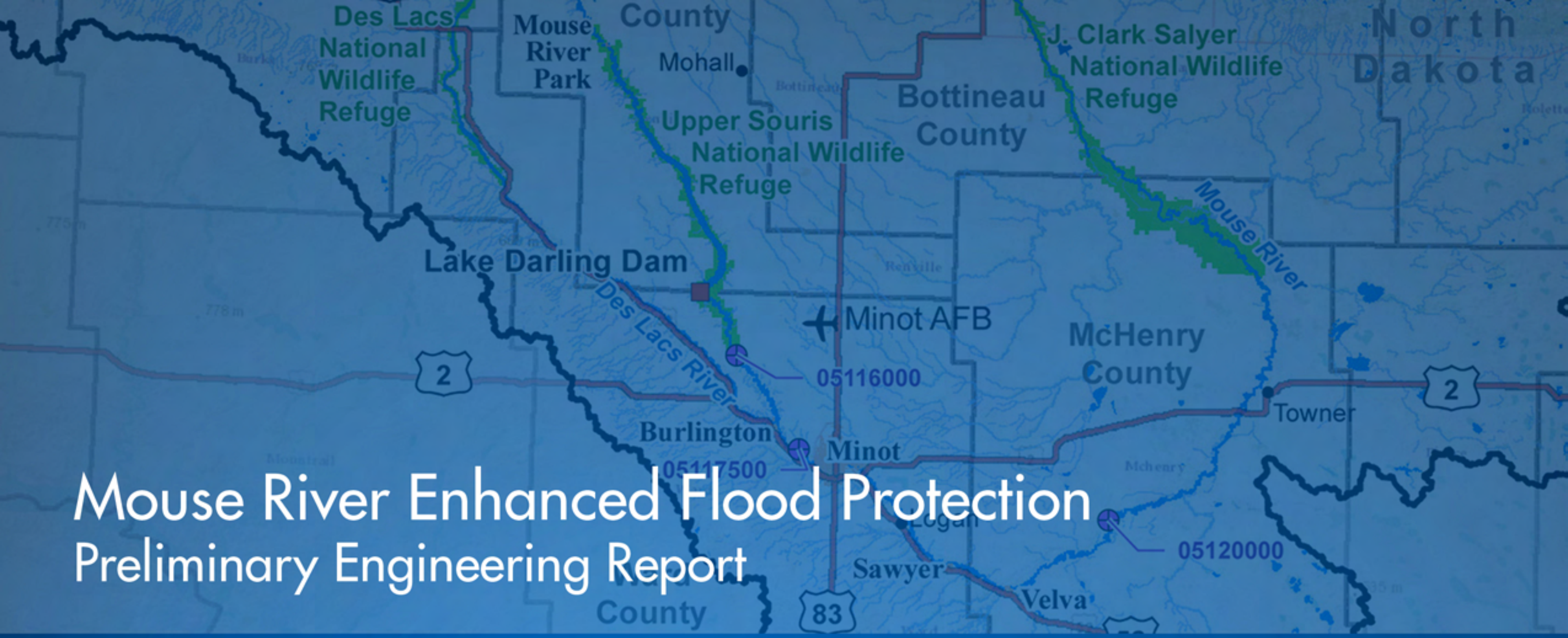


Mouse River Enhanced Flood Protection

Preliminary Engineering Report

Prepared for North Dakota State Water Commission

BARR

ACKERMAN-ESTVOLD engineering and management consulting, inc.

CPS

moore engineering, inc.

Photo: Gemar Photography

Mouse River Enhanced Flood Protection Plan

Preliminary Engineering Report

February 29, 2012

Table of Contents

Note:

This Technical Memorandum was prepared by Barr Engineering, with portions of the content contributed by Ackerman-Estvold Engineering, Moore Engineering, and CPS, Ltd.

List of Tables

List of Figures

List of Appendices

The following individuals were in responsible charge of the preparation of this report:

William J. Forsmark, PE
Principal in Charge

REGISTERED PROFESSIONAL ENGINEER
SCOTT A SOBIECH
PE-5980
DATE 2/28/12
NORTH DAKOTA

Scott Sobiech, PE
Engineer of Record

Executive Summary

The sun sets over the Mouse River and Zoo Bridge in Minot. (Photo: Gemar Photography, Minot)

The Mouse River, known also by its French name, the Souris, is about 435 miles in length, flowing from the Canadian province of Saskatchewan, to Velva, North Dakota (its most southern point), then back north into Manitoba.

According to the National Weather Service, the Mouse River reached 1,561.72 feet above sea level on Sunday, June 25, 2011, topping the 130-year-old record by almost 4 feet.

On June 25, 2011, the Mouse River flowed under Minot's Broadway Bridge at a record rate of 27,400 cubic feet per second (cfs)—more than five times the rate that existing channels and levees had been designed to handle and close to nine times the rate of any flood documented since construction of four upstream storage reservoirs. Not since 1882, a time when commercial production of automobiles was just beginning, had flows in excess of 20,000 cfs been seen. For days, during the 2011 flood, water levels were too high for cars to safely cross numerous area bridges.

The record-breaking flow overwhelmed most flood fighting efforts along the entire reach of the Mouse River through North Dakota, causing extensive damage to homes, businesses, public facilities, infrastructure, and rural areas. According to the U.S. Army Corps of Engineers (USACE), 4,700 commercial, public, and residential structures in Ward and McHenry counties sustained building and content damage totaling more than $690 million.

If no emergency flood fighting measures had been implemented, potential building and content damages would total roughly $900 million. This includes the 1,500 structures protected by the emergency levees but still considered at risk. This estimate does not reflect the cost of rebuilding in areas outside of the flood zone, where real estate values are particularly high.

The heroic efforts of residents, volunteers, local officials, and state and federal agencies prevented significant damages. Still, more than 11,000 residents were displaced by the 2011 flood. A preliminary alignment plan was a high priority so that affected residents and business owners could make decisions on whether to rebuild or relocate. (Photo, above left, courtesy of FEMA)

Rural Considerations

The rural areas of the Mouse River Valley, upstream of Burlington and downstream of Velva, were also devastated by the 2011 flood. Damage came in the form of flooded homes and farmsteads, erosion, sedimentation and debris deposition, lost crop production, and road and bridge washouts. These areas will be the focus of further study to address the circumstances and constraints specific to agriculture. A workshop was held on February 16, 2012, to gather stakeholder input for the engineering evaluation of rural areas.

In the aftermath of the flood, local government recognized the need to develop a plan that could provide direction during recovery and better protect the Mouse River community from similar future events. The Souris River Joint Board issued a request to the North Dakota State Water Commission to retain an engineering team to develop a "Mouse River Enhanced Flood Protection Project," including preliminary alignments for levees and floodwalls. The Preliminary Engineering Report provides a summary of the efforts undertaken to develop a preliminary alignment, as well as engineering, environmental, and cost considerations for plan implementation.

Project Objectives and Scope

The primary objective for the Mouse River Enhanced Flood Protection Project (Project) is to develop a preliminary plan that can be used as a guiding document to help reduce the risk of damages from river flows comparable to those seen during the June 2011 flood. The scope of this study is the Mouse River Valley from Burlington to Velva and Mouse River Park.

There are a wide range of flood risk reduction alternatives available, ranging from restoration and maintenance of the existing channel modifications, levees, and upstream flood storage system, to complete removal of at-risk properties within the 2011 flooded area. Previous reports and studies were reviewed to determine the range of options that have been considered for the Mouse River Valley. A more comprehensive review and analysis of potential alternatives to the preliminary alignment plan presented here will be required to comply with the regulatory review process for implementing any major flood risk reduction plan.

A series of workshops and public meetings were held to get stakeholder input and feedback used in the development of the preliminary alignment plan. Community members were also able to stay informed and offer feedback through the Project website (www.mouseriverplan.com), Facebook, and Twitter. Over the course of the Project over 1,200 public comments were received.

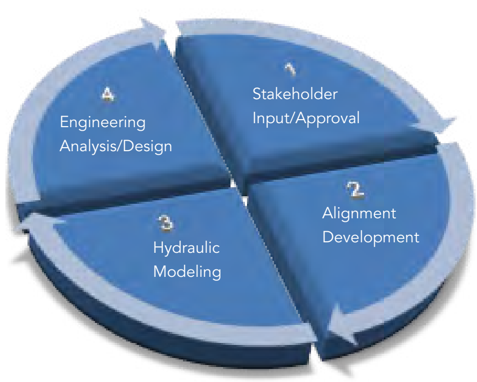
Preliminary Alignment Development Process

The development of a preliminary alignment, including measures such as levees and floodwalls, is a complex process that requires both significant technical analysis and substantial stakeholder input. Rapid identification of an alignment corridor is a key first step because it allows affected property owners to make informed decisions about rebuilding or relocating.

The preliminary alignment described in this report was developed through an iterative process consisting of: (1) obtaining stakeholder input, (2) alignment development, (3) performing detailed hydraulic modeling of the alignment, and (4) performing engineering analysis and design.

Initial input was gathered at an October 2011 workshop. The primary objective for this workshop, which consisted of presentations, dialog, and work sessions, was to engage participants in a discussion of priorities and strategies for flood risk reduction. The resulting consensus priorities and alignments were used to complete hydraulic modeling and plan refinements.

A draft preliminary plan was published on November 3, 2011, for public review and comment. Three additional cycles of input, alignment, and modeling revision (as well as dozens of intermediate iterations) occurred between November 3, 2011, and January 31, 2012. Plan revisions were posted to the Project website (www.mouseriverplan.com).



Project Objectives and Constraints

(1) Reduce the risk of flood damage to as many homes as reasonably possible

(2) Minimize the Project footprint and number of residential acquisitions required

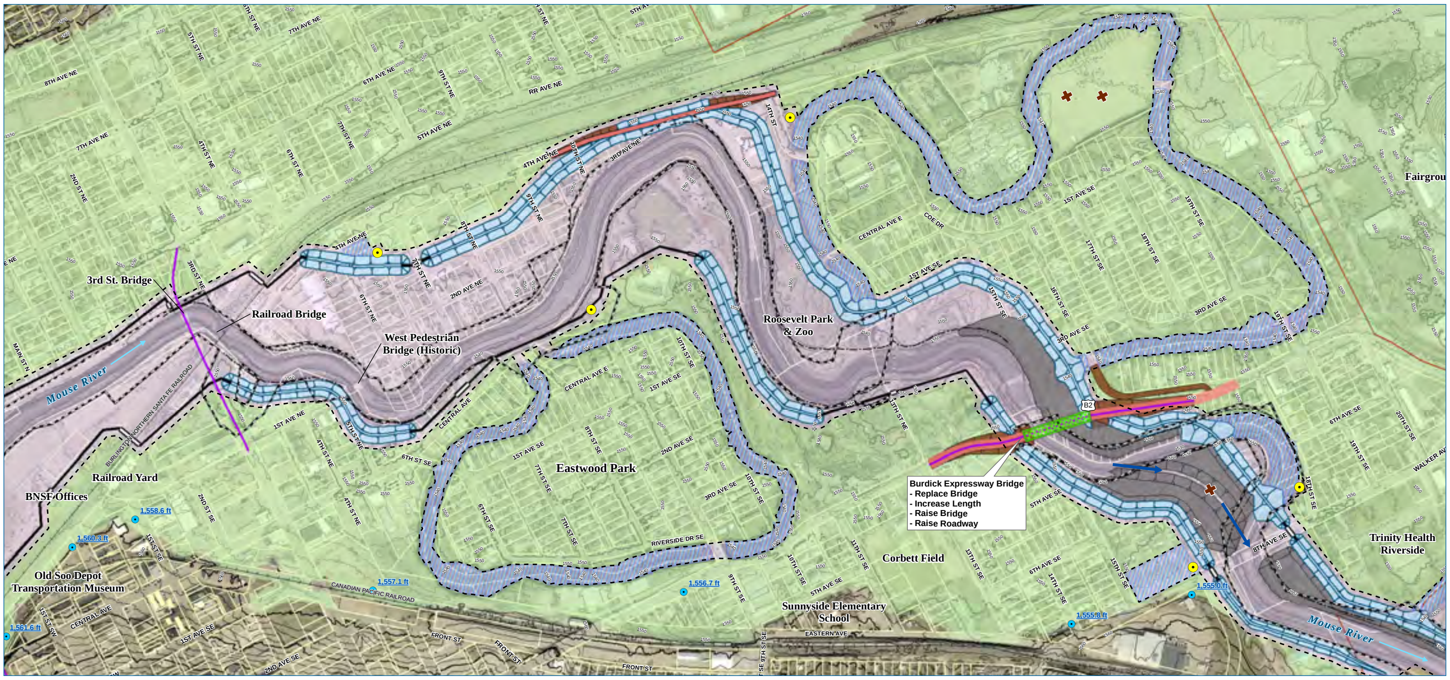
(3) Minimize increases in flood level water surface, flow rates, and duration

(4) Develop a Project that can be implemented at the lowest practical cost

(5) Establish key transportation corridors that can remain open during flood events

(6) Minimize environmental impacts to facilitate necessary regulatory approvals

(7) Design a Project that is consistent with the long-range objectives of the affected communities



The preliminary alignment plan includes levees, floodwalls, and river diversions and closure features to reduce the risk of flooding in populated areas along the Mouse River.

Primary Features

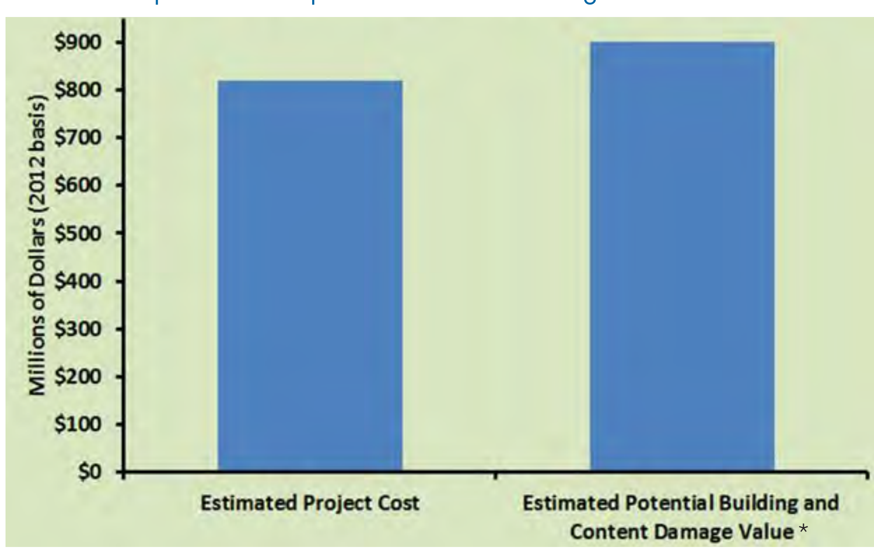
- 21.6 Miles — Levees
- 2.8 Miles — Floodwalls
- 30 — Transportation Closure Structures
- 33 — Stormwater Pump Stations

Description of the Preliminary Alignment

The preliminary alignment plan consists of levees, floodwalls, river diversions and closure features, transportation closure structures, interior pump stations, and 2011 floodplain buyouts. Levees comprise almost 90 percent of the alignment, totaling 21.6 miles. The remainder of the alignment consists of 2.8 miles of floodwalls, and 30 transportation closure structures (19 roadway and 11 railroad). In addition, the Project would require 33 stormwater pump stations.

The estimated total Project cost is $820 million, based on the current level of design and Project understanding. This Project cost is a point estimate, in current dollars, and does not consider the likelihood of cost escalation over the period of implementation. Of the estimated cost, $565 million is related to construction, $154 million is related to property acquisition, and the remaining $101 million covers planning, engineering, and program management costs.

Estimated Project Cost Compared to Potential Damages from Flood Similar to 2011



* *Project costs shown exclude the substantial costs related to emergency flood fighting, evacuations, damages to public infrastructure, lost commerce—and the incalculable human costs.*

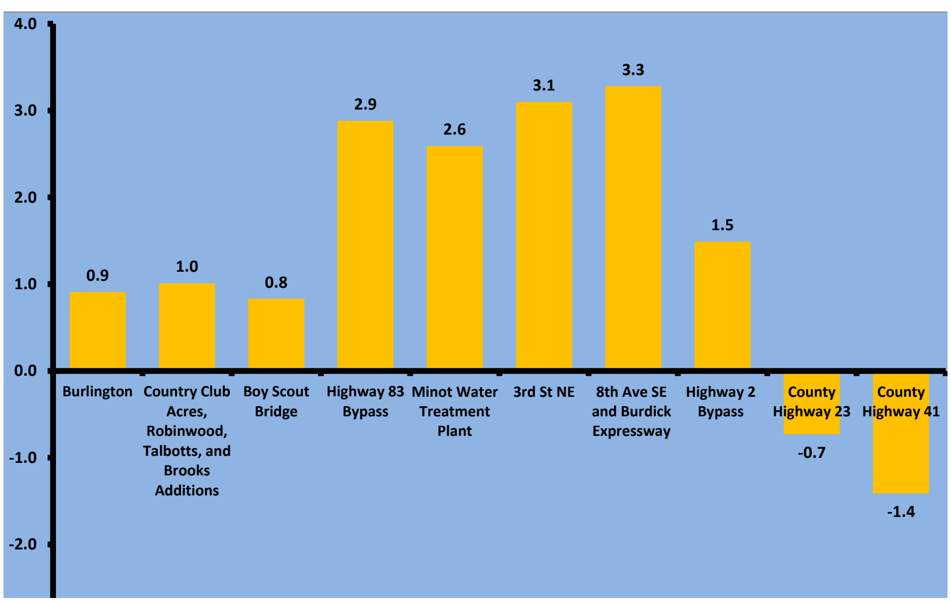
Impacts of Preliminary Alignment

Flood Level Impacts

One of the most critical design constraints of a flood risk reduction system is the estimation of the design water surface elevation. This defines the required height for constructed features such as levees and floodwalls. Potential hydraulic effects of the proposed alignment on upstream and downstream water surface elevations also need to be considered.

The Project will change the flood profile for the design flow (27,400 cfs) at most locations (see chart below). In the majority of cases, this is the result of efforts to narrow the floodplain—minimizing the Project footprint and the number of property acquisitions required.

Summary of Project Effect on 2011 Flood Profile (feet)



Property Impacts

Construction of levees, floodwalls, road raises, road realignments, etc., will require acquisition of property. The table below provides a summary of the estimated number of residential properties that would need to be accquired to implement the Project. This estimate is limited by information available in the Project area.

Summary of Residential Properties to be Acquired for the Preliminary Alignment Project

	Up-stream	Minot	Down-stream	Total
Number of Residential Properties[1]	90	278	15	383

[1] Residential properties includes parcels classified as single family, two-family, and multi-family with a dwelling unit. Data is not readily available for estimating the number of housing units represented by this property count.

Pre-Construction Implementation Steps

- ✓ Identifying funding mechanisms (local, state, federal)
- ✓ Extending the Project to consider rural areas downstream of Velva
- ✓ Investigating additional Project alternatives (e.g., lesser design events, reservoir modification, combinations, etc.)
- ✓ Adopting a final plan
- ✓ Performing the necessary field investigations (e.g., geotechnical investigations, wetlands, surveys, etc.)
- ✓ Completing engineering and environmental studies (e.g., hydrologic, hydraulic, geotechnical, socio-economic, biological resources, etc.)
- ✓ Developing detailed design
- ✓ Obtaining permitting and regulatory approvals (e.g., NEPA compliance; USACE Section 10, 404, and 408 approvals; Section 401 water quality certification; FEMA certification, etc.)
- ✓ Acquiring Project properties
- ✓ Preparing the corridor
- ✓ Continuing stakeholder and agency coordination

Implementation of an Enhanced Flood Risk Reduction Project

Implementation of an enhanced flood risk reduction plan is a multi-step process. Phased implementation may provide desirable flexibility for funding and construction of high-priority elements. Steps that must be completed prior to construction are listed in the table shown at left.

The estimated time frame for planning, engineering, environmental, and regulatory steps for the entire Project could be 5 years—or longer. Select components or individual levee system modifications, which have minimal environmental impacts, could potentially proceed on a separate path and at a faster pace. Construction of a project similar to the preliminary alignment plan described in this report is likely to take a minimum of 5 years, and could be phased over an extended period if necessary.

Rendering of the Maple Diversion area, part of the Enhanced Flood Risk Reduction Project

1.0 Introduction and Background

The purpose of this preliminary engineering report is to provide a summary of the efforts undertaken to reduce flood risk along the Mouse River in North Dakota. This includes a preliminary alignment plan, as well as engineering, environmental, and cost considerations for plan implementation.

The preliminary alignment plan and associated engineering presented here consider the existing levels of development throughout the Mouse River Valley floodplain that were damaged or at risk during the 2011 record flood. It accounts for existing flood risk reduction projects that have been constructed within valley and the upstream watershed area. This plan is an important step in flood recovery and planning, providing information that Mouse River communities and individual residents need to make decisions and move forward.

Throughout this report the term "risk reduction" is generally used to describe the preliminary alignment plan and features. Traditionally the term "flood control" was used to describe projects intended to reduce the potential for damages from flood flows. More recently, flood risk reduction has been adopted to more appropriately convey the concept that the potential for damages is reduced, rather than perpetuating the idea that project areas may be "protected" absolutely.

1.1 Study Area and Location

The study area for the Mouse River Enhanced Flood Protection project (Project) is located in north central North Dakota covering a four-county area (Renville, Ward, McHenry, and Bottineau) of the Mouse River Valley, as shown in **Figure 1-1** and **Figure 1-2**.

The Mouse River is known in Canada as the Souris River. It is also referred to as the Souris River by United States federal agencies such as the U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), and the Federal Emergency Management Agency (FEMA). The portion of the Souris River located in North Dakota is officially referred to by state agencies, and in state maps and documents, as the Mouse River. This report generally uses Mouse River to refer to portions of the river in North Dakota, and Souris River to refer to portions of the river in Canada.

The Souris River has its headwaters in Saskatchewan, Canada, as shown in **Figure 1-1**. It flows southeasterly into North Dakota near Sherwood, continues southeast through the cities of Burlington, Minot, Sawyer and Velva, then turns back north and re-enters Canada into Manitoba. Eventually it flows into the Assiniboine River near Brandon—which joins the Red River of the North at Winnipeg. Within North Dakota, as shown in **Figure 1-2**, the Mouse River first flows through Renville County, with the Lake Darling Dam and the Upper Souris National Wildlife Refuge as key features, then through Ward County where a major tributary, the Des Lacs River, joins it at Burlington. It continues on through the cities of Minot and Sawyer, then passes into McHenry County and the city of Velva, and finally passes through Bottineau County and the J. Clark Salyer National Wildlife Refuge and exits back into Canada near Westhope. The principal areas of focus for the Project are shown in **Figure 1-2** and include Mouse River Park at the upstream end of Lake Darling, and the area inundated by the June 2011 flood. This includes the communities of Burlington, Minot, Sawyer, Logan, and Velva, and the residences, farmsteads, and developments located between Burlington and Velva.

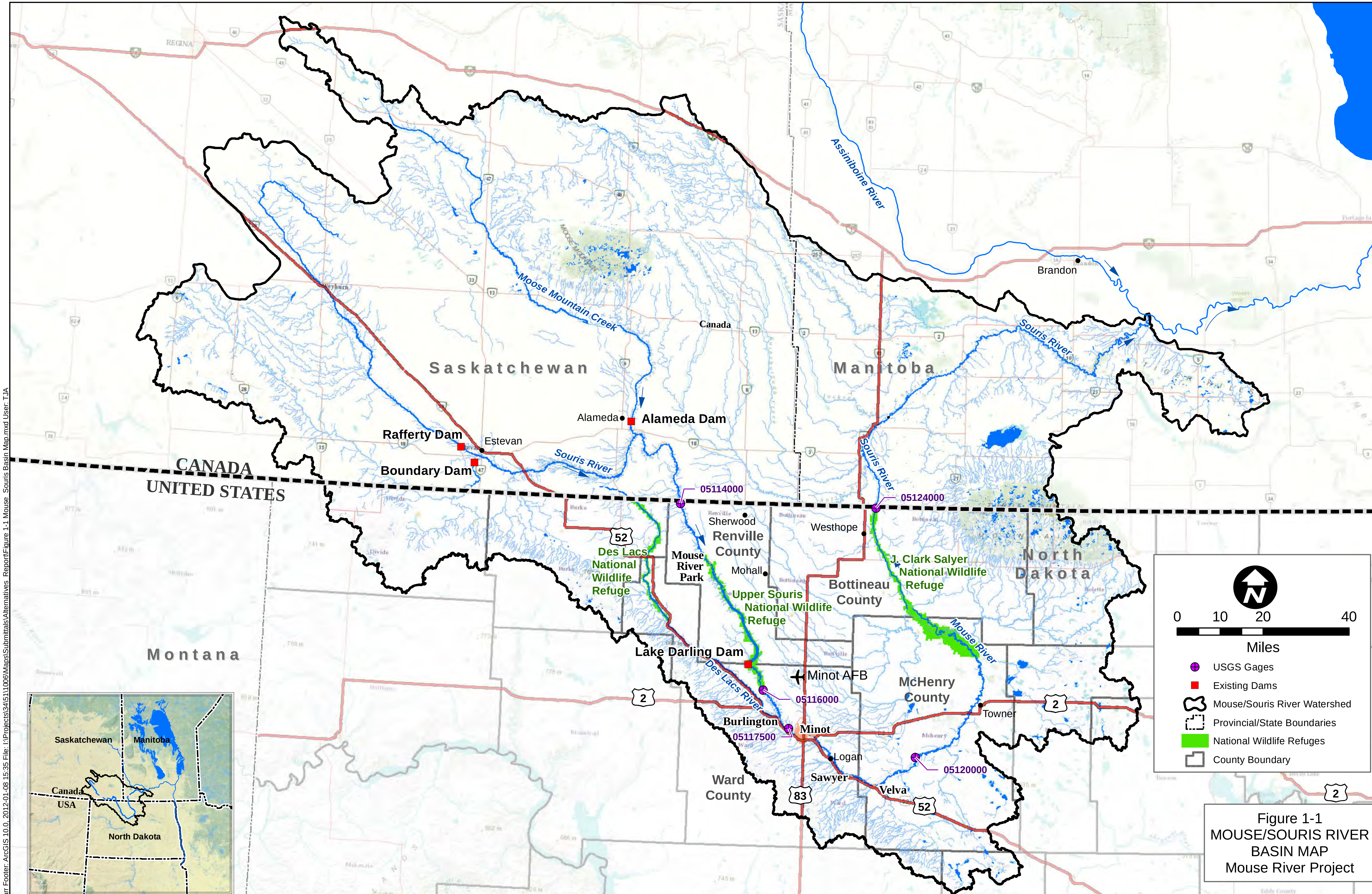
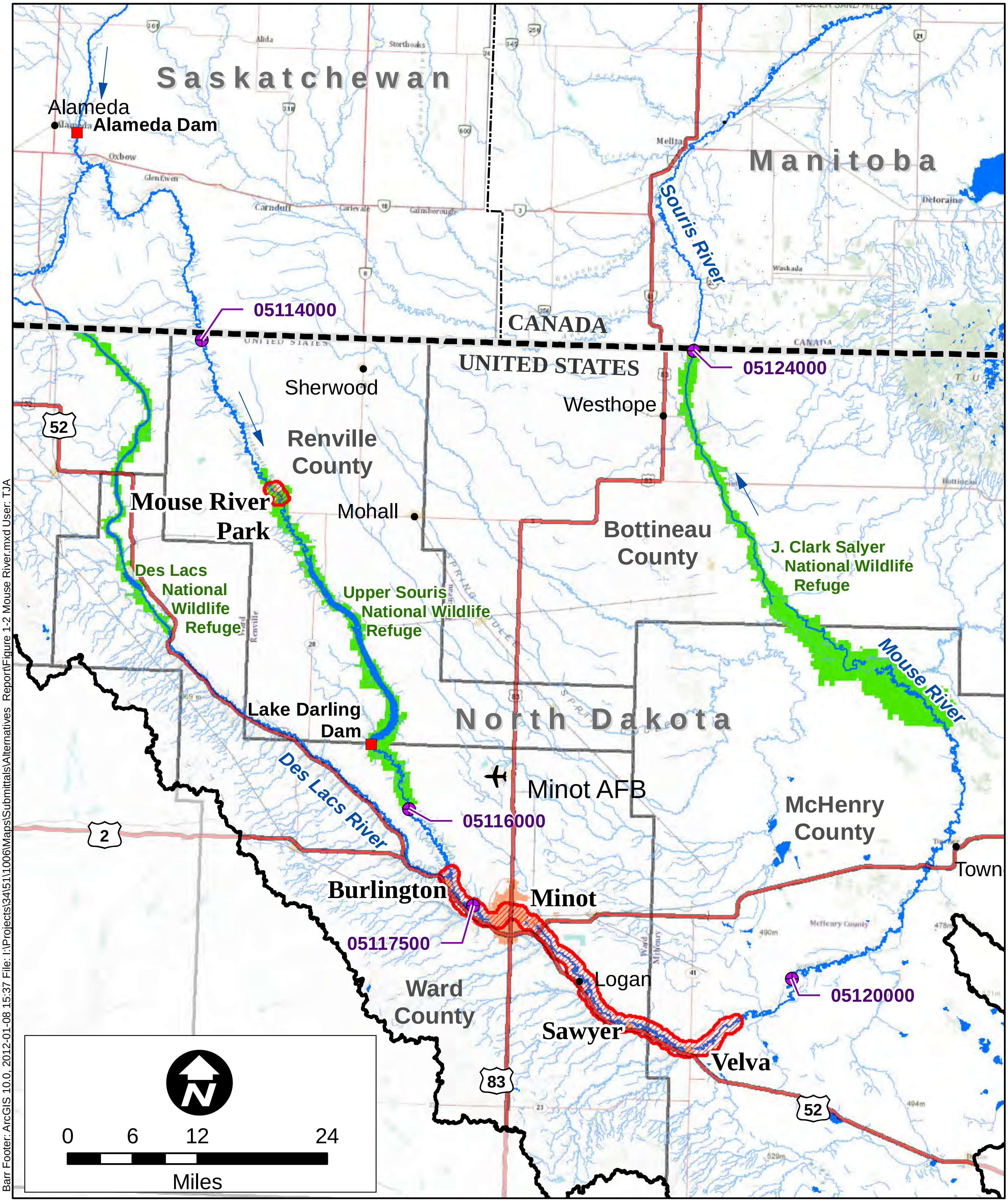


Figure 1-1
MOUSE/SOURIS RIVER
BASIN MAP
Mouse River Project

Barr Footer: ArcGIS 10.0, 2012-01-08 15:35 File: I:\Projects\34\51\1006\Maps\Submittals\Alternatives_Report\Figure 1-1 Mouse_Souris Basin Map.mxd User: TJA



USGS Gages
Existing Dams
Mouse/Souris River Watershed
Provincial/State Boundaries
National Wildlife Refuges
County Boundary
Principal Area of Focus for Mouse River Enhanced Flood Protection Study

Figure 1-2
MOUSE RIVER
Mouse River Project

1.2 Study Background

The Project was initiated by the North Dakota State Water Commission (NDSWC) in response to a request for assistance from the Souris River Joint Water Resources Board (SRJB) after the record-breaking June 2011 flood on the Mouse River. In mid-June, heavy rains in the upstream portions of the watershed in Saskatchewan exceeded the storage capacity of upstream reservoirs, already full from the April snowmelt. The inflow was passed downstream, resulting in flood flows along the Mouse River which exceeded the previous record floods of 1882 and 1904. The peak flow recorded at the USGS gage above Minot was 26,900 cfs. Floods (from 1904) with recorded peak discharges greater than 5,000 cfs for the Mouse River at or above Minot are summarized in **Table 1-1**.

The 2011 flood overwhelmed most levees and flood-fighting efforts along the entire reach of the Mouse River through North Dakota, causing extensive damage to homes, businesses, public facilities, infrastructure, and rural areas. Preliminary estimates indicate that in excess of $690 million of damage was caused to over 4,700 commercial, public, and residential structures in Ward and McHenry counties. A satellite image of portions of the flooded area was taken at the flood peak on June 25, 2011. **Figure 1-3** presents this satellite image of the flooded area through the city of Minot.

After experiencing this massive flood, residents of the Mouse River Valley requested that a project plan be developed that could protect them from events of this magnitude. In August 2011, the SRJB submitted a request to the NDSWC to retain an engineering firm to develop such a project. The NDSWC acted on this request on August 17, 2011, and on August 24, 2011, a request for qualifications was published for the development of a preliminary engineering report to evaluate alternatives to meet this objective. Proposals were received from six engineering teams by September 8, 2011. A team led by Barr Engineering Company was selected to develop the report and on September 22, 2011, a contract was signed between the NDSWC and Barr Engineering.

On October 5-7, 2011, the Barr team facilitated a start-up workshop in Minot with the NDSWC and other stakeholders along the Mouse River.

Table 1-1 Floods Greater than 5,000 cfs, Souris River above Minot

USGS Gage 05117500 (data from USGS - 1903 to 2011) [(1),(2)]

Year	Date	Peak Streamflow (cfs)
2011	June 25	26,900
1904	April 20	12,000
1976	April 17	9,350
1969	April 19	6,020
1979	May 09	5,960
1975	May 13	5,700

(1) Based on historic newspaper accounts, and as summarized in USGS reports, a flood in 1882 occurred in Minot that was about 3 feet higher than the 1904 flood and may have been comparable to the 2011 flood.

(2) Prior to 1934 the USGS gage data was taken at Minot. After 1934 the USGS gage data has been taken at the present gage location above Minot (USGS Gage 05117500 as shown on **Figure 1-1** and **Figure 1-2**)

0 1,250 2,500 5,000
Feet

Figure 1-3
MINOT GEOEYE SATELLITE PHOTO
June 25, 2011
Mouse River Project

1.3 Prior Reports and Existing Projects

Studies and planning to address flooding problems in the Souris River Basin have been conducted starting in the 1930s and have resulted in the implementation of several flood risk reduction projects in the basin. A brief summary of key past studies and resulting projects follows:

1930s to 1960:

- 1930: A USACE report recommended a study of flood control alternatives including reservoir storage near Foxholm, North Dakota, and floodway through Minot.
- 1935: A USACE report conducted as a follow-up to the 1930 report concluded that neither reservoir storage nor local protection provided sufficient benefits to permit federal participation in flood control projects.
- 1935-1936: The USFWS constructed three migratory waterfowl refuges in the Souris River Basin—one on the Des Lacs River and two on the Souris River (shown in **Figure 1-2**). The Des Lacs Refuge consists of eight dams. The J. Clark Salyer Refuge consists of five low dams. The Upper Souris Refuge consists of four dams, including the 30-foot high Lake Darling Dam.
- 1938: A USACE review of earlier studies concluded that storage in the Lake Darling Reservoir, operated by the USFWS, could have been used to reduce damages from seven of the eight floods of record and that further flood control improvement was not justified.
- 1957: A USACE examination of the Mouse River in the vicinity of Minot recommended that additional studies be conducted.

1960s to 2000:

- Studies conducted from the 1960s through the 1990s resulted in several Congressional authorizations for federal flood control projects in the Souris River Basin. These authorizations and the resulting projects are described below and summarized in Table 1-2.
- 1965: Flood Control Act (Public Law [P.L.] 89-298) authorized construction of components for flood control on the Mouse River:
    - The Burlington Dam
    - Channel modifications and enlargement at Minot
- 1969: The USACE issues a report and draft Environmental Impact Statement (EIS) for Burlington Dam and other related flood-control features on the Mouse River; included is a

recommendation for early construction of the channel modifications and enlargement at Minot.

- 1970: Senate (June 25) and House (July 14) Public Works Committee resolutions authorized the channel modifications and enlargement features at Minot as recommended in the 1969 USACE report.
- 1970: The Flood Control Act (P.L.91-611) authorized construction of the remaining components for flood risk reduction in the Souris River Basin as recommended in the 1969 USACE report:
  - Burlington Dam, a single-purpose flood control dam and reservoir on the Mouse River near Burlington, about 1.5 miles upstream of the confluence of the Des Lacs and Mouse rivers, with about 633,000 acre-feet of flood storage
  - Modification of nine USFWS refuge dams, including a 4-foot raise of the Lake Darling Dam
  - Diversion tunnel connecting the Des Lacs River to the Burlington Reservoir
  - Levees at Velva
  - Levees at seven subdivisions between Burlington and Minot
  - Levees at Sawyer
  - Regulation of future floodplain land use downstream of Burlington Dam
- 1981: Senate Report 97-256 states that the USACE is to take no further action to construct the Burlington Dam until expressly directed to do so by Congress.
  - 1981: Energy and Water Development Appropriations Act of 1982, approved December 4, 1981 (P.L.97-88), authorized construction of a raise of the existing Lake Darling Dam and other project features for flood risk reduction in the Souris River Basin that were previously included in the authorization of the Burlington Dam project. These features were authorized separately, in large part, because Congress had directed the USACE not to take further actions to construct the Burlington Dam until expressly directed to do so.
  - Raise of Lake Darling Dam by 4 feet.
  - Levees at Velva
  - Levees at Sawyer
  - Levees at six subdivisions between Burlington and Minot
  - Flood proofing of rural residences
  - Modification of refuge structures in the Upper Souris and the J. Clark Salyer refuges

- 1986: Water Resources Development Act (P.L. 99-662) rescinds authorization for the Burlington Dam and authorizes multiple project features for flood risk reduction in the Souris River Basin.

    - Flood storage in the Alameda and Rafferty dam projects in Saskatchewan
    - Gated spillway at Lake Darling Dam
    - Levees at Sawyer
    - Levees at Renville County Park
    - Levees at six subdivisions between Burlington and Minot
    - Structural and non-structural measures in rural reaches of the Mouse River
    - Modification of USFWS structures in Upper Souris and J. Clark Salyer refuges
    - Development of a flood warning system

A summary of the existing federal flood risk reduction projects implemented from various studies and Congressional authorizations is presented in Table 1-2.

Table 1-2 Summary of Existing Federal Flood Control Projects, Souris River Basin

Authorizing Legislation	Location of Constructed Components	Year Constructed	Design Flow (cfs)	Primary Project Features
Flood Control Act - October 1965 (P.L. 89-298)				
	City of Minot	1971-1979	5,000	Channel Enlargements
Flood Control Act - December 1970 (P.L. 91-611)				
	City of Velva	1987	14,700	Levees
Water Resources Development Act - 1986 (P.L. 99-662)				
	Alameda Dam			Flood Storage
	Rafferty Dam			Flood Storage
	Modifications to Lake Darling Dam			Flood Storage
	Mouse River Park	1992	4,000	Levees
	City of Burlington (Johnson's Addition)	1990	5,000	Levees
	Brooks' Addition	1990	5,000	Levees
	Talbott's	1990	5,000	Levees
	Country Club Acres/Robinwood Estates	1990	5,000	Levees
	King's Court & Rostad's Addition	1990	5,000	Levees
	Terracita Vallejo	1990	5,000	Levees
	City of Sawyer	1991	5,900	Levees
	Rural Residences	varies	varies	Structural/Non-Structural

1.4 2011 Flood Event

Since the flood control projects authorized by the U.S. Congress in the Water Resource Development Act (WRDA) of 1986 were completed in the 1990s, communities and residents throughout North Dakota's Mouse River Valley felt relatively at ease with the level of flood risk reduction provided by those projects. Most of the communities and developed areas were identified as having reduced risk for the 100-year flood and were removed from the identified 100-year floodplain. The 100-year flood peak flows in Minot were estimated to be about 5,000 cfs. After the flood control projects were in place, the largest flood flow, until June 2011, was in 2009 when a peak flow of 3,370 cfs occurred. Although there were still localized concerns with flood issues related to tributary streams, the Mouse River was perceived to be reasonably controlled.

The 2011 flood challenged that perception in a way that the valley's residents had not anticipated. Though there was heavy water content in the upper Souris Basin snowpack, at the end of March, the probability of flows at Minot reaching 7,000 cfs was estimated to be only 15-20%. However, rain in the upper basin in Saskatchewan during April and May runoff resulted in mid-May inflows into Lake Darling exceeding 7,000 cfs. Releases from Lake Darling were targeted below 7,000 cfs; with the addition of the downstream runoff, flows at Minot would stay below 8,000 cfs. Because flows at this level were above the flood control project design, by mid-May, emergency flood fighting was taking place throughout the valley. In most cases these efforts were reasonably successful at preventing damage. In mid-June up to 5 inches of additional rain in the upper basin resulted in forecasts of flows exceeding 20,000 cfs. At that time efforts shifted from flood-fighting to evacuation of areas where levees were expected to be overtopped. Most of the permanent and emergency flood-fight levees along the Mouse River were overtopped. Based on preliminary estimates, over 4,700 structures were flooded along the U.S. portion of the Mouse River Valley, with damages exceeding $690 million dollars.

About 1,500 structures in the valley were successfully protected by the levee system, saving an estimated $200 million in additional damages. Thus, a total of 6,200 structures are estimated to be at risk during a flood comparable to the June 2011 event, with an estimated damage potential of around $900 million.

Developing a strategy to reduce the risk of damages from future floods of comparable magnitude is a high priority for the region. The need for identification of potential additional levee and floodwall barrier alignments is urgent, so that real estate needed for such a project can be identified. The rebuilding of affected areas must focus on providing the desired additional flood risk reduction, while recognizing community desires to improve the overall livability of the area including housing, business, transportation corridors (including road and railroad), recreational and park facilities, and historic and cultural resources. However, first and foremost, is the development of a plan that will provide area residents and businesses with a degree of confidence that actions are being taken to reduce their risk of being devastated by future floods.

Working with city and county officials and residents of Burlington, Minot, and Ward County, FEMA developed a "Souris Basin Regional Recovery Strategy," (reference [1]). In this recovery strategy, the top long-term recovery priorities identified by the public were developing affordable housing, creating a Souris Valley greenway with recreational amenities, and conducting a transportation study for the region.

1.5 Planning Objectives and Constraints

The principal planning objective for the Project, as outlined in this report, is to develop a preliminary flood risk reduction plan for the Mouse River Basin from Burlington to Velva and for Mouse River Park that will reduce the risk of damages from river flows comparable to those of June 2011. This area includes the communities of Burlington, Minot, Logan, Sawyer, and Velva, as well as rural developments, farmsteads, and residences between Burlington and Velva. The principal focus is evaluation of local protection alternatives such as levees and floodwalls. Other alternatives considered are described in **Section 3.0** of this report. Preliminary design criteria were established during the October Start-Up Workshop held in Minot. The key criteria consisted of the following:

- Project target design flow of 27,400 cfs at U.S. Highway 83 (Broadway Bridge) in Minot (peak flow as measured by the USGS)
- Project target design flow of 29,700 cfs at Mouse River Park (equivalent to the peak discharge measured by the USGS gage at Sherwood, North Dakota)
- The top of the flood protection features is assumed to be 3 feet above the modeled target design flow water surface.
- Wherever possible, Project features should be designed using USACE guidance to facilitate review and approval by the USACE for levee certification.

Critical planning objectives and constraints of the Project must recognize the urgent needs of the community to recover from the disaster and address the critical housing shortage in the region. Identified objectives and constraints consist of the following:

- Provide protection to as many homes as reasonably possible.
- Wherever possible, minimize the Project footprint to minimize the number of homes to be acquired for the Project.
- Minimize adverse effects to unprotected features, both upstream and downstream. This includes minimizing any increases in flood level water surface, flow rate, or high flow duration.
- Cost effectiveness should be considered so that a Project can be developed at the lowest practical cost.
- Key transportation corridors should be operable and open to traffic during the design flood event, including the Broadway Bridge, Highway 83 Bypass, Highway 2 Bypass, and the Burdick Expressway.
- Implementation considerations should include minimizing environmental impacts so that necessary permits, including USACE Section 404 permits, can be obtained.
- The Project should be consistent with the long-range objectives of the effected communities and stakeholders.

1.6 Statement of Purpose and Need

To guide the development of the Project, a statement of purpose and need was developed at the October Start-Up Workshop.

The purpose of the Project is based on four parallel goals:

- Reduce the risk of property damage due to future flooding along North Dakota's Mouse and Des Lacs rivers, or otherwise encourage the removal or relocation of at-risk structures from the 2011 floodplain.
- Maintain operation of critical elements of the public transportation system during and after a flood event similar to the 2011 flood.
- Implement risk mitigation strategies that would facilitate an increase in the peak release target out of the reservoirs to shorten the duration of overland flooding in agricultural areas throughout the Mouse River Basin.
- Assist in the development of policy objectives that reduce the risk of property damage due to flooding within the 2011 floodplain.

While the responses of flooded property owners vary greatly, many are awaiting the identification of a proposed solution prior to making a commitment to rebuild. Where possible, the identification of a preferred alternative should occur prior to re-occupation of flooded structures within the Mouse River Basin.

2.0 Existing Flood Risk Reduction Elements

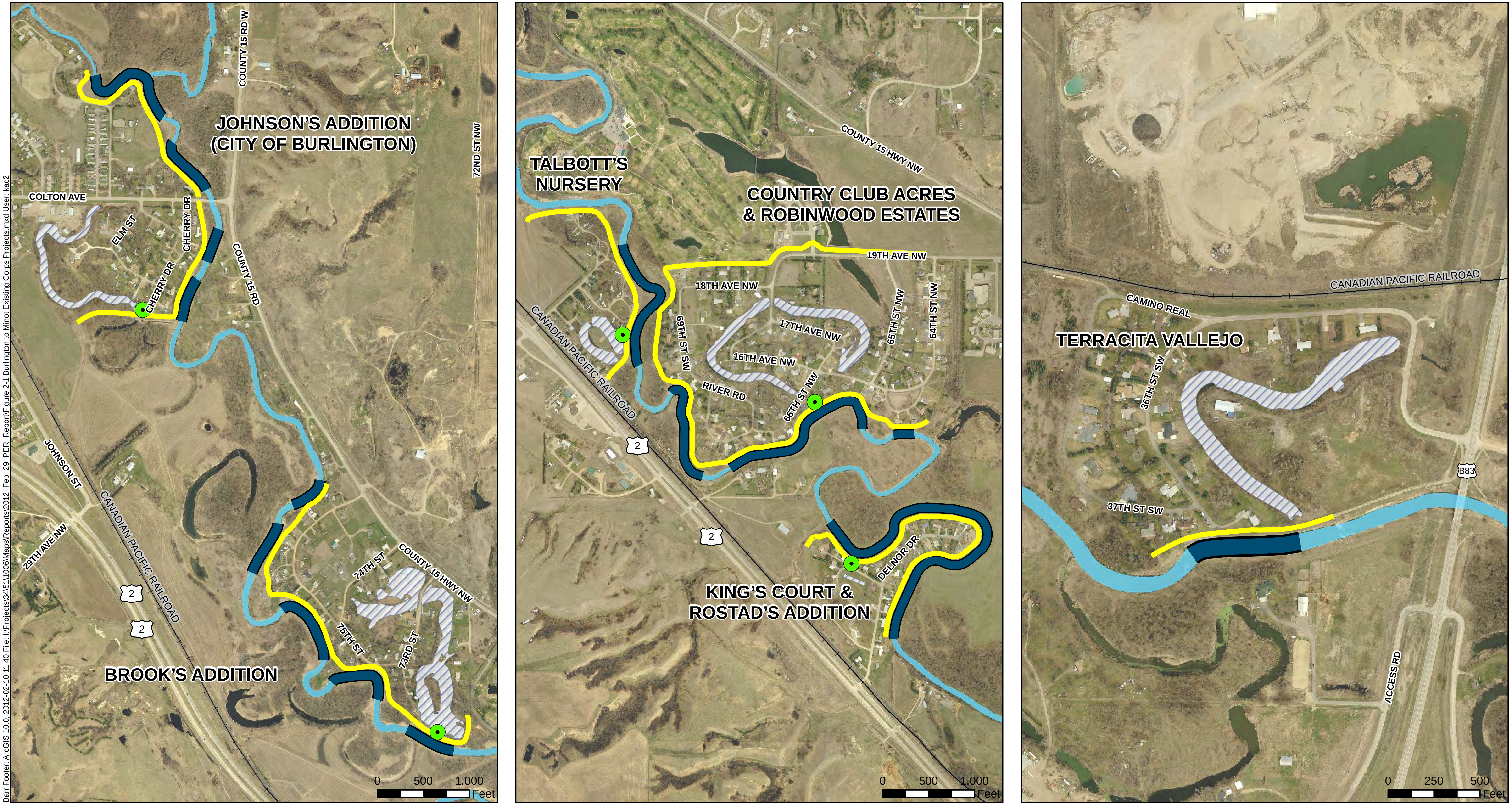
Flood risk reduction measures for developed areas of the Mouse River Valley have been established over the last 40 years. These generally consist of upstream reservoir flood storage, levees, channel modifications, and pump stations. This section of the preliminary engineering report provides a summary of flood risk reduction measures currently in place on the Mouse River/Souris River. The location of existing flood risk reduction measures are shown on **Figure 1-1** (Existing Dams) and **Figure 2-1**, **Figure 2-2**, and **Figure 2-3** (levee and channel modification components).

2.1 Summary of Existing Project Elements

The existing projects that have been developed to reduce the risk of flood damages along the Mouse River in North Dakota have been developed by the U.S. Army Corps of Engineers (USACE) as a Souris River Basin project. The Souris River Basin project was developed over a series of years in three, separate, congressional actions and implemented in three phases. The first phase was a channel modification project in Minot. The second phase was a levee project in Velva. The third phase contained multiple features including flood storage in Alameda and Rafferty Dams in Saskatchewan; construction of a gated spillway and flood storage at Lake Darling Dam; levees at Sawyer, Renville County Park (Mouse River Park), and six subdivisions between Burlington and Minot; structural and nonstructural measures for rural residents along the Souris River; modification of U.S. Fish and Wildlife (USFW) structures in the Upper Souris and J. Clark Salyer National Wildlife refuges; and development of a flood warning system.

2.2 Upstream Reservoir Storage

There are four upstream dams operated to manage flows on the Souris River to reduce flood flows in accordance with a 1989 International Agreement between the United States and Canada. These four dams are Rafferty Dam, Alameda Dam, and Boundary Dam in Saskatchewan and Lake Darling Dam in North Dakota (**Figure 1-1**). The Saskatchewan Water Authority and the USACE have respective responsibilities for management of the flood control operations of these dams. All four dams are operated for multiple purposes and about half of the potential flood control storage is available only through lowering of the normal reservoir pool levels. In addition to flood storage these reservoirs are used for recreation, irrigation, and power plant operations. Therefore, the operation of these dams to reduce flood flows is dependent on reliable runoff forecasts. This assures that reservoir levels can be lowered, when necessary, to provide flood storage, then restored to normal operating levels to meet other needs.



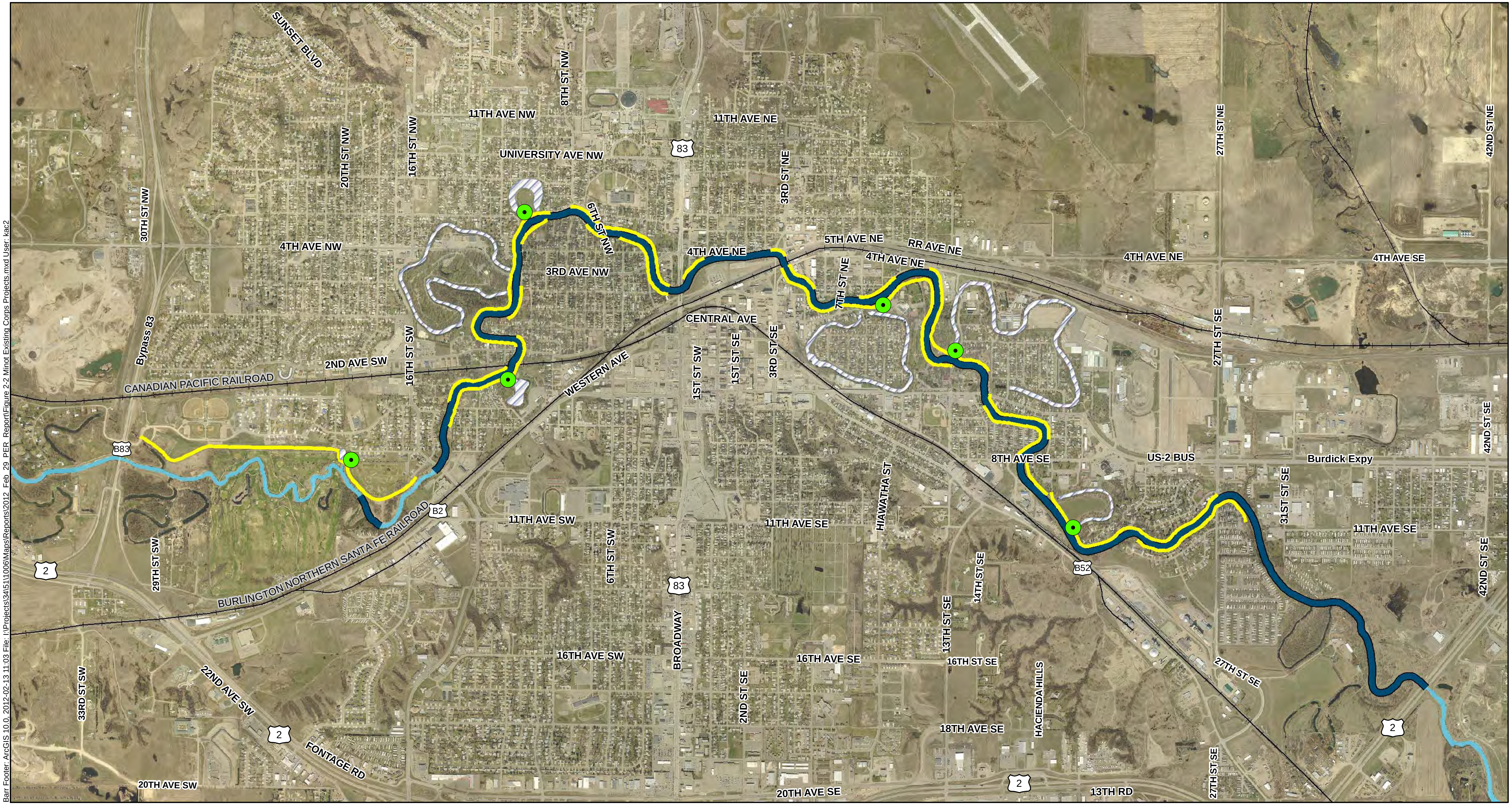
Barr Footer: ArcGIS 10.0, 2012-02-10 11:40 File: I:\Projects\34\51\1006\Maps\Reports\2012_Feb_29_PER_Report\Figure 2-1 Burlington to Minot Existing Corps Projects.mxd User: kac2

- Pump Stations
- Levee Centerline
- Channel Modifications
- Ponding Areas
- Mouse River

Coordinate System: NAD83, North Dakota State Plane Coordiante System, North Zone
Vertical Datum: NGVD29 2010 Aerial Photo

Figure 2-1

BURLINGTON TO MINOT
EXISTING FEDERAL PROJECTS
Preliminary Engineering Report
Mouse River Project



Pump Stations
Ponding Areas
Levee Centerline
Mouse River
Channel Modifications

0 900 1,800 3,600 Feet

Figure 2-2

MINOT EXISTING FEDERAL PROJECTS
Preliminary Engineering Report
Mouse River Project

Coordinate System: NAD83, North Dakota State Plane Coordiante System, North Zone
Vertical Datum: NGVD29 2010 Aerial Photo

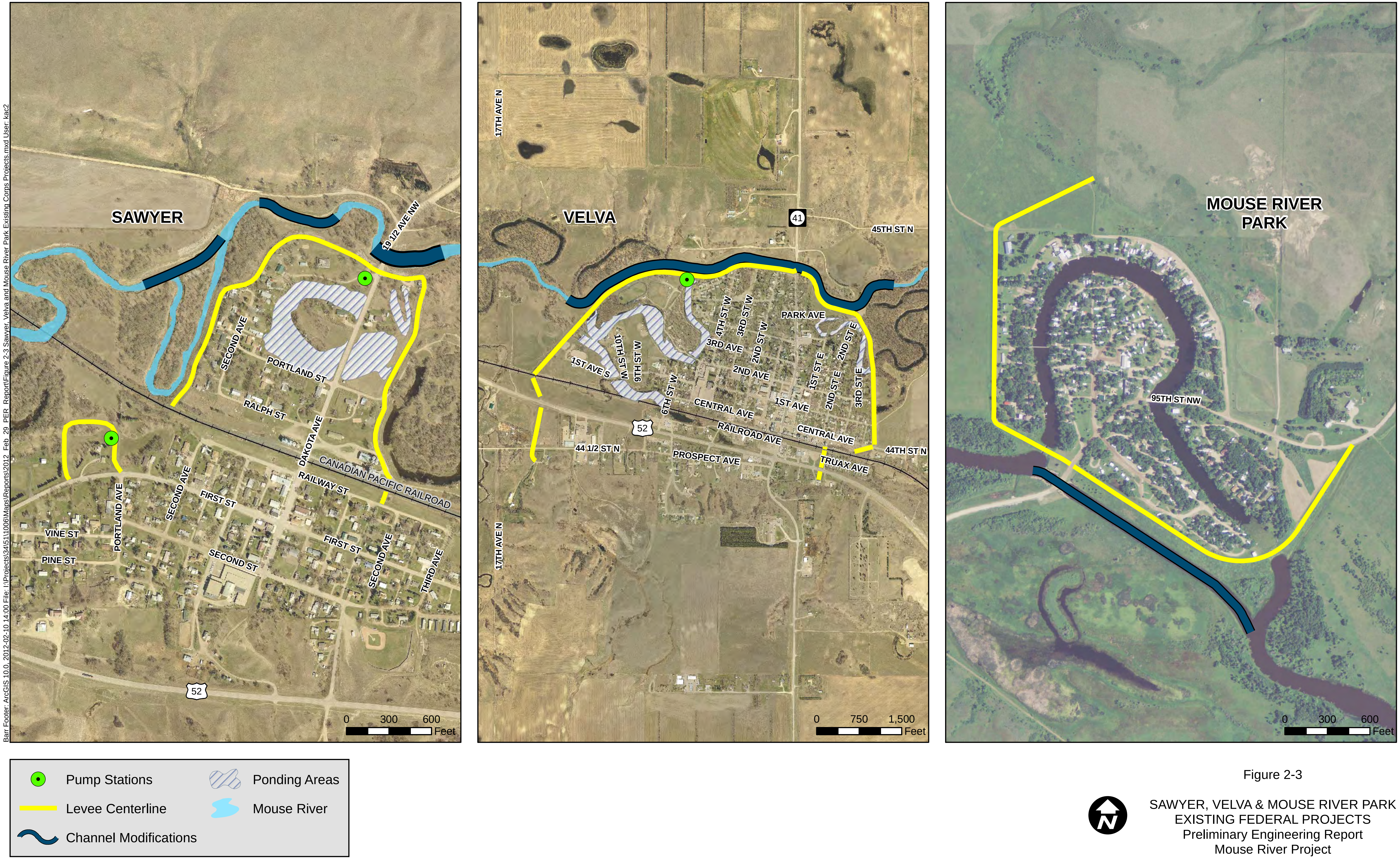


Figure 2-3

SAWYER, VELVA & MOUSE RIVER PARK
EXISTING FEDERAL PROJECTS
Preliminary Engineering Report
Mouse River Project

Coordinate System: NAD83, North Dakota State Plane Coordiante System, North Zone
Vertical Datum: NGVD29 2010 Aerial Photo

Barr Footer: ArcGIS 10.0, 2012-02-10 14:00 File: I:\Projects\34\51\1006\Maps\Reports\2012_Feb_29_PER_Report\Figure 2-3 Sawyer, Velva and Mouse River Park Existing Corps Projects.mxd User: kac2

The objectives of the operating agreement for the reservoirs are: (1) to reduce flood flows at Minot to non-damaging levels, with a maximum target flow of 5,000 cfs; (2) to reduce flood flows at urban and rural areas downstream of Rafferty Dam, Alameda Dam, and Lake Darling Dam; and (3) to the extent possible, maintain the water supply related benefits of these projects. A summary of the water storage in the four dams is presented in **Table 2-1**. Extensive coordination takes place between the USACE and the Saskatchewan Water Authority and other federal and state agencies in the operation of these dams to achieve the objectives of the agreement.

Table 2-1 Summary of Upstream Flood Storage, Souris/Mouse River Basin

	Rafferty Dam	Boundary Dam	Alameda Dam	Lake Darling Dam	Total System Flood Storage
	Storage (acre-feet)	Storage (acre-feet)	Storage (acre-feet)	Storage (acre-feet)	Storage (acre-feet)
Maximum Storage Level	513,000	49,800	153,700	158,600	
Full Supply Level	356,400	49,800	85,500	110,100	
Normal Spring Drawdown Level	318,100	49,800	76,400	99,000	
Maximum Spring Drawdown Level	247,500	36,200	41,100	53,000	
Maximum Spring Flood Storage	265,500	13,600	112,600	105,600	497,300
Normal Spring Flood Storage	194,900	0	77,300	59,600	331,800
Normal Summer Flood Storage	156,600	0	68,200	48,500	273,300

For normal spring drawdown levels, the Rafferty, Boundary, Alameda, and Lake Darling dams provide around 330,000 acre-feet of storage area to reduce flood flows. For anticipated major spring runoff events, if the reservoirs are drawn down to their maximum agreed-upon levels, there could be about 500,000 acre-feet of storage available for flood control. After spring runoff, when the reservoirs are at normal full-supply levels, there could be about 275,000 acre-feet of storage. Each of these reservoirs can only provide storage for rainfall or runoff events located upstream of the reservoir embankment. No reservoir storage would be available to mitigate runoff from a rainfall or snowmelt event downstream of Lake Darling, or located in the Des Lacs River watershed.

2.3 Burlington to Minot

Flood control project features in the reaches of the Mouse River from the city of Burlington to the upstream side of the city of Minot were federally designed and constructed by the USACE based on the project authorized by the 1986 Water Resources Development Act (Public Law [P.L.] 99-662) and Section 105 of the fiscal year 1988 Continuing Appropriations Act (P.L. 100-202). These project features are described in the *Operations and Maintenance Manual* for the Burlington to Minot project prepared by the USACE (reference [2]). The project features are located at Johnson's Addition (city of Burlington), Brooks' Addition, Talbott's, Country Club Acres and Robinwood Estates, King's Court and Rostad's Addition, and Terracita Vallejo. The project features at the city of Burlington are operated and maintained by the city of Burlington; the remaining project features are operated and maintained by the Souris River Joint Water Resource Board.

2.3.1 City of Burlington (Johnson's Addition)

The project consists of about 4,800 feet of levee, five sections of adjacent channel modifications over about 2,800 feet of river channel (including a cut-off channel about 400-feet long), an interior drainage system, a ponding area, a 2,000 gpm pumping station, and a sandbag/earthen closure structure. Completed in 1991, the project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard.

2.3.2 Brooks' Addition

The project consists of about 4,600 feet of levee, five sections of adjacent channel modifications over about 3,200 feet of river channel, one 2,000 gpm pumping station, and a ponding area. The project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard; construction was completed in1991.

2.3.3 Talbott's

The project consists of about 2,600 feet of levee, three sections of adjacent channel modifications over about 1,500 feet of river channel, one 2,000 gpm pumping station, and a ponding area. The project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard; construction was completed in 1993.

2.3.4 Country Club Acres and Robinwood Estates

The project consists of about 8,400 feet of levee, three sections of adjacent channel modifications over about 2,700 feet of river channel, one 2,000 gpm pumping station, and two connected ponding areas. The project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard; construction was completed in 1993.

2.3.5 King's Court and Rostad's Addition

The project consists of about 4,100 feet of levee, about 4,000 feet of channel modifications adjacent to the levee, one 4,000 gpm pumping station, and a ponding area. The project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard; construction was completed in 1993.

2.3.6 Terracita Vallejo

The project consists of about 900 feet of levee, channel modifications on about 600 feet of river channel, a ponding area, and a portable Crisafulli pump. An existing emergency levee, about 1,800-feet long, on the west side of the development was also left in place without any upgrades. The project was designed for a flood flow of 5,000 cfs with 3 to 3.8 feet of freeboard; construction was completed in 1990.

2.4 City of Minot

The flood control project features in the city of Minot were federally designed and constructed by the USACE based on the project authorized by the Flood Control Act of 1965 (P.L. 89-298) and modified based on recommendations by the USACE Chief of Engineers in House Document 286, 87th Congress, 2d Session, and House Document 321, 91st Congress, 2d Session. The project is operated and maintained by the city of Minot. The project features consist primarily of channel modifications and channel cutoffs and are part of an authorized federal project that extends from Burlington to Logan, which included flood control storage in the Burlington Dam. The project features in Minot were constructed separate from and before any of the other components of the authorized project. The city of Minot project extends from the Highway 83 Bypass on the west (upstream) to the Highway 2 Bypass on the east (downstream). These project features are detailed in the *Operations and Maintenance Manual* for the project, prepared by the USACE (November 1981).

The project was designed to accommodate flows up to 5,000 cfs with freeboard. This was estimated to be the 100-year frequency flood peak discharge with the implementation of upstream reservoir storage in the authorized plan. The city of Minot project features consist of the following elements:

- Channel excavation: Almost the entire river through Minot was modified; excavation was done on one side of the channel, providing a channel bottom width from 35 to 40 feet, with side slopes generally 1 vertical on 3 horizontal. The channel excavation extends from approximately Twenty-First Street SW on the west (upstream) to the Highway 2 Bypass on the east (downstream).

- Channel cutoffs: There are nine channel cutoffs in the city of Minot with channel bottoms from 35- to 40-feet wide. Several of the more prominent channel cutoffs are in the Roosevelt Park, Eastwood Park, and Oak Park areas.
- Channel control structures: Channel control structures are located within the cutoff channels to maintain a pool in the river or divert normal stream flows around the original channel loops that were cut off. Four of the control structures are comprised of reinforced concrete and are located in the cutoff channels at Roosevelt Park, Eighth Street SE, Ramstad Park and Oak Park.
- Levees: Levees were constructed adjacent to the channel wherever natural ground provided less than 2 feet of freeboard above the 100-year water surface. In areas where levees were constructed, the top of levee was set at 3 feet above the design water surface. One significant reach of levee is located on the west side of Minot from about Twenty-First Street SW to the Highway 83 Bypass. Several other smaller and shorter sections of levee exist through the city.
- Pumping stations: There are six pumping stations located in Minot to handle the interior drainage due to storm sewer system modifications and/or channel cutoffs required by the channel modifications or the levees.
- Ponding areas: Seven areas have been acquired for use as temporary ponding areas.

2.5 City of Sawyer

The flood control project features at the city of Sawyer were federally designed and constructed by the USACE based on the overall project authorized by the 1986 Water Resources Development Act (P.L. 99-662) and Section 105 of the fiscal year 1988 Continuing Appropriations Act (P.L. 100-202). The project is operated and maintained by the city of Sawyer. It consists of about 5,180 feet of levee, a cut-off channel, control structure, interior drainage system, ponding areas, pumping station, and closure structures. Construction was completed in 1991. These project features are described in detail in the *Operations and Maintenance Manual*, prepared by the USACE (reference [3]).

The project was designed to pass 5,500 cfs. This was estimated to be the 33-year peak discharge with the Lake Darling project (1993) in place and implementation of flood control storage in the Canadian dams at Rafferty and Alameda. The discharge for a water surface at the top of levee is estimated at 11,900 cfs.

Levees: The levee consists of upgraded emergency levees and new levee construction. The main component around the city is about 4,130-feet long. It starts near the railroad crossing on the west side of the city, heads north toward the Mouse River, following it to the east across Highway 23, then turns south—tying into high ground near the railroad crossing on the city's east side. The secondary component of the levee goes around a residence on the west side of the city near First Street. The top of levee has at least 3.3 feet of freeboard above design water surface. The levees were designed so that overtopping would occur on the downstream end of the project.

Pumping station: One pumping station, with a pumping capacity of 1,000 gpm, is located at the north side of the project on the upstream side of the Highway 23 Bridge. At the residential ring levee segment, a submersible 500 gpm pump was provided to pump from a gatewell.

Ponding areas: A ponding area is located in an abandoned oxbow channel on the north side of the city and is connected to the pumping station.

Channel modifications: The channel was enlarged and modified over a length of about 950 feet; a cut-off channel of about 755 feet cuts off about 2,400 feet of the existing river channel. The channel bottom widths are all 40–50 feet. Channel side slopes are generally 1 vertical on 3 horizontal. A sheet pile and riprap cut-off control structure is located in the cut-off channel to divert low river flows through the existing river loop which was cut off by the project.

Closures: An earthfill closure is required at the upstream crossing of the railroad tracks by the levee. A sandbag closure is also needed at the residential ring levee where the levee ties into Highway 10.

2.6 City of Velva

The flood control project features at the city of Velva were federally designed and constructed by the USACE based on the overall project authorized by the Flood Control Act of 1970 (P.L. 91-611) and the 1982 Energy and Water Development Appropriations Act. The project is operated and maintained by the city of Velva. It consists of about 2 miles of levee, seven closures, raises to a portion of Prospect Avenue, and a 6,500-foot channel modification of the Mouse River. Interior flood control facilities consist of two ponding areas with outlets and sluice or flap gates, a pumping station, ditches, and interceptor sewers. Completed in 1987, the project also includes erosion protection and a control structure. These project features are described in detail in the *Operations and Maintenance Manual* for the project prepared by the USACE (reference [4]).

The project was designed to pass 14,700 cfs. This was estimated to be the 100-year peak discharge with the implementation of a 4-foot raise of Lake Darling, which was part of the authorized plan. The discharge estimated for the top of levee water surface elevation at the downstream end was 26,000 cfs.

Levees: The levee runs from high ground on the southwest corner of the city (upstream) near Prospect Avenue and Highway 52 to the north, follows the south bank of the Mouse River to the northeast corner of the city, then proceeds south to tie into high ground on the southeast corner of the city near Prospect Avenue and Highway 52. The total length of the levee is 10,200 feet. The top of the levee was designed with 6.3 feet of freeboard above the design water level at the upstream end and 2 feet at the downstream end. The elevation was selected so that overtopping, if it occurred, would happen first at the downstream end. Pumping stations: A pumping station is located in the northwest corner of Velva Park, on the northwest side of the project and connected to the ponding area on the west side of the city.

Ponding areas: There are two ponding areas—one, each, on the west and east side of the city.

Channel modifications: The modified channel has a bottom width of 50 feet. It begins about 4,350 feet west (upstream) of the Highway 41 bridge and extends about 2,130 feet downstream of the bridge. The channel modification includes a control structure about 2,155 feet upstream of the Highway 41 Bridge.

Closures: There are seven closures required: sandbag closures at the railroad tracks on the west side of the city; Highway 41 and Railway Avenue on the east side of the city; a stop log closure at the southeast end of the levee; and earthfill closures at First Avenue, Highway 52, and Prospect Avenue.

2.7 Other River Reaches

Some additional flood control project features in the reaches of the river outside of the cities of Burlington, Minot, Sawyer, and Velva—and the developments between Burlington and Minot—were federally designed and constructed by the USACE based on the project authorized by the 1986 Water Resources Development Act (P. L. 99-662) and Section 105 of the fiscal year 1988 Continuing Appropriations Act, (P.L. 100-202). These features consisted of non-structural flood proofing at 10 rural residences upstream of Lake Darling and 80 rural residences between Minot and Towner, and a levee system at Renville County Park (also known as Mouse River Park).

3.0 Project Alternatives

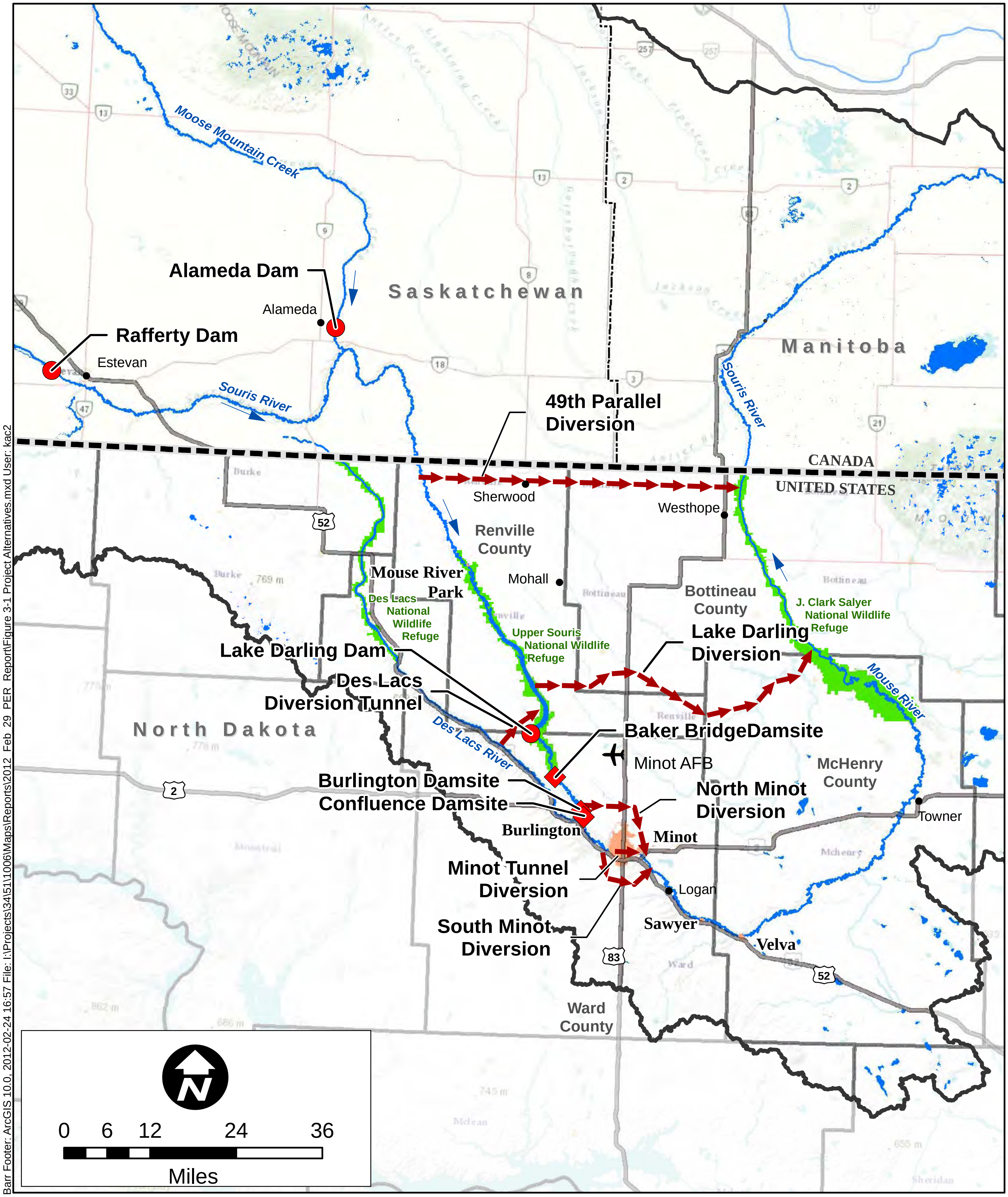
The scope of the preliminary alignment plan is to reduce the risk of flood damage from river flows comparable to the record flood of June 2011, and consists of a levee and floodwall project designed for flows up to 27,400 cfs. However, there are an array of alternative approaches to reducing flood risk to residents and businesses in the Mouse River Valley. Potential alternatives range from the no-action approach of restoring and maintaining the existing channel modification, levee, and upstream flood storage system, to complete removal of damageable properties within the 2011 flooded area, with combinations of options in between these extremes.

For a project of this magnitude, it is important to evaluate a range of viable alternatives to demonstrate that the proposed Mouse River Enhanced Flood Protection project (Project) is in the best interests of the public and complies with necessary regulatory permitting or approval requirements. A comprehensive review of potential alternatives to the preliminary alignment Project was not developed for this preliminary engineering report. It is likely that additional alternatives analysis will be required to comply with federal permit requirements and obtain approval from the U.S. Army Corps of Engineers (USACE) to modify the existing federal projects.

Previous reports and studies were reviewed to determine the range of flood risk reduction alternatives considered for the Mouse River Valley. A partial list of alternatives that have been or could be considered—including a preliminary assessment of implementation considerations— is discussed here and summarized in **Table 3-1**. The location of several of these alternatives is shown in **Figure 3-1**. Additional information on alternatives can be found in **Appendix I**.

Table 3-1 Potential Alternatives for Flood Risk Reduction for Mouse River Valley

Alternative	Implementability Considerations
Upstream Flood Storage	
Construction of New or Additional Storage	
Canadian Dams	Unlikely - High cost, Large land requirement, Environmental Impacts
Souris River in US	Unlikely - High cost, Large land requirement, Environmental Impacts
Des Lacs River in US	Unlikely - High cost, Large land requirement, Environmental Impacts
Operational Modifications of Existing Dams	
Alameda, Rafferty & Boundary Dams	Possible -Limited effectiveness, Impacts on other reservoir storage purposes
Lake Darling Dam	Possible - Limited effectiveness, Impacts on other reservoir purposes, Environmental Impacts
Diversions	
Upstream Diversions	
49th Parallel Diversion	Unlikely - High cost, Large land requirements, Environmental Impacts
Lake Darling Diversion	Unlikely - High cost, Large land requirements, Environmental Impacts
Local Site Diversions	
Minot North Diversion	Unlikely - High cost, Limited effectiveness, Large land requirements
Minot South Diversion	Unlikely - High cost, Limited effectiveness, Large land requirements
Minot Tunnel (South)	Unlikely - High cost, Limited effectiveness
River Loop High Flow Diversions	Likely - Supplement to levees, Reduced land impact
Levees and Floodwalls	Likely - Cost effective, Land required is generally most prone to flooding
Channel Modifications	Unlikely - High cost, Limited effectiveness, Environmental Impacts
Removing Drains in Upstream Basin	Unlikely - Limited effectiveness, Landowner opposition
Floodproofing	Unlikely - Limited effectiveness, Social acceptance and livability Issues
Relocation/Buyouts	Unlikely - High cost, Large land requirements, Local acceptability issues
Increased Floodplain Regulations	Possible - Limited effectiveness, Only addresses future development
No Action - Maintain current levee, channel modification and flood storage system	Possible - Does not achieve objective, Low cost option, Allows rebuilding in existing flood-prone locations



Mouse/Souris River Watershed
National Wildlife Refuges
Provincial/State Boundaries
County Boundary

Figure 3-1
ALTERNATIVES LOCATION MAP
Mouse River Project

3.1 General Alternatives

Alternative evaluations are normally accomplished at several levels of detail, starting with the complete list of potential alternatives and proceeding through a screening process to identify those that show the greatest potential for achieving Project objectives. The complete list of alternatives is considered at a very preliminary level of detail, with the most promising alternatives being considered in the greatest level of detail.

Many previous flood risk reduction studies were based on identifying alternatives that could reduce flood damage in the Mouse River Valley and be considered economically justified using federal criteria. These studies resulted in projects that were generally designed to pass 5,000 cfs at non-damaging levels, using a combination of upstream flood storage, levees, channel modifications, and flood proofing features. In these previous studies, the alternatives to the constructed projects were eliminated from further consideration for a variety of reasons including economic, environmental, or implementability concerns, or an inability to meet study objectives. A number of non-implemented alternatives included major upstream flood storage, large upstream diversion projects and a variety of localized channel modification and diversion projects. Dams were considered at Baker Bridge, Burlington and confluence dam sites as shown on **Figure 3-1**. Diversions were considered at the 49th Parallel, Lake Darling, Des Lacs Tunnel, North Minot, South Minot and Minot Tunnel as shown on **Figure 3-1**. Information on those alternatives is presented in **Appendix I.**

Providing protection from a flood of similar magnitude to the 2011 event would require considerably expanded versions of the alternatives previously evaluated; it is highly likely that the concerns which originally caused these alternatives to be dismissed remain. A list of alternatives which could be considered to the preliminary alignment Project and a preliminary assessment of the implementability considerations for each is presented in Table 3-1**.** Since the existing upstream flood storage was fully used during the 2011 flood and the volume of runoff that occurred from June rainstorms exceeded the capability of the dams to effectively contain flood flows to 5,000 cfs, it became apparent to local and state water management officials that an expanded system of levees and floodwalls was the most effective way to reduce the risk of future flood damages.

3.2 Potential Combination Alternatives

Among the more likely alternatives to achieve reductions of flood risk from a flood of the magnitude of the 2011 flood would be either the preliminary alignment plan presented in this report, or a combination of an increase in upstream flood storage with a reduced scale of an expanded levee and floodwall system similar to the preliminary alignment plan. A potential increase in upstream flood storage could be implemented by modifying the operating plans of existing reservoir systems to allow lower spring drawdowns of pool levels and higher release rates during flood events. These possible combinations could be evaluated in future Project efforts, with the objective of reducing overall Project costs, Project-related water-level increases, environmental impacts, and the number residential properties required to implement the Project. The USACE has already been asked to evaluate possible modifications at Lake Darling and the International Joint Commission (IJC) is considering a reevaluation of operating plans and procedures for the Alameda, Rafferty, Boundary, and Lake Darling dams that are governed by an international agreement between Canada and the United States. The level of detail of future alternatives evaluations will likely be determined, in part, by the findings and conclusions of those studies and by future permitting and agency approval requirements.

3.3 Alternative Alignments and Features of Selected Plan

Alternative alignments and Project features were considered at the various locations throughout the Mouse River study reach through an iterative process of identification, evaluation, and screening as described in Section **4.0**. Several alternative alignments of levees and floodwalls and several alternative high-flow diversion alignments were considered. The selection criteria was based on a design flood comparable to the 2011 flood that would: (1) reduce the flood risk to as many homes and developed properties as possible; (2) keep the number of homes and residences to be acquired for the Project as low as possible; (3) keep upstream and downstream water-level increases at reasonable levels; and (4) keep the Project cost as low as practical. The Project consists of a combination of levees, floodwalls, channel improvements, high flow diversions, and floodplain buyouts. This Project removes about 500 homes and businesses from the flood prone areas along the Mouse River through acquisition and buyouts and reduces the risk of flood damages to over 5,000 homes and businesses that remain. Additional alignment and Project feature evaluations will be necessary as detailed engineering investigations, detailed design, and additional environmental studies are conducted.

4.0 Flood Risk Reduction Strategy Development

This preliminary engineering report focuses on the reaches of the Mouse River at Mouse River Park and from Burlington to Velva. This includes the communities of Burlington, Minot, Logan, Sawyer, and Velva, as well as the developments, farmsteads, and residences within that reach. Rural areas along the Mouse River, upstream of Burlington to the Canadian border and downstream of Velva to the Canadian border, may be considered in later phases of Project planning and development.

4.1 Plan Formulation

The development of a preferred preliminary alignment is a complex process that requires both significant technical analysis and substantial stakeholder input. A key objective for development of a preliminary alignment plan was to assist the cities and counties in identifying the corridor needed for a project. This would lessen the impact on affected property owners by allowing them to begin the rebuilding process with some degree of assurance that they would not be adversely affected by subsequent implementation of the Mouse River Enhanced Flood Protection project (Project).

To facilitate initial stakeholder input and quickly collect as much information as possible, a start-up workshop was held in Minot October 5-7, 2011. The over-arching objective for the workshop was to engage local stakeholders in dialog regarding flood risk reduction priorities. Specific objectives included:

- Confirming Project scope, objectives, and schedule
- Getting input from local representatives and residents to identify flood protection priorities
- Developing preliminary flood risk reduction strategies, concepts, and alternatives based on ideas from the stakeholder and consultant group
- Developing options for a working flood risk reduction alignment that had broad consensus from the stakeholder group

The workshop included a mix of presentations, interactive dialog, and working sessions. Breakout sessions were held for the following three major study areas to allow for focused dialog:

- The area between Burlington and Minot
- The city of Minot
- The area between Minot and Velva

Issues and concerns for Mouse River Park and other rural areas outside of the study limits were also acknowledged and discussed.

Below is a list of key design considerations and priorities identified at the workshop. These priorities were used by the consulting team to help guide the development of preliminary alignment and engineering efforts. A more detailed summary of stakeholder input and priorities identified during the workshop is provided in **Appendix I**.

- Reduce the flood risk associated with a flood of comparable magnitude to the June 2011 event for as many homes and critical infrastructure features as reasonably possible
- Minimize impacts on the Northwest Area Water Supply (NAWS) line
- Limit water surface elevation (WSE) increase over the 2011 observed flood level to between 1 and 2 feet
- Manage flow velocities to prevent erosion damage and reduce the need for erosion control measures
- Minimize the Project alignment footprint, wherever possible, to reduce required property acquisitions and Project costs
- Incorporate 3 feet of freeboard into the flood risk reduction features (levees, floodwalls, etc.)
- Keep critical transportation routes (e.g. Highway 83 Bypass, Broadway Bridge, Burdick, Highway 2 Bypass, and Highway 52) passable during a flood event similar in magnitude to the 2011 event
- Environmental impacts should be avoided wherever possible

4.1.1 Alignment Development Process

The above criteria were used to develop the initial draft conceptual alignment using the process outlined in **Figure 4-1**. This simplified alignment development flow chart illustrates that design constraints and estimates of water surface elevations are essential to developing a reliable flood risk reduction project. If design constraints are not achieved by the proposed alignment, the alignment must be iteratively adjusted.

One of the most critical design constraints is the estimation of the design water surface elevation so that the height of the constructed features can be established. Consideration must also be given to the potential hydraulic effects that the proposed alignment and resultant water surface elevation may have on upstream and downstream water surface elevations. The U.S. Army Corps of Engineers' (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) model was used to compute water surface elevation and velocity impacts of preliminary alignment Project features. HEC-RAS was selected as the primary tool for this report because it had previously been used by the USACE to model the study reach and is the most commonly used tool to establish FEMA published flood elevations. Additional detail about the hydraulic model conducted for this report is in **Section 6.1** and **Appendix C**.

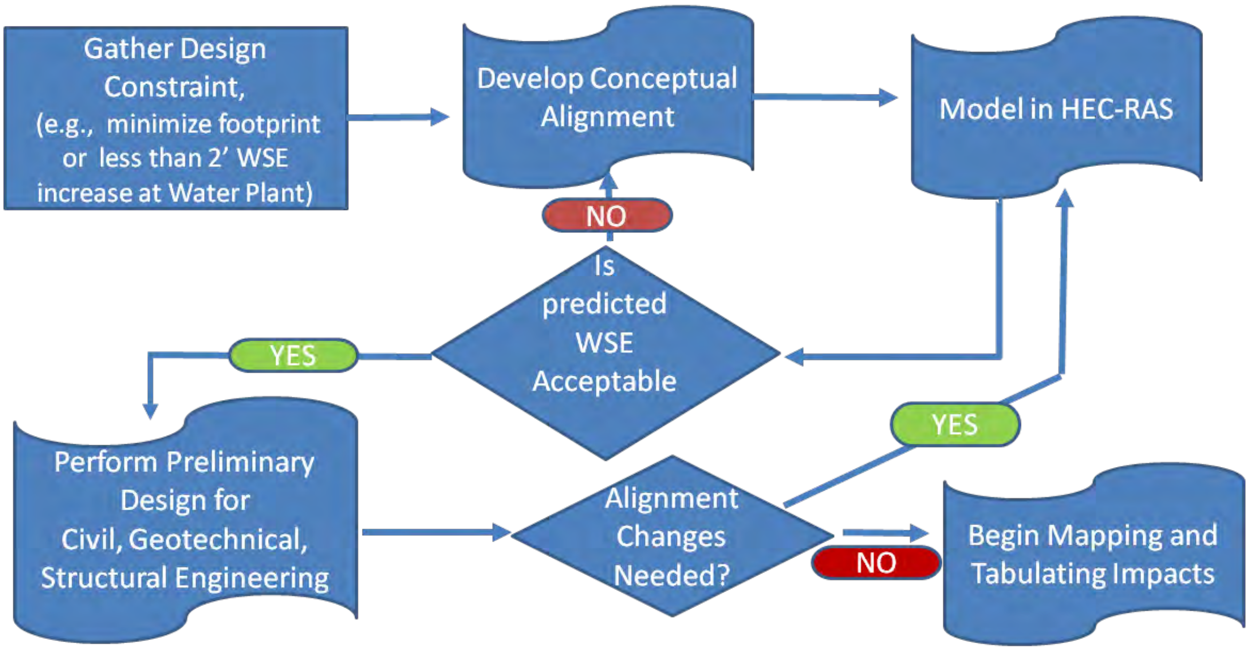


Figure 4-1 Simplified Schematic of the Alignment Development Process

As with most computer simulations, the accuracy of the HEC-RAS model is highly dependent on the input data and data available to substantiate the model predictions. After a thorough review of the USACE's existing HEC-RAS model, the engineering team decided to build a new HEC-RAS model, making use of better input data such as LiDAR, as-built records, and field survey data. This new, "existing conditions" HEC-RAS model was calibrated to 2011 surveyed maximum water surface elevations collected along the study reach. **Figure 4-2** shows a comparison between the observed high-water elevation (black diamonds) and the computed 2011 peak water surface profile (shown in blue) between Burlington and Velva. The calibrated hydraulic model for this portion of the Project used a 27,400 cfs flow, which was the peak flow measured by the USGS at the Broadway Bridge in Minot. The model's ability to closely predict the observed 2011 high-water elevation builds confidence that the HEC-RAS computer simulations accurately reflect real-world conditions.

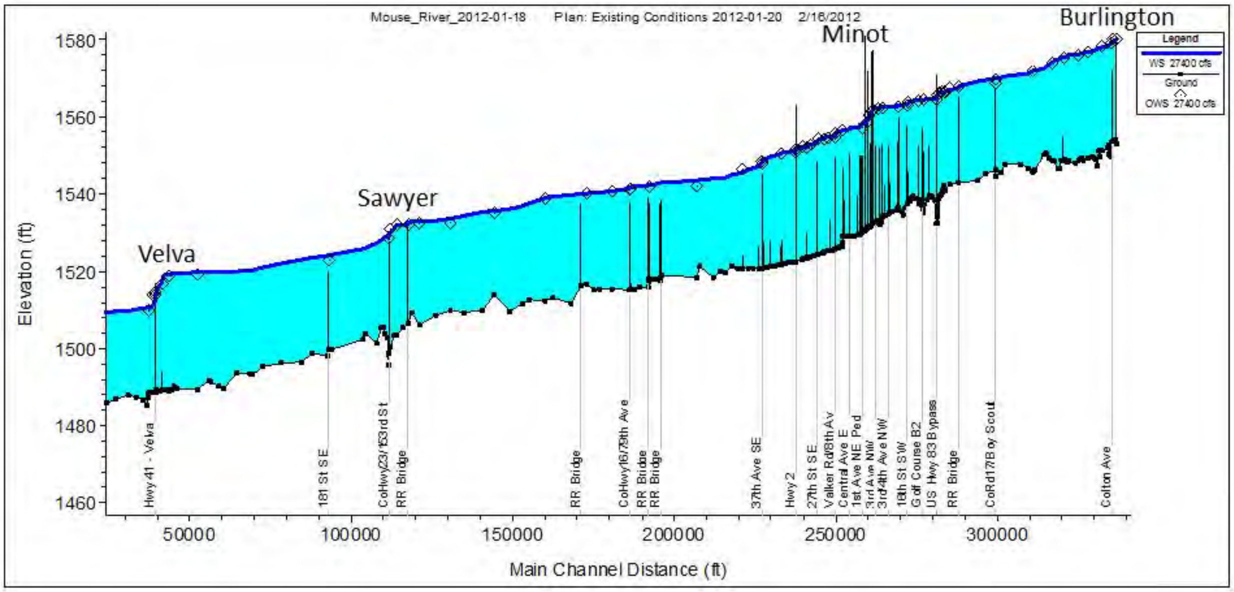


Figure 4-2 HEC RAS Calibrated Water Surface Profile between Burlington and Velva

4.1.2 Minimized Project Footprint Investigation

The calibrated model allowed the engineering team to begin investigating various flood risk reduction feature alignments. One of the first alignments investigated assumed floodwalls throughout Minot to minimize the potential impact on property. This initial modeling looked at two similar alignments as highlighted in **Figure 4-3**. One configuration assumed the floodwalls would be at the river bank stations in the HEC-RAS model (see yellow alignment on **Figure 4-3**). For modeling purposes, the bank stations were defined as the location where the 2-year water surface elevation intersected the slope. This configuration would allow the floodwall to be constructed as close to the river as possible and minimize the impact to nearby properties. The second configuration would involve setting floodwalls back from the bank stations about 45 feet on each side of the river through Minot (green alignment on **Figure 4-3**).

Figure 4-4 summarizes the impacts on the water surface elevations between Burlington and the Highway 2 Bypass, assuming the two floodwall-only alignments. Restricting the floodplain from what occurred in 2011 to either of the two floodwall alignments shown in **Figure 4-3** has a significant impact on computed water surface elevations. If floodwalls were constructed at the 2-year bank stations, model simulations indicate that the water surface elevation at the Broadway Bridge would be about 10 feet higher than what was observed in 2011. This floodwall configuration would also cause an increase of about 18 feet above the observed 2011 flood elevation at the Highway 83 bypass. Flood levels upstream of Minot would also increase significantly, including an increase of over 5 feet at Colton Avenue in Burlington. If the floodwalls were setback 45 feet, flood levels at Broadway and the Highway 83 Bypass would increase above 2011 observed levels by roughly 6 and 10 feet, respectively. While this configuration has less impact on flood levels, the effect of squeezing the floodplain would still result in almost a 4-foot increase at the Boy Scout Bridge.

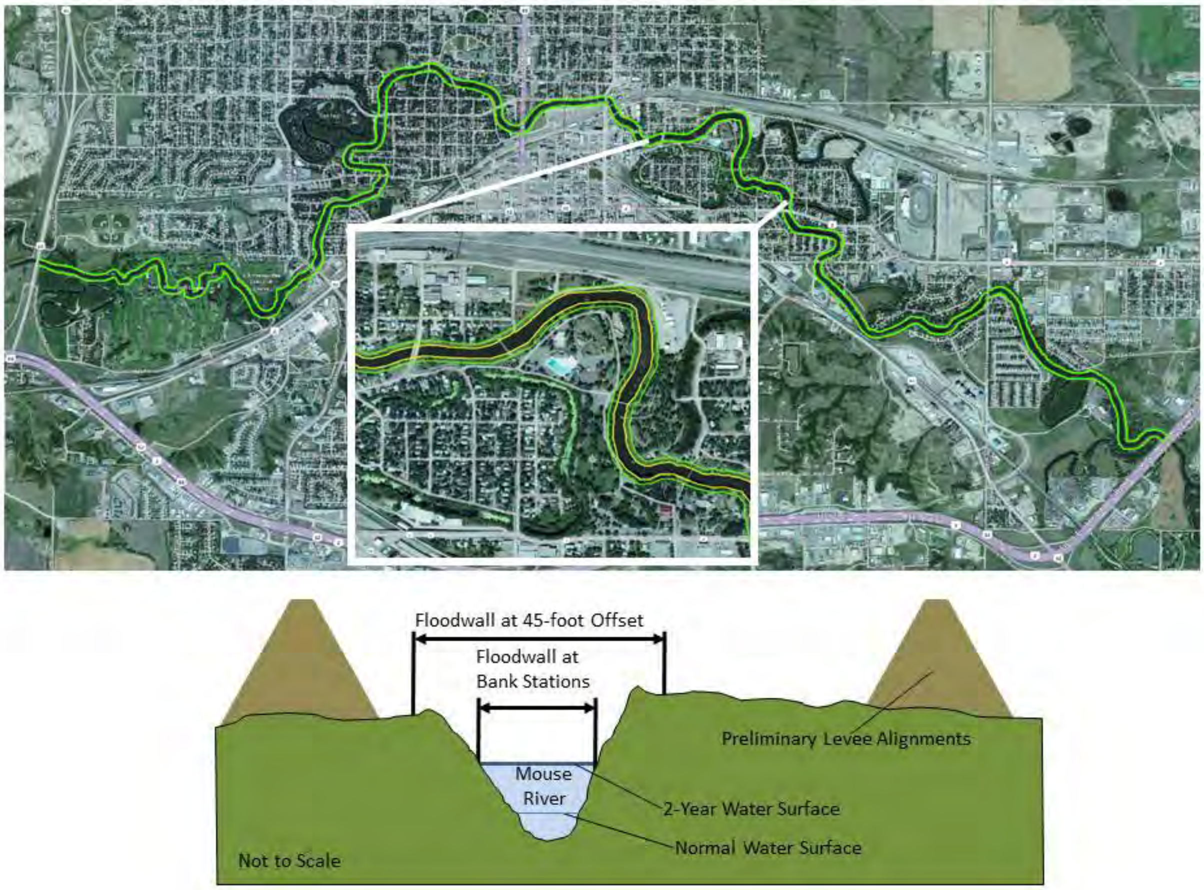


Figure 4-3 Flood Wall Option Alignment through Minot

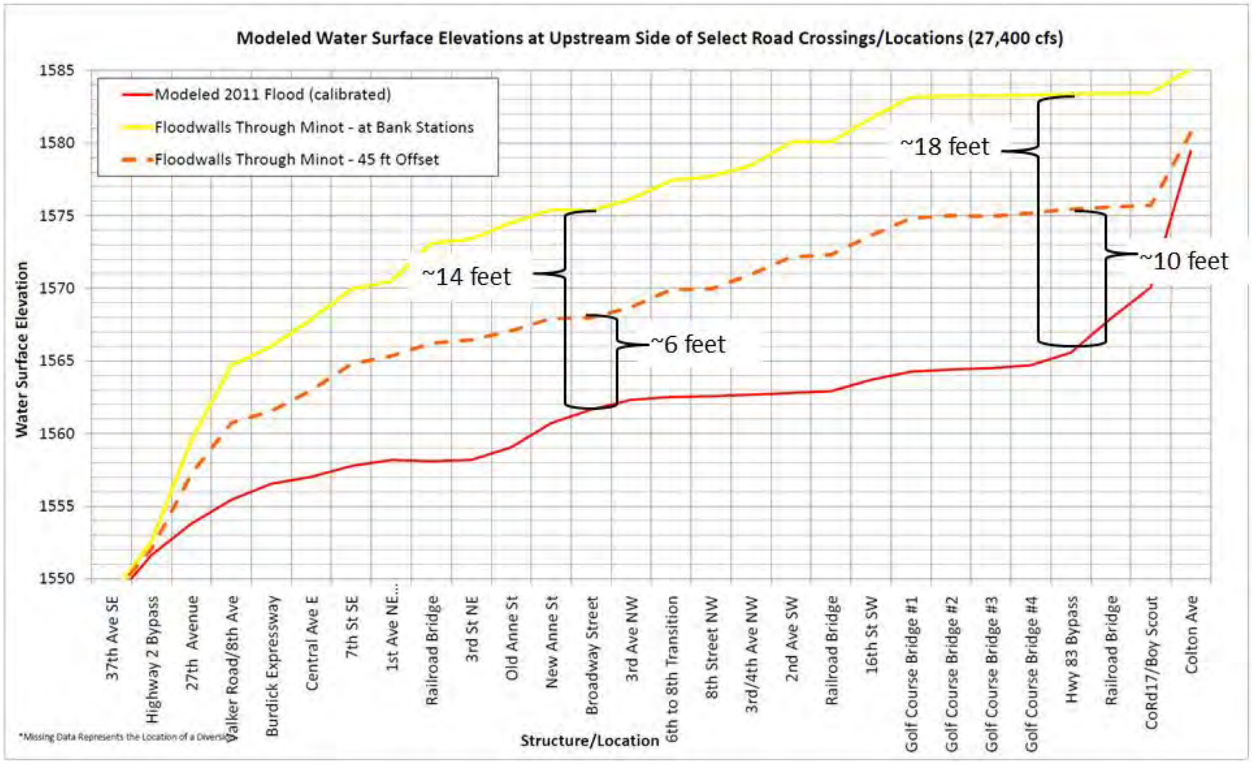


Figure 4-4 Computed Peak Water Surface Elevations with Assumed Floodwalls at 2-Year River Bank Stations and a 45-Foot Offset between Burlington and Highway 2 Bypass

4.1.3 November 3, 2011, Draft Conceptual Alignment

The development of the November 3 draft conceptual alignment was evaluated using a HEC-RAS hydraulic model calibrated to the June 2011 flood event for the Mouse River from Burlington to Velva. **Figure 4-5** compares the estimated water surface profile that would result from the draft conceptual alignment (green line) to the water surface profile calibrated to the 2011 flood event (red line). A comparison of the two profiles presented in **Figure 4-5** indicates that the alignment published on November 3 met the key design constraint of limiting the water surface elevation increase over the 2011 observed flood level to between 1 and 2 feet. In fact, the Highway 23 bridge improvements included at Sawyer would improve the hydraulic efficiency of the system and result in a slightly lower water surface level than was observed in 2011.

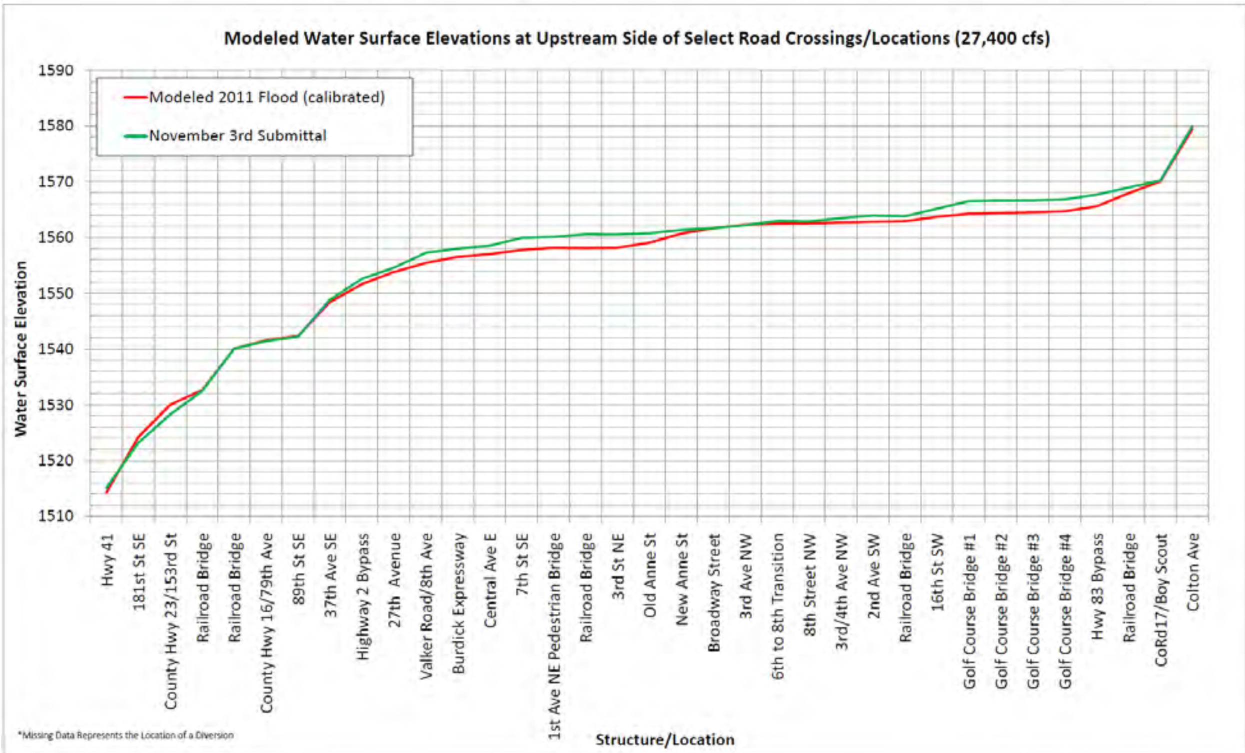


Figure 4-5 HEC RAS Modeled Water Surface Elevation at Upstream Side of Select Road Crossings/Location (27,400 cfs)

This initial draft conceptual alignment plan was published on November 3, including a series of maps of the Project area (1 inch = 1,000 foot scale) showing "Likely Project Limits" and "Uncertain Project Limits," based on the best available information. **Appendix J** includes a complete set of maps for the initial draft conceptual alignment plan. An example of these maps is shown in **Figure 4-6**. The Project features used in the draft conceptual alignment were primarily levees and floodwalls and used a freeboard/risk and uncertainty allowance of 3 feet to determine the top of the flood barriers above the Project design water surface profiles. The draft conceptual alignment was presented to the public at a series Public Meetings/Open Houses, November 8–10, 2011, in Minot. While the November 3 alignment met the hydraulic performance design constraints, stakeholder feedback indicated that the number of Minot-area homes impacted by the Project was too great.

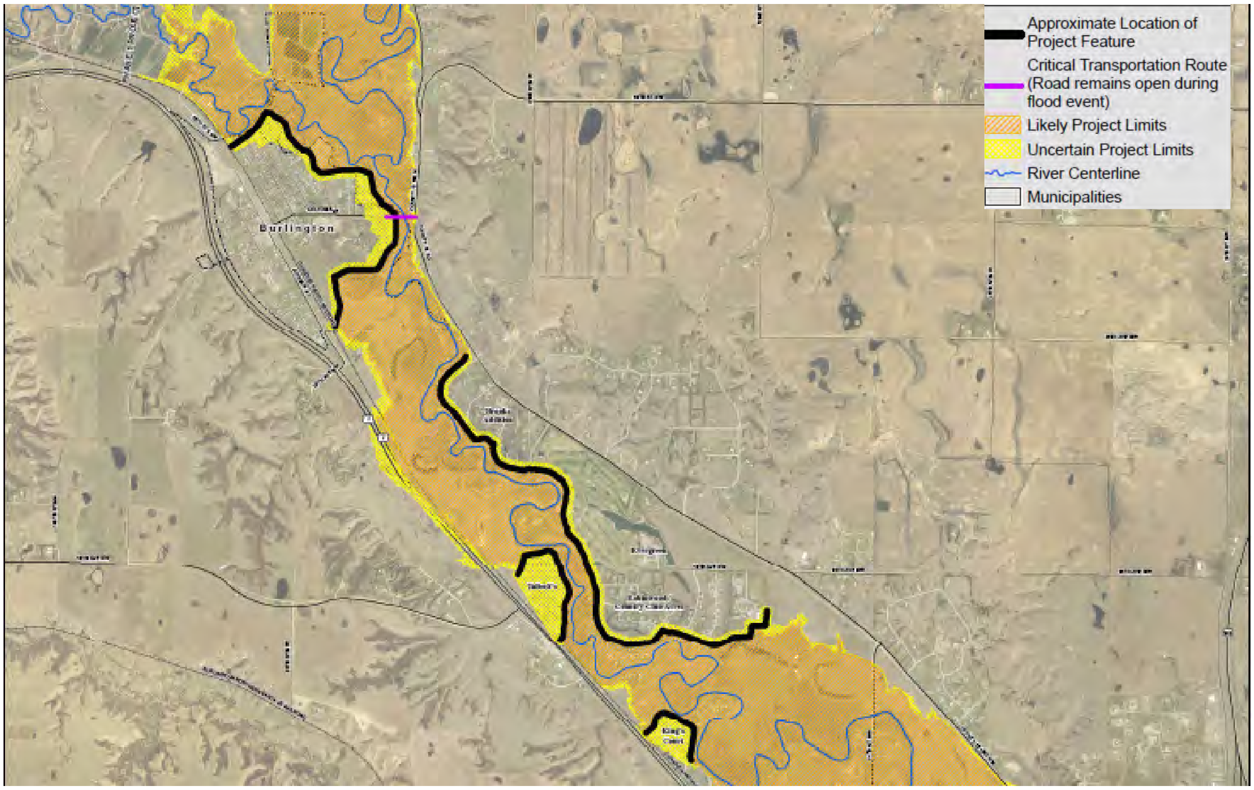


Figure 4-6 Example November 3 Alignment Map for Burlington to Kings Court

4.1.4 November 30, 2011, Alignment

Based on input from the public, the North Dakota State Water Commission (NDSWC), the Souris River Joint Board (SRJB), the cities, and other stakeholders, as well as continued review and evaluation by the consulting team, a variety of alignment and design modifications were considered and evaluated. Modifications that reduced adverse impacts to homes and critical infrastructure, reduced the Project footprint and the number of residences to be acquired, and reduced the length or number of constructed features (levees, floodwalls, closures, pump stations, road raises, and bridge modifications) were incorporated into a revised alignment. Revisions from the November 3 plan included:

- Further review of the Kings Court/Del Nor Drive neighborhood located between Burlington and Minot
- Levee alignment changes around the Terracita Vallejo neighborhood
- Consideration of a high-flow diversion in the Lincoln Elementary School neighborhood as an alternative to the levee and floodwall alignment following the existing river channel between

Second Street SW and the Broadway Bridge; this resulted in consideration of two high-flow diversion alignments: the Lincoln Diversion and the Maple Diversion.

- Major alignment change to incorporate a high-flow diversion in the El Rio Drive/Twenty-Seventh Street SE neighborhood as an alternative to the levee and floodwall alignment which follows the existing river channel between Souris Court and Thirty-First Street SE
- Minor levee and floodwall alignment changes in several locations within the city of Minot
- Levee alignment changes around Apple Grove and Eastside Estates
- Levee alignment changes and bridge modifications in Sawyer
- Further review of the river channel alignment downstream of the Highway 41 bridge and improvements to the Highway 41 bridge at Velva

Consideration of the major alignment changes for the high-flow diversions in the Lincoln Elementary School neighborhood and the El Rio Drive/Twenty-Seventh Street SE neighborhood were significant enough that neighborhood meetings were held November 22–23, 2011, to present these changes to residents.

On November 30, 2011, a revised set of alignment maps (1 inch = 300-foot scale) reflecting the adjustments described above, with identified Project features and alignments, was presented to the NDSWC, the SRJB, and the public. **Appendix J** includes a complete set of maps and information published on November 30, 2011. **Figure 4-7** shows an example of the alignment maps issued on November 30.

In the developed areas through the city of Minot, the flood protection system alignment was significantly influenced by the river meander patterns and flow restrictions at bridges. Efforts to minimize increases in water surface levels while protecting critical infrastructure and minimizing the number of homes within the Project limits also influenced the alignment. The width of the Project limits through the city of Minot is generally between 550 and 1,100 feet. For comparison, the width of the Mouse River inundation in rural areas with no levee protection is typically between 2,500 and 5,000 feet at the Project target flow.

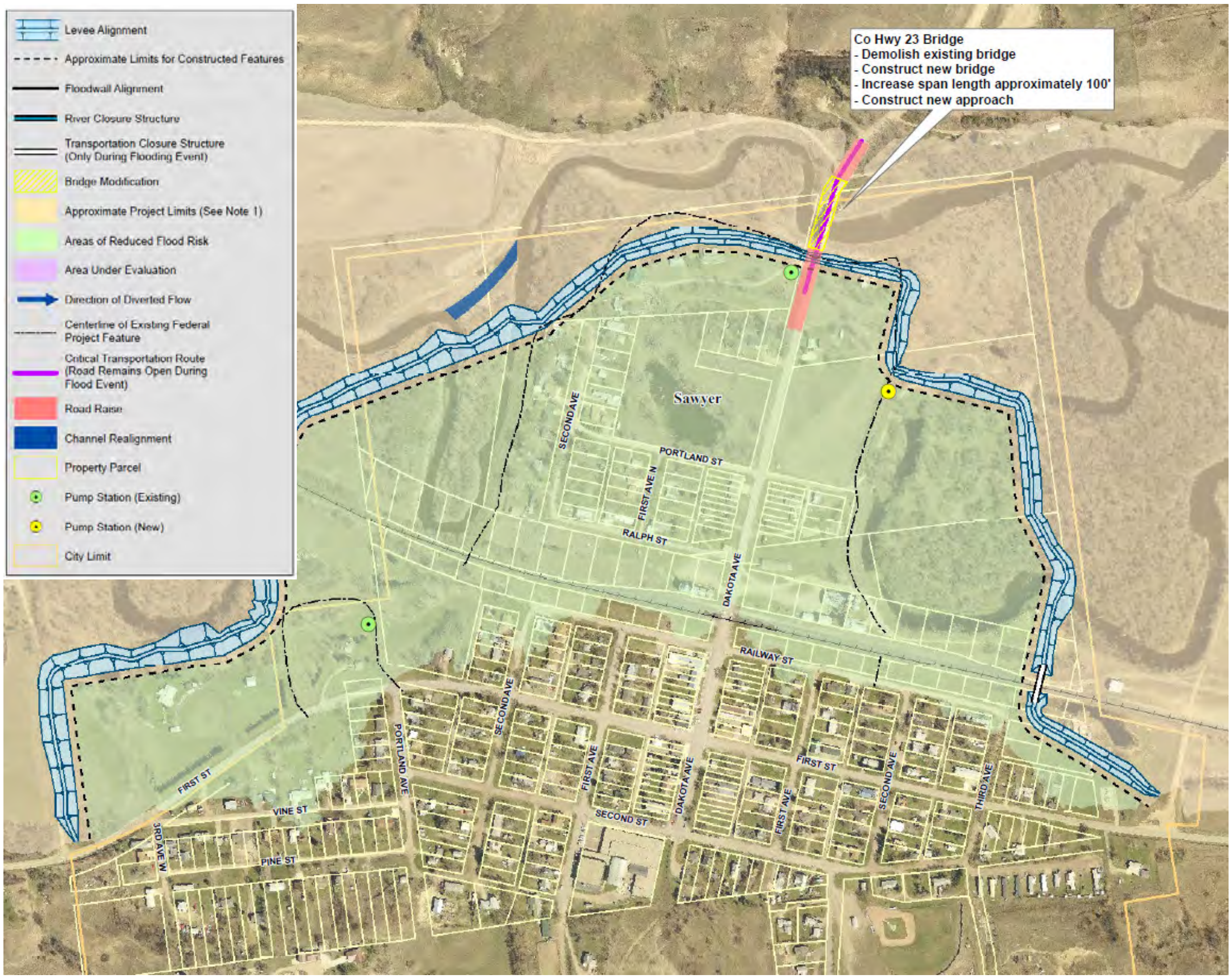


Figure 4-7 Example Alignment Map Published on November 30, 2011, for Sawyer

An estimate of the number and types of properties affected by the November 30, 2011, draft alignment was developed using digital geographic information systems (GIS) and air photos to overlay available property information with the revised draft alignment Project limits. The estimate of affected properties is limited by the accuracy and completeness of the available information. The city of Minot's GIS-based property parcel database is the best available data source for identifying affected property within the city of Minot. However, property information outside the city limits is not available in a GIS format. For these areas it was necessary to use air photos to estimate the number of affected properties.

Table 4-1 provides a summary of the estimated number of properties adversely have been affected or left unprotected by the November 30 alignment.

Table 4-1 Estimate of Properties Affected by November 30, 2011 Alignment

Property Zoning Classifications	Estimated Number of Affected Properties (1, 4)
Non-residential	203
Manufactured Home	4
Residentially Zoned with House / Building (2,3)	680
Residentially Zoned with No House / Building	134
Estimated Total Number of Affected Properties	1,021

(1) Table 4-1 includes properties that are either fully or partially affected, including properties that may have only a small portion of area affected.

(2) Residential zoning classification includes parcels classified as single family, two-family, and multi-family. Data is not readily available for estimating the number of housing units represented by this property count.

(3) Residentially zoned property estimates include estimates of rural properties (using aerial photos) impacted by construction of flood protection features and properties that could remain but would be susceptible to inundation from the target flood event. Protection, relocation, or no- action options would be available for susceptible properties.

(4) The affected properties in Mouse River Park are not included in Table 4-1 i

In the city of Minot, it is estimated that about 380 residential properties with structures would have been adversely affected by the November 30 draft alignment. This number is about 100 fewer than the November 3 alignment. Approximately 80 homes outside of Minot would be adversely affected from construction of the revised draft alignment features, including properties in Burlington, Logan, Sawyer, Velva, and rural subdivisions. In addition, within the Project limits, approximately 230 rural residential properties would be unprotected and susceptible to inundation during a target flow event. Options for these unprotected residents would need to be evaluated on an individual basis.

Subsequent evaluations and adjustments to the alternative alignments in these reaches continued into December and January in an effort to reduce the number of residential homes affected while minimizing the increase in computed water surface elevation for the 2011 event. On January 17, 2012, a memorandum providing additional details on the alternative alignments in the Lincoln Elementary School neighborhood was provided to the NDSWC and subsequently coordinated with the SRJB and the city of Minot.

4.1.5 High-Flow Diversions

4.1.5.1 Twenty-Seventh Street SE High-Flow Diversion

The alignment alternative in the El Rio Drive/27th Street SE neighborhood consists of a high-flow diversion channel that would divert flood flows near the west end of El Rio Drive and Twenty-Fifth

Street SE along a channel constructed north of the Canadian Pacific Rail main line and rail spur and CHS/Sun Prairie Grain property. The Twenty-Seventh Street SE diversion would extend east across 27th Street SE to reconnect with the existing Mouse River channel as shown in **Figure 4-8**. River closure structures would be located on the Mouse River, south of Souris Court and south of Thirty-First Street SE.

Several key design considerations were taken into account while developing the Twenty-Seventh Street SE high-flow diversion. These are:

- Minimize upstream water surface elevation increase
- Keep Twenty-Seventh Street SE open for 5,000 cfs
- Allow for future CHS expansion
- Minimize the number of affected homes
- Handle flows from Livingston Coulee

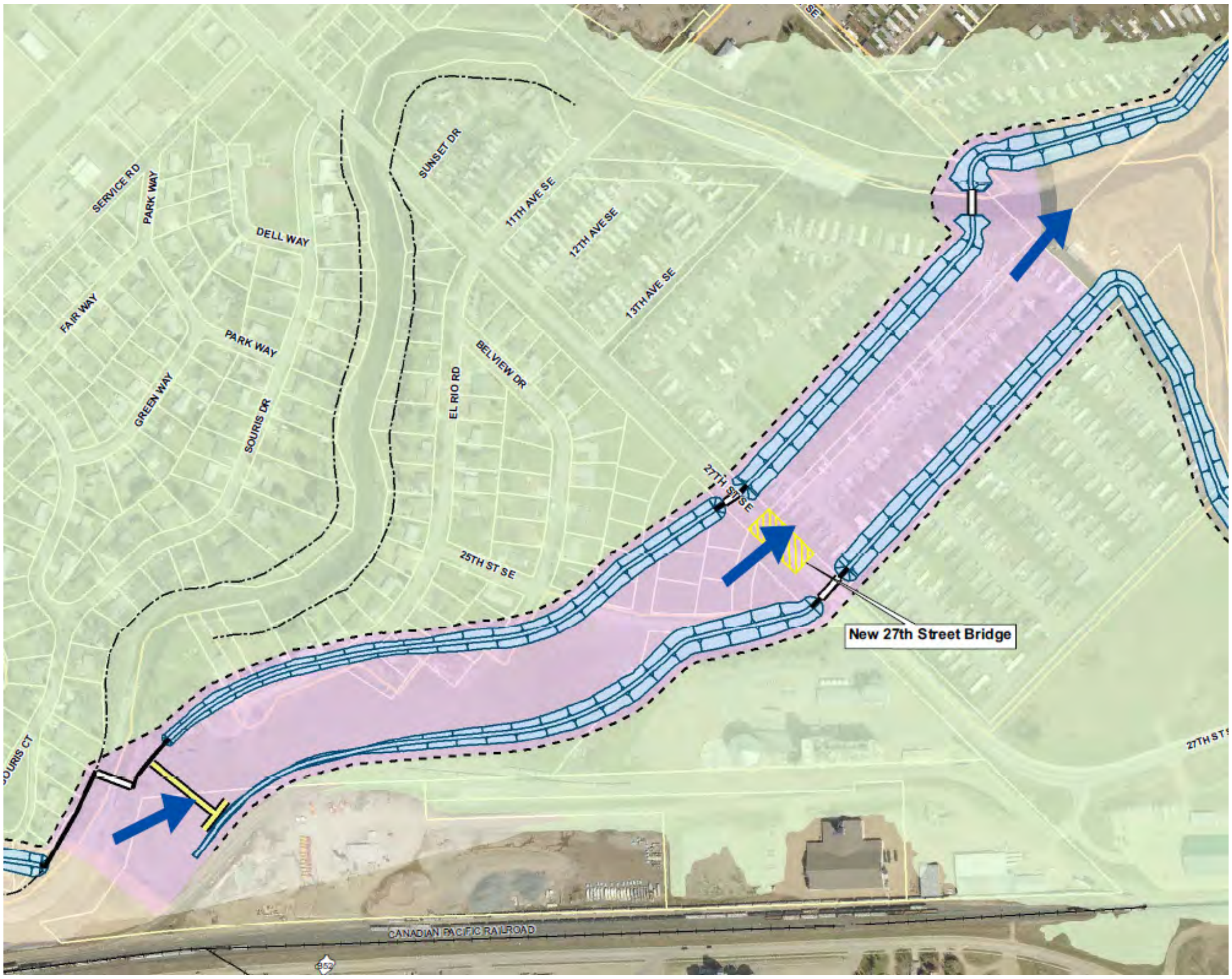


Figure 4-8 Twenty-Seventh Street SE High-Flow Diversion Configuration

4.1.5.2 Ramstad/Lincoln Neighborhood Alignment Alternatives

Alignment alternatives through the Ramstad/Lincoln neighborhoods were revised with the objective of reducing the number of affected residential properties and addressing comments from the city and the public. This review and analysis resulted in the identification of three alternatives as shown in **Figure 4-9** and summarized below.

- Ramstad Loop (existing river alignment with no diversion)—The Ramstad alignment consists of flood control improvements along the existing river channel between Second Avenue SW and the Broadway Bridge. The Ramstad alignment configuration consists primarily of levees, floodwalls, and channel improvements set farther back from the river than the existing flood control system to accommodate the design flow of 27,400 cfs with 3 feet of freeboard.
- Lincoln Diversion—The Lincoln Diversion alignment consists of a high-flow diversion along the north side of the existing Canadian Pacific and Burlington Northern Santa Fe railroad

embankments from the area near Tenth Street SW and Second Avenue SW, extending east to the Broadway Bridge. Two river closure structures would be located on the Mouse River; one near the intersection of Tenth Street SW and Second Avenue SW, and one just upstream of the Broadway Bridge.

- Maple Diversion—The Maple Diversion alignment consists of a high-flow diversion starting along the south side of the existing Canadian Pacific Railroad embankment near Second Avenue SW, extending through Moose Park and the old Magic City Lumber property, crossing the Canadian Pacific tracks west of the Sixth Street SW underpass, then following the same alignment as the Lincoln Diversion, extending east to the Broadway Bridge. Two river closure structures would be located on the Mouse River: one just upstream of the existing Canadian Pacific railroad bridge near Second Avenue SW, and one just upstream of the Broadway Bridge.

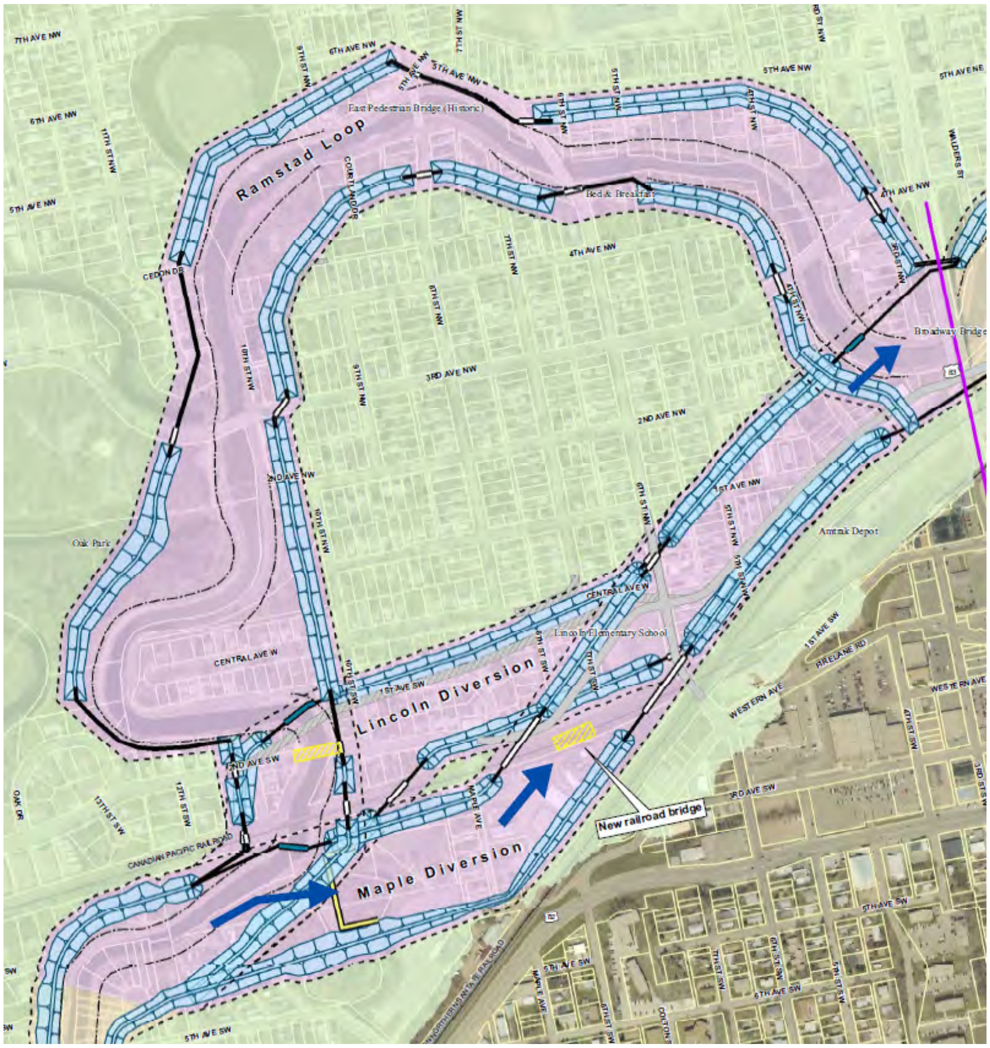


Figure 4-9 Comparison of Alignment Alternative in the Lincoln/Ramstad Neighborhood

The Lincoln and Maple alignments are high-flow diversions, while the Ramstad alignment follows the existing river alignment. During normal flow conditions, Mouse River flows would be conveyed through the river closure structures along the existing river channel. The existing river channel and levee system would remain in place and provide protection up to 5,000 cfs, potentially allowing the diversion channel to be used for recreational purposes during non-flood times. As water levels rise above a predetermined level (e.g., 5,000 cfs), the river closure structures would divert all flow to the high-flow diversion channel.

The general characteristics of each of the three Ramstad /Lincoln neighborhood alignment alternatives are summarized in **Table 4-2**. The table includes information on the features associated with each alignment (i.e., levees, floodwalls, and closures), an estimate of the number of affected properties, and estimated upstream water-surface flood level affects.

Table 4-2 Ramstad/Lincoln Neighborhood Alternative Alignment Comparison

	Ramstad Alignment (Existing River Channel with Levees and Floodwalls)	Lincoln High-Flow Diversion Alignment	Maple High-Flow Diversion Alignment
Affected Residential Properties[1]	188	156	96
Affected Mobile Home Parks	1	1	1
Feature Information			
Levees	13,400 feet	5,600 feet	6,400 feet
Flood Walls	2,038 feet	0 feet	0 feet
Pump Stations	5	2	2
Road Closures	9	3	3
Rail Closures	2	2	2
River Closures	0	2	2
Upstream Water Surface Impacts During Flood Events	All three alignments are similar by design		

[1] Includes residential properties with buildings (2010 pre-flood)

The two diversion alignments result in a smaller Project footprint, less extensive levees, fewer pump stations, fewer closure structures, and fewer residential properties affected within the Project footprint as compared to the Ramstad alignment. The two diversions were preliminarily designed to result in upstream water surface levels that are essentially the same as those estimated for the Ramstad alignment as shown on **Figure 4-10**. At a public meeting on January 31, 2012, the Minot City Council selected the Maple Diversion as the preferred alignment to include in the development of this report. **Figure 4-11** is an artist's rendering of what the Lincoln or Maple diversions might look like after construction.

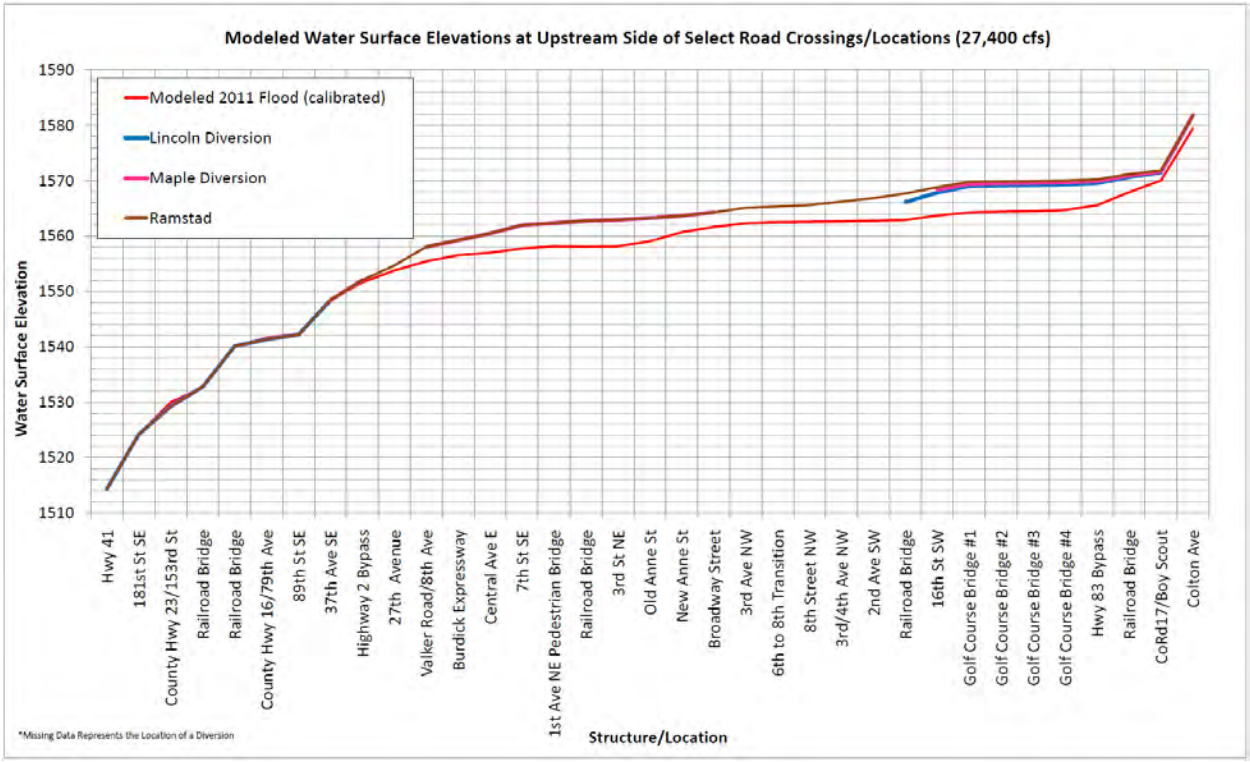
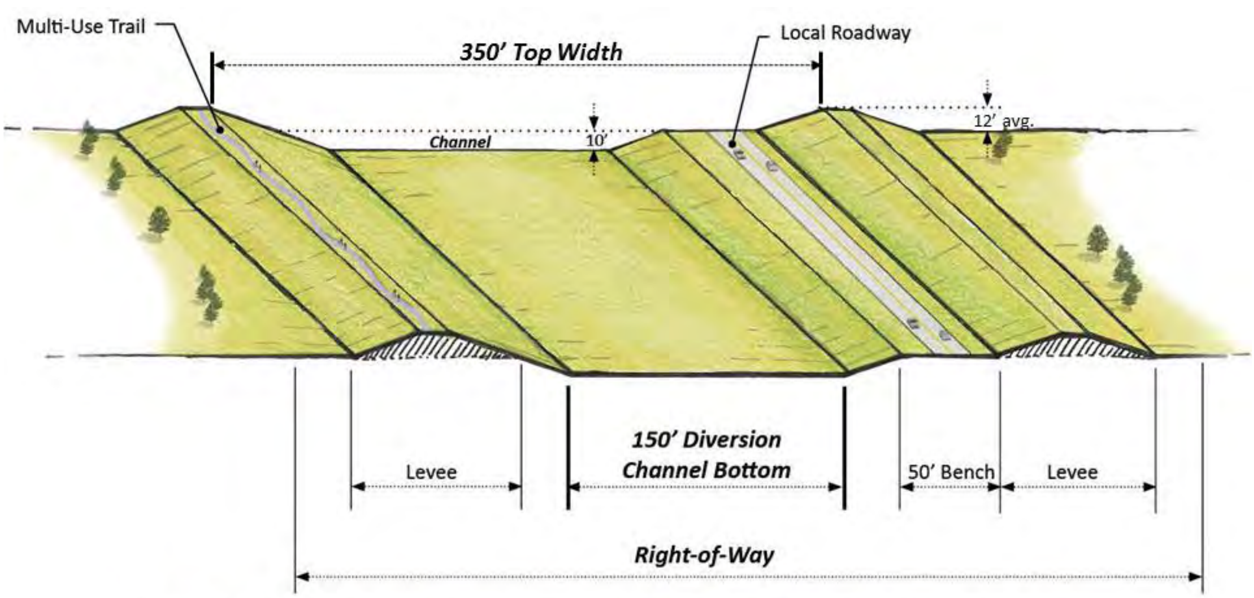


Figure 4-10 Simplified Water Surface Profile Comparing the Lincoln/Ramstad Neighborhood Alignment Options to Computed 2011 Flood Levels



- Note: Side slopes will likely need some form of erosion protection (still under design)

Figure 4-11 Visualization of the Maple Diversion East of Sixth Street

4.1.6 Narrowing in on the Preferred Plan

While the various alignment alternatives considered reduce the number of affected residential properties in Minot to less than 300 (**Table 4-3**), there was concern that the increase in water levels above the 2011 observed elevations might be too large at the west end of Minot and upstream, especially adjacent to the Minot Water Treatment Plant (WTP). The estimated increase in the water surface elevation above the 2011computed level is about 5 feet at the WTP (**Figure 4-12**). This increase continues to transfer upstream and results in a 3.5- to 4-foot increase at the Boy Scout Bridge. Numerous options to mitigate the increase in computed water levels at the WTP to between 2 and 3 feet (**Figure 4-13**) were considered. This design constraint was a key element used to develop the preliminary alignment maps shown in **Appendix A** and described in subsequent sections of this report. An example of the preliminary alignment maps is shown in **Figure 4-14**.

Additional design criteria, considerations, and constraints will need to be accounted for if a flood risk reduction project in the basin proceeds. This will likely include changes to water surface elevations, environmental impacts, permitting requirements, channel morphology, sediment transport and deposition, ice and debris handling, long-term operations and maintenance, impacts to existing federal projects, Project costs, and construction schedule and sequencing. Right-of-way acquisition policies, cost-sharing, and sources and availability of funding for the Project will all become critical elements in the further development of the plan.

Table 4-3 Comparison of the Estimated Number of Residential Properties in Minot with Structures for the Various Alignments

	November 30, 2011 Alignment	November 30, 2011 Alignment with Lincoln High-Flow Diversion Alignment	November 30, 2011 Alignment with Maple High-Flow Diversion Alignment
Affected Residential Properties with Buildings	380	350	290

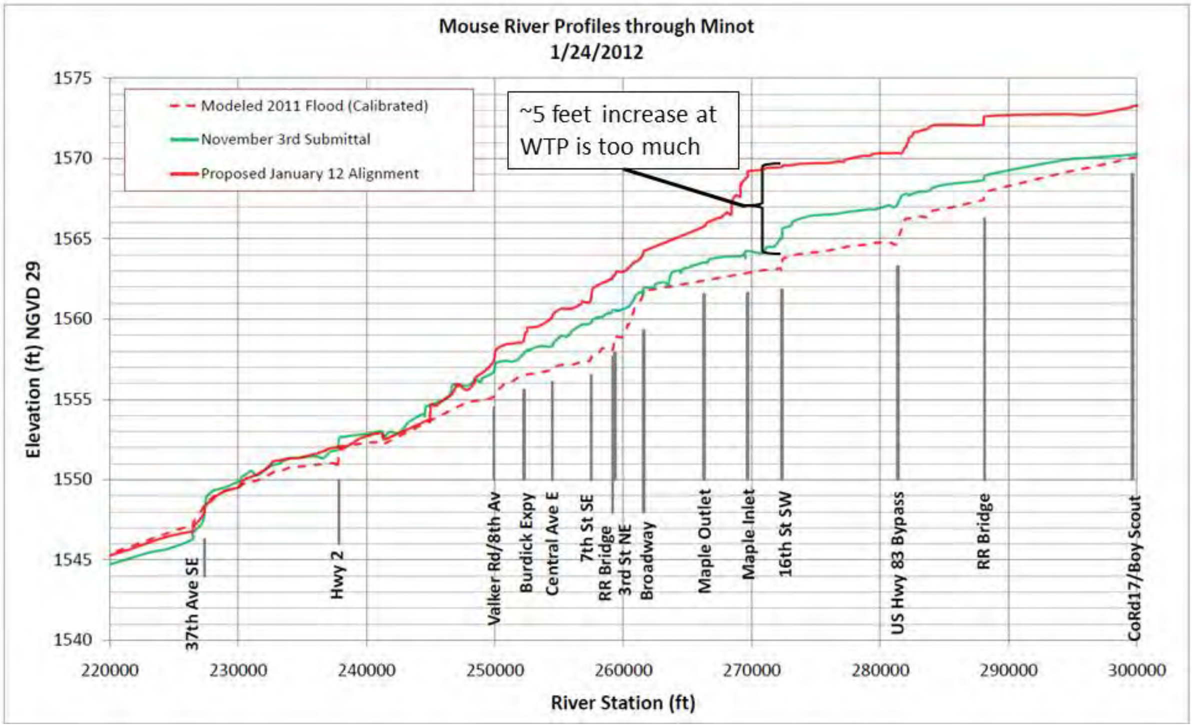


Figure 4-12 Comparison of Computed Water Surface Profiles Through the City of Minot for Existing Conditions, November 3 Submittal and Reduced Footprint Alignment Developed in Mid-January

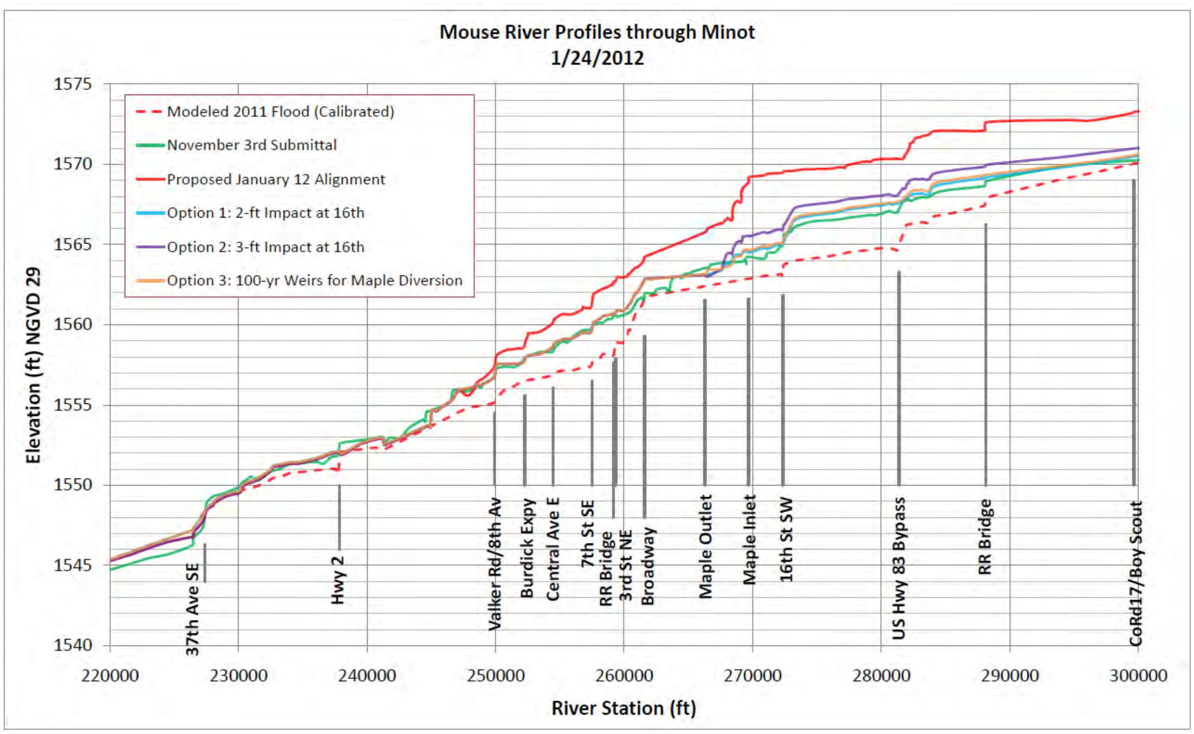


Figure 4-13 Comparison of Computed Water Surface Profiles Illustrating Reduced Water Level Increases West of Minot's WTP

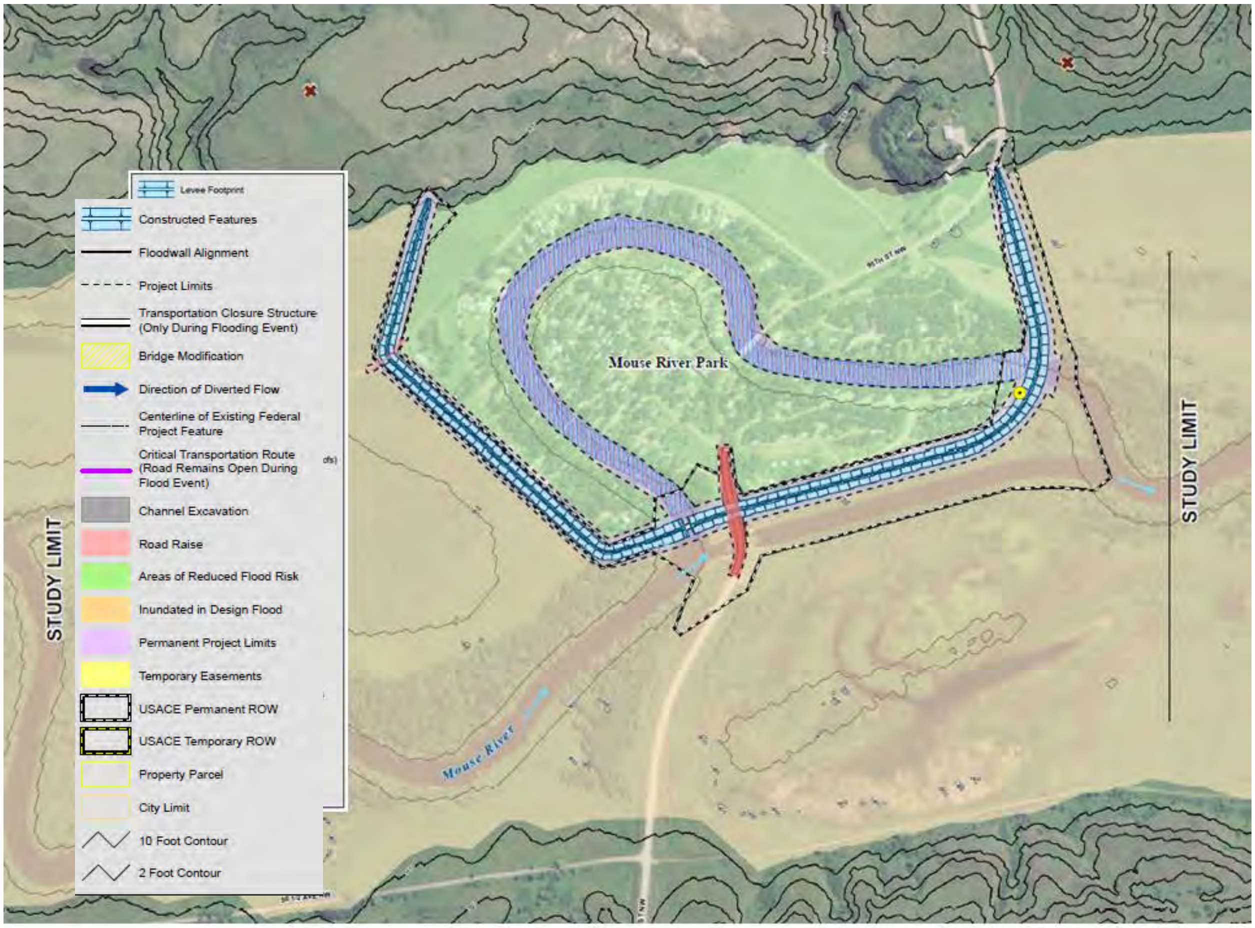


Figure 4-14 Example Preliminary Alignment Map for Mouse River Park

5.0 Data Collection and Review

This section summarizes the data collected and used in the development of the Mouse River Enhanced Flood Protection project (Project).

5.1 Past Reports

A summary of U.S. Army Corps of Engineers (USACE) reports used in the development of the Project is presented in Section **1.3** of this report. In addition to these reports, studies of the Puppy Dog Coulee, Bonnes Coulee, Chaparelle Levee, West Peterson Coulee, and Livingston Coulee were obtained and used in the development of the Project alignment.

5.2 Hydraulic Models

The U.S. Army Corps of Engineers' (USACE) HEC-RAS model of the Mouse River from Burlington to Velva was used during the 2011 flood fight to estimate water surface elevations throughout the corridor for expected flow rates. The model was consistently found to over-predict high water levels for the peak flows. The consultant team obtained a copy of the model and subsequently rebuilt and calibrated it to surveyed 2011 peak water levels. In addition to the HEC-RAS model, the USACE's HEC-2 model of the Mouse River was obtained for use in evaluating Mouse River Park. HEC-1 models of the Gassman, Livingston, and Puppy Dog coulees were obtained for use in Project development.

5.3 As-Built Drawings

As-built drawings of several Mouse River bridge crossings were obtained for use in the calibration of the HEC-RAS model and evaluation of options for increasing conveyance in locations where the bridges were overtopped by the 2011 flood.

Levee alignments, channel widths, and pump station locations of the existing federal project were displayed on the as-built drawings of the project obtained from the USACE. Utility drawings, showing water and sewer locations, were obtained from the communities of Burlington, Minot, Sawyer, and Velva, and used to evaluate infrastructure impacts of the Project. SRT Communications provided drawings of their buried and above-ground communications facilities. Other critical infrastructure drawings obtained include the Minot Water Treatment Plant, Burlington sewer lagoon and water reservoir, Minot street plans, and several maps showing water well locations throughout the corridor.

5.4 Soil Boring Logs

Soil boring logs taken during development of the existing federal project were obtained from the USACE. This data provided the basis for assumptions used in the geotechnical analysis.

5.5 Photographs

A multitude of photographs taken at the peak of the 2011 flood were obtained from the city of Minot, Ackerman-Estvold Engineering, and others and used in the calibration of the HEC-RAS model.

5.6 Geographic Information Systems

A majority of the digital information obtained for the Project was in Geographic Information Systems (GIS) format. ERSI's ArcMap 10 mapping software was used to display the data.

Property information including boundaries, property identification numbers, and ownership information was obtained from the city of Minot. The data set included parcel information extending 2 miles beyond the city limits. This information was used to compute property impacts by Project features. A table of affected properties was intersected with the City Assessor's property valuation table to compute property acquisition costs through the city. Property lines for Burlington, Sawyer, and Velva were also obtained; however, the data set for these communities contained only the line work and did not have any of the associated data attributes.

In 2010, Ward County performed a Light Detection and Ranging (LiDAR) survey of the county and developed county-wide 2-foot topography. The survey also captured aerial photographs. This topographic information was used to develop new cross-sections for input into the HEC-RAS model, develop flood inundation areas along the Project corridor, and to design Project features.

The North Dakota Department of Transportation funded an effort to capture aerial photographs of the Mouse River corridor at the peak of the flood. These geo-referenced photographs were used to delineate the peak flood inundation areas.

Wetlands coverage was obtained from the National Wetland Inventory and used to estimate the impacts of Project features on wetlands.

5.7 Survey

Field surveys were performed when as-built drawings of infrastructure and topographic features were not available. In October 2011, a field crew performed a topographic survey of the Mouse River Park levees. Field crews were also deployed at this time to collect information at bridge crossings including low-cord elevations, top-of-rail elevations, abutment locations and elevations, and pier geometry. The clearance heights between the low cord of the bridges and the top of rail of underlying railroad tracks between Broadway and Third Street were measured by a survey crew in January 2012.

In response to questions from Minot aldermen, a curbside reconnaissance survey was performed in January 2012 to evaluate the status of homes along Ramstad/Lincoln/Maple alternative alignments. The survey was performed by identifying the properties within each of the alternative alignments and performing a visual inspection to estimate the number of dwelling units within each structure and its state of repair. Properties were classified as inactive (abandoned or demolished) and active (gutted, in construction, or occupied). Structures that had been gutted and/or reconditioned were considered active. Structures where no work had been undertaken were considered abandoned. The information was delivered to the city of Minot in an email dated January 30, 2011, and was used in the decision to select the Maple Diversion alternative.

6.0 Preliminary Alignment Engineering

The development of the preliminary alignment plan consisted of hydraulic, geotechnical, structural, and civil engineering evaluations and preliminary design. This section of the preliminary engineering report provides a summary of the engineering and evaluation efforts completed in the development of the preliminary alignment plan. More detailed supporting documentation is provided in **Appendix C** through **Appendix F**.

6.1 Hydrologic and Hydraulic Analysis

The design of the Mouse River Enhanced Flood Protection project (Project) was based on a thorough evaluation of the hydraulics, or flood flow characteristics, of the Mouse River. The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center–River Analysis System (HEC-RAS) software was used for this evaluation. The HEC-RAS software computes water surface elevations, velocities, and other flow information along the Project alignment.

The HEC-RAS model was calibrated based on the high-water levels measured during the June 2011 flood to represent existing conditions without the Project features. The existing conditions HEC-RAS model was also calibrated to high-water marks for floods similar to the 1-percent-annual-chance flood. The result is a model that closely represents the documented flood conditions, demonstrating its validity for water surface elevations under the preliminary alignment Project.

For each of the alignments presented in this report, flood protection features were incorporated into the calibrated model to estimate the water surface levels that could be expected after construction. This proposed conditions model was used to evaluate levee alignment alternatives, bridge modifications, overbank excavation, high-flow diversions, and other flood control features.

A detailed review of the hydrology of the Mouse River watershed was not conducted as part of this study. Background information was obtained from several sources, including data compiled by the USACE.

6.1.1 Hydrologic Background

Hydrologic background information related to the 2011 flood, including a description of the Souris River watershed, the meteorological and hydrologic conditions leading up to the 2011 flood, and the hydraulic routing of the flood were obtained from the USACE. This section summarizes information about the Mouse River watershed, the flow-frequency relationship for the river, and information about the 2011 flood. Additional discussion and hydrologic data is contained in **Appendix C**.

6.1.1.1 Mouse River Watershed

The Mouse River watershed encompasses some 26,600-square miles, including portions of the Canadian Provinces of Saskatchewan and Manitoba, and the state of North Dakota. A map of the Mouse River watershed is shown in **Figure 1-1**. Upstream of Minot, the Mouse River drainage area is roughly 10,600-square miles (reference [5]).

There are four major reservoirs in the Mouse River Basin upstream of Burlington. Three of the reservoirs are located in Saskatchewan, including the Boundary Reservoir on Long Creek and the Rafferty Reservoir on the Souris River, both near Estevan, and the Alameda Reservoir on Moose Mountain Creek near Alameda. The fourth major reservoir is Lake Darling, on the Mouse River near Minot, North Dakota. The location of each of the four major reservoirs is shown on **Figure 1-1**. These reservoirs control the flows of the Mouse River.

6.1.1.2 Flow Frequency

U.S. Geological Survey (USGS) stream gage data has been collected along the Mouse River since 1903. Information on these gages is included in **Appendix C**.

The Ward County and McHenry County Flood Insurance Studies (reference [6], [7]) provide information on Mouse River flood flows between Burlington and Velva. These flows are based on stream flow records and hydrologic modeling of floods through the reservoir system. These flows consider the reservoir-operating plan that has been adopted by the governments of the United States and Canada (reference [8]). The reservoir operating plan attempts to limit peak discharges at Minot to 5,000 cfs for floods up to the 1-percent-annual-chance flood. These flows are summarized in **Table 6-1**.

Table 6-1 Summary of Flood Discharges from Ward County and McHenry County Flood Insurance Studies

Location	Drainage Area (sq. miles) [1]	10-Percent Annual Chance Flow (cfs)	2-Percent Annual Chance Flow (cfs)	1-Percent Annual Chance Flow (cfs)	0.2-Percent Annual Chance Flow (cfs)
at Foxholm	3,270	2,380	4,150	4,550	31,800
at Minot Broadway Bridge	3,900	3,200	5,000	5,000	40,000
at Sawyer	4,230	3,500	6,060	6,980	42,600
at Velva	4,330	3,590	6,380	7,580	43,400

[1] Drainage area represents the contributing drainage area reflected in USGS stream gage information.

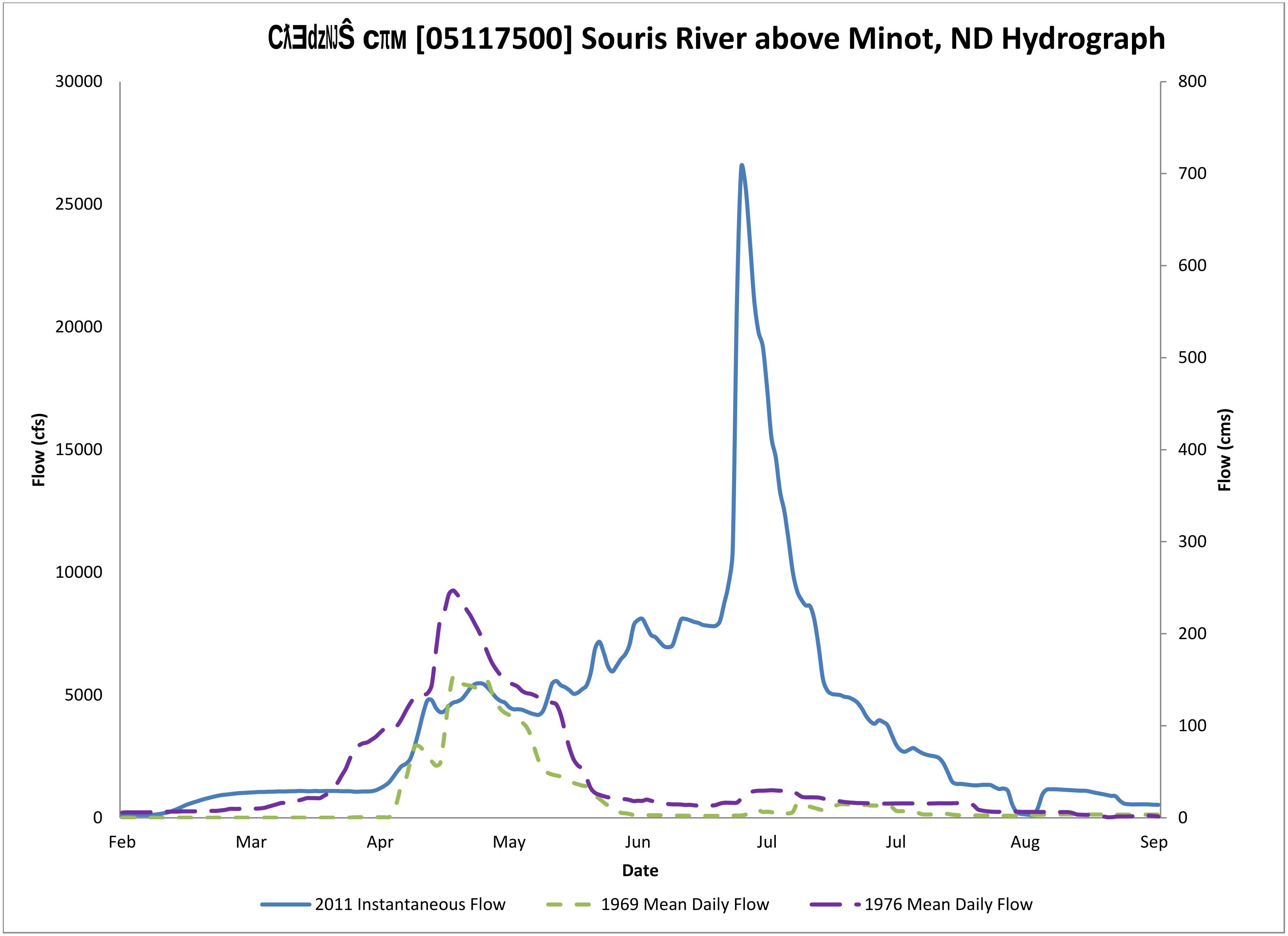
The stream gage data used to develop the flood insurance studies does not consider recent data including the 2011 flood. The USACE and other government agencies responsible for operation of the upstream reservoirs are considering additional hydrologic studies that would refine and update the flow frequency relationship for the Mouse River.

The 50-percent-annual-chance (2-year) flow was estimated to be 1,150 cfs using stream gage data for the Souris River near Sherwood and Verendrye, North Dakota. This flow was used in the HEC-RAS model to approximate bank-full conditions.

6.1.1.3 Historic Flood Events

The largest flood of record for the Mouse River occurred during June 2011. This flood was produced by a combination of high soil-moisture content, above-average snow pack, persistent moderate spring rainfall, and moderate-to-large summer rainfall. The peak discharge of 27,400 cfs was measured at the Broadway Bridge in Minot on June 25, 2011. This peak discharge was adopted as the Project design flow. The USACE estimated the 2011 flood to be a 0.2 (500-year) annual chance flood.

Other Mouse River floods occurred in 1969 (6,020 cfs) and 1976 (9,350 cfs). The flood hydrograph at Minot for the 1969, 1976, and 2011 floods are shown in Figure 6-1. **Table 1-1** lists the largest recorded floods along the Mouse River.


[05117500] Souris River above Minot, ND Hydrograph
Flow (cfs)
Flow (cms)
30000
25000
20000
15000
10000
5000
0
800
700
600
500
400
300
200
100
0
Feb
Mar
Apr
May
Jun
Jul
Jul
Aug
Sep
Date
2011 Instantaneous Flow
1969 Mean Daily Flow
1976 Mean Daily Flow

6.1.2 Hydraulic Analysis

An analysis of the flood flows for the Mouse River was completed using the USACE HEC-RAS model. This section describes the development of an existing-conditions model and a design model used to evaluate the Project.

6.1.2.1 Initial USACE HEC-RAS Model

A HEC-RAS model for the Mouse River, developed by the St. Paul District USACE, was used as the basis for the updated model used in developing the preliminary alignment. This model was originally developed in the 1970s as a HEC-2 model. The model was updated in the 1980s as part of the Velva project and in 1997 for the flood insurance study. The USACE recently merged the model with other HEC-2 models to complete a continuous model from Lake Darling to downstream of Velva. In 2011 the USACE geo-referenced cross-sections and digitized the centerline of the Mouse River to use the model for flood forecasting. The USACE model was generally calibrated for flows of 10,000 cfs or smaller. **Appendix C** provides more detailed information on the initial USACE HEC-RAS model.

6.1.2.2 Existing Conditions HEC-RAS Model

Because the USACE model was calibrated for 10,000 cfs flows, the model required substantial updates to calibrate to 27,400 cfs. A new existing-conditions model was developed by extracting new cross-section geometry from LiDAR data merged with river bathymetry from the initial USACE HEC-RAS model, estimating Manning's n values from land cover and land use data sets, defining ineffective flow areas, and entering bridge geometry data from as-built records or field survey data. High-water marks obtained during the 2011 flood were used to refine and calibrate the existing-conditions HEC-RAS model. Model cross sections were extended past the high ground for 27,400 cfs inundation conditions. The existing-conditions HEC-RAS model was initially calibrated using high-water marks measured on April 28, 2011, when the measured discharge was 5,300 cfs. The model was further refined by calibration to high-water marks measured during the peak of the June 2011 flood. The following model parameters were modified during the calibration process:

- Bank stations
- Flow lengths
- Manning's n values
- Contraction and expansion coefficients
- Ineffective flow areas
- Bridge modeling methods

Additional discussion on the development of the existing-conditions HEC-RAS model is presented in **Appendix C**.

6.1.2.3 Calibration Model Results

The results of the HEC-RAS existing-conditions model calibration are shown on the flood profile in Figure 6-2 . The red Xs on the figure reflect the measured high-water marks. The plots June 2011 high-water marks were used for calibration of the design flow (27,400 cfs) profile and the April high-water marks were used for calibration of the 5,300 cfs flow.

The modeled water surface calibrated well with the observed high water marks for both the design flow (27,400 cfs) and the April 28, 2011 flow based on a statistical evaluation of the data. Based on the strong correlation between the modeled and observed water surface elevations, the model can reasonably be assumed to predict the resulting water surface for various changes in configuration considered for the preliminary alignment plan development.

6.1.3 Hydraulic Evaluation of Project

The development of the preliminary alignment was based largely on hydraulic modeling of the Project. A HEC-RAS design model was developed that considered the levee and floodwall alignments as well as other modifications in the floodplain such as bridges and diversions. The design model calculates the flood profile. It accounts for the narrowing of the floodplain due to the Project.

Modeling of the Project required changes to the existing-conditions model to account for containment of flows within the various levees and floodwalls. The existing-conditions model evaluated flooding conditions in which the floodplain width was often in excess of 2,000 feet. This area also included significant ineffective flow areas and areas with a high Manning’s roughness. The Project will generally confine flows by levees and floodwalls, with relatively few ineffective flow areas and lower Manning’s roughness than the existing wide floodplain.

Data and methods used to develop the design HEC-RAS model are summarized below. Additional discussion of these model parameters is presented in **Appendix C**.

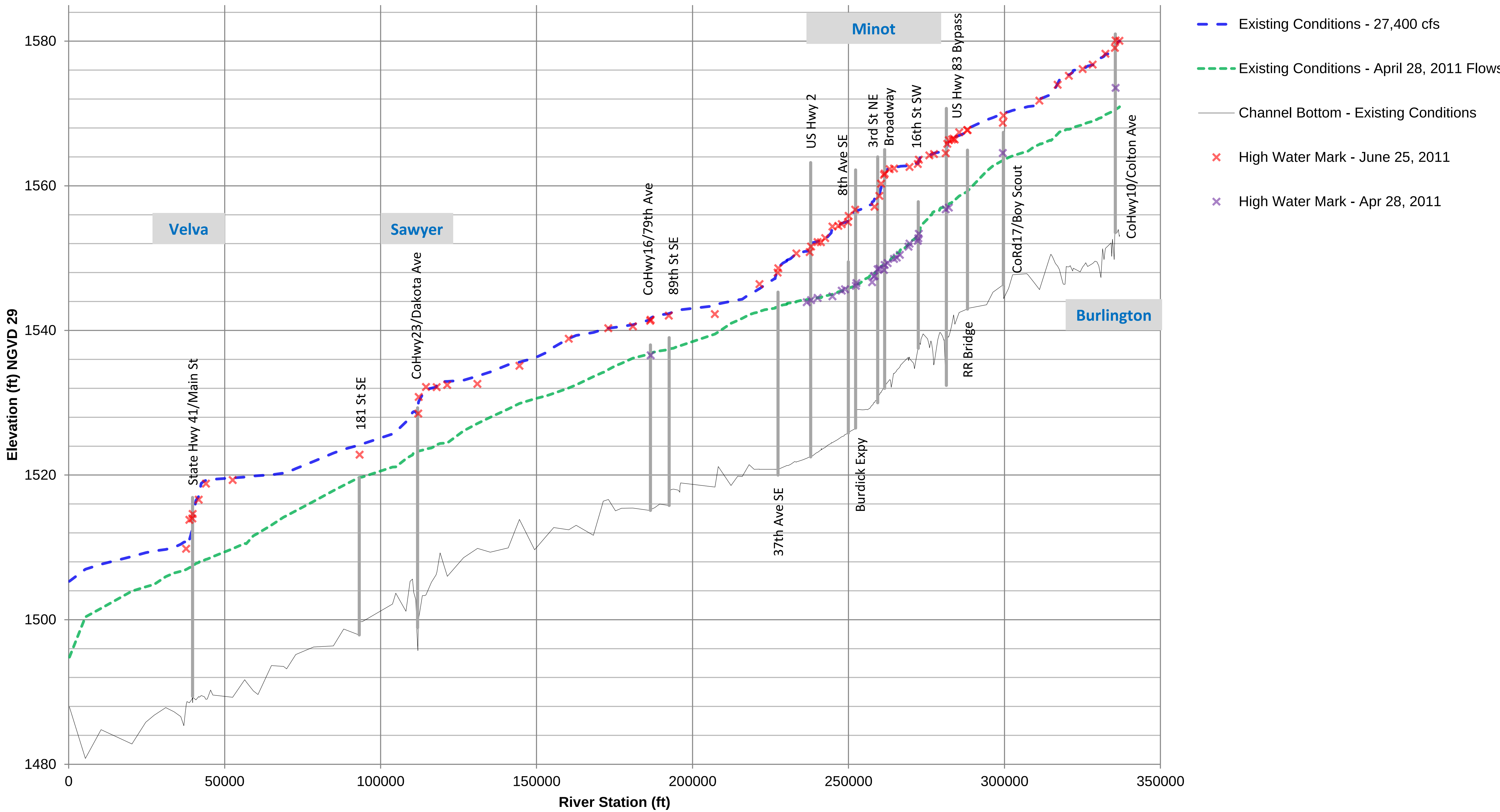


Figure 6-2 Flood Profile for Existing Conditions Model Calibration

6.1.3.1 Evaluation of Project Features

The Project levee and floodwall alignments were evaluated using the HEC-RAS design model. Model cross sections were updated to reflect various levee and floodwall alignments and bridge modifications. The model was also modified to incorporate locations where overbank material will be excavated between the channel bank and levees or floodwalls. This will add flow capacity and help mitigate flood profile increases due to narrowing of the floodplain. With these modifications, the design model calculated the change in the flood profile for the alternatives considered. A more comprehensive discussion on Project features is provided in Section 6.4 and Appendix C.

6.1.3.2 Project Flood Profile

The HEC-RAS design model was used to calculate changes in the flood profile due to containment of flow between the levees and floodwalls.

Figure 6-3 shows existing condition and Project condition flood profiles for the river between Velva and Burlington. **Figure 6-4** focuses on the existing and Project flood profiles in and around Minot. The Project does not change the 1,150 cfs flood profile or the 5,000 cfs flood profile because there is little change within the existing channel.

The Project will change the flood profile for the design flow (27,400 cfs) at many locations. **Table 6-2** lists locations along the Mouse River and anticipated Project-related changes to high-water marks measured during the 2011 flood. Specific information on the flood levels at various locations along the Mouse River and efforts to limit and mitigate these increases are discussed in **Appendix C**.

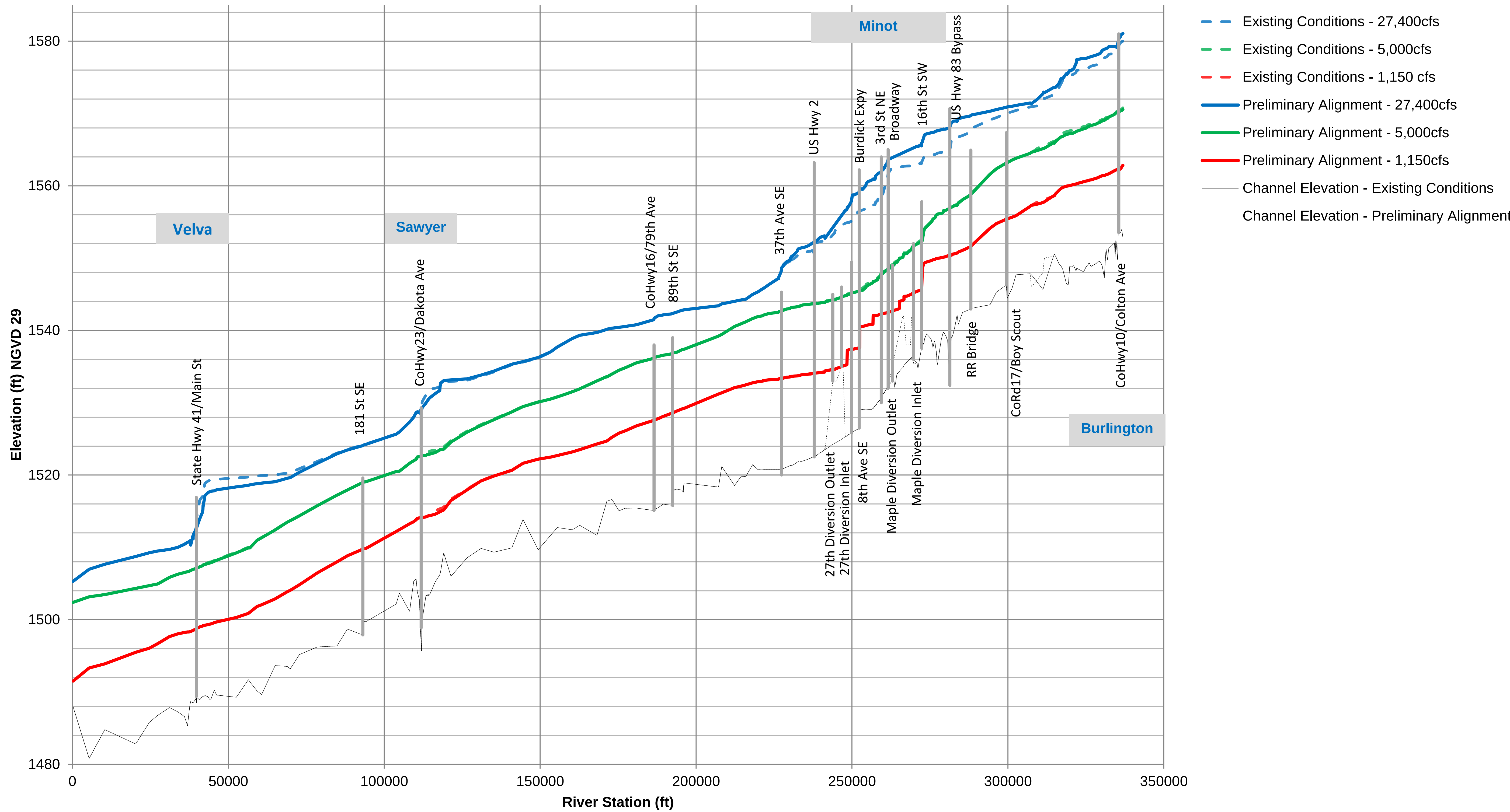


Figure 6-3 Flood Profile for Existing and Project Conditions - Burlington to Velva

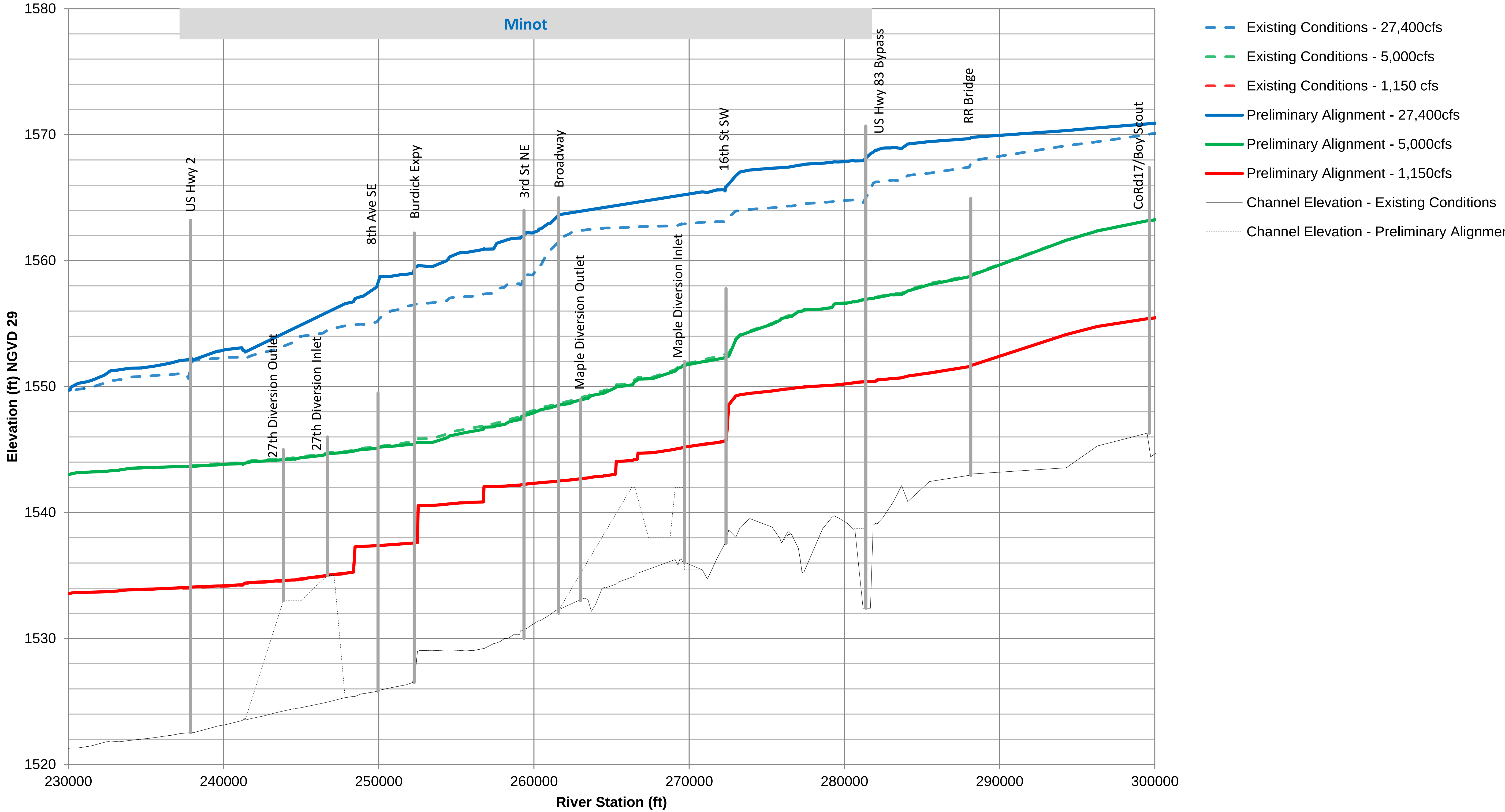


Figure 6-4 Flood Profile for Existing and Project Conditions - Minot

Table 6-2 Summary of Project Effect on 2011 Flood Profile

Location	Change In Flood Profile for the Design Flow Compared to Observed 2011 HWMs
County Highway 41 Bridge	Reduction of up to 2 feet
County Highway 23 Bridge	Reduction of up to 1 foot
Downstream Side of Highway 2 Bypass	Increase of approximately 1 foot
Eighth Avenue SE and Burdick Expressway	Increase of approximately 3 feet
Third St. NE	Increase of approximately 4 feet
Minot Water Treatment Plant	Increase of between 2.5 and 3 feet
Highway 83 Bypass Bridge	Increase of approximately 2.5 feet
Boy Scout Bridge (County Road 17)	Increase of approximately 1 foot
Robinwood, Talbott's, and Brooks Additions	Increase of between 1.0 and 1.5 feet
Burlington	Increase of approximately 1 foot

Appendix C includes elevation vs. discharge curves for numerous locations along the Project. These curves show the existing and flood elevations for the range of flows from 0 to 34,000 cfs. These curves indicate the following:

- The Project has a negligible change on flood elevations for flows of 5,000 cfs and less.
- Between Burlington and the Maple Diversion, the Project increases flood levels for flows larger than approximately 15,000 cfs, and has a small effect on flood levels for smaller flows.
- In Minot, between the Maple and Twenty-Seventh Street Diversions, the Project increases flood levels for flows larger than approximately 5,000 cfs.
- In rural areas downstream of Minot, the existing and Project flood levels are similar for all flows.

6.1.4 Risk and Flood Management Considerations

As the Project moves toward final design, further refinement of Project features and an assessment of risk will be needed. This section describes risk and floodplain management considerations for preliminary and subsequent design.

6.1.4.1 Risk Based Management

A risk based analysis will be required as part of the USACE Section 408 permit process. The USACE provides guidelines for formulating and evaluating flood risk management measures (reference [9]).

The scope of this preliminary design did not include completion of a risk analysis that considers economic benefits and flood damage reduction estimates. Instead, the preliminary flood protection plan for the Mouse River Basin reduces the risk of damages from river flows comparable to the record June 2011 flood. The hydraulic modeling and design of the system included:

- Detailed calibration of the hydraulic model to the design discharge
- Incorporation of a 3-foot freeboard standard into the design of levee and floodwall heights
- A sensitivity analysis for key modeling parameters such as Manning's n value

As the Project moves toward final design, the hydraulic modeling and design elements will need to be further refined to reduce the uncertainty and to consider other factors that could affect the Project's potential flood damage reduction. Examples of elements that could be considered are:

- Refinement of upstream reservoir operation procedures
- Establishment of confidence limits for critical parameters
- Detailed unsteady flow modeling
- Detailed modeling using two-dimensional or steady-state models at critical locations
- Quantification of the expected annual exceedance probability
- Evaluation of the potential for scour and sedimentation of the channel
- Consideration of phased or stage construction of the Project
- Policies for development of areas not protected by the Project

6.1.4.2 Ice and Debris Management

Ice has not been known to affect flood levels of the Mouse River with the exception of an ice dam that delayed the crest of the 1969 flood (reference [10]). Debris has been observed in the river and at crossings during large floods, but has not caused blockage of bridges and corresponding increases in upstream water surface elevation. Many bridges and approach roadways in the study area are inundated with several feet of water during the design flow. At these locations, ice and debris are not expected to be a concern during the design flood.

River closure structures at the upstream and downstream end of the diversions will be designed with consideration for ice and debris. These closures could have features to catch debris upstream of the closure gates, as well as redundant gates, to increase the reliability of closure during a major flood event.

6.1.4.3 Project Resiliency

The Project is designed to convey the design flow with 3 feet of freeboard. An assessment of the ability to contain larger floods was completed using the HEC-RAS design model. Because of the variability in the width of the Project and the slope of the flood profile, some levee/floodwall sections will have the potential to contain flows greater than the design flow. **Table 6-3** lists the estimated flow at which levees or floodwalls will begin to overtop at representative communities.

Table 6-3 Approximate Flood Flow Causing Levees and Floodwalls to Overtop

Community Protected	Flood Flow (cfs)
Burlington	36,000
Country Club area	38,000
Terracita Vallejo	37,000
Minot	33,000
Upstream of Highway 2	39,000
Apple Grove	41,000
Sawyer	40,000
Velva	33,000

Design modifications subsequent to this study should consider some of the following measures to provide greater Project resiliency and reduce flood risk:

- Consider adjusting freeboard requirements, depending on the results of a risk assessment.
- Identify locations where flows will begin overtopping the levee system and enhance the design to minimize damages to the levee and protected property. Typically, it is desirable to minimize the potential for overtopping of the levee and floodwall at the upstream end of the Project.
- Allow for temporary raising of the levees during flood fighting activities. This could include floodwalls and road closures that have more than 3 feet of freeboard.
- Consider "tie-back levees" that would limit the inundation area in the event of a levee breach or overtopping. The preliminary alignment includes a levee along the north side of the river in Minot that extends from the Highway 83 Bypass to the downstream side of the Twenty-Seventh Street diversion. An additional tieback levee would help reduce the potential for inundation of homes in this area.

6.1.5 Erosion Control and Sediment

The erosion control measures developed for the Project are based on accepted guidelines for erosion control, the existing Minot flood control project design, the performance of the existing project during the 2011 flood, and a velocity analysis using hydraulic computations. The preliminary engineering drawings in Appendix B show the locations where erosion protection is needed. Erosion protection will supplement riprap placed along the channel by the USACE for the existing flood protection system. The preliminary engineering drawings also provide typical erosion control cross sections and details.

For this study, erosion protection is considered to be riprap. Riprap was chosen because it is commonly used on flood control projects and generally performed well during the 2011 flood. During Project design, additional value engineering and aesthetic consideration should be considered to identify alternatives (e.g., turf reinforcement mat, interlocking block, block mat systems, etc.) that may provide better aesthetics and lower cost. A more comprehensive discussion is provided in Appendix C.

6.2 Interior Flood Risk Reduction Systems Assessment

Preliminary assessment of the Project's needs for interior drainage infrastructure focused on the sizing of pump stations for the interior 1-percent-annual-chance event and assumed simultaneous design flows in the Mouse River (i.e., blocked gravity outfalls). The assessment considered existing flood risk reduction measures constructed by the USACE and local municipalities. The results of this assessment provide a rough order of magnitude estimate for the Project's interior drainage infrastructure needs. A detailed description of this assessment is in Appendix D.

6.2.1 Existing Systems

Existing interior drainage flood risk reduction measures are largely the result of a USACE Souris River Basin flood control project initiated in the early 1970s. The existing interior drainage systems (pump stations and storm sewers) were sized using the 2-percent-annual-chance event for low-river stage (non-flood) conditions and a higher frequency storm event for high-river stage (flood) conditions. As-built drawings for these pump stations are available as part of the operation and maintenance manuals prepared by the USACE. These manuals are listed in the References section of this report (reference [11]).

6.2.2 System Design

The Project used a simplified design process for the preliminary design of pump stations and associated infrastructure. The following sections describe the key interior drainage analysis and results.

6.2.2.1 Hydrology

Peak discharge rates and runoff volumes were calculated in HydroCAD version 10.0 using the Soil Conservation Service method. Pump station sizing was based on the 1-percent chance design storm (4.60 inches in 24 hours). Curve numbers were assigned to watersheds based on land use observed in aerial photos taken in 2010. Time-of-concentration values were estimated based on land use, topography, and available information on stormwater management and conveyance systems for the area.

Future design phases should consider a range of rainfall depths and durations, the Standard Project Storm, historical rainfall data, and coincident probability analysis to optimize the size of the interior drainage facilities.

6.2.2.2 Hydraulics

The hydraulic factors considered for pump station design were as follows:

1. Ponding area storage volume—Ponding areas provide detention storage that helps reduce the required pump capacity. Existing ponding areas were utilized for Project pump stations wherever possible. Storage volumes were calculated based on LiDAR topography.
2. Zero-damage elevation—The zero-damage elevation is the highest water surface elevation that can occur in the ponding area without causing damage to the first floor of structures in the interior drainage area. The zero-damage elevations were estimated using LiDAR topography to find the lowest ground elevation adjacent to a structure within the interior drainage area.
3. Tailwater elevation—The tailwater elevation in the river affects the seepage rate through the levees and determines the design head for the pump required to discharge water into the river during flood conditions. The design head on each pump station was set to the top-of-levee elevation at each pump station’s river outlet.
4. Seepage through levees—When the inflow rate is greater than 30 percent of the pump capacity required for the design storm event, seepage becomes a factor in determining design pump capacity. In this scenario, the design pump capacity is equal to 70 percent of the capacity required for the design storm event, plus the seepage inflow rate.
5. Minimum pump station size—A minimum pump station capacity of 2000 gpm was assumed for all new and replacement pump stations.

Future design phases will need to evaluate non-flood conditions when gravity outlets are open and flood conditions when gravity outlets are partially and fully blocked. An appropriate degree of protection will need to be established for each condition. To optimize the sizing of the system and ensure the interior drainage system provides adequate levels of protection to areas not adjacent to ponding areas, additional hydrologic and hydraulic modeling of the interior storm drain networks will be needed. Pump Station Sizing

The preliminary analysis of interior drainage areas identified 33 locations where pump stations will be needed.

6.2.2.3 Pump Station Locations

Proximity to ponding areas was considered in selecting pump station locations. Other priorities included limiting property impacts, minimizing storm drain infrastructure requirements upstream and downstream of the pump station, and minimizing required modifications to the electrical grid.

These site factors should be revisited in greater detail in future design phases.

Pump stations were named based on nearby landmarks or streets. The Project area was broken up into regions defined as follows:

- **Mouse River Park** is a community with seasonal homes just north of Tolley, in Renville County.
- **Burlington** consists of the area from the City of Burlington, downstream to Kings Court.
- **Minot West** consists of the area from Terracita Vallejo to Broadway.
- **Minot East** consists of the area from Broadway to Highway 2.
- **Minot South** consists of the area from Highway 2 to Logan.
- **Sawyer** consists of the city of Sawyer.
- **Velva** consists of the city of Velva.

6.2.2.4 Pump Station Size Categories

Pump stations were placed into one of four categories depending on the design discharge rate. **Table 6-4** summarizes the four pump station categories.

Table 6-4 Project Pump Station Categories

Category	Station Description	Design Discharge Range	Structure
1	Small submersible	≤ 7,000 gpm	Precast concrete wet well and adjacent above-grade control panel
2	Large submersible	8,000 to 25,000 gpm	Cast-in-place concrete wet well and adjacent above-grade control panel
3	Trench well submersible	26,000 to 85,000 gpm	Cast-in-place concrete wet well with small electrical building
4	Large vertical turbine	> 85,000 gpm	Structure built into the levee or floodwall housing pumps

Drawings S21 through S24 in **Appendix F** show representative layouts and dimensions for the four pump station categories.

6.2.3 Results

Based on Project conditions, pump stations were required in 33 locations: five existing pump stations would remain as is, 11 would be replaced, and 17 new stations would be added. **Table 6-5** summarizes the Project pump stations and several key design parameters. The table also provides a comparison (where available) between Project and existing interior drainage design.

The Project would build upon the existing interior drainage infrastructure. Documentation from the USACE project was instrumental in evaluating the hydrology, hydraulics, and existing infrastructure within the area. The results of the preliminary design were compared to the available information regarding the USACE project to identify where existing and preliminary alignment Project systems are similar and different.

Appendix D contains the detailed analysis and supporting documentation of the interior drainage portion of the Project.

Table 6-5 Post-Project Pump Station Summary

Pump Station Name	Exhibit D3 Map #	Status	Pump Type	Design Pump Capacity (gpm)
Mouse River Park	1	New	Small Submersible	2,000
Valley Avenue	4	New	Small Submersible	2,000
Johnsons Addition	4	Replacement	Small Submersible	2,000
Brooks Addition	5	Replacement	Small Submersible	2,000
Talbott's	5	Replacement	Small Submersible	2,000
Country Club Acres	6	Replacement	Small Submersible	3,000
Kings Court	6	Existing	Small Submersible	4,000
Terracita Vallejo	8	Replacement	Large Submersible	12,000
Lighthalls	8	New	Small Submersible	2,000
Perkett Ditch	8	Replacement	Trench Well Submersible	40,000
12th Street SW	9	New	Small Submersible	2,000
Moose Lodge	9	Replacement	Small Submersible	3,000
Ramstad Park	10	Existing	Large Submersible	15,000
6th Street SW	10	New	Trench Well Submersible	40,000
Broadway	10	New	Trench Well Submersible	70,000
4th Avenue NE	11	New	Small Submersible	2,000
8th Street NE	11	Replacement	Trench Well Submersible	60,000
Roosevelt Park	11	Replacement	Trench Well Submersible	70,000
15th Street SE	11	New	Small Submersible	2,000
18th Street SE	11	New	Small Submersible	2,000
Souris Court	12	Replacement	Large Submersible	8,000
Farmers Union	12	New	Small Submersible	2,000
Livingston Coulee	12	New	Large Vertical Turbine	360,000
Keller	13	New	Large Submersible	11,000
River Oaks	13	New	Small Submersible	2,000
Apple Grove	13	New	Small Submersible	2,000
East Side Estates	14	New	Small Submersible	2,000
Chaparelle	14	New	Small Submersible	2,000
Sawyer West	23	New	Small Submersible	2,000
Sawyer North	23	Existing	Small Submersible	1,000
Sawyer Ring Levee	23	Existing	Small Submersible	500
Velva Park	28	Existing	Small Submersible	6,800
Velva East	28	New	Small Submersible	7,000

6.3 Geotechnical Analysis

The purpose of the geotechnical analysis was to provide reasonable geotechnical parameters for the preliminary design of Project features. The geotechnical analyses included a review of the existing geotechnical conditions found along the Project alignment; evaluation of typical soils and properties; evaluation of seepage at levees and structures; evaluation of slope stability and settlement of levees; and bearing capacity and settlement of the floodwalls, closure structures, and pump stations. Recommendations are provided for preliminary under-seepage controls at levees and floodwalls and for design of foundations. Additional technical details about the available geotechnical data, analyses performed, results, and recommendations are provided in **Appendix E**.

The geotechnical design and recommendations are based on available information provided during initial review of the Project and not considered detailed enough for final design. Further investigation and detailed review is required for final design of all of the levees and structures discussed. Additional geotechnical information will allow for design of the Project features based on conditions at each of the particular locations.

6.3.1 Geotechnical Properties

Available geotechnical information for the Project area includes design and operations and maintenance reports for the existing flood control features. As-built drawings of area bridges are also available. In general, area soils consist of poorly sorted clay till, including reworked clay, silt, and sand materials. The percentage of predominantly sand soils or sand overlying clay soils is much higher within the Mouse River channel than the surrounding till plain.

Generalized soil conditions were developed for representative sections along the Project alignment. The upper-40 feet of borings were reviewed to determine the stratigraphy type; this was anticipated to be the primary zone of influence for levees and structures (non-bridge structures). The generalized soil profiles were divided among the eight stratigraphy types listed in **Table 6-6**.

Table 6-6 Description of Generalized Soil Profiles

Soil Profile Number	Description of General Soil Stratigraphy
1	Full sand
2	Thick sand over clay
3	Thin sand over clay
4	Interbedded clay and sand with sand on top
5	Interbedded clay and sand with clay on top
6	Thin clay over sand
7	Thick clay over sand
8	Full clay

Laboratory test data was used, where available, to develop geotechnical characteristics for each soil type. Generally, these consisted of index tests such as Atterberg Limits, grain-size distribution, and moisture content. The index properties provide vital information on the behavior of the soils and foundation material.

Based on review of boring logs, groundwater in the Project area is generally between 12 and 15 feet below grade, but can be less than 4 feet and more than 60 feet in some locations. The geology of the area suggests that groundwater depth is likely to be governed by the level of the river at the time the groundwater reading is taken. During dry periods the river level is low and flow is toward the river; when the river rises out of its banks, flow is away from the river and groundwater may begin to seep upward on the protected side of the levee system. The limiting case for design of the levees and floodwalls is likely to be groundwater level during flood events. For preliminary design of structures, the groundwater level was considered at the ground surface on the protected side of the levee. For preliminary design of the levees and floodwall seepage analyses, a seepage model was used to estimate the groundwater conditions during the design flood event.

Since the Project is located in a low seismic zone, seismic loads were not evaluated for the preliminary design. This should be reviewed during detailed design to determine if additional analysis is necessary.

6.3.2 Levees

6.3.2.1 Existing Levees

Existing Mouse River channel side slopes range from 0.5 horizontal (H):1 vertical (V), or steeper, to about 3H:1V. The steeper slopes have experienced significant erosion in many areas. Areas where slopes were re-graded as part of existing flood control construction are typically at 3H:1V.

Existing levees were constructed from locally available semi-pervious materials, generally consisting of sandy silty clay. During previous flood fighting activities, temporary levees have been constructed by clearing an alignment footprint, dumping and spreading clay material with dozers, and compacting the clay material by passing loaded trucks. The emergency levees reportedly performed well, with only two portions of levee showing cracks due to rotational failure.

Temporary levees are constructed along the Mouse River during flood fights for flows greater than 5,000 cfs

6.3.2.2 Preliminary Design of Levees

The typical levee cross section developed for the Project is shown in **Figure 6-5**. The levee section has side slopes of 3 horizontal to 1 vertical (3H:1V), with a minimum top width of 15 feet. For comparison, the existing Mouse River levees also have side slopes of 3H:1V and a minimum crest width of 10 feet. These have reportedly performed as designed during past flood events.

The Project levee height through developed areas of Minot averages about 13-feet high, including a minimum of 3 feet of freeboard for the design flood event. The typical levee layout also includes a 30-foot wide clear zone beyond the landside toe of the levee for seepage control measures, inspection, and maintenance access. The preliminary engineering also considered levee and channel bank stability. In areas where the levee is in close proximity to the existing river channel, an offset is incorporated into the alignment between the riverside levee toe and the top of the river channel. The levee alignment and footprint will vary based on changing design heights along the Project corridor.

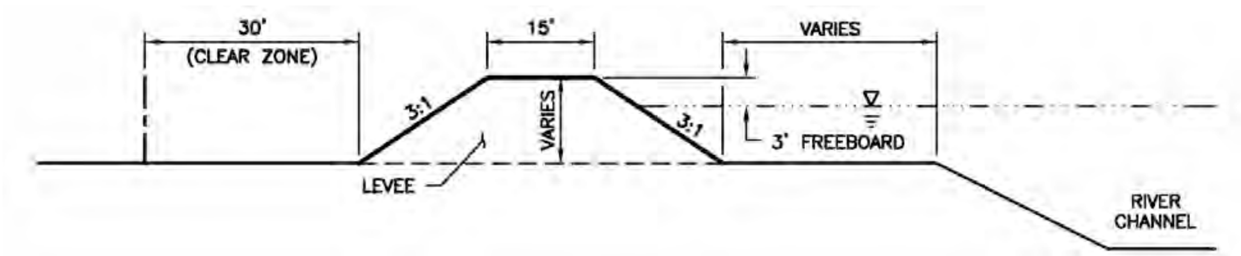


Figure 6-5 Typical Levee Configuration

While previous designs assumed minimal seepage through or beneath the levees, the increased design flood levels and variable nature of foundation conditions through Minot, including granular materials, indicate that seepage may be considerable in some areas.

6.3.2.3 Levee Seepage Analyses

Levee seepage analysis is important because groundwater levels have a significant effect on levee stability. In addition, high rates of seepage can result in boils or internal erosion of soils that can jeopardize levee integrity. Preliminary geotechnical parameters and levee geometry were used to model seepage through and beneath the levee.

High seepage rates can lead to boils where fine-grained soil materials are carried away from the ground surface downstream of levees and earth embankments

Levee seepage was modeled using SEEP/W, a computer modeling program developed by Geo-Slope International and included in the GeoStudio 2007 suite of analytical software. SEEP/W uses the finite-element analysis technique to model the movement and pore-water pressure distribution within porous materials such as soils. SEEP/W can analyze both simple and highly complex seepage problems and results can be imported into SLOPE/W, a finite element stability analysis program, to integrate seepage and stability analyses.

Results of the seepage modeling indicated that seepage control measures are needed along significant portions of the preliminary alignments. Seepage control measures generally consist of seepage cutoffs, seepage berms, seepage trenches, toe drains, relief wells, or a combination of these measures. Analysis of seepage for preliminary levee geometry over the site-specific soil stratigraphy indicates that seepage blankets, cutoffs, or toe drains are the most suitable methods for managing seepage. Space limitations along most of the levee alignment make seepage blankets less desirable. Cutoffs or toe drains are recommended for the preliminary design.

6.3.2.4 Levee Stability Analysis

Levee stability analyses were performed for the preliminary levee cross section, including landside stability and riverside stability. Landside stability was evaluated using SLOPE/W, assuming maximum flood stage and appropriate seepage control measures in the levee section. The soils present along the Mouse River corridor are generally suitable for support of the levees. The results indicate the 3H:1V landside levee slope is stable and meets the minimum required factors of safety.

Riverside stability was evaluated for a rapid drawdown condition, where water levels are rapidly reduced from maximum flood stage to normal flow conditions. The proximity of the levee to the river channel slopes and the side slope of the river channel has a significant effect on riverside slope stability. Therefore, the riverside rapid drawdown analysis was used to establish minimum setbacks from the top of the river channel side slope to the base of the riverside levee toe for various levee heights, foundation soil stratigraphy, and river channel side slopes. The resulting offsets presented in **Table 6-7** assume that river channel side slopes steeper than 3H:1V are stabilized with some means of armor protection.

Table 6-7 Preliminary Minimum Levee Offsets for Steep River Channel Slopes

Base Stratigraphy	Minimum Offset Required for Various Channel Side Slopes (feet)			
	0.5:1	1:1	2:1	3:1
Full sand	45	40	25	5*
Sand to 22 feet over clay	45	40	25	5*
Sand to 15 feet over clay	40	35	20	5*
Interbedded clay and sand with sand on top	45	40	25	5*
Interbedded clay and sand with clay on top	30	25	10	0
Clay to 10 feet over sand	40	35	15	0
Clay to 22 feet over sand	35	25	15	0
Full clay	35	25	15	0

*5-foot offset required to accommodate results of the staged rapid drawdown analysis. Transient analyses performed during the final design phase may show no offset is required.

6.3.3 Floodwalls

Floodwalls are located along the Project alignment where a typical levee section would not fit. Floodwalls will consist of reinforced concrete cantilever T-type walls with a shallow-footing base slab and a vertical stem extending above ground to the design elevation (including 3 feet of freeboard). The base slab is set at a depth of 7 feet below finished grade for frost protection. A steel sheet pile cutoff is assumed along the upstream edge of the base slab, extending into the foundation, to control underseepage and provide scour protection for the foundation. The floodwall alignment considered floodwall and channel bank stability. In areas where the floodwall is in close proximity to the existing river channel an offset is incorporated into the alignment between the riverside floodwall footing and the top of the river channel. Floodwall design was developed for typical heights of 5 feet, 10 feet, and 15 feet.

6.3.3.1 Floodwall Seepage Analyses

Uncontrolled seepage below rigid structures, such as the floodwalls, can lead to instability and failure of the structure. Under-seepage beneath floodwall structures was analyzed through seepage modeling similar to the levee seepage analyses.

Floodwall under-seepage was modeled for steady-state conditions at the maximum flood stage. Floodwall design was generally developed for 5, 10, or 15 feet of head. However, only the 5-foot and 15-foot head conditions, which represent the critical seepage cases. The 5-foot case was considered critical because it represents the minimum base length of the foundation. The 15-foot case was considered critical because it represents the largest head differential. It was assumed that the 10-foot case is not as critical and conceptual results for preliminary design and cost estimating could be inferred from the other cases.

Sheet pile seepage cutoff, toe drain and collector trench, and deep-trench drains or relief wells were evaluated to reduce the gradients and filter foundation materials to minimize the potential for migration and piping.

Steel sheet pile cutoffs were incorporated below the riverside base of the floodwall foundation to control seepage rates, reduce uplift forces on the floodwall foundation, and provide an additional measure of surface erosion protection. Sheet pile cutoff depths will range from 10-to-50 feet below the floodwall foundation. Based on the seepage analyses, toe drains and trenches on the landside edge of the floodwall were also incorporated to collect the water and route it to a seepage collection system.

6.3.4 Bearing Capacity and Settlement of Foundations

Bearing capacity and settlement are the primary factors used in determining foundation size for structures such as floodwalls and pump stations. These analyses were done using guidance from USACE and Naval Facilities Engineering Command.

6.3.4.1 Bearing Capacity

Bearing capacity analyses were performed for each of the eight soil stratigraphy types, based on drained or undrained conditions depending on the soil types encountered and the assumed foundation parameters. The Terzaghi-Meyerhof bearing capacity equation was used to determine bearing capacity for the flood wall structures. Considering that the floodwalls will generally be much longer than the foundations will be wide, a simplified bearing capacity analysis was used. The most critical case for bearing capacity is the design flood condition.

Table 6-8 presents the recommended preliminary strength-based gross allowable bearing capacity values.

Table 6-8 Recommended Allowable Soil Bearing Capacity

Stratigraphy Type	Allowable Soil Bearing Capacity
Type 1 (all sand)	3,000 psf
Type 2 (thick sand over clay)	1,600 psf
Types 3-4 (thin/interbedded sand over clay)	1,400 psf
Types 5-8 (clay at foundation depths)	1,500 psf

6.3.4.2 Settlement Analysis

Settlement of the native soils beneath the levee and flood control structures will depend on the nature of the soil—granular (sands), or cohesive (clays). For foundations which bear primarily on sandy soils, settlement will generally be immediate; the soils will consolidate as fill is placed or the structure is constructed. For foundations or levees which bear primarily on clayey soils, both immediate and long-term consolidation settlement will occur.

Settlement estimates assume the entire soil profile was either sand or clay. These are the two extreme cases of potential soil types that will be encountered. However, the magnitudes of estimated settlement for the worst-case conditions and the anticipated most-likely conditions were similar. The settlement for the multi-layer soil profiles will, therefore, likely have similar overall magnitude of settlement as the all sand and all clay soil profiles.

The potential settlement values reported vary greatly depending on the soil conditions, depth to "rock" (relatively incompressible materials), and final foundation design. Anticipated settlements for the soil conditions identified in the majority of the borings will be less than 12 inches, and likely range from 3-to-8 inches. Based on the wide range of settlement computed in the analyses, settlement will govern foundation design over bearing capacity. .

If estimated settlement of Project features is determined to be excessive, settlement may be reduced by improving subgrade soils (such as densification of granular soils or replacement methods for cohesive soils) prior to construction. However, improvement methods may be costly. Levees tend to tolerate settlement better than other structures, and crest settlement can be corrected with periodic raises to maintain the design crest elevation.

Floodwalls and pump stations will be much more sensitive to settlement than levees. Settlement in excess of a few inches can be considered intolerable for concrete structures. Therefore, it will be critical to better define soil types, strengths, and compressibility characteristics beneath the concrete structures during the final design phase investigations. Excess settlement estimates or bearing pressures for structures may be reduced by increasing foundation sizes, using deep foundations, or employing ground improvement techniques.

6.3.5 Borrow sources

6.3.5.1 Levee Fill

An office review of available topographic, soil, and geological maps, aerial photographs, historical boring logs and well data, and information on existing engineering projects was made as part of the Project. This data was used to establish a starting point for future detailed borrow source investigations, and to provide a basis for estimating costs associated with obtaining borrow for levee construction. An extensive investigation into potential borrow sources is beyond the scope of this report. Borrow source investigation will be a key component of future final design tasks. A summary of potential borrow sources is discussed in the paragraphs below.

Levee material for previous construction consisted of sandy, silty clay, reportedly in great abundance in the early 1970s. During subsequent flood protection activities, several nearby pits have been used for emergency levee construction. Where specific pit names have been identified, research has shown that impervious fill was previously obtained and used for flood control. The quantity of acceptable levee fill from existing pits is not currently known. Therefore, new borrow sites may need to be identified for the quantity of fill required for this Project. In general, past engineering projects report abundant glacial till material consisting of sandy, silty clay that could be used as levee fill. This is located in the valley walls, on either side of the Mouse River Valley corridor. Where levees will be setback from existing levees—depending on the setback distance—it may be desirable to investigate using the existing levee as source material for the new levee. We have assumed that all levees will be constructed of impervious fill such as lean clay (CL) or clayey sand (SC).

The data was used to develop a contingency planning matrix of borrow-source alternatives. The planning matrix is shown in Exhibit G6.1, Appendix G. The planning matrix describes, in general terms, the various options for obtaining borrow for the Project, as well as the positive and negative attributes of each option. In general, it is most desirable to obtain borrow as close to the levee site as possible. Obtaining borrow near the Project site, using off-road equipment, is generally more economical than obtaining borrow further away, using other methods. These sources need to be balanced with their impacts to the seepage and stability of the levees. For example, a borrow pit excavation located within 200 feet landside of a levee with high water levels during a flood event, could experience significant seepage or—worse—instability.

Potential borrow sources generally consist of existing pits, but some new sources are proposed. It should be noted that the potential borrow sources identified are preliminary in nature, and a detailed subsurface investigation program consisting of test pits, soil borings, and lab testing will be required to characterize and quantify available materials. In addition, environmental and cultural resource clearance may need to be obtained, along with any easements or ownership required to secure the use of the site. Potential borrow sources identified for this Project are shown in Exhibit E-7, Appendix E.

6.3.5.2 Rock and Aggregate Materials

Bedding, filter, road base, subbase aggregates, and drainage fill materials appear to be readily available from gravel pits located within reasonable distances from the Project. These materials are also reportedly available in undeveloped sand and gravel terrace deposits along the Mouse River Valley walls. In order to meet gradation requirements, processing of these materials will be required.

Riprap is reportedly available from offsite sources by rail.

Concrete aggregate is reportedly available from local redi-mix concrete suppliers.

Potential borrow sources listed above are preliminary in nature; a detailed subsurface investigation program consisting of test pits, soil borings, and lab testing will be required to characterize and quantify available materials. In addition, environmental and cultural resource clearance may need to be obtained, along with any easements or ownership required to secure the use of the site.

6.4 Civil Design

Civil design focused on Project elements related to alignment including definition of Project features, feature geometry, vertical profiles, and corridor requirements. The primary objective of this effort was to establish the space requirements for Project development and establish reasonable quantities for the baseline cost estimate. Technical feasibility of Project elements has generally been established in the geotechnical or structural design. USACE standards and guidelines were used for the preliminary design development. Preliminary civil design included the following elements:

- Project alignment—including location of levees, floodwalls, high-flow diversions, river closures, and bridge modifications—based on the iterative results of hydraulic modeling and stakeholder input
- Project corridor—including Project features and clear zones—to establish a permanent right-of-way and preliminary considerations for temporary construction easements
- Alignment and geometry design of channel modifications based on hydraulic modeling results including overbank excavations, channel realignments, and high-flow diversions
- Vertical profiles and cross sections of Project features—including identification of existing ground, top of structure, and freeboard—based on design water surface elevations derived from hydraulic modeling results
- Location of interior flood risk reduction pump stations
- General considerations for Project preparations including clearing and grubbing, demolition of existing structures, vegetation, and soil correction
- Avoidance or minimization of environmental impacts to existing wetlands and river channels

6.4.1 Project Alignment

Development of the draft alignment was an iterative process of stakeholder input and engineering analysis. The following criteria were used to develop the preliminary alignment of Project features. Additional discussion regarding development of the preliminary alignment is included in **Section 3.0** of this report.

- Reduce the flood risk associated with the design flow of 27,400 cfs (29,700 cfs at Mouse River Park) for as many homes and critical infrastructure features as reasonably possible. Minimize the Project footprint where appropriate to reduce required property acquisitions and Project costs.

- Integrate hydrologic and hydraulic modeling results to accommodate required design flows and minimize flow velocities to reduce erosion. Top-of-design features were based on the hydraulic modeling effort for the design flood event and included 3 feet of freeboard.
- Incorporate geotechnical analysis of the existing channel-bank stability that established the required setbacks for Project levee and floodwall features. Setbacks are defined in **Appendix E** and were integrated into the design using the top of the existing river bank, average river bank side slopes, and toe of channel bank side slopes from topographic information. Setbacks were applied to levee and floodwall alignments to meet stability requirements based on geotechnical analysis.
- Define clear zone and right-of-way as part of the Project corridor. Permanent right-of-way limits are shown for the entire flood protection corridor. The right-of-way assumes a 30-foot clear zone from the landside toe of levees, and 40-foot clear zone form the landside edge of floodwall footings. Considerations in establishing the clear zones included a 15-foot vegetative buffer, space for seepage and drainage controls, and access space for inspection and maintenance activities.
- Identify anticipated temporary construction easements necessary for construction of Project features.
- Develop cost-effective integrated flood protection features.

The Project alignment was divided into three major geographic sections, consisting of upstream, Minot, and downstream reaches. Within these reaches, individual contiguous alignments, labeled by adjacent community, were identified. Stationing was established along the Project channel centerline from upstream to downstream. Project features are identified by reach, community, and stationing—and in some cases, by sequential numbering from upstream to downstream.

6.4.2 Development of Project Feature Geometry

This section discusses the geometry of features and identifies corridor assumptions required for the Project. The features include levees, floodwalls, high-flow diversion channels, channel realignment, and overbank excavation.

6.4.2.1 Levees

Levees are earthen embankments designed to confine flood flows from seasonal high-water conditions and are subject to water loading for only a few weeks per year. Where space allows, levees are preferred over floodwalls because of their relative ease of construction and flexibility for flood fighting. The typical levee cross section developed for the Project is shown in **Figure 6-6**.

Levee heights vary from minimal, in areas where Project features tie-in to high ground, to a maximum of approximately 27 feet in areas where the levee extends through the existing river channel.

Levees will have a 15-foot top width with side slopes of 3H:1V. The core of the levee will consist of impervious fill from local borrow areas. Topsoil and grassy vegetation will be established on slopes to prevent erosion.

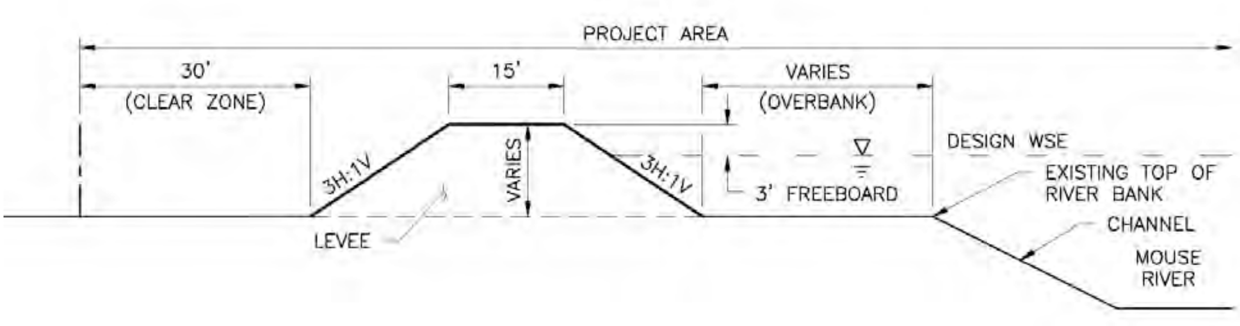


Figure 6-6 Typical Levee Cross Section

6.4.2.2 Floodwalls

Floodwalls consist of vertical wall sections to confine flood flows. For this preliminary engineering effort, a reinforced concrete inverted-T cantilever wall section was developed; this is typically the most economical floodwall configuration.

Figure 6-7 shows a typical project floodwall cross section and examples of architecturally enhanced floodwalls. Because of their more complex design, higher stresses on structural members, limitations on temporary raises during emergency flood-fighting, and higher construction costs, floodwalls are typically used only where adequate space is not available to construct levees.

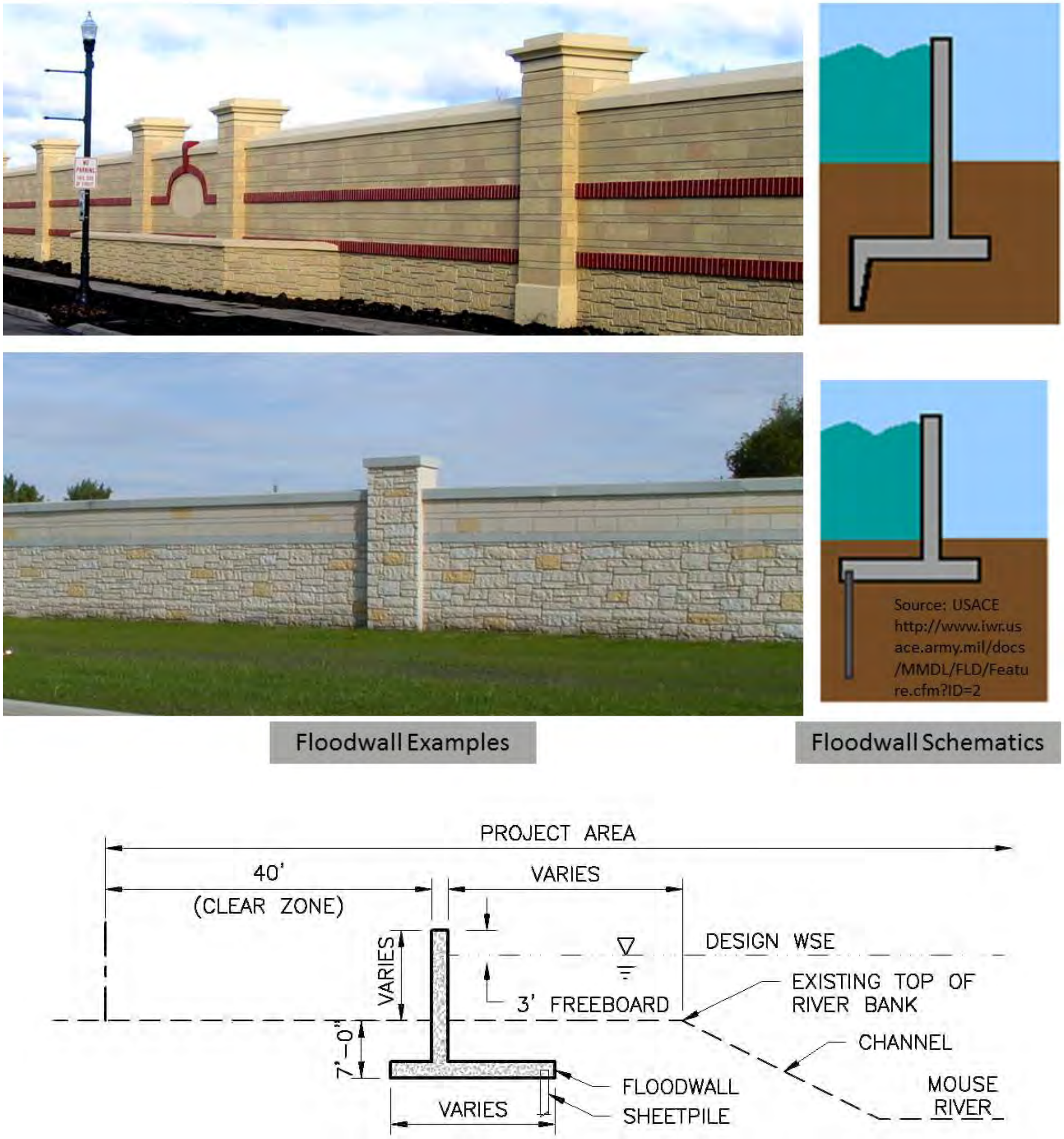


Figure 6-7 Typical Floodwall Cross Section and Example Photos

6.4.2.3 High Flow Diversion Channels

High-flow diversions consist of new channels set above the existing river channel to convey flood flows and bypass a portion of the existing channel. Two high-flow diversions are included in this Project to reduce the number of residential properties affected by construction. The two locations are in Minot and are referred to as the Maple Diversion and the Twenty-Seventh Street SE Diversion.

Water will only flow through these diversions during events that exceed the 100-year flow rate. As such, the diversion channel bottom will be at a higher elevation than the existing river channel bank.

Control structures will be located at the upstream (inlet) and downstream (outlet) ends of each diversion. Flows below the 100-year flow rate will flow through the existing river channel.

River closure structures will be constructed in the existing river channel upstream and downstream of each of the high-flow diversion channels. During normal flows the closure structure will be open, allowing water to continue through the original river channel. When a flood event occurs the structures will be closed and all river flows will be diverted into the high-flow diversion channel. The bottom width and elevation of the high-flow diversion channel will vary based on required channel capacity and use of channel space in non-flood conditions. A rendering of a Maple Diversion is shown in **Figure 6-8**. The slope on the sides of the channel excavation will be 3H:1V.

Erosion control may be necessary on the bottom and sides of the excavated channel. Erosion protection measures could consist of rock riprap (with or without vegetation), managed vegetation, surface reinforcement, or cable concrete, depending on non-flood channel use and desired aesthetics.

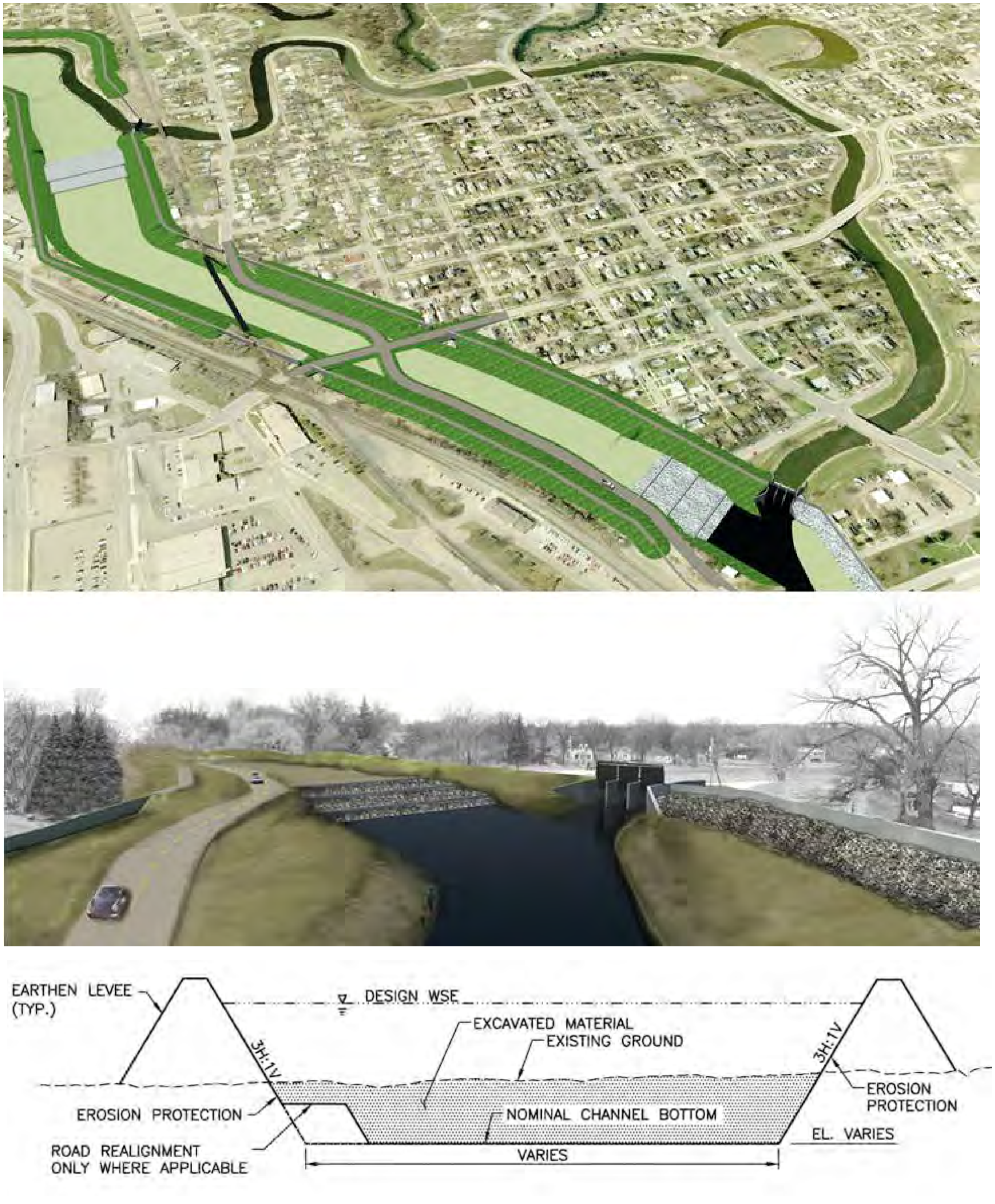


Figure 6-8 Rendering of Maple Diversion

6.4.2.4 Channel Realignments

The existing Project channel is being re-aligned at three areas: King's Court, Eighteenth Street SE, and Sawyer. At each of these locations the existing channel will be closed off with a levee; flows will be managed through the dead loop with a gatewell system, similar to existing dead loops on the Mouse River. The gatewells will be open to allow river flows through the dead loops during non-flood conditions, and the gatewells will be closed during flood events. A new channel alignment will be excavated to convey all river flows up to the design flow event. The bottom elevation of the channel will vary based on channel capacity during the design flood event and the acceptable design water surface elevation. Geometry for channel realignments will closely mimic the existing channel geometry in proximity to the realignment. The slope on the sides of the channel excavation will range from 4–5H:1V. Erosion control may be necessary on the bottom and sides of the excavated channel.

Channel realignment corridors will be similar to levee corridors where flood protection measures are located on each side of the realignment. In areas where flood protection is not immediately adjacent, the channel realignment will be treated in a manner similar to other typical river corridors. A typical channel realignment cross section is shown in **Figure 6-9**.

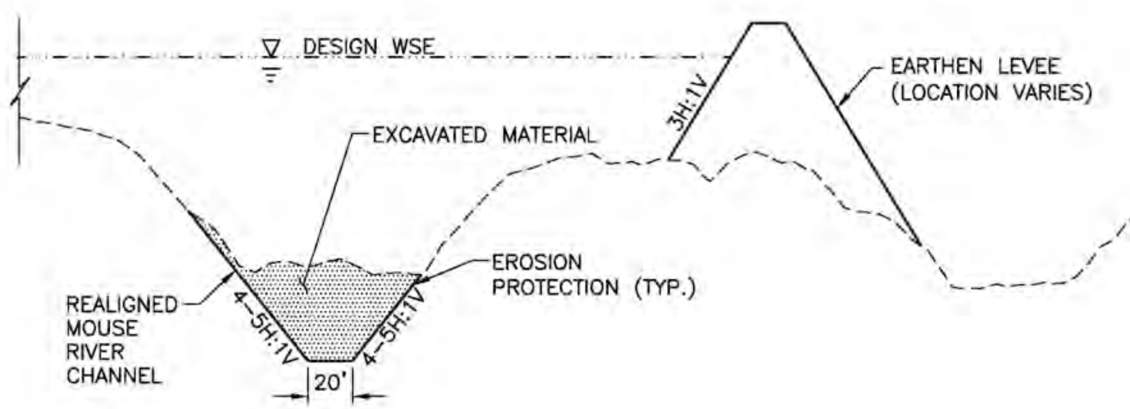


Figure 6-9 Typical Channel Realignment Cross Section

6.4.2.5 Overbank Excavation

Overbank excavations are incorporated to increase the cross section capacity for water flow during flood events to minimize the increase in upstream water surface levels. Overbank excavations are primarily within Minot, in areas where Project space is restricted. To minimize impacts to the existing river and wetlands the bottom elevation of the excavated section will typically be at, or above, the 2-year flood event water surface elevation (approximately 1,150 cfs river flow). The slope on the side of the excavation will be 3H:1V and will typically extend from the bank of the existing channel to a constructed Project feature as shown on **Figure 6-10**. Erosion control may be necessary on the bottom and sides of the excavated portions of the channel.

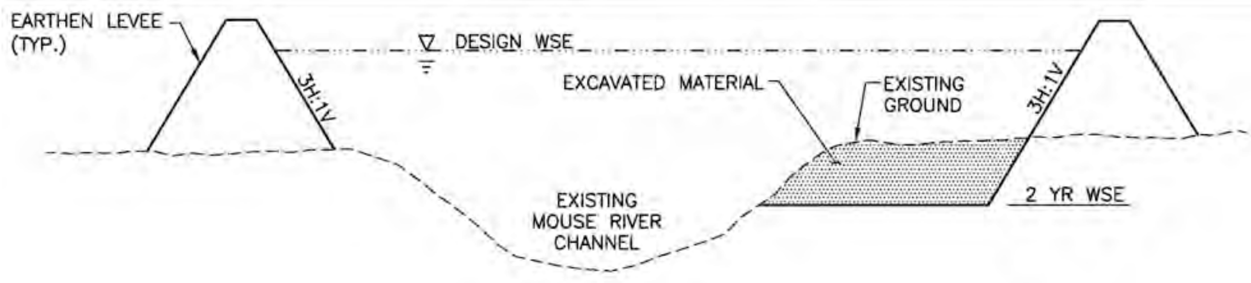


Figure 6-10 Typical Overbank Excavation

6.4.3 Alignment of Project Features

The following is a summary of the Project alignment. Discussion is primarily focused on individual communities, subdivisions, or cities in areas of greater population. Possible flood risk reduction measures for individual rural homes or structures are not included in this section. Project alignments were developed balancing various criteria including stakeholder input, engineering analyses, and regulatory requirements. The top-of-levee and floodwall elevations were defined by the hydraulic model results for the target flow, plus a minimum of 3 feet of freeboard.

The presentation of Project features is organized by geographic location from upstream to downstream. Right and left designations are oriented facing downstream.

Table 6-9, General Project Feature Summary, provides a summary of Project features and characteristics by community. Additional detail is shown on the draft preliminary engineering drawings included in **Appendix B**.

6.4.3.1 Mouse River Park

The preliminary alignment for Mouse River Park consists of a raise of the existing levees to accommodate a flow of 29,700 cfs with 3 feet of freeboard. In addition, all of the existing project structures need modification for the new target design discharge. An improved ramp will be constructed for the main roadway access to Mouse River Park, Ninety-Fifth Street NW, to cross the revised levee. The ramp will have a 25 mph design speed and be constructed at a width of 30 feet. The existing pump station and gatewell will need to be modified and adjusted for the increased levee height. See drawings C-US-06 through C-US-08 in **Appendix B** for more information.

Table 6-9 General Project Feature Summary

Category	Item	Units	Mouse River Park	Burlington	Brooks Addition / MCC / Robinwood	Talbotts	King's Court	Terracita Vallejo	Minot	Apple Grove	River Oaks	Eastside Estates	Chaparelle	Sawyer	Velva
Hyraulics	Design Flood Flow	cfs	29,700	27,400	27,400	27,400	27,400	27,400	27,400	27,400	27,400	27,400	27,400	27,400	27,400
Internal Drainage	Number of Existing Pump Stations		1	----	----	----	1	----	1	----	----	----	----	2	----
	Number of Proposed Pump Stations		----	2	2	1	----	1	15	1	1	1	1	1	2
Flood Protection	Length of Levee	feet	5,310	7,758	13,566	3,185	4,825	3,583	46,249	6,825	0	6,255	1,600	7,394	7,421
	Length of Floodwall (excluding closure structure)	feet	----	995	----	----	----	57	11,803	40	1,638	118	0	88	68
	Number of Roadway Closures		----	1	----	----	----	----	16	----	----	1	----	----	1
	Number of Railroad Closures		----	----	----	----	----	1	4	1	----	1	----	2	2
	Number of New River Closures		----	----	----	----	----	----	4	----	----	----	----	----	----
	Elev. of Flood Protection (Upstream)[1]	feet	1,612	1,584	1,582	1,579	1,575	1,573	1,571	1,555	1,555	1,553	1,550	1,536	1,521
	Elev. of Flood Protection (Downstream) [1]	feet	1,611	1,582	1,576	1,578	1,574	1,571	1,555	1,555	1,555	1,551	1,550	1,532	1,514
	Average Height of Flood Protection[1]	feet	6[2]	11	11	11	10	14	13	10	10	9	5[2]	10	3[2]
	Maximum Height of Flood Protection[1]	feet	7[2]	23	21	18	23	27	24	19	12	11	8[2]	22	8[2]
	Freeboard Above Design WSE	feet	3	3	3	3	3	3	3	3	3	3	3	3	3
	Number of Levee Ramps		2	1	----	----	----	----	1	1	----	1	1	----	0
Infrastructure	Sanitary Sewer	feet	----	2,530	4,470	----	----	----	13,560	----	----	640	----	----	270
	Watermain	feet	----	2,930	3,040	----	----	490	27,360	----	----	590	----	----	----
	Storm Sewer	feet	----	2,915	930	----	----	----	26,405	----	----	60	----	----	1,070
	Number of Bridges to be Modified		----	1	----	----	----	----	3	----	----	----	----	1	1
	Number of New Bridges		----	----	----	----	----	----	2	----	----	----	----	----	----
	Length of Road Re-alignment (horizontal road adjustments only)	feet	----	1,477	3,033	----	----	500	8,345	351	0	616	203	0	0
	Length of Road Raise (includes Bridge Approaches and Highways only)	feet	600	1,406	----	----	----	----	7,113	0	0	14,000	0	330	12,344
Channel Modifications	Length of Channel Diversion/Re-alignment	feet	----	----	----	----	6,667	----	8,800	0	0	0	0	503	0
	Overbank Excavation Area	Acres	----	9	33	----	----	4	43	28	9	0	0	4	8
	Number of Proposed Boulder Drop Structures		----	----	----	----	----	----	1	----	----	----	----	1	----
	Number of Bridges with Scour Protection (Existing and Proposed)		----	1	----	----	2	----	16	----	1	3	2	1	1

(1) includes Freeboard, Dimension from Existing Ground elevation
(2) Existing Levee - Average Height of Raise

6.4.3.2 Burlington

The major components of the preliminary alignment for the city of Burlington consist of new levees and floodwalls, replacement of the Colton Avenue Bridge, road closures, and interior pump stations.

The levee will start on the northwest end of the alignment at the existing CP Railway embankment near Old Settler's Park Road. To minimize impacts to the community and avoid the Del Lacs River, the levee transitions to a floodwall and extends along the current location of Old Settler's Park Road. Old Settler's Park Road is shifted south, away from the floodwall, to maintain clear zone requirements. The floodwall alignment then shifts to the north to avoid impacts to the cemetery. A closure structure is planned where the alignment crosses Old Settler's Park Road.

The preliminary alignment attempted to minimize impacts to the Burlington Sports Complex by avoiding the existing athletic fields. Access to the Burlington Sports Complex is provided by a roadway ramp located to the east of the complex at River Road. This access point is indicated as the single access to this complex.

Additional flood risk reduction features at Burlington include levees, Colton Avenue Bridge replacement, and infrastructure modifications. See drawings C-US-09 through C-US-12 in **Appendix B** for more information.

6.4.3.3 Minot Country Club and Surrounding Developments

The Minot Country Club and the surrounding communities of Brooks Addition, Country Club Acres, Robinwood, and Talbott' include flood risk reduction features such as levees, interior pump stations, and ponding storage and rerouting of an existing ditch system east of the Dakota Boys and Girls Ranch.

The levee on the left side of the river begins in Brooks Addition near the intersection of County Highway 15 and Seventy-Fifth Street NW. The levee alignment extends downstream towards the Minot Country Club between Seventy-Fifth Street NW and the Mouse River. The levee alignment at the Country Club was established to minimize possible impacts to the functionality of the golf course. It is anticipated that the existing golf course clubhouse will be relocated by the owner. South of the Country Club, the levee follows the existing levee alignment through the community of Robinwood. At the southern-most end of Robinwood, the levee alignment has been offset north of the existing levee to achieve the required hydraulic capacity. The levee then extends northeast and ultimately ties into higher ground on the east side of Robinwood near the Boys and Girls Club.

The existing ditch extending from County Road 15, along Nineteenth Avenue NW and behind homes fronting Sixty-Fourth Street NW, will be realigned to the east of the Dakota Boys and Girls Ranch. Realignment is required to avoid significant pumping requirements and internal drainage issues associated with existing runoff from this ditch. A levee is located along the Mouse River to reduce the flooding risk to the Talbott's community. Upgrades in this area consist of a raise of the existing levee system, modified to reflect geotechnical design criteria identified in Section 6.3. Both ends of the alignment tie into existing high ground on the west side of the community, near Highway 2. An interior pumping station and ponding storage area is located within the community.

See drawings C-US-13 through C-US-19 in Appendix B for more information on these alignments.

6.4.3.4 King's Court

The King's Court community is nearly surrounded by the Mouse River. Residents have indicated they would only support an alignment that had little-to-no impact on existing residences. For purposes of planning, the Project includes a combination of levees, gatewells at existing channel crossings, and realignment of the existing river channel.

A levee is planned to begin on the west side of King's Court, which ties into existing ground just east of Highway 2. The alignment then proceeds easterly and crosses the existing Mouse River channel. The levee wraps around King's Court, again crossing the existing river channel, before connecting to high ground east of Highway 2. Control structures, such as gatewells, will be constructed to allow river flow and circulation through the original channel alignment. Gatewells will be closed during significant flood events to direct flow through the channel realignment.

The channel realignment, shown outside of the King's Court community, will be nearly identical in overall length in comparison to the existing channel. The constructed channel starts approximately 1,500 feet upstream of the levee/river crossing. The alignment follows an existing oxbow and meanders before reconnecting to the river downstream. The flow area of the newly constructed channel will be similar to that of the existing river channel.

See drawings C-US-22 and C-US-24 in Appendix B for more information on these alignments.

6.4.3.5 Terracita Vallejo

The Terracita Vallejo community lies on the left side of the Mouse River near Highway 83, just west of Minot. An alignment consisting of a levee, floodwall, railroad closure, and internal pumping station is planned to reduce the flood risk for this community.

A levee begins at the hillside north of the existing Canadian Pacific (CP) Railway, extending south towards the west side of the community. A closure structure with floodwall transition sections is shown at the railroad's intersection with the flood protection alignment. The closure structure allows for normal railroad operation and protection of the community during flood events. The levee extends southward from the railroad, on the west side of the community, before turning and extending to the east and matching in to high ground near Highway 83 bypass. A portion of levee crossing, an old oxbow area, has significant levee heights of approximately 27 feet total. Internal drainage will be handled with a pump station and ponding storage.

See drawings C-US-20 and C-US-21 in **Appendix B** for more information on these alignments.

6.4.3.6 Minot

The city of Minot is considered a separate reach, due to the numerous existing structures, historical features, transportation corridors, bridges, residential communities, and industrial and commercial entities affecting the Project. The city of Minot reach is bounded by the Highway 83 Bypass to the west and Highway 2 to the east. The Mouse River bisects the community, meandering through the heart of the city. Existing flood protection consists mainly of levees bordering the existing Mouse River channel. The major components of the preliminary alignment for the city of Minot consists of new levee and floodwalls; high-flow diversions; river channel realignment; overbank excavation; interior pump stations; closures for roads, railroads, and river; bridge modifications; and new bridge construction.

For discussion of flood protection features within this reach, familiar landmarks and key structures were used to identify specific areas. For preliminary engineering drawings of the entire Minot reach, see drawings C-M-01 and C-M-21 in Appendix B.

6.4.3.6.1 Souris Valley Golf Course

The Mouse River is bordered on both sides by the Souris Valley Golf Course just downstream of the Highway 83 Bypass Bridge. The flood protection in this area consists of levees. At Seventh Avenue SW, a road raise is required to match the top-of-levee elevation. South of Jack Hoeven Park, the levee location is determined by the required 40-foot setback distance from the levee landside toe, to the existing Northwest Area Water Supply pipeline (NAWS). Previous review by the USACE indicated that a 40-foot setback is required between the NAWS pipeline and the levee to ensure protection of the levee in case of a pipeline failure. Right of the Mouse River, flood protection in the form of a levee borders a small development between Highway 83 and the golf course. The levee alignment ties into Fourteenth Avenue SW (no road raise required), protecting the west side of the development. An existing oxbow borders properties on the north and the levee impacts approximately 67,100-square feet of wetland to minimize impacts to existing homes. East of the development the alignment is shown in the rear yards of existing parcels to minimize impacts to the existing fairway and green within the golf course.

6.4.3.6.2 Wee Links Golf Course

Attempts were made to avoid impacts to the existing Wee Links Golf Course; however, due to the required setback from the NAWS pipeline, required design flows, and hydraulic modeling results, flood protection is as shown on the drawings within the course area. The existing levee system will remain in place to provide 100-year protection for the golf course.

6.4.3.6.3 Water Treatment Facility/Sixteenth Street SW Bridge

Based on conversations with city personnel, the water treatment facility was identified as a critical area for flood protection. A floodwall, located between the river channel and the facility, will contain flood flows while minimizing impacts to existing infrastructure and maintaining access to the facility. The wall will transition to the Sixteenth Street SW right closure structure. The existing inlet structure, located in close proximity to the river channel, will need to be relocated. Relocation is anticipated to be upstream, with penetration through the levee. Roadway closures are shown on both sides of the Sixteenth Street SW Bridge, with no modifications anticipated to the bridge structure.

6.4.3.6.4 Maple Diversion

Several options were considered for the flood protection alignment between Sixteenth Street SW and North Broadway. Ultimately, the city of Minot selected the Maple Diversion as the preferred option. The general alignment was selected to minimize the total length of constructed flood protection, minimize impacts to existing homes/structures, and reduce property acquisitions.

Approaching the diversion from upstream, a levee is located on both sides of the channel, aligned to minimize impacts to existing residential homes. The alignment then turns easterly, following the Canadian Pacific (CP) Railroad. A floodwall is located on the left as a transition to the river closure structure, minimizing impacts to the railroad and river channel.

The inlet weir shown crossing the channel marks the beginning of the Maple Diversion. The weir structure will contain flows less than the design 100-year event within the existing river channel and allow higher flows to discharge into the diversion channel. The diversion crosses Maple Street SW and parallels the Burlington Northern Santa Fe (BNSF) railroad along the right side of the alignment.

The CP Railway will cross over the diversion channel on a new bridge to accommodate design flows, as determined by hydraulic modeling results. The railroad bridge is approximately 500-feet long.

Transportation corridors, including Second Avenue SW and Sixth Street NW, will be reconstructed inside of the diversion channel with no bridges required.

An outlet weir marks the end of the Maple Diversion which restricts backwater flow into the diversion channel. Roadway and railroad closure structures are located where these features cross the diversion alignment.

A river closure, located on the existing river channel just upstream of the diversion outlet, protects the existing channel areas between the river closures.

6.4.3.6.5 BNSF Railway

Discussions with BNSF Railway helped identify a floodwall alignment between the Broadway and railroad bridges. The alignment is generally located between the railroad alignment and the river channel due to the congested nature of the land further south.

Left of the river channel, a floodwall is aligned parallel to Fourth Avenue NW to maintain a through street and minimize property acquisitions/impacts to existing homes.

6.4.3.6.6 Eastwood Park and Roosevelt Zoo

Right of the existing river channel, a floodwall is aligned to maintain Central Avenue as a through street and allow access to the Roosevelt Park and Zoo. Discussions with the city of Minot officials identified a need to protect the existing pool and bathhouse facility buildings. The floodwall will protect these features, leaving the skate park on the riverside of the flood protection feature. As the floodwall transitions to levee, the alignment continues through the park, located as close to the river channel as possible, to maintain continuity of the park's open space. The levee transitions back to floodwall again as the alignment approaches the East Burdick Expressway. Floodwall is shown to avoid impacts to existing zoo exhibits and buildings.

6.4.3.6.7 Fourth Avenue NE Road Raise

The BNSF Railway and Fourth Avenue NE are located in close proximity to the river channel. To maintain Fourth Avenue NE as a through road, without impacts to the railroad, the levee and road were combined into a single element. The road will be raised to the necessary design flood elevation and the levee will be incorporated into the road raise section. The road raise maintains approximately

30 feet from the toe of slope to the existing railroad. Existing railroad right-of-way and allowable clear zone will need further review in this area.

6.4.3.6.8 Eighteenth Street SE Channel Realignment

Due to geotechnical setback requirements, levees or floodwalls between the existing river channel and Eighteenth Street SE are not feasible without significant impacts to the street and existing residences. Therefore, a channel realignment is located directly west of Eighteenth Street to minimize existing channel fill and create sufficient channel flow capacities. River channel fill will be minimized to levee crossings; gatewells will be constructed to allow river flow and circulation through the original channel alignment. Flow area for the newly constructed channel will be similar to the existing river channel, with rock boulder drop structures for grade control.

6.4.3.6.9 Eighth Avenue SE

This bridge will remain in place with no anticipated modifications. The bridge will be inundated during the design flood, so roadway closures are included.

6.4.3.6.10 Souris Court

The levee and floodwall alignment minimizes impacts to existing homes located at the end of Souris Court while maintaining required flow capacity within the existing channel. A floodwall is indicated in the rear yards of several homes to allow construction of the river closure structure without impacting channel flow.

6.4.3.6.11 Twenty-Seventh Street SE Diversion

Several alignments and configurations were considered for flood protection alignment between Souris Court and downstream of Twenty-Seventh Street SE. The alignment preferred by the city of Minot consists of a 300-foot wide (inside-to-inside top-of-levee) high-flow diversion along the existing railroad and grain elevator property. The general alignment was selected to minimize the total length of constructed flood protection, minimize impacts to existing homes/structures, and reduce property acquisitions.

Approaching the diversion from upstream, a river closure is located on the existing river channel just downstream of the diversion inlet weir. The inlet weir along the channel bank marks the beginning of the Twenty-Seventh Street SE Diversion. The weir structure will contain flows within the existing channel up to the 100-year flow, and allow flows greater than this to discharge into the diversion channel. The diversion parallels the CP Railway and railroad spurs on the right side of the diversion channel. A new bridge will cross the diversion channel at Twenty-Seventh Street SE to accommodate required channel flow capacity and keep Twenty-Seventh Street SE open to traffic. The bridge is approximately 150-feet long. An outlet weir is located at the downstream end of the diversion, restricting backwater flow into the diversion channel. A river closure is located just upstream of the diversion outlet, restricting backflow into the existing river channel.

6.4.3.6.12 Minot Bridge Summary

- Highway 83 Bypass Bridge—This transportation corridor marks the upstream section of the Minot reach. As part of the Project, the bridge will be modified from a 220-foot span to approximately 350 feet. The bridge will also be raised approximately 3.5 feet. The modifications are required to develop increased flow area under the bridge and keep this critical transportation route open during the design flood event. The roadway approach south of the bridge will be raised to 1 foot above the design water surface elevation to maintain transportation access. Modifications include overbank excavation in the area under the bridge and immediately adjacent to it.
- Broadway Bridge—This bridge, located just downstream of the Maple Diversion, was identified as a critical transportation route during flood events. Floodwalls are shown crossing under the existing bridge, with no modifications anticipated to the bridge span length or elevation. The floodwall alignment left of the river, diverges toward the channel to avoid impacts to the existing bridge. Further review will be necessary to verify vertical floodwall heights, bridge superstructure elevations, and pier locations.
- Third Street Bridge—This bridge and roadway were identified as a critical transportation route during flood events. Thus, floodwalls are shown passing under the existing bridge superstructure. Further review will be necessary to verify vertical floodwall heights, bridge superstructure elevations, and pier locations.
- Railroad Bridge—Meetings and communication with BNSF regarding the existing railroad bridge, just downstream of the Third Street Bridge, will be ongoing. The current plan shows no modifications to the BNSF Railroad Bridge.
- West Pedestrian Bridge (historic)—This bridge will remain in place with no anticipated modifications.
- Seventh Street Bridge—Since this roadway was identified as a non-critical route during flood events, roadway closure structures are shown on both sides of the bridge crossing.
- Fourteenth Street SE Pedestrian Bridge—This bridge will remain in place with no anticipated modifications. A closure structure is located at the right-side access; a ramp is for the left-side approach.

- Burdick Expressway Bridge—Highway B2 and the Burdick Expressway Bridge were identified as critical transportation routes through Minot in the event of a flood. Based on required design flows and hydraulic modeling requirements, modifications to this bridge structure are essential. Bridge modifications will include realignment to the south to allow for traffic flow on the existing bridge during construction, increased span length, bridge deck raise, and adjusted roadway approaches. The bridge will be modified from a 200-foot span length to approximately 395 feet. The bridge will also be raised approximately 10 feet. Channel excavation will be performed around the new structure in conjunction with the bridge modifications. Levee alignments will tie into the bridge abutments and match into the roadway approaches.
- Highway 2 Bridge—This transportation corridor marks the downstream end of the Minot reach. As part of the Project, a second set of bridges will be added to increase the overall total span length to approximately 380 feet from the existing total of 180 feet. The modifications are required to develop increased flow area under the bridge to keep this critical transportation route open during the design flood event. The roadway approach south of the bridge will be raised to 1 foot above the design water surface elevation to maintain transportation access. Modifications include overbank excavation in the area under the bridge and immediately adjacent to it.

6.4.3.7 Apple Grove

The preliminary alignment for the Apple Grove community consists of levees, a railroad closure structure, roadway up-and-over ramp, an interior pump station, and ponding storage.

The levee alignment begins at the modified embankment of the U.S. 2 Bridge located north of Apple Grove. It extends around the community, generally following the Mouse River, then turns south to avoid an existing section of remnant oxbow. The alignment continues until it intersects the Canadian Pacific railroad grade and terminates into high ground north of Highway 52. A railroad closure structure will be provided at the railroad grade intersection. A ramp will be provided to maintain access to the road crossing located just north of the railroad.

The alignment was designed to minimize the impact to adjacent property and wetlands while providing required hydraulic capacity in the Mouse River channel for the design flood. Approach modifications at the U.S. 2 Bridge ensure access to the community during the design flood event. Overbank excavation is included on both the left and right river banks in the vicinity of the modified

U.S. 2 Bridge. The overbank excavation provides increased hydraulic capacity through the bridge reach, while reducing channel and overbank velocities during the design flood.

See drawings C-DS-05 through C-DS-07 in **Appendix B** for more information on this alignment.

6.4.3.8 River Oaks

The River Oaks community lies on the left side of the Mouse River, near Highway 2, just east of Minot. An alignment consisting of floodwall and an internal pumping station is planned to reduce the flood risk for this community.

Floodwall was chosen here because of the close proximity of existing residential lots to the river bank. The walls minimize impacts to homes and adjacent property, while maintaining required geotechnical setbacks from the river bank. The alignment generally follows the Mouse River through the rear yards of existing homes before terminating into existing high ground near the end of Rivers Edge Drive. A pump station is planned for internal drainage control.

Overbank excavation is included on the left river bank, just downstream of the end of the floodwall. The overbank excavation provides increased hydraulic capacity through this reach, while reducing channel and overbank velocities during the design flood.

See drawing C-DS-08 in **Appendix B** for more information on this alignment.

6.4.3.9 Eastside Estates

The major components of the preliminary alignment for the rural community of Eastside Estates are new levees, a roadway up-and-over ramp, road closure, railroad closure, and an interior pump station.

The levee alignment starts at Highway 52 and proceeds north between Puppy Dog Coulee and the community. West and north of the development, the levee reduces the flood risk to Eastside Estates from both the Mouse River and Puppy Dog Coulee. It continues south and crosses Highway 52, connecting to high ground.

The levee alignment crosses the Canadian Pacific Railroad at two locations. A railroad closure structure will be required at the east crossing. The west crossing does not require a closure structure but will require a seepage cutoff. A road closure structure will be provided at the levee intersection with Thirty-Seventh Avenue SE and a ramp will be provided at the intersection of Thirty-Third Avenue SE and Fiftieth Street SE.

Additional hydrologic and hydraulic investigation will be necessary for runoff and flows from Puppy Dog Coulee. A coincident flood frequency analysis that includes both the Mouse River and Puppy Dog Coulee will be required. The reduction of flood risk to Eastside Estates will result in unavoidable impact to certain properties located outside of the community near Puppy Dog Coulee.

See drawing C-DS-09 through C-DS-11 in **Appendix B** for more information on this alignment.

6.4.3.10 Chaparelle

The existing high-water berm was constructed in the spring of 2011 to protect against breakout flows from Puppy Dog Coulee. According to city engineer Ackerman-Estvold, during the June 2011 flood, this dike was inundated to the first row of sandbags added to the top of berm. Therefore, system improvements are needed to meet the Project design requirements. Major components of the preliminary alignment include levee raise, roadway up-and-over ramp, internal pump station, and pump station ponding storage.

The levee horizontal alignment begins at an area of high ground located just to the northwest of Chaparelle and extends easterly, where it ties into a ramp at the existing entrance road connecting Chaparelle to Highway 52. The levee continues just south of the entrance road, ultimately connecting to existing high ground. The vertical alignment of the levee crest was established based on Mouse River hydraulic model results for the Project. The Project mainly involves a vertical raise of the existing levee.

The planned levee alignment will require further evaluation. Due to the influence of Puppy Dog Coulee on design water surface elevations in the vicinity, a coincident flood frequency analysis that includes both the Mouse River and Puppy Dog Coulee will be required to establish final levee alignment and elevations.

See drawing C-DS-12 in **Appendix B** for more information on this alignment.

6.4.3.11 Sawyer

The major components of the preliminary alignment for the rural community of Sawyer consist of new levees, gatewells at existing channel crossings, realignment of the existing river channel, modifications to the existing County Highway 23 Bridge, railroad closures, and interior pump stations.

The levee alignment begins and ends at First Street and wraps around the entire Sawyer community. The new levee crosses the existing main Mouse River channel near the northwest corner of Sawyer and creates a new dead loop. The dead loop will provide a large storage area for internal drainage facilities. Control structures, such as gatewells, will be constructed to allow river flow and circulation through the original channel alignment. Gatewells will be closed during significant flood events to direct flow through the channel realignment. Realignment of the Mouse River channel will be north of the new levee and dead loop area. The flow area of the newly constructed channel will be similar to the existing river channel, with a rock boulder drop structure for grade control. The modified channel will provide increased hydraulic capacity within the channel reach.

Overbank excavation is included on both the left and right river banks in the vicinity of the modified County Road 23 Bridge. The overbank excavation provides increased hydraulic capacity through the bridge reach, while reducing channel and overbank velocities during the design flood. Modifications to the County Road 23 Bridge are required to develop increased flow area under the bridge and keep this critical transportation route open during the design flood event

Railroad closure structures will be required at two locations where the levee alignment intersects the Canadian Pacific Railroad on the west and east sides of Sawyer.

See drawings C-DS-13 through C-DS-15 in **Appendix B** for more information on this alignment.

6.4.3.12 Velva

Enhanced flood risk reduction is provided in the city of Velva, primarily through a minor raise of the existing levee on the east and west sides of the city. A section on the north side of the city, approximately 2,300-feet long, and a 1,700-foot section near the southwest corner of the city require no raise because the existing levee provides greater than 3 feet of freeboard during the design flood. Flood risk reduction measures for the Velva community consist of existing levee raise, railroad closures, a road closure, and internal pumping stations.

The levee alignment begins on the west side of Velva, just to the north of U.S. 52, east of Bonnes Coulee. The levee raise generally follows the existing federal levee alignment and extends northeast to a point where the existing levee height and cross section provide greater than 3 feet of freeboard during the design flood; no further levee raise included. From this point, the existing federal levee alignment generally follows the Mouse River and extends east, intersecting the Highway 41 Bridge and approach modifications. Downstream of the Highway 41 Bridge, the levee alignment extends south, where it intersects Central Avenue and the Canadian Pacific Railroad and ties into high ground.

As part of the Project, the State Highway 41 Bridge will be modified. The modifications are required to provide increased flow area under the bridge and keep this critical transportation route open during the design flood event.

Overbank excavation is included on the left river bank in the vicinity of the modified State Highway 41 Bridge. The river channel and bridge modifications lower the design water surface profile along the north side of Velva to an acceptable level below the existing levee crest elevation during the design flood. These measures minimize the number and severity of impacts to properties adjacent to the north side of Velva.

Railroad closure structures will be required at two locations where the levee alignment intersects the Canadian Pacific Railroad on the west and east sides of Velva. A road closure structure will be provided at the levee intersection with Central Avenue East.

See drawings C-DS-16 through C-DS-19 in **Appendix B** for more information on this alignment.

6.4.4 Bridge Alignment Modifications

This section discusses assumptions regarding bridge modifications for the project. Modifications include horizontal and vertical realignments, roadway approaches, and channel alterations. For preliminary engineering drawings of the showing bridge modifications see drawings S-26 through S-33 in **Appendix B**.

6.4.4.1 Colton Avenue Bridge

Modification of the Colton Ave Bridge in the city of Burlington will be made to meet the design flow hydraulic criteria and keep the bridge open during flood events. The existing two-lane, 122-foot long bridge will be demolished and replaced with a 225-foot bridge of similar width, located along the same alignment. The bridge will also be raised approximately 9 feet. The lowest point of the bottom chord of the bridge will be placed a minimum of 1 foot above the design flood event, so the bridge can remain open to traffic. The roadway approaches east and west of the bridge will be raised to meet the new top-of-bridge-deck elevation. The new roadway approach on the west side of the bridge will pass over the top-of-levee elevation at its intersection with the levee alignment. The intersection of Colton Avenue with County Highway 15W/County Highway 17, to the east of the bridge, will need to be modified to account for the raised elevation of Colton Avenue. Overbank excavation, under and immediately adjacent to the new bridge, on the right and left banks, will provide additional flow conveyance under the bridge.

6.4.4.2 Highway 83 Bypass Bridge

Modifications of the Highway 83 Bypass Bridge on the west side of Minot will be made to meet the design flow hydraulic criteria and keep the bridge open during flood events. The existing two-lane, 220-foot long bridge will be demolished and replaced with a 350-foot bridge of similar width, located along the same alignment. The bridge will also be raised approximately 1-to-3 feet. The lowest point of the bottom chord of the bridge will be placed a minimum of 1 foot above the design flood event, so that the bridge can remain open to traffic. The roadway approach south of the bridge will be raised to a minimum 1 foot above the design water surface elevation to maintain transportation access during the design flood event. The frontage roads east and west of the Highway 83 Bypass will also need to be modified to match the new elevations at their intersections with the bypass. Overbank excavation, under and immediately adjacent to the new bridge, on the right bank, will provide additional flow conveyance under the bridge.

6.4.4.3 Canadian Pacific (CP) Railroad Bridge

A single track of the Canadian Pacific (CP) Railroad passes through the Maple Diversion near the intersection of Second Ave SW and First Ave SW in Minot. The finished grade of the Maple Diversion will be about 19 feet lower than existing ground. A 500-foot long, single-track railroad bridge will be constructed at this location, so that the existing track's horizontal and vertical alignments remain essentially unchanged and flow can pass through the diversion channel. The bridge elevation is lower than the design water surface elevation, so the bridge will overtop during high-flow events. Under lower flows, water will pass under the bridge only.

6.4.4.4 Burdick Expressway Bridge

Modification of the Burdick Expressway Bridge in Minot will be made to meet the design flow hydraulic criteria and keep the bridge open during flood events. The four-lane, 200-foot long bridge will be demolished and replaced with a 394-foot bridge of similar width, just south of the existing location. The bridge will also be raised approximately 13 feet. The lowest point of the bottom chord of the bridge will be placed a minimum of 1 foot above the design flood event, so the bridge can remain open to traffic. The new alignment will allow the existing bridge to remain open during construction of the new bridge. The roadway approaches, east and west of the bridge, will be matched to the new bridge alignment and raised to meet the new top-of- bridge-deck elevation. The new roadway approaches, on either side of the bridge, will pass over the top-of-levee elevation at their intersection with the levee alignments. Overbank excavation, under and immediately adjacent to the new bridge, on the left bank, will provide additional flow conveyance under the bridge.

6.4.4.5 27th Street Bridge

The Twenty-Seventh Street Diversion will bisect Twenty-Seventh Street SE as it currently exists. The finished grade of the Twenty-Seventh Street Diversion will be about 14 feet lower than existing ground. A 147-foot long, two-lane bridge will be constructed in this location, so that the existing road's horizontal and vertical alignments remain essentially unchanged and flow can still pass through the diversion channel. The bridge length, elevation, and open flow area were based on hydraulic modeling parameters. The bridge elevation is lower than the design water surface elevation, so the bridge will overtop during high-flow events. Under lower flows, water will pass under the bridge only.

6.4.4.6 Highway 2 Bridge

Modification of the Highway 2 bridge on the east side of Minot will be made to meet the design flow hydraulic criteria and keep the bridge open during flood events. There are currently two 180-foot long, two-lane bridges at the Highway 2intersection with the Mouse River—one eastbound and one westbound. The two existing bridges will remain in place, unchanged. Two additional 200-foot long bridges will be installed: one along the existing westbound highway alignment and one along the existing eastbound highway alignment. The new bridges will be located about 50 feet west of the existing bridges, along the existing horizontal alignment, and follow the same general vertical alignment as the existing bridge. The lowest point of the bridge's bottom chord will be placed about 3 feet above the design flood event, so the bridge can remain open to traffic. The roadway approaches on the south side of the new bridges will be raised to pass over the top-of-levee elevation at its intersection with the levee alignment. A channel will be excavated under the new bridges to provide flow conveyance.

6.4.4.7 County Highway 23 Bridge at Sawyer

Modification of the County Highway 23 Bridge in the city of Sawyer will be made to meet the design flow hydraulic criteria and keep the bridge open during flood events. The existing two-lane, 150-foot long bridge will be demolished and replaced with a 275-foot bridge of similar width, located along the same alignment. The bridge will also be raised approximately 3-to-5 feet. The lowest point of the bottom chord of the bridge will be placed a minimum of 1 foot above the design flood event, so that the bridge can remain open to traffic. The roadway approaches, north and south of the bridge, will be raised to meet the new top-of-bridge-deck elevation. The new roadway approach on the south side of the bridge will pass over the top-of-levee elevation at its intersection with the levee alignment. Overbank excavation, under and immediately adjacent to the new bridge, on the right and left banks, will provide additional flow conveyance under the bridge.

6.4.4.8 County Highway 41 Bridge at Velva

Modification of the County Highway 41 Bridge in the city of Velva will be made order to meet the design flow hydraulic criteria and keep the bridge open during flood events. The existing two-lane, 151-foot long bridge will be demolished and replaced with a 250-foot bridge of similar width, located along the same alignment. The bridge will also be raised approximately 3 feet. The lowest point of the bottom chord of the bridge will be placed a minimum of 1 foot above the design flood event, so that the bridge can remain open to traffic. The roadway approach south of the bridge will be raised to meet the new top-of-bridge-deck elevation. The new roadway approach on the south side of the bridge will pass over the top-of-levee elevation at its intersection with the levee alignment. Overbank excavation, under and immediately adjacent to the new bridge, on the left bank, will provide additional flow conveyance under the bridge.

6.4.5 Representative Cross Sections

Based on meetings, workshops, and informal conversations with Project stakeholders, Barr identified critical cross sections within all reaches of the Project. Critical cross sections visually represent existing and Project conditions to portray constraints within a given river section. Identified on the cross sections are: side slopes, design water surface elevations, flood reduction measures, river channel, and freeboard. Critical sections are shown for the upstream, Minot, and downstream reaches on Drawings C-US-25, C-M-19 to C-M-20 and C-DS-20 to C-DS-21 in **Appendix B**.

6.4.6 Demolition and Corridor Preparation

Preparation of the Project corridor prior to construction of Project features will require extensive preliminary data gathering, field investigations, detailed demolition drawings, and technical specifications. Typically, demolition-related work is most intensive in urban areas, due to increased infrastructure, however, the entire Project will typically have the following common elements: removal of building structures (residential and commercial), utilities (municipal and private), and roadways (private driveways and city streets). The levee corridor will also be cleared of all trees, fallen timber, brush, vegetation, loose stone, and similar debris. The corridor will be grubbed, stripped, and an exploration trench will be excavated. Finally, unsuitable soils will be removed from the foundation footprint and the existing soils will be scarified. The following tasks are required to prepare the corridor for construction of the new levee.

6.4.6.1 Structure Demolition

Residential and commercial building structures will be removed within the new levee right-of-way and on the riverward side of the levee. Complete structure removal will be performed, including the removal of basements, foundations, drain tiles, and bedding aggregate(s). Appurtenant items will be removed in similar fashion, including sidewalks and private utilities (including water, sanitary sewer, and all other underground utilities). Removal will be performed down to subsoils of low permeability. The excavations will be filled with earth from levee borrow sources and compacted in lifts in accordance with the levee embankment construction specifications for the Project. Backfill material will be from the borrow locations identified for the Project. These excavations may require water management and be dewatered as needed.

6.4.6.2 Street Demolition

Streets and utilities in the public right-of-way will be removed to prepare the area for levee construction. Roadway pavements and base aggregates will be removed down to subsoils of low permeability. Public and private utilities existing under the street will be removed and/or abandoned. The excavations will be filled with earth from levee borrow sources and compacted in lifts in accordance with the levee embankment construction specifications for the Project. Backfill material will be from the borrow locations identified for the Project. These excavations may require water management and be dewatered as needed.

6.4.6.3 Vegetation Removal

USACE guidelines specify that the minimum width of the vegetation-free zone shall be the width of the levee, floodwall, or embankment, including all critical appurtenant structures, plus 15 feet on each side, as measured from the outer edge of the outermost critical structure per guidance (reference [12]).

6.4.6.4 Exploration Trench

Prior to construction of new levees, an exploration trench of 6-foot depth (Type I) and 10-foot depth within demolished structure footprints (Type II) will be excavated at the centerline of the levee. The exploration trench will be observed and inspected to verify that the corridor is clear of unknown utility penetrations, drain tile, buried logs, voids, or other debris (reference [13]). Backfill will only be placed after careful inspection of the excavated trench to ensure that seepage channels or undesirable materials are not present.

6.4.6.5 Final Foundation Preparation

Unsuitable foundation soils may be encountered in some areas within the footprint of the levee. Organic or soft soils within the levee corridor should be removed and replaced with acceptable compacted impervious fill. The surface upon which the first lift of levee fill will be placed should be thoroughly scarified to a depth of 6 inches, just prior to placement of the first lift of levee fill. The levee fill should not be placed on saturated soils.

6.5 Structural Design

Structural engineering for this report consisted of stability analyses, global sizing of major structures, and sizing of major components for the structural features identified on the Project. Structural features include floodwalls, closure structures (railroad and roadway), high-flow diversion structures, river closure structures, interior drainage structures, and bridge replacements.

The primary objective of this effort was to determine the feasibility of designs and establish enough design to develop reasonable quantities for the baseline cost estimate. Detailed design of structural members was not developed for this effort. For features such as river closure structures, pump stations, and gate wells, the overall structure size and member thicknesses were determined from previous project examples of similar configuration. The design of structural features generally followed the governing USACE criteria; however, only the control flood event load case was evaluated under the general assumption that this would be the governing load case.

Water levels for hydrostatic loading were based on the hydraulic modeling effort associated with the design flood event. Features were designed with 3 feet of freeboard from the design flood event for closure structures and floodwalls, and 1 foot of freeboard for bridges.

The general assumptions and codes used for the structural design are outlined in the Basis of Design (BOD) document provided in **Appendix F** to this report. Also included in the BOD document are tables outlining the Project structures.

6.5.1 Floodwalls

Floodwalls are used as a barrier for flood flows where space constraints prevent the use of levees. Water elevations on the riverside of the floodwall were determined from hydraulic modeling output for the target design flood flows. A combination of water height above finished grade on the riverside of the floodwall and underlying soil type was used for classifying the structures, as described in **Table 6-10**.

Table 6-10 Summary of Floodwall Types

Floodwall Type	Maximum Water Height above Finished Grade on Riverside of Floodwall at Target Flood Level	Soil Type (see Table 6-6)
A	5 feet	Type 1 thru 8
B1	10 feet	Type 1
B2	10 feet	Types 2 thru 4
B3	10 feet	Types 5 thru 8
C1	15 feet	Type 1
C2	15 feet	Types 2 thru 4
C3	15 feet	Types 5 thru 8
D	18.5 feet	Type 1

For the purpose of determining floodwall costs, a standard reinforced-concrete cantilever T-wall was assumed for this Project, as shown in **Figure 6-11**. For seepage control, steel sheet pile (SSP) was assumed to be placed under the foundation of the floodwalls to a minimum depth of 10-feet from the bottom of the foundation. Keys at the bottom of the foundations were used for floodwalls higher than 13 feet above ground to increase sliding resistance.

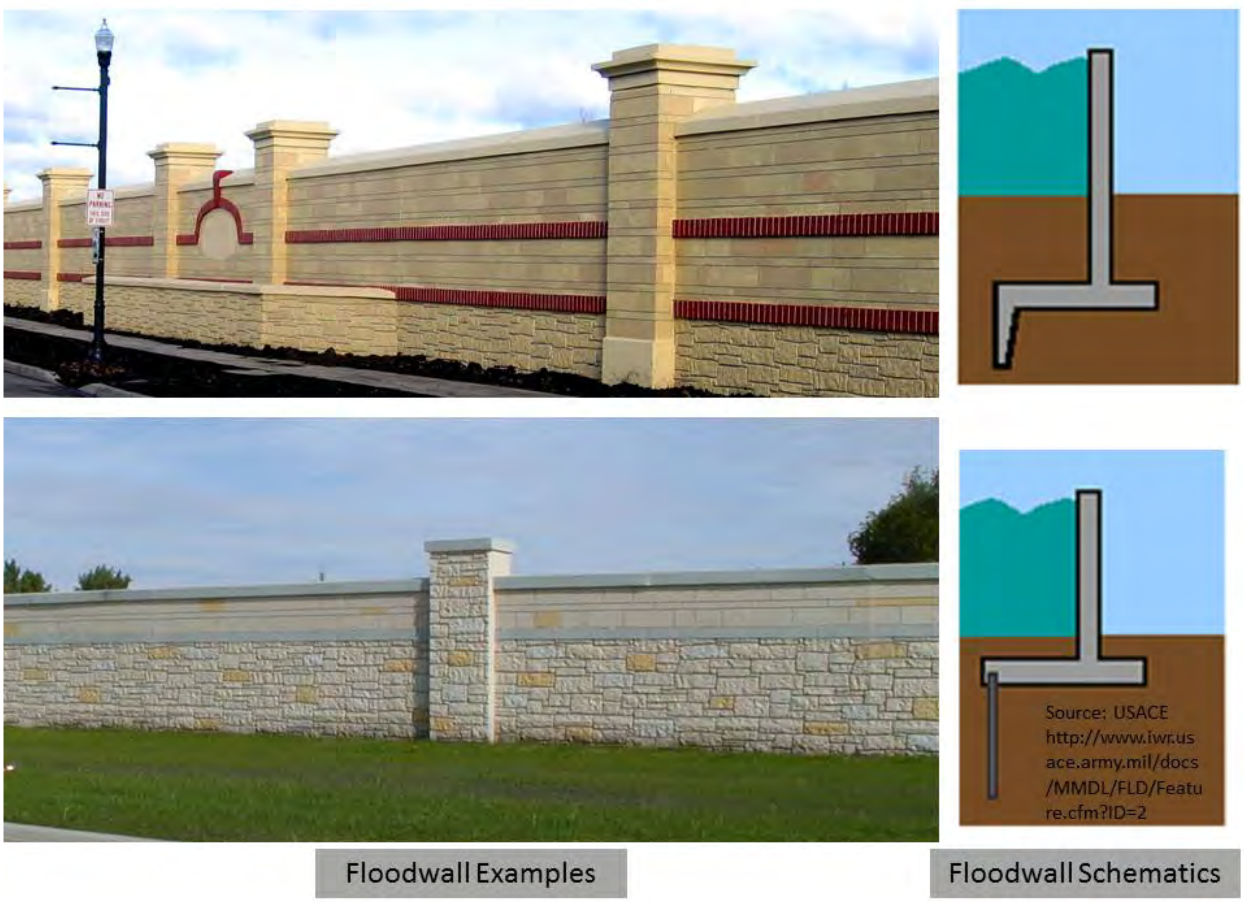


Figure 6-11 Floodwall Examples and Schematics

A summary of floodwall type, water height for design flood event, and estimated total length of each floodwall section is presented in **Table 6-11**.

Table 6-11 Floodwall Summary

STRUCTURE NAME[1,2]	FLOOD-WALL TYPE	FLOODWALL HEIGHT ABOVE FINISHED GRADE (FT)	FLOOD-WALL LENGTH (FT)
OLD SETTLERS PARK ROAD (R)	A	6.97	995
CP RAIL WEST 37TH STREET SW (L)	A	6.07	57
16TH STREET SW (R)	B1	9.2	812
16TH STREET SW (L)	C1	15.3	103
MAPLE AVENUE DIVERSION UPSTREAM (L)	C1	14.83	388
CP RAIL WEST 6TH STREET NW (L)	B1	12.15	225
2ND AVENUE SW (L)	C1	15.79	150
6TH STREET NW (L)	C1	15.84	165
CP RAIL WEST 6TH STREET NW (R)	B1	11.91	210
6TH STREET NW (R)	D	21.51	250
MAPLE AVENUE DIVERSION DOWNSTREAM (L)	C1	15.62	692
4TH AVENUE NW WEST 3RD STREET SE-1 (L)	C2	15.08	2306
4TH AVENUE NW EAST 3RD STREET SE - 2(L)	C2	16.12	0
BNSF RAIL EAST 3RD STREET NE (L)	C2	14.87	0
BNSF RAIL LOT (R)	A	8	1815
BNSF RAIL WEST 3RD STREET NE (R)	B2	10.53	670
7TH STREET (L)	B3	12.08	130
7TH STREET (R)	B2	12.14	1962
ROOSEVELT PARK (R)	C2	14.68	0
ZOO PED BRIDGE (R)	C2	13.2	1130
8TH AVENUE SE (R)	B1	9.43	65
8TH AVENUE SE (L)	B1	11.83	72
27TH STREET SE DIVERSION UPSTREAM (L)	C3	16.76	535
27TH STREET SE (L)	B3	10.67	86
27TH STREET SE (R)	A	7.37	80
27TH STREET SE DIVERSION DOWNSTREAM (L)	C3	17.34	0
CP RAIL EAST OF HIGHWAY 52 (R)	A	7.29	40
RIVERS EDGE DRIVE FLOODWALL	B2	12.49	1638
37TH AVENUE SE (R)	B1	8.21	47

STRUCTURE NAME[1,2]	FLOOD-WALL TYPE	FLOODWALL HEIGHT ABOVE FINISHED GRADE (FT)	FLOOD-WALL LENGTH (FT)
CP RAIL EAST OF EASTSIDE ESTATES (R)	A	6.09	70
CP RAIL WEST OF DAKOTA AVENUE (R)	B3	8.69	43
CP RAIL EAST OF DAKOTA AVENUE (R)	B3	10.44	45
CP RAIL WEST VELVA (R)	A	3.15	26
CENTRAL AVENUE EAST VELVA (R)	A	7.15	17
CP RAIL EAST VELVA (R)	B2	8.02	25

[1] See C Drawings in **Appendix B**
[2] Facing downstream (L) is left and (R) is right

Only the design flood load case was evaluated, and both long-term and short-term soil conditions (drained and undrained condition) were analyzed. The bottom of the base slab is embedded 7 feet below the ground surface for frost protection. Vertical loads consist of concrete weight, water, buoyant soil, and uplift pressures along the floodwall base. Driving loads consist of water and soil loads on the river side of the floodwall. Resisting loads consist of soil and water pressures on the landside of the floodwall. Uplift pressures were calculated, conservatively, using line-of-creep method under the foundation base slab neglecting the sheet pile cutoff wall. Calculation of uplift was assumed to be linearly decreasing from full head on the riverside to floodwall to zero head at the ground surface on the landside of the floodwall. These assumptions over-estimate the uplift pressures and provide a reasonable level of conservatism for the preliminary design. Uplift should be recalculated for final design.

Floodwalls were designed to meet allowable bearing pressure requirements, maintain compression along the entire base slab, and meet sliding stability requirements. Wall thicknesses were developed based on factored hydrostatic pressures for the full height of the floodwall on the river side of the wall. Slab thicknesses were designed to accommodate the resulting stresses from the factored full height hydrostatic loading case.

6.5.2 Transportation Closure Structures

Roadway and railroad closures are used where access through a floodwall is required during non-flood conditions. Closures consist of bulkheads or roller gates and, like the floodwalls, were designed for 5, 10, or 15 feet of water above the sill (base) of the closure opening. The closures tie into adjacent floodwalls on both sides. A summary of the closure structures is included in **Table 6-12**.

Table 6-12 Closure Structure Summary

STRUCTURE NAME[1,2]	CLOSURE HEIGHT ABOVE FINISHED GRADE (FT)	CLOSURE OPENING LENGTH (FT)	TYPE OF CLOSURE
OLD SETTLERS PARK ROAD (R)	6.97	44	BULKHEAD (ROAD)
CP RAIL WEST 37TH STREET SW (L)	6.07	20	BULKHEAD (RAILROAD)
16TH STREET SW (R)	9.2	82	ROLLER GATE
16TH STREET SW (L)	15.3	70	BULKHEAD (ROAD)
MAPLE AVENUE DIVERSION UPSTREAM (L)	14.83	0	RIVER
CP RAIL WEST 6TH STREET NW (L)	12.15	20	BULKHEAD (RAILROAD)
2ND AVENUE SW (L)	15.79	60	ROLLER GATE
6TH STREET NW (L)	15.84	85	BULKHEAD (ROAD)
CP RAIL WEST 6TH STREET NW (R)	11.91	20	BULKHEAD (RAILROAD)
6TH STREET NW (R)	21.51	70	BULKHEAD (ROAD)
MAPLE AVENUE DIVERSION DOWNSTREAM (L)	15.62	0	RIVER
4TH AVENUE NW WEST 3RD STREET SE-1 (L)	15.08	52	ROLLER GATE
4TH AVENUE NW EAST 3RD STREET SE - 2(L)	16.12	52	ROLLER GATE
BNSF RAIL EAST 3RD STREET NE (L)	14.87	113.4	BULKHEAD (RAILROAD)
BNSF RAIL LOT (R)	8	59	ROLLER GATE
BNSF RAIL WEST 3RD STREET NE (R)	10.53	140	BULKHEAD (RAILROAD)
7TH STREET (L)	12.08	52	BULKHEAD (ROAD)
7TH STREET (R)	12.14	128	ROLLER GATE
ROOSEVELT PARK (R)	14.68	40	ROLLER GATE
ZOO PED BRIDGE (R)	13.2	30	ROLLER GATE
8TH AVENUE SE (R)	9.43	60	BULKHEAD (ROAD)
8TH AVENUE SE (L)	11.83	60	BULKHEAD (ROAD)
27TH STREET SE DIVERSION UPSTREAM (L)	16.76	0	RIVER
27TH STREET SE (L)	10.67	52	ROLLER GATE

STRUCTURE NAME[1,2]	CLOSURE HEIGHT ABOVE FINISHED GRADE (FT)	CLOSURE OPENING LENGTH (FT)	TYPE OF CLOSURE
27TH STREET SE (R)	7.37	80	ROLLER GATE
27TH STREET SE DIVERSION DOWNSTREAM (L)	17.34	0	RIVER
CP RAIL EAST OF HIGHWAY 52 (R)	4.29	20	BULKHEAD (RAILROAD)
RIVERS EDGE DRIVE FLOODWALL	12.49	0	NONE
37TH AVENUE SE (R)	6.11	52	ROLLER GATE
CP RAIL EAST OF EASTSIDE ESTATES (R)	4.03	20	BULKHEAD (RAILROAD)
CP RAIL WEST OF DAKOTA AVENUE (R)	5	20	BULKHEAD (RAILROAD)
CP RAIL EAST OF DAKOTA AVENUE (R)	5.94	20	BULKHEAD (RAILROAD)
CP RAIL WEST VELVA (R)	3.15	21	BULKHEAD (RAILROAD)
CENTRAL AVENUE EAST VELVA (R)	5.47	44	ROLLER GATE
CP RAIL EAST VELVA (R)	5.47	38.5	BULKHEAD (RAILROAD)

[1] See C Drawings in **Appendix B**

[2] Facing downstream (L) is left and (R) is right

The bulkheads, also sometimes referred to as stoplogs, were designed as fabricated steel sections with horizontal beams and a front skin plate. An example bulkhead closure structure is shown in **Figure 6-12**. Bulkheads were designed in height categories for up to 5 feet of head, up to 10 feet of head, and up to 15 feet of head, and for widths of either 20 or 40 feet. The bulkheads are supported at the ends within structural grooves or slots embedded in the concrete abutment piers at either side of the closure opening. The opening widths were sized based on road or railroad width plus a minimum 8-foot buffer on each side. Where openings were larger than 40-feet, intermediate supports will be provided, consisting of removable steel posts that can be secured to the sill and braced to an offset footing. No design was developed for the preliminary alignment effort. A sill or seating surface will be constructed at the opening for bulkhead or gate sealing. The sill extends across the full width of the roadway with a 7-foot deep footing for frost protection and a SSP seepage cut-off beneath the sill footing to match the adjacent floodwall cut-off. Concrete approach slabs will extend from both sides of the sill. Bulkhead slots and intermediate support connections will be covered with steel plates or similar protection to prevent damage from traffic and ice conditions. Railroad closure design assumed the sill is at the rail tie elevation and that rail removal is not necessary for bulkhead installation. Bulkheads will be designed to fit and seal around the rails.

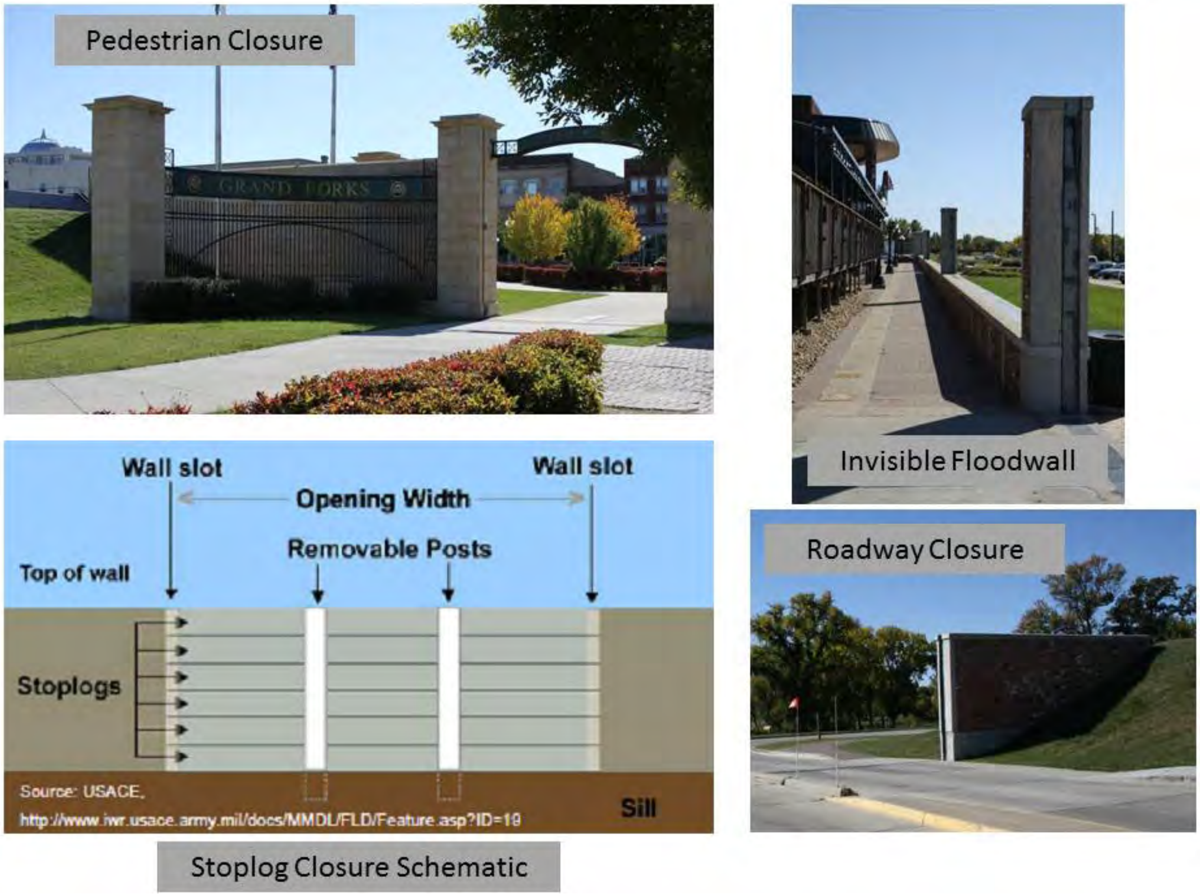


Figure 6-12 Example Bulkhead (Stoplog) Closure Structures

Due to the number of closures and the manpower required to install bulkheads in all of the openings, only about half of the closures are designed as steel bulkheads, including all railroad closures. The other half of the closures will be roller-gate type closures developed in accordance with USACE guidelines. A typical roller-gate type closure is shown in **Figure 6-13**. The gate details were not developed for this preliminary engineering report, but were generally sized for the opening and head pressure.

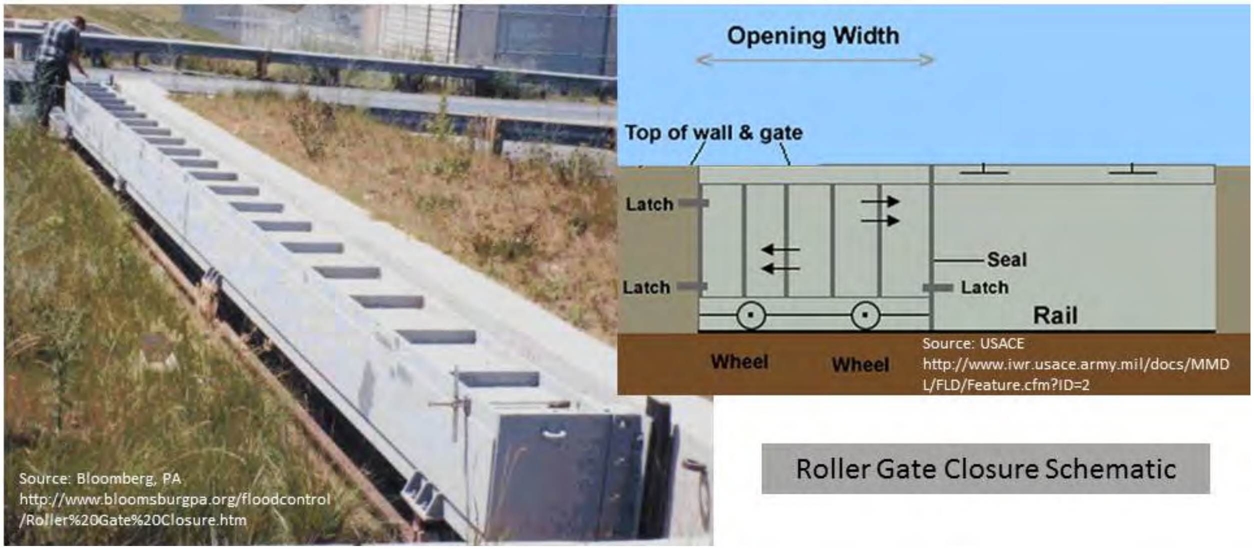


Figure 6-13 Example Roller Gate Closure Structure and Schematic

6.5.3 High Flow Diversion Control Structures

Four diversion structures were developed for the Project, consisting of an inlet and an outlet structure for each of the two high-flow diversions. Each of the diversion structures consists of a fixed crest structure that maintains flows in the existing channel during low and normal high flows, and allows river flow to discharge over the fixed crest into the high-flow diversion channel during extreme flow events (above the 100-year flood). During extreme flood events the river closure structure gates (see section 6.5.4) will be closed to divert the water over the diversion structure and through the diversion channel.

The high-flow diversion inlet structures were assumed to be a series of cantilevered SSP walls driven into the river bank and capped with reinforced concrete, forming a several-step drop in elevation from the river bank fixed weir crest to the diversion invert elevation, as shown in Figure 6-14. The downstream diversion consists of a fixed SSP weir crest at the 100-year tailwater elevation and a series of SSP weirs that step up to the primary river channel invert elevation, as shown in Figure 6-15. The diversions extend across the width of the diversion channel, generally perpendicular to the diversion flow.

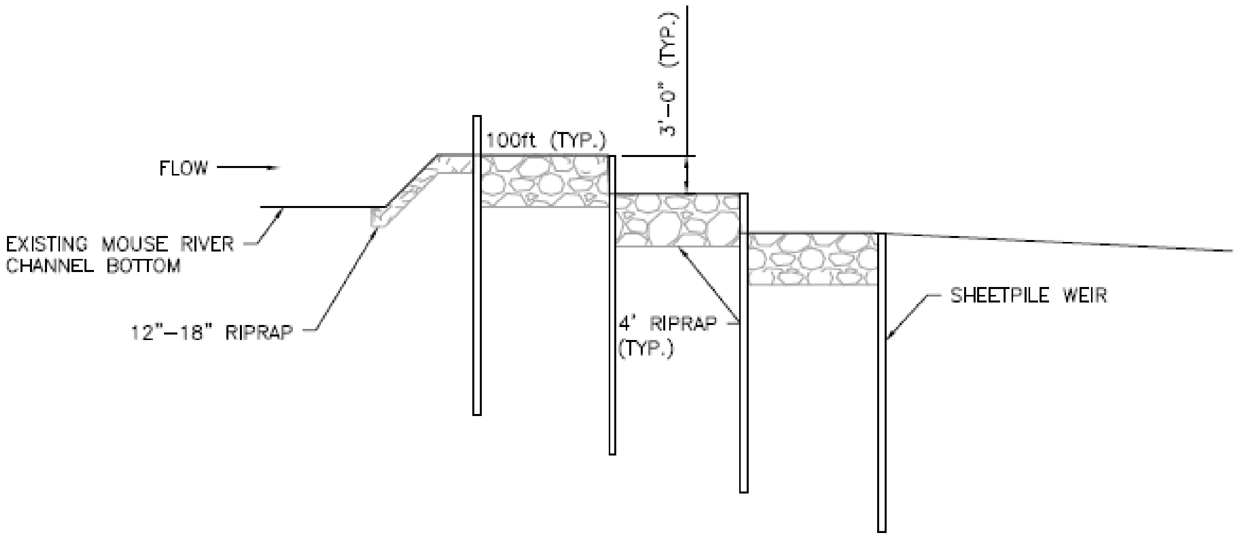


Figure 6-14 Typical Upstream Diversion

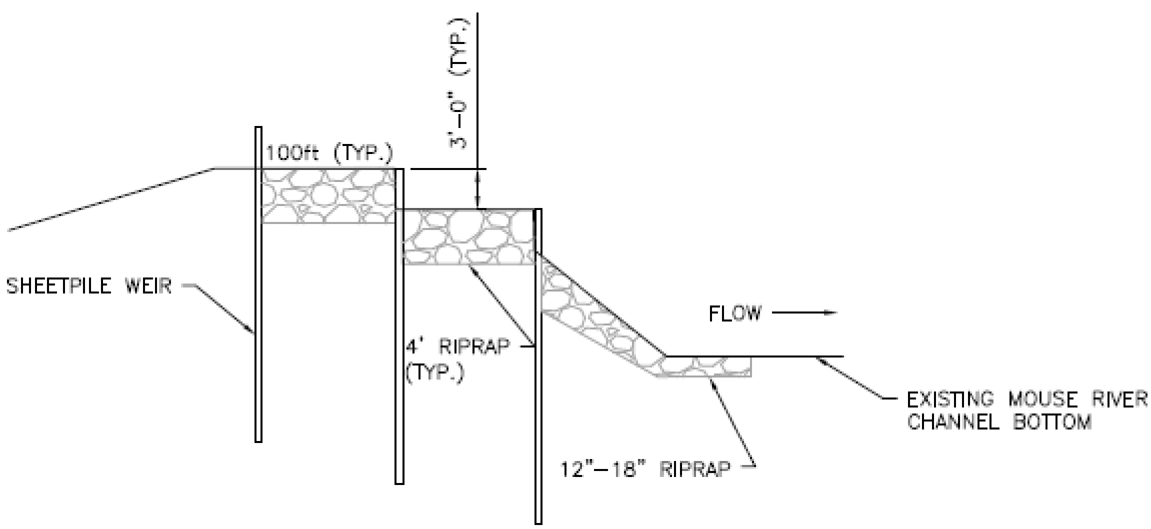


Figure 6-15 Typical Downstream Diversion

6.5.4 River Closure Structures

River closure structures consist of reinforced concrete gate structures within the river which allow low and normal high flows to pass into the existing river channel. In the event of 100-year flood flows these structures close, diverting water to a high-flow diversion channel. A rendering of a typical river closure structure is shown in **Figure 6-16**. The structures were sized to pass the 100-year flood. The river closures are assumed to be gated structures with three vertical slide or roller gates, 24-feet in width. The width was based on a qualitative review of flow requirements and to allow for recreational boating (canoe or kayak) during normal flow conditions. The structure piers and abutment wall thicknesses were based on structure configurations for similar projects as well as the height of the structure or walls. The length of the structure (upstream to downstream) was based on the height of the adjacent levee and assuming a 15-foot crest width and 3:1 slope on the levees. The abutment walls follow these contours and retain the adjacent levee soils. The structures were conservatively assumed to be founded on steel H-piles, giving adequate global sliding stability.

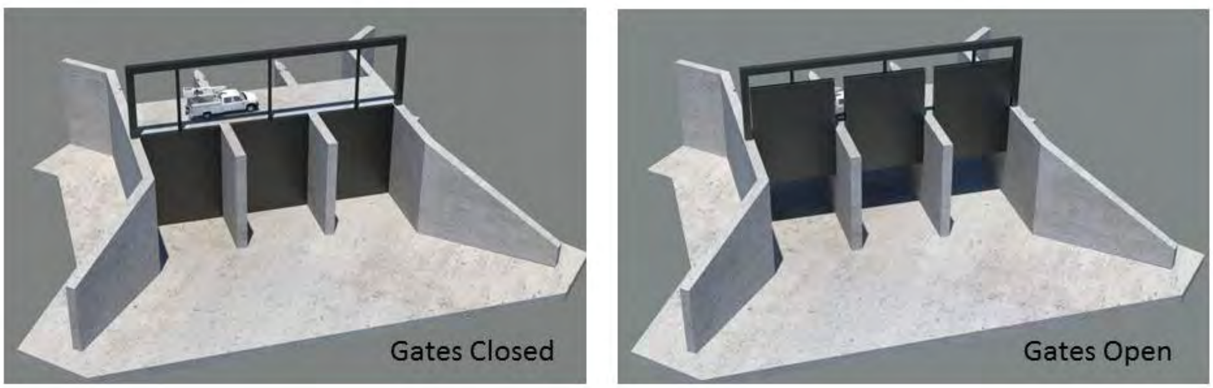


Figure 6-16 Closure Structure Rendering

6.5.5 Interior Drainage Structures

Interior drainage structures consist of pump stations and gate wells. The pump stations were divided into four categories based on pump station capacity requirements. The categories consist of small pre-cast submersible stations (less than 7,000 gpm), cast-in-place submersible stations (8,000– 25,000 gpm), trench well submersible stations (26,000–85,000 gpm), and large vertical turbine pump stations (over 85,000 gpm). The submersible pump stations and trench well submersible pump stations also have an adjacent gate well structure/gravity outlet. The large vertical turbine pump stations are assumed to have an adjacent discharge bay within the levee and discharge directly to the flood side. The pump stations and gate wells are used to control flow of water within the flood-protected areas. A summary of the pump station capacities and types is presented in **Table 6-13**.

Table 6-13 Pump Stations

Pump Station Name	Pump Station Design Capacity (gpm)	Pump Station Type
Mouse River Park	2,000	Small Submersible
Valley Avenue	2,000	Small Submersible
Johnson's Addition	2,000	Small Submersible
Brooks Addition	2,000	Small Submersible
Talbott's	2,000	Small Submersible
CC Acres	3,000	Small Submersible
Kings Court	4,000	Existing Small Submersible
Terracita Vallejo	12,000	Large Submersible
Lighthalls	2,000	Small Submersible
Perkett Ditch	40,000	Trench Well Submersible
12th Street SW	2,000	Small Submersible
Moose Lodge	3,000	Small Submersible
Ramstad Park	15,000	Existing Large Submersible
6th Street SW	40,000	Trench Well Submersible
Broadway	70,000	Trench Well Submersible
4th Avenue NE	2,000	Small Submersible
8th Street NE	60,000	Trench Well Submersible
Roosevelt Park	70,000	Trench Well Submersible
15th Street SE	2,000	Small Submersible
18th Street SE	2,000	Small Submersible
Souris Court	8,000	Large Submersible
Livingston Coulee	360,000	Large Vertical Turbine
Farmers Union	2,000	Small Submersible
Keller	11,000	Large Submersible
Apple Grove	2,000	Small Submersible
River Oaks	2,000	Small Submersible
East Side Estates	2,000	Small Submersible
Chaparelle	2,000	Small Submersible
Sawyer West	2,000	Small Submersible
Sawyer North	1,000	Existing Small Submersible
Sawyer Ring Levee	500	Existing Small Submersible
Velva Park	6,800	Existing Small Submersible
Velva East	7,000	Small Submersible

The two smaller categories of pump stations and gate wells are pre-cast reinforced concrete round structures (small submersible stations) or cast-in-place reinforced concrete box-shaped structures (larger submersible stations). The layout and dimensions of these pump stations were based on the pumping requirements and past experience with similar projects. The structural elements of these pump stations and gated control structures were sized based on past experience with similar projects. Detailed design and analyses for flotation, foundation bearing, or member sizing were not completed.

The trench well submersible stations are reinforced concrete box trench structures founded on a reinforced concrete base slab. The layout and dimensions of these stations were based on the pumping requirements and the Hydraulics Institute standards for design of trench well type pumping stations. The structural elements were sized based on past experience with similar structures. The associated gate well structure is also a reinforced concrete structure founded on a base slab and was sized based on flow requirements and past experience on similar projects.

The large vertical turbine pump stations are reinforced concrete structures founded on reinforced concrete slabs. Overall layout and size of the pump stations was based on pumping requirements and the Hydraulics Institute and USACE standards for design of large pumping stations. The structural elements were sized based on past experience with similar structures. The large pump stations were assumed to be integral to the levee or floodwall so that the pumps would discharge directly to the flooded side of the protection works. A separate gate well structure for pump discharge piping would not be necessary.

Excavation and dewatering is anticipated for the construction of the pump stations and gate wells.

6.5.6 Bridge Modifications

Bridge modifications are required in several locations to maintain critical transportation routes during flood events and reduce erosion where existing bridge openings result in extremely high-flow velocities. Bridges were raised to allow for at least 12 inches of freeboard from the low bridge cord to the control flood event. The bridges were lengthened to provide additional flow capacity to reduce velocities for the design event. No structural design was completed for this preliminary engineering report, but general bridge alignments and profiles were developed as shown on the drawings. The alignments are based on hydraulic requirements. The number of bridges affected and the size of the bridges is provided in Appendix F.

6.6 Transportation

Transportation considerations include development of a critical transportation network to provide reliable transportation corridors during the target flood, road realignment and grade raises to accommodate preliminary alignment features, and accommodation of railroad infrastructure.

Critical Transportation Network

The Mouse River enters North Dakota from Saskatchewan near Sherwood, North Dakota, and exits the state near Westhope, North Dakota, where it crosses into the province of Manitoba. A major flood of the Mouse River that inundates the transportation network essentially creates an island in north central North Dakota, including parts of Ward, Renville, Bottineau, and McHenry counties. During the June 2011 flood, this "island" was effectively isolated from the remainder of the state. Only two transportation corridors remained open to traffic for the duration of the event: the roadway crossing the Lake Darling Dam and the US Highway 83 Bypass in Minot.

During the June 2011 flood, nine major roadways in Minot were closed due to high water. All nine of these roadways are classified as collectors, minor arterials, or principal arterials—primarily because they cross the Mouse River or the BNSF and Canadian Pacific railroads. Closure of these roadways, which form the majority of the city's major street network, forced all traffic to Broadway (US Highway 83) and the US Highway 83 Bypass. While Broadway was not inundated during the flood, the roadway was closed before and during its peak to ensure a primary north-south route across the Mouse River for emergency service and flood fighting crews. Road closures outside the city of Minot also forced through-city traffic to the few roadways that remained open. During the event, travel delays in excess of two hours were common. Subsequent closure of the US Highway 83 bypass occurred post-flood because of significant scour and flood-related damage at the Mouse River Bridge.

The inability to traverse the city greatly impacted the provision of emergency services (fire, police, and ambulance), access to medical care, and access to essential supplies. It also severely hindered the flood fighting efforts of agencies and residents.

The objective of the preliminary alignment plan is to establish a network of principal arterial corridors that will enable essential road transportation during the design flood event. This consists of US Highways 2, 52, and 83, and their associated bypasses. This network will provide residents with access to all essential goods and services during an event.

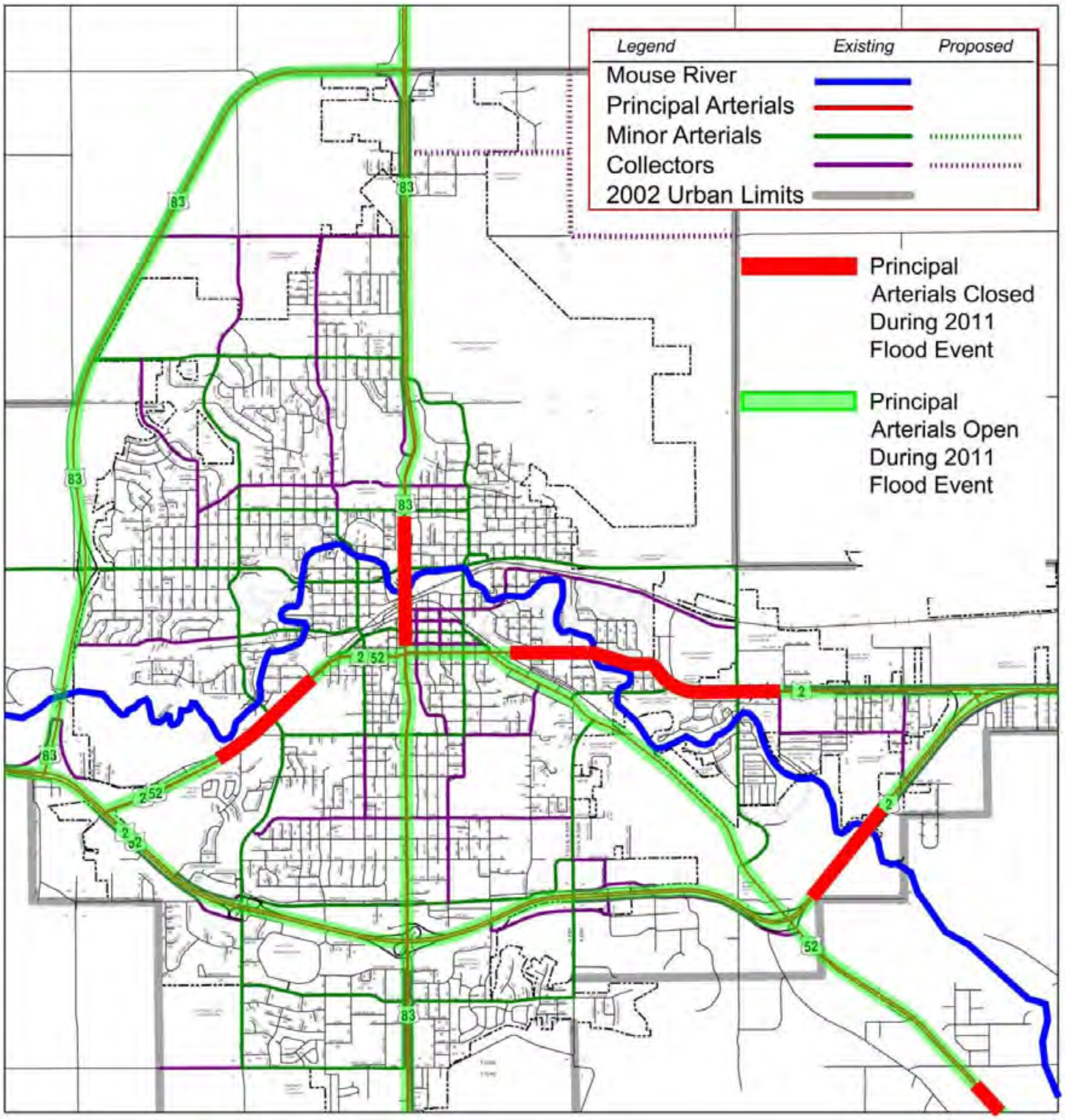


Figure 6-17 Functional Transportation Network (June 2011)

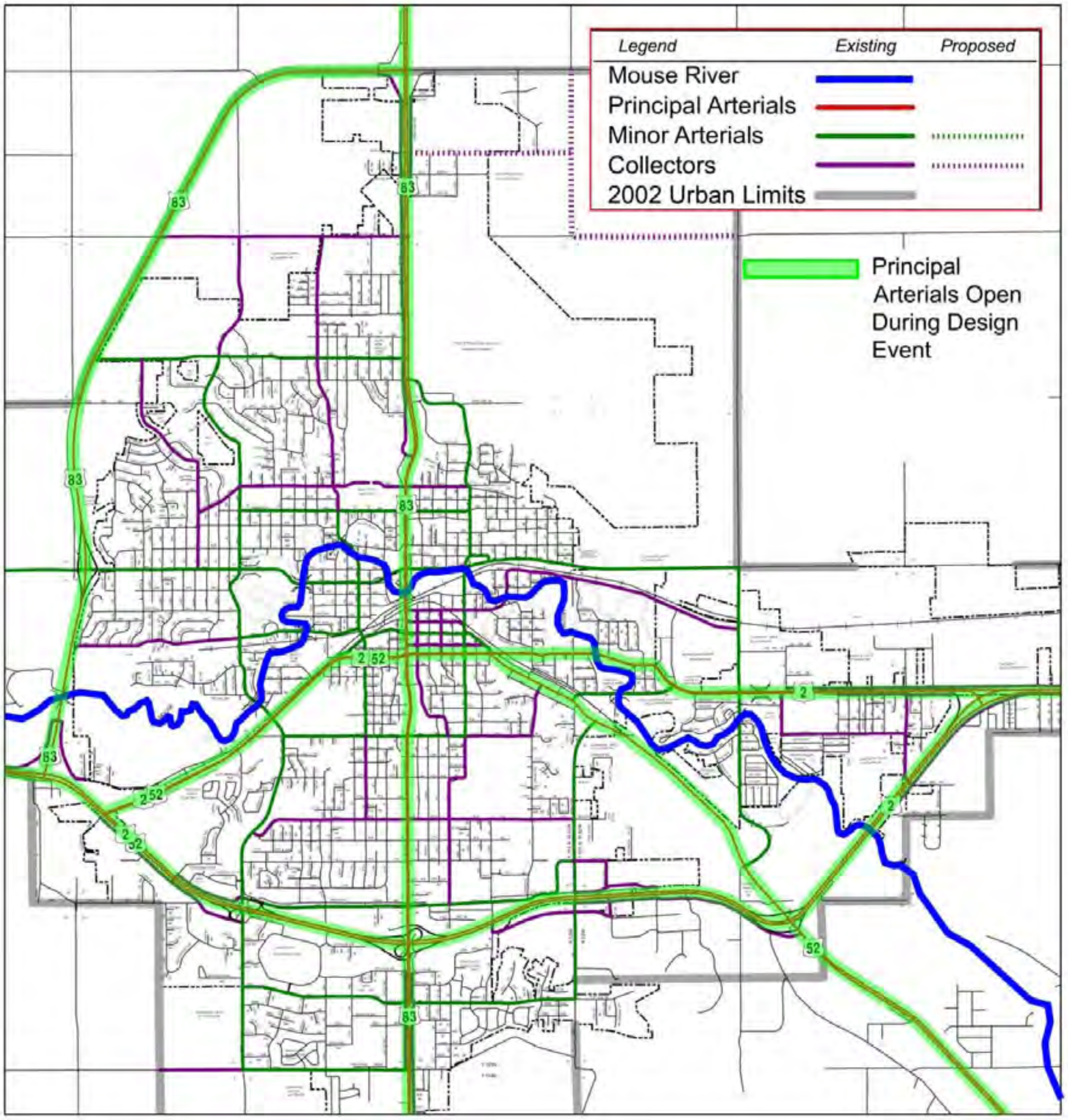


Figure 6-18 Functional Transportation Network (Post-Project)

6.6.1 Road Realignments

In locations where Preliminary alignment features encroach on existing roads and adequate space is available, roads will be realigned.

In some locations, this will result in dead ends. Further discussion with Project stakeholders is necessary to determine the feasibility of reconnecting these terminated roadways on a case-by-case basis. The primary disadvantage of reconnecting the otherwise terminated roadways is the additional impact to adjacent properties and subsequent need for additional acquisitions. Where the flood protection shifts away from the roadway or ends, roadways will match back into existing alignments.

Realigned roads are discussed in greater detail below, and roadway realignments are depicted within the R drawings in **Appendix B**.

6.6.1.1 Old Settler's Park Road

Old Settler's Park Road in Burlington runs adjacent to the Des Lacs River for approximately 2,000 feet. To maintain transportation routes and accommodate construction of the floodwall, which encroaches on the existing Old Settler's Park Road alignment, the existing roadway must be realigned. To define the new roadway location, the minimum offset from the floodwall was defined and the roadway relocated to match. Where the flood protection shifts away from Old Settler's Park Road, the realigned road will match back into the existing alignment to avoid impacts to the existing Peace Lutheran Church cemetery.

6.6.1.1 Second Avenue Southwest and Sixth Street West at Maple Diversion

The Maple Diversion is the city of Minot's preferred alternative for the area where the Canadian Pacific Railroad tracks cross the Mouse River at Broadway. The Maple Diversion impacts two urban collector routes that are vital to everyday transportation within the city of Minot: Second Avenue Southwest and Sixth Street West. While these are not arterial routes that are critical to transportation during the design flood event (27,400 cfs), they are local collectors that need to remain open during floods up to the current 100-year event (5,000 cfs). These roadways function as urban collectors because they traverse the Mouse River at Second Avenue Southwest (south of Oak Park) and the Sixth to Eighth Street Bridge (southwest of Erik Ramstad Middle School). Additionally, Sixth Street is one of a limited number of local roads that cross the BNSF and Canadian Pacific railroad crossings within Minot without grade controls. The Sixth Street underpass is located at the intersection of Sixth Street SW, the BNSF railroad, and the Canadian Pacific railroad.

Prior to the 2011 flood, the city of Minot was planning for reconstruction of the roadway beneath the Sixth Street underpass to allow taller vehicles to travel beneath the railroad structures. Current roadway-to-low-chord clearances through the Sixth Street underpass are less than 11 feet. The improvements at the Sixth Street underpass include lowering the roadway by approximately 2 feet to increase the clearance beneath the railroad structures to approximately 13 feet. This increased clearance is intended to allow taller vehicles, including fire trucks, to use the Sixth Street underpass. Planned improvements also include upgrading the existing stormwater system to keep the underpass open for flood events up to the 100-year local rainfall event. Flooding of the underpass during relatively frequent rainfall events (2-year events or smaller) currently limits access.

The Sixth Street roadway will cross the underpass at its present location. The roadway grade will be lowered from its current elevation north of the underpass to allow for the increased conveyance capacity of the Maple Diversion at the diversion's roadway crossing (see Drawing R-16 in Appendix B). The roadway will be closed whenever the Maple Diversion conveys Mouse River flood flows.

The Second Avenue SW roadway will be constructed parallel to, and within, the Maple Diversion on the north side of the diversion alignment from east of the Second Avenue SW Bridge (south of Oak Park) to Sixth Street. An intersection will be constructed at Sixth Street, and Second Avenue will continue eastward, still within the diversion, and transition to the south side of the Maple Diversion alignment. The roadway will connect with the existing roadway that provides access to the BNSF crew office, east of Broadway on the south side of the Mouse River (see Drawing R-15 in Appendix B). This roadway will also be closed whenever the Maple Diversion conveys Mouse River flood flows.

6.6.2 Road Raises

Critical transportation routes that will remain within Mouse River inundation areas will be raised in locations to keep the roadway open during the design event. The critical transportation routes (arterials) will be raised to a minimum of one foot above the design event water surface elevation, measured at the edge of the lowest traveled lane of roadway. Roadways that cross a levee or run parallel and on top of it will be realigned and raised to accommodate the revised geometry. (See "R" drawings in Appendix B).

Ninety-Fifth Street NW south of Mouse River Park

Ninety-Fifth Street NW, south of Mouse River Park, needs to be raised to match the levee. The road extends to match the levee. Once the road extends beyond the levee, the road will slope down to match the existing road at a 6-percent grade. Vertical curves designed to satisfy sight-stopping-distance criterion for a design speed of 25 mph, as recommended by AASHTO, have been used.

Refer to Drawing R-01 in **Appendix B**.

6.6.2.1 U.S. Highway 83 Bypass - East Access Road

The east access road to the Highway 83 Bypass, shown on Drawing R-02, will be raised to match the adjacent levee elevation to close off the levee. The elevation of the road will match the levee until the alignments diverge, where the raised road section slopes to match the existing road at a 4-percent grade. Vertical curves will be designed to meet sight- stopping-distance criterion for a design speed of 25 mph (see Drawing R-11 in **Appendix B**).

6.6.2.2 Sixteenth Street SW / Forest Road

Sixteenth Street SW is a north-south connector road consisting of a 4 lane street section with a posted speed limit of 25 mph. The City of Minot noted that this street is susceptible to flooding from events much smaller in magnitude than the design flood event. North of the existing Sixteenth Street SW bridge crossing over the Mouse River, the vertical road alignment will be raised approximately four to five feet to provided traffic access for higher river flaws than the current configuration. Between roadway closure structures, Sixteenth Street SW will have a minimum road surface elevation of 1558 with no anticipated impacts to the existing bridge. Access to Forest Road SW will be eliminated in this vicinity due to the location of the levee.

6.6.2.3 Fourth Avenue NE in Minot

Fourth Avenue NE in Minot is in conflict with the levee for a length of approximately 1,000 feet. This area is bound on the north by BNSF's mainline track and on the south by the Mouse River. There is limited width to maintain the existing roadway and construct a levee and there is no room to construct a floodwall and accommodate the relocation of Fourth Avenue NE without impacting the BNSF Railroad right of way.

To maintain roadway access, the levee and road will be joined, with the roadway extending along the top of the levee for approximately 300 feet. To match the two levee ramps, 4-percent slopes have been designed with vertical curves to satisfy sight-stopping-distance criterion for a design speed of 25 mph, the current posted speed for this road (see Drawing R-17 in **Appendix B**).

6.6.2.4 U.S. Highway 52

U.S. Highway 52 is classified as a rural arterial, and has been identified by stakeholders as a critical transportation route to remain open during the design event. Two sections of Highway 52 need to be raised to keep the road grade above the target flow level.

Approximately 1.33 miles of U.S. Highway 52, south of Eastside Estates, will be raised. This reach is a four-lane divided highway. The horizontal geometry of the highway will remain unchanged. The road will be raised approximately 7-to-8 feet to maintain a minimum of 1 foot above the flood water surface elevation. Vertical sag curves were designed to meet comfort criteria for a design speed of 65 mph (see Drawing R-21 in **Appendix B**).

Approximately 2.5 miles of U.S. Highway 52 west of Velva will be raised to keep the road grade above the target flow level. This is a two-lane undivided highway. The horizontal geometry of the highway will not change from the existing alignment. The road will be raised approximately 6-to-7 feet to maintain a minimum of 1 foot above the flood water surface elevation. Vertical curves will be designed to meet comfort criteria in sag curves and sight stopping distance in crest curves (see drawing R-22 in **Appendix B**).

6.6.3 Levee Ramps

Ramps will need to be constructed for service roads, field access, and other rural access in addition to those shown in the R section of the Drawings. Ramp sections will be designed according to USACE guidelines (reference [13]). Road sections, including surface aggregate or bituminous pavement, will be separate from the design levee section.

6.6.4 Railroads

The operations of two Class I railroads were significantly affected by the June 2011 flood and would, potentially, be affected by the Project. The BNSF Railway and Canadian Pacific Railway both have main line freight operations through the valley and BNSF also has AMTRAK passenger service operating on its tracks. Both railroads would have reduced risk of flood damage along reaches of their track and operations on the protected side of the Project’s levee/floodwall system. Both also have sections of track that will remain outside the Project line of protection and would continue to be subject to flooding. Additionally, at locations where levees or floodwalls cross the railroad tracks, closure structures would interrupt through-rail service during major flooding.

BNSF has major yard operations in Minot and operates two mainline tracks through the city. A portion of the mainline tracks and the yards are susceptible to inundation during larger flood events. BNSF operates about 30 trains per day through Minot; AMTRAK operates two trains per day—one east bound and one west bound. In addition to the intermodal and grain freight, BNSF freight traffic includes drilling supplies to the western North Dakota oil fields and oil shipments from these wells to the refineries in the southern United States. BNSF has expressed a desire to raise their track and bridge to prevent mainline service interruption during major flood events. During the June 2011 flood BNSF mainline freight operations through Minot were out of service for 11 days on one of the mainline tracks and 15 days on the other mainline track. Their support facilities were affected for several additional weeks. The AMTRAK depot in Minot was out of service for about 5 months after the flood; during that period Minot passengers were forced to board or disembark the train in Stanley, Rugby, or Williston, North Dakota.

CP Railway operates a mainline through the Mouse River Valley, running diagonally from north central North Dakota to the extreme southeastern corner of the state. This is the primary connection from their system in Saskatchewan and Alberta to the central United States. The CP Railway tracks are, generally, located within the river valley from Velva to Foxholm; several tracks were significantly affected by the 2011 flood. CP Railway currently operates about 16 trains, per day, through the Mouse River Valley and has expressed concern that the Project and the operation of closure structures may increase the time their tracks are out of service during major flood events. During the 2011 flood, service was interrupted on CP's Mouse River line for about 23 days. Repair of flood-related damage to their facilities took even longer.

6.6.4.1 BNSF Considerations

The Project would protect significant portions of the BNSF mainline tracks and other facilities in Minot, including the AMTRAK depot. To achieve this protection, installation of two railroad closure structures is required. These will be located where the levees/floodwalls cross the BNSF tracks on both the west and the east sides of the existing BNSF Bridge over the Mouse River in downtown Minot. No changes are proposed to the existing BNSF Bridge or the grade of the BNSF tracks. The location of the two railroad closure structures, as well as the Project alignment and features in the vicinity of BNSF tracks and facilities, is shown in **Appendix A**.

BNSF has expressed a desire to have their mainline fully operational during the design flood event. The Project, as presented in this report, does not accommodate this desire and shows two railroad closure structures across the BNSF mainlines. Based on the Project design presented, pertinent elevation information at the railroad closure locations is presented in **Table 6-14**. Water level increases at the railroad closures estimated for both the design flood of 27,400 cfs and a flood of 15,000 are shown in **Table 6-14**. Project-related increases to design flood flows would be about 3.8 feet. For a flood flow of 15,000 cfs, the water level increases would be about 1foot. No increase in water levels is expected for flood flows of 5,000 cfs.

During the design flood of 27,400 cfs, the railroad closures would be shut when the water level reached the railroad grade elevation and opened when the water level returned to the railroad grade level, taking the mainline out of service. Operation of the railroad closure structures would require the mainlines to remain out of service for approximately two more days. If closures were made to the structures before the water level reached railroad grade elevation, this could result in additional out-of-service time.

To address BNSF's desire to keep mainlines in service during a major flood event a preliminary evaluation of related Project modifications was completed. That evaluation showed that a redesign of Project features in the vicinity of the BNSF Bridge, modifications to the existing BNSF Bridge, and a major raise of the tracks in the vicinity of the bridge would be required. At the 2011 flood peak, the existing BNSF tracks and bridge were overtopped by about 5-to-6 feet of water. To avoid similar flooding, a track raise of about 7-to-8 feet in the vicinity of the bridge would be required, as well as modifications to the levee/floodwall alignment so that, in Project-protected areas, tracks could transition to the existing grade in the shortest practical distance. Keeping the required vertical clearance of the overhead bridges would be an important consideration. Preliminary layouts that meet the BNSF criteria for track-grade changes and overhead clearance showed that the track could be brought back down to the existing grade before passing under the Broadway Bridge; however, the Third Street NE Bridge, and potentially two pedestrian bridges, would need to be modified to provide the necessary clearance. Additional information on this evaluation is presented in Appendix I, Plan Formulation.

Further evaluations of the track and bridge raise options for the BNSF mainlines, the effect of railroad closures out-of-service time, and railroad closure structure design and operation would be made in future phases of Project development.

6.6.4.2 CP Railway Considerations

The Project would protect significant segments of the CP Railway tracks through Minot and in the developments/communities of Apple Grove, Eastside Estates, Sawyer, and Velva, located downstream of Minot. To achieve this protection requires the installation of nine railroad closure structures where the levees/floodwalls cross the CP Railway tracks. The existing CP Railway Bridge over the Mouse River in Minot would be within the protected area; however, a new railroad bridge for CP tracks would be required over the Maple Diversion channel. No changes are proposed to the existing CP bridges or the grade of CP tracks. The nine railroad closures would be located at:

- Terracita Vallejo: Northwest corner of the development where the levee ties into high ground
- City of Minot: Two closures—on the west and east sides of the new railroad bridge over the Maple Diversion, about midway between the existing CP Railway bridge over the Mouse River and the Broadway Bridge
- Apple Grove: On the east (downstream) side of the Apple Grove development and east of the Highway 2 Bypass Bridge, downstream of Minot
- Eastside Estates: On the east (downstream) sides of Eastside Estates, downstream of Minot
- Sawyer: Two closures—On the west (upstream) and east (downstream) sides of the levee at the city of Sawyer
- Velva: Two closures—on the west (upstream) and east (downstream) sides of the levee at the city of Velva

These locations are shown on the Project alignment sheets in **Appendix A**.

CP Railway has expressed concern that the Project might increase the time that their tracks would be out of service. Out-of-service time would, in large part, be determined by the operation of the closures over the tracks and any Project-related increases in water surface levels that could extend the duration of flooding on CP tracks outside of the Project area. Increased velocities related to the Project could also cause erosion outside of the Project area. During the 2011 flood, CP Railway service through the Mouse River Valley was down for about 23 days.

If the Project were in place, with railroad closures as planned, the CP Railway mainline track would be out of service for a similar amount of time.

Table 6-14 presents pertinent elevation and flood-duration information at the CP Railway closure locations, with and without Project conditions, for the design flood of 27,400 cfs and for a flood flow of 15,000 cfs. At some of the railroad closures the Project would cause tracks to be overtopped for an additional 1-to-3 days. However, at two closure locations where June 2011 flooding caused the longest service disruption, due to overtopping, there would be no Project-related increase in out-of-service. Further evaluation of railroad closure operations and CP Railway out-of-service time would need to be conducted during future design phases of the Project and during development of the operation manual and procedures.

Project effects on the CP Railway tracks and facilities in rural areas upstream and downstream of Minot not protected by the Project were not fully evaluated. For most reaches downstream of Minot, the Project-related increases in water levels are generally less than 0.2 feet. For upstream reaches, Project-related increases generally range from 1-to-3 feet. The effects would be better defined and evaluated in the next phase of Project design.

Table 6-14 Pertinent Elevation Information at Railroad Closure Structures (NGVD29)

			Project Design Flow @ 27,400 cfs						Flood Flow @ 15,000 cfs		
Railroad Closure Location	Closure Description	Railroad Grade Elevation (LiDAR)	Existing Flood Elevation from HEC-RAS Model in Feet	Project Flood Elevation from HEC-RAS Design Model in Feet	Flood Elevation Increase Due to Project in Feet	Days Rail Overtops at Existing Conditions	Days Rail Overtops with Project Conditions	Increase in Days Overtopped Due to Project	Existing Flood Elevation from HEC-RAS Model in Feet	Project Flood Elevation from HEC-RAS Design Model in Feet	Flood Elevation Increase Due to Project in Feet
CP - 1	Terracita Vallejo	1565.1	1566.8	1569.3	2.5	5	8	3	1564.1	1564.3	0.2
CP - 2 & 3	Minot - Maple Diversion Bridge	1556.5	1562.8	1564.4	1.6	16	16	0	1559.1	1559.5	0.4
CP - 4	Apple Grove	1549.9	1550.5	1551.3	0.8	2	3	1	1547.7	1548.0	0.3
CP - 5	Eastside Estates - East	1545.1	1548.6	1548.7	0.1	14	14	0	1546.2	1546.2	0.0
CP - 6	Sawyer - West	1529.9	1532.9	1533.1	0.2	8	9	1	1529.7	1529.8	0.1
CP - 7	Sawyer - East	1525.8	1528.8	1528.8	0.0	0	0	0	1526.6	1526.6	0.0
CP - 8	Velva - West	1518.7	1519.3	1517.8	-1.5	0	0	0	1513.7	1513.0	-0.7
CP - 9	Velva - East	1511.9	1510.9	1510.9	0.0	0	0	0	1509.1	1509.1	0.0
BNSF - 1 & 2	Minot - BNSF Bridge	1553.5	1558.1	1561.9	3.8	15	17	2	1556.1	1557.1	1.0

6.7 Infrastructure Modifications

The construction of a flood risk reduction system will impact existing public and private utilities. Existing utility grids cross the Mouse River corridor in several locations, and several utilities experienced failures as a result of the June 2011 flood. Generally, the failure mode for gravity utilities (sanitary sewer, storm sewer, etc.) was collapse of the main line or failure of the conduit-to-conduit seal due to hydrostatic pressure on the pipe. The primary failure mode for pressure utilities (water, sanitary sewer force mains, etc.) was scour of the river channel that eroded the bedding beneath the utility conduit, causing the conduit to shift, overstress, and fail.

6.7.1 Design Criteria

Inadequately designed or constructed pipelines, utility conduits, or culverts beneath or within levees can cause serious damage to the levee. Each pipe crossing should be evaluated for its potential to damage the integrity of the flood protection system. During high water, seepage concentrates along the outer surface of pipes, resulting in piping of fill or foundation material. High water also results in uplift pressures that may cause buoyancy of some structures. Seepage may also occur because of pipe leakage (reference [13])

Pipeline crossings through levees should be avoided where practical. Where pipeline crossings are necessary to maintain the integrity of the existing utility system, the preferred means of crossing the levee (as identified by the USACE) is over the top. The placement of utilities over the top of the levees (i.e., not within the levee prism) would subject the wet utilities (water and sanitary sewer) to freezing temperatures and subsequent damage. The minimum recommended depth of water and sanitary sewer utilities is 8 feet from finished grade to the top of the pipe. Alternatives, including insulation of wet utility lines to prevent freezing, may be considered during detailed design.

Major factors to be considered in deciding whether a utility should be routed under or over a levee (reference [13]) include the following:

(1) The height of the levee
(2) The duration and frequency of high-water stages against the levee
(3) The susceptibility to piping and settlement of levee and foundation soils
(4) The type of pipeline (low- or high-pressure line, or gravity drainage line)
(5) The structural adequacy of pipe and pipe joints, and the adequacy of backfill compaction
(6) The feasibility of providing closure in the event of ruptured pressure lines, or in the event of failure of flap valves in gravity lines during high water

(7) The ease and frequency of required maintenance
(8) The cost of acceptable alternative systems
(9) Possible consequences of piping or failure of the pipe
(10) Previous experience with the owner in constructing and maintaining pipelines

In order for existing utilities to remain in place beneath a levee, the utility pipe must: (1) be known to be in good condition, (2) have adequate strength to withstand levee loading, (3) have sufficient flexibility in joints to adjust under expected settlement and stretching of pipe, (4) have provisions for rapid closure in the event of leakage or rupture, and (5) have pervious backfill under the landside third of the levee where foundation materials are susceptible to piping (USACE).

Water distribution system elements will require modification to accommodate the Project features. The criteria governing the design of the water utilities is set forth in the *Recommended Standards for Water Works* (reference [14]).

Gravity sanitary sewer systems also cross the river or are located within the Project alignment. To reduce the likelihood of significant infiltration and inflow to the sanitary sewer system, the existing gravity sanitary sewer system should be decommissioned through the Project footprint, and the sanitary sewer should cross the Project alignment via a lift station and force main. The criteria governing the design of the sanitary sewer utilities is set forth in the *Recommended Standards for Wastewater Facilities* (reference [15]).

6.7.2 Water Distribution System Impacts

Effects and improvements to the water distribution system were determined based on GIS data supplied by the various communities and utilities. A detailed records review and topographic survey will be required prior to proceeding with detailed design to determine with a higher degree of certainty the extent of impact to the water distribution utility.

Generally the improvements consist of reconstruction of the affected portions of the water distribution system, and placement of isolation valves on the landside of all water line crossings with the Mouse River.

6.7.2.1 Mouse River Park

Detailed water utility information was not readily available for Mouse River Park. Water service to Mouse River Park is supplied by the Upper Souris Water Users District. The Project features cross the Upper Souris Water Users District water line once. This crossing will likely require reconstruction.

6.7.2.2 City of Burlington

The city of Burlington operates a municipal water system. The city's primary source of water is the Northwest Area Water Supply (NAWS) system. In addition to NAWS, the city operates a water treatment facility as a redundant water supply and as a supplemental supply during periods of high demand. The Project features affect two existing water supply wells (one of which is currently out of service), the raw water transmission line from the wells to the water treatment facility, and portions of the city's existing water distribution grid.

The improvements include reconstruction of one municipal supply well, the construction of a new water transmission line, and modifications to the existing water distribution system to accommodate construction of the Project features.

6.7.2.3 Rural Upstream Subdivisions

Brooks Addition is supplied with potable water via the North Prairie Rural Water District. The Project features affect the water supply line that serves the subdivision. The improvements include reconstruction of the affected portion of the water line to accommodate the construction of the Project features.

The Robinwood and Country Club Acres subdivisions are supplied with potable water by the West River Water and Sewer District. The Project features affect the water supply line that feeds the subdivisions, along with portions of the existing water distribution grid. The improvements include reconstruction of the affected water lines.

Terracita Vallejo is supplied with potable water by the North Prairie Rural Water District. The Project features affect the water supply line that serves the subdivision. The improvements include reconstruction of the affected portion of the water line to accommodate the construction of the Project features.

6.7.2.4 City of Minot

The city of Minot operates a municipal water system and is currently supplying water to the Northwest Area Water Supply (NAWS) system and the North Prairie Rural Water District system. The city's water is currently supplied by a series of groundwater wells that draw from the Minot and

Sundre Aquifers. A project is planned by the North Dakota State Water Commission and the city of Minot to deliver Missouri River water to Minot for treatment and distribution.

6.7.2.4.1 36" NAWS Transmission Line

The Project features may affect portions of the existing 36" NAWS transmission line that conveys potable water from the Minot Water Treatment Plant High Service Pump Station to the west. The areas of potential impact include: (1) the transmission line crossing of the Mouse River on the west side of the US Highway 83 Bypass, (2) an area in the vicinity of the Perkett Pump Station, (3) the transmission line crossing beneath the levee in the vicinity of the Wee Links golf course, and (4) the transmission line crossing of the Mouse River on the northeast side of Sixteenth Street Southwest. The improvements include the reconstruction of the affected portions of this transmission line to accommodate the construction of the Project features.

48" Sundre Transmission Line

The Project features affect the 48" Sundre raw water transmission line in the vicinity of the Minot Water Treatment Plant, within the Maple Diversion alignment, in the vicinity of Broadway, and along 4th Avenue North from Broadway to 3rd Street Northeast. The improvements include the reconstruction of the affected portions of this transmission line to accommodate the construction of the Project features.

6.7.2.4.2 Mouse River Intake Structure

The Project features affect the Mouse River raw water intake structure located adjacent to the Minot Water Treatment Plant. The improvements include reconstructing the intake structure to the southwest of the existing location, adjacent to the water treatment plant access road.

6.7.2.4.3 Various Water Transmission and Distribution Lines

For the purpose of this report, water transmission lines are considered to be lines with sizes of 12 inches or greater. The Project features affect various water distribution and transmission lines. The improvements include reconstructing or relocating the affected portions of the water distribution system and looping portions of the distribution system that would otherwise have been terminated at a dead end to maintain adequate circulation and water quality.

6.7.2.5 Rural Downstream Subdivisions

Apple Grove and Eastside Estates subdivisions are supplied with potable water by the North Prairie Rural Water District. The Project features affect the water supply lines that serve the subdivision.

The improvements include the reconstruction of the affected portion of the water lines to accommodate the construction of the Project features.

6.7.2.6 City of Sawyer

The city of Sawyer operates a municipal water system. The city's water source is provided by groundwater wells within the city of Sawyer. The Project features do not affect the city's water distribution system.

6.7.2.7 City of Velva

The city of Velva operates a municipal water system. The city's water sources consist of the Downing Spring (an artesian spring originating in the hills southeast of Velva), and a municipal well southeast of Velva. The Project features do not affect the city's water distribution system.

Table 6-15 Water Distribution System Impact Summary

Community / Reach	Water Distribution Line Recon-struction (Linear Feet) (1)	Water Transmission Line Recon-struction (Linear Feet) (2)	Notable Impacts	Appendix / Sheet Reference
Mouse River Park	0	0	None	N/A
Burlington	2,900	0	Municipal Well	B / U-US-02-04
Upstream Rural	3,500	0	None	B / U-US-05-10
Minot	9,900	17,600	36" NAWS Transmission Line 48" Sundre Transmission Line Water Treatment Plant River Intake	B / U-M-02-14
Downstream Rural	600	0	None	B / U-DS-02-04
Sawyer	0	0	None	N/A
Velva	0	0	None	B / U-DS-05-06

(1) Water distribution lines 10 inches in diameter and smaller
(2) Water distribution lines 12 inches in diameter and larger

6.7.3 Sanitary Sewer System Impacts

Effects and improvements to the sanitary sewer system were determined based on GIS data supplied by the various communities. A detailed records review and topographic survey will be required prior to proceeding with detailed design to determine, with a higher degree of certainty, the extent of impact to the sanitary sewer utility.

Generally, improvements consist of reconstruction of the affected portions of the water distribution system, decommissioning gravity sanitary sewer within the Project footprint, and construction of lift stations and force mains to convey wastewater across the Project corridor, with isolation valves on the landward sides of all force main crossings with the Mouse River.

6.7.3.1 Mouse River Park

Sanitary sewer service in Mouse River Park consists of privately owned holding tanks that serve each residence. Private sanitary sewer systems within the Project footprint will require removal and reconstruction elsewhere on the affected property.

6.7.3.2 City of Burlington

The city of Burlington operates a municipal sanitary sewer system. The June 2011 flood overtopped the city’s wastewater lagoons, located north of the city along the Mouse River. Damage to the wastewater lagoons included erosion of the riverside embankment, which will be mitigated by placing riprap along the riverside slope. There was also deposition of sediment within the wastewater lagoon cells. This will be mitigated by raising the top of the embankment surrounding the lagoons to a minimum of 1-foot above the design event. The improvements include modifications to the existing sanitary sewer system to accommodate the construction of the Project features.

6.7.3.3 Rural Upstream Subdivisions

Sanitary sewer service in Brooks Addition consists of privately owned septic systems and drain fields. Private sanitary sewer systems within the Project footprint will require removal and reconstruction elsewhere on the affected property if the dwelling remains intact.

Robinwood and Country Club Acres are served with sanitary sewer service by the West River Water and Sewer District. The Project features affect the existing sanitary sewer lift station that serves these subdivisions, along with portions of the sanitary sewer collection system. The improvements include reconstruction of the lift station and impacted elements of the collection and conveyance system.

Sanitary sewer service in Terracita Vallejo consists of privately owned septic systems and drain fields. Private sanitary sewer systems within the Project footprint will require removal and reconstruction elsewhere on the affected property if the dwelling remains intact.

6.7.3.4 City of Minot

The city of Minot operates a municipal sanitary sewer system. The project features impact several existing sanitary sewer crossings on the Mouse River. Generally, these crossings are gravity mains.

Gravity utilities are preferable to pressurized utilities for levee crossings from a risk management perspective (reference [13]). The construction of gravity sewers across the Mouse River would result in the placement of manholes between the Project features (i.e., within the flooded region). Without proper treatment and maintenance at manholes to prevent significant infiltration and inflows during the design event, the system could be compromised and property damage could be experienced due to failure of the sanitary sewer system.

The sanitary sewer crossings consist of lift stations and force mains that traverse the Project corridor. Alternatives, including the construction of gravity sewer main crossings with provisions to prevent significant infiltration and inflow, may be considered during detailed design. Force mains are preferred instead of gravity mains for the following reasons:

(1) To allow the sanitary sewer utility to be placed deeper within the stream bed to minimize potential displacement or damage due to scour
(2) To eliminate the need for manholes or other appurtenances within the Project corridor that could serve as locations for potential inflow during larger events
(3) The distance from landward toe to landward toe across the Project corridor is in excess of 400 feet, which is the recommended maximum distance between manholes
(4) To utilize pressure-rated and sealed conduits across the Project corridor that limit infiltration to the sanitary sewer system
(5) The maximum operating pressures within the force mains are relatively low (less than 30 psi) and the downstream end of the crossings typically discharge to free surface conditions to a receiving gravity sewer
(6) Overbank excavation and diversion channels limit the potential for use of gravity sewers across the Project features due to grade conflicts
(7) Pipeline velocities will be sufficient to provide for self-cleansing of the conduit, resulting in a higher level of reliability for valve closures in the event of a failure

The Project features in the vicinity of the Eastside Estates subdivision southeast of Minot do not provide flood risk reduction benefits to the city of Minot’s Puppy Dog Lift Station. This lift station is a critical component of the city’s sanitary sewer system that serves a majority of south Minot and is intended to serve substantial future development. The improvements include the reconstruction of the Puppy Dog Lift Station to the west of its current location, within the zone of reduced risk, on the landward side of the levees in that location.

The Project features impact various sanitary sewer collection lines and force mains. The improvements include reconstructing or relocating the affected portions of the sanitary sewer collection and transmission system.

6.7.3.5 Rural Downstream Subdivisions

The Apple Grove subdivision is served with sanitary sewer through an agreement with the Ward County Water Resources District and the city of Minot. The Project features may affect a portion of the force main that conveys sanitary sewage from the subdivision toward the city of Minot's Puppy Dog Coulee sanitary sewer collector. The improvements include the reconstruction of the affected portion of the force main to accommodate the construction of the Project features.

Sanitary sewer service in Eastside Estates consists of privately owned septic systems and drain fields. Private sanitary sewer systems within the Project footprint will require removal and reconstruction elsewhere on the affected property if the dwelling remains intact.

6.7.3.6 City of Sawyer

The city of Sawyer operates a municipal sanitary sewer system. The Project features do not affect elements of the city's sanitary sewer system.

6.7.3.7 City of Velva

The city of Velva operates a municipal sanitary sewer system. The June 2011 flood caused a substantial amount of erosion on the riverside of the embankment for the wastewater lagoons that serve the city. Future damage will be minimized by placing riprap along the riverside slope.

The construction of Project features will also affect the city's existing master lift station. To accommodate the Project features, the lift station will have to be reconstructed in the general vicinity of the existing lift station, on the landward side of the levee, and a portion of the existing force main will be reconstructed through the Project limits.

Table 6-16 Sanitary Sewer System Impact Summary

Community / Reach	Gravity Sanitary Sewer Construction (Linear Feet)	Sanitary Sewer Force Main Construction (Linear Feet)	Lift Station Locations	Lift Station Capacity (gpm)	Appendix / Sheet Reference
Mouse River Park (1)	N/A	N/A	None	N/A	N/A
Burlington	800	1,800	None	N/A	B / U-US-02-04
Upstream Rural (1)	2,400	2,100	Robinwood	250 (2)	B / U-US-05-10
Minot (1)	5,700	7,800	West WTP Maple Street 3rd Street 8th Street West Roosevelt Roosevelt Zoo Farmers Union Puppy Dog	550 (3) 140 (3) 320 (3) 480 (3) 2,100 (3) 1,100 (3) 150 (3) 6,250 (4)	B / U-M-02-14
Downstream Rural (1)	100	600	None	N/A	B / U-DS-02-04
Sawyer	0	0	None	N/A	N/A
Velva	100	100	Velva Master	350 (2)	B / U-DS-05-06

(1) Privately owned stand-alone sanitary sewer systems are utilized in Mouse River Park, Brooks Addition, Terracita Vallejo, Lighthalls Addition and Eastside Estates

(2) Replacement of existing lift station of same capacity

(3) Estimated capacity utilizing contributing area, equivalent dwelling unit density, dwelling unit population density, infiltration and inflow

(4) Source: Preliminary Engineering Report – Puppy Dog Sewer System, 2006

6.7.4 Private Utility Impacts

The construction of Project features will affect existing private or franchise utility infrastructure. Private utilities are commonly referred to as franchise utilities because these companies have contractual permission to utilize the public right-of-way for the placement of their utilities, with various local exceptions. Generally, franchise agreements between local governments and utility companies require that the utility company be responsible for relocating any utilities that conflict with the location of public improvements.

Coordination with franchise utilities will be necessary as more detailed design is developed.

Table 6-17 Non-Municipal Utility Providers

Utility Company	Service Type
Xcel Energy	Electric
Verendrye Electric Cooperative	Electric
Otter Tail Power	Electric
Montana Dakota Utilities	Natural Gas, Electric
Souris River Telecommunications	Telecommunications
Midcontinent Communications	Telecommunications
Reservation Telephone Cooperative	Telecommunications
North Prairie Rural Water District	Rural Water
Upper Souris Water Users District	Rural Water
Northwest Area Water Supply	Regional Water Supply
Enbridge	Crude Oil Transmission
Minot Air Force Base	Missile Communications

6.8 Operation and Maintenance Considerations

The Project will need to be maintained in a constant state of readiness for potential operation throughout the entire year. Although, historically, major floods have occurred following spring snowmelt events, the rainfall events of June were a major factor in the 2011 event. In addition, the three major upstream dams and reservoirs must also be considered as potential dam failure situations. With the Project in place, the residents and communities that have had their flood risk reduced will expect the Project to be completely operational for whatever flood event comes along, without regard to cause. The following considerations will need to be addressed before construction is complete to assure that these on-going responsibilities are clearly understood, that operational and maintenance procedures are fully coordinated and documented in detailed operation and maintenance manuals, and that the cost implications are accounted for in ongoing funding commitments by the entity responsible for operating and maintaining the Project. It will be necessary to establish agreements for communication, operation, and cooperation between the Project sponsor and local entities, including municipalities, railroads, and private business affected by operation of the Project during routine maintenance and flood events. Adherence to proper operation and maintenance procedures will be especially critical in those periods when no major floods are experienced and public concerns and expectations have shifted to priorities other than the threat of flooding.

6.8.1 Levees

Levees will need regular on-going attention to maintain healthy, grassy vegetation at an appropriate height and consistency; to keep woody vegetation off the slopes and crest; to correct any erosion on the slopes or crest; to repair any erosion protection features on the levee slopes; to add proper earthen fill along the crest where settlement has lowered the crest below the design height; to ensure that access to the levees is available as designed; to maintain seepage drains; and to conduct annual engineering inspections.

During flood events, levees will need to be inspected regularly to see that slopes are stable, the crest is at the design elevations, and seepage is being properly managed.

After major flood events, the levees will need to be inspected for any damage, and the levee will need to be restored to serviceable conditions.

6.8.2 Floodwalls

Floodwalls will need regular on-going attention to prevent woody vegetation in proximity to the foundation; ensure that access to the floodwalls is available as designed; repair any deterioration, settlement, or movement to wall or foundation components; maintain seepage drains; and conduct annual engineering inspections.

During flood events, floodwalls will need to be inspected for any signs of damage or leakage.

After major flood events, floodwalls will need to be inspected for any damage and restored to serviceable conditions.

6.8.3 Transportation Closures

Transportation closures will need regular on-going attention to prevent woody vegetation in proximity to the foundation; conduct annual engineering inspection (including stoplogs and gates); repair any deterioration to closure frames, stoplogs, or gate components; and exercise regular installation and removal of stoplogs and gates. The regular, routine operation of the railroad closures will require close coordination with the railroads to minimize effects on train service operation. These routine maintenance procedures should be coordinated with the railroads and documented in the operational agreements with the railroads.

During flood events, stoplogs and gates will need to be set in place and inspected regularly during high water to be sure they are operating properly.

After major flood events, closure stoplogs and gates will need to be removed or opened, inspected, and returned to non-flood storage positions. Any damaged equipment will need to be restored to operational condition.

6.8.4 Pump Stations

Pump stations will need regular, on-going attention to maintain the building, pumps, gates, valves, and other operating equipment. A specific schedule and procedure for routine operation of the pumps, gates, valves, and other equipment will need to be developed and documented in the Project operation and maintenance manual.

During flood events, pump stations will need to be closely monitored to close gravity stormwater drains, run pumps, and inspect ponding areas and pump station equipment to assure they are operating properly.

After major flood events, pump station equipment will need to be inspected and restored to operating condition.

6.8.5 Utilities

Utilities stations will need on-going attention to maintain closure valves and isolation equipment in good operating condition.

During flood events, utilities will need to be shut off, or inspected regularly, to assure they are properly sealed or isolated and do not compromise the flood risk reduction system.

After major flood events, these same systems will need to be inspected and restored to operating condition.

6.8.6 Emergency Flood Fighting

Procedures will need to be identified in the Project operation and maintenance manual for actions to be taken in the event that a flood exceeding the Project design condition is forecast, or failure or overtopping of portions of the Project occurs. Staff responsible for the operation and maintenance of the project should also have proficient knowledge of emergency flood-fight actions, beyond the normal range of Project operation and design.

6.8.7 Flood Forecasting Coordination

A key component of Project operation will be based on flood forecasts issued by the National Weather Service in coordination with other agencies. Successful operation of the Project will depend on timely monitoring of the forecast river levels in anticipation of and during flood events. Timing of road and railroad closures, operation of the pumping stations, and operation of gates on the river diversion structures, will need to be made at the appropriate time for the Project to function as designed.

7.0 Environmental Considerations

This section provides an overview of the environmental factors considered in the preliminary alignment plan project area. Special attention was directed to the general area within the Mouse River Enhanced Flood Protection project (Project) limits as shown on the maps in **Appendix A**. A larger corridor was used to identify and evaluate potential environmental impacts from the Project.

Currently known environmental considerations in the study reach do not appear to present significant impediments to the Project or Project features as now developed. However, the large size of the preliminary alignment Project, the interconnectivity of Project areas, required federal permits, and the resulting affect on wetlands, the existing river channel, and socio-economic impacts to the community will at minimum require an environmental assessment (EA) and likely and environmental impact statement (EIS). It is possible that select portions of the Project could proceed without an EIS if the work is outside the 100-year floodplain, has minimal impact on wetlands, and can be implemented as a stand-alone Project that would not rely on other aspects of the Project being completed.

Continued dialogue with agency and jurisdictional representatives as well as other stakeholders will provide additional insights on approaches to minimize unavoidable environmental impacts and incorporating features that may provide net gains to habitat values and recreational access to the river corridor in the study reach. Non-structural elements such as alternative water management regimes from upstream reservoirs may also factor into enhanced riverine habitat and recreational benefits. Coupled with appropriate mitigation and remediation, the Project has the potential to increase environmental values from the existing condition and to reduce the potential for environmental damages from releases of contaminants resulting from a flood. The potential to increase environmental values from the existing condition will be limited by the presence of the existing flood risk reduction elements discussed in Section **2.0**, as well as the highly variable flow regime of the Mouse River.

7.1 National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) was enacted in 1969 with the purpose of requiring federal agencies to consider significant environmental impacts arising from projects under agency jurisdiction (this has been interpreted to mean federal permits as well). NEPA's other main purpose was to provide for public participation in the decision-making process of proposed projects or actions.

NEPA requires that the environmental review process applies to all "'major federal actions significantly affecting the quality of the human environment." Any federal participation, permit, or approval can be enough to make a project a "major" action. As a result, many "private" projects are also required to perform an extensive environmental review. In 1972 the courts defined major actions as a project that "requires substantial planning, time, resources or expenditure." Major actions have also been interpreted as projects "costing over one million dollars, or requiring a substantial amount of time for planning and construction, the displacement of people or animals, or the topographical reshaping of large areas." The Courts have also interpreted the "significance requirement" to include direct as well as indirect effects on the human environment.

Normally an EA would be completed to describe the project needs, potential environmental effects, and alternative actions. The EA provides the project information needed for evaluating the environmental impacts and determining whether an EIS must be prepared. However, if there is a predetermination from a federal permitting agency that an EIS will likely be required because of the project scope, scale or potential impacts, an EA can be used as a scoping document to define the information that should be included in an EIS.

Large complex projects such as the Mouse River Enhanced Flood Protection Project have many levels of ecological, social, historic/cultural, and economic impacts which can be both beneficial and adverse. The scale of the Project alone would likely require an EIS-level review. The U.S. Army Corps of Engineers (USACE), one of the permitting agencies for the Project, has also indicated that an EIS will likely be needed. Under NEPA the EIS must evaluate both the beneficial and adverse impact of the Project. The EIS must also describe alternatives to the Project and possible measures for mitigating adverse impacts.

7.2 Existing Setting

The neighborhoods in Mouse River Park and the communities of Burlington, Minot, Sawyer, and Velva are located along the Mouse River in the Northern Black Prairie and Drift Plains of the Northern Glaciated Plains eco-region. The geology of the area is characterized in **Appendix E**. Urbanized corridors and developed riparian areas, along with the presence of existing flood risk reduction features built between 1971–1993 (including levees, flow control structures, and channel modifications), create a disturbed non-continuous river and river corridor throughout the study reach.

Species typically found in developed and disturbed urbanized environments are the primary inhabitants. Recreational access to the river in the study area is limited; the primary activity is seasonal sport fishing at channel flow control features. The fishery potential of the river is inhibited by the variable flow regime and regularly occurring periods of zero flow and low dissolved oxygen.

The Mouse River is classified as Class 1A (33-16-02.1-09), by the North Dakota Department of Health (NDDH). This classification is indicative of water quality that supports propagation and/or protection of resident fish species and is suitable for municipal and domestic use following appropriate treatment. The North Dakota 2010 Integrated Section 305(b) Water Quality Assessment Report and Section 303 (d) List of Waters Needing Total Maximum Daily Loads indicates that the river is noted for poor water quality and low-flow-related impairments (reference [16]).

North Dakota Natural Heritage (NDNH) database records, US Fish and Wildlife Service (USFWS) records, and North Dakota Game and Fish (NDGF) records show no federally listed aquatic resident species in the Mouse River Project reach from the Mouse River Park to Velva, North Dakota (2011 inundation zone). Two fish species, the trout perch (*Percopsis omiscomaycus*) and pearl dace (*Margariscus margarita*) are identified by NDGF as species of conservation priority within the Project reach. NDGF capture records identify 24 fish species in the Mouse River. Dominant species in the Project reach are common shiner (*Notropis cornutus*), sand shiner (*Notropis stramineus*), creek chub (*Semotilus atromaculatus*), and black bullhead (*Amerius melas*).

The USFWS official Endangered Species Act species lists for Ward and McHenry counties identify the gray wolf (*Canis lupus*) as endangered, the piping plover (*Charadrius melodus*) threatened, Sprague’s pipit (Anthus spragueii) candidate, and the whooping crane (*Grus americanus*) endangered. Geospatial analysis of NDNH database showed no incidences of federal threatened or endangered species or state-listed species in the Project area identified as the 2011 inundation zone. The USFWS identifies the Mouse River corridor as critical habitat for the piping plover. The potential for migratory species such as the whooping crane to utilize habitats in the Project area is possible. Neo-tropical bird species may also utilize the Project area as nesting habitats. Consultation with the USFWS will be necessary to develop Project plans that minimize potential impacts to migratory species. Early USFWS input suggests this can be accomplished with a minimum of impact to the Project features, with efforts primarily related to timing of construction-related activities. The Upper Souris National Wildlife Refuge (NWR), located upstream of the study area; the J. Clark Salyer NWR, located downstream; and the nearby Wintering River and Cottonwood Lake NWR attract a majority of the migratory waterfowl.

7.3 Wetlands

The Northern Black Prairie and Drift Plains eco-regions are characterized by the presence of temporary and seasonal wetlands in addition to riparian wetlands. National Wetland Inventory Maps from the USFWS web-based mapping tool were downloaded in October 2011. Geospatial analysis was used to evaluate wetland presence within the 2011 flood inundation zone and to determine if Project features would potentially impact wetlands and waters. Wetland areas included river channel habitat. Features identified in the November 30, 2011, revised draft alignment were the elements used for evaluation. Each feature was bounded by a 50-foot buffer for purposes of impact evaluation.

The results of the preliminary wetland impact analysis show that approximately 6.0 acres of forested wetlands and 39.0 acres of non-forested wetlands could be impacted by the construction of the flood risk reduction features. Primary wetland types impacted include: Palustrine Forested Emergent Temporarily Flooded (PFO/EMA), Palustrine Forested Freshwater Temporarily Flooded (PFOA), Palustrine Emergent Aquatic Bed Semi-Permanently Flooded (PEM/ABF), Palustrine Emergent Seasonally Flooded (PEMC), and Riverine Lower Perennial Unconsolidated Bottom Permanently Flooded (R2UBH).

Based on prior experience with NWI map products in North Dakota and their potential to underestimate wetland presence by 40%, additional investigation of wetlands via field survey delineation is needed.

Preliminary discussions with NDGF and the USFWS suggest that mitigation of unavoidable wetland impacts by establishing a fee title purchase of lands to create an appropriate wetland bank for block mitigation is preferred to separated, small-parcel mitigation. The Interagency North Dakota Mitigation Banking Guidance Document (**Appendix H**) provides guidance on establishing a wetland mitigation bank. Recent experience with easement-based wetland mitigation in North Dakota corroborates fee title purchase as the preferred option for establishing a wetland mitigation bank. The primary difficulty is likely to be locating an appropriate parcel and willing seller.

7.4 Cultural Resources

Section 106 of the National Historic Preservation Act (NHPA) of 1966 (Public Law [P.L.] 89-665), as amended, requires that a federal agency take into account the effect of an undertaking on properties either listed on or determined eligible for the National Register of Historic Places. It also requires that the Council on Historic Preservation be afforded a reasonable opportunity to comment. An undertaking is defined as a project, activity, or program funded, in whole or in part, under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; and those requiring a federal permit, license, or approval. The Project will require federal permitting under Sections 401 and 404 of the Clean Water Act (33 U.S.C. §1251) and Section 408 (33 U.S.C 408) of the Rivers and Harbors Act. Section 106 regulations require a federal agency to preserve and protect historic properties in the area of a federal undertaking to the extent feasible and, where not feasible, to ensure that the appropriate level of documentation is completed prior to alteration, relocation, or demolition. The National Environmental Policy Act (NEPA) (P.L. 91-190) requires an EA or EIS as part of the planning and decision-making process. Historic and other cultural resources are to be taken into consideration.

Cultural, historical, and archeological resources investigations have previously been conducted in the Mouse River Valley; the most recent collection of information is in the 2008 North Dakota Comprehensive Plan for Historic Preservation: Archeological Component; Souris River Study Unit (reference [17]). Information from this document, along with geospatial analysis and further document research at the State Historical Society of North Dakota archives, will be used to conduct a Level I survey when the draft final alignment and Project features have been developed. The Level I survey will help guide appropriate mitigation efforts during design. A Level II, reconnaissance inventory may follow to help guide the anticipated Level III intensive cultural resources investigation that will be necessary in some portions of the study area. A Level III survey includes field-based investigations by a North Dakota-permitted professional cultural resources specialist.

Following field-based investigations it is likely that some cultural, historic, and archeological resource mitigation will be necessary to protect or preserve identified features. Minor modifications to Project elements may accomplish some of this mitigation, whereas other historic resources may need specific mitigation measures.

7.5 Hazardous, Toxic, and Radioactive Waste (HTRW)

A review of regulatory databases was performed to provide a preliminary understanding of potential environmental sites and releases that could be within 500 feet of the November 2011 estimated construction and inundation extents of the Project. The regulatory database review is the result of a systematic search of relevant state and federal databases that document the presence and status of environmentally impacted sites. A “desktop” database review such as this is considered a first step towards compiling information for a Hazardous, Toxic, and Radioactive Waste (HTRW) Assessment for the Project.

The regulatory database report shows 384 database listings. The majority of these listings could be attributed to specific site locations provided by the regulatory database review or via mapping websites; site locations have not been field verified. Based on the site information and location data reviewed, it was determined that 51 regulated sites were within approximately one block of the Project (including the Maple alignment). The site locations are provided on figures in **Appendix H**.

A preliminary evaluation of potential environmental impacts associated with these 51 sites was performed using the regulatory database report, readily available internet information, and professional judgment to estimate possible environmental clean-up costs. Further detail on the identified sites, cost estimating process, and associated assumptions can be found in Section **11.0** and **Appendix G**. A full HTRW assessment, including field verification, will be completed once the alignment location has been finalized. Environmental clean-up cost estimates can be further refined when additional detail on potential environmental sites and associated contamination is clarified through the HTRW assessment process or subsequent file review and/or site-specific investigations.

The next step in evaluating potential environmental concerns will be to conduct a full HTRW assessment of the proposed construction and flood inundation extents. The purpose of the HTRW assessment is to identify potential environmental risks to human health and safety. The HTRW assessment will do this through the process described in a USACE guidance document (reference [18]*)*. This process includes a review of aerial photographs, maps, and other select historical documents; a site walk-through from public right-of-ways; and interviews with state and local officials familiar the Project extent. The results of these efforts will be used to assess potential historic and current land uses that may have resulted in an undiscovered release of petroleum products or hazardous materials to the environment. For release sites already identified through the regulatory databases, a review of readily available release site files from the appropriate state agency will be reviewed for additional details on the identified contamination.

The results of the HTRW assessment and associated release site file reviews will be used to design a soil and groundwater investigation scope. Investigation locations will be selected to assess potential new release sites identified through the HTRW process and to define the extent and magnitude of contamination at existing release sites within the Project area. The results of the environmental investigation will be used to provide greater clarity on anticipated environmental clean-up scope and costs.

In preparation for construction, a Project-specific Response Action Plan (RAP) will be developed to provide instruction for the handing and management of contaminated soils and groundwater encountered during construction. Work within areas that are not the subject of a RAP will be conducted under a Project-specific Environmental Contingency Plan (ECP). The ECP will be developed to anticipate how to identify, investigate, and manage different types of unforeseen environmental hazards discovered during construction. Both the RAP and ECP will be submitted to the appropriate regulatory agency for review and approval prior to commencement of construction. Construction should be halted to reassess conditions if evidence of unexpected contamination is found, contaminated soil should be handled and managed onsite or disposed of offsite in accordance with state and local regulations.

A pre-demolition survey should also be conducted prior to demolition of any building within the construction extents to assess the potential for asbestos-containing material (ACM), lead-based paint, and other hazardous building materials. The presence of these materials should be documented and properly abated prior to construction.

During the construction work lubricants, fuel, coolant, antifreeze, and other hazardous materials will be used to maintain and operate heavy equipment. Spill prevention control measures should be planned for to minimize the possibility of a release or spill of hazardous materials, and any spill should be immediately be cleaned up. All solid and liquid wastes generated during the construction work, planned or otherwise, should be managed in accordance with applicable regulations.

7.6 Pre-Demolition Inspection/Abatement

Existing buildings and structures will be cleared for construction of the Project. Prior to demolition, an asbestos and hazardous material survey (e.g., lead paint, mercury switches, etc.) will be completed for buildings and structures by inspectors certified by NDDH. The buildings will need to be vacated for the inspection, which will involve destructive testing of building components. A report will be prepared documenting the results of the survey and listing items required for abatement, along with estimated abatement quantities. The abatement will be conducted in vacated buildings prior to demolition, using abatement crews that are NDDH-certified and following National Emission Standards for Asbestos requirements.

8.0 Coordination and Input

Coordination activities were conducted with stakeholders throughout the entire Mouse River Enhanced Flood Protection project (Project), with input solicited through a variety of measures including meetings, emails, phone conversations, video teleconferences, a Project website, email newsletters, Facebook, Twitter, press releases, media briefings, and written communication. Much of the daily contact was on an informal basis, including obtaining data and sharing information. Press releases, media briefings, public meetings, and major agency briefings were handled through a more formal process. The major communication and coordination efforts conducted during the development of the plan are summarized here, with additional information presented in **Appendix J**

The Project started in late September 2011 and concluded in February 2012. Key milestones were:

- September 26, 2011: Contract award
- September 30, 2011: Tour of Grand Forks/East Grand Forks Flood Risk Reduction Project
- October 5-7, 2011: Start-up workshop in Minot
- November 3, 2011: Public release of draft of preliminary alignment plan
- November 8-10, 2011: Public meetings in Minot
- November 30, 2011: Public release of preliminary alignment plan
- January 31, 2012: Minot city council public meeting on alignment selection among Ramstad Levee, Lincoln Diversion, and Maple Diversion options and the 27th Street SE Diversion and Green Valley Levee options
- February 29, 2012: Delivery of preliminary engineering report to the North Dakota State Water Commission (NDSWC)

Tour of the Grand Forks/East Grand Forks flood project

8.1 Souris River Joint Board (SRJB) and Counties

The SRJB was the local entity that had requested the NDSWC for assistance in the development of an enhanced flood risk reduction project for the Mouse River Valley. The SRJB is comprised of representatives of the four counties that cover the Mouse River Valley: Renville, Ward, McHenry and Bottineau. Meetings were held with the SRJB starting shortly after the engineering team was selected and continued throughout the evaluations and development of the Project. The first meeting with the SRJB was held October 4, 2011, with members of the engineering team presenting the strategy for project management and development. Input from the public was received at this meeting. Additional meetings with the SRJB and with other representatives of the four counties were held as the plan features were developed. The representatives of the SRJB were focused on making sure that the preliminary alignment plan included components that addressed the flood problems throughout the entire reach of the Mouse River, within the four-county area. Representatives of the SRJB also

participated in the September 30 tour of the Grand Forks/East Grand Forks flood risk reduction project, in the October Start-Up Workshop and in public meetings held November 8–10, 2011.

A meeting to address the issues in the rural areas both upstream and downstream of the primary study reach was held on February 16, 2012 and was attended by the SRJB, representatives of the four counties and other interest groups from the rural areas. Photographs taken at the Grand Forks/East Grand Forks tour, the Startup workshop, the public meetings and the rural area interests meeting are included in **Appendix K.**

To facilitate initial stakeholder input and quickly collect as much information as possible, a start-up workshop was held in Minot October 5-7, 2011 Rural stakeholders input meeting for areas not addressed in Preliminary Project Plan

8.2 City of Minot

Minot is the largest city in the northwest/north central part of North Dakota and is the fourth largest city in North Dakota. It received the greatest damages from the June 2011 flood in the Mouse River Valley and the damages incurred at Minot affected the entire region, including activities taking place in the oil field developments to the west. How the Project is developed in Minot affects not only residents of the city of Minot but also the surrounding area and the region. Coordination with the Minot public works staff, parks staff, and the mayor and city council occurred throughout the

Project—beginning with the tour of the Grand Forks/East Grand Forks project and the Start-Up Workshop, where city staff members gave extensive feedback on important considerations for plan development. The engineering team received tours of Minot accompanied by city staff, to familiarize team members with the infrastructure, buildings, facilities, and neighborhoods that are important to the city and its residents. These tours including bridges, water treatment facilities, parks and the zoo, historic homes, churches, schools, industrial facilities, critical transportation routes, railroads, public buildings, state fairground facilities, and flooded residential neighborhoods.

Engineering data and parcel information from the city's files were provided. These were used to determine the effects of various alternatives on properties and infrastructure. Detailed briefings were given to city staff at several times between November 2011 and February 2012 when hydraulic model results were available for alternative alignments. Beginning in early January weekly coordination meetings were held with city staff, including the following key meetings:

- January 12—Meeting with city staff: Information was presented on the results of hydraulic modeling showing the increased water surfaces for the design event for a number of alternative alignments, especially relating to options for the Maple Diversion and the Twenty-Seventh Street SE Diversion. City staff provided guidance to keep water surface level increases at the water treatment plant (16^{th} Street SW) to less than 2 feet for the design flood event. A memorandum of this meeting is shown in **Appendix J.**
- January 19—Conference call with city staff: Presented hydraulic modeling results related to the Maple Diversion and to water surface increases at Sixteenth Street and the water treatment plant. A memorandum of this meeting is shown in **Appendix J.**
- January 24—Meeting with Minot city council and city staff: Updated information and a summary of the Project work through Minot were provided by the engineering team. The briefing included hydraulic modeling, impacts and changes to the floodplain, levee/floodwall alternative alignments considered, and the hydraulic challenges of each alternative. Three possible alignment options in the Lincoln Elementary School area were discussed at length. The presentation given at this meeting is shown in **Appendix J.**
- January 26—Conference call with city staff: The need for selection of a preferred alternative alignment in the Lincoln Elementary School and Twenty-Seventh Street SE areas was discussed. Plans were developed by the city council to hold a public meeting on January 31 for the purpose of hearing from the affected residents and for the city council to reach a decision on a preferred alignment option.

- January 31—City council public meeting: A presentation was made by the engineering team to the city council and the public, focusing on the three alternative alignment options in the Lincoln Elementary School area and alignment options in the 27th Street SE area. The options in the Lincoln Elementary school area were the Ramstad Levee plan, the Lincoln Diversion plan, and the Maple Diversion plan. The options in the 27th Street SE area were the Green Valley levee plan and three variations of 27th Street SE diversion plan. Public comments were received and questions were answered. At the conclusion of the public comment period, the city council adopted a resolution to select the Maple Diversion alignment and one of the 27th Street SE Diversion alignments as the preferred options. The presentation given at this meeting and the Minot Daily News coverage is included in **Appendix J.**

Minot City Council held a public meeting on January 31, 2012 to collect citizen input on high flow diversion alignment alternatives

8.3 Burlington, Sawyer, Logan and Velva

Members of the engineering team met with representatives of the cities Burlington, Sawyer, Logan and Velva periodically as needed throughout the study.

8.4 Federal Agencies

Federal agency coordination was conducted primarily with the U.S. Army Corps of Engineers (USACE) because existing flood risk reduction projects along the Mouse River were designed, constructed, and inspected by the USACE and any modifications to existing federal projects will require approval from the USACE. The USACE is also instrumental in the coordination and operation of upstream flood storage in the basin. Although Lake Darling is a USFWS project, the USACE controls releases during periods of flooding and coordinates with the Saskatchewan Water Authority in their operation of the Alameda, Boundary, and Rafferty dams. In addition, wetland impacts of the Project may also require a USACE permit.

8.4.1.1 USACE

Regular communication was held with USACE staff since the start of the Project. This has included information gathering and sharing of design, study, hydraulic modeling, flood fighting, and alignment development information. The Project area falls under the jurisdiction of two Corps districts: the St. Paul District for civil works and flood fighting, and the Omaha District for regulatory and permitting. USACE staff from both districts participated in the Start-Up Workshop. Primary communication has been maintained with the St. Paul District, with St. Paul and Omaha staff coordinating internally.

Regular communication has included meetings, phone calls, and emails—often on a weekly basis. This communication covered many topics including the status of the preliminary alignment plan, hydraulic modeling, permit requirements, existing USACE project data, USACE flood recovery activities, and operational considerations of the upstream reservoir system. Additional information and memorandums of the meetings with the USACE are included in **Appendix J**. Several formal meetings and interactions occurred including the following:

- October 5-7—Start-up workshop: St. Paul and Omaha District Corps staff participated in the small- and large-group dialog in Minot.
- October 21—Meeting and video conference: Representatives from Barr, the St. Paul District, and the North Dakota State Water Commission (NDSWC) discussed flood protection strategy development and setup and calibration of the updated HEC-RAS hydraulic model
- November 18—Meeting: Briefing at the St. Paul District offices to provide Project status update and a discussion of issues associated with the preliminary alignment plan. The St. Paul District Engineer and the Chief of Engineering and Construction were in attendance, along with personnel from the areas of hydraulics and hydrology, design, levee inspections, and project management.
- January 11—Meeting: A briefing for state and federal agencies was held in Bismarck to provide a Project status update and a discussion of issues associated with the current plan, especially as related to environmental issues and Section 404 permitting. An Omaha District Corps representative was in attendance.

8.4.1.2 Other Federal Agencies

Representatives of the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), and the U.S. Fish and Wildlife Service (USFWS) were consulted during the development of this preliminary engineering report. Data collection and analysis by the USGS was obtained, discussed, and used in hydraulic model and plan development. The flood recovery work undertaken by FEMA including their "Souris Basin Regional Recovery Strategy" report for Minot, Burlington, and Ward County, was considered in Project development (reference [1]). Representatives of FEMA were also present at the Start-Up Workshop and at public meetings held in November. A USFWS representative was present at the agency briefing held January 11, 2012, in Bismarck, North Dakota.

8.5 State Agencies

Communication between the NDSWC and engineering team members was conducted on a continuous basis. Other state agencies were contacted on a periodic basis, mostly by the NDSWC. State agency representatives participated in the agency briefing and coordination meeting held in Bismarck on January 11.

8.6 Public

The public was engaged at a variety of stages through the development of the preliminary alignment with opportunities for input and comments and updates on alignment development. Public engagement was done through a series of public and neighborhood meetings as well as on-going use of social media and opportunities to provide written comments.

8.6.1 Public Meetings

Public meetings had two primary objectives, information and communication. Information was presented to the public on the objectives of the study, the information being gathered, the analyses that were being conducted, and schedule for plan development. Information was obtained from the public regarding their concerns with the development of the plan and the scope of the plan features. The goal was to establish communication between the engineering team, the community and county leaders, the NDSWC and the public to assure that all pertinent information and views were considered as the plan was developed.

Formal public meetings were held in Minot November 8–10, 2011. Three evening meetings were held at the State Fairgrounds with the meetings on November 8 and 9 focused on residents of Minot and the meeting on November 10 focused on those living in the areas upstream and downstream of Minot. Meetings were well attended, with 400 to 600 persons at each meeting. The first hour was structured as an open house, with several sets of Project alignment maps located throughout the meeting hall and members of the engineering team available to discuss Project features on a one-on-one or small-group basis. The second phase of each meeting consisted of a presentation by the NDSWC and the engineering team on the purpose of the study and the preliminary alignments being presented. After the presentation, the public was invited to ask questions or make statements. Time was allotted at the end of the meetings for individuals to, again, meet with engineering team members on a one-on-one or small-group basis. The presentation made at the public meetings and the Minot Daily News articles on the meetings are included in **Appendix J**, and the Alignment Maps dated November 3, 2011 that were the basis of the plan presented at the meetings are shown in **Appendix I**.

Formal public meetings were held in Minot November 8–10, 2011 to collect stakeholder input on the preliminary draft alignment.

8.6.2 Neighborhood Meetings

Neighborhood meetings were held on November 22, 2011, with residents of the neighborhoods in the vicinity of Lincoln Elementary School and in the Twenty-Seventh Street SE/Green Valley area to discuss the high- flow diversion alternatives developed after the public meetings of November 8-10. These meetings were held to get feedback on the diversion alignments as they were being developed, and before the November 30 draft preliminary alignment plan was released. On December 6, 2011 a meeting was held with residents of the Kings Court neighborhood.

8.6.3 Web site, Facebook, Twitter

A Project website was set up at www.mouseriverplan.com. The website was operational in late October 2011 and updated on a regular basis. The website provided individuals the opportunity to get updated information and to submit comments or questions on the plan under development. Residents were also encouraged to use social media via Facebook or Twitter to submit input or ask questions about the Project. The engineering team then had the opportunity to engage the respondents in discussions about the plan, answer questions, and clarify information on the plan. Members of the public could also use the site as a forum to exchange opinions and views concerning plan features and related topics. Visitors to the website could register to receive email updates and newsletters on the Project. Press releases were also made available on the website. The alignment maps that were posted on the website are included in **Appendix I**. The alignment maps were made available to the public as soon as they were updated through the website on the following schedule:

- November 3—Initial draft concept plan maps and technical memorandum: These maps and the technical memorandum were the basis for presentation of the preliminary alignment at the November 8-10 public meetings. These maps covered the entire Mouse River study reach.
- November 30—Preliminary draft alignment maps and technical memorandum: These maps and the technical memorandum incorporated modifications to the alignments reflecting comments received at the public and stakeholder meetings and further evaluations by the design team. These maps covered the entire Mouse River study reach.
- December 21—Revised Lincoln Diversion alignment map: This updated map presented modifications to the Lincoln Diversion plan that had been presented in the November 30 maps.
- January 16—Revised Twenty-Seventh Street SE Diversion map and new map of the Maple Diversion: These updated maps presented modifications to the previous Twenty-Seventh Street SE Diversion alignment shown in the November 30 maps and a new high-flow diversion alignment in the Lincoln Elementary School area called the Maple Diversion. There were three alignment options for the Lincoln School area: the Ramstad Levee option (Nov 30), the Lincoln Diversion option (Dec 21), and the Maple Diversion option (Jan 16).
- March 1 (planned) Project alignment maps and preliminary engineering report. The Project alignment maps, as presented in the preliminary engineering report, along with the report dated February 29, 2012, are planned to be posted for public review and comment.

8.6.4 Public Comments

Both verbal and written public comments were received at the November 8-10 public meetings. Additional public comments were received via emails, Facebook, and Twitter messages. Over 1,200 comments were received between the Start-Up Workshop and February 3, 2012. All comments received were considered in the plan formulation and design. A complete compilation of the written comments received is included in **Appendix J.**

8.7 Railroads

Two major railroads, BNSF and CP Railway, traverse the Mouse River Valley and were damaged by the June 2011 flood. Both railroads will be benefited by the Project but there may be potential disruptions to their facilities. To facilitate communication and to address their concerns early in the plan development process, coordination was conducted with both BNSF and CP Railway during the study.

BNSF was contacted early in the study for bridge information at Minot to assist in developing the hydraulic model due to major flood flow restrictions and very high velocities in that reach of the river. After preliminary alignment plans were published on the Project website and made available for public review on November 30, both BNSF and CP Railway were informed of the alignments and their input was requested.

In early December, BNSF provided initial comments and requested a conference call to discuss the plan as it related to their facilities and operations. A primary consideration for BNSF was to keep the mainline in service during the design flood event. They requested that consideration be given to classifying their mainline as a “critical transportation facility” and that a raise of their mainline be considered in the preliminary planning phases. The consideration of their comments is discussed in **Section 6.6.4.1** and also in **Appendix I.**

In mid-December CP Railway indicated that they were reviewing the alignments and requested additional information related to crossings of their tracks by levees and floodwalls. Preliminary elevation data at the CP Railway crossings was provided, including June 2011 high-water marks, top-of- railroad grade, and top-of-flood barrier. In early January a meeting was held with CP Railway representatives to discuss the alignments and the information on Project crossings. In late January a conference call was held with CP Railway representatives to discuss some of their specific concerns related to Project design and operation. Their primary concerns related to any potential Projectinduced water-level increases and increased durations of flooding that would lengthen the out-of-service time for their mainline during a flood event. These concerns are discussed in Section **6.6.4.2**.

After the Minot city council selected the last segment of alignment options on January 31, both BNSF and CP Railway were informed of the revised alignment that would be presented in the preliminary engineering report. They were advised that the Project was scheduled to be presented to the NDSWC on February 29, 2012, and that the report would be distributed for public, agency, and other stakeholder review and comment in early March. They were also advised that any comments they wished to provide, before or after distribution of the report, would be welcomed. Memorandums of the coordination with both BNSF and CP Railway are included in **Appendix J.**

8.8 Other

Coordination was also conducted with many area businesses and other interested groups including Cenex Harvest States, Magic City Implement, Keller Paving, Cloverdale, realtors, developers, the Minot Park District and the Minot Public Schools.

Media coverage during the plan development process from September 2011 through mid-February 2012 is included in **Appendix J.**

9.0 Property Impacts

Acquisition of rights-of-way for Mouse River Enhanced Flood Protection project (Project) features is necessary before construction of those features can begin. This section of the report provides a summary of the properties affect by the Project and a general description of the methods used to estimate the number of impacts properties. An estimate of the number and types of properties affected by the preliminary alignment was developed using digital geographic information systems (GIS) and air photos to overlay available property information with the preliminary alignment Project limits as shown on **Maps 1 through 28** in **Appendix A**.

The preliminary alignment shows areas that would either be inundated by flood waters or affected by construction of flood risk reduction measures and a clear zone that will be necessary for permanent easements to access, operate, and maintain the flood protection features. It may be necessary to acquire property for some features that are outside of the preliminary alignment Project limits, but the locations of such features cannot be determined at this stage of Project definition. In many cases, there will be some latitude in the final locations and it may be possible to use vacant property, public property, or willing sellers for these features.

The estimate of affected properties presented below is limited by the accuracy and completeness of the available information. A property acquisition team will need to develop greater detail on property identification and assessment.

9.1 Property Impact Analysis Methods

Two methodologies were used to estimate the properties and residential structures affected by the preliminary alignment plan footprint. Within the City of Minot parcel data with zoning, land and building value (pre-flood) was available from the City and was used to identify residential parcels affected. In Project areas upstream and downstream of Minot this data was not available and aerial photography was used to identify residential structures.

9.1.1 City of Minot

Geographic Information System (GIS) software was used to identify parcels with Minot city limits within or directly adjacent to the preliminary alignment plan Project Limits. Land within the existing U.S. Army Corps of Engineer right-of-way (USACE ROW) was excluded from the calculation of affected properties because it is already part of the existing flood risk reduction systems. Parcels were classified as either:

Classification 1: Parcels with homes that need to be acquired for Project construction

Classification 2: Parcels where the residence or major structures do not appear to be affected by the Project but portions of the parcel would need to be acquired for Project construction

Parcels were evaluated using 2010 aerial photography to determine make classification determinations. For Classification 1 the total number of affected parcels was estimated along with pre-flood assessed values for the land and building. For Classification 2 a similar exercise based on per acre values were applied to the area of the parcel that would be partially affected.

Some of the parcels within Minot did not have values available. These were primarily non-residential parcels, and many of these were determined to be public owned parcels.

9.1.2 Areas Upstream and Downstream of Minot

Houses, farmsteads and other clusters of buildings in and near the design flood inundation area and Project limits outside of Minot were identified using 2010 aerial photography. The location of each of these structures was established in GIS using a point centered on the primary building in a cluster. For instance where there is a house and a separate garage, the point was located on the house. Each point was classified as either a residential structure (house or farmstead) or “other” (such as a business). Points were tabulated within the Project limits that were identified as possible candidates for ring levees where they were residential structures within or immediately adjacent to the design flood (27,400 cfs) inundation area. In addition, residential properties not within but adjacent to the Project Limits were identified where right of way may need to be acquired. The total number of residential properties and non-residential buildings/clusters in each of these categories were tabulated.

For residential structures identified as candidates for ring levees, the mean depth of water for the design flood was estimated using County LiDAR data and hydraulic model output for water surface elevation data at each location for the target flood event. The water depth results were categorized by depths for 5 feet or less, between 5 and 10 feet, and between 10 and 15 feet for use in estimating ring levee costs. Summary of Property Impacts

Table 9-1 provides a summary of the estimated number of properties that need to be acquired along the preliminary alignment Project. The count provided below excludes properties that may have only a small portion of area affected because it is assumed that only a portion of the partially affected property would need to be acquired. **Table 9-2** provides a summary of the additional property that will need to be acquired beyond the properties listed in **Table 9-1** that is outside the existing USACE ROW in order to construct the Project.

Table 9-1 Estimated Number of Properties to be Acquired for the Preliminary Alignment Project

Property Zoning Classifications	Upstream	Minot	Downstream	Total
Non-residential	not available	106	not available	106
Manufactured Home	not available	2	not available	2
Residentially Zoned with House / Building[1]	90	278	15	383
Residentially Zoned with No House / Building	not available	92	not available	92
Total Number of Properties	90	478	15	583

(1) Residential zoning classification includes parcels classified as single family, two-family, and multi-family. Data is not readily available for estimating the number of housing units represented by this property count.

Table 9-2 Summary of Area Partially Impacted by the Preliminary Alignment Project [1]

	Upstream	Minot	Downstream	Total
Number of Properties[2]	not available	273	not available	not available
Total Acreage	132	192	183	507

(1) Acres and parcel numbers are for those areas that are not within existing USACE Right-of-Way
(2) For upstream and downstream reaches parcel data were not available, therefore only acreages are given

In the city of Minot, it is estimated that about 278 Minot residential properties with structures would be need to be acquired for the preliminary alignment. This number is about 100 fewer than the November 30 alignment. An estimated 92 residential properties without structures on the property at the time of the 2011 flood event were not included in the residential property count for the revised draft alignment.

Approximately 105 homes outside of Minot would need to be acquired for construction of the preliminary alignment features, including properties in Mouse River Park, Burlington, Sawyer, Velva, and rural subdivisions.

10.0 Opinion of Probable Cost

This Opinion of Probable Cost (OPC) is intended to provide information for consideration during decision-making and planning at this feasibility-level stage of the Mouse River Enhanced Flood Protection project (Project). After preliminary alternative evaluations and alignment revisions were presented in January 2012, further design was completed and quantity takeoffs and real estate acquisitions have been estimated for the Project. The cost estimate is of a level of detail intended to evaluate the feasibility of the Project as defined at this time.

10.1 Basis of Cost

The cost estimates and associated information in this section are intended to provide background information to understand the basis for the development of the OPC, based on the alignment at this time. Costs are based on analysis and assumptions consisting primarily of the following:

- Material cost quotes obtained from local suppliers;
- Estimates of equipment, labor and work crews obtained from local and regional contractors;
- Preliminary work analysis related to earthwork associated with channel and levee construction;
- Assembly of reference unit cost data from recent regional bid tabulations, similar flood risk reduction projects, published cost data, and other typically observed costs;
- Quantity calculations based on analysis, design, and drawings included in this report;
- Referenced categorical cost breakdowns of similar feasibility-level and EIS-level cost estimates, as performed by U.S. Army Corps of Engineers (USACE) and others, including more than 20 recent regional and national projects with relevant project scopes emphasizing flood control, levee, pump station, and transportation work elements;
- Acquisition costs are based on estimated pre-flood assessed values of affected properties;
- For more defined Project features, deterministic methods are used to estimate costs based on quantity takeoffs and estimated unit costs for assemblies and individual components;
- For less defined Project features, stochastic and parametric methods are used where Project definition limits the degree to which feature quantities can be itemized, counted, or measured. In some of these cases, allowances are included to estimate the cost typically required for such work.

The cost estimate approach used for this OPC focuses on the major cost items. In accordance with USACE guidance (reference [19]), the OPC focuses on the 20% of Project elements that are expected to result in 80% of the total estimated costs. Selected Project elements exceeding 5% of the total estimated construction cost have been grouped together for the purposes of calculating estimated costs at this stage. For the full detailed Basis of Estimate (BOE) and supporting documentation, see additional narrative and exhibits in **Appendix G**.

10.2 Opinion of Cost Breakdown

Preliminary cost estimates were developed for the following elements directly associated with the Project:

- Infrastructure modifications
- Ecological mitigation
- Roads, road raises, railroads and bridges
- Channel improvements and hydraulic structures
- Levees, floodwalls and closures
- Interior flood damage reduction systems (Pumping Stations)
- Recreation facilities
- Cultural resource investigations and mitigation
- Hazardous, toxic, and radioactive waste (HTRW)

Preliminary cost estimates were also developed for the following items required for the overall Project, but not associated with specific elements:

- Lands and easements
- Planning, engineering and design
- Permitting and regulatory approvals
- Construction management

10.3 Project Features

Project costs have been estimated for the following three zones: upstream of Minot, Minot, and downstream of Minot. The following is a summary of key Project features in these zones. This list is not inclusive. For a full breakdown of Project features included in the OPC, see **Appendix G**.

Table 10-1 Project Construction Feature Summary

Category	Item	Units	Reaches Upstream of Minot[1]	Reaches Through Minot[1]	Reaches Downstream of Minot[1]	All Project Reaches[1]
Flood Risk Reduction Features	Length of Levee	feet	38,200	46,300	29,500	114,000
	Length of Floodwall	feet	1,100	11,800	2,000	14,900
	Number of Roadway Closures		1	16	2	19
	Number of Railroad Closures		1	4	6	11
	Number of River Closures		0	4	0	4
	Number of Pump Stations		8	16	9	33
	High Flow Diversion or Channel Realignment	feet	6,700	8,800	500	16,000
Municipal Infrastructure	Sanitary Sewer	feet	7,000	13,600	900	21,500
	Watermain	feet	6,500	27,400	600	34,500
	Storm Sewer	feet	3,800	26,400	1,100	31,400
	Number of Bridges to be Modified		1	5	2	8
	Road Re-alignment (horizontal road adjustments only)	feet	5,000	8,300	1,200	14,500
	Road Raise (includes Bridge Approaches and Highways only)	feet	2,000	7,100	26,700	35,800

[1] Lengths are rounded to the nearest 100 feet.

10.4 Opinion of Probable Cost

An OPC was developed for the Project in accordance with the methodology, basis of cost, cost breakdown, and Project features summarized above and described in greater detail in **Appendix G**. **Table 10-2** provides a summary of the OPC.

Table 10-2 Point Estimate: Opinion of Probable Cost

Cost Breakdown/Element	Opinion of Probable Cost
Mobilization/Demobilization	$34M
Infrastructure Modifications	$48M
Ecological Mitigation	$4M
Roads, Road Raises, Railroads, and Bridges	$56M
Channel Improvements and Hydraulic Structures	$96M
Levees, Floodwalls, and Closures	$219M
Interior Flood Damage Reduction Systems (Pumping Stations)	$68M
Recreation Features	$11M
Cultural Resource Investigations and Mitigation	$5M
Hazardous Waste Mitigation	$24M
Estimated Construction Costs[1 2 3 4]	**$565M**
Lands and Easements	$154M
Planning, Engineering, and Design	$57M
Permitting and Regulatory Approvals	$4M
Construction Management	$40M
Estimated Total Project Cost [1 2 3 4]	**$820M**

1 Includes contingency (for additional information see **Appendix G**).
2 Includes costs for the upstream of Minot reach, Minot reach and downstream of Minot reach as defined herein.
3 This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06 and USACE EI 01D010 (9/1/97)) cost estimate is based on feasibility-level design alternatives, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. The estimated accuracy range for the total project cost, as the project is defined, is -20% to +40%. The accuracy range is based on professional judgment considering the level of design completed, the complexity of the project, and the uncertainties in the project as scoped. This accuracy range is not intended to include costs for future scope changes that are not part of the project as currently scoped or risk contingency. For a full discussion see **Appendix G**.
4 Does not include temporal escalation costs, operation and maintenance costs, relocations, or betterments.

A general breakdown of the estimated costs of construction features and lands and easements is shown in the tables below.

Table 10-3 Point Estimate: Summary of Construction Feature Costs

OPC[1]: Construction Features			
Upstream of Minot	**Minot**	**Downstream of Minot**	**Total**
$69M	$334M	$84M	$487M
14%	69%	17%	100%

[1] See footnotes in **Table 10-1** and **Appendix G** for estimate basis.

Table 10-4   Point Estimate: Summary of Land and Easement Costs

OPC[1]: Land and Easements			
Upstream of Minot	**Minot**	**Downstream of Minot**	**Total**
$54M	$87M	$13M	$154M
35%	56%	9%	100%

[1] Acres and parcel numbers are for those areas that are not within existing USACE Right-of-Way
[2] For upstream and downstream reaches parcel data were not available, therefore only acreages are given

10.5 Opinion of Probable Cost Considerations

The OPC was developed based on feasibility-level designs, unit prices that are benchmarked against 2011 and 2012 regional prices for similar construction scopes, and engineering judgment. This feasibility-level OPC is intended to correspond to a Class 4 estimate, characterized by 10-15% design completion (per ASTM E 2516-06 and USACE EI 01D010 9/1/97). The OPC is based on feasibility-level design alternatives, alignments, quantities, and unit prices. Costs will change with further design. A contingency of 25% for construction costs and 30% for lands and easements has been established for the OPC based on referenced projects, published references, and preliminary cost-risk analysis. Time value-of-money escalation costs are not included. Operation and maintenance costs are not included. The OPC is a point estimate within an estimated accuracy range. The estimated accuracy range for the total Project cost, as the Project is defined, is -20% to +40%. The accuracy range is based on professional judgment considering the level of design completed, the complexity of the Project, and the uncertainties in the Project as scoped. This accuracy range is not intended to include costs for future scope changes that are not part of the Project as currently scoped or risk contingency. Future cost estimate should incorporate construction schedule and time-value of money escalation and consider uncertainties associated with these elements. A construction schedule is not available at this time. For a full discussion of contingency, risk and uncertainty, see **Appendix G**.

The OPC is considered a feasibility-level construction estimate, and has been developed on the basis of similar projects and the consulting team's experience and qualifications. The estimate represents our best judgment as experienced and qualified professionals familiar with the Project, based on Project-related information available, current information about probable future costs, and a feasibility-level development of design for the Project. The OPC will change as more information becomes available and further design is completed. Given the level of Project definition, uncertainty exists related to the limited design work completed to-date including, but not limited to, uncertainties associated with quantities, unit prices, and design detail. In general, it can be anticipated that as the future level of Project definition increases, the uncertainty associated with these items will decrease.

Since the consulting team has no control over the eventual cost of labor, materials, equipment, or services furnished by others; the contractor's methods of determining prices; competitive bidding or market conditions; the consulting team cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from the OPC.

11.0 Implementation Elements

To implement an enhanced flood risk reduction plan for the Mouse River Valley, there are many tasks that need to be completed beyond those accomplished in the development of this preliminary engineering report. This section describes the major tasks associated with moving the Mouse River Enhanced Flood Protection project (Project) to implementation.

Phasing of Project implementation may provide desirable flexibility for Project funding and allow for the early construction of higher priority Project elements. There is a broad spectrum of potential ways to phase the implementation of the preliminary alignment plan. While this section describes the steps necessary to implement the entire Project, it would be possible to implement construction of the Project in a phased manner over an extended period of years.

The design development will need to incorporate regular stakeholder interaction, and will need to incorporate considerations such as public use, greenways, recreation and aesthetic elements of the Project.

The size of the preliminary alignment Project and the resulting affect on wetlands and the existing river channel will most likely require a federal environmental impact statement (EIS). It is possible that select portions of the Project could proceed without an EIS if the work is outside the 100-year floodplain, does not affect any wetlands, and can be implemented as a stand-alone project that would not rely on other aspects of the Project being completed.

The effect of the preliminary alignment Project on existing federal flood risk reduction project features will require Section 408 technical review by the U.S. Army Corps of Engineers (USACE). Any change to existing federal project features, including physical changes or changes to water surface levels will trigger this review process and require USACE approval to implement. It is possible that select portions of the Project could proceed without a USACE Section 408 review and approval if the work is outside the 100-year floodplain, entirely located on the landside of any existing federal flood risk reduction project features, and can be implemented as a stand-alone project that would not rely on other aspects of the Project being completed.

It will be necessary to develop and evaluate the entire Project to determine the sizing and inter-relationship of all components and features prior to environmental and technical review. However, implementation could be phased to construct portions of the Project in earlier phases and wait on other aspects of the work. This phasing would need to be described in the regulatory review process to allow for evaluation of engineering and environmental implications.

Figure 11-1 provides a graphical presentation of implementation tasks and their inter-relationships.

11.1 Rural Area Studies

The Souris River Joint Board (SRJB) made a request to the North Dakota State Water Commission (NDSWC) for engineering assistance to develop a plan for enhanced flood was to address the needs of the entire Mouse River Valley, including rural areas. This preliminary engineering report addresses only Mouse River Park and the Mouse River Valley between Burlington and Velva, North Dakota. A study of potential measures to provide relief or reduced flood risk for rural areas in the other reaches of the Mouse River Valley still needs to be done. The Rural Area planning and design effort should be carefully coordinated with ongoing efforts of this study/design so that any impacts to upstream and downstream flood levels caused by this Project are accounted for in the solutions for the rural areas.

11.2 Engineering Investigations

The design and evaluation undertaken for the preliminary engineering report relied primarily on existing information and was accomplished at about a 2510 to 15-percent design level. Additional, detailed investigation and analysis design is needed to develop Project features to the level at which they could be implemented. Some of the major Additional field investigations, including geotechnical investigations and surveys, will be necessary. A representative list of engineering investigations includes the following:

- Collection of site specific survey data
- Geotechnical site investigations including drilling and analysis of collected samples
- Archeological and cultural investigations of the corridor
- Geomorphic studies of sediment transport and scour potential of the main channel and diversions to determine long term Project maintenance and capacity impacts
- Ice and debris investigations to determine their effects on channel and structure capacity
- Hazardous toxic radioactive waste investigations (HTRW) on the corridor
- Traffic studies for the bridge and roads to be redesigned so that the new designs capture future traffic needs
- End use and master planning studies to determine the role of recreational features into the Project as well as items like Project appearance, restoration details and acceptable vegetation for use in design
- System operations plans

- Project phasing and delivery study
- Other studies as needed

11.3 Project Alternatives Evaluation

Implementation of the Project will require additional evaluation of alternatives. The level of alternative evaluation will vary depending on the permitting requirements for the Project and the specific characteristics and potential implementability considerations of each alternative. **Appendix I** of this report presents past studies of flood risk reduction measures for the basin and possible alternatives for further consideration. Requirements for USACE Section 404 permit and USACE Section 408 approval to modify an existing project require evaluation of alternatives to assure compliance with the National Environmental Policy Act. Recognizing that there are federal investments in existing dams, levees, and channel modification projects throughout the Mouse River Valley, the relationship between the Project and potential modifications to existing projects should be evaluated. An alternatives evaluation would likely be required to address the potential environmental and social effects, implementability considerations, and cost effectiveness of a number of more practical/feasible alternatives to the Project. These alternatives would likely include operational changes to the existing upstream dams, additional flood storage by the raising of the Lake Darling Dam, and revisions/modifications to the Project features and/or alignment. Some alternatives related to the upstream dams, including Lake Darling, are already under evaluation by the USACE and the International Joint Commission. If federal funding for construction of the Project is anticipated, a comprehensive evaluation of alternatives would be required to ensure compliance with federal laws and guidelines related to the evaluation and development of water projects. Development of a benefit/cost analysis, consistent with national economic development policies, would also likely be required.

11.4 Detailed Feature Design

This report provides preliminary design for the major Project features. Additional detailed engineering and design work will be necessary to develop plans and specifications suitable for bidding and construction, and for supporting documentation suitable for regulatory review and permitting. This work will include review of the overall Project scope to identify portions of the Project that could proceed without the more rigorous regulatory review process necessary for the major flood risk reduction elements, and to consider staging and prioritizing project implementation. Detailed engineering will also include refinement and value engineering of the Project alignment and features. A representative list of expected engineering work includes the following:

- Hydrology and hydraulics, including two-dimensional modeling of the river through the Project area, coincidental hydrology to evaluate and refine interior flood risk reduction features, and physical model studies for some of the more complex hydraulic features
- Detailed design of flood risk reduction features, including levees, floodwalls, river closures, transportation closures, etc.
- Local road work, including road re-alignments and grade changes
- Bridge work, including bridge modifications and replacements
- Utility work, including replacement or modification of utilities that are either require relocation for Project construction or would be compromised by the Project

11.5 Environmental Studies

Additional environmental studies will be necessary to better define existing conditions, evaluate the potential impact of the Project, and identify potential mitigation measures. The following list highlights the major environmental studies that will likely be needed.

- Wetland delineation and mitigation investigations
- Archeological and cultural investigations of the corridor
- Hazardous toxic radioactive waste investigations (HTRW) on the corridor
- Socio-economic evaluations
- Recreational resources evaluations
- Biological resources evaluations
- Environmental assessment and/or an environmental impact statement

11.6 Permitting and Regulatory Reviews

Before proceeding with construction, it will be necessary to complete detailed review of the Project for engineering and environmental regulatory compliance, including a Section 404 environmental review and Section 408 engineering review. A more detailed description of these regulatory processes is included in Section **12.0** of this report.

11.7 Acquisitions

Acquisition of rights-of-way for Project features is necessary before construction of those features can begin. Most rights-of-way will need to be acquired in fee title. Some temporary construction easements will also be necessary. Flood easements across land that experiences increase inundation is ultimately affected by the Project but upon which no Project feature is constructed may need to purchase in addition to fee purchase of property needed for construction. Analysis of where such easements may be needed (a legal effort not an engineering effort) and then an analysis of what land is subject to this requirement (an engineering effort) will likely be needed.

Recognizing that major damage has occurred to most structures along the Project alignment, an accelerated acquisition program would benefit all parties. It would assist individuals with damaged property to receive early compensation and allow them to relocate—rather than rebuild at their present location and risk being acquired/disrupted when the Project proceeds toward construction. Accelerated acquisition would also allow Project sponsors maximum flexibility in phasing construction of various Project features.

A voluntary acquisition program, using state and local funds, is already in progress for properties within the November 30 alignment footprint. The funding and scope of this initial acquisition program is limited, and additional acquisition phases will be required to secure all property necessary to construct the Project. Federal funding for the acquisition of properties damaged by the 2011 flood has been very limited and funding through the FEMA Hazard Mitigation Grant Program involves deed restrictions which do not allow the construction of flood risk reduction Project features. The potential use of any federal funds for rights-of-way acquisition must fully consider the risks of deed or other restrictions that would the use of acquired property for Project construction.

11.8 Project Funding

It will be necessary to establish the source or sources of funding necessary to proceed with detailed design, permitting, and construction.

Project sponsors have indicated a preference to fund the design and construction of the Project with non-federal sources. However, federal funding remains a source to be considered. If the Project sponsor requested federal funding to design and construct the Project, the USACE would likely be the lead federal agency for design development, engineering reviews, environmental permitting, and construction management and oversight. Federal guidelines would need to be followed for all Project-related activities, including a cost-sharing agreement between the USACE and the non-federal sponsor. It is likely that the non-federal costs would be shared by state and the local sponsors.

If federal funding is not used, a cost-share arrangement would likely be established between the state and local sponsors.

11.9 Corridor Preparation and Advance Construction

Some of the work associated with the Project may be necessary regardless of Project implementation as part of the 2011 flood recovery efforts, or could proceed without completion of Project final design and regulatory review efforts. This could include work such as utility and road relocations and demolition of existing structures and infrastructure within the Project footprint. Completion of this work in advance of the detailed design and regulatory review could reduce the construction schedule for flood risk reduction features. Advance elements would need to be outside of the 100-year floodplain, and could not affect any of the existing federal flood risk reduction project features.

11.10 Stakeholder Input

It will be important to continue to provide updates and opportunity for input from the broad stakeholder group throughout the planning, design and construction phases of the Project. The existing public interaction has worked well to share Project information and progress, and to field questions and comments. This same level of communication and interaction should continue to attain stakeholder and public support for the Project.

11.11 Project Construction

Construction of Project features can only proceed once the design, acquisitions, and regulatory approvals have been completed. The Project may be designed, bid, and constructed in phases. Analysis of the inter-relationship of Project features would need to be conducted to develop a construction-phasing plan allowing for completion of individual features in stages. This analysis would include a determination of the Project’s effects on existing federal projects and the requirements to receive the USACE Section 408 approval. The construction phasing plan will be structured so that the phases that provide the most benefit in terms of reduced flood risk are sequenced first so dollars spend early in the process provide the most benefit to the residents in the area.

11.12 Operation and Maintenance

After construction is complete, on-going resources will be required to operate the Project in both flood and non-flood conditions, perform routine maintenance and inspection, and complete post-flood repairs to restore the Project to serviceable conditions.

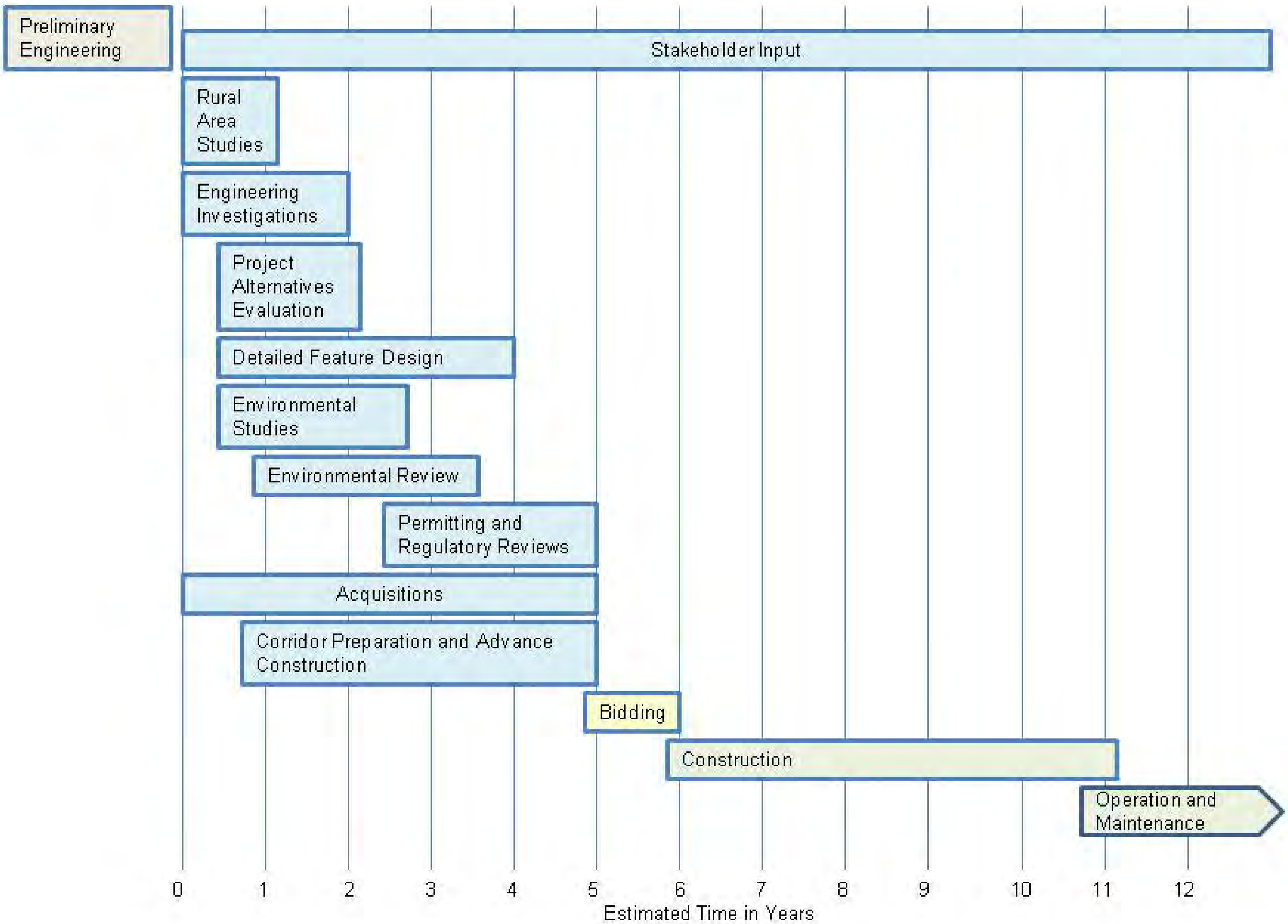


Figure 11-1 Project Implementation Steps

12.0 Permitting and Regulatory Considerations

The following sections provide a brief description of the potential permitting responsibilities for the Mouse River Enhanced Flood Protection project (Project). **Table 12-1** provides a brief, non-comprehensive listing of major permitting and regulatory considerations.

Table 12-1 Major Required Permits and Approvals

Agency	Permit or Approval	Reason
Federal		
U.S. Army Corps of Engineers (USACE)	Section 408 Approval	Major modification to an existing federal project
	Section 404 Individual Permit	Impacts to waters of the United States including wetlands
	Section 10 Individual Permit	Impacts to navigable water
	Section 106 Consultation (North Dakota Historic Preservation Office)[1]	Condition of federal permit (USACE permit)
U.S. Fish and Wildlife Service (USFWS)	Section 7 Consultation	Condition of federal permit (USACE permit)
Federal Emergency Management Agency (FEMA)	Conditional Letter of Map Revision Letter of Map Revision	Modifications within the 100-year floodplain
	Levee Certification	To demonstrate that the levees meet 44CFR65.10
State		
North Dakota Department of Health (NDDH)	NPDES Construction Stormwater Permit	For construction activity disturbing one or more acres
	Section 401 Certification	Water quality certification ensures that federally permitted activities are in compliance with water quality standards
North Dakota—Office of the Engineer	Construction Permit	Construction of levees
	Sovereign Lands Permit	Project involves potential dredging and filling
North Dakota Department of Transportation (NDDOT)		Working within DOT ROW

12.1 Federal Agencies

12.1.1 FEMA

The Federal Emergency Management Agency (FEMA) is responsible for reviewing impacts to the 100-year flood elevation. For alternatives that include work within the 100-year floodplain, FEMA may require completion of a no-rise certificate or a conditional letter of map revision (CLOMR), followed by a letter of map revision (LOMR). A CLOMR and LOMR would be necessary to demonstrate that the Project does not increase the base flood elevations (BFE).

FEMA has criteria for certifying that flood risk reduction projects provide a specific level of protection against the base flood event. FEMA reviews documentation provided by the levee owner, demonstrating that the levee has been certified by a professional engineer and meets current design criteria. Following a review of submitted documentation, FEMA will map areas protected by a levee as moderately at risk (Zone X) on flood insurance rate maps.

12.1.2 USACE

The U.S. Army Corps of Engineers (USACE) issues permits for work within navigable waters (i.e., below the ordinary high-water line for the Mouse River) or within jurisdictional wetlands. The USACE reviews and approves modifications to the existing levee system.

The Project described in this report will likely be considered a major action with the potential for significant impact on the quality of the human environment. As a result, the Project will require USACE approval under Section 10 of the Rivers and Harbors Act of 1899 and under Section 404 of the Clean Water Act. An environmental review will need to be conducted to meet the requirements of the National Environmental Policy Act of 1969 (NEPA), National Historic Preservation Act of 1966, Council of Environmental Quality Regulations Endangered Species Act of 1973, Section 404 of the Clean Water Act, and other applicable laws and regulations. Under NEPA, applicable projects are assessed in relation to the environmental conditions of the area and the impact that alternatives would have upon those environmental conditions. It has always been the intent of the NEPA process to ensure that informed decision making, with respect to the environment, occurs when considering the need for a project and its alignment and design.

While attempts were made to avoid or minimize environmental impacts during the development of the Project, it is still recommended that an environmental impact statement (EIS) be prepared. Based on recent discussions with regulatory agencies, and the fact that various Project components have, historically, been linked to the USACE’s Lake Darling flood control project, it appears likely that the EIS will need to encompass the entire study area. The EIS will assess the impacts of the proposed action and reasonable alternatives, identify and evaluate mitigation alternatives, and discuss potential environmental monitoring. Coordination with responsible federal, state, and local agencies; the general public; interested private organizations and parties; and affected Native American tribes will assist in the determination of significant environmental issues and resources. The EIS will be a valuable tool to help guide and refine the design process. The information compiled will also be valuable when completing the required Section 404 and 408 permitting processes.

Early coordination with other agencies and the public is an essential part of the Project development process. This coordination can help in determining the appropriate level of documentation required and in shaping discussion related to Project purpose and need. It will also help in identifying the NEPA and permit requirements of other agencies, the range of alternatives, impacts to resources, possible mitigation measures, and opportunities for environmental enhancement.

12.1.2.1 USACE Section 408 Approval

Because proposed improvements to the existing federal flood control systems along the Mouse River are significant, USACE Section 408 approval will be required. Section 14 of the Rivers and Harbors Act of 1899, as amended in 1985 to include “public works” (33 United States Code [USC] 408; hereinafter referred to as “Section 408”), authorizes the Secretary of the Army to permit alterations and modifications to existing USACE projects as long as the modifications do not adversely impact the integrity, operations and maintenance, or flood-fight capability of the existing project. The Secretary of the Army has delegated this approval authority to the Chief of Engineers of the USACE. The types of alterations and modifications under Section 408 that require approval by the Chief of Engineers include degradations, raisings, and realignments of levee systems.

The Section 408 submittal requires strict adherence to a variety of both engineering and regulatory requirements, including USACE design standards and design review, and environmental protection compliance in accordance with NEPA (EIS or EA, HTRW, Endangered Species Act, National Historic Preservation Act, etc.). The technical analysis must include, but is not limited to, the following information:

- Enough detail to ensure technical adequacy of the design including hydrology, hydraulics, geotechnical, structural, mechanical, electrical, etc.
- Assessment of anticipated local and system-wide resultant impacts (i.e., impacts on system integrity)
- Upstream and downstream impacts of the proposed alterations, including potential impacts to existing floodplain management and water control management plans of federal projects within the basin
- A risk assessment and discussion of residual risk, completed in accordance with USACE regulations (reference [20])

The submittal packet may need to include additional information beyond the impacts of the proposed alteration to flood conveyance, structural integrity, operation and maintenance, flood-fighting capabilities, and construction plans and specifications.

The USACE Section 408 approval process, which will begin with the St. Paul District office, is summarized in **Figure 12-1**. The process requires an agency technical review (typically conducted by the District office), a safety assurance review or independent external peer review, review and approval by the USACE Division in Vicksburg, and final approval by Headquarters in Washington D.C. It is currently understood that the finding of no significant impact (FONSI) or record of decision (ROD)—depending whether an EIS or EA is completed—will not be signed until the Section 408 process is complete and the authorization signed by the USACE Director of Civil Works.

In an effort to advance the Project more quickly, the engineering team continues to look for opportunities to split it into smaller components (e.g., Sawyer or Velva). However, discussions with the USACE St. Paul District staff suggest that the entire Project may need to go through the 408 approval process as a single entity, because of the extensive interconnections among components.

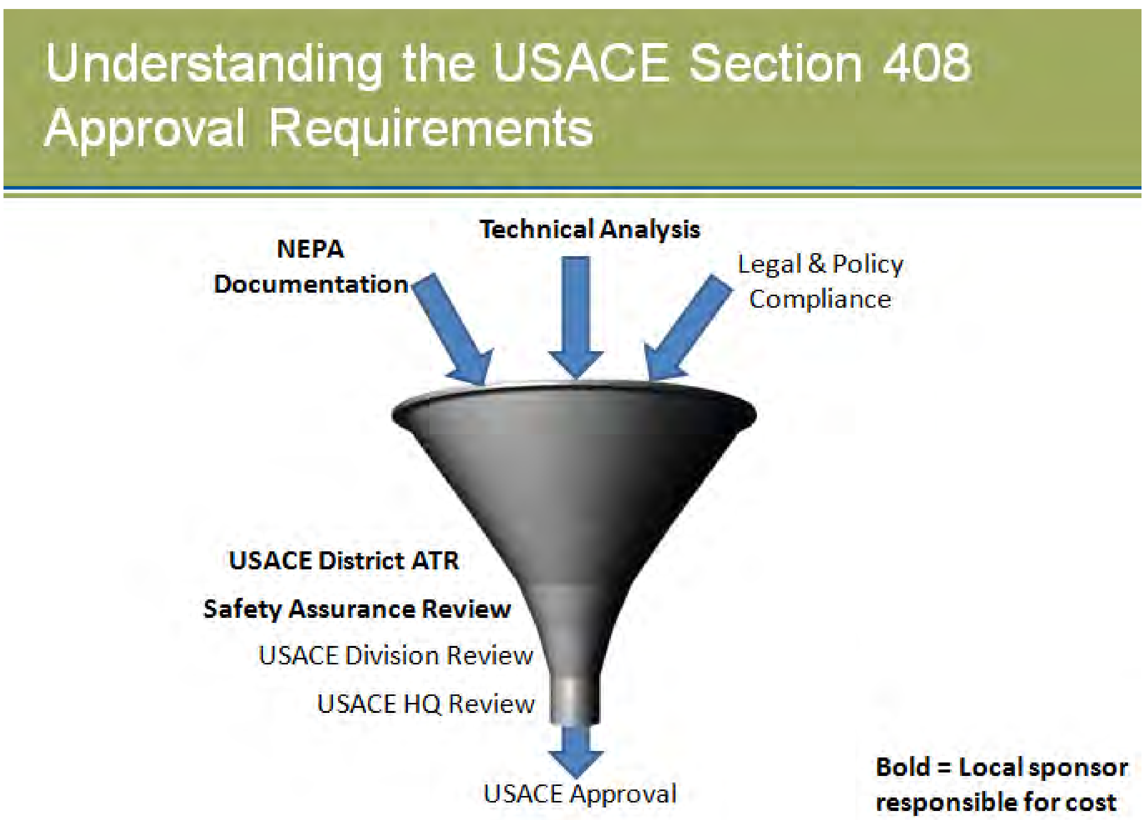


Figure 12-1 Generalized USACE Section 408 Approval Requirements

12.1.2.2 Section 404 Permitting

Because the Project involves placement of fill-in waters and work in navigable waters, it will also require federal permitting under Sections 401 and 404 of the Clean Water Act. This permitting is done by the USACE Omaha District. It is recommended that the public interest and technical evaluation data required for a Section 404 permit and/or a Section 10 permit be compiled concurrently with the technical evaluation and environmental protection compliance data required for a Section 408 permit. This will facilitate a timely, concurrent, USACE review.

12.2 State Agencies

A Section 401 water quality certification permit from the North Dakota Department of Health (NDDH), a sovereign lands permit, and construction permit from the North Dakota Office of the State Engineer will need to be obtained before implementing the Project.

12.3 Local Regulatory Considerations

Local permitting considerations include municipal and county permits. The construction contractors will be responsible for acquiring all local licenses/permits required to comply with state and municipal laws, codes and regulations (road, borrow, construction, etc.,), before starting construction activities. The contractor will also need to acquire the national pollutant discharge elimination system (NPDES) permit from the NDDH.

13.0 Conclusions and Recommendations

The 2011 Mouse River flood was an enlightening event for communities along the Mouse River, highlighting the shortcomings of the existing flood risk reduction system and demonstrating the need for an enhanced system that would reduce the risks posed by flows of similar magnitude (27,400 cfs at the Broadway Bridge in Minot). On September 21, 2011, the North Dakota State Water Commission (NDSWC) selected the Barr Engineering team to develop the Mouse River Enhanced Flood Protection plan, to include the communities of Mouse River Park, Burlington, Minot, Logan, Sawyer, and Velva, and the residences, farmsteads, and developments located between Burlington and Velva.

To determine the flood management features necessary for acceptable flood risk reduction and define the land needs and costs associated with developing a Mouse River Enhanced Flood Protection project (Project), the following activities were performed:

1. Reconnaissance of the Project area and research of existing geotechnical, hydrologic and hydraulic information, and available transportation and infrastructure engineering data
2. Development of a preliminary Project configuration including levee and floodwall alignments, heights, and ground contact zones (footprints), incorporating measures identified as priorities by the stakeholders for meeting flood protection goals
3. Identification of relevant regulatory requirements and consideration of these aspects in plan development
4. Preparation of drawings, maps, and preliminary design descriptions
5. Preparation of a preliminary engineering report, including cost estimate, with sufficient detail to be used as the basis for a final design
6. Solicitation of stakeholder input throughout the process

13.1 Conclusions

The resulting Project includes flood risk reduction features consisting of levees, concrete floodwalls, transportation closure structures, river closure structures, high-flow diversions, bridge modifications, channel realignments, overbank excavation, pump stations, interior drainage modifications, and floodplain buyouts. Additional Project features include roadway raises and realignments, as well as modifications to municipal utilities. Levees comprise almost 90 percent of the total alignment, totaling 21.6 miles. The remainder of the alignment consists of 2.8 miles of floodwalls and 30 transportation closure structures. The current alignment will require the acquisition of approximately 583 properties within the 2011 floodplain to construct flood management features, including 278 residential parcels in Minot.

The engineer's opinion of probable cost is estimated at $820,000,000, based on February 2012 price levels as shown in **Table 13-1**. This corresponds to a class 4 cost estimate (ASTM E 2516-06) supported by a Project design that is 10-15% complete. This accuracy of this estimate is judged to be from -20% ($656M) to + 40% ($1,148M) of the point cost estimate. This estimate does not consider the cash-flow for such a project or the time-value of money associated with Project expenditures over an extended period of time, or the impact that inflation will have on Project costs. In addition, local sponsors will need to plan for the costs associated with long-term maintenance and operation of the systems.

Table 13-1 Summary of Opinion of Probable Cost

Cost Breakdown Element	Opinion of Probable Project Cost
Construction Costs	$565M
Lands and Easements	$154M
Planning, Permitting, Engineering, Design & Construction Management	$101M
Estimated Total Project Cost	$820M

The estimated time frame for planning, engineering, environmental, and regulatory tasks could take 5 years or longer. Select components of the Project could proceed on a separate path and faster pace if they have minimal environmental impacts and do not affect existing federal flood protection. Construction of a project similar to the one described in this report is likely to take a minimum of 5 years, and could be phased over a longer period. Work associated with preparation of the Project corridor could be accomplished in advance of the flood risk reduction permitting and construction, including land acquisition and road and utility relocations.

The engineering analysis and preliminary design work was primarily based on review of available data, with limited collection of new data. Collection of more complete and up-to-date site specific data and investigations in the next stages of study or design will result in modifications to the configuration, cost, and function of Project features presented in this report. Other key engineering conclusions and recommendations, presented below, are based on information available at the time this report was prepared.

1. The flood of record for the Mouse River occurred in June 2011, causing over $690 million in damages. The heroic efforts of residents, volunteers, local officials, and state and federal agencies prevented an additional $200 million in potential damages. The potential damage could have totaled roughly $900 million, if emergency flood fighting measures were not implemented to save an additional 1,500 buildings. This estimate does not reflect the cost of rebuilding in areas outside of the flood zone, where real estate values are particularly high. It also excludes the substantial costs related to emergency flood fighting, evacuations, damages to public infrastructure, interruption of commerce—and the incalculable human costs.
2. Implementation of the Project will require the acquisition and removal of flood damaged homes and businesses. Removing buildings from the risk of future flood damages is considered to be one of most effective non-structural alternatives for flood risk reduction projects. So, although the residents and the city consider the acquisition of homes to be a major disruption to the community the relocation/buyout of these properties from the 2011 floodplain of the Mouse River is a very positive part of the overall project. This alternative is one favored by environmental interests and can play a role in the alternatives evaluation process of the 404 and 408 process.
3. Significant coordination and communication with stakeholders, agencies, and members of the public was vital to Project development. Stakeholder input was solicited through meetings, emails, phone conversations, video teleconferences, a Project website, Facebook, Twitter, press releases, media briefings, and written communication.
4. One of the most important factors in developing a reliable flood management plan is an accurate estimate of flood levels. To accomplish this, a new existing-conditions HEC-RAS model was developed using updated data such as LiDAR, as-built records, and field survey data. This new HEC-RAS model was calibrated to within an average deviation of less than one-tenth of a foot from the surveyed 2011 high water surface elevations. This provides confidence that the model simulations accurately reflect real-world conditions and that the model can be used in a predictive manner.
5. The Project will change the flood profile for the design flow (27,400 cfs) at most locations along the Project corridor (**Figure 13-1**). In the majority of these cases, this is the result of efforts to narrow the floodplain—minimizing the Project footprint and the number of property acquisitions required. As more detailed design is accomplished, alignment adjustments could potentially result in reduced or increased water surface level in some areas.

Figure 13-1 Summary of Project Effect on 2011 Flood Profile

6. Currently known environmental considerations in the study reach do not appear to present significant impediments to the Project or Project features in their current condition. However, an environmental impact statement (EIS) encompassing the entire study area will likely be required prior to construction because of the large size of the preliminary alignment Project, the interconnectivity of Project areas, required federal permits, and the resulting effect on wetlands, the existing river channel, and socio-economic impacts to the community.
7. Several federal and state regulatory programs will need to be addressed if the Project moves to construction. These key programs include:
    a. Technical review and approval of the flood risk reduction plan by the U.S. Army Corps of Engineers (USACE) under Section 408 of the River and Harbors Act of 1899 and as amended in 1985 to include “public works”
    b. Environmental review by the USACE under Section 10 of the Rivers and Harbors Act of 1899
    c. Environmental review by the USACE under Section 404 of the Clean Water Act

   d. Water quality certification from the North Dakota Department of Health under Section 401 of the Clean Water Act
   e. Sovereign lands permit from the North Dakota Office of the State Engineer
   f. Construction permit from the North Dakota Office of the State Engineer
   g. Post-construction no-rise certificate or a Letter of Map Revision demonstrating to the Federal Emergency Management Agency (FEMA) that the Project does not increase the base flood elevations (BFE)
8. As a condition of obtaining federal regulatory approvals to modify existing federal projects, additional evaluation of Project alternatives will likely be required.
9. In order for the flood risk management features to be shown on updated FEMA flood insurance rate maps, the systems must be certified by a professional engineer in accordance with 44 CFR 65.10.

13.2 Recommendations

Based on the preliminary engineering analysis the Project presented in this report is a viable alternative to reduce risk associated with a flood of the magnitude of the 2011 event. There are many tasks that would need to be completed to implement the Project. We recommend proceeding with the following tasks for implementing the Project.

1. Study potential measures to provide relief or reduced flood risk for rural areas: The Souris River Joint Board (SRJB) request for engineering assistance included review of enhanced flood protection for the entire Mouse River Basin, including rural areas. This preliminary engineering report only addresses Mouse River Park the area of the basin between Burlington and Velva. A study of potential measures to provide relief or reduced flood risk for rural areas needs to be undertaken.
2. Perform field investigations and additional engineering analyses: Detailed field investigations (e.g., additional surveying, geotechnical investigations, wetlands, HTRW, historic, cultural) and engineering analyses are needed before proceeding with development of detailed design. These investigations should be prioritized to take advantage of the approaching warm weather season; doing so may prevent the loss of a year (or more) in the Project implementation schedule.
3. Conduct a more rigorous value engineering exercise for the Project alignment and features to identify areas of potential cost savings.

4. Acquire property: A voluntary program is already in place for acquiring property within the preliminary alignment footprint. Additional acquisitions will be necessary to secure all of the property necessary to construct the Project.
5. Prepare an EIS: While measures were incorporated in the development of the Project to avoid or minimize environmental impacts, the magnitude of the Project and the effects on wetlands and the existing river channel will likely require that an EIS be prepared. The EIS will be a valuable tool to help guide and refine the design process. The EIS information will also be valuable for completing the required Section 404 and 408 review documents.
6. Evaluate Project alternatives: To satisfy NEPA, Section 404, and Section 408 requirements a thorough evaluation of Project alternatives will need to be completed.
7. Conduct a risk and uncertainty analysis: As the Project moves toward final design, hydraulic modeling and design elements will need to be refined to reduce uncertainty and consider other factors that could affect its potential to reduce flood damage. Examples of elements that could be considered in subsequent risk and uncertainty assessments include:
    a. Refinement of upstream reservoir operation procedures
    b. Establishment of confidence limits for critical parameters
    c. Detailed unsteady flow modeling to fully address questions of how the Project's impact on the floodplain storage will affect upstream and downstream areas
    d. Detailed modeling using two-dimensional or steady state models at critical locations to gain a better understanding of the flow dynamics and improve the overall resiliency of the Project
    e. Evaluation of the potential for scour and sedimentation of the channel
    f. Detailed surface water modeling of the interior drainage areas to optimize the pump station sizing and potentially reduce the overall Project cost
8. Re-evaluate basin hydrology: Updated hydrologic analysis is needed to assess the flood risk potential of the current reservoir operations. It has been over 20 years since the hydrologic flood frequency analyses were done. This analysis is needed to revise upstream reservoir operating plans and understand how potential revisions might affect the Project design.
9. Perform sensitivity analysis: Sensitivity hydrologic analyses of the June 2011 rainstorm patterns should be conducted to determine the flood flows that might have occurred if the storms had centered just upstream of Minot and downstream of the Canadian reservoirs. This would be helpful in assessing the residual flood risk in Minot even with modified operating plans for the upstream reservoirs.

10. Conduct coincidental frequency analysis: Additional assessment of local hydrology including coincident flood frequency analysis to better define interior pump station and pond sizing and levee heights.
11. Maintain on-going coordination with agencies: This includes USACE, USFWS, FEMA, NDSWC, SRJB, NDDH, NDDOT, etc.
12. Conduct public meetings during the process and communication through various means to keep the public informed on the progress and allow form commentary and input on the design.
13. Develop a coordination and communication plan to keep affected property owners informed.

References

[1] Federal Emergency Management Agency, "Souris Basin Regional Recovery Strategy: Minot, Burlington and Ward County, ND," Federal Emergency Management Agency, 2011.

[2] U.S. Army Corps of Engineers, *Operation and Maintenance Manual, Flood Control Project Souris River Basin Burlington to Minot Stages 1-4, Ward County, North Dakota.*, 1993.

[3] U.S. Army Corps of Engineers, *Operation and Maintenance Manual, Flood Control Project Souris River Basin, Sawyer Improvements, Sawyer, North Dakota.*, 1993.

[4] S. P. D. U.S. Army Corps of Engineers, *Operation and Maintenance Manual: Flood Control Project Souris River Basin, Velva, North Dakota. April 1989,*, 1992.

[5] USGS, "http://waterdata.usgs.gov," [Online].

[6] Federal Emergency Management Agency, "Flood Insurance Study, Ward County, North Dakota, and Incorporated Areas," Federal Emergency Management Agency, 2002.

[7] Federal Emergency Management Agency, "Flood Insurance Study, McHenry County, North Dakota, and Incorporated Areas," Federal Emergency Management Agency, 2011.

[8] United States, *Agreement between the government of the United States of America and the Government of Canada for water supply and flood control in the Souris River Basin,*, 1989.

[9] U.S. Army Corp of Engineers, Engineering and Design Manual EM 1110-2-16-19: Risk-Based Analysis for Flood Damage Reduction Studies, U.S. Army Corp of Engineers, 1996.

[10] P. Rice, "40 Days, 40 Nights of Ordeal: A Look at the Flood of 1969," 2011. [Online]. Available: http://pages.minot.k12.nd.us/nodak/flood/showNews.php?story=01.

[11] S. P. D. U.S. Army Corps of Engineers, *Operation and Maintenance Manual: Flood Control Project Souris River Basin, Minot, North Dakota.*, 1981.

[12] U.S. Army Corp of Engineers, "Guidance Document ETL 1110-2-571: Guidelines for Landscape Planting and Vegetation Management at Floodwalls, Levees, Embankment Dams, and Appurtenant Structures," U.S. Army Corp of Engineers, Washington, 2009.

[13] U.S. Army Corp of Engineers, Engineering and Design Manual EM 1110-2-1913: Design and Construction of Levees, Washington: U.S. Army Corp of Engineers, 2000.

[14] Great Lakes Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, "Recommended Standards for Water Works: Policies for the Review and Approval of Plans and Specifications for Public Water Supplies," Health Research Inc., Health Education Services Division, Albany, 2007.

[15] Great Lakes Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, "Standards for Wastewater Facilities: Policies for the Design, Review, and Approval of Plans and Specifications for Wastewater Collection and Treatment Facilities," Health Research Inc., Health Education Services Division, Albany, 2004.

[16] North Dakota Department of Health, "North Dakota 2010 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads," North Dakota Department of Health, Bismarck, 2010.

[17] State Historical Society of North Dakota, "North Dakota Comprehensive Plan for Historic Preservation: Archaeological Component; Souris River Study Unit," State Historical Society of North Dakota, Bismarck, 2008.

[18] U.S. Army Corps of Engineers, "Water Resource Policies and Authorities: Hazardous, Toxic, and Radioactive Waste (HTRW) Guidance for Civil Works Projects," U.S. Army Corp of Engineers, Washington, 1992.

[19] U.S. Army Corps of Engineers, *Guidance Document ETL 1110-2-573,* 2008.

[20] U.S. Army Corps of Engineers, "Risk Analysis for Flood Damage Reduction Studies: ER 1105-2-101," U.S. Army Corps of Engineers, Washington, 2006.

[21] U.S. Army Corps of Engineers, *Flood Control Souris River at Minot, North Dakota Design Memorandum No. 1,* 1972.

[22] F. J. Anderson and L. A. Manz, *Geology of the Minot Area - Geological Investigations No. 46,* 2007.

[23] A. E. Kehew, *Geology and Geotechnical Conditions of the Minot Area, North Dakota,* 1983.

[24] J. P. Bluemle, *Geology of Renville and Ward Counties North Dakota,* North Dakota Industrial Commissions - Geological Survey Division, 1989.

[25] U.S. Army Corps of Engineers, *Guidance Document ETL 1110-2-573,* 1980.

[26] U.S. Army Corps of Engineers, *2011 Post-Flood Report for the Souris River Basin,* U.S. Army Corps of Engineers, St. Paul District, Water Management & Hydrology Section, 2011.

[27] U.S. Army Corps of Engineers, *Flood Control Souris River, Minot, North Dakota, Design Memorandum No. 2 Interior Drainage,* 1973.

[28] Barr Engineering Company, *Mouse River Enhanced Flood Protection Plan, Technical Memorandum: Draft Preliminary Project Alignment,* 2011.

[29] S. P. D. U.S. Army Coprs of Engineers, *Updated Final Environmental Impact Statement, Flood Control, Burlington Dam, Souris River, North Dakota.,* 1975.

[30] S. P. D. U.S. Army Corps of Engineers, *Draft Environmental Impact Statement, Flood Control, Burlington Dam, Souris River, North Dakota.,* 1977.

[31] Barr Engineering Company, *2012. Memorandum, Comparative Analysis of Minot Diversion Alignments.,* 2012.

[32] Barr Engineering Company, *Memorandum, Update to Draft Preliminary Alignment for Mouse River Enhanced Flood Protection Plan (NDSWC Project No. 1974).,* 2011.

[33] Barr Engineering Company, *Mouse River Enhanced Flood Protection Plan, Technical Memorandum: Revised Draft – Preliminary Project Alignment,* 2011.

[34] U.S. Army Corps of Engineers, *Operation and Maintenance Manual Attachments to Stage 1: Tierrecita(sic) Vallejo, Flood Control Project Souris River Basin Burlington to Minot Stages 1-4, Ward County, North Dakota.*, 1992.

[35] U.S. Army Corps of Engineers, *Operation and Maintenance Manual, Appendix D As-Built Drawings, Burlington to Minot Stages 1-4, Flood Control Project, Souris River Basin, Ward County, North Dakota.*, 1992.

[36] H.-G. R. Solutions, *Periodic Inspection Report, Souris River at Sawyer (East), North Dakota Flood Control Project, Sawyer, North Dakota.*, 2010.

[37] H.-G. R. Solutions, *Periodic Inspection Report, Souris River at Velva, North Dakota Flood Control Project, Velva, North Dakota.*, 2010.

[38] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 1: Hydrology and Hydraulic Analysis, Flood Control, Burlington Dam, Souris River, North Dakota.*, 1974.

[39] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 13: Flood Control Project, Lake Darling Project Sawyer Improvements, Souris River, North Dakota.*, 1987.

[40] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 2: General – Phase I – Plan Formulation, Flood Control, Burlington Dam, Souris River, North Dakota.*, 1977.

[41] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 2: Phase I – Plan Formulation, Addendum No. 1, Flood Control, Souris River, North Dakota, Burlington Dam.*, 1975.

[42] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 4: Velva Improvements, Lake Darling Flood Control Project, Souris River, North Dakota.*, 1982.

[43] S. P. D. U.S. Army Corps of Engineers, *Design Memorandum No. 9: Flood Control Project, Lake Darling Burlington to Minot Improvements, Souris River, North Dakota.*, 1986.

[44] S. P. D. U.S. Army Corps of Engineers, *Operation and Maintenance Manual: Appendix A – As-built Drawings, Flood Control Project Souris River Basin, Minot, North Dakota.*, 1980.

[45] Association for the Advancement of Cost Engineering, *AACE International Recommended Practice No. 18R-97 Cost Estimate Classification System - As Applied in Engineering, Procurement and Construction for the Process Industries,* 2005.

[46] American Society for Testing Materials (ASTM) Subcommittee E06.81, *ASTM E 2516-11 Standard Classification for Cost Estimate Classification System,* Vols. 04.12 - Book of Standards, 2011.

Appendices