Preliminary Engineer’s Report

Newfolden / Middle River Subwatershed Flood Damage Reduction Project

Prepared For:
Middle-Snake-Tamarac Rivers Watershed District

April 1, 2019

PRELIMINARY ENGINEER'S REPORT

NEWFOLDEN / MIDDLE RIVER SUBWATERSHED FLOOD DAMAGE REDUCTION PROJECT

Middle-Snake-Tamarac Rivers Watershed District

April 1, 2019

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

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Appendix A. Additional Figures and Tables

Appendix B. Opinion of Probable Cost for Alternatives Considered

Appendix C. Geotechnical Investigation Report

Appendix D. RRWMB Step 1 Application

Acronyms

ASH	Auxiliary Spillway Hydrograph
BFE	Base Flood Elevation
BWSR	Minnesota Board of Water and Soil Resources
CD	County ditch
CFS	Cubic Feet per Second
CLOMR	Conditional Letter of Map Revision
CN	Curve Number
CRP	Conservation Reserve Program
CSAH	County State Aid Highway
CSP	Corrugated Steel Pipe
DEM	Digital Elevation Model
EAW	Environmental Assessment Worksheet
FBH	Free Board Hydrograph
FDR	Flood Damage Reduction
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GLS	Glacial Lake Sediment
JD	Judicial Ditch
LiDAR	Light Detection and Ranging (survey technology)
LMGT	Lake Modified Glacial Till
LTFS	Long Term Flood Solutions
MnDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MSTRWD	Middle-Snake-Tamarac Rivers Watershed District
NAVD 88	North American Vertical Datum of 1988
NEH	National Engineering Handbook
NLCD	National Landcover Dataset
NOAA	National Oceanic and Atmospheric Administration
P&N	Purpose & Need Statement
PMP	Probable Maximum Precipitation
R	SCS Storage Coefficient
RCB	Reinforced Concrete Box
RCP	Reinforced Concrete Pipe

RCPA	Reinforced Concrete Pipe Arch
Red River	Red River of the North
ROW	Right-of-Way
RRBWMA	Red River Basin-Wide Modeling Approach
RRFDRWG	Red River Flood Damage Reduction Work Group
RRWMB	Red River Watershed Management Board
SSP	Smooth-Steel Casing Pipe
SWPPP	Stormwater Pollution Prevention Plan
T_C	Time of Concentration
TP 11	Technical Paper 11
TSAC	Technical and Scientific Advisory Committee
USACE	United States Army Corp of Engineers
USGS	U.S. Geological Survey
WCA	Wetland Conservation Act
WSE	Water Surface Elevation

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1 Introduction

The City of Newfolden (City) partnered with the Middle-Snake-Tamarac Rivers Watershed District (MSTRWD) in 2017 to hire HDR to perform a flood damage reduction study within the Middle River Subwatershed near the City of Newfolden, Minnesota. The primary goal is to remove the City from the FEMA floodplain. This document presents the findings of that study, recommends a preferred alternative, and documents the preliminary design of the preferred alternative. All elevations in this report are in the North American Vertical Datum of 1988 (NAVD 88).

1.1 Middle River

The Middle River Subwatershed is located in northwestern Minnesota and is one of three subwatersheds that form the Middle-Snake-Tamarac Rivers Watershed District. The Middle River (River) joins the Snake River before entering the Red River of the North. The Middle River has a drainage area of approximately 295 square miles and is 95 miles in length. The Subwatershed's location is provided in Figure 1-1.

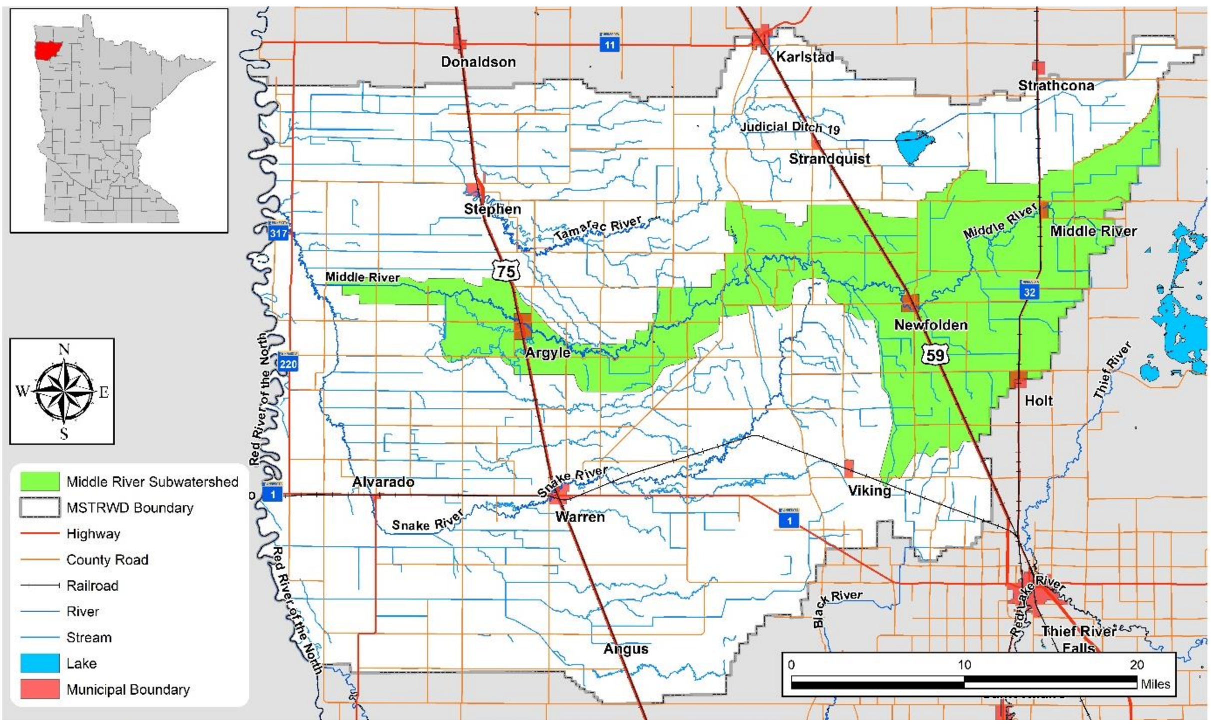

Figure 1-1: Project Location

1.2 Flood Damage Reduction Process

The proposed Flood Damage Reduction (FDR) project (Project) is being conducted in compliance with the provisions of Minnesota Statutes. The engineering tasks associated with this Project include performing survey, meeting with area landowners, reviewing and analyzing the flooding problems, preparing this report, presenting this report to regulatory agencies for advisory comments, and conducting a preliminary public hearing.

2 Project Need

2.1 Performance of the Middle River Subwatershed

The Middle River subwatershed has a diverse land cover with the eastern portion of the watershed composed of grasslands and wooded areas and agricultural land scattered throughout. The western portion is located in the Red River Valley where the landscape is significantly lower in elevation and consists primarily of agricultural land. The significant change in topography results in runoff flowing at a higher rate from the eastern half of the subwatershed and then slowing as it reaches the Red River Valley in the west. Flooding occurs in the western portion of the watershed due to the land cover and flat topography in the west and steep topography in the east.

The topographic changes and land use diversity throughout the subwatershed is displayed in Figure 2-1 and Figure 2-2.

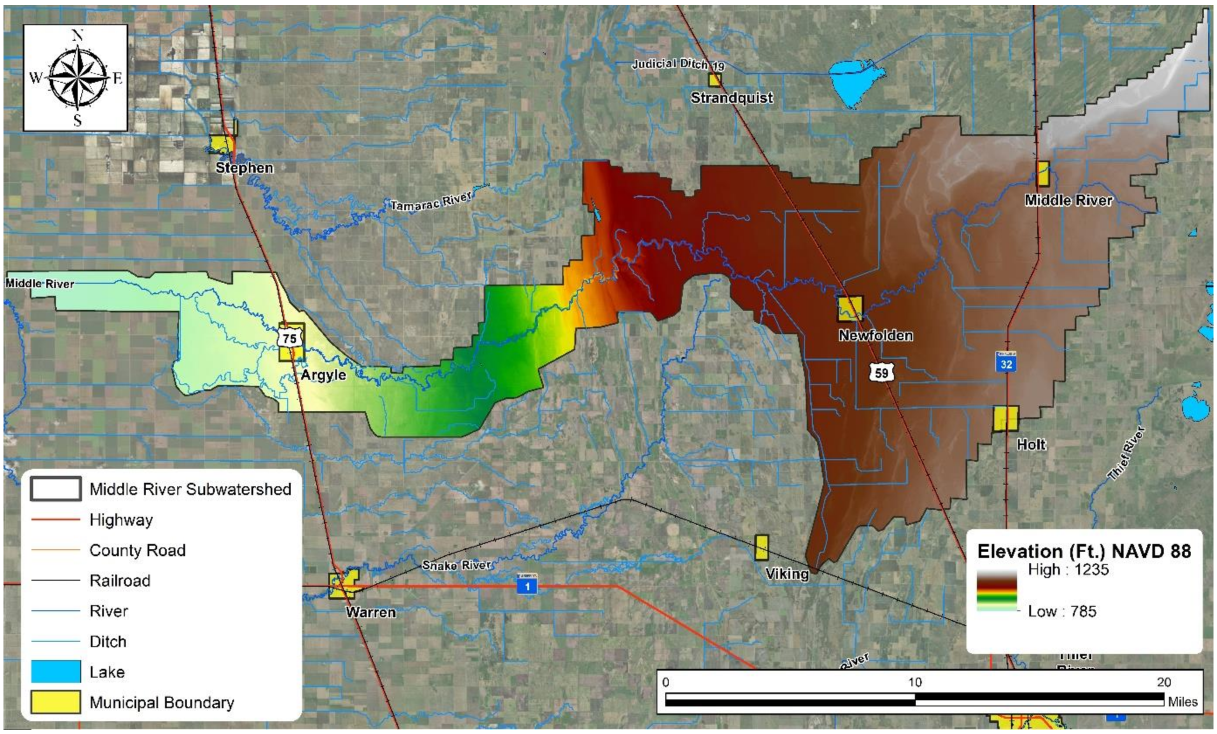

Figure 2-1. Middle River Subwatershed Topography

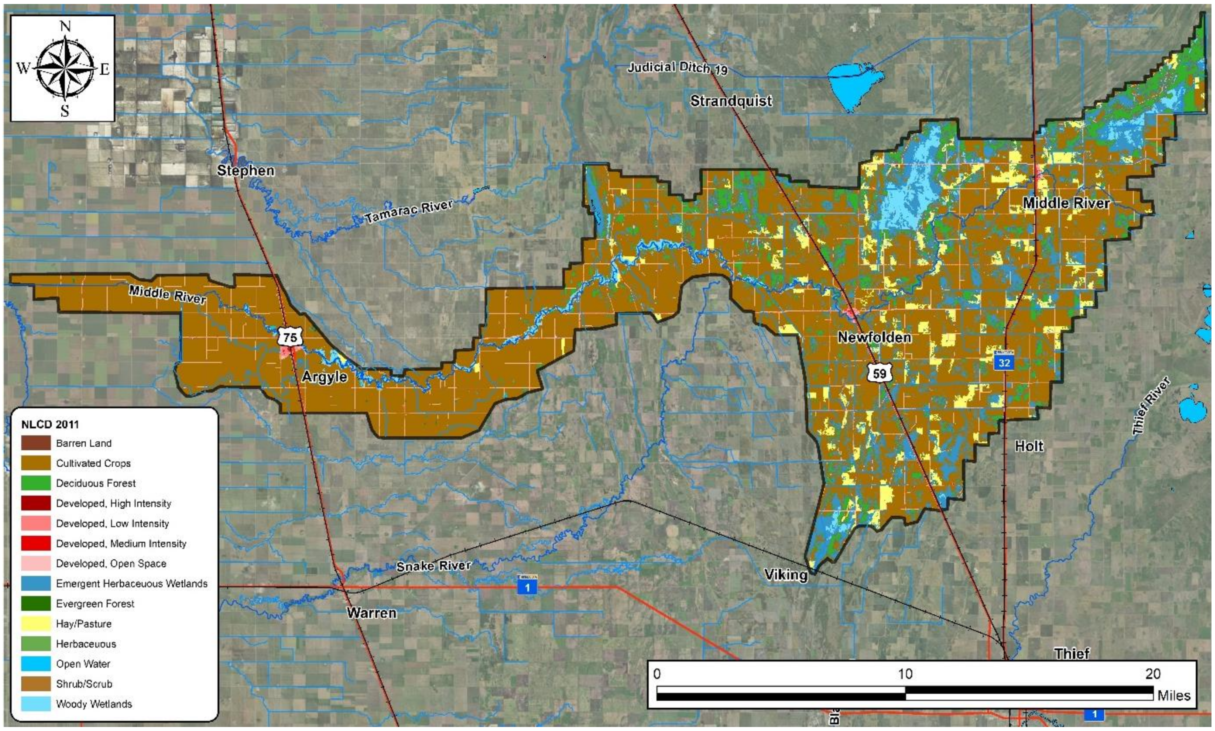

Figure 2-2. Middle River Subwatershed Land Use

2.2 City of Newfolden

Until 2015, the Department of Homeland Security's Federal Emergency Management Agency (FEMA) had not completed a Flood Insurance Rate Map (FIRM) or a Flood Insurance Study (FIS) for the City of Newfolden (City). The FEMA model from the 1980's was continuous through Newfolden, but the area was not mapped. FEMA has now released a preliminary FIRM and FIS for the City and it has placed the eastern half of the City in the 1% Annual Chance Floodplain. Due to the results of this study, the City of Newfolden is required to adopt a floodplain ordinance and all residents with structures within the floodplain area that are enrolled with a federally secured mortgage to obtain flood insurance. The preliminary FIRM as of October 20th, 2016 for the City of Newfolden is displayed in Figure 2-3.

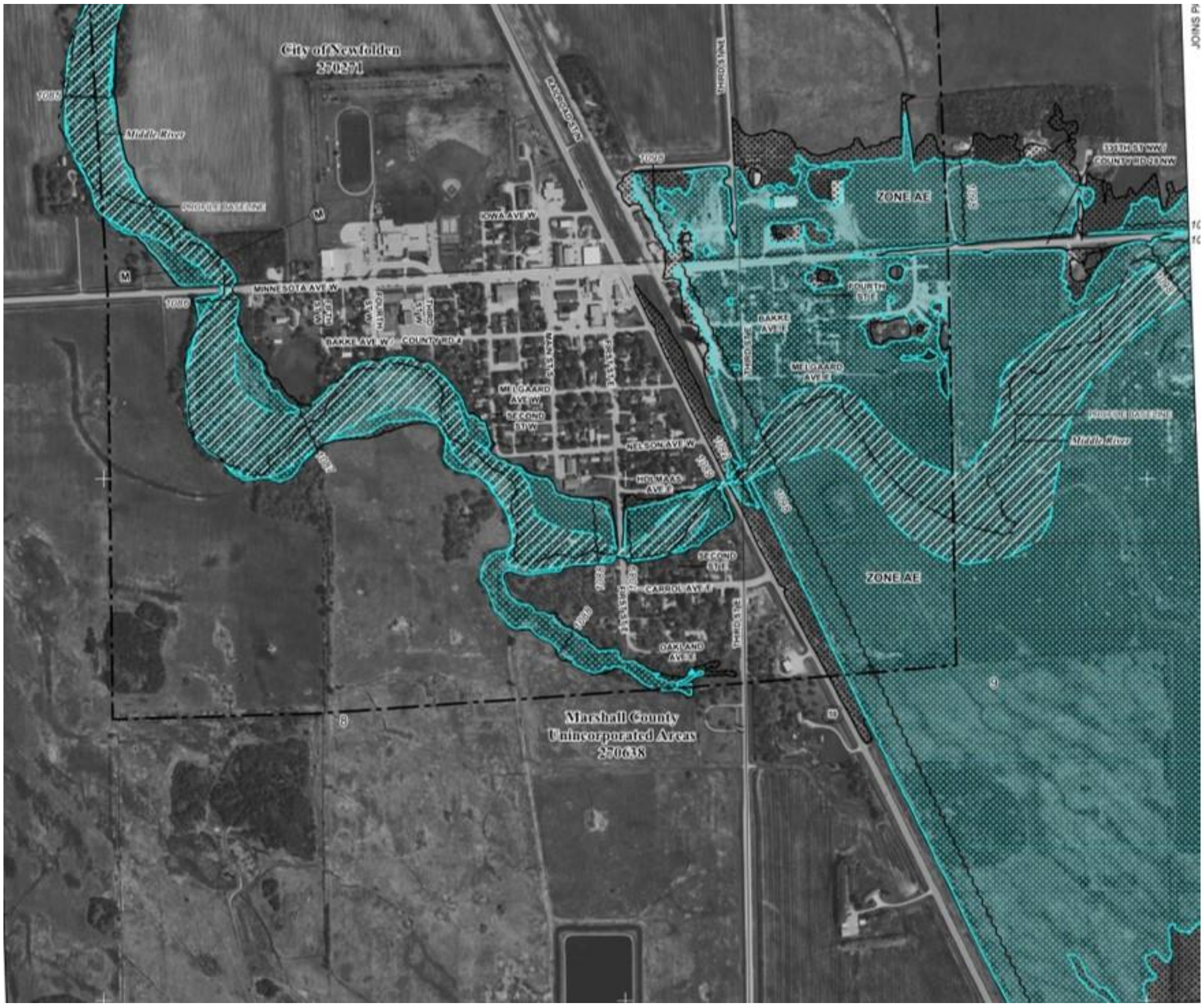

Figure 2-3. FEMA Preliminary Flood Insurance Rate Map (FIRM) of Newfolden, MN

Problem areas within the subwatershed are not localized to a specific region but are widespread. In October of 1996, 21 residents of the Middle River subwatershed filed a petition for the MSTRWD to construct an impoundment site on the Middle River to relieve flooding. The MSTRWD does not currently have a flood control project in place within the Middle River subwatershed but is exploring opportunities to enhance the region and alleviate flood and environmental risks. Placement of a flood control project near the City of Newfolden would have the dual benefit of flood damage reduction and protection for the City and its residents.

Figure 2-4 and Figure 2-5 display a portion of the flooding that occurred during the 2017 spring snowmelt. This snowmelt was considered minor in relation to historical records but still resulted in nuisance flooding. The peak flow recorded by the U.S. Geological Survey (USGS) Gage #05086900 occurred on March 29th, 2017 and was 550 cubic feet per second (cfs). This gage is located upstream of the City approximately 2.85 miles. The recorded historical peak flow at the same location occurred in May 1996 and was 2,300 cfs. The pictures below were taken on March 30th, 2017.

Figure 2-4. Railroad culverts inundated (Downstream Side)

Figure 2-5. Middle River west of State Highway 59 within Newfolden

2.3 Project Work Team

The Project Work Team process has been used to develop this Project. The Project Work Team consists of local landowners, the MSTRWD, the City of Newfolden, and several local, state, and federal agencies, including the Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MNDNR), the United States Army Corps of Engineers (USACE), and the Minnesota Board of Water and Soil Resources (BWSR).

3 Project Description and Design Criteria

3.1 Project Goals / Purpose & Need

The purpose of the project is to remove the City of Newfolden from the 1% Annual (100 Year) Floodplain a minimum of 1' below the accepted Base Flood Elevation (BFE) set by FEMA. This Purpose & Need (P&N) statement was formulated through the Project Work Team process and has been accepted by the team. The preliminary BFE referenced for the alternatives is 1,098.1'. This elevation is from the preliminary Flood Insurance Study dated October 20th, 2016. The minimum 1' reduction is a factor of safety for future development that may occur within the floodplain and potential increases to the BFE if remapping occurs.

The Project's primary goal is to meet the P&N statement, while providing downstream flood reduction benefits, and improvements to the local flooding near the Project location.

3.2 Red River Basin Region Wide Goal Initiative

A 20 percent reduction goal in peak flows along the Red River of the North during a flood event similar to the 1997 flood has been established by the Red River Basin Commission. The plan in place specifies that each tributary along the Red River must strive to meet their individual specific goals in reducing both peak flow and volume that have been set for them in the Red River Basin Commission's (RRBC) Long Term Flood Solutions (LTFS) Basin Wide Flood Flow Reduction Strategy Report. The goals for the Middle River Subwatershed were determined to be a 35% peak flow reduction and a 23% overall volume reduction at the USGS gage on the Middle River at Argyle, MN (USGS Gage 05087500). This 35% peak flow reduction is equivalent to 1,330 cubic feet per second (cfs) and the 23% volume reduction is equivalent to storing 15,067 acre-feet of water. The

MSTRWD has constructed several impoundment facilities since 1997 and is continually looking for opportunities to contribute toward the overall flood damage reduction goals and enhance the region. There are currently no impoundment facilities within the Middle River Subwatershed.

In 2012, two HEC-HMS models of the MSTRWD major subwatersheds were developed for the United States Army Corps of Engineers (USACE) as part of the Red River of the North Basin-Wide Modeling Approach Project. These models were modified further in 2014 as part of the Middle-Snake-Tamarac Rivers Watershed District Expanded Distributed Detention Strategy. The intent of this project was to identify areas within the subwatersheds where storage facilities could potentially be constructed and have a significant impact on the overall reduction goals for the watershed. The results of the project revealed that the Middle River subwatershed, especially near Newfolden, MN, is a strategic area for storage facilities and has the potential to greatly reduce peak flows for the watershed.

The MSTRWD has identified four regional assessment locations in their Ten Year Watershed Management Plan for the Middle River Subwatershed. These locations assist in evaluating the flood damage reduction and water quality goals set by the MSTRWD. Each regional assessment location has been assigned an approximate storage value by the MSTRWD. This value is the approximate storage required upstream of each location to meet the flow and volume reduction goals set by the RRBC. The four regional assessment locations within the Middle River subwatershed with their individual storage goals are displayed in Figure 3-1.

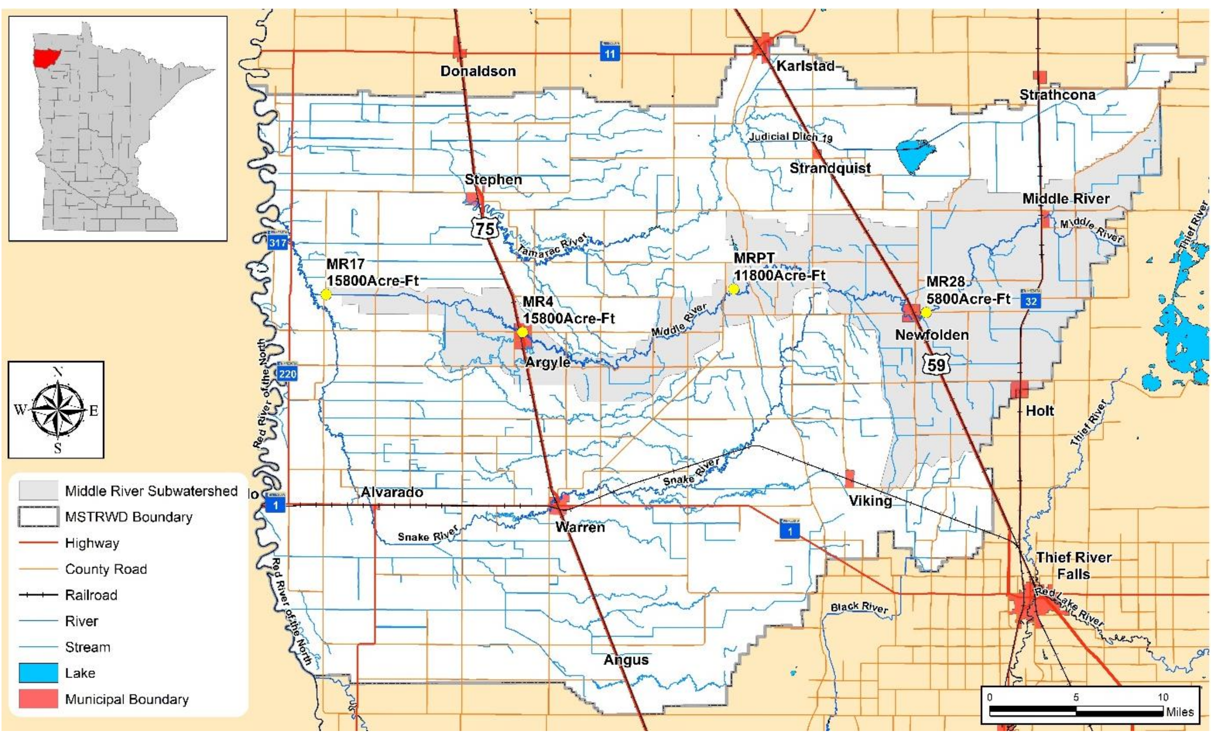

Figure 3-1. Middle River Subwatershed Regional Assessment Locations

3.3 Red River Basin Flood Mitigation Strategies

The Red River Flood Damage Reduction Work Group (RRFDRWG) Agreement of December 1998 is the framework for FDR projects in the Red River Basin. The purpose of the mediation process was to reach an agreement on long-term solutions for reducing flood damage and ensuring the protection and enhancement of natural resources. The MSTRWD encourages participation by local, state and federal governments, natural resource agencies, conservation organizations, and local citizens in the planning process. The Project is consistent with the Mediation Agreement goals adopted by the RRWMB and RRFDRWG.

The RRFDRWG formed a Technical and Scientific Advisory Committee (TSAC) to provide a series of technical papers that provide guidance to FDR methods. Technical Paper 11 (TP 11) was designed to provide guidance on where specific FDR methods can be placed in the Red River Basin to achieve the greatest benefits locally and downstream.

TP 11 has divided the Red River Basin into three timing zones for flows entering the main stem of the Red River of the North. These zones are the "Early Zone", "Middle Zone", and "Late Zone" runoff areas. Each area has recommended potential flood damage reduction measures that can be implemented to reduce flooding throughout the watershed. The Middle River Subwatershed is located near the border of the "Middle Zone" and "Late Zone". Table 3-1 provides a list of the flood reduction measure types, how they may be implemented within the Middle River Subwatershed, and the effectiveness in meeting the project goal. These reduction measures become important to consider for State Flood Damage Reduction and Red River Watershed Management Board funding. In order to obtain the maximum funding from either of these sources, it is beneficial to have a multi-purpose project that benefits the local and regional subwatersheds.

Table 3-1. Red River Basin Flood Damage Reduction Measures

Reduction Measure Types	Potential Applications within Middle River Subwatershed	Appropriateness / Ranking
Reduction of Flood Volumes	Conversion of upland areas to alternate land use, creation of wetlands, or cropland BMP's to reduce downstream runoff volumes and rates	Likely or substantial positive effects on downstream flooding
Increase Crossing Capacity	Increasing the flow capacity of the existing railroad structure within the Middle River or construct a diversion of the Middle River to reduce flood damages within Newfolden	Negative impact to downstream flooding
Protection / Avoidance	Evacuation of the floodplain or flood proofing of structures	Negative impact to the City of Newfolden & local economy
Temporary Flood Storage	Create Impoundments to reduce downstream peak flow rates	Likely or substantial positive effects on downstream flooding

3.3.1 Reduction of Flood Volumes

TP 11 specifies that a significant reduction in flood volumes could be attained by the creation or restoration of wetlands, converting cropland to grassland or forest, or implementing cropland BMP's such as forms of conservation tillage.

Transforming lands could potentially have a negative impact on the local economy and landowners. Requiring landowners to convert existing cropland to unproductive lands or implement best management practices would not be a practical solution as a flood control measure due to the limited percentage of land in production that is existing near Newfolden and the likely resistance from landowners due to loss of income. There is currently a high percentage of land that is forested or native grasslands in the surrounding area and upstream of Newfolden. Therefore, converting the remaining land would not result in benefits greater than the costs. As a result, this alternative has been dismissed from further consideration.

3.3.2 Increase Road Crossing Capacity

Increases to the railroad crossing capacity would reduce the flooding impacts east of the railroad tracks within Newfolden. An approach to increase the capacity could be to horizontally bore a smooth-steel casing pipe (SSP) through the existing railroad embankment, construct a new crossing with increased culvert sizes, or construction of a bridge. Another potential approach would be to divert a portion of the flow from the Middle River around the City of Newfolden to regulate the flows through the city. Each of these approaches could alleviate the flooding damages east of the railroad tracks but may also increase flow rates and the potential flooding in downstream areas. Technical Paper 11 states that there would be "likely negative impacts to downstream flooding" as a result of increasing conveyance capacities. As a result, this strategy would be difficult to fund through the Red River Watershed Management Board or the State Flood Damage Reduction program. Obtaining a Minnesota Department of Natural Resources Public Waters Permit and a MSTRWD permit without a retention area to mitigate the increased flow would be difficult due to the increased flow rates and potential downstream flood impacts. These strategies were outlined in the "Concept Feasibility Study" dated October 17, 2016 and were carried forward to the alternatives analysis since they could address the Purpose & Need statement either as a stand-alone alternative or within a comprehensive project.

3.3.3 Protection / Avoidance

Protection or avoidance is the removal of assets from the possibility of being impacted by flood damage. This strategy could be implemented within the City of Newfolden by the following:

- Buy-out of flood threatened homes and structures within the floodplain and restrict development in those areas
- Construct levees through the City along the Middle River
- Raise homes and structures above the BFE
- Flood-proof homes and structures at their current locations

The buy-out of flood threatened homes and structures would remove the entire eastern half of the city, force dozens of families to find new homes, and cause a tremendous negative impact to the area economy. The construction of levees would not address the Purpose & Need statement, would potentially result in the buyout of several homes, and could negatively impact landowners upstream and adjacent to the levee by increasing the floodwater elevation. Raising and the flood-proofing of homes also does not address the Purpose & Need statement and could cause an economic strain on landowners. Raising homes and structures also leads to uncertainty each year that natural occurrences such as ice jams could lead to a higher than anticipated flood elevation. As a result, this strategy was removed from further consideration but the results from the levee alternative were documented and studied in the "Concept Feasibility Study" dated October 17, 2016. This study does address the pros and cons of this strategy for this analysis.

3.3.4 Temporary Flood Storage

Flood storage is an effective method to reduce flood damage when impoundments are created to capture water at specific times of the local hydrograph. Impoundments can be designed for all three areas within the Red River Basin but are most effective at reducing downstream flooding when they are located within the "Middle" or "Late" zones. These locations would remove water from the early limb and peak of the local hydrograph. This would reduce the local water from contributing to the peak of the main river flows. Impoundments located in the "Early" area would be designed to remove water from the falling limb of the local hydrograph to prevent the later water from contributing additional water to a flood situation.

The "Concept Feasibility Study", determined that temporary flood storage could be an effective method in reducing the BFE at Newfolden and provide local drainage benefits. The BFE reduction will likely require a risk assessment to determine credible potential failure modes and consequences and analyze whether the project will successfully reduce the risks to the desired level. The reduced risk determination would then be reflected in reduced BFE's. The Feasibility Study documented the vetting of ten potential impoundment sites. From the study, five favorable sites were recommended as alternatives to carry forward for further analysis. These five sites were carried forward in the "Alternatives Analysis Study" dated April 2, 2018 as stand-alone alternatives and as a comprehensive alternative in conjunction with other flood reduction measures for further evaluation.

3.4 Alternatives and Options Considered

The alternatives evaluated from the "Concept Feasibility Study" and the "Alternatives Analysis Study" were modifications to the railroad crossing structure within the Middle River, two levee alignments protecting the eastern portion of Newfolden, two diversion channel alignments to direct flows from the Middle River around Newfolden, and six impoundment sites. A comprehensive project was also considered which would include a combination of the alternatives previously listed.

3.4.1 Railroad Crossing Structure Modification

Six culvert structure alternatives under the railroad were initially analyzed. The structures vary in size and type from a single smooth-steel pipe to multiple box culverts. The goal of a one foot reduction was applied to the results and it was concluded that the minimum structure required to meet the reduction goal would be the addition of two 60" Smooth-Steel Pipes. Based on this level of study, a structure with a minimum flow area of approximately 39 square feet would be required in addition to the existing structures to meet the P&N statement.

3.4.2 Levee Construction

Two levee alignments were analyzed to protect Newfolden east of the railroad tracks. These levees would require formal levee certification by an engineer, have a minimum side slope of 3:1 (H:V), and be constructed to a top elevation that is a minimum of three feet above the BFE to account for the required freeboard.

The first levee alignment would start at the Newfolden Co-Op Elevator and be constructed south, parallel to the railroad tracks. The levee would then pass east along East Melgaard Avenue to the eastern city limits. At that point, it would follow the city limits north until it reaches East Minnesota Avenue. This alignment would not provide protection to at least three homes due to their close proximity to the Middle River and may require the buyout of the homes or buildings. This alignment would also require the relocation of utilities and potentially the realignment or modification of existing City streets.

The second alignment would be identical to the first alignment but would continue east of East Melgaard Avenue and include the field directly east of the existing City limits. This additional land was included to account for potential future developments and provide additional flood protection. Each levee alignment is displayed in Figure A-3 of Appendix A of the "Alternatives Analysis Study".

3.4.3 Impoundment Sites

To meet the goals set by the Project Team, temporary storage of floodwaters upstream or downstream of Newfolden through the use of impoundment sites has been analyzed as an alternative. Using the regional assessment locations previously discussed, a LiDAR-derived digital elevation model (DEM) was utilized in ArcGIS to assess the Middle River Subwatershed and locate sites which have the potential to temporarily store excess runoff and therefore reduce peak discharges that would impact Newfolden. Sites were identified where there was a sufficient difference in topography for gated storage and where there would be minimal impact to residences and farms. These sites were further analyzed to determine where feasible bypass ditches could be constructed to divert runoff into the impoundment sites. The potential sites evaluated were ranked based on eight criteria to create an overall ranking matrix of the sites. The ranking criteria relates to storage capabilities, environmental impacts, landowner impacts, and constructability. The complete list of ranking criteria from the "Alternatives Analysis Study" is displayed in Table 3-2 and Table B-1 of Appendix B in the "Alternatives Analysis Study".

Table 3-2. Impoundment Site Ranking Matrix

Rating Multiplier	3.5		1		0.5		3		4		2.5		2		1.5			
SITE	Drainage Area Captured (Sq. Mi)	Rank	Elevation Drop Across Site (Ft)	Rank	Embankment Height (Ft)	Rank	Acres of Wetlands Impacted	Rank	AC-FT Storage	Rank	Inches of Runoff Captured	Rank	Number of Landowners Affected	Rank	Footprint (Acres)	Rank	Sum	Final Rank
A	22.7	4	10.0	6	12.0	5	27	5	1640.7	6	1.4	8	5	6	411	5	101.0	7
B	20.7	5	10.5	5	12.5	6	4	1	2493.0	3	2.3	4	2	2	463	6	63.5	1
C	62.7	1	11.5	2	13.5	8	6	2	2256.8	4	0.7	10	3	3	622	8	74.5	2
D	33.5	2	11.5	2	13.5	8	65	9	2876.1	2	1.4	7	7	10	642	9	99.0	6
E	25.0	3	6.0	8	8.0	2	50	7	1582.0	8	1.2	9	5	6	581	7	117.5	9
F	19.5	6	11.0	4	13.0	7	8	4	1630.5	7	1.6	6	3	3	293	3	94.0	4
G	9.7	7	9.0	7	11.0	4	6	3	1747.0	5	3.4	2	3	3	292	2	76.5	3
H	8.9	8	17.5	1	19.5	10	467	10	11318.0	1	23.8	1	5	6	1295	10	97.5	5
I	4.5	10	4.5	10	6.5	1	44	6	452.9	10	1.9	5	5	6	134	1	129.5	10
J	7.7	9	6.0	8	8.0	2	52	8	991.4	9	2.4	3	1	1	364	4	116.0	8

Legend	
1	Most Favorable
2	
3	
4	
5	
6	
7	
8	
9	
10	Least Favorable

Storage volume and drainage area were chosen as the priority ranking criteria for each site. Each potential drainage area was chosen using LiDAR to determine where runoff could be captured based on topography and existing waterways. The watershed planning tool on the Red River Basin Decision Information Network website was used to calculate the drainage area captured by each waterway that would be directed into the impoundment site. The total inches of runoff over the drainage area that the impoundment site would effectively store was determined by dividing the storage capacity by the total drainage area. Using ArcGIS, the potential site footprint was estimated and the gated storage elevation was determined based on the adjacent land elevation of the upstream ditches or roads. A stage-storage curve was created to determine the capacity of the gated storage. Two feet of freeboard was then added to the gated storage elevation to obtain the top of embankment elevation to provide the recommended freeboard. Using the flooded footprint, the impacts to wetlands and landowners was then determined. Table 3-2 summarizes the ranking procedure outlined in the following section. A total of ten sites were ranked with a value of one being the most favorable and a value of ten as the least favorable. A weighted value was assigned to each ranking criteria, with a higher weight assigned to the criteria that were deemed to be more influential in site feasibility. The weighted rank values where then summed for each of the sites with the lowest total receiving a final rank of one and the largest value a rank of ten.

Site Analysis

The top five retention sites based on the results of the matrix displayed in Table 3-2 were analyzed. The sites included Site A, Site B, Site C, Site F, and Site G. The location of these sites is displayed in Figure 3-2. A majority of the landowners within these sites were contacted in order to obtain feedback regarding these locations, identify poorly draining areas, and their current interest in participating in the alternatives process. The sites were then analyzed to determine the feasibility of capturing a large volume of water that would reduce the water surface elevation a minimum of 1' below the existing BFE for the eastern portion of Newfolden. These sites are all preliminary and changes may occur in geometry, storage capacity, and effectiveness. If an impoundment site alternative is chosen to proceed in the planning process, a topographic survey and further design will be required.

HEC-RAS was used to analyze the potential effects the top five sites would have on reducing the flood impacts east of the railroad tracks in Newfolden. Each of the sites was modeled by modifying the existing conditions unsteady HEC-RAS model in order to keep the geometry consistent. Site specific operating plans for each of the potential sites, inlet/outlet structure sizing, and ditch capacities were approximated. A summary of the results is provided in the following sections. The layout of each site was determined based on maximizing the benefits to Newfolden and the local drainage area. Future discussions will be held with landowners if a specific alternative moves forward in the project process for consideration.

Site A

Site A is located in section 10 of New Folden Township, one mile east of Newfolden. The tentative footprint is approximately 460 acres and impacts four landowners. There is an average of eight feet in elevation difference across the site from east to west. There would be approximately 2,300 acre-feet of storage at the maximum elevation of 1109.5' and the top of the embankment walls would be at an elevation of 1111.5'. Water would be diverted from the County Ditch 2 (CD 2) and County Ditch 25 Lateral 4 (CD 25 Lat. 4) drainage areas by constructing a gated structure within the ditch channel. A new inlet ditch would be constructed parallel to County State Aid Highway (CSAH) 28 on the south edge and would transport the diverted flows to the site. Minor diking would occur along the ditch near the site to prevent water from breaking into the neighboring landscape when the impoundment was at maximum capacity. Exterior ditches would be constructed along the dry side of the embankment walls to direct exterior runoff around the site. The outlet would be located on the west wall of the site and discharge to the Middle River through an existing coulee.

Site B

Site B is located in Section 11 of New Folden Township, two miles east of Newfolden. The current footprint is approximately 480 acres and impacts one landowner. There is an average of twelve feet in elevation difference across the site from east to west. There would be approximately 2,500 acre-feet of storage at an elevation of 1119.0' and the top of the embankment walls would be at an elevation of 1122.0'. Water would be diverted from the CD 2 and CD 25 Lat. 4 drainage areas by replacing the existing reinforced concrete arch pipe (RCPA) with a small diameter culvert and constructing an inlet channel to bypass flows to the impoundment site. The new inlet channel would be constructed parallel to CSAH 28 on the south side. Minor diking would occur along the ditch near the site to prevent water from breaking into the neighboring landscape when the impoundment was at maximum capacity. Exterior ditches would be constructed along the dry side of the embankment walls to direct exterior water around the site. The outlet would be located on the west wall of the site and discharge to the Middle River through an improved ditch along the southern side of CSAH 28.

Site C

Site C is located in Section 3 of Marsh Grove Township and is three miles west of Newfolden. The current footprint is approximately 625 acres and impacts three landowners. There is approximately ten feet in elevation difference across the site from east to west. There is approximately 2,250 acre-feet of storage at an elevation of 1073.0' and the top of the embankment walls would be at an elevation of 1075.0'. Water would be diverted from Judicial Ditch 15 (JD 15) along the north side of CSAH 28 through the construction of an inlet ditch and a gated structure within JD 15. Dikes would be required along the diversion ditch in order to prevent water from high flows from breaking out into adjacent overland areas. Exterior ditches would be constructed on the dry side of the embankment walls to direct exterior runoff around the site. The outlet would be located in the northwest corner of the site and discharge under 180th Avenue Northwest to an improved existing ditch. This site provides downstream storage for Newfolden. To achieve the most for Newfolden, flows from County Ditch 40 (CD 40) could be diverted west through the railroad tracks and enter the County Ditch 15 system (CD 15). The CD 15 system would then be diverted west to the JD 15 system. Each system would need modifications to increase their capacity.

Site F

Site F is located in Section 36 of New Main Township and Section 31 of Spruce Valley Township. It is approximately four miles northeast of Newfolden. The proposed footprint is approximately 300 acres and impacts three landowners. There is approximately eleven feet in elevation difference from east to west across the site which equates to approximately 900 acre-feet of storage. The maximum water surface elevation within the site is 1124.0' and the top of embankments walls is at an elevation of 1126.0'. Water would be diverted from County Ditch 2 (CD 2) to the northeast corner of the site by constructing a gated structure within CD 2 and directing flows to an inlet ditch. In order for the impoundment to fill to its maximum elevation, a gate or weir structure would be required at the inlet to prevent the stored water from back flowing through the inlet ditch as the water in CD 2 recedes. Exterior ditches would be constructed along the dry side of the embankment walls for exterior runoff at the site. The outlet would be located in the west wall of the site and would outflow to an existing coulee.

Site G

Site G is located in Section 33 of New Maine Township, which is approximately 1.5 miles north of Newfolden. The proposed footprint is approximately 396 acres and impacts three landowners. There is an average of eleven feet of elevation difference across the site from north to south. There is approximately 2,200 acre-feet of storage at an elevation of 1106.0 feet. The top of the embankment walls would be at an elevation of 1109.0 feet. Water would be diverted from Judicial Ditch (JD) 21 to the west on the north side of County Road 30 (350th St. NW), pass under County Highway 8, and flow south into the site. Exterior ditches would be constructed along the dry side of the embankment walls for local runoff at the site. The outlet would be on the southern wall and discharge back into JD 21.

3.4.4 Pierce Impoundment Site

The Pierce Impoundment Site is located on the JD 21 system at Hawkes Manufacturing Inc. Hawkes Manufacturing Inc. currently has a peat harvesting site approximately five miles north of Newfolden. The impoundment site would utilize the storage and berms created when the peat is harvested. There are currently six potential sites that could be transitioned into temporary storage locations and additional sites will be created as future harvests take place. The site would capture flows from the JD 21 system through earthwork and the construction of gates or weirs. These sites would discharge back into JD 21. Hawkes Manufacturing Inc. and the six parcels are displayed in Figure 3-3.

3.4.5 Diversion Channel

A diversion channel was proposed north of Newfolden along the southern side of 340th Street Northwest. The channel would begin at the Middle River at an invert of approximately 1097.0' and divert high water approximately 2.25 miles west under County Highway 8 to the railroad tracks. The channel would then pass water into the existing JD 21 outlet, through the railroad tracks, and under U.S. Highway 59 into an existing coulee to the river. The bottom width would be approximately 20 feet and have side slopes of 4:1 (H:V). The existing coulee would be improved by increasing the capacity, stabilizing the banks by cutting the slopes back, and implementing rock drop structures to prevent erosion at the river.

A second diversion channel alignment was analyzed on the north side of County Road 30. The channel would begin at the Middle River and divert high water to the west for approximately 2.25 miles to JD 21. The water could then travel around Newfolden within an improved JD 21 channel or continue to travel west to the location of Site G. Diverting the water upstream of Site G would provide the opportunity for storable water from the Middle River. The second diversion channel would require a deep cut through a ridge containing a mixture of silty gravel. The side slopes required would be at a minimum of 4:1 (H:V). The top width of the channel is approximately 200 feet in areas through the ridge and approximately 20 feet in depth. Each diversion alignment is displayed in Figure A - 9 in Appendix A of the "Alternatives Analysis Study".

3.4.6 Comprehensive Project

A comprehensive project was considered to maximize the benefits by combining multiple alternatives into one project. The combinations include the construction of an impoundment site with a diversion channel alignment or an impoundment site with a diversion channel and railroad crossing improvement. Combining multiple project aspects into one provides an increase in flood damage reduction and a greater factor of safety for the City.

A summary of the alternatives is displayed in Figure 3-2 and Table 3-3. The Pierce Site is displayed in Figure 3-3.

Table 3-3: Alternatives Summary

Railroad Crossing Improvement	Levee East of Railroad Tracks	Impoundment Site	Diversion Channel	Comprehensive Project
48" SSP	Existing City Limits	Site A	North Diversion Channel	Site A + Diversion
54" SSP	Expanded City Limits	Site B	South Diversion Channel	Site B + Diversion
60" SSP		Site C		Site C + Diversion
2 – 54" SSP		Site G		Site G + Diversion
2 – 60" SSP		Site F		Site F + Diversion
Box Culverts		Pierce Site		Impoundment Site + Diversion Channel + Crossing Improvement

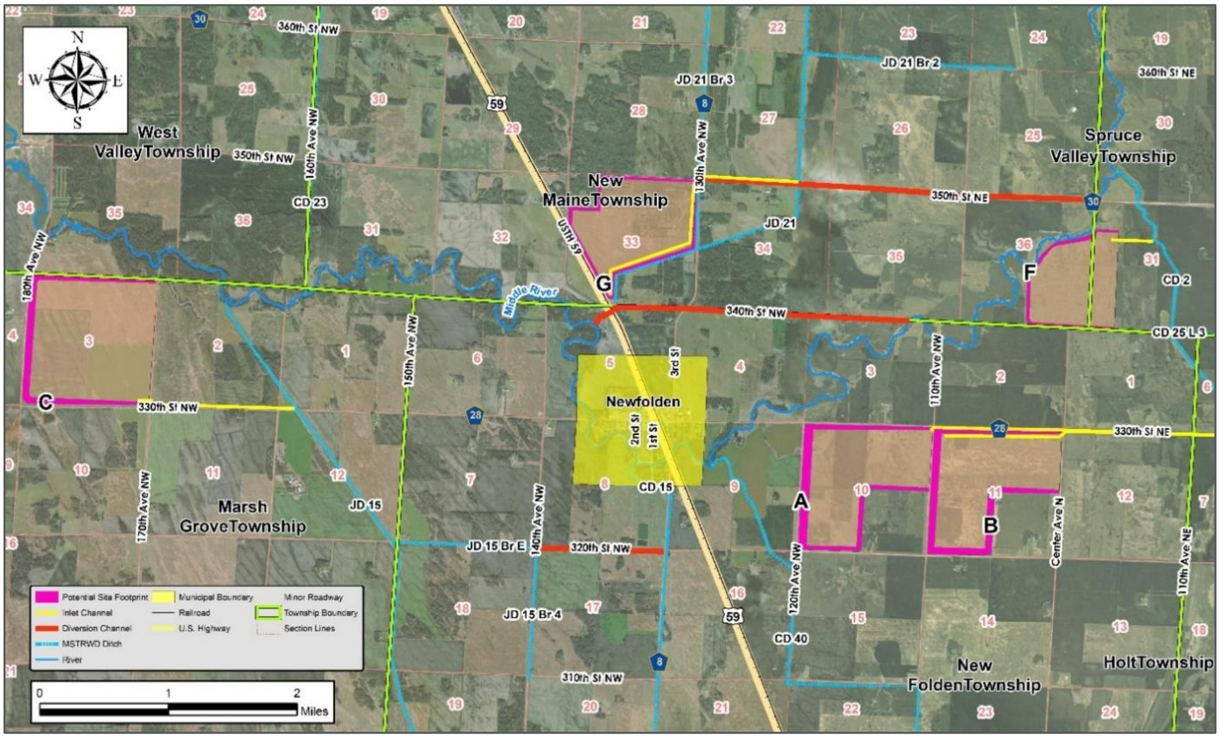

Figure 3-2: Alternative Locations

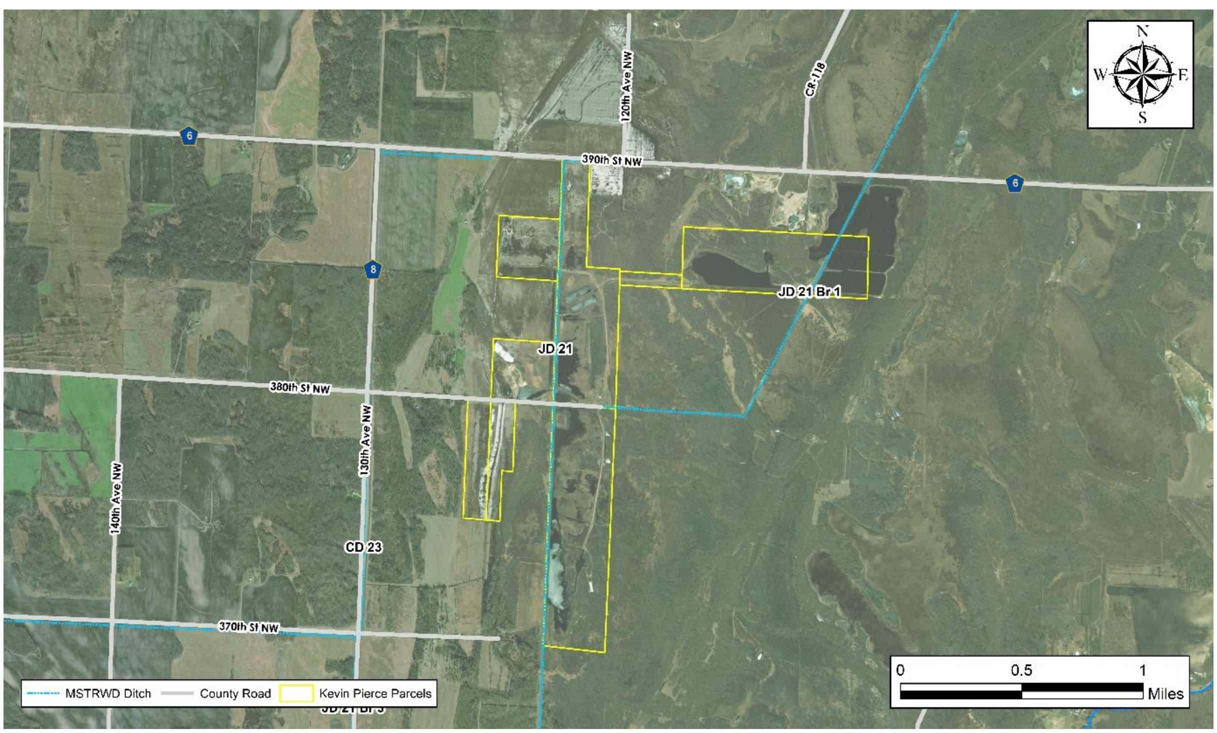

Figure 3-3. Pierce Site Location

4 Project Investigation

4.1 Data Collection

Data collected to evaluate the alternatives are listed in Table 4-1.

Table 4-1. Data Sources

Data	Date	Source	Vertical Datum	Description
Survey Data	2018	HDR	NAVD 1988	Survey of existing drainage systems including ditch geometry, culverts, utilities, and Site topography
LiDAR	2008	International Water Institute	NAVD 1988	1 Meter DEM and 2-foot contours

4.2 Hydrology

The HEC-HMS hydrologic model of the Snake and Middle River basins that was developed for the U.S. Army Corps of Engineers (USACE) in 2012 as part of the Red River Basin-Wide Modeling Approach (RRBWMA) project was used as a base model for the hydrologic analysis. Guidance developed since the creation of the base HEC-HMS model has been used to revise the model and develop the hydrologic analysis for this Project. The following sub-sections describe the revisions made to the model.

4.2.1 Subwatersheds

The project drainage area is approximately 257 square miles and made up of 57 subwatersheds with 106 square miles lying upstream of Newfolden, MN. The outlet location of the model resides near Argyle, MN. The contributing drainage area for each subwatersheds is displayed in Figure 4-1 and Table A-1 of Appendix A.

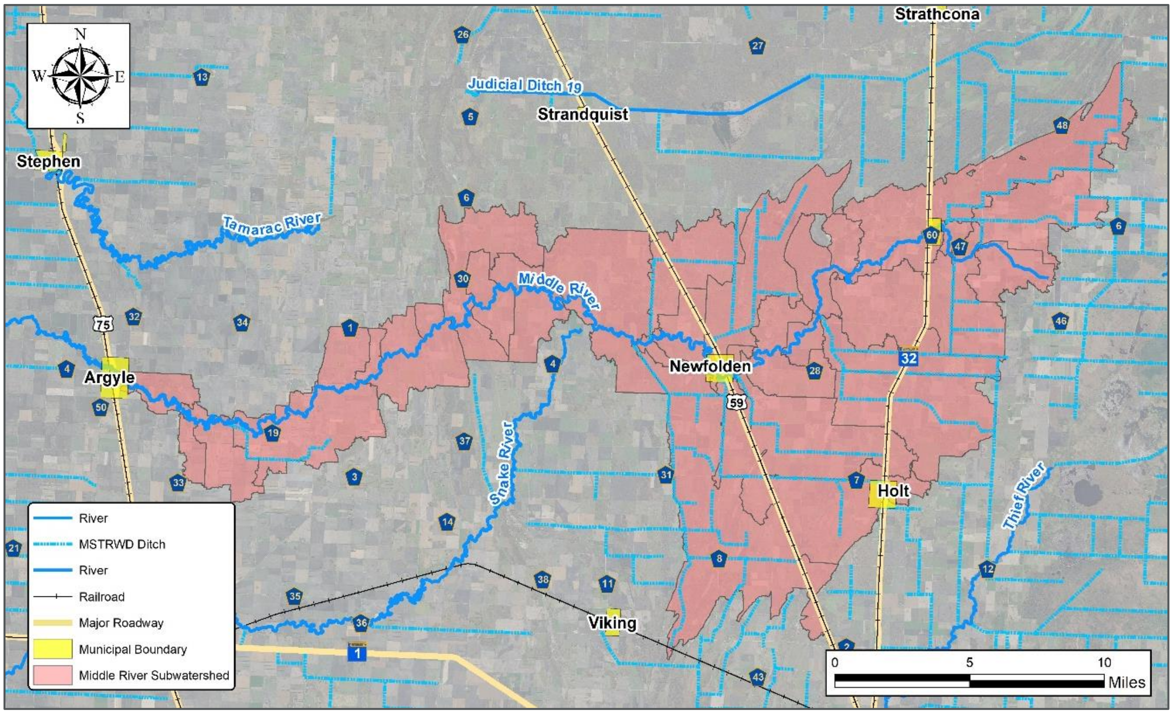

Figure 4-1: Subwatershed Drainage Areas

4.2.1 Time of Concentration

The time of concentration (T_c) is the travel time of a particle of water from the most hydraulically distant point in the subwatershed to the outlet. The T_c data in the USACE HEC-HMS model was derived using a Travel Time Routine that had previously been developed by the MnDNR. The tool applies a gridded version of the Manning's equation to calculate flow velocities throughout the contributing watershed drainage area using the 2001 National Landcover Dataset (NLCD) landuse, slope, and stream network as inputs. These flow velocities are converted into travel times and summed along the flow paths that terminate in the watershed outlet. The resulting output grid has an estimate of travel time from any given cell to the watershed outlet. The maximum difference in travel time within a subwatershed to the subwatershed's outlet is set as the T_c.

4.2.2 Design Storm Data

The Project design is based on the 100-year 10-day spring snowmelt event. A rainfall/precipitation depth grid was developed based upon the resultant runoff depth shown in United States Department of Agriculture (USDA) "Earths Dams and Reservoirs TR 60" for each subwatershed within the Project area.

The 100-year, 25-year, and 10-year 24-hour precipitation events were also analyzed for each impoundment alternative to analyze the inundation extent of each site. The precipitation depths for the 24-hour events were based on the Precipitation Frequency Atlas from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 8 data. This data was obtained at the central location of each subwatershed to provide an average rainfall depth.

The average precipitation depths used in the HEC-HMS analysis are displayed in Table 4-2.

Table 4-2: Average Design Precipitation Depths

Rainfall Event	Average Precipitation Depth (In)
10-Year 24-Hour	3.65
25-Year 24-Hour	4.55
100-Year 24-Hour	6.10
100-Year 10-Day	8.70

4.2.3 Design Rainfall Distribution

The 100-year 10-day distribution was obtained from Figure 6-4 of the Minnesota Hydrology Guide (Principle Spillway Hydrograph). This distribution was used within the USACE Red River Basin model to simulate the spring snowmelt event.

The 24-hour events were based upon a site specific rainfall distribution method as described in the United States Department of Agriculture (USDA) National Engineering Handbook (NEH) Chapter 4: Storm Rainfall Depth and Distribution (Draft) Appendix 4C. An individual rainfall distribution was created for the 10-year, 25-year, and 100-year 24-hour rainfall events.

4.2.4 Precipitation Losses

The basin models use the SCS Curve Number (CN) as a loss method. The 24-hour scenario CN values were determined by hydrologic soil group types (Soil Survey Geographic Database) and the landuse (2011 National Land Cover Data) prevalent in the area. Using the USDA National Engineering Handbook Chapter 9 and the USACE hydrologic modeling approach for the Red River of the North Basin models, a composite curve number for each subwatershed was calculated. The curve numbers for each landuse and soil type are displayed in Table 4-3.

Table 4-3: Landuse Curve Number Values

Landuse Type	Hydrologic Group				Reference
	A	B	C	D	
Residential	61	75	83	87	*NEH-9: Residential (1/4 ac)*
Commercial	89	92	94	95	*NEH-9: Commercial and Businesses*
Industrial	81	88	91	93	*NEH-9: Industrial*
Open Space	49	69	79	84	*NEH-9: Open Space, Fair Condition*
Agriculture	67	78	85	89	*RRBWMA: 80% row, 20% grains, contoured, Good Condition*
Meadow	30	58	71	78	*NEH-9: Meadow, Good Condition*
Woods/Grass Combination	30	55	70	77	*NEH-9: Woods, Good Condition*

Landuse Type	Hydrologic Group				Reference
	A	B	C	D	
Impervious	98	98	98	98	*NEH-9: Paved parking lots, roofs, driveways*
Vacant	39	61	74	80	*NEH-9: Pasture, Good Condition*
Water	100	100	100	100	-

4.2.5 Hydrograph Shape

The hydrograph transformation used in the RRBWMA is the Clark synthetic unit hydrograph. T_c and the SCS storage coefficient (R) were used as inputs for this method. A summary of the model inputs for each subwatershed are displayed in Table A-1 of Appendix A.

4.2.6 Peak Excess Runoff and Flows

Excess precipitation (runoff) hydrographs from each of the subwatersheds was obtained from the HEC-HMS model for each design scenario. The excess runoff is the precipitation that is not infiltrated into the soil and becomes surface flows and the design runoff for the Project. Table A-2 of Appendix A provides the peak flow rates for each subwatershed during the design scenario.

4.3 Hydraulics

The MNDNR created a steady-state hydraulic model using HEC-RAS 4.1.0 to assist FEMA with the City of Newfolden floodplain mapping initiative. HDR assisted in this modeling process by conducting a survey of the hydraulic structures located along the Middle River from 110th Avenue Northwest to 340th Street Northwest. This model was used as a starting point for the analysis.

HEC-RAS version 5.0.5 was used to perform all hydraulic computations of the existing conditions as well as the proposed design of the alternatives. The following methods and data were used for the hydraulic components of the analysis.

4.3.1 General Assumptions

Several assumptions were used in the development of the HEC-RAS models. These assumptions were implemented to simplify certain components of the models that were not required for this analysis. Additional modeling and survey will be required to address these assumptions.

- Where as-built and survey data were not available, ditch invert elevations were taken from available NAVD 1988 LiDAR data for the Red River Basin.
- All features within the existing drainage systems are assumed to be in good condition and functioning correctly.

4.3.2 Hydraulic Model Development

HDR modified the original MnDNR 1D steady-state HEC-RAS model by applying 2D flow areas along the overbank areas and converting the 1D portion of the model from a steady-state flow condition to an unsteady-state flow. Lateral structures were created to connect the 1D cross-sections to the 2D flow areas. This allowed the flows to pass between the 1D/2D areas to accurately determine the inundation extents. The 1D cross-section geometry obtained from the MnDNR was not altered.

A field survey of all ditches, hydraulic structures, and overbank areas along the alternative alignments was completed and used to create an existing ground surface in AutoCAD Civil 3D 2018. LiDAR data was obtained from the Red River Basin Mapping Initiative from the International Water Institute for the Red River of the North watershed. The existing ground surface was overlaid on the LiDAR surface and used to create an updated terrain of the Project area.

Existing landuse information was obtained from the NLCD 2011 data. The landuse information used in the model is displayed in Table 4-4.

The hydraulic structures were input into the model based on the gathered survey data and using aerial imagery where information was not known.

The runoff hydrographs for each of the design scenarios were obtained from the HEC-HMS runoff analysis previously discussed. These runoff hydrographs were input as a precipitation boundary condition within at their respective geographical location within the geometry.

The existing conditions model results for the 100-year 10-day spring snowmelt event are displayed in Figure 4-2. The results are consistent with the FEMA Preliminary FIRM.

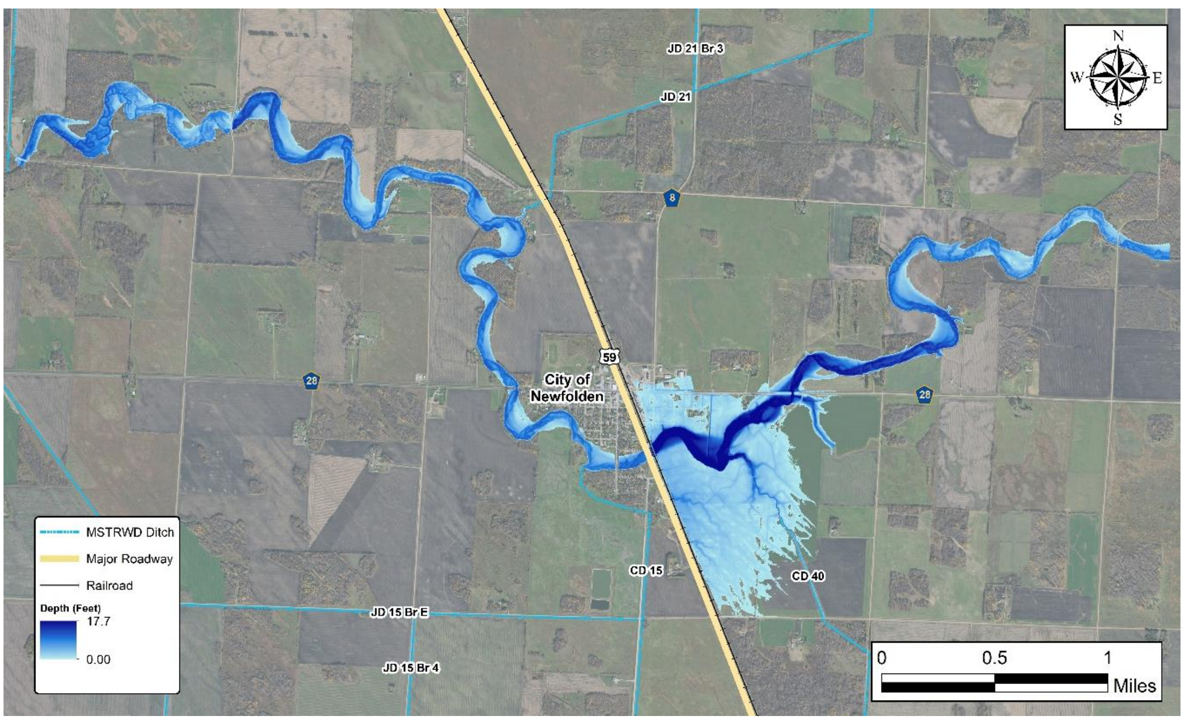

Figure 4-2. HEC-RAS 100-Year 10-Day Existing Model Conditions

4.3.3 Hydraulic Losses

System losses throughout the hydraulic models were accounted for through defining flow retardation resulting from overland Manning's values as well as loss coefficients and surface roughness for culverts. Manning's n values associated with landuse classifications are summarized in Table 4-4. Loss coefficients used in the hydraulic structures are summarized in

Table 4-5. Standard roughness values were used where applicable for the culverts are summarized in Table 4-6.

Table 4-4. NLCD Classifications Manning's n Values

NLCD Name	Manning's n
Cultivated crops	0.035
Deciduous forest	0.16
Developed, high intensity	0.15
Developed, low intensity	0.1
Developed, medium intensity	0.08
Developed, open space	0.04
Emergent herbaceous wetlands	0.07
Evergreen forest	0.16
Grassland/herbaceous	0.035
Open water	0.04
Pasture/hay	0.03
Shrub/scrub	0.1
Woody wetlands	0.12

Table 4-5: Hydraulic Loss Coefficients

Description	Loss Coefficient
Culvert Entrance Loss	0.5
Culvert Exit Loss	1.0

Table 4-6: Hydraulic Structure Manning's n Values

Description	Manning's n
Precast Reinforced Concrete Pipe/Box	0.013
Corrugated Steel/Metal Pipe	0.024

4.3.4 Design Flows

The existing conditions 100-year 10-day spring snowmelt peak flows used in the hydraulic analysis for each alternative are displayed in Table 4-7. These flows are within 3% of the flows used in the FEMA HEC-RAS model.

Table 4-7. 100-Year 10-Day Spring Snowmelt Design Flows

Location	Peak Flow Rate (cfs)
USGS Gage #05086900 (2.85 miles upstream of Newfolden)	2,200

Location	Peak Flow Rate (cfs)
City of Newfolden Immediately Upstream of Railroad Tracks	2,500

4.3.5 Existing Railroad Structures at Newfolden

The existing Canadian Pacific railroad waterway structures, located within the Middle River east of Highway 59 at Newfolden, MN, consists of two 96" corrugated steel pipes (CSP) and three 66" reinforced concrete pipes (RCP). An image of the downstream side of the railroad structures is displayed in Figure 4-3.

Figure 4-3. Existing Railroad Structures at Newfolden

As described, the primary Project goal is to remove the City of Newfolden from the 1% Annual Chance Floodplain. Based on the results of the MnDNR HEC-RAS model, the railroad structures restrict the flow of the Middle River through town thus causing a backwater effect which increases the probability of flooding to the eastern portion of Newfolden.

5 Selection of Preferred Alternative

5.1 Comparison of Alternatives

Five types of alternatives were analyzed that would potentially remove the City of Newfolden from the the1% Annual Chance Floodplain (100-year event). Each of the alternative types was analyzed based on meeting the Project design goals, Project implementation, and overall cost.

The pros and cons of each alternative were considered prior to the narrowing process. The findings from this study show that a modification to the railroad crossing will remove Newfolden from the floodplain, improve upstream drainage, and provide increased safety for train traffic. As a result to the improved flow capacity, there are increases in potential flood impacts downstream. These increases limit the potential funding partners and also make obtaining the required permits difficult. An improvement to only the railroad crossing would also leave the City susceptible to ice and log jams.

A levee would remove the City of Newfolden from the floodplain but would require certification and the potential relocation of utilities, infrastructure, and homes. This would all add a large cost to the project and if a future remapping of the area found that there was an increase in the BFE, the project would require modifications and recertification. A levee would also increase the potential flood impacts upstream and downstream.

The construction of a detention site or comprehensive project would remove Newfolden from the floodplain, improve upstream and downstream drainage, provide local flood benefits, alleviate the large head of water on the railroad crossing, and provide some environmental benefits. Due to their complexity and multiple benefits, they often have a greater funding source. This is beneficial because these projects are large and do have a high cost associated with them.

A diversion channel that would direct high flows from the Middle River around the City would remove Newfolden from the floodplain and provide improved upstream drainage. Similar to the railroad crossing improvement a diversion channel would increase the potential flood impacts downstream, limit the funding partners, and would be difficult to obtain the required permits.

The pros and cons of each alternative type is summarized in Table 5-1 through Table 5-4.

Table 5-1. Pros and Cons for Improved Railroad Crossing

Pros	Cons
Improves drainage flooding / drainage upstream	Increases flows and water elevations downstream
Removes Newfolden from floodplain	Difficult to obtain permitting
Increases level of safety for train traffic	Limited funding partners (No FDR or RRWMB)
	Susceptible to ice and log jams

Table 5-2. Pros and Cons for Diversion Channel

Pros	Cons
Improves drainage along system	Increases flows and water elevations downstream
Removes Newfolden from floodplain	Difficult to obtain permitting
Provides improved drainage upstream	Limited funding partners (No FDR or RRWMB on its own)
	Does not address railroad crossing issues

Table 5-3. Pros and Cons for Levee

Pros	Cons
Removes Newfolden from floodplain	Large costs (Relocating of utilities, infrastructure, homes, etc.)
	Increases flows and water elevation upstream/downstream
	Must be certified
	Can be insufficient if BFE is re-evaluated in future

Table 5-4. Pros and Cons for Impoundment Sites / Comprehensive Project

Pros	Cons
Improves drainage along system	Large costs
Removes Newfolden from floodplain	Potential wetland impacts
Reduces peak flows / volumes downstream	FEMA certification & risk analysis
Improves rural flooding along drainage systems	
Can provide riparian and environmental benefits	
Alleviates large head of water on railroad crossing	

5.1.1 Alternatives Screening

To begin the narrowing of alternatives, each was evaluated by the P&N statement. If the alternative met the criteria of removing Newfolden a minimum of 1' below the accepted Base Flood Elevation (BFE) set by FEMA, as stated in the P&N, it was not eliminated. This removed all improvements to the railroad crossing that did not increase the hydraulic capacity a minimum of approximately 39 square feet. This is equivalent to two 60" Smooth Steel pipes. The two levee alternatives were removed since they each increased the water surface elevations upstream and downstream of the railroad tracks. This occurred because the existing storage area within the City was removed with the construction of a levee. The water is then forced to rise on the surrounding landscape and create greater head pressure on the existing culverts. This increases the flows passing through the existing culverts and results in a higher water surface elevation and flow downstream. Detention sites C, G, F, and the Pierce location did not provide the storage capacity required to meet the P&N goal as a stand-alone alternative. As a result, these sites were also removed as viable alternatives. Each of the alternatives removed are still options for a comprehensive project but not as a stand-alone alternative.

Railroad Crossing Improvement	Levee East of Railroad Tracks	Impoundment Site	Diversion Channel	Comprehensive Project
~~48" SSP~~	~~Existing City Limits~~	Site A	North Diversion Channel	Site A + Diversion
~~54" SSP~~	~~Expanded City Limits~~	Site B	South Diversion Channel	Site B + Diversion
~~60" SSP~~		~~Site C~~		Site C + Diversion
~~2 – 54" SSP~~		~~Site G~~		Site G + Diversion
2 – 60" SSP		~~Site F~~		Site F + Diversion
Box Culverts		~~Pierce Site~~		Impoundment Site + Diversion Channel + Crossing Improvement

The remaining alternatives were then analyzed based on their local benefits such as not increasing flows upstream or downstream and improving the local drainage. The remaining railroad improvement alternatives and the diversion alternatives will improve local drainage but will also increase flows downstream. The additional flows downstream will increase the potential for flood damages to structures. These increases dismissed the railroad crossing improvements and diversion alternatives as viable options.

Railroad Crossing Improvement	Levee East of Railroad Tracks	Impoundment Site	Diversion Channel	Comprehensive Project
~~48" SSP~~	~~Existing City Limits~~	Site A	~~North Diversion Channel~~	Site A + Diversion
~~54" SSP~~	~~Expanded City Limits~~	Site B	~~South Diversion Channel~~	Site B + Diversion
~~60" SSP~~		~~Site C~~		Site C + Diversion
~~2 – 54" SSP~~		~~Site G~~		Site G + Diversion
~~2 – 60" SSP~~		~~Site F~~		Site F + Diversion
~~Box Culverts~~		~~Pierce Site~~		Impoundment Site + Diversion Channel + Crossing Improvement

The map displayed in Figure 5-1 shows the areas of increased flows and water surface elevations created by the installation of two additional 60" SSP. As stated previously, this is the minimum railroad crossing improvement required to meet the P&N. Directly downstream of the railroad crossing, the model shows an increase of 0.3' – 0.5' in water surface elevation. This increase appears to become negligible downstream near the City of Argyle, Minnesota, because floodwaters begin to break out of the Middle River and this overland flooding is difficult to attribute to a specific flooding source. The increase in flows downstream of the railroad tracks as a result of the modified crossing is approximately 100 – 150 cubic feet per second (cfs).

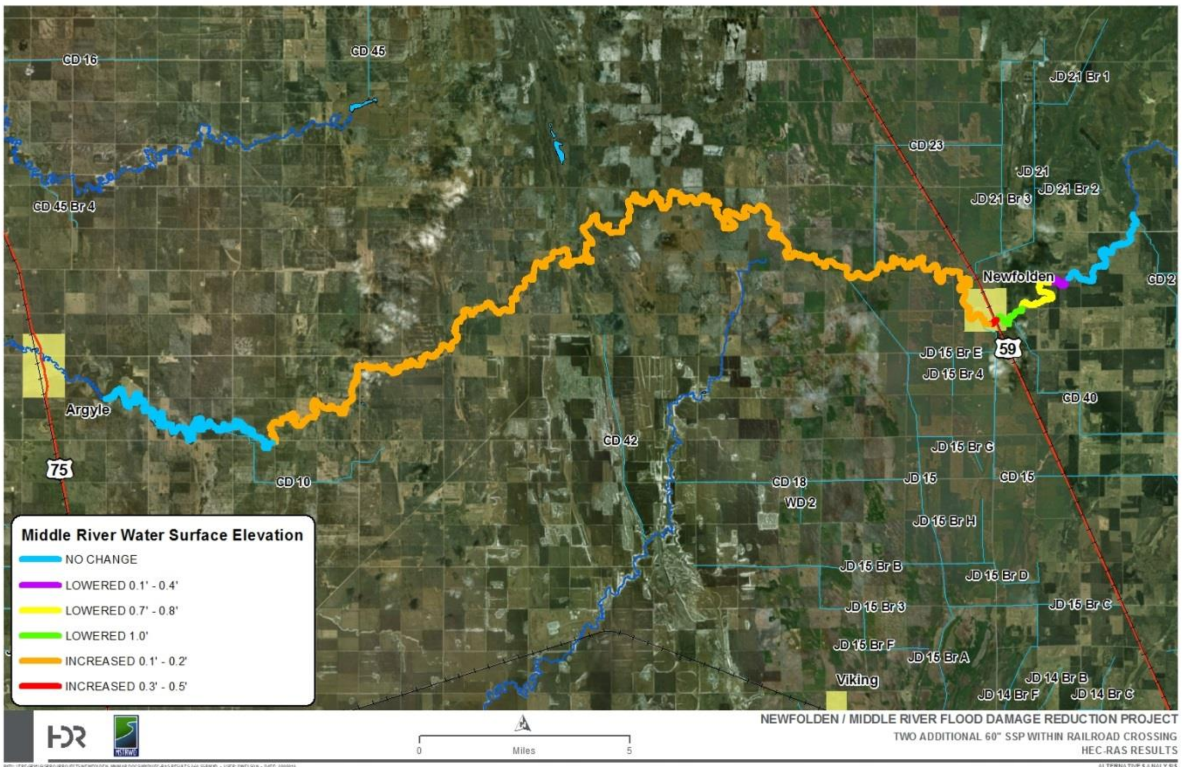

Figure 5-1. Downstream Impacts Resulting from Minimum Railroad Crossing Improvement

Each of the remaining alternatives include a detention site that would provide runoff storage that will meet the P&N, provide local drainage improvements, and not increase flood potential upstream or downstream. Public safety is always a concern when designing and operating a flood control project. These detention sites are required to follow design guidelines set by the Minnesota Dam Safety Standards and obtain a dam safety permit through the MnDNR. This ensures that these projects are designed and operated with the safety and well-being of the public as the main priority. Even so, all risk cannot be removed from anything that is done in all aspects of life. It is preferred that these sites not be constructed with homes or farmsteads immediately downstream of the embankment wall when possible. Using that recommendation as criteria for choosing preferred alternatives, Site A, Site A + Diversion, Site F + Diversion, and Site C + Diversion were removed from the remaining alternatives because there are homes located within 1,000 feet or less of the downstream embankment wall.

Railroad Crossing Improvement	Levee East of Railroad Tracks	Impoundment Site	Diversion Channel	Comprehensive Project
48" SSP	Existing City Limits	Site A	North Diversion Channel	Site A + Diversion
54" SSP	Expanded City Limits	Site B	South Diversion Channel	Site B + Diversion
60" SSP		Site C		Site C + Diversion
2 – 54" SSP		Site G		Site G + Diversion
2 – 60" SSP		Site F		Site F + Diversion
Box Culverts		Pierce Site		Impoundment Site + Diversion Channel + Crossing Improvement

The remaining alternatives are Site B, Site B as a comprehensive project, Site G + Diversion, or Site G as a comprehensive project. The two recommended alternatives for further study are Site B as a stand-alone project and Site G + South Diversion channel. Based on this level of analysis, Site B provides the storage capabilities necessary for removing Newfolden from the floodplain, as well as improving the local drainage along the CD 2 and CD 25 systems. Site G provides sufficient storage from the JD 21 system to mitigate the flows produced by the South Diversion channel and improves the local drainage along JD21. The South Diversion channel was chosen because it had less impact on the existing homes along the alignment and required less volume to be excavated than the North Diversion. The North Diversion impacted several structures and home sites.

Each of the preferred alternatives could also include a modification to the railroad crossing. A modification is not required to meet the P&N statement but would add an additional factor of safety for the City and its residents. The Pierce Site could also be constructed in addition to Site G to provide additional flood mitigation along JD 21. Figure 5-2 displays each of the recommended alternatives and their location in relation to Newfolden, as well as the optional railroad crossing modification.

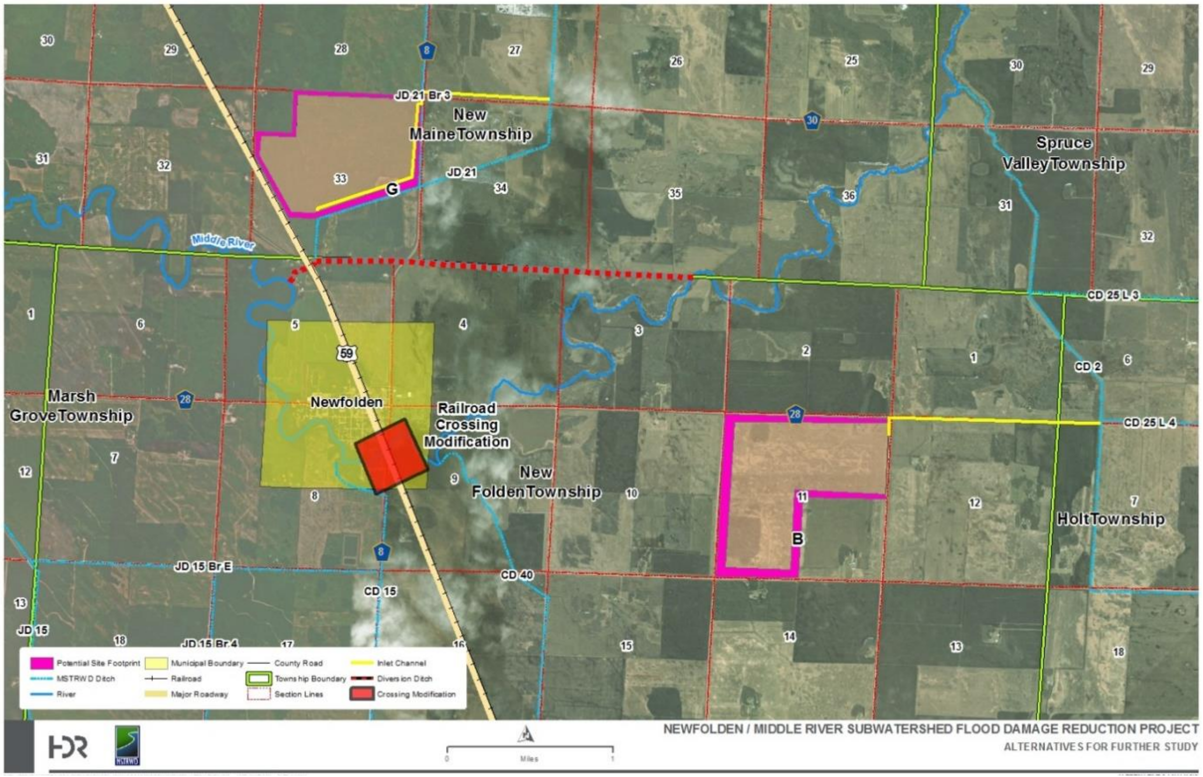

Figure 5-2. Preferred Alternatives Recommended for Further Study

5.2 Opinion of Probable Cost

Table 5-5 displays estimated costs for each of the proposed alternatives based on 2018 rates. A complete analysis of estimated quantities and unit costs for each alternative is provided in Appendix B.

Table 5-5. Engineer's Estimate of Probable Project Costs

Alternative	Construction[1]	Engineering & Administration[2]	Utility Relocation	Materials Testing	ROW Acquisition	Contingencies[3]	Total Estimated Project Cost
Site B	$3,077,044	$769,261	$10,000	$7,519	$1,075,800	$307,705	$5,247,329
Site G	$2,986,262	$746,566	$50,000	$9,780	$594,000	$298,627	$4,685,235
Diversion Channel	$2,426,964	$242,697*	$24,000	$21,600	$80,000	$242,697	$3,037,958
Railroad	$1,693,829	$338,766	$10,000	$300	$7,000	$423,458**	$2,473,353

[1] Summation of estimated quantities and unit costs (see Appendix B).
[2] 25 percent of estimated construction costs
[3] 10 percent of estimated total project costs

*10 percent of estimated construction costs
**25 percent of estimated total project costs

6 Preliminary Design of Preferred Alternative

6.1 Alternatives

On April 2nd, 2018, the MSTRWD Board of Managers accepted the "Alternatives Analysis Study" and directed HDR to conduct preliminary engineering for a preferred alternative. Each alternative would also have the option for a railroad modification. The following sections provide a preliminary analysis and recommends an alternative for final design.

6.2 Design Criteria

Design criteria were established to analyze the hydraulic adequacy of each alternative while maintaining a cost efficient design.

6.2.1 Maximum Water Surface Elevations & Downstream Impacts

The 100-year 10-day spring snowmelt event and 24-hr auxiliary spillway hydrograph (ASH) were used to determine the size and general features of the primary outlet structure. The 24-hour freeboard hydrograph (FBH) was used to size the emergency spillway to prevent overtopping of the impoundment embankment crest. The upstream and downstream impacts were considered in the spillway and outlet design. The structures were sized such that the existing infrastructure (i.e. roadways and railroad tracks) would not be impacted or inundated as a result of the Project. The alternatives were also sized in a manner that would not contribute to increased flows within the Middle River downstream of the Project location.

The 100-year 10-day spring snowmelt event was used to establish the maximum water surface within the impoundment. The 100-year 10-day rainfall/runoff event yields greater volume than the 100-year 24-hour event and is the event that has historically resulted in the largest flood impacts to the region.

In addition to the snowmelt event, the 10-year, 25-year, and 100-year 24-hour rainfall events were analyzed to determine the local flood improvements from each of the impoundment sites. These events have a tendency to occur over a smaller area than a spring snowmelt event and have a greater contribution to agricultural damages.

6.2.2 Design Storm Data

Precipitation depths were based on information provided in the Precipitation Frequency for Midwestern States, USA – NOAA Atlas 14 Volume 8. The computed depths for the ASH and FBH were developed based on TR-60 using a low hazard dam classification.

<u>Site G</u>

The ASH value is computed as:

$$ASH = P_{100}$$

The FBH value is computed as:

$$FBH = P_{100} + 0.12*(PMP - P_{100})$$

<u>Site B</u>

The ASH value is computed as:

$$ASH = P_{100} + 0.06*(PMP – P_{100})$$

The FBH value is computed as:

$$FBH = P_{100} + 0.26*(PMP – P_{100})$$

Where:

P_{100} is either the 100-Year 24-Hour or 100-Year 6-Hour event

Probable Maximum Precipitation (PMP) is either the 24-Hour PMP or 6-Hour PMP event for an area of 10 mi^2, consistent with the choice of P_{100}.

The PMP event was obtained from the Hydrometeorological Report Number 51. Based on Figure 20. – All season PMP (in.) for 24 hr 10 mi^2, the PMP was estimated at 27.4 inches for Site G and Site B. Table 6-1 provides the design rainfall depths.

Table 6-1. Design Storm Rainfall Depths

Rainfall Event	Site G Precipitation Depth (In)	Site B Precipitation Depth (In)
10-Year 24-Hour	3.65	3.65
25-Year 24-Hour	4.55	4.55
100-Year 24-Hour	6.10	6.10
100-Year 10-Day	8.70	8.70
Auxiliary Spillway Hydrograph (ASH 24-Hour)	6.10	7.40
Freeboard Hydrograph (FBH 24-Hour)	8.70	11.60

6.3 Diversion Channel

The Diversion Channel will bypass flows from the Middle River when the River reaches a water level associated with a 2 – 10-year frequency event. Two Diversion Channel alignments were considered. The original South Diversion and the South Diversion Alternative Alignment. The South Diversion alignment will bypass flows west along 340th Street Northwest where they pass through State Highway 59 and will enter into Judicial Ditch (JD) 21. The South Diversion is approximately 0.65 miles longer than the Alternative Alignment and includes an additional crossing structure. The South Diversion Alternative Alignment would bypass flows through a natural coulee from the Middle River in the northwest quarter of Section 3 of New Folden Township. The flows would be directed north to 340th Street Northwest, at which point they will follow the South Diversion alignment to the west. The South Diversion and South Diversion Alternative Alignment are displayed in Figure 6-1.

Through hydraulic analysis of each alignment, it was concluded that the South Diversion Alternative Alignment would not meet the P&N goal of reducing the BFE at Newfolden a minimum of one foot. This was due to the three foot decrease in water surface elevation within the Middle River from the South Diversion inlet location. The South Diversion alignment is the preferred diversion alternative. The following sections detail the design of the South Diversion alignment.

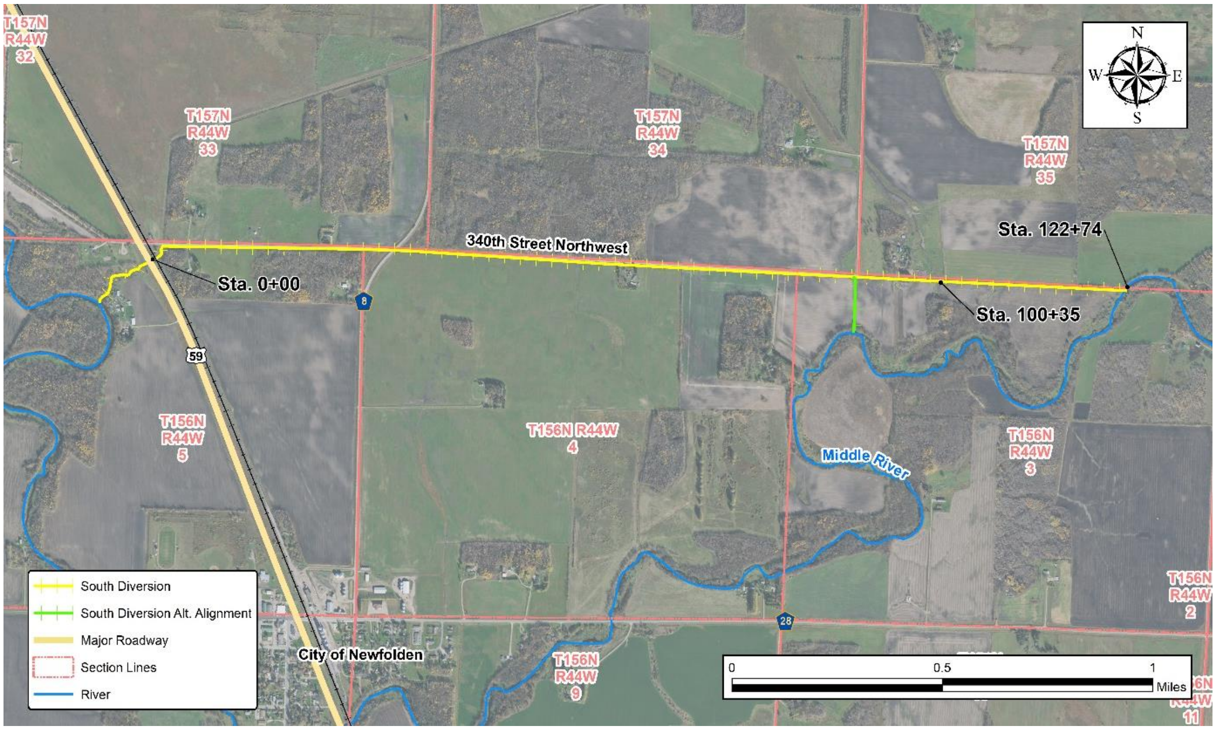

Figure 6-1. South Diversion Channel Alignments

6.3.1 Diversion Channel Cross-Section

Table 6-2 provides the proposed diversion channel geometry that meets the design criteria previously discussed. The typical cross-section is displayed in Figure 6-2.

Table 6-2: Proposed Ditch Geometry

Station	Description	Bottom Width (ft)	Average Depth (ft)	Side Slopes (H:V)
0+00 – 100+05	Diversion Channel	20	10 - 14	4:1
100+10 – 100+35	Diversion Channel	20 – 30 (Transition)	10 - 14	4:1
100+35 – 122+74	Diversion Channel	30	10 - 14	4:1

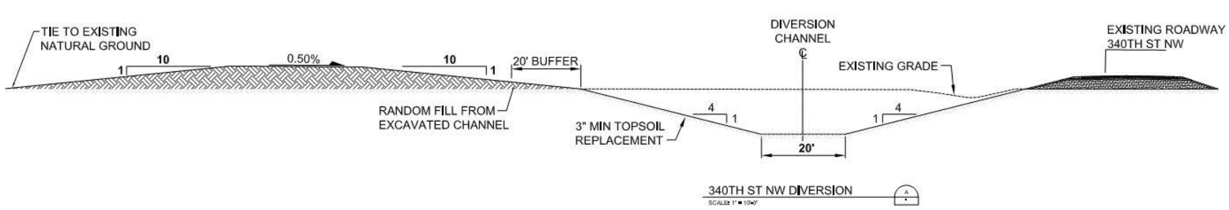

Figure 6-2. Typical Diversion Channel Cross-Section

6.3.2 Diversion Inlet Structure

The diversion channel inlet at the Middle River is a sheet pile weir structure. The inlet will have a top crest width of 30 feet at an elevation of 1097.0' and will be constructed into the banks of the River at a 4:1 (H:V) slope. A 10 foot concrete apron will be constructed on the downstream side of the weir six inches below the crest elevation to prevent scouring. Fractured granite will also be placed upstream and downstream of the structure for stability. Concrete bollards immediately upstream of the weir will be considered during final design to prevent large sheets of ice from entering the channel. Figure 6-3 displays the typical cross-section of the sheet pile inlet weir.

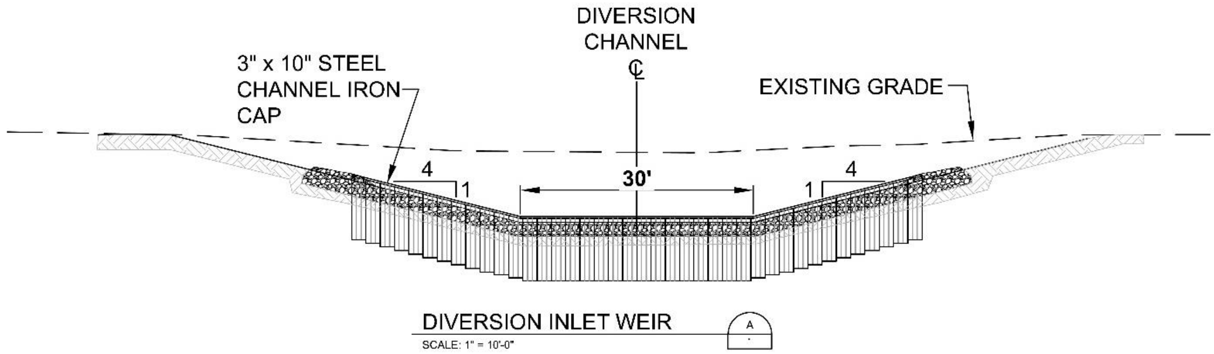

Figure 6-3. Diversion Channel Inlet Weir

6.3.3 In-Channel Hydraulic Structures

The proposed culverts were sized using the HEC-RAS 2D model discussed in Section 4.3. Figure 6-4 and Table 6-3 displays the culvert schedule for the Diversion Channel alternative. The water surface profile for the 100-year 10-day spring snowmelt event is displayed in Figure 6-5.

Table 6-3: Proposed Culvert Schedule

Location	Station	Existing Culvert	Proposed Shape	Proposed Size	Proposed Length (ft)	Proposed Material
Hwy 59	0+00	-	RCB	12' x 8'	117	Concrete
Railroad Crossing	1+00	(2) 84" RCP (1) 74" RCP	-	-	-	-
Driveway	5+55	18" CSP	Round	(2) 84"	120	Corrugated Steel
County Road 8	31+00	-	RCB	12' x 8'	217	Concrete
Driveway	79+73	-	Round	(2) 84"	148	Corrugated Steel
Field Crossing	94+63	-	Round	(2) 84"	136	Corrugated Steel

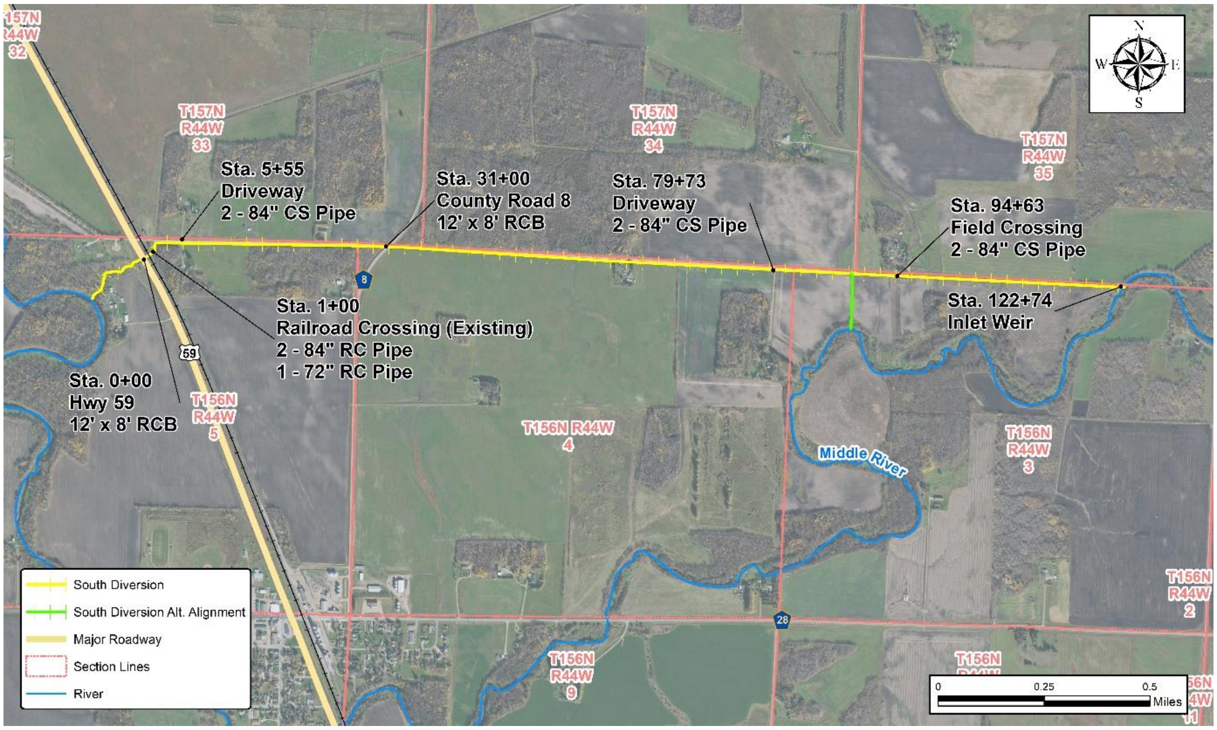

Figure 6-4. Diversion Channel Culvert Locations

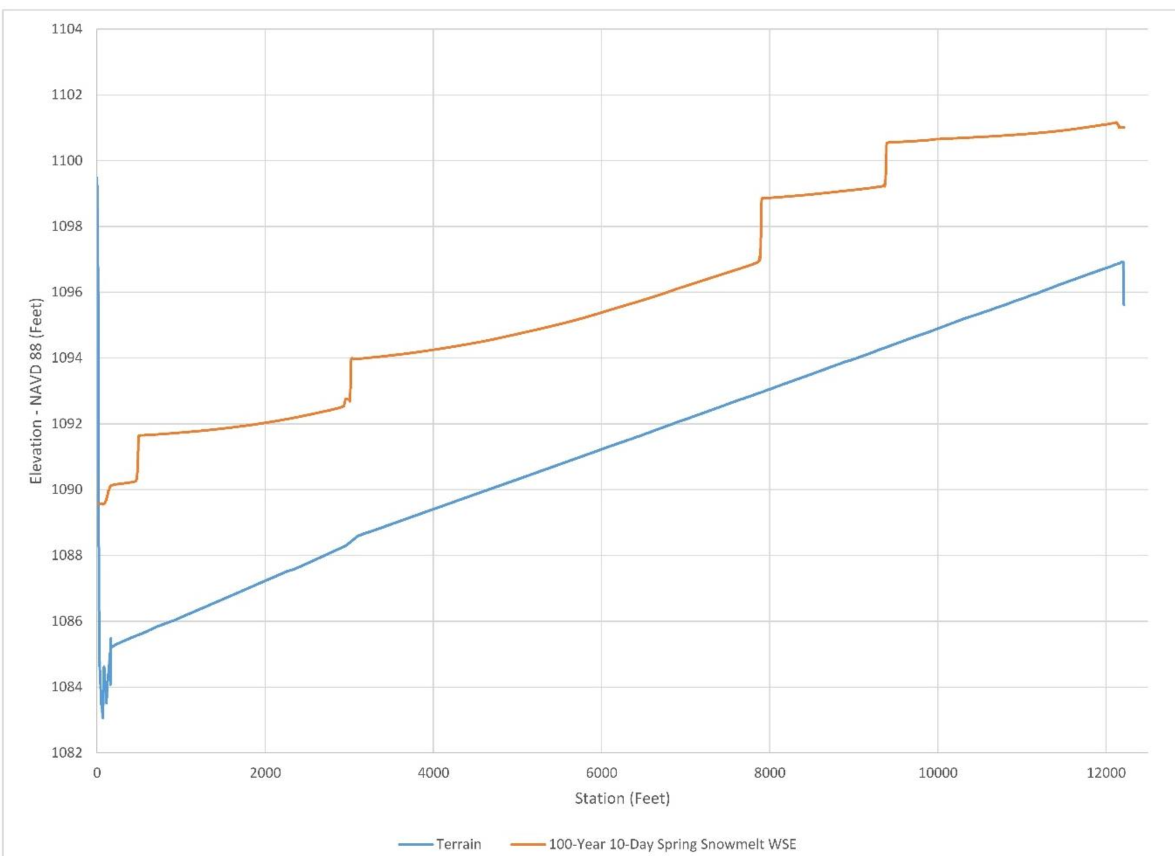

Figure 6-5. Diversion Channel 100-Year 10-Day Spring Snowmelt WSE Profile

A rating curve was developed within the Diversion Channel upstream of the railroad crossing location. Figure 6-6 displays the flow versus stage within the Diversion Channel for the 100-year 10-day spring snowmelt event. The peak flows for the snowmelt event within the Diversion Channel are approximately 350 cfs.

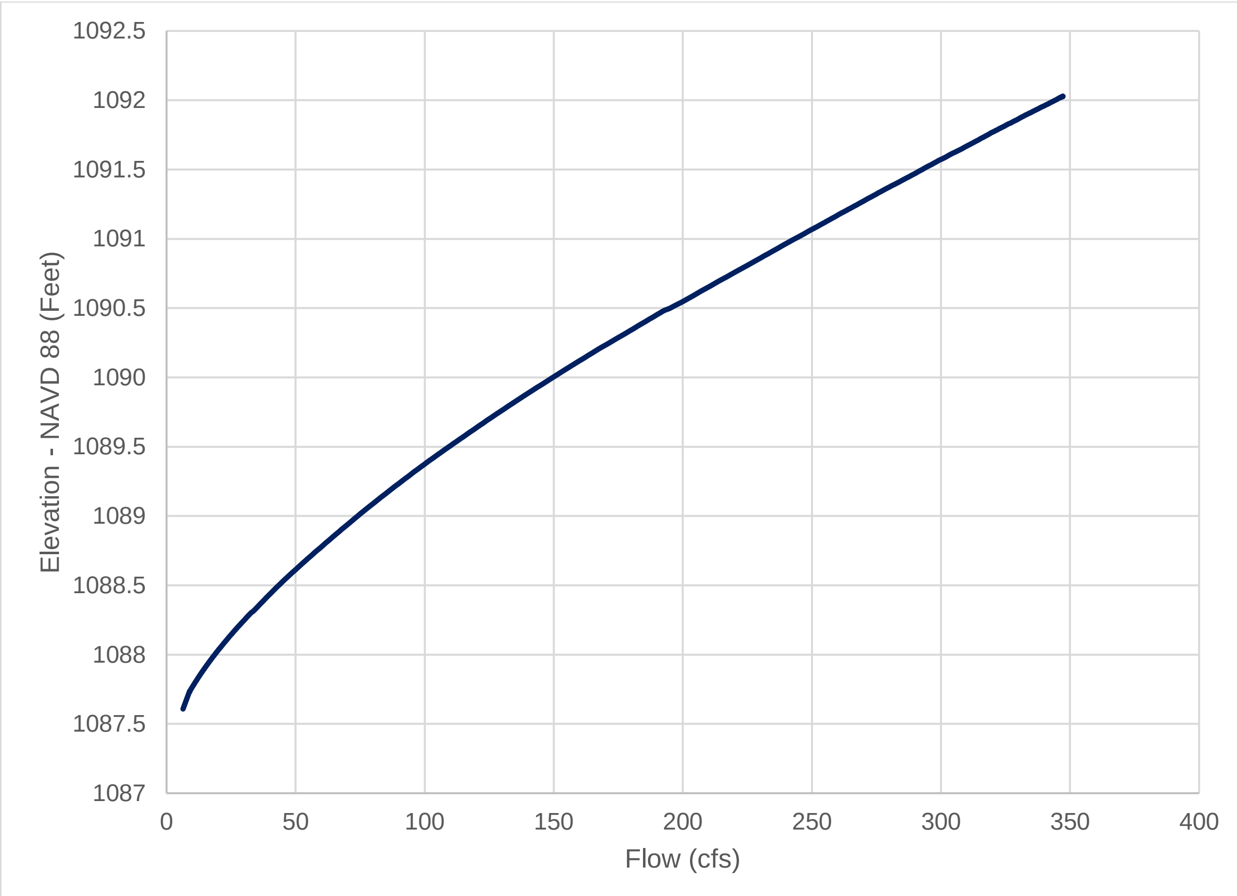

Figure 6-6. Diversion Channel Rating Curve

6.3.4 Outlet Improvements

The Project will discharge flows to the Middle River through a natural meandering coulee that currently discharges flow from JD 21 to the Middle River. This coulee, or outlet conveyance channel, is located north of the City west of Hwy 59. Improvements and channel rehabilitation measures will be implemented through the length of the outlet conveyance channel to stabilize the channel and minimize adverse impacts to the surrounding area. The location and existing topography of the outlet channel are displayed in Figure 6-7. The following sub-sections discuss the existing conditions at the location of the proposed outlet structure and as well as design alternatives.

Figure 6-7. Outlet Channel Plan View

Existing Conditions

The outlet conveyance channel is approximately 800 feet long and drops 10 feet in elevation between Hwy 59 and the Middle River (average 1.25% grade). The channel depth ranges from 10 feet near Hwy 59 to 17 feet near the Middle River. The soils in and around the coulee appear to be a mixture of sand, silt, and clay material with an underlying layer of fine gravel. A combination of recurrent peak flows, steep slopes, and erodible soils have caused significant head cutting, erosion, and sediment deposition in the channel, as shown in Figure 6-8 and Figure 6-9.

Figure 6-8. Erosion of Existing Channel

Figure 6-9. Head Cutting and Instability

Drop Structure Alternatives

Intermittent drop structures will be incorporated throughout the outlet channel. Each structure will be located and designed so that the energy created by peak flows can be dissipated in a controlled manner. Two types of drop structures have been considered and are discussed below.

Fractured Granite Chutes

This option would consist of three chutes constructed of fractured granite, each with a height of approximately 4 feet. Each chute would be 75 to 100 feet long with a grade between 5 and 7 percent. Fractured granite riprap would be sized to dissipate energy and would be placed in a matrix formation to remain in place during high flow events. Gradual channel grades between the structures would provide for stable and low-velocity flows to sustain a stable meandering channel. For visual reference, Figure 6-10 shows a conceptual layout of a fractured granite chute.

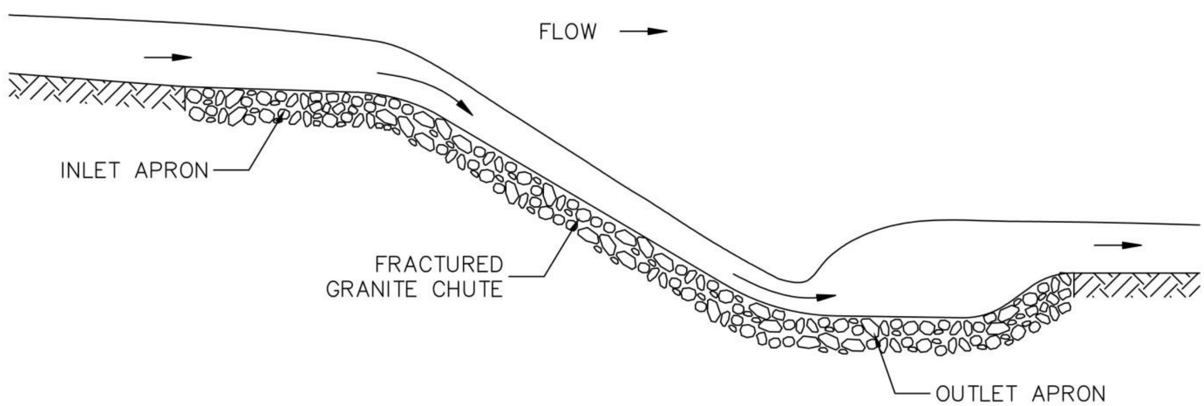

Figure 6-10. Example Fractured Granite Chute Profile

Constructed Stepped Pools

Constructed stepped pools are 3 to 6 inch tall vertical drops constructed of boulders or logs. The channel would have 20 to 40 drops spaced throughout the length of the channel. Gradual channel grades between the structures would provide for stable and low-velocity flows to sustain a stable meandering channel. Figure 6-11 shows a conceptual layout of a constructed step pool.

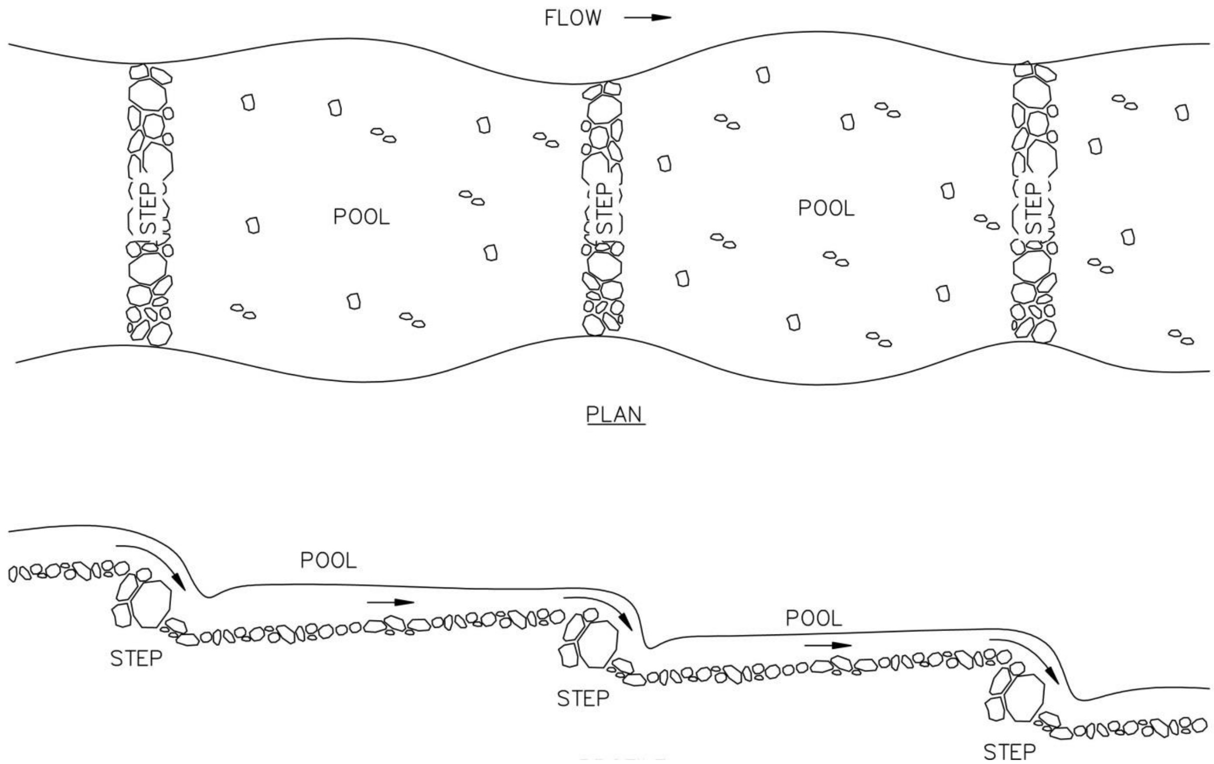

Figure 6-11. Example Step Pool Plan and Profile

Outlet Alternatives Summary

The outlet channel will consist of a one-stage channel with multiple drop structures spaced throughout the length of the channel to dissipate energy and prevent erosion. Dimensions and grade of the one-stage channel will be dependent on results of the on-site soils investigation and future hydraulic modeling. Drop structure type will be selected based on feasibility, cost, maintenance considerations, and aesthetic appeal during final design.

6.3.5 Diversion Channel Landowners

Discussions have been held with the landowners along the Diversion Channel alignment to inform them of the design concepts. Figure 6-12 displays the landowners along the proposed alignment.

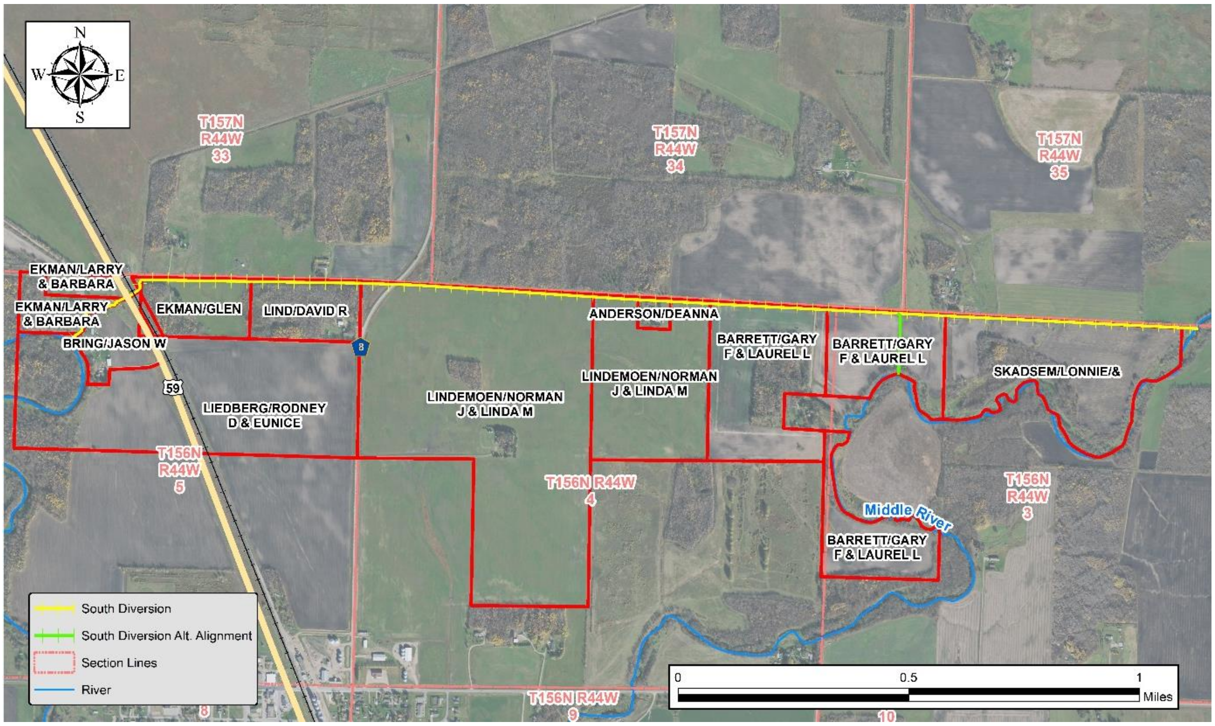

Figure 6-12. Diversion Channel Landowners

6.4 Site G and Site B Impoundments

6.4.1 Site G

Site G captures runoff from approximately 11 square miles of the JD 21 system. The site has the ability to capture 2,200 acre-feet of the approximately 5,000 acre-feet that passes through the JD 21 system during the 100-year 10-day spring snowmelt event. The maximum pool elevation of 1106.0 feet will be reached and the remaining flow will bypass the site through the existing JD 21 system and in the exterior drainage ditches to the Middle River. The 24-hour events previously discussed will not fill the impoundment to its maximum capacity. The drainage area and 24-hour inundation extents within Site G are displayed in Figure 6-13 and Figure 6-14.

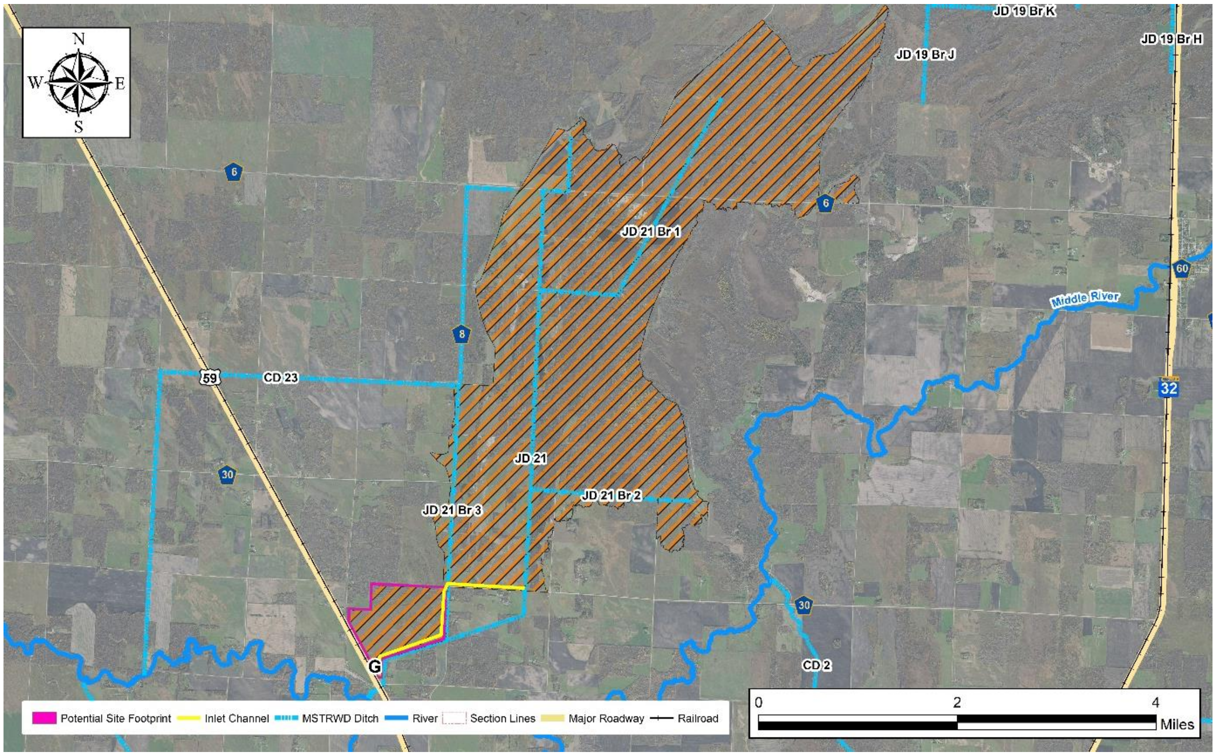

Figure 6-13. Site G Drainage Area

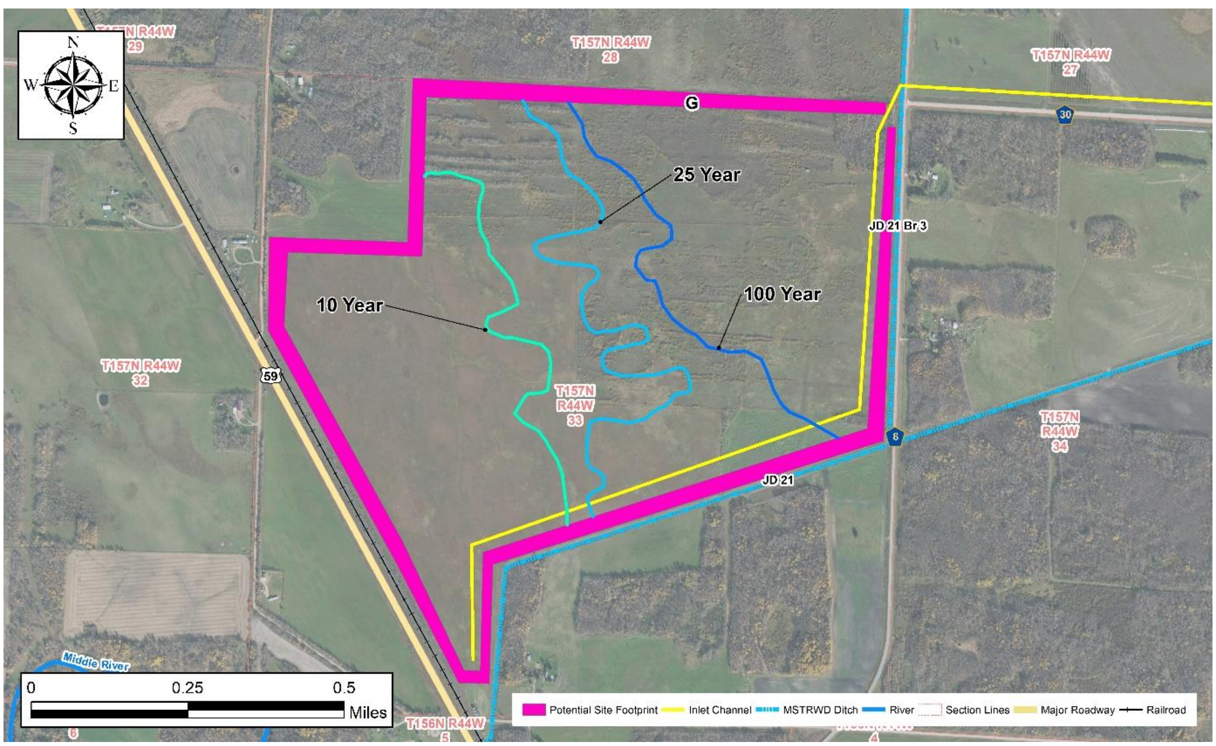

Figure 6-14. Site G 24-Hour Flood Event Inundation Extents

6.4.2 Site B

Site B captures runoff from approximately 16 square miles from the CD 2 and CD 25 Lat. 4 systems. The site has the ability to capture 2,500 acre-feet of the approximately 6,000 acre-feet that passes through the contributing systems during the 100-year 10-day spring snowmelt event. The maximum pool elevation of 1119.0 feet will be reached and the remaining flow will bypass the site through the existing CD 2 system and in the exterior drainage ditches to the Middle River. The 24-hour events previously discussed will not fill the impoundment to its maximum capacity. The drainage area and 24-hour inundation extents within Site G are displayed in Figure 6-15 and Figure 6-16.

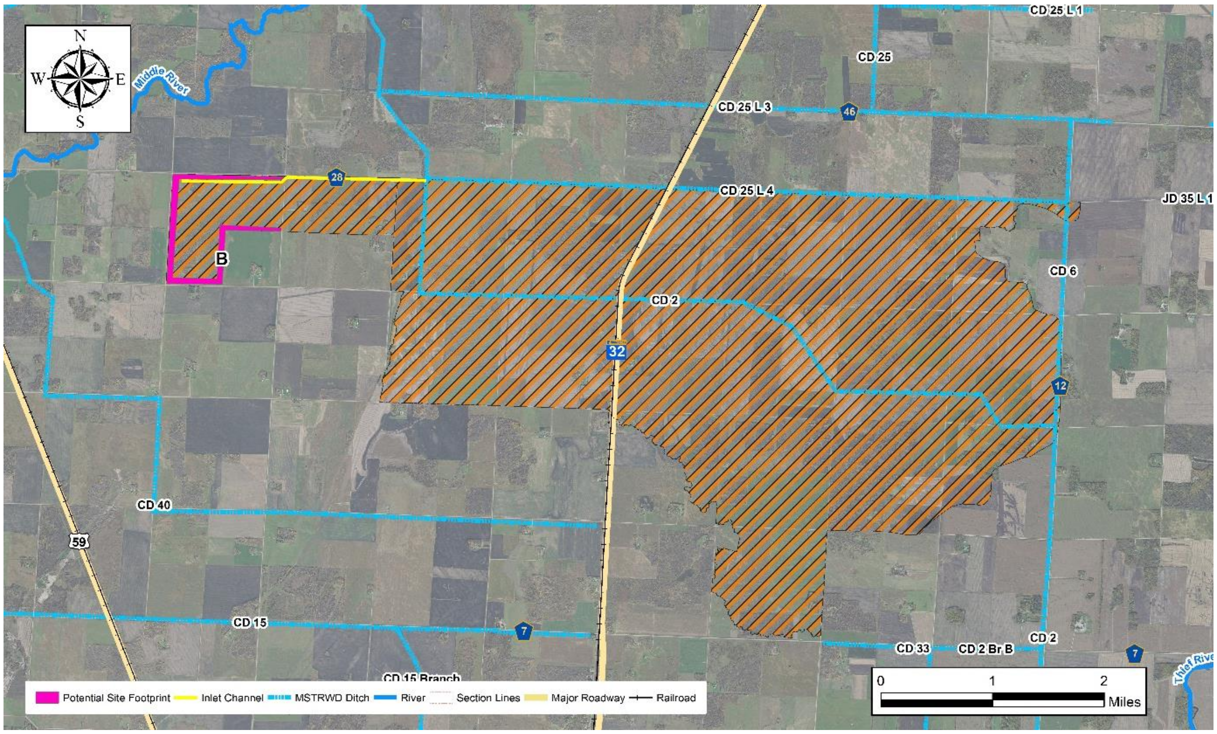

Figure 6-15. Site B Drainage Area

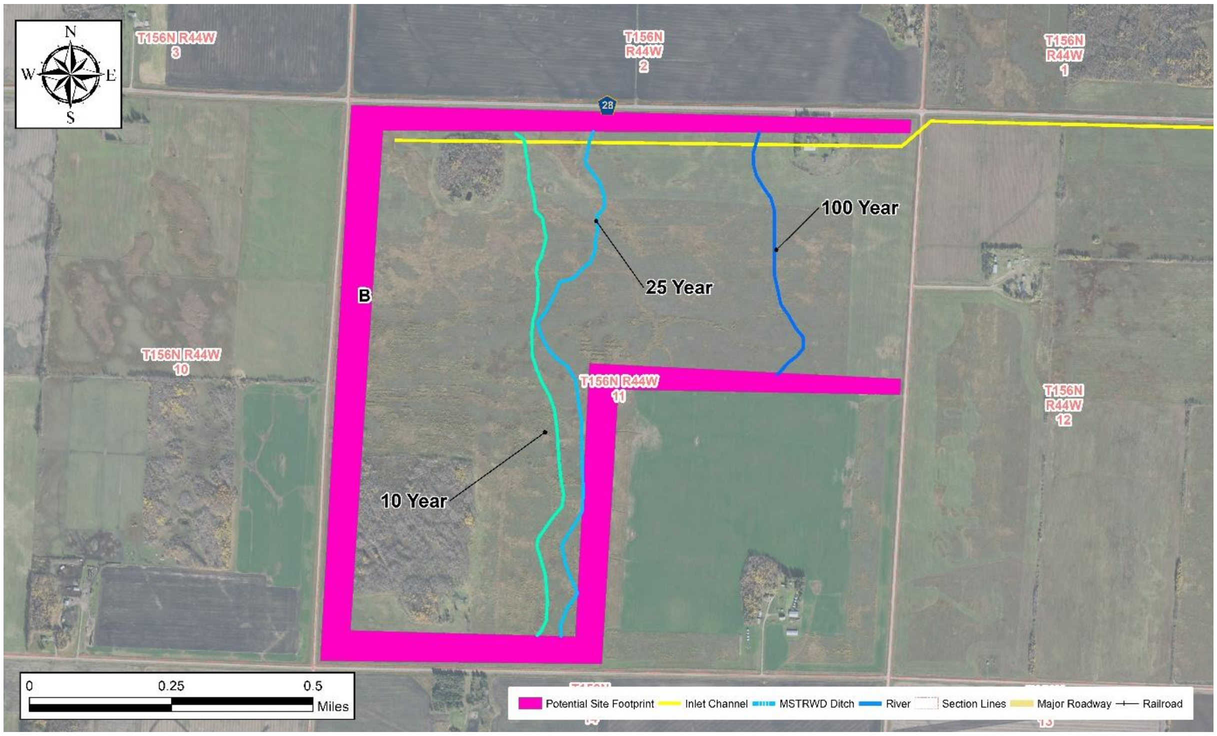

Figure 6-16. Site B 24-Hour Flood Event Inundation Extents

6.4.3 Inlet Channel

The impoundment inlet channels are four to seven feet in depth on average. Each has a bottom width of 10 feet and 4:1 (H:V) side slopes. The excess spoil will be graded at a 10:1 (H:V) side slope with a 20 foot grassed buffer. The typical inlet channel cross-sections for Site G and Site B are displayed in Figure 6-17 and Figure 6-18.

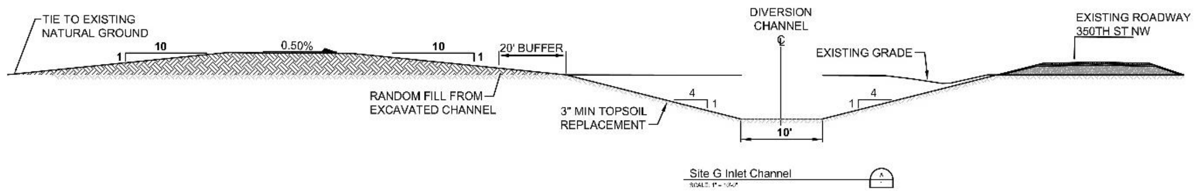

Figure 6-17. Site G Inlet Channel

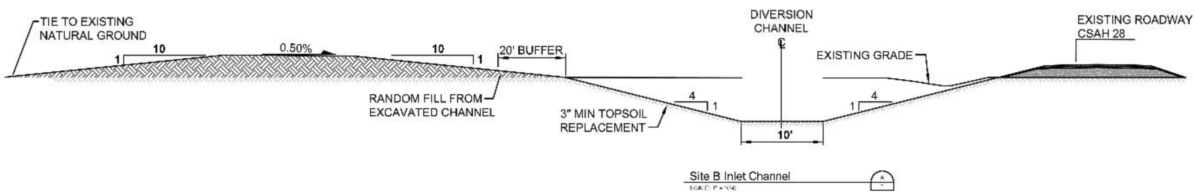

Figure 6-18. Site B Inlet Channel

6.4.4 Typical Embankment Cross-Section

Site G

The embankment cross-section for the site will have a 12 foot wide levee top, exterior side slopes of 4:1 (H:V) and interior side slopes of 5:1(H:V). The 5:1 side slope provides an increased resistance to erosion, improved wave dissipation, under seepage resistance, and the overall stability of the embankment is improved. The top of embankment is at an elevation of 1109.0 feet and has a maximum height of approximately 13 feet above existing ground. This elevation provides three feet of freeboard above the maximum water surface elevation of 1106.0 feet. The embankment will be constructed using lean clay material and will have a key trench that is 10 feet in width. The key trench will be required to be recessed one foot into the existing clay soils. Figure 6-19 displays the typical embankment cross-section.

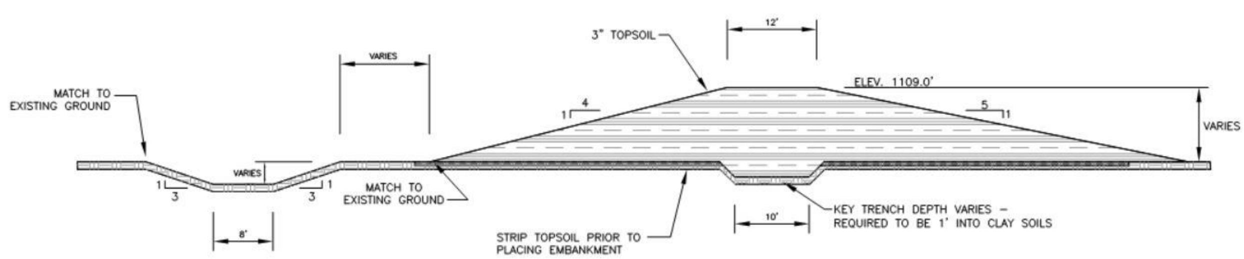

Figure 6-19. Site G Typical Embankment Cross-Section

Site B

The embankment design of Site B is similar as described for Site G. The top of embankment is at an elevation of 1122.0 feet and has a maximum height of approximately 13.5 feet above existing ground. This elevation provides three feet of freeboard above the maximum water surface elevation of 1119.0 feet. Figure 6-20 displays the typical embankment cross-section.

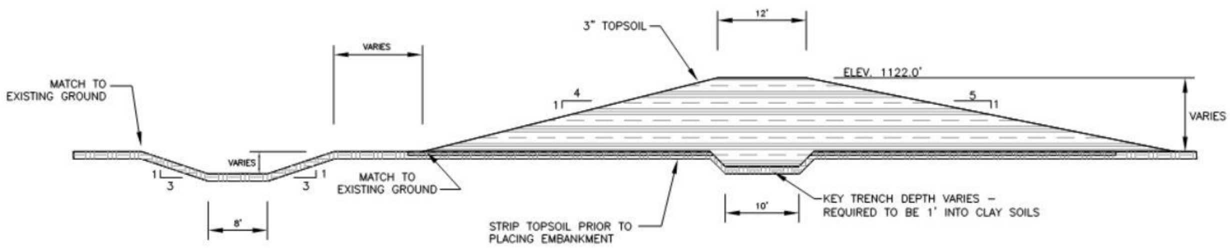

Figure 6-20. Site B Typical Embankment Cross-Section

6.4.5 Site Characteristics

Hydraulic Structures

Site G

A 48 inch corrugated steel pipe (CSP) is proposed through 350th Street Northwest in-place of the existing 115" x 72" reinforced concrete pipe arch (RCPA). This will reduce the flows downstream within JD 21 and encourage the majority of flow within the inlet channel. An inlet channel structure at the impoundment is not required. The adjacent landscape is sufficient in retaining the water within the impoundment and inlet channel when the maximum water surface elevation is reached. The crossing north of the inlet channel within JD 21 Branch 3 will have a 36 inch CSP with a flap gate in-place of the existing 18 inch CSP. The south side of the inlet channel will have a rock weir construction set at the maximum water surface elevation. This weir will allow water to bypass the impoundment once it is at capacity and flow into JD 21. The hydraulic structures for Site G are displayed in Figure 6-21.

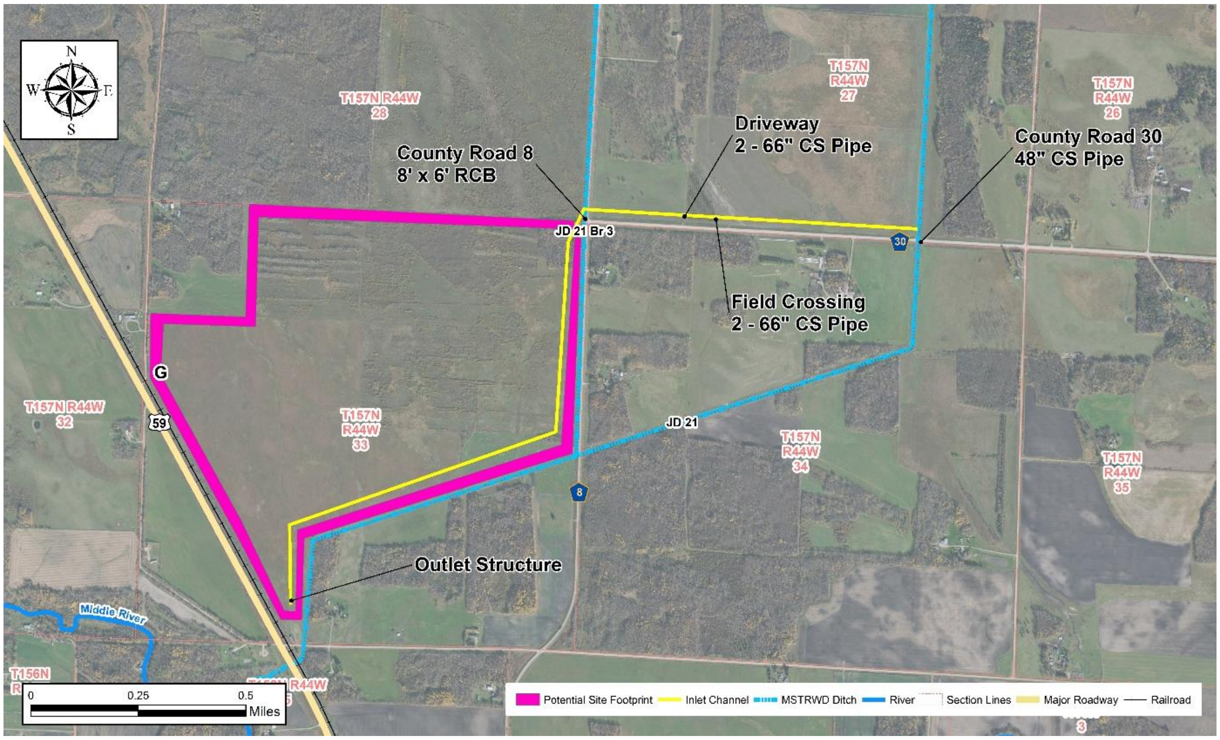

Figure 6-21. Site G Hydraulic Structures

Site B

A 48 inch corrugated steel pipe (CSP) is proposed through Marshall County State Aid Highway 28 in-place of the existing 115" x 72" reinforced concrete pipe arch (RCPA). This will reduce the flows downstream within County Ditch (CD) 2 and encourage the majority of flow within the inlet channel. An inlet channel structure at the impoundment is not required. The adjacent landscape is sufficient in retaining the water within the impoundment and inlet channel when the maximum water surface elevation is reached. A crossing north of the inlet channel within the CSAH 28 right-of-way will have a 36 inch CSP with a flap gate. This crossing will have a rock weir construction set at the maximum water surface elevation. This weir will allow water to bypass the impoundment once it is at capacity and flow west to the Middle River. The hydraulic structures for Site B are displayed in Figure 6-22.

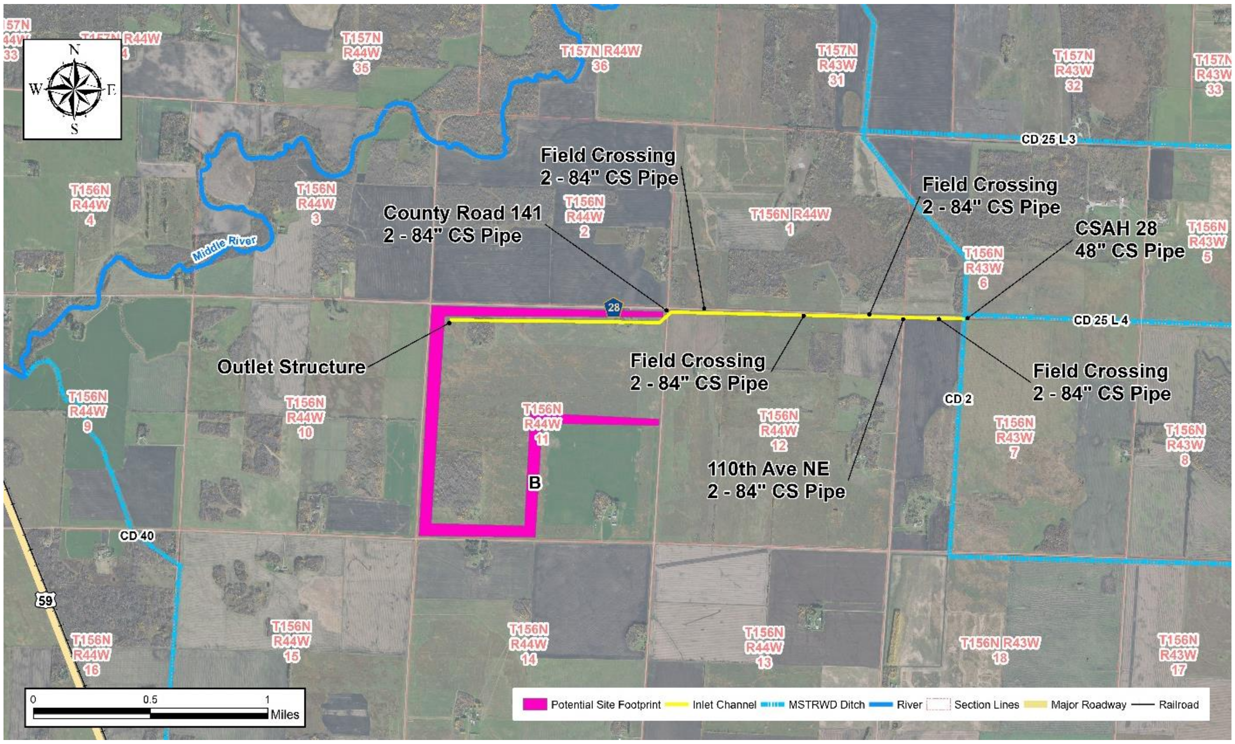

Figure 6-22. Site B Hydraulic Structures

Hydraulic Data

The elevation-storage curve for Site G and Site B is displayed in Figure 6-23. Each facility is designed to provide gated and non-gated storage up to the 100-year 10-day spring snowmelt event, with the ability to safely pass greater events over the principle and emergency spillways.

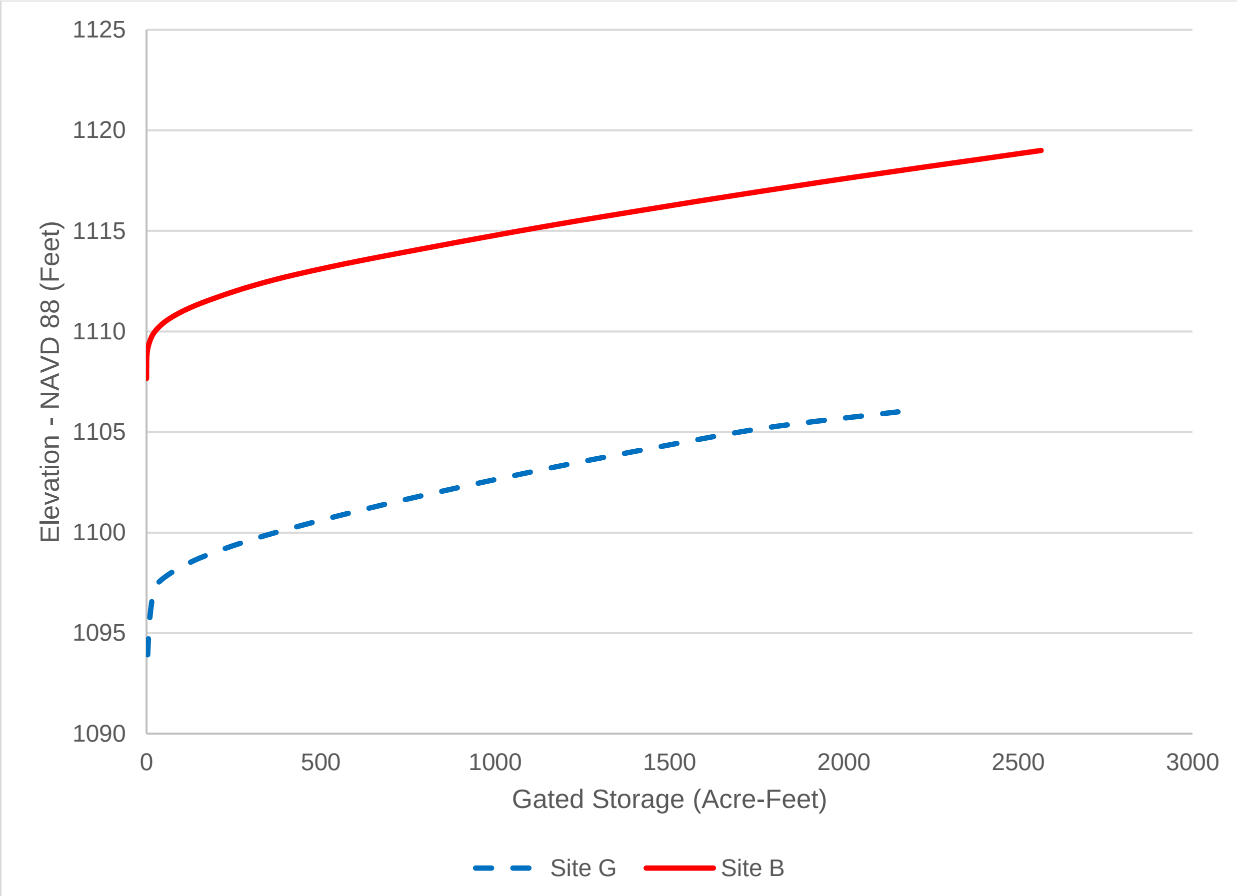

Figure 6-23. Elevation-Storage Curves for Impoundment Sites

Principal Outlet (Gated)

The outlet structure for each impoundment site will consist of a reinforced concrete pipe with a gate size of 4 feet in width and 6 feet in height. There will be a secondary outlet consisting of a drop inlet weir with a length of 80 feet set at the maximum pool elevation. The gate and drop inlet will discharge into a reinforced concrete box culvert that is 10 feet in width and 6 feet in height.

The principle outlet will follow design guidelines as stated in TR 60. These guidelines state that the principle outlet shall have the capacity to adequately drawdown the impoundment from its maximum pool elevation within 10 days or less. The principle outlet structure design is displayed in Figure 6-24.

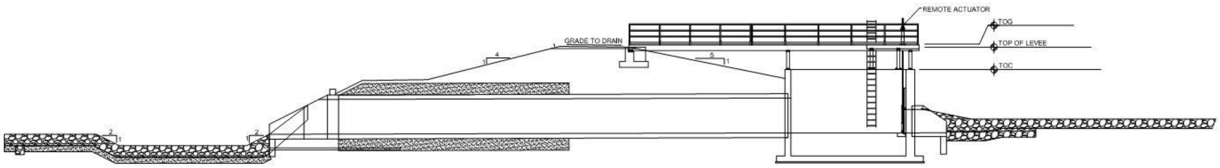

Figure 6-24. Principle Outlet Structure

Auxiliary Outlet (Ungated)

The auxiliary outlet was set at an elevation that would safely pass flows from the ASH design event. The gate to the outlet structure was closed and the impoundment was set at the maximum pool elevation. The ASH event was then passed into the impoundment.

The elevations for each of the Site's respective drop inlet was set such that flows passed over the emergency spillway at a depth of approximately 0.10 feet.

Table 6-4 displays the design characteristics for each of the impoundment sites.

Table 6-4. Auxiliary Spillway Design Characteristics

Alternative	Weir Length (Ft)	Crest Elevation (Ft)	Peak WSE for ASH (Ft)
Site G	80	1106.0	1107.1
Site B	80	1119.0	1120.1

Figure 6-25 displays the discharge hydrograph for each of the impoundment sites for the ASH.

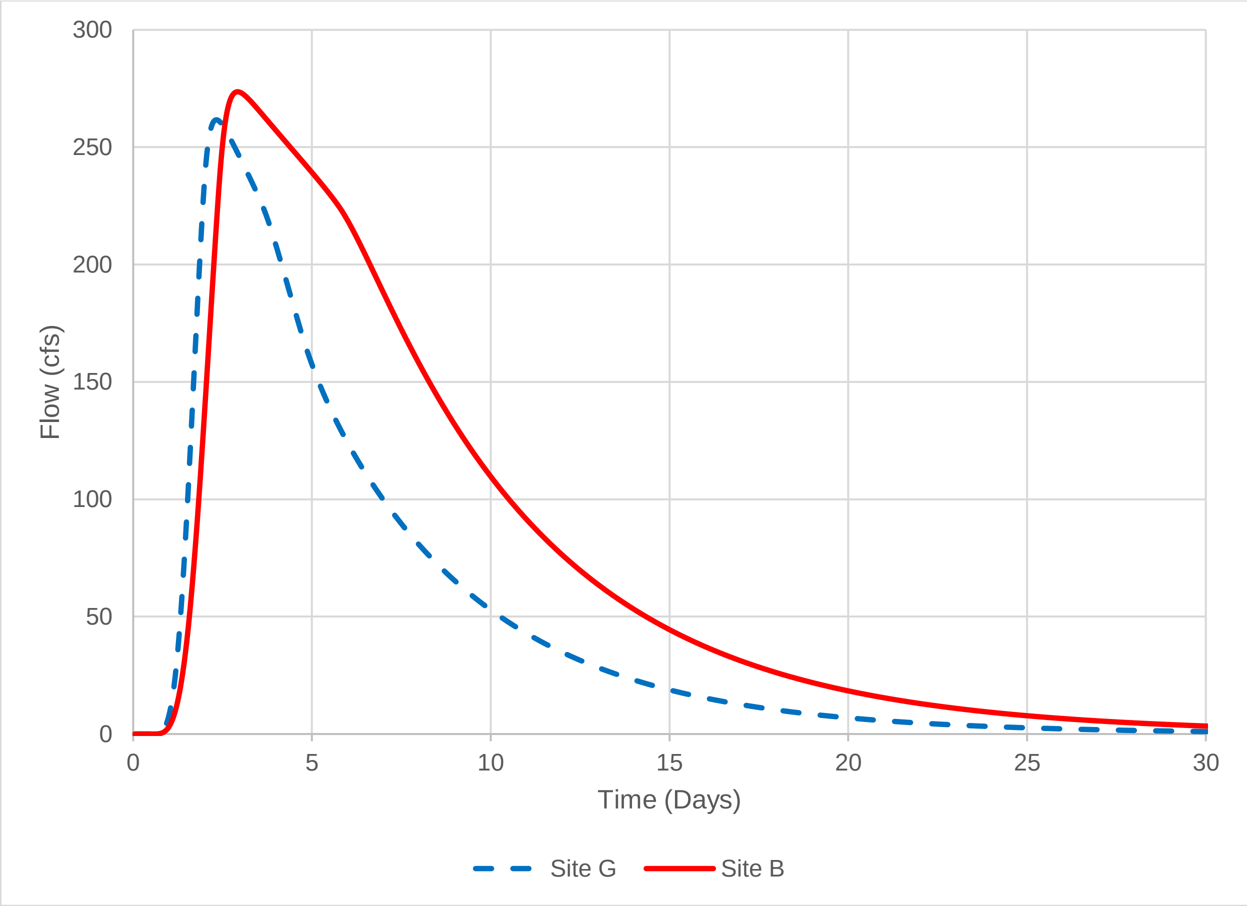

Figure 6-25. Auxiliary Spillway Discharge Hydrographs

Emergency Spillway (Ungated)

The emergency spillway for Site G and Site B were determined through hydraulic analysis. The goal of the emergency spillway design is to provide a sufficient factor of safety while the impoundment is operating. The spillways were designed by setting each impoundment at its respective maximum water surface elevation and passing the ASH and FBH through each site. The spillways will discharge into exterior ditching for each site, which outlets to the Middle River. Table 6-5 displays the design characteristics for each of the impoundment sites.

Table 6-5. Emergency Spillway Design Characteristics

Alternative	Spillway Width (Ft)	Crest Elevation (Ft)	Peak WSE for FBH (Ft)
Site G	500	1107.0	1107.3
Site B	500	1120.0	1120.3

Interior and Exterior Ditches

Exterior ditches will be constructed along the outer perimeter of the impoundment to divert local runoff around the site and to provide relief if the maximum water surface elevation is reached. A series of ditches may be constructed on the interior to aid in draining the impoundment during normal operation.

Hydraulic Summary

The implementation and operation of each impoundment site resulted in a reduction of the peak water surface elevation for the 100-year 10-day spring snowmelt event within the Middle River. The existing versus proposed water surface profile for the Middle River upstream and downstream of the railroad is displayed in Figure 6-26.

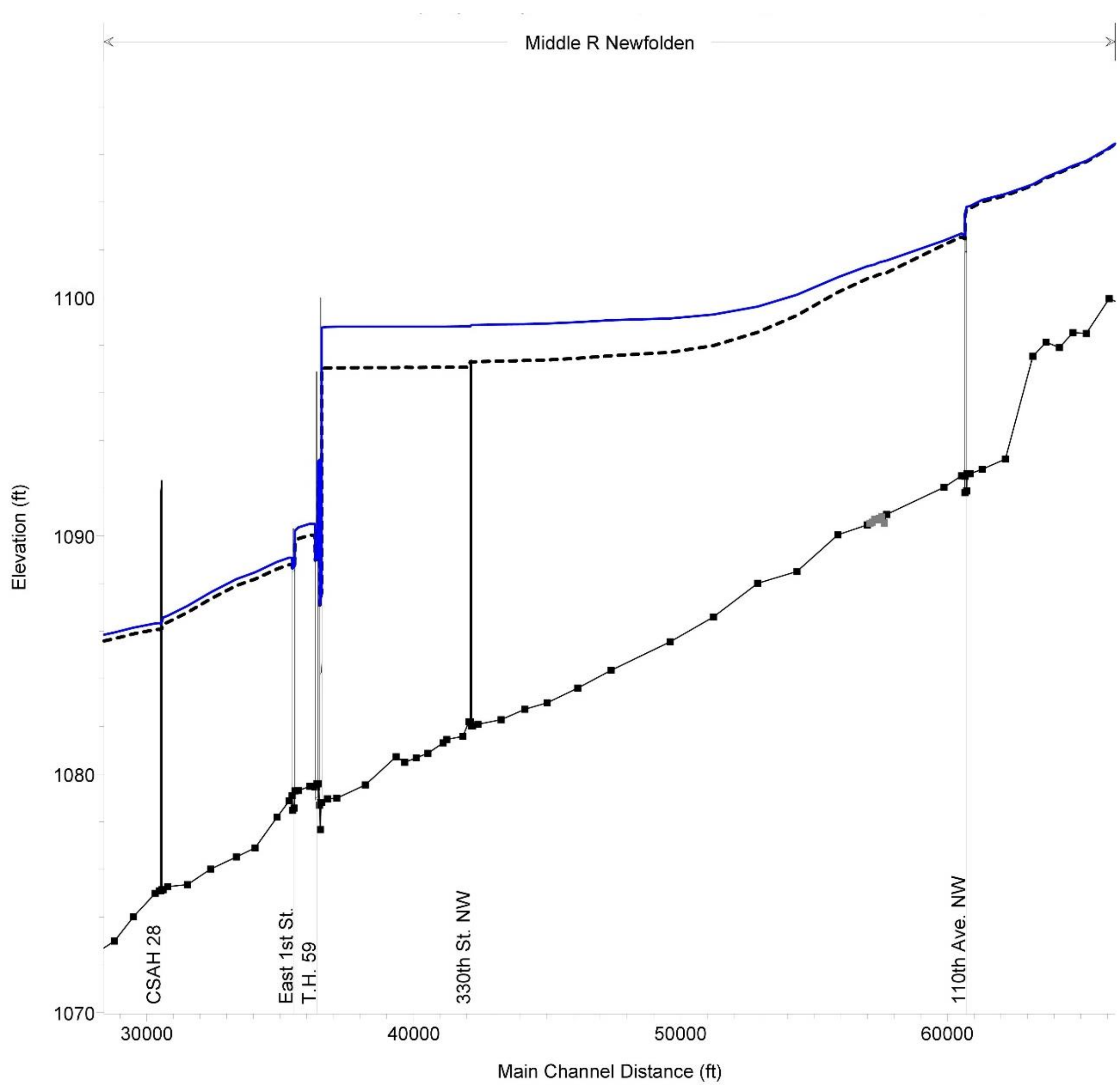

Figure 6-26. Existing vs. Proposed 100-Year 10-Day Water Surface Profile

Site B and Site G + Diversion Channel each reduce the peak flows and volume within the Middle River. An example of the pre- and post Project 100-year 10-day spring snowmelt hydrograph for the Site G + Diversion alternative within the Middle River is displayed in Figure 6-27. The removal of approximately 2,200 acre-feet of water from the peak and falling limb of the hydrograph is displayed. This water would then be stored up to 30 days within the impoundment and released in a matter similar to the example at day 40.

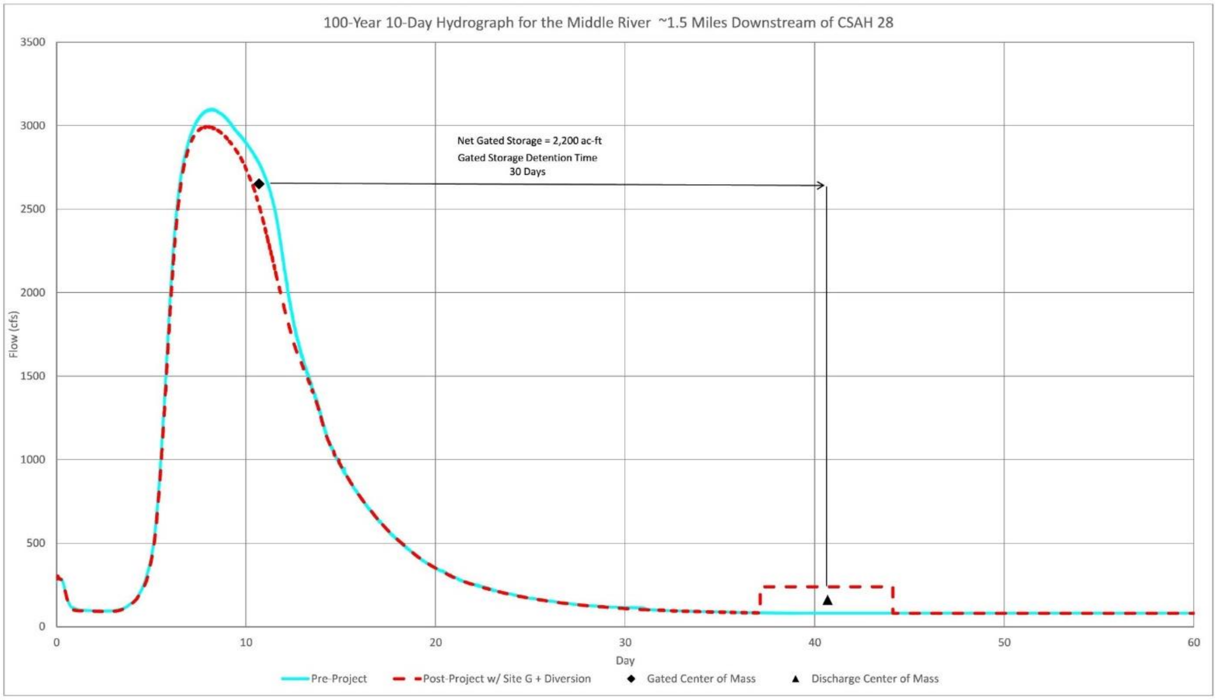

Figure 6-27. Existing vs. Proposed 100-Year 10-Day Middle River Hydrograph

6.4.6 Land Ownership and Land Use

Site G

There are three landowners within the proposed impoundment footprint and two landowners along the inlet channel alignment. Discussions have been held with the landowners to inform them of the design concepts. The existing land use for within the impoundment site is a mix of native grasslands enrolled in the USDA Conservation Reserve Program (CRP). Figure 6-28 displays the landowners for the proposed site.

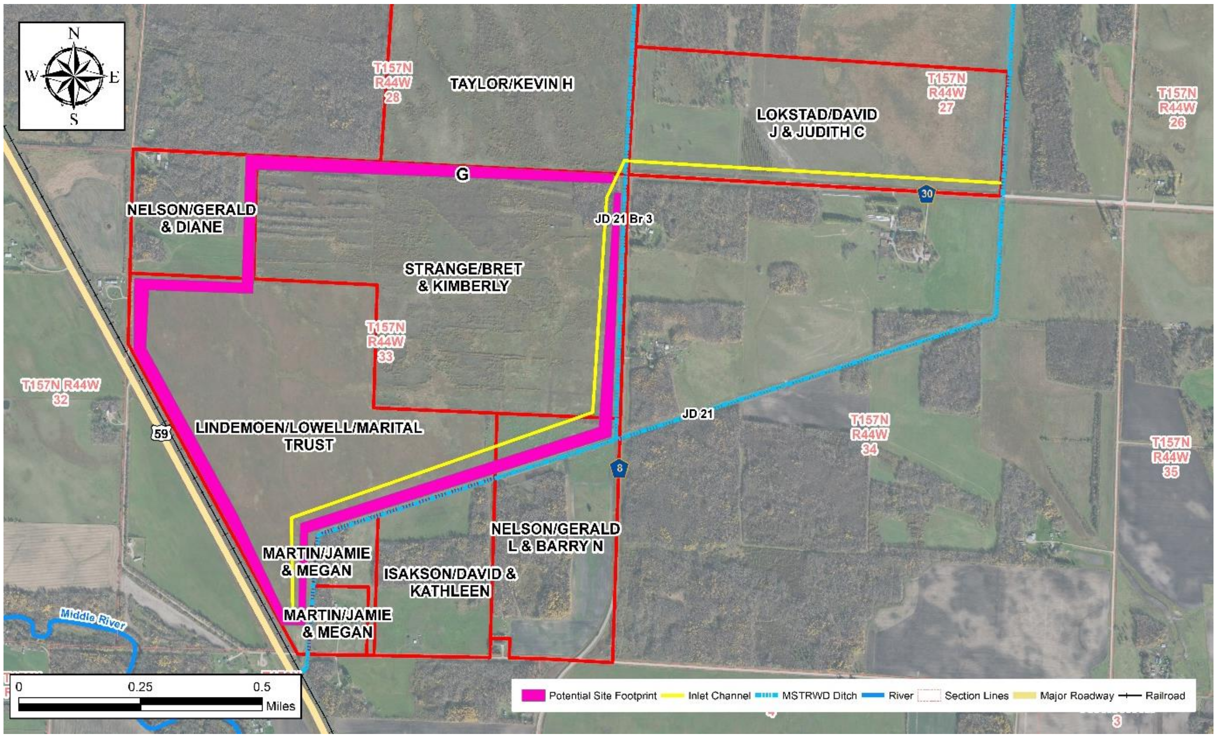

Figure 6-28. Site G Landowners

Site B

There is one landowner within the proposed impoundment footprint and four landowners along the inlet channel alignment. Discussions have been held with the landowners to inform them of the design concepts. The existing land use for within the impoundment site is a mix of native grasslands enrolled in CRP. Figure 6-29 displays the landowners for the proposed site.

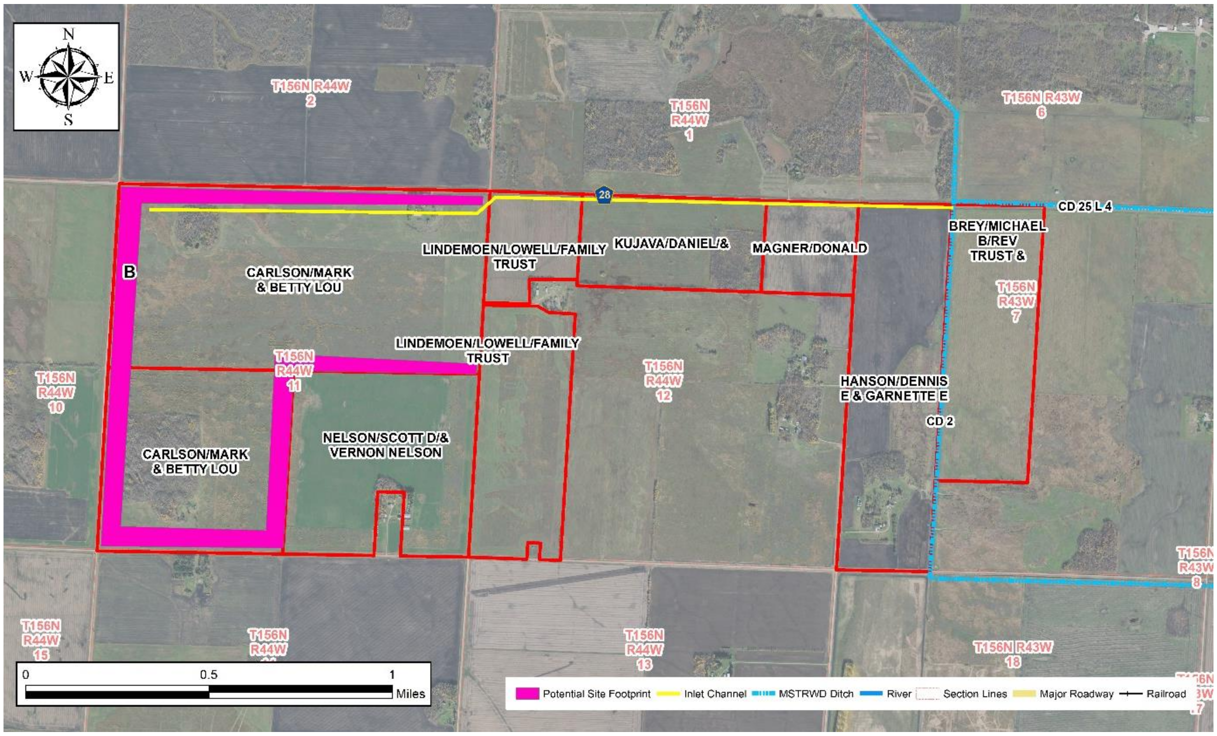

Figure 6-29. Site B Landowners

6.5 Railroad Structure Modification

Each of the preferred alternatives include the option for the modification of the railroad structure at Newfolden. A modification is not required for either of the alternatives to meet the Purpose & Need of the Project but would provide an additional factor of safety for the City, would reduce the peak water surface elevation for the 100-year 10-day spring snowmelt event, and would address the diminishing condition of the existing hydraulic structures.

The proposed modification would include the replacement of the two 96" CSP and three 66" RCP or the jack and bore additional smooth-steel pipes through the existing railroad embankment.

The additional reduction in water surface elevation in addition to an impoundment alternative is approximately 0.6 feet.

6.5.1 Land Ownership

The existing landowner within the railroad modification footprint is the Canadian Pacific Railway. Depending on the modification considered, the Minnesota Department of Transportation (MnDOT) right-of-way (ROW) would be impacted with the construction of a shoo-fly. A shoo-fly would be required if new hydraulic structures were to be constructed through the existing railroad embankment to serve as a temporary track during construction. Figure 6-30 displays the landowners for the railroad crossing modification within the Middle River.

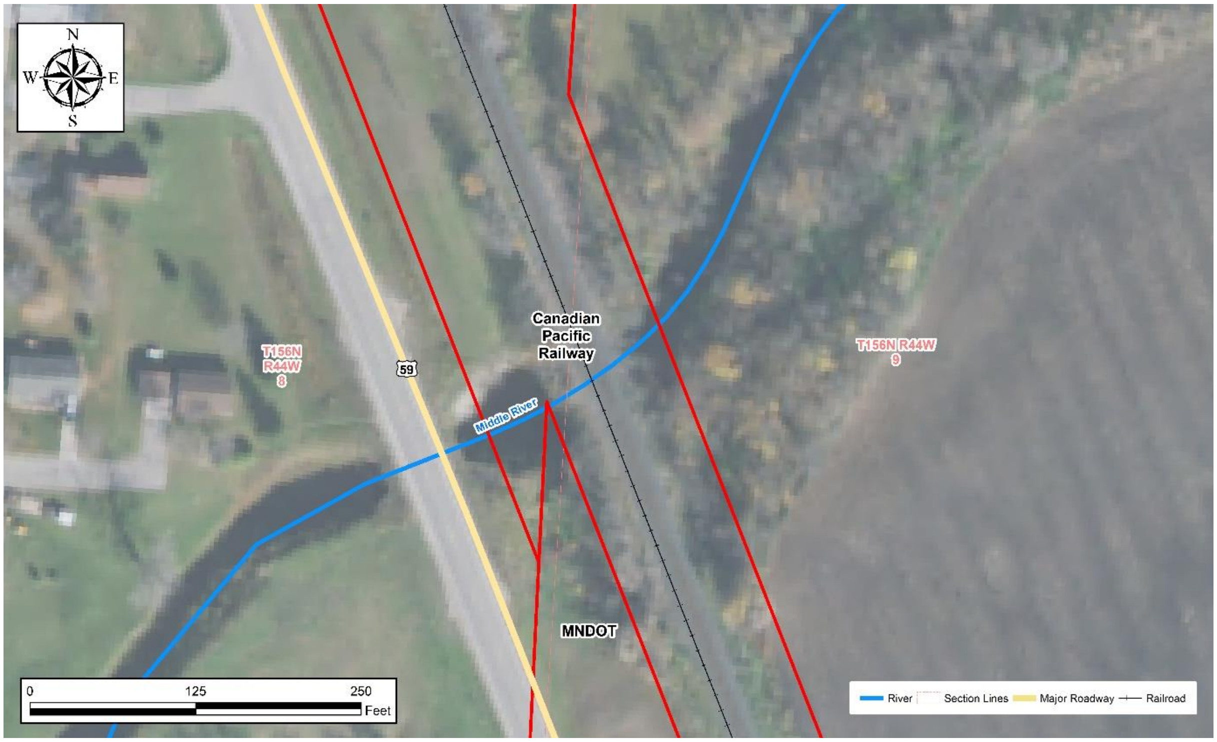

Figure 6-30. Railroad Crossing Modification Landowners

7 Additional Considerations

7.1 Operating Plan

The water surface elevations and extent of flooding within downstream channels will be used to determine the discharge of flows from the impoundment sites. If the flood stage at any control point exceeds the maximum allowed elevation, the discharge flows must be reduced. The site specific control points have not been identified at this time.

In accordance with the Red River Water Management Board (RRWMB) criteria for the Red River of the North (Red River), each impoundment location could hold water up to a maximum of 30 days while the Red River is at flood stage. Table 7-1 displays some of the operating plan considerations.

Table 7-1. Operating Plan Considerations

Gate Control Operation	Operating Trigger at Gage Locations		
	All Flood Events	Downstream	
Pool Elevation	Local County Ditch	Grand Forks Stage	Oslo Stage
Below ~Max Pool Elev.	Local Flooding	40	30

The trigger locations are known gage-stages where flood damages begin to occur and are considered "moderate flood stage". The release of floodwaters from each site would occur after stages have receded. The USGS / National Weather Service flood stages at downstream gage sites will be used to better address the timing of flows from the Middle-Snake-Tamarac Rivers Watershed.

Once flooding has subsided downstream, the stored water within the impoundment will be released in a controlled manner until the Site is returned to its dry state. The operating plan will not include a permanent pool elevation.

The MSTRWD reserves the right to modify the operational parameters and locations of the trigger points as operational experience is gained.

7.2 Geotechnical Investigation

A geotechnical investigation was performed by Northern Technologies, LLC of Fargo, North Dakota. The results from the geotechnical exploration and engineering review are in Appendix C.

7.2.1 Geotechnical Borings

A total of 15 standard penetration borings were completed for Site B, Site G, and the South Diversion Channel. The location of each boring is displayed in Figure 7-1.The borings extended to a depth of 16 to 46 feet. The borings had an average topsoil depth of 0.2 to 4.5 feet which can is classified as Glacial Lake Sediment (GLS). These soils consisted of sand and silty sand. The remainder of each boring consisted of medium to stiff Lake Modified Glacial Till (LMGT). These soils were comprised of lean clay, silty clay, silt, and some occasional sand.

Groundwater was encountered at several of the boring locations from a depth of 1 to 15 feet. The groundwater was encountered within the sand and silt layers. These layers may be water bearing during the spring thaw or after heavy precipitation and can vary annually. Location specific information can be found in the boring logs contained within the geotechnical exploration and engineering review are in Appendix C.

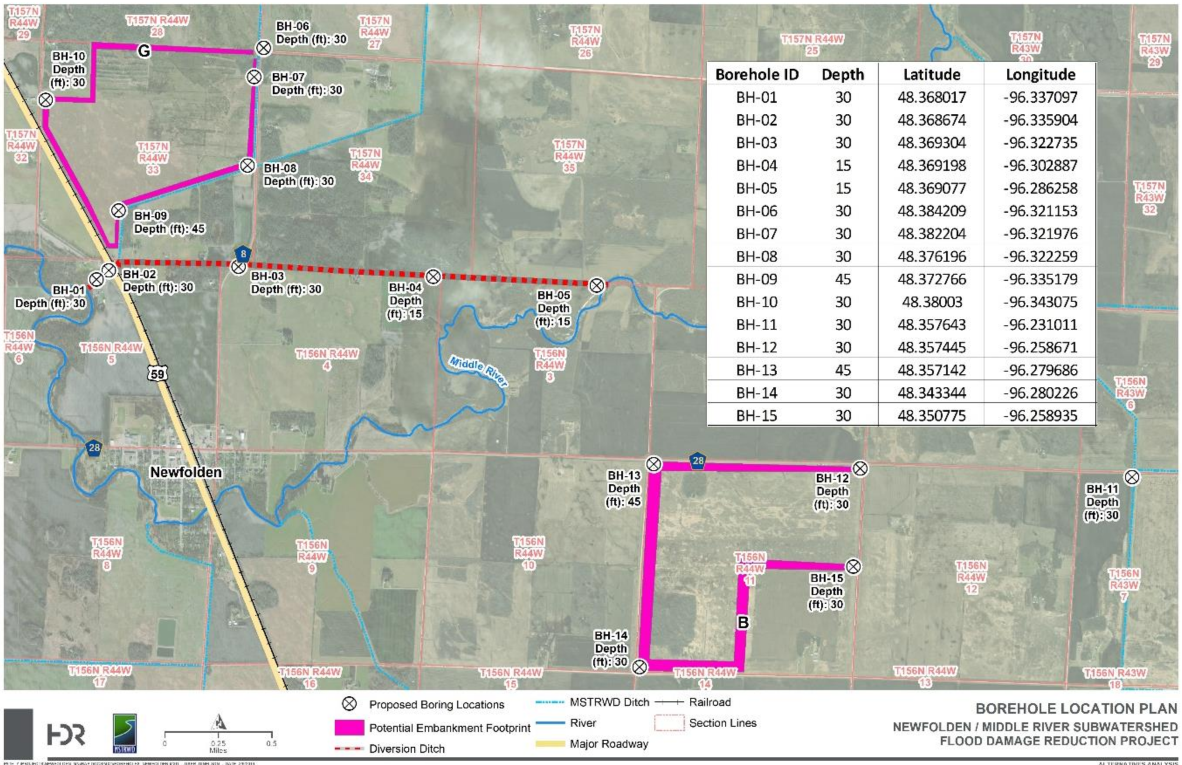

Figure 7-1. Geotechnical Boring Locations

7.2.2 Geotechnical Considerations

The construction and performance of an embankment is considered feasible at Site B and Site G. There are no concerns of potential slope instability or excessive settlement with the construction of an embankment for either site. To prevent seepage under the embankment, a key trench comprised of lean clay is to be constructed to a depth of one foot into the existing clay layer.

The Diversion Channel will have side slope of 4:1 (H:V) at a minimum. The construction of the proposed trapezoidal ditch is considered feasible and there should be minimal concerns of potential slope instability, excessive sloughing, or erosion of ditch banks due to excessive water velocities within the main Diversion channel. Proper erosion control measures will be established in final design.

7.3 Side Inlets and Approaches

Side inlets will be installed where berms are constructed and at every major field ditch inlet as appropriate. Each side inlet will be equipped with an apron at the inlet and flap gate on the outlet as well as a minimum of five cubic yards of MnDOT Class II riprap to reduce possibility of backflow and erosion. The majority of these pipes will be 18 inch corrugated steel pipe (CSP). Larger pipes will be considered for larger drainage areas.

7.4 Spoil Placement

Spoil from the Diversion Channel and inlet ditch excavation will be placed adjacent to the ditch, creating a berm within the permanent and/or temporary ROW. It is estimated that the berm will have a 10:1 (H:V) inslope, a top width of 20 feet, and a 10:1 (H:V) backslope for maintenance and/or agricultural purposes.

7.5 Roadway Impacts

New culvert structures will be constructed through County Road 8, County Road 30, and 340th Street Northwest with the construction of Site G. Site B will require the construction of new culvert structures through County Road 141, 110th Avenue Northeast, and several field crossings. The Diversion Channel will require the construction of new culverts through County Road 8, as well as multiple driveways and field crossings. These impacts will temporarily close each respective roadway during the installation of the new culverts. No additional or new modifications to the roadway design will take place and they will be returned at a minimum to their respective state before construction.

7.6 Site Access

Access to the Site G and Site B principle outlet structures will be provided for operational and maintenance purposes. Access points will also be provided as necessary to the land adjacent to each alternative for the private landowners.

7.7 Wetland Avoidance and Mitigation

Wetlands occur within each of the proposed impoundment sites. Delineations, mitigation, and coordination with permitting agencies will be conducted in a future phase, and construction will not begin until all permits are received. Table 7-2 displays the wetlands contained within each alternative footprint.

Table 7-2. Wetland Impacts

Alternative	Total Acres
Site B	6
Site G	14
Diversion Channel	1
Railroad Modification	0.2

7.8 Right of Way

Right of way (ROW) information was estimated using Marshall County parcel information. Additional ROW in the form of a temporary and permanent easement will be obtained for the Project along these roadways. The Project will pursue a 20 foot wide minimum buffer zone. Temporary ROW will be purchased, as needed, beyond the permanent ROW to provide for construction access and spoil disposal. Exact ROW needs will be determined during final design. Anticipated ROW corridor widths are shown in Table 7-3. The ROW parallel to roadways is measured from the roadway centerline.

Table 7-3. Right-of-Way

Location	Existing Right-of-Way Width from Roadway Centerline (Ft)	Average Additional Right-of-Way Width Required (Ft)
Diversion Channel	16.5	140

Location	Existing Right-of-Way Width from Roadway Centerline (Ft)	Average Additional Right-of-Way Width Required (Ft)
Site G Inlet Channel	33.5	75
Site B Inlet Channel	50	80

7.9 Utilities

HDR conducted a Gopher State One Call to obtain design-locate information for all utilities located within the impoundment and diversion alternative footprints. The identified utilities include underground and overhead electric, telephone, and fiber optic cable. These utility conflicts as well as others identified are shown in Figure 7-2 and Table 7-4. Utilities within the railroad modification were not located and it is unknown if there are utilities located within the existing railroad embankment.

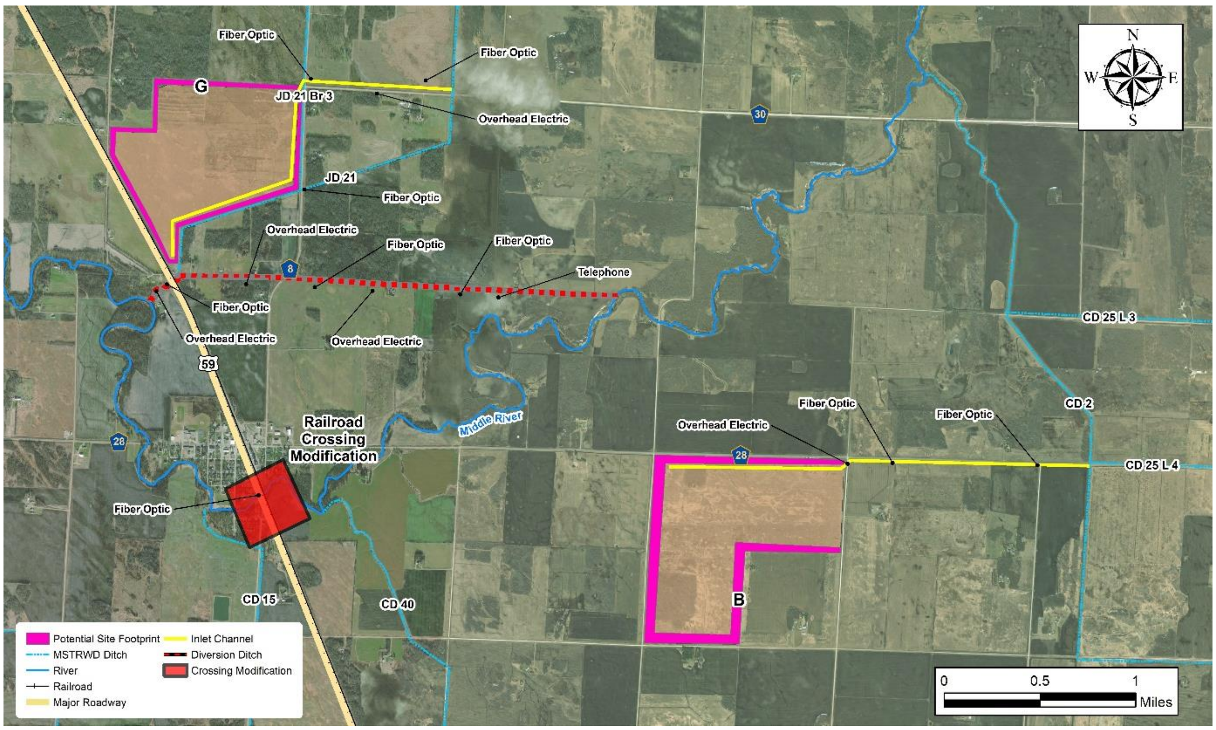

Figure 7-2. Utility Locations

Table 7-4. Utility Schedule

Utility (Type)	Location	Obstruction Location
Fiber Optic	Site G Inlet Channel	Adjacent / Crosses
Overhead Electric	Site G Inlet Channel	Adjacent – Across Road
Telephone	Diversion Channel	Adjacent
Overhead Electric	Diversion Channel	Crosses
Fiber Optic	Diversion Channel	Adjacent
Fiber Optic	Site B Inlet / Outlet Channel	Crosses

Utility (Type)	Location	Obstruction Location
Overhead Electric	Site B Inlet Channel	Crosses
Fiber Optic	Railroad Corridor	Adjacent

7.10 Potential Groundwater Impacts

It is not anticipated that either impoundment alternatives will have an impact on the local groundwater as a result of the occasional storage of surface water. It is also not anticipated that a modification to the railroad crossing will have an impact on the local groundwater. There is the potential impact to the dewatering of groundwater with the diversion channel alternative due the excavation of material through a gravel ridge. Investigation of these potential impacts would occur during final design.

7.11 Environmental Consequences

It is not anticipated that either alternative is expected to cause negative environmental consequences. The impoundment sites may store water for a limited number of days. The remainder of the time, the present landuse of CRP would be maintained.

The primary purpose of the Project is flood damage reduction but there is also potential to incorporate natural resource enhancement features in the Project area. These enhancements may include erosion control measures, channel restoration, wetland restorations, and stabilization of the contributing ditch systems.

7.12 Water Quality

Based on the Minnesota Pollution Control Agency 2018 Impaired Waters List, the Middle River is impaired for dissolved oxygen, turbidity, fish bioassessments, and aquatic macroinvertebrate bioassessments. There is limited water quality information available for each of the site specific drainage areas. Fish and Wildlife

It is anticipated that the Project will enhance fish and wildlife habitat. Wetland and upland habitats exist on the Project Site. The upland habitat will be subject to periods of inundation in accordance to the operating plan.

8 Social, Economic, and Environmental Impacts

8.1 Adequacy of the Outlet

The outlet for the proposed alternative is the Middle River which has a drainage area of approximately 106 square miles upstream of Newfolden, while the size of the project drainage area is as much as 14 square miles. The retention component of the Project will reduce the peak and volume within the Middle River downstream of the Site.

The Project is consistent with the Mediation Agreement goals adopted by the RRWMB and Red River Basin Flood Damage Reduction Work Group. The flood water is considered to be in the middle area for the Red River of the North based on the Flood Damage Reduction Work Group Technical Paper #11. The peak of the Middle River at Newfolden is approximately 4.5 days before the peak on the Red River. Reducing the peak and storing late water at Newfolden has a positive impact on removing water contributing to the peak on the Red River. Flood Damage Reduction (FDR) measures, such as a gated impoundment, receives a positive rating in a middle area and a diversion receives a "variable" rating.

A Step 1 application was submitted to the Red River Watershed Management Board on July 17th, 2018. On August 21st, 2018, the Step 1 submittal was approved by the Board. The Step 1 application is included in Appendix D.

8.2 Funding

Potential funding partners for the Project may include MnDNR State funding through the FDR grant program, RRWMB, MSTRWD, the City of Newfolden, and others. An example of how the total Project costs may be distributed is displayed in Table 8-1.

Table 8-1. Funding Breakdown

Total Project Cost	MN –FDR $5,775,000 (75%)
	RRWMB $1,360,000 (17.7%)
	MSTRWD $365,000 (4.7%)
	City of Newfolden $200,000 (2.6%)

8.3 Social & Economic Impacts

The Project will produce a positive economic impact for the long-term growth and development of the benefitting area. The initial Project investment will be equalized over time by the reduced flood damage costs to the surrounding rural and urban areas. Given the area and extents of the Project, the benefits should impact the community at present, and the long-term planning and expansion of the community.

This Project will benefit local landowners by reducing property damage and crop loss due to flooding. Public benefits include increased assurances created by the reduction in flood damages to the City and will promote residential and commercial growth.

9 Compatibility with Existing Plans, Statutes, Rules and Permits

9.1 Middle-Snake-Tamarac Rivers Watershed District Plan

It is the intention of the Board to manage the waters and related resources within the Watershed District in a reasonable and orderly manner to improve the general welfare and public health of the residents of the Watershed District in accordance with their 10-year overall comprehensive plan.

The managers of the MSTRWD accept the responsibilities with which they are charged as a governing body by Minnesota Statutes. Said Board of Managers, in the conduct, duties and responsibilities conferred upon them, do not intend to usurp the authority or responsibilities of other agencies or governing bodies; however, said Board of Managers will not avoid their responsibilities and obligations.

9.2 Minnesota Statutes and Rules

Section 103D of Minnesota Statutes pertains to Watershed Districts. Section 103D.335, Subd. 5 enables watershed districts to exercise the power to "…make necessary surveys or utilize other reliable surveys and data and develop projects to accomplish the purposes for which the district is organized." Section 103D.335, Subd. 8 gives the watershed district the power to "…construct, clean, repair, alter, abandon, consolidate, reclaim, or change the course or terminus of any public ditch, drain, sewer, river, watercourse, natural or artificial, within the district." In addition, Section 103D.335, Subd. 9 give the power to "…acquire, operate, construct, and maintain dams, levees, and reservoirs, and appurtenant works.

Also required by Section 103D.711 is the preparation of an "Engineer's Report". Requirements relative to the content of the report include:

- A scaled map of the area to be improved.
- Location of the proposed improvements; location of respective outlets.
- The watershed of the Project Area; the location of existing highways, bridges and culverts.
- All lands, highways, and utilities affected, together with the names of the owners thereof, so far as known; the outlines of any public lands and public bodies of water affected; potential benefiting lands; easement maps; and principal Project features.

This report is intended to satisfy the requirements of 103D.605, 103D.701, and 103D.711

9.3 State Environmental Review

Minnesota Rules Chapter 4410 requires the preparation of an Environmental Assessment worksheet (EAW). The mandatory preparation of an EAW (Minnesota Rules 4410.4300, subpart 27) is necessary "for projects that will change or diminish the course, current, or cross-section of one acre or more of any public water or public waters wetland except for those to be drained without a permit pursuant to Minnesota Statutes, chapter 103G." Based on the public waters inventory map for Marshall County, the Project is not considered a public watercourse. The Project is not anticipated to disturb more than one acre of public water wetlands so an EAW is not anticipated.

9.4 US Army Corps of Engineers Section 404

A Section 404 permit may be required by the USACE because wetland impacts may occur by the construction and operation of the proposed project, such as wetland inundation, bounce, flood frequency and water depth, in addition to wetland impacts from the construction footprint. USACE permitting authorities will be consulted regarding the proposed Project. The permit will also review any additional wetland impacts due to construction. Construction will not begin until all permits are received.

9.5 Minnesota Department of Natural Resources

The proposed Project requires a dam safety permit from the MnDNR in accordance with Minnesota Rules 115.0300. The purpose of these rules is to regulate the construction and enlargement of dams, as well as the repair, alteration, maintenance, operation, and abandonment, in such a manner as to best provide for public health, safety, and welfare.

The Newfolden / Middle River Subwatershed Impoundment will likely be classified as a Class III (TR 60 Class A) low hazard dam. Issuance of the dam safety permit follows a thorough review of the dam design by the MnDNR.

A Minnesota Department of Natural Resources Public Waters Permit, in accordance with Minnesota Rules 6115.015, may be required. The Middle River is considered a public water and discharging flows from the proposed Project may trigger a Public Waters Permit.

9.6 Wetland Conservation Act

It is anticipated that a Wetland Conservation Act (WCA) permit may be required for the proposed Project. The permit will include a review of all wetland impacts do to the footprint, operation, bounce, flood frequency, water depth, and construction of the proposed Project. Construction will not begin until all permits are received.

9.7 National Pollutant Discharge Elimination System Requirements (NPDES)

A storm water permit will be required for the construction of this Project. The permitee will develop a stormwater pollution prevention plan (SWPPP) that focuses on discharges from the site into public waters. Each party under regulation determines the most appropriate best management practices (BMPs) that should be implemented to minimize pollution for the specific site. The final engineering plans for this Project will address the SWPPP by means of seeding, mulch, fiber rolls, silt fence, filter fabric, and riprap.

9.8 FEMA Map Revision

The remapping of the City of Newfolden due to the design of a flood damage reduction project will first go through the process of submitting a Conditional Letter of Map Revision (CLOMR) to the MnDNR for review and then to FEMA. Once the CLOMR is approved by FEMA, the project would be constructed and following the completion of the project, a Letter of Map Revision (LOMR) would be submitted to FEMA finalize the remapping effort.

10 Conclusions and Recommendations

The "Alternatives Analysis Study" completed by HDR in 2018 evaluated alternatives to remove the City of Newfolden from the 1% Annual (100 Year) Floodplain, reduce local flooding near the Project location, and provide downstream flood reduction benefits.

Following the Alternatives Analysis, the MSTRWD Board of Managers directed further investigation and the preliminary design of Site B and Site G + South Diversion Channel, including a railroad modification option for each alternative.

Each of the alternatives were analyzed based on meeting the Project design goals, Project implementation, and overall cost. Table 10-1 summarizes meeting these design criteria in a weighted matrix. Each of the criteria were weighted based upon their relative importance. A positive value was assigned the when the alternative met the design criteria and a negative value was assigned when it was not. The cost criteria was weighted with a higher value assigned to the less expensive alternative. The weighted values were then totaled for each alternative and the highest rank being most favorable.

Table 10-1. Alternatives Matrix

	Goals			Project Implementation				Flood Reduction Measures						
Alternatives	**Remove Newfolden from Floodplain**	**Provide Downstream Flood Reduction**	**Contribute to 20% Reduction on Red**	**Cost**	**Multiple Funding Partners**	**Permitting Concerns**	**Landowner Support**	**Flood Volume Reduction**	**Increase Crossing Capicity**	**Protection of City**	**Temporary Flood Storage**	**Reduce Rural Flooding**	**Maintain D/S WSE**	**Increase Rail Safety**
Site B	No	Yes	Yes	$5,247,329	Yes	moderate	Against	Yes	No	No	Yes	Yes	Yes	No
Site G	No	Yes	Yes	$4,685,235	Yes	moderate	For	Yes	No	No	Yes	Yes	Yes	No
Diversion Channel	Yes	No	No	$3,037,958	No	moderate	Neutral	No	No	Yes	No	No	No	No
Railroad	Yes	No	No	$2,473,353	No	low	Neutral	No	Yes	Yes	No	No	No	Yes
Diversion Channel with Site G	Yes	Yes	Yes	$7,723,193	Yes	moderate	Neutral	Yes	No	Yes	Yes	Yes	Yes	No
Railroad with Site B	Yes	Yes	Yes	$7,720,682	Yes	low	Against	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Alternatives	**Weighting**							**Ranking**
Site B	-15	5	2	9	5	2	-5	3
Site G	-15	5	2	12	5	2	5	16
Diversion Channel	15	-5	-2	15	-5	2	2	22
Railroad	15	-5	-2	18	-5	5	2	28
Diversion Channel with Site G	15	5	2	3	5	2	2	34
Railroad with Site B	15	5	2	6	5	5	-5	33

Preliminary design concluded that Site B and Site G + Diversion Channel, with or without a railroad modification, would each meet the P&N statement, reduce Middle River flows, improve the local flood impacts, and contribute to the Red River Basin flood reduction goals. The greatest difference between the two alternatives is the increased factor of safety for the City with the implementation of Site G + Diversion Channel. The flood potential for the City is due to the flows within the Middle River. An impoundment location can reduce the runoff contributing to the flood event but there are cases where the drainage area for an impoundment site is a non-factor in a flood event. If this were to occur, an impoundment site would not reduce the flood risks for the City. Due to the Diversion Channel's close proximity to the City and its ability to bypass flows from the Middle River entering Newfolden from the North will provide more consistent protection. The Diversion Channel will also provide a reduction in overland flows from entering Newfolden from the North. Site G will be required with the Diversion Channel to mitigate flows downstream and to provide local rural flood protection.

The recommended alternative to be carried forward into final design is Site G with the Diversion Channel. An additional railroad modification option would be contingent upon the development of the Project partnerships. The railroad modification in conjunction with an impoundment and diversion channel meets the Project goals and would provide additional flood benefits for the City. It is expected that discussions will be had with Canadian Pacific Railway to discuss this study and future Project considerations. Figure 10-1 displays the recommended alternatives for final design with the railroad modification included. The proposed inundation extents and depth is displayed in Figure 10-1.

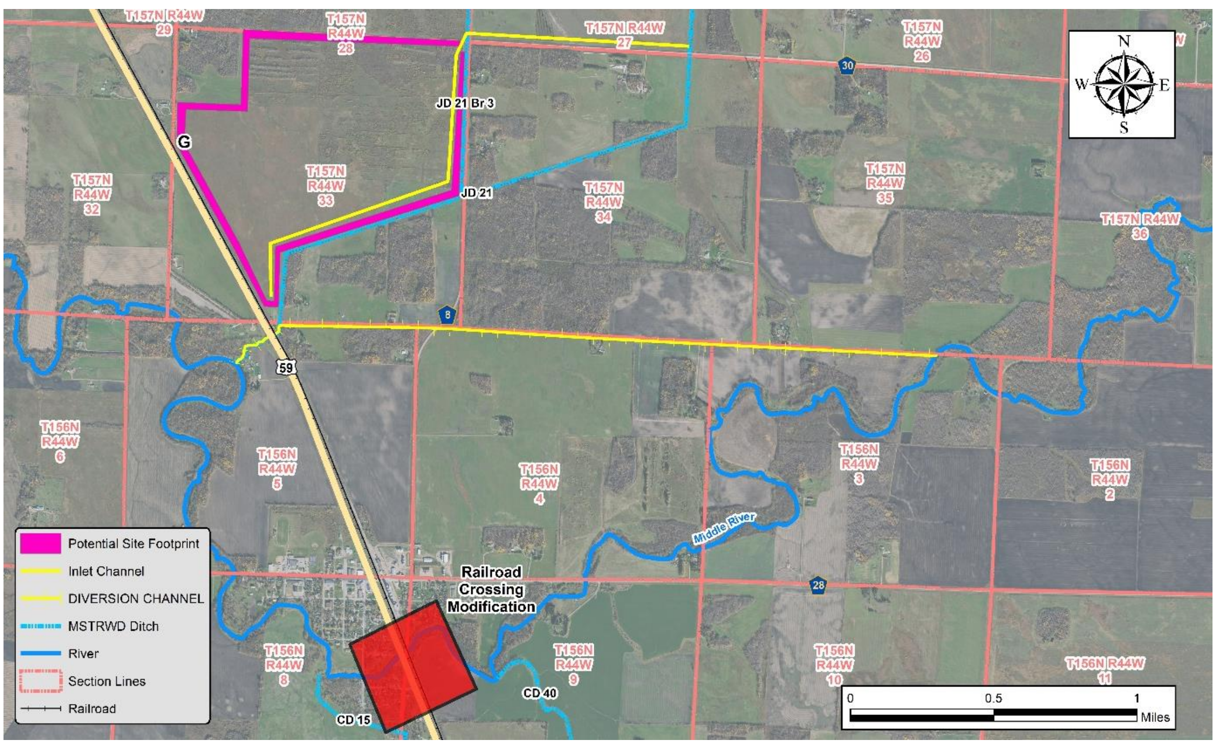

Figure 10-1. Recommended Alternative Site G and Diversion Channel

Final design is anticipated to begin Summer 2019. An approximate timeline of past and future tasks is displayed in Table 10-2.

Table 10-2: Potential Project Timeline

Task	Spring 2018	Summer 2018	Fall 2018	Winter 2019	Spring 2019	Summer 2019	Fall 2019	Winter 2020	Spring 2020	Summer 2020	Fall 2020	Winter 2021	Spring 2021	Summer 2021	Fall 2021
Establish Project Partnerships	X	X	X	X	X	X									
Develop Funding Package		X	X	X	X	X	X								
Initiate Project					X										
Project Mgmt / Coord / Meetings	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Survey		X				X									
Screening of Alternatives	X														
Preliminary Engineering of Selected Alternatives		X	X	X											
Soil Borings and Wetland Delineation			X												
Final Engineering / Design / Plans & Specs						X	X	X	X	X					
Preliminary Hearing					X										
Landowner Meetings	X	X			X	X	X	X	X	X					
Land Acquisition								X	X	X					
Permitting								X	X	X					
Final Hearing									X	X					
Construction											X		X	X	X

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Appendix A. Additional Figures and Tables

Table A-1. Existing Subwatershed Characteristics

HEC-HMS Subwatershed	Drainage Area (Square Miles)	Curve Number	Tc (Hours)	R
Snake-1023a	5.21	87.9	24.4	68.5
Snake-1023b	0.70	86	11.1	31.1
Snake-1027	8.75	85.5	22.6	55.0
Snake-1048a	2.60	79.4	26.5	50.0
Snake-1048b	1.48	82.3	12.3	23.3
Snake-1050	15.27	87.3	48.9	124.8
Snake-1050a	7.09	85.4	39.4	100.4
Snake-1063a	14.16	76.1	33.8	69.8
Snake-1063b	1.19	78.2	15.7	32.3
Snake-1064a	0.57	82.4	9.1	16.4
Snake-1064b	0.12	76.0	4.5	8.1
Snake-1069	0.28	82.0	14.4	28.0
Snake-1082a	7.90	74.8	27.0	40.1
Snake-1082b	2.14	70.3	19.2	28.5
Snake-1190a	2.38	79.6	21.2	24.7
Snake-1190b	0.84	76.8	15.9	18.5
Snake-1195	13.96	85	35.2	79.9
Snake-1276	17.80	84.8	58.3	131.1
Snake-1290a	4.39	79.7	30.2	37.1
Snake-1290b	0.67	78.8	15.8	19.4
Snake-1290c	1.79	75.2	18.1	22.1
Snake-1332	29.43	83.0	103.8	207.3
Snake-1750a	0.30	72.4	7.4	15.8
Snake-1750b	4.52	85.2	21.4	45.7
Snake-1750c	2.91	78	19.9	42.5
Snake-1751a	0.62	77.6	8.3	18.1
Snake-1751b	1.30	84.7	13.6	29.6
Snake-1755a	2.12	85.7	12.5	30.5

HEC-HMS Subwatershed	Drainage Area (Square Miles)	Curve Number	Tc (Hours)	R
Snake-1755b	6.17	83.5	26.8	65.2
Snake-1755c	0.47	83.5	7.1	17.3
Snake-1756	0.15	85.8	3.1	8.1
Snake-1760a	3.84	83.6	47.2	72.7
Snake-1760b	2.30	78.9	15.7	24.2
Snake-1760d	2.22	76.4	12.3	18.9
Snake-1760e	1.75	78.4	11.6	17.9
Snake-1761a	12.33	77.0	25.5	43.5
Snake-1761b	3.39	85.3	92.6	157.9
Snake-1761c	0.59	84.7	50.6	86.2
Snake-1765a	10.80	74.5	36.3	48.6
Snake-1765b	3.53	74.0	14.9	20.0
Snake-1765c	0.53	81.4	13.2	17.6
Snake-1765e	0.25	73.4	5.2	7.0
Snake-1765f	0.67	67.8	8.2	11.0
Snake-1766a	6.20	72.8	24.8	35.1
Snake-1766b	1.95	69	17.5	24.7
Snake-1766c	1.03	69.6	10.3	14.6
Snake-1766d	1.06	65.0	14.2	20.1
Snake-908a	4.82	86.8	17.4	52.9
Snake-908b	9.36	84.3	29.8	90.9
Snake-914	13.75	76.3	36.4	110.8
Snake-924a	0.83	85.2	8.6	23.1
Snake-924b	0.24	85.6	4.9	13.1
Snake-945	3.05	86.8	35.2	93.3
Snake-972	8.72	80.6	31.8	59.9
Snake-978b	1.23	77.1	10.9	24.1
Snake-978c	3.21	73.1	21.5	47.3
Snake-978d	2.29	80.8	27.0	59.6

Table A-2. Subwatershed Peak Flows

HEC-HMS Subwatershed	Drainage Area (Square Miles)	Peak Flow (cfs)
Snake-1023a	5.21	172.1
Snake-1023b	0.7	37.6
Snake-1027	8.75	318.6
Snake-1048a	2.6	86.8
Snake-1048b	1.48	84.4
Snake-1050	15.27	325
Snake-1050a	7.09	171
Snake-1063a	14.16	358.5
Snake-1063b	1.19	51.9
Snake-1064a	0.57	40.5
Snake-1064b	0.12	11.1
Snake-1069	0.3	15.5
Snake-1082a	7.9	256.2
Snake-1082b	2.14	74.8
Snake-1190a	2.38	113.3
Snake-1190b	0.84	45
Snake-1195	13.96	388.1
Snake-1276	17.8	345
Snake-1290a	4.39	163.3
Snake-1290b	0.67	36.8
Snake-1290c	1.79	83.6
Snake-1332	29.43	392.9
Snake-1750a	0.3	17.9
Snake-1750b	4.52	182.4
Snake-1750c	2.91	107.5
Snake-1751a	0.62	38.8
Snake-1751b	1.3	69.2
Snake-1755a	2.12	113.2
Snake-1755b	6.17	193.7
Snake-1755c	0.47	33.4

HEC-HMS Subwatershed	Drainage Area (Square Miles)	Peak Flow (cfs)
Snake-1756	0.15	15.7
Snake-1760a	3.84	105.5
Snake-1760b	2.3	117.8
Snake-1760d	2.22	125
Snake-1760e	1.75	105.7
Snake-1761a	12.33	423.1
Snake-1761b	3.39	56
Snake-1761c	0.59	14.8
Snake-1765a	10.8	302.5
Snake-1765b	3.53	168.9
Snake-1765c	0.53	31.7
Snake-1765e	0.25	19
Snake-1765f	0.67	37.1
Snake-1766a	6.2	207.7
Snake-1766b	1.95	73.6
Snake-1766c	1.03	53.7
Snake-1766d	1.06	40.3
Snake-908a	4.82	185.8
Snake-908b	9.36	240
Snake-914	13.75	261
Snake-924a	0.83	52.7
Snake-924b	0.24	20.9
Snake-945	3.05	79.9
Snake-972	8.72	264
Snake-978b	1.23	64.4
Snake-978c	3.21	99.4
Snake-978d	2.29	71.9

Appendix B. Opinion of Probable Cost for Alternatives Considered

Newfolden / Middle River Subwatershed Flood Damage Reduction Project				
Site B - Engineer's Opinion of Most Probable Cost				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$77,000.00	$77,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	AC	10	$3,000.00	$30,000.00
COMMON EXCAVATION (P)	CY	150,371	$2.50	$375,928.00
COMMON BORROW	CY	455,939	$4.00	$1,823,756.00
AGGREGATE SURFACING, CLASS 5	CY	1,000	$12.00	$12,000.00
84" CAS PIPE CULVERT	LF	1,056	$185.00	$195,360.00
18" SIDE INLET PIPES W/ APRON AND FLAP	EA	16	$2,630.00	$42,080.00
OUTLET STRUCTURE	LS	1	$400,000.00	$400,000.00
RIPRAP CLASS III	CY	900	$70.00	$63,000.00
SEEDING	ACRE	77	$90.00	$6,930.00
SEED MIXTURE, 25-141	POUND	4,543	$3.70	$16,810.00
MULCH MATERIAL TYPE 1	TON	154	$110.00	$16,940.00
DISK ANCHORING	ACRE	77	$40.00	$3,080.00
FERTILIZER, TYPE 1	TON	7.7	$800.00	$6,160.00
Subtotal				$3,077,044.00
Engineering and Administration	25%			$769,261.00
Utility Relocation	LS	1	$ 10,000.00	$10,000.00
Materials Testing (Construction)	2% of Earthwork Cost			$7,519.00
Right of Way Acquisition	ACRE	489	$ 2,200.00	$1,075,800.00
Contingencies	10%			$307,705.00
Total Construction				**$5,247,329.00**

Newfolden / Middle River Subwatershed Flood Damage Reduction Project				
Site G - Engineer's Opinion of Most Probable Cost				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$74,500.00	$74,500.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	LF	17	$5,000.00	$85,000.00
COMMON EXCAVATION (P)	CY	195,586	$2.50	$488,967.00
COMMON BORROW	CY	409,375	$4.00	$1,637,502.00
AGGREGATE SURFACING, CLASS 5	CY	1,000	$12.00	$12,000.00
8' x 6' PRECAST CONCRETE BOX CULVERT	LF	116	$850.00	$98,600.00
8' x 6' PRECAST CONCRETE BOX CULVERT END SECTION	EA	2	$12,000.00	$24,000.00
48" CAS PIPE CULVERT	LF	92	$80.00	$7,360.00
66" CAS PIPE CULVERT	LF	376	$100.00	$37,600.00
18" SIDE INLET PIPES W/ APRON AND FLAP	EA	16	$2,630.00	$42,080.00
OUTLET STRUCTURE	LS	1	$400,000.00	$400,000.00
RIPRAP CLASS III	CY	750	$70.00	$52,500.00
SEEDING	ACRE	28	$90.00	$2,520.00
SEED MIXTURE, 25-141	POUND	1,652	$3.70	$6,113.00
MULCH MATERIAL TYPE 1	TON	56	$110.00	$6,160.00
DISK ANCHORING	ACRE	28	$40.00	$1,120.00
FERTILIZER, TYPE 1	TON	2.8	$800.00	$2,240.00
Subtotal				$2,986,262.00
Engineering and Administration	25%			$746,566.00
Utility Relocation	LS	1	$ 50,000.00	$50,000.00
Materials Testing (Construction)	2% of Earthwork Cost			$9,780.00
Right of Way Acquisition	ACRE	396	$ 1,500.00	$594,000.00
Contingencies	10%			$298,627.00
Total Construction				**$4,685,235.00**

Newfolden / Middle River Subwatershed Flood Damage Reduction Project				
Diversion Channel - Engineer's Opinion of Most Probable Cost				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$56,200.00	$56,200.00
CLEARING AND GRUBBING	LF	4	$5,000.00	$20,000.00
COMMON EXCAVATION (P)	CY	432,000	$2.50	$1,080,000.00
COMMON EXCAVATION HAULING	CY	60,000	$4.00	$240,000.00
AGGREGATE SURFACING, CLASS 5	CY	4,000	$12.00	$48,000.00
12' x 8' PRECAST CONCRETE BOX CULVERT	LF	274	$1,100.00	$301,400.00
12' x 8' PRECAST CONCRETE BOX CULVERT END SECTION	EA	2	$14,500.00	$29,000.00
12' x 8' PRECAST CONCRETE BOX SKEWED END SECTION	EA	2	$28,000.00	$56,000.00
84" CAS PIPE CULVERT	LF	568	$190.00	$107,920.00
18" SIDE INLET PIPES W/ APRON AND FLAP	EA	24	$2,630.00	$63,120.00
DIVERSION INLET WEIR	EA	1	$58,000.00	$58,000.00
TYPE SP 9.5 WEARING COURSE MIXTURE (2,B)	TON	280	$200.00	$56,000.00
GRANULAR BEDDING (P)	TON	1,350	$9.00	$12,150.00
RIPRAP CLASS III	CY	3,000	$90.00	$270,000.00
SEEDING	ACRE	45	$90.00	$4,050.00
SEED MIXTURE, 25-141	POUND	2,655	$3.70	$9,824.00
MULCH MATERIAL TYPE 1	TON	90	$110.00	$9,900.00
DISK ANCHORING	ACRE	45	$40.00	$1,800.00
FERTILIZER, TYPE 1	TON	4.5	$800.00	$3,600.00
Subtotal				$2,426,964.00
Engineering and Administration	10%			$242,697.00
Utility Relocation	LS	1	$ 24,000.00	$24,000.00
Materials Testing (Construction)	2% of Earthwork Cost			$21,600.00
Right of Way Acquisition	ACRE	20	$ 1,500.00	$30,000.00
Building Site Acquisition	EA	1	$ 50,000.00	$50,000.00
Contingencies	10%			$242,697.00
Total Construction				**$3,037,958.00**

Newfolden / Middle River Subwatershed Flood Damage Reduction Project				
Railroad Embankment - Engineer's Opinion of Most Probable Cost				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$43,000.00	$43,000.00
CLEARING AND GRUBBING	ACRE	2	$5,000.00	$10,000.00
COMMON EXCAVATION (P)	CY	6,000	$2.50	$15,000.00
COMMON BORROW	CY	6,000	$4.00	$24,000.00
AGGREGATE SURFACING, CLASS 5	CY	711	$12.00	$8,532.00
8' x 8' PRECAST CONCRETE BOX CULVERT	LF	300	$950.00	$285,000.00
8' x 8' PRECAST CONCRETE BOX CULVERT END SECTION	EA	6	$12,000.00	$72,000.00
SHOO-FLY	LS	1	$1,200,000.00	$1,200,000.00
RIPRAP CLASS III	CY	500	$70.00	$35,000.00
SEEDING	ACRE	2	$90.00	$180.00
SEED MIXTURE, 25-141	POUND	118	$3.70	$437.00
MULCH MATERIAL TYPE 1	TON	4	$110.00	$440.00
DISK ANCHORING	ACRE	2	$40.00	$80.00
FERTILIZER, TYPE 1	TON	0.2	$800.00	$160.00
Subtotal				$1,693,829.00
Engineering and Administration	20%			$338,766.00
Utility Relocation	LS	1	$ 10,000.00	$10,000.00
Materials Testing (Construction)	2% of Earthwork Cost			$300.00
Temporary Right of Way Acquisition	ACRE	7	$ 1,000.00	$7,000.00
Contingencies (Includes Ballast and Rail)	25%			$423,458.00
Total Construction				**$2,473,353.00**

Appendix C. Geotechnical Investigation Report

GEOTECHNICAL EXPLORATION
AND ENGINEERING REVIEW

Newfolden/Middle River Subwatershed Flood Damage Reduction Project
Rural Newfolden, Minnesota

NTI Project No. 18.FGO.06666

NTI
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Unearthing confidence™

December 10, 2018

Middle-Snake-Tamarac Rivers Watershed District (MSTRWD)
453 North McKinley St.
Warren, MN 56762

Attn: Mr. Joel Praska, Administrator

Subject: Geotechnical Exploration (factual)
Proposed Newfolden/Middle River Subwatershed Flood Damage Reduction Project
Rural Newfolden, Minnesota
NTI Project No. 18.FGO.06666

In accordance with your request and subsequent August 31, 2018 authorization, Northern Technologies, LLC (NTI) conducted a Geotechnical Exploration for the above referenced project. Our services included advancement of exploration borings and preparation of a factual engineering report with respect to our geotechnical services. Our work was performed in general accordance with our proposal of August 28, 2018.

Soil samples obtained at the site will be held for 60 days (from issue of report) at which time they will be discarded. Please advise us in writing if you wish to have us retain them for a longer period. You will be assessed an additional fee if soil samples are retained beyond 60 days.

We appreciate the opportunity to have been of service on this project. If there are any questions regarding the soils explored or our review and recommendations, please contact us at your convenience at (701) 232-1822.

Northern Technologies, LLC

Daniel Gibson

Dan Gibson, P.E.
Senior Engineer

Josh Holmes, P.E.
Senior Engineer

cc: HDR

GEOTECHNICAL EXPLORATION
AND ENGINEERING REVIEW

Newfolden/Middle River Subwatershed Flood Damage Reduction Project
Rural Newfolden, Minnesota

NTI Project No. 18.FGO.06666

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APPENDICES

Appendix A - Geotechnical Evaluation of Recovered Soil Samples, Field Exploration Procedures, General Notes, Classification of Soils for Engineering Purposes

Appendix B - Laboratory Summary, Atterberg Limits Testing, Hydrometer Testing, Proctor Test, Unconfined Compression Tests, Consolidation Test, Hydraulic Conductivity Test, C-U Triaxial Test

Appendix C - Boring Logs, MDH Sealing Records, Site Diagram

GEOTECHNICAL EXPLORATION AND ENGINEERING REVIEW

Newfolden/Middle River Subwatershed Flood Damage Reduction Project
Rural Newfolden, Minnesota

NTI Project No. 18.FGO.06666

1.0 INTRODUCTION

1.1 Site / Project Description

The proposed Newfolden/Middle River Subwatershed Flood Damage Reduction Project is to be constructed in rural areas to the north and east of Newfolden, Minnesota as shown on the appended Borehole Location Plan provided by HDR. The project will consist of a diversion channel and embankments to reduce flood damage in the Newfolden area. The purpose of our investigation was to identify soils and perform laboratory testing as directed by HDR.

1.2 Scope of Services

The purpose of this report is to present a summary of our geotechnical exploration and laboratory testing for founding of the project. Our "scope of services" was limited to the following:

1. Explore the project subsurface by means of fifteen (15) standard penetration borings extending to depths of 16 to 46 feet, and conduct laboratory tests (as directed by HDR) on representative samples to characterize the engineering and index properties of the soils.
2. Prepare a factual report presenting our findings from our field exploration and laboratory testing based on the Scope of Work provided by HDR.

2.0 EXPLORATION PROGRAM RESULTS

2.1 Exploration Scope and Procedures

Site geotechnical drilling occurred on October 16, 17, & 18, 2018 with individual borings advanced at approximate locations as presented on the diagrams and corresponding coordinates within the appendices. Coordinates on the boring logs may differ slightly than the original plan to allow for access or avoidance of utilities. HDR staked the boring locations and provided elevations. NTI performed the borings in relatively close proximity to the staked locations.

NTI and its sub consultant (Soil Engineering Testing) performed the field exploration and laboratory under guidance from ASTM Standards and common practice within the geotechnical engineering field. We provide additional information on field and laboratory procedures within the report appendices.

2.2 Surface Conditions

The property for the proposed Newfolden/Middle River Subwatershed Flood Damage Reduction Project is currently farm fields, grasslands, wooded areas, and roadway ditches. Surfaces consist of grass cover and fallow farm land at the boring locations.

2.3 Subsurface Conditions

Please refer to the boring logs within the appendices for a detailed description and depths of stratum at each boring. The boreholes were abandoned using high solids bentonite grout per Minnesota Department of Health statutes. Minor settlement of upper infill soil and grout will occur with Owner responsible for final closure of the boreholes. The general geologic origin of retained soil samples is listed on the boring logs. The upper portion of the soil profile for each boring was sampled using auger flights and is approximate.

The overall subsurface soil profile at the borings consists of approximately 0.2 to 4.5 feet of topsoil and topsoil/fill underlain by relatively thin layers of loose to medium dense Glacial Lake Sediment (GLS) soils followed by medium to stiff Lake Modified Glacial Till (LMGT) which extends to the termination depth of the borings (maximum 46 feet). The GLS soils are comprised of sand and silty sand. LMGT soils are comprised of lean clay, silty clay, silt, occasional layers of sand. The soils have varying color, moisture content and unit weight. The LMGT clay soils have trace amounts of sand and gravel. Additional comment on the evaluation of recovered soil samples is presented within the report appendices and boring logs.

2.4 Groundwater Conditions

The drill crew observed the borings for groundwater and noted cave-in depth of borings, if any, during and at the completion of drilling activities. These observations and measurements are noted on the boring logs.

Measurable groundwater was encountered from depths of 1 to 15 feet below grade at select boring locations during and / or at the completion of drilling operations. Boring logs noted if samples were saturated during classification of the samples. The groundwater was contained within silt and sand soils that were generally confined by clay soils above and/or below the sand and silt layers. Additionally, occasional silt and sand seems are likely present and may be water bearing during spring thaw or times of heavy precipitation at all boring locations. The moisture content of lens soils and host clays can vary annually and per recent precipitation. Such soils and other regional dependent conditions may produce groundwater entry of project excavations.

2.5 Laboratory Test Program

2.5.1 SPT and Hand Penetrometer – Boring logs include SPT "N"-values and hand penetrometer readings obtained on cohesive soils during laboratory classification of retained soils.

2.5.2 Moisture and Density – We performed moisture and density testing on the samples requested by HDR as well as a number of other samples. Moisture and dry density of the soils ranged from 9 to 24 percent (excluding topsoil) and 108 to 134 lbs/ft^3, respectively. Results of all tests are included within the boring logs and testing summary.

2.5.3 Atterberg Limits (LL/PL) – We performed a total of fifteen (15) Atterberg limit tests on samples selected by HDR. The liquid limits (LL) ranged from 13 to 33 and the plastic limits (PL) ranged from 9 to 19. Results of all tests are included within the boring logs, testing summary, and Appendix B.

2.5.4 Hydrometer / Grain Size Analysis – Four (4) hydrometer / Grain Size Analysis tests were performed on samples chosen by HDR. The results are included in Appendix B of this report.

2.5.5 Standard Proctor Test – A single Standard Proctor test was conducted on a composite sample from augur cuttings of soils encountered from 1 to 10 feet below grade at soil boring SB-13. The test report is included within Appendix B.

2.5.5 Unconfined Compression Tests and CU Test (3 pressures) – We performed two unconfined compression tests and one UU Triaxial Test on samples chosen by HDR. Results are included in the testing summary and/or on individual reports within the appendices of this report. Additional information and data on the compressive strength of soils is included within the pocket pen. column on the boring logs.

2.5.6 Consolidation Test – We performed a single consolidation test on a thin wall tube sample obtained at a depth of 15 feet at soil boring SB-13. The result of the test is in Appendix B.

2.5.7 Hydraulic Conductivity Test – A single hydraulic conductivity or permeability test was performed on a thin wall tube sample obtained at a depth of 15 feet at soil boring SB-9. The result of the test is in Appendix B.

3.0 CLOSURE

The area coverage of borings in relation to the entire project is very small. For this and other reasons, we do not warrant conditions below the depth of our borings, or that the strata logged from our borings are necessarily typical of the site.

This factual report has been prepared for the exclusive use of Middle-Snake-Tamarac Rivers Watershed District (MSTRWD) and HDR for specific application to the proposed Flood Damage Reduction Project in rural Newfolden, Minnesota. Northern Technologies, LLC has endeavored to comply with generally accepted geotechnical engineering practice common to the local area. Northern Technologies, LLC makes no other warranty, expressed or implied.

Northern Technologies, LLC

Daniel Gibson

Dan Gibson, P.E.
Senior Engineer

Josh Holmes, P.E.
Senior Engineer

DG:jh

Attachments

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APPENDIX A

GEOTECHNICAL EVALUATION OF RECOVERED SOIL SAMPLES

We visually examined recovered soil samples to estimate distribution of grain sizes, plasticity, consistency, moisture condition, color, presence of lenses and seams, and apparent geologic origin. We then classified the soils according to the Unified Soil Classification System (ASTM D2488). A chart describing this classification system and general notes explaining soil sampling procedures are presented within the appendices.

The stratification depth lines between soil types on the logs are estimated based on the available data. Insitu, the transition between type(s) may be distinct or gradual in either the horizontal or vertical directions. The soil conditions have been established at our specific boring locations only. Variations in the soil stratigraphy may occur between and around the borings, with the nature and extent of such change not readily evident until exposed by excavation. These variations must be properly assessed when utilizing information presented on the boring logs. We request that you, your design team or contractors contact NTI immediately if local conditions differ from those assumed by this report, as we would need to review how such changes impact our recommendations. Such contact would also allow us to revise our recommendations as necessary to account for the changed site conditions.

FIELD EXPLORATION PROCEDURES

Soil Sampling – Standard Penetration Boring:

Soil sampling was performed according to the procedures described by ASTM D-1586. Using this procedure, a 2 inch O.D. split barrel sampler is driven into the soil by a 140 pound weight falling 30 inches. After an initial set of six inches, the number of blows required to drive the sampler an additional 12 inches is recorded (known as the penetration resistance (i.e. "N-value") of the soil at the point of sampling. The N-value is an index of the relative density of cohesionless soils and an approximation of the consistency of cohesive soils.

Soil Sampling – Power Auger Boring:

The boring(s) was/were advanced with a 6 inch nominal diameter continuous hollow stem flight auger. As a result, samples recovered from the boring are disturbed, and our determination of the depth, extent of various stratum and layers, and relative density or consistency of the soils is approximate.

Soil Classification:

Soil samples were visually and manually classified in general conformance with ASTM D-2488 as they were removed from the sampler(s). Representative fractions of soil samples were then sealed within respective containers and returned to the laboratory for further examination and verification of the field classification. In addition, select samples were submitted for laboratory tests. Individual sample information, identification of sampling methods, method of advancement of the samples and other pertinent information concerning the soil samples are presented on boring logs and related report attachments.

General Notes

DRILLING & SAMPLING SYMBOLS		LABORATORY TEST SYMBOLS	
SYMBOL	**DEFINITION**	**SYMBOL**	**DEFINITION**
C.S.	Continuous Sampling	W	Moisture content-percent of dry weight
P.D.	2-3/8" Pipe Drill	D	Dry Density-pounds per cubic foot
C.O.	Cleanout Tube	LL, PL	Liquid and plastic limits determined in accordance with ASTM D 423 and D 424
3 HSA	3 ¼" I.D. Hollow Stem Auger	Q_u	Unconfined compressive strength-pounds per square foot in accordance with ASTM D 2166-66
4 FA	4" Diameter Flight Auger		
6 FA	6" Diameter Flight Auger		
2 ½ C	2 ½" Casing		
4 C	4" Casing		**Additional insertions in Qu Column**
D.M.	Drilling Mud	Pq	Penetrometer reading-tons/square foot
J.W.	Jet Water	S	Torvane reading-tons/square foot
H.A.	Hand Auger	G	Specific Gravity – ASTM D 854-58
NXC	Size NX Casing	SL	Shrinkage limit – ASTM 427-61
BXC	Size BX Casing	pH	Hydrogen ion content-meter method
AXC	Size AX casing	O	Organic content-combustion method
SS	2" O.D. Split Spoon Sample	M.A.*	Grain size analysis
2T	2" Thin Wall Tube Sample	C*	One dimensional consolidation
3T	3" Thin Wall Tube Sample	Q_c*	Triaxial Compression
			* See attached data Sheet and/or graph

Water Level Symbol

Water levels shown on the boring logs are the levels measured in the borings at the time and under the conditions indicated. In sand, the indicated levels can be considered reliable groundwater levels. In clay soils, it is not possible to determine the groundwater level within the normal scope of a test boring investigation, except where lenses or layers of more pervious water bearing soil is present and then a long period of time may be necessary to reach equilibrium. Therefore, the position of the water level symbol for cohesive or mixed soils may not indicate the true level of the groundwater table. The available water level information is given at the bottom of the log sheet.

Descriptive Terminology

DENSITY		CONSISTENCY	
TERM	**"N" VALUE**	**TERM**	**"N" VALUE**
Very Loose	0-4	Soft	0-4
Loose	5-8	Medium	5-8
Medium Dense	9 – 15	Rather Stiff	9 – 15
Dense	16 – 30	Stiff	16 – 30
Very Dense	Over 30	Very Stiff	Over 30

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon.

Relative Proportions

TERMS	RANGE
Trace	0-5%
A little	5-15%
Some	15-30%
With	30-50%

Particle Sizes

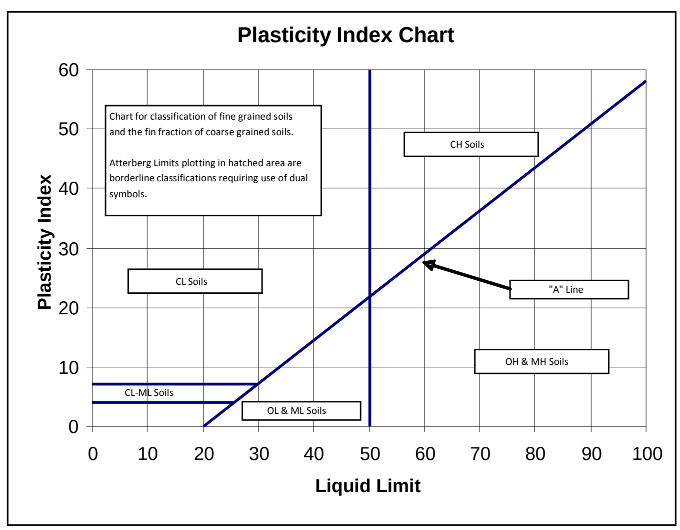
Boulders		Over 3"
Gravel -	Coarse	¾" – 3"
	Medium	#4 – ¾"
Sand -	Coarse	#4 - #10
	Medium	#10 - #40
	Fine	#40 - #200
Silt and Clay		Determined by plasticity characteristics.

Note: Sieve sizes are U.S. Standard.

Classification of Soils for Engineering Purposes

ASTM Designation D-2487 and D 2488 (Unified Soil Classification System)

Major Divisions			Group Symbol	Typical Names		Classification Criteria
Course Grained Soils More than 50% retained on No. 200 sieve *	***Gravels*** 50% or more of coarse fraction retained on No. 4 sieve.	Clean Gravels	**GW**	Well –graded gravels and gravel-sand mixtures, little or no fines.	***Classification on basis of percentage of fines.*** Less than 5% passing No. 200 Sieve: GW, GP, SW, SP More than 12% passing No. 200 Sieve: GM, GC, SM, SC From 5% to 12% passing No. 200 Sieve: Borderline Classification requiring use of duel symbols.	$C_u = D_{60} / D_{10}$ greater than 4. $C_z = (D_{30})^2 / (D_{10} \times D_{60})$ between 1 & 3.
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines.		Not meeting both criteria for GW materials.
		Gravels with Fines	**GM**	Silty gravels, gravel-sand-silt mixtures.		Atterberg limits below “A” line, or P.I. less than 4. Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.		Atterberg limits above “A” line with P.I. greater than 7.
	Sands More than 50% of coarse fraction passes No 4 sieve.	Clean Sands	**SW**	Well-graded sands and gravelly sands, little or no fines.		$C_u = D_{60} / D_{10}$ greater than 6. $C_z = (D_{30})^2 / (D_{10} \times D_{60})$ between 1 & 3.
			SP	Poorly-graded sands and gravelly sands, little or no fines.		Not meeting both criteria for SW materials.
		Sands with Fines	**SM**	Silty sands, sand-silt mixtures.		Atterberg limits below “A” line, or P.I. less than 4. Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.		Atterberg limits above “A” line with P.I. greater than 7.
Fine Grained Soils More than 50% passes No. 200 sieve *	***Silts and Clays*** Liquid Limit of 50% or less		**ML**	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.		
			OL	Organic silts and organic silty clays of low plasticity.		
	Silts and Clays Liquid Limit greater than 50%.		**MH**	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.		
			CH	Inorganic clays of high plasticity, fat clays.		
			OH	Organic clays of medium to high plasticity.		
	Highly Organic Soils		**Pt**	Peat, muck and other highly organic soils.		



APPENDIX B

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
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SUMMARY OF LABORATORY RESULTS

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Borehole	Sample #	Depth (ft)	Water Content (%)	Dry Density (pcf)	Liquid Limit	Plastic Limit	Maximum Size (mm)	% < #200 Sieve	Unconfined Compression Peak (psf)	Unconfined Compression %	Void Ratio	Other Tests
SB-01	2	2.0	12.0	121.3	33	12						
SB-01	3	4.5	13.1	117.1								
SB-01	4	7.0	12.9	121.1								
SB-01	5	9.5	13.1	124.0								
SB-01	6	12.0	13.7	122.7								
SB-01	8	17.0	13.0	126.4								
SB-01	9	19.5	20.5	114.9								
SB-01	10	24.5	12.7	126.3								
SB-01	11	29.5	14.9	122.5								
SB-02	1	0.0	19.4									
SB-02	2	2.0	16.0	112.4								
SB-02	3	4.5	13.4	122.7								
SB-02	4	7.0	14.1	124.6								
SB-02	5	9.5	15.7	115.7								
SB-02	6	12.0	15.1	121.6	30	12						
SB-02	8	17.0	13.5	125.4								
SB-02	9	19.5	11.8	127.6								
SB-02	10	24.5	13.3	123.3								
SB-02	11	29.5	12.9	127.5								
SB-03	1	0.0	16.7									
SB-03	3	4.5	23.8	107.7								
SB-03	4	7.0	10.0		15	9						
SB-03	5	9.5	13.2	128.0								
SB-03	6	12.0	14.2	130.4								
SB-03	8	17.0	13.3	123.4								
SB-03	9	19.5	12.7	126.7								
SB-03	10	24.5	13.2	125.9								
SB-03	11	29.5	14.4	121.7								
SB-04	1	0.0	20.3									
SB-04	5	9.5	13.3	129.7								
SB-04	6	12.0	13.4	131.7								
SB-04	7	14.5	13.0	129.5								
SB-05	1	0.0	18.8									
SB-05	2	2.0	17.5									
SB-05	3	4.5	21.4	120.1								
SB-05	4	7.0	8.9	133.9								
SB-05	5	9.5	12.2									
SB-05	6	12.0	14.7	119.2								

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SUMMARY OF LABORATORY RESULTS

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Borehole	Sample #	Depth (ft)	Water Content (%)	Dry Density (pcf)	Liquid Limit	Plastic Limit	Maximum Size (mm)	% < #200 Sieve	Unconfined Compression		Void Ratio	Other Tests
									Peak (psf)	%		
SB-05	7	14.5	12.5	124.0								
SB-06	3	4.5	22.7				4.75	12				
SB-07	3	4.5	12.9				9.5	63				
SB-08	2	2.0	17.9	109.4	20	11						
SB-08	3	4.5	14.4	121.5								
SB-08	4	7.0	11.7	125.6								
SB-08	5	9.5	13.2	118.2								
SB-08	6	12.0	12.1	130.7								
SB-08	7	14.5	13.2	128.5								
SB-08	8	17.0	14.2	123.9								
SB-08	9	19.5	13.6	125.8								
SB-08	10	24.5	14.9	120.4								
SB-08	11	29.5	17.1	115.5								
SB-09	1	0.0	29.9									
SB-09	2	2.0	12.8				9.5	23				
SB-09	3	4.5	15.7	123.2	25	11			3570	12.6		
SB-09	4	7.0	14.0	126.3								
SB-09	5	9.5	14.2	122.5								
SB-09	6	12.0	13.8	121.3								
SB-09	8	17.0	16.6									
SB-09	9	19.5	13.3	125.3	25	12						
SB-09	10	24.5	14.0	123.3								
SB-09	11	29.5	8.8	130.2								
SB-09	12	34.5	6.4	127.2								
SB-09	13	39.5	6.0		13	10						
SB-09	14	44.5	9.4									
SB-10	2	2.0	24.0				2	19				
SB-11	5	9.5	12.9	126.0	22	11						
SB-12	4	7.0	11.0		23	11						
SB-12	11	29.5	17.3	117.3	22	11						
SB-13	1	0.0	20.4									
SB-13	2	2.0	10.2	116.7								
SB-13	Bag	3.0	11.9	121.6								
SB-13	3	4.5	12.6	125.4								
SB-13	4	7.0	13.4	122.0	25	11						
SB-13	5	9.5	14.0	126.8	24	12			4730	15.0		
SB-13	6	12.0	12.8	122.2								
SB-13	7	14.5	14.7	114.7							0.470	

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SUMMARY OF LABORATORY RESULTS

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Borehole	Sample #	Depth (ft)	Water Content (%)	Dry Density (pcf)	Liquid Limit	Plastic Limit	Maximum Size (mm)	% < #200 Sieve	Unconfined Compression		Void Ratio	Other Tests
									Peak (psf)	%		
SB-13	8	17.0	16.6	114.2								
SB-13	9	19.5	12.4	123.5								
SB-13	10	24.5	13.7	120.9								
SB-13	11	29.5	20.6	106.8								
SB-13	12	34.5	13.9	118.3	27	12						
SB-13	13	39.5	8.2	128.8								
SB-13	14	44.5	8.2	128.6								
SB-14	10	24.5	15.7	119.5	31	12						
SB-15	6	12.0	13.2	123.6	26	19						

ATTERBERG LIMITS' RESULTS

ASTM D4318

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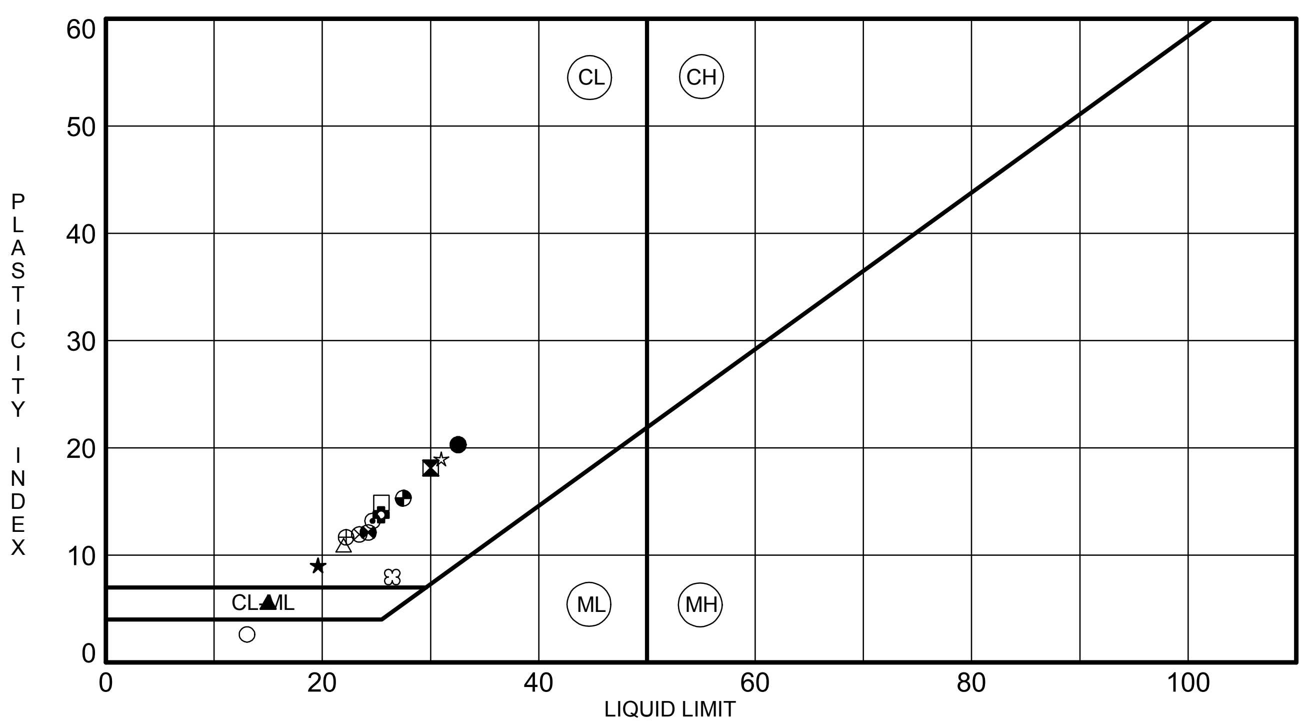
Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Data

	BOREHOLE	SAMPLE #	DEPTH	LL	PL	PI	Fines	Classification
●	SB-01	2	2.0	33	12	21		LEAN CLAY (CL)
⧗	SB-02	6	12.0	30	12	18		LEAN CLAY (CL)
▲	SB-03	4	7.0	15	9	6		SILTY LEAN CLAY (CL-ML)
★	SB-08	2	2.0	20	11	9		LEAN CLAY (CL)
⊙	SB-09	3	4.5	25	11	14		LEAN CLAY (CL)
✿	SB-09	9	19.5	25	12	13		LEAN CLAY (CL)
○	SB-09	13	39.5	13	10	3		SILT (ML)
△	SB-11	5	9.5	22	11	11		LEAN CLAY (CL)
⊗	SB-12	4	7.0	23	11	12		LEAN CLAY (CL)
⊕	SB-12	11	29.5	22	11	11		LEAN CLAY (CL)



Cc:

Submitted by,
Northern Technologies, LLC

Dan Gibson
(12/7/18)

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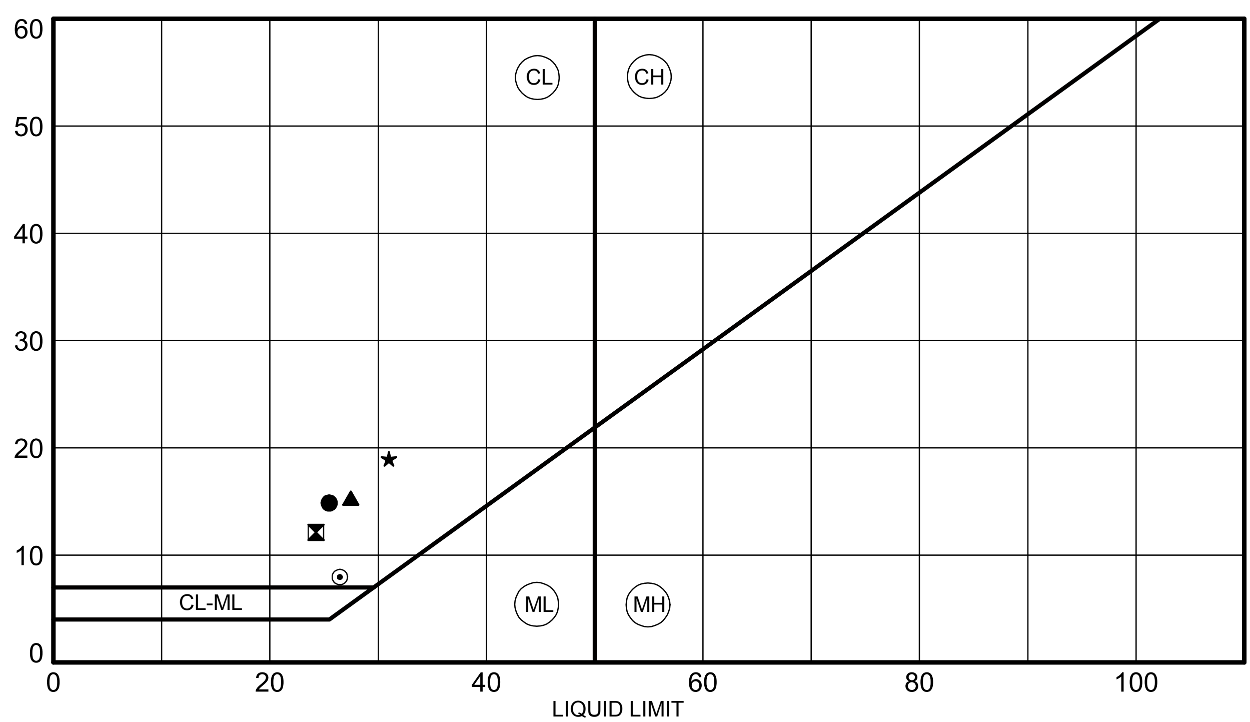
ATTERBERG LIMITS' RESULTS

ASTM D4318

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Data

	BOREHOLE	SAMPLE #	DEPTH	LL	PL	PI	Fines	Classification
●	SB-13	4	7.0	25	11	14		LEAN CLAY (CL)
⊠	SB-13	5	9.5	24	12	12		LEAN CLAY (CL)
▲	SB-13	12	34.5	27	12	15		LEAN CLAY (CL)
★	SB-14	10	24.5	31	12	19		LEAN CLAY (CL)
⊙	SB-15	6	12.0	26	19	7		LEAN CLAY (CL)



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GRAIN SIZE DISTRIBUTION

ASTM C136 & D422

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

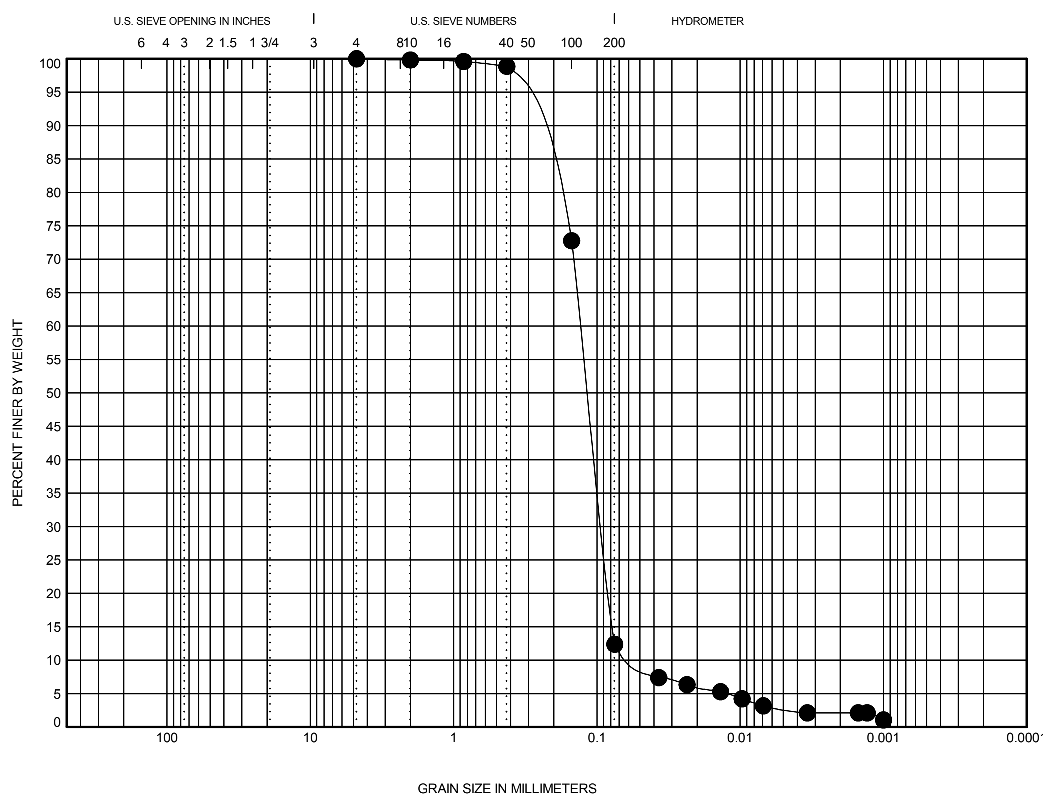
Sample Information

Boring Number:	SB-06	Date Sampled:	10/17/2018
Sample Number:	3	Sampled By:	NTI
Sample Depth (ft):	4.5	Sample Type:	SS
Classification:	SILTY SAND, fine grained		

Sample Data

Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
1.21	2.42	4.75	0.13	0.092	0.054	0.0	87.6	9.7	2.7

Sieve Name	Percent Finer	Project Specs
#4	100.0	
#10	99.8	
#20	99.6	
#40	98.9	
#100	72.8	
#200	12.4	



Hydrometer

Particle Size (mm)	Percent Finer
0.074 mm	12.3
0.02 mm	6.0
0.005 mm	2.7
0.002 mm	2.1
0.001 mm	1.1

Notes:

Cc:

Submitted by,
Northern Technologies, LLC

Chris Nelson
(12/7/18)

GRAIN SIZE DISTRIBUTION

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Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

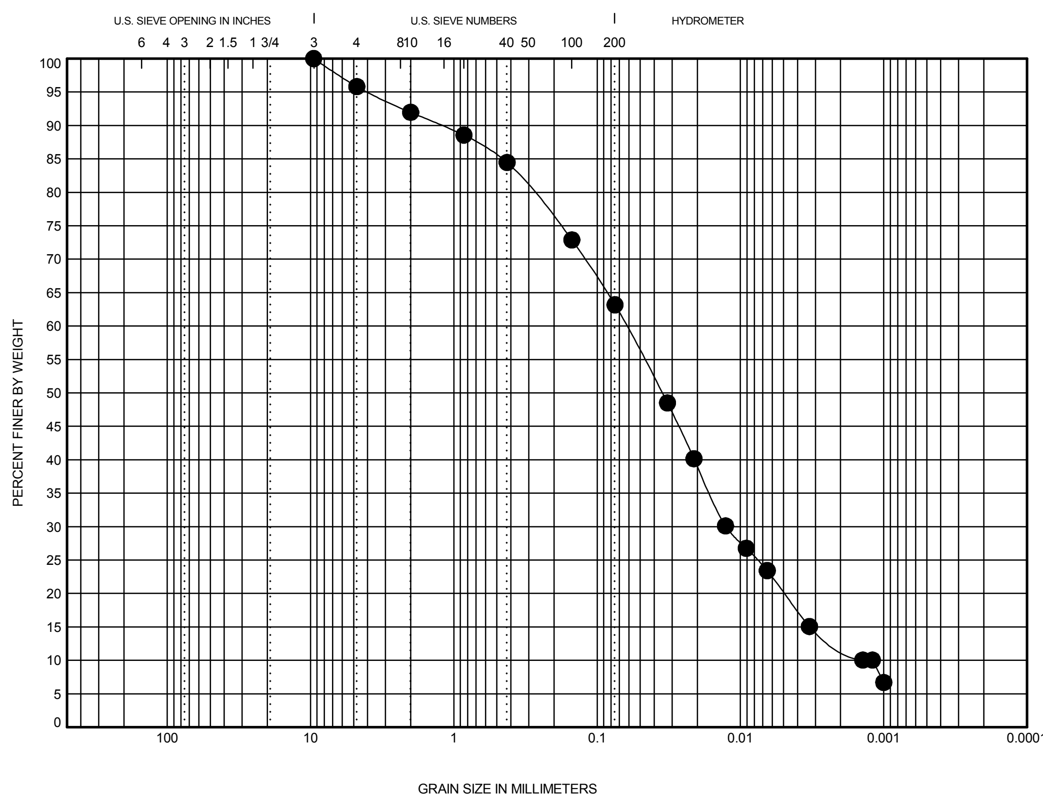
Sample Information

Boring Number:	SB-07	Date Sampled:	10/17/2018
Sample Number:	3	Sampled By:	NTI
Sample Depth (ft):	4.5	Sample Type:	SS
Classification:	SILT, with sand, trace of gravel		

Sample Data

Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
2.11	52.19	9.5	0.063	0.013	0.001	4.2	32.6	43.0	20.2

Sieve Name	Percent Finer	Project Specs
3/8"	100.0	
#4	95.8	
#10	92.0	
#20	88.6	
#40	84.5	
#100	72.9	
#200	63.2	



Hydrometer

Particle Size (mm)	Percent Finer
0.074 mm	62.9
0.02 mm	39.1
0.005 mm	20.2
0.002 mm	12.1
0.001 mm	6.7

Notes:

Cc:

Submitted by,

Northern Technologies, LLC

Chris Nelson
(12/7/18)

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GRAIN SIZE DISTRIBUTION

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Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Information

Boring Number:	SB-09	Date Sampled:	10/17/2018
Sample Number:	2	Sampled By:	NTI
Sample Depth (ft):	2	Sample Type:	SS
Classification:	SILTY SAND, fine to coarse grained, trace of gravel		

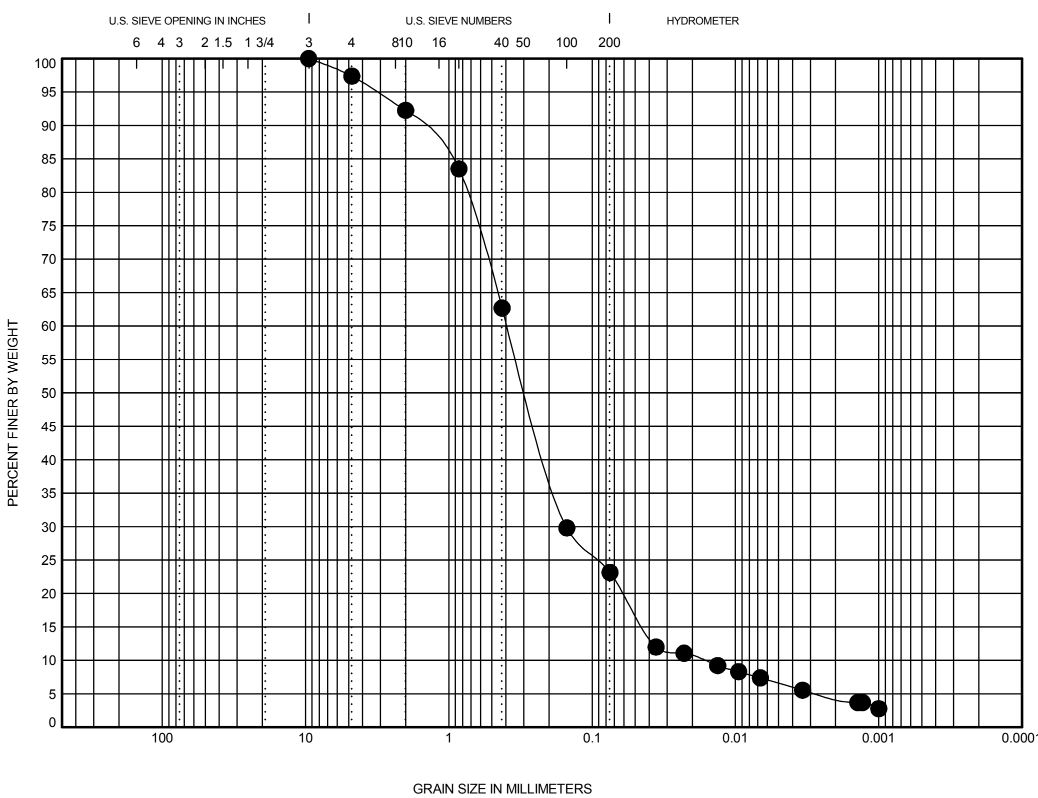
Sample Data

Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
3.49	23.36	9.5	0.39	0.151	0.017	2.6	74.2	16.6	6.6

Sieve Name	Percent Finer	Project Specs
3/8"	100.0	
#4	97.4	
#10	92.3	
#20	83.5	
#40	62.7	
#100	29.8	
#200	23.1	

Hydrometer

Particle Size (mm)	Percent Finer
0.074 mm	22.9
0.02 mm	10.6
0.005 mm	6.6
0.002 mm	4.4
0.001 mm	2.8



Notes:

Cc:

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GRAIN SIZE DISTRIBUTION

ASTM C136 & D422

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

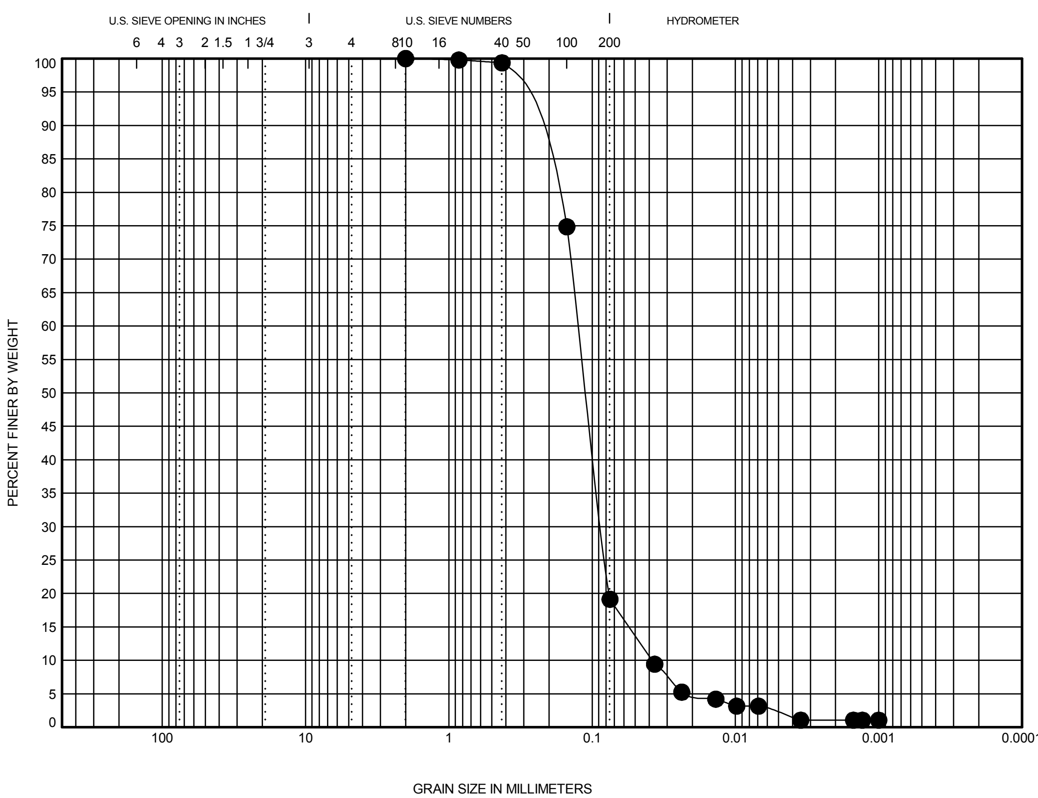
Sample Information

Boring Number:	SB-10	Date Sampled:	10/17/2018
Sample Number:	2	Sampled By:	NTI
Sample Depth (ft):	2	Sample Type:	SS
Classification:	SILTY SAND, fine to medium grained		

Sample Data

Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
1.55	3.26	2	0.125	0.086	0.038	0.0	80.9	17.0	2.1

Sieve Name	Percent Finer	Project Specs
#10	100.0	
#20	99.8	
#40	99.4	
#100	74.8	
#200	19.1	



Hydrometer

Particle Size (mm)	Percent Finer
0.074 mm	18.9
0.02 mm	4.9
0.005 mm	2.1
0.002 mm	1.0
0.001 mm	1.0

Notes:

Cc:

Submitted by,
Northern Technologies, LLC

Chris Nelson
(12/7/18)

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LABORATORY COMPACTION CHARACTERISTICS OF SOIL

Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Information

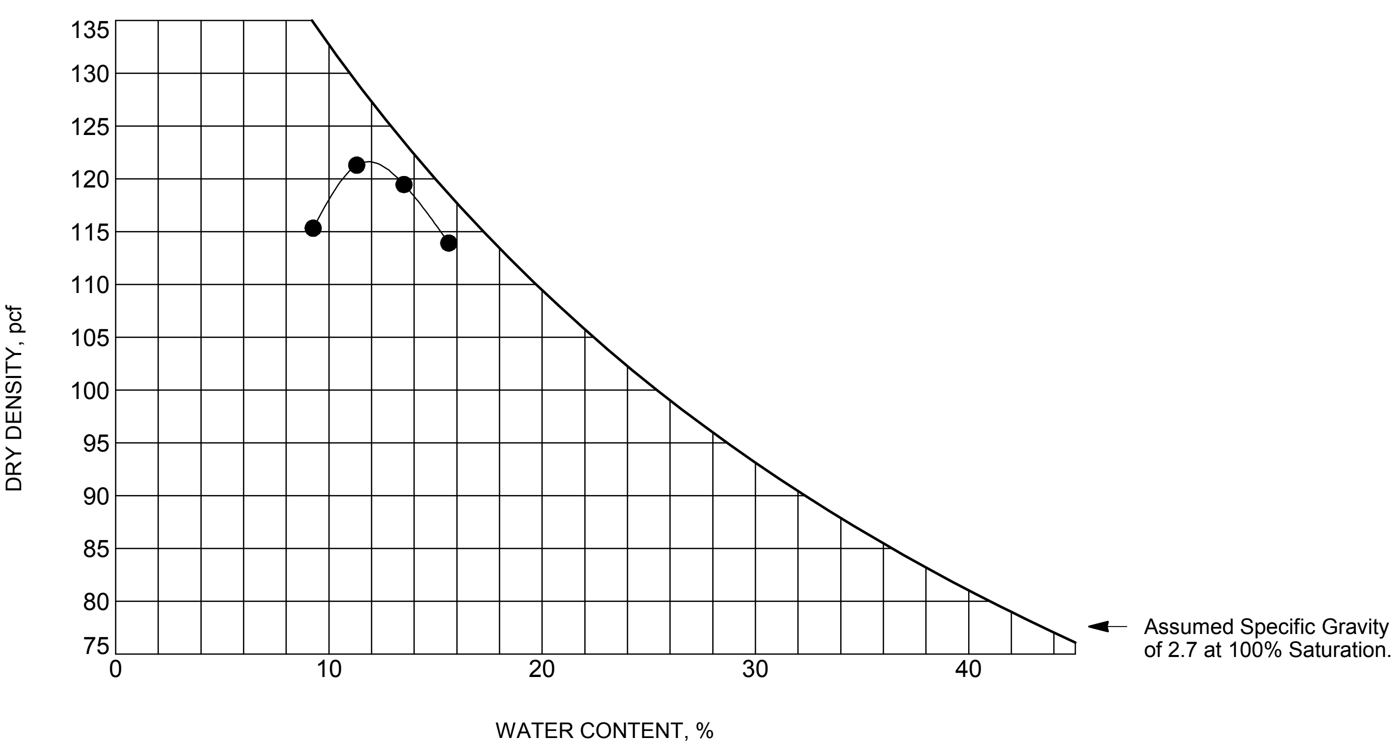
Sample Location:	SB-13	Date Sampled:	10/17/2018
Sample Number:	NA	Sample Type:	Bag Samples
Soil Description:	Lean Clay, trace of gravel, light brown		

Laboratory Information

Test Method:	ASTM D698 Method A	Rammer Type:	Manual
Preparation Method:	Dry		

Sample Data

Maximum Dry Density:	121.6 pcf	Liquid Limit:	
Optimum Water Content:	11.9 %	Plastic Limit:	



Comments:

Cc:

Submitted bv.
Northern Technologies, LLC

Chris Nelson
(12/10/18)

UNCONFINED COMPRESSION TEST

ASTM D2166

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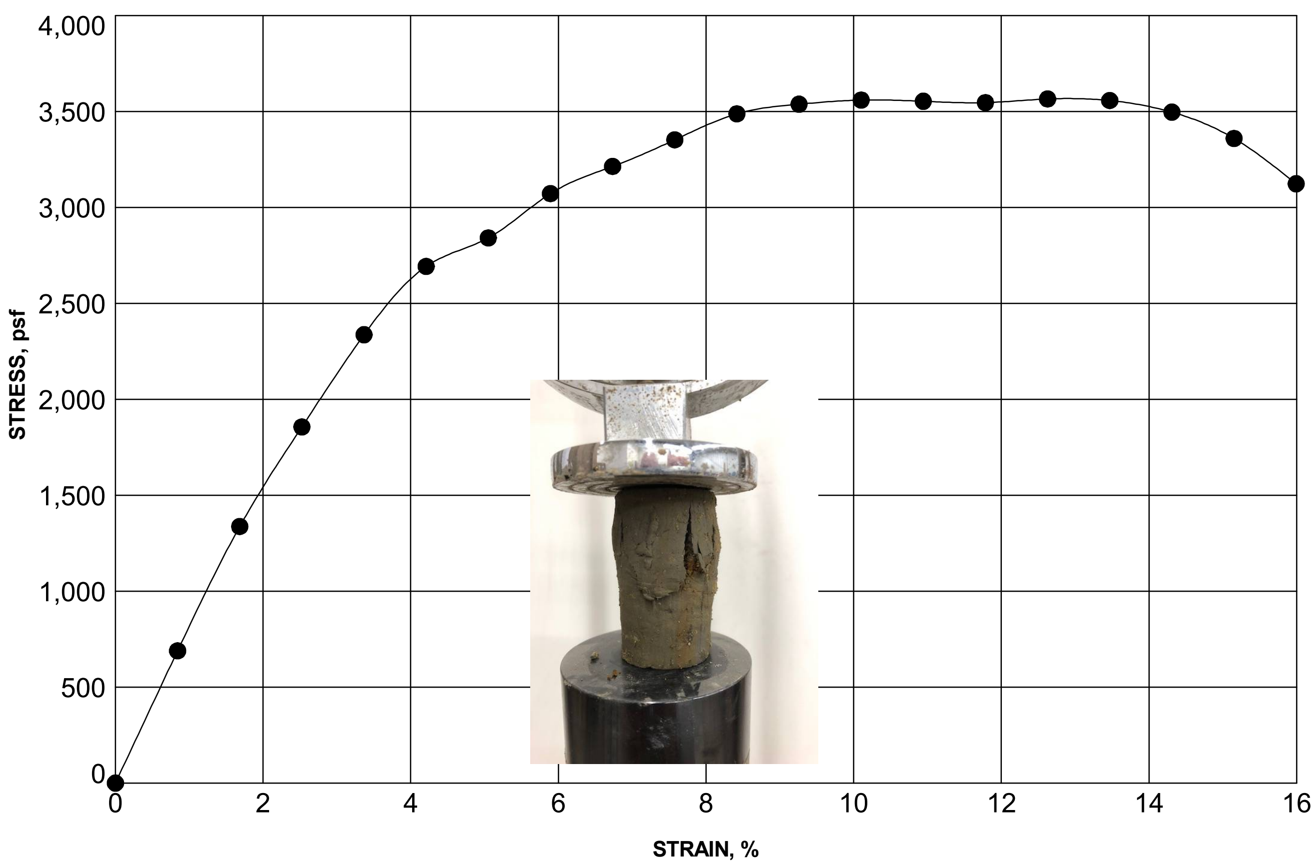
Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Information

Borehole:	SB-09	Sample Number:	3	Depth (ft):	4.5
Classification:	LEAN CLAY (CL)				

Sample Data

Dry Density:	123	Liquid Limit:	25	Peak (psf):	3570 @ 12.6%
Moisture Content (%):	16	Plastic Limit:	11		



Comments:

Cc:

Submitted by,
Northern Technologies, LLC

Chris Nelson
(12/7/18)

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UNCONFINED COMPRESSION TEST

ASTM D2166

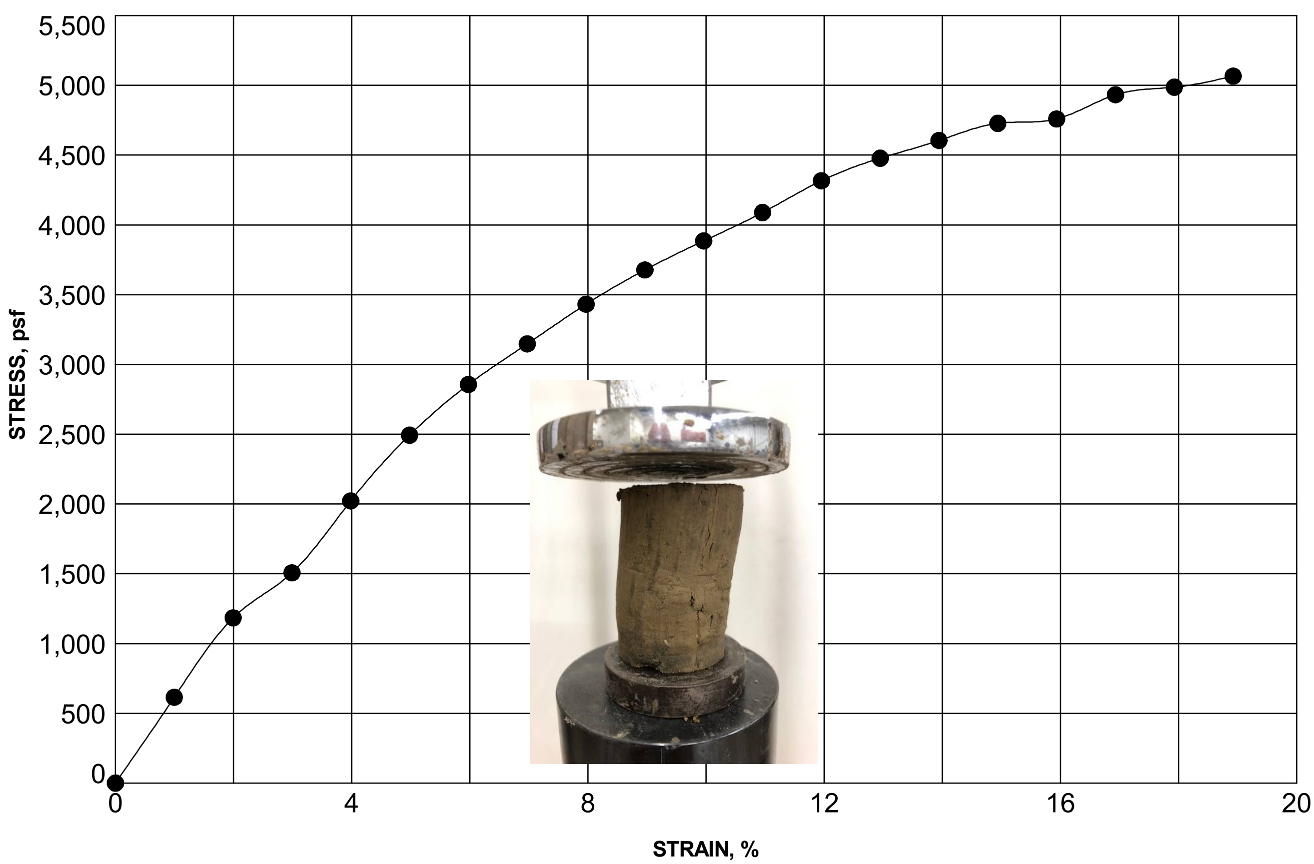
Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Information

Borehole:	SB-13	Sample Number:	5	Depth (ft):	9.5
Classification:	LEAN CLAY (CL)				

Sample Data

Dry Density:	127	Liquid Limit:	24	Peak (psf):	4730 @ 15.0%
Moisture Content (%):	14	Plastic Limit:	12		



Comments:

Cc:

Submitted by,
Northern Technologies, LLC

Chris Nelson
(12/7/18)

NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103
P: 701.232.1822 F: 701.232.1864
www.NTIgeo.com

CONSOLIDATION TEST

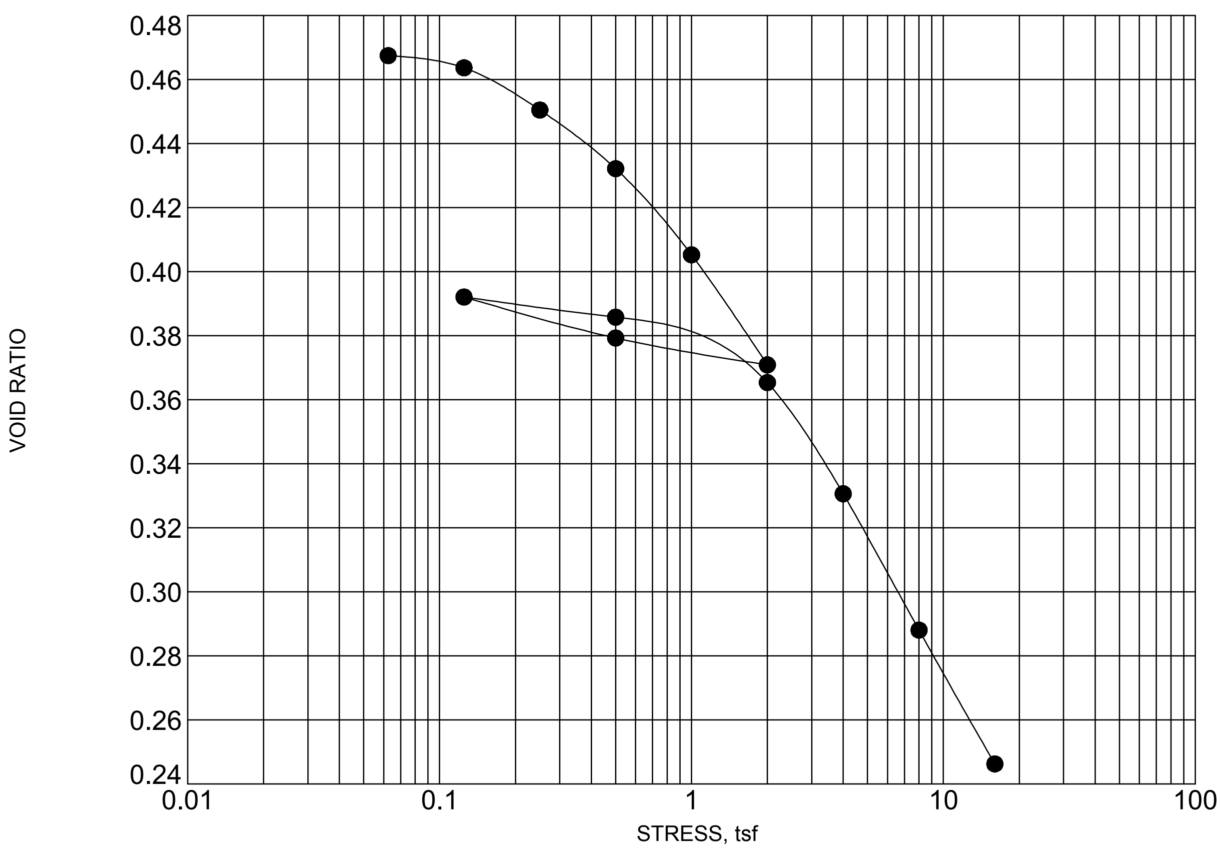
Report To:	MSTRWD 453 North McKinley St. Warren, MN 56762	Project:	Newfolden / MR Subwatershed Flood Damage Reduction
		Project Number:	18.FGO06666.000
Attention:	Joel Praska	Location:	Newfolden, Minnesota

Sample Information

Borehole:	SB-13	Sample Number:	7	Depth (ft):	14.5
Soil Classification:	SANDY LEAN CLAY (CLS)				

Sample Data

Deg of Sat (%)	MC (%)	γ_d	LL	PI	Sp Gravity	Overburden (tsf)	Pc (tsf)	Cc	Cr	Initial Void Ratio
	15	115			2.70					0.470



Comments:

Cc:

Submitted by,
Northern Technologies, LLC

Chris Nelson
(12/10/18)

Hydraulic Conductivity Test Data ASTM D5084

Project: Newfolden — Date: 11/26/2018

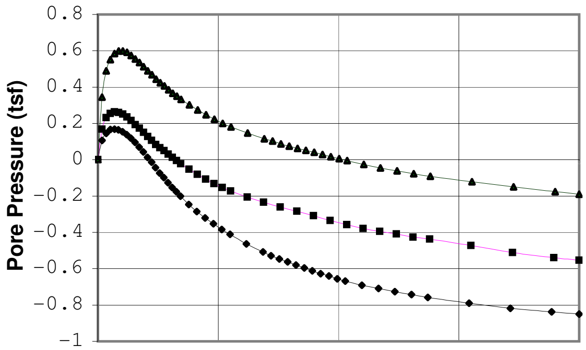
Client: Northern Technologies, LLC — Job No.: 11715

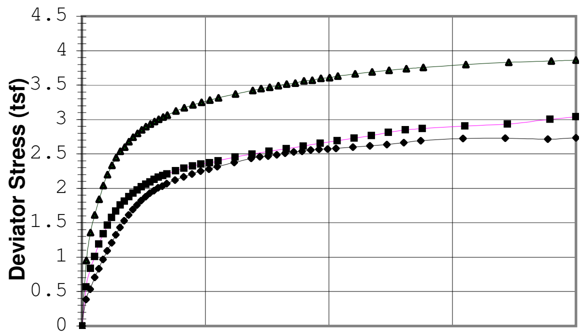
Boring No.:	9						
Sample No.:	7						
Depth (ft):	15						
Location:							
Sample Type:	TWT						
Soil Type:	Clayey Sand w/gravel (SC)						
Atterberg Limits							
LL							
PL							
PI							
Permeability Test	Intact						
Before Test Conditions: Saturation %:							
Porosity:							
Ht. (in):	2.81						
Dia. (in):	2.87						
Dry Density (pcf):	136.4						
Water Content:	8.1%						
Test Type:	Falling						
Max Head (ft):	5.0						
Confining press. (Effective-psi):	2.0						
Trial No.:	8-12						
Water Temp °C:	22.0						
% Compaction							
% Saturation (After Test)	100.7%						
Coefficient of Permeability							
K @ 20 °C (cm/sec)	**1.6×10^{-8}**						
K @ 20 °C (ft/min)	**3.3×10^{-8}**						
Notes:							

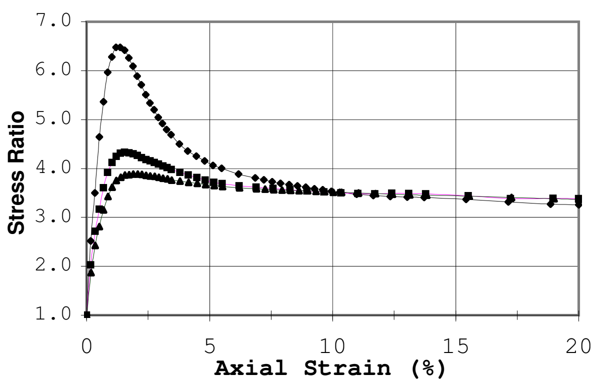
TRIAXIAL TEST ASTM: D 4767

Job No. **11715**
Date: **11/28/18**

Project: **Newfolden / Northern Technologies, LLC**
Boring #: **7** Sample #: **7** Type: **3T** Depth (ft): **14.5-16**
Soil Type: **Sandy Lean Clay w/a little gravel (CL)**





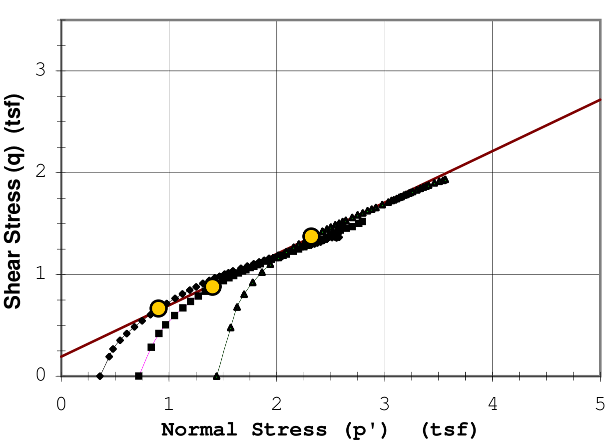


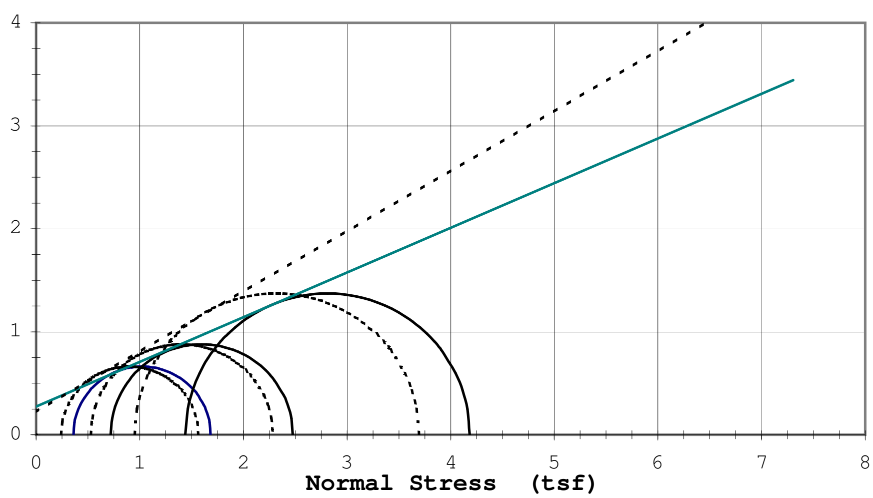
Failure Criterion:	**Max. Stress Ratio**		
Angle of internal friction, φ' =	**30.3 °**		
Apparent Cohesion, c' =	**0.22 (tsf)**		
Test Date:	11/16/18	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00073	Plasticity Index:	
Strain Rate (%/min):	0.025	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.92	2.92	2.92		
Water Content (%)	17.5	16.7	16.5		
Dry Density (pcf)	112.6	113.2	113.6		
Void Ratio	0.49	0.48	0.48		
After Consolidation					
Diameter (in)	1.44	1.43	1.43		
Height (in)	2.92	2.90	2.90		
Water Content (%)	18.0	17.0	16.2		
Dry Density (pcf)	113.1	115.3	117.0		
Void Ratio	0.48	0.46	0.43		
Back Pressure (tsf)	4.4	8.5	6.6		
Minor Principal Stress (tsf)	0.36	0.72	1.44		
Max. Deviator Stress (tsf)	2.73	3.04	3.87		
Ultimate Deviator Stress (tsf)	2.73	3.04	3.87		
Deviator Stress at Failure (tsf)	1.32	1.76	2.74		
Max. Pore Pressure Buildup (tsf)	0.17	0.26	0.60		
Pore Pressure Parameter "B"	0.95	0.95	0.95		
Pct. Axial Strain at Failure	1.4	1.6	2.1		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.





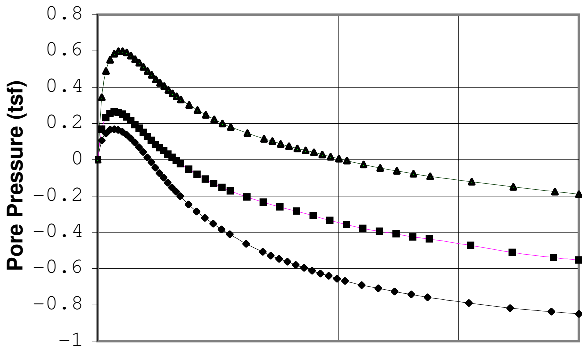
Rupture Envelope at Failure	
α = 26.8 °	a = 0.2 (tsf)

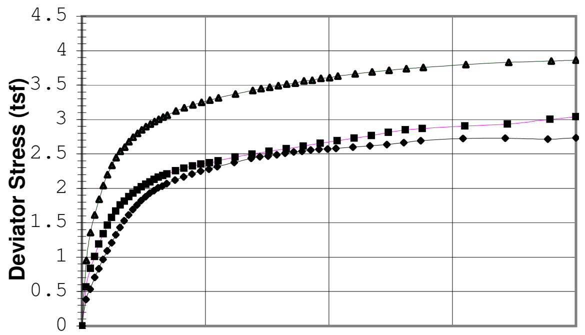
------------	Effective φ':	30.3 °	c'=	0.22 (tsf)
________	Total φ:	23.5 °	c=	0.27 (tsf)

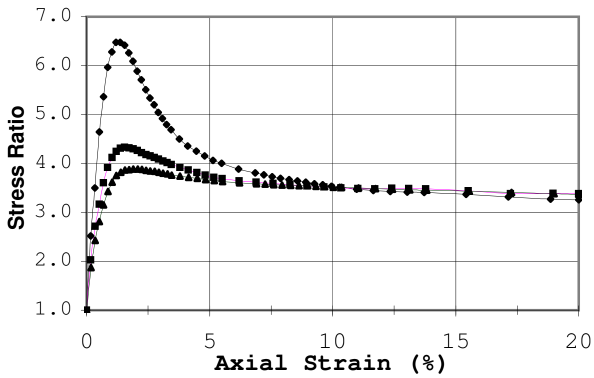
TRIAXIAL TEST ASTM: D 4767

Job No. **11715**
Date: **11/28/18**

Project: **Newfolden / Northern Technologies, LLC**
Boring #: **7** Sample #: **7** Type: **3T** Depth (ft): **14.5-16**
Soil Type: **Sandy Lean Clay w/a little gravel (CL)**







Failure Criterion:	Max. Deviator Stress
Angle of internal friction, ϕ' =	32.7 °
Apparent Cohesion, c' =	0.00 (tsf)

Test Date:	11/16/18	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00073	Plasticity Index:	
Strain Rate (%/min):	0.025	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.92	2.92	2.92		
Water Content (%)	17.5	16.7	16.5		
Dry Density (pcf)	112.6	113.2	113.6		
Void Ratio	0.49	0.48	0.48		
After Consolidation					
Diameter (in)	1.44	1.43	1.43		
Height (in)	2.92	2.90	2.90		
Water Content (%)	18.0	17.0	16.2		
Dry Density (pcf)	113.1	115.3	117.0		
Void Ratio	0.48	0.46	0.43		
Back Pressure (tsf)	4.4	8.5	6.6		
Minor Principal Stress (tsf)	0.36	0.72	1.44		
Max. Deviator Stress (tsf)	2.73	3.04	3.87		
Ultimate Deviator Stress (tsf)	2.73	3.04	3.87		
Deviator Stress at Failure (tsf)	2.73	3.04	3.87		
Max. Pore Pressure Buildup (tsf)	0.17	0.26	0.60		
Pore Pressure Parameter "B"	0.95	0.95	0.95		
Pct. Axial Strain at Failure	20.0	20.0	20.0		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

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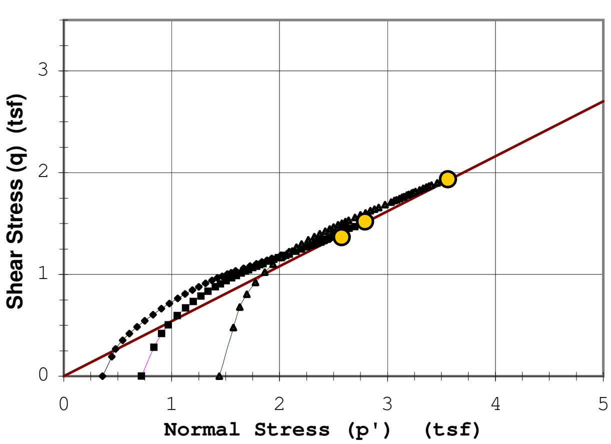
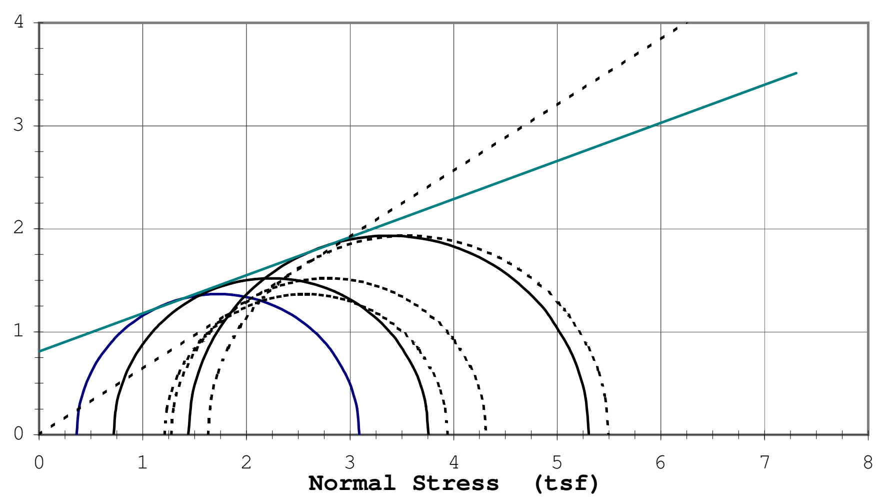
Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.





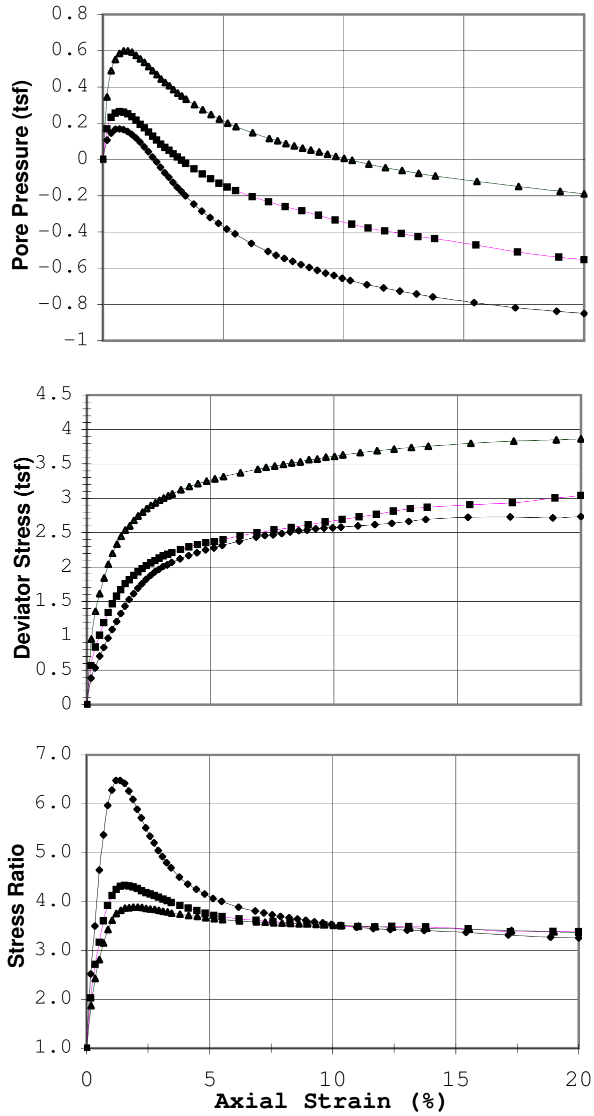
Rupture Envelope at Failure	
α = 28.4 °	a = 0.0 (tsf)

------------	Effective ϕ': 32.7 °	c'=	0.00 (tsf)
________	Total ϕ: 20.3 °	c=	0.81 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **11715**
Date: **11/28/18**

Project: **Newfolden / Northern Technologies, LLC**
Boring #: **7** Sample #: **7** Type: **3T** Depth (ft): **14.5-16**
Soil Type: **Sandy Lean Clay w/a little gravel (CL)**



Failure Criterion:	**Given Strain of: 15%**					
Angle of internal friction, ϕ' =	**33.4 °**					
Apparent Cohesion, **c'** =	**0.00 (tsf)**					
Test Date:	11/16/18	Liquid Limit:				
Test Type:	CU w/pp	Plastic Limit:				
Strain Rate (in/min):	0.00073	Plasticity Index:				
Strain Rate (%/min):	0.025	Spec. Gravity (Assumed):	2.69			

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.92	2.92	2.92		
Water Content (%)	17.5	16.7	16.5		
Dry Density (pcf)	112.6	113.2	113.6		
Void Ratio	0.49	0.48	0.48		
After Consolidation					
Diameter (in)	1.44	1.43	1.43		
Height (in)	2.92	2.90	2.90		
Water Content (%)	18.0	17.0	16.2		
Dry Density (pcf)	113.1	115.3	117.0		
Void Ratio	0.48	0.46	0.43		
Back Pressure (tsf)	4.4	8.5	6.6		
Minor Principal Stress (tsf)	0.36	0.72	1.44		
Max. Deviator Stress (tsf)	2.73	3.04	3.87		
Ultimate Deviator Stress (tsf)	2.73	3.04	3.87		
Deviator Stress at Failure (tsf)	2.69	2.87	3.75		
Max. Pore Pressure Buildup (tsf)	0.17	0.26	0.60		
Pore Pressure Parameter "B"	0.95	0.95	0.95		
Pct. Axial Strain at Failure	15.0	15.0	15.0		

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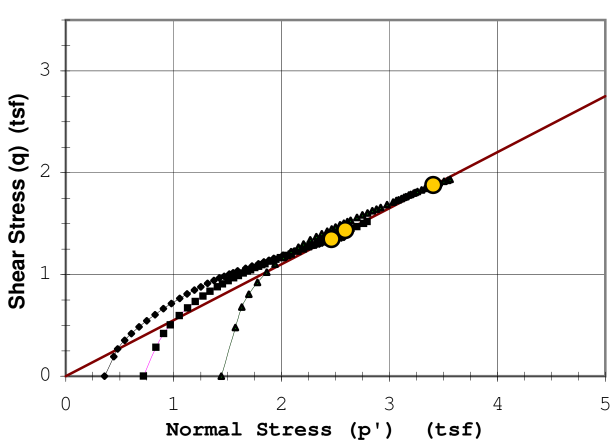
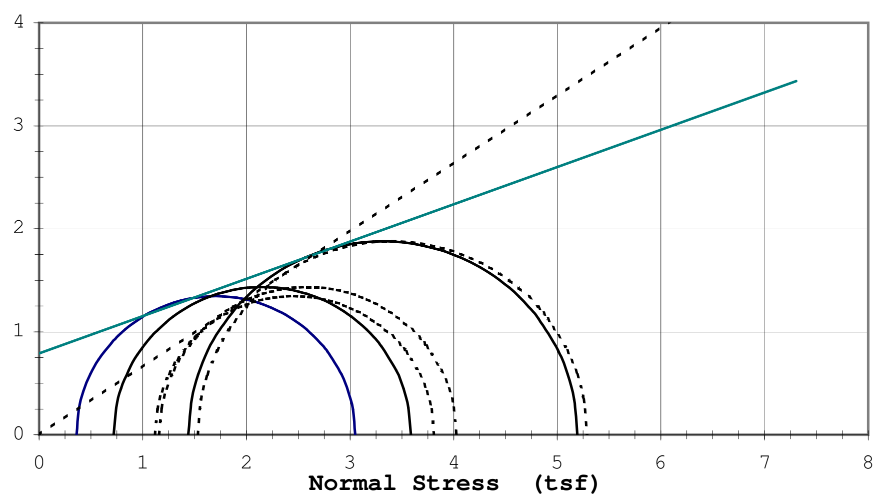
Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.





Rupture Envelope at Failure	
α = 28.8 °	a = 0.0 (tsf)

------------	Effective ϕ':	33.4 °	c'=	0.00 (tsf)
________	Total ϕ:	19.9 °	c=	0.79 (tsf)

Triaxial Data

Job: **11715**

Boring: 7 Sample: 7 Depth: 14.5-16 Date: 11/28/18

Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
0.17	0.38	0.11	0.17	0.57	0.17	0.18	0.95	0.34						
0.34	0.54	0.15	0.34	0.84	0.23	0.35	1.36	0.49						
0.51	0.71	0.17	0.52	1.01	0.25	0.52	1.61	0.55						
0.69	0.83	0.17	0.69	1.19	0.26	0.69	1.84	0.58						
0.86	0.97	0.16	0.86	1.34	0.26	0.87	2.04	0.60						
1.03	1.09	0.15	1.03	1.46	0.25	1.04	2.20	0.60						
1.20	1.21	0.14	1.21	1.57	0.23	1.21	2.33	0.59						
1.37	1.32	0.12	1.38	1.67	0.22	1.39	2.44	0.57						
1.54	1.43	0.10	1.55	1.76	0.19	1.56	2.54	0.55						
1.71	1.53	0.07	1.72	1.81	0.17	1.73	2.60	0.54						
1.89	1.61	0.04	1.90	1.88	0.15	1.90	2.68	0.51						
2.06	1.69	0.01	2.07	1.93	0.13	2.08	2.74	0.49						
2.23	1.76	-0.01	2.24	1.98	0.11	2.25	2.80	0.47						
2.40	1.82	-0.04	2.41	2.02	0.08	2.42	2.85	0.44						
2.57	1.88	-0.07	2.58	2.06	0.07	2.59	2.89	0.42						
2.74	1.93	-0.10	2.76	2.09	0.05	2.77	2.93	0.41						
2.91	1.96	-0.13	2.93	2.13	0.03	2.94	2.97	0.39						
3.09	2.01	-0.15	3.10	2.16	0.01	3.11	3.00	0.37						
3.26	2.03	-0.18	3.27	2.19	0.00	3.28	3.04	0.35						
3.43	2.07	-0.20	3.45	2.21	-0.02	3.46	3.06	0.33						
3.77	2.12	-0.25	3.79	2.25	-0.05	3.80	3.12	0.30						
4.11	2.17	-0.28	4.14	2.29	-0.08	4.15	3.17	0.27						
4.46	2.21	-0.32	4.48	2.32	-0.11	4.49	3.21	0.25						
4.80	2.25	-0.35	4.82	2.35	-0.13	4.84	3.25	0.22						
5.14	2.28	-0.38	5.17	2.37	-0.15	5.18	3.28	0.20						
5.49	2.32	-0.41	5.51	2.40	-0.17	5.53	3.32	0.18						
6.17	2.38	-0.46	6.20	2.45	-0.21	6.22	3.37	0.15						
6.86	2.44	-0.51	6.89	2.50	-0.23	6.91	3.42	0.12						
7.20	2.46	-0.53	7.58	2.54	-0.26	7.26	3.45	0.10						
7.54	2.47	-0.55	8.27	2.57	-0.28	7.60	3.47	0.09						
7.89	2.49	-0.56	8.96	2.61	-0.31	7.95	3.49	0.08						
8.23	2.51	-0.58	9.65	2.65	-0.33	8.29	3.52	0.06						
8.57	2.53	-0.60	10.34	2.69	-0.36	8.64	3.53	0.05						
8.91	2.54	-0.61	11.03	2.73	-0.38	8.98	3.56	0.04						
9.26	2.55	-0.63	11.72	2.76	-0.39	9.33	3.57	0.03						
9.60	2.56	-0.64	12.41	2.81	-0.41	9.67	3.60	0.02						
9.94	2.57	-0.66	13.10	2.85	-0.43	10.02	3.61	0.01						
10.29	2.58	-0.67	13.79	2.87	-0.44	10.37	3.63	0.00						
10.97	2.60	-0.69	15.51	2.91	-0.47	11.06	3.66	-0.03						
11.66	2.62	-0.71	17.23	2.93	-0.51	11.75	3.69	-0.04						
12.34	2.64	-0.73	18.96	3.00	-0.54	12.44	3.72	-0.06						
13.03	2.66	-0.74	20.00	3.04	-0.55	13.13	3.74	-0.08						
13.71	2.69	-0.76				13.82	3.75	-0.09						
15.43	2.72	-0.79				15.55	3.80	-0.12						
17.14	2.73	-0.82				17.27	3.83	-0.15						
18.86	2.71	-0.84				19.00	3.85	-0.18						
20.00	2.73	-0.85				20.00	3.87	-0.19						

APPENDIX C

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-01

Long: -96° 20' 12.876"
Lat: 48° 22' 5.16"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1093.266 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
∇ **AT TIME OF DRILLING** 15.50 ft / Elev 1077.77 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

Depth to bottom of layer (ft)	MATERIAL DESCRIPTION	Elevation (ft)
0.9	ORGANIC SILTY SAND, (OL) black, fine grained	1092.3
7.0	LEAN CLAY, (CL) light brown to light gray, stiff, trace sand	1086.3
9.0	LEAN CLAY, (CL) light brown to light gray, stiff, trace sand, trace gravel	1084.3
12.5	LEAN CLAY, (CL) brown, stiff, trace sand, trace gravel	1080.8
15.5 ∇	LEAN CLAY, (CL) dark gray, stiff, trace sand, trace gravel	1077.8
18.0	POORLY GRADED SAND, (SP) brown, fine to coarse grained, wet, dense	1075.3
19.0	LEAN CLAY, (CL) dark gray, stiff, trace sand, trace gravel	1074.3
23.0	SILTY FAT CLAY, (CH/CL) dark gray, rather stiff	1070.3
31.0	LEAN CLAY, (CL) dark gray, stiff, trace sand	1062.3

SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
AU 1									
SS 2	100	5-7-9 (16)	6.0	121	12	33	12	21	
SS 3	94	5-8-9 (17)	4.0	117	13				
SS 4	100	6-8-9 (17)	5.7	121	13				
SS 5	100	5-7-9 (16)	4.6	124	13				
SS 6	100	6-8-8 (16)	4.1	123	14				
SS 7	67	8-12-11 (23)							
SS 8	67	3-5-12 (17)	2.0	126	13				
SS 9	83	5-5-7 (12)	1.0	115	21				
SS 10	100	4-7-9 (16)	2.1	126	13				
SS 11	111	5-8-9 (17)	2.2	123	15				

Bottom of borehole at 31.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-02

Long: -96° 20' 8.52"
Lat: 48° 22' 6.708"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1093.013 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	ELEV.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0.7	ORGANIC SILTY SAND, (OL) dark brown, fine grained	1092.3	AU 1					19				
	LEAN CLAY, (CL) light brown to light gray, rather stiff, trace sand, trace gravel		SS 2	67	4-5-6 (11)	6.0	112	16				
			SS 3	89	3-4-7 (11)	4.1	123	13				
9.5		1083.5	SS 4	100	4-5-6 (11)	2.5	125	14				
11.5	LEAN CLAY, (CL) dark brown, rather stiff, trace sand, trace gravel	1081.5	SS 5	56	4-6-10 (16)	2.4	116	16				
	LEAN CLAY, (CL) brown, rather stiff, trace sand, trace gravel		SS 6	44	3-4-6 (10)	1.9	122	15	30	12	18	
16.5		1076.5	ST 7									
	LEAN CLAY, (CL) dark gray, rather stiff to stiff, trace sand, trace gravel		SS 8	100	2-3-6 (9)	1.7	125	13				
			SS 9	89	2-6-8 (14)	2.8	128	12				
			SS 10	56	6-10-11 (21)	1.9	123	13				
31.0		1062.0	SS 11	89	6-10-10 (20)	2.9	127	13				

Bottom of borehole at 31.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-03

Long: -96° 19' 21.468"
Lat: 48° 22' 9.876"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1100.962 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0.8	ORGANIC SILTY SAND, (OL) black, fine grained	1100.2	AU 1					17				
5.5	POORLY GRADED SAND WITH SILT, (SP-SM) brown, fine to coarse grained, medium dense	1095.5	SS 2	83	4-5-7 (12)							
			SS 3	67	1-3-3 (6)	2.5	108	24				
6.5	LEAN CLAY, (CL/CH) light brown to light gray, medium	1094.5										
10.5	SILTY LEAN CLAY, (CL-ML) light brown, rather stiff, trace sand, trace gravel	1090.5	SS 4	56	2-5-6 (11)	4.1		10	15	9	6	
			SS 5	100	3-6-8 (14)	3.5	128	13				
31.0	LEAN CLAY, (CL) dark gray, rather stiff to stiff, trace sand, trace gravel	1070.0	SS 6	94	2-4-6 (10)	0.6	130	14				
			ST 7									
			SS 8	89	2-4-7 (11)	2.7	123	13				
			SS 9	67	7-9-9 (18)	2.7	127	13				
			SS 10	111	6-10-11 (21)	1.6	126	13				
			SS 11	122	7-10-10 (20)	2.7	122	14				

Bottom of borehole at 31.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-04

Long: 96° 18' 10.44"
Lat: 48° 22' 9.048"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1107.192 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
▽ **AT TIME OF DRILLING** 1.00 ft / Elev 1106.19 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0–0.8	ORGANIC SILTY SAND, (OL) black (Elev. 1106.4)	AU 1					20				
0.8–4.5	▽ POORLY GRADED SAND, (SP) light brown, fine grained, wet, medium dense (Elev. 1102.7)	SS 2	56	1-4-6 (10)							
4.5–6.5	SILTY SAND, (SM) gray, fine grained, moist, medium dense (Elev. 1100.7)	SS 3	67	2-4-6 (10)							
6.5–10.0	POORLY GRADED SAND, (SP) gray, fine grained, wet, loose (Elev. 1097.2)	SS 4	78	3-3-3 (6)							
10.0–16.0	LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel (Elev. 1091.2)	SS 5	94	2-4-6 (10)	2.3	130	13				
		SS 6	89	2-4-6 (10)	1.8	132	13				
		SS 7	89	2-4-7 (11)	2.1	130	13				

Bottom of borehole at 16.0 feet.
Borehole grouted.

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-05

Long: -96° 17' 9.528"
Lat: 48° 22' 8.508"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1104.952 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
▽ **AT TIME OF DRILLING** 5.00 ft / Elev 1099.95 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0.4	ORGANIC CLAY WITH SAND, (OL) dark brown, trace gravel	1104.5	AU 1					19				
	LEAN CLAY, (CL) light brown, rather stiff, trace sand, trace gravel		SS 2	44	3-5-9 (14)	4.2		18				
5.0 ▽	SILT, (ML) light brown, moist, rather stiff, trace sand	1100.0	SS 3	100	3-6-9 (15)	1.5	120	21				
7.0	LEAN CLAY, (CL) light brown, rather stiff to stiff, trace sand, trace gravel	1098.0	SS 4	89	3-5-7 (12)	4.8	134	9				
			SS 5	44	7-9-15 (24)			12				
11.5	LEAN CLAY, (CL) brown to dark gray, stiff, trace sand, trace gravel	1093.5	SS 6	89	7-9-13 (22)	3.9	119	15				
15.5		1089.5	SS 7	111	5-7-11 (18)	4.4	124	13				
16.0	LEAN CLAY, (CL) dark gray, stiff, trace sand, trace gravel	1089.0										

Bottom of borehole at 16.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-06

Long: -96° 19' 16.14"
Lat: 48° 23' 3.264"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1106.683 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
▽ **AT TIME OF DRILLING** 5.00 ft / Elev 1101.68 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.
0.8	ORGANIC SILTY SAND, (OL) black, fine grained	1105.9
5.0 ▽	POORLY GRADED SAND WITH SILT, (SP-SM) light brown, fine grained, medium dense	1101.7
8.0	SILTY SAND, (SM) brown, fine grained, wet, medium dense	1098.7
11.5	FAT CLAY, (CH) gray, medium, trace sand	1095.2
17.5	SILT, (ML) gray, moist, rather stiff	1089.2
23.0	FAT CLAY, (CH) gray, rather stiff, trace sand	1083.7
30.5	LEAN CLAY, (CL) gray, stiff, trace sand, trace gravel	1076.2

SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
AU 1									
SS 2	72	3-4-7 (11)							
SS 3	78	3-5-7 (12)			23				12
SS 4	78	3-2-3 (5)	1.4						
SS 5	94	2-3-5 (8)	1.3						
SS 6	78	2-4-7 (11)	4.9						
SS 7	78	3-4-9 (13)	3.3						
SS 8	89	2-4-6 (10)	2.0						
SS 9	122	2-4-7 (11)	2.0						
SS 10	111	4-6-11 (17)	1.7						
SS 11	183	4-6-10/0"	1.9						

Bottom of borehole at 30.5 feet.
Borehole grouted.

NTI Northern Technologies, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-07

Long: -96° 19' 19.1136"
Lat: 48° 22' 55.9344"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1104.681 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elevation	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
0.8	ORGANIC SILTY SAND, (OL) black	1103.9	AU 1									
5.0	SILT, (ML) brown to light brown, rather stiff, with sand, trace gravel	1099.7	SS 2	89	3-5-6 (11)							
	LEAN CLAY, (CL) gray to dark gray, medium to stiff, with sand, trace gravel		SS 3	83	2-3-3 (6)	1.4		13				63
			SS 4	72	2-3-5 (8)	1.6						
			SS 5	100	1-3-6 (9)	2.0						
			SS 6	100	3-6-8 (14)	2.4						
			ST 7			1.8						
			SS 8	94	3-5-8 (13)	2.4						
			SS 9	100	3-5-8 (13)							
			SS 10	100	4-9-10 (19)	1.2						
31.0		1073.7	SS 11	100	4-9-10 (19)	2.1						

Bottom of borehole at 31.0 feet.
Borehole grouted.

BORING NUMBER SB-08

NTI Northern Technologies, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

Long: -96° 19' 19.164"
Lat: 48° 22' 34.608"

CLIENT MSTRWD **PROJECT NAME** Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000 **PROJECT LOCATION** Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18 **GROUND ELEVATION** 1100.469 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI **GROUND WATER LEVELS:**
DRILLING METHOD 3 1/4 in H.S.A **AT TIME OF DRILLING** --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson **AT END OF DRILLING** ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA **AFTER DRILLING** ---
NOTES

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
0–0.7		ORGANIC SILTY SAND, (OL) black (1099.8)	AU 1									
0.7–10.0		LEAN CLAY, (CL) light brown, soft to rather stiff, trace sand, trace gravel (1090.5)	SS 2	67	3-2-1 (3)	0.6	109	18	20	11	9	
			SS 3	78	2-3-5 (8)	1.4	121	14				
			SS 4	94	3-4-6 (10)	3.0	126	12				
10.0–12.0		LEAN CLAY, (CL) dark brown, rather stiff, trace sand, trace gravel (1088.5)	SS 5	100	4-5-7 (12)	3.8	118	13				
12.0–31.0		LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel (1069.5)	SS 6	89	3-4-6 (10)	3.3	131	12				
			SS 7	89	2-4-5 (9)	1.9	129	13				
			SS 8	111	3-4-6 (10)	2.0	124	14				
			SS 9	111	2-4-6 (10)	2.2	126	14				
			SS 10	111	3-6-8 (14)	5..2	120	15				
			SS 11	111	3-7-8 (15)	2.7	116	17				

Bottom of borehole at 31.0 feet.
Borehole grouted.

BORING NUMBER SB-09

NTI NORTHERN TECHNOLOGIES, LLC
Fargo
3522 4th Ave S
Fargo, North Dakota 58103

Long: -96° 20' 6.864"
Lat: 48° 22' 14.232"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1093.245 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0		0.6 ORGANIC SILTY SAND, (OL) black 1092.7	AU 1					30				
		SILTY SAND, (SM) light brown to light gray, fine to coarse grained, loose, trace gravel	SS 2	56	1-2-4 (6)			13				23
5		4.0 LEAN CLAY, (CL) gray, rather stiff, trace sand, trace gravel 1089.2	SS 3	67	3-4-5 (9)	2.0	123	16	25	11	14	
		7.0 LEAN CLAY, (CL) dark gray, rather stiff to very stiff, trace sand, trace gravel 1086.2	SS 4	111	2-4-6 (10)	2.2	126	14				
10			SS 5	83	4-4-5 (9)	1.3	123	14				
			SS 6	89	3-4-6 (10)	2.6	121	14				
15			ST 7									
			SS 8	44	6-9-12 (21)	1.1		17				
20			SS 9	100	4-6-10 (16)	2.4	125	13	25	12	13	
25			SS 10	89	3-6-9 (15)	2.1	123	14				

(Continued Next Page)

BORING NUMBER SB-09

Long: -96° 20' 6.864"
Lat: 48° 22' 14.232"

CLIENT MSTRWD **PROJECT NAME** Newfolden / MR Subwatershed Flood Damage Reduction

PROJECT NUMBER 18.FGO06666.000 **PROJECT LOCATION** Newfolden, Minnesota

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
		LEAN CLAY, (CL) dark gray, rather stiff to very stiff, trace sand, trace gravel *(continued)*										
30			SS 11	89	12-20-28 (48)	6.0	130	9				
33.0		(1060.2)										
		SANDY LEAN CLAY, (CL) gray, very stiff, trace gravel										
35			SS 12	111	20-55-46 (101)	6.0	127	6				
40			SS 13	100	47-70			6	13	10	3	
45			SS 14	100	52-68	3.6		9				
45.5		(1047.7)										

Bottom of borehole at 45.5 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-10

Long: -96° 20' 34.944"
Lat: 48° 22' 47.856"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1095.869 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING 1.00 ft / Elev 1094.87 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0.4	ORGANIC SILTY SAND, (OL) black	1095.4	AU 1									
	SILTY SAND, (SM) light brown, fine to medium grained, wet, medium dense		SS 2	56	2-5-5 (10)			24				19
5.5		1090.4	SS 3	67	2-3-2 (5)							
	LEAN CLAY, (CL) gray, medium to rather stiff, trace sand		SS 4	89	1-2-4 (6)	2.4						
			SS 5	94	2-4-7 (11)	4.8						
11.5		1084.4										
	LEAN CLAY, (CL) dark gray, rather stiff to stiff, trace sand, trace gravel		SS 6	89	2-4-6 (10)	1.4						
			SS 7	100	2-4-5 (9)	2.0						
			SS 8	122	3-4-6 (10)	1.8						
			SS 9	100	3-4-6 (10)	1.7						
			SS 10	111	3-7-10 (17)	4.4						
31.0		1064.9	SS 11	122	3-7-10 (17)	2.3						

Bottom of borehole at 31.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-11

Long: -96° 13' 51.276"
Lat: 48° 21' 28.044"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1131.395 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
0		FILL, FAT CLAY, brown to black	AU 1									
2.5		BURIED TOPSOIL, ORGANIC CLAY WITH SAND, (OL) black (elev. 1128.9)	SS 2	78	2-4-7 (11)							
4.5		LEAN CLAY, (CL) brown, medium to stiff, trace sand, trace gravel (elev. 1126.9)	SS 3	89	2-3-5 (8)	2.5						
			SS 4	100	3-4-7 (11)	3.3						
10			SS 5	89	3-9-13 (22)	4.7	126	13	22	11	11	
13.0		LEAN CLAY, (CL) olive gray, stiff, trace sand, trace gravel (elev. 1118.4)	SS 6	133	3-13-13 (26)	6.0						
14.0		LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel (elev. 1117.4)										
15			SS 7	56	4-7-8 (15)	2.0						
			SS 8	89	3-4-7 (11)	3.4						
20			SS 9	100	3-4-6 (10)	2.7						
23.0		LEAN CLAY, (CL) light brown, rather stiff, trace sand, trace gravel (elev. 1108.4)										
25			SS 10	100	3-5-8 (13)	2.0						
30			SS 11	111	3-5-8 (13)	5.5						
31.0		(elev. 1100.4)										

Bottom of borehole at 31.0 feet.
Borehole grouted.

BORING NUMBER SB-12

PAGE 1 OF 1

Long: -96° 15' 30.636"
Lat: 48° 21' 27.216"

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1120.968 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
▽ **AT TIME OF DRILLING** 15.00 ft / Elev 1105.97 ft
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
0.7	ORGANIC SILTY SAND, (OL) black, fine grained	1120.3	AU 1									
	LEAN CLAY, (CL) light brown, soft to medium, trace sand, trace gravel		SS 2	56	2-2-2 (4)	1.5						
6.5		1114.5	SS 3	78	2-3-5 (8)	2.1						
	LEAN CLAY, (CL) brown, stiff, trace sand, trace gravel		SS 4	94	5-8-13 (21)	6.0		11	23	11	12	
12.0		1109.0	SS 5	89	5-9-11 (20)	6.0						
15.0 ▽	LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel	1106.0	SS 6	89	2-4-6 (10)	2.6						
17.5	SILTY SAND, (SM) gray, fine grained, moist, very dense	1103.5	SS 7	78	5-16-17 (33)							
	LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel		SS 8	94	5-5-8 (13)	1.2						
			SS 9	94	2-4-7 (11)	2.2						
27.0		1094.0	SS 10	100	2-4-6 (10)	1.3						
31.0	LEAN CLAY, (CL) dark gray, rather stiff, trace sand, trace gravel	1090.0	SS 11	100	2-5-6 (11)	2.0	117	17	22	11	11	

Bottom of borehole at 31.0 feet.
Borehole grouted.

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-13

Long: -95° 16' 48.144"
Lat: 48° 21' 25.812"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1109.352 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
0–0.8		ORGANIC CLAY WITH SAND, (OL) black (0.8; 1108.6)	AU 1					20				
0.8–9.0		LEAN CLAY, (CL) light brown to light gray, rather stiff, trace sand (9.0; 1100.4)	SS 2	67	3-5-7 (12)	6.0	117	10				
			SS 3	78	2-4-5 (9)	2.5	125	13				
			SS 4	78	3-4-5 (9)	2.5	122	13	25	11	14	
9.0–11.5		LEAN CLAY, (CL) brown, rather stiff, trace sand, trace gravel (11.5; 1097.9)	SS 5	89	3-4-6 (10)	2.6	127	14	24	12	12	
11.5–16.5		SANDY LEAN CLAY, (CL) brown, stiff, trace gravel (16.5; 1092.9)	SS 6	89	3-6-10 (16)	2.5	122	13				
			ST 7	52		1.6	115	15				
16.5–		LEAN CLAY, (CL) dark gray, rather stiff to very stiff, trace sand, trace gravel	SS 8	89	3-6-10 (16)	2.4	114	17				
			SS 9	89	5-6-8 (14)	2.5	123	12				
			SS 10	94	2-5-8 (13)	3.4	121	14				

(Continued Next Page)

NTI NORTHERN TECHNOLOGIES, LLC
Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-13

Long: -95° 16' 48.144"
Lat: 48° 21' 25.812"

CLIENT MSTRWD **PROJECT NAME** Newfolden / MR Subwatershed Flood Damage Reduction

PROJECT NUMBER 18.FGO06666.000 **PROJECT LOCATION** Newfolden, Minnesota

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES
		LEAN CLAY, (CL) dark gray, rather stiff to very stiff, trace sand, trace gravel *(continued)*										
30			SS 11	100	5-7-12 (19)	3.5	107	21				
35			SS 12	111	6-8-14 (22)	4.2	118	14	27	12	15	
40			SS 13	111	10-26-36 (62)	6.0	129	8				
45		46.0	SS 14	111	12-22-35 (57)	6.0	129	8				
		1063.4										

Bottom of borehole at 46.0 feet.
Borehole grouted.

BORING NUMBER SB-14

PAGE 1 OF 1

Long: -96° 16' 47.928"
Lat: 48° 20' 35.016"

NTI NORTHERN TECHNOLOGIES, LLC

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1110.355 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elevation
0.4	ORGANIC CLAY WITH SAND, (OL) black	1109.9
7.0	LEAN CLAY, (CL) brown, medium to rather stiff, trace sand, trace gravel	1103.4
9.0	LEAN CLAY, (CL) brown to dark gray, rather stiff, trace sand, trace gravel	1101.4
12.0	LEAN CLAY, (CL) dark brown, stiff, trace sand, trace gravel	1098.4
19.0	LEAN CLAY, (CL) dark gray, rather stiff to stiff, trace sand, trace gravel	1091.4
23.0	SANDY LEAN CLAY, (CL) light brown, rather stiff, trace gravel	1087.4
31.0	LEAN CLAY, (CL) dark gray, rather stiff, trace sand	1079.4

SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
AU 1									
SS 2	67	1-3-5 (8)	2.1						
SS 3	83	3-4-5 (9)	3.9						
SS 4	100	3-5-7 (12)	4.4						
SS 5	100	4-6-11 (17)	4.4						
SS 6	89	3-7-10 (17)	3.0						
SS 7	11	6-7-8 (15)	1.5						
SS 8	67	6-10-10 (20)	1.5						
SS 9	89	3-5-8 (13)	6.0						
SS 10	39	4-5-5 (10)	0.9	120	16	31	12	19	
SS 11	67	5-6-4 (10)	1.5						

Bottom of borehole at 31.0 feet.
Borehole grouted.

Fargo
3522 4th Ave S
Fargo, North Dakota 58103

BORING NUMBER SB-15

Long: -96° 15' 31.032"
Lat: 48° 21' 2.448"

CLIENT MSTRWD
PROJECT NAME Newfolden / MR Subwatershed Flood Damage Reduction
PROJECT NUMBER 18.FGO06666.000
PROJECT LOCATION Newfolden, Minnesota
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 1117.051 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Chris Nelson **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NR **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0		0.2 ORGANIC CLAY WITH SAND, (OL) dark brown 1116.9	AU 1									
		LEAN CLAY, (CL) brown, rather stiff to stiff, trace sand, trace gravel	SS 2	89	2-5-7 (12)	4.0						
5			SS 3	22	4-8-10 (18)							
			SS 4	78	3-6-9 (15)	4.0						
10			SS 5	100	3-7-9 (16)	2.9						
		14.0 1103.1	SS 6	89	5-8-10 (18)	3.0	124	13	26	19	7	
15		LEAN CLAY, (CL) dark gray, stiff to rather stiff, trace sand, trace gravel	SS 7	100	4-7-9 (16)	2.4						
			SS 8	100	5-7-9 (16)	2.4						
20			SS 9	133	5-6-8 (14)	1.6						
25			SS 10	111	2-4-6 (10)	1.4						
		27.0 1090.1										
30		SILTY FAT CLAY, (CH/CL) dark gray, rather stiff, trace sand, trace gravel										
		31.0 1086.1	SS 11	111	3-5-6 (11)	1.6						

Bottom of borehole at 31.0 feet.
Borehole grouted.

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING SEALING RECORD
Minnesota Statutes, Chapter 103I

Minnesota Well and Boring Sealing No.: H 362967
Minnesota Unique Well No. or W-series No. (Leave blank if not known):

WELL OR BORING LOCATION
County Name: Marshall

Township Name	Township No.	Range No.	Section No.	Fraction (sm. → lg.)
New Maine	157 N	44 W	33	NE ¼ SE ¼ SW ¼

Date Sealed: 10/17/2018
Date Well or Boring Constructed: 10/17/2018

GPS LOCATION – decimal degrees (to four decimal places)
Latitude ______ Longitude ______

Depth at Time of Sealing: 30 ft.
Original Depth: 30 ft.

Numerical Street Address or Fire Number and City of Well or Boring Location: Various Locations in New Maine Twp.

AQUIFER(S)
☐ Single Aquifer ☐ Multiaquifer

WELL/BORING
☐ Water-Supply Well ☐ Monit. Well
☒ Env. Bore Hole ☐ Other

STATIC WATER LEVEL
☒ Measured Date Measured: 10/17/2018 ☐ Estimated
DRY ft. ☒ below ☐ above land surface

Show exact location of well or boring in section grid with "X."
Sketch map of well or boring location, showing property lines, roads, and buildings.

N / W / E / S — ½ Mile — 1 Mile

See Attached Map

CASING TYPE(S)
☐ Steel ☐ Plastic ☐ Tile ☒ Other: N/A

WELLHEAD COMPLETION
Outside: ☐ Pitless Adapter/Unit ☐ At Grade ☐ Well Pit ☐ Buried ☒ Other
Inside: ☐ Basement Offset ☐ Well House ☐ Well Pit ☐ Buried ☒ Other

PROPERTY OWNER'S NAME/COMPANY NAME: Middle-Snake-Tamarac Rivers Watershed District
Property owner's mailing address if different than well location address indicated above:
453 N McKinley St.
Warren, MN 56762

CASING(S)

Diameter	Depth	Set in oversize hole?	Annular space initially grouted?
N/A in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
___ in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
___ in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown

WELL OWNER'S NAME/COMPANY NAME: Same as above
Well owner's mailing address if different than property owner's address indicated above: Same as above

SCREEN/OPEN HOLE
Screen from N/A to ___ ft. Open Hole from ___ to ___ ft.

OBSTRUCTIONS
☐ Rods/Drop Pipe ☐ Check Valve(s) ☐ Debris ☐ Fill ☒ No Obstruction
Type of Obstructions (Describe) ___
Obstructions removed? ☐ Yes ☐ No Describe ___

PUMP
☒ Not Present ☐ Present, Removed Prior to Sealing ☐ Other
Type ___

If not known, indicate estimated formation log from nearby well or boring.

GEOLOGICAL MATERIAL	COLOR	HARDNESS OR FORMATION	FROM	TO
Glacial Drift			0	End

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE
☐ No Annular Space Exists ☐ Annular Space Grouted with Tremie Pipe ☒ Casing Perforation/Removal
Casing Diameter
N/A in. from ___ to ___ ft. ☐ Perforated ☐ Removed
___ in. from ___ to ___ ft. ☐ Perforated ☐ Removed
Type of Perforator: N/A

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ☒ No TN# ___

GROUTING MATERIAL(S) (One bag of cement = 94 lbs., one bag of bentonite = 50 lbs.)
Grouting Material: Bentonite Grout from 0 to End ft. ___ yards ___ bags
___ from ___ to ___ ft. ___ yards ___ bags
___ from ___ to ___ ft. ___ yards ___ bags

OTHER WELLS AND BORINGS
Other unsealed and unused well or boring on property? ☐ Yes ☒ No How many? ___

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING
Newfolden Flood Redux
(FGO06666)
BH-06 through BH-10

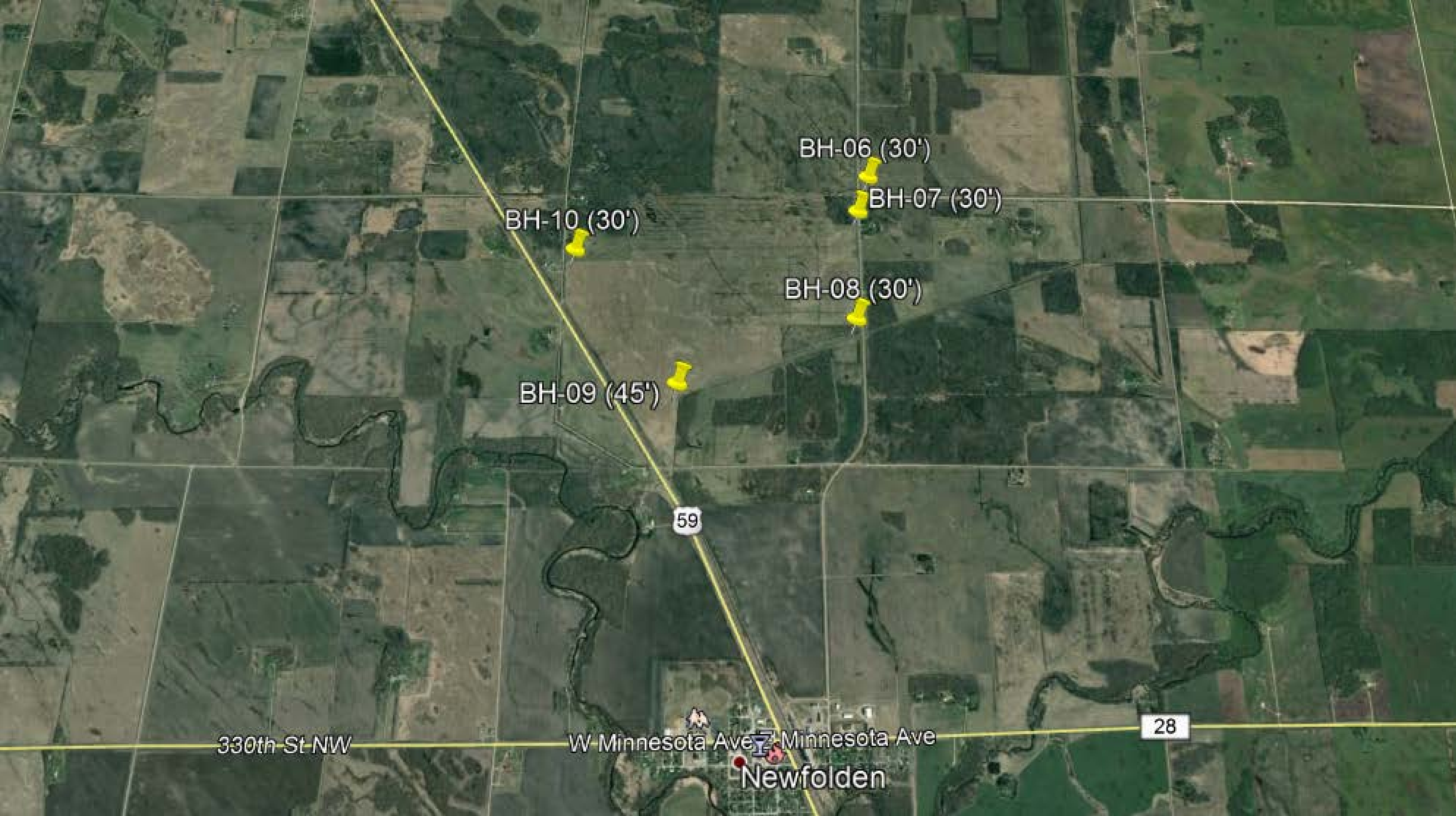
LICENSED OR REGISTERED CONTRACTOR CERTIFICATION
This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Northern Technologies, LLC — *Licensee Business Name*
3574 — *License or Registration No.*

Christopher Kaiser for Bill Canty — *Certified Representative Signature*
Certified Rep. No.
11/16/2018 — *Date*

Bradley Halvorson — *Name of Person Sealing Well or Boring*

MINN. DEPT OF HEALTH COPY
H 362967


BH-06 (30')
BH-07 (30')
BH-10 (30')
BH-08 (30')
BH-09 (45')
59
28
330th St NW
W Minnesota Ave
Minnesota Ave
Newfolden

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING SEALING RECORD

Minnesota Statutes, Chapter 103I

Minnesota Well and Boring Sealing No.: H 362968

Minnesota Unique Well No. or W-series No. (Leave blank if not known):

WELL OR BORING LOCATION

County Name: Marshall

Township Name	Township No.	Range No.	Section No.	Fraction (sm. → lg.)	Date Sealed	Date Well or Boring Constructed
New Folden	156 N	44 W	4	NE ¼ SW ¼ NW ¼	10/17/2018	10/17/2018

GPS LOCATION – decimal degrees (to four decimal places)

Latitude ________ Longitude ________

Depth at Time of Sealing 46 ft. Original Depth 45 ft.

Numerical Street Address or Fire Number and City of Well or Boring Location: Various Locations in New Folden Twp.

AQUIFER(S): ☐ Single Aquifer ☐ Multiaquifer

WELL/BORING: ☐ Water-Supply Well ☐ Monit. Well [✓ Env. Bore Hole] ☐ Other ________

STATIC WATER LEVEL: [✓ Measured] Date Measured 10/17/2018 ☐ Estimated

15.00 ft. [✓ below] ☐ above land surface

Show exact location of well or boring in section grid with "X."

N W E S ½ Mile 1 Mile

Sketch map of well or boring location, showing property lines, roads, and buildings.

See Attached Map

CASING TYPE(S): ☐ Steel ☐ Plastic ☐ Tile [✓ Other] N/A

WELLHEAD COMPLETION

Outside: ☐ Pitless Adapter/Unit ☐ At Grade ☐ Well Pit ☐ Buried [✓ Other] ________

Inside: ☐ Basement Offset ☐ Well House ☐ Well Pit ☐ Buried [✓ Other] ________

PROPERTY OWNER'S NAME/COMPANY NAME

Middle-Snake-Tamarac Rivers Watershed District

Property owner's mailing address if different than well location address indicated above

453 N McKinley St.
Warren, MN 56762

CASING(S)

Diameter	Depth	Set in oversize hole?	Annular space initially grouted?
N/A in. from ____	to ____ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
____ in. from ____	to ____ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
____ in. from ____	to ____ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown

WELL OWNER'S NAME/COMPANY NAME

Same as above

Well owner's mailing address if different than property owner's address indicated above

Same as above

SCREEN/OPEN HOLE

Screen from N/A to ____ ft. Open Hole from ____ to ____ ft.

OBSTRUCTIONS

☐ Rods/Drop Pipe ☐ Check Valve(s) ☐ Debris ☐ Fill [✓ No Obstruction]

Type of Obstructions (Describe) ________

Obstructions removed? ☐ Yes ☐ No Describe ________

GEOLOGICAL MATERIAL	COLOR	HARDNESS OR FORMATION	FROM	TO
If not known, indicate estimated formation log from nearby well or boring.				
Glacial Drift			0	End

PUMP

[✓ Not Present] ☐ Present, Removed Prior to Sealing ☐ Other ________

Type ________

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE

☐ No Annular Space Exists ☐ Annular Space Grouted with Tremie Pipe [✓ Casing Perforation/Removal]

Casing Diameter

N/A in. from ____ to ____ ft. ☐ Perforated ☐ Removed

____ in. from ____ to ____ ft. ☐ Perforated ☐ Removed

Type of Perforator N/A

VARIANCE

Was a variance granted from the MDH for this well? ☐ Yes [✓ No] TN# ________

GROUTING MATERIAL(S) (One bag of cement = 94 lbs., one bag of bentonite = 50 lbs.)

Grouting Material Bentonite Grout from 0 to End ft. ____ yards ____ bags

________ from ____ to ____ ft. ____ yards ____ bags

________ from ____ to ____ ft. ____ yards ____ bags

OTHER WELLS AND BORINGS

Other unsealed and unused well or boring on property? ☐ Yes [✓ No] How many? ________

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

Newfolden Flood Redux
(FGO06666)
BH-1, 02 and BH-12 through BH-15

LICENSED OR REGISTERED CONTRACTOR CERTIFICATION

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Northern Technologies, LLC — 3574

Licensee Business Name — *License or Registration No.*

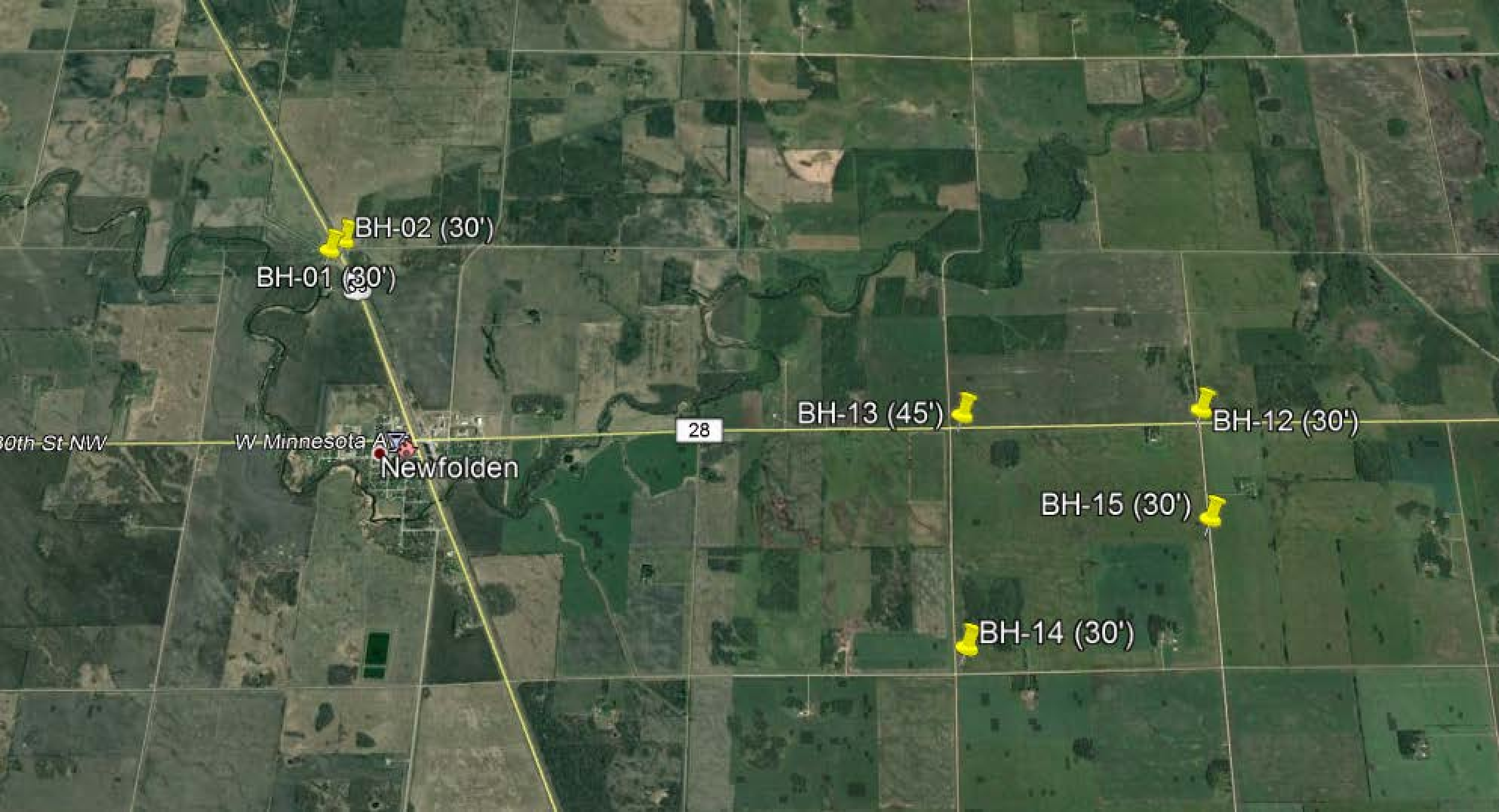
Christopher Kaiser for Bill Canty — 11/16/2018

Certified Representative Signature — *Certified Rep. No.* — *Date*

Bradley Halvorson

Name of Person Sealing Well or Boring

MINN. DEPT OF HEALTH COPY H 362968


BH-02 (30')
BH-01 (30')
BH-13 (45')
BH-12 (30')
28
30th St NW
W Minnesota A
Newfolden
BH-15 (30')
BH-14 (30')

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING SEALING RECORD
Minnesota Statutes, Chapter 103I

Minnesota Well and Boring Sealing No. / Minnesota Unique Well No. or W-series No. (Leave blank if not known): H 362969

WELL OR BORING LOCATION

County Name: Marshall

Township Name	Township No.	Range No.	Section No.	Fraction (sm. → lg.)	Date Sealed	Date Well or Boring Constructed
New Folden	156 N	44 W	3	NE ¼ NW ¼ NE ¼	10/17/2018	10/17/2018

GPS LOCATION – decimal degrees (to four decimal places)
Latitude ______ Longitude ______

Depth at Time of Sealing 16 ft. Original Depth 15 ft.

Numerical Street Address or Fire Number and City of Well or Boring Location: Near 340th St NW and 130th Ave NW

AQUIFER(S): ☐ Single Aquifer ☐ Multiaquifer

WELL/BORING: ☐ Water-Supply Well ☐ Monit. Well ■ Env. Bore Hole ☐ Other

STATIC WATER LEVEL: ■ Measured Date Measured 10/17/2018 ☐ Estimated
1.00 ft. ■ below ☐ above land surface

Show exact location of well or boring in section grid with "X." (N, S, E, W; ½ Mile; 1 Mile)

Sketch map of well or boring location, showing property lines, roads, and buildings.

See Attached Map

CASING TYPE(S): ☐ Steel ☐ Plastic ☐ Tile ■ Other N/A

WELLHEAD COMPLETION
Outside: ☐ Pitless Adapter/Unit ☐ At Grade ☐ Well Pit ☐ Buried ■ Other
Inside: ☐ Basement Offset ☐ Well House ☐ Well Pit ☐ Buried ■ Other

PROPERTY OWNER'S NAME/COMPANY NAME: Middle-Snake-Tamarac Rivers Watershed District

Property owner's mailing address if different than well location address indicated above:
453 N McKinley St.
Warren, MN 56762

CASING(S)

Diameter	Depth	Set in oversize hole?	Annular space initially grouted?
N/A in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
___ in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown
___ in. from ___	to ___ ft.	☐ Yes ☐ No	☐ Yes ☐ No ☐ Unknown

WELL OWNER'S NAME/COMPANY NAME: Same as above

Well owner's mailing address if different than property owner's address indicated above:
Same as above

SCREEN/OPEN HOLE: Screen from N/A to ___ ft. Open Hole from ___ to ___ ft.

OBSTRUCTIONS: ☐ Rods/Drop Pipe ☐ Check Valve(s) ☐ Debris ☐ Fill ■ No Obstruction
Type of Obstructions (Describe) ______
Obstructions removed? ☐ Yes ☐ No Describe ______

GEOLOGICAL MATERIAL	COLOR	HARDNESS OR FORMATION	FROM	TO
If not known, indicate estimated formation log from nearby well or boring.				
Glacial Drift			0	End

PUMP: ■ Not Present ☐ Present, Removed Prior to Sealing ☐ Other
Type ______

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE
☐ No Annular Space Exists ☐ Annular Space Grouted with Tremie Pipe ■ Casing Perforation/Removal
Casing Diameter
N/A in. from ___ to ___ ft. ☐ Perforated ☐ Removed
___ in. from ___ to ___ ft. ☐ Perforated ☐ Removed
Type of Perforator N/A

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ■ No TN# ______

GROUTING MATERIAL(S) (One bag of cement = 94 lbs., one bag of bentonite = 50 lbs.)
Grouting Material Bentonite Grout from 0 to End ft. ___ yards ___ bags
___ from ___ to ___ ft. ___ yards ___ bags
___ from ___ to ___ ft. ___ yards ___ bags

OTHER WELLS AND BORINGS
Other unsealed and unused well or boring on property? ☐ Yes ■ No How many? ______

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

Newfolden Flood Redux
(FGO06666)
BH-04, 05

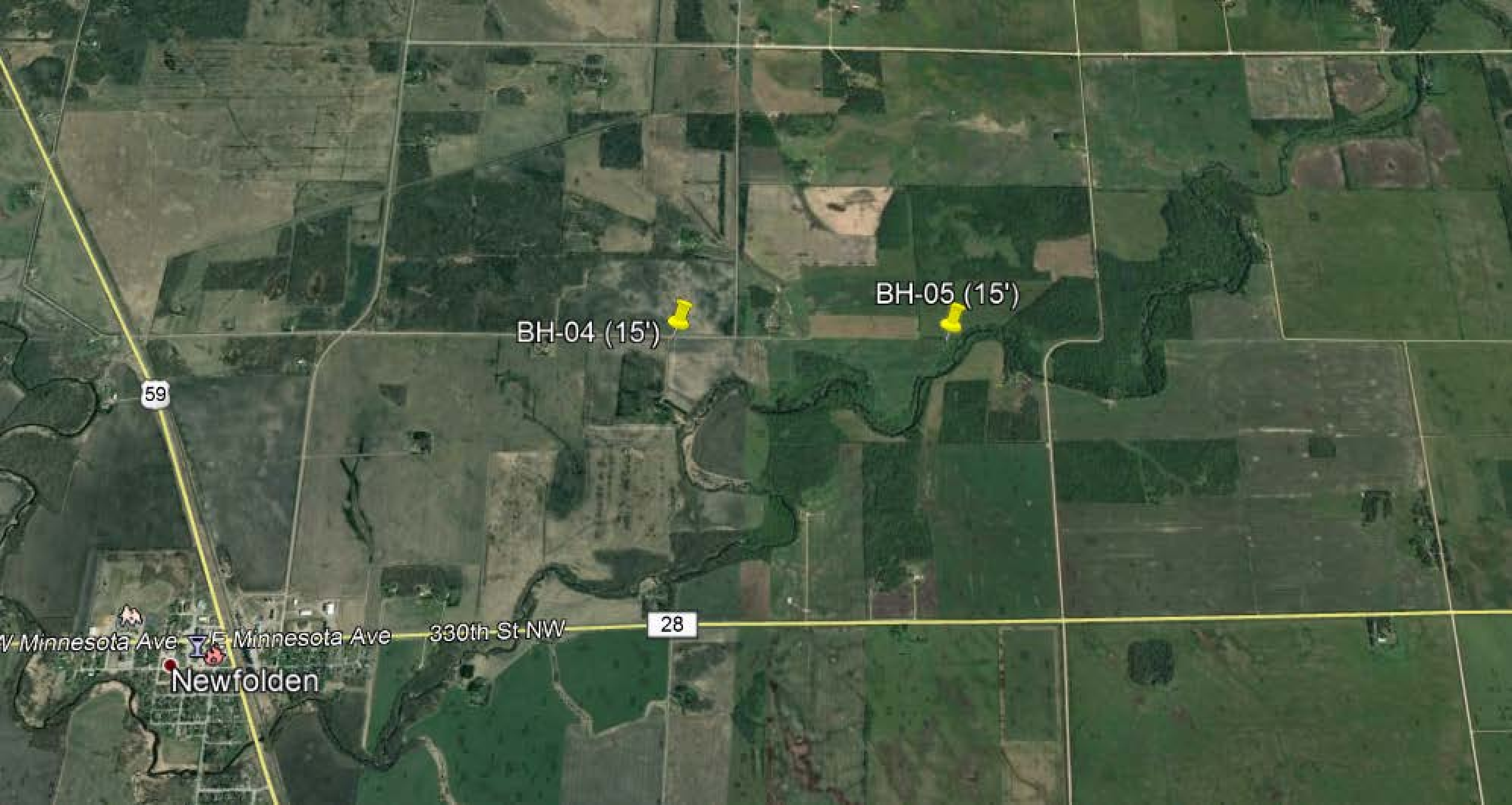
LICENSED OR REGISTERED CONTRACTOR CERTIFICATION
This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Northern Technologies, LLC — 3574
Licensee Business Name — *License or Registration No.*

Christopher Kaiser for Bill Canty — 11/16/2018
Certified Representative Signature — *Certified Rep. No.* — *Date*

Bradley Halvorson
Name of Person Sealing Well or Boring

MINN. DEPT OF HEALTH COPY H 362969


BH-05 (15')
BH-04 (15')
59
28
W Minnesota Ave
E Minnesota Ave
330th St NW
Newfolden

WELL OR BORING LOCATION

County Name: Marshall

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING SEALING RECORD

Minnesota Statutes, Chapter 103I

Minnesota Well and Boring Sealing No. / Minnesota Unique Well No. or W-series No. (Leave blank if not known): H 362970

Township Name	Township No.	Range No.	Section No.	Fraction (sm. → lg.)	Date Sealed	Date Well or Boring Constructed
Holt	156 N	43 W	7	NE ¼ NW ¼ NW ¼	10/17/2018	10/17/2018

GPS LOCATION – decimal degrees (to four decimal places)

Latitude______ Longitude______

Depth at Time of Sealing 31 ft. Original Depth 30 ft.

Numerical Street Address or Fire Number and City of Well or Boring Location: Near 110th Ave NE and 330th St NE

Show exact location of well or boring in section grid with "X."

N / W / E / S — ½ Mile — 1 Mile

Sketch map of well or boring location, showing property lines, roads, and buildings.

See Attached Map

AQUIFER(S)
[ ] Single Aquifer [ ] Multiaquifer

WELL/BORING
[ ] Water-Supply Well [ ] Monit. Well
[x] Env. Bore Hole [ ] Other______

STATIC WATER LEVEL
[x] Measured Date Measured 10/17/2018 [ ] Estimated
DRY ft. [x] below [ ] above land surface

CASING TYPE(S)
[ ] Steel [ ] Plastic [ ] Tile [x] Other N/A

WELLHEAD COMPLETION
Outside: [ ] Pitless Adapter/Unit [ ] At Grade [ ] Well Pit [ ] Buried [x] Other______
Inside: [ ] Basement Offset [ ] Well House [ ] Well Pit [ ] Buried [x] Other______

PROPERTY OWNER'S NAME/COMPANY NAME
Middle-Snake-Tamarac Rivers Watershed District

Property owner's mailing address if different than well location address indicated above
453 N McKinley St.
Warren, MN 56762

CASING(S)

Diameter	Depth	Set in oversize hole?	Annular space initially grouted?
N/A in. from ____	to ____ ft.	[ ] Yes [ ] No	[ ] Yes [ ] No [ ] Unknown
____ in. from ____	to ____ ft.	[ ] Yes [ ] No	[ ] Yes [ ] No [ ] Unknown
____ in. from ____	to ____ ft.	[ ] Yes [ ] No	[ ] Yes [ ] No [ ] Unknown

WELL OWNER'S NAME/COMPANY NAME
Same as above

Well owner's mailing address if different than property owner's address indicated above
Same as above

SCREEN/OPEN HOLE
Screen from N/A to ____ ft. Open Hole from ____ to ____ ft.

OBSTRUCTIONS
[ ] Rods/Drop Pipe [ ] Check Valve(s) [ ] Debris [ ] Fill [x] No Obstruction

Type of Obstructions (Describe)______

Obstructions removed? [ ] Yes [ ] No Describe______

GEOLOGICAL MATERIAL	COLOR	HARDNESS OR FORMATION	FROM	TO
If not known, indicate estimated formation log from nearby well or boring.				
Glacial Drift			0	End

PUMP
[x] Not Present [ ] Present, Removed Prior to Sealing [ ] Other______
Type______

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE
[ ] No Annular Space Exists [ ] Annular Space Grouted with Tremie Pipe [x] Casing Perforation/Removal

Casing Diameter
N/A in. from ____ to ____ ft. [ ] Perforated [ ] Removed
____ in. from ____ to ____ ft. [ ] Perforated [ ] Removed

Type of Perforator N/A

VARIANCE
Was a variance granted from the MDH for this well? [ ] Yes [x] No TN#______

GROUTING MATERIAL(S) (One bag of cement = 94 lbs., one bag of bentonite = 50 lbs.)

Grouting Material Bentonite Grout from 0 to End ft. ____ yards ____ bags
______ from ____ to ____ ft. ____ yards ____ bags
______ from ____ to ____ ft. ____ yards ____ bags

OTHER WELLS AND BORINGS
Other unsealed and unused well or boring on property? [ ] Yes [x] No How many?______

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

Newfolden Flood Redux
(FGO06666)
BH-11

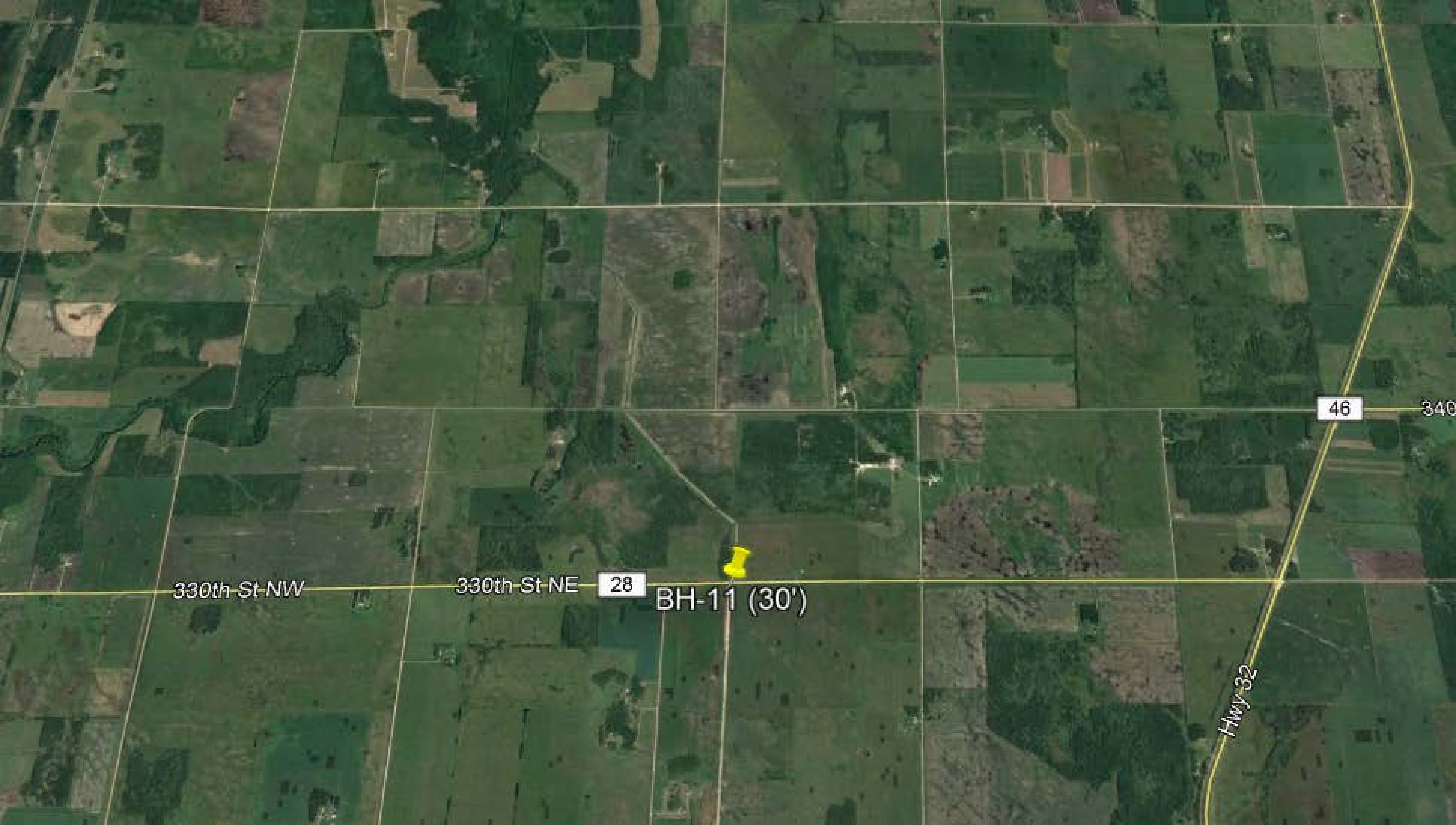
LICENSED OR REGISTERED CONTRACTOR CERTIFICATION
This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

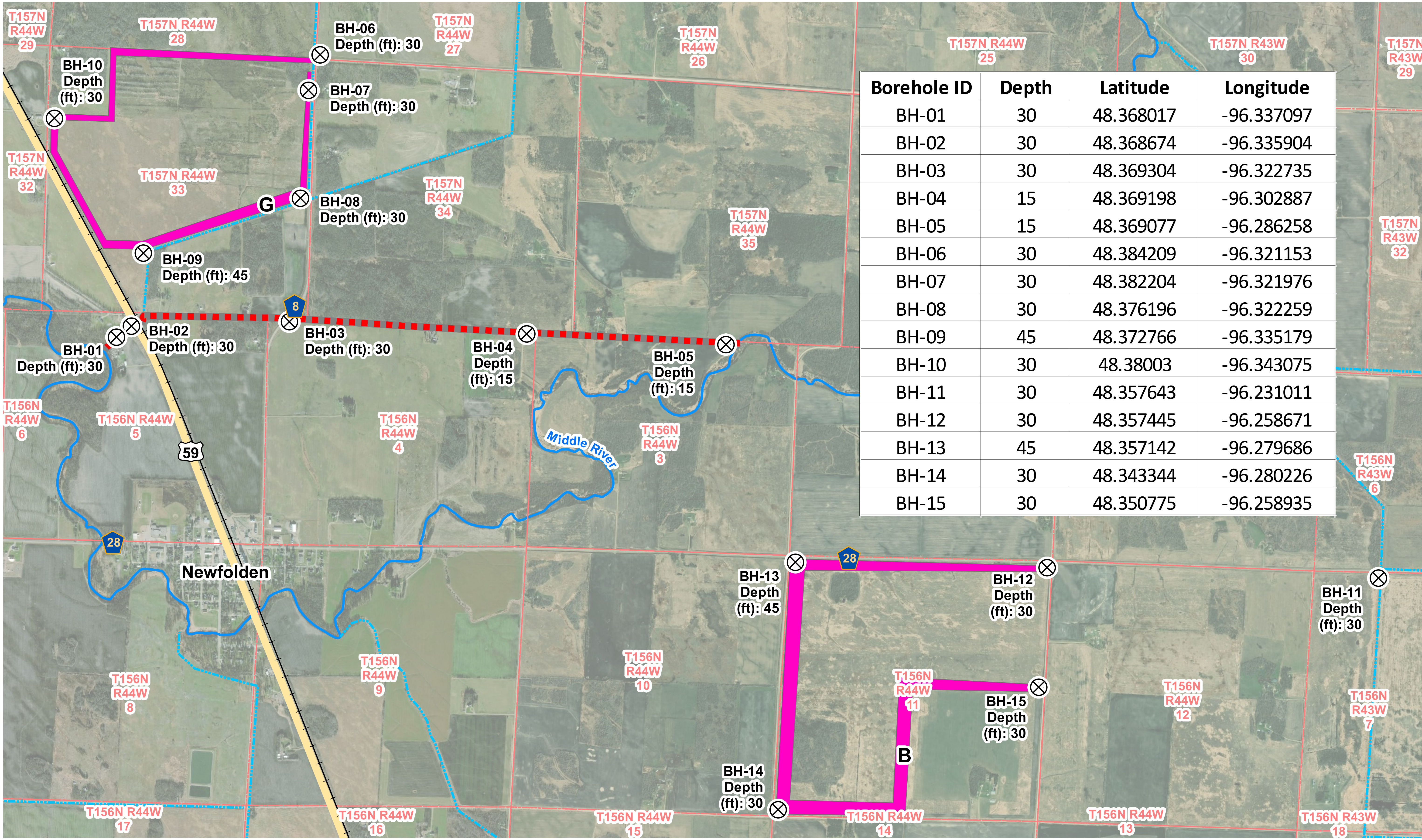
Northern Technologies, LLC — 3574
Licensee Business Name — *License or Registration No.*

Christopher Kaiser for Bill Canty — 11/16/2018
Certified Representative Signature — *Certified Rep. No.* — *Date*

Bradley Halvorson
Name of Person Sealing Well or Boring

MINN. DEPT OF HEALTH COPY H 362970


330th St NW
330th St NE
28
BH-11 (30')
46
Hwy 32



Borehole ID	Depth	Latitude	Longitude
BH-01	30	48.368017	-96.337097
BH-02	30	48.368674	-96.335904
BH-03	30	48.369304	-96.322735
BH-04	15	48.369198	-96.302887
BH-05	15	48.369077	-96.286258
BH-06	30	48.384209	-96.321153
BH-07	30	48.382204	-96.321976
BH-08	30	48.376196	-96.322259
BH-09	45	48.372766	-96.335179
BH-10	30	48.38003	-96.343075
BH-11	30	48.357643	-96.231011
BH-12	30	48.357445	-96.258671
BH-13	45	48.357142	-96.279686
BH-14	30	48.343344	-96.280226
BH-15	30	48.350775	-96.258935

Proposed Boring Locations
Potential Embankment Footprint
Diversion Ditch
MSTRWD Ditch
River
Major Roadway
Railroad
Section Lines

0 0.25 0.5 Miles

HDR MSTRWD

BOREHOLE LOCATION PLAN

NEWFOLDEN / MIDDLE RIVER SUBWATERSHED FLOOD DAMAGE REDUCTION PROJECT

PATH: Y:\PROJECTS\NEWFOLDEN, MN\MAP DOCS\MXD\BOREHOLES_NEWFOLDEN.MXD - USER: DINELSON - DATE: 8/1/2018

ALTERNATIVES ANALYSIS

Appendix D. RRWMB Step 1 Application

Step 1

Date:	Tuesday, July 17, 2018
Project:	Newfolden / Middle River Subwatershed Flood Damage Reduction Project
To:	Red River Watershed Management Board, 11 5th Avenue East | Ada, MN 56510
From:	Nate Dalager, PE
Subject:	Step 1 Application

The Middle-Snake-Tamarac Rivers Watershed District Board of Managers respectfully requests your consideration of a flood damage reduction project that will provide critical local flood damage reduction benefits for the City of Newfolden community.

History

The City of Newfolden is located in northwestern Minnesota in Marshall County and lies within the Middle River Subwatershed. In 2016, FEMA published preliminary Flood Insurance Rate Maps (FIRM) as a result of the Marshall County FIRM update they are performing. Based on the preliminary results of the update, a majority of the eastern portion of the City of Newfolden was placed in the 1% Annual (100-year) Chance Floodplain. The Middle River enters Newfolden from the east and passes through several culverts under the railway. These culverts are insufficient to convey peak flows, resulting in increased flooding east of the tracks and potential failure of the railroad structure under flooding conditions. Having the ability to better manage water levels in the Middle River at the City of Newfolden would provide upstream and downstream flood damage reduction benefits and natural resource enhancements.

Project Description

The design goal of this Project is to remove the City of Newfolden from the 1% Annual Chance Floodplain while providing upstream and downstream flood damage reduction benefits.

To meet the goals of this Project, design criteria were set in order to analyze the hydraulic adequacy of each alternative while maintaining a cost efficient design. The following design criteria were used for the flood damage reduction Project design:

- Remove Newfolden from the 1% Annual (100-year) Floodplain a minimum of one foot below the FEMA Base Flood Elevation (BFE).
- No increase in potential flood damage downstream / upstream.
- Provide secondary flood damage reduction in agricultural areas upstream and downstream of the Project site.

Solutions

The proposed Project suggests the following solutions to meet the stated purpose and needs:

- Reduce the volume of runoff to the Middle River by retention methods.
- Bypass high flows from the Middle River around Newfolden.
- Develop an operating plan.

hdrinc.com

213 LaBree Ave N, Suite 203, Thief River Falls, MN 56701-2022
(218) 681-6100

Newfolden / Middle River Subwatershed Mediation Team

The Project team has been working closely with the Board of Managers of the Middle-Snake-Tamarac Rivers Watershed. The Board has received input from the team throughout the alternatives analysis phase of the Project. With the input from the resources expertise and varying backgrounds, flood control and natural resources values have been integrated.

Costs

The total estimated cost for the Project is $6,000,000.

Project	State FDR/Other	RRWMB	MSTRWD/Newfolden	Total
Newfolden / Middle River Subwatershed FDR Project	$3,890,000	$1,360,000	$750,000	$6,000,000

Summary

The Project is consistent with the Mediation Agreement goals adopted by the RRWMB and Red River Basin Flood Damage Reduction Work Group. The flood water is considered to be in the middle area for the Red River of the North based on the Flood Damage Reduction Work Group Technical Paper #11. The peak of the Middle River at Newfolden is approximately 4.5 days before the peak on the Red River. Reducing the peak and storing late water at Newfolden has a positive impact on removing water contributing to the peak on the Red River. Flood Damage Reduction (FDR) measures, such as a gated impoundment, receives a positive rating in a middle area and a diversion receives a "variable" rating.

The MSTRWD feels that the proposed Project addresses the RRWMB and Red River Basin Flood Damage Reduction Work Group Mediation Agreement goals and objectives as outlined in Technical paper #11. In addition, the proposed Project will also have significant potential to remove a community from the 100-year floodplain while addressing flooding problems within the District.

The following items are included in this submittal:

- Alternatives Analysis Report
- Star Value
- Project Evaluation Worksheet

We hereby request that you evaluate this Step 1 submittal for this project.

Sincerely,

HDR Engineering, Inc.

Nate Dalager, P.E.
Project Engineer

213 LaBree Ave N, Suite 203, Thief River Falls, MN 56701-2022
(218) 681-6100

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	**Newfolden FDR Project**	**RRWMB**		Enter Project Name. (Status eg Step)
Watershed District:	**Middle-Snake-Tamarac Rivers Watershed District**			Enter Name of Watershed District.
Project Location:	**Newfolden, MN**			Enter Project Location.

Estimated Total Cost:	**$ 6,000,000**			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	**$ 1,360,000**	CPI (1984=100)	CPI (2018=100)	
Year of Estimate:	**2018**	**249.71**	**100.00**	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	**2000**	**172.20**	**68.96**	

Drainage Area (square miles)	**10.0**	Enter the drainage area in square miles used to compute the runoff volume.

Storage Volume(s):	**Acre-feet**	**Inches**	**Adj. Storage (ac-ft)**	
Drawdown	**0**	0.00	0	The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown storage.
Gated (1)	**2,200**	4.13	2,157	
Ungated (Spillway)	**0**	0.00	0	
Ungated (2)	**0**	0.00	0	
Total Storage (8.1 inches Max.)	2,200	4.13	2,157	
Volume Adjustment Factor	0.98	43		

Est. of Ungated Detention Time	**Volume (ac-ft)**	**Elevation (ft)**	**Discharge (cfs)**	
Emergency Spillway	**0**	0	0	Note: this section is provided for reference only. The values are not used in the calculations.
10% of Ungated	**0**	0	0	
90% of Ungated Volume	0			
	Average Discharge (cfs)		0	
	Discharge in AF per day		0	
	Average Detention Time (days)		not applicable	

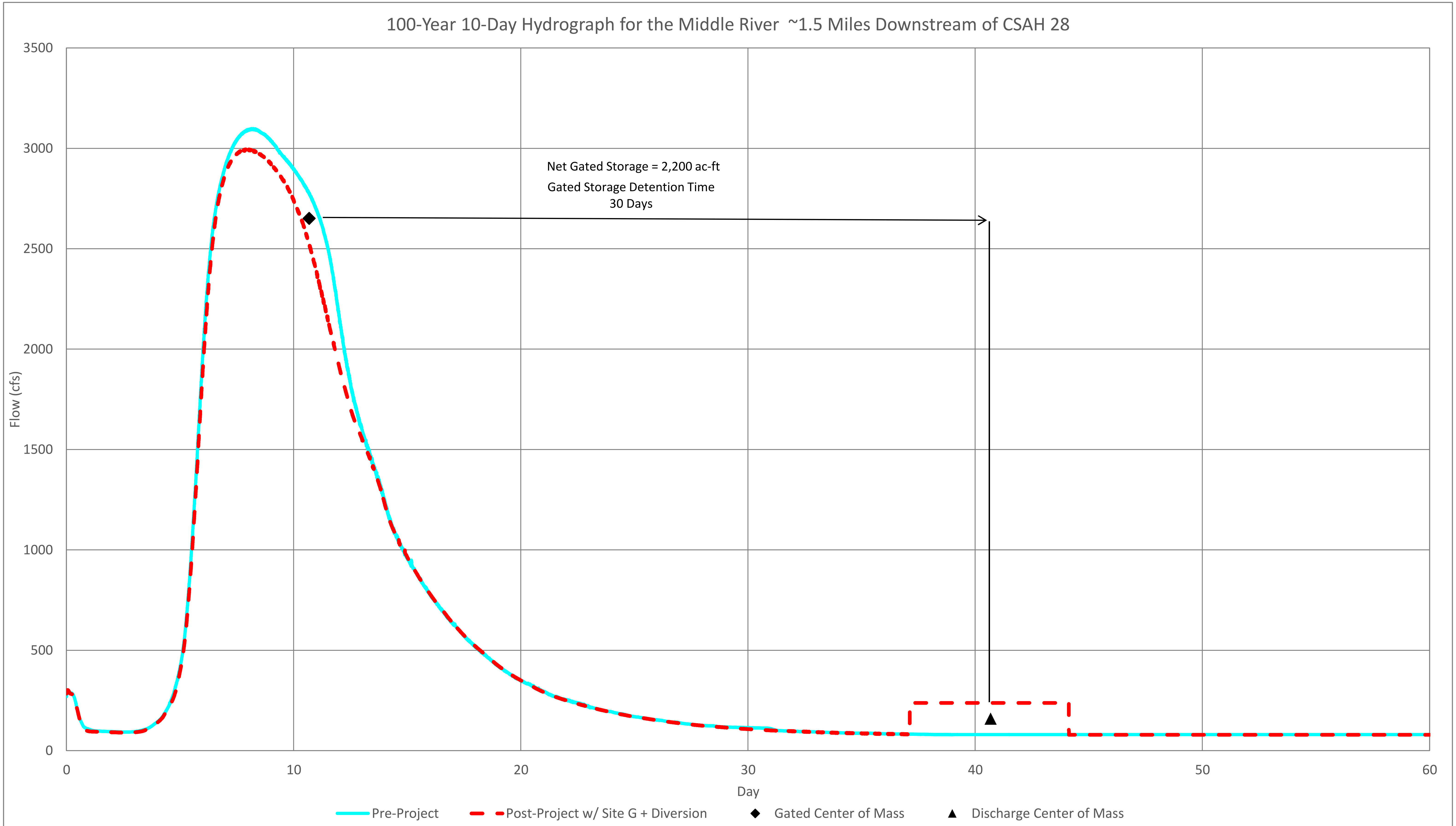
Detention Time:		
Gated (1) from Operation plan	**30.0**	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	**0.0**	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	**0.0**	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	**0.0**	Offset of center of mass of inflow hydrogragh to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	**-4.5**	**Existing Relative T**	2.83	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	**Routed Relative T**	**Adj. Storage (Ac-ft)**	**Star Value**	
Drawdown Storage (30 - 2.83)	27.17	0	0	Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.
Gated (1) Storage (24.67 - 2.83)	21.83	2,157	47,101	
Gated (2) Storage (2.83 - 2.83)	0.00	0	0	
Ungated) Storage (2.83 - 2.83)	0.00	0	0	
Star Value		**2,157**	**47,101**	STAR VALUE

	2018 dollars	**2000 dollars**	
Total Cost per Star Value	**$ 127.39**	**$ 87.85**	Total Cost divided by STAR Value
RRWMB Cost per Star Value	**$ 28.87**	**$ 19.91**	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Newfolden FDR		Enter source data.
Frequency/Date of Preparation:	100-Year 10-Day	17-Jul-18	Enter frequency and date.


100-Year 10-Day Hydrograph for the Middle River ~1.5 Miles Downstream of CSAH 28
Net Gated Storage = 2,200 ac-ft
Gated Storage Detention Time
30 Days
Flow (cfs)
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
Day
Pre-Project
Post-Project w/ Site G + Diversion
Gated Center of Mass
Discharge Center of Mass