Engineer’s Report

Klondike Clean Water Retention Project #11

Two Rivers Watershed District

Roseau/Kittson Counties, MN

June 28, 2017

ENGINEER'S REPORT

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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.

Nathan P. Dalager, P.E.
License Number 25309

HDR Engineering, Inc.
213 LaBree Ave N, Suite 203
Thief River Falls, Minnesota 56701-2022

Table of Contents

Tables

Figures

Appendices

ACRONYMS AND ABBREVIATIONS

BMP Best Management Practices

BSPWT Big Swamp Project Work Team

BWSR Board of Water and Soil Resources

CD County Ditch

CMP Corrugated Metal Pipe

CN Curve Number

EAW Environmental Assessment Worksheet

EPA Environmental Protection Agency

FDR Flood Damage Reduction

FEMA Federal Emergency Management Agency

FT Foot

GIS Geographic Information System

HEC-HMS Hydrologic Engineering Center Hydrologic Modeling System

HEC USACE Hydrologic Engineering Center United States Army Corps of Engineers

HEC-RAS Hydrologic Engineering Center River Analysis System

IN Inch

JDA Joint Ditch Authority

KCWRP #11 Klondike Clean Water Retention Project #11

Lat Lateral

LTFS Long Term Flood Solutions

MnDNR Minnesota Department of Natural Resources

MPCA Minnesota Pollution Control Agency

NAVD88 North American Vertical Datum of 1988

NOAA National Oceanic and Atmospheric Administration

NRCS Natural Resources Conservation Service, formally the SCS

NRE Natural Resource Enhancement

NWS National Weather Service

PWT Project Work Team

RCP Reinforced Concrete Pipe

RRBC Red River Basin Commission

SD State Ditch

SCS Soil Conservation Service

SWCD Soil and Water Conservation District

SWMM Stormwater Management Model

TC Time of Concentration

TMDL Total Maximum Daily Load

TRWD Two Rivers Watershed District

USACE United States Army Corps of Engineers

USDA United States Department of Agriculture

USGS United States Geologic Survey

WSE Water Surface Elevation

WMA Wildlife Management Area

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Executive Summary

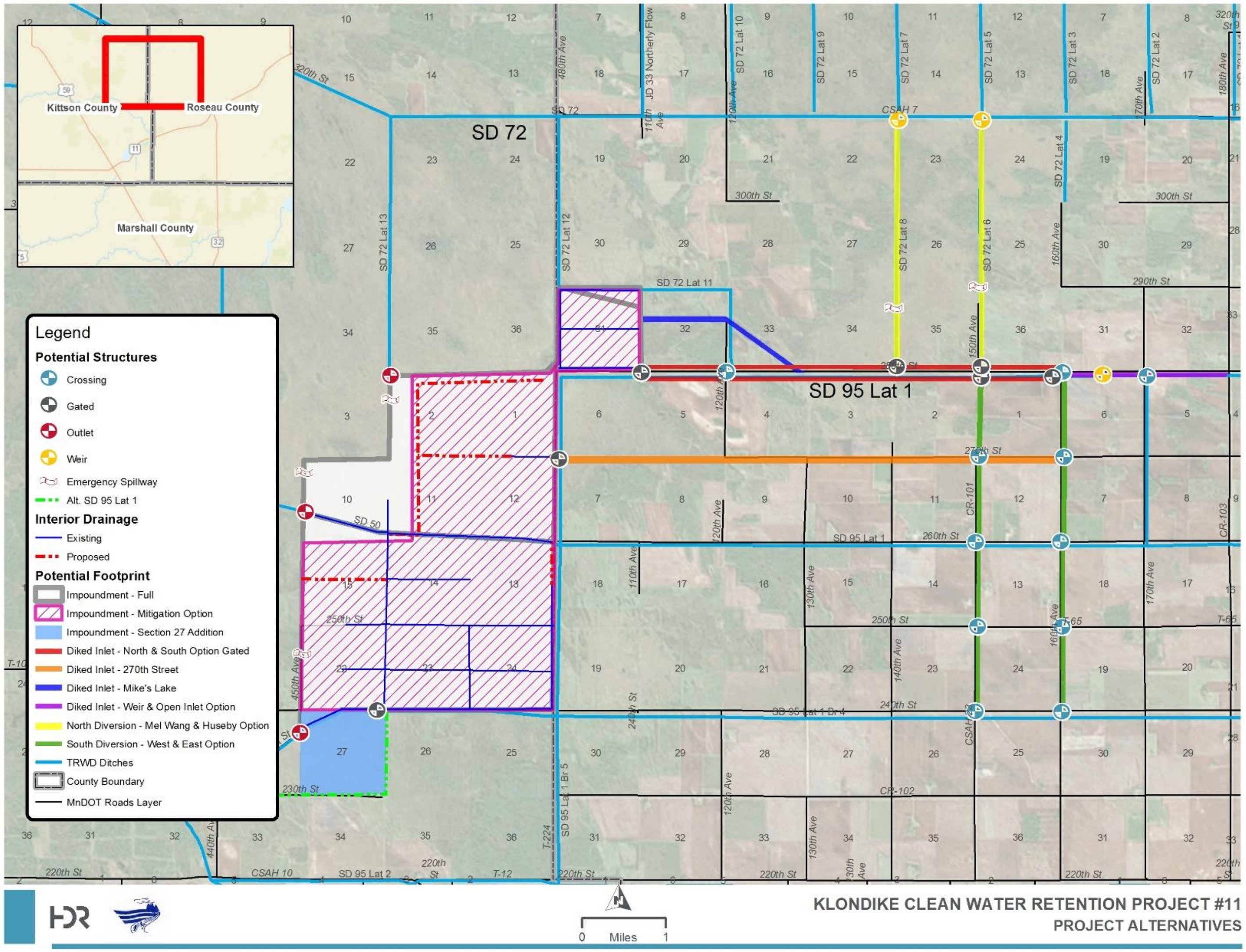
This Engineer's Report evaluates the feasibility and potential costs of a flood retention project located eight miles east and one mile north of Lake Bronson in Kittson and Roseau Counties, Minnesota. The purpose of the project is to reduce flood damages along the State Ditch (SD) 72 and the State Ditch (SD) 95 systems, and also to contribute to the regional goal of 20% flow reduction of the 1997 flood's peak on the Red River of the North, which will address the severe and repeated damage that currently occurs to public infrastructure, private property, and agricultural lands.

This important flood damage reduction project is known as the Klondike Clean Water Retention Project #11 (KCWRP #11). The project concept includes an approximately 12 square mile impoundment (18 mile perimeter with average embankment height of 7 feet) and a diked inlet channel with diversion channels. This project will have a gated storage of up to 42,000 acre feet from a 191.5 square mile drainage area. The impoundment is located near the boundary between Kittson and Roseau County (county line) along SD 95 Lateral (Lat) 1. The elevation of natural ground in the impoundment area is approximately 1012 feet, and the proposed high water elevation is 1017. Three outlets will allow the water to exit the impoundment to the North Branch, Middle Branch, or South Branch of the Two Rivers. Due to the flat topography, in order to fill the impoundment, with natural ground at elevation 1012, the inlet will extend upstream with embankments and begin at an elevation higher than 1012. Consequently, the start of the inlet will be at least 5 miles east of the Roseau – Kittson County line. The Diked Inlet will be minimally sloped towards the Impoundment and the water will need to build up hydraulic head in order to move with a hydraulic grade into the Impoundment. In summary, the project includes four main features and each feature has a variety of alternatives considered (Table ES - 1). Figure ES - 1 shows the project concept and main feature alternatives.

Table ES - 1. Project Features and Feature Alternatives

Project Feature	Description	Alignment Alternatives	Notes
Diked Inlet	The channel that feeds the impoundment	• Diked Inlet South • Diked Inlet North • Mike's Lake Option • 270th Street Option	Inlet structure alternatives include: three options Gated, Weir, and Open
North Diversion	Two 3-mile long diversion channels that connect SD 72 to the Diked Inlet	• Mel Wang • Huseby	Both alternatives will be utilized, these ditches are already in place and may be widened
South Diversion	One 4-mile long diversion channel that connects two southern branches of SD 95 Lat 1 to the Diked Inlet	• East Option • West Option	Only one alternative will be selected, there are no existing ditches in these locations
Impoundment	A reservoir storing all flows from the Diked Inlet	• Full Impoundment • Mitigation Option • Section 27 addition	

Figure ES - 1. Project Concept – Impoundment, Inlet, and Diversion Alternatives



Following assessment, six overall project alternatives were considered, with optional diversions which can be built to increase the drainage area controlled by the project. Table ES - 2 lists the six alternatives considered and the à la carte (on the menu) alternatives for diversions. Costs were estimated for each alternative to aid in recommendations of the preferred alternative. The recommendations are based upon an assessment of each project feature and its overall effectiveness in reducing flood damages. HDR recommends Alternative 1-3 (Figure ES - 2). This alternative, along with the North Diversion – Huseby Option, North Diversion – Mel Wang Option, and South Diversion – East Option could be constructed in a phased approach. Phase 1 would need to include the Diked Inlet and a portion of the retention area. Phase 2 should complete the impoundment and necessary outlets. Phase 3 would include the diversions.

Table ES - 2. Project Alternatives

Alternative #	Diked Inlet	Impoundment	Diversions		
1-1	Gated Option	Full Impoundment Option	**À la Carte Alternatives**	North Diversion	Huseby Option
1-2	Weir Option				Mel Wang Option
1-3	Open Inlet Option				None
2-1	Gated Option	Mitigation Option - Impoundment which avoids DNR-owned land in Section 11		South Diversion	East Option
2-2	Weir Option				West Option
2-3	Open Inlet Option				None

Figure ES - 3 and Figure ES - 4 show typical cross sections of the Impoundment and Diked Inlet respectively. The Impoundment embankment cross-section consists of an impermeable layer of compacted clay on the upstream side of the embankment, with random fill on the downstream side of the embankment. The random fill can consist of any combination of sand, silt, or clay. Due to the presence of peat and organics at the site, the cross section shows the sub cut geometry for removing peat/organics prior to construction. Figure ES - 4 shows the newly built embankment of the Diked Inlet having similar geometry to the Impoundment embankment. The existing SD 95 Lat 1 will become the pilot channel and a new SD 95 Lat 1 will be constructed on the south side of the Diked Inlet. The other embankment of the Diked Inlet shows that the existing road will be raised and reinforced in order to perform as an embankment when the project is impounding water. The material used to raise the existing road will be an impermeable layer of clay. Side slopes and geometry of the embankments are shown in the figures.

Figure ES - 2. Recommended Alternative 1- 3

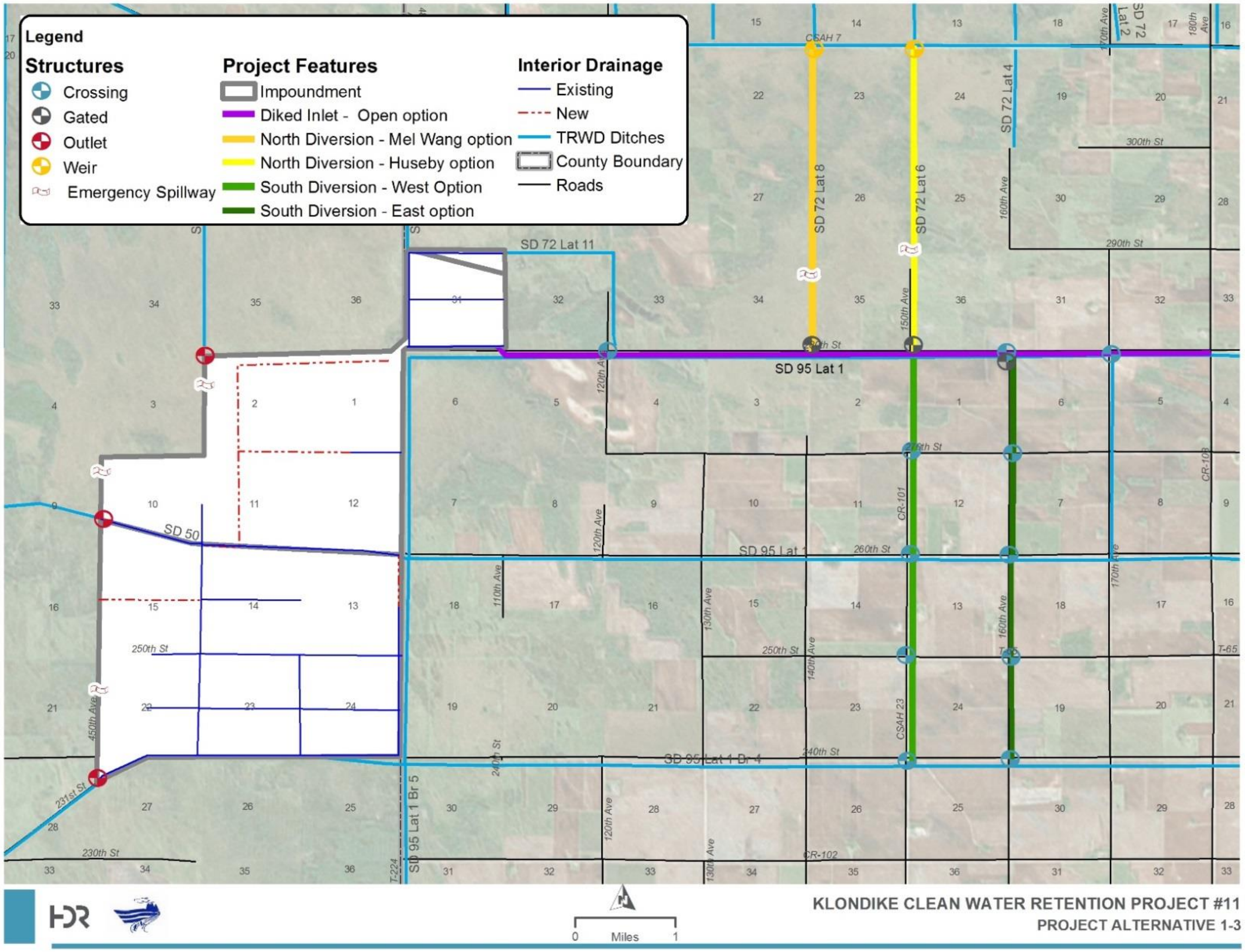


Figure ES - 3. Typical Cross Section of Impoundment Embankment

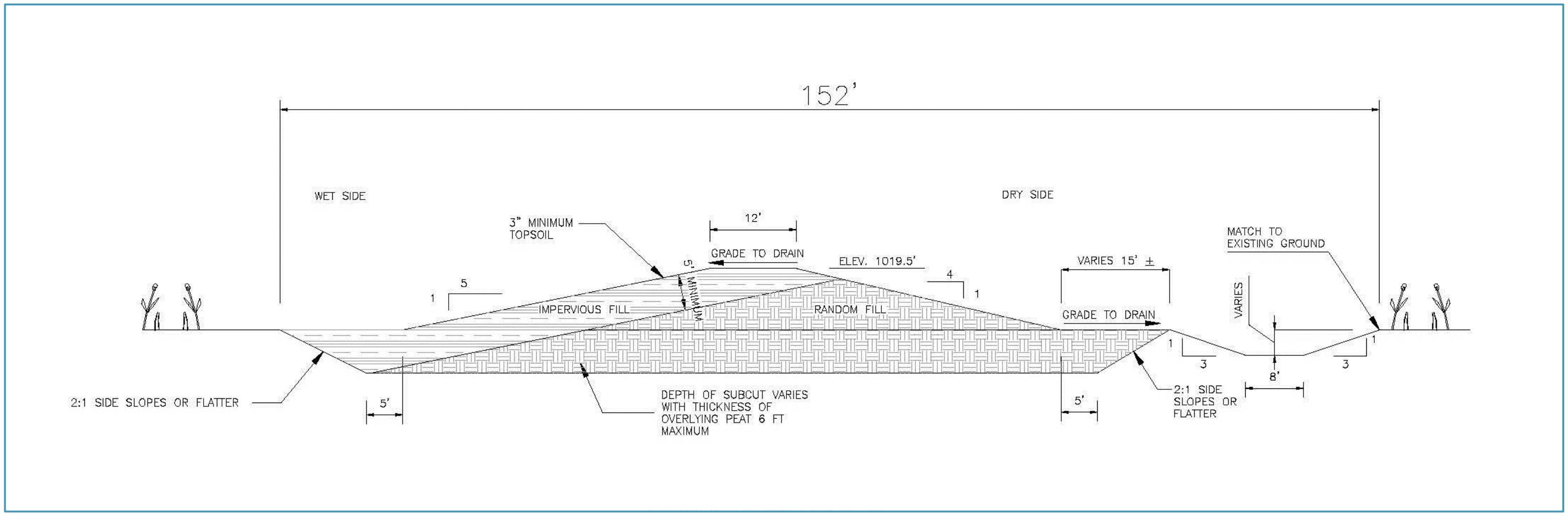
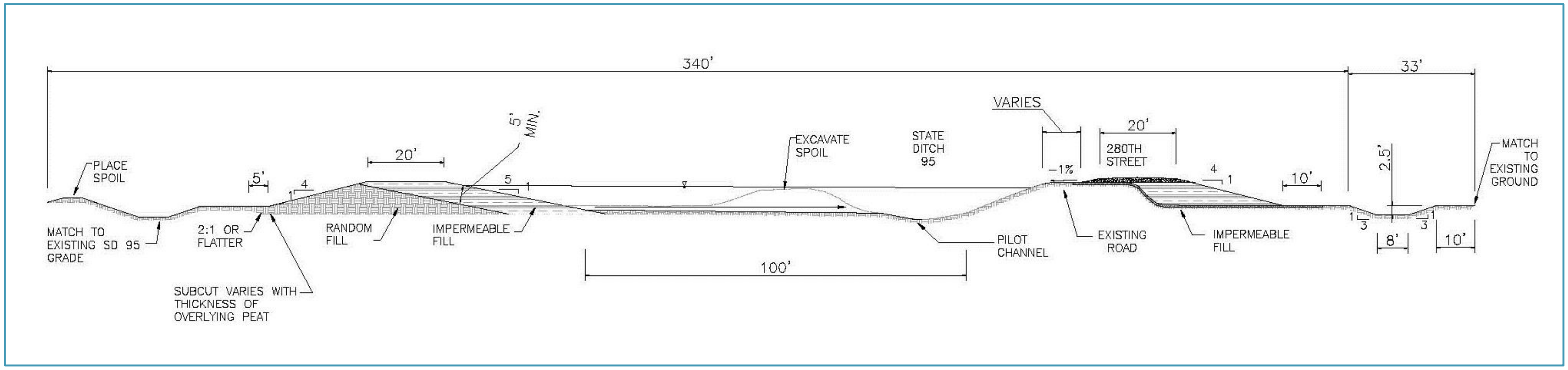


Figure ES - 4. Typical Cross Section of Diked Inlet



The TWRD will manage the KCWRP#11 to reduce local and regional flood damages, improve water quality, and enhance natural resources. This will result in lower peak flows and shorter durations of uncontrolled flooding on the surrounding lands and downstream of the project, and stabilize water levels to benefit the downstream areas. A separate environmental assessment is being completed, in order to analyze the potential for natural resource enhancements with this project. The operating plan provides a general description of how to maximize flood control and water quality benefits and identifies general concepts at which to operate the control gates to allow flows into and out of the project. This project will reduce flooding on SD 95, SD 50, SD 72, the Red River, and on the North Branch, Middle Branch, and South Branches of the Two Rivers. During a spring snowmelt event equal to the 1997 flood, the Two Rivers Watershed's peak flow to the Red River will be reduced by 15% and volume by 10%.

1 Introduction

The Two Rivers Watershed District (TRWD) has prepared an Engineer's Report to evaluate the feasibility and potential costs of a flood retention project located eight miles east and one mile north of Lake Bronson in Kittson and Roseau County, Minnesota (Figure 1-1). This important flood damage reduction project is known as the Klondike Clean Water Retention Project #11 (KCWRP #11).

For the purposes of this report, all elevations discussed in this report are in North American Vertical Datum of 1988 (NAVD88).

1.1 Project Purpose & Need

The purpose of the project is to reduce flooding along the SD 72 and the SD 95 systems, and also to contribute to the regional goal of 20% flow reduction of the 1997 flood’s peak on the Red River of the North, which will address the severe and repeated damage that currently occurs to public infrastructure, private property, and agricultural lands.

1.2 Region Wide Goal

A region-wide goal has been established to reduce peak flows along the Red River of the North (Red River) mainstem by 20 percent during a flooding event similar to the 1997 flood. In order to reach this goal, each tributary of the Red River has been provided with both peak flow and volume reduction goals as set forth in the Red River Basin Commission’s (RRBC) Long Term Flood Solutions (LTFS) Basin Wide Flood Flow Reduction Strategy Report. It is estimated that this project will result in a peak flow reduction of 15% and a volume reduction of 10% at the location above the Red River. See Table 1-1 below for reduction information at three sites. Figure 1-2 shows the hydrologic zones in the TRWD.

Table 1-1. Estimated Peak Flow and Volume Reductions for KCWRP #11

Location	Existing		Proposed		Difference	
	Volume (ac-ft)	Peak Flow (cfs)	Volume (ac-ft)	Peak Flow (cfs)	Volume (%)	Peak Flow (%)
Above Lake Bronson	151,093	8,765	147,440	7,526	-2%	-14%
USGS05094000 – South Branch of Two Rivers Below Lake Bronson	157,729	9,124	153,925	7,907	-2%	-13%
Above Red River	423,526	19,078	379,137	16,251	-10%	-15%

1.3 Source of Flooding

The source of flooding causing the need for the KCWRP #11 is a combination of SD 95 drainage area, crossover flows from the Roseau River watershed, and SD 72. These ditch systems currently in place do not have the capacity to carry the water that enters them, and consequently, water breaks out of the ditches and creates large scale overland flooding. See Figure 1-3 for existing ditch capacities calculated for TRWD based on cross-sectional area, slope, and roughness. This results in crop losses, damage to roads, culverts, and bridges, causes erosion and sedimentation, and causes flooding in farmsteads (Two Rivers Watershed District News, 2014).

1.4 Project Concept

As shown in Figure 1-4, the proposed project consists of an approximately 12 square mile impoundment (18 mile perimeter with average embankment height of 7 feet) and a diked inlet channel with three diversion channels. This project will have a gated storage of up to 42,000 acre feet from a 191.5 square mile drainage area. The impoundment is located near the boundary between Kittson and Roseau County (county line) along SD 95 Lat. The elevation of natural ground in the impoundment area is approximately 1012, and the proposed high water elevation is 1017. Three outlets will allow the water to exit the impoundment to the North Branch, Middle Branch, or South Branch of the Two Rivers. Due to the flat topography, in order to fill the impoundment, with natural ground at elevation 1012, the inlet will extend upstream with embankments and begin at an elevation higher than 1012. Consequently, the start of the inlet will be at least 5 miles east of the county line. The diked inlet will be minimally sloped towards the impoundment and the water will need to build up hydraulic head in order to move with a hydraulic grade into the impoundment. These embankments will be built as far upstream as necessary to meet freeboard requirements at the high water elevation.

Figure 1-1. Project Location

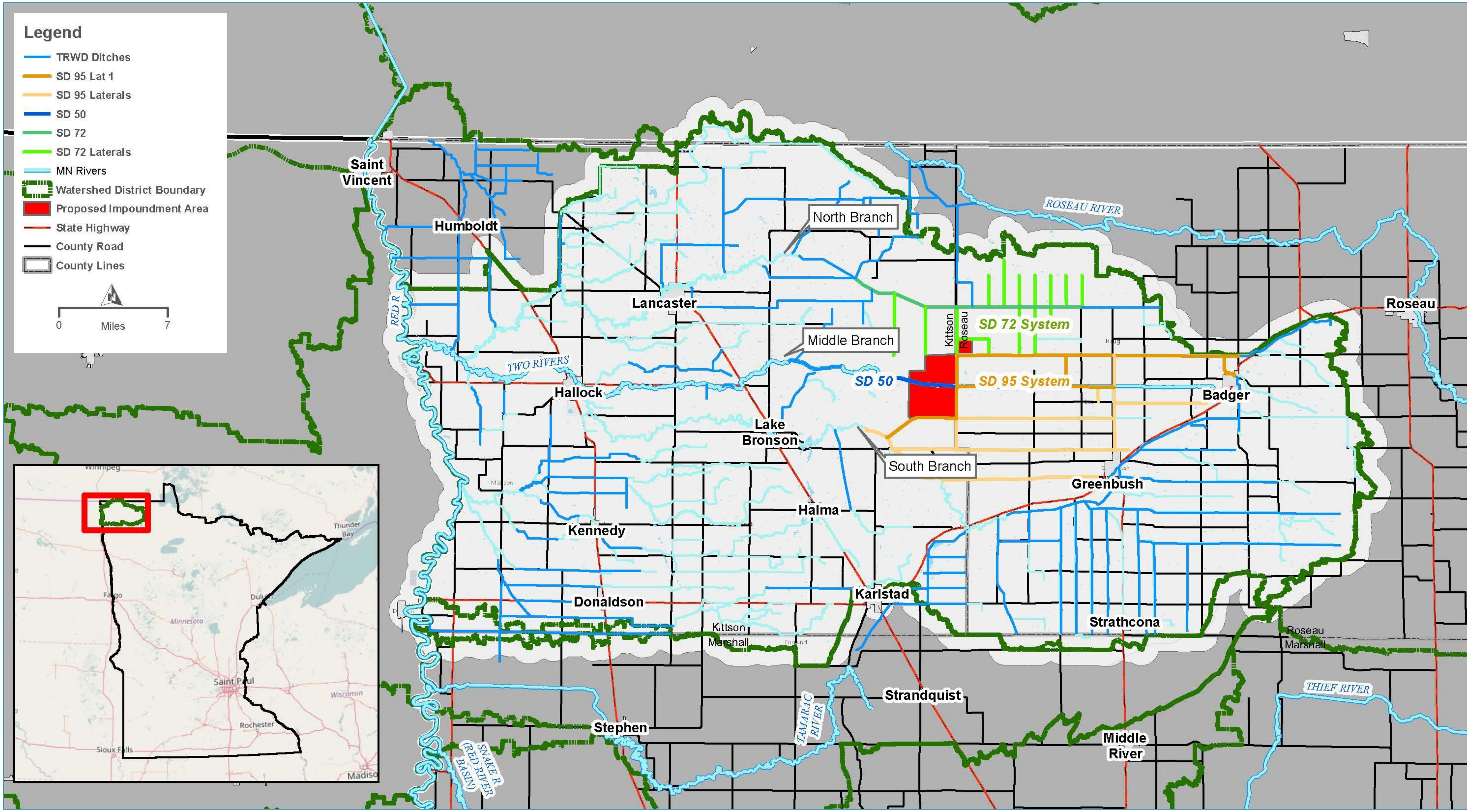


Figure 1-2. Hydrologic Zones - Klondike Clean Water Retention Project #11

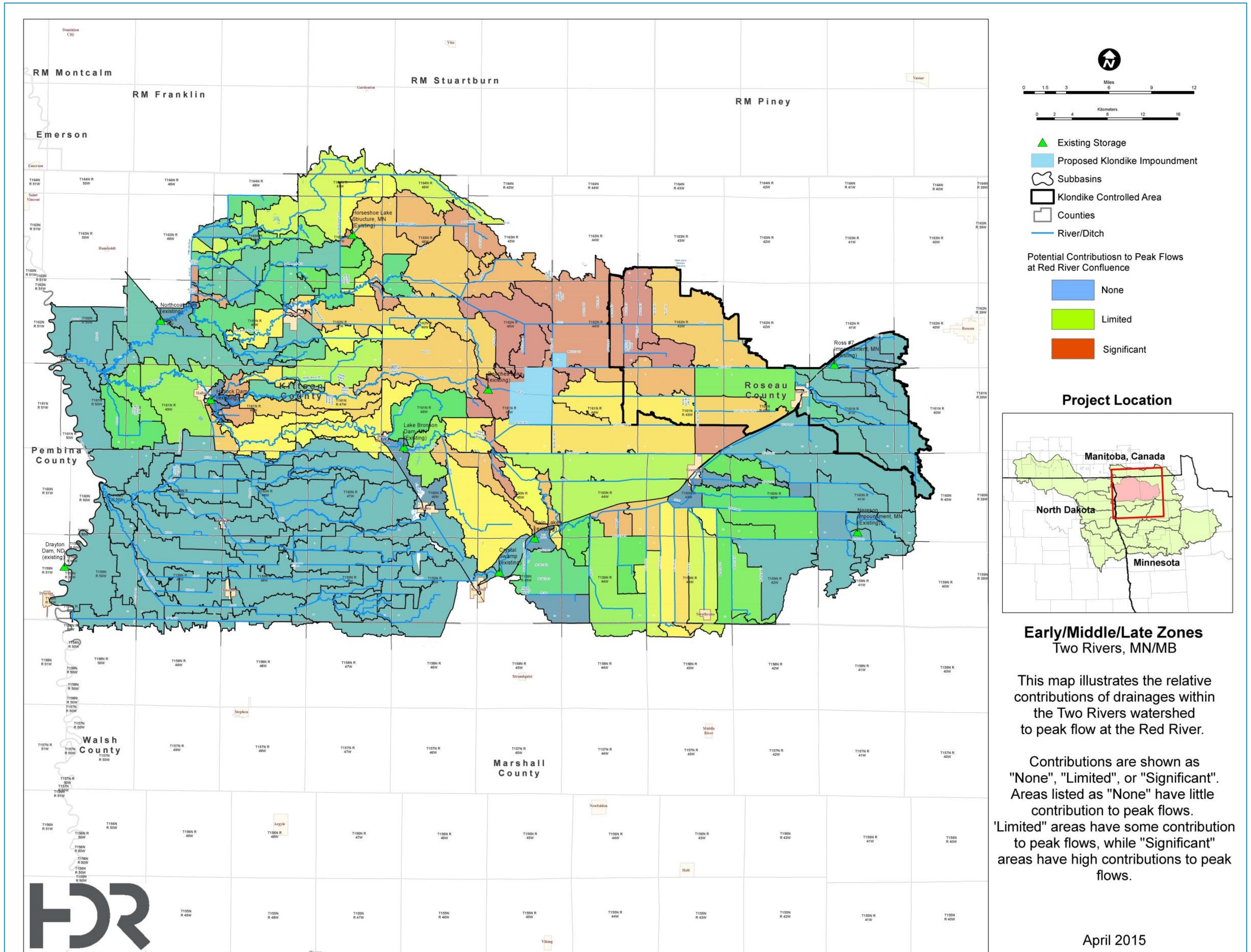


Figure 1-3. Ditch Capacities

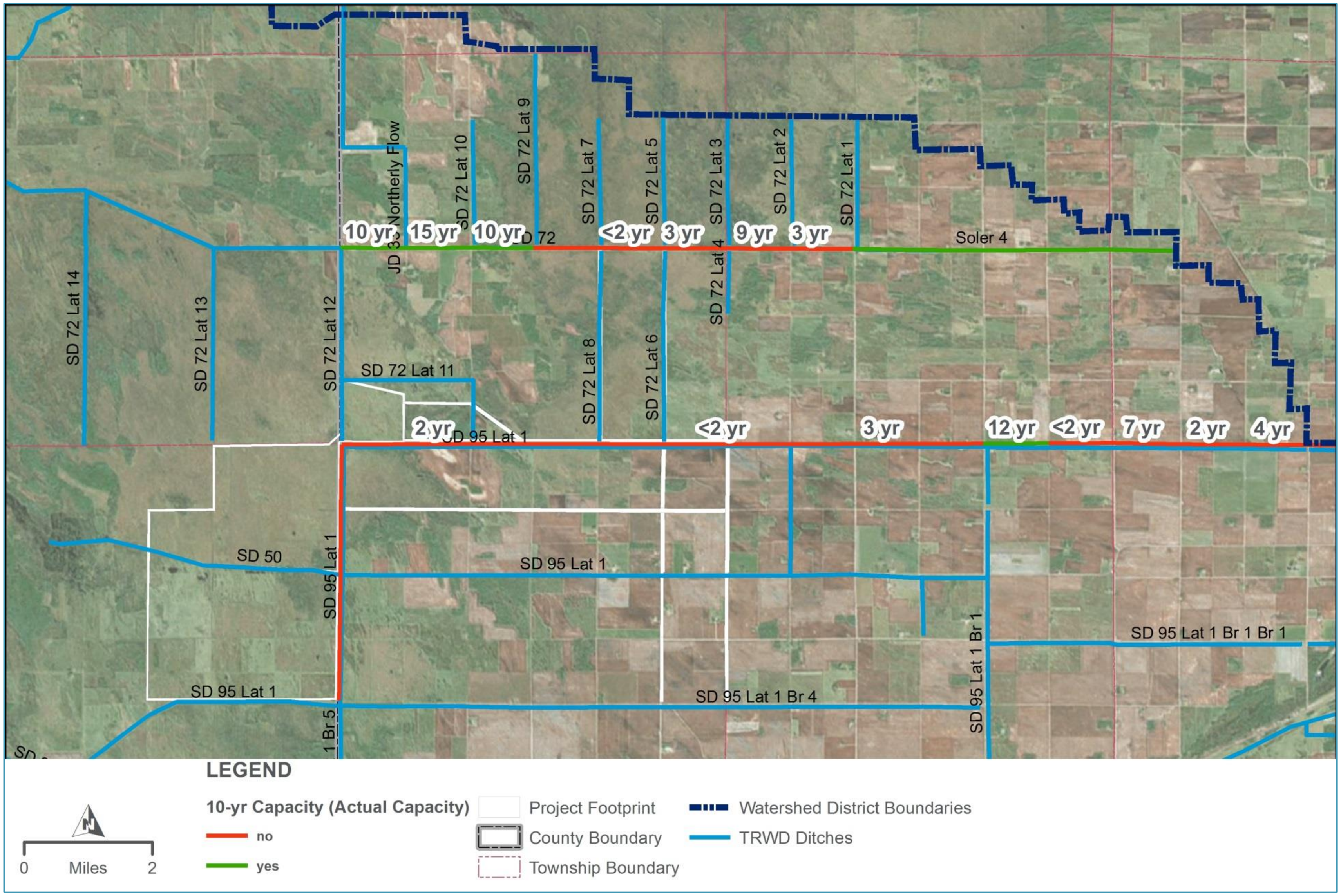
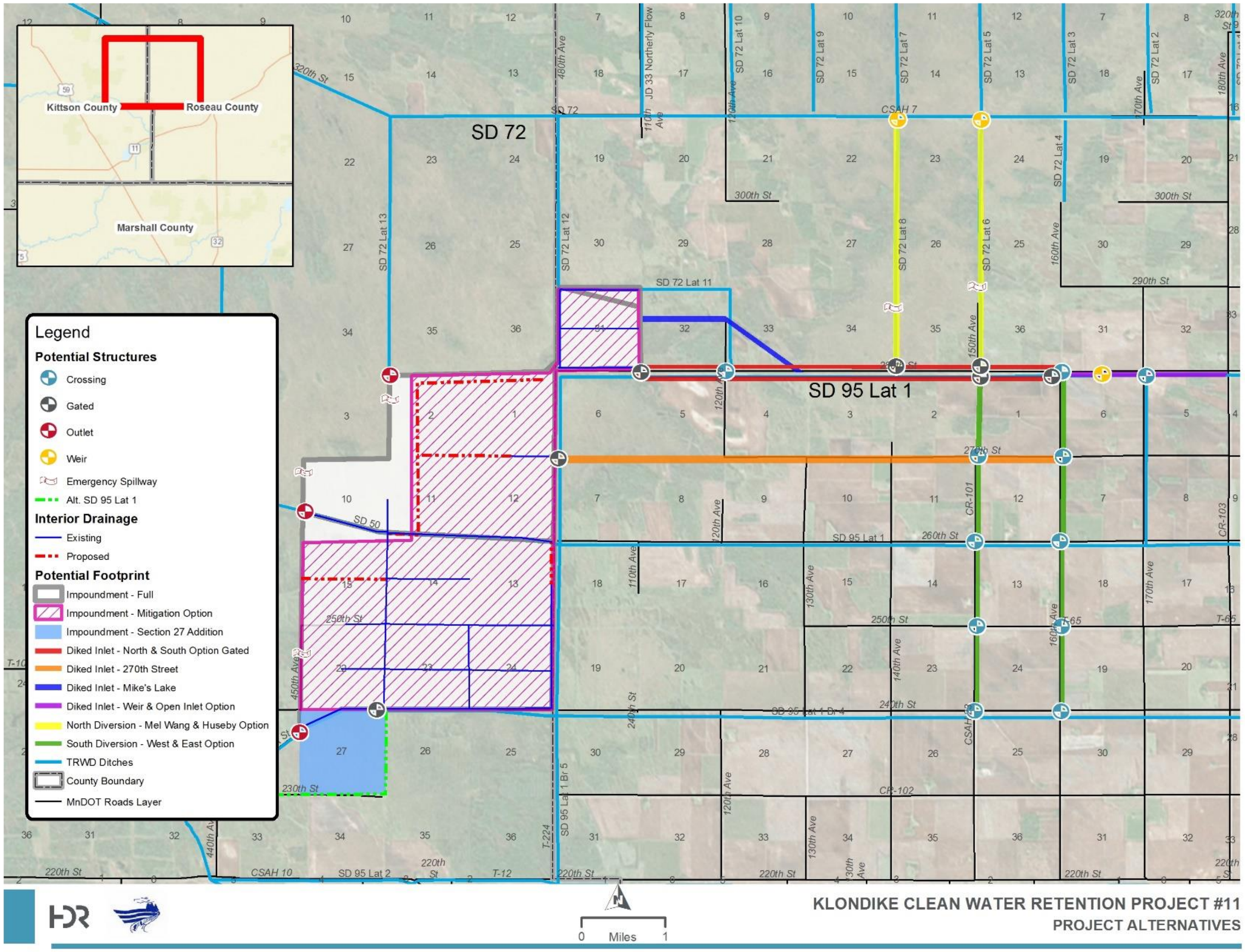


Figure 1-4. Project Concept – Impoundment, Inlet, and Lateral Ditching



2 Summary of Activities

2.1 Project Setting

As shown in Figure 1-1 the project is located 13.5 miles south of the Canadian border, in Roseau and Kittson Counties, Minnesota (7 miles north and 10 miles west of Greenbush, or 8 miles east and 1 mile north of Lake Bronson). The Roseau River is located 9 miles north of the project location. The proposed diversion channels are located in Roseau County and a majority of the proposed impoundment area lies in Kittson County. Figure 2-1 shows the drainage areas of each diversion, with a maximum of 191.5 square miles contributing to the project and receiving runoff from Badger Creek, Roseau River, Lat 1 of SD 95, and parts of SD 72. This project will reduce flooding on SD 95, SD 50, SD 72, the Red River, and on the North Branch, Middle Branch, and South Branches of the Two Rivers.

A large portion of the project's drainage and impoundment area is classified as cultivated agricultural land. The northeast section of the north diversion drainage areas consist of wetlands (freshwater emergent wetland and freshwater frosted/shrub wetland) and deciduous shrubbed grassland. The impoundment also contains areas of freshwater emergent wetland and freshwater frosted/shrub wetland in the north and east. Large tracts of wetlands of are present north of the impoundment. The land cover in the project area is shown in Figure 2-2.

The project area is located in the Tallgrass Aspen Parklands Province and the Lake Agassiz, Aspen Parklands Section which is composed of a single landform, the basin of Glacial Lake Agassiz. The Tallgrass Aspen Parklands can be described as a fire-maintained mosaic of prairies, brushland, woodlands, forests on uplands, wet prairies, meadows, fens, and wet forests in wetlands. The terrain is gently rolling.

2.2 Background

In the 1940s, Lat 1 of SD 95 was constructed, which diverted a 45 – 50 square mile drainage area known as Badger and Skunk Creek away from the Roseau River and directly into the Two Rivers Watershed. Since that time, lands located between the City of Badger, MN and areas near the Roseau-Kittson County line have been subject to inundation, flooding, erosion, and sedimentation.

In addition, there have been periodic overflows from the Roseau River crossing into the Two Rivers Watershed. These overflows enter the SD 72 system, eventually exceeding their capacity and continuing into the SD 95 system.

The Two Rivers Watershed District began studying the area in the 1980s and early 1990s under a project investigation known as "Juneberry Ridge," but plans were dropped due to litigation governing the Red River Valley. In 1998 a group of landowners in Barto and Polonia Townships submitted a ditch/drainage petition to the TRWD under Minnesota Drainage law, Statute 103E. However, the determination was made that drainage improvements could not be undertaken until an adequate outlet was provided for the system downstream.

2.2.1 Big Swamp Project Work Team

In 2009, the TRWD convened the Big Swamp Project Work Team (BSPWT) to further study the situation and come up with a project concept and alternatives. The BSPWT consisted of local landowners, Roseau/Kittson County commissioners and engineers, TRWD board managers, TRWD engineer and administrator, township supervisors from 4 townships, the Mayor of Badger, and representatives of the following agencies: United States Army Corps of Engineers, the Natural Resources Conservation Service, The Nature Conservancy, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, and Minnesota Board of Water and Soil Resources. The BSPWT held 18 meetings over 3 years, building the foundation of this important flood damage reduction and natural resource enhancement project known as the Klondike Clean Water Retention Project #11 (KCWRP #11).

2.2.2 Flood Modeling

Over the past decade, several large-scale modeling efforts have been conducted throughout the Red River Basin to assist in determining the amount of effort required to meet the flow and volume reduction goals in each tributary basin of the Red River. A HEC-HMS model for the Two Rivers Watershed District has been developed as part of the Red River of the North Basin-Wide Modeling project. These models were also utilized in 2013 for the TRWD Expanded Distributed Detention Strategy project to determine locations for potential detention sites within the TRWD. This was an effort to assess which areas of the watershed have the highest ability to reduce peak flows and volume contributing to the Red River flooding.

2.3 BSPWT Project Goals

The project has two general goals: flood damage reduction (FDR) and natural resource enhancement (NRE). The BSPWT established the following goals and opportunities:

The specific FDR goals include:

- Manage overflows from SD 51 (Roseau River) and SD 69 into Two Rivers system
- Reduce overflows from SD 72 into SD 95
- Provide adequate drainage capacity for up to a 10-year runoff event
- Provide adequate outlet for the various systems
- Reduce damage to crops and infrastructure
- Reduce the duration of flooding on crop land and infrastructure
- Contribute to the regional goal of reducing peak flows to the Red River

The specific NRE goals include:

- Protect and enhance the naturally existing rich fen and other biotic communities located in the area
- Address current TMDL (Total Maximum Daily Load) impairments downstream (erosion, turbidity, flashy hydrograph)
- Improve fisheries
- Set target goals for the North, Middle, and South branches of the Two Rivers
- Create moist soils units within footprint of impoundment to increase wetland bird habitats

2.3.1 Flood Damage Reduction (FDR)

As mentioned in the introduction, a region-wide goal has been established to reduce peak flows along the Red River of the North (Red River) mainstem by 20 percent during a flooding event similar to the 1997 flood. As shown in Table 1-1 it is estimated that this project will result in a peak flow reduction of 15% and a volume reduction goal of 10% above the Red River which is significant progress for one project.

This project will store up to 42,000 acre-feet of flood water, which may come from any or all drainage areas depicted in Figure 2-1 as well as the Roseau River. By following an operating plan, this gated storage will reduce the amount and duration of flooding on the SD 72 and 95 systems and reduce the peak flows of the Two Rivers into the Red River. Figure 2-3 shows the FEMA floodplain in the project area. The Standard Digital Flood Insurance Rate Map (DFIRM) database was utilized. FEMA Zone A is prevalent through Roseau County along SD 95 Lat 1. Zone A refers to areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage.

Figure 2-1. Drainage Areas

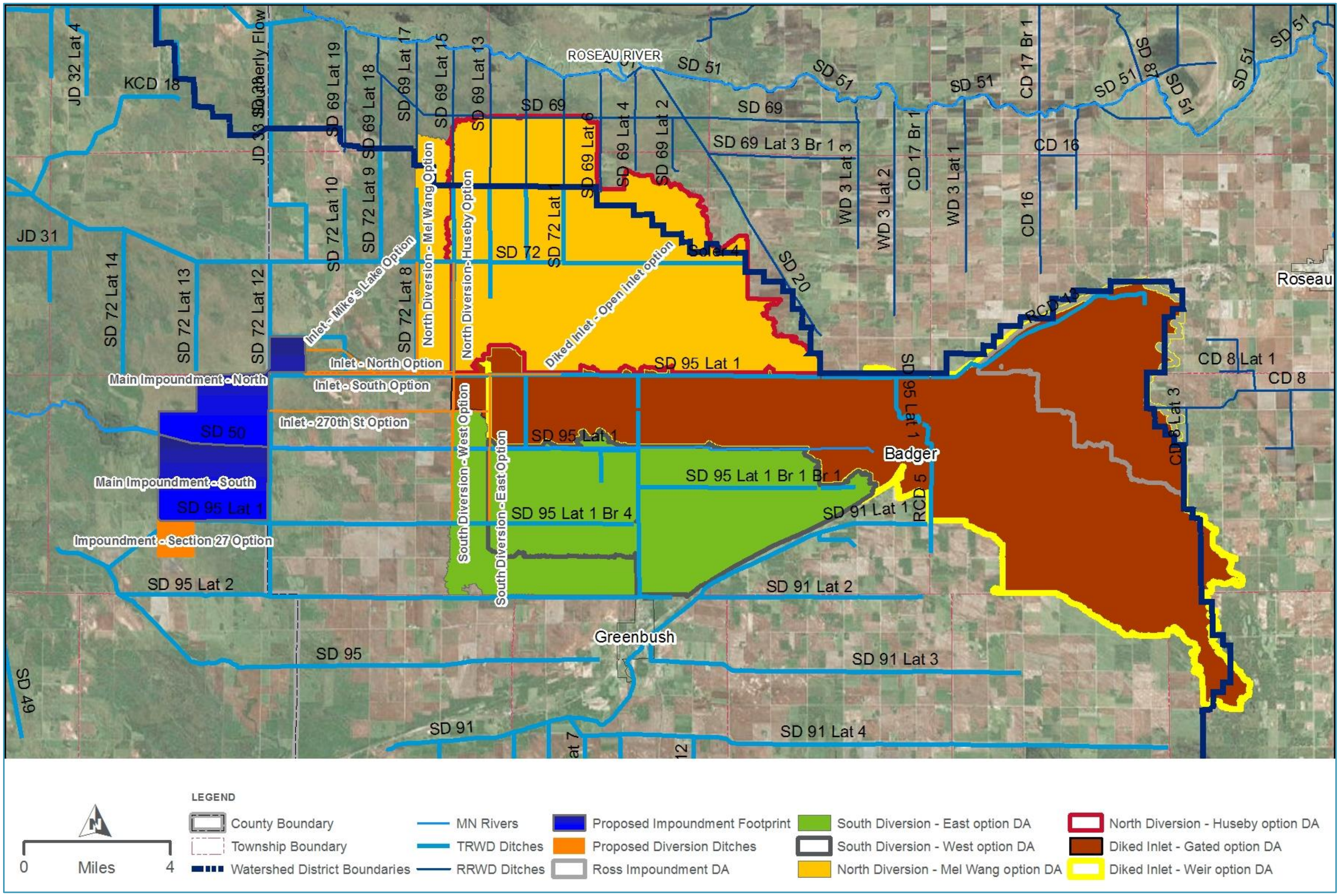


Figure 2-2. Land Cover

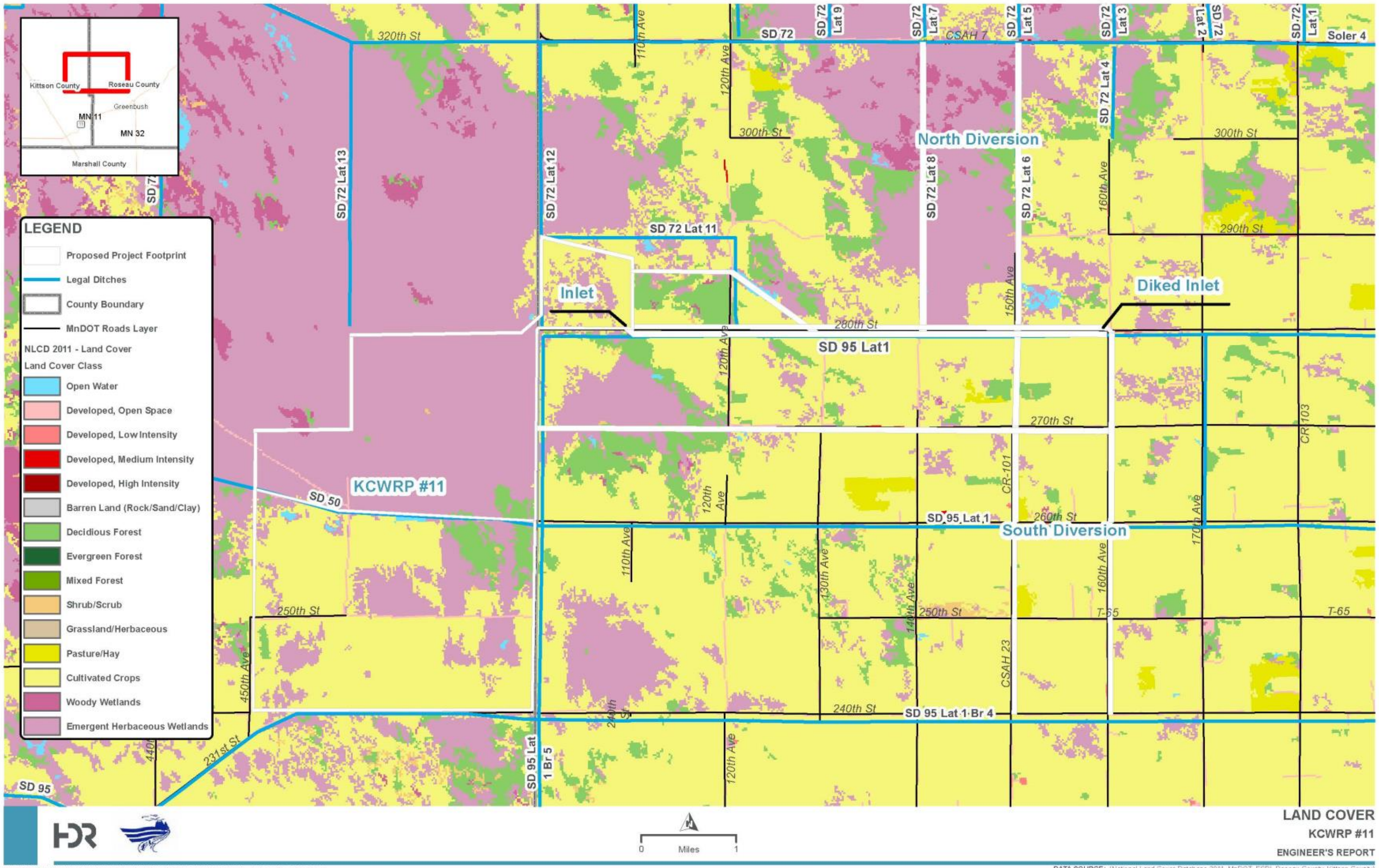
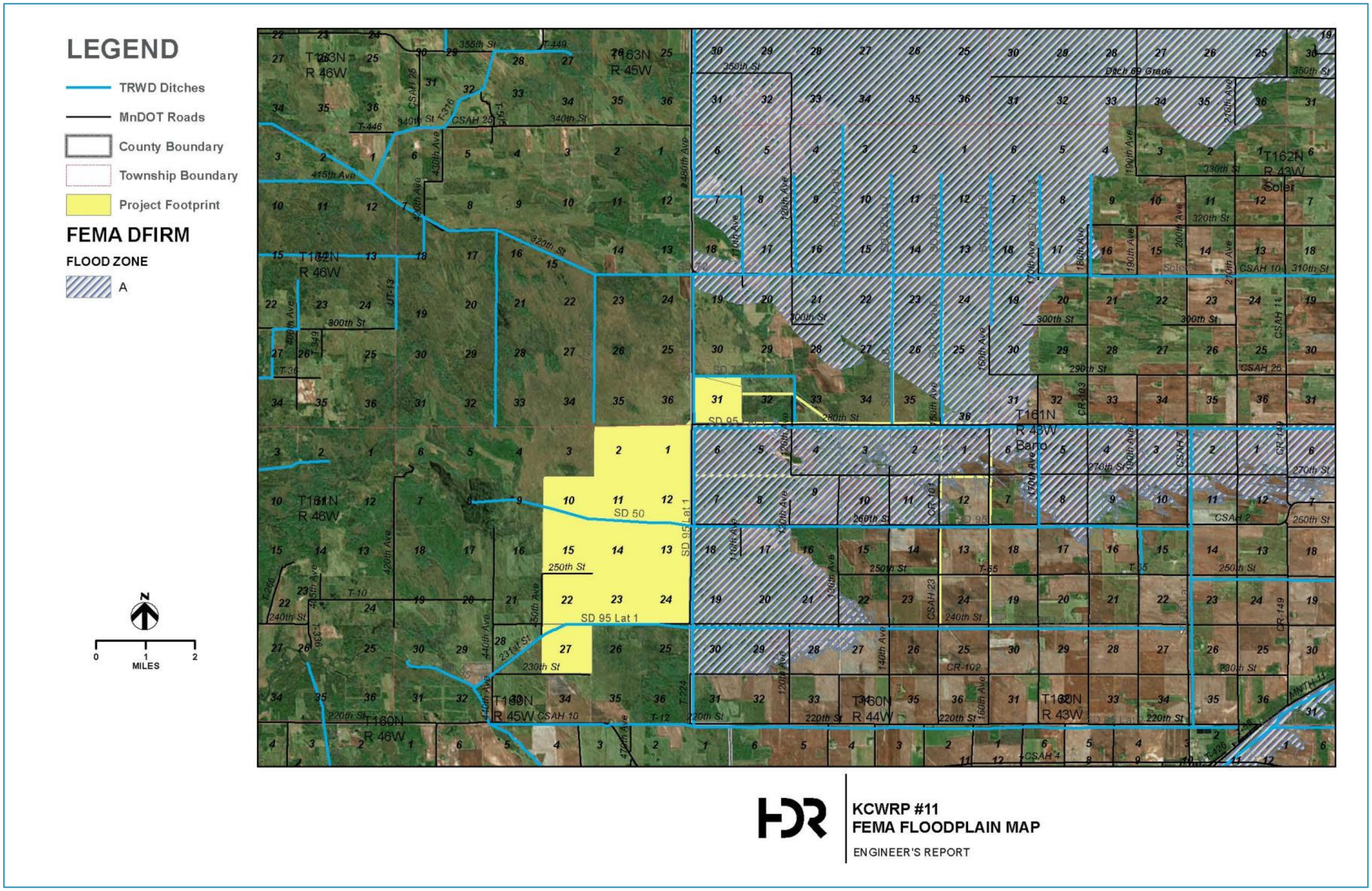


Figure 2-3. FEMA Floodplain Map



2.3.2 Natural Resource Enhancement (NRE)

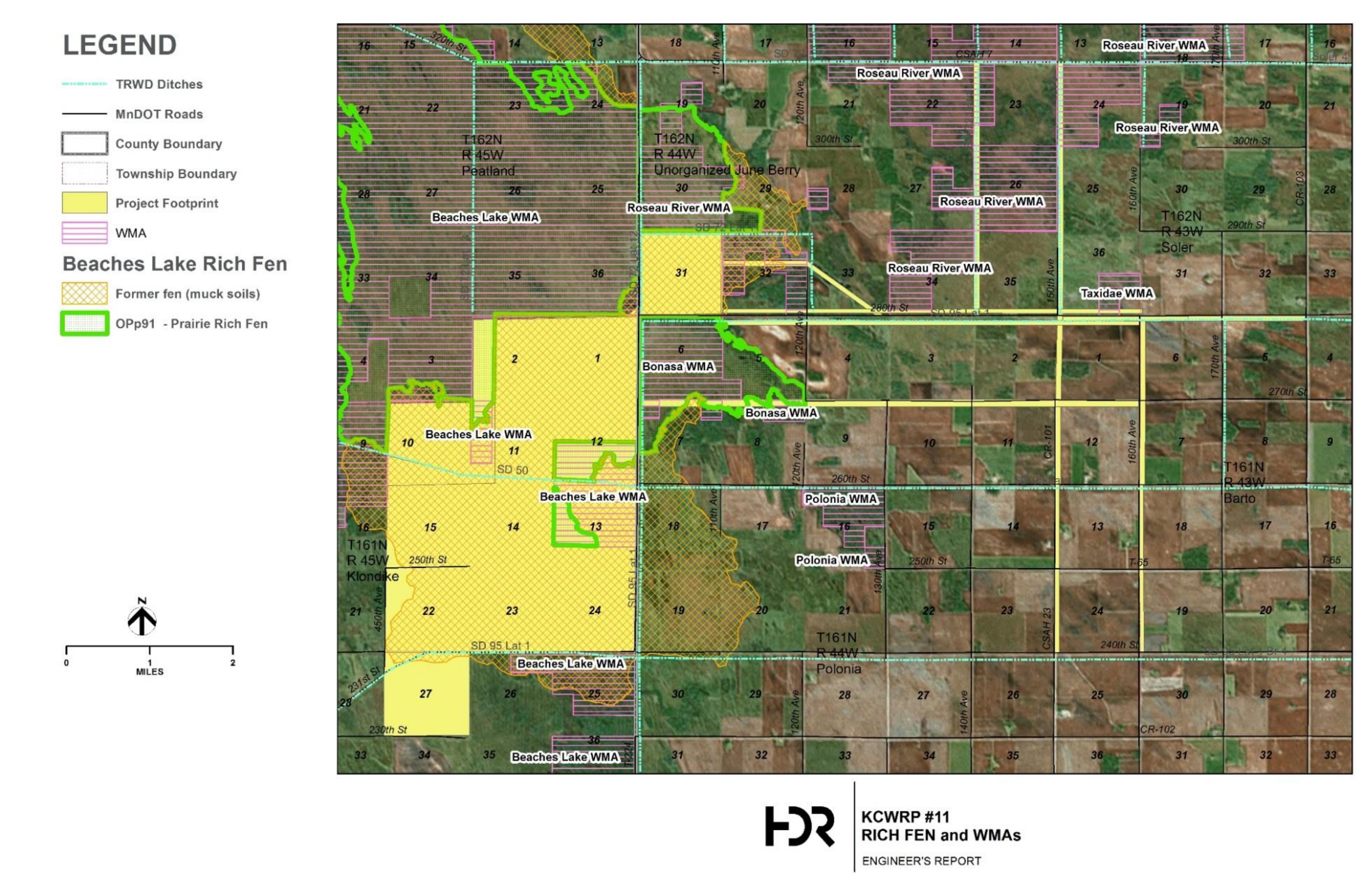
This project may provide natural resource enhancement opportunities. A separate environmental assessment is being completed, in order to analyze the potential for natural resource enhancements with this project. Generally with these types of retention projects, storing water in the impoundment will improve the quality of the water released by allowing the sediments to precipitate out during retention. The water quality impairments in the three branches of Two Rivers could be improved through the project via an operating plan which addresses downstream impacts. The project has potential to outlet to all three branches of Two Rivers. Since the lower sections of the Lower and Middle Two Rivers are impaired for turbidity, this is an important step in sediment reduction.

Rich Fen

Another goal is to protect and enhance the rich fen in the project area that has been identified by the county biological survey. Working closely with the MnDNR, this project design will work to protect this naturally existing biotic community. The open rich fen ecosystems are located in the Beaches Lake Wildlife Management Area (WMA). The project footprint will be impacting 3 WMA units - Beaches Lake, Bonasa, and Roseau River - by direct effects of construction and altered hydrology. These ecosystems are sensitive to changes in hydrology and invasion by invasive species. This open rich fen is a rare ecosystem in the state and this particular tract of land is one of the largest examples in the state. The rich fen contains a plant community that relies on surface and ground water interaction to maintain its chemical makeup which leads to scientifically significant plant species. This ecosystem supports many native plants and animals and serves as a refuge against habitat loss. Figure 2-4 shows the project footprint in relation to the WMA's. Figure 2-4 also shows the existing location of the rich fen which is present on the north side of the impoundment as well as in Section 13 inside the impoundment. The former footprint of the fen (before the land was used for agricultural purposes) is shown to have covered most of the impoundment area.

Through careful planning and design, the project will attempt to enhance the rich fen. A fen management plan is being developed by the TRWD and MnDNR which will inform any decisions regarding the rich fen. The state of Minnesota has been mandated by legislation to assist the TRWD in creation and implementation of a rich fen management plan by December 31st, 2017. The TRWD, MnDNR, MCPA, and HDR have met on December 8, 2016 and January 9, March 13, May 8, and June 12, 2017 to plan and create the Rich Fen Management Plan and coordinate on activities related to the KCWRP #11 such as monitoring and environmental compliance.

Figure 2-4. Rich Fen and WMA's in Relation to Project Footprint



3 Project Features

This section will introduce the unique features of the KCWRP #11, as well as the various options for each feature. Table 3-1 provides the overall project alternatives, which will be explained in detail in Section 4.2. The four project features discussed in this section are defined as follows:

- Diked Inlet – the channel that feeds the impoundment
- North Diversion – a three-mile long diversion channel that connects SD 72 to the Diked Inlet
- South Diversion – a four-mile long diversion channel that connects two southern branches of SD 95 Lat 1 to the Diked Inlet
- Impoundment – reservoir storing all flows from the Diked Inlet

Table 3-1. Overall Project Alternatives

Alternative #	Diked Inlet	Impoundment	Diversions		
1-1	Gated Option	Full Impoundment Option	**Á la Carte Alternatives**	North Diversion	Huseby Option
1-2	Weir Option				Mel Wang Option
1-3	Open Inlet Option				None
2-1	Gated Option	Impoundment which avoids DNR-owned land in Section 11 (Mitigation Option)		South Diversion	East Option
2-2	Weir Option				West Option
2-3	Open Inlet Option				None

3.1 Diked Inlet

One of the required features of the KCWRP #11 is an inlet channel which will convey flows into the impoundment area. Three outlets will discharge the stored water into the downstream North Branch, Middle Branch, or South Branch of the Two Rivers. In order to fill the impoundment to elevation 1017, the inlet will begin at an elevation higher than 1012 to obtain enough slope in the inlet. This occurs five miles east of the county line in SD 95 Lat 1. The inlet will gradually slope towards the impoundment and approach natural ground elevation, requiring embankments on both sides essentially becoming an extension of the reservoir. Figure 3-1 shows the basic concept of an ideal impoundment site and a site that is too flat for creating a reservoir with just a simple embankment. Figure 3-2 conceptually shows the method to create a controlled reservoir when the topography is too flat to contain a significant amount of storage with a simple embankment. The concept drawing shows that a diked inlet allows the drainage area to be retained at the site by gravity if it extends far enough upstream.

Figure 3-1. Impoundment Concept and Topography

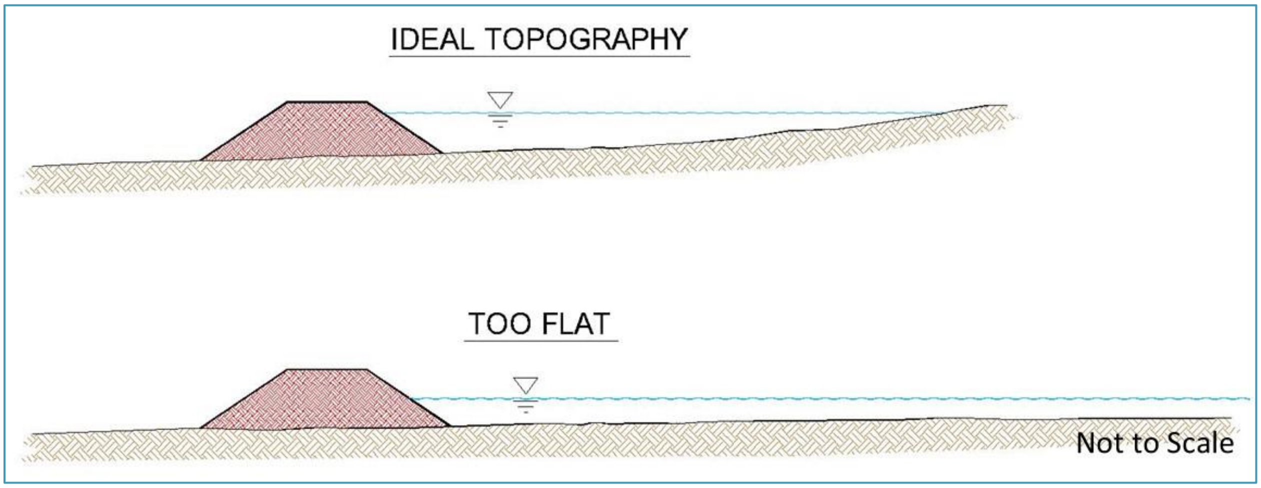


Figure 3-2. Diked Inlet Concept

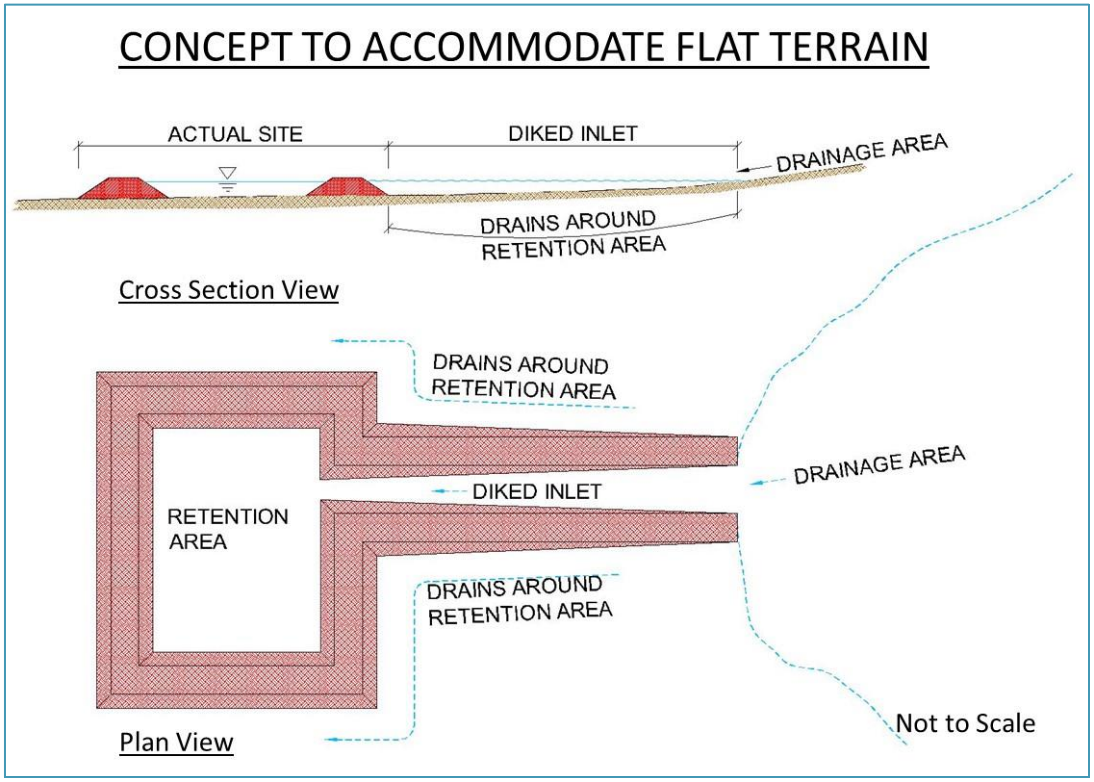


Table 3-2 and Figure 3-3 show the Diked Inlet alignments that have been considered. The Diked Inlet – South Option would be aligned to the south of 280th Street. The Diked

Inlet – North Option would be aligned to the north of 280th Street. The length of the Diked Inlet for the North and South options will vary, depending on which type of inlet control alternative is selected (gated, weir, or open). If the either of the North or South Diked Inlet options are selected, the existing road will be raised and reinforced in order to perform as an embankment when the project is impounding water. Another embankment will be built opposite the existing road with a 20-foot top width and 5:1 (horizontal:vertical) side slope on the wet side and 4:1 (horizontal:vertical) side slope on the dry side. This sizing is designed to safely hold water and to allow farm equipment to navigate between fields as it currently does. Each alternative also maintains exterior drainage by including ditches on the north and south side of the Diked Inlet. The exterior ditches will have an 8-foot wide bottom with 3:1 side slopes. These will allow local drainage to occur while the project is operating. The Diked Inlet will need a crossing one mile east of the impoundment for 120th Avenue to maintain access across SD 95 Lat 1. Figure 3-4 shows a typical cross-section for the Diked Inlet – South Option.

For this report it is assumed that all organics, peat, and non-native fill will be removed down to native soils prior to construction. Figure 3-4 shows the sub cut geometry for removing the organics, peat, and non-native fill for the newly built embankment side of the Diked Inlet. The newly built embankment will consist of an impermeable layer of clay on the wet side of the embankment, with random fill on the dry side of the embankment. The Diked Inlet embankment that includes the existing 280th Street will be will be raised and reinforced with an impermeable layer of clay.

The remaining two alignments include the natural flow pattern through Mike's Lake and the 270th Street alignment (Figure 3-3).

Table 3-2. Diked Inlet Alignments

Alignment Alternative	Comments
Diked Inlet – South Option	Aligned south of 280th St., utilizing SD 95 Lat 1 as a pilot channel. For exterior drainage a new Lat 1 SD 95 ditch would be constructed on the south side (matching existing size/grade).
Diked Inlet – North Option	Aligned north of 280th St. New pilot channel would be built.
Diked Inlet – Mike's Lake Option	Utilizing Mike's Lake flow pattern.
Diked Inlet – 270th St Option	Aligned along 270th St.

3.1.1 Pilot Channel

An important aspect of the Diked Inlet and Impoundment will be a pilot channel. This feature is going to promote flow through the inlet to the impoundment and ultimately to the outlet, allowing a complete drawdown to a dry impoundment. For the Diked Inlet – South Option, the existing SD 95 Lat 1 can act as the pilot channel up to the impoundment. From there, the pilot will be extended into the impoundment at a constant grade. That allows water to always flow into and through the impoundment, therefore keeping it dry when not in operation.

3.1.2 Road Raise

As shown in Figure 3-4, 280th Street will be raised and reinforced to act as the north or south side of the Diked Inlet. This modified embankment section should be checked for through seepage, underseepage, and foundation and embankment stability. No boreholes have been taken through 280th St to determine the in-situ soil properties of the existing embankment for design purposes.

When adding material to 280th Street to raise and widen the embankment, follow construction recommendations as per USACE EM 1110-2-1913 manual.

Figure 3-3. Diked Inlet Alternatives

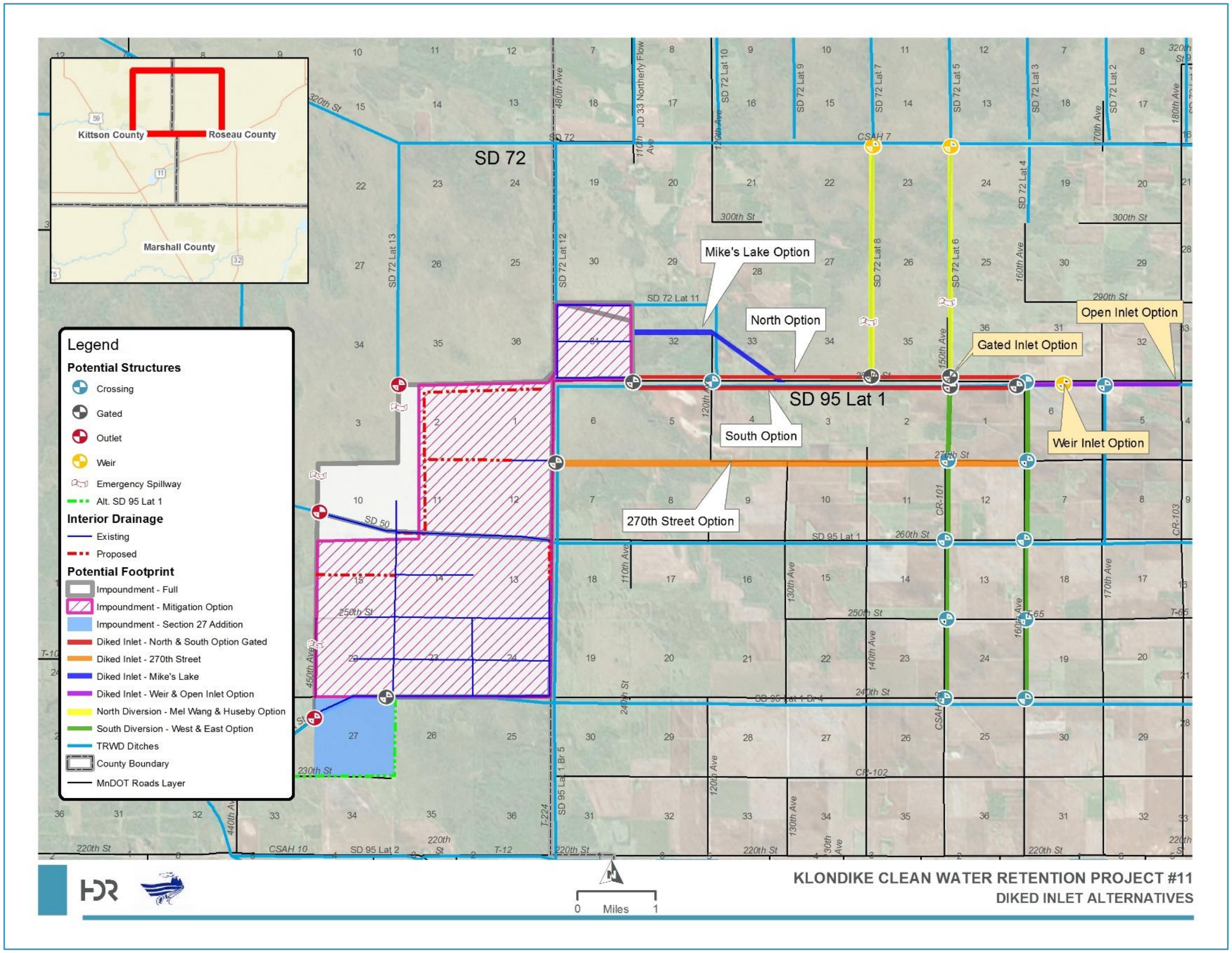
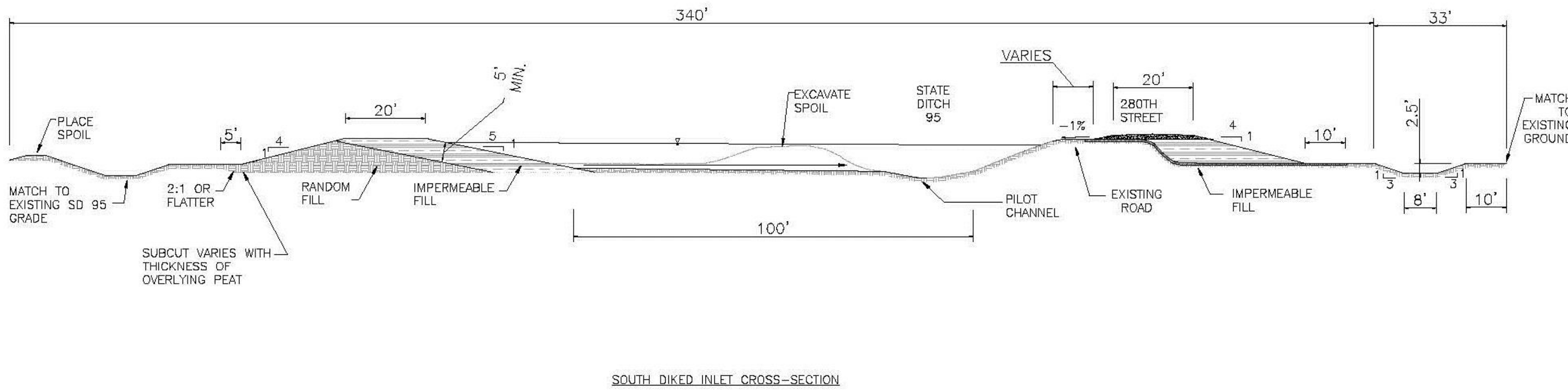


Figure 3-4. Typical Diked Inlet Cross Section



3.2 North Diversion

Two existing lateral ditches connect SD 72 to SD 95 and are located four and five miles from the Kittson/Roseau County line (Laterals 6 and 8 of SD 72). Figure 3-5 shows the two ditches for the proposed North Diversions; Mel Wang and Huseby. These existing ditches are capable of flowing either north or south depending on which ditch system is experiencing higher water levels and if flap gates are in place. The BSPWT initially established a goal of reducing flows from SD 72 into SD 95, but later expressed a desire to include these laterals in the project as a way to store water from SD 72 in the event that Roseau River overflows into the system. Both existing ditches could be enlarged and used to collect water from SD 72 and divert it into the Diked Inlet. Figure 3-6 and Figure 3-7 show typical cross-sections of the existing laterals. They are similar in size with 10 to15 foot bottom widths and steep side slopes.

The proposed North Diversion channels include expanding the existing channel (currently with a 10 to15 foot bottom width) to a 25-foot bottom width with 3:1 (horizontal:vertical) side slopes. Control structures will be located at each end of the three-mile channels. As mentioned above, it is planned to grade the ditches to flow south, therefore the Joint Ditch Authority (JDA) would need to approve changes to the legal grade. The Huseby ditch currently has a crossing that contains two (2) 36-inch corrugated steel culverts with flap gates that would be removed as part of the project.

Both North Diversion channels will need to contain emergency spillways to allow high flows to follow existing drainage patterns overland to the west. The spillways for the Mel Wang and Huseby diversions are proposed at elevations of 1019 and 1020 respectively. At the start of each diversion channel (the north end), a weir at an elevation of 1017 will control the inlet flow. The outlets (south end) will have culverts with gated control. These gates will be operated to control flows into the Diked Inlet and prevent flows from leaving the Diked Inlet during SD 95 events. For more details on these structures, refer to Section 3.5 of this report. Details of both North Diversion channels are discussed below.

Figure 3-5. North Diversion Alternatives

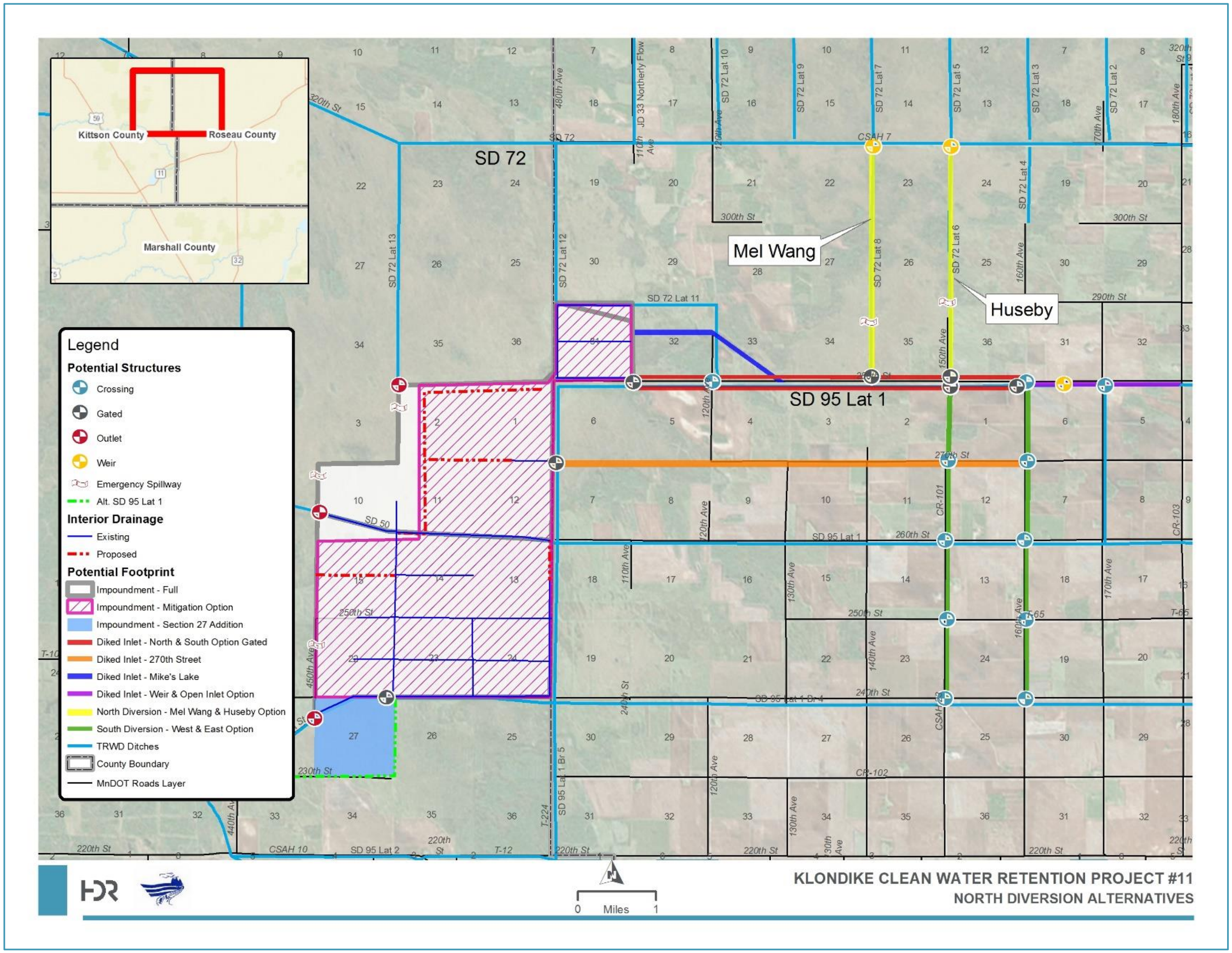


Figure 3-6. SD 72 Lateral 6 (Huseby Ditch) Existing Cross Section

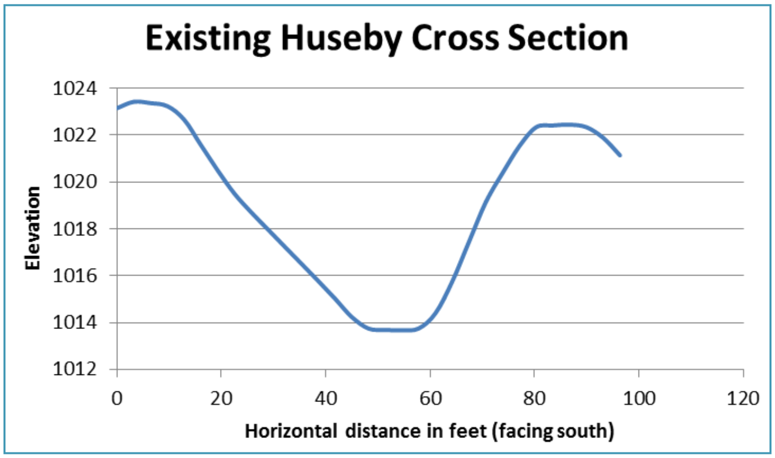
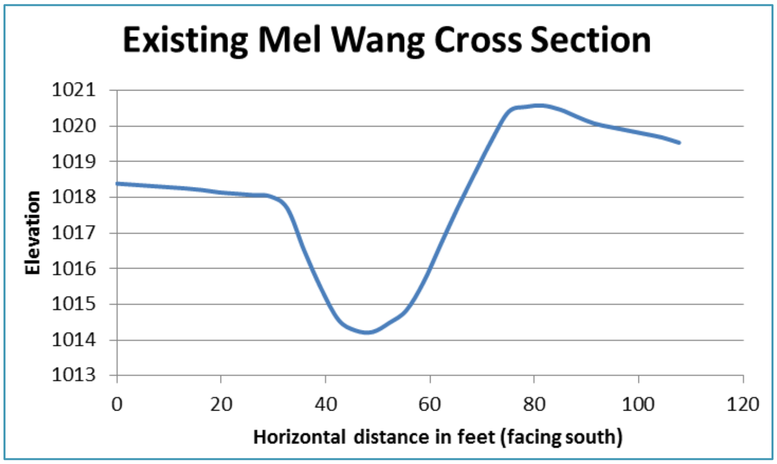


Figure 3-7. SD 72 Lateral 8 (Mel Wang Ditch) Existing Cross Section



3.2.1 North Diversion – Huseby Option

Currently the Huseby ditch can flow either north or south. The JDA will need to be contacted regarding changes to the legal grade. Regardless, control structures will be needed on each end of the diversion channel for the project to operate. In an effort to keep low flows from entering the SD 95 system, there will be a low head weir at the north end of the channel. Therefore, water surface elevations must reach 1017.0' in SD 72 before the channel starts to convey flow south towards the project. There will be an emergency spillway on the west berm. At the south end there will be large box culverts with sluice gates. The operation of the gates will depend on downstream conditions and whether the KCWRP #11 is in operation. When filling the impoundment the gates can be open to allow flows into the Diked Inlet, as long as the water surface elevation in the Diked Inlet is below the emergency spillway elevations in the diversions. Preliminary operating procedures for the Huseby Option are presented in Section 7.8 of this report.

3.2.2 North Diversion – Mel Wang Option

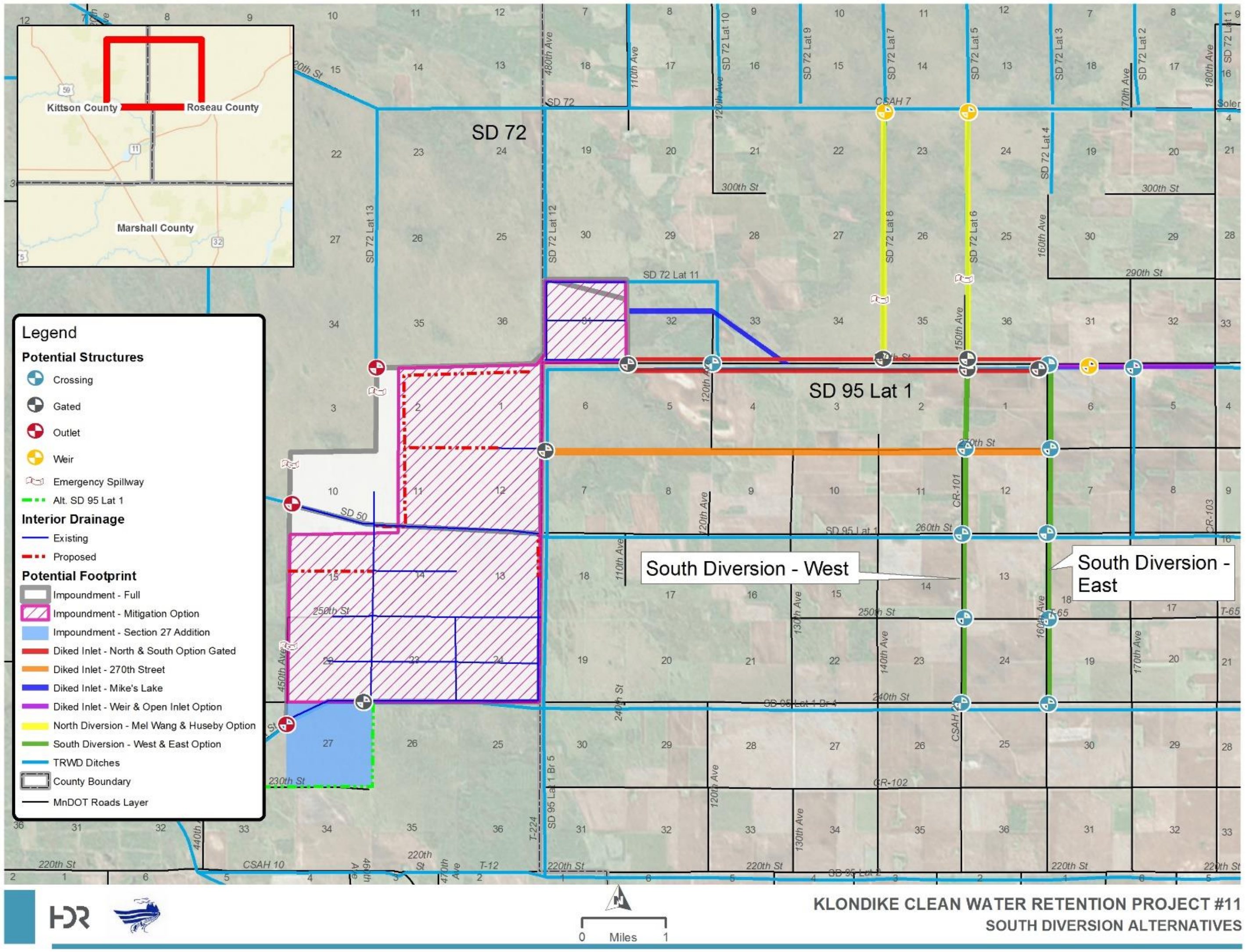
The existing Mel Wang ditch is very similar to the Huseby ditch in that it also conveys flows north or south. The channel has been allowed at times to drain into SD 95 Lat 1, but can cause problems when SD 95 Lat 1 is full. This project will allow the Mel Wang to only accept high flows from SD 72 with a weir at the north end. There will be emergency spillways on both berms. The south end will have two large box culverts with sluice gates that outlet into the Diked Inlet. The gates will have an operating plan similar to the North Diversion – Huseby Option that will consider downstream impacts.

3.3 South Diversion

A large drainage area south of SD 95 Lat 1 can be diverted into the Diked Inlet through the South Diversion (Figure 2-1). There are two SD 95 Lat 1 branches that flow west and into SD 95 Lat 1 Br 5 at the county line. These branches could be diverted into the Diked Inlet by constructing a four-mile long diversion channel that flows north into existing SD 95 Lat 1 (from 240th Street to 280th Street and into SD 95 Lat 1). Two alignments of this project feature were considered: along either 150th Avenue or 160th Avenue (Figure 3-8). The alternatives are called "South Diversion – West" and "South Diversion – East." The South Diversion will have to be newly constructed; there is no existing ditch in these locations.

Only one of the proposed South Diversion channels will be constructed. The South Diversion channel will be trapezoidal with a twenty five foot bottom width and 3:1 (horizontal:vertical) side slopes. This preliminary sizing was optimized in the hydraulic modeling to reduce flooding to adjacent land. This will be verified with geotechnical analysis. Steeper slopes were chosen because the land adjacent to these channels is mainly agricultural and three-to-one side slopes will minimize the footprint and amount of land affected. The existing structures in both branches of SD 95 Lat 1 are four-foot circular, gated metal pipes. The new structures, smaller than the existing structures, promote high flows to enter the diversion channel. The diversion is proposed to have raised-invert box culverts, thus allowing low flow to continue west and bypass the project. At each of the road crossings along the proposed diversion, a set of box culverts (10' x 6') is proposed. For more details on the structures proposed for the South Diversion, see Section 3.5 of this report.

Figure 3-8. South Diversion Alternatives



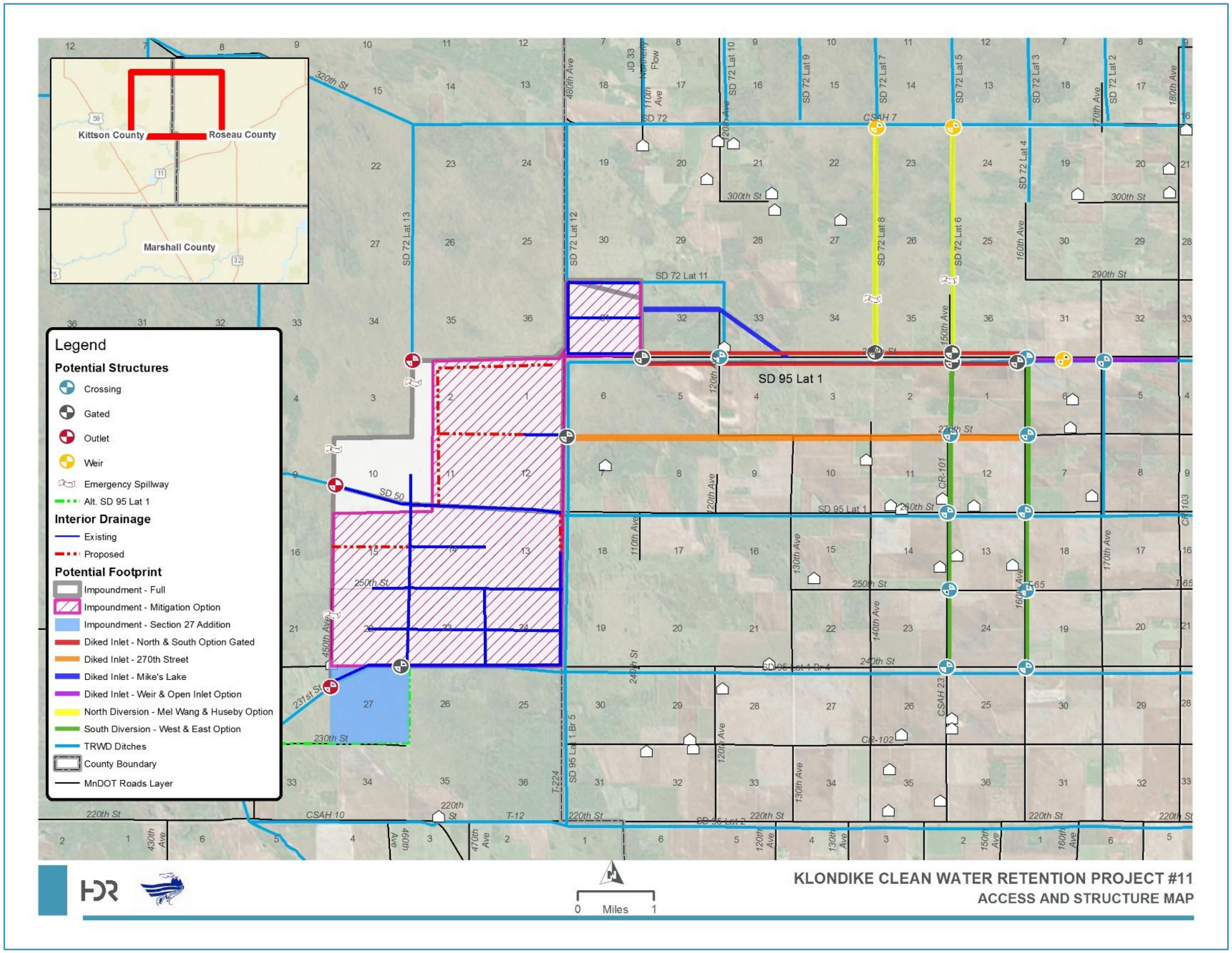
3.3.1 South Diversion – West

The South Diversion – West Option is aligned alongside 150th Ave. At this alignment location, the diversion channel would outlet into the Diked Inlet/SD 95 Lat 1 5 miles east of the county line. This location captures the largest possible drainage area.

3.3.2 South Diversion – East

The South Diversion – East Option is aligned along 160th Ave. This alignment would outlet into the Diked Inlet/SD 95 Lat1 at 6 miles east of the county line, therefore having a slightly reduced drainage area compared to the South Diversion – West Option. However, when comparing the potential impacts of the two alignments, the east Option would significantly reduce the effect on existing structures and field crossings. Figure 3-9 shows the locations of existing buildings. The eastside of 150th Ave (South Diversion – West Option) has nine (9) existing field entrances and one (1) private driveway, while the eastside of 160th Ave (South Diversion – East Option) has six (6) existing field entrances. These would have to be re-constructed or re-located as part of the project.

Figure 3-9. Access and Structure Map



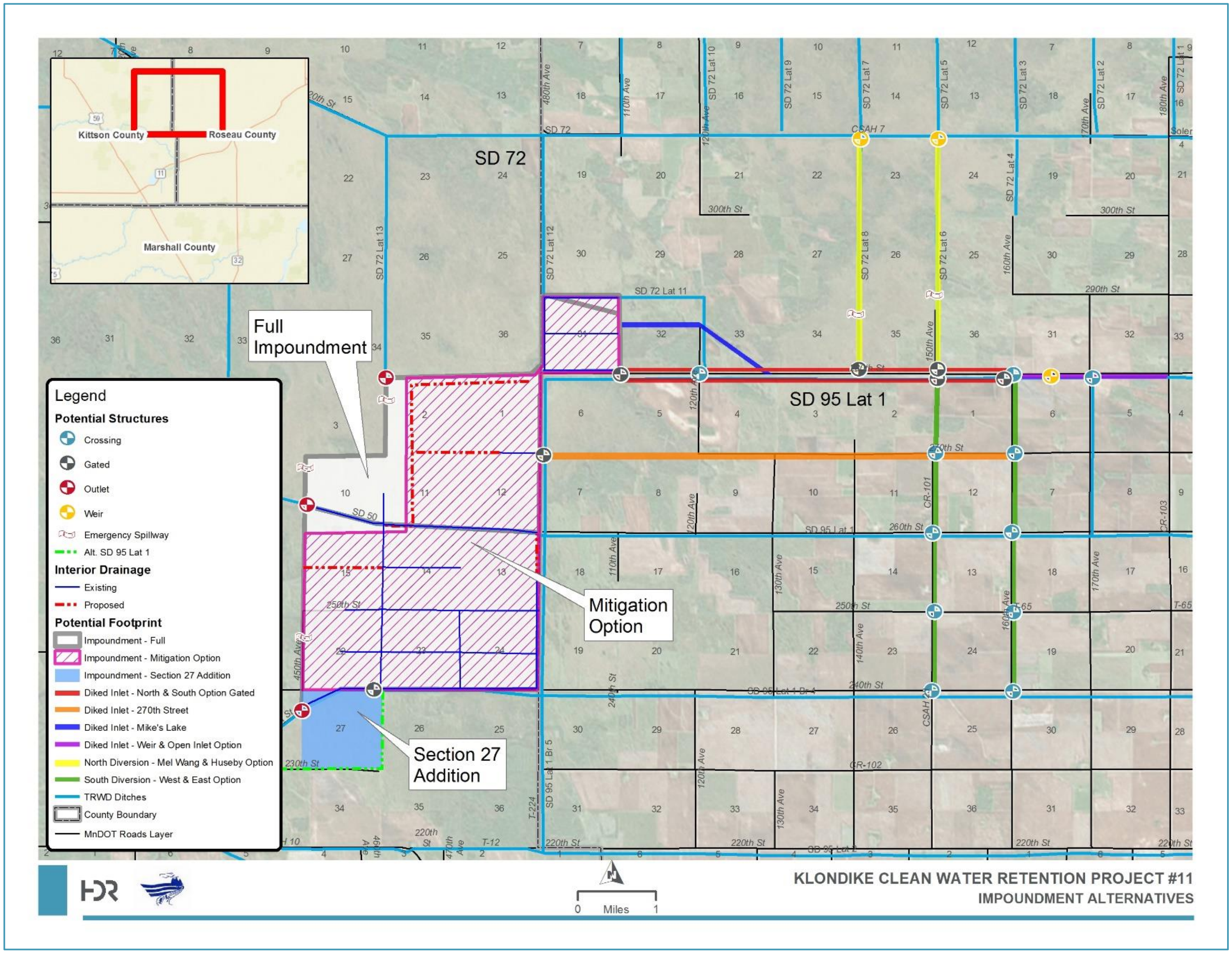
3.4 Impoundment

Table 3-3 and Figure 3-10 shows the three impoundment alternatives. The land currently owned and legislated to be obtained by the Two Rivers Watershed District has formed the shape of the full impoundment alternative. It consists of Section 31 of Juneberry Township 162 North, Range 44 West and Sections 1, 2, 10 – 15, and 22 – 24 of Klondike Township 161 North, Range 45 West. The alignment of the impoundment area will largely depend on land acquisitions by TRWD from MnDNR. The MnDNR has been legislated to exchange their lands in Section 12 and 13 within the proposed impoundment for the TRWD land in Section 27. See Appendix A for the legislation. The Mitigation Option has embankments along the boundary of former agricultural land in Section 2, then south to SD 50, excluding Section 10 from the impoundment area. The third impoundment alternative utilizes the Section 27 of Klondike Township, requiring a connection that crosses SD 95 Lat 1. The embankment system that makes up the impoundment is proposed to have 3 outlet structures, more than 18 miles of earthen embankment, and 3 emergency spillways.

Table 3-3. Impoundment Alternatives

Alternative	Location	Storage Capacity (ac-ft)
Full	Include all TRWD sections of land (owned and legislatively granted)	40,000
Mitigation Option	Exclude Section 10 and state land in Section 11	35,000
Section 27 addition	Include TWRD-owned land in Section 27 Klondike Township (requires connection structure across SD 95 Lat 1)	2,300

Figure 3-10. Impoundment Alternatives



3.4.1 Typical Impoundment Embankment

The impoundment embankments will be constructed with an impermeable layer of clay on the wet side of the embankment, with random fill on the dry side of the embankment. The random fill section can consist of clay, sand, or silt. Figure 3-11 depicts the typical embankment section for the impoundment. With a maximum water surface elevation of 1017.0 in the impoundment, embankments will be built to 1019.5 to allow for some wave action, and settlement during the life of the system. The embankment will have a top width of 12' and 5:1 (horizontal:vertical) side slopes on the wet side of the embankment and 4:1 (horizontal:vertical) side slopes on the dry side of the embankment. This will allow for construction activities and maintenance to comfortably take place along the entire length of the impoundment embankments. The 5:1 side slope will also allow for improved wave dissipation and erosion resistance, under seepage resistance, and improved overall stability of the embankment. The impoundment will have exterior ditches to drain adjacent lands and runoff away from the embankments. Figure 3-11 also shows the sub cut geometry for removing peat/topsoil/organics/fill.

Borrow Material

Clay material is available throughout the site at depths varying from 0 to 40 feet deep. Borehole logs show sand layers present at varying depths and thickness. This material can be utilized in the random fill section of the embankment.

Figure 3-12 shows the borehole locations and the estimated depth to clay. It contains data obtained from the USDA Soil Data Viewer in the project area. The data was combined with HDR and Braun Intertec field exploration findings to produce a raster in ArcGIS of the depth of underlying clay which will assist in determining project quantities and costs of excavation. The darker areas on the map represent the clay that is close to ground surface.

Figure 3-13 shows possible borrow site locations. Borrow sites will be located in uplands and low quality wetlands within the impoundment. Borrow sites cannot be located in high quality wetlands. Borrow from ditches and other excavations can also be used whenever possible. It is anticipated that borrow for the Diked Inlet will be obtained along Diked Inlet corridor. Borrow guidelines as per EM 1110-2-1913, Design and Construction of Levees should be followed. A borrow plan will be developed and will be shown in detail in the construction specifications.

Figure 3-11. Impoundment Embankment Cross Section

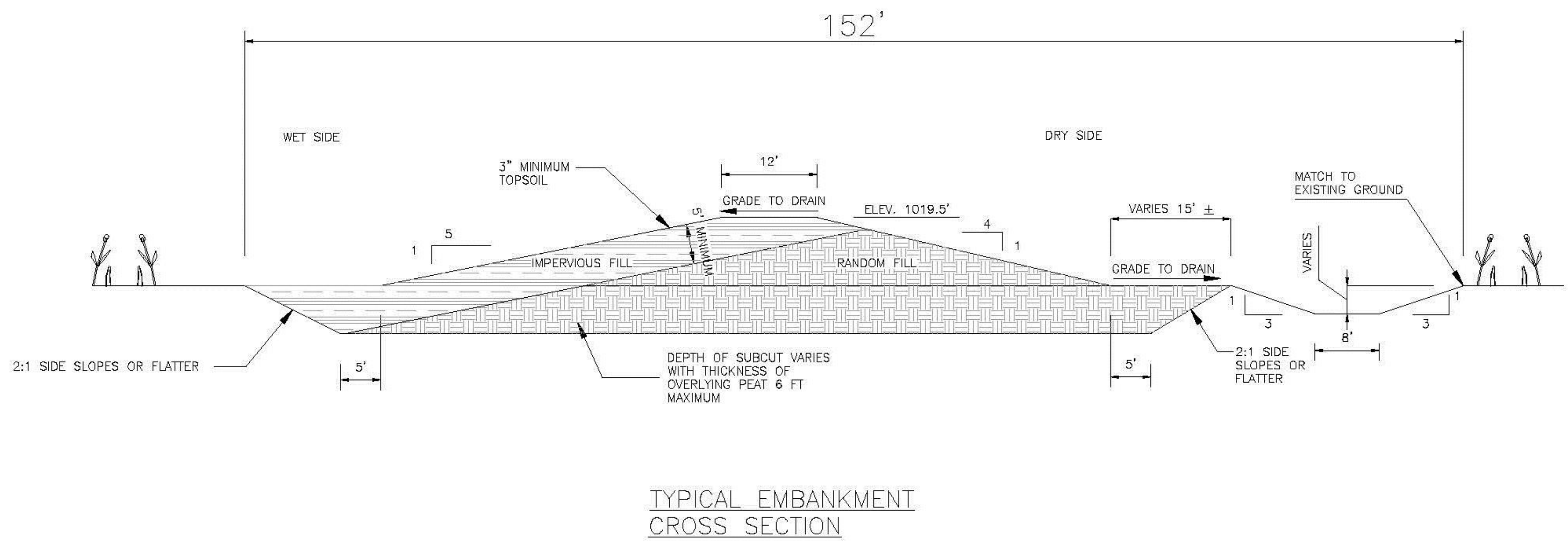


Figure 3-12. Soil Boring Depth to Clay

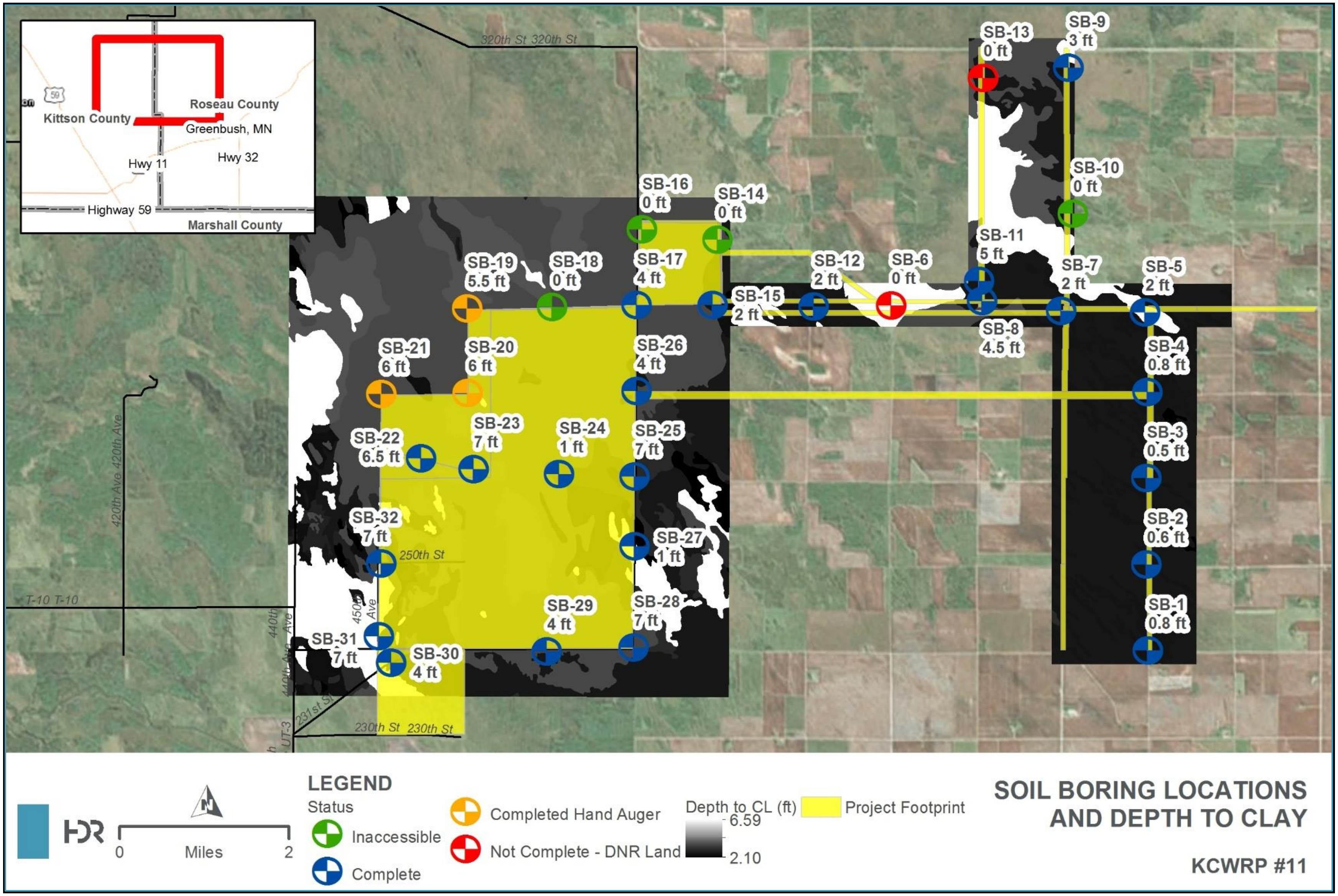
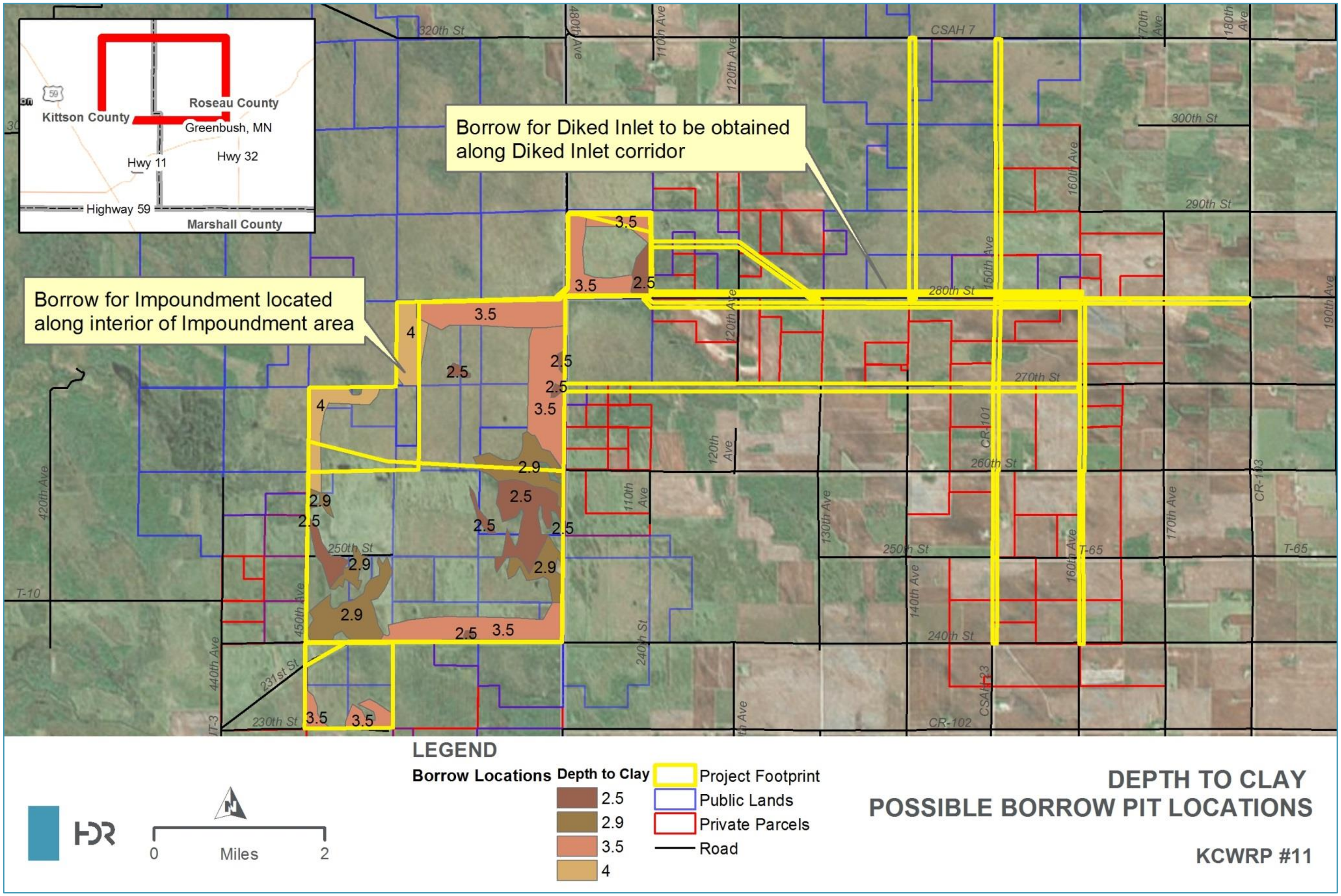


Figure 3-13. Borrow Plan (For Informational Purposes Only)



3.5 Structures

The locations of the structures are shown Figure 1-4.

3.5.1 Outlet Structures

Three outlets will allow the water to exit the impoundment to the North Branch, Middle Branch, or South Branch of the Two Rivers (Figure 1-4). The outlets are referred to as SW Outlet, W Outlet, and NW Outlet based on their location in the impoundment. Table 3-4 below contains outlet structure details including outlet elevations, culvert sizing, gate sizing, and outflows.

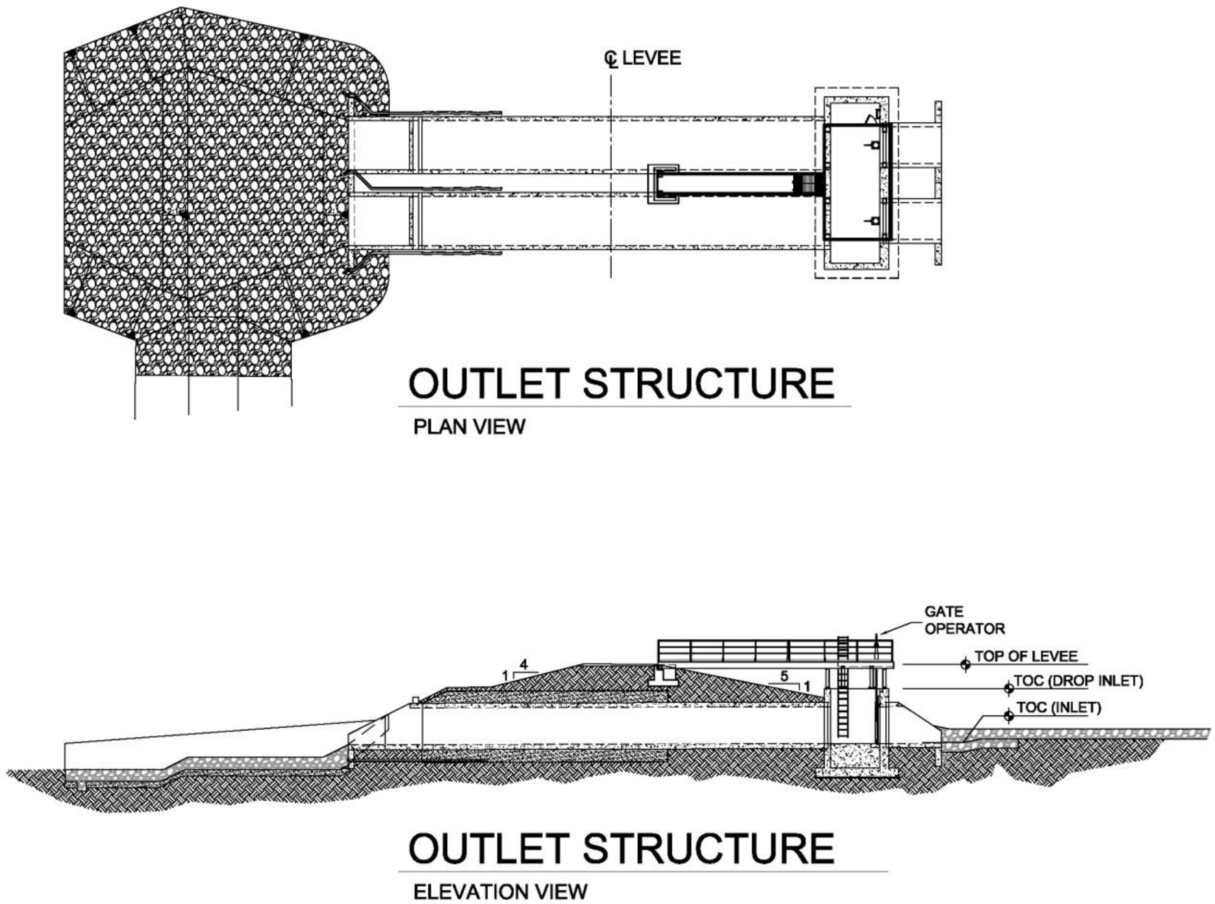
Table 3-4. Outlet Structure Details

Feature	SW Outlet	W Outlet	NW Outlet
Top of Embankment [ft]	1019.5	1019.5	1019.5
Primary Outlet Invert [ft]	1006.0	1008.0	1008.2
Primary Outlet Culvert Size [W'xH']	Two (2) - 8' x 8'	Two (2) - 5' x 5'	Two (2) - 6' x 8'
Primary Outlet Gate Size [W'xH']	Two (2) - 6' x 6'	One (1) - 5' x 5'	Two (2) - 5' x 5'
Maximum Outflow [cfs]	700	250	450
Secondary Outlet Maximum Weir Crest Elevation [ft]	1016.7	1016.8	1016.8
Secondary Outlet Minimum Weir Length [ft]	60	40	60
Emergency Spillway Elevation [ft]	1017.0	1017.0	1017.0
Emergency Spillway width [ft]	250	250	250

Figure 3-14 shows a typical detail of the outlet structures. All three outlet structures will be similar. A pair of sluice gates on the inside of the structure can be manually closed during filling of the impoundment. The outlet culverts will also consist of a precast concrete box culvert with a maximum size of 8 feet by 8 feet. These culverts are fixed to the inside of the drop inlet, or riser, structure. Therefore, the primary sluice gates and the drop inlet would both convey water into the outlet culverts. When the impoundment water surface reaches the drop inlet, it discharges at a rate to prevent the failure of the emergency spillway for the 100-year storm events and the emergency spillway hydrograph (ESH). The impoundment is designed to be dry when not in operation.

The maximum velocities at the outlet will occur when the impoundment is full and both the gated and drop inlets are discharging flow. An energy dissipating stilling basin is planned, along with the appropriate rip-rap sections downstream. The design will require control of seepage around the pipe through use of anti-seep technologies including careful compaction of select clay borrow and use of filter drains.

Figure 3-14. Typical – Outlet Structure



The impoundment will contain three emergency spillways located near outlets. The spillways will be a 250 feet long earthen section of embankment at an elevation of 1017. They have been designed to convey the emergency spillway hydrograph in accordance with TR-60.

3.5.2 Inlet Structures

The three Diked Inlet structure alternatives are:

- Gated Option – a set of sluice gates control inflows to the Diked Inlet and when closed, stores the water in the project (see Figure 3-15)
- Weir Option – a low weir allows automatic inflows to the Diked Inlet and storage up to the crest (see Figure 3-16)
- Open Inlet Option – Diked Inlet is extended upstream so that inflows and storage are maintained automatically (see Figure 3-17)

Figure 3-3 shows the location of these options. Table 3-5 contains elevation, sizing, and outflow details for each of the options. These alternatives have been designed to allow portions of the 10-day 100-year inflows to bypass the Diked Inlet. The full pool elevation of the impoundment has also been considered in these designs, which creates the need for two channels. One channel (Diked Inlet) is an extension of the impoundment, while the other channel (new SD 95 Lat 1) acts as bypass drainage and local drainage when the KCWRP #11 is in operation. For more details on the hydrology and hydraulics, including inflow hydrographs, refer to Sections 5 and 6 of this report.

Table 3-5. Diked Inlet Structure Alternative Details

	Alternative		
	1-1	1-2	1-3
Type of Control	Gated	Weir	Open Inlet
Length of Diked Inlet	4 mi	5.5 mi	7 mi
Maximum Outflow	1700 cfs	1700 cfs	1400 cfs

Figure 3-15. Gated Inlet Option

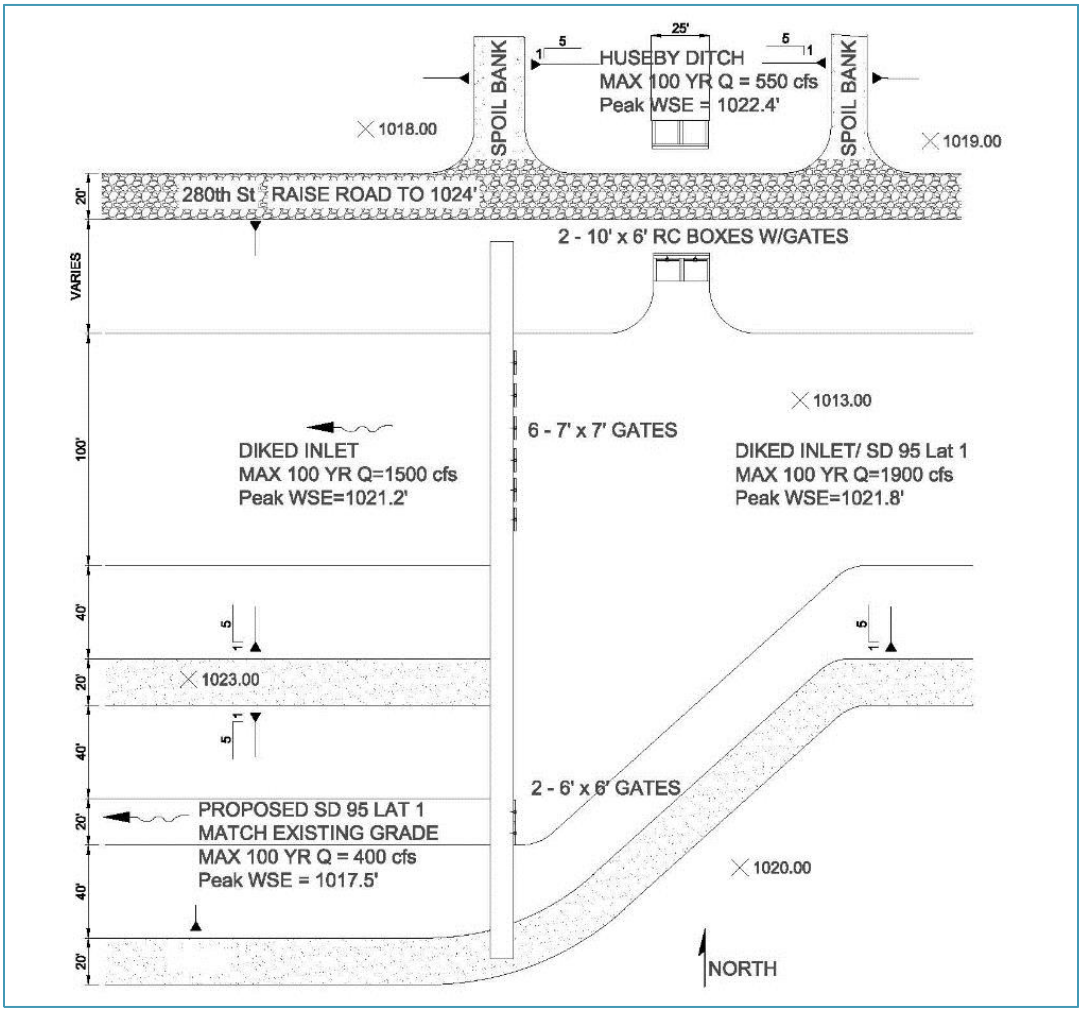


Figure 3-16. Weir Inlet Option

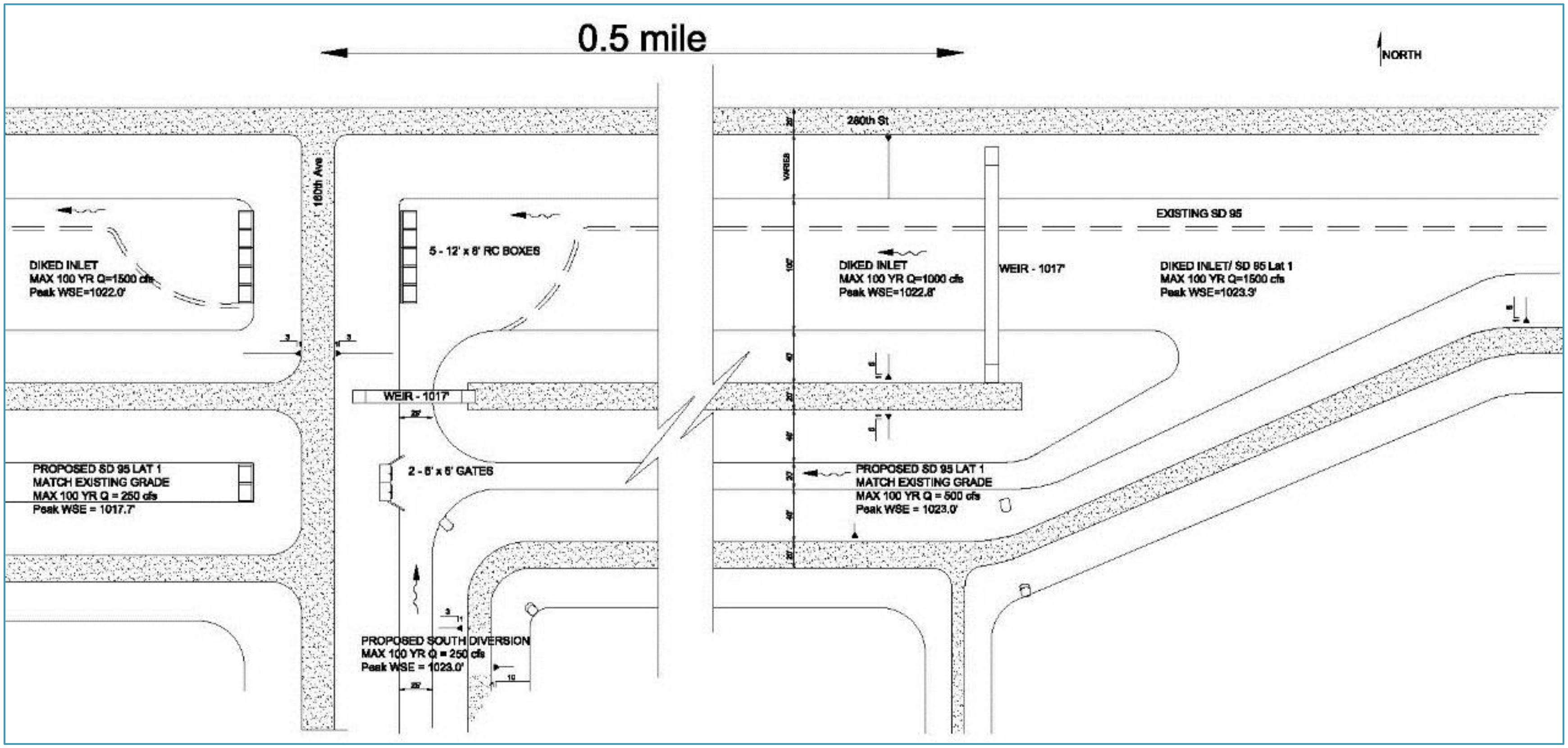
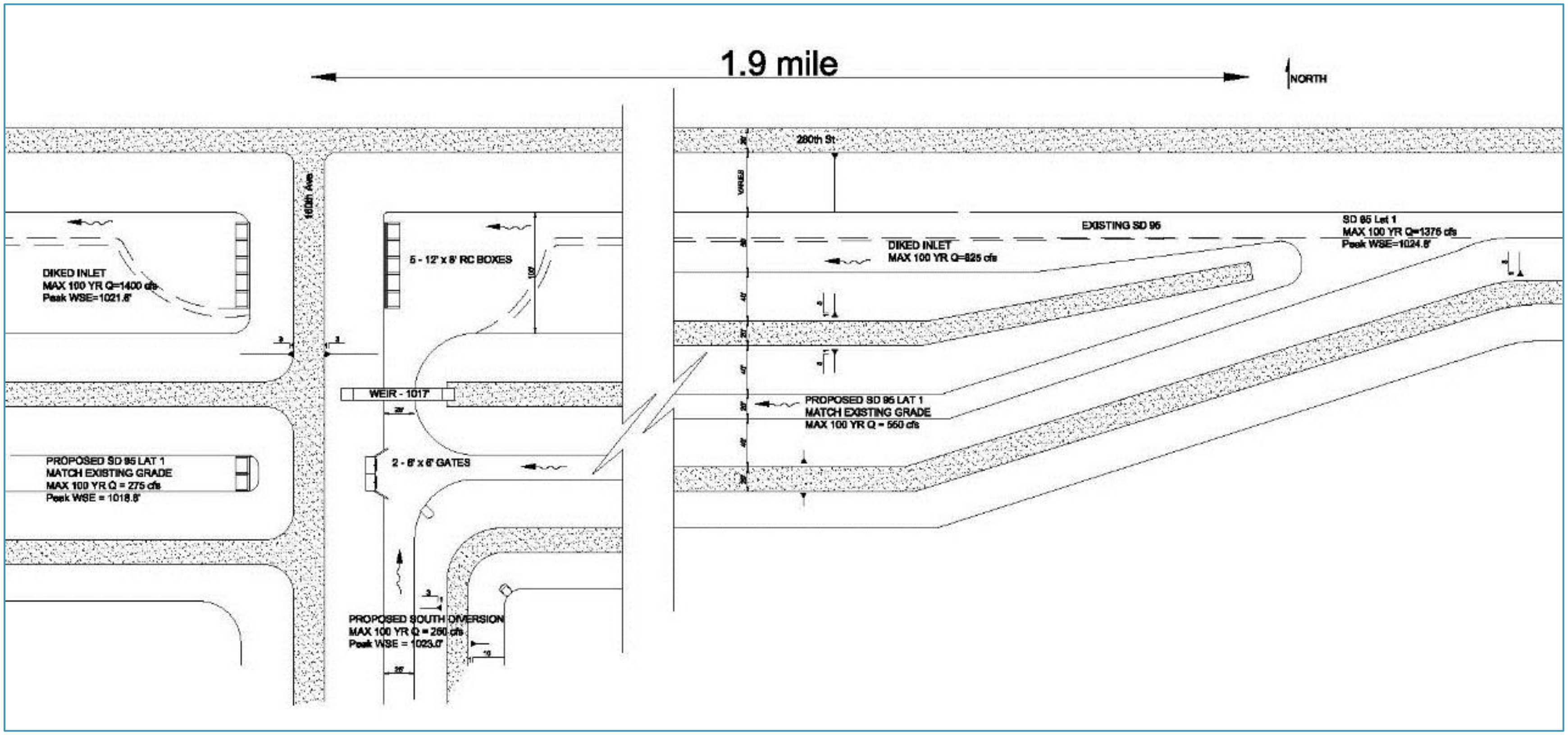


Figure 3-17. Open Inlet Option



The structures at the south end of the North Diversion (Table 3-6) will be as follows:

- Huseby Option – Gated box culverts (Figure 3-18)
- Mel Wang Option – Gated box culverts (Figure 3-19)

Table 3-6. North Diversion Structure Details

Feature	North Diversion - Mel Wang Option	North Diversion - Huseby Option
Top of Embankment [ft]	1022	1023
Outlet Invert [ft]	1014.0	1014.4
Outlet Size	(2) - 10' x 6' gated RC Boxes	(2) - 10' x 6' gated RC Boxes
Maximum Outflow [cfs]	500	500
Emergency Spillway Elevation [ft]	1019.0	1020.0

Both North Diversions will contain emergency spillways. When the North Diversion is operating, the water surface elevation must be less than 1019 in the Diked Inlet in order to prevent flow from leaving the system. During a 10-day 100-year event, the peak flows from the North Diversion arrive later than the peak flows in the SD 95 system. Through careful operation, the North Diversion can still convey the peak flows from SD 72 into the Diked Inlet.

Figure 3-18. North Diversion Structure – Huseby Option

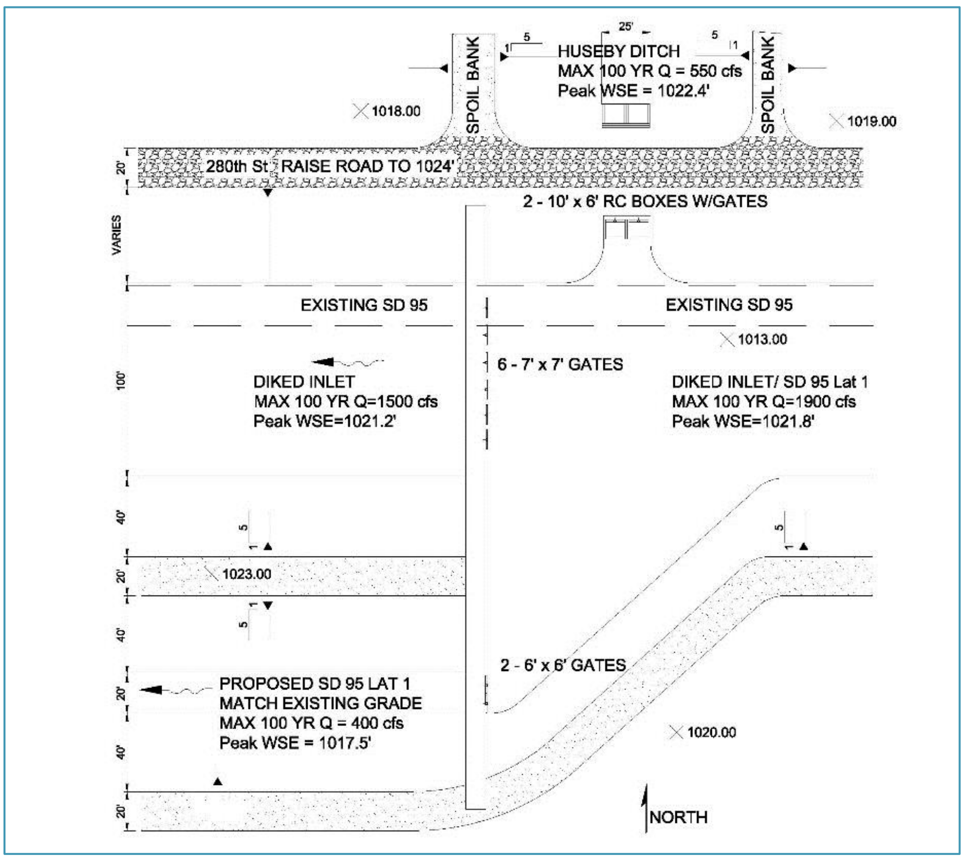
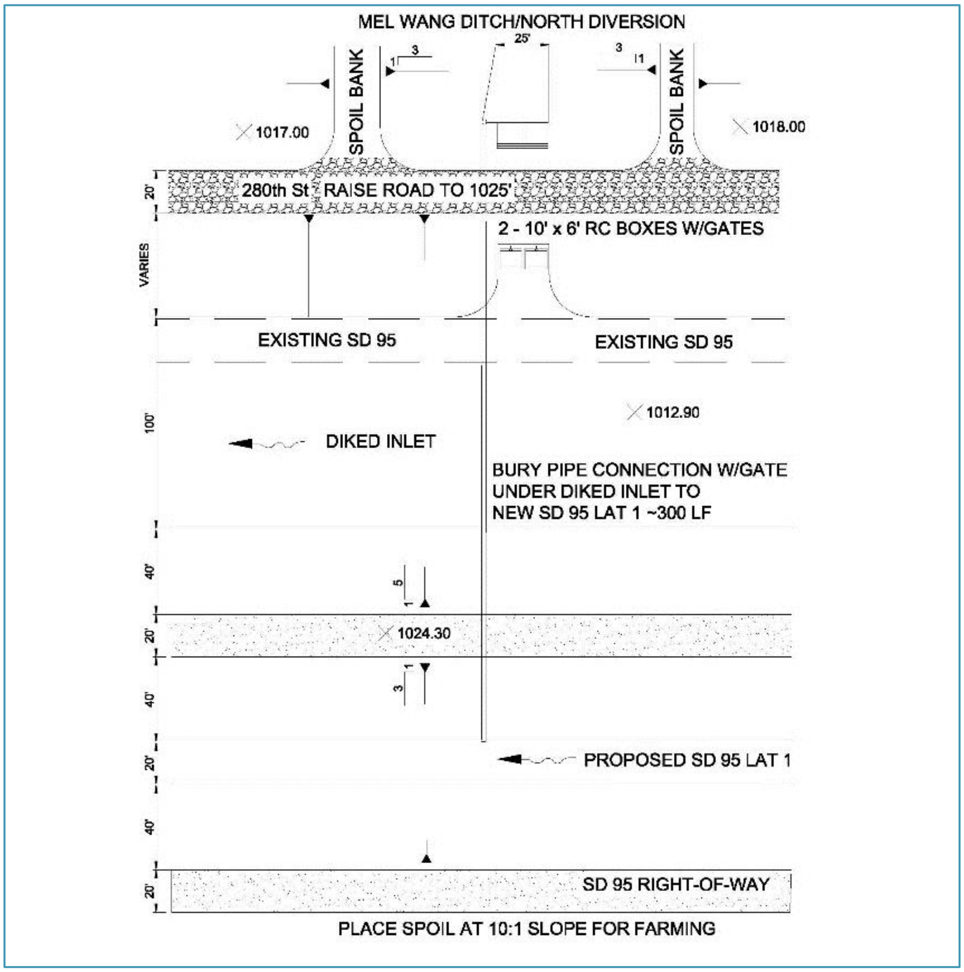


Figure 3-19. North Diversion Outlet Structure – Mel Wang Option



3.5.3 Diversion Structures

For the North Diversion, both the Huseby and Mel Wang options are proposed to have a weir at the inlet (north end) (Figure 3-20 and Figure 3-21). The weir will be set at an elevation of 1017 to automatically control the full impoundment pool and also accept inlet flows from SD 72. As shown in Figure 3-20, the 10-day 100-year Roseau River overflows will flow back to the east and over the inlet structure into the proposed North Diversion. Since the downstream channel of SD 72 is capable of conveying 10-year flows, this design is intended to operate at larger than 10-year events.

Figure 3-20. North Diversion Inlet Structure – Huseby Option

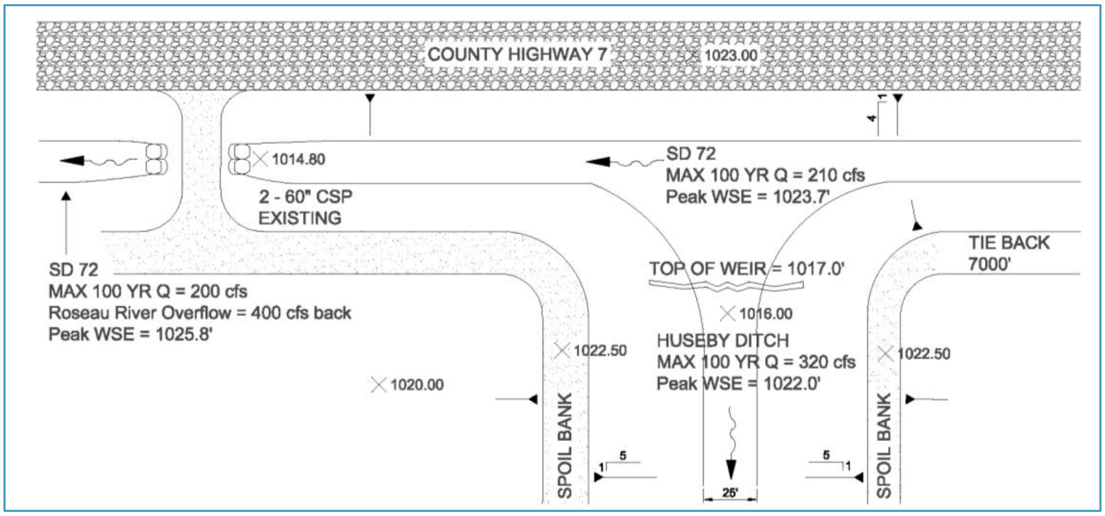
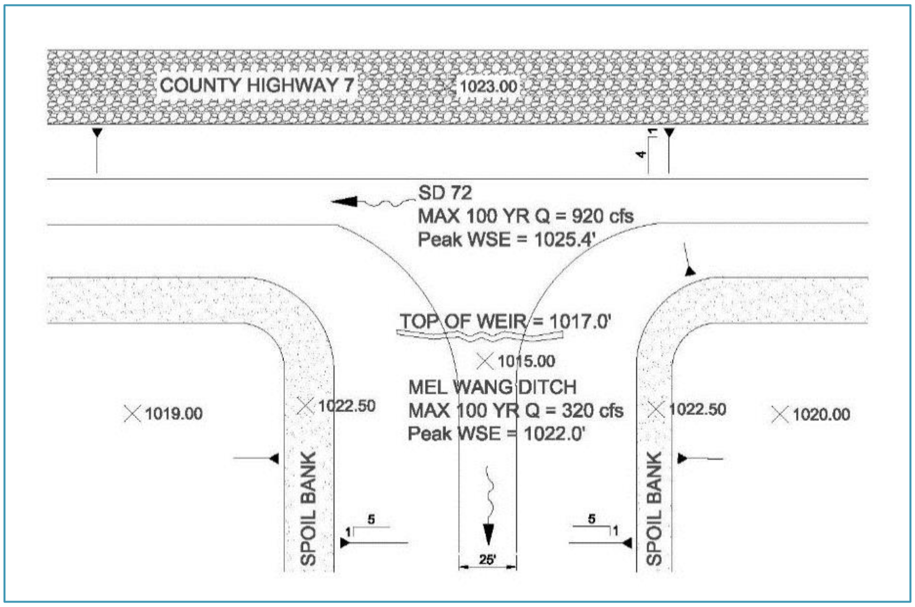


Figure 3-21. North Diversion Inlet Structure – Mel Wang Option

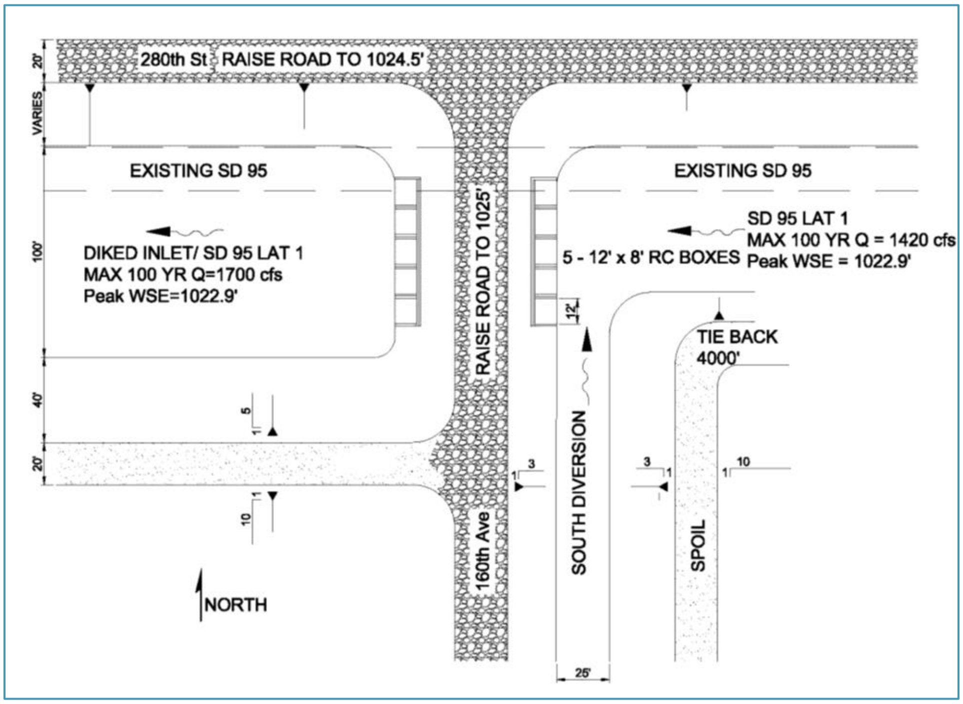


3.5.4 Crossings

The Diked Inlet may require three crossing structures:

- 120th Avenue (to maintain access across SD 95 Lat 1)
- 160th Ave (Figure 3-22)
- 170th Ave (required for Alternative 1-3 and 2-3)

Figure 3-22. Crossing at 160th Ave – Alternative 1-1 & 2-1



The South Diversion will require four crossings:

- Replacing the existing structures in both branches of SD 95 Lat 1 (located two and four miles south of the Diked Inlet) will be required. They will be replaced with four-foot circular, gated metal pipes. High flow will be diverted north through raised-invert box culverts. Low flow will continue west and bypass the project.
- At the 250th Street and 270th Street road crossings (located one and three miles south of the Diked Inlet) sets of box culverts will be required.

3.5.5 Miscellaneous Structures

The KCWRP #11 may include miscellaneous structures that are not explicitly described in this report. These include a gated outlet from the Diked Inlet into SD 95 Lat 1, side water inlet pipes, connection to the Section 27 impoundment alternative, interior impoundment cells, outlet culvert connection to SD 72 Lat 13, canal gates in SD 72 Lat 13, and downstream SD 50 crossing in Beaches Lake WMA. These structures may warrant consideration in future project design tasks, but for this report they were eliminated from detailed study. This is due to uncertainty about whether they are necessary, and in most cases will not be necessary depending on the alternatives carried forward.

3.6 Exterior Drainage

In all cases, the project will provide exterior drainage, which will be equal or greater than the existing drainage. When the project is operating (storing water), exterior ditches will convey flows that cannot enter the project. For example, during a 10-day 100-year event, the KCWRP #11 will allow some flows to bypass the project. These flows will be conveyed around the project in a controlled fashion to the outlet channels (SD 72, SD 50, and SD 95 Lat 1).

4 Project Alternatives and Design Criteria

This section describes the different alternatives selected for analysis along with the design criteria used to evaluate each alternative.

4.1 Alternatives Considered But Eliminated from Detailed Study

The project feature alternatives that have been eliminated from detailed study are listed below along with the reasoning.

Diked Inlet – Mike's Lake Option. Mike's Lake (also known as Hanks Lake) is designated as a DNR Public Water, therefore impacts must be avoided.

Diked Inlet – 270th St Option. This alternative is not recommended due to the existing drainage patterns that direct surface water north and west.

Diked Inlet – North Option. This alternative is not recommended as it would impact an unnamed DNR Public Water located to the north of the 280th Street.

Impoundment – Section 27. Adding Section 27 of Klondike Township to the impoundment was not considered because the cost to build a structure that crosses SD 95 Lat 1 to connect the main impoundment to Section 27 does not justify the 2,300 acre feet of storage gained.

South Diversion – West Option. This alignment of the South Diversion has been eliminated from detailed study due to the impacts to adjacent field entrances and driveways.

4.2 Project Alternatives and Right of Way

Table 4-1 lists the six alternatives considered. Table 4-2 provides a design summary of the six alternatives including elevation, drainage area, and storage information.

Figure 4-1 shows the proposed impoundment layouts with land ownership. Land ownership was considered in all of the alternatives and meetings have been held with landowners about the project concepts. Land use in the Project area is primarily agricultural or wetland. In addition to lands already acquired, TRWD will need to acquire additional right-of-way at locations shown in Figure 4-1. The cross-sectional Diked Inlet footprint (Figure 3-4) of approximately 340' will be necessary, as well as portions of the land on the east side of the North and South Diversions. The dimensions of the diversions are shown and explained in Section 3. A portion of Section 36 in Peatland Township will be needed to connect the Impoundment in Section 31 of June Berry Township with Section 1 of Klondike Township. Appendix E lists each 40-acre tract which a portion thereof may be needed to implement the recommended alternative and summarizes the total acreage for each alternative.

The Diked Inlet is essentially an extension of the retention area, and therefore requires control up to the full pool elevation. This report analyzes three different alternatives for the upstream control within the Diked Inlet:

- Gated Option – a set of sluice gates control inflows to the Diked Inlet and when closed, stores the water in the project
- Weir Option – a low weir allows automatic inflows to the Diked Inlet and storage up to the crest
- Open Inlet Option – Diked Inlet is extended upstream so that inflows and storage are maintained automatically

Table 4-1 also contains À la Carte Alternatives for the North and South Diversions. The North Diversion options would be constructed to divert water from SD 72 into the Diked Inlet. The South Diversion would divert water from Branches 3 and 4 of SD 95 Lat 1 into the Diked Inlet.

The landscape of the retention area is generally flat and natural ground elevation is approximately elevation 1012. Storing water at elevation 1017 in this area would equate to over 42,000 acre-feet of volume if using the "full" impoundment alternative. As shown in Figure 2-1 the drainage areas terminate 5 miles east of the impoundment area. This is where the existing ditches have inverts above an elevation of 1012, enabling the water to build hydraulic head and flow into the impoundment.

The following sections describe the six alternatives and include maps showing each alternative. For the purposes of this report, both North Diversions and the South Diversion – East Option were included in calculations and cost estimates.

Table 4-1. Project Alternatives

<table>
<tr><th>Alternative #</th><th>Diked Inlet</th><th>Impoundment</th><th colspan="3">Diversions</th></tr>
<tr><td>1-1</td><td>Gated Option</td><td rowspan="3">Full Impoundment Option</td><td rowspan="6">Á la Carte Alternatives</td><td rowspan="3">North Diversion</td><td>Huseby Option</td></tr>
<tr><td>1-2</td><td>Weir Option</td><td>Mel Wang Option</td></tr>
<tr><td>1-3</td><td>Open Inlet Option</td><td>None</td></tr>
<tr><td>2-1</td><td>Gated Option</td><td rowspan="3">Impoundment which avoids DNR-owned land in Section 11 (Mitigation Option)</td><td rowspan="3">South Diversion</td><td>East Option</td></tr>
<tr><td>2-2</td><td>Weir Option</td><td>West Option</td></tr>
<tr><td>2-3</td><td>Open Inlet Option</td><td>None</td></tr>
</table>

Table 4-2. Design Summary

Feature	Alternative					
	1-1	1-2	1-3	2-1	2-2	2-3
Top of Embankment	1,019.5 ft					
Emergency Spillway	1,017.0 ft					
Project Drainage Area	182.1 mi^2	180.9 mi^2	180.9 mi^2	180.6 mi^2	179.4 mi^2	179.4 mi^2
Gated Storage (in runoff)	39,716 acre-ft (4.09")	39,728 acre-ft (4.12")	39,811 acre-ft (4.13")	34,751 acre-ft (3.61")	34,784 acre-ft (3.64")	34,788 acre-ft (3.64”)
Ungated Storage (in runoff)	2,245 acre-ft (0.23")	2,248 acre-ft (0.23")	2,259 acre-ft (0.23")	1,982 acre-ft (0.21")	1,989 acre-ft (0.21")	1,992 acre-ft (0.21”)
Total Storage (in runoff)	41,961 acre-ft (4.32")	41,976 acre-ft (4.35")	42,070 acre-ft (4.36")	36,733 acre-ft (3.81")	36,772 acre-ft (3.84")	36,780 acre-ft (3.84”)

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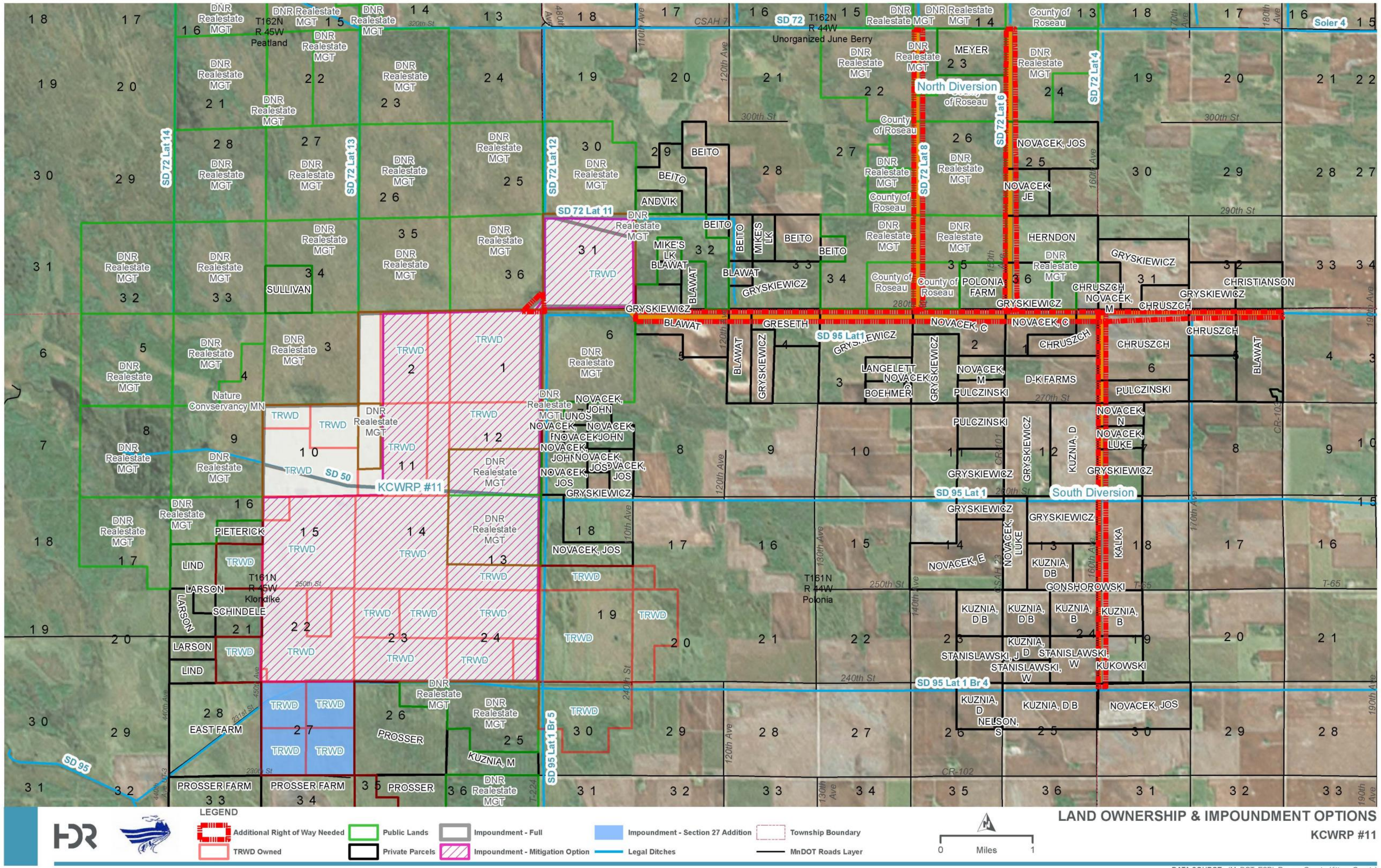
Figure 4-1. Land Ownership and Impoundment Alternatives



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4.2.1 Alternative 1-1

Figure 4-2 shows Alternative 1-1. Alternative 1-1, 1-2 and 1-3 all have the full impoundment alignment which includes the DNR-owned land in Section 11 of Klondike Township (Figure 4-1). Alternative 1-1 has a Diked Inlet which has gated control on the inlet end (east end) allowing full control over flows entering the project. This gated control is located 5 miles east of the Kittson-Roseau County line.

4.2.2 Alternative 1-2

Figure 4-3 shows Alternative 1-2. Alternative 1-2 differs from 1-1 in that the Diked Inlet is weir controlled at 6.5 miles east of the Kittson-Roseau County line. The new SD 95 Lat 1 will be gated at the 160th Ave crossing. Operation of these gates will start filling the project or allow low flows to bypass.

4.2.3 Alternative 1-3

Figure 4-4 shows Alternative 1-3. Alternative 1-3 differs from Alternative 1-1 in that the Diked Inlet is has an open inlet starting 8 miles east of the Kittson-Roseau County line. Section 3 of this report details the open inlet option for the Diked Inlet. This alternative requires the crossing at 160th Ave to be equipped with gates to the new SD 95 Lat 1 as well.

4.2.4 Alternative 2-1

Figure 4-5 shows Alternative 2-1. Alternatives 2-1, 2-2, and 2-3 have an alternative impoundment alignment which excludes the DNR-owned land in Section 11 of Klondike Township (Figure 4-1). Section 10 is also excluded from the impoundment area allowing it to be used for mitigation. Other than the impoundment alignment, Alternative 2-1 is the same as Alternative 1-1.

4.2.5 Alternative 2-2

Figure 4-6 shows Alternative 2-2. Alternative 2-2 differs from 2-1 in that the Diked Inlet is weir controlled at 6.5 miles east of the county line. A gated crossing for the new SD 95 at 160th Ave is required to complete this alternative.

4.2.6 Alternative 2-3

Figure 4-7 shows Alternative 2-3, which includes the Diked Inlet – Open option. The Diked Inlet is open on the upstream end at approximately 8 miles east of the county line. A new SD 95 Lat 1 will be needed to convey any bypass flows and local drainage that cannot be stored by the project.

Figure 4-2. Alternative 1-1 – Includes À la Carte Diversion Alternatives

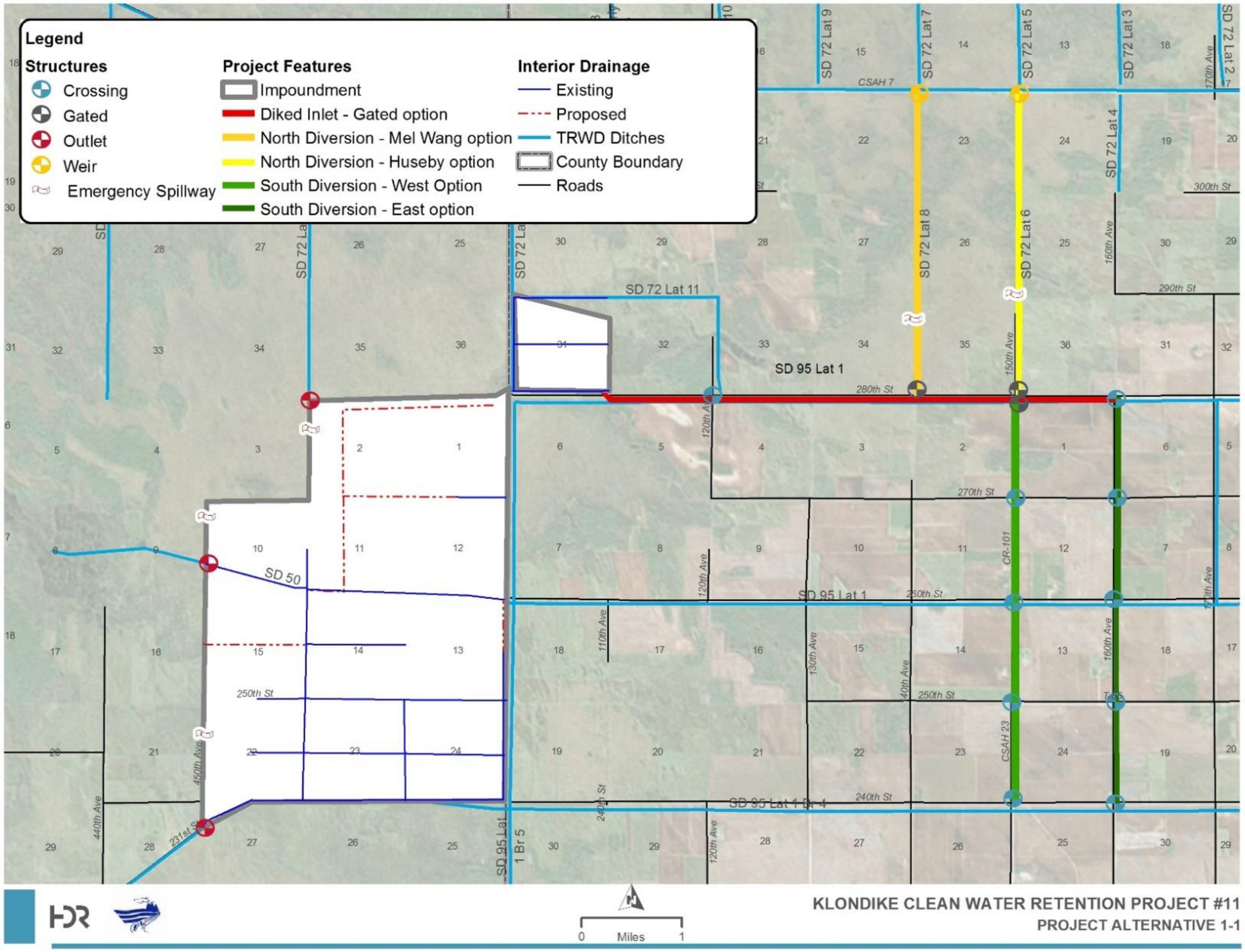


Figure 4-3. Alternative 1-2 – Includes À la Carte Diversion Alternatives

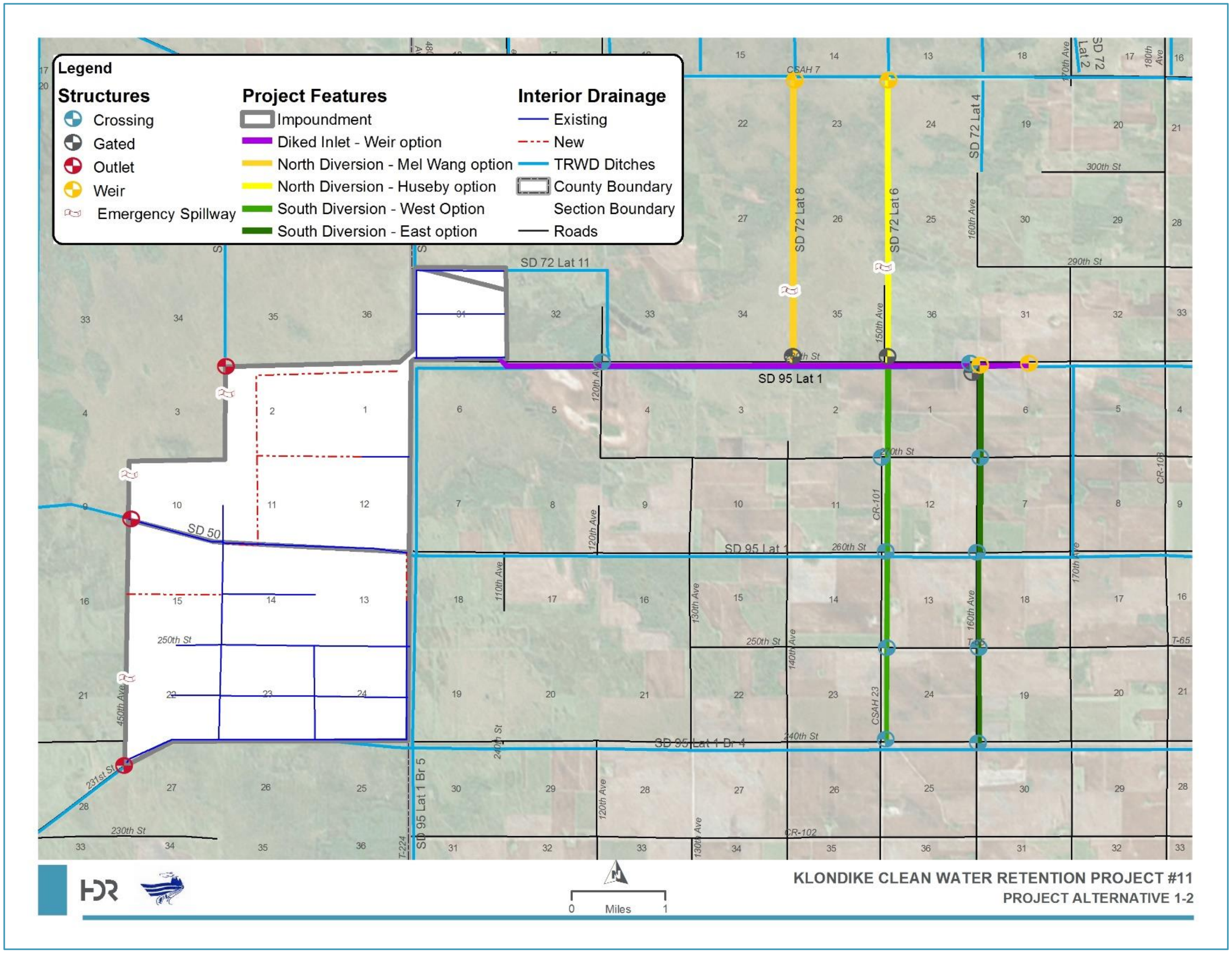


Figure 4-4. Alternative 1-3 – Includes À la Carte Diversion Alternatives

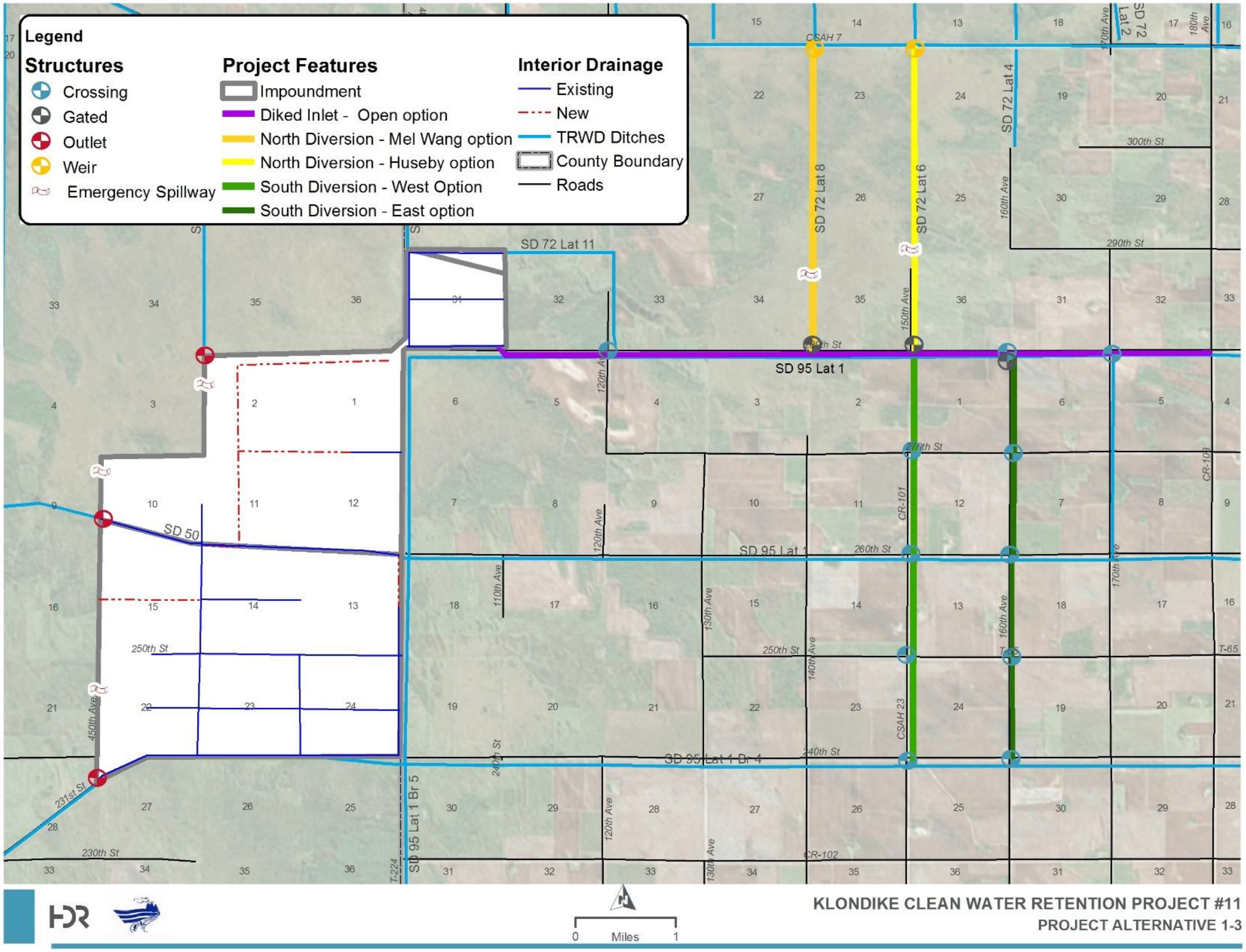


Figure 4-5. Alternative 2-1 – Includes À la Carte Diversion Alternatives

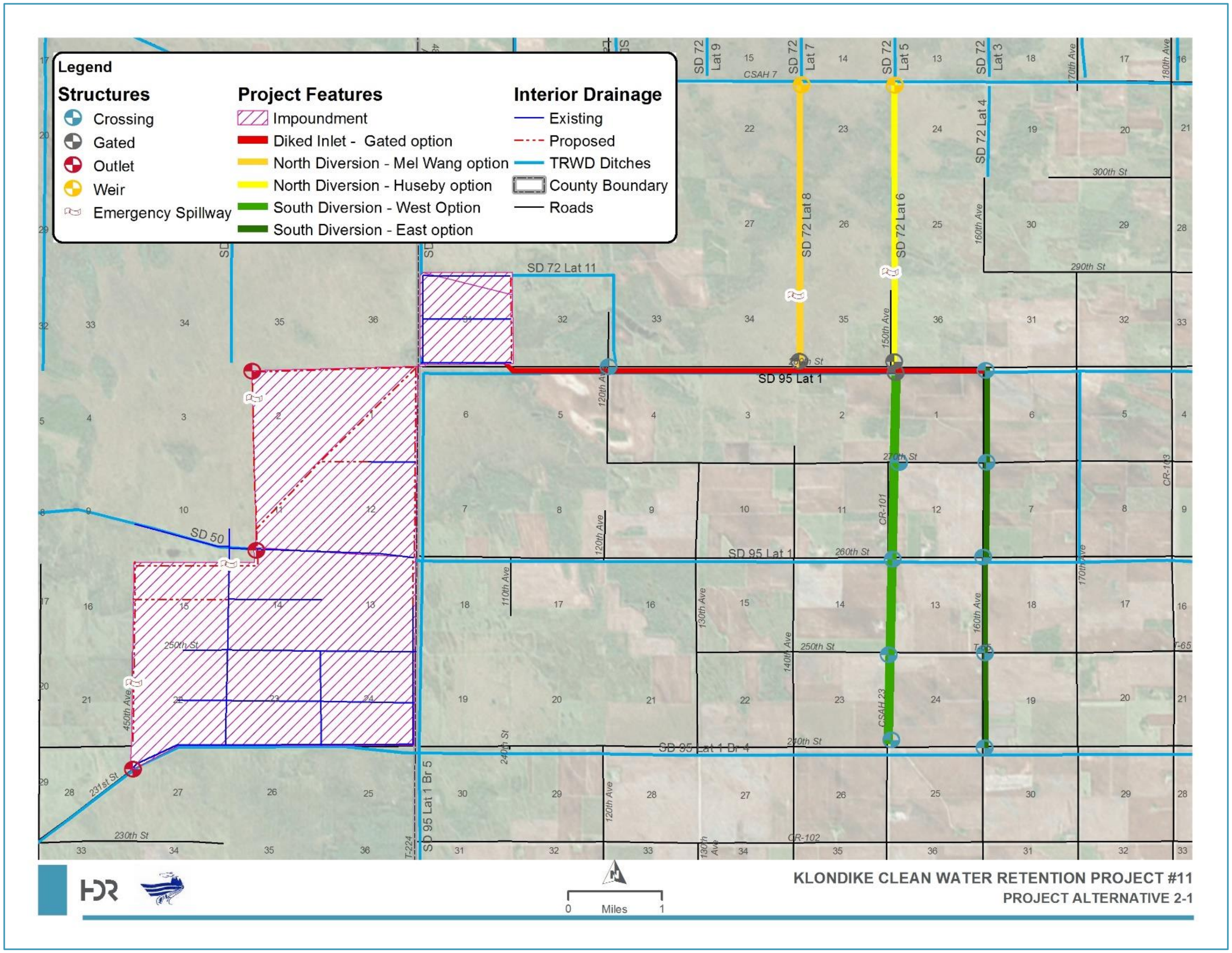


Figure 4-6. Alternative 2-2 – Includes À la Carte Diversion Alternatives

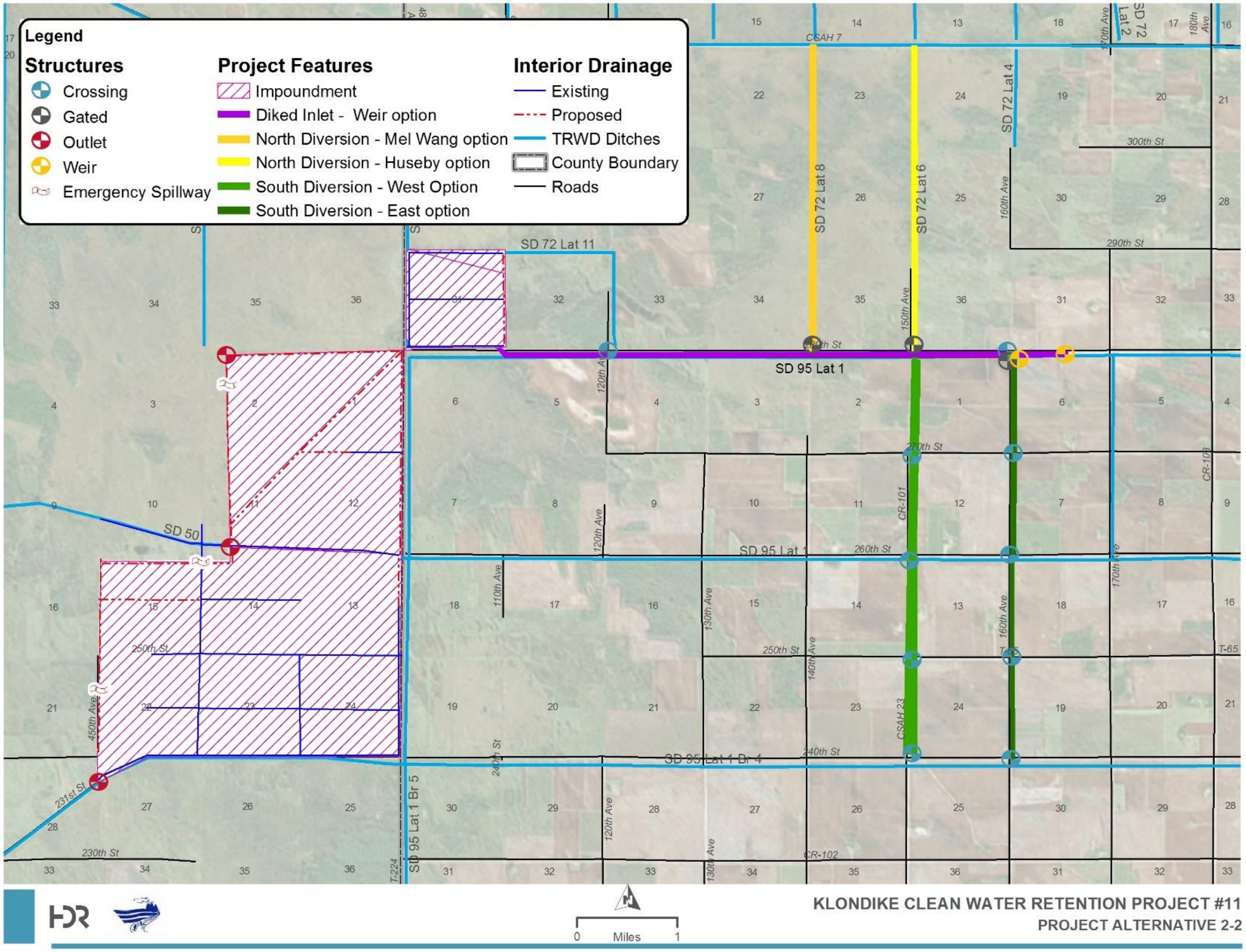
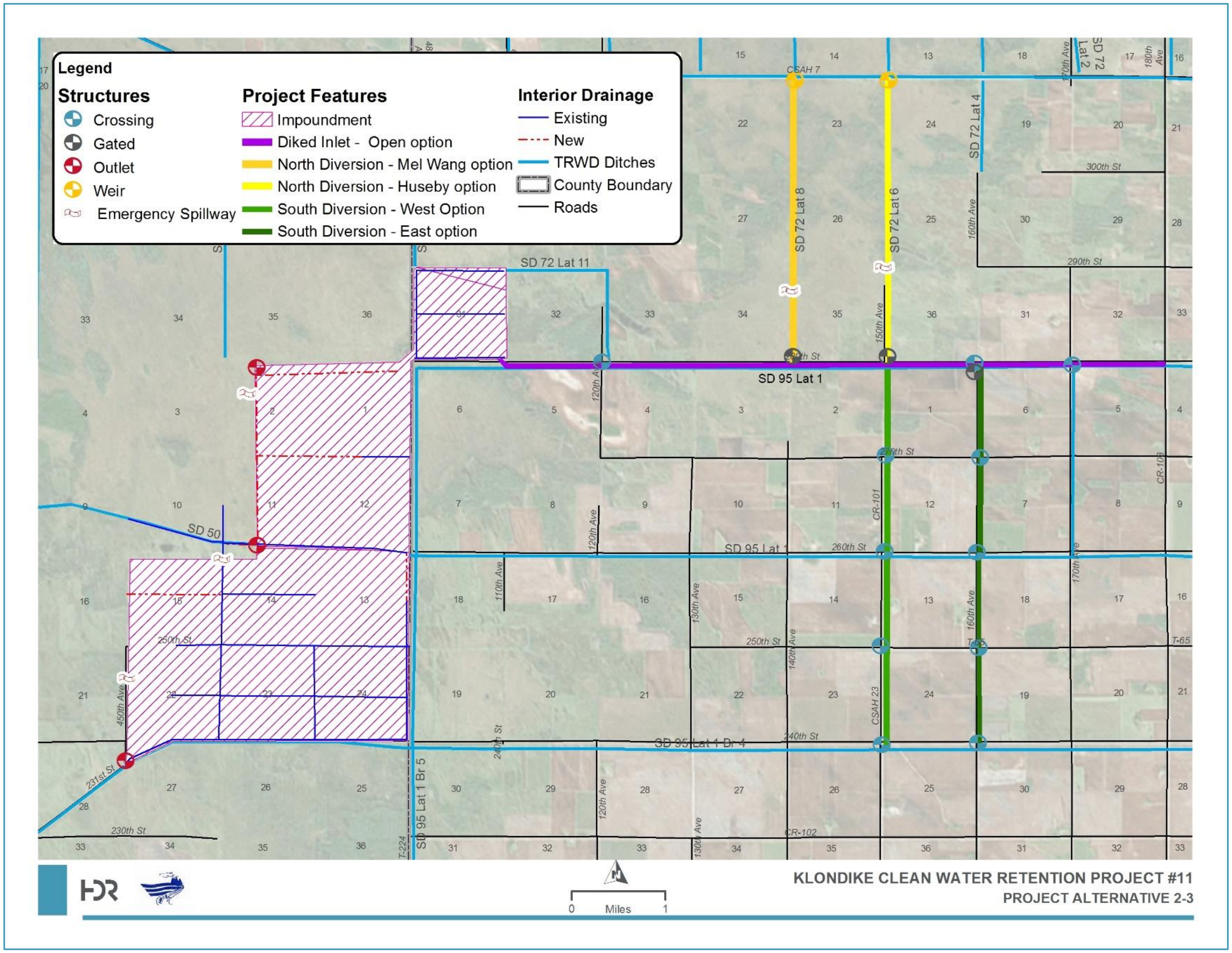


Figure 4-7. Alternative 2-3 – Includes À la Carte Diversion Alternatives



4.3 Design Criteria

This section describes the alternatives considered and design criteria used to evaluate each alternative. A description of the hydrologic model used to generate design hydrographs is also presented.

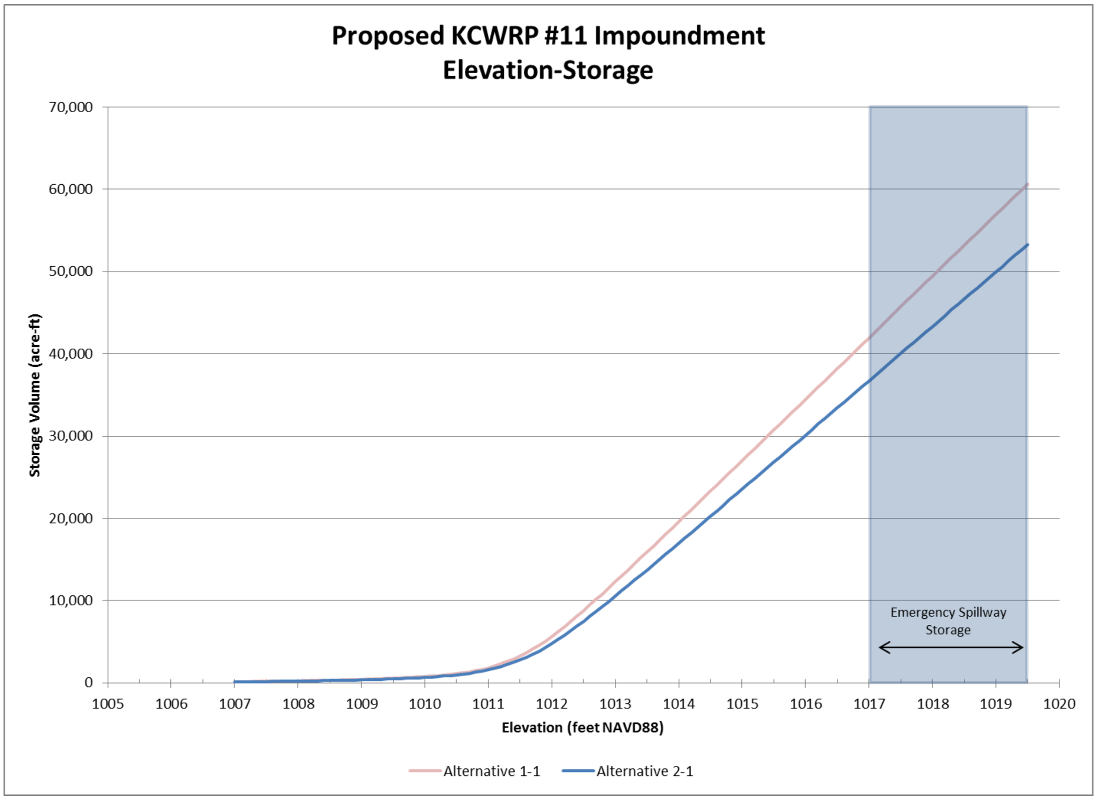
The design of the flood storage impoundment follows normal and customary engineering approaches applied in the State of Minnesota. These include use of reference documents from the State of Minnesota, Federal agencies, professional engineering judgment, and design methods used on similar projects in the greater Red River basin.

4.3.1 Maximum Water Surface Elevation

The 100-year 10-day duration and 24-hour Emergency Spillway Hydrograph (ESH) were used to size the primary outlet. The 24-hour Free Board Hydrograph (FBH) was used to size the emergency spillway, establish maximum pool elevations, and minimize the chance of embankment crest overtopping. The outlet capacity was designed to minimize damage on the downstream outlet channels. For these scenarios, the impoundment was set at the full pool elevation as required in TR60.

The design of the KCWRP #11 is predicated on the assumption that existing downstream ditch systems will convey the 2-year design flows within their banks without overflowing. During events less than a 2-year event, outflows from the impoundment will be limited to no more than the 2-year design flow of the ditch system. Figure 4-8 shows the elevation-storage curves for the two different impoundment alternatives.

Figure 4-8. Elevation-Storage Curves



4.3.2 Design Storm Data

Precipitation depths were based on information provided in the Precipitation Frequency for Midwestern states, USA – NOAA Atlas 14 Volume 8. The 10-year and 100-year rainfall events were revised slightly upwards from those contained in the above referenced documents based upon research conducted by Huff and Angel (Rainfall Frequency Atlas of the Midwest, Midwest Climate Center, 1992). Hydrologic design data is contained in Table 4-2.

The computed depths for the ESH and FBH were developed based on TR-60. Based on a low hazard dam with an upstream dam, the ESH value is computed as:

$$ESH = P_{100} + 0.12*(PMP – P_{100})$$

The FBH value is computed as:

$$FBH = P_{100} + 0.40*(PMP – P_{100})$$

Where:

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

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 NWS Technical Paper Number 40 and Hydrometeorological Report Number 51. Based on a drainage area of 191.5 mi^2, the 24-Hour PMP is 21.85 inches. Table 4-3 provides the design rainfall depths.

Table 4-3. Design Storm Rainfall Depths

Event	Precipitation Depth (inches)
10-year 24-hour	3.40
25-year 24-hour	4.26
100-year 10-Day	8.59
100-year 24-hour	5.80
PMP 24-hour	21.85
ESH 24-Hr	7.73
FBH 24-Hr	12.22

5 Hydrology

HDR completed a hydrologic analysis as part of the KCWRP #11 - Task Order #2. Complete results are in HDR's Hydraulic Modeling Technical Memorandum (HDR, 2015). The following section provides an overview of the analysis.

5.1 Design Rainfall Distribution

The modeling utilized the Soil Conservation Service (SCS) Type II rainfall distributions. The SCS Type II distribution is a synthetic storm hyetograph for use in the United States for storms of 24 hours in duration. This same distribution is also recommended in the NRCS TR-60 document for developing 10-day precipitation events for the design of small dams. HDR utilized this distribution for the 24-hour precipitation and 10-day rainfall events.

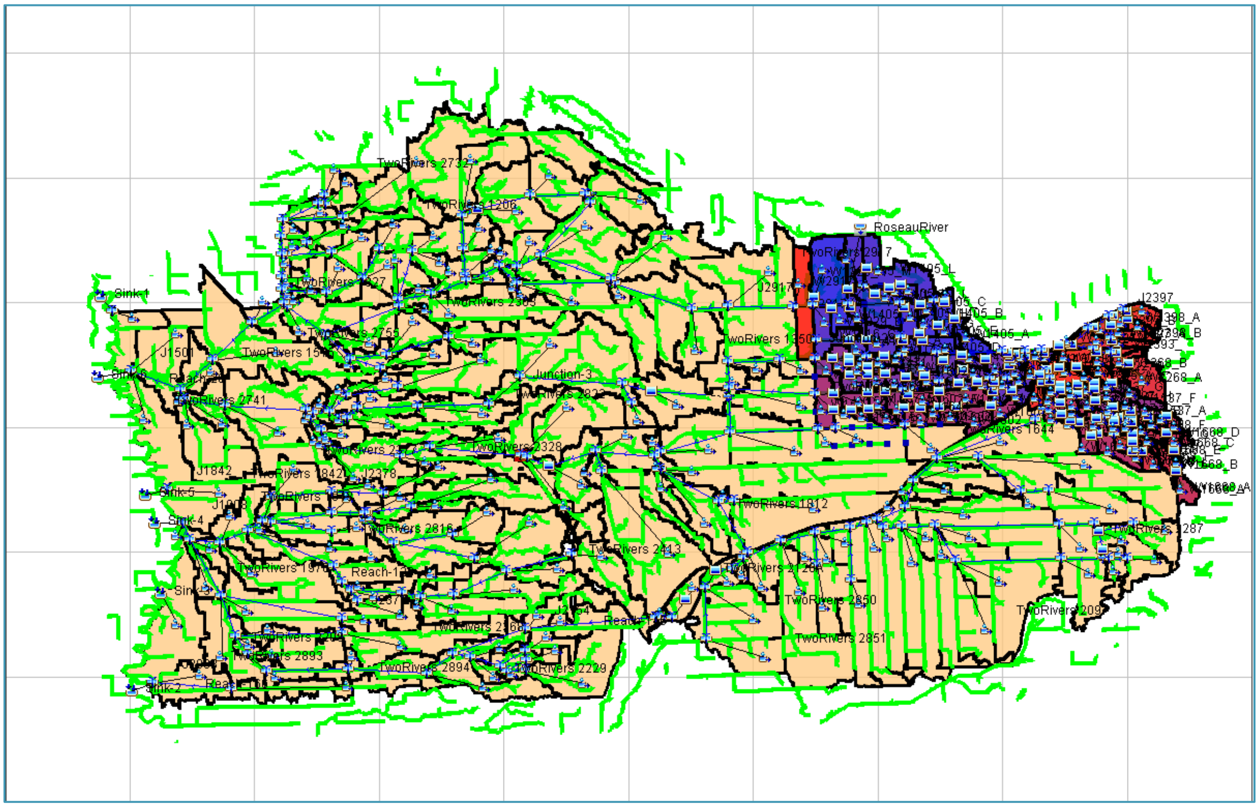
Type II rainfall distribution for 100-year 24-hour and 100-year 10-day (Type II 10-day distribution compares to mass curve C from Figure 21.1 in National Engineering Handbook 4, yielding a Q1-day/Q10-day ratio of 0.4) event was also modeled with curve numbers (CN) reduced according to the Minnesota Hydrology Guide. NRCS TR-60 provides a dimensionless duration curve for use with the ESH and FBH. All other storm events utilized the SCS Type II rainfall distribution.

Precipitation depths for the 100-year 10-day, 25-year 24-hour, and 10-year 24-hour events were based on information provided in the Precipitation Frequency Atlas for Midwestern states, USA - NOAA Atlas 14 Volume 8. Depths were assigned to each subbasin through a gridded design. The ten day precipitation model is a snowmelt precipitation grid taken from the Red River HMS, which was calibrated to the 1997 snowmelt event and has a median depth of 8.81 inches. The twenty-four hour events are modeled with the SCS Type II distribution of precipitation.

5.2 Rainfall-Runoff Model

HDR Engineering, Inc. developed a rainfall-runoff model of the Two Rivers watershed. Figure 5-1 displays the HEC-HMS schematic node locations for this project.

Figure 5-1. TRWD HMS Model Layout



5.3 Drainage Area

The Two Rivers HEC-HMS model contains 205 subbasins having an average size of 7.1 square miles. The USACE and HDR developed a watershed hydrologic model of the Two Rivers watershed as part of the Red River of the North Basin-Wide Modeling Approach, HEC-HMS Phase II Hydrologic Modeling (October 2012). A relationship of Roseau River overflow into the Two Rivers watershed was extracted from a HEC-1 model developed by JOR Engineering, Inc. Breakout flows begin when the Roseau River reaches 2,000 cfs and peaks at 2,133 cfs when the Roseau River reaches 6,310 cfs. The HEC-HMS model assumed the breakout flows enters the SD 72 system at Soler, which is two miles east of the North Diversion – Huseby Option; however, the overflows are known to enter SD 72 at a point downstream. Therefore, the model was updated and the location of Roseau River overflows were modeled to enter SD 72 in between laterals 6 and 8. Table 5-1 shows the drainage areas.

Table 5-1. Contributing drainage areas at project locations

Project Feature	Drainage Area ($miles^2$)
North Diversion – Mel Wang Option	55.1
North Diversion – Huseby Option	49.0
South Diversion – West Option	39.7
South Diversion – East Option	30.3
Diked Inlet – Gated Option	84.8
Diked Inlet – Weir Option/Open Inlet Option	83.6
Impoundment – Full Option	11.9
Impoundment – Mitigation Option	10.5
Maximum total	191.5
Minimum total	174.8

5.4 SCS Curve Numbers

The basin models use the SCS Curve Number as a loss method, the Clark Unit Hydrograph as a transform method, and a recession baseflow method. CN values were determined by hydrologic soil type (Soil Survey Geographic Database) and the landuse (NLCD 2001) data. SCS curve numbers ranged between 61 and 74, based on the soil types present and the farming practices currently being used within the drainage area. For the 24-hour event, sub-basins were assumed to be 0% impervious, while for the 10-day event, sub-basins were assumed 100% impervious. Curve numbers were not adjusted for the 10-day event, because the 100% impervious sub-basins assume that there is no infiltration into the soil, effectively negating the curve numbers.

5.5 Time of Concentration

The time of concentration (T_c) was developed using the Minnesota Department of Natural Resources travel time routine. This tool used the 2001 National Landcover Dataset (NLCD) landuse, slope, and stream network as inputs.

5.6 Hydrograph Shape

The hydrograph transformation uses the Clark synthetic unit hydrograph. Time of concentration (T_c) and the SCS storage coefficient (R) are used as inputs for this method.

5.7 Peak Flows and Runoff Volumes

Extracting the resulting hydrographs for each design event from the HMS model provided peak flows and volumes at each project feature. These hydrographs are used as model inputs for the hydraulic modeling in EPA SWMM and HEC-RAS. Table 5-2, Table 5-3, and Table 5-4 provide the peak flows and volumes generated for the project feature alternatives.

Table 5-2. 100-year 10-day Peak Inflows and Runoff Volumes

Project Feature (location)	Peak Inflow (cfs)	Total Volume (ac-ft)
North Diversion – Mel Wang Option	2,433	153,879
North Diversion – Huseby Option	607	13,492
Diked Inlet – Gated Option	1,494	26,719
Diked Inlet – Weir/Open inlet options	1,457	26,147
South Diversion – West Option (Branch 4)	524	5,166
South Diversion – East Option (Branch 4)	357	3,266
South Diversion – West Option (Branch 3)	489	6,226
South Diversion – East Option (Branch 3)	344	4,613

Table 5-3. 25-year 24-hour Peak Inflows and Runoff Volumes

Project Feature (location)	Peak Inflow (cfs)	Total Volume (ac-ft)
North Diversion – Mel Wang Option	340	7,787
North Diversion – Huseby Option	244	4,278
Diked Inlet – Gated Option	728	7,768
Diked Inlet – Weir/Open inlet Options	720	7,580
South Diversion – West Option (Branch 4)	286	1,518
South Diversion – East Option (Branch 4)	189	921
South Diversion – West Option (Branch 3)	134	1,796
South Diversion – East Option (Branch 3)	96	1,293

Table 5-4. 10-year 24-hour Peak Inflows and Runoff Volumes

Project Feature (location)	Peak Inflow (cfs)	Total Volume (ac-ft)
North Diversion – Mel Wang Option	239	3,464
North Diversion – Huseby Option	170	2,943
Diked Inlet – Gated Option	505	5,080
Diked Inlet – Weir/Open inlet options	499	4,955
South Diversion – West Option (Branch 4)	194	1,022
South Diversion – East Option (Branch 4)	131	632
South Diversion – West Option (Branch 3)	91	1,112
South Diversion – East Option (Branch 3)	47	784

6 Hydraulics

As a part of KCWRP #11 – Task Order #2 HDR developed hydraulic models to simulate project performance and further develop the project concept. This preliminary design started by creating a model that would fully convey the 100-year, 10-day runoff event from each diversion and inlet drainage area. The results can be seen in Figure 6-1. Note that the impoundment fills to elevation 1017 on day 14, however, there is excess flow diverted into the reservoir and over the three spillways. That is, all flows after day 14 are exceeding the capacity of the reservoir. The next step was to create a design which would use the reservoir capacity in a more efficient manner. Modifying the channel dimensions and structure sizes, another model was created to allow flows to bypass the impoundment. These results are shown in Figure 6-2, showing that the impoundment would fill to elevation 1017 with minimal use of the North Diversion (blue inflows).

This preliminary modeling concluded that the KCWRP #11 would be able to reduce peak flows and volumes in all three branches of Two Rivers, primarily on SD 95 Lat 1, which flows into the South Branch of Two Rivers. Another scenario was completed in which a 10-year, 10-day runoff event in the Two Rivers watershed coincided with a 100-year, 10-day runoff event in the Roseau River watershed. These results are shown in Figure 6-3 below. The impoundment was only filled to elevation 1014, bypassing a great amount of floodwater on SD 72. The option to be able to use the KCWRP #11 as storage for this Roseau River overflow was deemed necessary.

Figure 6-1. Maximum diversion results for 100-year, 10-day spring runoff event

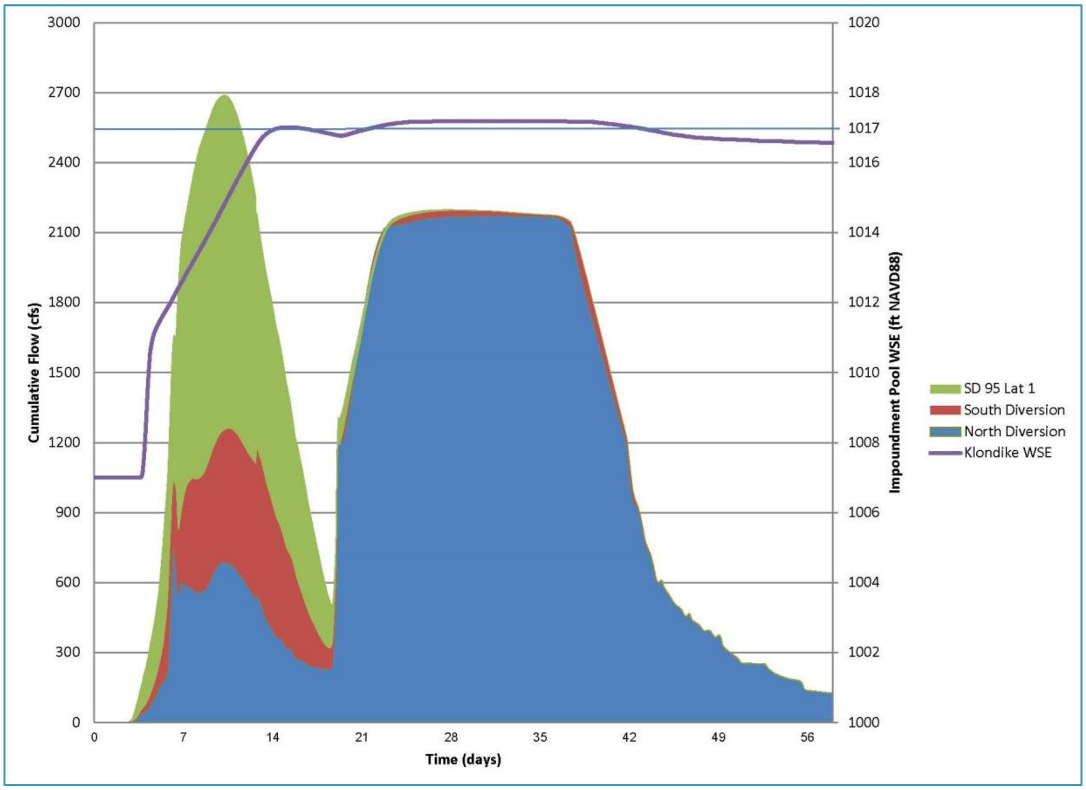


Figure 6-2. Modified diversion results for 100-year, 10-day spring runoff

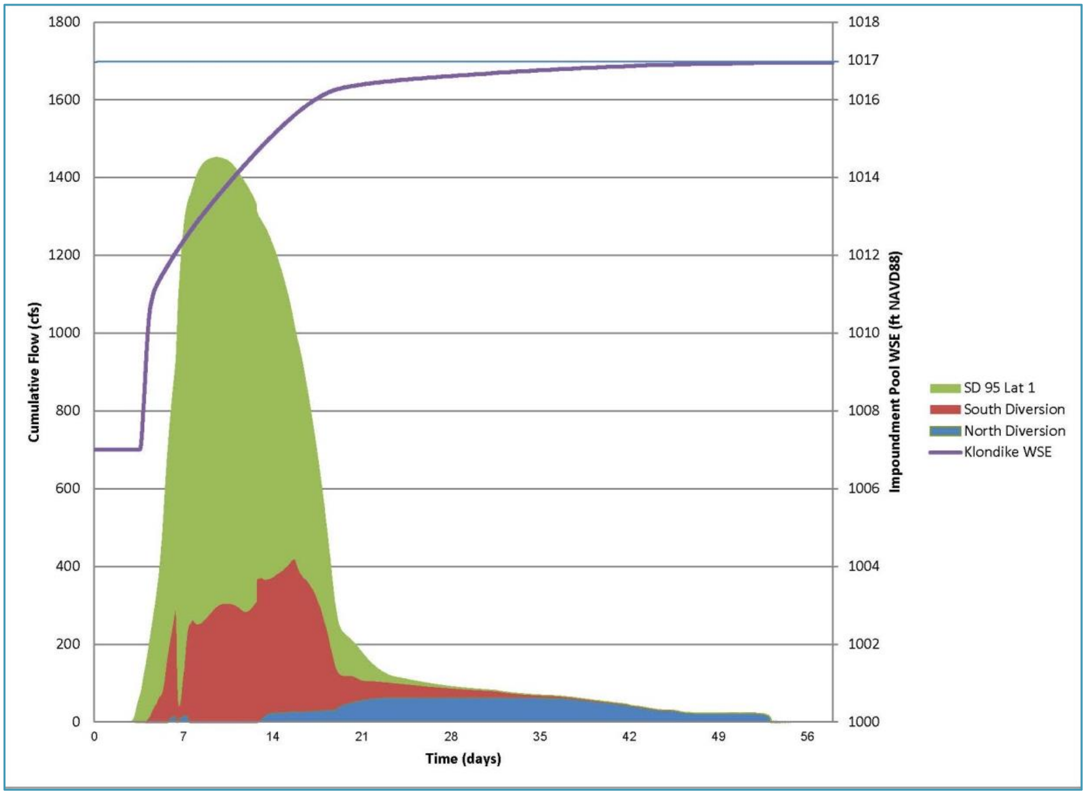
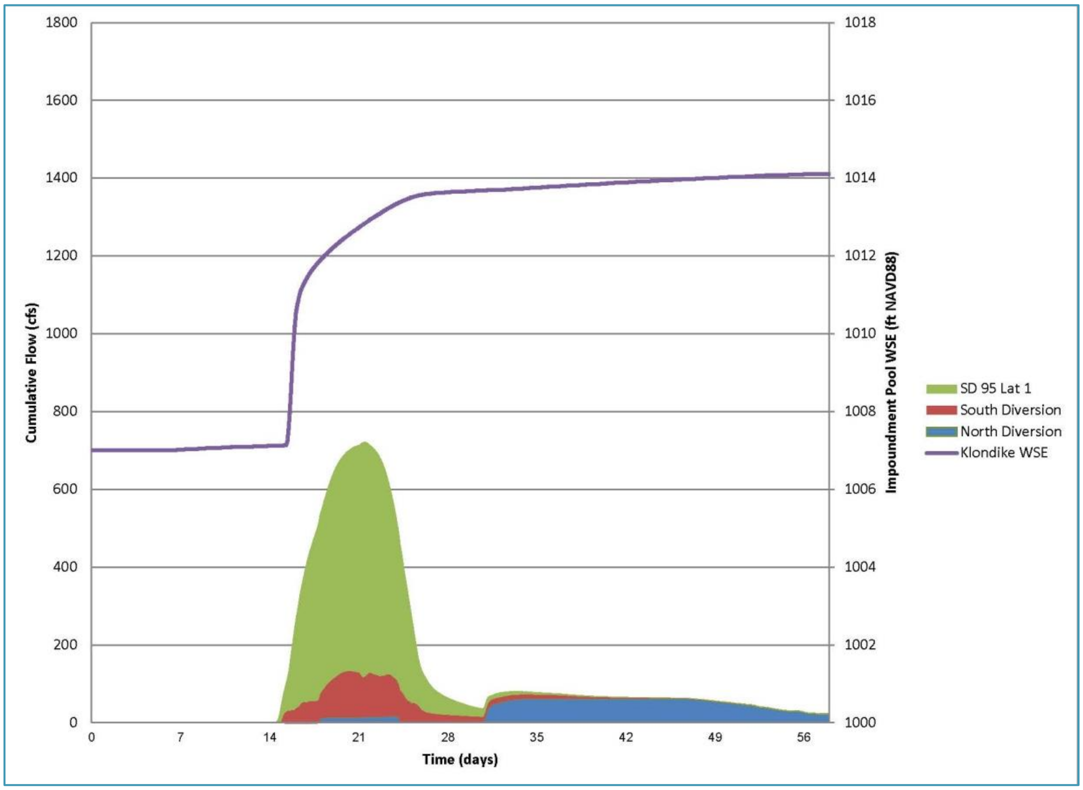


Figure 6-3. Modified diversion results for mixed event



For the development of this Engineer's Report, HDR incorporated detailed survey results which were collected during Task Order #2 allowing for a 2D model to be developed in the newly released HEC-RAS 5.0. Using a combination of AutoCAD Civil 3D and ArcGIS, separate digital elevation models for each alternative were created and input into the 2D Model. Figure 6-4 through Figure 6-9 show pre- and post-project inundation maps of the area for different events. The proposed results shown are for Alternative 1-1.

Figure 6-4. HEC-RAS 2D Inundation for 10-year Event Existing Conditions

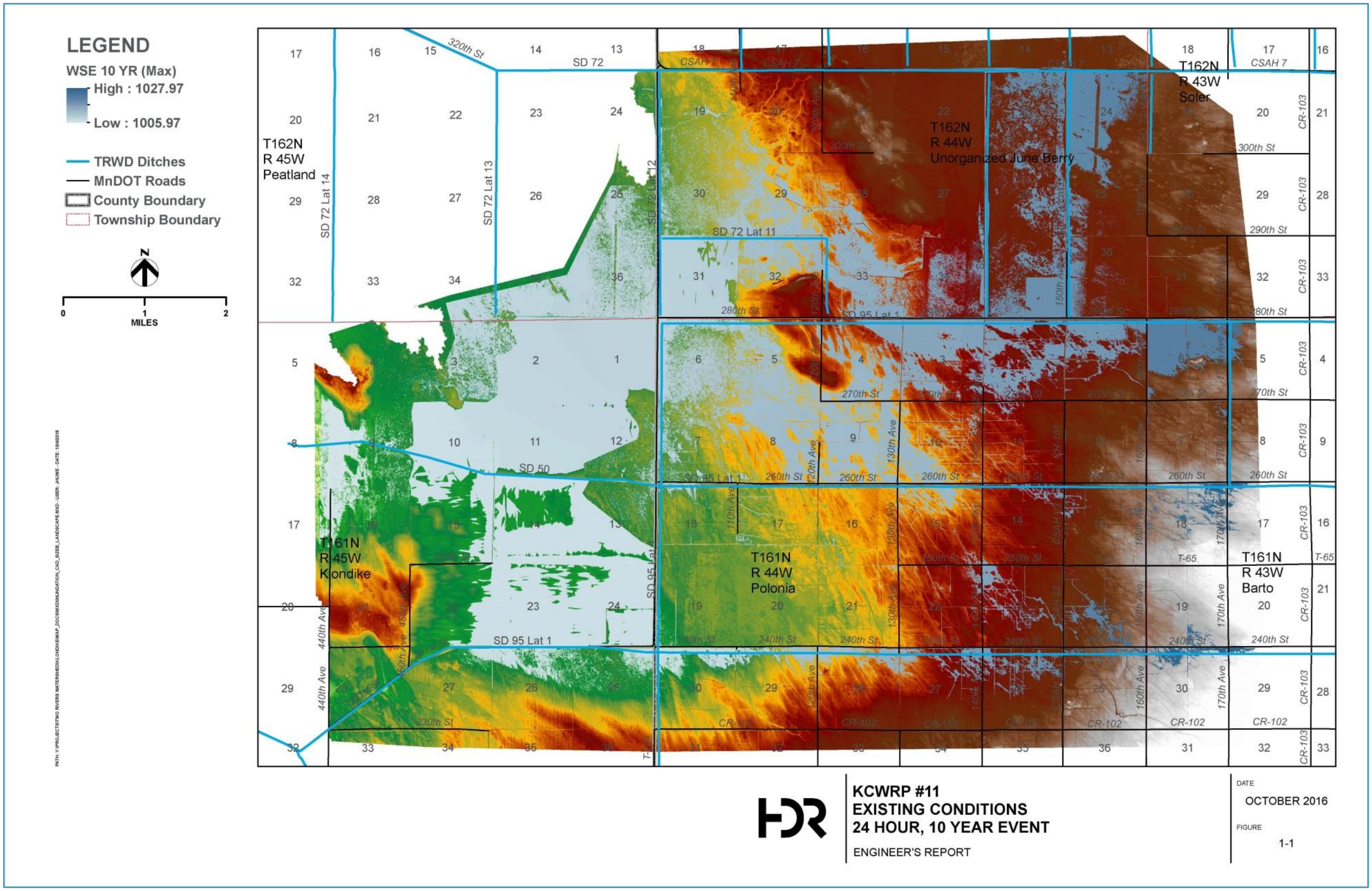


Figure 6-5. HEC-RAS 2D Inundation for 10-year Proposed Conditions

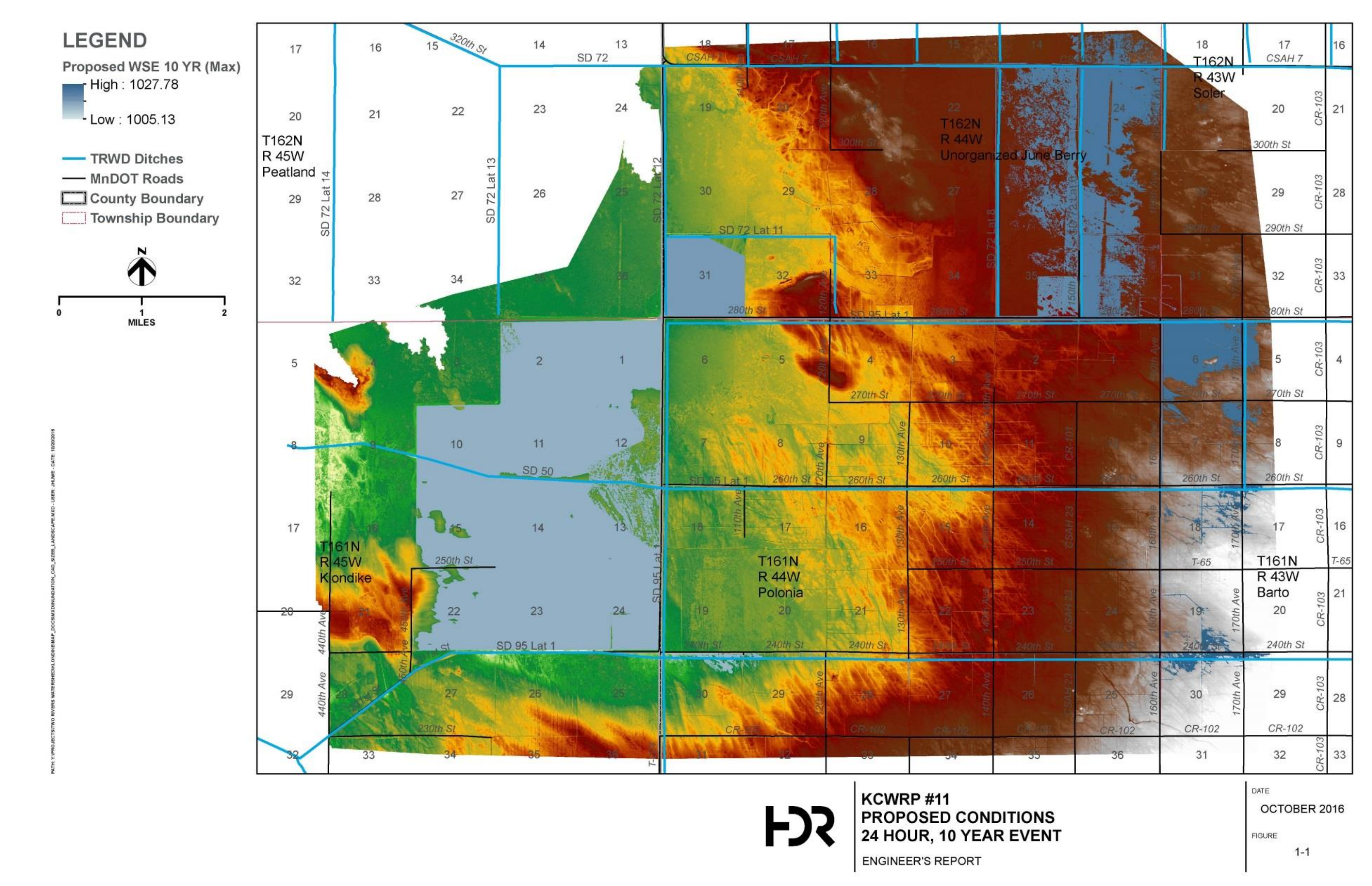


Figure 6-6. HEC-RAS 2D Inundation for 25-year Event Existing Conditions

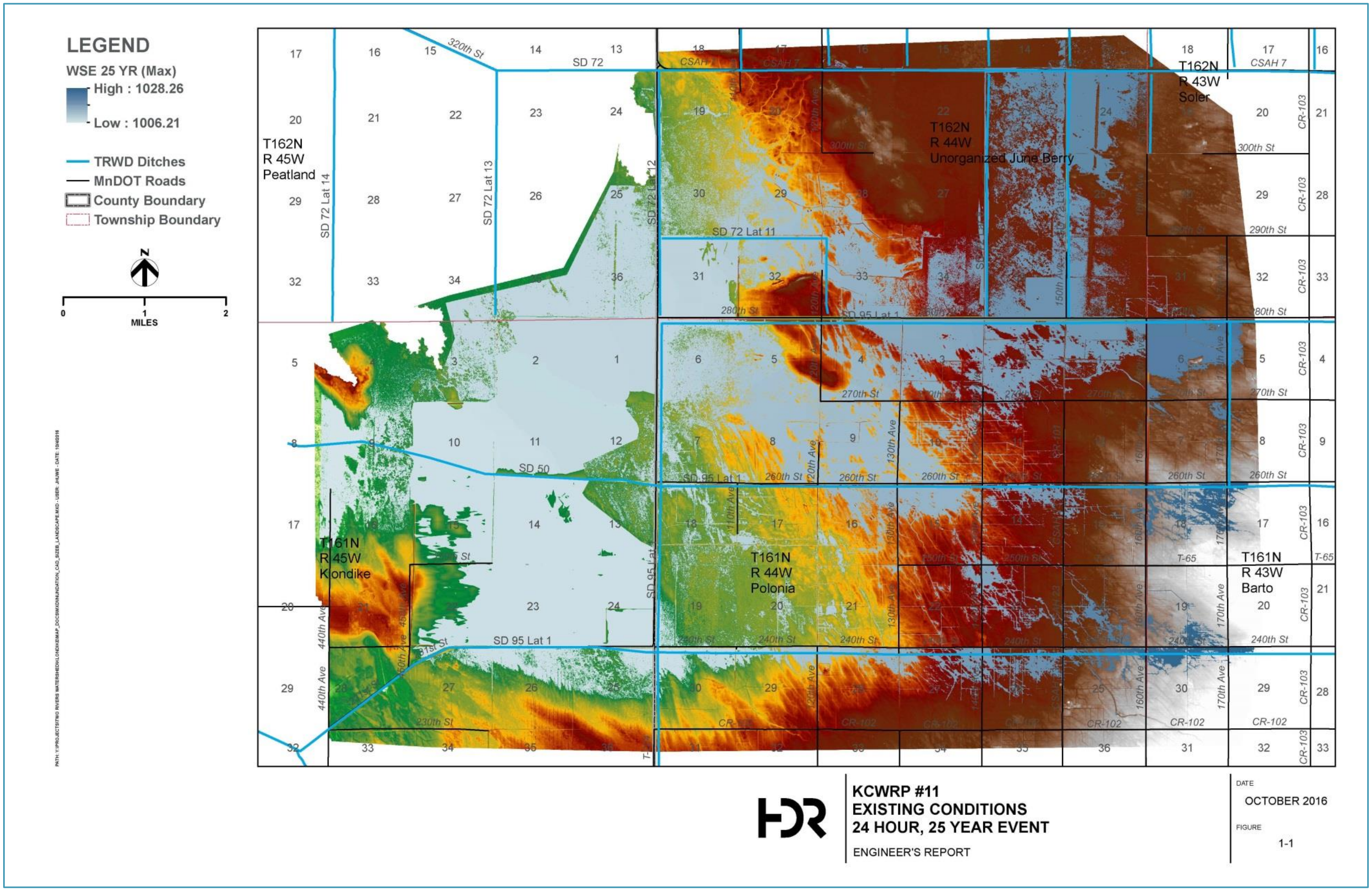


Figure 6-7. HEC-RAS 2D Inundation for 25-year Proposed Conditions

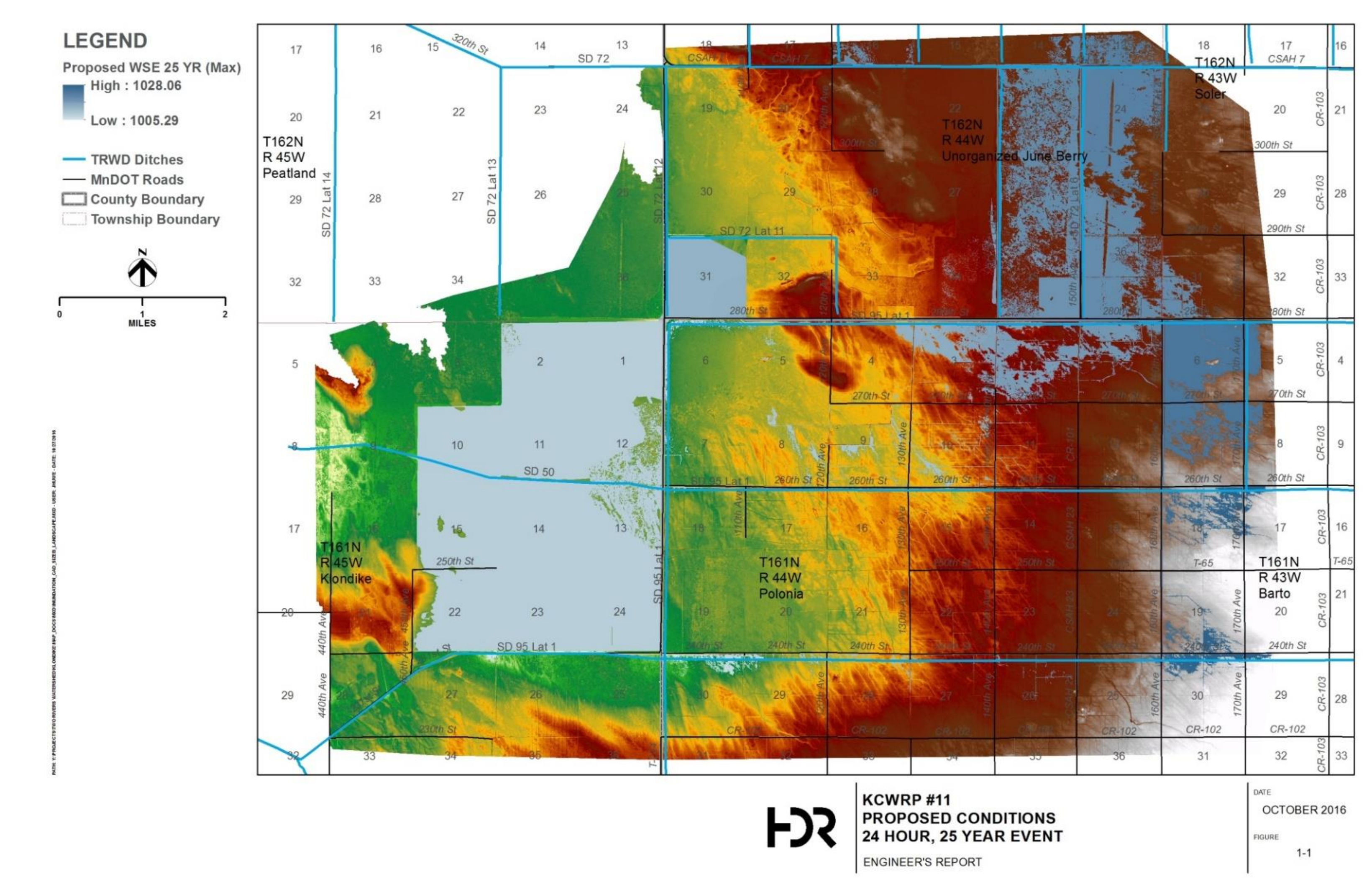


Figure 6-8. HEC-RAS 2D 10 Day 100 Year Event Existing Inundation

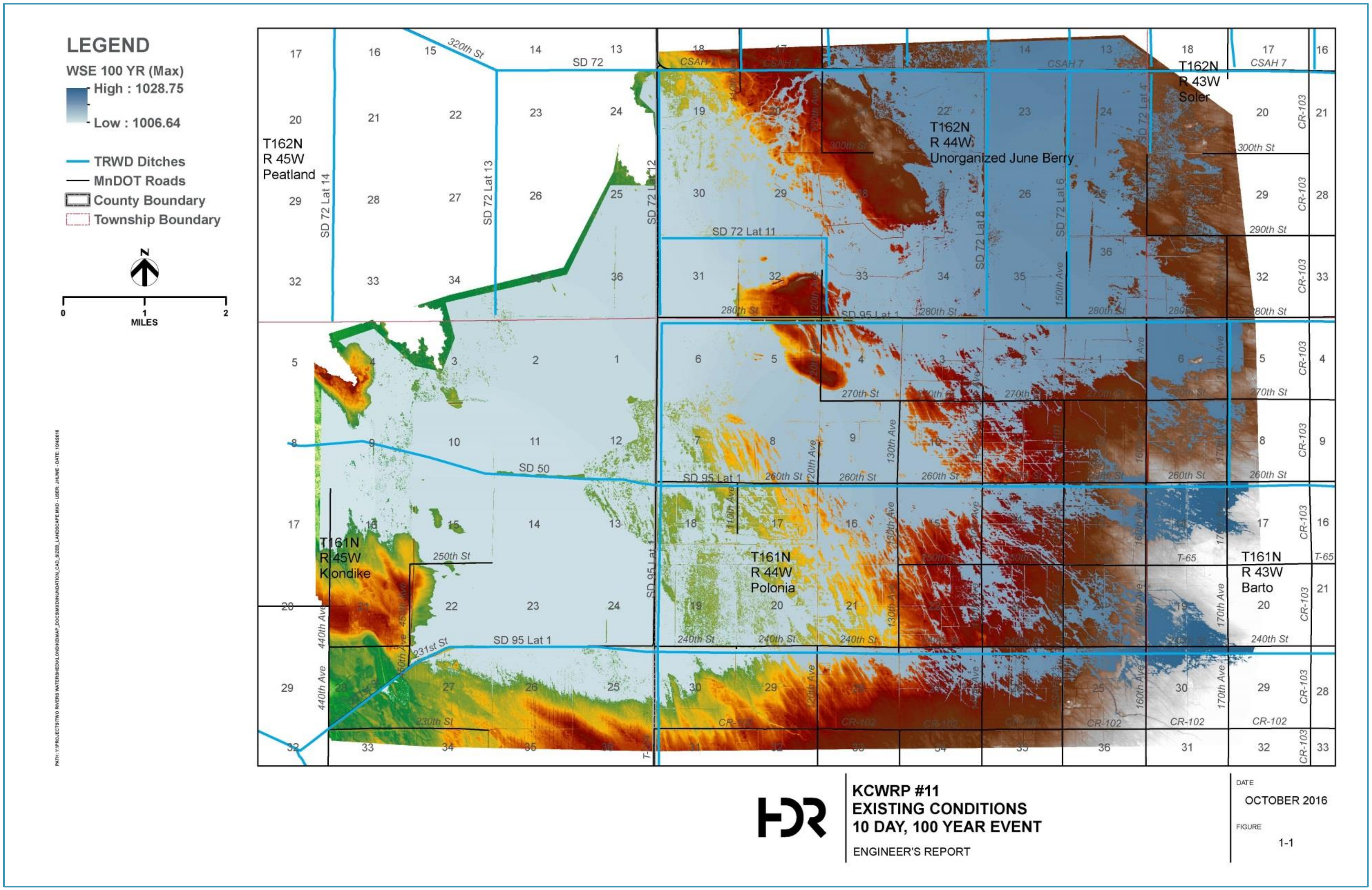
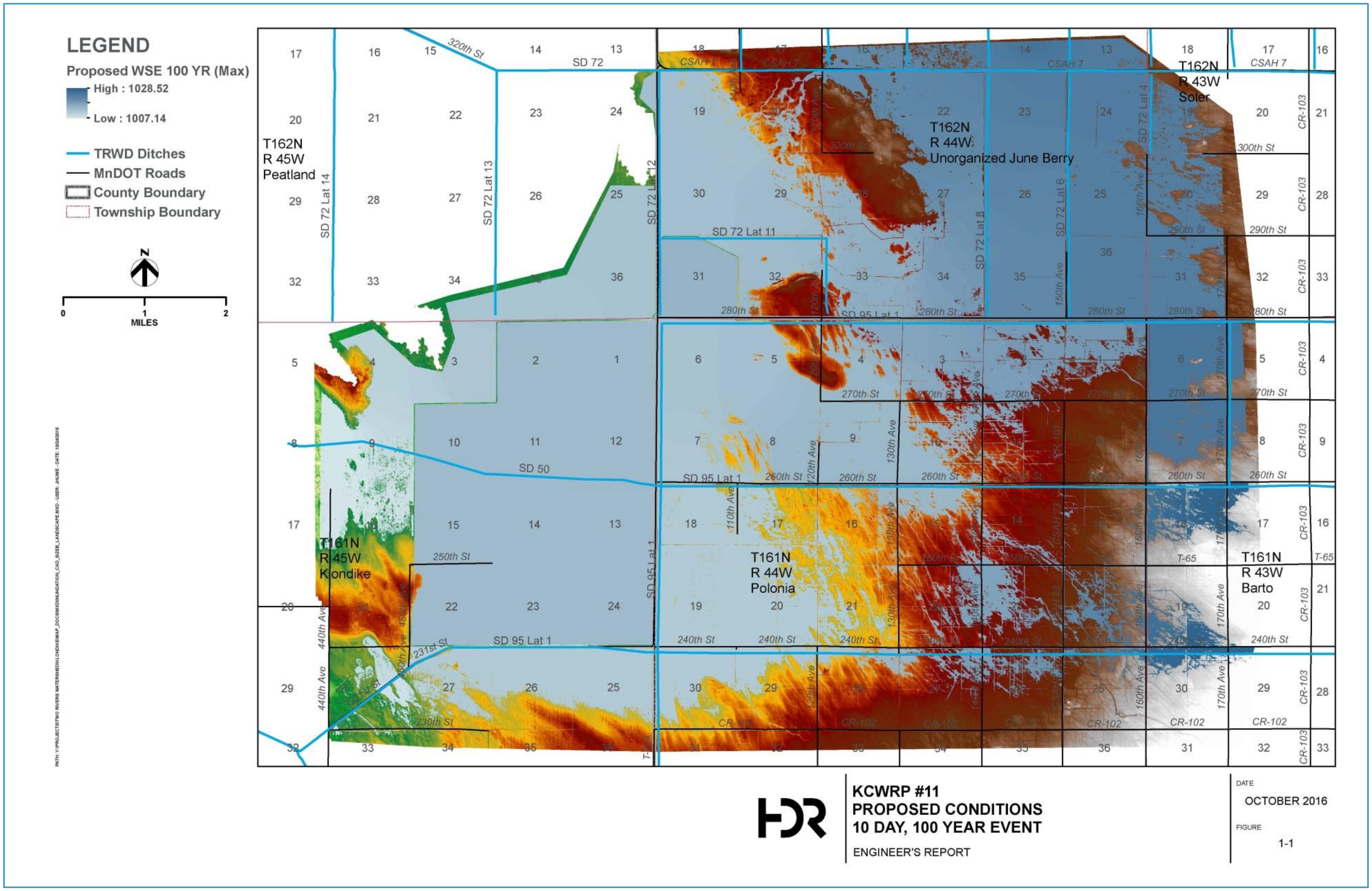


Figure 6-9. HEC-RAS 2D 10 Day 100 Year Event Proposed Inundation



6.1 Structure Sizing

Table 6-1 shows the sizing, elevations, and lengths of the various structures.

Table 6-1. Summary of Outlet Structures

Feature	SW Outlet	W Outlet	NW Outlet
Top of Embankment [ft]	1019.5	1019.5	1019.5
Primary Outlet Invert [ft]	1006.0	1008.0	1008.2
Primary Outlet Culvert Size [W'xH']	Two (2) - 8' x 8'	Two (2) - 5' x 5'	Two (2) - 6' x 8'
Primary Outlet Gate Size [W'xH']	Two (2) - 6' x 6'	One (1) - 5' x 5'	Two (2) - 5' x 5'
Maximum Outflow [cfs]	700	250	450
Secondary Outlet Maximum Weir Crest Elevation [ft]	1016.7	1016.8	1016.8
Secondary Outlet Minimum Weir Length [ft]	60	40	60
Emergency Spillway Elevation [ft]	1017.0	1017.0	1017.0
Emergency Spillway Width [ft]	250	250	250

6.2 Principal Outlet (Gated)

The minimum gate size was determined by attempting to dewater the impoundment from its peak storage within 10 days as specified in TR-60, while maintaining less than full capacity flow in the downstream outlets. A gate discharge coefficient of 0.65 was used and a roughness coefficient of 0.013 was used for the conduit. A weir coefficient of 2.75 was used for the drop inlets. A low hazard dam classification was used in developing the Emergency Spillway and Freeboard Hydrographs. Normal operations of the KCWRP #11 will completely drawdown the impoundment between events.

An EPA SWMM model was run without any dewatering. The impoundment fills to elevation 1017.0 at day 25. The model was modified to contain 3 primary gated outlets with secondary drop inlet weirs. This model was run iteratively to find the max crest elevation as well as the minimum gate sizes to substantially dewater the impoundment. Results are shown in Table 6-1 and Figure 6-10. Substantial dewatering of this large impoundment within 10 days was found to be infeasible considering outlet channel capacities. It was found to take approximately 18 days to dewater the impoundment to 15% of the peak volume.

6.3 Secondary Outlet (Drop Inlet)

An EPA SWMM model was run with the outlet gates closed and all inlet gates open to determine the secondary outlet (drop inlet) sizing required to ensure the emergency spillway will not fail. The starting WSE was set to the lowest drop inlet crest elevation (1016.7’). Results are shown in Table 6-1 and Figure 6-11.

Figure 6-10. Primary Outlet – Dewatering Results

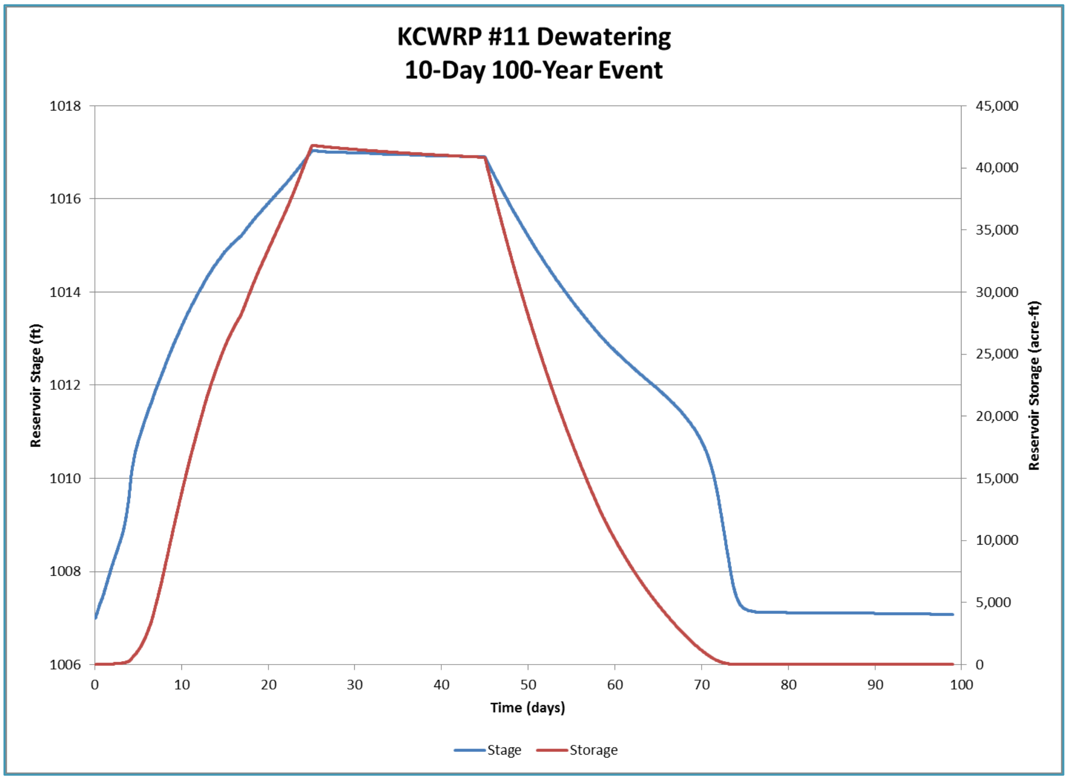
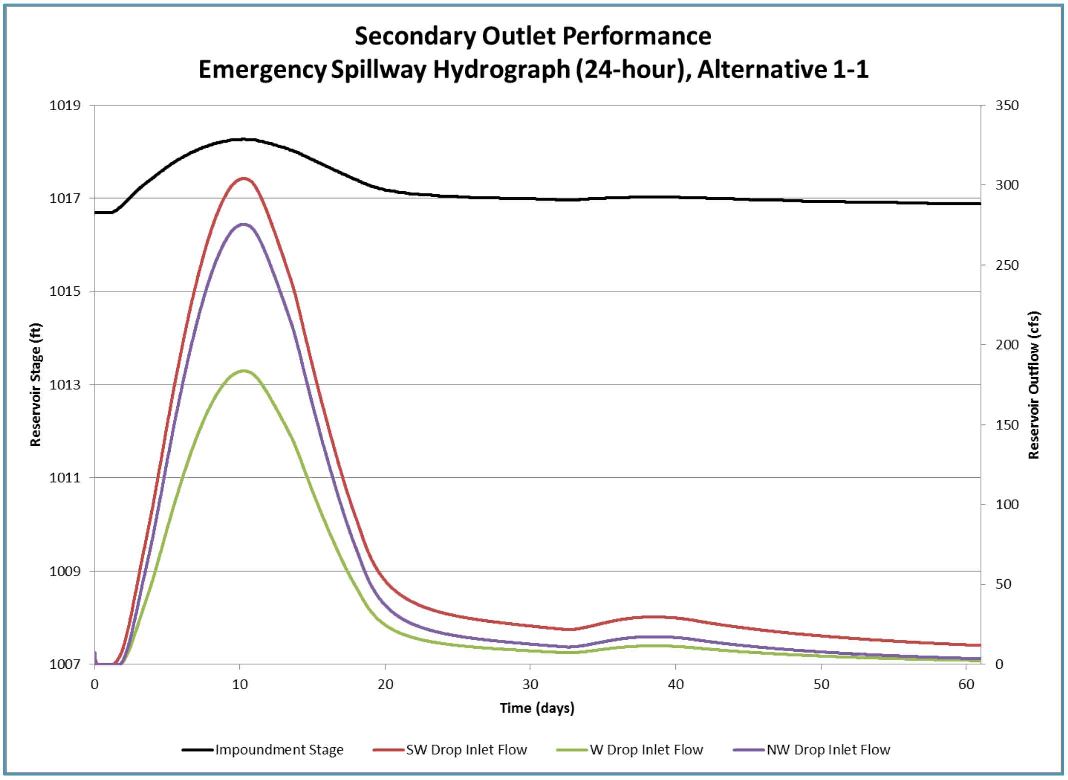


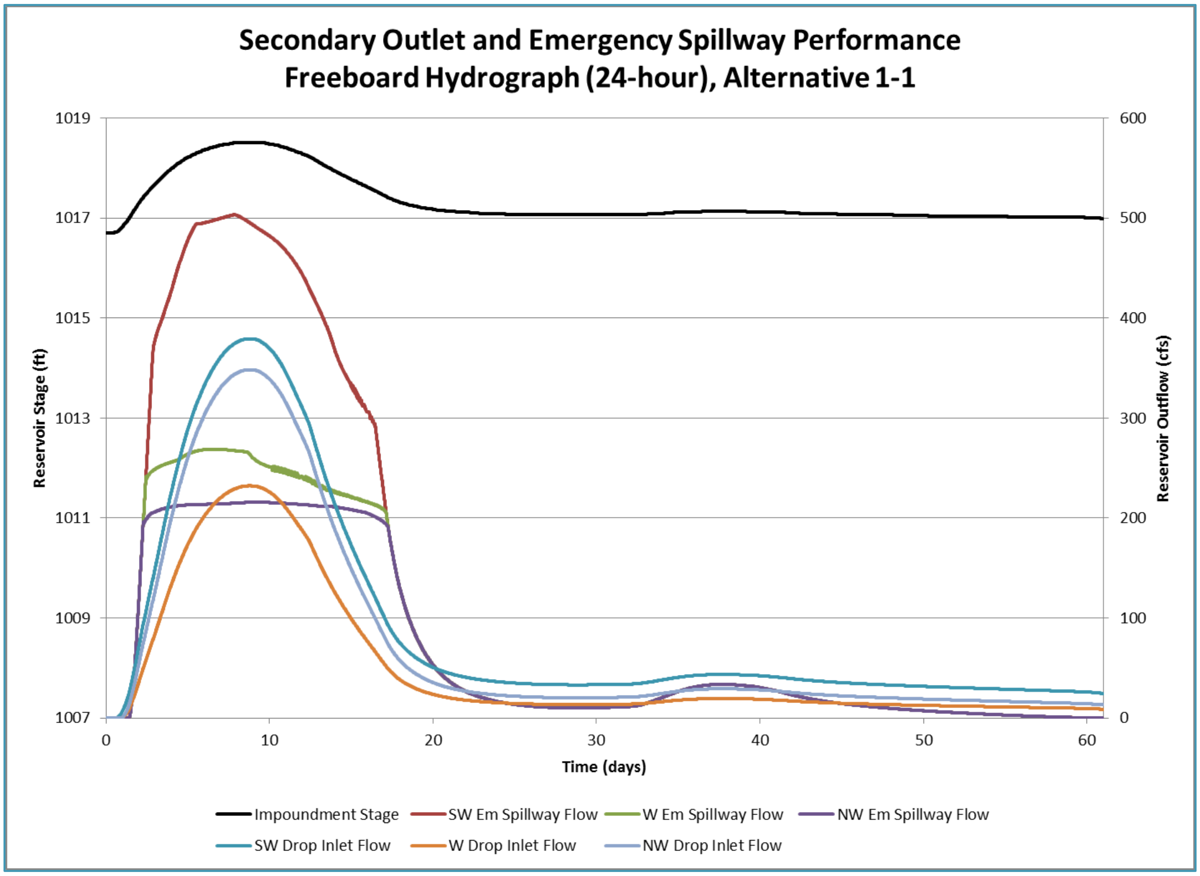
Figure 6-11. Secondary Outlet Performance



6.4 Emergency Spillway

An EPA SWMM model was used to size the emergency spillways. The starting WSE was set to the lowest drop inlet crest elevation of 1016.7' and broad-crested weirs with C = 2.8 were used for each of the 3 emergency spillways. Results are shown in Table 6-1 and Figure 6-12. The Impoundment stage starts at 1016.7 and rises to a maximum stage of 1018.5 before returning to below the emergency spillway at elevation 1017. The minimum capacity of an emergency spillway from TR-60 is $237*DA^{0.493}$. For a 191.5 mi^2 drainage area (DA), the minimum discharge capacity is 3,161 cfs. Assuming headwater elevation of 1018.5' and a crest breadth of 15 feet, the minimum crest width required is 589.5 feet. The total design spillway width of 750 feet has a discharge capacity of 4,022 cfs and therefore meets the capacity requirements of TR-60 while maintaining 1 foot of freeboard in the emergency spillways.

Figure 6-12. Secondary Outlet and Emergency Spillway Performance



7 Other Considerations

7.1 Geotechnical Evaluation

HDR has completed a Geotechnical Memorandum for the KCWRP #11 (Appendix B). This report includes soil exploration, testing, seepage, and slope stability analysis results. The conclusions of the memorandum are included here.

Published information from the Minnesota Geological Survey (MGS, 1982) indicates peat deposits and lake-modified till of the Erskine Moraine associated with the Des Moines Lobe. The topography of the site dips gently in elevation from the east to the west. The maximum embankment height of the Impoundment will be approximately 8.5 feet at the west and south perimeter and the maximum embankment height of the Diked Inlet will be approximately of 4.8 feet near it's east end.

TRWD contracted Braun Intertec of Fargo, North Dakota to perform a geotechnical exploration of potential project locations. HDR selected 32 locations for soil borings at depths of 15 or 40 feet. Figure 7-1 shows the locations and depths of these borings. Braun was on-site in August 2016 and completed 17 soil borings. Samples were analyzed by Braun for several key engineering properties including moisture content, unit weights, Atterberg limits, and sieve-hydrometer analyses. In addition to the Braun Intertec borings, HDR field staff completed 3 soil hand borings in October 2016 and an additional 6 soil borings were completed in May 2017 by Interstate Drilling. The remaining 6 boreholes were not completed due to access problems and landownership (see Figure 7-1).

Detailed geotechnical information on design, borehole logs, and laboratory test results can be found in Appendix B.

The results of these investigations indicate that, in general, the KCWRP #11 site is underlain by a thin layer of topsoil and/or a layer of organics, peat, or non-native fill varying in thickness from one to four feet. In most boreholes, a clay layer described as Glacial Till underlays the organics, peat, or non-native fill to the maximum depths explored in each boring. Variably thick sand layer(s) described as Glacial Outwash were located in some of the boreholes at varying depths.

The thickness of the Glacial Outwash (sand layer) varied from 3 to 6 ft at the test boring locations. In some areas, the Glacial Outwash was encountered below the Glacial Till (clay).

Groundwater was encountered at depths ranging from 4.5 to 24 feet below ground surface in five of the seventeen Braun Intertec borings. The three HDR hand augured borings showed groundwater present at ground surface

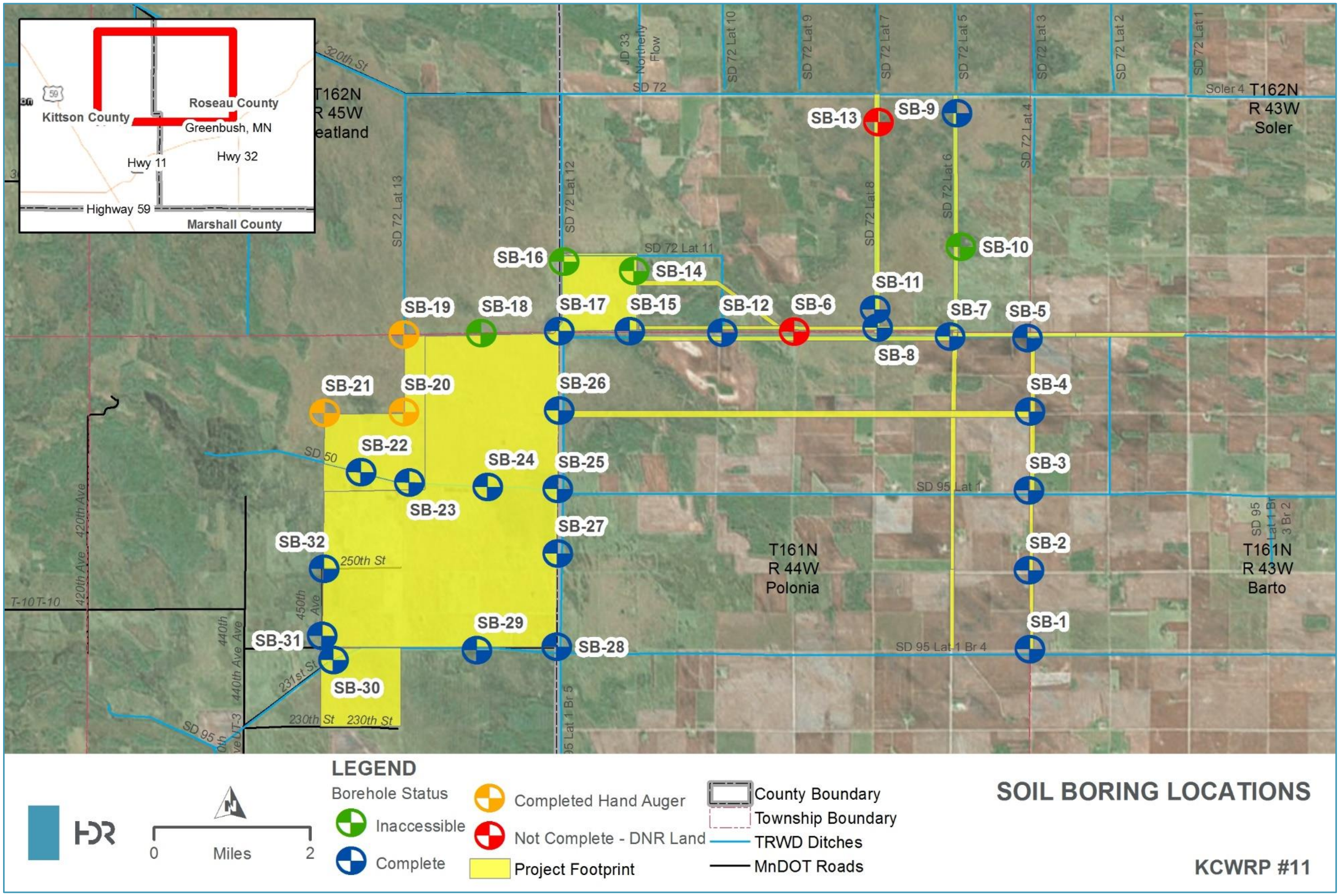
Poor foundation materials (e.g. peat, organics) in some sections of the Impoundment embankment and Diked Inlet are present. To prepare for construction it is recommended to excavate existing topsoil, organics, peat, or non-native fill within the project footprint of the Impoundment and Diked Inlet. Excavated material cannot be placed on wetlands. It is anticipated that any non-usable material can be used to fill in the borrow sites.

The Impoundment embankment and the south embankment of the Diked Inlet are to be composed of an impermeable layer of clay on the wet side of the embankment, with random fill on the dry side of the embankment. The random fill area can be composed of sand, silts, or clay (no organics) while the impermeable clay layer must be comprised of inorganic, compacted clay. For the north embankment of the Diked Inlet, the embankment that will be installed next to the existing road will be comprised of impermeable inorganic, compacted clay. An alternative to removing the peat would be would be to build the embankment over the peat. Topsoil, organics, and non-native fill would still have to be removed from the Impoundment and Diked Inlet footprint. Peat sampling, testing, and analysis as well as additional detailed engineering will be needed to complete this option. This option would require construction observation and staged construction to allow for differential settlement and stabilization.

The laboratory testing program did not include tests on all soil layers to assess the material properties of the foundation soils. The properties were based on several factors, including published correlations and the results of past testing of similar soils. The values of the properties selected for use in the stability analyses are considered reasonable and conservative for the materials present at the site. The results of the stability analyses indicated that acceptable factors of safety can be achieved and that stable embankments for the proposed Diked Inlet and Impoundment can be constructed at the site. Since the on-site foundations soils are relatively competent in strength and stiffness, there should be no concerns of potential slope instability or excessive settlement under the weight of the new embankments.

Seepage results for the Impoundment and Diked Inlet cross sections show no seepage concerns in the design. It should be noted the analysis of settlement of the Diked Inlet and Impoundment embankments has not been completed at this stage in the project. For the purposes of preliminary estimates, a six inch overbuild section (assuming peat/organic clay has been undercut and removed) is assumed for embankment heights 8 feet or greater.

Figure 7-1. Soil Boring Map



7.2 Roadway

280th Street will follow the top of the north embankment of the Diked Inlet and will be raised to a minimum elevation of 1024.5 to prevent flooding of the roadway surface. The approximate total length of the affected 280th Street roadway is 6, 6.5 or 8 miles depending on the alternative selected.

The South Diversion will be located to the east of 160th Avenue. The road will be raised to an elevation of 1025 to prevent flooding of the roadway surface. The approximate total length of the affected 160th Avenue roadway is four miles.

7.3 Access

Maintenance roads will be constructed running along the exterior slope of the Impoundment embankment and along the crest. Maintenance roads will also be constructed running along the exterior slopes of the Diked Inlet embankments and along the crest of the south embankment (280th Street will serve as access for the north embankment).

Field access points will be designed with sufficient width and turning radius. Field access points will be provided as necessary around the perimeter of the project.

7.4 Invasive Species

Because construction will be taking place in the area of DNR WMAs containing rich fen areas and because wetlands are present, it is important that no new invasive species are introduced and that any existing invasive species not be spread further. Contractors and project managers should follow Best Management Practices (BMPs) for preventing the spread of invasive species. Further analyses will be completed as a part of this project, but are not included in this report.

7.5 Wetland Avoidance and Mitigation

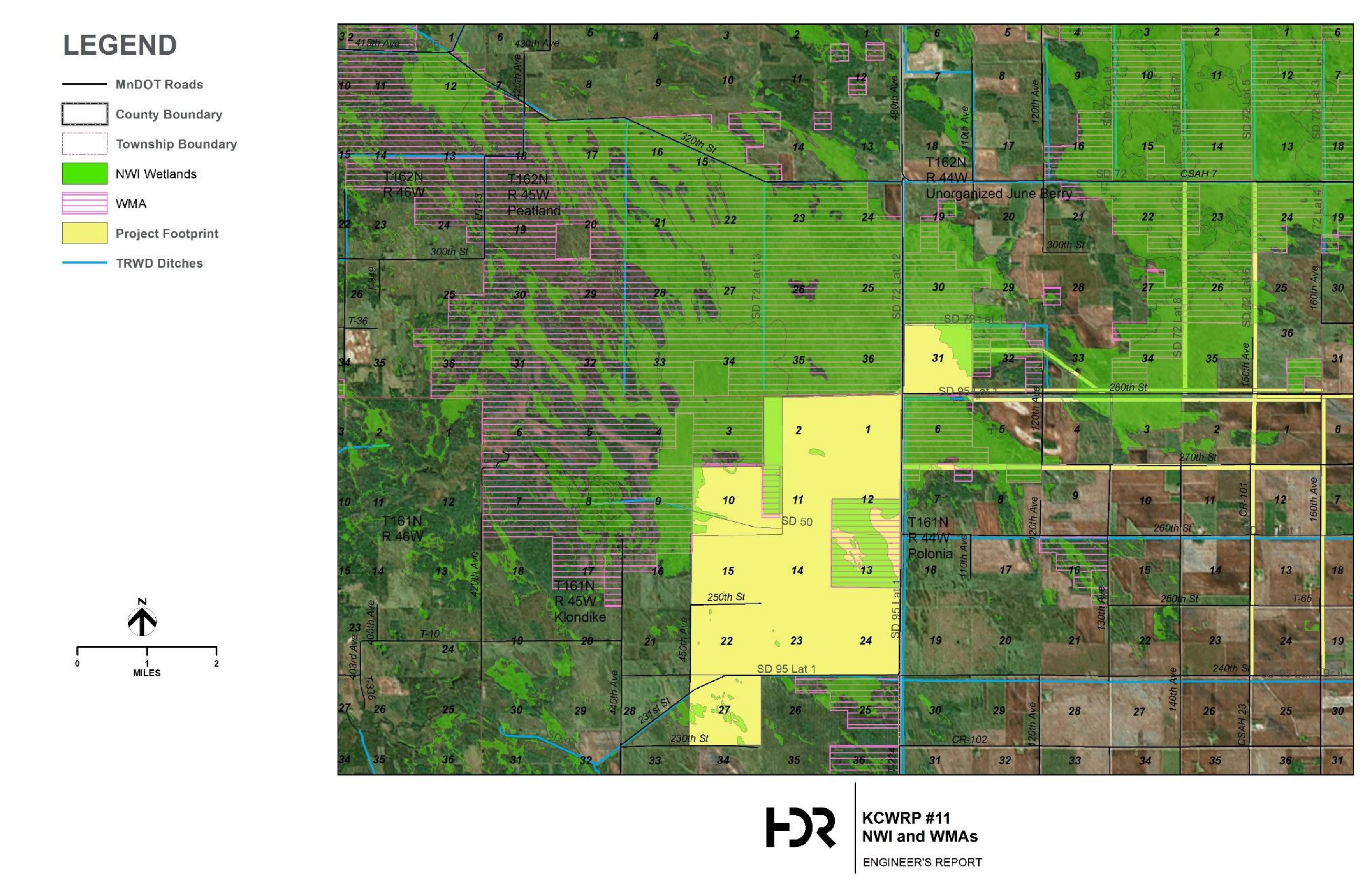
Any wetland disturbed by construction equipment, excavation, or fill material must be permitted in accordance with the BWSR's Wetland Conservation Act (WCA) and Section 404 of the USACE's Clean Water Act (CWA). NWI (National Wetlands Inventory) data show wetlands present in the area of the North Diversions, the Diked Inlet, and the outer areas of various sections of the Impoundment (Figure 7-2). Table 7-1 provides estimated wetland impacts based on the NWI data. Figure 7-2 also shows that the WMAs overlap with the NWI data. Section 2.3.2 of this report discusses the rich fen included in the WMAs. Wetland disturbance should be avoided and minimized if possible, however to compete this project, there will be wetland impacts.

TRWD will coordinate the development of a wetland delineation, permit application, and mitigation plan prior to construction. Wetland mitigation can be accomplished through the creation, enhancement, or restoration of wetlands. A common way to create additional wetland acreage is through scraping existing vegetation, grading of small berms, planting native vegetation, and placement of ditch plugs and/or spillways.

Table 7-1. Estimated Impacts Based on NWI

Alternative	Wetland Acres Impacted
1-1	370.1
1-2	370.1
1-3	370.1
2-1	319.3
2-2	319.3
2-3	319.3
À la Carte Diversions	214.9

Figure 7-2. National Wetland Inventory (NWI) and Wildlife Management Areas (WMAs)



7.6 Potential Groundwater Impacts

Three of the boreholes show the groundwater level located in the glacial outwash layer (upper sand layer) underlain by glacial till (clay). This could indicate the presence of an aquifer in the sand layer. The placement of the embankment and the sub cut geometry in the areas where removal of peat/topsoil/organics/fill is needed could isolate the shallow aquifer within the immediate footprint of the impoundment. However, it is not anticipated that this will have widespread effects on local or regional groundwater patterns.

7.7 Environmental Consequences

The TRWD is working on the Environmental Assessment (EA) for the project. It will provide details on potential negative environmental effects of the proposed KCWRP #11 project and ways to avoid or minimize impacts before the project is permitted and built. This project is not expected to cause significant negative environmental consequences.

7.7.1 Water Quality

The MPCA states that intensive watershed water quality monitoring was completed in 2014 and a Monitoring and Assessment Report was completed in 2016. Stressor identification work was completed in 2015 and the Stressor Identification Report in February 2017. A TMDL study and WRAPS report is expected to be completed in 2017. MPCA water monitoring stations are located downstream of the impoundment at all three outlets. The lower sections of the Lower and Middle Two Rivers are impaired for turbidity and monitoring information would provide important information on sediment reduction results.

7.7.2 Fish and Wildlife

It is anticipated that this project will enhance fish and wildlife habitat. As indicated in Section 2.3.2, Natural Resource Enhancement (NRE), the project goals include significant efforts to conduct NREs in the project area. Upland habitats will be subjected to periodic inundation in accordance with the Project purpose and operating plan. Historically, these habitats have been subjected to frequent inundation and are adjacent to agricultural production.

7.8 Operating Plan

7.8.1 Operation Goals

The goal of the operating plan is to manage the KCWRP #11 to reduce local and regional flood damages, improve water quality, and enhance wildlife habitat. This will result in lower peak flows and shorter durations of uncontrolled flooding on the surrounding lands and downstream of the project and reduce erosion downstream. The operating plan provides a general description of how to maximize flood control and water quality benefits and identifies general concepts at which to operate the control gates to allow flows into and out of the project. Table 7-2 below provides a summary of the operating plan.

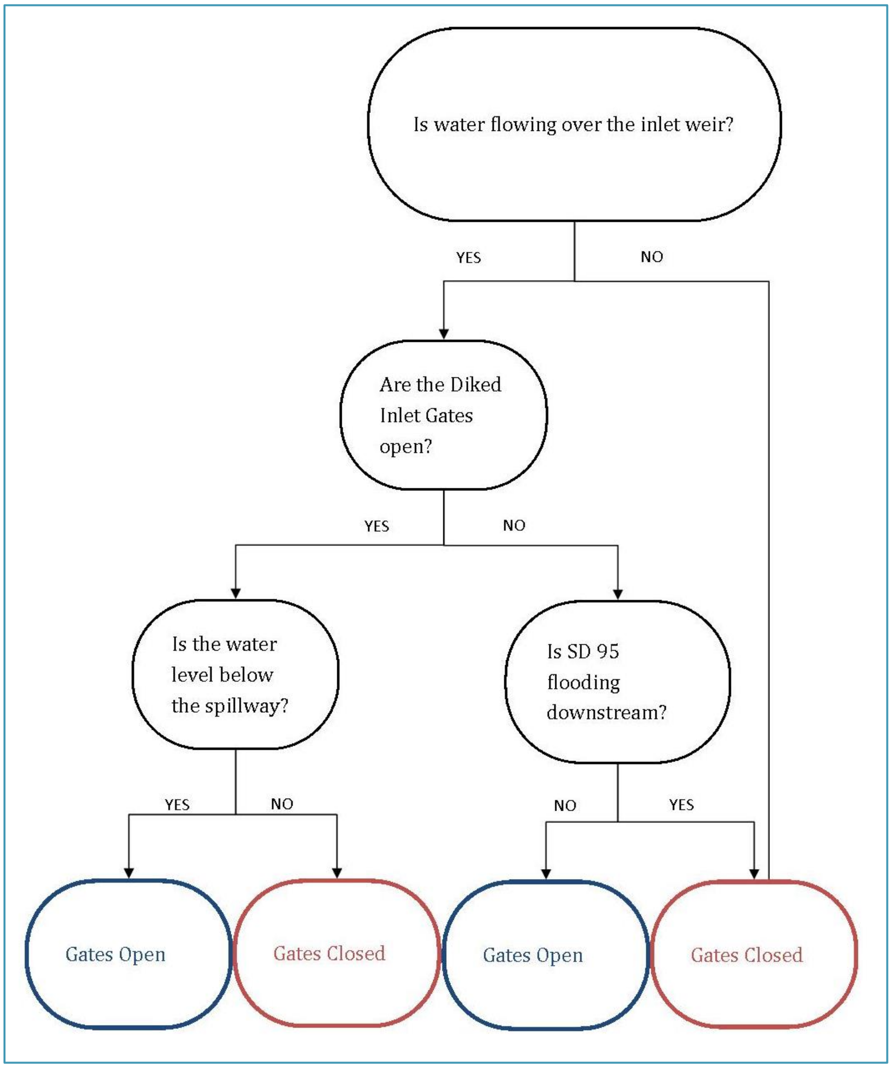
Table 7-2. Operating Plan Summary

Operating Plan Summary	
Normal Operation	Majority of flows would be routed through KCWRP #11
< 10 Year Event	Operation of inlet/outlet structures based upon local triggers • Intended to keep local agriculture drainage functioning
> 10 Year Event	Operation would be mostly automated, based upon inlet elevations and downstream trigger points • Project fills at design stages

7.8.2 General Operation

Operation of the KCWRP #11 will vary depending on the size of the flood event. For smaller events (2- to 10-year floods) where the capacity of the ditch systems are not exceeded, the operation of the project will be subject to local triggers upstream and downstream of the project. The purpose of operation during smaller events is intended to keep local agriculture drainage functioning. During larger events, (i.e., greater than a 10-year event) the project will start operating automatically. The North Diversion inlet weirs will be overtopped and flows will reach the Diked Inlet gates. These gates will be operated based on an operating plan. See Figure 7-3 for an example of decision chart for operating the North Diversion gates based on water levels in the system. The South Diversion will automatically receive flows and direct them north to the Diked Inlet where they will join flows in SD 95 Lat 1. The KCWRP #11 outlet gates will be closed during full operation for retention. Under normal operation the SD95 Lat 1 outlet will remain open one foot to pass regular inflows in the system.

Figure 7-3. North Diversion Gate Operation Decision Chart



Alternatives will store up to 42,000 acre-feet of flood water. By following an operating plan, this gated storage will reduce the amount and duration of flooding on the SD 72 and 95 systems and reduce the peak flows of Two Rivers into the Red River. It is estimated that during a spring snowmelt event equal to the 1997 flood, this project will result in a peak flow reduction of 15% and a volume reduction of 10% above the Red River.

The proposed project will collect and store runoff and provide gated flood control that can be released from the impoundment through outlets to the North Branch, Middle Branch, or South Branch of the Two Rivers. By managing outflow from the impoundment, the frequency and severity of downstream flooding will be reduced. The design goal is to fill the reservoir during frequent events and up to the 100-year, 10-day event without engaging the emergency spillway, and to provide emergency spillway capacity for inflows in accordance with dam safety requirements.

This project will reduce flooding on SD 95, SD 50, SD 72, the Red River, and on the North Branch, Middle Branch, and South Branches of the Two Rivers.

7.8.3 Trigger Points

There are not any USGS gages in the upstream drainage area of the KCWRP #11, however the TWRD operates the Ross #7 impoundment upstream. Estimated runoff can be inferred by checking rain gages at Ross #7, by reviewing the upstream river gage on the Roseau River at Ross http://water.weather.gov/ahps2/hydrograph.php?wfo=fgf&gage=rssm5 and downstream gages at Lake Bronson http://water.weather.gov/ahps2/hydrograph.php?wfo=fgf&gage=lkbm5 and Hallock http://water.weather.gov/ahps2/hydrograph.php?wfo=fgf&gage=HLLM5 with the predicted peak flow estimates from the National Weather Service (NWS). Rainfall values over the watershed should also be used with the current hydrologic model to estimate the magnitude of the flood. Other local trigger points will be established in order to inform the operation.

Trigger points for the releasing of water will be determined based on local trigger stages, or downstream USGS gages located at Lake Bronson, MN and Hallock, MN. The stage of the river at Lake Bronson and Hallock must fall below a certain elevation before flows will be released from the project area. Outflows will be metered such that the prescribed stage downstream for flood damage reduction would not be exceeded.

8 Opinion of Most Probable Cost

Appendix C presents best possible estimates of the complete construction of each of the six project alternatives. Table 8-1 provides a summary of the estimates for each of the six alternatives and the à la carte option which summarizes both North Diversion options and the South Diversion – East option. Alternative pricing includes the diversions as described.

Table 8-1. Cost Estimate Summary

Alternative	Earthwork	Structures	Erosion Control	Total Estimated Cost
1-1	$22,431,395	$4,024,270	$470,978	**$39,672,857**
1-2	$23,585,767	$3,560,470	$476,593	**$40,580,073**
1-3	$24,468,786	$3,631,670	$494,139	**$42,029,664**
2-1	$23,009,702	$4,024,270	$470,978	**$40,371,361**
2-2	$24,164,074	$3,560,470	$476,593	**$41,278,577**
2-3	$25,047,093	$3,631,670	$494,139	**$42,728,168**
À la carte Diversions	$2,512,868	$970,960	$20,293	**$3,719,570**

9 Recommendations

9.1 Phasing

Due to the size and cost of the project, the construction should be completed in phases. Figure 9-1 through Figure 9-3 below show three phases of the KCWRP #11 which would allow the project to function throughout the process. The three phases are as follows:

- Phase 1 - Diked Inlet and gated storage on Section 31 June Berry
- Phase 2 - Full Impoundment
- Phase 3 - North and South Diversions

9.2 Alternative Selection

The hydrologic and hydraulic data indicates that the project should contribute flood reduction along the SD 50, 72 and 95 systems to help address the severe and repeated damage that currently occurs to public infrastructure, private property, and agricultural lands. These three systems provide an adequate outlet for this project. Each alternative performs comparably well, especially during the 10-day, 100-year event, but the full impoundment (Alternatives 1-1, 1-2, and 1-3) provides greater flood damage reduction results because of the additional capacity of the reservoir. As stated in the executive summary, Alternative 1-3 is the recommended alternative including *À la Carte Alternatives* of both North Diversions (Mel Wang and Huseby) and the South Diversion – East. This alternative was selected based on required footprint, performance, feasibility, and overall cost. Because of the simplified Dike Inlet structure, this alternative allows for automatic operation in the event of a flood. This alternative provides operational flexibility, FDR and NRE, as well as landowner and significant agency consensus at this stage of the KCWRP #11 development.

Figure 9-1. Phase 1 - Diked Inlet and Section 31 June Berry

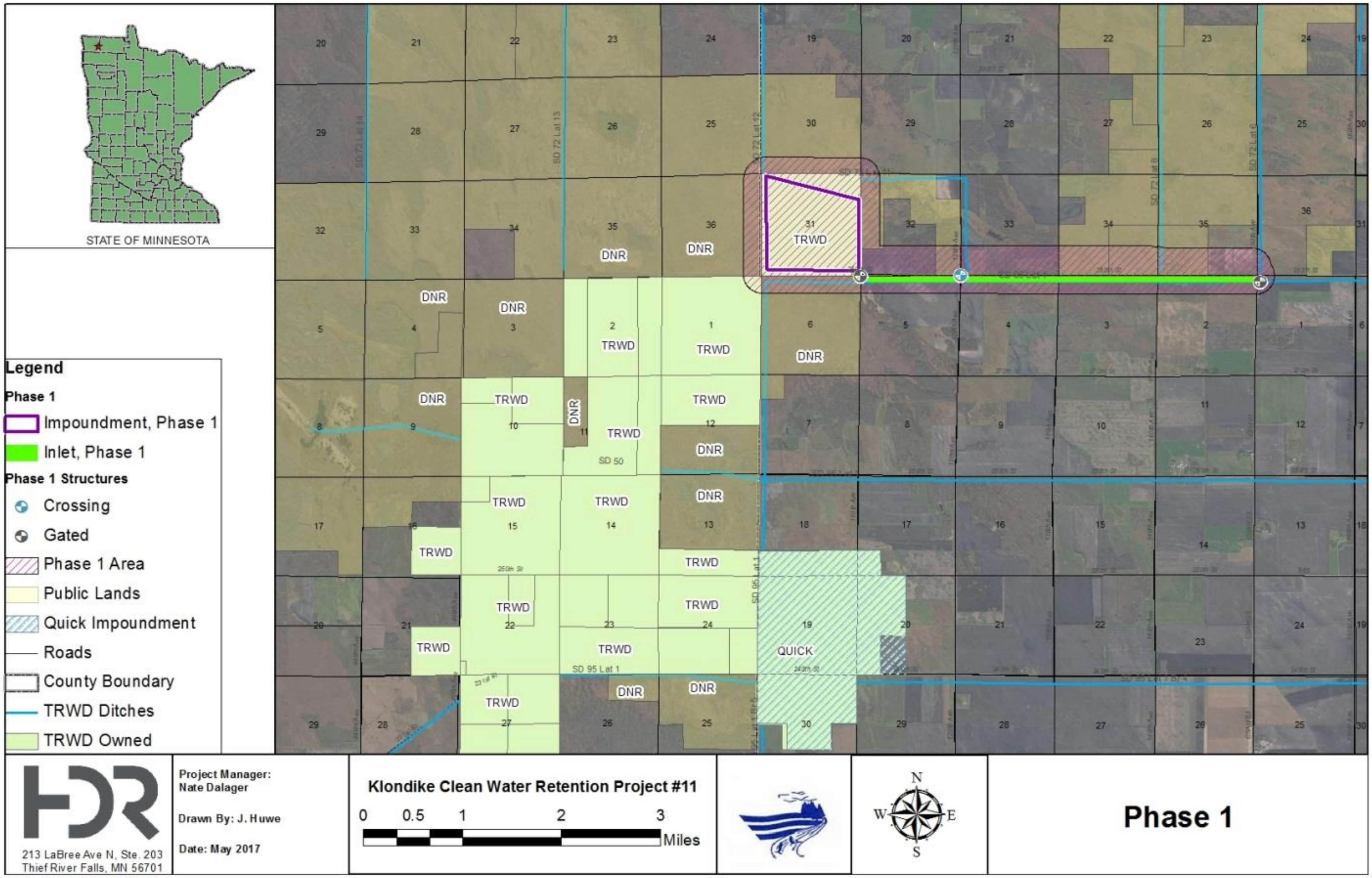


Figure 9-2. Phase 2 - Full Impoundment

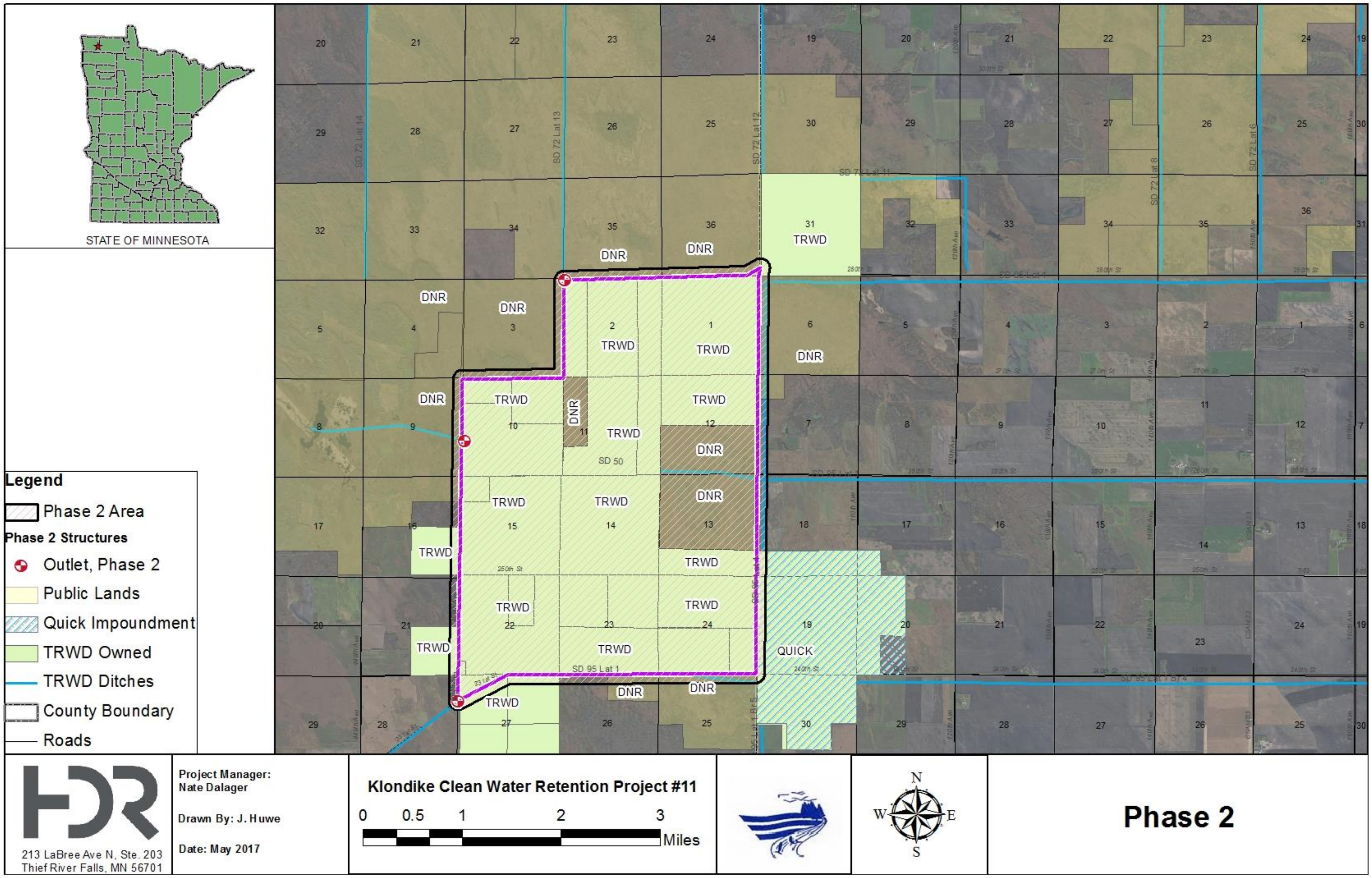
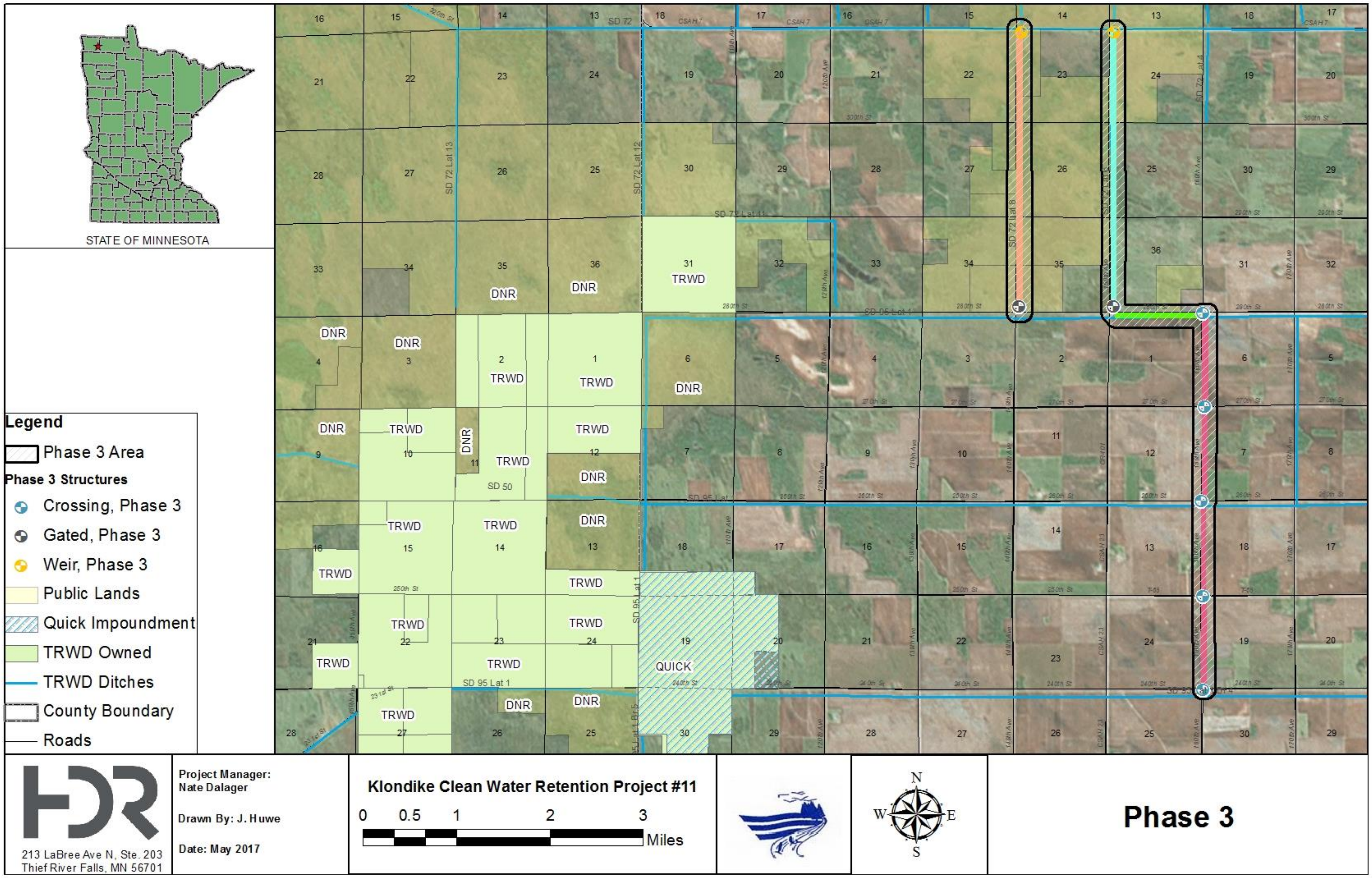


Figure 9-3. Phase 3 - North and South Diversions



10 Compatibility with Existing Plans, Statutes, Rules, and Permit Needs

10.1 Adequacy of the Outlets

As mentioned in Section 3.5.1, three outlets (NW, W, and SW outlets) will allow water to exit the impoundment downstream to the North, Middle, and South Branches of the Two Rivers. The project would be operated to benefit the SD 50, SD 72, and SD 95 systems, and releases from the Impoundment would only be allowed based on the parameters of an operating plan and based upon the downstream systems' adequacy.

An estimate of the downstream outlet capacities in SD 95 Lat 1, SD 50, and SD 72 is shown below. During Impoundment dewatering, the allowable discharge rates will be based on downstream triggers, and the adequacy of the outlet will be managed in this manner.

Overall, the ditch systems will provide an adequate outlet for Impoundment dewatering discharges. Repair or improvement of these outlets would be subject to future evaluations. The rating curves below show a range of grades and their maximum discharges based on existing cross-sections.

Figure 10-1. State Ditch 95 Lateral 1 Outlet Channel Rating Curve

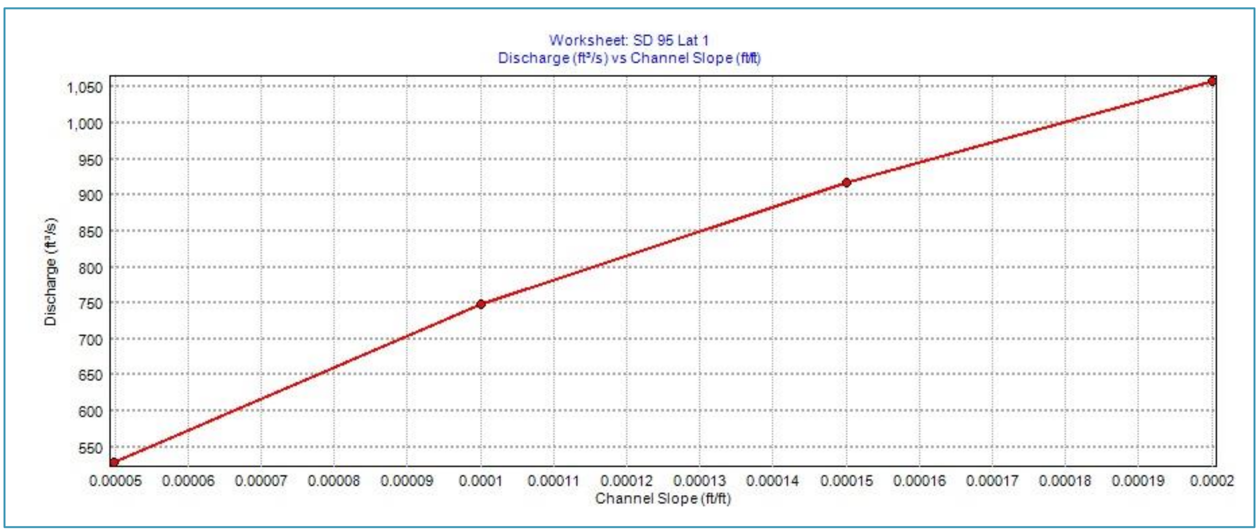


Figure 10-2. State Ditch 50 Outlet Channel Rating Curve

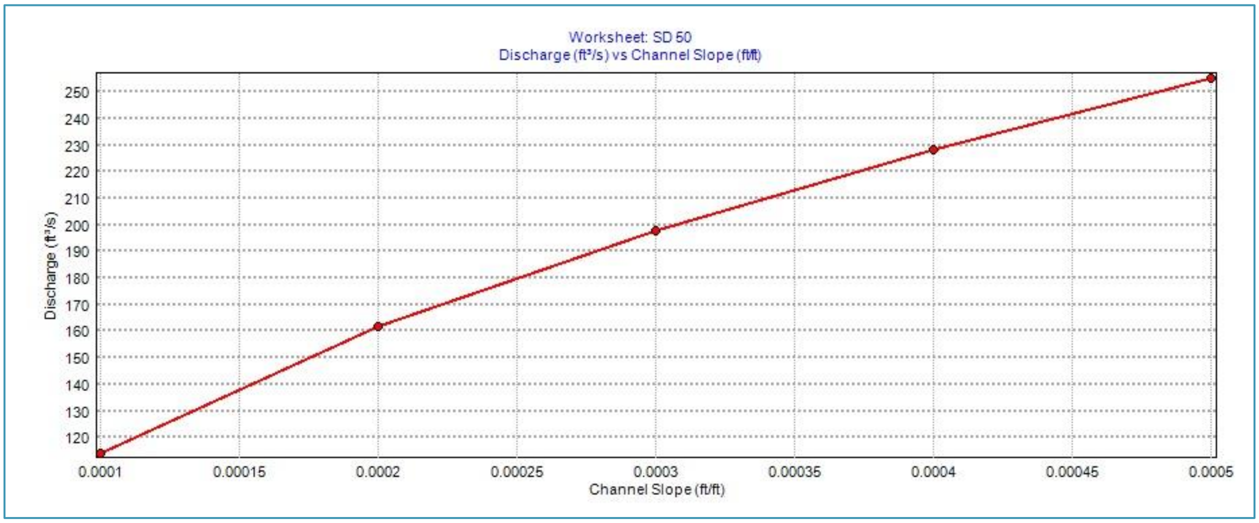
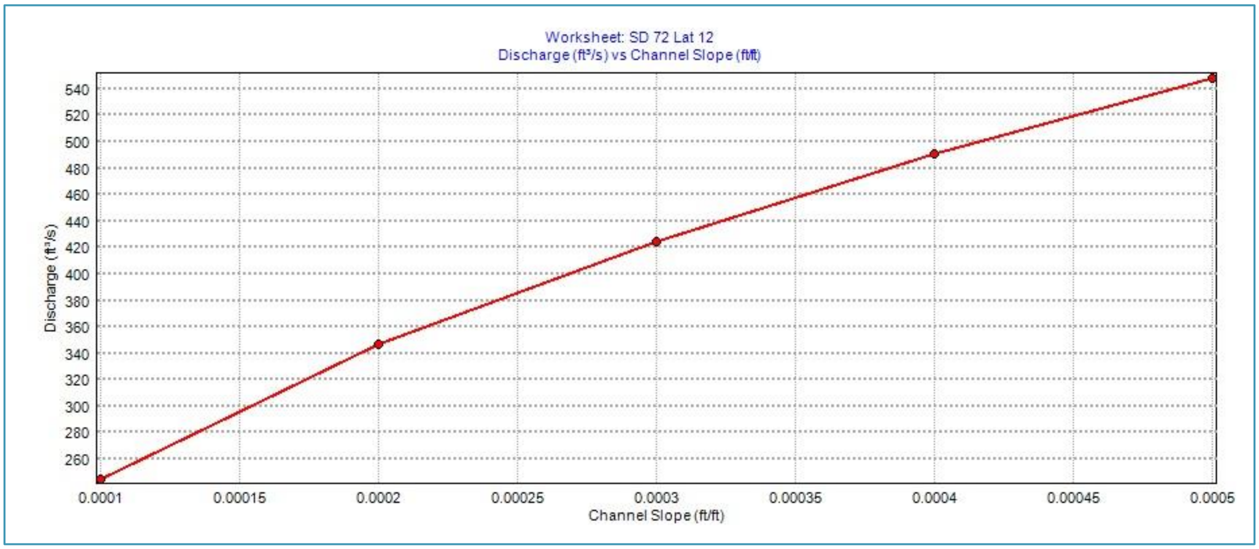


Figure 10-3. State Ditch 72 Outlet Channel Rating Curve



10.2 Overall Plan of the Two Rivers Watershed District

The Two Rivers Watershed District currently has ongoing investigations dealing with water quality and water quantity. The District is actively involved with flood control initiatives, water quality studies, educational initiatives, drainage ditch management, culvert inventories, and other water management activities. These programs and monitoring activities provide the Board of Managers with the data and information they need to make informed decisions regarding the water resources of the District.

The Two Rivers Watershed District Statement is as follows:

It is the stated mission of the Board of Managers of the Two Rivers Watershed District *to carry out all facets of the Minnesota Watershed Act as set forth in Minnesota Statute, Chapter 103D. It is the District's further mission to carry forth all activities and powers given under the Minnesota Drainage Code in Minnesota Statute, Chapter 103E. In* *carrying out its mission, the District will encourage the wise use of the water natural resources within its boundaries and promote the general health and welfare of the citizens residing there.*

The overall goals for the TRWD include:

Flood Damage Reduction Goals:

- Coordinate with other Boards the delivery of flow to the Red River
- Maintain, modify, construct, or improve properly functioning watercourses to provide protection to agricultural land for a 10 - year event, while ensuring that there are no resulting downstream adverse impacts
- Reduce the duration, peak, and frequency of overland flooding
- Reduce damages to and loss of residential areas from flooding for a 100-year event (minimum)
- Enhance and protect ground water supplies

Natural Resource Goals:

- Reduce erosion & sedimentation
- Participate in efforts to enhance, establish, and protect stream corridors and riparian areas
- Participate in efforts to enhance, provide, & protect habitats
- Support the expansion of water based recreation
- Provide educational and outreach opportunities

The KCWRP #11 will contribute to several of these TRWD goals.

10.3 Roseau County Local Water Management Plan

The purpose of the updated Local Water Management Plan for Roseau County is:

1. To actively work on the existing local priority concerns and to identify future potential priority concerns so that our water resources and related land resources are protected, managed and developed.
2. To update and continue the process of developing and applying an action plan to promote sound water and related land resource management in the county.
3. To continue working towards effective environmental protection and management in Roseau County through focusing on priority concerns and recognizing potential priority concerns.
4. This water plan is also recognized as the Roseau County SWCD Comprehensive Plan.

Goals in this water plan that contribute to the KCWRP #11 include:

- Priority Concern 1: Erosion & Sedimentation of Surface Waters, Stormwater Runoff and Wetlands
- Priority Concern 2: Flood Control and Flood Damage Reduction
- Priority Concern 3: Surface Water Protection and Improvement
- Priority Concern 4: Managing Existing Ditch Systems

10.4 Kittson County Local Water Management Plan

The purpose of the Local Water Management Plan (LWMP) for Kittson County is:

1. To identify existing and potential problems or opportunities for protection, management, and development of water resources and related land resources in Kittson county.
2. To develop and implement a plan of action to promote sound hydrologic management of water and related land resources in Kittson county.
3. To work toward effective environmental protection and management in Kittson county.

Goals in this water plan that contribute to the KCWRP #11 include:

- Flood damage reduction, water quality, and storm water issues (page 67 of the plan, included in Priority Concern 2: Surface Water).

10.5 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, 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.

Additional Statutory requirements in Statute 103E will be considered for the KCWRP #11. The State Ditch 72 and State Ditch 95 systems are adjacent to and affected by the proposed Project, and the upstream section of State Ditch 50 lies within the proposed Impoundment. The TRWD will need the approval of the Joint County Drainage Authority (Kittson and Roseau County) to proceed with the KCWRP #11 and any associated drainage system modifications and improvements. The process will likely involve a petition from the TRWD to the Joint County Drainage Authority, after which a public hearing will be held to review and evaluate the proposal.

10.6 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." With the construction of the new embankments and exterior drainage ditches, the project will disturb more than one acre of public water wetlands and the TRWD will prepare an EAW.

10.7 U.S. Army Corps of Engineers Section 10 or Section 404

A Section 404 permit will be required by the USACE due to the fact that excavation and fill will take place through a wetland that contributes to the Two Rivers. Meetings will be held with USACE permitting authorities regarding the proposed project. The permit may require a review of operational parameters, such as wetland inundation, bounce, flood frequency, and water depth, in addition to wetland impacts from the construction footprint. Construction will not begin until all permits are received.

10.8 Minnesota Department of Natural Resources

The proposed project will likely require a dam safety permit from the MnDNR in accordance with Minnesota Rules 6115.0300. 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 Impoundment embankment will likely be classified as a Class III low hazard dam.

A MnDNR Public Waters Work Permit is required for the proposed work to be done within the channels inletting and outletting to the Two Rivers.

11 References

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Appendix A

TRWD and MNDNR Land Exchange Legislation

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Appendix A

CHAPTER 154--S.F. No. 2760 signed 5/22/2016

Sec. 34. KLONDIKE CLEAN WATER RETENTION PROJECT; KITTSON COUNTY.

Subdivision 1. **School trust land exchange.** (a) Notwithstanding the riparian restrictions of Minnesota Statutes, section 94.342, subdivision 3, the commissioner of natural resources shall, with the approval of the Land Exchange Board as required under the Minnesota Constitution, article XI, section 10, and according to the remaining provisions of Minnesota Statutes, sections 94.342 and 94.343, exchange the school trust land described in paragraph (c) for land of equal or greater value owned by the Two Rivers Watershed District.

(b) The conveyance must be in a form approved by the attorney general. The attorney general may make necessary changes to the legal description to correct errors and ensure accuracy.

(c) The land that may be exchanged is located in Kittson County and is described as: the South Half, Section 12, Township 161 North, Range 45 West.

(d) The commissioner has determined that the state's land management interests would best be served if the land was exchanged to facilitate the Klondike clean water retention project.

Subd. 2. **Land recommendation.** The commissioner of natural resources, in consultation with the Two Rivers Watershed District, shall make recommendations regarding the disposition of the acquired wildlife management area land that is included in the Klondike clean water retention project. The commissioner must make the recommendations within six months after the completion of the project's environmental assessment worksheet.

Subd. 3. **Rich fen enhancement.** The commissioner of natural resources and the Two Rivers Watershed District shall, as part of the Klondike clean water retention project, implement a cooperative rich fen management plan that provides for the long-term enhancement and protection of the rich fen.

Subd. 4. **Completion.** The requirements under subdivisions 1 to 3 must be completed by December 31, 2017, or as provided in the Klondike preliminary project plan approved by the Two Rivers Watershed District, whichever is later.

Subd. 5**.** **Wetland credits.** Any wetland mitigation credits resulting from projects on lands exchanged or conveyed under this section must be used to mitigate transportation projects consistent with Minnesota Statutes, section 103G.222, subdivision 1, paragraphs (l) and (m).

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Appendix B

Geotechnical Memorandum

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Geotechnical Memo

Date: Wednesday, May 03, 2017

Project: Klondike Clean Water Retention Project #11
Two Rivers Watershed District
Roseau and Kittson County, MN
Project No.: 239979

To: File

From: Kerrie Berg, Water Resources, HDR Engineering Inc.

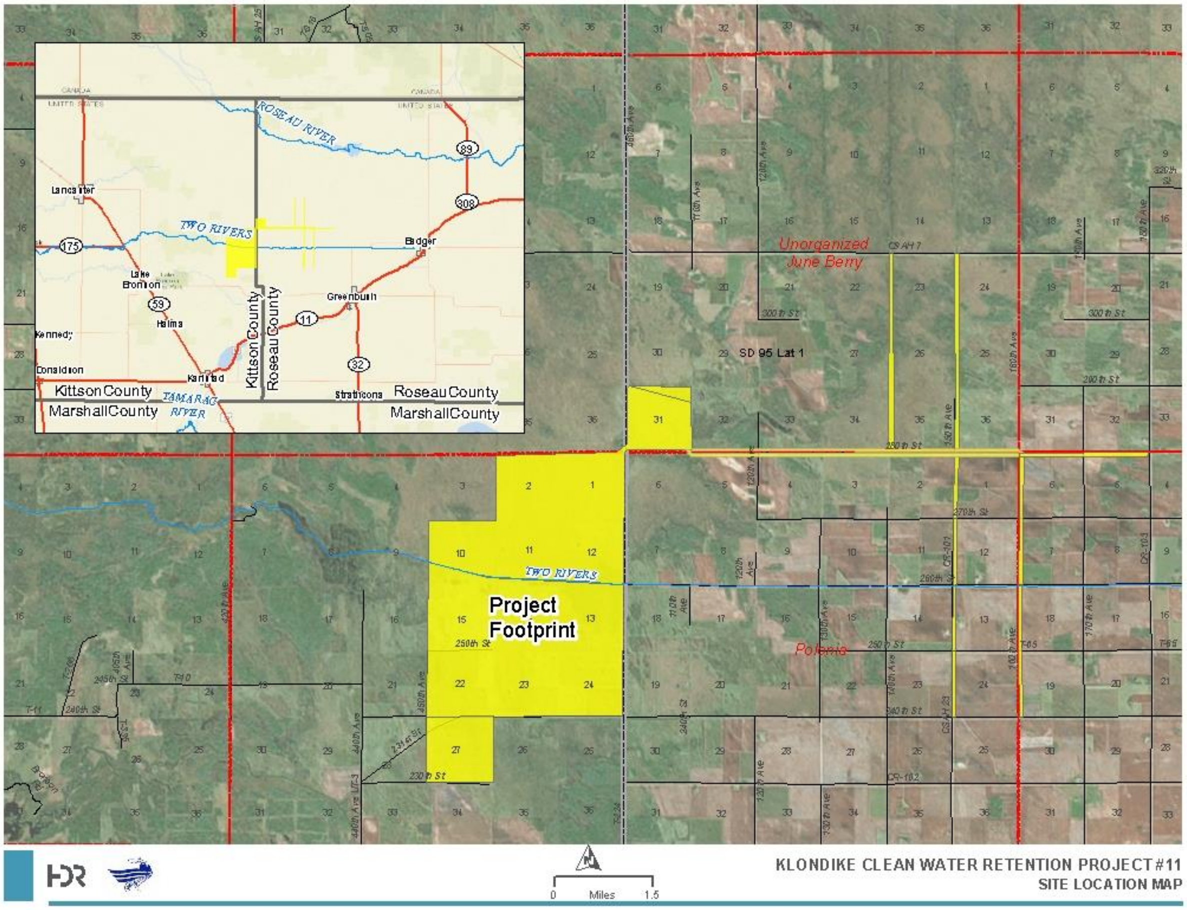
Matthew Schuster, PE, PhD, Geotechnical Engineer, HDR Engineering Inc.

Subject: Geotechnical Memo, Design Recommendations

1. Introduction

The Klondike Clean Water Retention Project #11 (KCWRP #11) is located eight miles east and one mile north of Lake Bronson in Roseau and Kittson County, Minnesota. Roseau and Kittson County are in northern Minnesota and the project is approximately 13.5 mile south of the Canadian border. Figure 1 shows the location of the project. The purpose of the project is to provide flood control benefits and natural resources enhancement. The source of flooding causing the need for the KCWRP #11 is a combination of State Ditch 95 (SD 95) drainage area, Roseau River overflow and State Ditch 72 (SD 72). These ditch systems currently in place do not have the capacity to carry the water that enters them, and consequently water breaks out of the ditches and creates large scale overland flooding. The primary purpose of the memorandum is to evaluate subsurface soil conditions to be used in evaluation of the slope stability and seepage of the proposed Impoundment Levee and Diked Inlet.

Figure 1. Project Location – Klondike Clean Water Retention Project #11



2. Geology

We have reviewed published information from Minnesota Geological Survey (MGS, 1982). The quaternary maps indicated peat deposits and lake-modified till of the Erskine Moraine associated with the Des Moines Lobe. Portions of the geologic map of the project site are shown in Attachment A.

3. Subsurface Exploration and Laboratory Testing

Two Rivers Watershed District (TRWD) contracted Braun Intertec to perform subsurface exploration and laboratory testing. The program consisted of subsurface exploration at 32 locations along the proposed Diked inlet, Impoundment, and North and South diversion locations as well as limited laboratory tests on soil samples to determine soil parameters for seepage and slope stability analysis. Braun was on-site August, 13, 15 – 19, and 22, 2016 and completed 17 soil borings. The remaining borings were not completed by Braun Intertec due to wet conditions and site access problems. It is our understanding that soft ground and the presence of peat were the cause of the site access problems. On October 3, 2016, HDR field staff completed 3 soil hand borings. Laboratory tests were performed by Braun on selected soil samples. The laboratory testing was performed in accordance with ASTM procedures. The tests consisted of moisture contents, unit weights, Atterberg limits, and sieve-hydrometer analyses. Table 1 below summarizes the lab testing performed:

Table 1. Laboratory Test Summary

Soil Test	Number of Tests	BH#	Depth Below Ground Surface (ft)
Moisture contents	6	SB01	3.0 and 5.0
		SB05	5.0 and 7.5
		SB08	5.0 and 7.5
Unit weights	3	SB01	5.0
		SB05	5.0
		SB08	5.0
Atterberg limits	3	SB01	2.5
		SB05	7.5
		SB08	7.5
Sieve-hydrometer analyses	3	SB01	2.5
		SB05	7.5
		SB08	7.5

These tests were performed to aid in soil classification and determination of engineering properties of the soil. Attachment B shows the borehole locations and Attachment C contains the borehole logs and the laboratory test results. Table 2 below shows the ground surface elevations of the boreholes.

Table 2. Borehole Elevations

Borehole #	Elevation (ft)
SB-1	1026.20
SB-2	1024.30
SB-3	1025.00
SB-4	1022.10
SB-5	1019.90
SB-7	1018.30
SB-8	1019.60
SB-9	1021.70
SB-11	1017.80
SB-12	1017.70
SB-15	1011.90
SB-19	1011.50
SB-20	1011.94
SB-21	1010.58
SB-23	1012.80
SB-24	1011.00
SB-26	1013.20
SB-27	1013.00
SB-31	1014.80
SB-32	1015.00

Subsurface conditions are described below.

Topsoil

A topsoil layer between 0.5 and 2 feet in thickness is present at the ground surface for all boreholes except SB23, SB24, SB26, and SB31. Borings SB23, SB24, SB26, and SB31 are generally within the swamp areas where fill or organic clay/peat were observed at the top of the ground surface.

Fill

A fill layer between 2 and 4 feet in thickness is present in boreholes SB23 and SB31.

Peat

In Boreholes SB8, SB9, SB11, SB23, and SB24 a peat layer between 1 and 4 feet in thickness is present. SPT values between 2 and 5 blows per 12 inches indicate a soft to rather soft state of compactness. A pocket penetrometer test at SB09 in the peat layer of 0.5 tsf indicates a soft consistency. Also, the borehole log notes in SB8, SB9, SB11, SB23, and SB24 state that the peat layer is "very soft" and that the layer is a "swamp deposit". The peat layer in SB8, SB9, and SB11 is located beneath the topsoil layer and in SB23 below the fill layer. In borehole SB24 the peat layer is located at ground surface.

In the three HDR hand augured boreholes (SB19, SB20, and SB21), a peat layer between 3.5 and 4 feet is thickness is present.

Organic Clay

Organic Clay is present in SB23 and SB26 with a thickness between 3 and 4 feet. SPT values between 3 and 4 blows per 12 inches indicate a soft to rather soft state of compactness. The organic layer in SB23 is located below the peat layer. In borehole SB26 the organic clay layer is located at ground surface. Borehole log notes state that the layer is a "swamp deposit".

Glacial Outwash - Upper Sand Layer (Silty Sand/Sand with Silt)

In Boreholes SB31 and SB32 beneath the fill and topsoil layer respectively, a Glacial Outwash – Upper Sand layer (*Silty Sand/Sand with Silt*) is present 3 to 6 feet in thickness. SPT values between 15 and 23 blows per 12 inches indicate a medium dense state of compactness.

Upper and Lower Glacial Till (Sandy Clay and/or Clay with Sand)

In the boreholes, beneath the top layer of soil (whether it be topsoil, fill, organic clay, or peat) a Glacial Till (clay) layer between 9 and 40 feet in thickness is present with varying amounts of silt, sand, and gravel. In all boreholes except SB03, SB04, SB05, and SB09, the Glacial Till layer extends to the bottom of the borehole.

Sieve-hydrometer analyses were conducted on samples from SB1, SB5, and SB8 at depths of 2.5, 7.5, and 7.5 feet below ground surface respectively. Results indicate gravel, sand, silt, and clay contents of 2 to

4%, 27 to 39%, 31 to 50%, and 21 to 26% respectively and the plots can be found in Attachment C. The moisture contents of samples range from 13% to 22% (of dry weight). Density (unit weight) testing was conducted on samples from SB1, SB5, and SB8 at depths of 5.0 feet below ground surface. Wet density (unit weight) ranged from 120 to 145 lb/ft^3 and dry density (unit weight) ranged from 98 to 128 lb/ft^3. Laboratory results for the unit weight for the in-situ clay are summarized in Table 3 below.

Table 3. Laboratory Results for Unit Weight in In-Situ Clay Layer

BH#	Depth Below Ground Surface (ft)	Dry Unit Weight (lb/ft^3)	Wet Unit Weight (lb/ft^3)
SB01	5.0	128	145
SB05	5.0	98	120
SB08	5.0	124	141

The Glacial Till is defined as a lean clay as indicated by Atterberg limit tests conducted on samples from boreholes SB1, SB5, and SB8.

The glacial clay layer can be split into sub-layers as the upper portion (5 to 10 feet) was observed to be softer (lower blow counts, lower pocket penetrometer, lower unit weights, higher moisture content).

- The Upper Glacial Till layer has a soft to very stiff consistency with pocket penetrometer results ranging from 0.5 to 2.5 tsf. However, the average pocket penetrometer is 1.5 tsf indicating a stiff consistency. Average SPT results in the Upper Glacial Till layer equal 7 BPF (blows per foot) correlate to a medium consistency.
- The Lower Glacial Till layer has a firm to hard consistency with pocket penetrometer results ranging from 1.0 to greater than 4.5 tsf with an average of 4.1 tsf (indicating a very stiff consistency). Average SPT results in the layer showed 33 BPF (blows per foot) correlating to a hard consistency.

Glacial Outwash - Lower Sand Layer (Silty Sand)

In Boreholes SB3, SB4, SB5, and SB9, beneath the clay layer, a Glacial Outwash - Lower Sand Layer (silty sand) is present. In SB3, SB4, and SB9 the Glacial Outwash layer extends to the end of the borehole. In SB5 the Glacial Outwash layer present below the clay layer starts at 12.5 feet below ground surface and is 2.5 feet in thickness. In SB5 a Glacial Outwash layer is also present from 38 feet below ground surface to the end of the borehole. SPT values between 40 and 103 blows per 12 inches indicate a dense to very dense state of compactness.

Silt

In borehole SB5, a silt layer is located between clay layers at 30 feet below ground surface and is 3 feet in thickness.

Groundwater

Subsurface water was observed in five borings (SB01, SB05, SB26, SB31, SB32) during Braun Intertec drilling. Subsurface water was not observed within any of the other Braun Intertec borings. At borings SB04, SB08, and SB12, mud rotary drilling techniques prohibited measurement of the groundwater levels. No long-term groundwater table measurements were made as borings were backfilled immediately after drilling. Table 4 summarizes the observed groundwater table information.

The HDR hand augured borings (SB19, SB20, and SB21) showed groundwater present at ground surface. Table 5 summarizes the HDR's groundwater observations.

Table 4. Groundwater Table Information Braun Intertec Borings

Braun Intertec Borehole	Depth Below Ground Surface (ft)	Water Level Elevation (ft) during drilling
SB01	24	1002.2
SB05	12	1007.9
SB26	7	1006.2
SB31	4.5	1010.3
SB32	4.5	1010.5

Table 5. Groundwater Table Information HDR Hand Augur Borings

HDR Borehole	Depth Below Ground Surface (ft)	Water Level Elevation (ft) during hand auguring
SB19	0	1011.5
SB20	0	1011.94
SB21	0	1010.58

At SB05, SB31, and SB32 groundwater levels are located in the Glacial Outwash layer (Upper Sand Layer) underlain by Glacial Till (clay). This could indicate the presence of an aquifer in the sand layer.

Since the clay soils are relatively slow draining, considerable time may be required for static groundwater level to be determined. The groundwater readings represent conditions at the time of the borings. Shallow groundwater may be present, especially in the peat areas. These variations may impact construction and require temporary dewatering during construction. It should be noted that groundwater levels will fluctuate seasonally and in response to climatic conditions.

4. Soil Parameters

Soil parameters used in the geotechnical analysis were obtained from a number of sources and are summarized in the Table 6 below. Each parameter is discussed in detail in the following paragraphs.

Table 6. Soil Parameters

Soil Type	ɣ (lbs/ft³)	S (CD)		Q (UU)		k_x (ft/sec)	K_y/k_x	M_v
		c'(lbs/ft²)	ϕ'	c(lbs/ft²)	ϕ			
Glacial Till - Upper	120	0	28	750	0	3.28E-08	0.25	0.0005
Glacial Till - Lower	130	0	28	2000	0	3.28E-08	0.25	0.0002
Glacial Till - Borrow Material	120	0	28	750	0	3.28E-08	0.25	0.0005
Glacial Outwash - Upper	115	0	35	0	35	9.84E-06	0.25	0.0002
Glacial Outwash - Lower	134	0	38	0	38	9.84E-06	0.25	0.0001
Peat	70	0	30	250	30	3.28E-06	1.00	0.0067

Unit Weight

Laboratory results were utilized for selecting the unit weight for the in-situ Glacial Till (clay). It was assumed that the Glacial Till fill (borrow material) used for building the embankment will have the same unit weight as the Upper Glacial Till.

The unit weight for the Lower and Upper Glacial Outwash (sand) layer was determined using blow count information from the borehole logs in conjunction with Table 5.3 from Muni Budhu 2000.

The unit weight for the peat was developed using an estimated saturated unit weight from the Muskeg Engineering Handbook by Ivan C. Macfarlane, 1969.

Drained Strengths

Drained strengths were developed from several sources. Drained strengths for the Upper and Lower Glacial Till (clay) were developed from test results for plasticity index (PI) used in conjunction with the plot of peak friction angle vs. PI in Duncan et al. in CGPR#4, 1989. Although we would anticipate the Upper and Lower Glacial Till (clay) layers having long-term cohesion (likely 50 to 100 psf) given its fines content (CGPR #4), we have generally adopted a conservative long-term cohesion of 0 psf. However, for the drawdown condition at the diked inlet, we assumed a nominal cohesion of 25 lbs/ft² in the Upper Glacial Till layer to limit the surficial (infinite slope) failure surfaces and reduce conservatism.

The drained strength for the Lower and Upper Glacial Outwash (sand) layer was determined using blow count information from the borehole logs in conjunction with Table 5.3 from Muni Budhu 2000.

Due to lack of field and laboratory date available, the friction angle for the peat layer selected was 30 degrees using the DST Design Guideline for Peat (2008).

Undrained Strengths

Undrained strengths for the Upper and Lower Glacial Till (clay) layers were determined utilizing the N values and pocket penetrometer data from the borehole logs.

An undrained shear strength of 750 psf was chosen for the Glacial Till (clay) borrow material to be consistent with the strength of the Upper Glacial Till (clay), which is conservative given the recommendations for borrow material in Table 1 in USACE, Compacted Strength of Fill, 1986.

Pocket penetrometer data was only available from with one reading within the peat layer on the borehole logs. It was of 0.5 tsf in SB05 (indicating at undrained shear strength of 500 psf). The 500 psf value was reduced using a correction factor of ½ as suggested by Mesri and Ajlouni (2007).

Unless the peat and organic clay is entirely undercut and removed within the embankment, which is recommended, supplemental laboratory testing (moisture content, Atterberg limits, strength testing, consolidation testing) should be performed to better to better characterize the peat parameters.

Drained strengths were used for the Lower and Upper Glacial Outwash (sand) units due to the fact that they are granular materials.

Permeability, K_y/K_x, M_v, and O_w

Permeability values and K_y/K_x ratios for the Glacial Till, Glacial Outwash, and Borrow material were determined from Table 1 - *Permeability Values Recommended by the Board of Senior Consultants for the Natomas Levee Improvement Project (January 31, 2010).*

Due to lack of information available, permeability for the peat was developed from Mesri and Ajlouni (2007). Permeability testing of the materials should be considered to better characterize the drainage characteristics.

Coefficient of Compressibility values (Mv) we determined from Table C10.4.6.3-1 of the AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014.

The same Saturated Volumetric Water Content (O_w) was calculated for all soil layers utilizing and average water content from the borehole logs of 16%.

5. Seepage Analysis and Slope Stability

Seepage analysis and slope stability was evaluated using the Geo-Studio 2016 version 8.16.1.13452 SEEP/W and SLOPE/W software and the adopted strength and drainage parameters summarized in Table 5. In addition to soil parameters, information related to cross section geometry and design water surface was required for the stability models.

Cross Section Geometry and subsurface stratigraphy

Cross sections for the stability models (Impoundment Levee ad Diked Inlet) were developed using available topographic information and the proposed geometries illustrated in Figures 2 and 3. The top of the ground surface for the proposed geometries in Figures 2 and 3 was generally assumed to correspond with the top of the ground surface for the applicable borings and the subsurface stratigraphy (major soil type and thicknesses of respective layers) underlying the Impoundment Levee and Diked Inlet.

Figure 2. Typical Cross Section of Impoundment

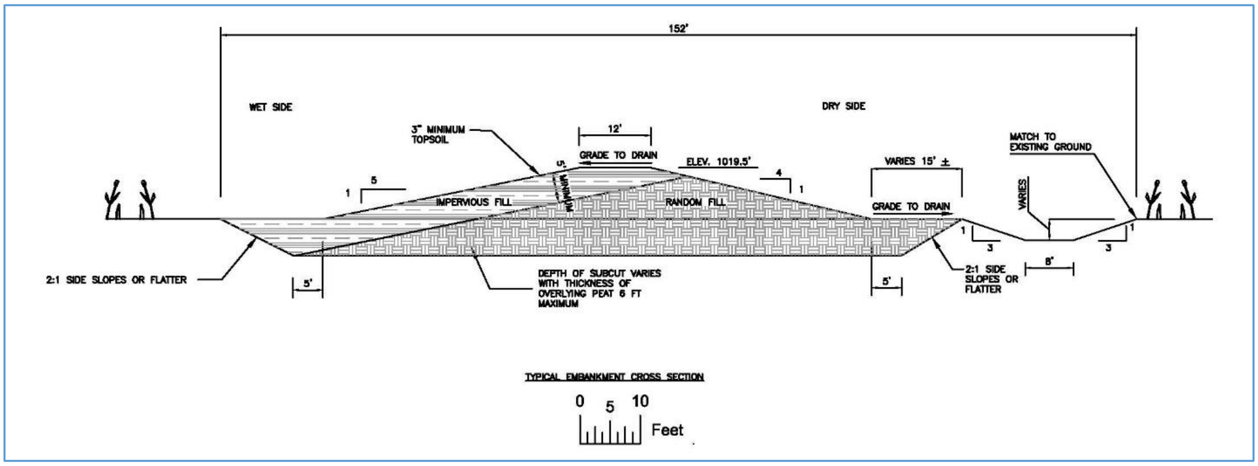
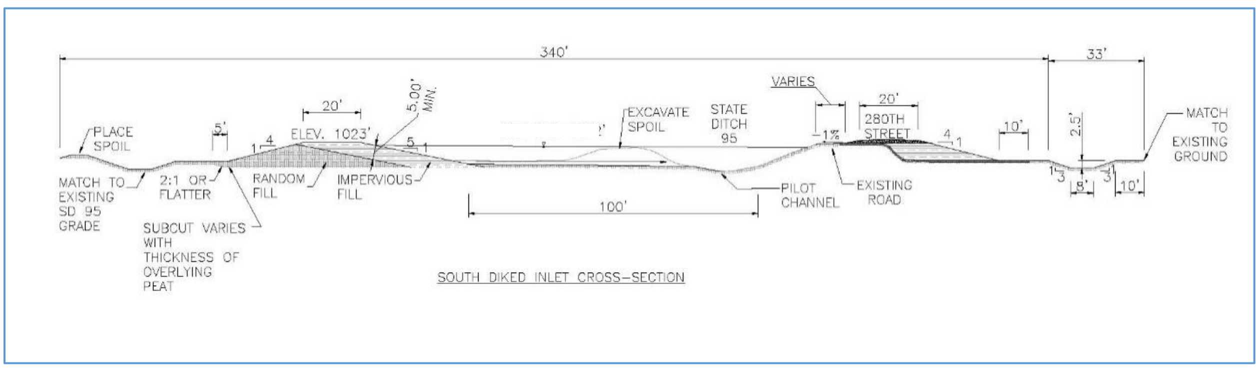


Figure 3. Typical Cross Section of Diked Inlet



Design Water Surfaces

For the model, the water level at ground surface was assumed for end of construction. A water surface elevation of 1017 feet was assumed for the Impoundment sections, 1021 (SB08 section) and 1023 (SB05 section) feet were assumed for the Diked Inlet sections. This correlates with the elevation of a 100 year event.

Design Criteria

Seepage and slope stability criteria and guidance as defined in EM 1110-2-1913, “Design and Construction of Levees” was used to evaluate the Impoundment Levee and Diked Inlet.

Design Conditions

The above information was used to develop stability models for the short- term (end of construction), long term (steady state seepage), and sudden drawdown conditions, which were evaluated as recommended in EM 1110-2-1913.

Short Term - End of Construction

Stability models for this condition simulate the response of the soils immediately after the construction of the embankments. This is considered an unconsolidated and undrained condition since the soils have not had sufficient time to consolidate or to drain off the excess pore pressures that result from the additional loading. Results and output contained in this report are for failures modeled on the dry side of the embankment. Although not shown in this report, the wet side was analyzed as well.

Long Term - Steady State Seepage

Stability models for this condition simulate the response of the soils to steady state seepage conditions in the absence of excess pore pressures. Drained soil strengths are used for this analysis. Results and output contained in this report are for failures modeled on the dry side of the embankment. Although not shown in this report, the wet side was analyzed as well.

Sudden Drawdown

As stated in EM 1110-2-1913, "Design and Construction of Levees" this case represents the condition whereby a prolonged flood stage saturates at least the major part of the wet embankment portion and then falls faster than the soil can drain. This causes the development of excess pore water pressure which may result in the slope on the wet side of the embankment becoming unstable. Failure was modeled on the wet side.

Factor of Safety

The levee was evaluated using the USACE criteria for levees as defined in EM 1110-2-1913. It states that a minimum factor of safety of 1.3 is required for the short term condition. For the long term stability condition a factor of safety of 1.4 is required. For sudden drawdown, the condition that was modeled was for pool levels prior to drawdown for conditions where these water levels are unlikely to persist for long periods preceding drawdown. The modeled pool levels prior to drawdown were 1017 feet in elevation for the Impoundment sections and 1021 (SB08 section) and 1023 (SB05 section) feet in elevation for the Diked Inlet sections. A minimum factor of safety of 1.0 is required for this condition. All factors of safety determined for the embankment were above or equal to minimum requirements.

Seepage and Stability Analysis

Seepage and slope stability analysis were performed at two critical Impoundment embankment sections and two critical Diked Inlet sections based on the estimated height of the embankment and the encountered subsurface conditions at the site. Figures 2 and 3, which were presented previously, show typical cross sections of the Impoundment and Diked Inlet. From review of the test borings at the site as well as the existing topography, these critical locations were determined to be as follows:

- At a section along the Impoundment with subsurface stratigraphy resembling SB31 and SB32 using a levee height of 8.5 feet. The subsurface stratigraphy consists of topsoil or fill underlain by a 6 feet Glacial Outwash layer (Upper Sand Layer) underlain by the Glacial Till layer (Clay Layer). The elevation at the top of the Impoundment levee was modeled at 1019.5 feet in elevation. The water level inside the impoundment was modeled at 1017 feet elevation.
- At a section along the Impoundment with subsurface stratigraphy resembling the 4 foot peat layer at SB21 underlain by the Glacial Till layer (clay layer) using a levee height of 8.5 feet. The Glacial Till layer was modeled using information from surrounding Braun Intertec boreholes. The elevation at the top of the Impoundment levee was modeled at 1019.5 feet in elevation. The water level inside the impoundment was modeled at 1017 feet elevation.
- At a section along the north embankment of the Diked Inlet with subsurface stratigraphy resembling SB5. The section was modeled using geometry from the hydraulic model for 100 year event. The north embankment consists of the existing 280th Street being built up with borrow clay. This location was analyzed due to the 2.5 foot thick Glacial Outwash (sand) layer found in between the Glacial Till (clay) layer at 12.5 feet below ground surface. The elevation at the top of the Diked Inlet was modeled at 1026.5 feet in elevation. The water level inside the Diked Inlet was modeled at 1023 feet in elevation. The water level on the dry side was modeled to the top of the ditch on the dry side of the embankment as per the 100 year event.
- At a section along the south embankment of the Diked Inlet with subsurface stratigraphy resembling SB8. The section was modeled using geometry from the hydraulic model for 100 year event. This location was analyzed due to peat layer that extends to 4.5 feet below ground surface. The elevation at the top of the Diked Inlet was modeled at 1022 feet in elevation. The water level inside the Diked Inlet was modeled at 1021 feet in elevation. The water level on the dry side was modeled to the top of the ditch dry side of the embankment as per the 100 year event.

Seepage Analysis Results

Seepage analysis was based on USACE EM 1110-2-1913 manual guidelines that state the maximum allowable exit hydraulic gradient should be 0.5. The three cross sections that have a random fill area in the embankment were modeled with Glacial Till (clay) borrow, then Glacial Outwash (sand) borrow. Attachment D includes figures of the SEEP/W seepage analysis results. The Diked Inlet section that models the north embankment (building up 280th Street) specifies that Glacial Till (clay) borrow must be used for the embankment build up due to the unknown materials in the existing 280th Street embankment. The SEEP/W *Saturated Only* Material Model was used.

As specified in EM 1110-2-1913, the maximum allowable exit gradient was not greater than 0.5. Seepage results for the Impoundment and Diked Inlet cross sections show no seepage concerns in the design.

Slope Stability Analysis Results

The minimum factors of safety calculated for each section under the various loading conditions are represented in Table 7. Attachment E includes figures of the SLOPE/W slope stability analysis results.

As with the seepage analysis, the three cross sections that have a random fill area in the embankment were modeled with Glacial Till (clay) borrow, then Glacial Outwash (sand) borrow. The analyses indicate that the proposed Impoundment and Diked Inlet sections exceed or equal the minimum requirements for each condition. However, it should be noted that these analyses assumed that overlying peat/topsoil/fill has been removed from beneath the embankment (with undercut extending a minimum of 5 feet outside the proposed footprint of the embankment) and replaced with suitable fill material. The phreatic surface created from the SEEP/W models was used for the SLOPE/W models.

Table 7. Factor of Safety Results for Slope Stability

Condition		Factor of Safety Required	Estimated Factor of Safety from Slope/w Analysis			
			Impoundment at SB31/32	Impoundment at SB21	Diked Inlet North Embankment at SB5	Diked Inlet South Embankment at SB8
Random Fill is Clay	**Short Term (end of construction)**	1.30	1.7	>2.0	>2.0	>2.0
	Long Term (steady seepage from full flood stage)	1.40	1.7	1.7	1.5	1.5
	Sudden Drawdown	1.00	1.2	1.4	1.2	1.3
Random Fill is Sand	**Short Term (end of construction)**	1.30	1.7	>2.0	N/A	>2.0
	Long Term (steady seepage from full flood stage)	1.40	1.6	1.5	N/A	1.7
	Sudden Drawdown	1.00	1.2	1.4	N/A	1.3

Building over Peat

With additional geotechnical design and field work including detailed peat and soil sampling and testing, constructing over peat (leaving the peat in place) may be an option. Also known as “floating” fill over peat, allowance for settlement must be taken into account. Often a design with a height of more than 6 to 10 feet staged construction would be required with one or two months waiting time in between 1 foot lifts to allow for strength gain in the peat (DST Design Guideline for Peat, 2008). Careful construction observation is important because if the peat doesn’t settle evenly cracks in the clay embankment could appear. Also, if the underlying peat bottom is sloping, vast quantities of fill can disappear by running out under the almost weightless peat before the situation finally stabilizes. Warning signs include cracks, a mud wave or sudden sink holes appearing in the embankment. Building over peat is not common practice, but it has been done successfully.

6. Other Considerations

Settlement

The analysis of settlement of the Diked Inlet and Impoundment levees has not been completed for this report. This issue will be addressed in the plans and specs phase of the Project and will likely result in overbuilding of at least a portion of the levee/embankment system. For the purposes of preliminary estimates, a six inch overbuild section (assuming peat/organic clay has been undercut and removed) is assumed for embankment heights 8 feet or greater.

7. Additional Work

Additional geotechnical work will be required if this Project advances to the plans and specifications phase.

Impoundment Levee and Diked Inlet

Additional field investigations and testing will be required along the embankment alignment to better define subsurface conditions and soil strengths. The additional field investigations will be most critical in locations where the embankment is highest or soft subsurface materials have been encountered and should include locations proposed during the preliminary field investigation, which were inaccessible due to soft surficial soils.. Obtaining and testing undisturbed samples is recommended to more accurately define the shear strength of the native soils along the alignment and to define settlement parameters. This will allow for more accurate stability analyses along the embankment as well as settlement analyses for the embankment.

Scour protection will be designed for overflow structures, inlets, and outlets for all culverts passing through the embankment, and for wave action on the embankment. Drainage fill will be designed for culverts passing through embankments.

8. Limitations

This report presents the preliminary findings, conclusions and recommendations for the seepage and slope stability analysis geotechnical aspects of the proposed Klondike Clean Water Retention Project #11 and related features. It has been prepared in accordance with generally accepted engineering practice and in a manner consistent with the level of care and skill for this type of project within this geographic area. No warranty, expressed or implied, is made.

The conclusions and recommendations presented herein are based on research and available literature, the results of field exploration and laboratory materials testing, and the results of engineering analyses. Only 17 geotechnical borings were drilled and limited laboratory testing was performed for the project. The borings represent the conditions at the explored locations, but may not be representative of the conditions throughout the project.

Geotechnical engineering and the geologic sciences are characterized by uncertainty. Professional judgments presented herein are based partly on our understanding of the proposed construction, partly on our general experience, and on the state-of-the-practice at the time of this writing.

9. Abbreviations

ASTM. American Society for Testing and Materials.

MGS. Minnesota Geological Survey.

USACE. United States Army Corps of Engineers.

10. References

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11. Attachments

Attachment A – Geologic Maps

Attachment B – Boring Locations

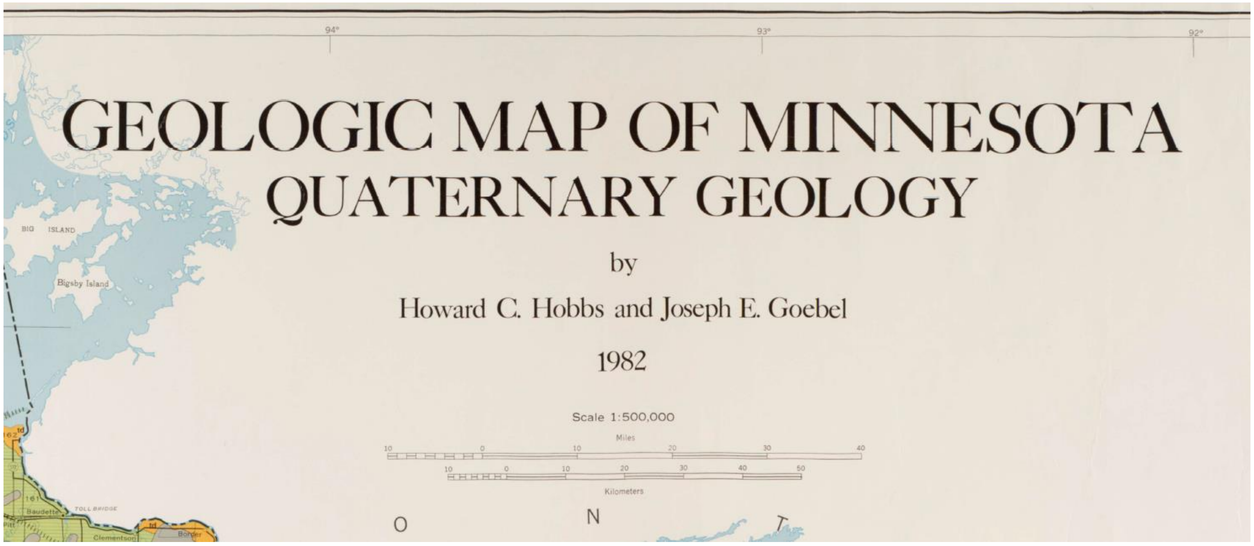
Attachment C – Borehole Logs and Laboratory Test Results

Attachment D – SEEP/W Seepage Analysis Results

Attachment E – SLOPE/W Slope Stability Analysis Results

Attachment A

Geologic Maps


94°
93°
92°
GEOLOGIC MAP OF MINNESOTA
QUATERNARY GEOLOGY
by
Howard C. Hobbs and Joseph E. Goebel
1982
Scale 1:500,000
Miles
Kilometers
BIG ISLAND
Bigsby Island
Baudette
TOLL BRIDGE
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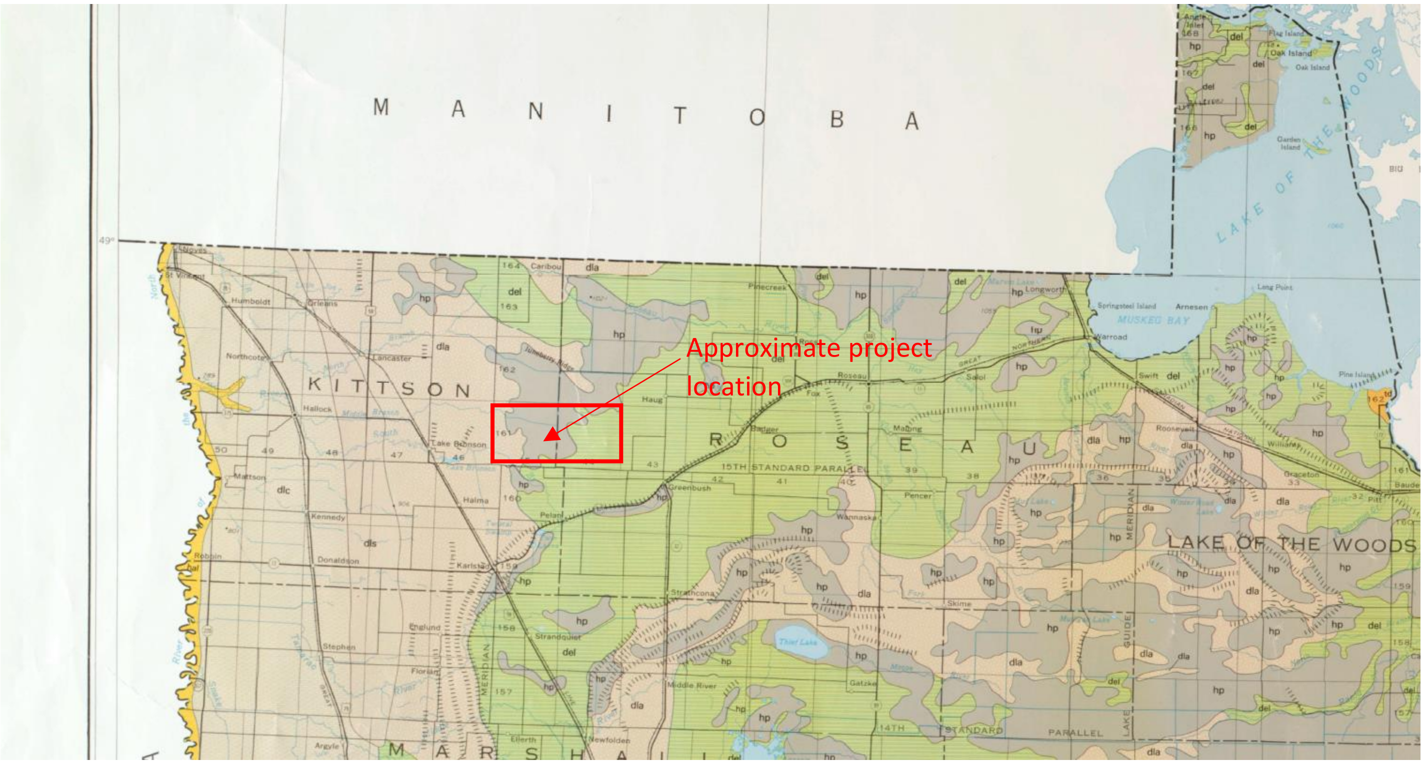
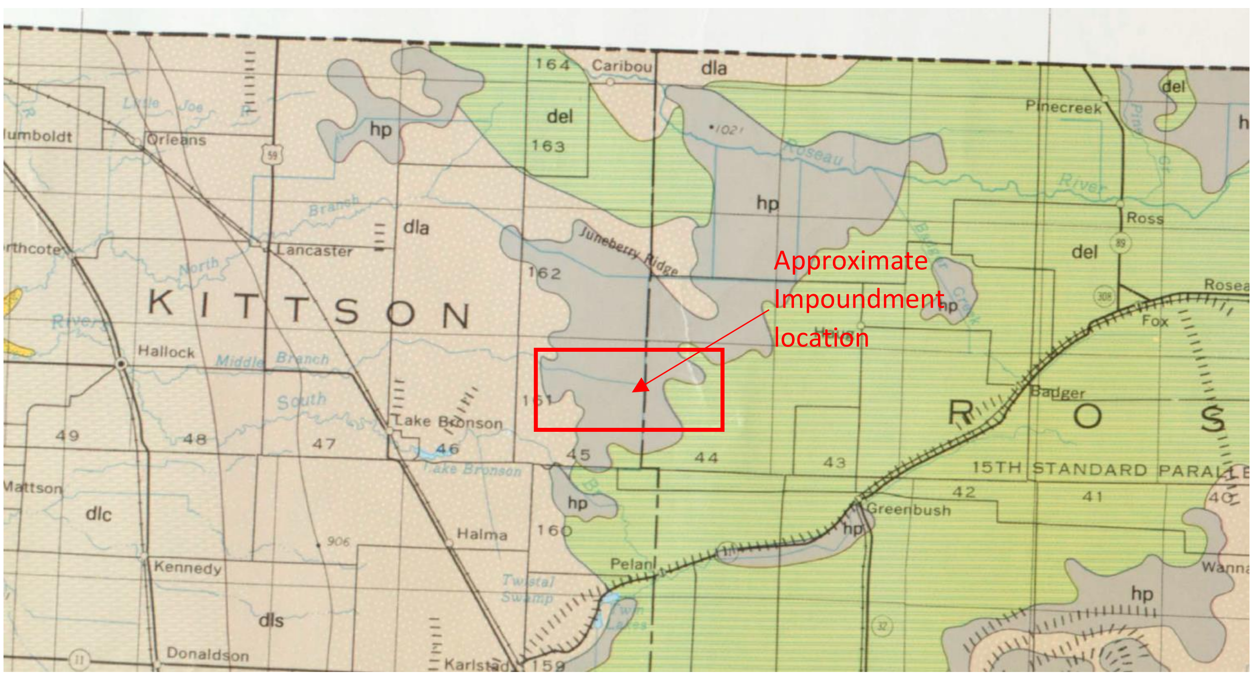

MANITOBA
KITTSON
ROSEAU
LAKE OF THE WOODS
15TH STANDARD PARALLEL
Approximate project location


KITTSON
ROS
Caribou
Orleans
Lancaster
Hallock
Lake Bronson
Halma
Kennedy
Donaldson
Mattson
Pelan
Greenbush
Badger
Fox
Ross
Pinecreek
Juneberry Ridge
15TH STANDARD PARALLE
Approximate Impoundment location

DESCRIPTION OF MAP UNITS

m MINE PITS AND DUMPS (HOLOCENE).

hp PEAT (HOLOCENE)—*organic deposits in wetlands; mapped only where contiguous deposit exceeds about 4 square miles.*

hal ALLUVIUM (HOLOCENE)—*sand and gravel, silt, and clay deposited in channels and floodplains of modern streams. Mapped only where the width of the floodplain exceeds about half a mile. Narrow valleys containing outwash or terrace units, as well as alluvium, are mapped as the dominant unit.*

td TERRACES (HOLOCENE TO PLEISTOCENE)—*remnants of former channels and floodplains above the levels of present floodplains, and below the levels of adjacent moraine or outwash surfaces. Predominantly sand and gravel, but finer grained material also occurs, especially in the terraces along small tributaries of the Mississippi River. Parts of some terraces are scoured surfaces rather than deposits.*

co COLLUVIUM (HOLOCENE TO PLEISTOCENE)—*unsorted slope sediment composed largely of rock rubble in a matrix of finer grained material. Bedrock outcrops commonly present.*

DEPOSITS ASSOCIATED WITH THE DES MOINES LOBE (PLEISTOCENE, LATE WISCONSINAN)—*gray calcareous drift (buff to brown where oxidized); shale and limestone clasts generally common, derived from Manitoba and eastern North Dakota; combined silt and clay typically exceeds 50% of till.*

ERSKINE MORAINE ASSOCIATION—*limestone clasts common, but shale relatively uncommon. Generally clayey because of reworked lake sediment. An extremely clayey till deposited by a readvance into Glacial Lake Agassiz is included in this association.*

del *Lake-modified till; wave-planed, mantled with lake sediments too thin and patchy to map separately.*

deg *Ground moraine; the easternmost part of this unit is thinly draped over bedrock hills.*

des *Stagnation moraine.*

BIG STONE MORAINE ASSOCIATION—*contemporaneous with the St. Louis sublobe (Culver and Sugar Hills moraine associations). Where it forms the outer boundary of the Des Moines lobe, it may include till of the Bemis and Altamont moraine associations.*

dsl *Lake-modified till.*

dsg *Ground moraine.*

dss *Stagnation moraine.*

CULVER MORAINE ASSOCIATION—*represents the southeastern part of the St. Louis sublobe. Generally reddish brown and clayey because it incorporated red sediment from earlier glacial lakes. Commonly noncalcareous; sporadically distributed shale and limestone clasts.*

dcl *Lake-modified till.*

dcg *Ground moraine.*

dce *End moraine; relatively subdued. The topography of much of this unit reflects underlying moraines such as the Mille Lacs-Highland moraine.*

SUGAR HILLS MORAINE ASSOCIATION—*represents the northwestern part of the St. Louis sublobe. Reddish-colored lake sediments incorporated only locally.*

dhg *Ground moraine.*

dhe *End moraine.*

ALTAMONT MORAINE ASSOCIATION—*includes correlatives of both the Altamont and Algona moraines of Iowa.*

dag *Ground moraine.*

das *Stagnation moraine.*

PINE CITY MORAINE ASSOCIATION—*represents the Grantsburg sublobe. Includes areas of interbedded red and gray drift resulting from incorporation of underlying Superior-lobe drift.*

dpg *Ground moraine.*

dpe *End moraine; the topography of much of this unit reflects the underlying St. Croix moraine.*

BEMIS MORAINE ASSOCIATION—*forms the outermost moraine association for the southern part of the Des Moines lobe.*

dbg *Ground moraine.*

dbe *End moraine.*

dbt *Shale-bearing loess-covered drift outside the Bemis moraine on the west side of the lobe. Older than the Bemis moraine, but much younger than the highly eroded old gray drift outside the Des Moines lobe.*

do OUTWASH—*undivided as to moraine association.*

GLACIAL LAKE SEDIMENT—*undivided as to moraine association.*

dla *Sand and gravel.*

dls *Silt and fine sand.*

dlc *Clay and clayey silt.*

DEPOSITS ASSOCIATED WITH THE SUPERIOR LOBE (PLEISTOCENE, LATE WISCONSINAN)—reddish-brown noncalcareous drift; clasts predominantly igneous and metamorphic rocks of the Canadian Shield, but also present are distinctive clasts from the Superior basin, including red sedimentary rocks, amygdaloidal basalt, red rhyolite and agate.

NICKERSON MORAINE ASSOCIATION—*clayey till, locally calcareous, resulting from the incorporation of pro-glacial lake sediment.*

sng *Ground moraine; includes clayey till along the North Shore of Lake Superior, some of which may be related to the Cloquet moraine association.*

sne *End moraine.*

CLOQUET MORAINE ASSOCIATION— *clayey till; thin and patchy throughout much of its extent.*

scg *Ground moraine.*

scs *Stagnation moraine; topography probably inherited from the Mille Lacs-Highland moraine association.*

MILLE LACS-HIGHLAND MORAINE ASSOCIATION—*sandy, stony till.*

smg *Ground moraine; drumlins and flutes common. In the fluted terrain along the North Shore of Lake Superior, the drift is thin, and the flutes are partly formed in bedrock.*

sme *End moraine.*

ST. CROIX MORAINE ASSOCIATION—*sandy, stony till; locally calcareous in the Twin Cities area because of incorporated local limestone bedrock.*

ssg *Ground moraine; the contact between this unit and the equivalent unit of the Rainy lobe (rsg) is arbitrarily located within a transitional zone.*

sse *End moraine.*

so OUTWASH—*undivided as to moraine association; includes scoured bedrock surfaces in meltwater channels.*

GLACIAL LAKE SEDIMENT—

sla *Sand and gravel; includes postglacial spit at Duluth.*

slc *Clay and clayey silt.*

DEPOSITS ASSOCIATED WITH THE RAINY LOBE (PLEISTOCENE, LATE WISCONSINAN)—*brown to gray noncalcareous drift; clasts predominantly igneous and metamorphic rocks of the Canadian Shield.*

VERMILION MORAINE ASSOCIATION—*contemporaneous with the Mille Lacs-Highland moraine association; till is extremely sandy and stony, containing only trace amounts of clay.*

rvg *Ground moraine; in most of this area, the till is thin and patchy over a hilly terrain of scoured bedrock.*

rve *End moraine; moraine ridges are narrow and generally lack collapse features.*

NASHWAUK MORAINE ASSOCIATION—*noncalcareous, brown silty till. No end moraine recognized; ice margin unknown; texture of the till implies that the ice retreated far enough north of the Mesabi Range to develop a proglacial lake; the ice then readvanced over the lake sediment, incorporating it into the till.*

rng *Ground moraine; includes areas of thin drift over bedrock.*

rns *Stagnation moraine; some of the hilly topography in the area of this unit may be inherited from the underlying St. Croix moraine association; some topographic expression is controlled by the bedrock surface.*

ST. CROIX MORAINE ASSOCIATION—*till is generally sandy and stony; near the St. Croix moraine it locally includes calcareous drift incorporated from the underlying Wadena-lobe drift.*

rsg *Ground moraine; drumlins locally common.*

rse *End moraine; locally composed largely of ice-contact sand and gravel. Parallel ridges appear to be large-scale thrust features composed mainly of the underlying Wadena lobe drift.*

ro OUTWASH—*undivided as to moraine association.*

DEPOSITS ASSOCIATED WITH THE WADENA LOBE (PLEISTOCENE, EARLY AND LATE WISCONSINAN)—*gray calcareous drift (buff where oxidized); limestone clasts common, but shale rare to absent.*

ITASCA MORAINE ASSOCIATION—*till is less clayey than the till of the Des Moines lobe. Contains many buried channels.*

wig *Ground moraine.*

wie *End moraine; contains numerous features believed to have been produced by ice-thrust.*

ALEXANDRIA MORAINE ASSOCIATION—*till is more sandy and less calcareous than the till of the Itasca moraine association.*

wag *Ground moraine; mostly drumlins.*

was *Stagnation moraine; mantled in places by drift of the Des Moines lobe, which overrode the moraine while it still contained stagnant ice.*

wo OUTWASH—*undivided as to moraine association.*

DEPOSITS INFERRED TO BE PRE-WISCONSINAN IN AGE

prd RED DRIFT (PLEISTOCENE, PRE-WISCONSINAN)—*traditionally assigned to the Illinoian Glaciation; predominantly ice-contact stratified drift.*

pgd GRAY DRIFT (PLEISTOCENE, PRE-WISCONSINAN)—*traditionally assigned to the Kansan Glaciation; may contain two or more separate drift sheets. Dissected, locally loess-covered.*

lr WEATHERING RESIDUUM OVER BEDROCK (PLEISTOCENE, PRE-WISCONSINAN)—*Loess-covered; includes remnants of highly eroded old drift and slopewash sediment.*

GEOMORPHIC FEATURES

BEACHES AND STRANDLINES OF GLACIAL LAKES—long, narrow, sand and gravel deposits and wave-cut scarps. Includes postglacial beach ridges on Upper Red Lake and Lake of the Woods.

ESKERS—long ridges of sand, gravel, cobbles, and boulders deposited in ice-walled channels of glacial streams. Length shown to scale; width exaggerated.

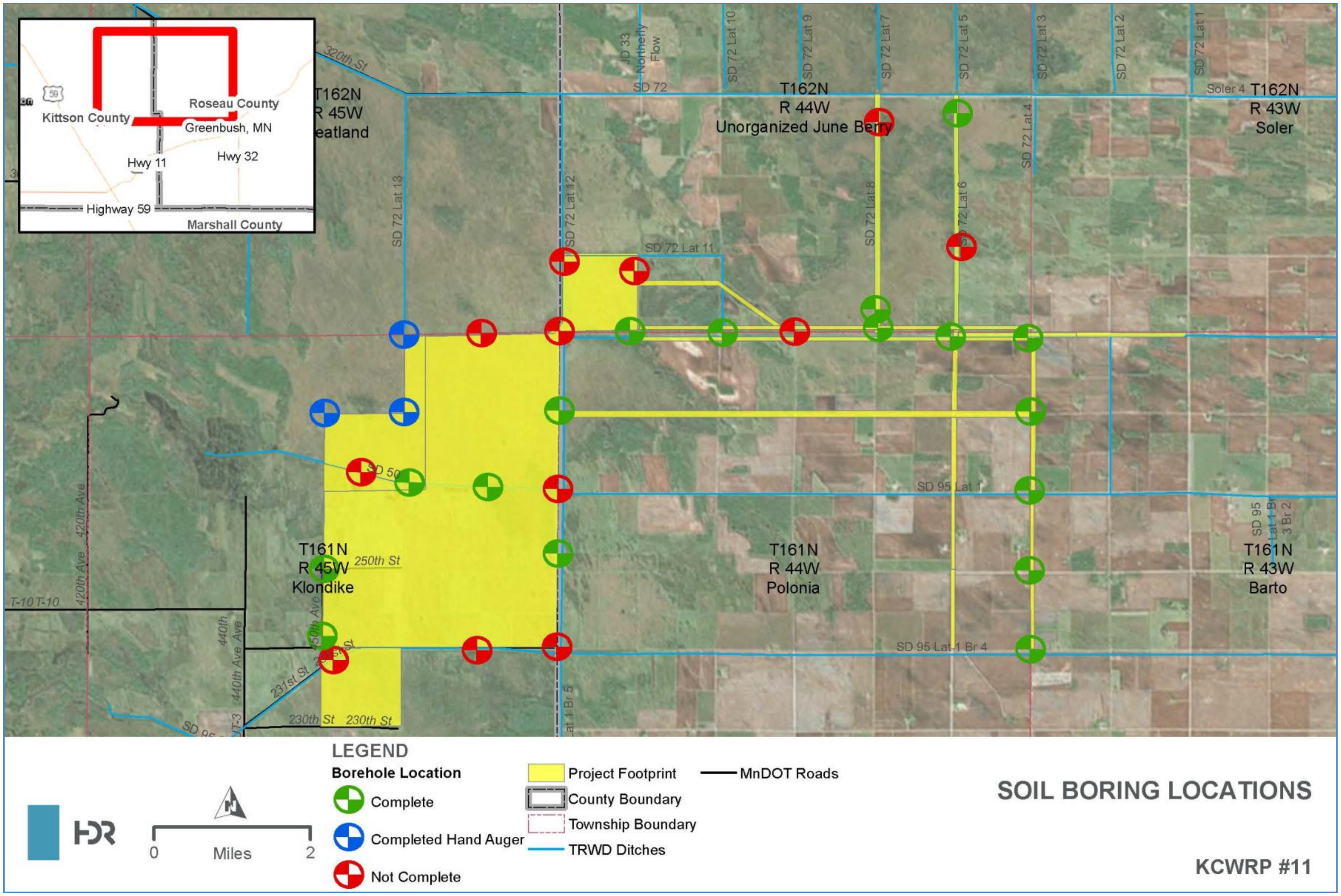
BURIED CHANNELS AND TUNNEL VALLEYS—distinct to subdued topographic troughs, now commonly occupied by chains of lakes, wetlands, and small streams. Tunnel valleys commonly contain eskers, many of which are too small to map.

MELTWATER CHANNELS—symbol used to indicate channels not otherwise shown on the map, e.g., channel cut into outwash of the same lobe.

DRUMLINS AND FLUTES—elongated and streamlined hills molded by the passage of glacial ice. Drumlins are composed of drift; flutes are largely bedrock with a veneer of drift. Some of these features have been mantled by thin drift of a subsequent ice advance.

Attachment B

Boring Locations


Kittson County
Roseau County
Greenbush, MN
Hwy 11
Hwy 32
Highway 59
Marshall County
320th St
T162N
R 45W
eatland
SD 72
T162N
R 44W
Unorganized June Berry
Soler 4
T162N
R 43W
Soler
SD 72 Lat 13
SD 72 Lat 12
SD 72 Lat 11
SD 72 Lat 10
SD 72 Lat 9
SD 72 Lat 8
SD 72 Lat 7
SD 72 Lat 6
SD 72 Lat 5
SD 72 Lat 4
SD 72 Lat 3
SD 72 Lat 2
SD 72 Lat 1
JD 33
Northerly Flow
SD 50
SD 95 Lat 1
SD 95 Lat 1 Br 4
250th St
420th Ave
440th Ave
231st St
230th St
T-10
T161N
R 45W
Klondike
T161N
R 44W
Polonia
T161N
R 43W
Barto
LEGEND
Borehole Location
Complete
Completed Hand Auger
Not Complete
Project Footprint
County Boundary
Township Boundary
TRWD Ditches
MnDOT Roads
0
Miles
2
SOIL BORING LOCATIONS
KCWRP #11

Attachment C

Borehole Logs and Laboratory Test Results

LOG OF BORING

BRAUN INTERTEC

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-01**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/15/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	qp tsf	Tests or Notes
0.8	CL	LEAN CLAY with SAND, trace roots, black, moist. (Topsoil)	6				
	CL	SANDY LEAN CLAY, trace Gravel, brown, moist, rather soft to hard. (Glacial Till)	4		15		LL=27, PL=11, PI=16
			6		13	2 1/2	WD= 145 pcf, DD= 128 pcf
		-with GRAVEL at 7 feet.	23				
			36			4.5+	
		-gray at 12 feet.	21			4.5+	An open triangle in the water level (WL) column indicates the depth at which groundwater was first observed while drilling.
			32			4.5+	
			69			4.5+	
				▽			
			*				*50/3 inches.
			*				*98/8 inches.
			*				*50/3 inches (set).
41.0			125			4.5+	
		END OF BORING.					

Water observed at a depth of 24 feet with 24 1/2 feet of hollow-stem auger in the ground.

Water not observed to cave-in depth of 28 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-02**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/13/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
0.6	CL	SANDY LEAN CLAY, trace Gravel and roots, black and brown, moist. (Topsoil)	5			
	CL	SANDY LEAN CLAY, trace Gravel, brown, wet to moist, rather soft to hard. (Glacial Till)	5		2 1/2	
			14			
			23		4.5+	
		-with GRAVEL at 9 1/2 feet.	29		4.5+	
		-gray at 12 feet.	30			
			28			
			25		4.5+	
			*			*73/3 inches.
			*			*50/3 inches.
			85			
41.0			*			*50/0 inches (set).
		END OF BORING.				
		Water not observed with 39 1/2 feet of hollow stem auger in the ground.				
		Water not observed immediately after withdrawal of auger.				
		Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-03**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/16/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
0.5	CL	SANDY LEAN CLAY, trace Gravel and roots, black and brown, moist. (Topsoil)	6			
	CL	SANDY LEAN CLAY, a little Gravel, brown, moist, rather stiff to hard. (Glacial Till)	21			
			40			
			9		2	
		-gray at 9 1/2 feet.	12		4	
		-with GRAVEL at 12 feet.	23		4.5+	
			25		4.5+	
			33		4.5+	
			*			*50/2 inches (set). No recovery.
31.0			103			
	SM	SILTY SAND, fine-grained, gray, moist, very dense. (Glacial Outwash)				
		-a little Gravel at 34 1/2 feet.	*			*50/3 inches (set).
41.0		-with GRAVEL at 39 1/2 feet.	92			
		END OF BORING.				
		Water not observed with 39 1/2 feet of hollow stem auger in the ground.				
		Water not observed immediately after withdrawal of auger.				
		Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-04**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/16/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
0.8	CL	LEAN CLAY with SAND, trace roots, black, moist. (Topsoil)	5			
7.0	CL	LEAN CLAY with SAND, gray and brown, wet, rather soft to medium. (Glacial Till)	5			
			6		1	
31.0	CL	SANDY LEAN CLAY with GRAVEL, brown, moist, very stiff to hard. (Glacial Till)	43			
			19		4.5+	
			40			
		-gray at 14 1/2 feet.	25		4.5+	
			34		4.5+	
			*			*88/8 inches.
			*			*50/3 inches.
41.0	SM	SILTY SAND with GRAVEL, fine- to coarse-grained, brown, waterbearing, very dense. (Glacial Outwash)	*			*70/2 inches.
			63			
		END OF BORING.				
		Water not observed with 25 feet of hollow stem auger in the ground.				
		Final groundwater levels not determined due to mud rotary drilling methods below 25 feet.				
		Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1607623 Soil Borings and Laboratory Testing Levees for State Ditch 95 System Various Locations NW of Greenbush Greenbush, Minnesota	BORING: **SB-05** LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/16/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	qp tsf	Tests or Notes
2.0	CL	LEAN CLAY with SAND, trace roots, brown and black, moist. (Topsoil)	6				
7.0	CL	LEAN CLAY with SAND, gray and brown, wet, rather soft. (Glacial Till)	5			1	
			4		22	1/2	WD= 120 pcf, DD= 98 pcf
12.0	CL	SANDY LEAN CLAY, trace Gravel, brown, moist, rather stiff to very stiff. (Glacial Till)	9		14	3 1/2	LL=29, PL=11, PI=18
			22			4.5+	
14.5	SP-SM	POORLY GRADED SAND with SILT, gray, moist, dense. (Glacial Outwash)	40	▽			
30.0	CL	SANDY LEAN CLAY, a little Gravel, gray, moist, hard to very stiff. (Glacial Till)	58				
			36				
			28			4.5+	
33.0	ML	SILT, gray, moist, very dense. (Glacial Outwash)	*				*118/7 inches.
38.0	CL	SANDY LEAN CLAY with GRAVEL, gray, moist, hard. (Glacial Till)	63				
41.0	SP-SM	POORLY GRADED SAND with SILT, with GRAVEL, brown, waterbearing, very dense. (Glacial Outwash)	56				

END OF BORING.

Water observed at a depth of 12 feet with 13 feet of hollow-stem auger in the ground.

Water observed at a depth of 13 1/2 feet with a cave-in depth of 28 feet immediately after withdrawal of auger.

Boring then backfilled with bentonite grout.

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-07**
LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/17/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
2.0	CL	LEAN CLAY with SAND, trace roots, brown, wet. (Topsoil)	4			
4.0	CL	LEAN CLAY with SAND, brown and gray, wet, rather soft. (Glacial Till)	4		1	
	CL	SANDY LEAN CLAY, a little Gravel, brown, wet to moist, medium to hard. (Glacial Till)	6		1 1/2	
			38			
		-with GRAVEL at 9 1/2 feet.	34		4.5+	
		-gray at 12 feet.	35		4.5+	
			22		4.5+	
			21		4.5+	
			25		4.5+	
			79			
			70		4.5+	
41.0			111			
		END OF BORING. Water observed at a depth of 39 1/2 feet with 41 feet of hollow-stem auger in the ground. Water not observed immediately after withdrawal of auger. Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-08**

LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/19/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	qp tsf	Tests or Notes
1.0	CL	LEAN CLAY with SAND, trace roots, black, wet. (Topsoil)	5				
4.5	PT	PEAT, fibrous, black, wet, very soft. (Swamp Deposit)	5				
41.0	CL	LEAN CLAY with SAND, trace Gravel, brown and gray, moist, medium to hard. (Glacial Till)	8		14	1 1/2	WD= 141 pcf, DD= 124 pcf
			22		17	4.5+	LL=28, PL=11, PI=17
		-a little GRAVEL at 9 1/2 feet.	25				
			34			4.5+	
			31				
		-with Gravel at 19 1/2 feet.	47			4.5+	
		-gray at 24 1/2 feet.	35			4.5+	
			72			4.5+	
			*				*98/7 inches.
			99				

END OF BORING.

Water not observed with 5 feet of hollow stem auger in the ground.

Final groundwater levels not determined due to mud rotary drilling methods below 5 feet.

Boring then backfilled with bentonite grout.

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-09**

LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/22/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
1.0	CL	LEAN CLAY with SAND, trace roots, brown, wet. (Topsoil)	2			
3.0	PT	PEAT, fibrous, black, wet, very soft. (Swamp Deposit)	2		1/2	
12.0	CL	LEAN CLAY with SAND, brown and gray, wet to moist, soft to hard. (Glacial Till) -with GRAVEL at 7 feet.	5		1 1/2	
			29		4.5+	
			39		4.5+	
16.0	SM	SILTY SAND, fine-grained, gray, moist, very dense. (Glacial Outwash)	53			
			60			
		END OF BORING. Water not observed with 14 1/2 feet of hollow stem auger in the ground. Water not observed immediately after withdrawal of auger. Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

BRAUN INTERTEC

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-11**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/22/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
1.0	CL	LEAN CLAY with SAND, trace roots, brown, wet. (Topsoil)	4			
	PT	PEAT, fibrous, black, wet, very soft. (Swamp Deposit)	3			
5.0						
	CL	LEAN CLAY with SAND, trace Gravel, dark gray, wet to moist, soft to very stiff. (Glacial Till)	3			
			19			
		-with GRAVEL at 9 1/2 feet.	21			
			26		4.5+	
16.0		-gray at 14 1/2 feet.	22			
		END OF BORING.				
		Water not observed with 14 1/2 feet of hollow stem auger in the ground.				
		Water not observed immediately after withdrawal of auger.				
		Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1607623 **Soil Borings and Laboratory Testing** **Levees for State Ditch 95 System** **Various Locations NW of Greenbush** **Greenbush, Minnesota**	BORING: **SB-12** LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/17/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
2.0	CL	SANDY LEAN CLAY, trace roots, black, wet. (Topsoil)	7			
	CL	SANDY LEAN CLAY, a little Gravel, brown, wet, rather soft to hard. (Glacial Till)	5			
			5		1 1/2	
		-with GRAVEL at 7 feet.	19		4.5+	
		-gray at 9 1/2 feet.	24		3	
			34			
			20		4.5+	
			26			
			23		4	
			22		4.5+	
			27		2 1/2	
41.0			42		4.5+	
		END OF BORING. Water not observed with 5 feet of hollow stem auger in the ground. Final groundwater levels not determined due to mud rotary drilling methods below 5 feet. Boring then backfilled with bentonite grout.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING

BRAUN INTERTEC

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-15**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/17/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
2.0	CL	SANDY LEAN CLAY, with roots, black, moist. (Topsoil)	5			
	CL	SANDY LEAN CLAY, trace Gravel, brown and gray, wet, rather soft to hard. (Glacial Till)	5			
		-a little Gravel at 4 1/2 feet.	23			
		-with GRAVEL at 7 feet.	23		4.5+	
			31			
			*			*50/2 inches.
16.0		-gray at 14 1/2 feet.	25		4.5+	
		END OF BORING.				
		Water not observed with 14 1/2 feet of hollow stem auger in the ground.				
		Water not observed immediately after withdrawal of auger.				
		Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2016\07623.GPJ BRAUN_V8_CURRENT.GDT 11/10/16 11:32

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-23**

LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/18/16**	SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
2.0	FILL	FILL: Silty Sand, fine- to medium-grained, trace Gravel, brown, moist.	FA			
4.0	PT	PEAT, fibrous, black, wet, very soft. (Swamp Deposit)	4			
7.0	OL	ORGANIC CLAY, black, wet, very soft. (Swamp Deposit)	3			
16.0	CL	LEAN CLAY with SAND, trace Gravel, brown and gray, wet, medium to very stiff. (Glacial Till) -a little Gravel at 9 1/2 feet. -with GRAVEL at 12 feet, gray.	6 11 28 23		 4.5+ 4.5+ 4.5+	
		END OF BORING. Water not observed with 14 1/2 feet of hollow stem auger in the ground. Water not observed immediately after withdrawal of auger. Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2016\07623.GPJ BRAUN_V8_CURRENT.GDT 11/10/16 11:32

LOG OF BORING

Braun Project B1607623 Soil Borings and Laboratory Testing Levees for State Ditch 95 System Various Locations NW of Greenbush Greenbush, Minnesota	BORING: SB-24 LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/18/16	SCALE: 1" = 8'

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
1.0	PT	PEAT, fibrous with roots, black, wet, very soft. (Swamp Deposit)	2			
	CL	LEAN CLAY with SAND, trace Gravel, brown, wet to moist, soft to very stiff. (Glacial Till)	3			
		-with a little Gravel at 4 1/2 feet.	4			
			10		4.5+	
		-with GRAVEL at 9 1/2 feet.	23		4.5+	
			20		4.5+	
16.0			17		4.5+	
		END OF BORING.				
		Water not observed with 14 1/2 feet of hollow stem auger in the ground.				
		Water not observed immediately after withdrawal of auger.				
		Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

BRAUN INTERTEC

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-26**

LOCATION: See sketch.

DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/18/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol		Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
4.0	OL		ORGANIC CLAY with roots, black, wet, very soft. (Swamp Deposit) -gray at 2 feet.	2 3			
16.0	CL		SANDY LEAN CLAY, trace Gravel, brown and gray, wet, soft to hard. (Glacial Till) -a little Gravel at 7 feet. -with GRAVEL at 9 1/2 feet. -gray at 14 1/2 feet.	3 16 18 * 36	▽	4.5+	*105/2 inches. No recovery.
			END OF BORING. Water observed at a depth of 7 feet with 7 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 8 feet immediately after withdrawal of auger. Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1607623 Soil Borings and Laboratory Testing Levees for State Ditch 95 System Various Locations NW of Greenbush Greenbush, Minnesota	BORING: SB-27 LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/19/16	SCALE: 1" = 8'

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
1.0	CL	LEAN CLAY, trace roots, black, moist. (Topsoil)	WH			
	CL	LEAN CLAY with SAND, trace Gravel, brown and gray, wet to moist, very soft to hard. (Glacial Till)	4		1	
			4		1 1/2	
			5		1	
			6		1 1/2	
		-with GRAVEL at 12 feet, gray.	44		4.5+	
16.0			39			
		END OF BORING. Water not observed with 14 1/2 feet of hollow stem auger in the ground. Water not observed immediately after withdrawal of auger. Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN℠ INTERTEC

LOG OF BORING

Braun Project B1607623 Soil Borings and Laboratory Testing Levees for State Ditch 95 System Various Locations NW of Greenbush Greenbush, Minnesota	BORING: SB-31 LOCATION: See sketch.

DRILLER: G. Bevre	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/18/16	SCALE: 1" = 8'

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
4.0	FILL	FILL: Silty Sand, fine- to medium-grained, trace roots, black and brown, wet. -black, brown and gray at 2 feet.	6 7		
7.0	SM	SILTY SAND, fine-grained, gray, waterbearing, medium dense. (Glacial Outwash)	16	▽	
16.0	CL	SANDY LEAN CLAY with GRAVEL, gray, wet, hard. (Glacial Till)	62 * 105 *		*50/2 inches. *50/3 inches.
		END OF BORING. Water observed at a depth of 4 1/2 feet with 5 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 7 feet immediately after withdrawal of auger. Boring then backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN℠ INTERTEC

LOG OF BORING

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: **SB-32**

LOCATION: See sketch.

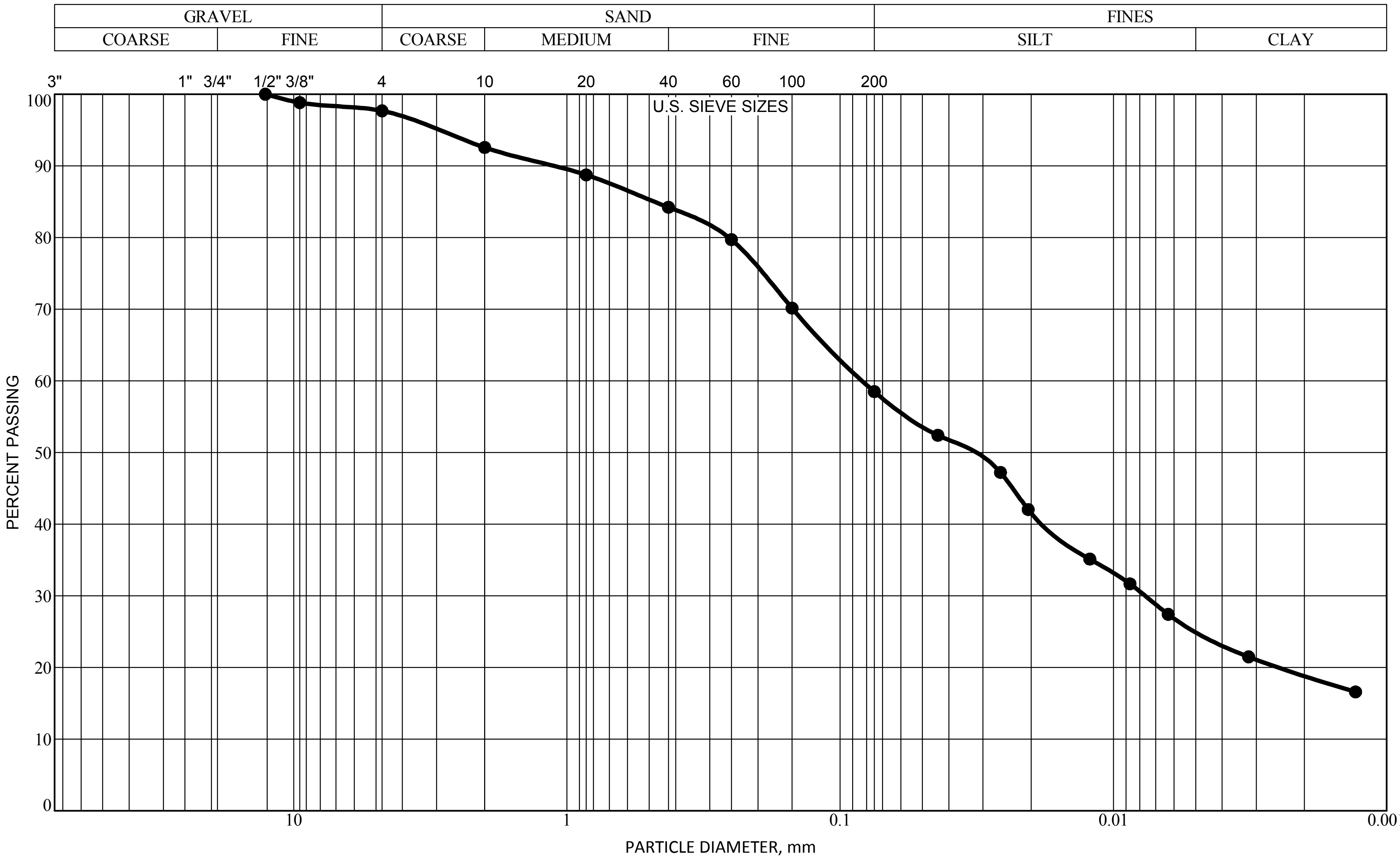
DRILLER: G. Bevre | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/18/16** | SCALE: **1" = 8'**

Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	qp tsf	Tests or Notes
1.0	SM	SILTY SAND, trace roots, black, moist. (Topsoil)	5			
7.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, brown, waterbearing, loose to medium dense. (Glacial Outwash)	23	∇		
			15			
16.0	CL	SANDY LEAN CLAY, brown and gray, wet to moist, rather soft to very stiff. (Glacial Till)	5		1	
			19			
			22			
		-gray at 14 1/2 feet.	26			
		END OF BORING.				
		Water observed at a depth of 4 1/2 feet with 4 1/2 feet of hollow-stem auger in the ground.				
		Water not observed to cave-in depth of 13 feet immediately after withdrawal of auger.				
		Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\AX PROJECTS\2016\07623.GPJ BRAUN_V8_CURRENT.GDT 11/10/16 11:32

GRAIN SIZE ACCUMULATION CURVE (ASTM)



Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: SB-01 DEPTH: 2.5'-3.5'

GRAVEL	2.3%
SAND	39.2%
SILT	33.1%
CLAY	25.4%
D60=0.082	Cu=
D30=0.008	Cc=
D10=	

CLASSIFICATION:
Sandy Lean Clay (CL)

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GRAIN SIZE ACCUMULATION CURVE (ASTM)

BRAUN[SM] INTERTEC

Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: SB-05 DEPTH: 7.5'-8.5'

GRAVEL	4.3%
SAND	38.8%
SILT	30.9%
CLAY	26.1%
D60=0.090	
D30=0.007	Cu=
D10=	Cc=

CLASSIFICATION:
Sandy Lean Clay (CL)

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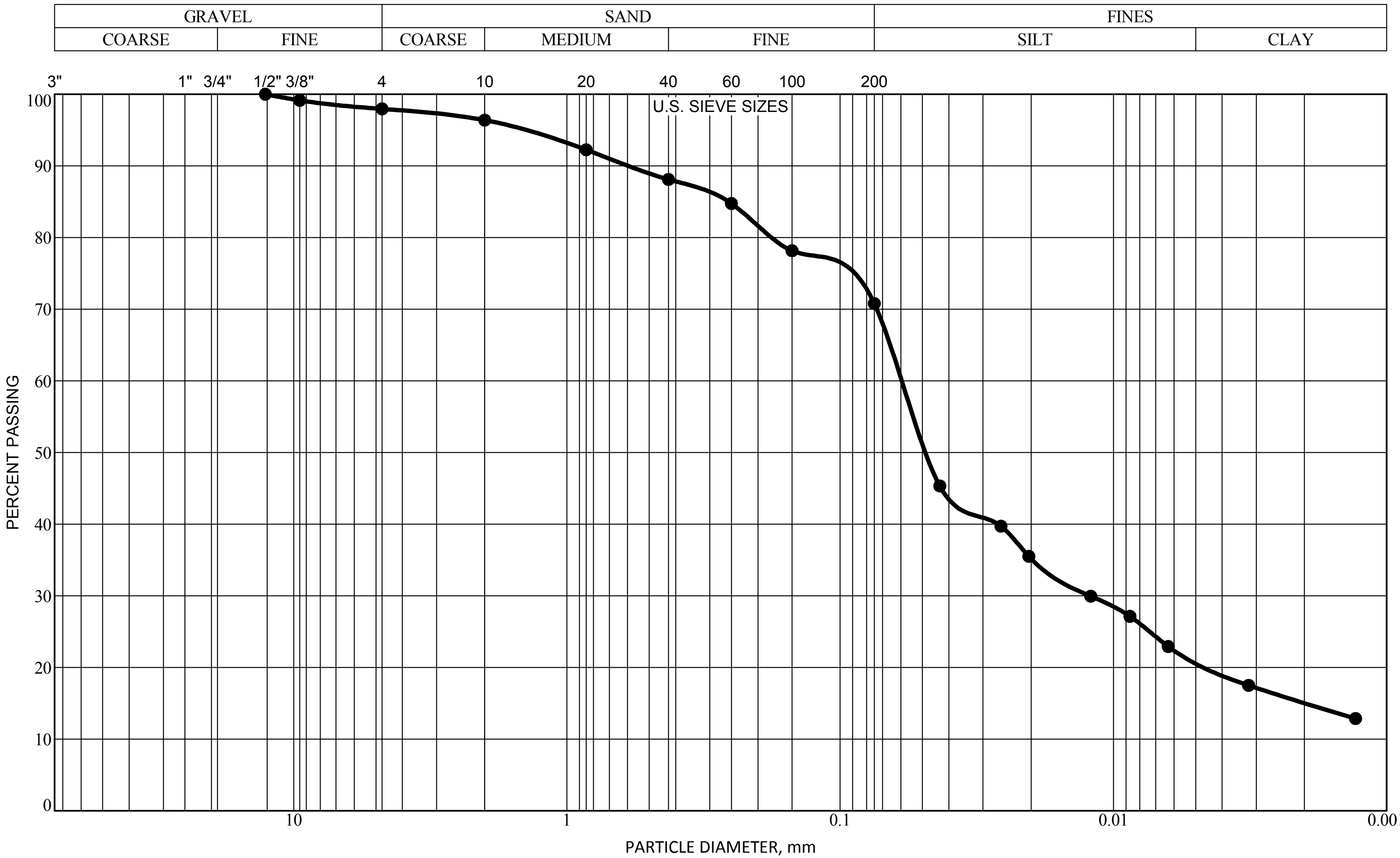
GRAIN SIZE ACCUMULATION CURVE (ASTM)



Braun Project B1607623
Soil Borings and Laboratory Testing
Levees for State Ditch 95 System
Various Locations NW of Greenbush
Greenbush, Minnesota

BORING: SB-08 DEPTH: 7.5'-8.5'

GRAVEL	2.0%
SAND	27.2%
SILT	49.7%
CLAY	21.1%
D60=0.059	
D30=0.012	Cu=
D10=	Cc=

CLASSIFICATION:
LEAN CLAY with SAND(CL)

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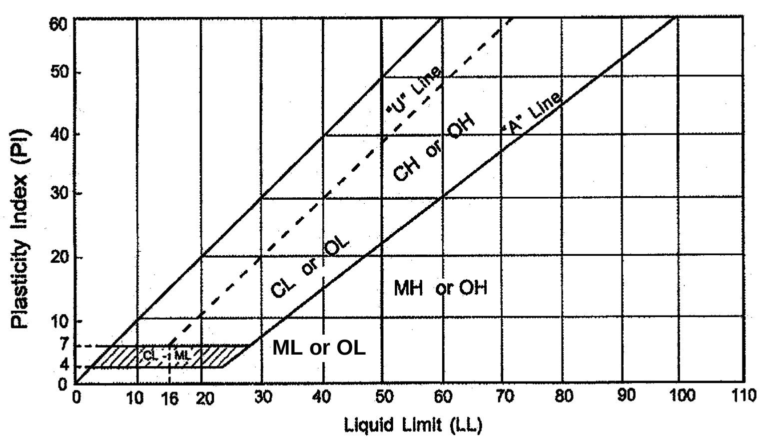
BRAUN INTERTEC

Descriptive Terminology of Soil

Standard D 2487
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [a]				Soils Classification: Group Symbol	Soils Classification: Group Name [b]
Coarse-grained Soils more than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines [e]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [c]	GW	Well-graded gravel [d]
			$C_u < 4$ and/or $1 > C_c > 3$ [c]	GP	Poorly graded gravel [d]
		Gravels with Fines More than 12% fines [e]	Fines classify as ML or MH	GM	Silty gravel [d f g]
			Fines classify as CL or CH	GC	Clayey gravel [d f g]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines [i]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [c]	SW	Well-graded sand [h]
			$C_u < 6$ and/or $1 > C_c > 3$ [c]	SP	Poorly graded sand [h]
		Sands with Fines More than 12% [i]	Fines classify as ML or MH	SM	Silty sand [f g h]
			Fines classify as CL or CH	SC	Clayey sand [f g h]
Fine-grained Soils 50% or more passed the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k l m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL OL	Organic clay [k l m n] Organic silt [k l m o]
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay [k l m]
			PI plots below "A" line	MH	Elastic silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH OH	Organic clay [k l m p] Organic silt [k l m q]
Highly Organic Soils		Primarily organic matter, dark in color and organic odor		PT	Peat

a. Based on the material passing the 3-inch (75mm) sieve.
b. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders or both" to group name.
c. $C_u = D_{60}/D_{10}$ $C_c = \dfrac{(D30)^2}{D_{10} \times D_{60}}$
d. If soil contains ≥15% sand, add "with sand" to group name.
e. Gravels with 5 to 12% fines require dual symbols:
   - GW-GM well-graded gravel with silt
   - GW-GC well-graded gravel with clay
   - GP-GM poorly graded gravel with silt
   - GP-GC poorly graded gravel with clay
f. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
g. If fines are organic, add "with organic fines: to group name.
h. If soil contains ≥15% gravel, add "with gravel" to group name.
i. Sand with 5 to 12% fines require dual symbols:
   - SW-SM well-graded sand with silt
   - SW-SC well-graded sand with clay
   - SP-SM poorly graded sand with silt
   - SP-SC poorly graded sand with clay
j. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
k. If soil contains 10 to 29% plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI < 4 or plots below "A" line.
p. PI plots on or above "A" lines.
q. PI plots below "A" line.



Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %
WD	Wet density, pcg	**S**	Percent of saturation, %
MC	Natural moisture content, %	**SG**	Specific gravity
LL	Liquid limit, %	**C**	Cohesion, psf
PL	Plastic limits, %	**Ø**	Angle of internal friction
PI	Plasticity index, %	**qu**	Unconfined compressive strength, psf
P200	% passing 200 sieve	**qp**	Pocket penetrometer strength, tsf

Particle Size Identification

Boulders................. over 12"
Cobbles .... 3" to 12"
Gravel
- Coarse .... 3/4" to 3"
- Fine................ No. 4 to 3/4"

Sand
- Coarse .... No. 4 to No. 10
- Medium.......... No. 10 to No. 40
- Fine................ No. 40 to No. 200

Silt .... <No. 200, PI< 4 or below "A" line
Clay .... <No. 200, PI ≥ 4 and on or about "A" line

Relative Density of Cohesionless Soils

Very Loose............ 0 to 4 BPF
Loose..................... 5 to 10 BPF
Medium dense .... 11 to 30 PPF
Dense .... 31 to 50 BPF
Very dense............ over 50 BPF

Consistency of Cohesive Soils

Very soft................ 0 to 1 BPF
Soft .... 2 to 3 BPF
Rather soft .... 4 to 5 BPF
Medium .... 6 to 8 BPF
Rather stiff .... 9 to 12 BPF
Stiff .... 13 to 16 BPF
Very stiff................. 17 to 30 BPF
Hard....................... over 30 BPF

Drilling Notes

Standard penetration test borings were advanced by 3 1/4" or 6 1/4" ID hollow-stem augers, unless noted otherwise. Jetting water was used to clean out auger prior to sampling only where indicated on logs. All samples were taken with the standard 2" OD split-tube samples, except where noted.

Power auger borings were advanced by 4" or 6" diameter continuous flight, solid-stern augers. Soil classifications and strata depths were inferred from disturbed samples augered to the surface, and are therefore, somewhat approximate.

Hand auger borings were advanced manually with a 1 1/2" or 3 1/4" diameter auger and were limited to the depth from which the auger could be manually withdrawn.

BPF: Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments, and added to get BPF. Where they differed significantly, they are reported in the following form: 2/12 for the second and third 6" increments, respectively.

WH: WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WR: WR indicates the sampler penetrated soil under weight of rods alone; hammer weight, and driving not required.

TW: TW indicates thin-walled (undisturbed) tube sample.

Note: All tests were run in general accordance with applicable ASTM standards.

Soil Borings KCWRP #11 Klondike Township Kittson County, MN	BORING: SB-19 LOCATION: NW corner of Section 2 Klondike Township

DRILLER: Jake Huwe	METHOD: Hand Auger (ASTM D 1452)	DATE: 10/3/2016

Depth Feet	Symbol		Description	WL	Notes
0.0				▽	Standing water
0.5			Cattail Mat, other plant material, roots		
1.0	PT		PEAT, black, organic, wet, very soft, homogeneous		
1.5					
2.0					
2.5					
3.0					
3.5					
4.0	OL/OH		sandy organic soil		
4.5	MH		sandy elastic SILT		poorly graded, fine
5.0	MH		sandy elastic SILT with gravel		gravel up to 0.5"
5.5	CH		fat CLAY with sand		
6.0	CH		fat CLAY		
			END OF BORING		Bagged samples and backfilled with excess material

Soil Borings KCWRP #11 Klondike Township Kittson County, MN	BORING: SB-20 LOCATION: SW corner of Section 2 Klondike Township
DRILLER: Jake Huwe / METHOD: Hand Auger (ASTM D 1452)	DATE: 10/3/2016

Depth Feet	Symbol		Description	WL	Notes
0.0				▽	Standing water
0.5			Cattail Mat, other plant material, roots		
1.0	PT		PEAT		black, wet, soft, fibrous material
1.5					
2.0					Mostly Peat with some fine sand dense and moist
2.5					
3.0					
3.5					
4.0	OL/OH		sandy organic soil		
4.5					
5.0	CL		sandy lean CLAY with gravel		
5.5	OL/OH		sandy organic soil with gravel		up to 1" gravel rock
6.0	CH		fat CLAY with sand		
6.5					
			END OF BORING		Bagged samples and backfilled with excess material

LOG OF BORING

Soil Borings KCWRP #11 Klondike Township Kittson County, MN			BORING: SB-21 LOCATION: NW corner of Section 10 Klondike Township
DRILLER: Jake Huwe	METHOD: Hand Auger (ASTM D 1452)		DATE: 10/3/2016

Depth Feet	Symbol	Description	WL	Notes
-0.5			▽	Standing water
0.0				
0.5		Cattail Mat, other plant material, roots		
1.0	PT	PEAT		black, organic, wet, very soft, weak, homogeneous
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				
4.5	OL/OH	sandy organic soil		gray brown and black, organic, moist, very soft, homogeneous
5.0				
5.5	MH	sandy elastic SILT with gravel		
6.0	CH	fat CLAY with sand		
		END OF BORING		Bagged samples and backfilled with excess material

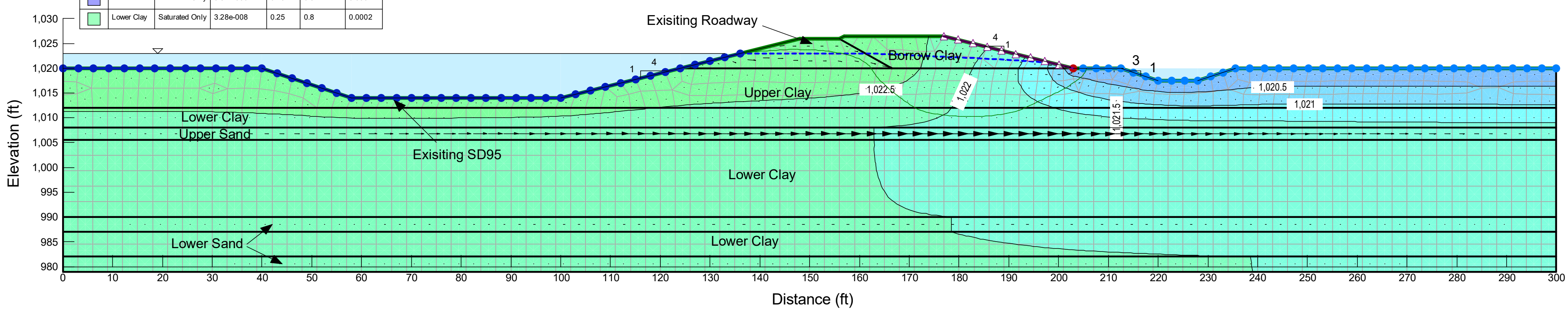
Attachment D

SEEP/W Seepage Analysis Results

Diked Inlet at SB05 - 280th Street Side
Steady-State Seepage
Embankment Extension - Clay

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft^3/ft^3)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Sand	Saturated Only	9.84e-006	0.25	0.8	0.0002
	Lower Sand	Saturated Only	9.84e-006	0.25	0.8	0.0001
	Lower Clay	Saturated Only	3.28e-008	0.25	0.8	0.0002

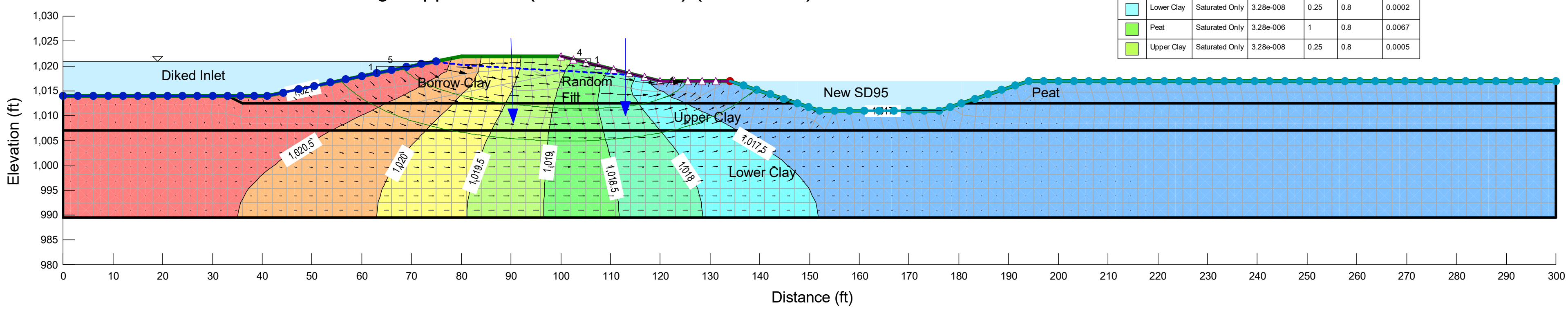
Vertical Gradient Through Upper 3 ft = (1020.85 - 1020)/(1020-1017) = 0.28



Diked Inlet at SB08 - New Embankment Side
Steady-State Seepage - Clay as Random Fill

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft^3/ft^3)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Lower Clay	Saturated Only	3.28e-008	0.25	0.8	0.0002
	Peat	Saturated Only	3.28e-006	1	0.8	0.0067
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005

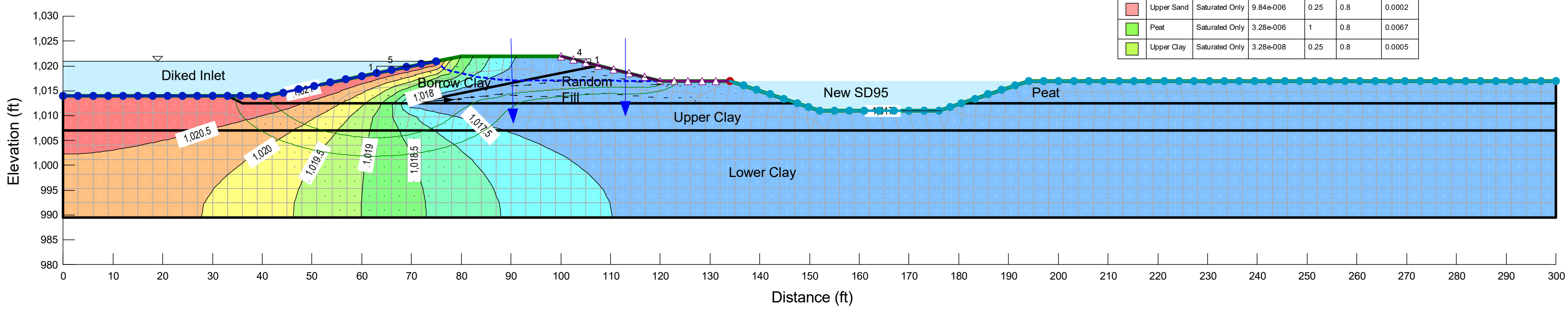
Vertical Gradient Through Upper 3 ft = (1017.22 - 1017)/(1017-1014) = 0.07



Diked Inlet at SB08 - New Embankment Side
Steady-State Seepage - Sand as Random Fill

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft^3/ft^3)	Mv (/psf)
(yellow)	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
(light blue)	Lower Clay	Saturated Only	3.28e-008	0.25	0.8	0.0002
(pink)	Upper Sand	Saturated Only	9.84e-006	0.25	0.8	0.0002
(green)	Peat	Saturated Only	3.28e-006	1	0.8	0.0067
(yellow-green)	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005

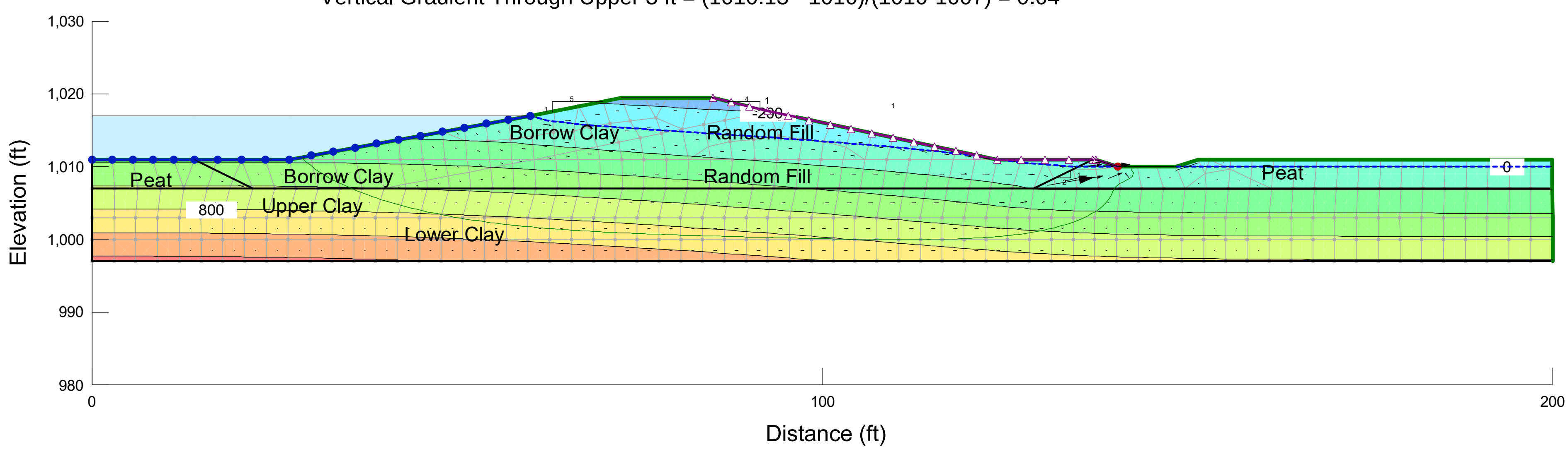
Vertical Gradient Through Upper 3 ft = (1017.07 - 1017)/(1017-1014) = 0.02



Impoundment at SB21
Steady-State Seepage - Clay as Random Fill

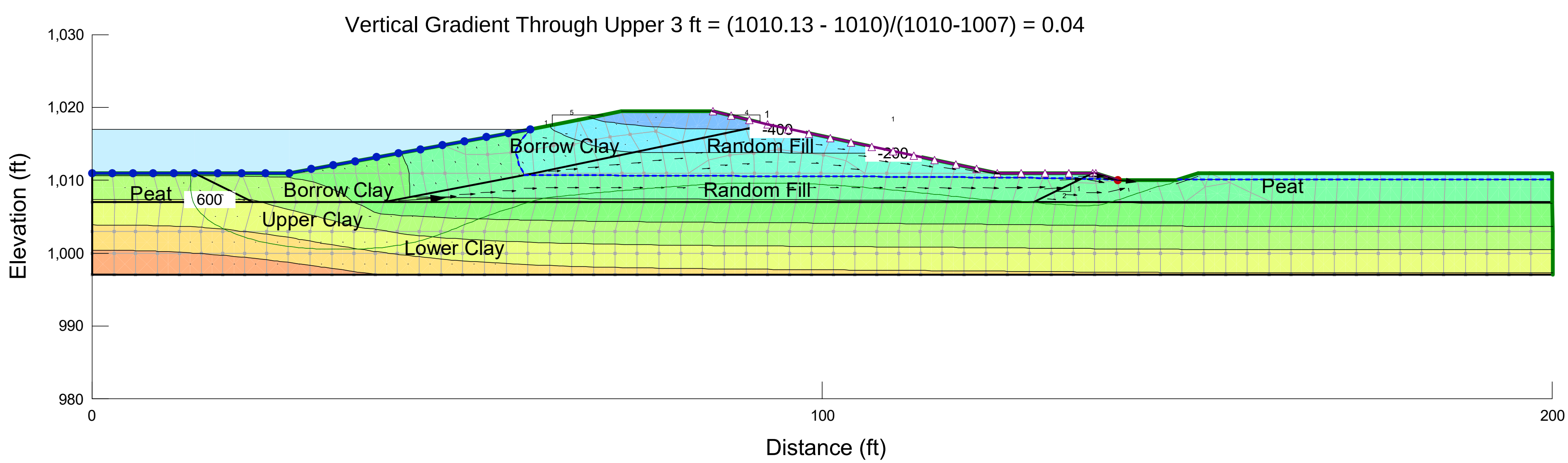
Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft³/ft³)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Peat	Saturated Only	3.28e-006	0.25	0.8	0.0067

Vertical Gradient Through Upper 3 ft = (1010.13 - 1010)/(1010-1007) = 0.04



Impoundment at SB21
Steady-State Seepage - Sand as Random Fill

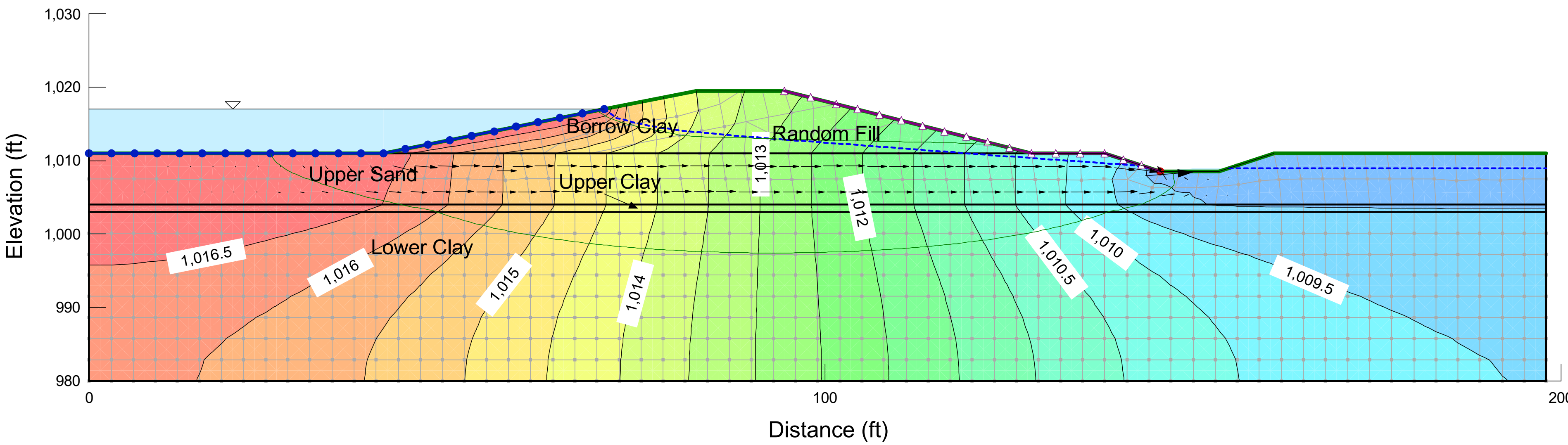
Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft³/ft³)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Sand	Saturated Only	9.84e-006	0.25	0.8	0.0002
	Peat	Saturated Only	3.28e-006	0.25	0.8	0.0067



Impoundment at SB31 and SB32
Steady-State Seepage - Clay as Random Fill

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft³/ft³)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Sand	Saturated Only	9.84e-006	0.25	0.8	0.0002
	Lower Clay	Saturated Only	3.28e-008	0.25	0.8	0.0002

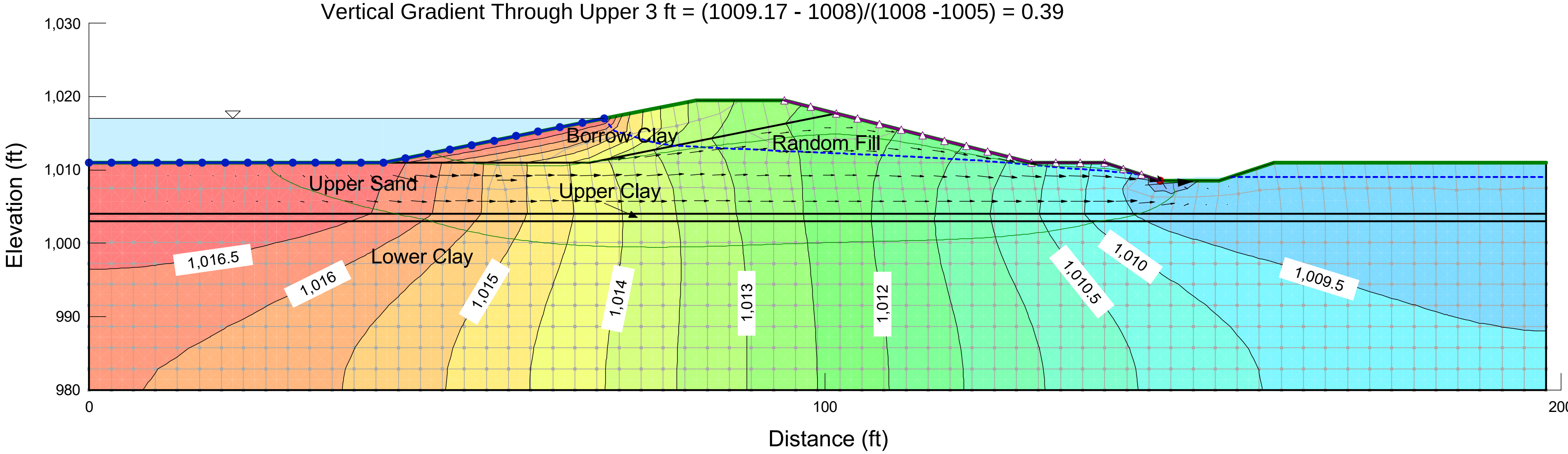
Vertical Gradient Through Upper 3 ft = (1009.17 - 1008)/(1008 -1005) = 0.39



Impoundment at SB31 and SB32
Steady-State Seepage - Sand as Random Fill

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content (ft³/ft³)	Mv (/psf)
	Borrow Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Clay	Saturated Only	3.28e-008	0.25	0.8	0.0005
	Upper Sand	Saturated Only	9.84e-006	0.25	0.8	0.0002
	Lower Clay	Saturated Only	3.28e-008	0.25	0.8	0.0002

Vertical Gradient Through Upper 3 ft = (1009.17 - 1008)/(1008 -1005) = 0.39

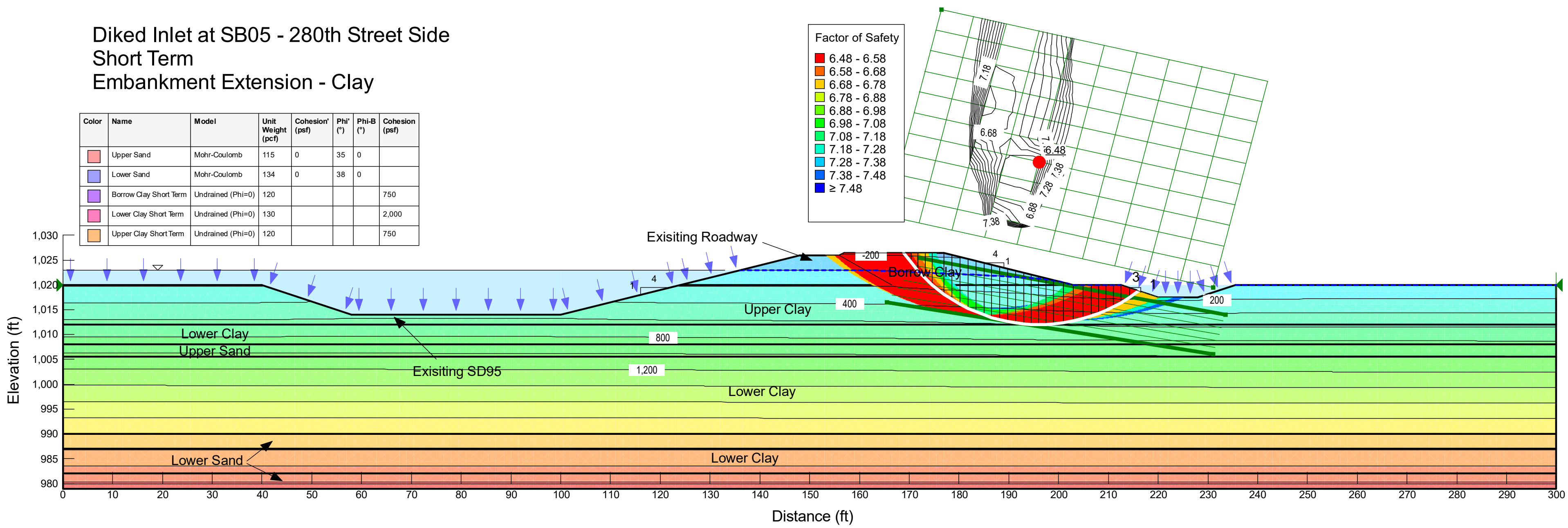


Attachment E

SLOPE/W Slope Stability Analysis Results

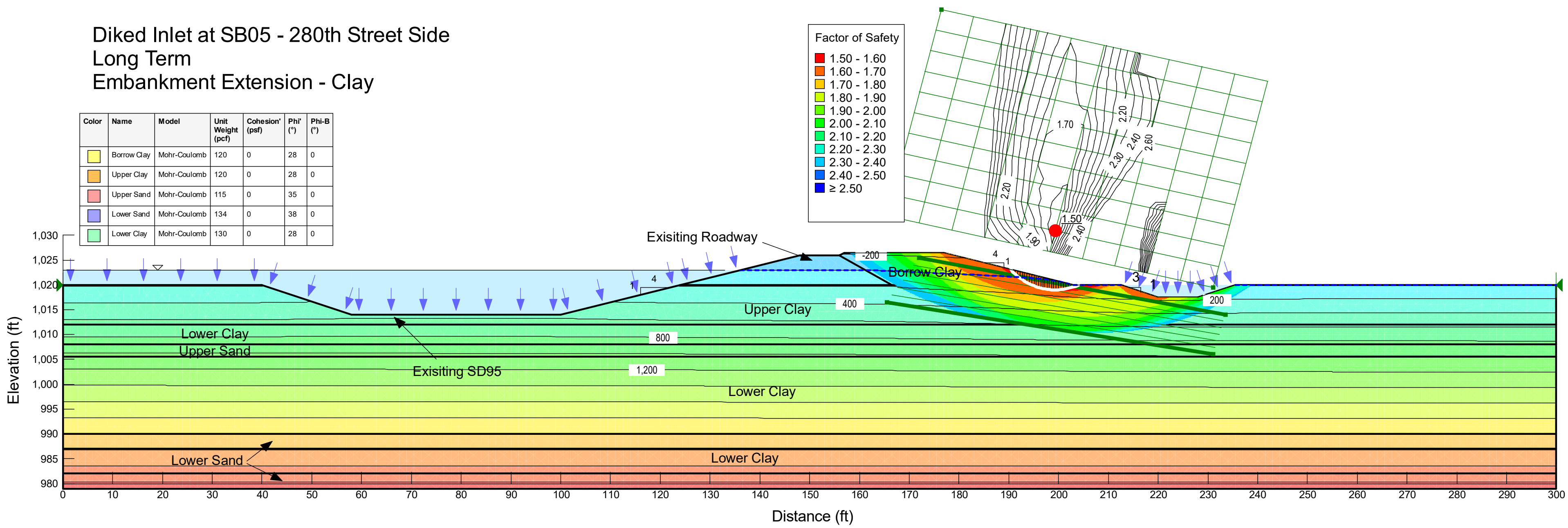
Diked Inlet at SB05 - 280th Street Side
Short Term
Embankment Extension - Clay

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	0	
	Lower Sand	Mohr-Coulomb	134	0	38	0	
	Borrow Clay Short Term	Undrained (Phi=0)	120				750
	Lower Clay Short Term	Undrained (Phi=0)	130				2,000
	Upper Clay Short Term	Undrained (Phi=0)	120				750



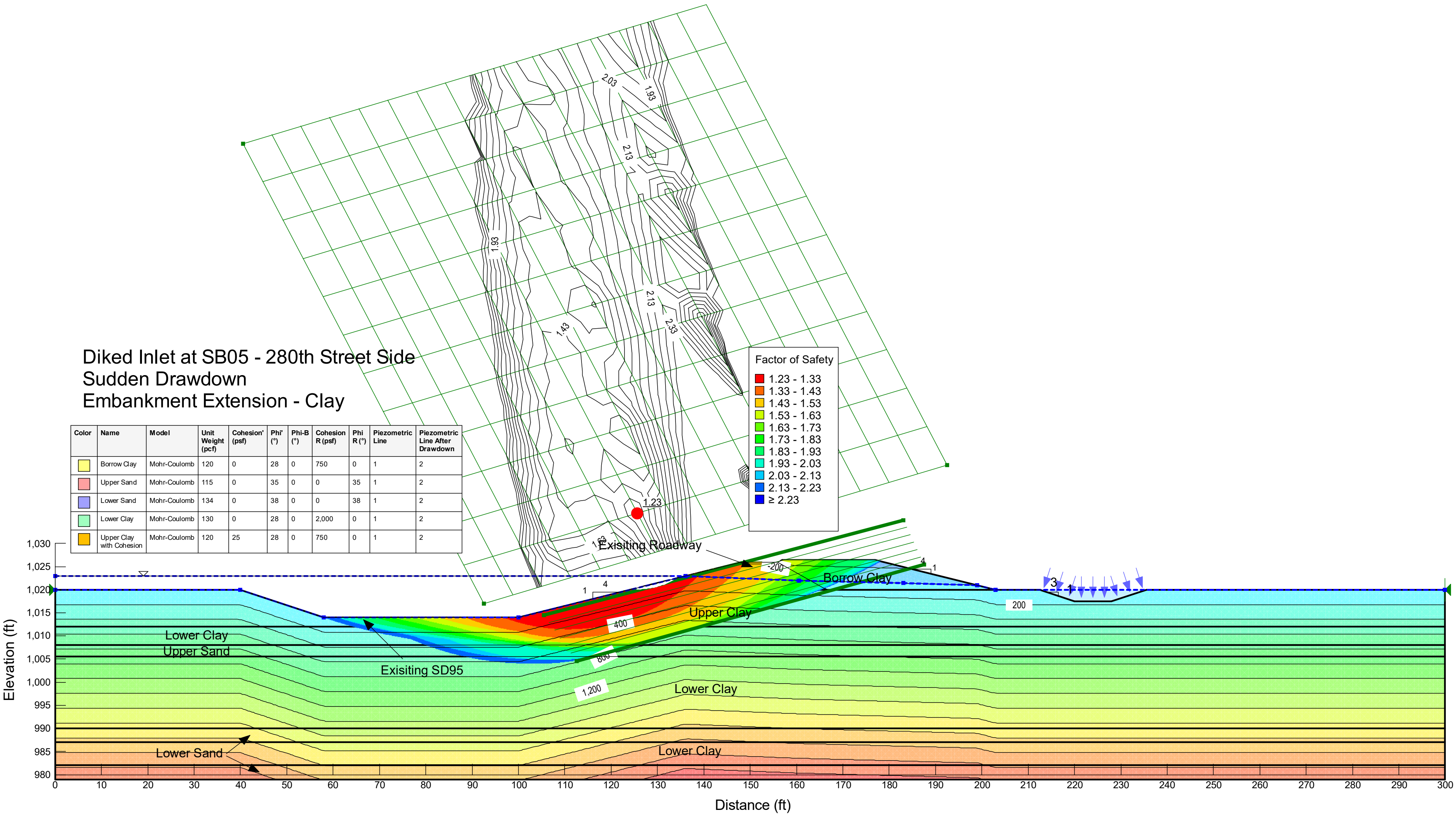
Diked Inlet at SB05 - 280th Street Side
Long Term
Embankment Extension - Clay

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Borrow Clay	Mohr-Coulomb	120	0	28	0
	Upper Clay	Mohr-Coulomb	120	0	28	0
	Upper Sand	Mohr-Coulomb	115	0	35	0
	Lower Sand	Mohr-Coulomb	134	0	38	0
	Lower Clay	Mohr-Coulomb	130	0	28	0

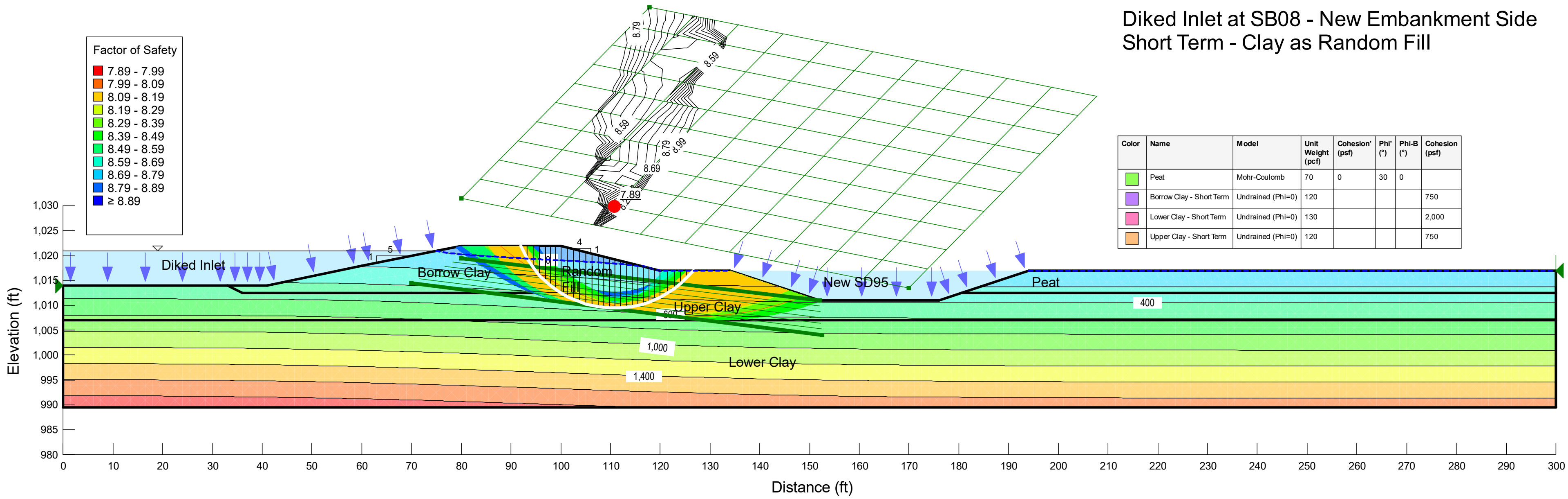


Diked Inlet at SB05 - 280th Street Side
Sudden Drawdown
Embankment Extension - Clay

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Upper Sand	Mohr-Coulomb	115	0	35	0	0	35	1	2
	Lower Sand	Mohr-Coulomb	134	0	38	0	0	38	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	0	2,000	0	1	2
	Upper Clay with Cohesion	Mohr-Coulomb	120	25	28	0	750	0	1	2

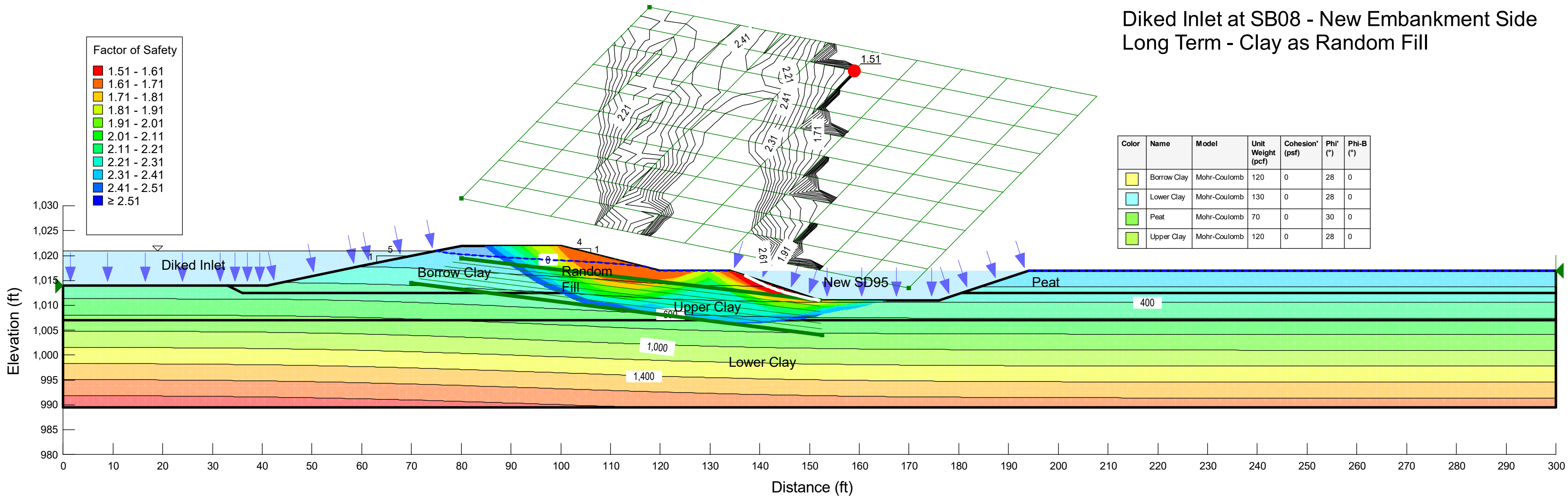


Diked Inlet at SB08 - New Embankment Side
Short Term - Clay as Random Fill



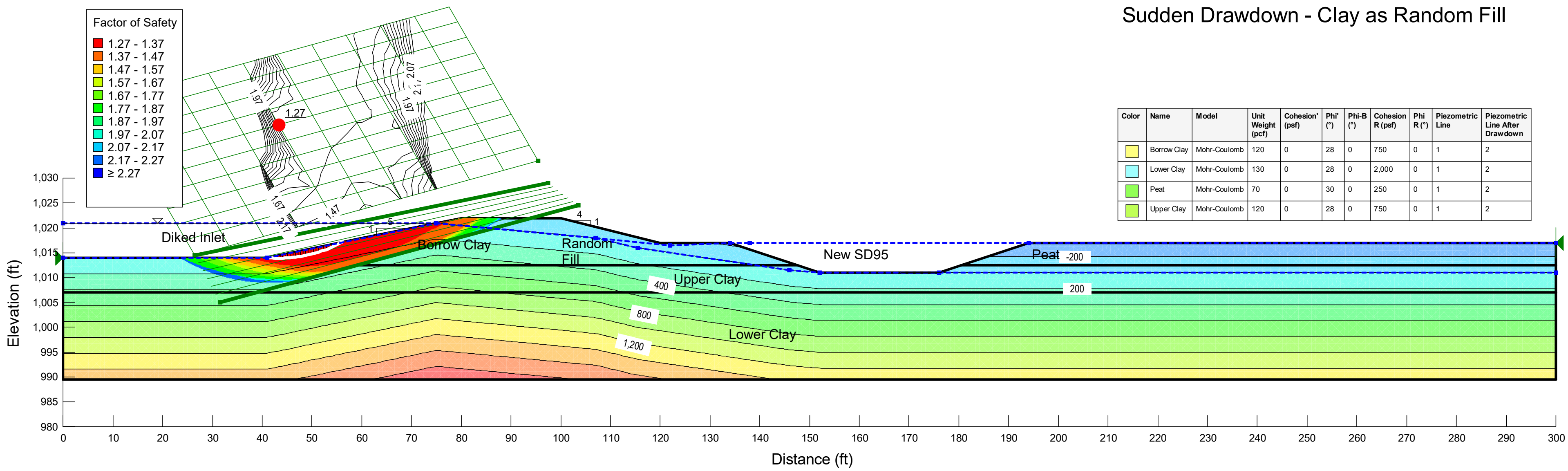
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion (psf)
	Peat	Mohr-Coulomb	70	0	30	0	
	Borrow Clay - Short Term	Undrained (Phi=0)	120				750
	Lower Clay - Short Term	Undrained (Phi=0)	130				2,000
	Upper Clay - Short Term	Undrained (Phi=0)	120				750

Diked Inlet at SB08 - New Embankment Side
Long Term - Clay as Random Fill



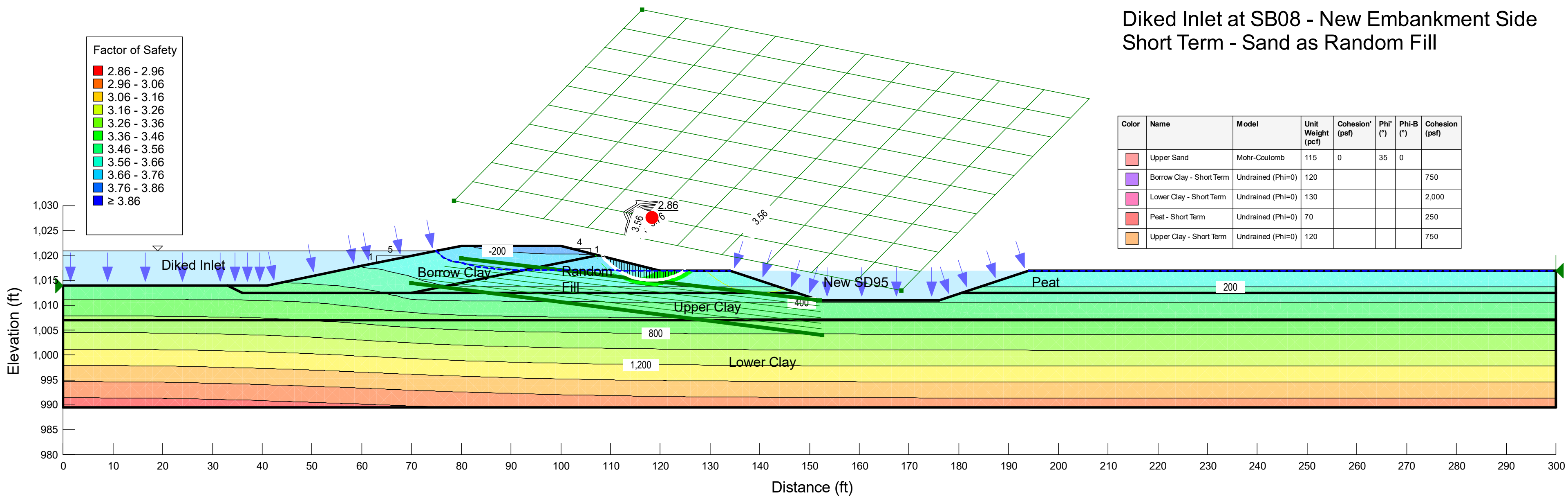
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Borrow Clay	Mohr-Coulomb	120	0	28	0
	Lower Clay	Mohr-Coulomb	130	0	28	0
	Peat	Mohr-Coulomb	70	0	30	0
	Upper Clay	Mohr-Coulomb	120	0	28	0

Diked Inlet at SB08 - New Embankment Side
Sudden Drawdown - Clay as Random Fill



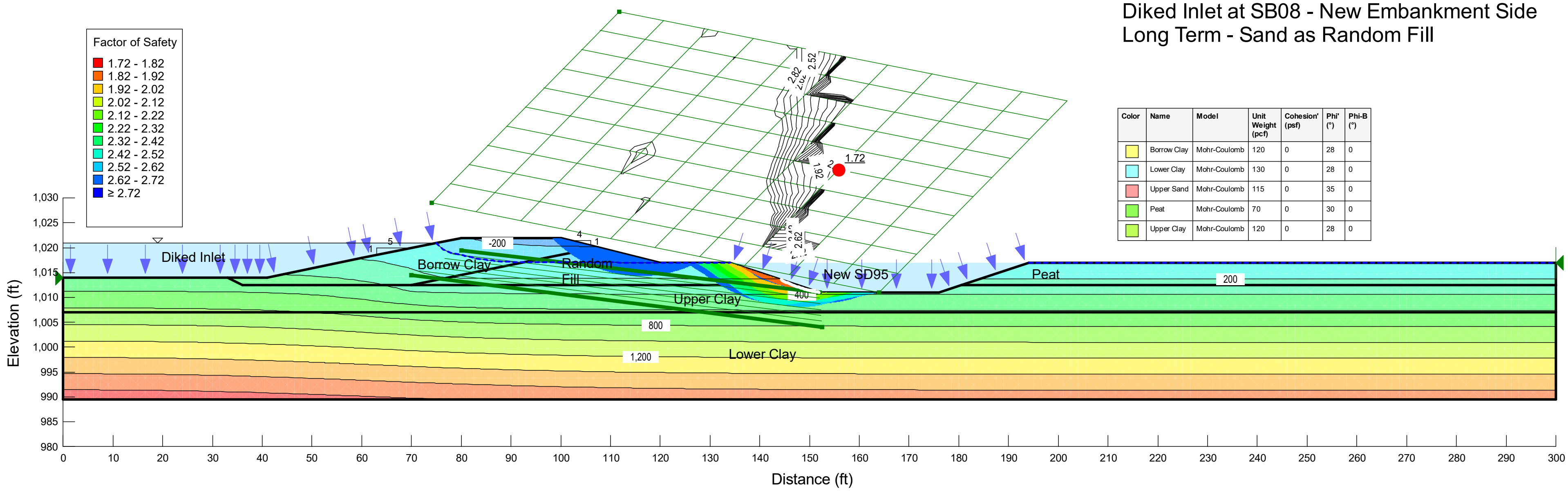
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	0	2,000	0	1	2
	Peat	Mohr-Coulomb	70	0	30	0	250	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2

Diked Inlet at SB08 - New Embankment Side
Short Term - Sand as Random Fill



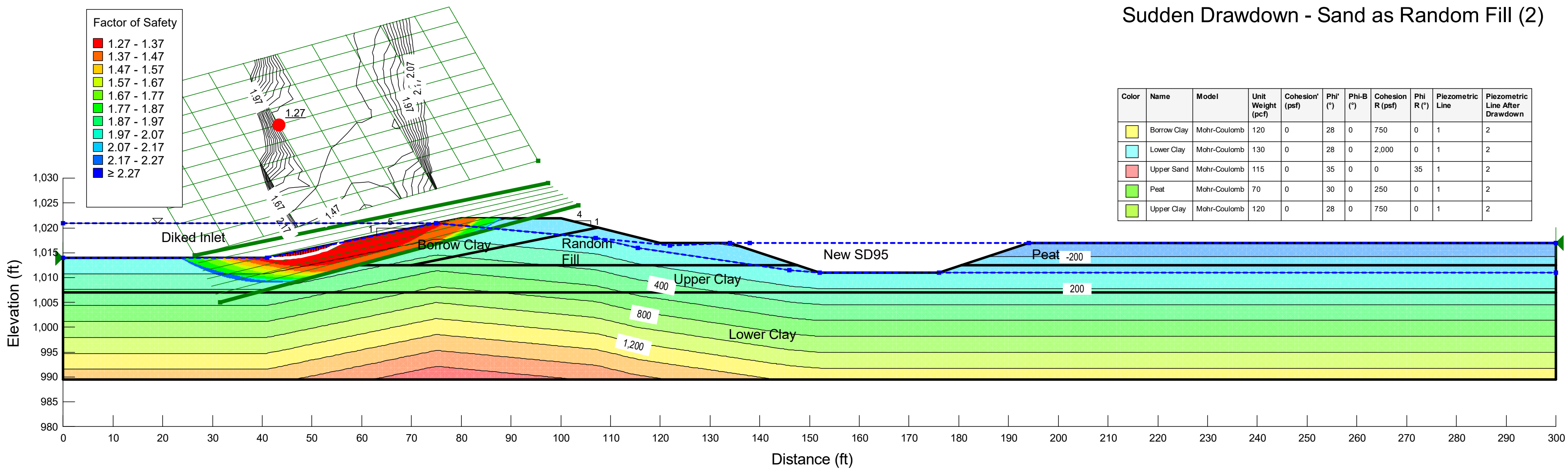
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	0	
	Borrow Clay - Short Term	Undrained (Phi=0)	120				750
	Lower Clay - Short Term	Undrained (Phi=0)	130				2,000
	Peat - Short Term	Undrained (Phi=0)	70				250
	Upper Clay - Short Term	Undrained (Phi=0)	120				750

Diked Inlet at SB08 - New Embankment Side
Long Term - Sand as Random Fill



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Borrow Clay	Mohr-Coulomb	120	0	28	0
	Lower Clay	Mohr-Coulomb	130	0	28	0
	Upper Sand	Mohr-Coulomb	115	0	35	0
	Peat	Mohr-Coulomb	70	0	30	0
	Upper Clay	Mohr-Coulomb	120	0	28	0

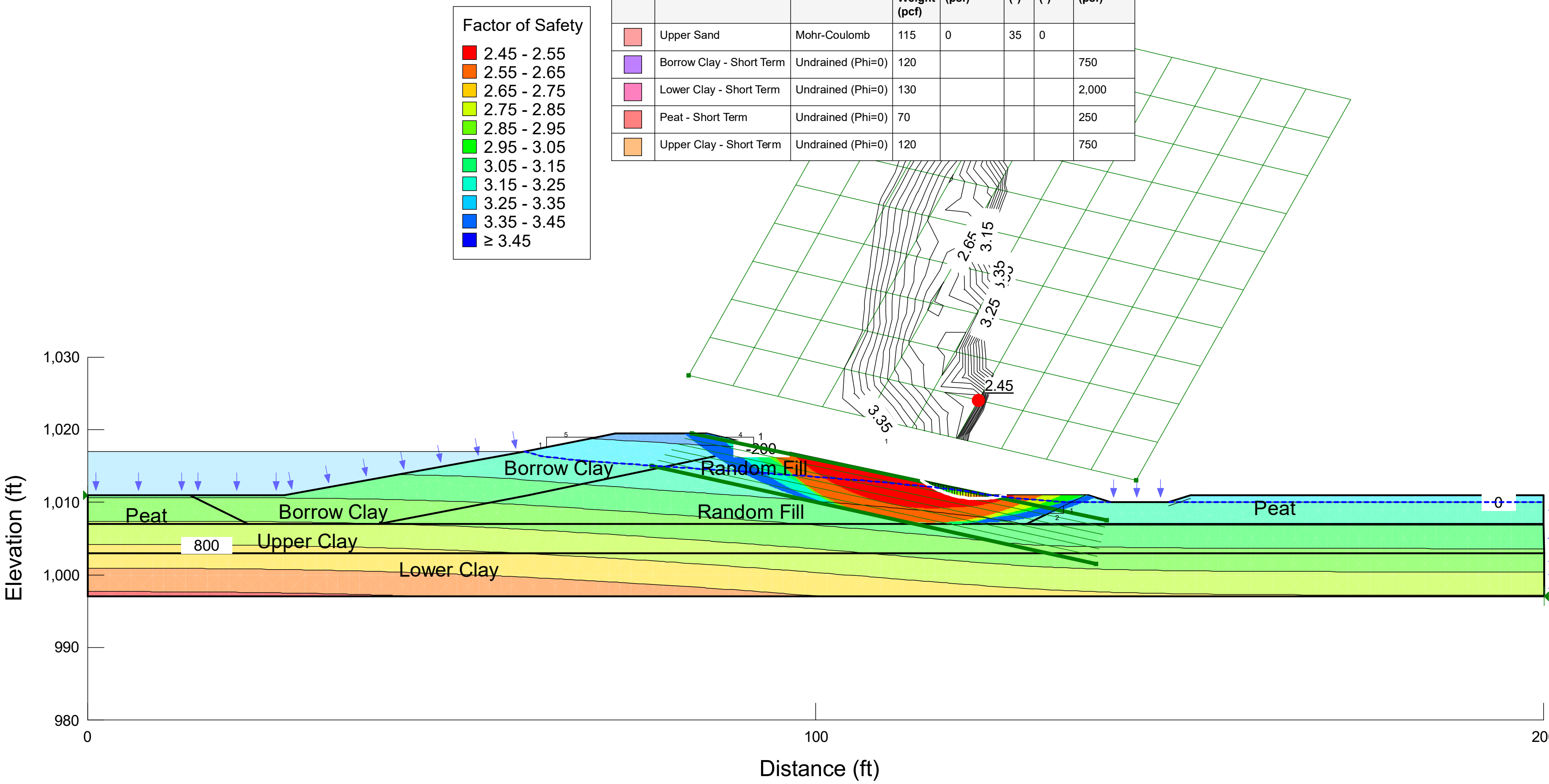
Diked Inlet at SB08 - New Embankment Side
Sudden Drawdown - Sand as Random Fill (2)



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	0	2,000	0	1	2
	Upper Sand	Mohr-Coulomb	115	0	35	0	0	35	1	2
	Peat	Mohr-Coulomb	70	0	30	0	250	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2

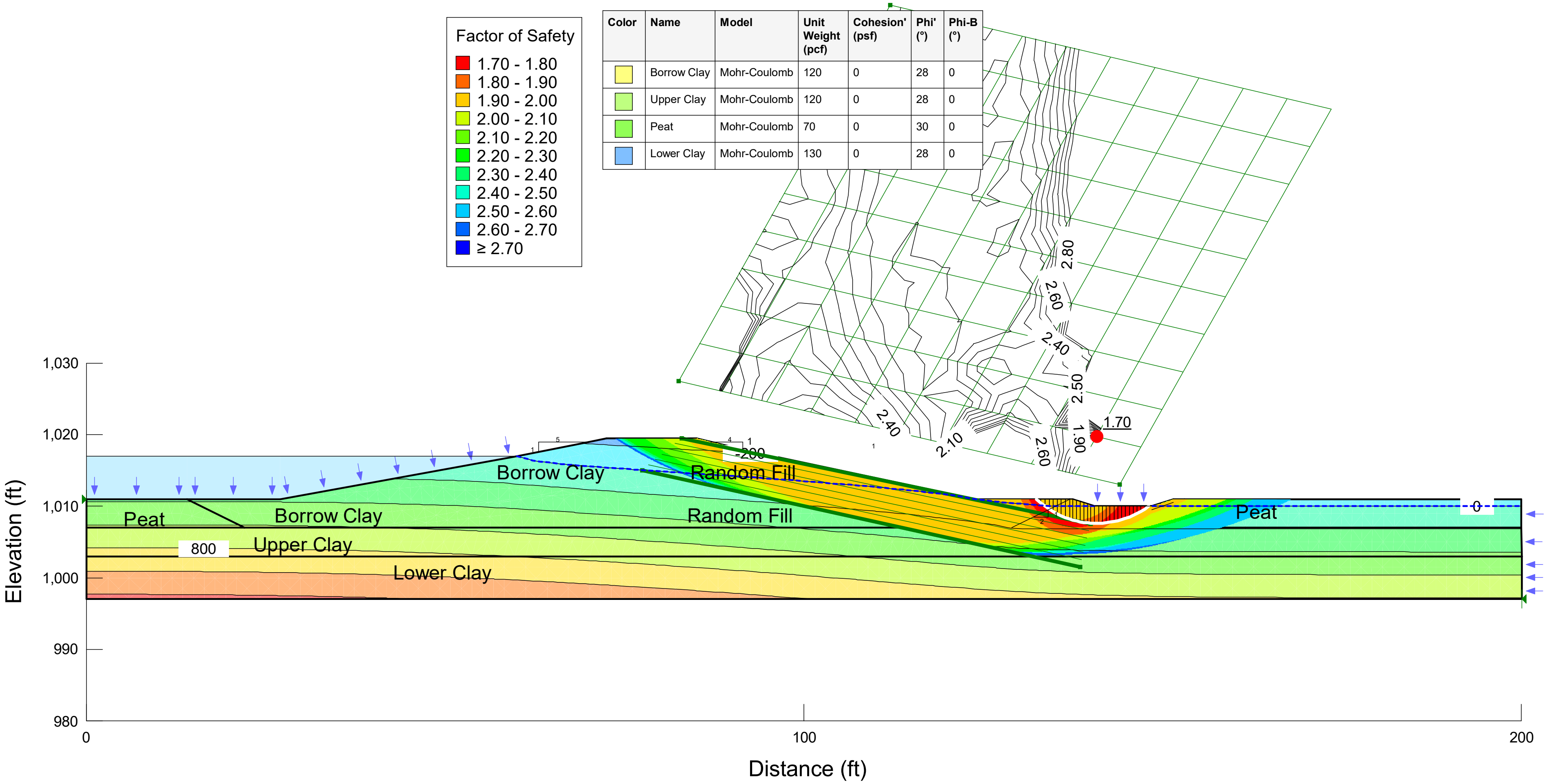
Impoundment at SB21
Short Term - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	0	
	Borrow Clay - Short Term	Undrained (Phi=0)	120				750
	Lower Clay - Short Term	Undrained (Phi=0)	130				2,000
	Peat - Short Term	Undrained (Phi=0)	70				250
	Upper Clay - Short Term	Undrained (Phi=0)	120				750



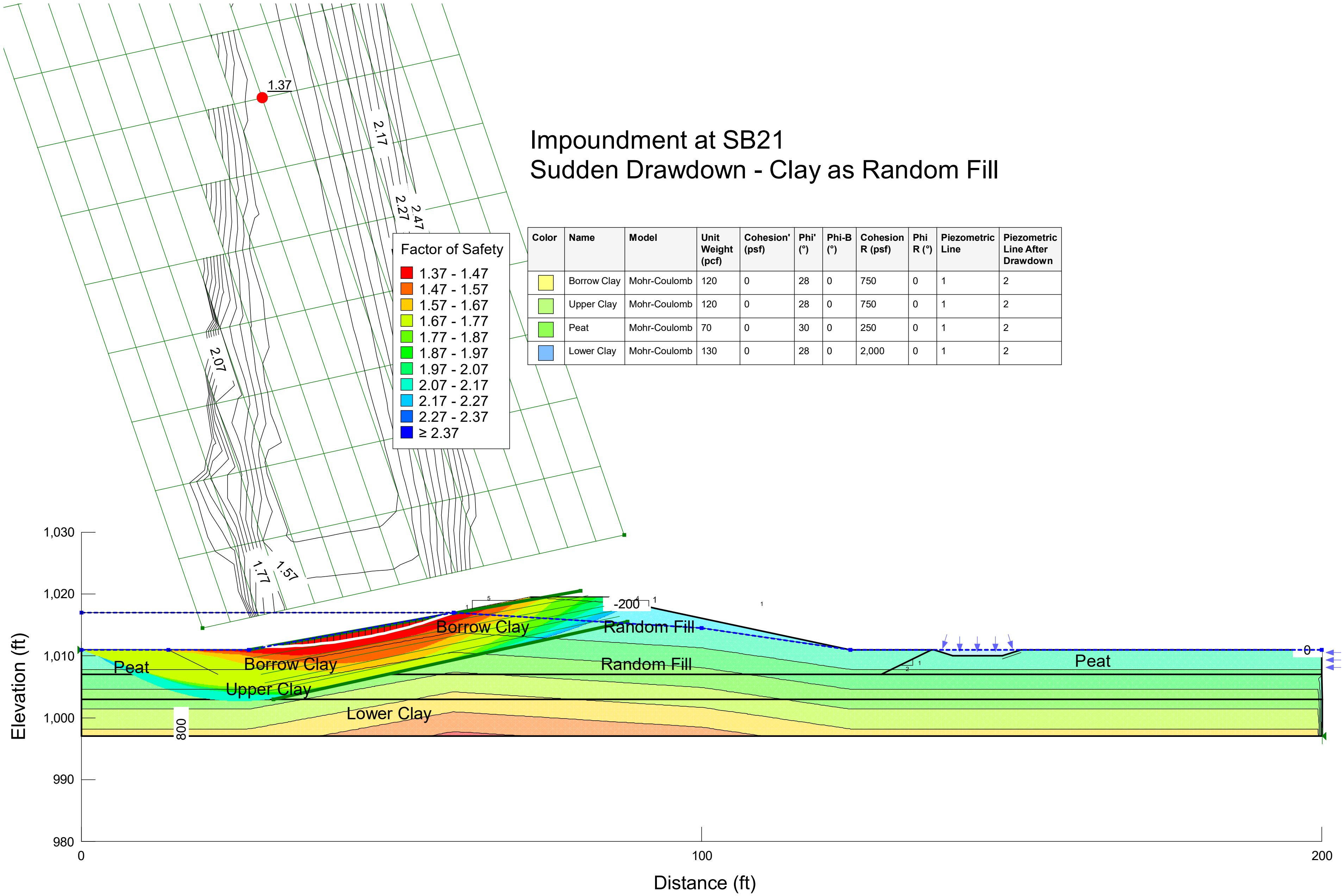
Impoundment at SB21
Long Term - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Borrow Clay	Mohr-Coulomb	120	0	28	0
	Upper Clay	Mohr-Coulomb	120	0	28	0
	Peat	Mohr-Coulomb	70	0	30	0
	Lower Clay	Mohr-Coulomb	130	0	28	0



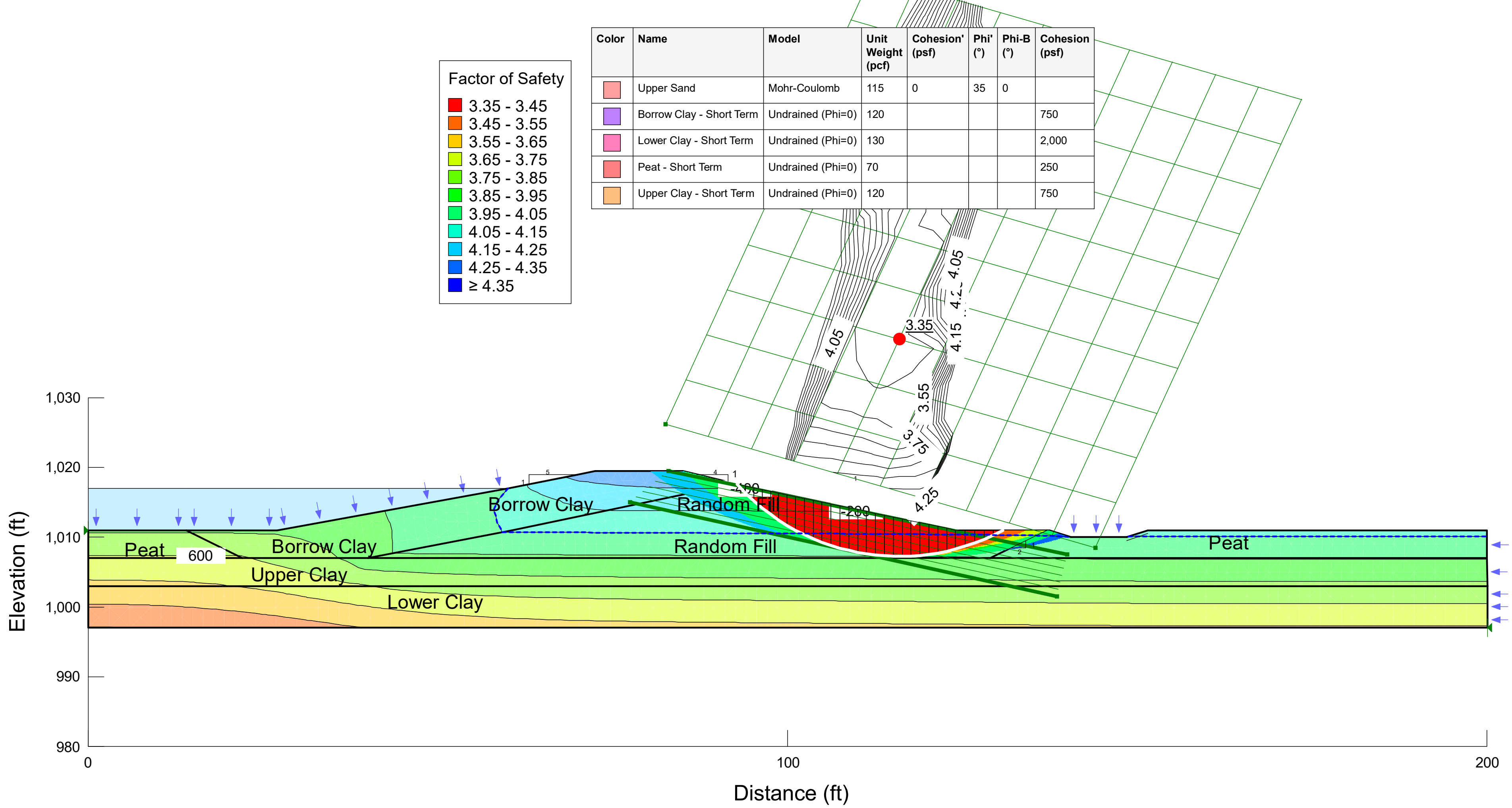
Impoundment at SB21
Sudden Drawdown - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Peat	Mohr-Coulomb	70	0	30	0	250	0	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	0	2,000	0	1	2



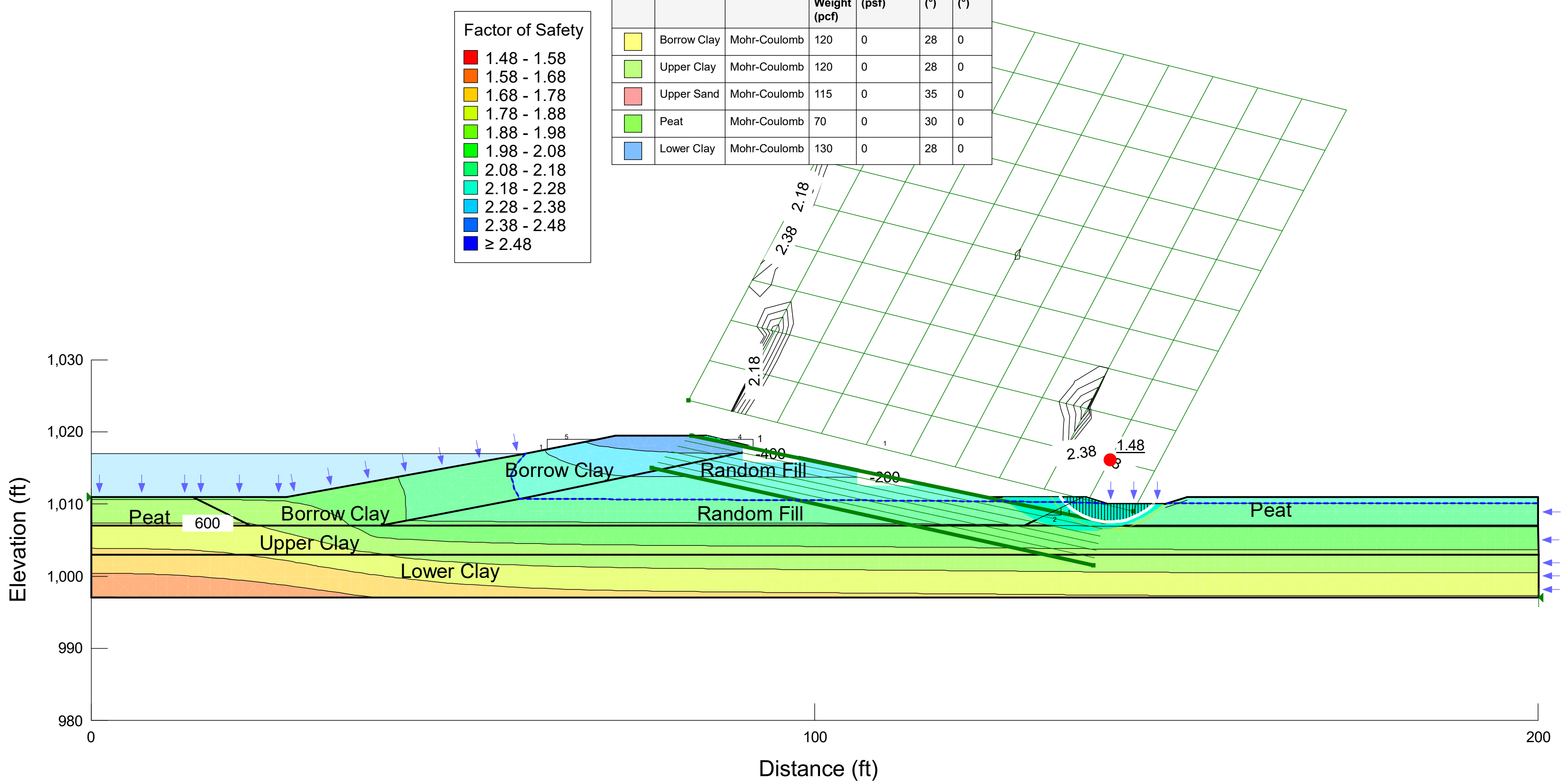
Impoundment at SB21
Short Term - Sand as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	0	
	Borrow Clay - Short Term	Undrained (Phi=0)	120				750
	Lower Clay - Short Term	Undrained (Phi=0)	130				2,000
	Peat - Short Term	Undrained (Phi=0)	70				250
	Upper Clay - Short Term	Undrained (Phi=0)	120				750



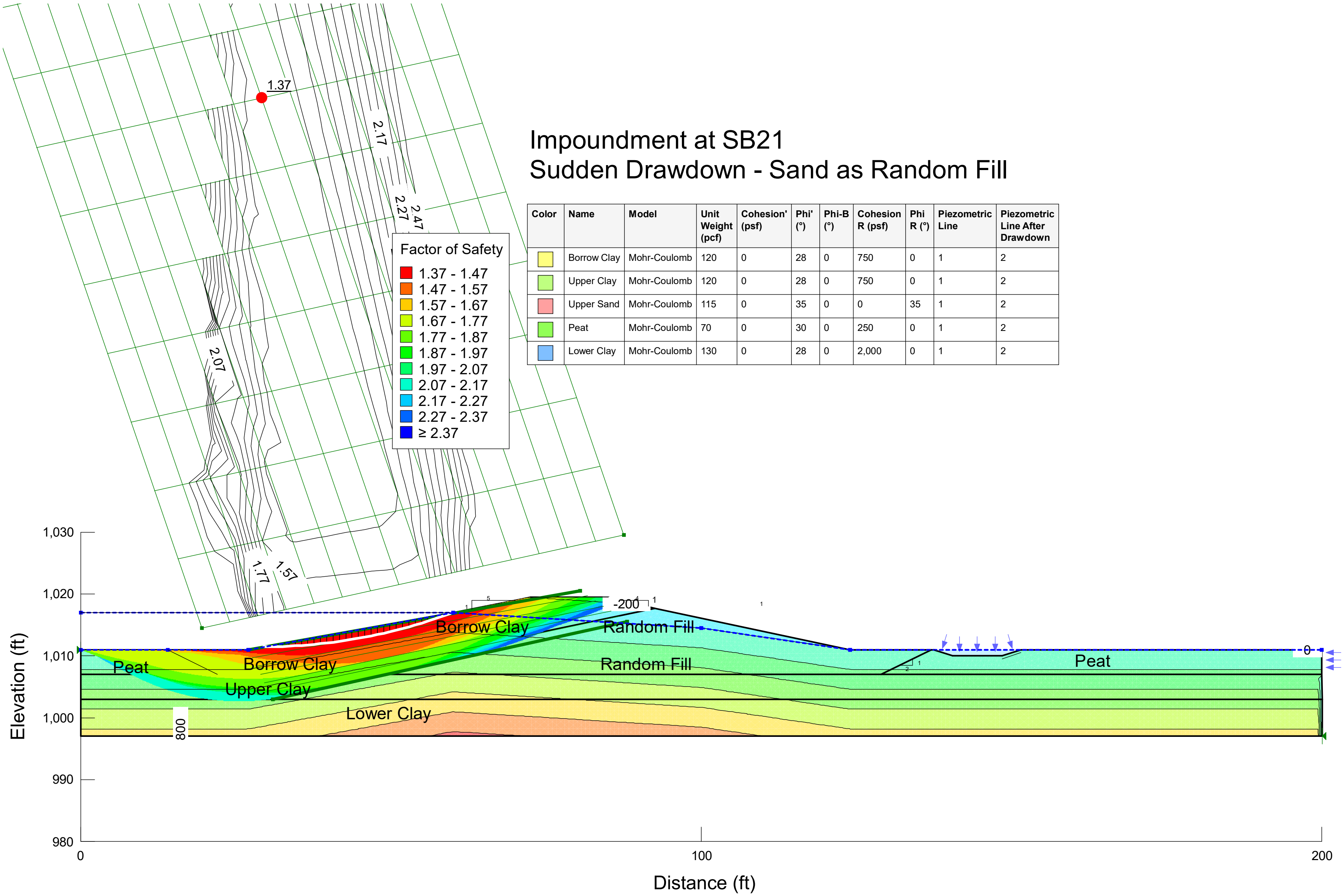
Impoundment at SB21
Long Term - Sand as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Borrow Clay	Mohr-Coulomb	120	0	28	0
	Upper Clay	Mohr-Coulomb	120	0	28	0
	Upper Sand	Mohr-Coulomb	115	0	35	0
	Peat	Mohr-Coulomb	70	0	30	0
	Lower Clay	Mohr-Coulomb	130	0	28	0



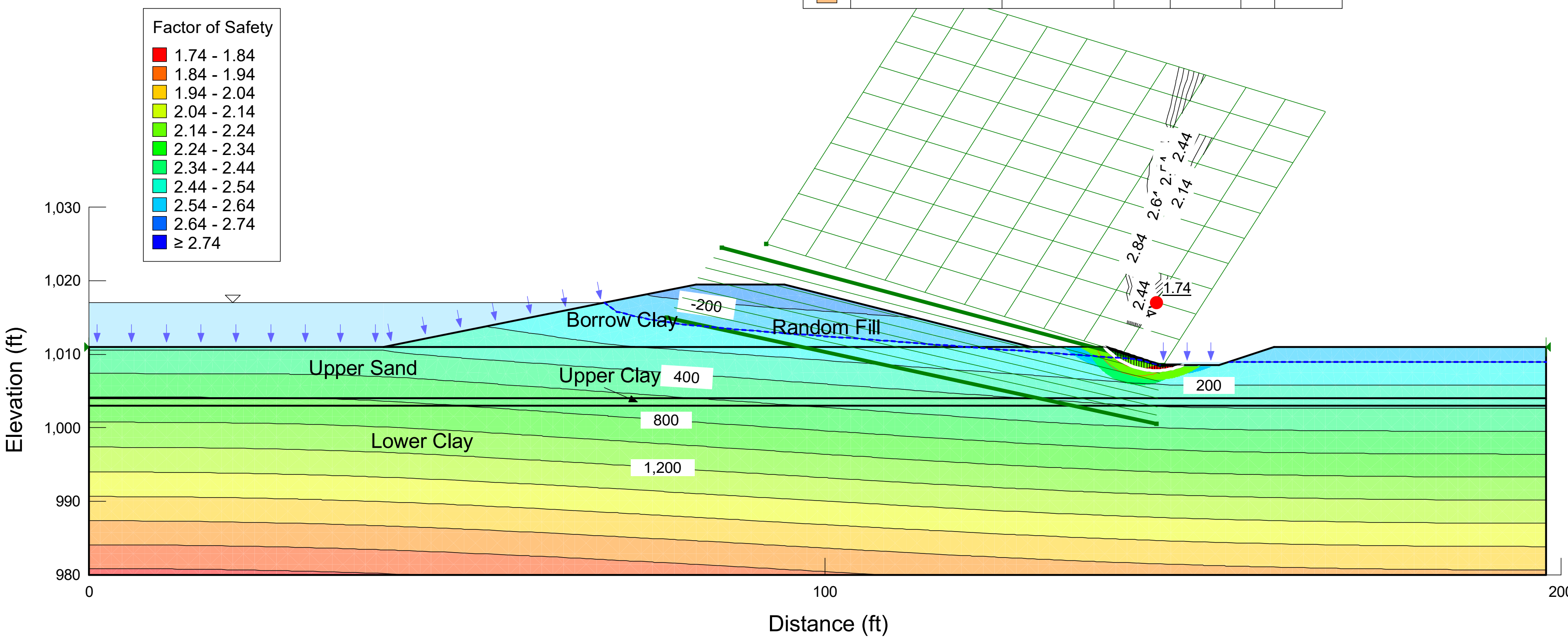
Impoundment at SB21
Sudden Drawdown - Sand as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	0	750	0	1	2
	Upper Sand	Mohr-Coulomb	115	0	35	0	0	35	1	2
	Peat	Mohr-Coulomb	70	0	30	0	250	0	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	0	2,000	0	1	2



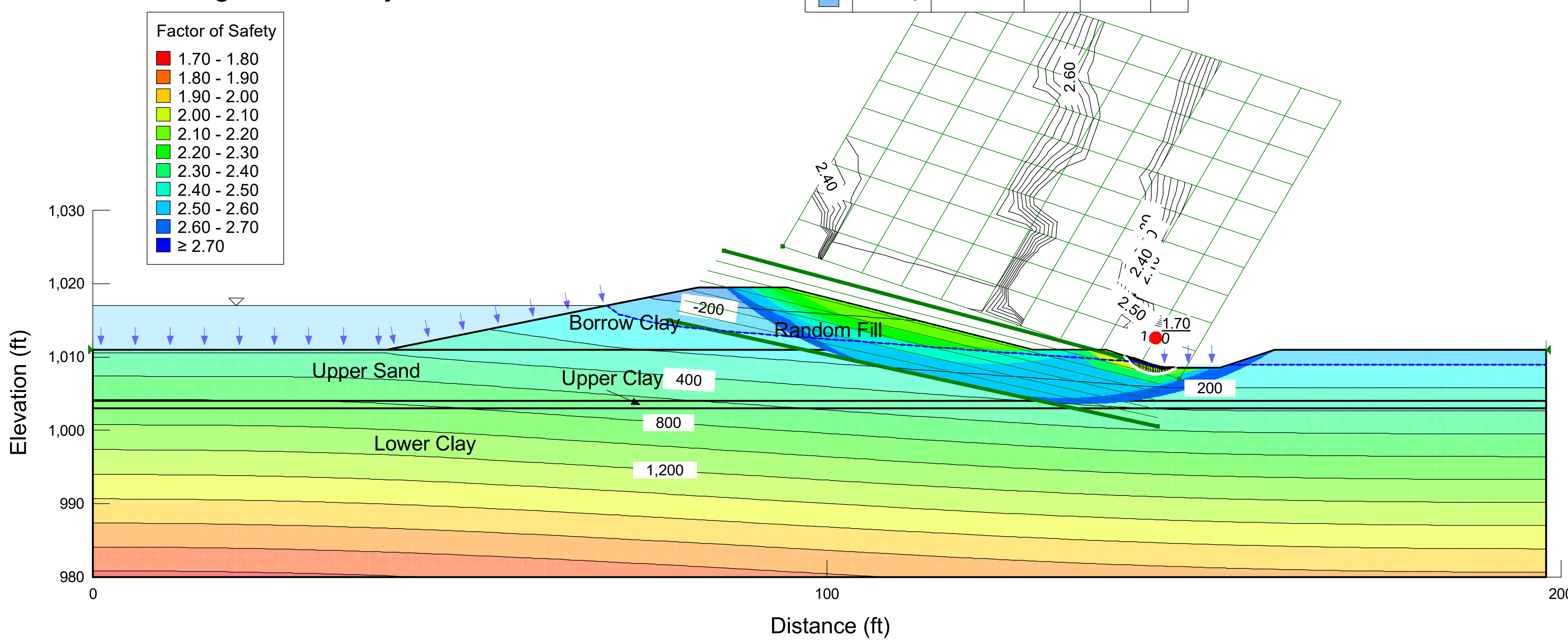
Impoundment at SB31 and SB32
Short Term - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	
	Borrow Clay - Short Term	Undrained (Phi=0)	120			750
	Lower Clay - Short Term	Undrained (Phi=0)	130			2,000
	Upper Clay - Short Term	Undrained (Phi=0)	120			750



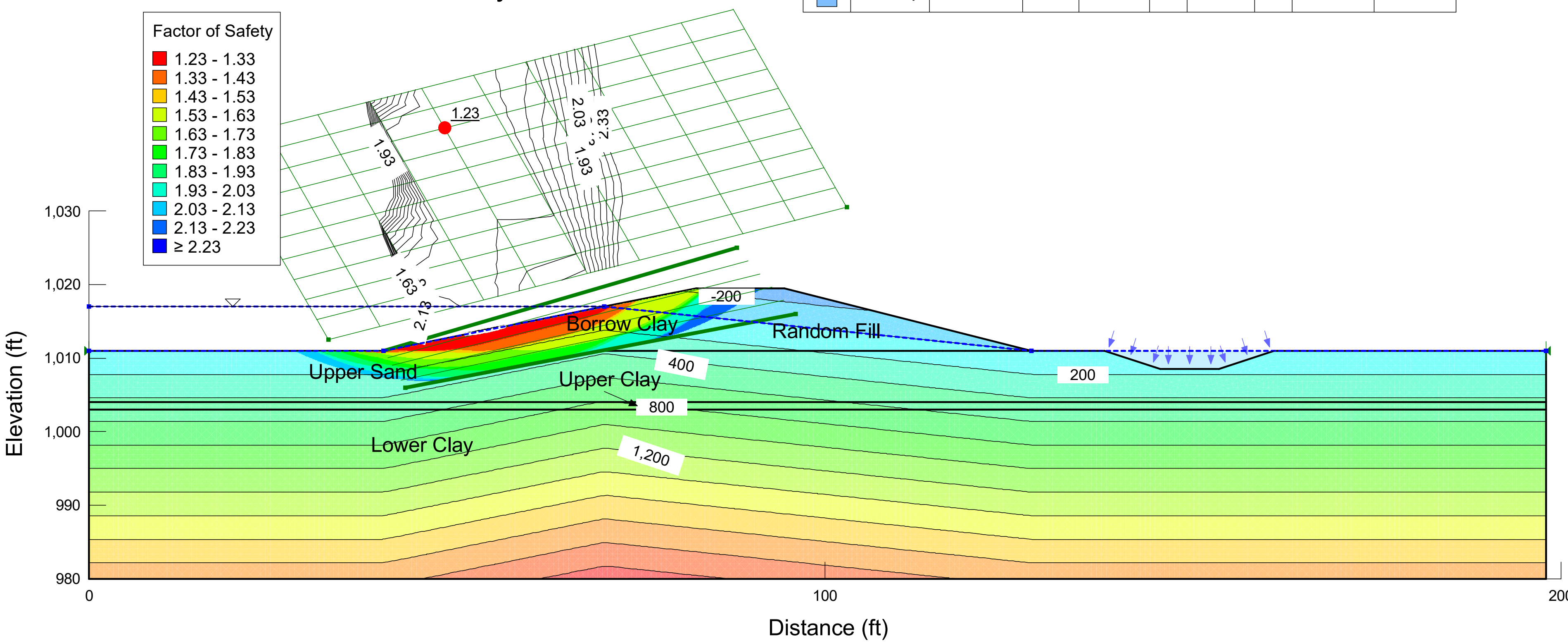
Impoundment at SB31 and SB32
Long Term - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Borrow Clay	Mohr-Coulomb	120	0	28
	Upper Clay	Mohr-Coulomb	120	0	28
	Upper Sand	Mohr-Coulomb	115	0	35
	Lower Clay	Mohr-Coulomb	130	0	28



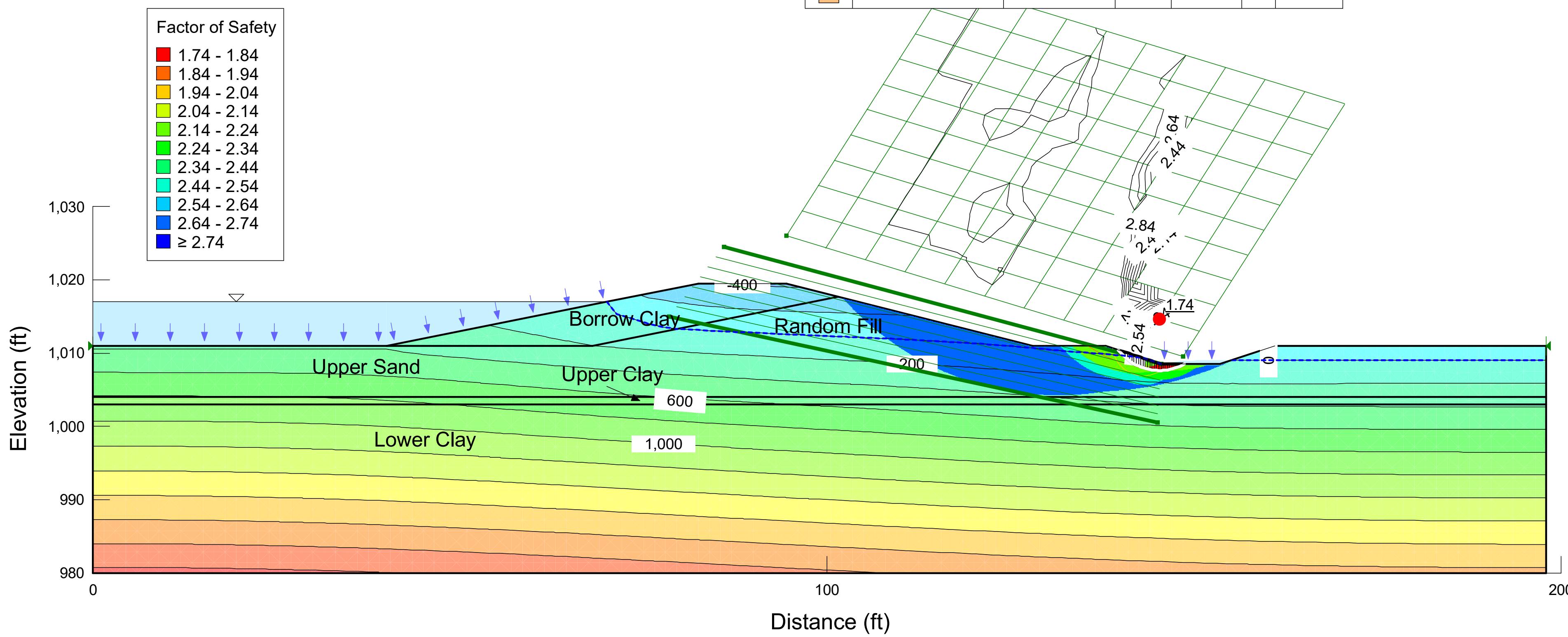
Impoundment at SB31 and SB32
Sudden Drawdown - Clay as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	750	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	750	0	1	2
	Upper Sand	Mohr-Coulomb	115	0	35	0	35	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	2,000	0	1	2



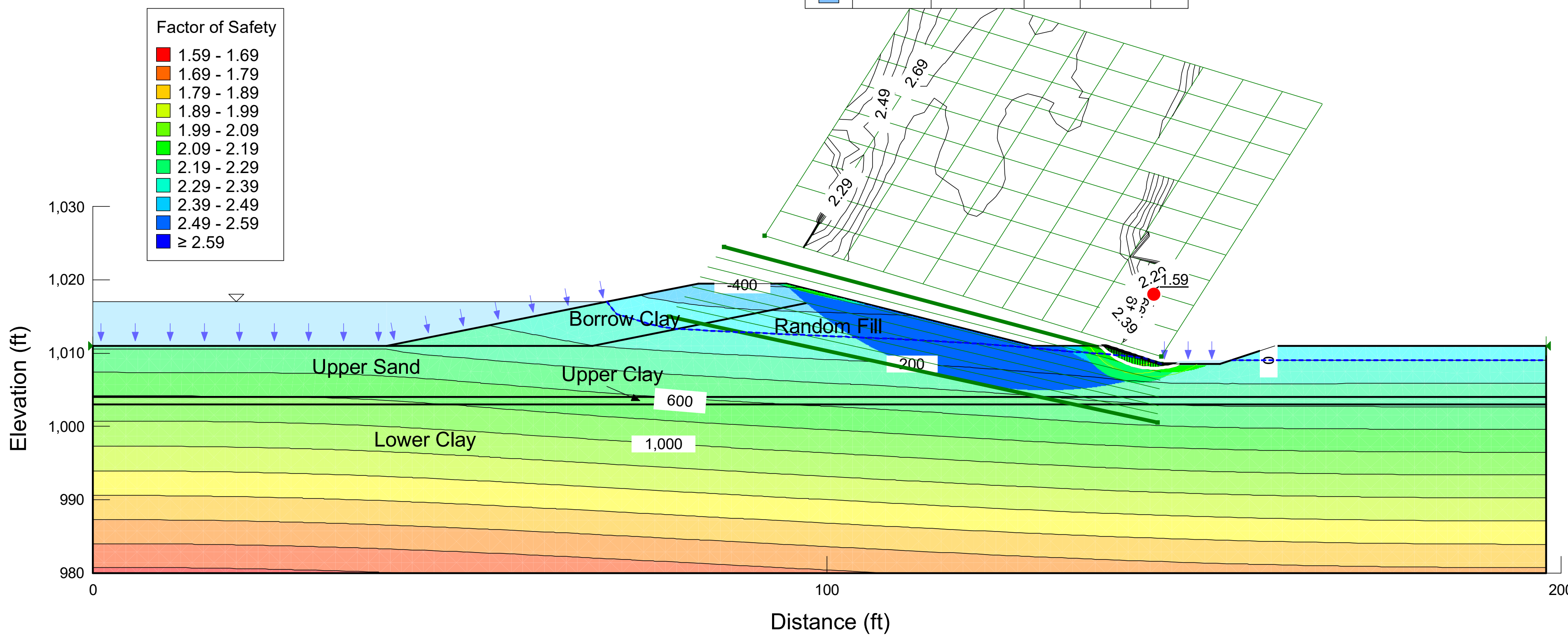
Impoundment at SB31 and SB32
Short Term - Sand as Random Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion (psf)
	Upper Sand	Mohr-Coulomb	115	0	35	
	Borrow Clay - Short Term	Undrained (Phi=0)	120			750
	Lower Clay - Short Term	Undrained (Phi=0)	130			2,000
	Upper Clay - Short Term	Undrained (Phi=0)	120			750



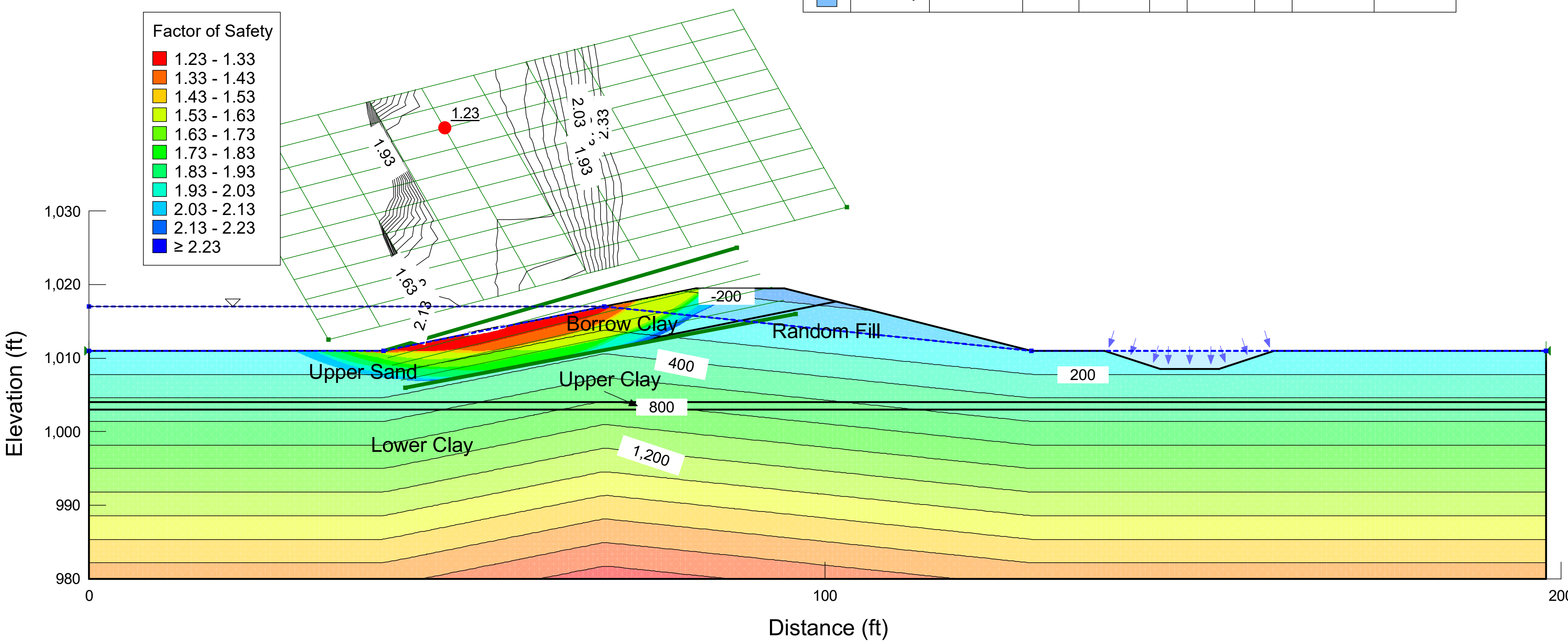
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Borrow Clay	Mohr-Coulomb	120	0	28
	Upper Clay	Mohr-Coulomb	120	0	28
	Upper Sand	Mohr-Coulomb	115	0	35
	Lower Clay	Mohr-Coulomb	130	0	28

Impoundment at SB31 and SB32
Long Term - Sand as Random Fill



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Borrow Clay	Mohr-Coulomb	120	0	28	750	0	1	2
	Upper Clay	Mohr-Coulomb	120	0	28	750	0	1	2
	Upper Sand	Mohr-Coulomb	115	0	35	0	35	1	2
	Lower Clay	Mohr-Coulomb	130	0	28	2,000	0	1	2

Impoundment at SB31 and SB32
Sudden Drawdown - Sand as Random Fill



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Appendix C

Cost Estimates

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Alternative 1 - 1

TWO RIVERS WATERSHED DISTRICT				
			ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES	UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1	$600,000.00	$600,000
CLEARING & GRUBBING	LS	1	$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	2,819,832	$2.75	$7,754,539
COMMON BORROW (P) - INLET EMBANKMENT	CY	967,835	$3.50	$3,387,424
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,066,591	$5.25	$10,849,601
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	25,000	$14.00	$350,000
GRANULAR BEDDING (P)	CY	707	$15.00	$10,605
12'X8' BOX CULVERTS	LF	250	$1,000.00	$250,000
12'X8' CONCRETE END SECTIONS	EACH	10	$11,500.00	$115,000
10'X6' BOX CULVERTS	LF	850	$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40	$9,000.00	$360,000
7'X7' SLUICE GATES	EACH	6	$23,000.00	$138,000
GATE ACTUATORS W/REMOTE	EACH	12	$8,000.00	$96,000
ORIFICE T-WALL	LF	308	$1,600.00	$492,800
POWER DELIVERY	LF	21,120	$2.25	$47,520
6'X6' SLUICE GATES	EACH	6	$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1	$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84	$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4	$3,000.00	$12,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88	$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80	$50.00	$4,000
WEIR T-WALL	LF	130	$1,000.00	$130,000
SOUTHWEST OUTLET STRUCTURE	LS	1	$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1	$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1	$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60	$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323	$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747	$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171	$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245	$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113	$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80	$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700	$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000	$36.00	$36,000
30" CS PIPE CULVERT	LF	500	$40.00	$20,000
36" CS PIPE CULVERT	LF	100	$45.00	$4,500
48" CS PIPE CULVERT	LF	100	$85.00	$8,500
18" CS PIPE APRON	EA	45	$160.00	$7,200
24" CS PIPE APRON	EA	20	$215.00	$4,300
30" CS PIPE APRON	EA	10	$300.00	$3,000
36" CS PIPE APRON	EA	2	$515.00	$1,030
48" CS PIPE APRON	EA	4	$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45	$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20	$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10	$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2	$900.00	$1,800
RANDOM RIPRAP	CY	1,639	$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000	$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533	$24.00	$60,800
TRAFFIC CONTROL	LS	1	$5,000.00	$5,000
SILT FENCE	LF	5,000	$2.10	$10,500
FLOATING SILT CURTAIN	LF	750	$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448	$2.50	$1,120
SEEDING	ACRE	123	$85.00	$10,457
SEED, MIXTURE 25-141	LB	8,612	$3.15	$27,127
MULCH MATERIAL, TYPE 1	TON	246	$80.00	$19,684
DISC ANCHORING	ACRE	123	$25.00	$3,076
FERTILIZER, TYPE 1	TON	12.30	$800.00	$9,842
SUBTOTAL				$27,484,817
LAND PURCHASED BY TRWD				$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	210		$300,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%		$2,748,482
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST		$439,831
CONTINGENCIES	10	%		$3,097,313
TOTAL CONSTRUCTION				**$39,670,443**

Alternative 1 - 2

TWO RIVERS WATERSHED DISTRICT			ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES	UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1	$600,000.00	$600,000
CLEARING & GRUBBING	LS	1	$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	3,019,127	$2.75	$8,302,600
COMMON BORROW (P) - INLET EMBANKMENT	CY	1,134,600	$3.50	$3,971,100
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,066,591	$5.25	$10,849,601
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	28,000	$14.00	$392,000
GRANULAR BEDDING (P)	CY	744	$15.00	$11,160
12'X8' BOX CULVERTS	LF	250	$1,000.00	$250,000
12'X8' CONCRETE END SECTIONS	EACH	10	$11,500.00	$115,000
10'X6' BOX CULVERTS	LF	850	$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40	$9,000.00	$360,000
6'X6' BOX CULVERTS	EACH	100	$750.00	$75,000
6'X6' CONCRETE END SECTIONS	EACH	2	$7,500.00	$15,000
GATE ACTUATORS W/REMOTE	EACH	6	$8,000.00	$48,000
POWER DELIVERY	LF	21,120	$2.25	$47,520
6'X6' SLUICE GATES	EACH	6	$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1	$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84	$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4	$3,000.00	$12,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88	$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80	$50.00	$4,000
WEIR T-WALL	LF	255	$1,000.00	$255,000
SOUTHWEST OUTLET STRUCTURE	LS	1	$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1	$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1	$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60	$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323	$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747	$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171	$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245	$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113	$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80	$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700	$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000	$36.00	$36,000
30" CS PIPE CULVERT	LF	500	$40.00	$20,000
36" CS PIPE CULVERT	LF	100	$45.00	$4,500
48" CS PIPE CULVERT	LF	100	$85.00	$8,500
18" CS PIPE APRON	EA	45	$160.00	$7,200
24" CS PIPE APRON	EA	20	$215.00	$4,300
30" CS PIPE APRON	EA	10	$300.00	$3,000
36" CS PIPE APRON	EA	2	$515.00	$1,030
48" CS PIPE APRON	EA	4	$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45	$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20	$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10	$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2	$900.00	$1,800
RANDOM RIPRAP	CY	1,639	$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000	$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533	$24.00	$60,800
TRAFFIC CONTROL	LS	1	$5,000.00	$5,000
SILT FENCE	LF	5,000	$2.10	$10,500
FLOATING SILT CURTAIN	LF	750	$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448	$2.50	$1,120
SEEDING	ACRE	133	$85.00	$11,294
SEED, MIXTURE 25-141	LB	9,301	$3.15	$29,297
MULCH MATERIAL, TYPE 1	TON	266	$80.00	$21,259
DISC ANCHORING	ACRE	133	$25.00	$3,322
FERTILIZER, TYPE 1	TON	13	$800.00	$10,629
SUBTOTAL				$28,200,924
LAND PURCHASED BY TRWD				$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	219		$315,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%		$2,820,092
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST		$462,466
CONTINGENCIES	10	%		$3,179,848
TOTAL CONSTRUCTION				**$40,578,331**

Alternative 1 - 3

TWO RIVERS WATERSHED DISTRICT			ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES	UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1	$600,000.00	$600,000
CLEARING & GRUBBING	LS	1	$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	3,263,160	$2.75	$8,973,689
COMMON BORROW (P) - INLET EMBANKMENT	CY	1,190,204	$3.50	$4,165,716
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,066,591	$5.25	$10,849,601
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	42,000	$14.00	$588,000
GRANULAR BEDDING (P)	CY	850	$15.00	$12,750
12'X8' BOX CULVERTS	LF	350	$1,000.00	$350,000
12'X8' CONCRETE END SECTIONS	EACH	14	$11,500.00	$161,000
10'X6' BOX CULVERTS	LF	850	$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40	$9,000.00	$360,000
6'X6' BOX CULVERTS	LF	100	$750.00	$75,000
6'X6' CONCRETE END SECTIONS	EACH	2	$7,500.00	$15,000
GATE ACTUATORS W/REMOTE	EACH	6	$8,000.00	$48,000
POWER DELIVERY	LF	21,120	$2.25	$47,520
6'X6' SLUICE GATES	EACH	6	$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1	$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84	$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4	$3,000.00	$12,000
SALVAGE AND RE-INSTALL 144" X 84" RC ARCH PIPE	LF	76	$200.00	$15,200
SALVAGE AND RE-INSTALL 144" X 84" RC ARCH APRON	EACH	4	$2,500.00	$10,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88	$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80	$50.00	$4,000
WEIR T-WALL	LF	155	$1,000.00	$155,000
SOUTHWEST OUTLET STRUCTURE	LS	1	$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1	$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1	$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60	$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323	$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747	$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171	$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245	$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113	$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80	$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700	$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000	$36.00	$36,000
30" CS PIPE CULVERT	LF	500	$40.00	$20,000
36" CS PIPE CULVERT	LF	100	$45.00	$4,500
48" CS PIPE CULVERT	LF	100	$85.00	$8,500
18" CS PIPE APRON	EA	45	$160.00	$7,200
24" CS PIPE APRON	EA	20	$215.00	$4,300
30" CS PIPE APRON	EA	10	$300.00	$3,000
36" CS PIPE APRON	EA	2	$515.00	$1,030
48" CS PIPE APRON	EA	4	$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45	$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20	$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10	$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2	$900.00	$1,800
RANDOM RIPRAP	CY	1,639	$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000	$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533	$24.00	$60,800
TRAFFIC CONTROL	LS	1	$5,000.00	$5,000
SILT FENCE	LF	5,000	$2.10	$10,500
FLOATING SILT CURTAIN	LF	750	$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448	$2.50	$1,120
SEEDING	ACRE	164	$85.00	$13,908
SEED, MIXTURE 25-141	LB	11,454	$3.15	$36,079
MULCH MATERIAL, TYPE 1	TON	327	$80.00	$26,180
DISC ANCHORING	ACRE	163.62	$25.00	$4,091
FERTILIZER, TYPE 1	TON	16	$800.00	$13,090
SUBTOTAL				$28,200,924
LAND PURCHASED BY TRWD				$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	246		$300,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%		$2,820,092
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST		$462,466
CONTINGENCIES	10	%		$3,179,848
TOTAL CONSTRUCTION				**$40,578,331**

Alternative 2 - 1

TWO RIVERS WATERSHED DISTRICT			ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES	UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1	$600,000.00	$600,000
CLEARING & GRUBBING	LS	1	$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	2,820,490	$2.75	$7,756,347
COMMON BORROW (P) - INLET EMBANKMENT	CY	967,835	$3.50	$3,387,424
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,174,240	$5.25	$11,414,761
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	25,000	$14.00	$350,000
GRANULAR BEDDING (P)	CY	707	$15.00	$10,605
12'X8' BOX CULVERTS	LF	250	$1,000.00	$250,000
12'X8' CONCRETE END SECTIONS	EACH	10	$11,500.00	$115,000
10'X6' BOX CULVERTS	LF	850	$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40	$9,000.00	$360,000
7'X7' SLUICE GATES	EACH	6	$23,000.00	$138,000
GATE ACTUATORS W/REMOTE	EACH	12	$8,000.00	$96,000
ORIFICE T-WALL	LF	308	$1,600.00	$492,800
POWER DELIVERY	LF	21,120	$2.25	$47,520
6'X6' SLUICE GATES	EACH	6	$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1	$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84	$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4	$3,000.00	$12,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88	$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80	$50.00	$4,000
WEIR T-WALL	LF	130	$1,000.00	$130,000
SOUTHWEST OUTLET STRUCTURE	LS	1	$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1	$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1	$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60	$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323	$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747	$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171	$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245	$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113	$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80	$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700	$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000	$36.00	$36,000
30" CS PIPE CULVERT	LF	500	$40.00	$20,000
36" CS PIPE CULVERT	LF	100	$45.00	$4,500
48" CS PIPE CULVERT	LF	100	$85.00	$8,500
18" CS PIPE APRON	EA	45	$160.00	$7,200
24" CS PIPE APRON	EA	20	$215.00	$4,300
30" CS PIPE APRON	EA	10	$300.00	$3,000
36" CS PIPE APRON	EA	2	$515.00	$1,030
48" CS PIPE APRON	EA	4	$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45	$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20	$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10	$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2	$900.00	$1,800
RANDOM RIPRAP	CY	1,639	$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000	$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533	$24.00	$60,800
TRAFFIC CONTROL	LS	1	$5,000.00	$5,000
SILT FENCE	LF	5,000	$2.10	$10,500
FLOATING SILT CURTAIN	LF	750	$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448	$2.50	$1,120
SEEDING	ACRE	123	$85.00	$10,457
SEED, MIXTURE 25-141	LB	8,612	$3.15	$27,127
MULCH MATERIAL, TYPE 1	TON	246	$80.00	$19,684
DISC ANCHORING	ACRE	123	$25.00	$3,076
FERTILIZER, TYPE 1	TON	12.30	$800.00	$9,842
SUBTOTAL				$28,051,785
LAND PURCHASED BY TRWD				$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	210		$300,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%		$2,805,178
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST		$451,171
CONTINGENCIES	10	%		$3,160,813
TOTAL CONSTRUCTION				**$40,368,947**

Alternative 2 - 2

TWO RIVERS WATERSHED DISTRICT				ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES		UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1		$600,000.00	$600,000
CLEARING & GRUBBING	LS	1		$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	3,019,785		$2.75	$8,304,408
COMMON BORROW (P) - INLET EMBANKMENT	CY	1,134,600		$3.50	$3,971,100
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,174,240		$5.25	$11,414,761
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	28,000		$14.00	$392,000
GRANULAR BEDDING (P)	CY	744		$15.00	$11,160
12'X8' BOX CULVERTS	LF	250		$1,000.00	$250,000
12'X8' CONCRETE END SECTIONS	EACH	10		$11,500.00	$115,000
10'X6' BOX CULVERTS	LF	850		$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40		$9,000.00	$360,000
6'X6' BOX CULVERTS	LF	100		$750.00	$75,000
6'X6' CONCRETE END SECTIONS	EACH	2		$7,500.00	$15,000
GATE ACTUATORS W/REMOTE	EACH	6		$8,000.00	$48,000
POWER DELIVERY	LF	21,120		$2.25	$47,520
6'X6' SLUICE GATES	EACH	6		$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1		$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84		$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4		$3,000.00	$12,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88		$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80		$50.00	$4,000
WEIR T-WALL	LF	255		$1,000.00	$255,000
SOUTHWEST OUTLET STRUCTURE	LS	1		$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1		$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1		$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60		$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323		$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747		$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171		$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245		$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113		$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80		$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700		$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000		$36.00	$36,000
30" CS PIPE CULVERT	LF	500		$40.00	$20,000
36" CS PIPE CULVERT	LF	100		$45.00	$4,500
48" CS PIPE CULVERT	LF	100		$85.00	$8,500
18" CS PIPE APRON	EA	45		$160.00	$7,200
24" CS PIPE APRON	EA	20		$215.00	$4,300
30" CS PIPE APRON	EA	10		$300.00	$3,000
36" CS PIPE APRON	EA	2		$515.00	$1,030
48" CS PIPE APRON	EA	4		$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45		$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20		$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10		$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2		$900.00	$1,800
RANDOM RIPRAP	CY	1,639		$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000		$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533		$24.00	$60,800
TRAFFIC CONTROL	LS	1		$5,000.00	$5,000
SILT FENCE	LF	5,000		$2.10	$10,500
FLOATING SILT CURTAIN	LF	750		$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448		$2.50	$1,120
SEEDING	ACRE	133		$85.00	$11,294
SEED, MIXTURE 25-141	LB	9,301		$3.15	$29,297
MULCH MATERIAL, TYPE 1	TON	266		$80.00	$21,259
DISC ANCHORING	ACRE	133		$25.00	$3,322
FERTILIZER, TYPE 1	TON	13		$800.00	$10,629
SUBTOTAL					$28,767,892
LAND PURCHASED BY TRWD					$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	219			$315,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%			$2,876,789
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST			$473,805
CONTINGENCIES	10	%			$3,243,349
TOTAL CONSTRUCTION					**$41,276,835**

Alternative 2 - 3

TWO RIVERS WATERSHED DISTRICT			ENGINEER'S ESTIMATE	
ITEM DESCRIPTION	UNITS	TOTAL ESTIMATED QUANTITIES	UNIT PRICE	TOTAL PRICE
MOBILIZATION	LS	1	$600,000.00	$600,000
CLEARING & GRUBBING	LS	1	$45,000.00	$45,000
COMMON EXCAVATION (P)	CY	3,263,817	$2.75	$8,975,497
COMMON BORROW (P) - INLET EMBANKMENT	CY	1,190,204	$3.50	$4,165,716
COMMON BORROW (P) - IMPOUNDMENT EMBANKMENT	CY	2,174,240	$5.25	$11,414,761
AGGREGATE SURFACING, CLASS 5 MODIFIED	TON	42,000	$14.00	$588,000
GRANULAR BEDDING (P)	CY	850	$15.00	$12,750
12'X8' BOX CULVERTS	LF	350	$1,000.00	$350,000
12'X8' CONCRETE END SECTIONS	EACH	14	$11,500.00	$161,000
10'X6' BOX CULVERTS	LF	850	$800.00	$680,000
10'X6' CONCRETE END SECTIONS	EACH	40	$9,000.00	$360,000
6'X6' BOX CULVERTS	LF	100	$750.00	$75,000
6'X6' CONCRETE END SECTIONS	EACH	2	$7,500.00	$15,000
GATE ACTUATORS W/REMOTE	EACH	6	$8,000.00	$48,000
POWER DELIVERY	LF	21,120	$2.25	$47,520
6'X6' SLUICE GATES	EACH	6	$20,000.00	$120,000
GATE CONTROL PANEL	EACH	1	$26,000.00	$26,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH PIPE	LF	84	$250.00	$21,000
SALVAGE AND RE-INSTALL 169" X 107" RC ARCH APRON	EACH	4	$3,000.00	$12,000
SALVAGE AND RE-INSTALL 144" X 84" RC ARCH PIPE	LF	76	$200.00	$15,200
SALVAGE AND RE-INSTALL 144" X 84" RC ARCH APRON	EACH	4	$2,500.00	$10,000
REMOVE 154" X 96" RC ARCH PIPE	LF	88	$100.00	$8,800
REMOVE 80" X 45" RC ARCH PIPE	LF	80	$50.00	$4,000
WEIR T-WALL	LF	155	$1,000.00	$155,000
SOUTHWEST OUTLET STRUCTURE	LS	1	$456,300.00	$456,300
WEST OUTLET STRUCTURE	LS	1	$406,000.00	$406,000
NORTHWEST OUTLET STRUCTURE	LS	1	$416,300.00	$416,300
REMOVE 15" CS PIPE CULVERT	LF	60	$10.00	$600
REMOVE 18" CS PIPE CULVERT	LF	323	$10.00	$3,230
REMOVE 24" CS PIPE CULVERT	LF	747	$10.00	$7,470
REMOVE 30" CS PIPE CULVERT	LF	171	$10.00	$1,710
REMOVE 36" CS PIPE CULVERT	LF	245	$15.00	$3,675
REMOVE 60" CS PIPE CULVERT	LF	113	$20.00	$2,260
REMOVE 72" CS PIPE CULVERT	LF	80	$25.00	$2,000
18" CS PIPE CULVERT	LF	2,700	$30.00	$81,000
24" CS PIPE CULVERT	LF	1,000	$36.00	$36,000
30" CS PIPE CULVERT	LF	500	$40.00	$20,000
36" CS PIPE CULVERT	LF	100	$45.00	$4,500
48" CS PIPE CULVERT	LF	100	$85.00	$8,500
18" CS PIPE APRON	EA	45	$160.00	$7,200
24" CS PIPE APRON	EA	20	$215.00	$4,300
30" CS PIPE APRON	EA	10	$300.00	$3,000
36" CS PIPE APRON	EA	2	$515.00	$1,030
48" CS PIPE APRON	EA	4	$1,250.00	$5,000
FLAP GATE FOR 18" CS PIPE	EA	45	$475.00	$21,375
FLAP GATE FOR 24" CS PIPE	EA	20	$515.00	$10,300
FLAP GATE FOR 30" CS PIPE	EA	10	$700.00	$7,000
FLAP GATE FOR 36" CS PIPE	EA	2	$900.00	$1,800
RANDOM RIPRAP	CY	1,639	$80.00	$131,123
ARMORFLEX OPEN CELL 20' SECTION	SF	12,000	$16.00	$192,000
ARMORMAX GEOTEXTILE SLOPE REINFORCEMENT	SY	2,533	$24.00	$60,800
TRAFFIC CONTROL	LS	1	$5,000.00	$5,000
SILT FENCE	LF	5,000	$2.10	$10,500
FLOATING SILT CURTAIN	LF	750	$7.00	$5,250
TEMPORARY DITCH CHECK, TYPE 2	LF	448	$2.50	$1,120
SEEDING	ACRE	164	$85.00	$13,908
SEED, MIXTURE 25-141	LB	11,454	$3.15	$36,079
MULCH MATERIAL, TYPE 1	TON	327	$80.00	$26,180
DISC ANCHORING	ACRE	163.62	$25.00	$4,091
FERTILIZER, TYPE 1	TON	16	$800.00	$13,090
SUBTOTAL				$29,919,933
LAND PURCHASED BY TRWD				$5,600,000
RIGHT-OF-WAY ACQUISITION	ACRE	246		$350,000
ENGINEERING AND ADMIN. (INC. LEGAL DITCH ENGINEERS REPORTS AND HEARINGS)	10	%		$2,991,993
MATERIALS TESTING (CONSTRUCTION)	2	% OF EARTHWORK COST		$491,119
CONTINGENCIES	10	%		$3,375,305
TOTAL CONSTRUCTION				**$42,728,350**

Appendix D

Site Photos

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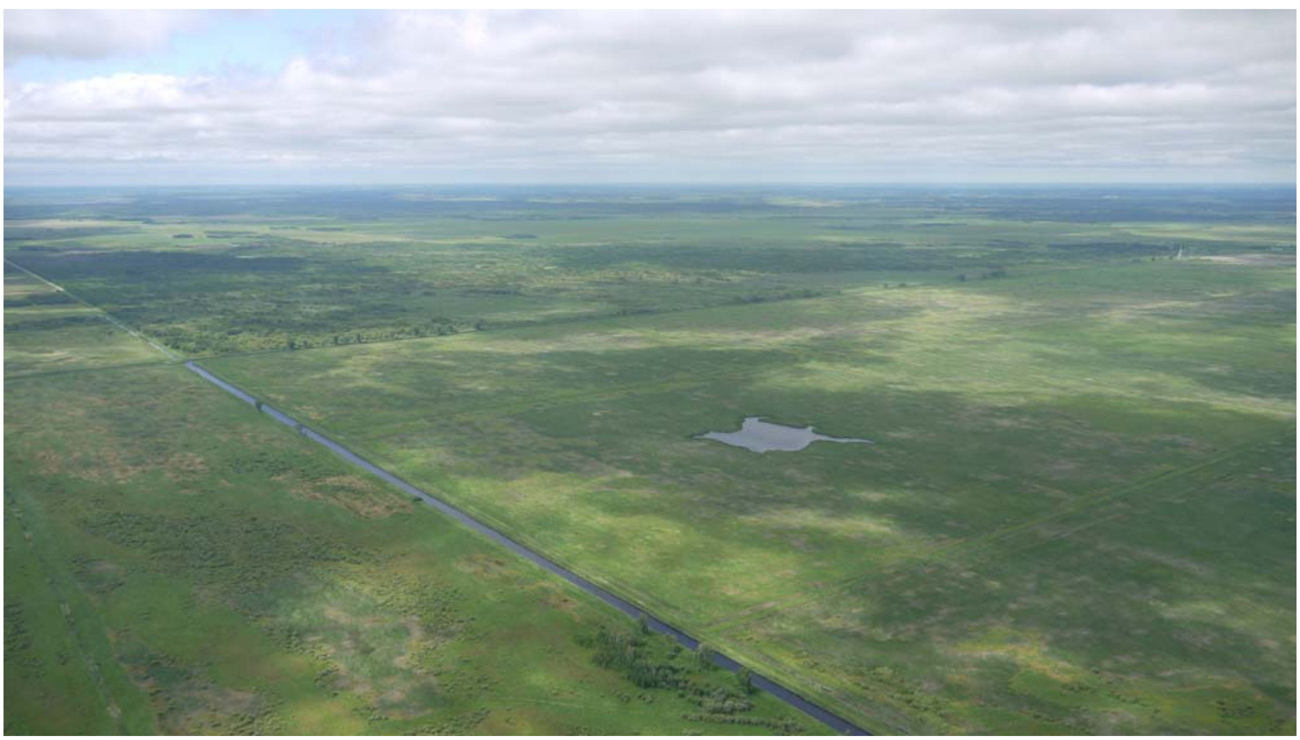
Site Pictures

1 Looking West - County Line with junction of SD 95 Lat 1 and SD 95 Lat 1 Br 3

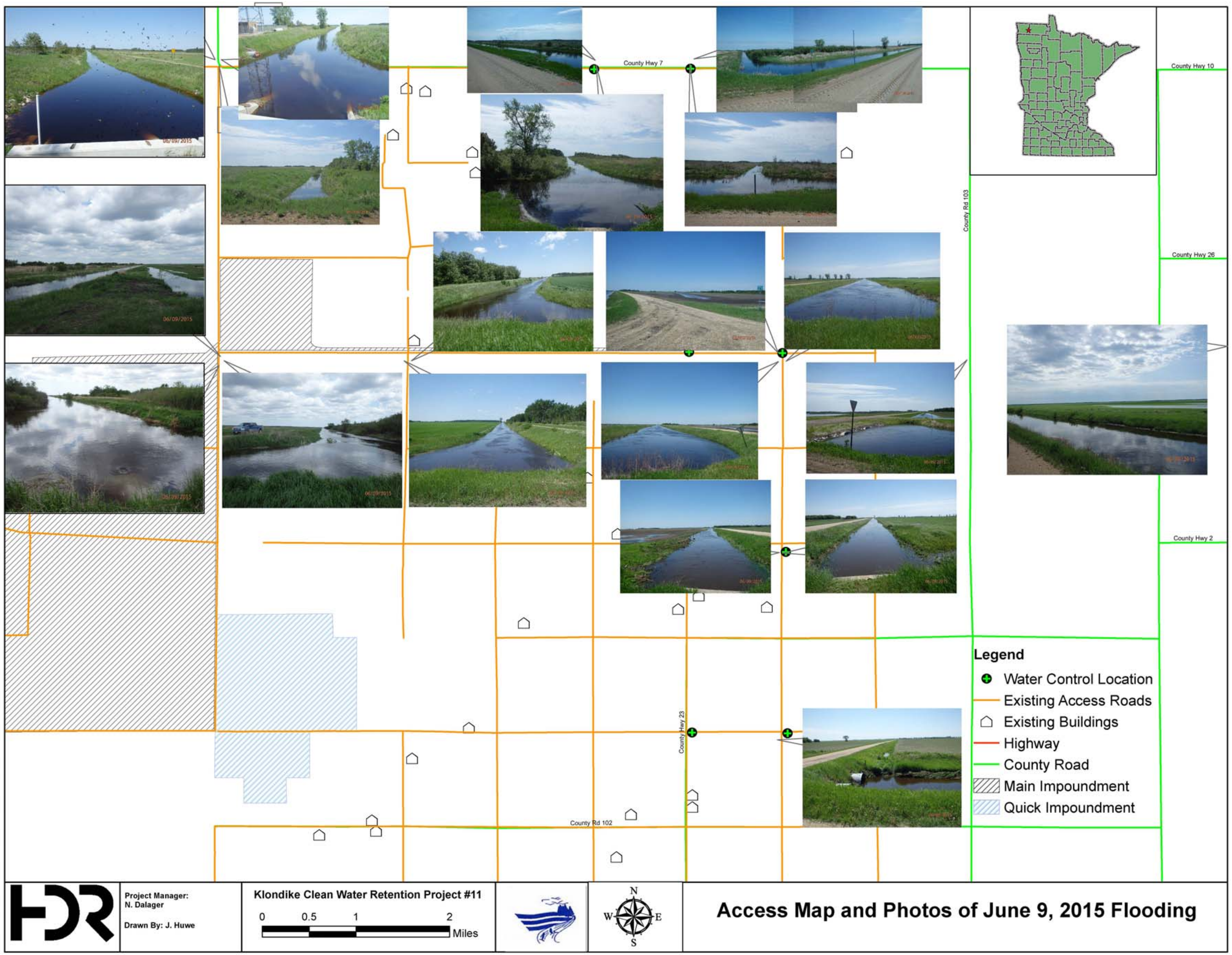
2 Looking Southwest at Section 24 Klondike



3 SD 72 Lat 8 Looking South from County Road 7

4 Former Groundwater Monitoring Wells

5 Looking South from SD 95 Lat 1 and SD 72 Lat 12


County Hwy 7
County Hwy 10
County Rd 103
County Hwy 26
County Hwy 2
County Hwy 23
County Rd 102
Legend
Water Control Location
Existing Access Roads
Existing Buildings
Highway
County Road
Main Impoundment
Quick Impoundment
Project Manager:
N. Dalager
Drawn By: J. Huwe
Klondike Clean Water Retention Project #11
0
0.5
1
2
Miles
N
W
E
S
Access Map and Photos of June 9, 2015 Flooding

Appendix E

Additional Right of Way Required to Implement the Project

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Additional Right of Way Required to Implement the Project

Section	40 Acre Tract (or portion thereof)	Township	County
36	SE 1/4 of SE 1/4	162 N 45 W	Kittson
23	SW 1/4 of SW 1/4	162 N 44 W	Roseau
23	NW 1/4 of SW 1/4	162 N 44 W	Roseau
23	SW 1/4 of NW 1/4	162 N 44 W	Roseau
23	NW 1/4 of NW 1/4	162 N 44 W	Roseau
24	SW 1/4 of SW 1/4	162 N 44 W	Roseau
24	NW 1/4 of SW 1/4	162 N 44 W	Roseau
24	SW 1/4 of NW 1/4	162 N 44 W	Roseau
24	NW 1/4 of NW 1/4	162 N 44 W	Roseau
25	SW 1/4 of SW 1/4	162 N 44 W	Roseau
25	NW 1/4 of SW 1/4	162 N 44 W	Roseau
25	SW 1/4 of NW 1/4	162 N 44 W	Roseau
25	NW 1/4 of NW 1/4	162 N 44 W	Roseau
26	SW 1/4 of SW 1/4	162 N 44 W	Roseau
26	NW 1/4 of SW 1/4	162 N 44 W	Roseau
26	SW 1/4 of NW 1/4	162 N 44 W	Roseau
26	NW 1/4 of NW 1/4	162 N 44 W	Roseau
32	SW 1/4 of SW 1/4	162 N 44 W	Roseau
32	SE 1/4 of SW 1/4	162 N 44 W	Roseau
32	SW 1/4 of SE 1/4	162 N 44 W	Roseau
32	SE 1/4 of SE 1/4	162 N 44 W	Roseau
33	SW 1/4 of SW 1/4	162 N 44 W	Roseau
33	SE 1/4 of SW 1/4	162 N 44 W	Roseau
33	SW 1/4 of SE 1/4	162 N 44 W	Roseau
33	SE 1/4 of SE 1/4	162 N 44 W	Roseau
34	SW 1/4 of SW 1/4	162 N 44 W	Roseau
34	SE 1/4 of SW 1/4	162 N 44 W	Roseau
34	SW 1/4 of SE 1/4	162 N 44 W	Roseau
34	SE 1/4 of SE 1/4	162 N 44 W	Roseau
35	SW 1/4 of SW 1/4	162 N 44 W	Roseau
35	SE 1/4 of SW 1/4	162 N 44 W	Roseau
35	SW 1/4 of SE 1/4	162 N 44 W	Roseau
35	SE 1/4 of SE 1/4	162 N 44 W	Roseau
35	NW 1/4 of SW 1/4	162 N 44 W	Roseau
35	SW 1/4 of NW 1/4	162 N 44 W	Roseau
35	NW 1/4 of NW 1/4	162 N 44 W	Roseau
36	SW 1/4 of SW 1/4	162 N 44 W	Roseau
36	SE 1/4 of SW 1/4	162 N 44 W	Roseau
36	SW 1/4 of SE 1/4	162 N 44 W	Roseau
36	SE 1/4 of SE 1/4	162 N 44 W	Roseau
36	NW 1/4 of SW 1/4	162 N 44 W	Roseau
36	SW 1/4 of NW 1/4	162 N 44 W	Roseau
36	NW 1/4 of NW 1/4	162 N 44 W	Roseau
1	NW 1/4 of NW 1/4	161 N 44 W	Roseau
1	NE 1/4 of NW 1/4	161 N 44 W	Roseau
1	NW 1/4 of NE 1/4	161 N 44 W	Roseau
1	NE 1/4 of NE 1/4	161 N 44 W	Roseau
2	NW 1/4 of NW 1/4	161 N 44 W	Roseau
2	NE 1/4 of NW 1/4	161 N 44 W	Roseau
2	NW 1/4 of NE 1/4	161 N 44 W	Roseau
2	NE 1/4 of NE 1/4	161 N 44 W	Roseau

Section	40 Acre Tract (or portion thereof)	Township	County
3	NW 1/4 of NW 1/4	161 N 44 W	Roseau
3	NE 1/4 of NW 1/4	161 N 44 W	Roseau
3	NW 1/4 of NE 1/4	161 N 44 W	Roseau
3	NE 1/4 of NE 1/4	161 N 44 W	Roseau
4	NW 1/4 of NW 1/4	161 N 44 W	Roseau
4	NE 1/4 of NW 1/4	161 N 44 W	Roseau
4	NW 1/4 of NE 1/4	161 N 44 W	Roseau
4	NE 1/4 of NE 1/4	161 N 44 W	Roseau
5	NW 1/4 of NW 1/4	161 N 44 W	Roseau
5	NE 1/4 of NW 1/4	161 N 44 W	Roseau
5	NW 1/4 of NE 1/4	161 N 44 W	Roseau
5	NE 1/4 of NE 1/4	161 N 44 W	Roseau
4	NW 1/4 of NW 1/4	161 N 43 W	Roseau
4	NE 1/4 of NW 1/4	161 N 43 W	Roseau
4	NW 1/4 of NE 1/4	161 N 43 W	Roseau
4	NE 1/4 of NE 1/4	161 N 43 W	Roseau
5	NW 1/4 of NW 1/4	161 N 43 W	Roseau
5	NE 1/4 of NW 1/4	161 N 43 W	Roseau
5	NW 1/4 of NE 1/4	161 N 43 W	Roseau
5	NE 1/4 of NE 1/4	161 N 43 W	Roseau
6	SW 1/4 of SW 1/4	161 N 43 W	Roseau
6	NW 1/4 of SW 1/4	161 N 43 W	Roseau
6	SW 1/4 of NW 1/4	161 N 43 W	Roseau
6	NW 1/4 of NW 1/4	161 N 43 W	Roseau
7	SW 1/4 of SW 1/4	161 N 43 W	Roseau
7	NW 1/4 of SW 1/4	161 N 43 W	Roseau
7	SW 1/4 of NW 1/4	161 N 43 W	Roseau
7	NW 1/4 of NW 1/4	161 N 43 W	Roseau
18	SW 1/4 of SW 1/4	161 N 43 W	Roseau
18	NW 1/4 of SW 1/4	161 N 43 W	Roseau
18	SW 1/4 of NW 1/4	161 N 43 W	Roseau
18	NW 1/4 of NW 1/4	161 N 43 W	Roseau
19	SW 1/4 of SW 1/4	161 N 43 W	Roseau
19	NW 1/4 of SW 1/4	161 N 43 W	Roseau
19	SW 1/4 of NW 1/4	161 N 43 W	Roseau
19	NW 1/4 of NW 1/4	161 N 43 W	Roseau

Additional Right of Way Required - Summary of Alternatives

Alternative	Acres
1-1	210
1-2	219
1-3	246
2-1	210
2-2	219
2-3	246