crossing with US Interstate 29 is modeled using HEC-RAS (see Section 3.2). Muskingum Cunge routing was used in the upper portions of the watershed, and for tributary streams contributing to the Forest River. While reach routing is critical for portions of the HEC-HMS model upstream of the HEC-RAS hydraulic model extent, it should be noted that reach routing generally does not affect inflows into the HEC-RAS model where the models overlap. This is because HEC-HMS subbasin outflows (not combined or routed outflows) are directly applied to the HEC-RAS model in areas where the two models overlap.

3.1.5 EXISTING DAMS

There are 8 existing dams in the Forest River Watershed as shown on **Figure 3.1.5**. All of the existing dams are within the planning area. The purposes of the dams are typically flood control with secondary purposes of recreation. Characteristics for the existing dams are shown in **Table 1**. The dam characteristics within the HEC-HMS model were developed based on as-built survey data and LiDAR. The rating curve for Matejcek Dam was developed from field survey data along with as-built plans and LiDAR.

Table 1: Existing Dams in the Forest River Watershed

Existing Dam	Purpose(s)	Hazard Classification	Year Constructed	Contributing Area (square miles)	Storage at Auxiliary Spillway[1] (acre-feet)
Sarnia[2]	Flood Control	Low	1981	19.7	766
Whitman	Flood Control / Recreation	Significant	1965	55	4,481
Matejcek	Flood Control / Recreation	High	1966	115.7	4,947
Bylin	Flood Control / Recreation	High	1964	20.8	3,677
Kratochvil	Flood Control	Low	1962	13.0	391
Soukup	Flood Control	Significant	1962	3.0	330
Chyle	Flood Control	Significant	1966	6.7	983
Fordville	Flood Control / Recreation	Significant	1978	49.5	4,990

[1]Storage volumes reported are effective flood storage above the Normal Pool Elevation
[2]Sarnia Dam was originally constructed in 1936 and was rebuilt in 1981

3.2 HYDRAULIC (HEC-RAS) MODEL

An unsteady HEC-RAS (v.5.0.7) model was developed and used to generate water surface profiles by hydraulically routing runoff hydrographs generated by the HEC-HMS model. Development of the HEC-RAS unsteady state hydraulic model began in 2013. The HEC-RAS model consists of channel cross sections, 1-dimensional storage areas, and 2-dimensional storage areas. The channel cross sections route flows in the Forest River, Ardoch Coulee, and various intermittent tributaries. Cross sections on the Forest River span from Matejcek Dam to the crossing with US Interstate 29. 1-dimensional storage areas were used to represent the elevation-storage relationship in the Matejcek Dam reservoir and for Lake Ardoch. 2-dimensional storage areas are located adjacent to the Forest River mainstem to route overland or breakout flows. Channel cross sections, 1-dimensional storage areas, and 2-dimensional storage areas in the HEC-RAS model schematic are shown on **Figure 3.2**.

3.2.1 STORAGE ROUTING

Storage routing is used to account for floodplain storage adjacent to the Forest River mainstem. Due to the complex routing of overland flooding, 2-dimensional storage areas are used for the Forest River Watershed. 2-dimensional storage areas allow the model to account for floodplain storage available for out of bank flows and are used to convey flows through the floodplain. Storage areas are connected to cross sections and other storage areas to hydraulically route flows through the floodplain. Internal storage connections are used to represent township roads that contain culverts or bridges to simulate flow through the roadways.

Matejcek Dam is modeled with a 1-dimensional storage area and the elevation-storage data was derived from LiDAR data. At the time of this report, bathymetric data below the normal pool of Matejcek Dam was being collected. Flood storage in the model for Matejcek Dam only includes LiDAR data and does not include the bathymetric data. This is not seen as a concern because the LiDAR data represents the flood storage above the normal pool elevation and any data below the normal pool is not relevant for this report.

3.2.2 CHANNEL BATHYMETRY AND HYDRAULIC STRUCTURES

Survey data for the Forest River Watershed Plan was collected by Houston Engineering, Inc. (HEI) at various times since the project had begun in 2013. Field survey data collected consisted of river channel hydraulic structures, river channel cross sections near hydraulic structures, river channel cross sections throughout the Forest River and Ardoch Coulee, and other hydraulically critical locations such as levee elevations at known breakout locations. The survey data that was collected is shown on **Figure 3.2.2**. Channel cross sections along the Forest River from Matejcek Dam to downstream of ND Highway 18 were spaced at approximately 500-feet.

Forest River channel cross section survey data in Sections 1, 11, and 12 in Inkster Township was not collected due to landowners not providing consent to access their property. To account for the missing survey data in the HEC-RAS model for this portion of the Forest River, cross section survey data upstream and downstream was analyzed to determine how the survey data differed from LiDAR data. It was determined that survey data was approximately 2.5 feet lower in elevation than LiDAR data. Therefore, the LiDAR channel elevations for cross sections in Sections 1, 11, and 12 in Inkster Township were lowered 2.5 feet to more accurately represent the channel bottom elevations where survey data was not available.

3.2.3 MANNING'S N-VALUES

Manning's N-values are set within the HEC-RAS cross sections to account for channel roughness. NLCD land use GIS grids were used to generate a Manning's N-value grid. The NLCD land cover categories were aggregated into four land use types; channels, agricultural or cropland, wetlands, and forested. Due to the cell size of the NLCD GIS grids (30 meters x 30 meters), portions of the river channels can be omitted from the NLCD grids. The NLCD grid was modified by generating a channel boundary and merging the channel with the NLCD grid. The NLCD grid was also used for flow routing computations in 2-dimensional areas. Manning's N-values were set through calibration and verification of the Forest River Watershed Plan HEC-RAS and HEC-HMS models as described in Section 3.3. The calibrated Manning's N-values in the existing conditions hydraulic model are shown in **Table 2**.

Table 2: Manning's N-Values by Land Use

Land Use	Manning's N-Value
Channel	0.05
Agricultural / Cropland	0.06
Wetlands	0.05
Forested	0.11

3.2.4 INFLOWS

Hydrographs generated from the HEC-HMS model were applied to the HEC-RAS model. HEC-HMS junction hydrographs were applied at the upstream extents to cross sections, or upstream of cross sections in 2-dimensional areas with boundary condition lines, within the HEC-RAS model. Further downstream, HEC-HMS subbasin hydrographs were applied to the cross sections and 1-dimensional storage areas within the HEC-RAS model.

3.2.5 TAILWATER

The tailwater boundary condition for the Forest River was estimated by entering a friction slope downstream of US Interstate 29. The slope was estimated from LiDAR data in the Forest River channel.

3.3 CALIBRATION AND VERIFICATION

Two historic rainfall events were used for calibration and verification of the HEC-RAS model for the Forest River Watershed Plan. A rainfall event in mid-June of 2016 was used to estimate model parameters in the Forest River hydrologic and hydraulic models. An event in May of 2010 was used to verify the parameters used in the models.

3.3.1 JUNE 2016 CALIBRATION EVENT

The hydrologic and hydraulic models were calibrated based on a rainfall event that occurred in the summer of 2016. Rainfall depths in the Forest River Watershed upstream of Lake Ardoch during the event ranged from 1.3 to 3.8 inches. The average total rainfall depth upstream of Lake Ardoch was approximately 2.7 inches. The majority of the rainfall that was modeled in the simulation occurred on June 17th from about 5 a.m. to 11 a.m. where an average of 2.2 inches of precipitation occurred. The remaining precipitation that was simulated occurred on June 19th from 3 a.m. to 7 a.m. Total rainfall depths throughout the Forest River Watershed during the event are shown on **Figure 3.3.1a**.

Documented historic data that was used for calibration of the model included: observed rainfall depths at gaging stations, NEXRAD rainfall data, discharge measurements at the Forest River USGS Streamgage 05084000 near Fordville, ND, and discharge measurements at the Forest River USGS Streamgage 05085000 at Minto, ND. The observed discharge hydrographs were used to derive daily flow volumes at the streamgages.

Runoff Curve Numbers for a 24-hour storm duration were initially applied for the calibration event (see **Appendix A**). Curve Numbers were adjusted to match the observed discharge volume through USGS gage sites at Fordville and Minto. The final Curve Numbers used in the simulation were slightly higher than an AMC II condition. This antecedent moisture condition was reviewed based on guidance from the *National Engineering Handbook (NEH)* (NRCS, 2004), and is valid based on a small rainfall occurring in the a few days prior to the event.

Pool elevations in the 8 upstream dams were set to the normal pool elevation. The rainfall that occurred prior to the simulated historic event happened approximately two days beforehand. This would allow enough time to draw pool elevations down to, or near the normal pool elevation. Baseflow was added to the HEC-RAS model to match discharge at both USGS gages before the rainfall event.

Portions of the levees along the Forest River between the community of Forest River and Minto have been surveyed between 2013 and 2018. Levees were generally surveyed in known breakout locations or where the removal of man-made levees was required. When surveyed levee elevations along the Forest River are compared to LiDAR data from 2008 (IWI), there are some significant changes. For the June 2016 event, surveyed levee elevations were used as opposed to LiDAR data where survey data was available.

Initial unit hydrograph parameters that were estimated in previous modeling efforts (Section 2) were further adjusted with the June 2016 rainfall event. Reasonable modifications were made to both R and Tc during calibration, and the final R/Tc ratios from calibration are shown on **Figure 3.3.1b**. The high R/Tc ratios downstream of Fordville indicate that time of concentration values are generally lower, and/or storage coefficients are higher than the initial parameters developed in Section 2. This is due to runoff in the lower portion of the watershed being drained by constructed ditches and legal drains. The structures at road crossings along the drainage system are typically designed for higher frequency rainfall events. During a lower frequency rainfall event, the structures attenuate flows. These structures that attenuate flows result in increased storage (higher R values) in the lower watershed.

Hydrographs in the hydraulic model were compared to the recorded discharge at the Forest River USGS Streamgage near Fordville, ND, and the Forest River USGS Streamgage at Minto, ND. The observed discharge hydrograph for the Streamgage near Fordville and simulated HEC-RAS model discharge hydrograph are shown on **Figure 3.3.1c**. The simulated HEC-RAS peak flow rate and volume are consistent with observed flow rates and volumes at the gage during the event. **Table 3** summarizes the peak flow rates and timing, as well as the 1-day through 3-day volumes centered on the peak flow rate (i.e. the 1-day through 3-day volumes were computed by finding the area under the hydrograph centered on the peak ±0.5 days, ±1.0 days, etc.). The observed discharge hydrograph for the Streamgage at Minto and simulated HEC-RAS model discharge hydrograph are shown on **Figure 3.3.1d**. The simulated HEC-RAS peak flow rate and volume are consistent with observed flow rates and volumes at the gage during the event. **Table 4** summarizes the peak flow rates and timing, as well as the 1-day through 3-day volumes centered on the peak flow rate. Observed volumes at gaging sites beyond 3 days were not considered because of a second rainfall event that came through the watershed on June 19th. The hydrologic model uses the Curve Number runoff method. This runoff method does not account for the initial abstraction that would occur during a second rainfall event in the hydrologic simulation. Therefore, the model results show a larger secondary peak from the second rainfall that occurred within the watershed.

Table 3: Peak Flow and Volume Comparison at USGS Gage 05084000 near Fordville, ND in June 2016

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05084000 at Fordville, ND	1,860	6/18/2016 3:00	2,610	3,681	4,394
HEC RAS Model	1,873	6/18/2016 3:00	2,639	3,579	4,219
%Difference	0.7%	-	1.1%	-2.8%	-4.0%

Table 4*:* Peak Flow and Volume Comparison at USGS Gage 05085000 at Minto, ND in June 2016

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05085000 at Minto, ND	1,980	6/20/16 5:00	3,801	7,026	9,619
HEC RAS Model	2,016	6/20/16 6:00	3,707	6,670	9,248
%Difference	1.8%	-	-2.5%	-5.1%	-3.9%

Parameters in the HEC-RAS model were also established during calibration. These parameters include Manning's N-values, overbank reach lengths, and storage area connection coefficients. Initial values were set based on guidance from the *HEC-RAS User's Manual* (USACE, 2016) and *HEC-RAS Technical Reference Manual* (USACE, 2016). Manning's N-values were generally assumed to be a crop covered condition (crop development and mature crop). A sensitivity analysis on Manning's N-values is discussed in **Appendix C**. Overbank reach lengths were digitized utilizing GIS and the resultant HEC-RAS model floodplain. Storage area connection coefficients were generally set based on Table 3-1 from the *HEC-RAS 2D Modeling User Manual* (USACE, 2016).

3.3.2 MAY 2010 VERIFICATION EVENT

After the hydrologic and hydraulic models were calibrated, a second historic event was simulated to verify the parameters in the calibration event. Most of the May 2010 rainfall event occurred from May 24th through the early hours of May 25th. Rainfall depths in the Forest River Watershed upstream of Lake Ardoch during the event ranged from 2.3 to 3.8 inches. The average total rainfall depth for the planning area was approximately 2.8 inches. Total rainfall depths from May 22nd to May 25th are shown on **Figure 3.3.2a**.

Documented historic data that was used for calibration of the model included: observed rainfall depths at gaging stations, NEXRAD rainfall data, discharge measurements at the Forest River USGS Streamgage

05084000 near Fordville, ND, and discharge measurements at the Forest River USGS Streamgage 05085000 at Minto, ND. The observed discharge hydrograph was used to derive daily flow volumes at the streamgage.

Runoff Curve Numbers were adjusted to produce the quantity of runoff volume recorded at the USGS gaging station near Fordville, ND and at the USGS gaging station at Minto, ND. 24-hour Curve Numbers were used with an average to dry antecedent moisture condition (between AMC I and AMC II). This antecedent moisture condition was reviewed based on guidance from the *National Engineering Handbook (NEH)* (NRCS, 2004), and is valid because of the amount of precipitation occurring prior to the event.

The observed discharge hydrograph and the simulated HEC-RAS model discharge hydrograph at the USGS Gage near Fordville, ND are shown in **Figure 3.3.2b**. The peak flow rate from the measured data at the streamgage and the HEC-RAS modeled results differ by less than 3% in Fordville and by less than 2% in Minto. In addition to a peak flow comparison, volume of runoff at the USGS Gage near Fordville, ND was compared for several durations centered on the peak discharge. **Table 5** summarizes the peak flow rates and timing, as well as the 1 through 3-day volumes centered on the peak flow rate. The observed discharge hydrograph for the Streamgage at Minto and simulated HEC-RAS model discharge hydrograph are shown on **Figure 3.3.2c**. The simulated HEC-RAS peak flow rate is consistent with the observed peak flow rate. **Table 6** summarizes the peak flow rates and timing, as well as the 1-day through 3-day volumes centered on the peak flow rate. While the peak flow rates are comparable, the timing of the two hydrographs is slightly off. This is due to the unknown levee elevations adjacent to the Forest River at breakout locations during the May 2010 event. Levees reconstructed and/or breached after the LiDAR collect (IWI, 2008-2009) caused uncertainty in the river geometrics at the time of the event.

The results from the May 2010 event at the USGS Streamgage near Fordville, ND verify the unit hydrograph parameters in the upper portion of the watershed, however, results at the USGS Streamgage at Minto, ND are highly dependent on the lower Forest River channel geometrics (i.e. levee breakout locations). Therefore, unit hydrograph parameters used downstream of Fordville, ND and upstream of Minto, ND in the June 2016 event will be used for synthetic events because of its proximity (with respect to time) to present day conditions.

Table 5: Peak Flow and Volume Comparison at USGS Gage 05084000 near Fordville, ND in May 2010

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05084000 at Fordville, ND	1,430	5/24/10 20:00	2,197	3,138	3,830
HEC RAS Model	1,467	5/24/10 20:00	2,275	3,348	4,152
%Difference	2.6%	-	3.5%	6.7%	8.4%

Table 6: Peak Flow and Volume Comparison at USGS Gage 05085000 at Minto, ND in May 2010

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05085000 at Minto, ND	908	5/26/10 5:00	1,693	2,952	4,016
HEC RAS Model	896	5/27/10 3:00	1,727	3,199	4,325
%Difference	-1.4%	-	2.0%	8.4%	7.7%

3.4 SYNTHETIC MODEL DEVELOPMENT

The HEC-HMS hydrologic model used to analyze synthetic rainfall events utilized the R and Tc parameters developed through calibration described in Section 3.3. Runoff Curve Numbers were set to initial values described in Section 3.1.2. Levee elevations in the lower Forest River Watershed were assumed to be consistent with the June 2016 calibration event (surveyed elevations where available, otherwise LiDAR). The calibrated HEC-RAS hydraulic model used to analyze synthetic rainfall events is described in Section 3.2.

Synthetic rainfall events were developed based on NOAA Atlas 14 rainfall depths with a 4-day duration. Rainfall depths were calculated for each subbasin using GIS gridded data. The gridded rainfall depths were then reduced based on areal reduction factors and guidance from *TP-49 Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States* (Miller, 1964). The 4-day duration average rainfall depths for the synthetic events are shown in **Table 7**. The 4-day duration storm was used for this analysis because it produces the greatest peak outflow downstream of Lake Ardoch compared to the 24-hour and 10-day duration storms. A sensitivity analysis was completed on the 24-hour, 4-day, and 10-day duration events and is discussed in **Appendix C**.

The rainfall distribution used for the synthetic events was developed using a “nesting” technique described in the *NEH, Part 630, Chapter 4* (NRCS, 2015). Individual distributions were developed for the 2-, 5-, 10-, 25-, 50-, 100-, 500-year events. “Nesting” the distribution means that all shorter duration storms are contained, or “nested”, within longer duration storms. That is, the 4-day storm contains the 5-minute storm, 10-minute storm, and so on.

Runoff Curve Numbers were adjusted to the appropriate 4-day duration to match the corresponding synthetic rainfall duration. Table 2.3b in *TR-60 Earth Dams and Reservoirs* (NRCS, 2005) provides a relationship between 24-hour and 10-day Curve Numbers. Interpolation of this data was used to generate 4-day Curve Numbers for the synthetic HEC-HMS hydrologic model.

Table 7: 4-Day Rainfall Depths

Return Period	NOAA Atlas 14 4-Day Rainfall Depth (inches)	HEC-HMS 4-Day Rainfall Depth* (inches)
2-year	2.84	2.68
5-year	3.54	3.35
10-year	4.17	3.94
25-year	5.14	4.86
50-year	5.95	5.62
100-year	6.82	6.44
500-year	9.10	8.60

* Average rainfall depth adjusted for areal reduction based on watershed size of 570 square miles

4 FOREST RIVER WATERSHED PLAN MODELING RESULTS

4.1 SYNTHETIC MODEL RESULTS

Multiple reporting locations were selected to evaluate modeling results throughout the watershed at geographically significant locations. These locations include North Dakota State Highways and township roads in both the Forest River and the modeled tributaries. The reporting locations are shown on **Figure B.1** in **Appendix B** and are further summarized below.

- Forest River at ND Highway 32 – First major stream crossing downstream of Matejcek Dam near the upstream extent of the hydraulic model
- Forest River at 134th Avenue NE – At USGS Streamgage 05084000 near Fordville, ND
- Forest River at ND Highway 18 – Stream crossing upstream of where flows begin breaking out of the Forest River channel
- Forest River at Walsh County Road 6 – Near the town of Forest River, ND
- Forest River at First Street Crossing – At USGS Streamgage 05085000 at Minto, ND
- Forest River at Walsh County Road 4 – Downstream of Lake Ardoch
- Forest River North Breakout at 148th Avenue NE – A perennial stream that enters the Forest River upstream of Minto, ND. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee Breakout at US Highway 81 – A perennial stream that enters Ardoch Coulee about 1 mile downstream of Highway 81. Breakout flows from the Forest River mainstem enter this stream.
- Ardoch Coulee at US Highway 81 – Stream crossing upstream of Lake Ardoch

Hydrographs for the 2-year through 100-year events at the reporting locations are shown in **Appendix B** on **Figure B.2** through **Figure B.10**. The 500-year event is not shown on the hydrographs due to the magnitude of the event. If the 500-year was shown, the other events would not be distinguishable. The peak discharges for the analyzed events are shown in **Table 8**.

Table 8: 4-Day Rainfall Peak Discharges (cfs)

Return Period	Forest River at ND Highway 32	Forest River at 134th Ave NE	Forest River at ND Highway 18	Forest River at Walsh County Road 6	Forest River at First Street Crossing	Forest River at Walsh County Road 4	Forest River North Breakout at 148th Ave NE	Ardoch Coulee Breakout at US Highway 81	Ardoch Coulee at US Highway 81
2-year	202	971	1,012	748	1,009	1,608	440	163	123
5-year	278	1,776	1,850	975	1,855	2,714	1,104	299	245
10-year	421	2,762	2,841	1,318	2,925	4,184	1,852	388	375
25-year	680	4,618	4,714	1,398	4,720	6,782	3,230	437	593
50-year	933	6,440	6,568	1,708	6,133	8,960	4,320	518	769
100-year	1,934	8,541	8,677	2,040	7,330	11,434	4,789	608	965
500-year	5,224	14,972	15,060	3,634	11,493	19,251	7,046	826	1,654

The inundation extents for the 2-year through 500-year events are shown in **Appendix B** on **Figure B.11** through **Figure B.17**. Flood damages, especially damages to agricultural lands, are caused both by the extent of the inundation and, almost equally as important, the duration of inundation. The total inundated acres and cropland inundated acres for the analyzed events based on duration is shown in **Table 9**. The inundated acreages are for the entire modeling extents and not just the planning extents. Cropland acres were estimated using the National Agricultural Statistics Service (NASS) (USDA, 2017).

Table 9: 4-Day Rainfall Inundation (acres)

Duration (hours)	2-year Event		5-year Event		10-year Event		25-year Event		50-year Event		100-year Event		500-year Event	
	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated	Total Inundated	Cropland Inundated
0-24	434	296	987	698	1,573	1,098	2,300	1,651	2,919	2,185	3,347	2,581	2,840	2,338
24-48	567	408	1,066	777	1,350	1,000	1,945	1,455	2,474	1,956	2,511	2,052	3,921	3,256
48-72	495	317	999	735	1,185	863	1,352	1,026	1,892	1,431	2,170	1,639	4,821	3,771
72-96	544	354	763	569	1,039	806	1,286	974	1,280	1,004	2,180	1,678	4,200	3,398
96-120	450	265	612	416	790	592	1,164	893	1,415	1,068	1,505	1,197	2,887	2,499
>120	4,583	1,903	6,130	2,846	7,193	3,585	8,847	4,829	10,316	5,944	12,142	7,413	16,705	11,371
Totals	7,073	3,543	10,557	6,041	13,130	7,944	16,894	10,828	20,296	13,588	23,855	16,560	35,374	26,633

In addition to agricultural land damages, structural damages also occur when buildings are inundated during a flood event. All buildings within the Forest River Watershed HEC-RAS modeling extents were identified and classified as either "Homestead" or "Non-Homestead". A structure was classified as "Homestead" if it appeared to be a residence. Examples of "Non-Homestead" buildings include garages, barns, shops, and other agricultural out-buildings. The total number of inundated structures for the analyzed events are shown in **Table 10**. The structures are also shown in **Appendix B** on **Figures B.11** through **Figure B.17**.

Table 10: 4-Day Rainfall Structure Inundation

Return Period	Homestead	Non-Homestead	Total Structures
2-year	0	24	24
5-year	5	56	61
10-year	14	72	86
25-year	26	122	148
50-year	36	179	215
100-year	42	220	262
500-year	168	495	663

4.2 WATERSHED INUNDATION CHARACTERISTICS

The Forest River Watershed is bisected by the Pembina Escarpment which divides the watershed into by two different geomorphic conditions. The upper portion of the watershed is characterized as the Prairie Pothole Region and the lower portion of the watershed is characterized as the Lake Agassiz Lake Plain. These distinctly different watershed characteristics results in a variety of flow conditions within the watershed.

The upper region of the Forest River Watershed is controlled by several dams including Matejcek Dam, which is located on the Forest River mainstem. Downstream of Matejcek Dam, the Forest River has a well-defined floodplain within a riverine valley. Contributing streams, including the North and South branches of the Forest River, enter the Forest River where the floodplain is well-defined. The deep riverine valleys are common to the Prairie Pothole Region. The transition from the Prairie Pothole Region to the Lake Aggasiz Lake Plain occurs along the drop off of the Pembina Escarpment. In the Forest River Watershed, the end of this transition occurs approximately two miles east of the Forest River crossing with ND Highway 18. At this location, the riverine valley in which the Forest River was contained becomes less evident, and breakout flows begin to travel overland through the floodplain that is no longer well-defined.

The lower region for the Forest River Watershed is characterized as having a perched river channel, meaning that the channel banks are higher than the adjacent floodplain. When flood waters exceed the capacity of the perched river system, they breakout of the channel and travel overland. The overland breakout flows cause significant damage to cropland during large runoff events. The Forest River also travels through the two rural communities of Forest River and Minto, ND. Significant runoff events cause damage to infrastructure in the cities as well as damage to farm sites throughout the watershed.

There are two major breakout locations upstream of Minto, ND that carry a significant amount of flow over cropland. The first is located west of the town of Forest River, ND. Through this breakout, flows travel north where they eventually enter an intermittent tributary. That tributary enters back into the Forest River upstream of Minto, ND (approximately 1 mile west of the town). The second major breakout occurs just east of the town of Forest River, ND. This breakout occurs as a result of decommissioned levees in the area. Flows breakout of the Forest River and travel east through cropland until they eventually reach Lake Ardoch. A third breakout location is located east (downstream) of Minto, ND. At this location, flows breakout of the Forest River channel and travel east, bypassing Lake Ardoch, and enter back into the Forest River approximately two miles downstream of Lake Ardoch.

In summary, the Forest River Watershed is characterized by two different geomorphic conditions. The upper portion of the watershed is characterized with a well-defined floodplain where a significant portion of the drainage area is controlled by retention structures. Further downstream, the channel transitions to a perched river system where large breakout flows travel through cropland and have the potential to affect structures in the lower region. The river system also has the potential to cause damage to the rural communities of Forest River and Minto, ND.

5 REFERENCES

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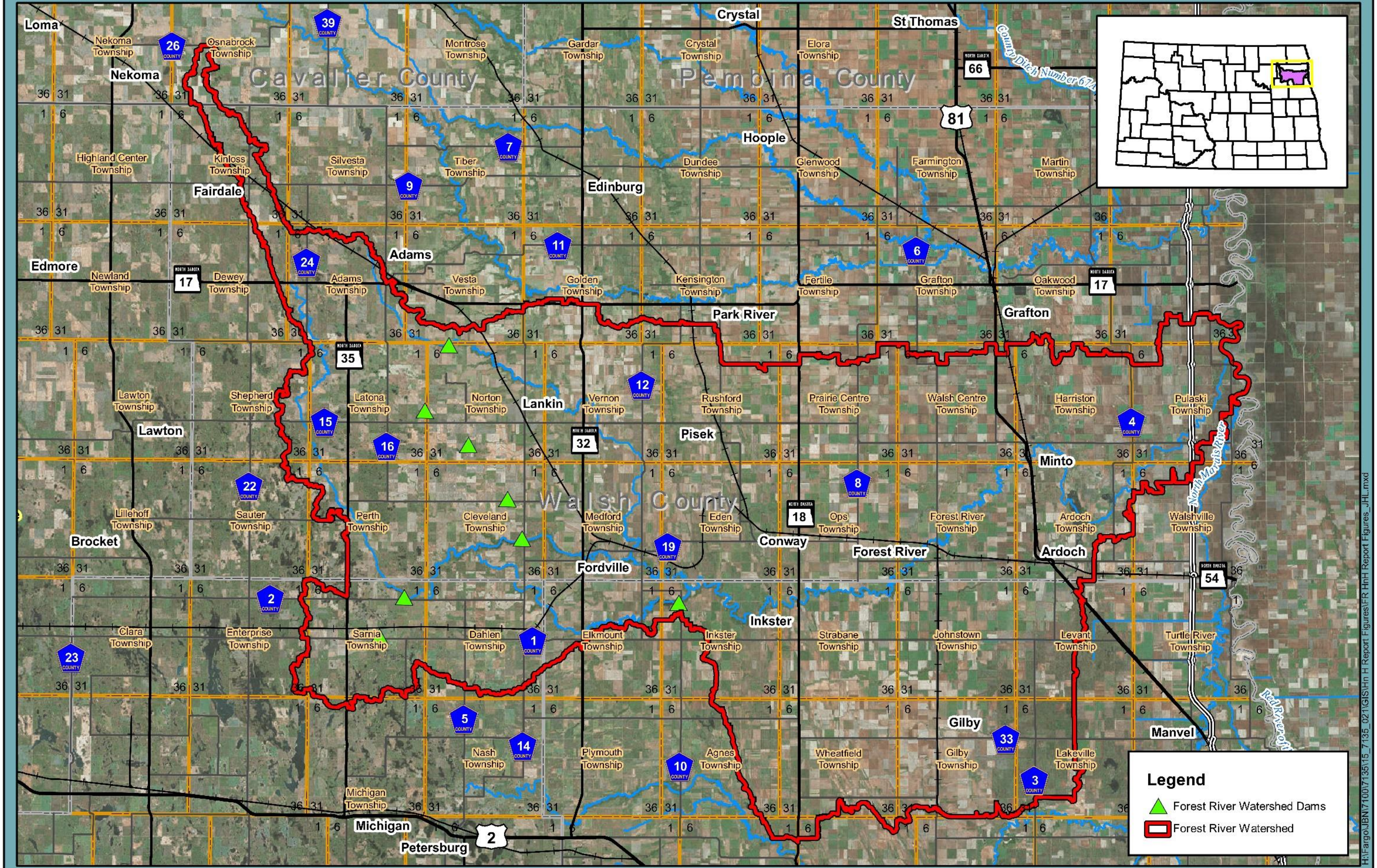
FIGURES



F-1

Figure 1: Forest River Watershed

Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

0 2.5 5 10 Miles

Houston Engineering Inc.

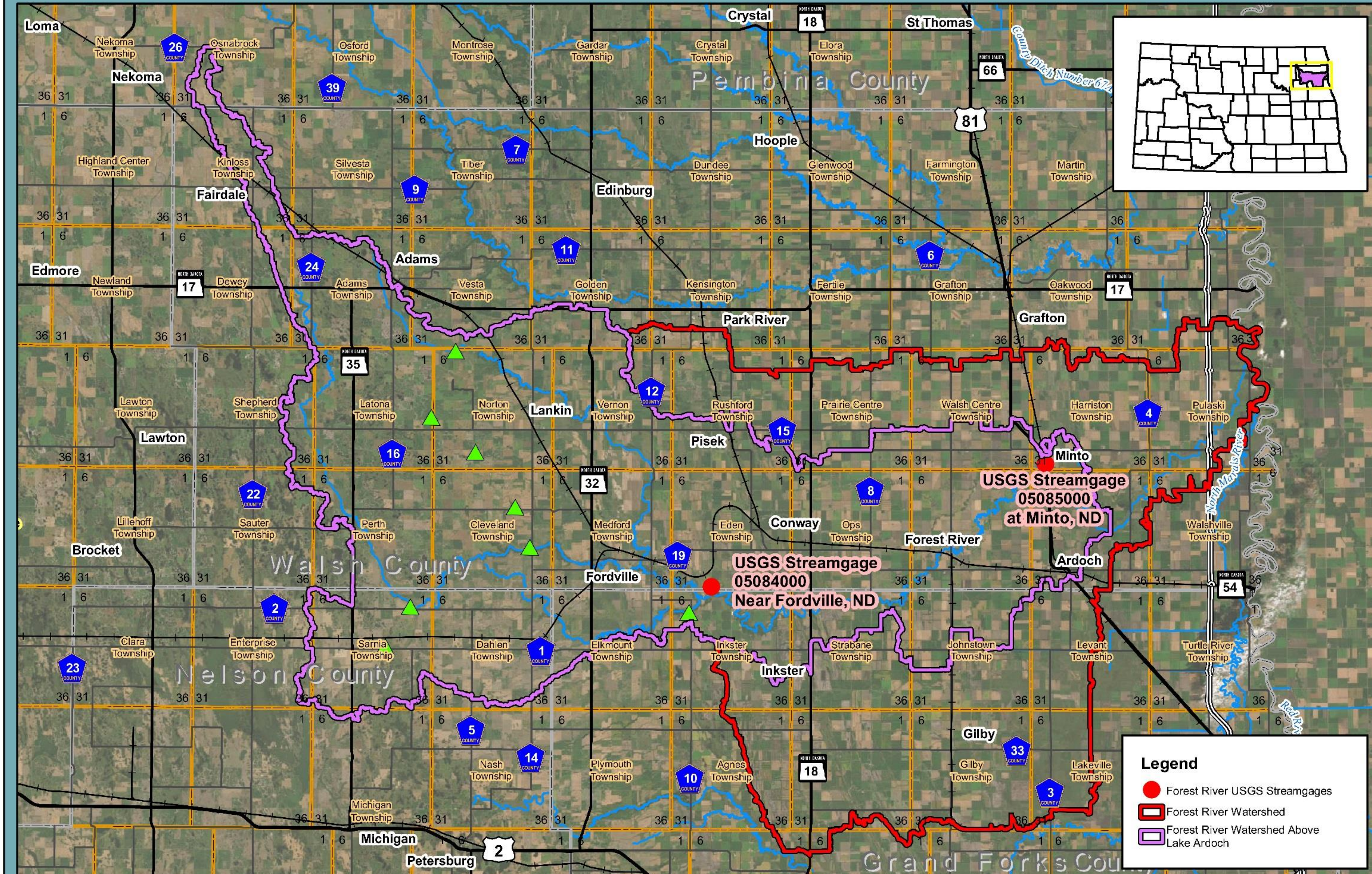
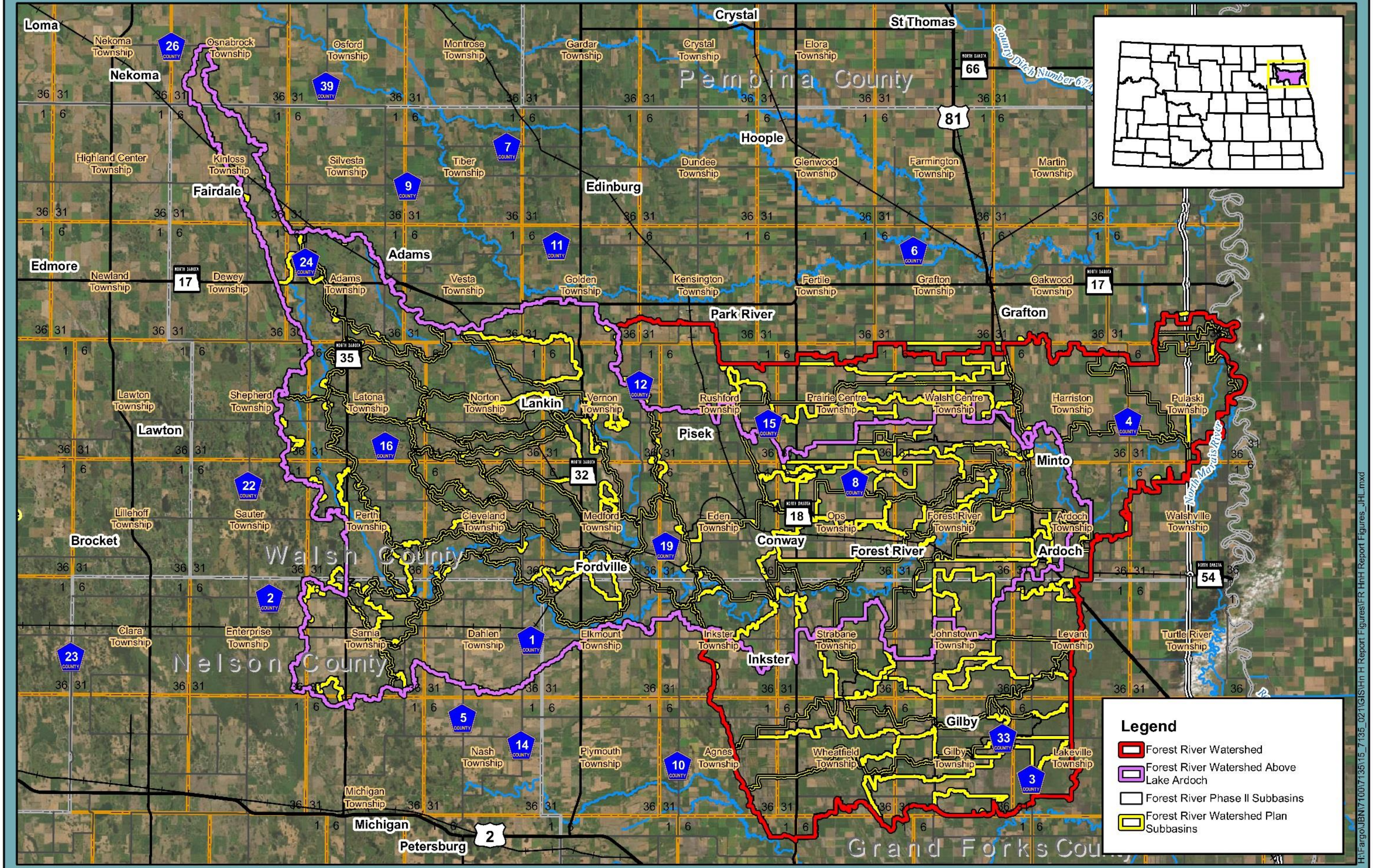


Figure 3: Forest River Watershed Above Lake Ardoch

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District



F-3.1.1

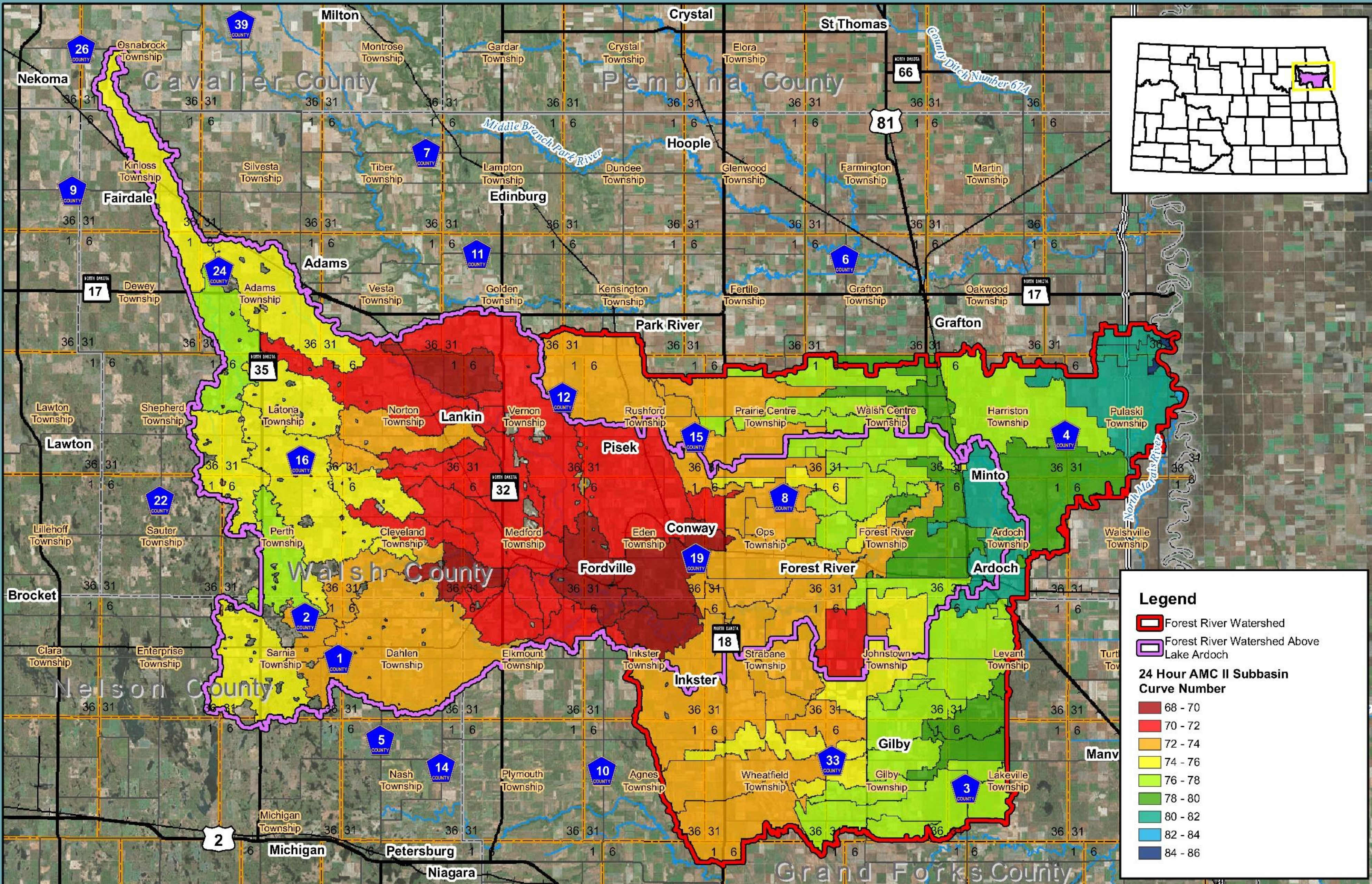
Figure 3.1.1: HEC-HMS Subbasins

Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

Houston Engineering Inc.



F-3.1.2

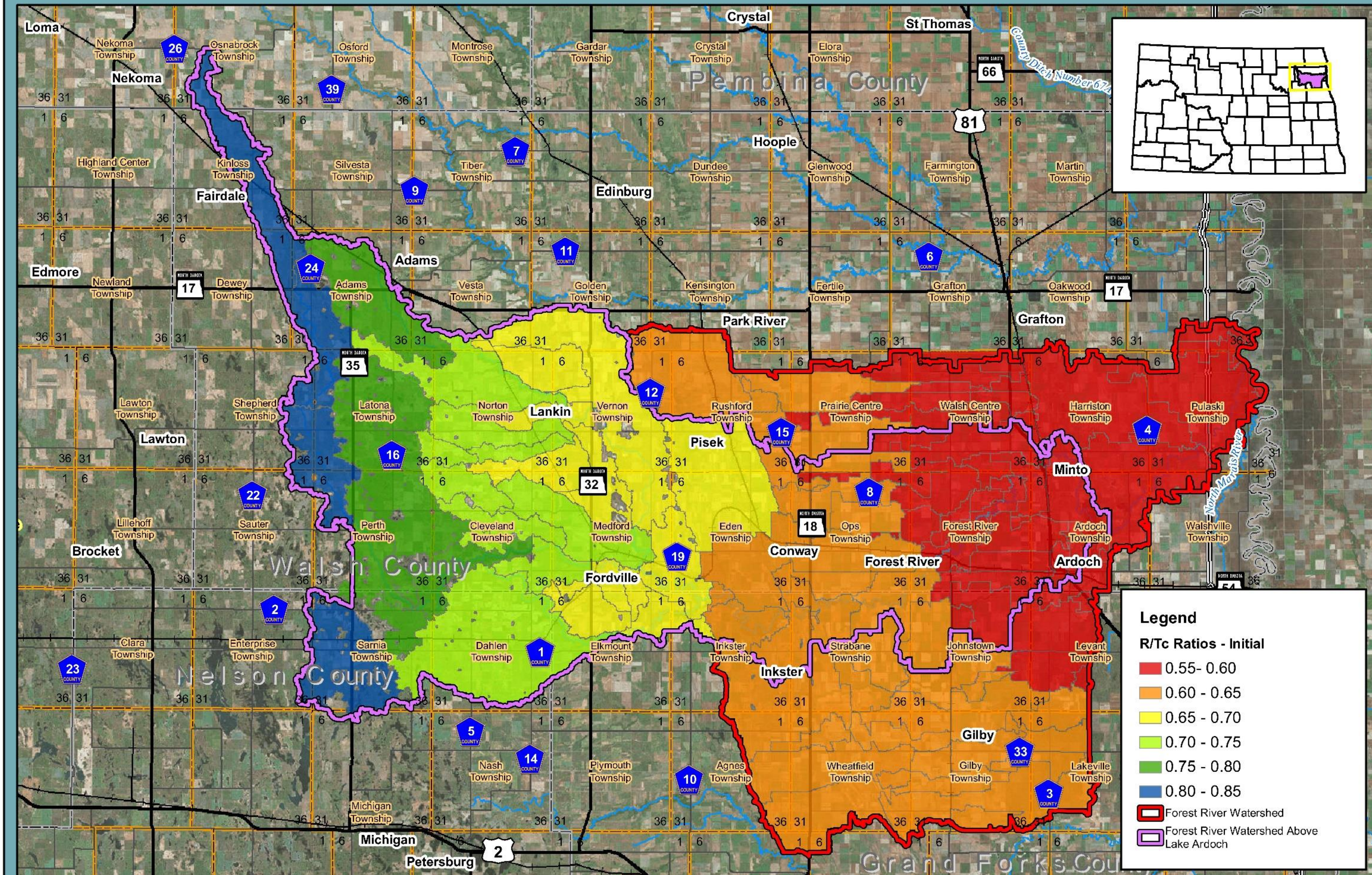
Figure 3.1.2: 24-hour AMC II CN Values

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N W E S

0 2.5 5 10 Miles

Houston Engineering Inc.



F-3.1.3

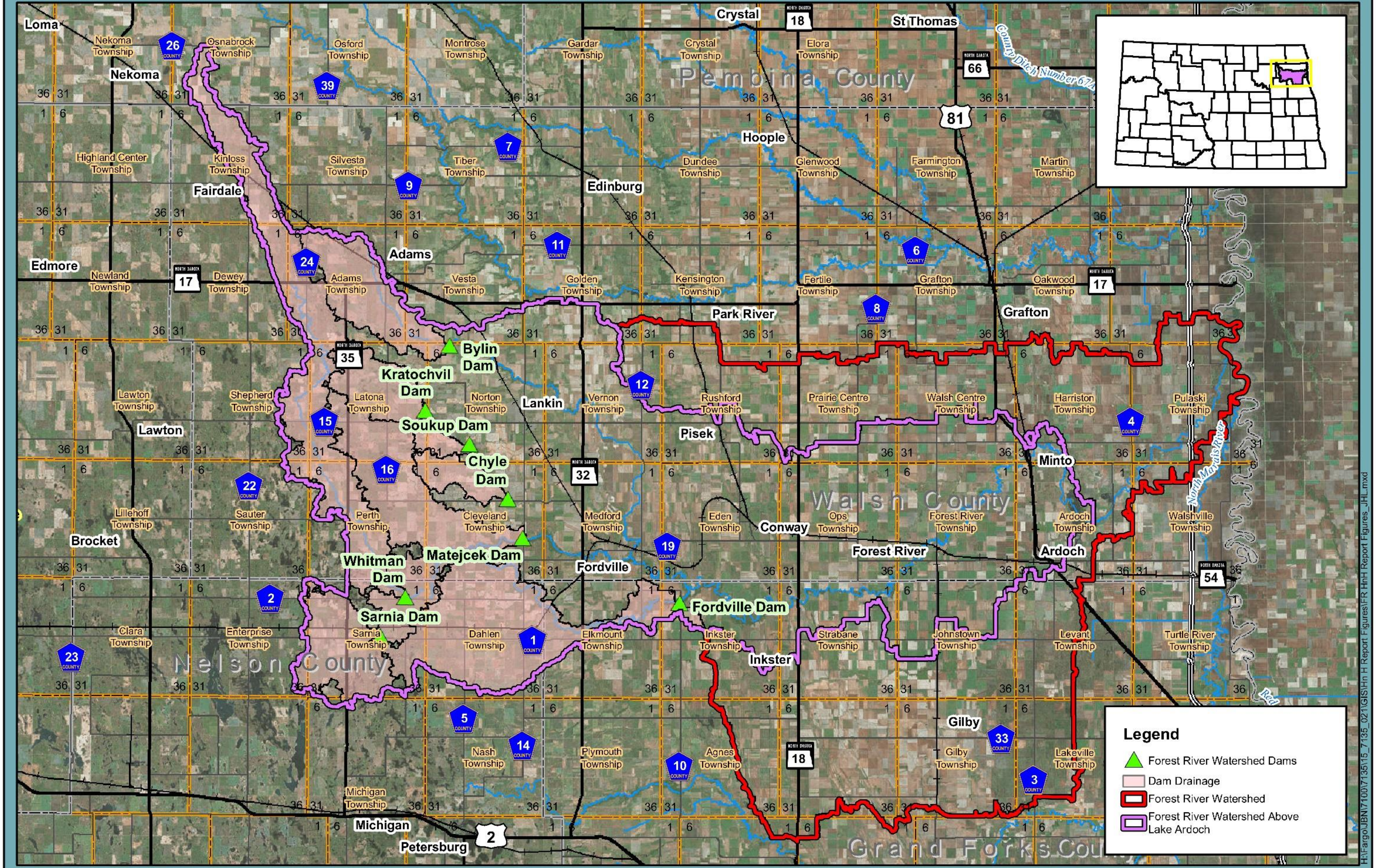
Figure 3.1.3: R/Tc Ratios - Initial

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N W E S

0 2.5 5 10 Miles

Houston Engineering Inc.



F-3.1.5

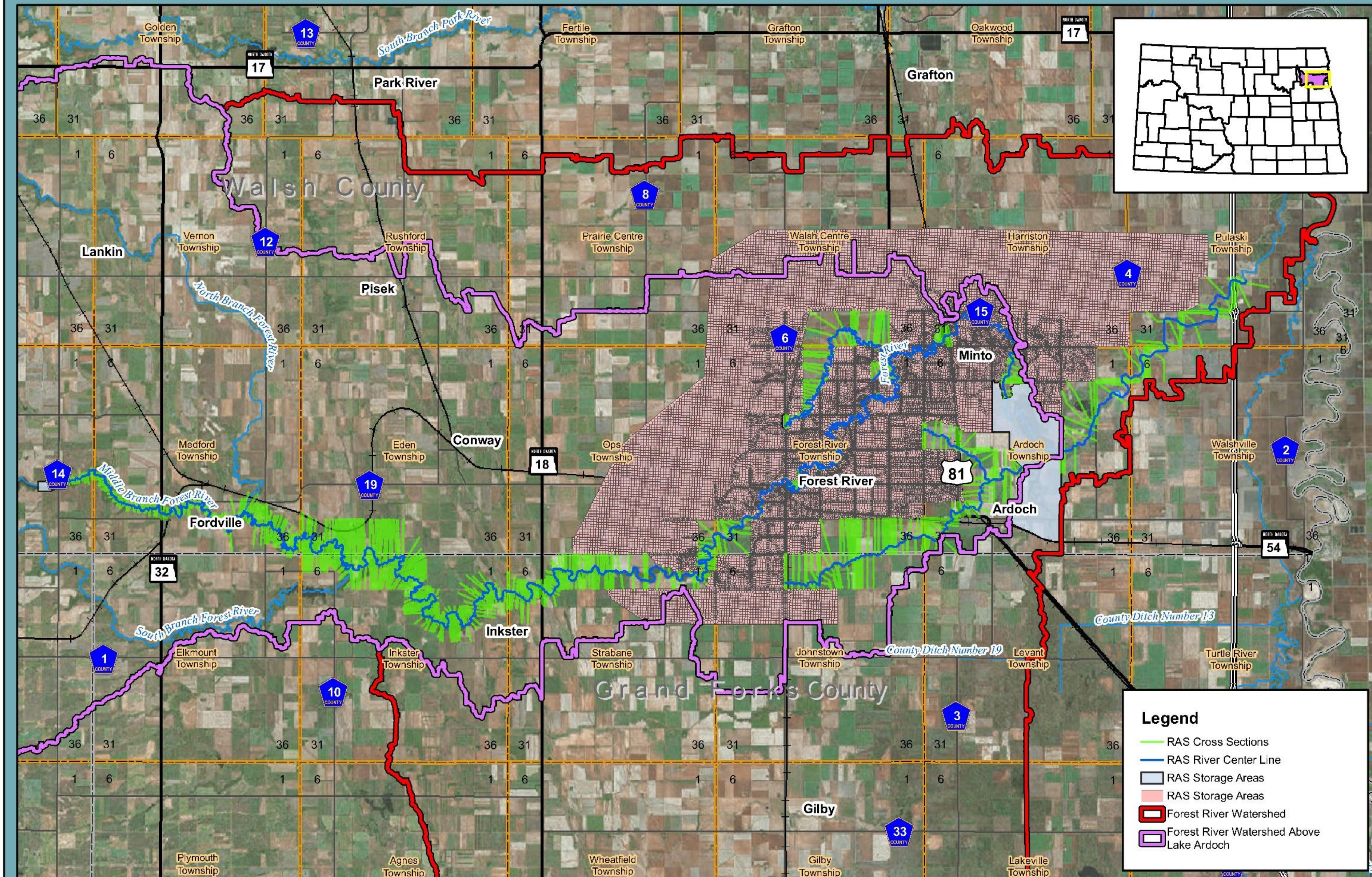
Figure 3.1.5: Existing Dams

Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

Houston Engineering Inc.



F-3.2

Figure 3.2: HEC-RAS Model Schematic

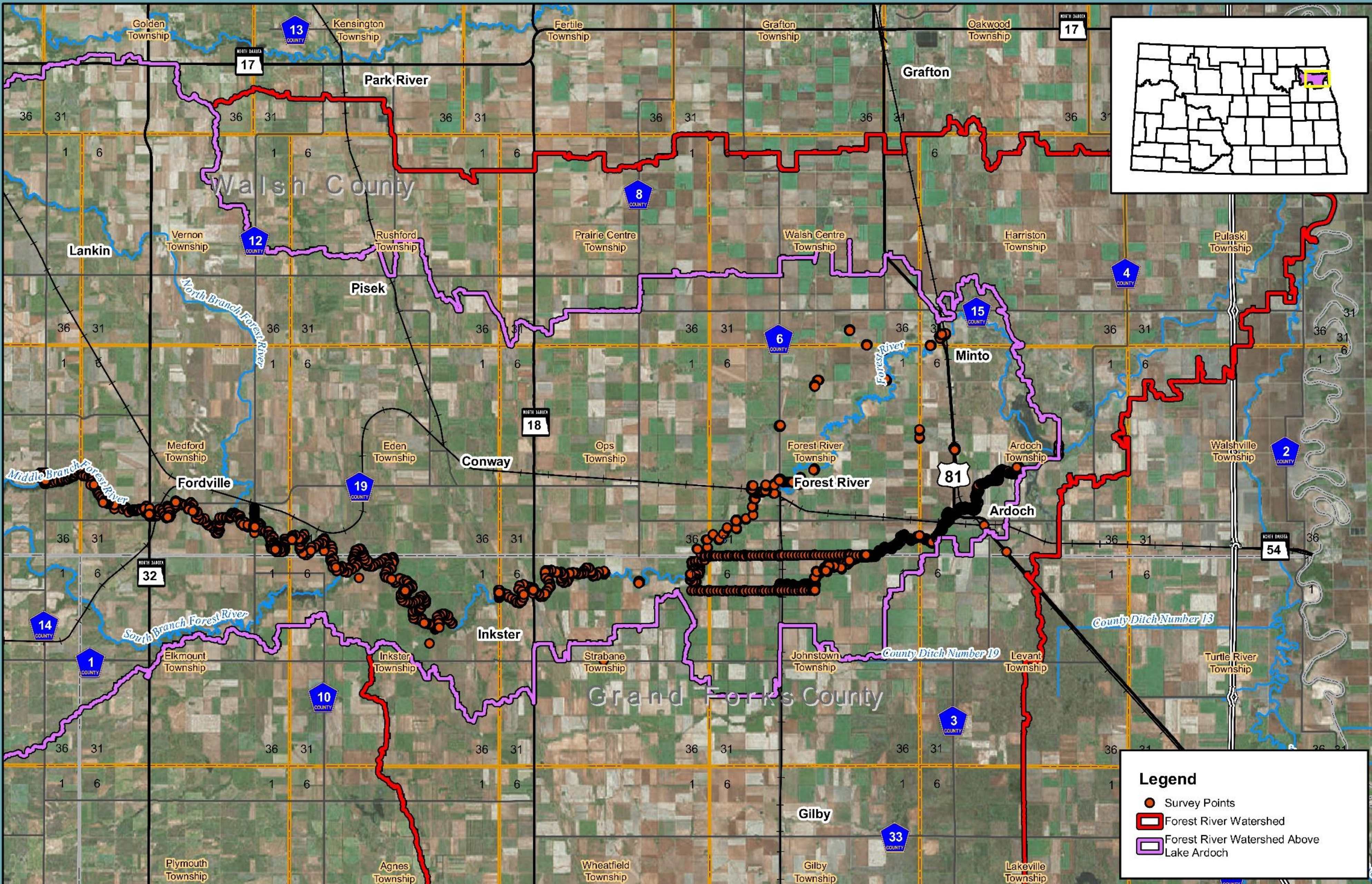
Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

0 1.5 3 6 Miles

Houston Engineering Inc.



F-3.2.2

Figure 3.2.2: Field Survey Data

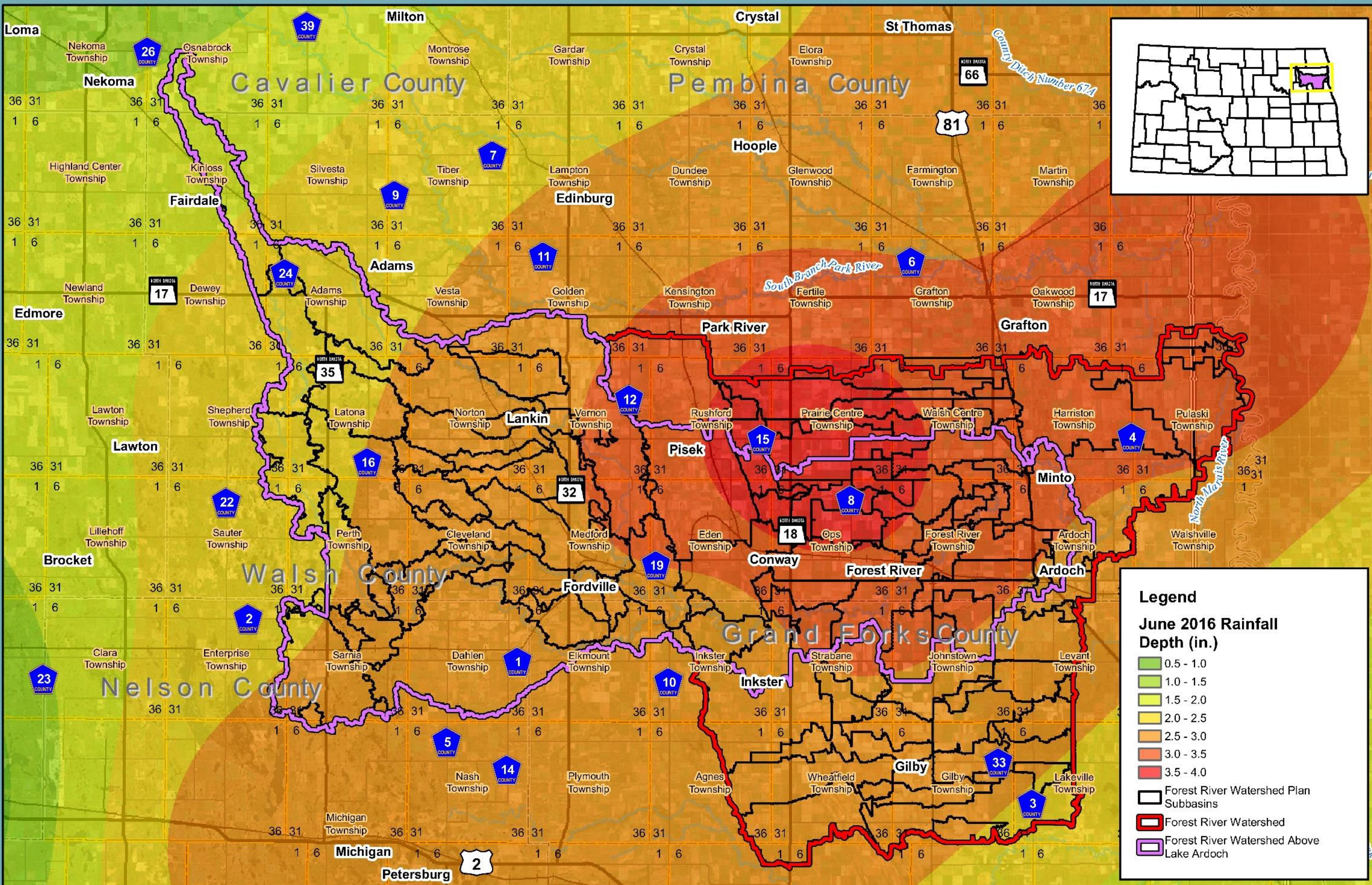
Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

0 1.5 3 6 Miles

Houston Engineering Inc.

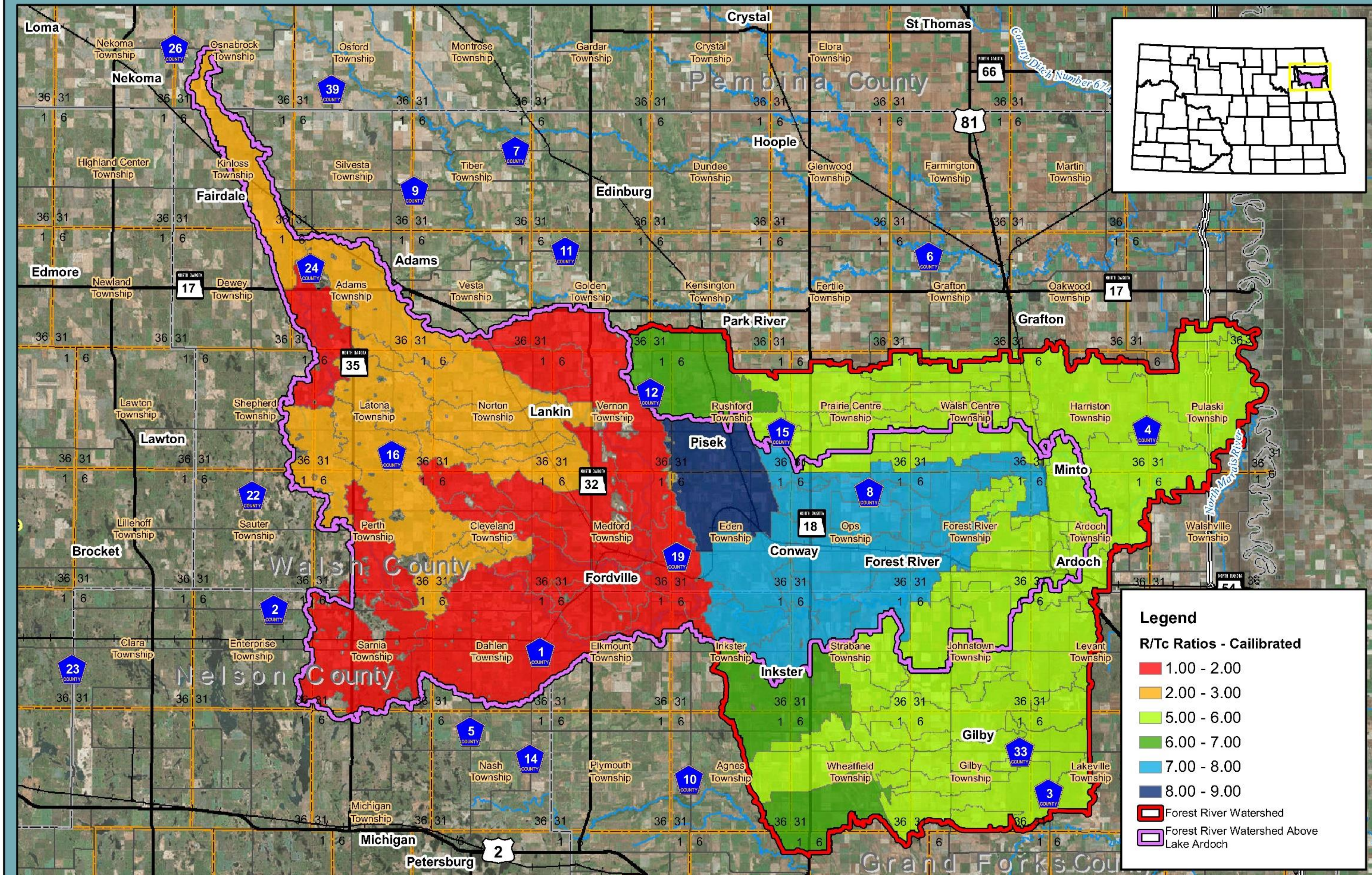


F-3.3.1a

Figure 3.3.1a: 2016 Historic Event Rainfall

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.



F-3.3.1b

Figure 3.3.1b: R/Tc Ratios - Calibrated

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.

Figure 3.3.1c: *2016 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)*

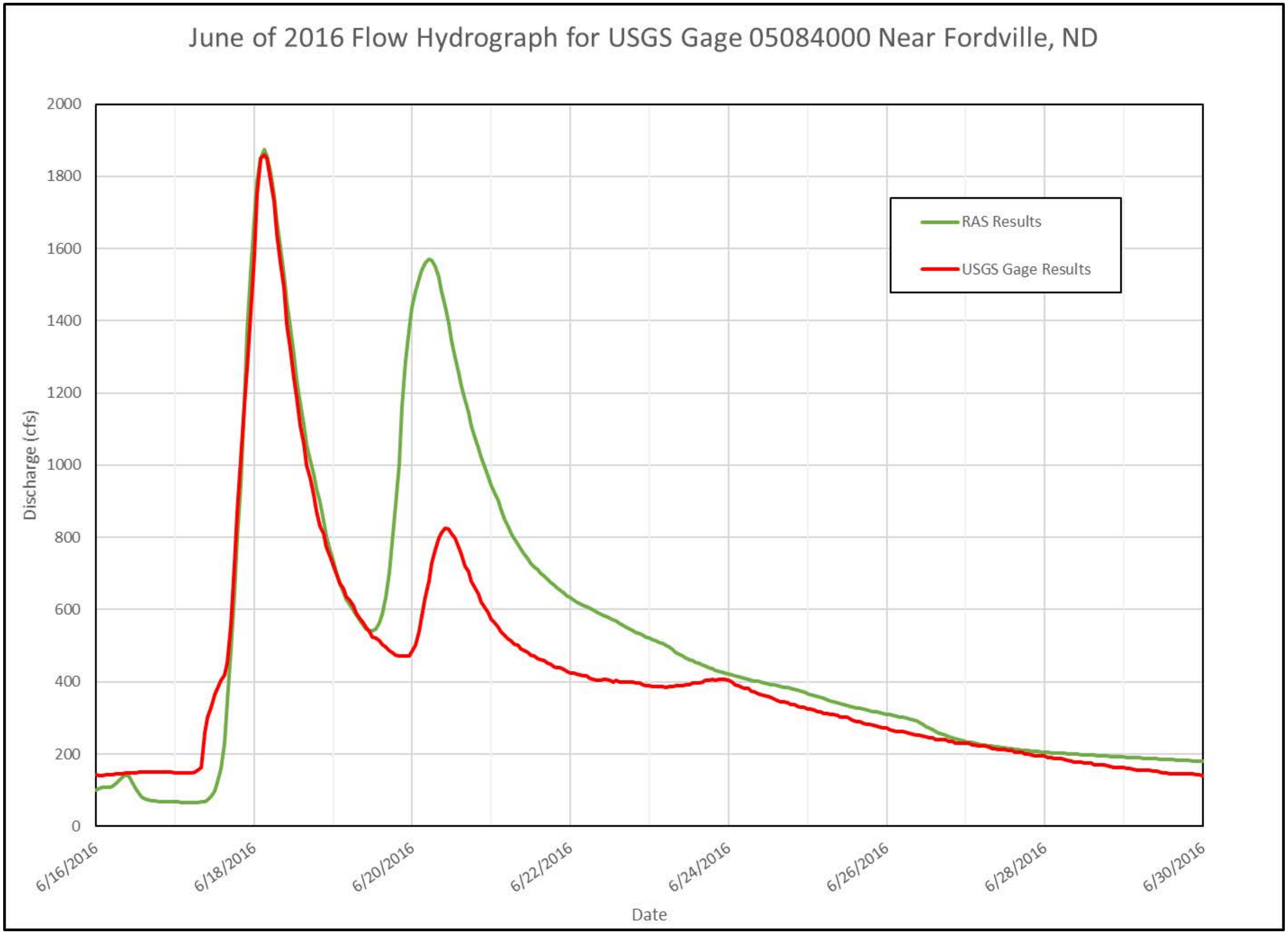
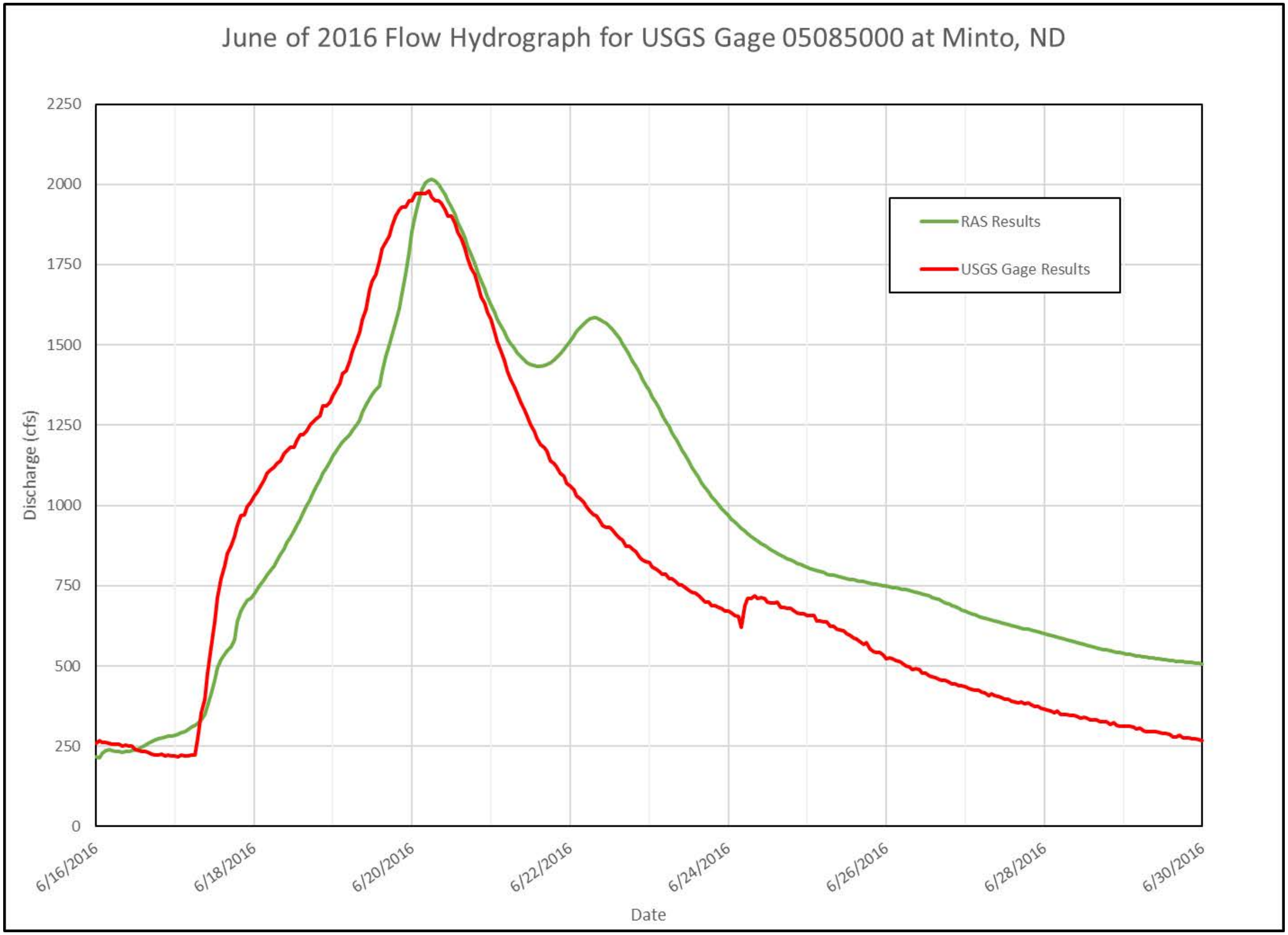
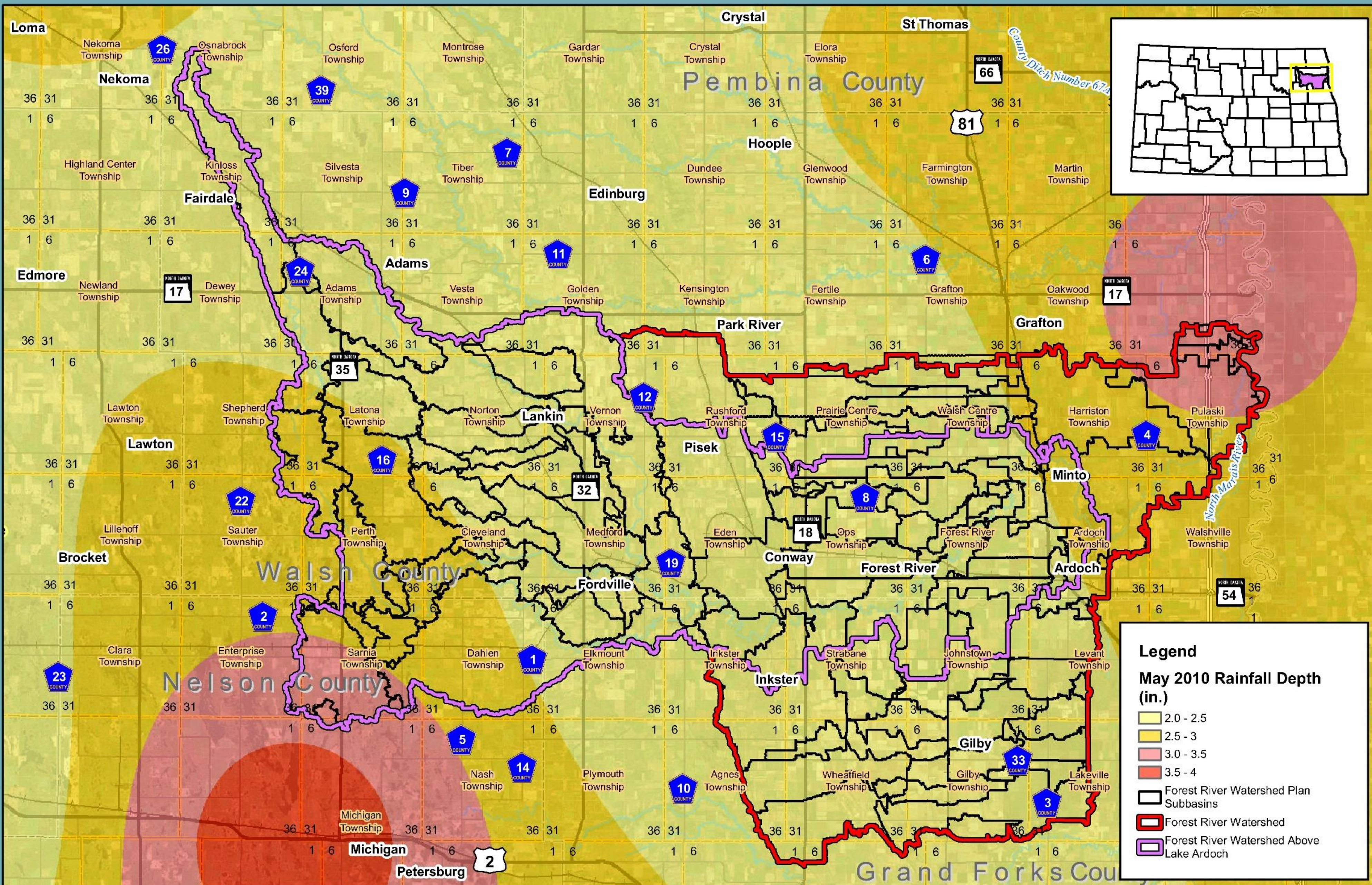


Figure 3.3.1d: *2016 Historic Event – Peak Discharge at Minto, ND (USGS Gage 05085000)*





F-3.3.2a

Figure 3.3.2a: 2010 Historic Event Rainfall

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

***Figure 3.3.2b:** 2010 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)*

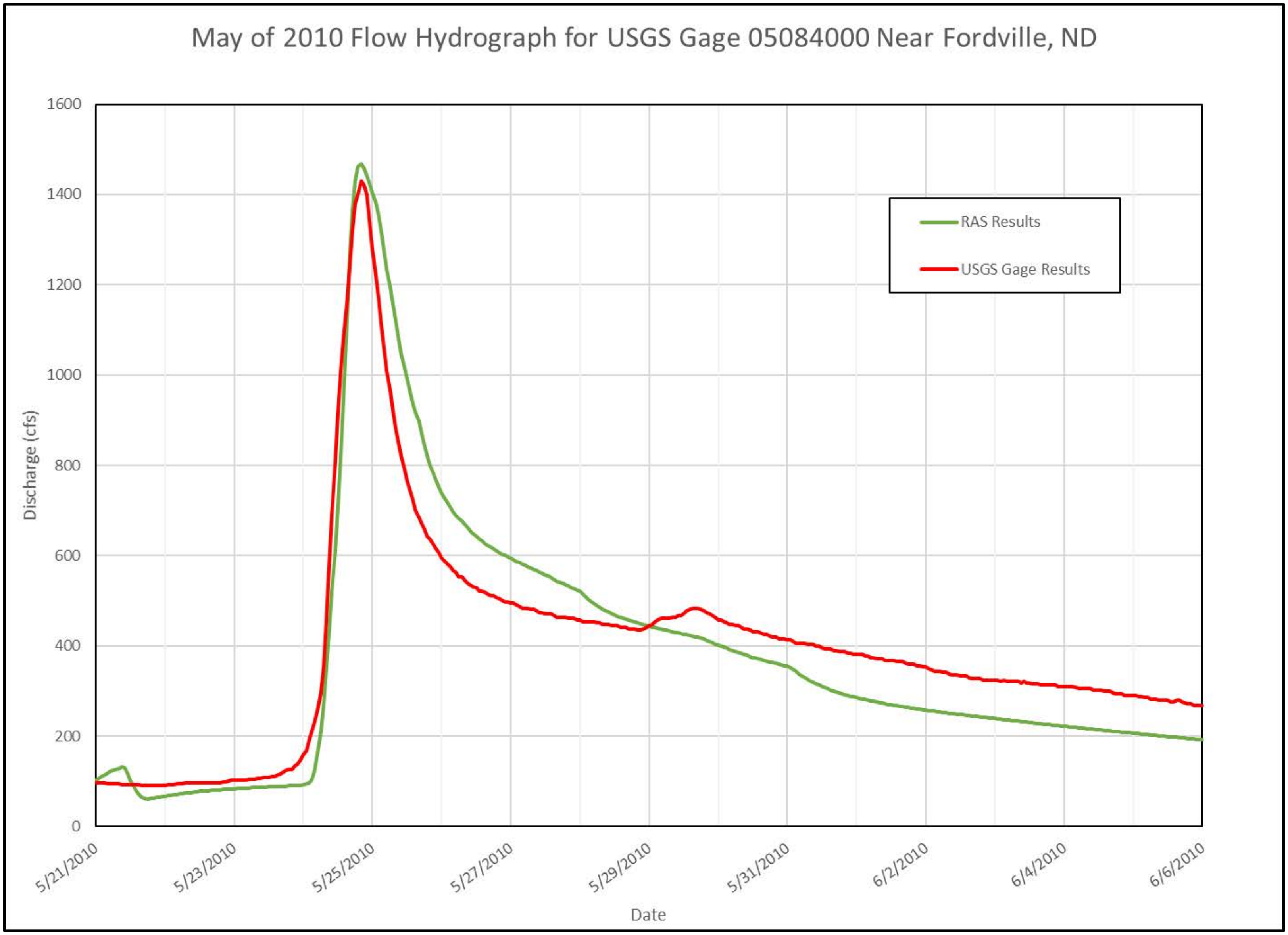
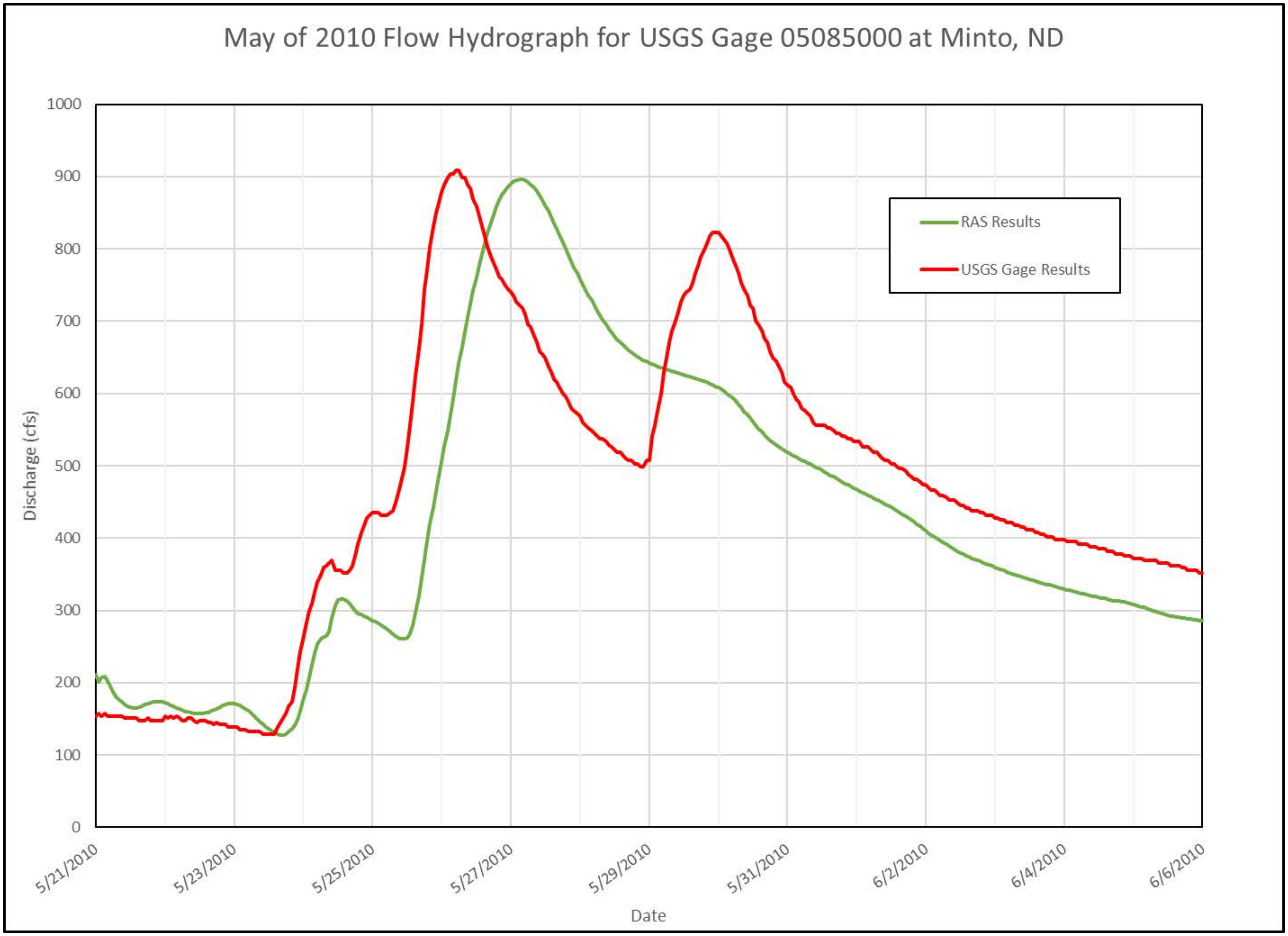


Figure 3.3.2c: *2010 Historic Event – Peak Discharge at Minto, ND (USGS Gage 05085000)*



APPENDIX A

Red River Basin 24-Hour Runoff Curve Number Conversion Table

APPENDIX A:

Red River Basin 24-Hour Runoff Curve Number Conversion Table

FM Metro Basin-Wide Modeling Approach
Runoff Curve Number (2001 NLCD/SSURGO)
11/11/2010

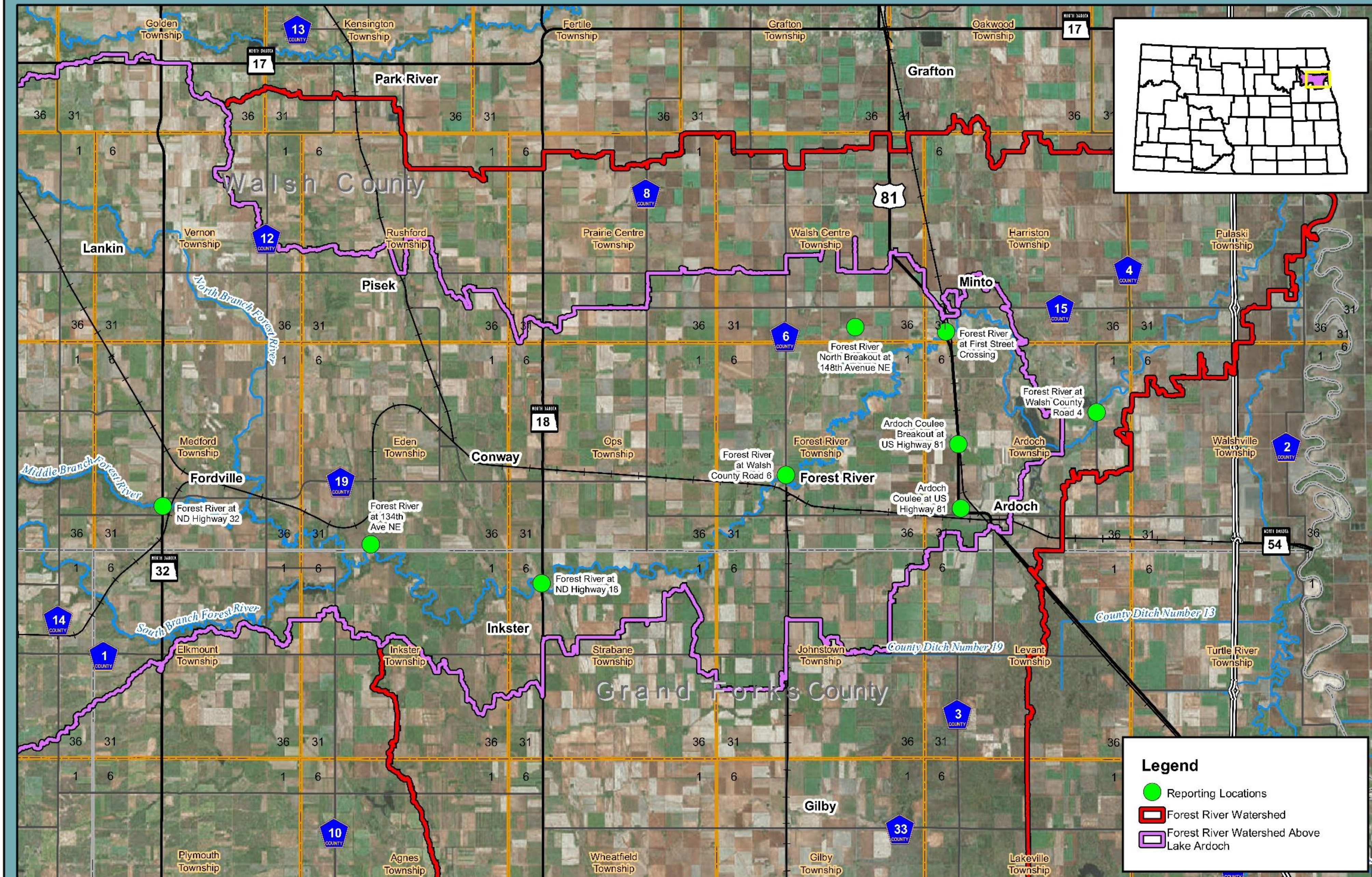
NLCD 2001 Info					Pervious CN by Hydrologic Soil Group						
Value/ Code	**Land Cover Code**	**Detailed Land Cover Class Definition**	**TR55 or MN Hydrology Guide Designation (MNHG)**	**% Impervious**	**A**	**B**	**C**	**D**	**A/D**	**B/D**	**C/D**
11	Open water	11. Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.	MNHG- Water Surfaces (lakes, ponds,...)		100	100	100	100	100	100	100
12	Perennial Ice/Snow	12. Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.	MNHG- Water Surfaces (lakes, ponds,...)		100	100	100	100	100	100	100
21	Developed, Open Space	21. Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	TR55-Residential Districts (98 for impervious areas and Open Space in Good condition for pervious areas) based on Percent Impervious Listed.	10	45	65	76	82	45	65	76
22	Developed, Low Intensity	22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.	TR55-Residential Districts (98 for impervious areas and Open Space in Good condition for pervious areas) based on Percent Impervious Listed.	35	60	74	82	86	60	74	82
23	Developed, Medium Intensity	23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.	TR55-Residential Districts (98 for impervious areas and Open Space in Good condition for pervious areas) based on Percent Impervious Listed.	65	77	85	90	92	77	85	90
24	Developed, High Intensity	24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.	TR55-Residential Districts (98 for impervious areas and Open Space in Good condition for pervious areas) based on Percent Impervious Listed.	90	92	94	96	96	92	94	96
31	Barren Land	31. Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	TR55-Developing Urban Areas (Newly graded areas (pervious areas only, no vegetation))		77	86	91	94	94	94	94
41	Deciduous Forest	41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	TR55-Woods (Fair Condition)		36	60	73	79	79	79	79
42	Evergreen Forest	42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	TR55-Woods (Good Condition)		30	55	70	77	77	77	77
43	Mixed Forest	43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.	TR55-Woods (Good Condition)		30	55	70	77	77	77	77
52	Scrub/Shrub	52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	TR55-Brush (brush-weed-grass mixture with brush major element)(Fair Condition)		35	56	70	77	77	77	77
71	Grassland/Herbaceous	71. Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	TR55-Meadow (continuous grass, protected from grazing and generally mowed for hay)(Fair Condition)		30	58	71	78	78	78	78
81	Pasture/Hay	81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	TR55-Pasture, grassland, or range - continuous forage for grazing (Fair Condition)		49	69	79	84	84	84	84
82	Cultivated Crops	82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.	TR55-Assume 80% Row Crop and 20% Small Grains in Good Condition - Contoured and Terraced (since most of are is less than 2% slope)		61	71	78	81	61	71	78
90	Woody Wetlands	90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	MNHG-Swamp(Vegetated)		78	78	78	78	78	78	78
95	Emergent Herbaceous Wetland	95. Emergent Herbaceous Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	MNHG-Swamp(open water)		85	85	85	85	85	85	85

APPENDIX B

Existing Conditions
Hydrographs and Inundation

APPENDIX B

Existing Conditions Hydrographs and Inundation



B-1

Figure B.1: Synthetic Model Results Reporting Locations

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N
W E
S

0 1.5 3 6 Miles

Houston Engineering Inc.

Figure B.2: *Forest River at ND Highway 32*

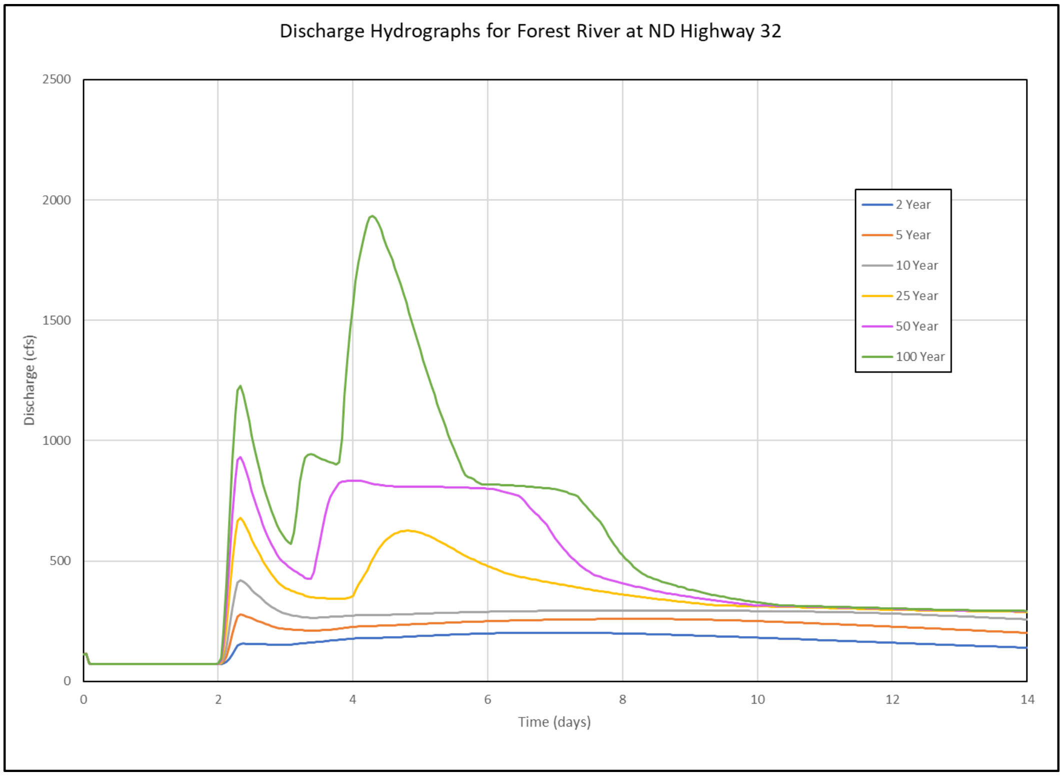


Figure B.3: *Forest River at 134th Ave NE*

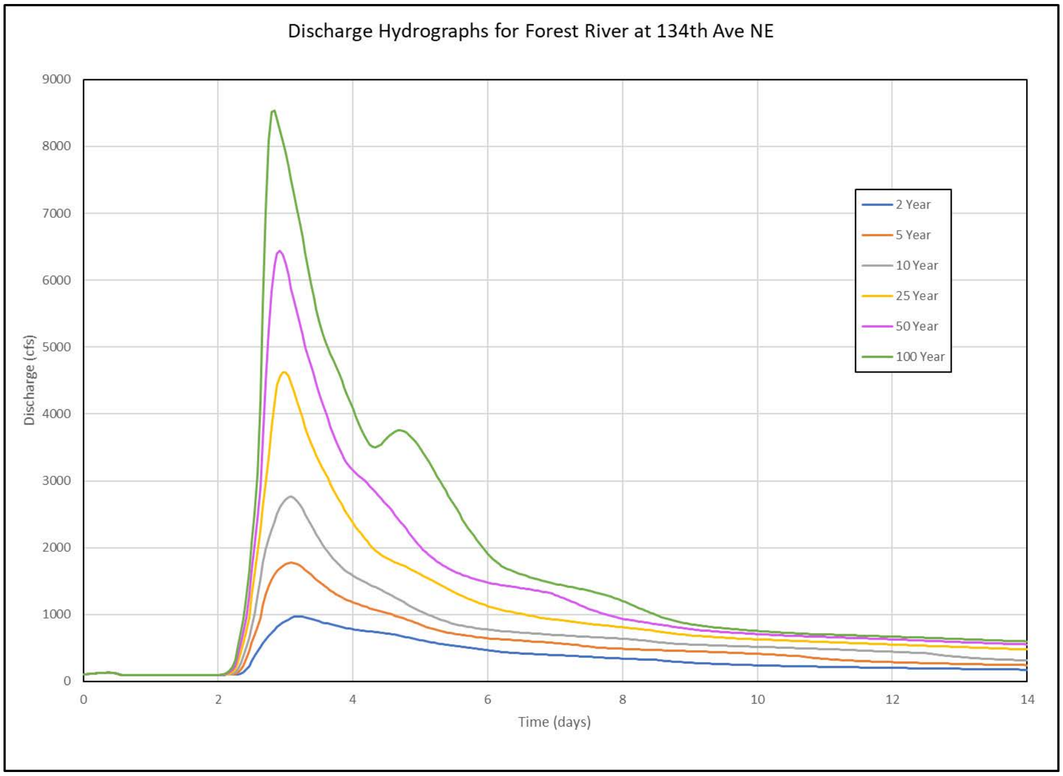


Figure B.4: *Forest River at ND Highway 18*

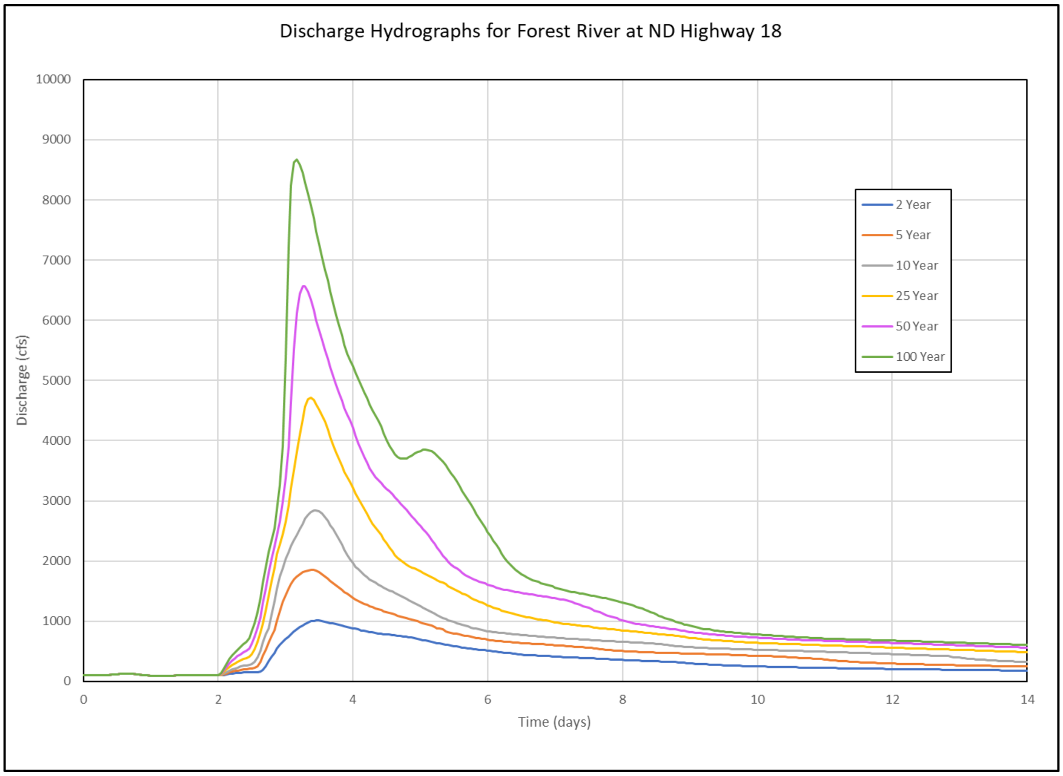


Figure B.5: *Forest River at Walsh County Road 6*

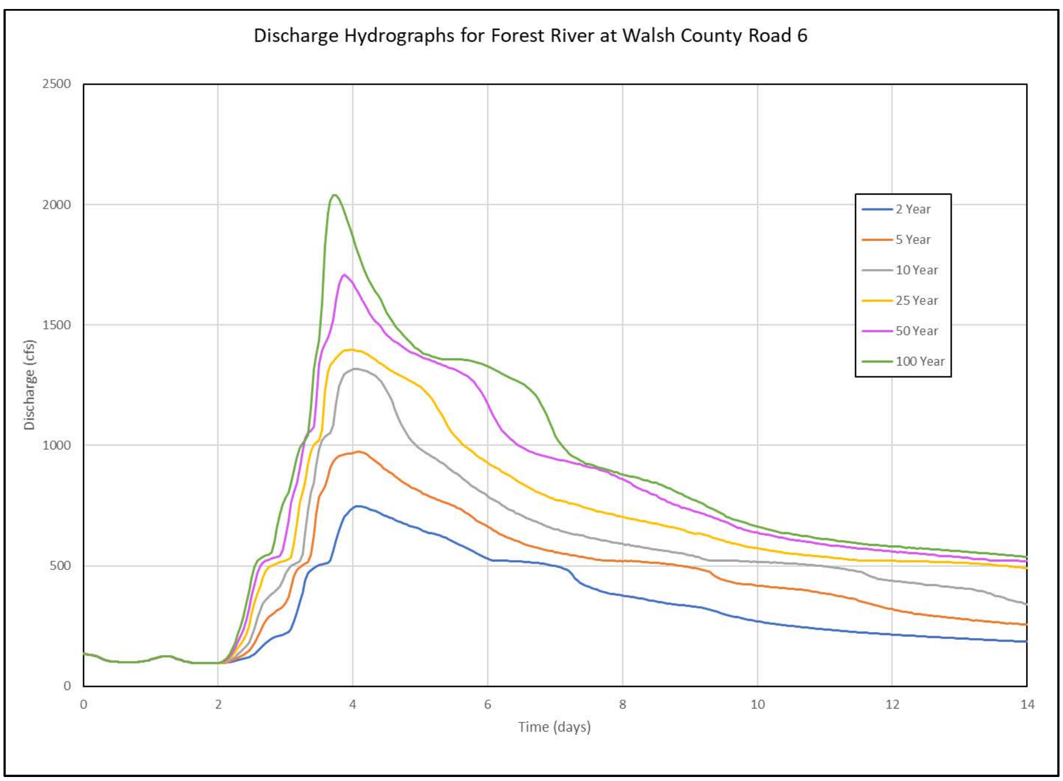


Figure B.6: Forest River at First Street Crossing

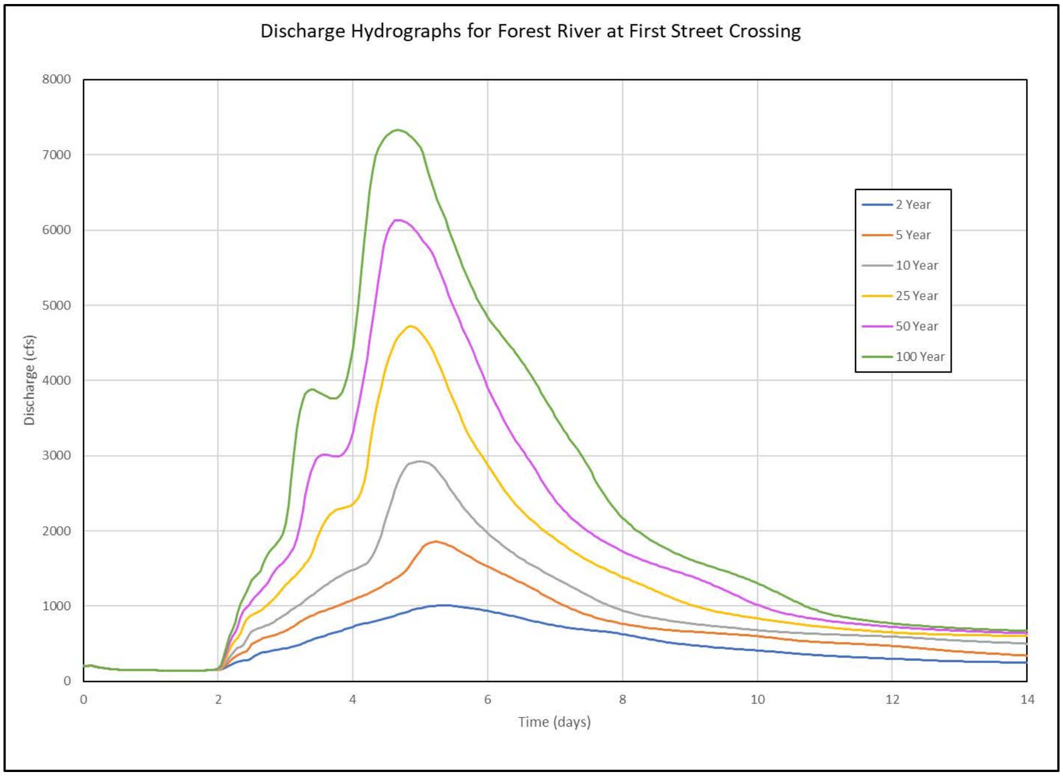


Figure B.7: Forest River at Walsh County Road 4

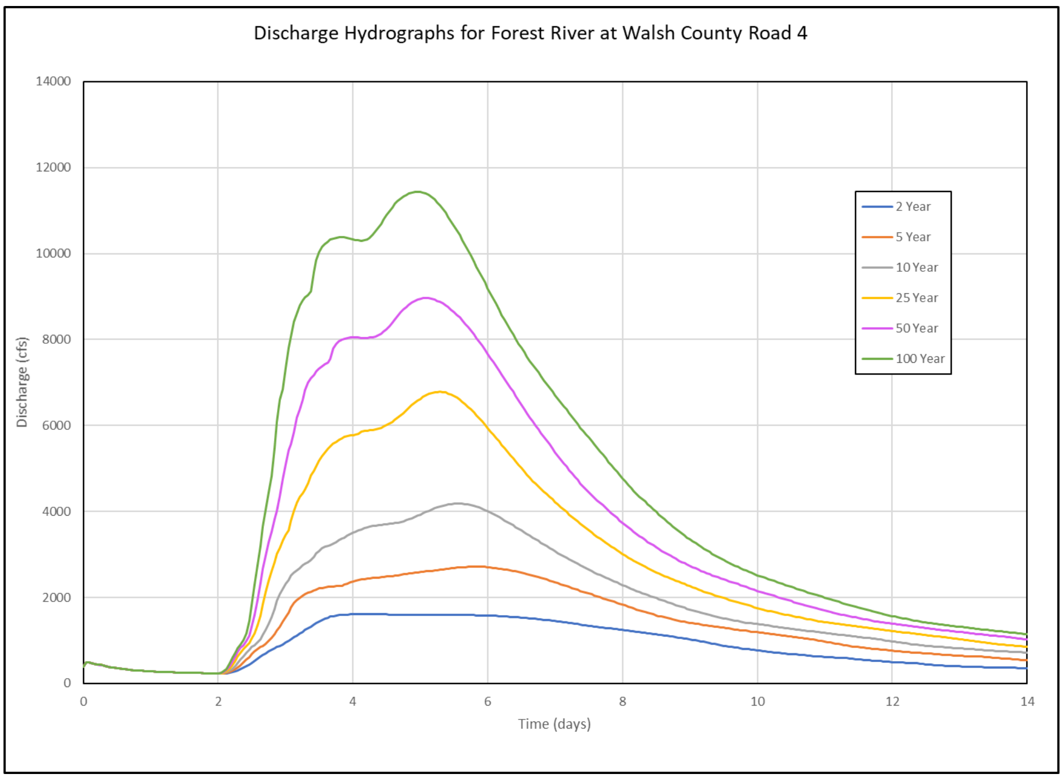


Figure B.8: *Forest River North Breakout at 148th Ave NE*

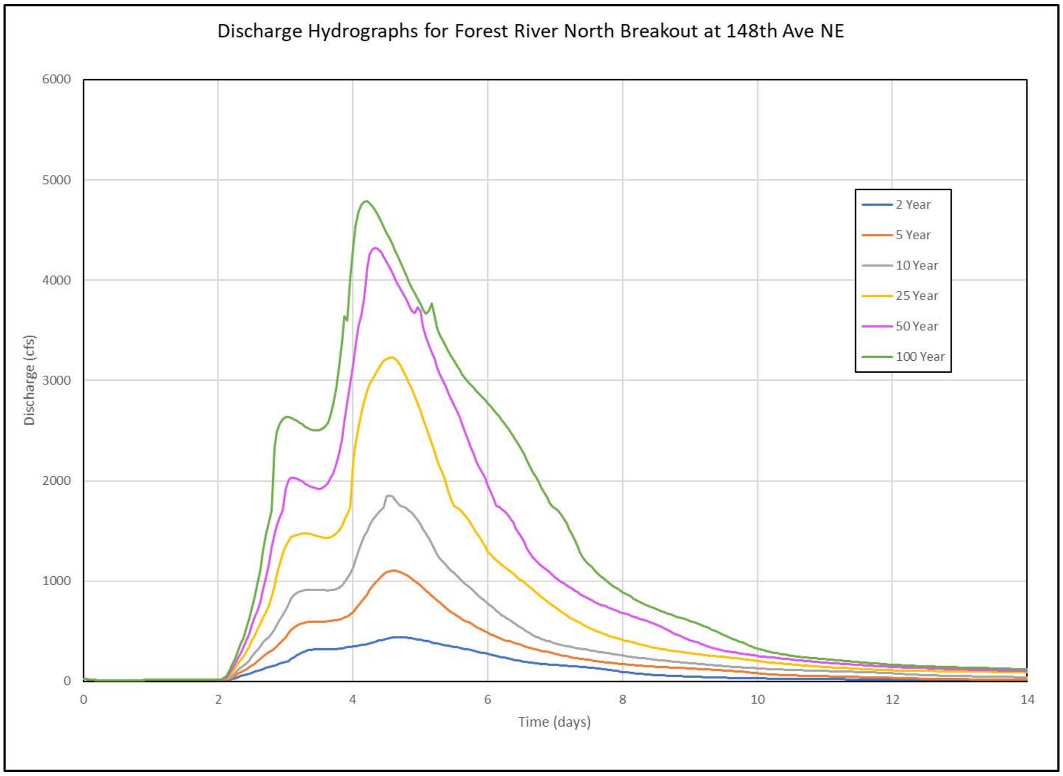


Figure B.9: *Ardoch Coulee Breakout at US Highway 81*

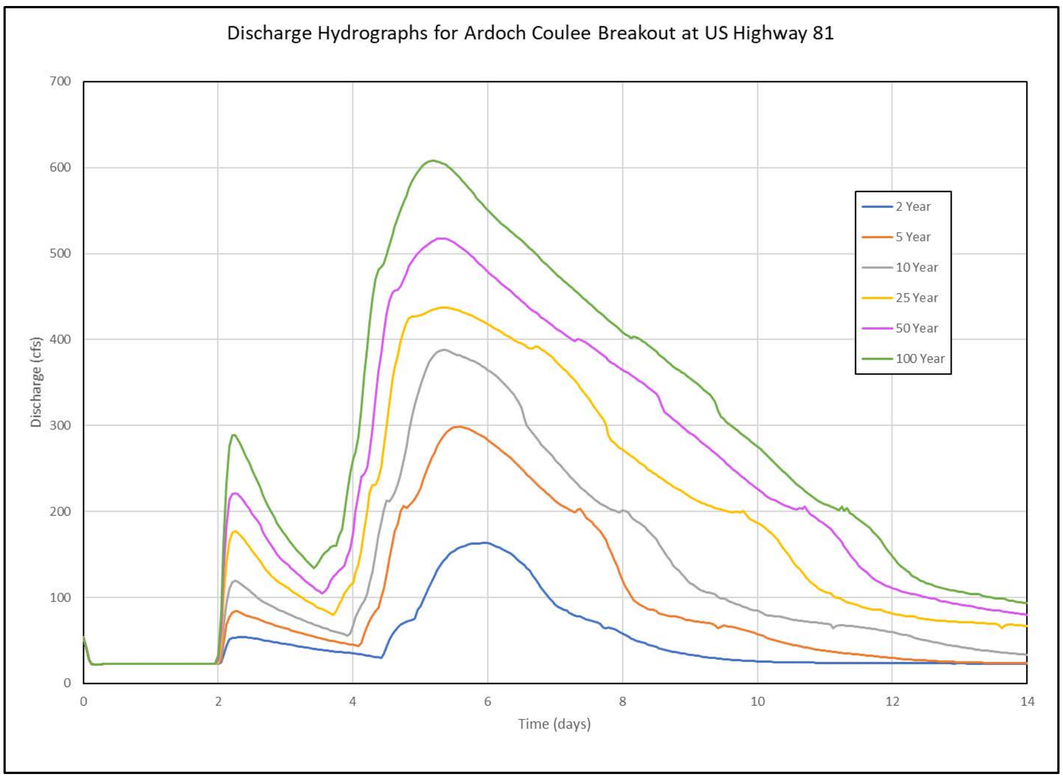
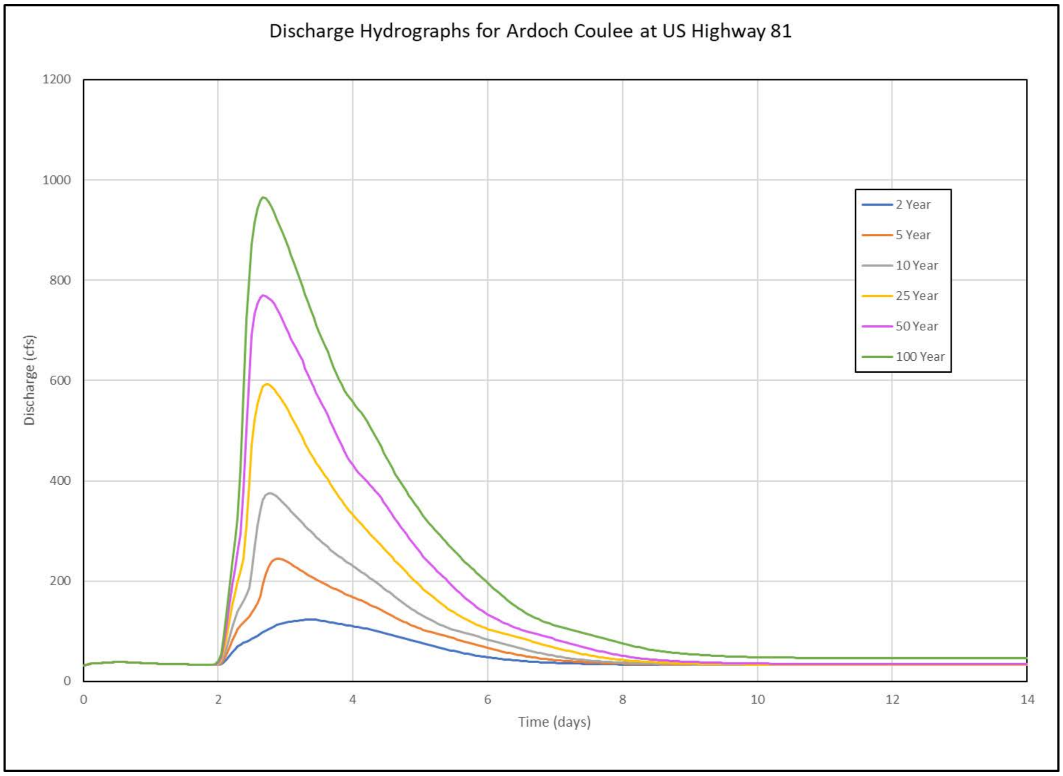
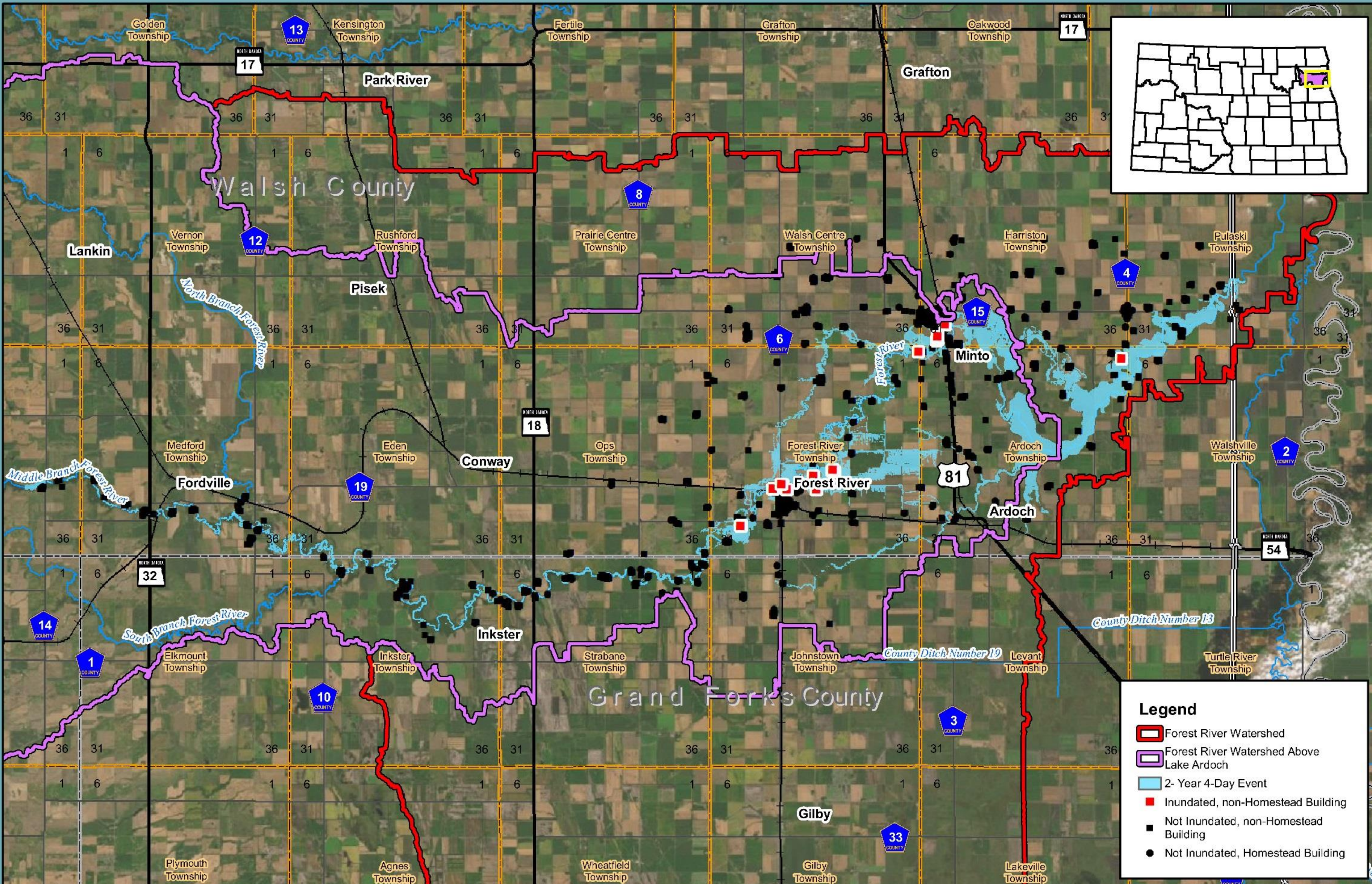


Figure B.10: *Ardoch Coulee at US Highway 81*



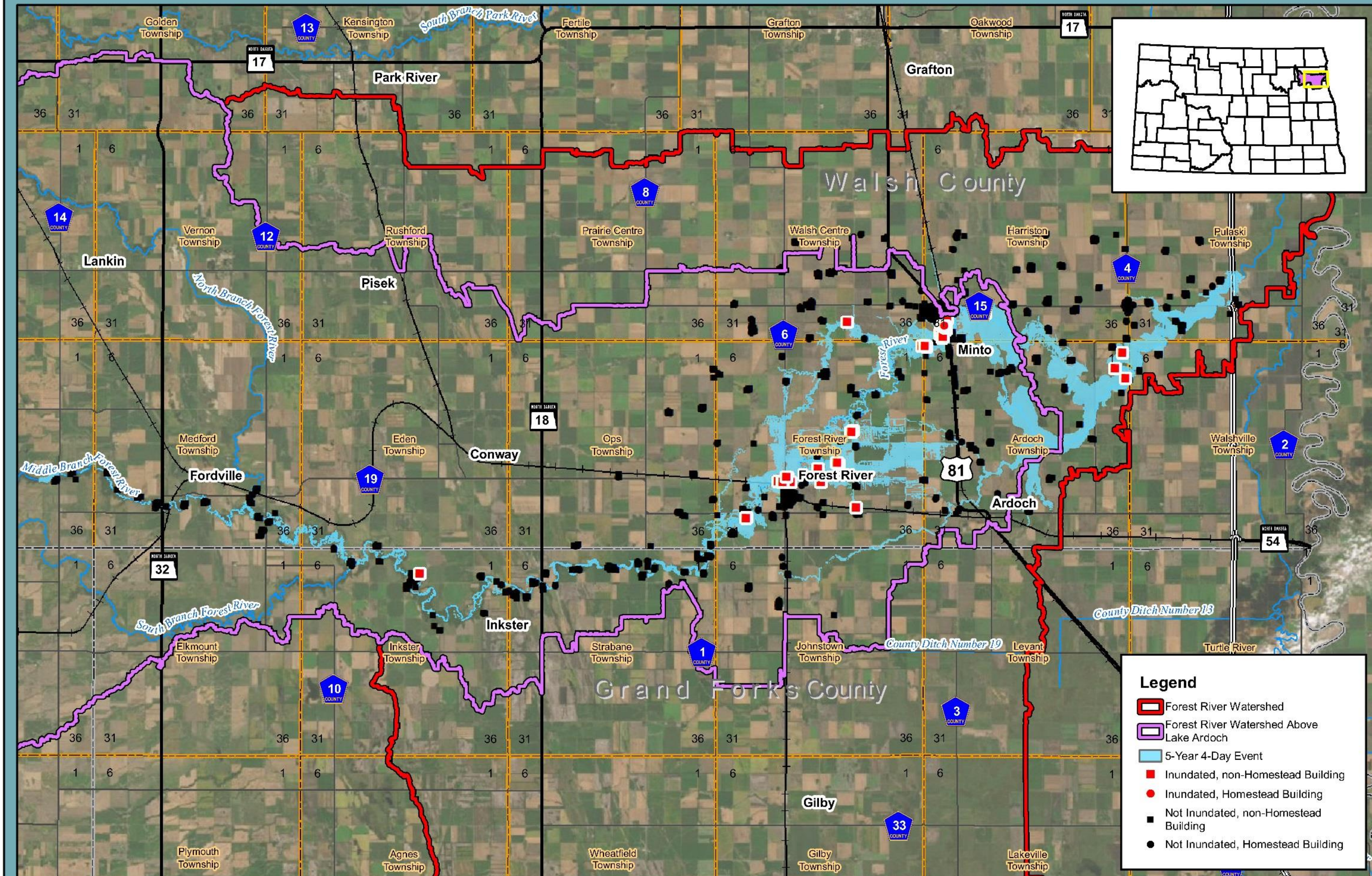


B-11

Figure B.11: 2-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.



B-12

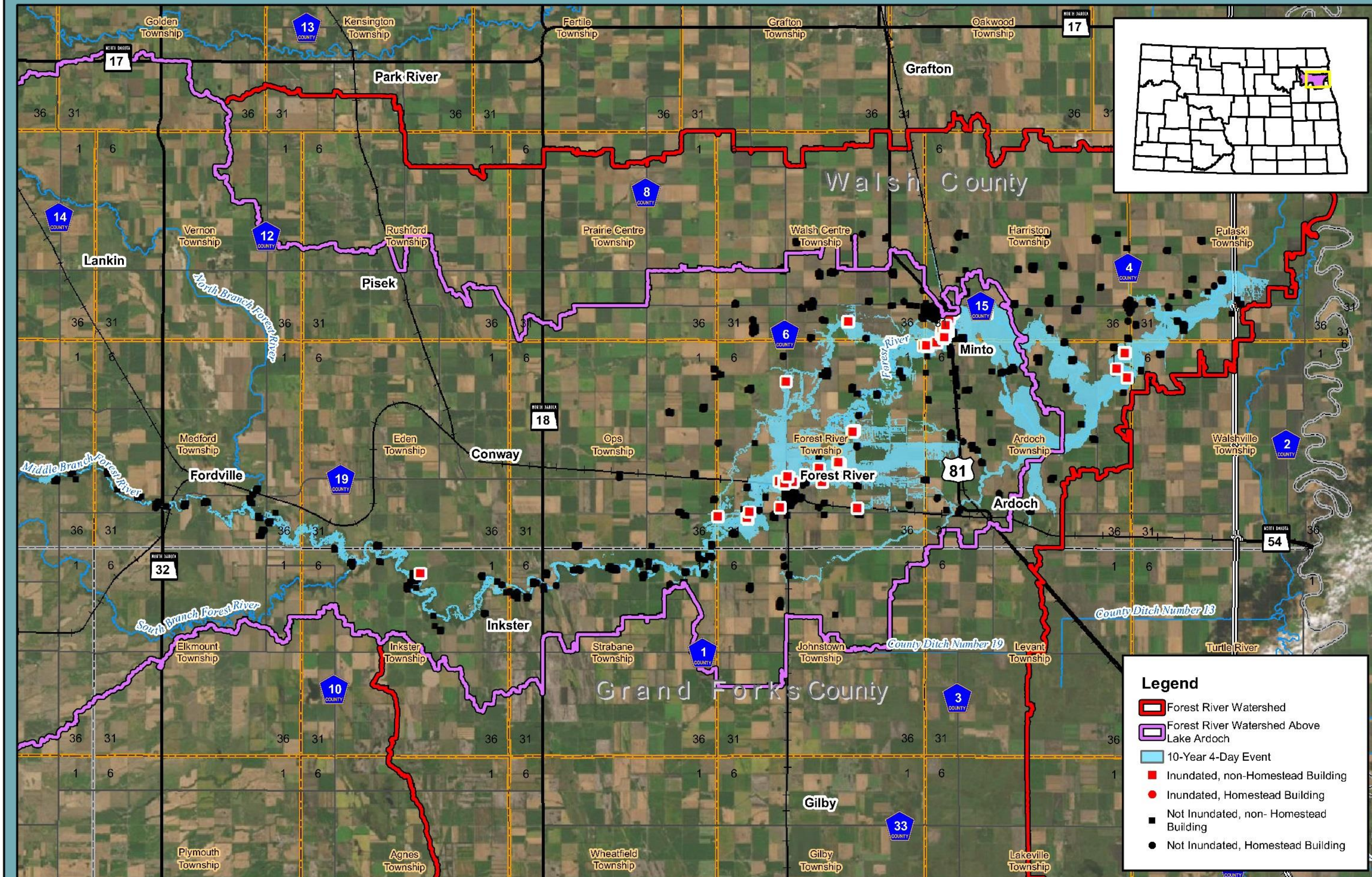
Figure B.12: 5-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N W E S

0 1.5 3 6 Miles

Houston Engineering Inc.



B-13

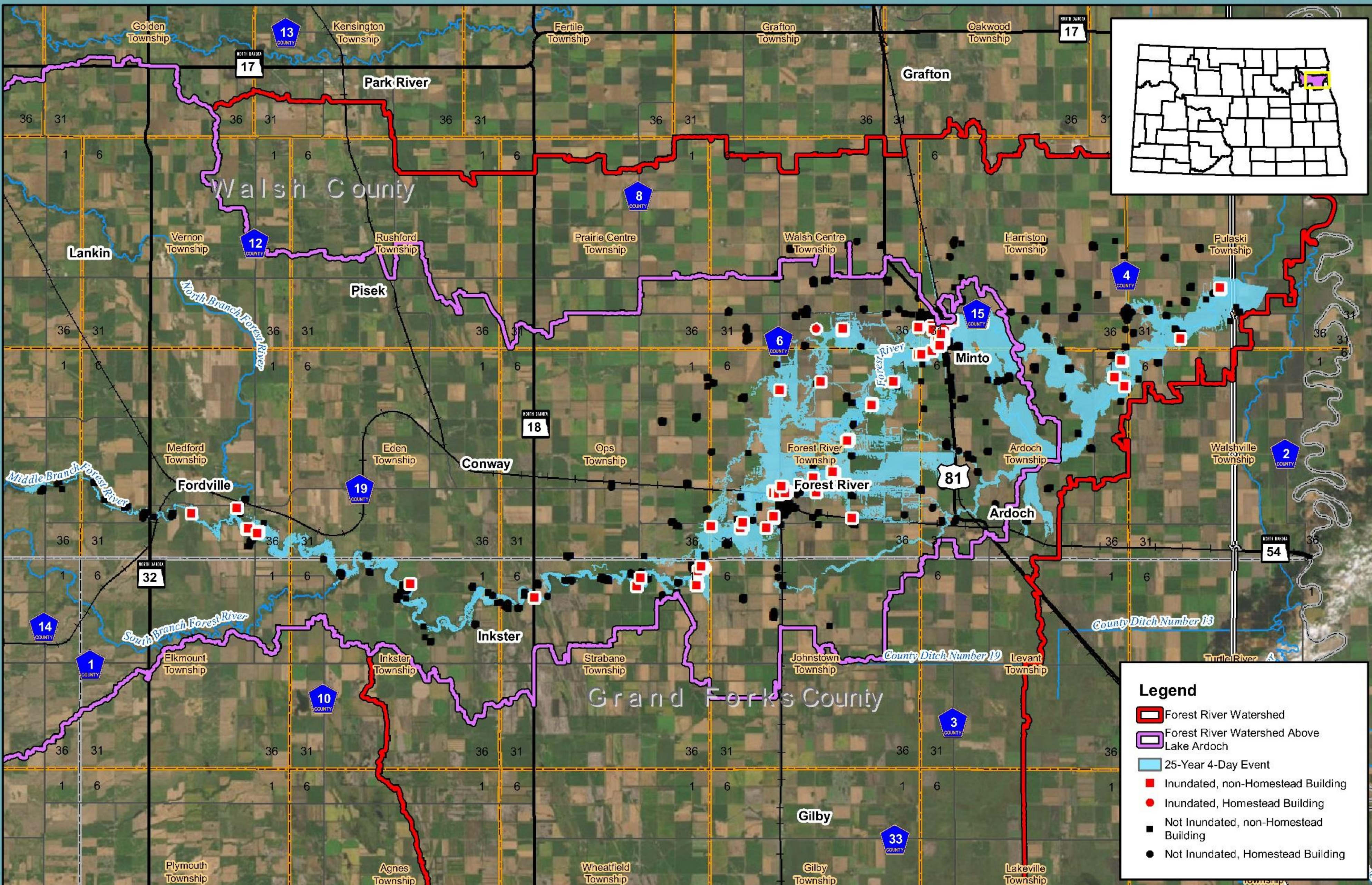
Figure B.13: 10-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N W E S

0 1.5 3 6 Miles

Houston Engineering Inc.

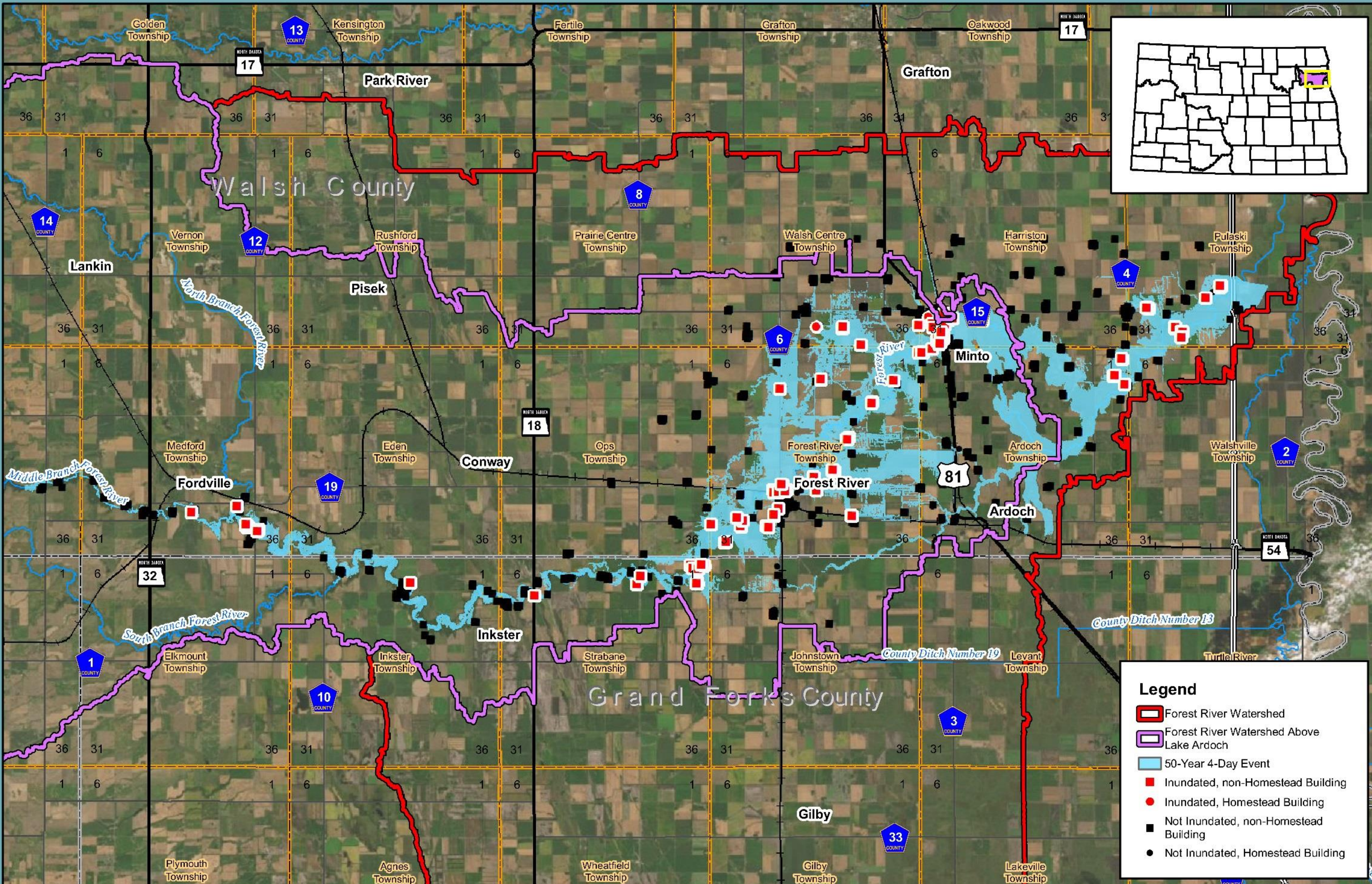


B-14

Figure B.14: 25-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.

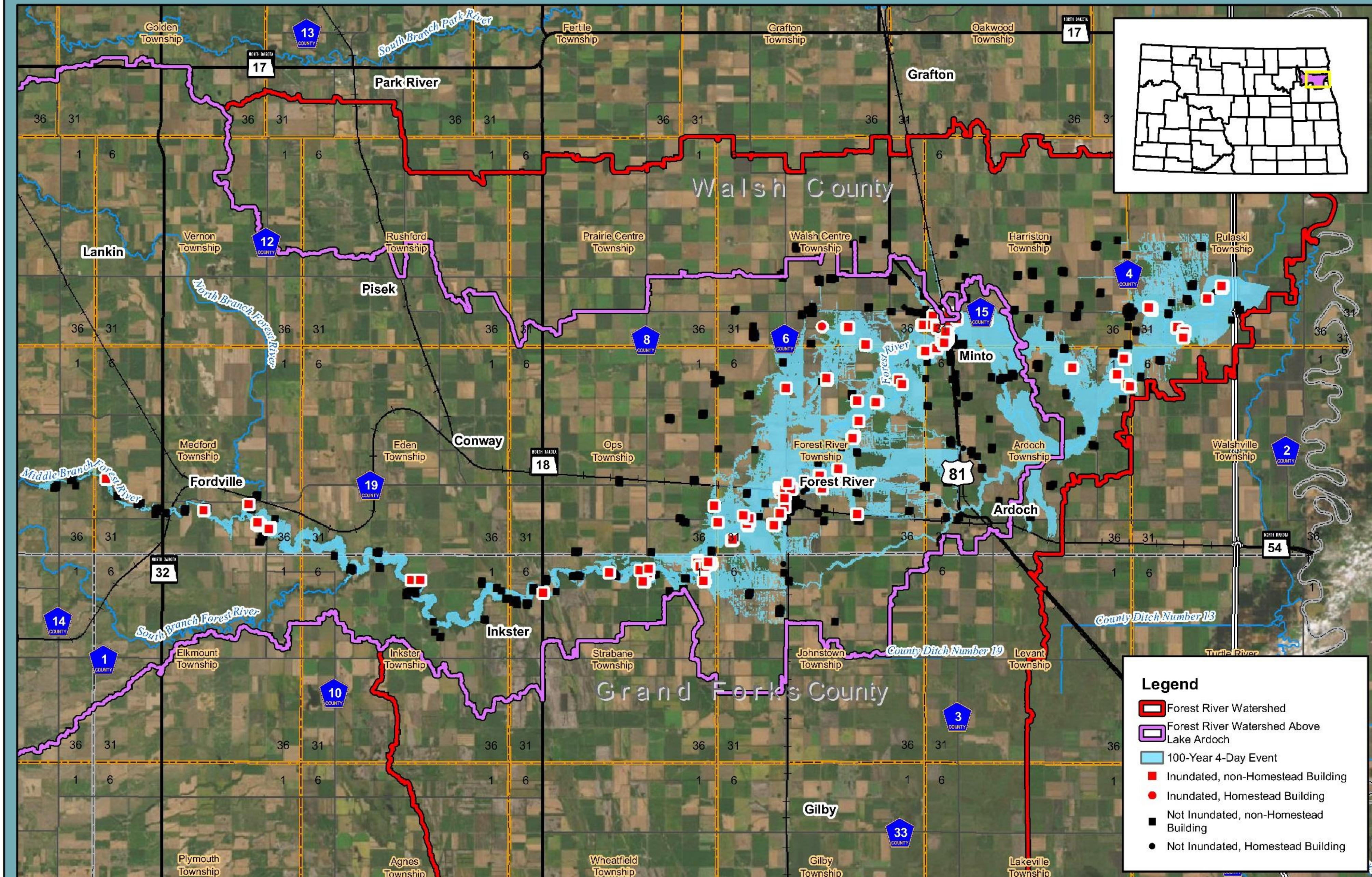


B-15

Figure B.15: 50-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.

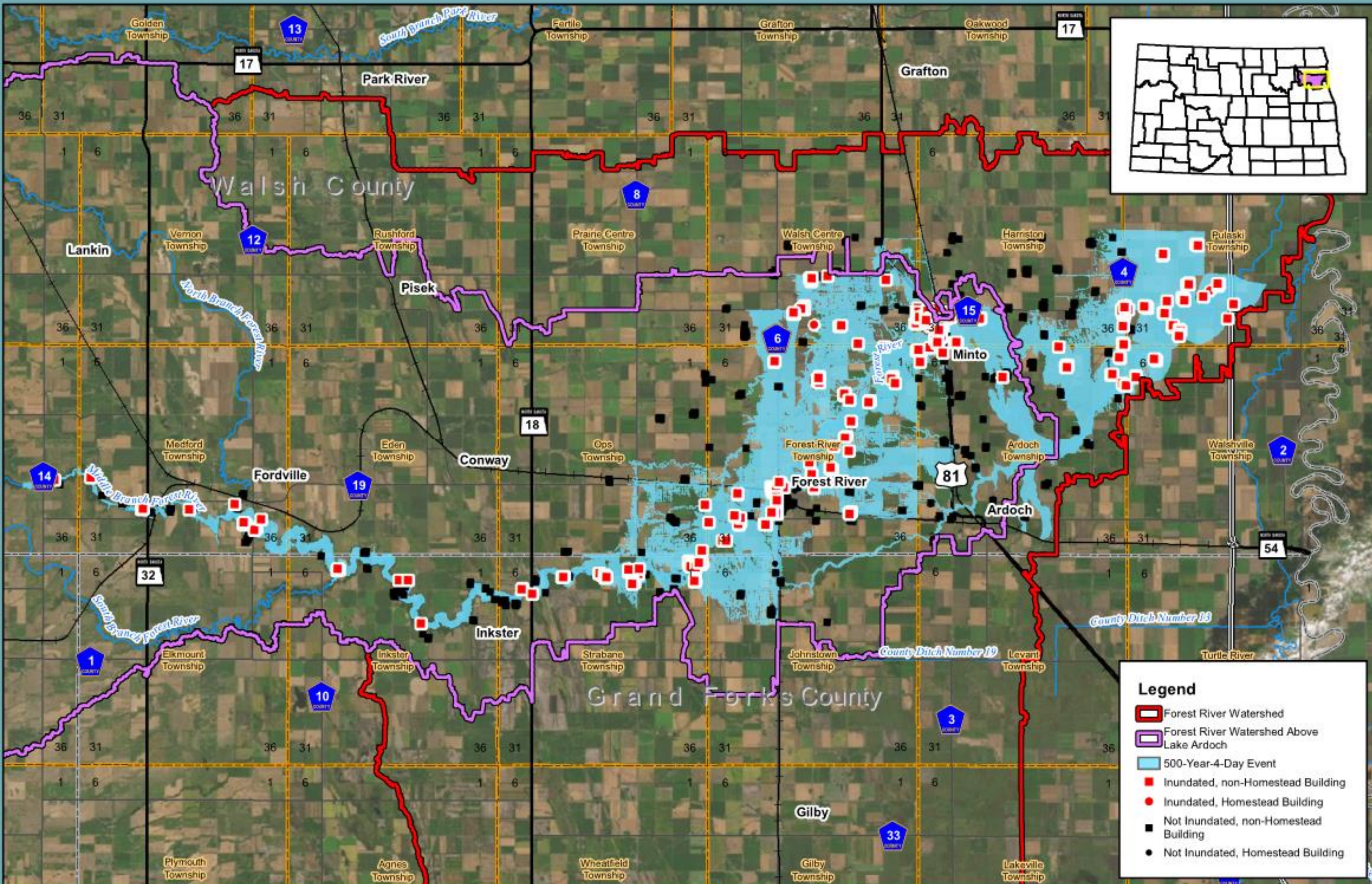


B-16

Figure B.16: 100-Year 4-Day Rainfall Inundation

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

Houston Engineering Inc.



B-17

Figure B.17: 500-Year 4-Day Rainfall Inundation

Forest River Watershed Plan

Existing Conditions Hydrology and Hydraulics Report

Walsh County Water Resource District

0 1.5 3 6 Miles

Houston Engineering Inc.

APPENDIX C

SYNTHETIC MODEL SENSITIVITY ANALYSIS

C.1 SYNTHETIC MODEL SENSITIVITY ANALYSIS

After the hydrologic and hydraulic models were calibrated, a sensitivity analysis was completed to assess the applicability of model parameters for floods occurring at different times of the year and for different rainfall event durations.

C.1.1 MANNING'S N-VALUES

The Manning's N-values in the hydraulic model were established through calibration of the June 2016 event, described in Section 3.3.1. During an early to mid-summer flood event, such as the calibration event, crops are maturing, and considerable vegetative cover is provided. To evaluate a minimal vegetative cover condition (crop residue cover), which would be representative of a spring or fall condition, Manning's N-values were adjusted. For a constant flow rate, it's expected that crop residue cover will decrease the channel retardance, thus increasing velocities, decreasing the water surface elevation, and decreasing inundation. A sensitivity analysis was completed by decreasing the Manning's N-value of cropland areas from 0.06 to 0.04 based on guidance from the *HEC-RAS Hydraulic Reference Manual* (USACE, 2016). The N-values used in the sensitivity analysis are shown in **Table 11.**

Table 11: Manning's N-Value Sensitivity – N-Value by Land Use

Land Use	Existing Conditions / Calibrated Manning's N-Value	Crop Residue Cover Manning's N-Value
Channel	0.05	0.05
Agricultural / Cropland	0.06	0.04
Wetlands	0.05	0.05
Forested	0.11	0.11

To evaluate the sensitivity analysis, discharge hydrographs for the 10-year and 100-year rainfall events were compared for the two conditions. Discharge hydrographs were calculated at the 9 reporting locations described in Section 4.1. **Figure C.1** shows the reporting locations, and the hydrographs are shown on **Figure C.2** through **Figure C.10**. The peak discharges for the 10-year and 100-year events at these locations are shown in **Table 12.**

Table 12: Manning's N-Value Sensitivity – Peak Discharges (cfs)

Return Period	10-year			100-year		
Manning's N-Value	Existing Conditions	Crop Residue Cover	*Difference (%)*	Existing Conditions	Crop Residue Cover	*Difference (%)*
Forest River at ND Highway 32	421	421	*0%*	1,934	1,934	*0%*
Forest River at 134th Ave NE	2,762	2,771	*0%*	8,541	8,607	*1%*
Forest River at ND Highway 18	2,841	2,853	*0%*	8,677	8,737	*1%*
Forest River at Walsh County Road 6	1,318	1,659	*21%*	2,040	2,571	*21%*
Forest River at First Street Crossing	2,925	3,039	*4%*	7,330	8,100	*10%*
Forest River at Walsh County Road 4	4,184	4,723	*11%*	11,434	12,740	*10%*
Forest River North Breakout at 148th Ave NE	1,852	1,621	*-14%*	4,789	5,341	*10%*
Ardoch Coulee Breakout at US Highway 81	388	511	*24%*	608	705	*14%*
Ardoch Coulee at US Highway 81	375	376	*0%*	965	964	*0%*

The total inundation area was also evaluated for the two Manning's N-value conditions. The total inundation for the 10-year and 100-year rainfall events are shown in **Table 13**.

Table 13: Manning's N-Value Sensitivity – Total Inundation (acres)

Land Use	Existing Conditions / Calibrated Manning's N-Value	Crop Residue Cover Manning's N-Value Sensitivity	*Difference (%)*
10-year	9,269	8,948	*-3.6%*
100-year	17,283	17,103	*-1.1%*

While the crop residue cover Manning N values produce higher peak flows at reporting locations throughout the watershed, higher levels of inundation are seen for the existing conditions, or vegetative cover scenario. Therefore, higher damages would occur with the vegetative cover condition where crops are maturing, and inundation is greater than the crop residue cover condition. So, the existing conditions or calibrated Manning N-value is ideal because it represents the most critical scenario with respect to damages in the watershed, and is deemed appropriate for use in synthetic rainfall analysis.

C.1.2 SYNTHETIC EVENT DURATIONS – 24-HOUR, 4-DAY, 10-DAY

Three synthetic event durations were simulated; 24-hour, 4-day, and 10-day, to determine which duration storm event produces highest peak flow and greatest impacts. The 24-hour and 10-day storms were developed in the same way as the 4-day duration event described in Section 3.4. NOAA Atlas 14 rainfall depths were calculated based on GIS gridded data, the rainfall depths were adjusted based on areal reduction factors in *TP-49* (Miller, 1964). The nested distribution for each duration and return period was calculated based on *NEH, Part 630, Chapter 4* (NRCS, 2015). Runoff Curve Numbers were adjusted to the appropriate duration to match the corresponding synthetic rainfall duration based on guidance from *TR-60* (NRCS, 2005). The average rainfall depths for each duration storm event are shown in **Table 14.**

Table 14: Rainfall Duration Sensitivity – Rainfall Depths

Return Period	NOAA Atlas 14 Rainfall Depth (inches)			HEC-HMS Rainfall Depth* (inches)		
	24-hour	4-day	10-day	24-hour	4-day	10-day
10-year	3.34	4.17	5.19	3.04	3.94	4.95
100-year	5.65	6.82	7.88	5.14	6.44	7.52

* Average rainfall depth adjusted for areal reduction based on watershed size of 570 square miles

Peak discharges were calculated downstream of Lake Ardoch for the three storm durations for the 10-year and 100-year events and are shown in **Table 15.** Discharge hydrographs downstream of Lake Ardoch for the three storm durations are shown on **Figure C.11**. Evaluation of the results indicates that the 4-day duration rainfall event produces the highest discharge downstream of the damage center. Therefore, the 4-day duration event was selected to be analyzed for the synthetic rainfall events for this study.

Table 15: Rainfall Duration Sensitivity – Peak Discharges (cfs)

Return Period	Forest River at Walsh County Road 4 Downstream of Lake Ardoch		
	24-hour	4-day	10-day
10-year	3,511	4,184	2,891
100-year	10,410	11,434	9,004

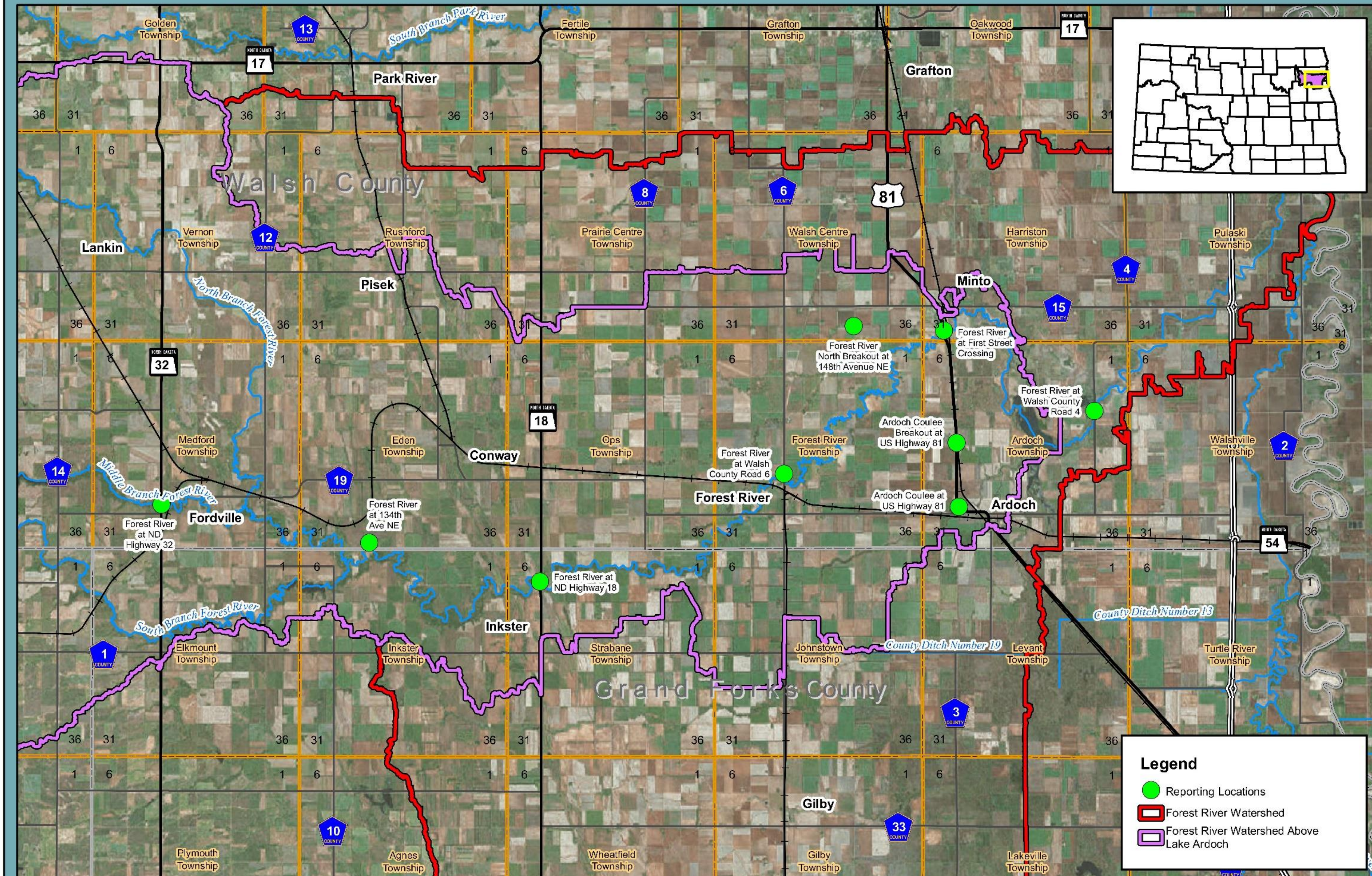
C.1.3 CURVE NUMBER – SEASONAL VARIATION

Runoff volumes can vary based on multiple factors including the time of year, vegetative cover, and water content within the soil. During the spring, most cropland is covered by a certain degree of crop residue cover depending on individual management practices by producers. During the spring, these types of soil conditions can often result in increased runoff due to decreased infiltration. During the growing season, these same lands consist of vegetative cover from growing crops. The vegetative cover results in decreased runoff due to increased infiltration. However, runoff during any time of the year is also influenced by the water content within the soil. In the Forest River Watershed, this is primarily driven by the amount of precipitation occurring prior to the rainfall event, and weather patterns allowing for drying of topsoil.

Due to the numerous factors that occur during a specific rainfall event, such as time of the year, vegetative land cover, water content of the soil, etc., synthetic rainfall scenarios are developed to simulate a typical event that would occur within a watershed. A primary focus of the planning effort is to reduce agricultural damages occurring as a result of rainfall events. Therefore, the growing season runoff Curve Number values were deemed appropriate for use in synthetic rainfall analysis. Growing season Curve Numbers used for synthetic rainfall scenarios are described in **Appendix A** of this report.

APPENDIX C

Synthetic Model Sensitivity Analysis



C-1

Figure C.1: Sensitivity Analysis Reporting Locations

Forest River Watershed Plan
Existing Conditions Hydrology and Hydraulics Report
Walsh County Water Resource District

N W E S

0 1.5 3 6 Miles

Houston Engineering Inc.

***Figure C.2:** Manning's N-Value Hydrographs – Forest River at ND Highway 32*

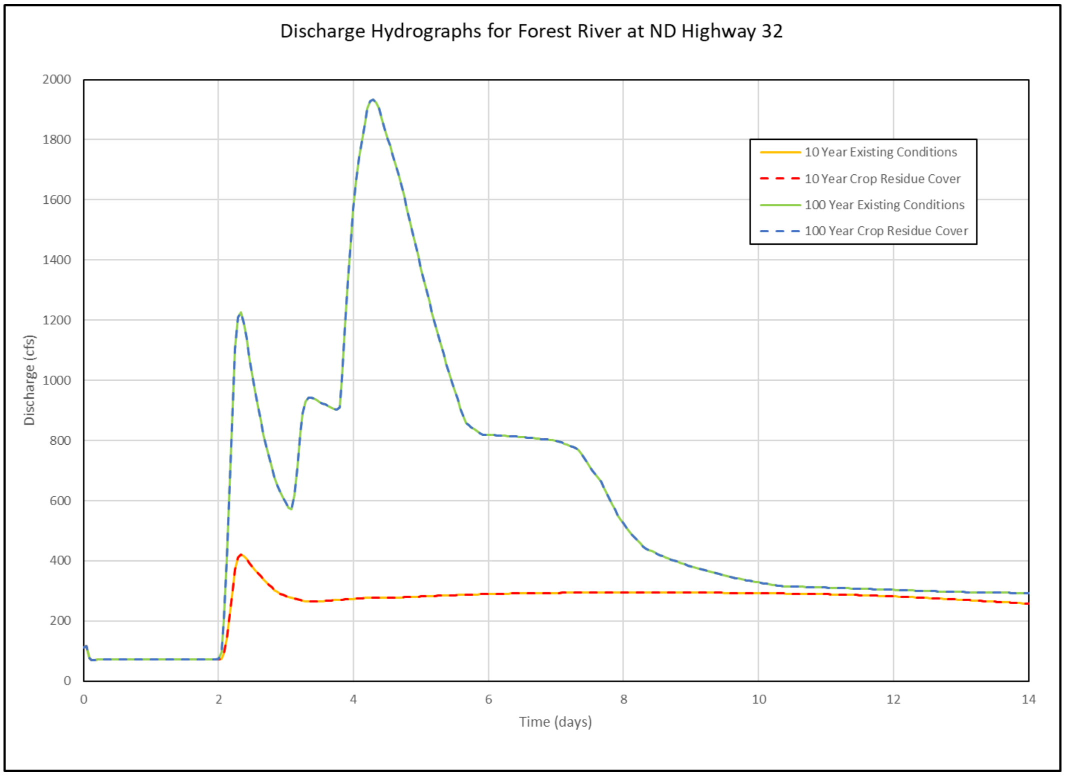


***Figure C.3:** Manning's N-Value Hydrographs – Forest River at 134th Ave NE*

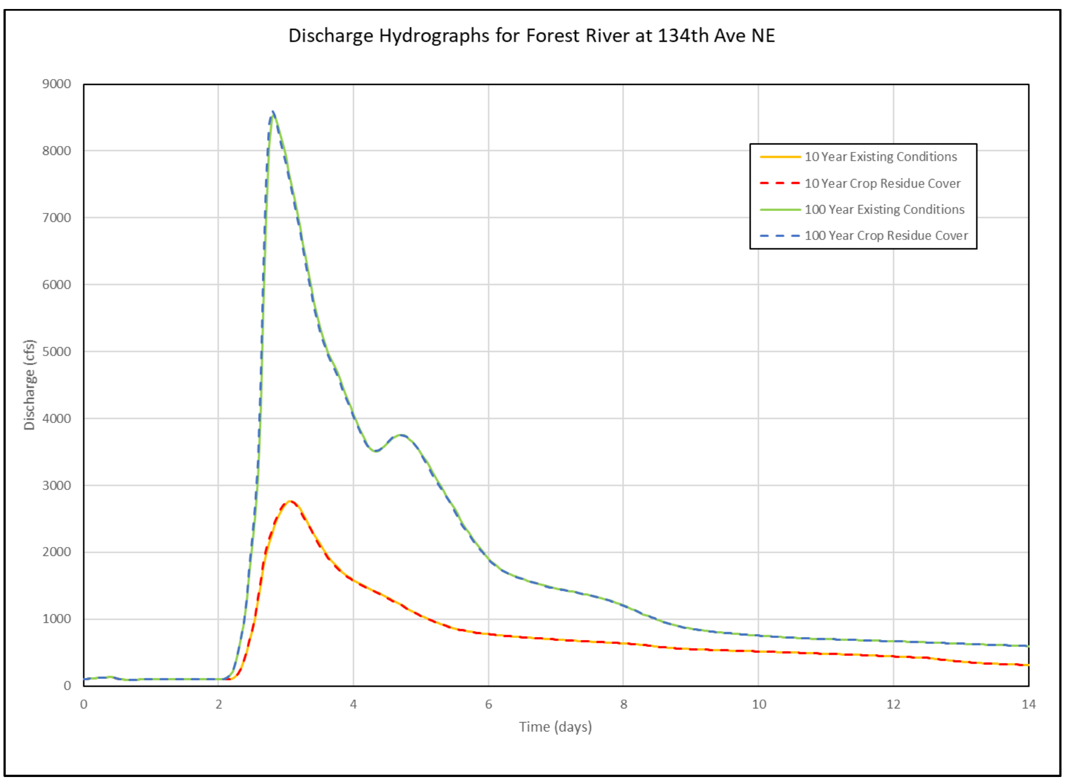


Figure C.4: *Manning's N-Value Hydrographs – Forest River at ND Highway 18*

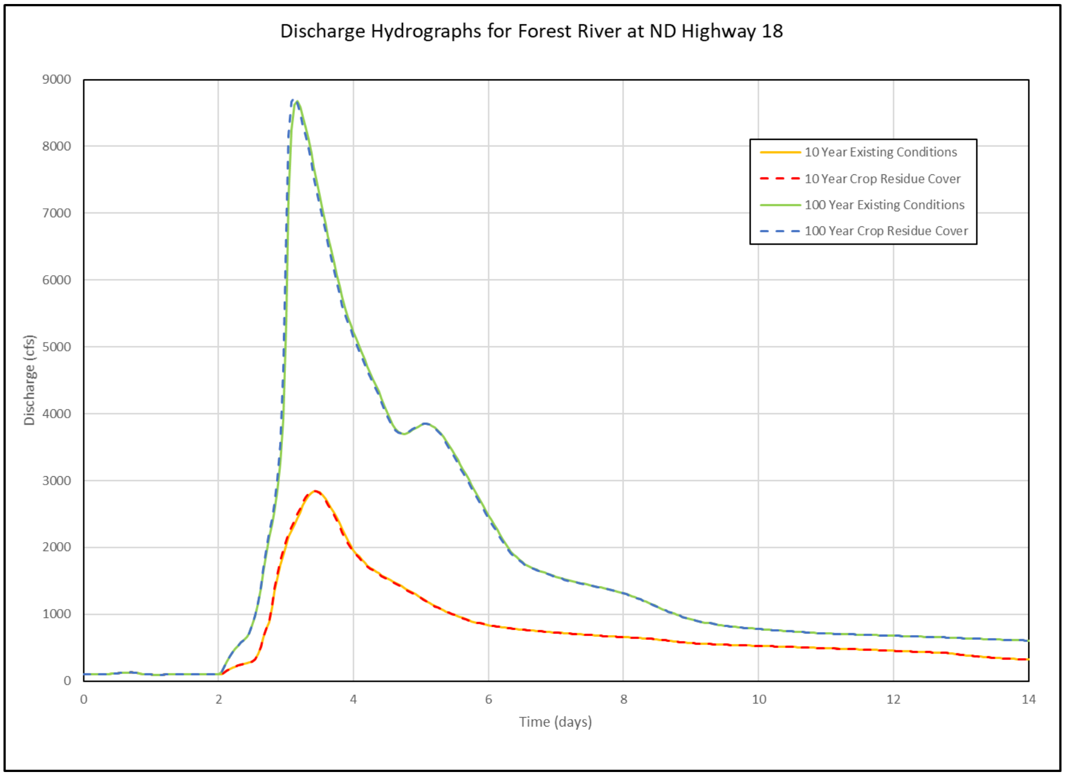


Figure C.5: *Manning's N-Value Hydrographs – Forest River at Walsh County Road 6*

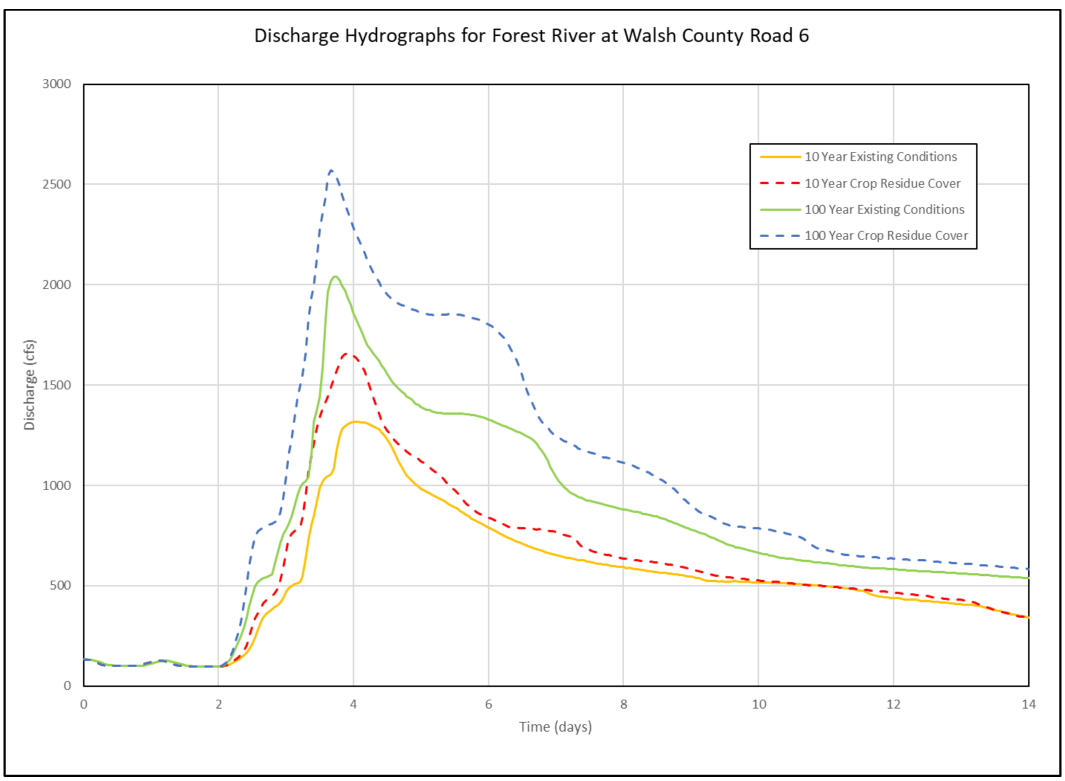


Figure C.6: Manning's N-Value Hydrographs – Forest River at First Street Crossing

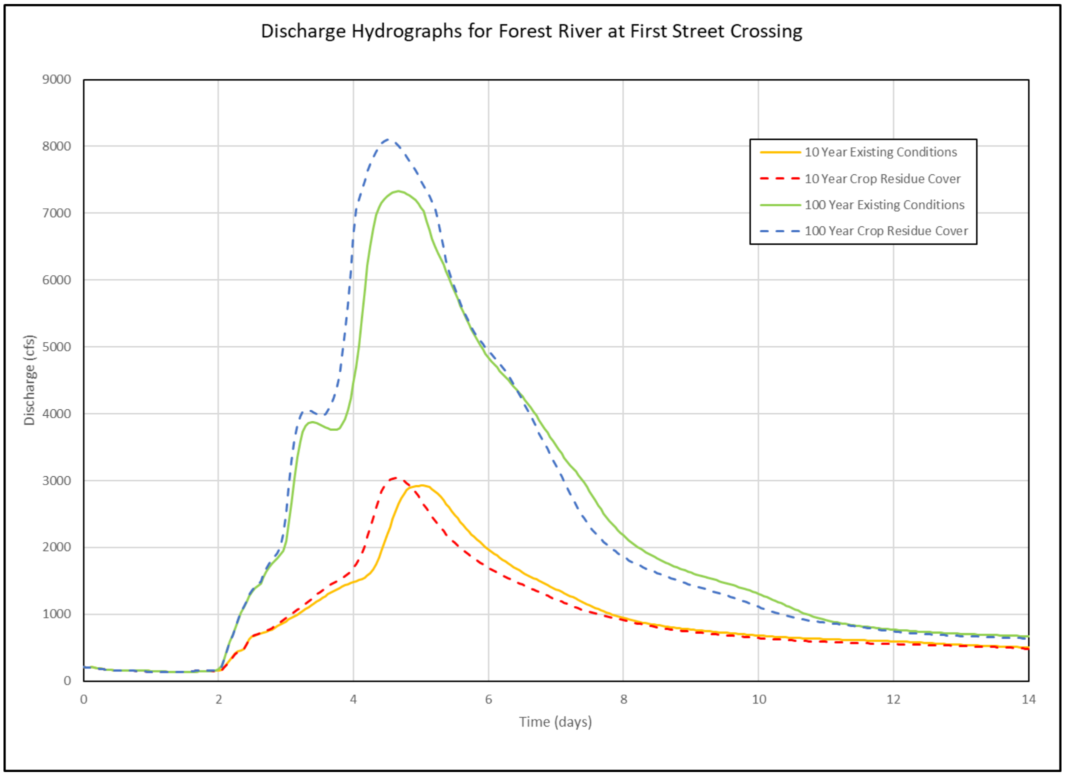


Figure C.7: Manning's N-Value Hydrographs – Forest River at Walsh County Road 4

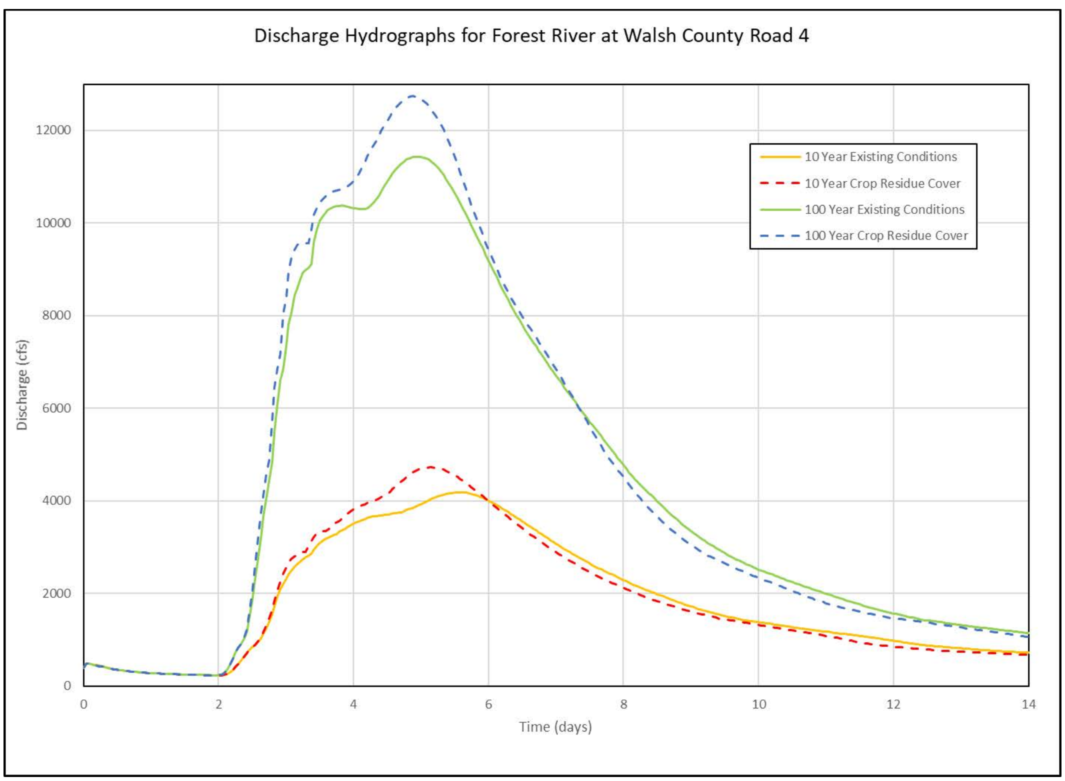


Figure C.8: Manning's N-Value Hydrographs – Forest River North Breakout at 148th Ave NE

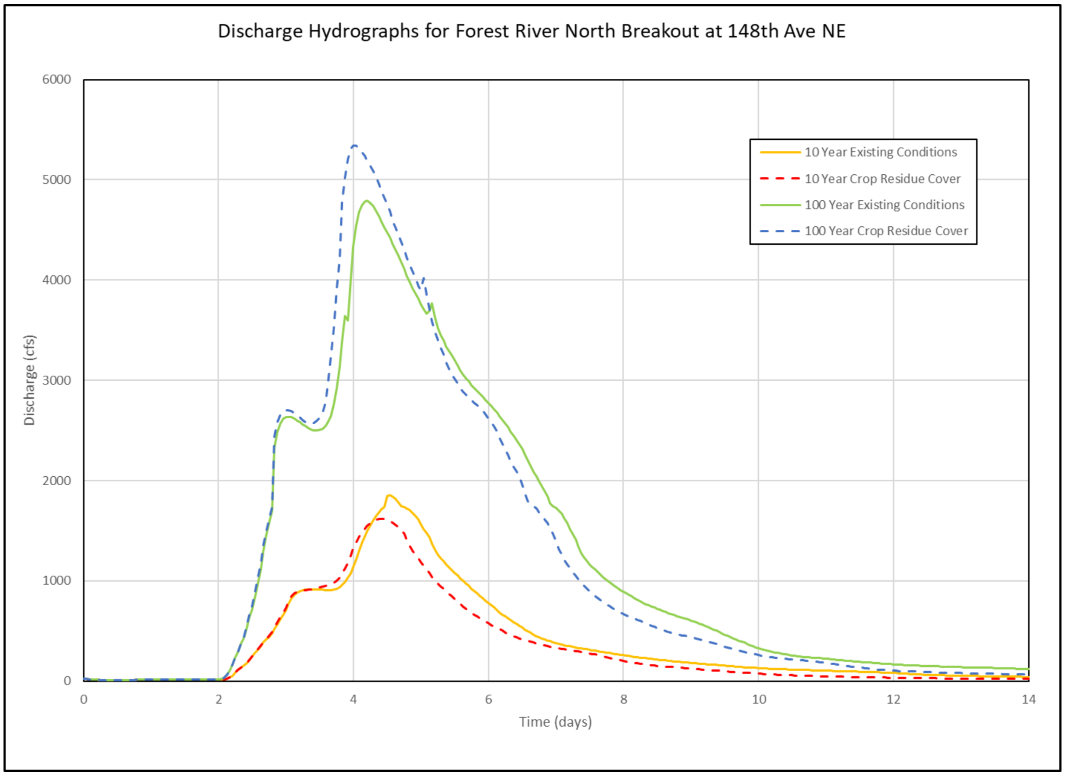


Figure C.9: Manning's N-Value Hydrographs – Ardoch Coulee Breakout at US Highway 81

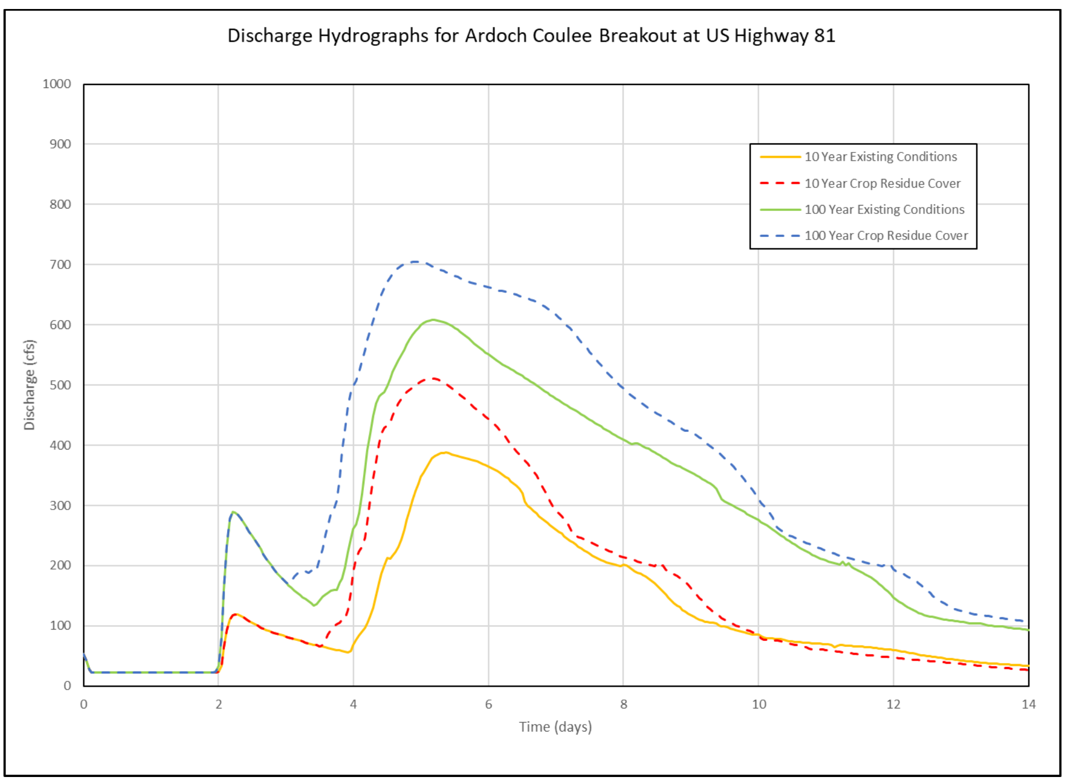


Figure C.10: *Manning's N-Value Hydrographs – Ardoch Coulee at US Highway 81*

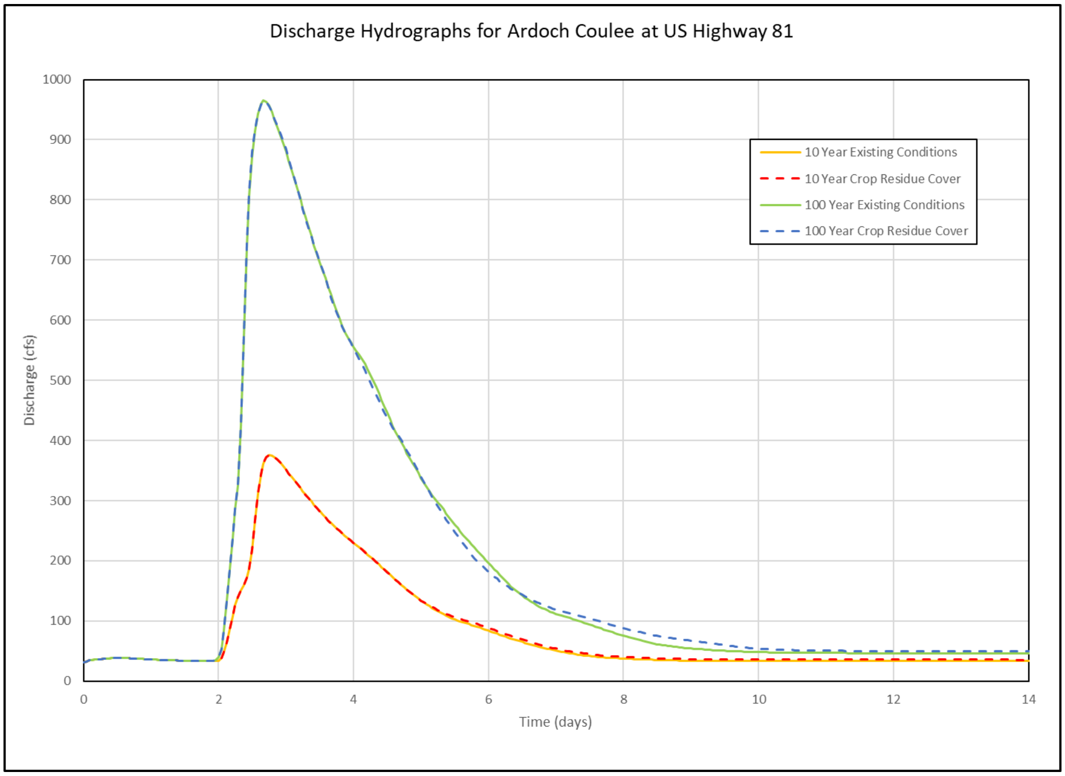
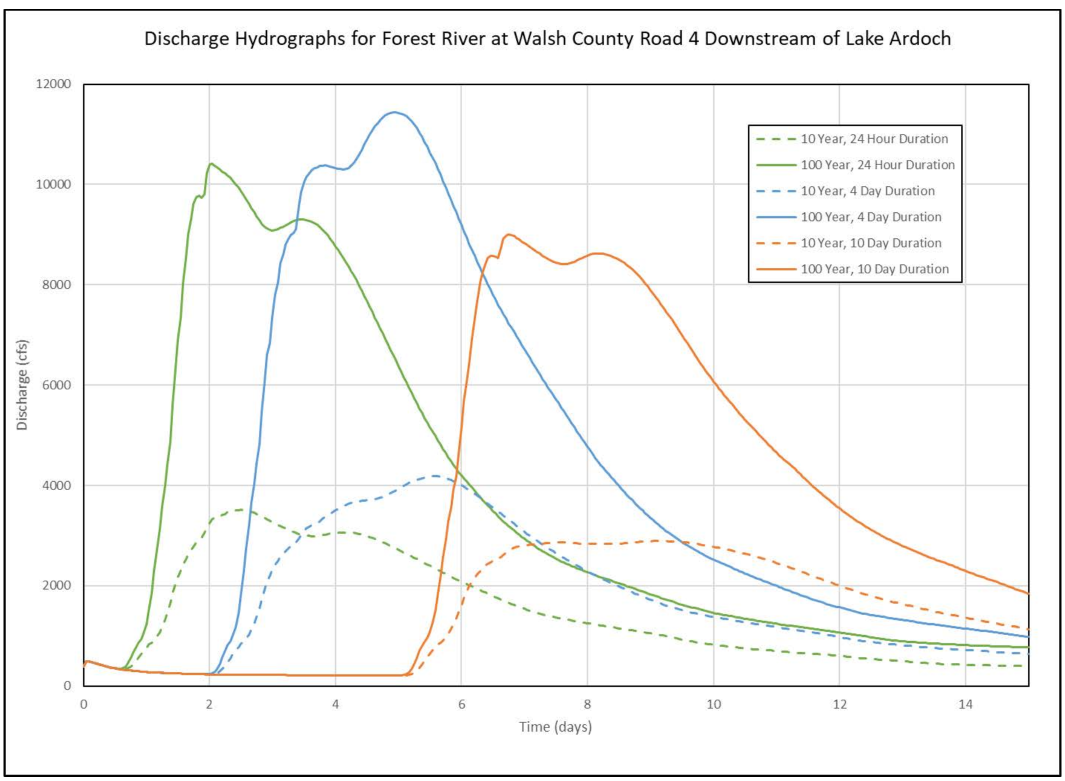


Figure C.11: *Duration Hydrographs – Downstream of Lake Ardoch*



APPENDIX D

OFFSITE WETLAND DELINEATION REPORT

OFFSITE WETLAND DELINEATION REPORT

Ardoch Coulee
Forest River, ND

Prepared for:

Forest River Watershed District

600 Cooper Avenue

Grafton, ND 58237

I hereby certify that this report was prepared by me or under my direct supervision.

Draft Print

02/21/2020 2:13:49 PM

Hannah G. Erdmann
Houston Engineering Inc.
CWDT #5254

Date: January 3, 2020

HEI Project no. 7135-0021

HoustonEngineering Inc.

1 INTRODUCTION

In November of 2019, staff from Houston Engineering, Inc. completed the components of an office wetland assessment to identify and delineate areas potentially meeting wetland criteria for a project on behalf of the Forest River Watershed District. Work was completed in accordance with the 1987 Army Corps of Engineers Wetland Delineation Manual, and the Great Plains Supplement Delineation Manual. **Attachment 1 – Project Location Map** shows the location of the subject property (i.e., project), which is located within Grand Forks County, North Dakota.

The purpose of this report is to identify 1) wetlands and waters that could be impacted by the project, and 2) to gather data regarding possible connections of these wetlands to jurisdictional wetlands. Further analysis of wetland impacts (full delineations) may be conducted as part of a Section 404 permit application if the wetlands are considered jurisdictional by the US Army Corps of Engineers.

2. DESCRIPTION OF THE PROJECT

The Forest River Watershed is planning a diversion project along the Forest River near Ardoch, North Dakota to reduce flood damages in surrounding communities. (**Attachment 1 – Project Location Map**). The project activities will include construction of a diversion from the Forest River which will travel through the survey area and connect with the unnamed coulee that flows northeast into Lake Ardoch.

3. DESCRIPTION OF THE SITE

The project is in Ops, Forest River, Johnstown, and Strabane Townships, south of the town of Forest River in Grand Forks County, North Dakota (general latitude: 48.185001, longitude: -97.483051). The land use in the area consists generally of annually tilled cropland and rural residential properties. The townships/range/sections are shown in **Table 1**.

Table 1. Ardoch Coulee project location information

Township (N)	Range (W)	Section(s)
154	53	3-10
	54	1, 12
155	53	31-34
	54	36

4. METHODS

The office delineation methods used for this assessment are described in the 1987 USACE Manual. Additionally, methodology from the Great Plains Regional Supplement to the Corps of Engineers Wetland Delineation Manual was followed (USACE 2010). The initial offsite review for the project site included assessment using U.S. Fish and Wildlife Service National Wetland Inventory (USFWS NWI 2019, **Table 2**), the digital soil surveys of Grand Forks County (USDA-NRCS 2019) (**Attachment 3**), and historic aerial photography from 2012 to 2017 (**Attachment 4**). Wetland areas were identified, and LiDAR was used to draw the extent of each wetland. We also used footage and imagery from drone flights within the project area. No formal wetland delineations were done at this time; thus we did not record complete data on wetland delineation data forms.

5. RESULTS

Site Description: The project is located 0.75 miles south of Forest River, Grand Forks County, North Dakota. Generally, the surrounding land is used for cultivated agriculture, some pastureland, and residential properties.

Description of Potential Wetland Areas: There are two Other Waters and 150 Wetlands in the vicinity of the proposed project (**Attachment 2 – Wetland Map** and **Table 2**).

Wetland types within the survey area include palustrine, emergent, temporary flooded/seasonally flooded (PEMA/C); palustrine, aquatic bed, semi-permanently flooded (PABF); riverine, intermittent, streambed, seasonally flooded (R4SBC); and palustrine, forested, temporarily flooded/seasonally flooded (PFOA/C).

Table 2: Offsite identified Other Waters and Wetlands and their characteristics.

Wetland number	NWI Listed	Latitude	Longitude	Acres
OW 1	R2UBG	48.200950	-97.506581	3.28
OW 2	R2UBG/PEM1C/PEM1A/PFOA/ PFUSA/R2USA	48.189036	-97.520245	28.83
1	not listed	48.201336	-97.535321	0.19
2	not listed	48.200877	-97.53542	0.10
3	not listed	48.200223	-97.534964	0.82
4	not listed	48.200888	-97.534493	0.13
5	not listed	48.201518	-97.533359	0.79
6	PEM1/PFOA/PFOC	48.200818	-97.53273	6.22
7	not listed	48.202185	-97.530731	0.31
8	not listed	48.198376	-97.533144	2.85
9	not listed	48.200375	-97.528088	0.56
10	R4SBC	48.1957	-97.529605	0.49
11	not listed	48.201486	-97.525877	0.45
12	not listed	48.200869	-97.525464	0.39
13	PEM1A	48.196374	-97.526464	1.28
14	not listed	48.186434	-97.526191	0.60
15	not listed	48.189963	-97.522345	1.07
16	PEM1C	48.196828	-97.520799	0.56
17	not listed	48.19749	-97.519132	0.45

18	not listed	48.189979	-97.518064	0.84
19	not listed	48.198786	-97.51656	1.37
20	PEM1C	48.194107	-97.516568	0.64
21	not listed	48.193093	-97.515702	0.53
22	PEM1C	48.198294	-97.515365	0.35
23	not listed	48.20218	-97.513114	0.33
24	not listed	48.188726	-97.513286	0.61
25	PEM1C	48.197306	-97.509328	4.24
26	not listed	48.186584	-97.511079	0.61
27	not listed	48.194842	-97.508542	0.09
28	PEM1/PFOA	48.199783	-97.50608	1.48
29	PEM1C	48.198608	-97.504824	0.40
30	not listed	48.197436	-97.505541	0.44
31	not listed	48.190188	-97.507607	0.32
32	not listed	48.18822	-97.505864	1.12
33	not listed	48.186912	-97.505903	0.99
34	not listed	48.186715	-97.504501	1.22
35	not listed	48.188647	-97.504696	0.48
36	not listed	48.188143	-97.503991	0.32
37	not listed	48.193319	-97.503275	0.35
38	not listed	48.192099	-97.501976	1.40
39	not listed	48.194051	-97.501949	0.19
40	not listed	48.196487	-97.501545	1.05
41	not listed	48.186074	-97.500807	1.55
42	not listed	48.188381	-97.499245	0.95
43	not listed	48.198893	-97.499588	0.34
44	not listed	48.198186	-97.49828	0.62
45	not listed	48.197456	-97.496516	0.52
46	not listed	48.192821	-97.497903	0.24
47	not listed	48.188508	-97.496726	0.22
48	not listed	48.199838	-97.494429	0.58
49	not listed	48.201635	-97.493111	1.55
50	not listed	48.201367	-97.49116	5.15
51	not listed	48.186366	-97.491492	1.17
52	not listed	48.194886	-97.489883	0.18
53	not listed	48.187051	-97.488578	0.80
54	not listed	48.185908	-97.487519	0.79
55	not listed	48.188836	-97.487905	0.19
56	not listed	48.194885	-97.485936	0.13
57	not listed	48.188707	-97.484609	0.70
58	not listed	48.19875	-97.480016	1.08

59	not listed	48.199228	-97.479373	0.16
60	not listed	48.201398	-97.47824	0.29
61	not listed	48.190265	-97.480778	0.39
62	not listed	48.189721	-97.480223	0.79
63	not listed	48.188453	-97.47788	0.56
64	not listed	48.193761	-97.476097	0.27
65	not listed	48.198831	-97.4761	0.78
66	not listed	48.187744	-97.476197	0.21
67	not listed	48.188614	-97.472734	1.47
68	PEM1C	48.187031	-97.47289	1.37
69	not listed	48.185712	-97.472112	1.92
70	not listed	48.193792	-97.469829	0.51
71	not listed	48.191841	-97.46969	0.49
72	not listed	48.189662	-97.469709	0.26
73	not listed	48.188345	-97.46991	0.23
74	not listed	48.185343	-97.469755	0.41
75	not listed	48.191658	-97.468577	0.49
76	not listed	48.187963	-97.469068	0.34
77	not listed	48.193506	-97.466591	0.42
78	not listed	48.190729	-97.462474	0.79
79	not listed	48.192519	-97.461674	0.25
80	not listed	48.189536	-97.461897	0.45
81	not listed	48.192716	-97.460589	0.19
82	not listed	48.191829	-97.460218	0.29
83	not listed	48.188012	-97.461085	0.17
84	not listed	48.189547	-97.458695	0.23
85	not listed	48.187033	-97.458885	0.31
86	R3SBC	48.196286	-97.456979	3.22
87	not listed	48.200136	-97.448378	0.51
88	not listed	48.196154	-97.449574	1.68
89	not listed	48.200822	-97.438612	5.53
90	not listed	48.200843	-97.430638	1.33
91	not listed	48.198735	-97.428396	0.92
92	PEM1C/PEM1F/PABF/R4SBC	48.188525	-97.440912	65.20
93	not listed	48.186117	-97.445312	0.98
94	PEM1A	48.18391	-97.52983	0.67
95	not listed	48.183452	-97.524486	0.17
96	not listed	48.184516	-97.519816	0.71
97	not listed	48.181653	-97.525486	0.24
98	not listed	48.177903	-97.53386	0.15
99	not listed	48.177299	-97.534486	0.38

100	not listed	48.174216	-97.522148	2.48
101	not listed	48.17111	-97.534607	1.34
102	not listed	48.170528	-97.535616	0.35
103	not listed	48.169858	-97.535035	0.57
104	not listed	48.172597	-97.524554	0.53
105	not listed	48.171815	-97.523381	2.21
106	not listed	48.171213	-97.524349	0.58
107	not listed	48.172389	-97.520683	0.75
108	not listed	48.170857	-97.522061	1.04
109	not listed	48.17024	-97.52106	0.62
110	not listed	48.174059	-97.516409	0.36
111	not listed	48.166977	-97.520783	1.95
112	not listed	48.166192	-97.519181	0.35
113	not listed	48.166266	-97.516246	0.97
114	not listed	48.166487	-97.515068	1.19
115	not listed	48.181187	-97.509677	0.49
116	not listed	48.178023	-97.509148	7.23
117	not listed	48.178556	-97.506524	1.43
118	not listed	48.176471	-97.50643	0.25
119	not listed	48.176065	-97.50118	1.18
120	not listed	48.174406	-97.504207	0.25
121	not listed	48.173633	-97.500046	1.25
122	PEM1Cx/R4SBC	48.181542	-97.493212	6.03
123	not listed	48.173265	-97.496904	0.37
124	R4SBC	48.172549	-97.497615	1.07
125	not listed	48.173292	-97.495142	0.37
126	R4SBC	48.169454	-97.491443	0.44
127	not listed	48.166234	-97.492688	0.48
128	not listed	48.172355	-97.486439	0.51
129	not listed	48.167614	-97.486739	1.16
130	not listed	48.183981	-97.474167	0.61
131	PEM1C/PABFx	48.182314	-97.463483	5.88
132	PEM1C	48.18014	-97.461799	0.22
133	not listed	48.175672	-97.461525	0.58
134	not listed	48.175252	-97.459035	0.25
135	not listed	48.172286	-97.462285	0.47
136	PEM1A	48.172465	-97.460552	1.02
137	R34SBC	48.174004	-97.454199	0.29
138	PEM1A	48.175383	-97.451529	2.28
139	PEM1Cx	48.177543	-97.448646	1.48
140	R4SBC	48.179604	-97.44918	1.04

141	not listed	48.171116	-97.460487	0.79
142	PEM1A	48.168808	-97.460383	2.34
143	not listed	48.168847	-97.457579	1.51
144	not listed	48.178726	-97.4362	0.79
145	not listed	48.178682	-97.435046	0.47
146	not listed	48.168708	-97.44271	3.24
147	not listed	48.168549	-97.44015	2.61
148	not listed	48.168845	-97.438503	1.88
149	not listed	48.166755	-97.441652	1.50
150	not listed	48.166643	-97.43691	3.88

Soil Hydric Ratings: Some soils in the survey area are considered hydric as shown in **Attachment 3**. Dominant soils (top 75 % of total acres within the survey area) are shown in **Table 3**.

Table 3: Dominant soils within the survey area.

Map unit symbol	Map unit name	Rating	Acres	Percent of survey area
I201A	Glyndon silt loam, 0 to 2 percent slopes	13	3,340.90	41.20%
I490A	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	20	519.7	6.40%
I468A	Divide loam, 0 to 2 percent slopes	5	633.8	7.80%
I594A	LaDelle silt loam, 0 to 2 percent slopes, occasionally flooded	5	321.3	4.00%
I202A	Gardena silt loam, 0 to 2 percent slopes	5	290.4	3.60%
I119A	Bearden silty clay loam, 0 to 2 percent slopes	10	257.2	3.20%
I356A	Ulen fine sandy loam, 0 to 2 percent slopes	12	251.8	3.10%
I159A	Wyndmere-Tiffany fine sandy loams, 0 to 2 percent slopes	40	188.4	2.30%
I193A	Bearden-Perella silty clay loams, 0 to 2 percent slopes	32	175.5	2.20%
I383A	Overly silty clay loam, 0 to 2 percent slopes	5	161.4	2.00%
Dominant soils sub-total			**6140.40**	**75.80%**
Non-dominant soils sub-total			**1960.29**	**24.20%**
Total			**8100.39**	**100.00%**

Description of Wetland Connection Status: The drainage of the larger area is generally to the east, toward a perennial stream that leads to Lake Ardoch, which drains into the Red River of the North approximately 17 miles northeast of the survey area (**Attachment 1 – Project Location Map**). The topography in this area consists of rolling hills to steep slopes with well-developed drainage patterns leading to larger bodies of water.

6. CONCLUSIONS

From this initial assessment, we did observe evidence of wetland presence at the site. We also observed Other Waters including the Forest River and unnamed streams. These aquatic resources may have surface water connections with navigable waters.

7. REFERENCES

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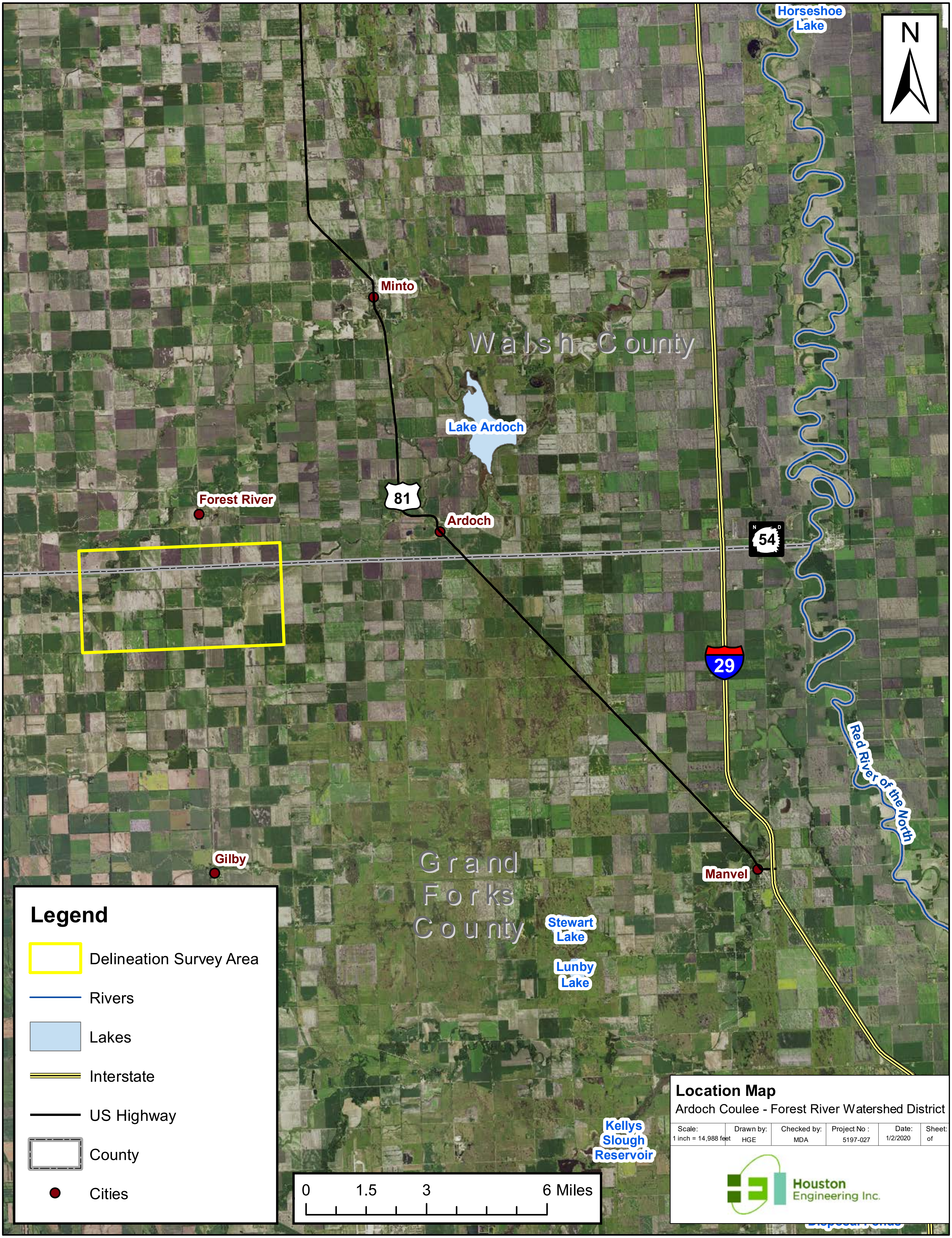
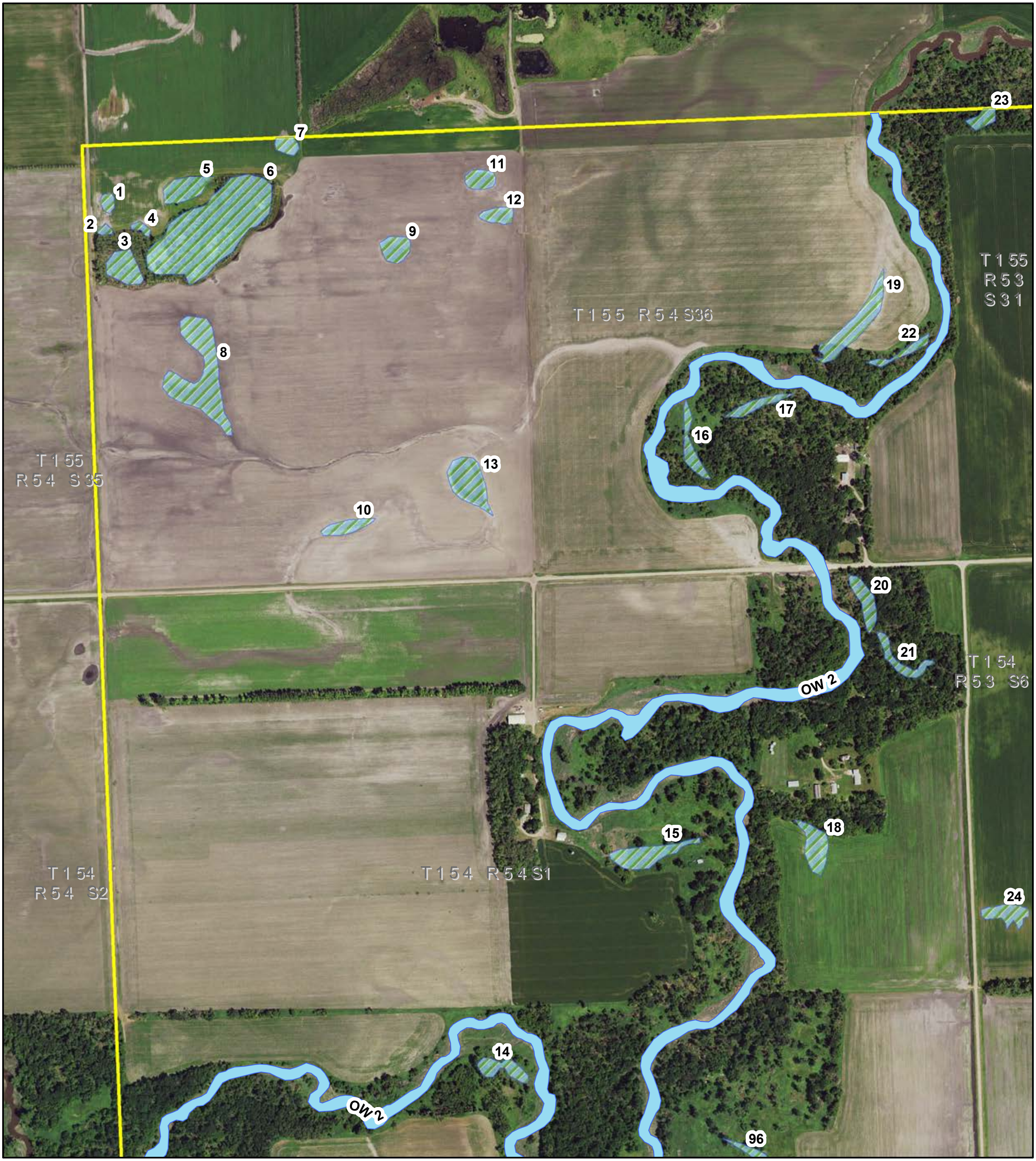
Attachment 1

Project Location Map


N
Horseshoe Lake
Minto
Walsh County
Lake Ardoch
81
Forest River
Ardoch
54
29
Red River of the North
Gilby
Manvel
Grand Forks County
Stewart Lake
Lunby Lake
Kellys Slough Reservoir
Legend
Delineation Survey Area
Rivers
Lakes
Interstate
US Highway
County
Cities
0
1.5
3
6 Miles
Location Map
Ardoch Coulee - Forest River Watershed District
Scale: 1 inch = 14,988 feet
Drawn by: HGE
Checked by: MDA
Project No : 5197-027
Date: 1/2/2020
Sheet: of
Houston Engineering Inc.

Attachment 2

Wetland Maps



Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 766 feet	HGE	MDA	5197-027	1/2/2020	1 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

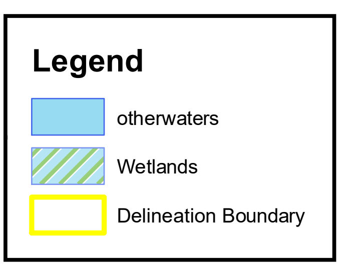
N

Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 761 feet	HGE	MDA	5197-027	1/2/2020	2 of 10

Houston Engineering Inc.



N

Wetland Map

Ardoch Coulee - Forest River Watershed District

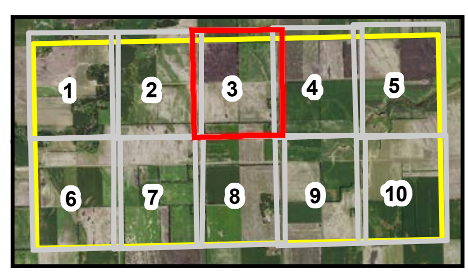
Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 770 feet	HGE	MDA	5197-027	1/2/2020	3 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N



Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 793 feet	HGE	MDA	5197-027	1/2/2020	4 of 10

Houston Engineering Inc.

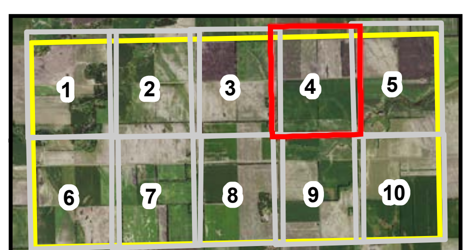
Legend

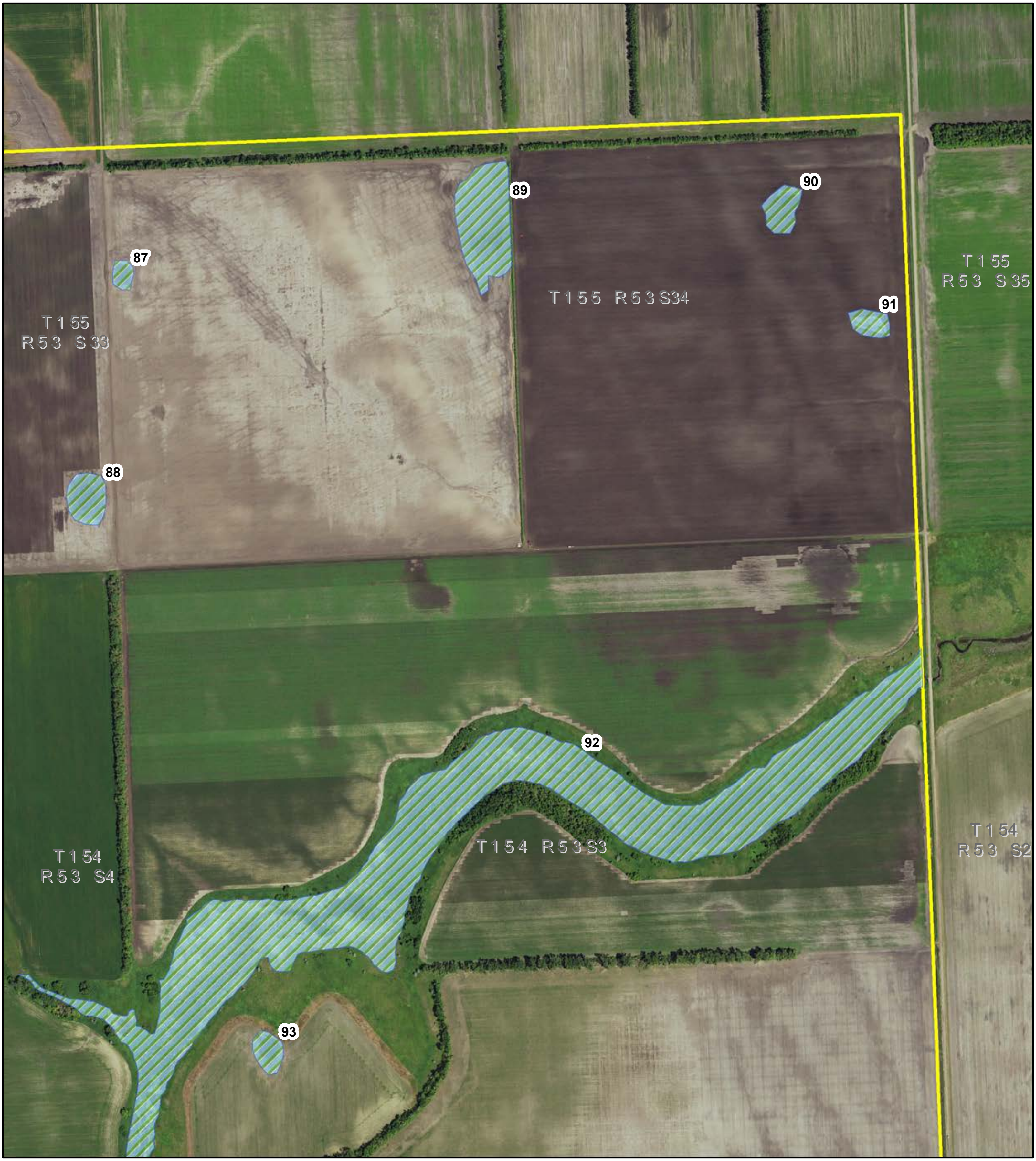
otherwaters

Wetlands

Delineation Boundary

N





Wetland Map

Ardoch Coulee - Forest River Watershed District

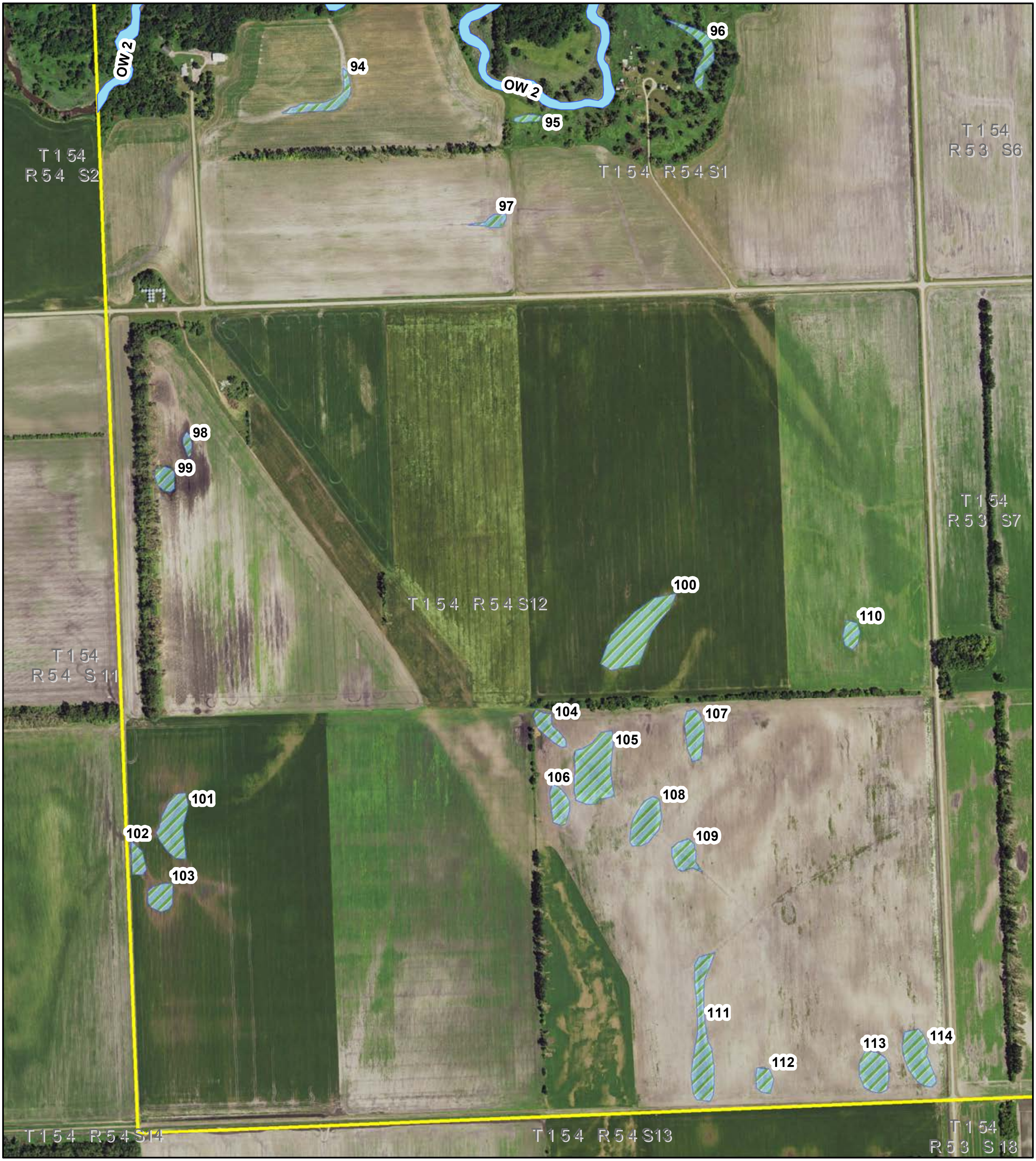
Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 812 feet	HGE	MDA	5197-027	1/2/2020	5 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N



Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 806 feet	HGE	MDA	5197-027	1/2/2020	6 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N

Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 799 feet	HGE	MDA	5197-027	1/2/2020	7 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N

Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 790 feet	HGE	MDA	5197-027	1/2/2020	8 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N

Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 788 feet	HGE	MDA	5197-027	1/2/2020	9 of 10

Houston Engineering Inc.

Legend

- otherwaters
- Wetlands
- Delineation Boundary

N

Wetland Map

Ardoch Coulee - Forest River Watershed District

Scale:	Drawn by:	Checked by:	Project No :	Date:	Sheet:
1 inch = 774 feet	HGE	MDA	5197-027	1/2/2020	10 of 10

Houston Engineering Inc.

Legend

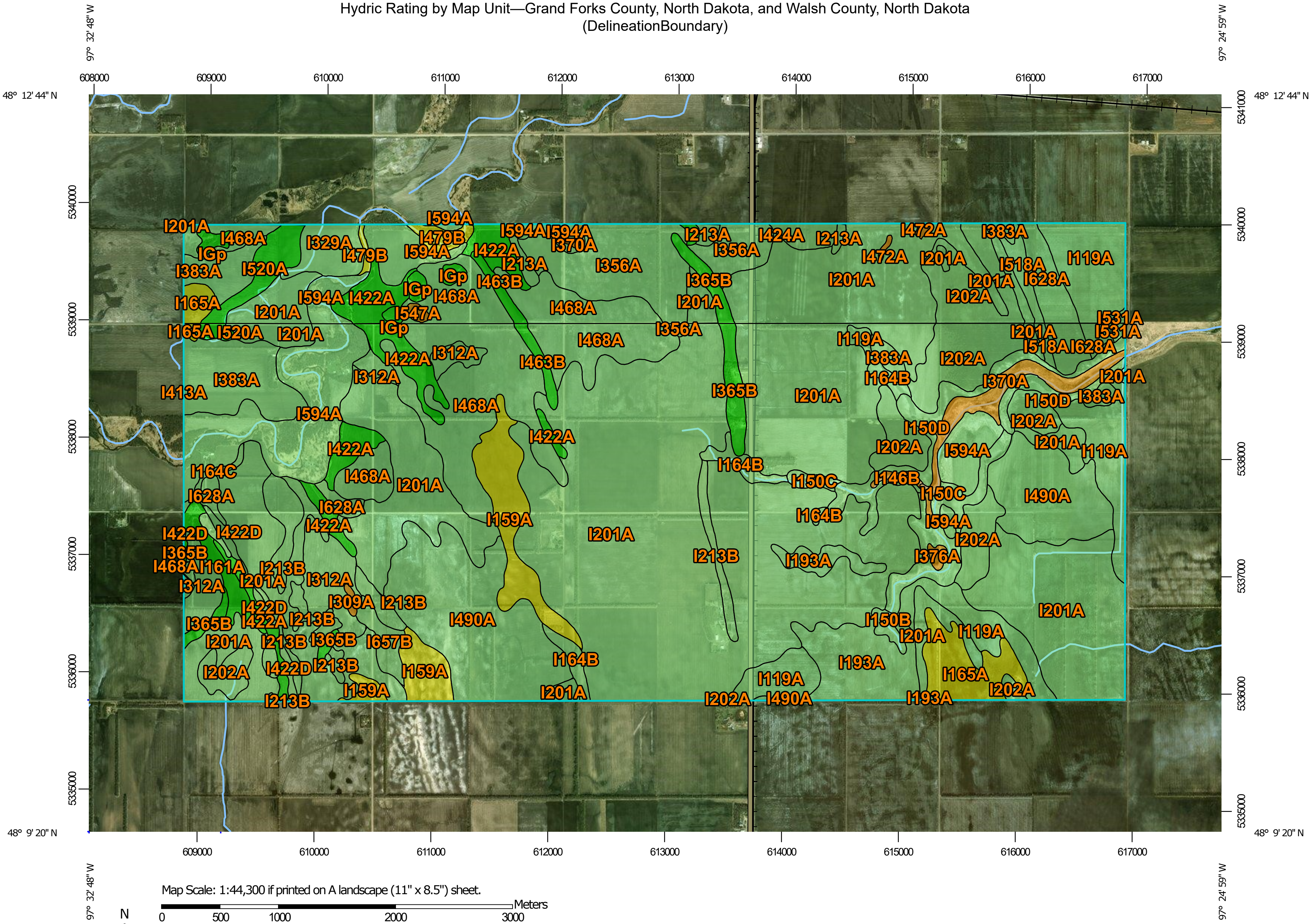
- otherwaters
- Wetlands
- Delineation Boundary

N

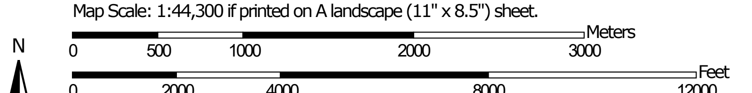
Attachment 3

Hydric Soil Rating Map

Hydric Rating by Map Unit—Grand Forks County, North Dakota, and Walsh County, North Dakota
(DelineationBoundary)



Map Scale: 1:44,300 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- Hydric (100%)
- Hydric (66 to 99%)
- Hydric (33 to 65%)
- Hydric (1 to 32%)
- Not Hydric (0%)
- Not rated or not available

Soil Rating Lines

- Hydric (100%)
- Hydric (66 to 99%)
- Hydric (33 to 65%)
- Hydric (1 to 32%)
- Not Hydric (0%)
- Not rated or not available

Soil Rating Points

- Hydric (100%)
- Hydric (66 to 99%)
- Hydric (33 to 65%)
- Hydric (1 to 32%)
- Not Hydric (0%)
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Grand Forks County, North Dakota
Survey Area Data: Version 23, Sep 16, 2019

Soil Survey Area: Walsh County, North Dakota
Survey Area Data: Version 20, Sep 16, 2019

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 7, 2014—Feb 28, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydric Rating by Map Unit

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
I119A	Bearden silty clay loam, 0 to 2 percent slopes	10	257.2	3.2%
I146B	Lamoure-Fluvaquents, channeled complex, 0 to 6 percent slopes, frequently flooded	94	7.4	0.1%
I150B	Zell, fine-silty-LaDelle silt loams, 2 to 6 percent slopes	5	12.1	0.1%
I150C	Zell, fine-silty-LaDelle silt loams, 1 to 9 percent slopes	15	100.9	1.2%
I150D	Zell, fine-silty-LaDelle silt loams, 1 to 15 percent slopes	15	122.7	1.5%
I159A	Wyndmere-Tiffany fine sandy loams, 0 to 2 percent slopes	40	188.4	2.3%
I161A	Vang loam, 0 to 2 percent slopes	0	43.2	0.5%
I164B	Zell-Gardena silt loams, 2 to 6 percent slopes	10	56.3	0.7%
I164C	Zell-Gardena silt loams, 6 to 9 percent slopes	10	9.5	0.1%
I165A	Bearden-Perella silty clays, 0 to 2 percent slopes	39	99.4	1.2%
I193A	Bearden-Perella silty clay loams, 0 to 2 percent slopes	32	175.5	2.2%
I201A	Glyndon silt loam, 0 to 2 percent slopes	13	2,921.9	36.0%
I202A	Gardena silt loam, 0 to 2 percent slopes	5	290.4	3.6%
I213B	Embden fine sandy loam, 2 to 6 percent slopes	5	127.3	1.6%
I309A	Arveson loam, 0 to 1 percent slopes	92	4.2	0.1%
I312A	Wyndmere fine sandy loam, 0 to 2 percent slopes	7	154.6	1.9%
I356A	Ulen fine sandy loam, 0 to 2 percent slopes	12	3.3	0.0%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
I365B	Arvilla sandy loam, 0 to 6 percent slopes	0	55.4	0.7%
I370A	Rauville silty clay loam, 0 to 1 percent slopes, frequently flooded	90	73.3	0.9%
I376A	Colvin silty clay loam, 0 to 1 percent slopes	95	6.3	0.1%
I383A	Overly silty clay loam, 0 to 2 percent slopes	5	161.4	2.0%
I413A	Lankin loam, 0 to 2 percent slopes	3	0.0	0.0%
I422A	Renshaw loam, 0 to 2 percent slopes	0	125.3	1.5%
I422D	Sioux loam, 2 to 15 percent slopes	4	19.5	0.2%
I463B	Sioux-Renshaw complex, 2 to 6 percent slopes	0	16.3	0.2%
I468A	Divide loam, 0 to 2 percent slopes	5	443.7	5.5%
I490A	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	20	519.7	6.4%
I518A	Overly silt loam, 0 to 2 percent slopes	5	7.5	0.1%
I520A	Bearden silty clay loam, levees and splays, 0 to 2 percent slopes	0	9.9	0.1%
I531A	Overly silty clay loam, 0 to 1 percent slopes, fans	5	3.9	0.0%
I594A	LaDelle silt loam, 0 to 2 percent slopes, occasionally flooded	5	321.3	4.0%
I628A	Bearden-Overly silty clay loams, 0 to 2 percent slopes	7	55.4	0.7%
I657B	Hecla fine sandy loam, 2 to 6 percent slopes	5	31.1	0.4%
IGp	Pits, gravel and sand	0	0.0	0.0%
Subtotals for Soil Survey Area			**6,424.3**	**79.1%**
Totals for Area of Interest			**8,121.9**	**100.0%**

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
I119A	Bearden silty clay loam, 0 to 2 percent slopes	10	117.5	1.4%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
I165A	Bearden-Perella silty clays, 0 to 2 percent slopes	39	19.2	0.2%
I201A	Glyndon silt loam, 0 to 2 percent slopes	13	419.0	5.2%
I202A	Gardena silt loam, 0 to 2 percent slopes	5	101.5	1.2%
I213A	Embden fine sandy loam, 0 to 2 percent slopes	3	22.2	0.3%
I329A	Fairdale silt loam, 0 to 2 percent slopes, occasionally flooded	4	58.2	0.7%
I356A	Ulen fine sandy loam, 0 to 2 percent slopes	12	251.8	3.1%
I365A	Arvilla sandy loam, 0 to 2 percent slopes	0	4.6	0.1%
I365B	Arvilla sandy loam, 0 to 6 percent slopes	0	23.5	0.3%
I370A	Rauville silty clay loam, 0 to 1 percent slopes, frequently flooded	90	3.2	0.0%
I383A	Overly silty clay loam, 0 to 2 percent slopes	5	56.8	0.7%
I422A	Renshaw loam, 0 to 2 percent slopes	0	85.4	1.1%
I424A	Embden loam, 0 to 2 percent slopes	5	25.3	0.3%
I463B	Sioux-Renshaw complex, 2 to 6 percent slopes	0	14.7	0.2%
I468A	Divide loam, 0 to 2 percent slopes	5	190.1	2.3%
I472A	Perella silty clay loam, 0 to 1 percent slopes	90	5.4	0.1%
I479B	Fairdale-Fluvaquents, channeled complex, 0 to 6 percent slopes, frequently flooded	33	26.7	0.3%
I518A	Overly silt loam, 0 to 2 percent slopes	5	23.1	0.3%
I520A	Bearden silty clay loam, levees and splays, 0 to 2 percent slopes	0	52.8	0.6%
I531A	Overly silty clay loam, 0 to 1 percent slopes, fans	5	2.5	0.0%
I547A	Colvin silt loam, 0 to 1 percent slopes	95	5.6	0.1%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
I594A	LaDelle silt loam, 0 to 2 percent slopes, occasionally flooded	5	105.3	1.3%
I628A	Bearden-Overly silty clay loams, 0 to 2 percent slopes	7	52.2	0.6%
IGp	Pits, gravel and sand	0	30.9	0.4%
Subtotals for Soil Survey Area			**1,697.6**	**20.9%**
Totals for Area of Interest			**8,121.9**	**100.0%**

Description

This rating indicates the percentage of map units that meets the criteria for hydric soils. Map units are composed of one or more map unit components or soil types, each of which is rated as hydric soil or not hydric. Map units that are made up dominantly of hydric soils may have small areas of minor nonhydric components in the higher positions on the landform, and map units that are made up dominantly of nonhydric soils may have small areas of minor hydric components in the lower positions on the landform. Each map unit is rated based on its respective components and the percentage of each component within the map unit.

The thematic map is color coded based on the composition of hydric components. The five color classes are separated as 100 percent hydric components, 66 to 99 percent hydric components, 33 to 65 percent hydric components, 1 to 32 percent hydric components, and less than one percent hydric components.

In Web Soil Survey, the Summary by Map Unit table that is displayed below the map pane contains a column named 'Rating'. In this column the percentage of each map unit that is classified as hydric is displayed.

Hydric soils are defined by the National Technical Committee for Hydric Soils (NTCHS) as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (Federal Register, 1994). Under natural conditions, these soils are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophytic vegetation.

The NTCHS definition identifies general soil properties that are associated with wetness. In order to determine whether a specific soil is a hydric soil or nonhydric soil, however, more specific information, such as information about the depth and duration of the water table, is needed. Thus, criteria that identify those estimated soil properties unique to hydric soils have been established (Federal Register, 2002). These criteria are used to identify map unit components that normally are associated with wetlands. The criteria used are selected estimated soil properties that are described in "Soil Taxonomy" (Soil Survey Staff, 1999) and "Keys to Soil Taxonomy" (Soil Survey Staff, 2006) and in the "Soil Survey Manual" (Soil Survey Division Staff, 1993).

If soils are wet enough for a long enough period of time to be considered hydric, they should exhibit certain properties that can be easily observed in the field. These visible properties are indicators of hydric soils. The indicators used to make onsite determinations of hydric soils are specified in "Field Indicators of Hydric Soils in the United States" (Hurt and Vasilas, 2006).

References:

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18.

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Soil Survey Staff. 2006. Keys to soil taxonomy. 10th edition. U.S. Department of Agriculture, Natural Resources Conservation Service.

Rating Options

Aggregation Method: Percent Present

Component Percent Cutoff: None Specified

Tie-break Rule: Lower