Grey Cloud Island Slough Crossing Project

(May 9, 2006 revision)

Final Report

Prepared by

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Executive Summary

May 9th, 2006
UMNECo
Grey Cloud Island Slough Crossing Design Team

FINAL REPORT

The Grey Cloud Island Slough is an offshoot of the main channel of the Mississippi River that separates Grey Cloud Island Township from the east bank of the Mississippi River. After an old bridge was replaced (one that connected the northern end of the island to the mainland) with an earthen dam containing metal culverts to allow water to flow through the slough, they eventually became clogged. As time went on, the flow of clean river water into the slough was stopped, which led to poor water quality and decimated the local fish population. The residents of Grey Cloud Island Township recently began searching for a solution to this problem.

The project was proposed to University of Minnesota Capstone Design teams, and UMNECo produced two separate "30% Designs." The aim of this was to give the township two options for restoring the water quality in the slough while protecting the crossing from being overtopped in a flood event greater than what it is currently built for.

The design includes information on:

- Hydraulics (both water elevation and culvert design)
- Roadwork Design (including roadway design and pavement design)
- Permitting
- Construction (methods and timeline)

From this design, a cost estimate was produced. This showed that the cost for a roadway design for a 100-year event (i.e. unchanged road elevation) is $630,000. The cost for increasing flood protection to the 500-year event was determined to be $1,560,000.

Because of the safety concerns that come with the crossing being overtopped by floodwaters, UMNECo Engineers recommend that Grey Cloud Island Township reconstruct the slough crossing to be able to withstand a 500-year flood event.

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Introduction

A large earthen dam was built across the mouth of the Grey Cloud Island Slough, replacing an old bridge that had connected the island to the mainland. The replacement crossing, pictured in Figure 1, featured corrugated metal pipe culverts to convey water into the slough, and a roadway built across the top to accommodate traffic (both residential for the people living in the township and commercial for a limestone quarry which operates on the island) on Grey Cloud Island Drive South.

Figure 1: The current slough crossing, as viewed from the north
(Picture taken February 3rd, 2006)

However, as time went on, the culverts became clogged with silts, sediments, and vegetation. As this process became more severe, water flow through these culverts became increasingly limited, eventually resulting in a total clog. Consequently, the ends of these culverts were buried, leaving no sign that they even existed. The slough had its northern end turned into a pool of water with

Consequently, the ends of these culverts were buried, leaving no sign that they even existed. The slough had its northern end turned into a pool of water with little flow through it. As the water to the south of the earthen dam began to sit and stagnate, phosphates built up and Eurasian water milfoil and algae began to thrive, quickly turning the once pristine channel into a swampy mess for the local residents of Grey Cloud Township. The slough runs the length of the island, and due to the poor water quality, can be seen from above, in Figure 2, as a light-green swath of water, in contrast to the otherwise healthy brown of the Mississippi.

This increase in milfoil and algal blooms caused fish populations to decline as well as created various water quality issues that motivated the people of Grey Cloud Township to explore options to restore the slough to its once natural beauty.

Figure 2: Satellite view of light-green discoloration of stagnant water
(photograph courtesy of GoogleEarth)

Problem Statement

This is the second part in a collaborative effort by University of Minnesota Capstone Design project groups to restore the water quality of the Grey Cloud Island Slough. The first effort focused on identifying the actual cause of the water quality problems and a theoretical solution to those problems that could be reasonably implemented. The design team of Quality Management Defenders (QDM) prepared a report, *Grey Cloud Island Water Quality Project* (Figure 3), pegging the cause of the problem to be a lack of water flow through the slough crossing.

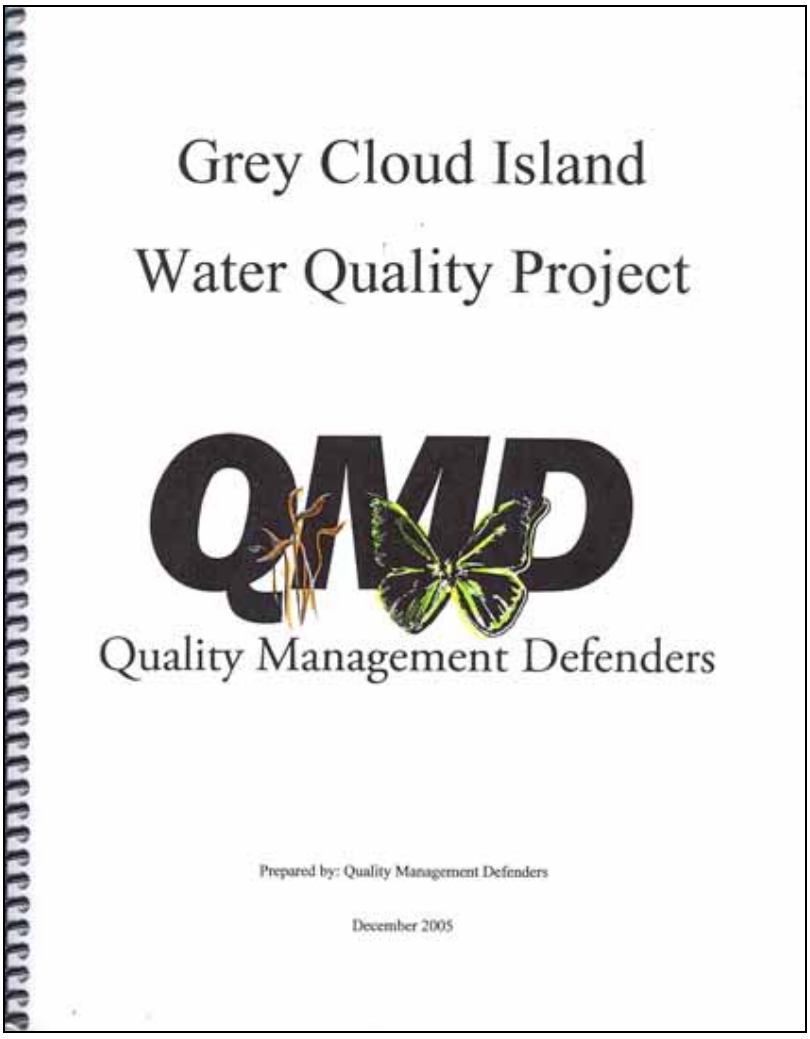

Figure 3: The QMD report cover page

The QMD team conducted water quality analyses and determined a minimum amount of flow from the main stream of the Mississippi River into the slough (approximately 70 cubic feet per second [cfs]) that would clean out the increased phosphorous loading as well as reduce the amount of milfoil and algae present in the channel.

The problem presented to UMNECo Engineers was to create a design for a new slough crossing using the information presented in the QMD report. The new crossing needs to maintain a balance of several components: community approval, low cost, ease of construction, simplicity of design, improving water quality, and minimizing environmental damage to the surrounding area. This design is known as a "30% design", comprised of a preliminary design of the crossing, a cost estimate of the project, a feasibility analysis, and a list of required permits. This process was then repeated, but the roadway elevation was raised to accommodate floodwaters at a 500-year elevation. This was done to provide the township with the option of constructing the new crossing to be able to withstand water overtopping the crossing in a 500-year flood event. All of these tasks are to be completed in accordance with all governmental agencies' permitting processes. These processes are detailed later in this report.

For more information regarding the water quality modeling, including phosphorous loading, algal blooms and Eurasian water milfoil, and modeling methodology, please consult the report titled *Grey Cloud Island Water Quality Project*, prepared by QDM in December of 2005.

Project Background

Location

Upper Grey Cloud Island is located in the southwest corner of Minnesota's Washington County, one of the seven primary counties that make up the greater Minneapolis-St Paul Metropolitan Area. Grey Cloud Island Township is bordered by the Mississippi River on the south and west, and on the north and east by St Paul Park and Cottage Grove, respectively. The location can be seen in Figure 4.

Figure 4: Map of Minnesota showing general location of the project

The location of the project, marked with a red star, can be better seen in location with Minnesota roads and municipalities in Figure 5.

Figure 5: Map of the Minneapolis/St Paul Metro area showing the location of Grey Cloud Island Slough and major roads and municipalities. (Image from MapQuest.com)

General Information

Upper Grey Cloud Island is a landmass created by a small offshoot of the Mississippi River. Located on the island is Grey Cloud Island Township, a municipality of 307 people (as of the 2000 census). The township has 1,595 acres of land and 18 miles of shoreline.

The township is comprised mostly of light residential lands, with the exception being the still-active limestone quarry located on the island. After the bridge was washed out during the 1965 Mississippi River flood event, an earthen crossing

was erected. The water flow was maintained by several corrugated metal culverts, which functioned as designed until the 1990s. It was at this time when local residents noticed deteriorating water quality in the slough.

In October of 2005, the St Paul Park City council voted to approve an annexation measure to take land from Grey Cloud Island Township (land that is not located on the island itself, but just north of the slough inlet) for a development called the River's Edge Project. This project is slated to have 1,900 housing units and as much as 40,000 square feet of retail/commercial space. Any proposed developments along the river would unquestionably affect water quality through excess runoff created by the development.

Methodology

In January of 2006, UMNECo was selected to continue the work on restoring Grey Cloud Island Slough's water quality. This process began with UMNECo Engineers studying the problems presented by rebuilding a slough crossing and ensuring that the solution suggested by the previous consulting firm (QMD) was the best solution.

In order to restore water flow through the slough, several options were considered. The possible solutions included: 1) reconstructing the earthen crossing with the road on top and a new culvert, 2) a bridge, 3) a tunnel, and 4) keeping the crossing in its current condition.

After conferring with Suresh Hettiarachchi, P.E., of HDR Engineering in Minneapolis, option 1 was selected as the most appropriate solution for restoring water flow into the slough. This decision was based on criteria including community approval, low cost, ease of construction, simplicity of design, improving water quality, and minimizing environmental damage to the surrounding area.

After a site visit in February of 2006 the design team began working on the new slough crossing. The project was split into four parts: Hydraulics, Roadway Design, Construction Methodology, and Permitting. Each part played a crucial role in the ultimate goal of reaching the "30% design", which was used for cost estimation. This allows for the township to use the design as base to apply for any financial aid they may wish to seek.

Hydraulics

Knowing the required water flows, flow velocity, and water elevations within the culvert are key to designing the roadway itself. QDM recommended a flow of 70 cfs and a flow velocity greater than 5 feet per second [fps] in the culvert to mitigate the water quality problems. To prevent erosion of the channel bed, the flow velocity should not exceed 9 fps.

Water Elevation

It was assumed that water quality issues within the Grey Cloud Island Slough occur during the months between May and October. Using monthly average flow rates published by the St. Paul District of the United States Army Corps of Engineers (USACE), it was determined that Mississippi River Pool No. 2 has an average flow rate of 16,350 cfs for the time period in question (Table 1).

Table 1. Monthly average flow rates [cfs] for Mississippi River Dam 2
(for the period from 1960 through 2002)

May	June	July	August	September	October	Average
27,700	21,700	17,400	10,900	9,400	11,000	16,350

The USACE also produces flood profiles for the Mississippi River. The profile for Pool No. 2 was used to determine the available head for the new culvert and the water elevation on the downstream side of Grey Cloud Island Drive South. Because these profiles provide water surface elevations in the main channel of the river, two assumptions were made regarding water surface elevations in the slough. First, the elevation on the upstream side of the crossing was assumed to be the same as the elevation at the slough entrance (River Mile 827.6 as measured in miles above the Ohio River). Second, the elevation on the downstream side of the crossing was assumed to be the same as the elevation at river mile 825.5. Because of the no-flow condition of the slough, the water surface elevation on the downstream side of the culvert is the same as the

elevation at the slough's exit. This elevation at this location corresponds to the main channel elevation at River Mile 825.5. These locations are shown in Figure 6.

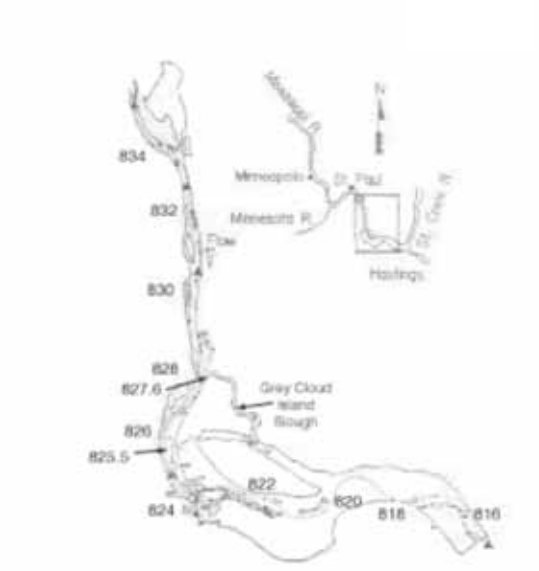

Figure 6. Aerial view of Mississippi River near Grey Cloud Island indicating River Miles above the Ohio River

The flood profiles produced by the USACE list elevations based on the National Geodetic Vertical Datum of 1929 (NGVD 1929). The topographic data provided by Washington County for use in roadway design were based on the North American Vertical Datum of 1988 (NAVD 1988). The National Geodetic Survey has created a conversion utility based on a given location's latitude and longitude. Using latitude 44.799 N and longitude 93.006 W, the correction factor for Grey Cloud Island was found to be 0.12 ft. This means that 0.12 ft must be added to NGVD 1929 elevations to obtain NAVD 1988 elevations for this location.

The water surface elevations at River Miles 827.6 and 825.5 were found for the 5-year, 10-year, 50-year, 100-year, and 500-year events. To calculate the available head for the new culvert, the difference in these two elevations was found and plotted against Mississippi River flow rates during the flood events

(Figure 7, page 15). A best-fit line was then used to find the available head for a flow of 16,350 cfs. A similar technique was used to determine the water surface elevation downstream of the crossing. A best-fit line was found once the elevations at River Mile 825.5 were plotted against flow rates during flood events (Figure 8, page 15).

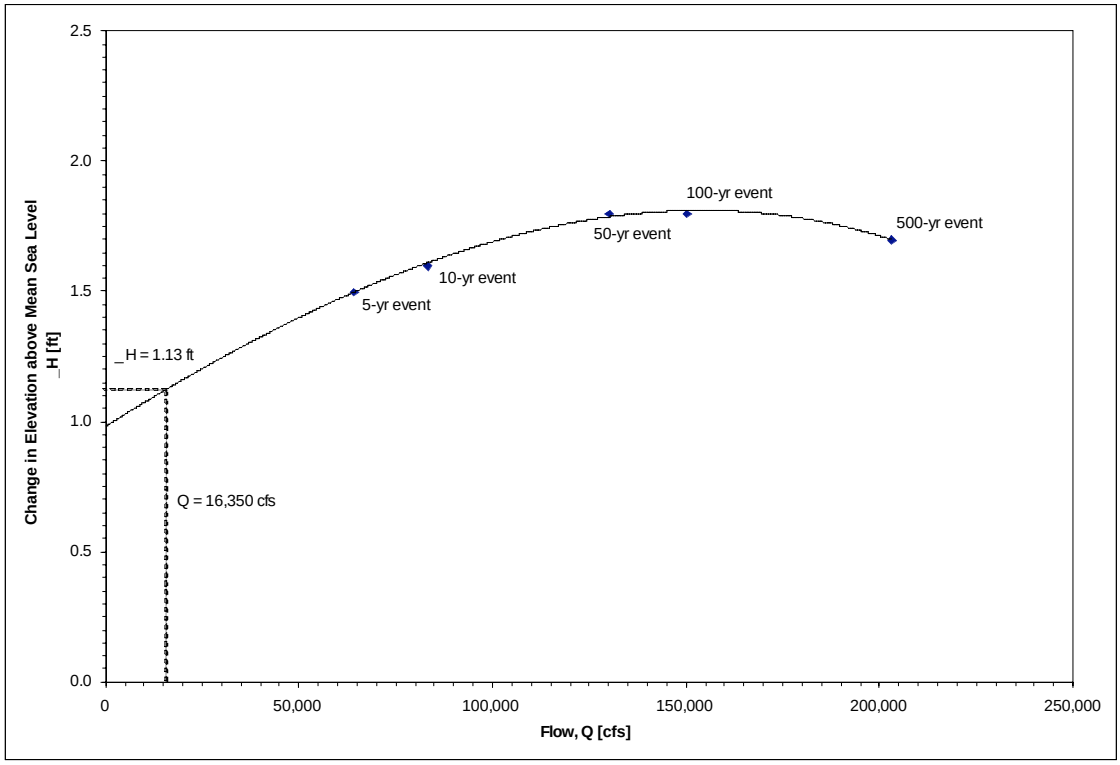

Figure 7. Available Head between Mississippi River Miles 827.6 and 825.5

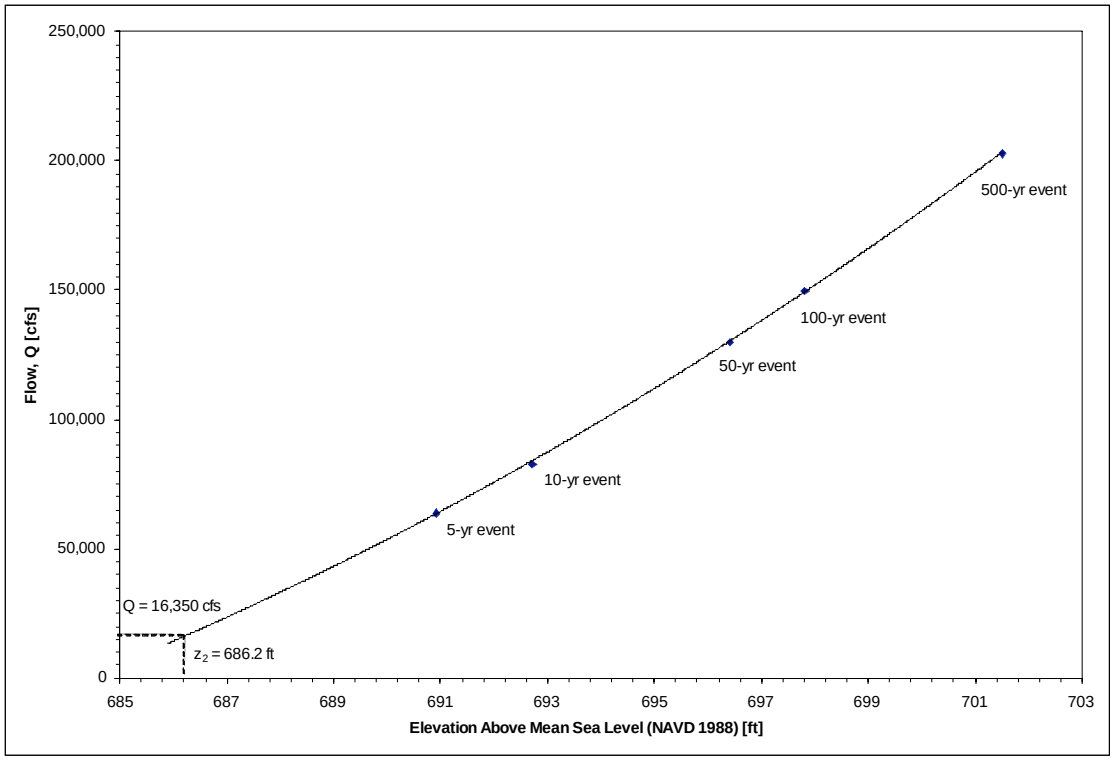

Figure 8. Water Surface Elevation at Mississippi River Mile 825.5

Culvert Design

The following equations from the Minnesota Department of Transportation (MnDOT) Drainage Manual were used to size the new culvert:

Energy

$$z_1 + \frac{V_1^2}{2g} = z_2 + \frac{V_2^2}{2g} + H_L \qquad \text{[Eqn. 1]}$$

Head Loss

$$H_L = [k_{exit} + k_{ent} + k_f]\frac{V_2^2}{2g} \qquad \text{[Eqn. 2]}$$

$$k_f = \frac{29n^2L}{R^{1.33}} \qquad \text{[Eqn. 3]}$$

$$R = \frac{A}{P} \qquad \text{[Eqn. 4]}$$

$$P = 2d + w \qquad \text{[Eqn. 5]}$$

$$V_2 = \frac{Q}{A} \qquad \text{[Eqn 6]}$$

where:

A = cross sectional area of the flow area in the barrel [ft^2]

d = depth of flow in the barrel [ft]

g = acceleration due to gravity [ft/s^2]

H_L = head losses [ft]

k_{ent} = entrance loss coefficient [-]

k_{exit} = exit loss coefficient [-]

k_f = friction loss coefficient [-]

L = length of the culvert barrel [ft]

n = Manning's roughness coefficient [-]

P = wetted perimeter of the flow area in the barrel [ft]

Q = flow rate [cfs]

R = hydraulic radius of the full culvert barrel [ft]

V_1 = entrance velocity [fps]

V_2 = exit velocity [fps]

w = width of flow in the barrel [ft]

z_1 = upstream water surface elevation [ft]

z_2 = downstream water surface elevation [ft]

A number of assumptions were made in regard to culvert design. The flow within the culvert was assumed to be subcritical. It was also assumed that wind set-up did not affect flow within the culvert. The roadway crossing the Grey Cloud Island Slough acts like a dam, creating a reservoir on the upstream entrance of the culvert. For this reason, entrance velocity, V_1, was assumed to be equal to zero. A concrete box culvert was selected for this particular project, based on recommendations from Suresh Hettiarachchi, P.E. and the previous report produced by QDM. A slope of 1% was assumed for culvert, with a Manning's roughness coefficient of 0.012. An entrance loss coefficient of 0.5 and an exit loss coefficient of 0.7 were also used. To determine the length of the culvert to be constructed, assumptions regarding roadway lane width, shoulder width, elevation, and side slope were made. The following table summarizes the numerical assumptions made for this design:

Table 2. Numerical assumptions used in culvert design

Q =	70	cfs	barrel slope =	1	%	lane width =	12	ft
g =	32.2	ft/s^2	n =	0.012		shoulder width =	4	ft
z_2 =	686.2	fps	k_{ent} =	0.5		roadway elevation =	701.83	ft
V_1 =	0	fps	k_{exit} =	0.7		side slope =	2:01	

Using the equations presented above, the culvert was designed by varying three variables: the width (span) of the culvert, the height (rise) of the culvert, and the depth of flow in the culvert. As mentioned before, the culvert design had to meet two initial criteria: a flow rate of 70 cfs and a flow velocity between 5 and 9 fps. Additional criteria were also identified in the process of this design. The culvert has 1.13 ft of available head, indicating that head losses in the culvert cannot exceed this number. It was determined that the culvert should flow half full in order to ensure the water at the surface of the channel was turbulent. This should guarantee that the water exiting the culvert has enough energy to

remove milfoil and algae at the water's surface. To ensure that the culvert maintains partly full flow the entire length of the culvert, the depth of the water at the entrance of the culvert should not exceed the rise of the culvert.

The QDM report recommended the use of a 4 ft (span) x 4 ft (rise) box culvert. Spans of 3 feet, 4 feet, and 5 feet were tested for a variety of rises and barrel water depths. It was assumed that the depth of flow at the culvert's exit was also the depth of flow within the culvert. Single and double barrel culverts were considered in order to determine which options met the velocity, head loss, and flow depth requirements. For the double barrel calculations, a flow rate of 35 fps was assumed for each barrel. Calculations for both the single and double barrel cases can be found in Appendix A.

Analysis of the culvert calculations indicated that because of the flow velocity and depth criteria, there was no significant advantage for using a double barrel culvert. The following single barrel culverts met the velocity, head loss, and entrance depth requirements: 4 ft x 4 ft, 5 ft x 3 ft, 5 ft x 4 ft, and 5 ft x 5 ft. Of these, the 5 ft x 5 ft box culvert was deemed the best option. The 4 ft x 4 ft culvert had an exit depth of 3 feet, indicating the culvert would flow 75% full. Because the culverts with 5 foot spans flowed closer to half full, these options were considered. The culverts with 5 foot spans had nearly identical flow velocities, entrance depths, and head loss. The 5 ft x 5 ft option was selected because it had the shortest overall length, while a flow depth of 2.4 feet was chosen because the flow would be nearest to half of the culvert's height. Table 3 summarizes the design characteristics of the new culvert.

Table 3. Design characteristics of new culvert

Rise =	5	ft	V_2 =	5.83	fps	H_L =	0.78	ft
Span =	5	ft	Exit depth =	2.4	ft	Inlet elevation =	684.7	ft
L =	84	ft	Entrance depth =	2.86	ft	Outlet elevation =	683.8	ft

An additional analysis was conducted to determine what would happen at this crossing during a 100-year and a 500-year flood event. The elevations on the upstream and downstream side of the crossing were determined from the USACE flood profile. Using this head difference, the discharge through the culvert was found using a nomograph produced by the American Concrete Pipe Association. For the 100-year event, a 5 ft x 5 ft culvert flowing full would discharge 215 cfs with a flow velocity of 8.6 fps. For the 500-year event, the same culvert flowing full would discharge 210 cfs with a flow velocity of 8.4 fps. The results, summarized in Table 4, are similar for both events because the head difference is nearly identical for both cases.

Table 4. Flood analysis results for 5 ft x 5 ft box culvert

$z_{1(100)}$ =	699.8	ft	$z_{1(500)}$ =	703.4	ft
$z_{2(100)}$ =	697.8	ft	$z_{2(500)}$ =	701.5	ft
$H_{(100)}$ =	2.0	ft	$H_{(500)}$ =	1.9	ft
$Q_{(100)}$ =	220	cfs	$Q_{(500)}$ =	215	cfs
$V_{2(100)}$ =	8.6	fps	$V_{2(500)}$ =	8.4	fps

During the 1965 flood event that washed out the bridge connecting Upper Grey Cloud Island to the mainland shows that water overtopping the roadway. The MnDOT Drainage Manual provides the following equation to determine the overtopping flow rate:

$$Q_r = k_t C_r L_r (HW_r)^{1.5} \qquad \text{[Eqn. 7]}$$

where:
- Q_r = overtopping flow rate [cfs]
- k_t = submergence coefficient [-]
- C_r = discharge coefficient [-]
- L_r = length of the roadway crest [ft]
- HW_r = upstream depth, measured above the roadway crest [ft]

Because the roadway is designed to accommodate the 100-year event, overtopping is not a concern for the 100-year event. For the 500-year flood event, the new roadway designed for the 100-year flood event (road elevation of 702.50 feet above mean sea level [amsl]) would be overtopped by 1.65 feet of water at its lowest elevation, corresponding to an overtopping flow rate of 112 cfs.

Roadwork Design

The new crossing must also be able to handle the traffic. The roadway design consists of two necessary parts: the roadway design and the pavement design.

Roadway Design

The main goal of the Grey Cloud Island Slough Crossing Project is to replace the currently plugged culvert that lies under Grey Cloud Island Drive. This will require removal of an existing portion of roadway during excavation, thus making it necessary to complete a new roadway design to ensure it can carry the needed and projected traffic capacity. In keeping with the goal of producing both a 100-year and 500-year design for the crossing, a redesign of the roadway was performed to set the low point elevation of the roadway above the 500-year flood water level elevation, to prevent overtopping.

Horizontal Curves

The existing horizontal alignment of Grey Cloud Island Drive in the project area consists of two curves and three tangent segments. The geography of the project area as well as property boundaries limited any right of way (ROW) expansion which would be necessary to improve upon the existing horizontal roadway alignment. Table 5 summarizes the existing curves which can be viewed in the project's plan set (Appendix B).

Table 5: Summary of existing horizontal curves

	PC Station	Angle	Radius [ft]	Length [ft]	PT Station
Curve 1	2+47.88	65° 33' 05"	254.00	290.60	5+65.48
Curve 2	8+14.88	112° 51' 27"	234.00	460.92	12+75.80

According to the MnDOT Road Design Manual Table 3-3.03B, the maximum speed which satisfies these radii is 30 mph; although the posted speed limit on

other sections of Grey Cloud Island Drive is 40 mph, a reduction must be made to 30 mph for these small radius curves.

Vertical Curves

Two sets of vertical alignments were created for Grey Cloud Island Drive. The first reflects the existing design and the second reflects a design in which the low point elevation is set above the 500-year flood level (703.00 feet [amsl]). Since this intended to be a preliminary design, no survey was performed on the project site. Two-foot contour topographic data used was from Washington County was used to create a surface in Autodesk Land Desktop in which the roadway design would be performed. Before a final design can be completed, a survey of the site must be performed to get accurate data on the existing elevations along the roadway.

The design of the existing vertical curve used the existing ground surface. The vertical alignment of Grey Cloud Island Drive has four vertical curves and five tangent sections. The design can be viewed on sheet C6.01 in the project's plan set located in the Appendix. The lowest point of the alignment is at station 6+00 at an elevation of 701.75 feet, which is approximately 2 feet above the 100-year flood level of 699.8 feet.

The second vertical alignment was designed using 30 mph design speed and using the AASHTO 2001 speed table and was also performed using Autodesk Land Desktop. This design can also be view in the appendix on sheet C6.04. The vertical alignment consists of two sag curves, two crest curves, and 5 tangent sections. The low point elevation is found at station 2+33.78 and is 705.64 feet [amsl], which is 2.34 feet above the 500-year flood level of 703.30 feet [amsl].

Roadway Cross Sections

Figure 9 gives the typical roadway cross-section used. The cross-section for each 0+25 station increment can be found in the appendix on sheets C7.01 – C7.10. The typical section was created by following MnDOT standards as follows:

- 30 miles per hour design speed
- Minor Arterial Road (rural cross-section)
- 12 foot driving lanes with a 2% cross slope
- 4 foot shoulders with a 4% slope
- 33 foot right of way
- side slopes which varied between 4:1 and 2:1
- 5 inch bituminous layer
- 7 inch aggregate layer

Although a 4:1 side slope is standard, a steeper 2:1 side slope was necessary for the sections crossing the slough because regulations prohibited the extension of the shoreline from its existing location. The 500-year design raised the road such that even a 2:1 slope could not meet the existing shoreline and thus necessitated the use of retaining walls. The design of the retaining walls however was outside of the scope of this preliminary design but will need to be performed prior to final design of the roadway.

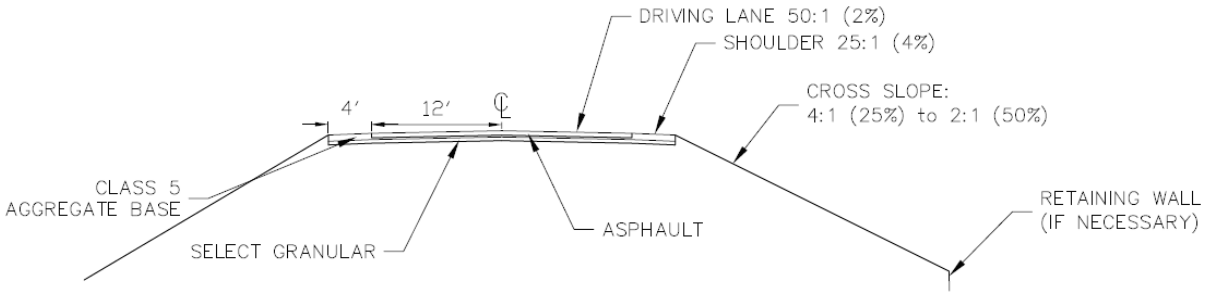

Figure 9: Typical roadway cross section

Culvert Cross Sections

During the construction of the culvert it will be necessary to excavate to a depth many feet below the roadway in order to reach the depth at which the culvert will be placed. With the depth of cut that will be encountered, it is necessary to ensure that the walls of the cut will not collapse on the workers installing the culvert. Washington County provided a typical cut section detail for culverts (shown in Figure 10) which takes the stability of the walls into account by specifying a 2:1 cross slope. The Washington County detail also specifies using a 10:1 cross slope from a depth of 4 feet below the roadway surface. This is done to minimize heave during the winter which would result in a driver feeling a bump as they drove over the road above the culvert.

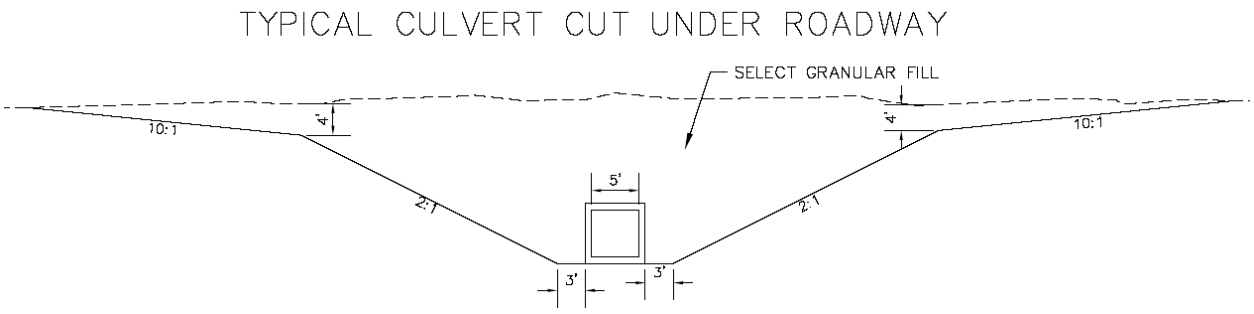

Figure 10: Typical cross section of cut under the roadway for the culvert

Pavement Design

The roadway on the rebuilt slough crossing must be specially designed to meet the challenges stemming from a roadway that will experience heavy frost heaving. This is due to water saturating the earthen crossing and freezing in the winter. While taking this into account, the pavement for the roadway was designed using MnDOT and American Association of State Highway and Transportation Officials **(**AASHTO) guidelines. Assumptions made in the pavement design were:

- sandy soil on-site
- Average Daily Traffic of 1700 vehicles (given by Washington County)
- population growth factor of 1.7 (given by Washington County)
- 20 year design life
- urban other principal roadway designation.

Granular equivalent (G.E.) factors were used to design the thickness of each layer of the pavement. The pre-reconstruction roadway was a built as a "bituminous roadway" and because of this, it will be cheaper to continue to use this in the new design.

The first step in designing the pavement for the section of road that will be rebuilt was to determine the amount of equivalent 18-kip single-axel load (ESALs) driven on the roadway. The following AASHTO equation was used to determine the amount of ESALs on this specific roadway[1]:

$$ESAL = (ADT_0)(T)(T_F)(G)(D)(L)(365)(Y) \qquad \text{[Eqn. 8]}$$

where: ESAL = equivalent 18-kip single-axel-load

ADT_0= average daily traffic = 1700 vehicles

T= percentage of trucks in the ADT = 15%

T_F = the number of 18-kip single-axel load applications per truck= 0.21

G = growth factor= 1.7

D = the direction distribution factor = 0.5

L= the lane distribution factor = 100%

Y = design period in years = 20 years

The AASHTO design guide specifies values for T, T_F, D, and L. The total number of ESALs for this road was determined to be 310,126. The computations for this ESAL number can be found in Appendix B. Another factor needed for the pavement design is the R-value. The R-value is the resistance value of the soil and can be roughly estimated from the AASHTO soil classification as shown in the figure below.

Table 6: MnDOT Soil Information.

Soil Classification			Strength Tests				MnPAVE Design Moduli							
Textural Class	AASHTO	Mn/DOT Soil Factor	R-Value (240 psi Exudation Pressure)		CBR Percentage	DCP mm/blow	Winter & Early Spring		Late Spring		Summer		Fall	
			Estimated	Measured Ave (SD)	Estimated	Estimated	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi
Gravel (G)	A-1	50-75	ND	ND	21	ND	350	50	-	-	-	-	-	-
Sand (S)	A-1 A-3	50-75	61	ND	21	13	350	50	60	8.7	73	10.5	85	12.4
Loamy Sand (LS)	A-2	50-75	39	60 (14)	6.2	14	350	50	52	7.6	63	9.2	75	10.8
sl pl S Loam pl S Loam	A-2 A-2,A-4	100-130 100-130	30 16	- 33 (16)	5.5 4.4	14 16	350 350	50 50	47 39	6.8 5.7	57 48	8.3 7.0	67 56	9.7 8.2
Loam (L)	A-4	100-130	14	20 (6)	4.2	18	350	50	35	5.0	42	6.1	50	7.2
Silt Loam (SiL)	A-4	100-130	11	25 (15)	3.9	31	350	50	19	2.7	23	3.3	27	3.9
Sandy Clay Loam (SCL)	A-6	100-130	17	21 (6)	4.5	16	350	50	42	6.1	51	7.4	60	8.7

The assumption was made that the natural soil is sandy with an R-value determined to be 30. This is the medium value for a sandy soil. Since there are currently no soil boring tests to design from, a conservative value was used to ensure safety.

The next step taken in the pavement design was computing the Granular Equivalent (G.E.) factor. This step followed MnDOT design standards and Washington County pavement design requirements. The chart requires the known values of ESALs and the R-value which both are known for this design. The R-value is 30 and the the ESALs is 310,126. The G.E. value for the Grey Cloud Island drive is 15.12 inches. With the G.E. value the pavement thickness and cross-section can be determined.

Each layer can be determined from the granular equivalent factor chart. How this chart works is that each inch of pavement or base is given a value. These values are all totaled up and they must be larger than the G.E. value for the existing soil and ESALs, which for this roadway is 15.12 inches. Table 5 lists all the GE factors for all types of bases and pavements[1]:

Table 7: Granular Equivalent (G.E.) Factors

Material	**Specification**	**Traffic Level**	**G.E. Factor**
Plant-mixed Bituminous Pavement	2350/2360	All traffic levels	2.25
Plant-mixed Bituminous Pavement	2331, 2340 Type 41, 47, 61	--	2.25
Plant-mixed Bituminous Pavement	2331, 2340 Type 31	--	2.00
Cold-inplace Recycling	2331	--	1.50
Rubblized Concrete Pavement (Pavement Breaking)	2331	--	1.50
Bituminous Pavement Reclamation	2331	--	1.00
Aggregate Base	3138 (Cl. 5, Cl. 6)	--	1.00
Aggregate Base	3138 (Cl. 3, Cl. 4)	--	0.75
Select Granular Material	3149.2B2	--	0.75

The proposed pavement for Grey Cloud Island Drive is as follows: 5 inches of bituminous, 3 inches of Class 5 Aggregate base, and 4 inches of Select granular. This totals to a G.E. value of 16.25 which is larger than the required 15.12 for this soil. The computations for this can be found in the appendix.

Permitting

One of the major parts of any construction project is permitting, and this project follows that trend by involving roads, waterways, utilities, and possible land development. The following government entities have been identified has having regulatory jurisdiction over this project: the United States Army Corps of Engineers, the Minnesota Department of Natural Resources, the Washington Conservation District, and the Washington County Department of Transportation & Physical Development.

Permitting Plan

The permitting portion of this project is fundamental to the project's cost and ability to be completed. As the design process moved forward, the importance of the permitting became more and more obvious. Because of this, it was necessary to create a permitting plan that could be used to help those involved with this project better understand what needs to be permitted, and when this process should start.

Since there are many agencies with a vested interest in this project, namely due to the fact that the slough crossing is located on a navigable waterway, the first thing is to ensure that all concerned parties are consulted. Once this happens, all parties will need to visually inspect the site. For this project, this process should occur during the early summer months so an accurate assessment of vegetation and animal life near the site can be made.

Construction is slated to begin in the winter, during the low-flow months of November or December. Because the permitting process can last up to eight months, it is imperative that this process begins during the springtime. Beginning the process this far in advance will allow for any project redesigns and resubmissions to be complete with enough time before the desired construction start date.

Permitting Information

The United States Army Corps of Engineers (USACE) derives its regulatory authority from Section 10 of the Rivers and Harbors Act of 1889 and Section 404 of the Clean Water Act. Under Section 10, a Corps' permit is required to do any work in, over, or under a Navigable Water of the U.S. The Mississippi River is classified as a Navigable Water based on its use for transportation for interstate commerce.[1] Under Section 404, a Corps' permit is required for the discharge of dredged or filled material into waters of the U.S., including wetlands. The USACE uses guidelines established by the Environmental Protection Agency (EPA) in deciding whether to issue or deny permits under Section 404. The EPA's Section 404(b)(1) guidelines require that activity in U.S. waters be the least environmentally damaging alternative that is feasible, and that adverse impacts are avoided, minimized, and ultimately compensated for.[2] The St. Paul District of the USACE issues two types of permits, general and individual. For a project of this nature, a general permit can be issued only if the culvert has the same diameter and inlet/outlet elevations as the structure currently in place.[3] Because the size and placement of the existing culvert is unknown, a Department of the Army Individual Permit is required of this project. Standard individual permits typically require a 30-day agency and public review and take 60 to 120 days or more to complete.[2]

The Minnesota Department of Natural Resources (DNR) issues Public Waters Work Permits based on Minnesota Statute 103G.245, Work in Public Waters. Under this statue, a permit is required to construct, reconstruct, remove, or make any change in a waterway obstruction on public waters. Activities that change the course or current of public waters by any means, including filling, excavating, or the placing of materials on the beds of public waters, also require a permit. There are two types of Public Waters Work Permits available from the DNR: general permits and individual permits. General permits are "pre-issued" permits issued on a statewide or county level. There are currently five

categories of general permits, one of which is bridge and culvert projects.[4] A maximum of 60 days is usually required for permit review.

The Minnesota Wetland Conservation Act of 1991 (WCA) provides a regulatory framework to maintain and protect wetlands within the State of Minnesota. Under the WCA, a wetland is defined by the presence of hydric soils, surface or subsurface hydrology, and hydrophytic vegetation.[5] The WCA requires that anyone proposing to drain, fill, or excavate a wetland try to avoid disturbing the wetland, try to minimize any impact on the wetland, and finally to replace any lost wetland acres, function, and values. This "sequencing" process is similar to the EPA's Section 404(b)(1) guidelines used by the USACE. Minimum replacement is generally two acres of replaced wetland for each acre drained or filled. The Local Government Unit (LGU) has the primary responsibility for administering the WCA. The LGU is usually a city or county, but may be another entity such as a watershed district or water conservation district.[6] In this case, the Washington Conservation District (WCD) is the LGU for this project because Grey Cloud Island Township does not have the capacity to serve this role. A maximum of 60 days is usually required for permit review.

These three levels of government (federal, state, local) have assembled a package of permit application forms. For public transportation projects requiring the preparation of a wetland replacement plan, the following form should be used:

> Form NA-026620-03C – Minnesota Local/State/Federal Application Forms for Water/Wetland Projects: Public Transportation and Linear Utility Projects – Part I

A copy of this form, including instructions, is included in the Appendix. This form requires inclusion of attachments including, but not limited to, a proposed timeline, project description, estimated project cost, project alternatives, watercourse/wetland impact summary, mitigation considerations, wetland

replacement summary, and applicable hydrology and hydraulic reports. Following agency review and public comment, the project will be accepted as proposed, approved with changes or conditions, withdrawn, or denied. An appeal process is in place for those wishing to challenge the decision of the regulating agencies.

Due to the fact that the water north of County Road 75 has been impounded at a higher than normal water surface elevation for some time, there is concern that fringe wetlands will be drained once normal flow is restored. The WCA provides exemptions for situations such as this, but the USACE may not make similar considerations. In terms of wetland mitigation, several design strategies are possible. Fish habitats can be established in the bottom of the box culvert and plant and vegetation can be restored along the earthen embankment. A fishing pier was constructed as part of a wetland mitigation strategy for a similar project on the southern end of Grey Cloud Island and is a possibility for this project.

Because Grey Cloud Island Drive South is also Washington County Road 75, the Washington County Department of Transportation & Physical Development maintains jurisdiction over the roadway and accompanying right of ways. Washington County requires a Right of Way Permit to work within the right of way, and an Event Permit on County Right of Way Permit to close the highway to traffic during construction. These permits require inclusion of detailed plans and drawings, a proposed timeline, a project description, and a construction plan including a traffic control plan. The applicant is responsible for the cost of traffic control. Because of its narrowness, the county will likely approve a complete shutdown of the road during construction.[6]

Construction

Planning

Many factors affect how a construction plan is developed. For the Grey Cloud Island Slough, determining the right time of year to start construction is important as construction is easiest during the months with low water flow in the Mississippi River. This is due in part to the need for dewatering as well as a general desire to mitigate damage to the environment; since the growing season is over in early December, this is the ideal time to start.

Erosion control will be much easier due to the hardening and freezing of soils. In addition, any unwanted runoff will be more easily confined due to the colder conditions. This start date does pose problems, however. During the winter months, asphalt concrete is unavailable from vendors. This was a concern while determining the construction start date, but environmental impact mitigation, coupled with a compacted gravel pavement, provides sufficient roadway for the few months before asphalt is available.

Finding an alternate route for traffic requires placing a detour. The only alternate entrance to the island is on the south side. Figure 11 shows the route where traffic will be rerouted.

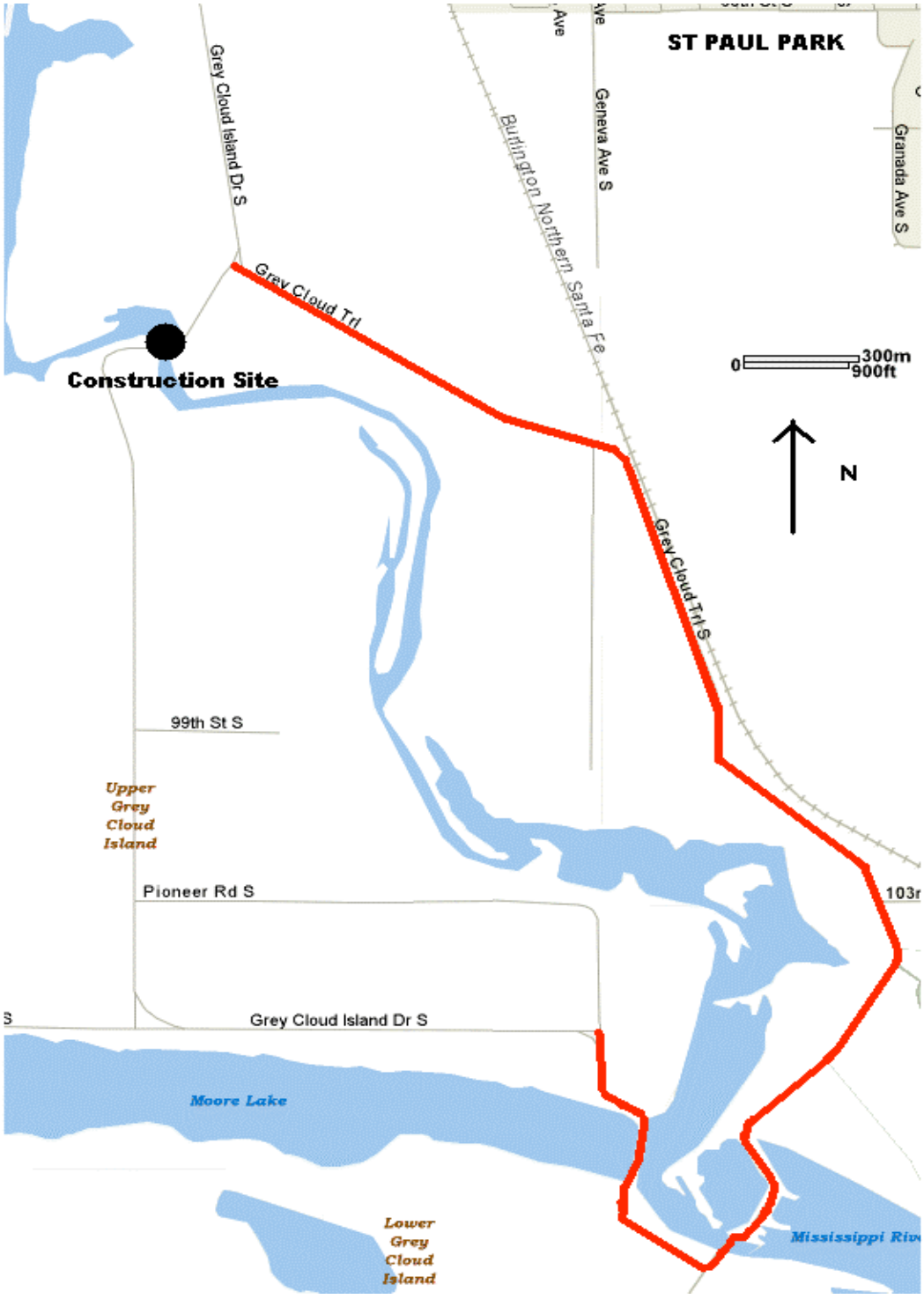

Figure 11: Grey Cloud Island Detour

Construction Timeline

The construction portion of the slough crossing's reconstruction of this project will take between 10 and 12 weeks; the exception is the asphalt paving. Approximately three week of contingency time has been included in the timeline. These delays could be but are not limited to machine breakdowns, labor problems, and bad weather.

The first task in this project is to install detour signage and close the project site. Washington County and MN/DOT will aide in providing the proper signage for this. This task should take no longer than one day.

The next task is removing trees and brush that are in the way of the project. There are approximately 2 acres of vegetation and it will take about a day to clear.

Utilities will then be marked and temporarily moved. According to Gopher State OneCall, gas, telephone, and cable lines are buried at this project site. Xcel Energy, Qwest, and Comcast have buried utilities that will need to be carefully rerouted or protected based on their discretion or law. This process is expected to take about three days.

Cofferdam installation is next. Installation is expected to take about ten days, and in addition to being the most time-consuming part of the project, the cofferdams will also be the most expensive. Two sets of single-layer shore-driven steel sheet piling will be set up according to figure 12.

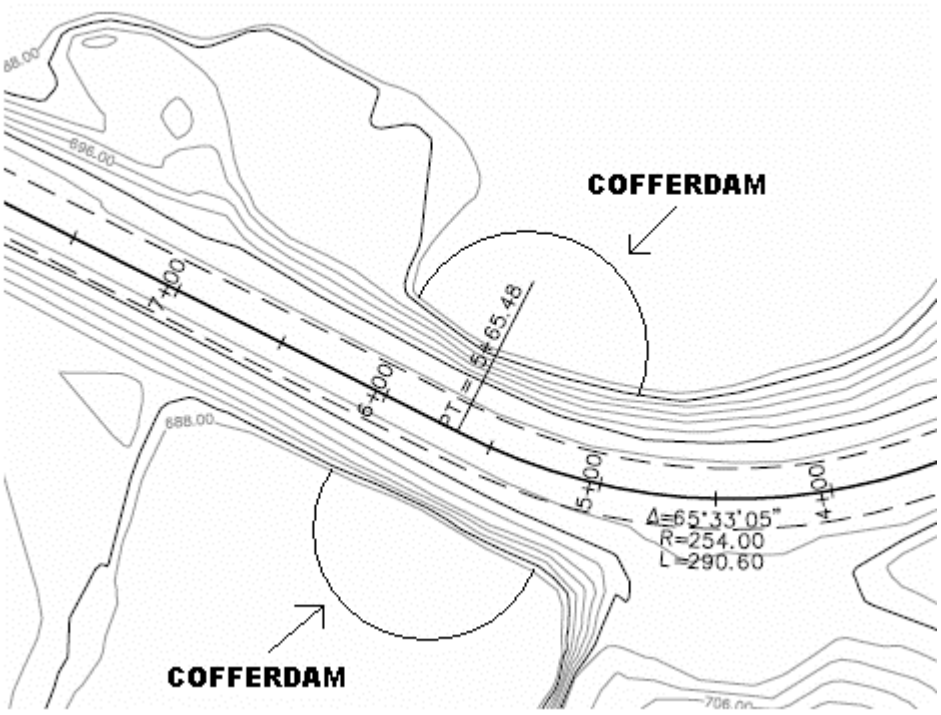

Figure 12: Cofferdam Placement

Each of the semi-circle cofferdams will be 175 feet long, protruding no more than 10 feet above the water, and will be driven approximately 20 feet into the ground. Dewatering inside the cofferdams will start once the walls have been completed, this will allow for culvert installation and placement. Dewatering will end when the cofferdams are no longer needed.

During the cofferdam installation several other tasks will take place: construction equipment needed for the rest of the project will be staged and removal of the roadway pavement and subgrade will take place. This will take anywhere between three and eight days depending on how much asphalt needs to be removed (160 ft for 100-year design or 1050 ft for 500-year design).

Once the cofferdam installation is complete and the area is sufficiently dewatered, the culvert trench will be excavated. This task will take approximately three days.

The next focus is on culvert installation. There will be a total of eleven 8-foot long pre-cast sections of 5 ft x5 ft concrete box culverts installed, with inlet and outlet controlling structures. In addition to installing the culvert, extra sheet piling will be installed in the trench for the 500-year profile. This is done to ensure that the culvert will not settle under the added soil pressures associated with the increase in soil weight. In either case, tests will be performed to make sure the soil is compacted enough before any sections of culvert are placed in the trench.

Filling in the trench and adding fill to raise the roadway level to the design profile is the next step. In addition to compacting the soil, utilities that had been moved temporarily will be placed back in the slough crossing.

Constructing a new subgrade will be required in areas where the asphalt pavement has been removed. Since asphalt won't be laid until spring, gravel will be put down on the subgrade to act as a temporary roadway until the spring.

After the subgrade and gravel have been, the dewatering process will end and the cofferdams will be removed. This task is projected to take 10 days. In addition to this, soil mats and rip-rap will be added for erosion control purposes. The road can be re-opened to traffic at this point of construction.

Cost Estimate

Two different cost estimates have determined: one for the 100-year design and one for the 500-year design. Table 6 contains a complete breakdown of costs and where the numbers came from. The estimated cost for the 100-year design is $630,000. This cost changes to $1,560,000 when the design is changed to accommodate the 500-year.

One of the biggest added costs when designing for a 500-year flood is the amount of roadway that needs to be reconstructed. In addition, there are added costs due to possible soil stabilization that is still unknown because of the added soil weight from raising the roadway to the 500-year design. The other significant cost difference between the two design stems from the retaining wall that is required when designing for the 500-year flood.

Table 8: Cost Breakdown[1]

	100-year flood	**500-year flood**
Tree/Brush Removal	$15,000	$15,000
Temporary Utility Re-routing	$10,000	$10,000
Cofferdam Installation and Removal	$265,000	$265,000
Removing existing pavement and Subgrade	$16,000	$105,000
Box Culvert Installation	$21,000	$66,500
Cut/Fill/Compaction	$24,600	$35,800
New Pavement and Subgrade	$64,000	$420,000
Retaining Wall	$0	$70,000
Erosion Control	$1,800	$2,400
Guard Rails	$6,170	$6,170
Dewatering	$8,000	$8,000
SUBTOTAL	**$431,570**	**$1,003,870**
added costs	30%	40%
	$129,471	*$401,548*
Engineering Costs (estimated 15%)	*$64,736*	*$150,581*
TOTAL COST ESTIMATE	***$630,000***	***$1,560,000***

Recommendations

After studying the situation and the designs, UMNECo recommends that the Grey Cloud Island Township select the 500-year flood design profile. Since the only other access to the island (the southern entrance) is designed for the 100-year flood event, access to the island during any flood event with an elevation above the 100-year level would risk overtopping the crossing, making it impossible for traffic exiting the island to do so safely.

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Minnesota Department of Transportation. Minnesota Department of Transportation Drainage Manual. Chapter 5: Culverts. (2000).

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Pavement Design Notes:

[1] Huang, Yang H. (2004) Pavement Analysis and Design. Upper Saddle River, NJ. Pearson Prentice Hall (pg. 266-273).

[2] MnDOT (2002) Best Practices for the Design and Construction of Low Volume Roads. Minneapolis, MN (pg 5).

[3] Stehr, Richard. (2003) "Granular Equivalent Factors for Bituminous Pavement Aggregate Base Design". Minneapolis, MN. Minnesota Department ofTransportation.

Permitting Notes:

[1] United States Army Corps of Engineers. "Overview of the Corps' Permit Programs." http://www.mvp.usace.army.mil/regulatory/default.asp?pageid=799 (accessed May 1st, 2006).

[2] United States Army Corps of Engineers. "Corps Permit FAQ – St. Paul District." http://www.mvp.usace.army.mil/regulatory/default.asp?pageid=740 (accessed May 1st, 2006).

[3] Minnesota Department of Natural Resources. "Requirements for Projects Involving Public Waters Work Permits." http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/requirements.html (accessed May 1st, 2006).

[4] Minnesota Board of Water and Soil Resources. "The Minnesota Wetland Conservation Act Manual." September 2004.

[5] Minnesota Board of Water and Soil Resources. "Wetland Conservation Act Fact Sheet." http://www.bwsr.state.mn.us/wetlands/wca/WCAfactsheet1.html (accessed May 1st, 2006).

[6] Minnesota Board of Water and Soil Resources. "Minnesota Local/State/Federal Application Forms for Water/Wetland Projects: Public Transportation and Linear Utility Projects – Part I (Form NA-026620-03C)." http://www.bwsr.state.mn.us/wetlands/wcamanual/form03_A.pdf (accessed May 1st, 2006).

Construction Notes:

[1]RS Means. Means Heavy Construction Cost Data. 2005.

Appendix Index

Appendix A: Hydraulics

CORPS OF ENGINEERS

U. S. ARMY

MINNESOTA RIVER
DRAINAGE AREA 16,550 SQ. M.

Q 500=203,000 CFS
Q 100=150,000 CFS
Q 50=130,000 CFS
Q 10= 83,000 CFS
Q 5= 64,000 CFS

VERMILLION RIVER
DRAINAGE AREA 215 SQ. M.

Q 500=205,000 CFS
Q 100=151,000 CFS
Q 50=131,000 CFS
Q 10= 84,000 CFS
Q 5= 64,000 CFS

ST. CROIX RIVER
DRAINAGE AREA
7,650 SQ. M.

BIG RIVER
DRAINAGE AREA 45 SQ. M.

Q 500=252,500 CFS
Q 200=217,500 CFS
Q 100=192,500 CFS
Q 50=168,000 CFS
Q 25=144,000 CFS
Q 10=113,500 CFS
Q 5=90,000 CFS
Q 2=58,000 CFS

FLOOD PROFILES UPSTREAM OF THE CONFLUENCE WITH THE SAINT CROIX RIVER HAVE BEEN TAKEN FROM THE 1979 STUDY.

FLOOD PROFILES DOWNSTREAM OF THE CONFLUENCE WITH THE SAINT CROIX RIVER (RIVER MILE 811.4 THROUGH 615.2) HAVE BEEN DEVELOPED FROM THE 2003 FLOW FREQUENCY STUDY.

ELEVATION ABOVE MEAN SEA LEVEL (1912 ADJUSTMENT)

720, 718, 716, 714, 712, 710, 708, 706, 704, 702, 700, 698, 696, 694, 692, 690, 688, 686, 684, 682, 680

DAM NO. 1 TAILWATER M. 847.5 Q=679.72

DAM NO. 1 POOL M. 841.6 Q=684.16

DAM NO. 2 POOL GAGE M. 815.4
TAILWATER GAGE M. 815.0 Q=600.0

PRESCOTT C.P. 3 M. 811.4 Q=669.28

DAM NO. 3 TAILWATER GAGE M. 796.91 Q=600.0

DAM NO. 3 POOL GAGE M. 796.61

500 YEAR
200 YEAR
100 YEAR
50 YEAR
25 YEAR
10 YEAR
5 YEAR
2 YEAR

1965
1969
1997
2001
1993

DAM NO. 2 POOL 687.2

DAM NO. 3 POOL 675.0

FT. SNELLING BRIDGE (NEW) M. 845.6	
MINNESOTA RIVER M. 844.0	
NEW LEXINGTON BRIDGE M. 843.24	
C. AND N.W. R.R. BRIDGE M. 841.4	
STATE HIGHWAY 49 BRIDGE M. 840.4	
ST. PAUL, MINN. M. 840.0	
WABASHA ST. BRIDGE M. 839.5	
ROBERT ST. BRIDGE M. 839.2	
MPLS. - ST.PAUL SANITATION PLANT M. 836.36	
C.G.W. RAILWAY BRIDGE M. 835.7	
SOUTH ST. PAUL M. 833.7	SO. ST. PAUL C.P. 2 M. 833.7 Q=600.0
494 HIGHWAY BRIDGE M. 832.4	
S. ST. PAUL SANITATION PLANT M. 832.3	
C.R.I. & P. R.R. BRIDGE M. 830.3	
GREY CLOUD SLOUGH M. 827.6	
PINE BEND M. 824.5	
GRAY CLOUD LANDING M. 822.6	
NININGER MINN. M. 817.6	
U.S. 61 HWY. BRIDGE M. 813.9	
HASTINGS R.R. BRIDGE M. 813.87	
VERMILLION RIVER M. 813.2	
MINN.-WISC. BOUNDARY M. 812.0	
ST. CROIX RIVER M. 811.4	
BIG RIVER M. 804.8	
DIAMOND BLUFF M. 799.97	

850, 848, 846, 844, 842, 840, 838, 836, 834, 832, 830, 828, 826, 824, 822, 820, 818, 816, 814, 812, 810, 808, 806, 804, 802, 800, 798, 796, 794

MILES ABOVE OHIO RIVER

U.S. ARMY CORPS OF ENGINEERS

2003 FLOW FREQUENCY STUDY

APPENDIX B

MISSISSIPPI RIVER
FLOOD PROFILES - 1912 ADJ

ST. PAUL DISTRICT

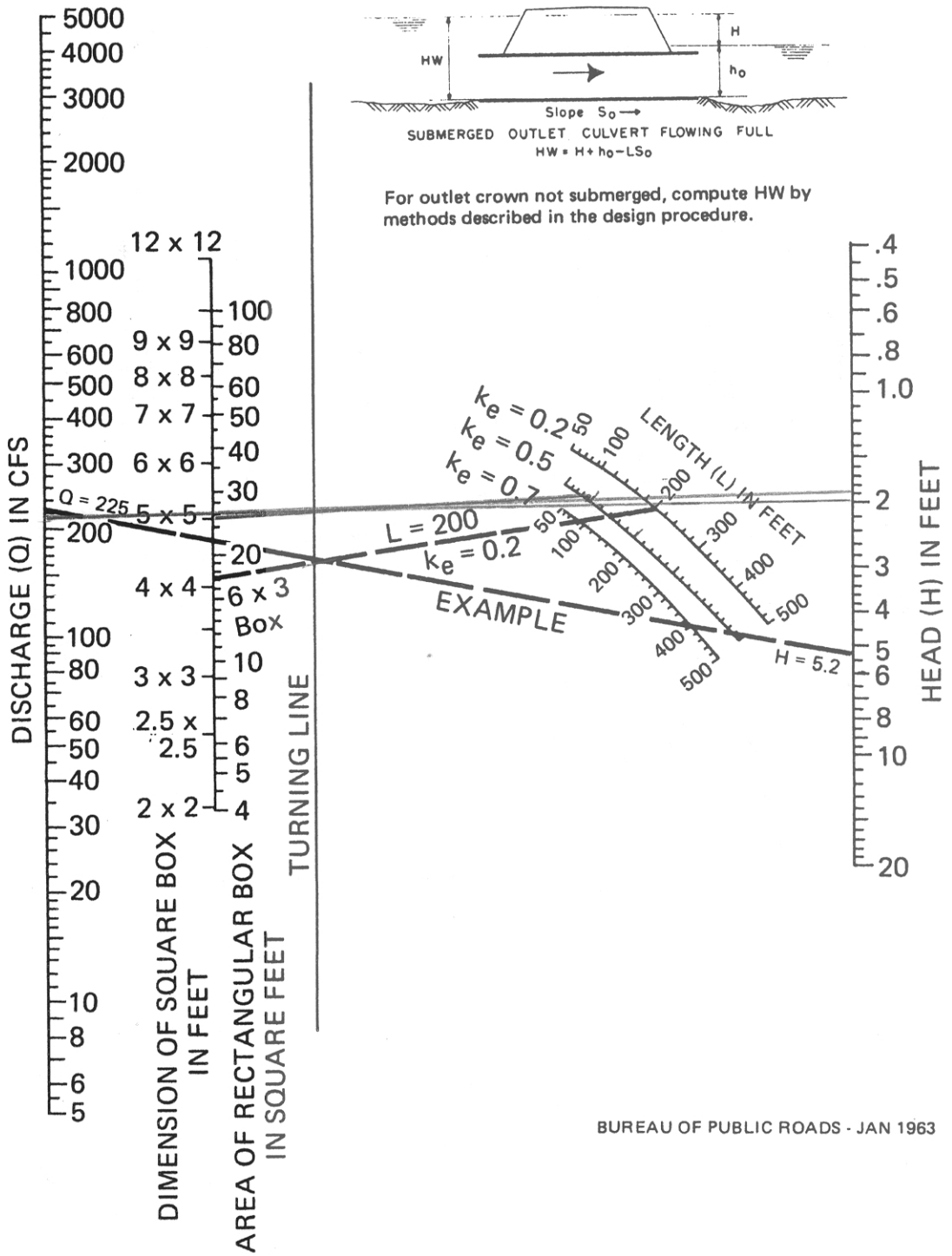
2, 5, 10, 25, 50, 100, 200 & 500 YEAR FLOOD
&
1965 HISTORIC FLOOD

RIVER MILES 796.8 TO 847.5

PLATE # 11

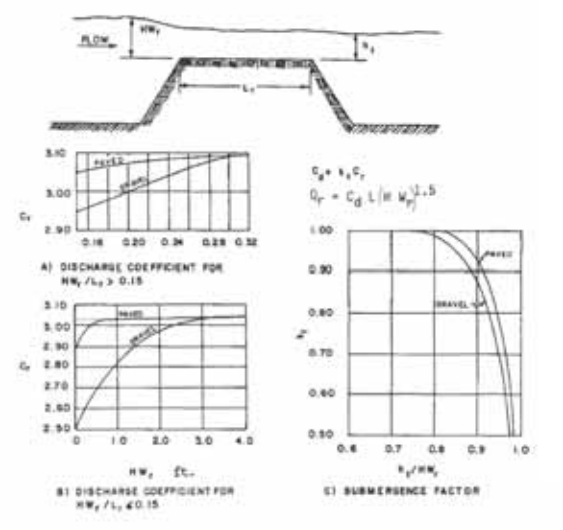
Figure 41

HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL
n = 0.012



ROADWAY OVERTOPPING CALCULATIONS

$$Q_r = k_t C_r L_r (HW_r)^{1.5}$$



where: Q_r = overtopping flow rate [cfs]

k_t = submergence coefficient [-]

C_r = discharge coefficient [-]

L_r = length of the roadway crest [ft]

HW_r = upstream depth, measured above the roadway crest [ft]

$\underline{HW_r}$
- lowest roadway elevation = 701.75 ft
- upsteam water surface elevation (500-year event) = 703.4 ft

HW_r = 703.4 ft – 701.75 ft = 1.65 ft

$\underline{L_r}$
- roadway lane width = 12 ft
- roadway shoulder width = 4 ft

L_r = 2*(12 ft + 4 ft) = 32 ft

$\underline{C_r}$
- HW_r/L_r = 0.05 ≤ 0.15

C_r = 3.3

$\underline{k_t}$
- h_r = 1.64 ft (assumed)
- h_r/HW_r = 0.99

k_t = 0.5

$Q_r = (0.5)(3.3)(32)(1.65)^{1.5}$ = 112 cfs

Culvert Design Calculations - single barrel

Span = 3 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 2 ft	1.0	23.33	16.45	
	1.1	21.21	13.24	
	1.2	19.44	10.88	
	1.3	17.95	9.10	
	1.4	16.67	7.72	
	1.5	15.56	6.64	
	1.6	14.58	5.76	
	1.7	13.73	5.05	
	1.8	12.96	4.46	
	1.9	12.28	3.97	
Rise = 3 ft	1.0	23.33	16.17	
	1.1	21.21	13.03	
	1.2	19.44	10.72	
	1.3	17.95	8.97	
	1.4	16.67	7.61	
	1.5	15.56	6.55	
	1.6	14.58	5.69	
	1.7	13.73	4.99	
	1.8	12.96	4.41	
	1.9	12.28	3.92	
	2.0	11.67	3.52	
	2.1	11.11	3.17	
	2.2	10.61	2.87	
	2.3	10.14	2.61	
	2.4	9.72	2.39	
	2.5	9.33	2.19	
	2.6	8.97	2.02	
	2.7	8.64	1.87	
	2.8	8.33	1.73	
	2.9	8.05	1.61	

Span = 4 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 2 ft	1.0	17.50	8.79	
	1.1	15.91	7.07	
	1.2	14.58	5.81	
	1.3	13.46	4.86	
	1.4	12.50	4.12	
	1.5	11.67	3.54	
	1.6	10.94	3.07	
	1.7	10.29	2.69	
	1.8	9.72	2.38	
	1.9	9.21	2.12	
Rise = 3 ft	1.0	17.50	8.65	
	1.1	15.91	6.97	
	1.2	14.58	5.73	
	1.3	13.46	4.79	
	1.4	12.50	4.07	
	1.5	11.67	3.50	
	1.6	10.94	3.04	
	1.7	10.29	2.66	
	1.8	9.72	2.35	
	1.9	9.21	2.09	
	2.0	8.75	1.88	
	2.1	8.33	1.69	
	2.2	7.95	1.53	
	2.3	7.61	1.39	
	2.4	7.29	1.27	
	2.5	7.00	1.17	
	2.6	6.73	1.08	3.45
	2.7	6.48	0.99	3.41
	2.8	6.25	0.92	3.39
	2.9	6.03	0.86	3.38

Span = 4 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 4 ft	1.0	17.50	8.52	
	1.1	15.91	6.86	
	1.2	14.58	5.65	
	1.3	13.46	4.73	
	1.4	12.50	4.01	
	1.5	11.67	3.45	
	1.6	10.94	3.00	
	1.7	10.29	2.63	
	1.8	9.72	2.33	
	1.9	9.21	2.07	
	2.0	8.75	1.86	
	2.1	8.33	1.67	
	2.2	7.95	1.52	
	2.3	7.61	1.38	
	2.4	7.29	1.26	
	2.5	7.00	1.16	
	2.6	6.73	1.07	3.48
	2.7	6.48	0.99	3.44
	2.8	6.25	0.91	3.42
	2.9	6.03	0.85	3.41
	3.0	5.83	0.79	3.41
	3.1	5.65	0.74	3.42
	3.2	5.47	0.69	3.44
	3.3	5.30	0.65	3.47
	3.4	5.15	0.61	3.50
	3.5	5.00	0.57	
	3.6	4.86	0.54	
	3.7	4.73	0.51	
	3.8	4.61	0.49	
	3.9	4.49	0.46	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 3 ft	1.0	14.00	5.37	
	1.1	12.73	4.32	
	1.2	11.67	3.55	
	1.3	10.77	2.97	
	1.4	10.00	2.52	
	1.5	9.33	2.17	
	1.6	8.75	1.88	
	1.7	8.24	1.65	
	1.8	7.78	1.46	
	1.9	7.37	1.30	
	2.0	7.00	1.16	
	2.1	6.67	1.05	2.93
	2.2	6.36	0.95	2.86
	2.3	6.09	0.86	2.82
	2.4	5.83	0.79	2.80
	2.5	5.60	0.72	2.79
	2.6	5.38	0.67	2.79
	2.7	5.19	0.62	2.80
	2.8	5.00	0.57	
	2.9	4.83	0.53	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 4 ft	1.0	14.00	5.29	
	1.1	12.73	4.26	
	1.2	11.67	3.51	
	1.3	10.77	2.94	
	1.4	10.00	2.49	
	1.5	9.33	2.14	
	1.6	8.75	1.86	
	1.7	8.24	1.63	
	1.8	7.78	1.44	
	1.9	7.37	1.29	
	2.0	7.00	1.15	
	2.1	6.67	1.04	2.96
	2.2	6.36	0.94	2.90
	2.3	6.09	0.86	2.85
	2.4	5.83	0.78	2.83
	2.5	5.60	0.72	2.82
	2.6	5.38	0.66	2.82
	2.7	5.19	0.61	2.84
	2.8	5.00	0.57	
	2.9	4.83	0.53	
	3.0	4.67	0.49	
	3.1	4.52	0.46	
	3.2	4.38	0.43	
	3.3	4.24	0.40	
	3.4	4.12	0.38	
	3.5	4.00	0.36	
	3.6	3.89	0.34	
	3.7	3.78	0.32	
	3.8	3.68	0.30	
	3.9	3.59	0.29	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 5 ft	1.0	14.00	5.21	
	1.1	12.73	4.20	
	1.2	11.67	3.46	
	1.3	10.77	2.90	
	1.4	10.00	2.46	
	1.5	9.33	2.12	
	1.6	8.75	1.84	
	1.7	8.24	1.62	
	1.8	7.78	1.43	
	1.9	7.37	1.27	
	2.0	7.00	1.14	
	2.1	6.67	1.03	2.99
	2.2	6.36	0.93	2.93
	2.3	6.09	0.85	2.89
	2.4	5.83	0.78	2.86
	2.5	5.60	0.71	2.86
	2.6	5.38	0.66	2.86
	2.7	5.19	0.61	2.87
	2.8	5.00	0.56	
	2.9	4.83	0.52	
	3.0	4.67	0.49	
	3.1	4.52	0.45	
	3.2	4.38	0.43	
	3.3	4.24	0.40	
	3.4	4.12	0.38	
	3.5	4.00	0.35	
	3.6	3.89	0.33	
	3.7	3.78	0.32	
	3.8	3.68	0.30	
	3.9	3.59	0.28	
	4.0	3.50	0.27	
	4.1	3.41	0.26	
	4.2	3.33	0.24	
	4.3	3.26	0.23	
	4.4	3.18	0.22	
	4.5	3.11	0.21	
	4.6	3.04	0.20	
	4.7	2.98	0.19	
	4.8	2.92	0.19	
	4.9	2.86	0.18	

Assumptions:

Q =	70	cfs	
g =	32.2	ft/s^2	
V_1 =	0	fps	
z_2 =	686.2	ft	(flow of 16,350 cfs on the Mississippi River)
z_R =	701.83	ft	(with culvert placement at station 5+50)
S_0 =	0.01		
n =	0.012		
k_{ent} =	0.5		
k_{exit} =	0.7		
lane width =	12	ft	
shoulder width =	4	ft	
slope =	2:1		

d_E =	entrance depth of flow	[ft]
g =	acceleration due to gravity	[ft/s^2]
H_L =	energy head loss	[ft]
k_{ent} =	entrance loss coefficient	[-]
k_{exit} =	exit loss coefficient	[-]
L =	length of the culvert barrel	[ft]
n =	Manning's roughness coefficient	[-]
Q =	design flow	[cfs]
S_0 =	slope of culvert	[-]
V_1 =	entrance velocity	[fps]
V_2 =	exit velocity	[fps]
z_2 =	downstream water surface elevation	[ft]
z_R =	roadway elevation	[ft]

meet V_2, H_L requirements

meet V_2, H_L, d_E requirements

Culvert Design Calculations - double barrel

Span = 3 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 2 ft	1.0	11.67	4.11	
	1.1	10.61	3.31	
	1.2	9.72	2.72	
	1.3	8.97	2.28	
	1.4	8.33	1.93	
	1.5	7.78	1.66	
	1.6	7.29	1.44	
	1.7	6.86	1.26	
	1.8	6.48	1.12	
	1.9	6.14	0.99	2.5
Rise = 3 ft	1.0	11.67	4.04	
	1.1	10.61	3.26	
	1.2	9.72	2.68	
	1.3	8.97	2.24	
	1.4	8.33	1.90	
	1.5	7.78	1.64	
	1.6	7.29	1.42	
	1.7	6.86	1.25	
	1.8	6.48	1.10	
	1.9	6.14	0.98	2.6
	2.0	5.83	0.88	2.5
	2.1	5.56	0.79	2.5
	2.2	5.30	0.72	2.4
	2.3	5.07	0.65	2.4
	2.4	4.86	0.60	
	2.5	4.67	0.55	
	2.6	4.49	0.50	
	2.7	4.32	0.47	
	2.8	4.17	0.43	
	2.9	4.02	0.40	

Span = 4 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 2 ft	1.0	8.75	2.20	
	1.1	7.95	1.77	
	1.2	7.29	1.45	
	1.3	6.73	1.21	
	1.4	6.25	1.03	2.12
	1.5	5.83	0.88	1.99
	1.6	5.47	0.77	1.90
	1.7	5.15	0.67	1.85
	1.8	4.86	0.59	
	1.9	4.61	0.53	
Rise = 3 ft	1.0	8.75	2.16	
	1.1	7.95	1.74	
	1.2	7.29	1.43	
	1.3	6.73	1.20	
	1.4	6.25	1.02	2.14
	1.5	5.83	0.87	2.02
	1.6	5.47	0.76	1.93
	1.7	5.15	0.67	1.88
	1.8	4.86	0.59	
	1.9	4.61	0.52	
	2.0	4.38	0.47	
	2.1	4.17	0.42	
	2.2	3.98	0.38	
	2.3	3.80	0.35	
	2.4	3.65	0.32	
	2.5	3.50	0.29	
	2.6	3.37	0.27	
	2.7	3.24	0.25	
	2.8	3.13	0.23	
	2.9	3.02	0.21	

Span = 4 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 4 ft	1.0	8.75	2.13	
	1.1	7.95	1.72	
	1.2	7.29	1.41	
	1.3	6.73	1.18	
	1.4	6.25	1.00	2.17
	1.5	5.83	0.86	2.05
	1.6	5.47	0.75	1.97
	1.7	5.15	0.66	1.92
	1.8	4.86	0.58	
	1.9	4.61	0.52	
	2.0	4.38	0.46	
	2.1	4.17	0.42	
	2.2	3.98	0.38	
	2.3	3.80	0.34	
	2.4	3.65	0.32	
	2.5	3.50	0.29	
	2.6	3.37	0.27	
	2.7	3.24	0.25	
	2.8	3.13	0.23	
	2.9	3.02	0.21	
	3.0	2.92	0.20	
	3.1	2.82	0.18	
	3.2	2.73	0.17	
	3.3	2.65	0.16	
	3.4	2.57	0.15	
	3.5	2.50	0.14	
	3.6	2.43	0.14	
	3.7	2.36	0.13	
	3.8	2.30	0.12	
	3.9	2.24	0.11	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 3 ft	1.0	7.00	1.34	
	1.1	6.36	1.08	1.94
	1.2	5.83	0.89	1.74
	1.3	5.38	0.74	1.62
	1.4	5.00	0.63	
	1.5	4.67	0.54	
	1.6	4.38	0.47	
	1.7	4.12	0.41	
	1.8	3.89	0.36	
	1.9	3.68	0.32	
	2.0	3.50	0.29	
	2.1	3.33	0.26	
	2.2	3.18	0.24	
	2.3	3.04	0.22	
	2.4	2.92	0.20	
	2.5	2.80	0.18	
	2.6	2.69	0.17	
	2.7	2.59	0.15	
	2.8	2.50	0.14	
	2.9	2.41	0.13	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 4 ft	1.0	7.00	1.32	
	1.1	6.36	1.07	1.97
	1.2	5.83	0.88	1.77
	1.3	5.38	0.73	1.65
	1.4	5.00	0.62	
	1.5	4.67	0.54	
	1.6	4.38	0.47	
	1.7	4.12	0.41	
	1.8	3.89	0.36	
	1.9	3.68	0.32	
	2.0	3.50	0.29	
	2.1	3.33	0.26	
	2.2	3.18	0.24	
	2.3	3.04	0.21	
	2.4	2.92	0.20	
	2.5	2.80	0.18	
	2.6	2.69	0.17	
	2.7	2.59	0.15	
	2.8	2.50	0.14	
	2.9	2.41	0.13	
	3.0	2.33	0.12	
	3.1	2.26	0.11	
	3.2	2.19	0.11	
	3.3	2.12	0.10	
	3.4	2.06	0.09	
	3.5	2.00	0.09	
	3.6	1.94	0.08	
	3.7	1.89	0.08	
	3.8	1.84	0.08	
	3.9	1.79	0.07	

Span = 5 ft

	d [ft]	V_2 [fps]	H_L [ft]	d_E [ft]
Rise = 5 ft	1.0	7.00	1.30	
	1.1	6.36	1.05	1.99
	1.2	5.83	0.87	1.80
	1.3	5.38	0.72	1.68
	1.4	5.00	0.62	
	1.5	4.67	0.53	
	1.6	4.38	0.46	
	1.7	4.12	0.40	
	1.8	3.89	0.36	
	1.9	3.68	0.32	
	2.0	3.50	0.29	
	2.1	3.33	0.26	
	2.2	3.18	0.23	
	2.3	3.04	0.21	
	2.4	2.92	0.19	
	2.5	2.80	0.18	
	2.6	2.69	0.16	
	2.7	2.59	0.15	
	2.8	2.50	0.14	
	2.9	2.41	0.13	
	3.0	2.33	0.12	
	3.1	2.26	0.11	
	3.2	2.19	0.11	
	3.3	2.12	0.10	
	3.4	2.06	0.09	
	3.5	2.00	0.09	
	3.6	1.94	0.08	
	3.7	1.89	0.08	
	3.8	1.84	0.07	
	3.9	1.79	0.07	
	4.0	1.75	0.07	
	4.1	1.71	0.06	
	4.2	1.67	0.06	
	4.3	1.63	0.06	
	4.4	1.59	0.06	
	4.5	1.56	0.05	
	4.6	1.52	0.05	
	4.7	1.49	0.05	
	4.8	1.46	0.05	
	4.9	1.43	0.04	

Assumptions:

Q =	35	cfs	
g =	32.2	ft/s^2	
V_1 =	0	fps	
z_2 =	686.2	ft	(flow of 16,350 cfs on the Mississippi River)
z_R =	701.83	ft	(with culvert placement at station 5+50)
S_0 =	0.01		
n =	0.012		
k_{ent} =	0.5		
k_{exit} =	0.7		
lane width =	12	ft	
shoulder width =	4	ft	
slope =	2:1		

d_E =	entrance depth of flow	[ft]
g =	acceleration due to gravity	$[ft/s^2]$
H_L =	energy head loss	[ft]
k_{ent} =	entrance loss coefficient	[-]
k_{exit} =	exit loss coefficient	[-]
L =	length of the culvert barrel	[ft]
n =	Manning's roughness coefficient	[-]
Q =	design flow	[cfs]
S_0 =	slope of culvert	[-]
V_1 =	entrance velocity	[fps]
V_2 =	exit velocity	[fps]
z_2 =	downstream water surface elevation	[ft]
z_R =	roadway elevation	[ft]

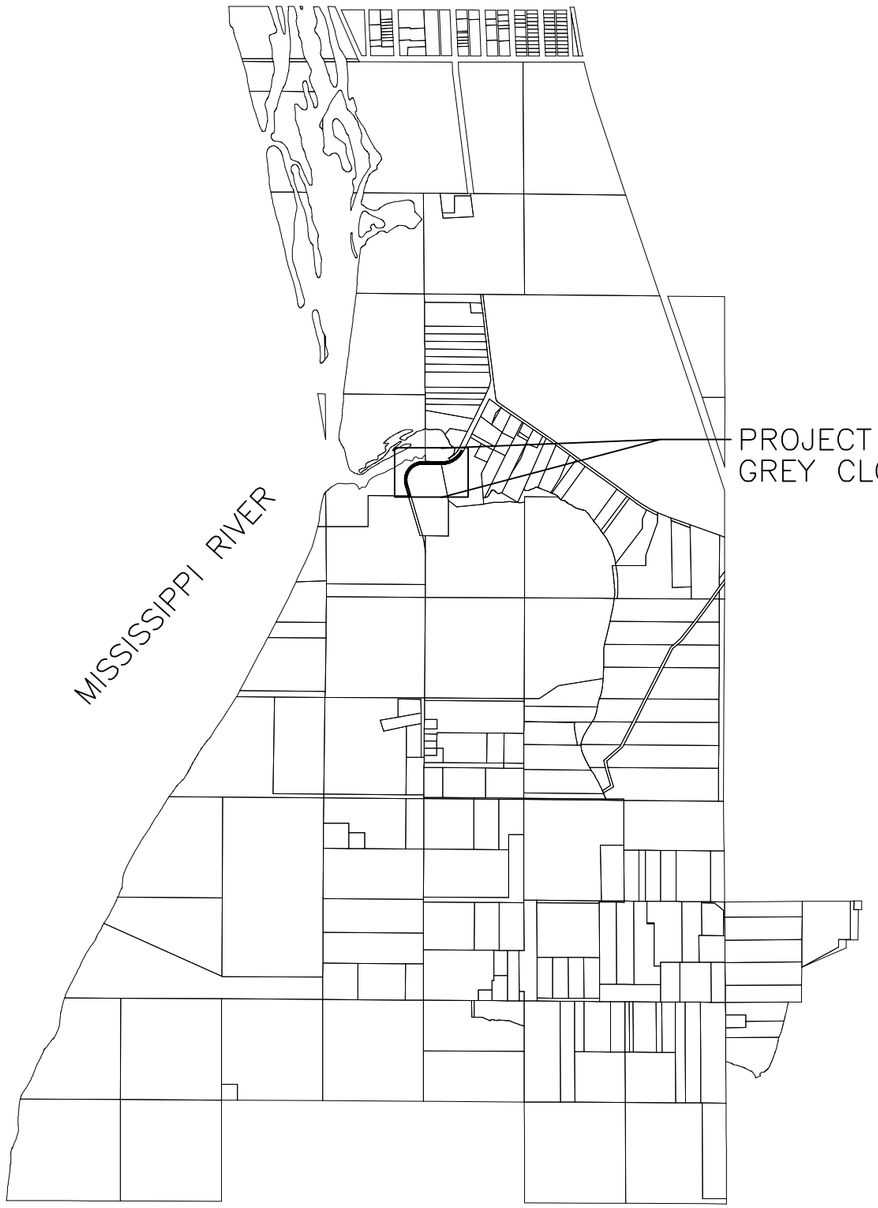
meet V_2, H_L requirements

meet V_2, H_L d_E requirements

Appendix B: Roadwork Design

GREY CLOUD ISLAND TOWNSHIP

GREY CLOUD ISLAND SLOUGH IMPROVEMENTS



VICINITY MAP

CITY PROJECT NO. 06001

2006

SHEET INDEX

DENNY HANNA – TOWNSHIP CHAIRPERSON

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APPROVED
DATE
PROJ. NO. 101-06-001

MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
TITLE SHEET

SHEET NUMBER
G1.01

MISSISSIPPI RIVER
NWL: 688.0 FT

GREY CLOUD ISLAND
SLOUGH
NWL: 686.2 FT

GREY CLOUD ISLAND DRIVE

CULVERT ℄

PC = 8+14.88

PT = 5+65.48

PC = 2+74.88

PT = 12+75.80

Δ=12°51'27"
R=234.00
L=460.92

Δ=65°33'05"
R=254.00
L=290.60

0 40 80
Scale in feet

N

PVI STA = 13+00
PVI ELEV = 727.32
A.D. = -6.68
K = 22.47
150.00' VC
EVCS: 13+75
EVCE: 727.89
BVCS: 12+25
BVCE: 721.74
0.76%
-7.44%

PVI STA = 10+00
PVI ELEV = 705.00
A.D. = 6.44
K = 31.06
200.00' VC
EVCS: 11+00
EVCE: 712.44
BVCS: 9+00
BVCE: 704.00

LP ELEV = 701.75
LP STA = 6+00
PVI STA = 6+00
PVI ELEV = 701.00
A.D. = 2.00
K = 150.00
300.00' VC
EVCS: 7+50
EVCE: 702.50
BVCS: 4+50
BVCE: 702.50
1.00%

EXISTING ℄ PROFILE

PVI STA = 1+50
PVI ELEV = 705.50
A.D. = 7.13
K = 21.03
150.00' VC
EVCS: 2+25
EVCE: 704.75
BVCS: 0+75
BVCE: 711.60
-1.00%
8.13%

100 YEAR WL
699.8'

13+00	12+00	11+00	10+00	9+00	8+00	7+00	6+00	5+00	4+00	3+00	2+00	1+00	0+00
728.0	728.0	725.8	723.2	719.9	716.4	712.6	708.9	706.2	704.4	703.1	703.3	702.8	702.2
	727.56	726.07	723.46	719.88	716.16	712.44	709.12	706.61	704.90	704.00	703.50	703.00	702.50
702.0	702.0	702.0	702.0	702.0	702.0	702.0	702.3	703.2	703.6	704.4	705.1	707.1	709.4	713.5	717.7
702.08	701.83	701.75	701.83	702.08	702.50	703.00	703.50	704.00	704.50	705.15	706.84	709.71	713.63	717.70

740 730 720 710 700 690

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MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

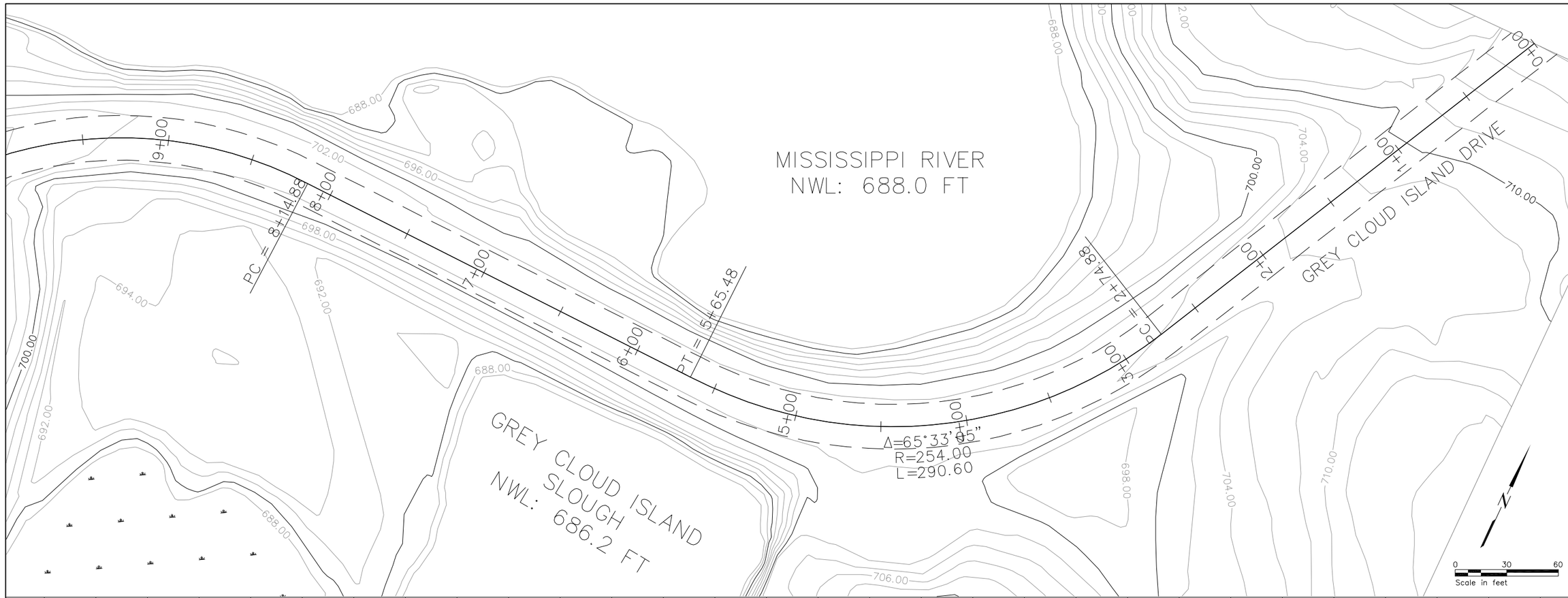
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

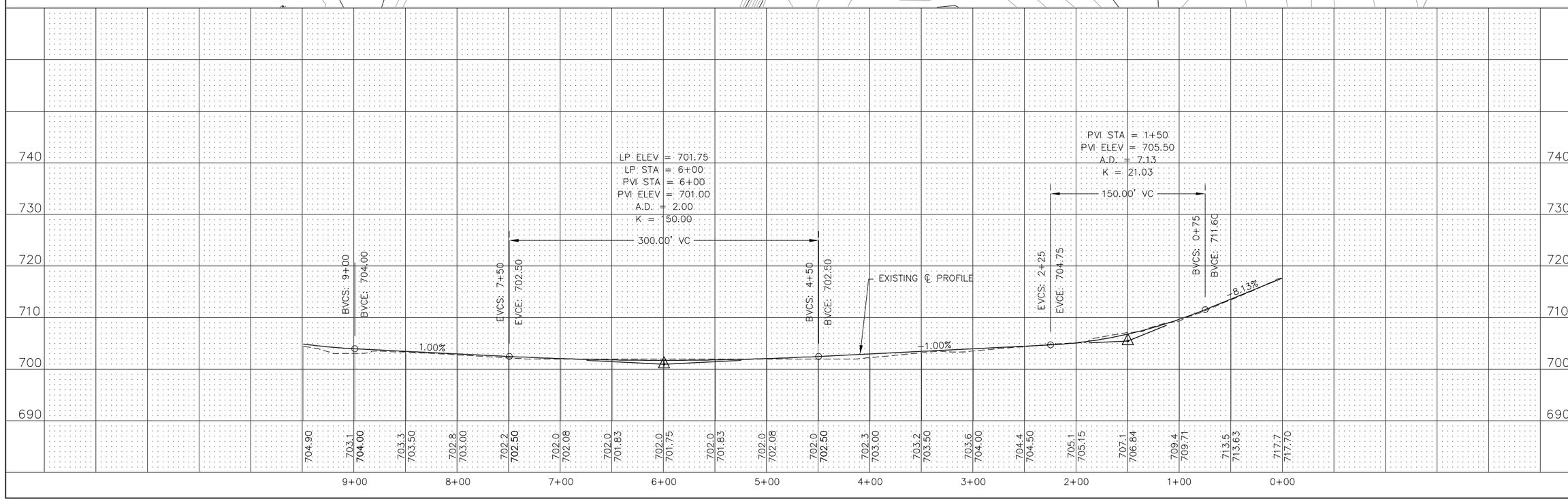
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

EXISTING ROADWAY PROFILE

SHEET NUMBER

C6.01





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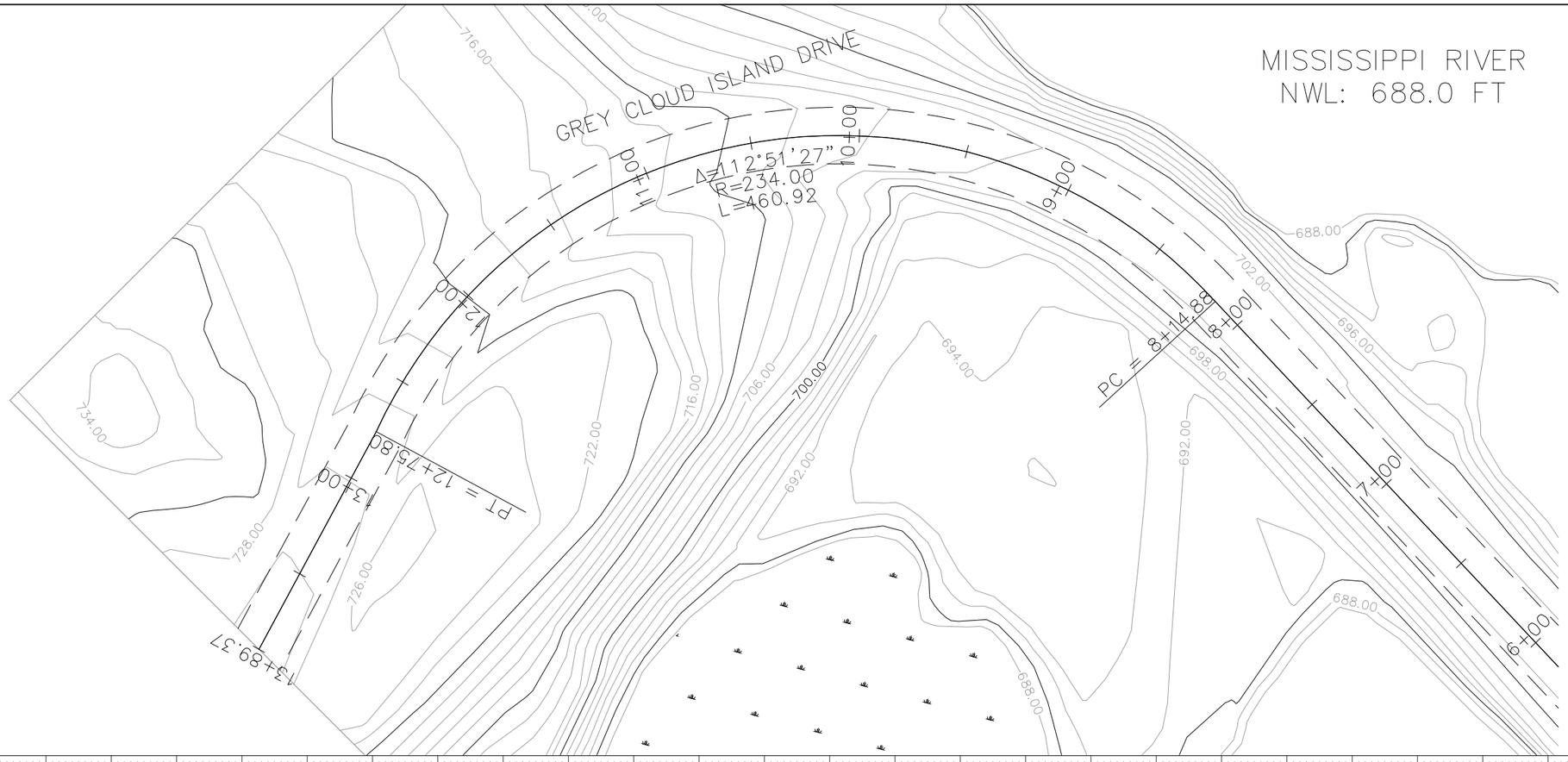
GREY CLOUD TOWNSHIP, MINNESOTA

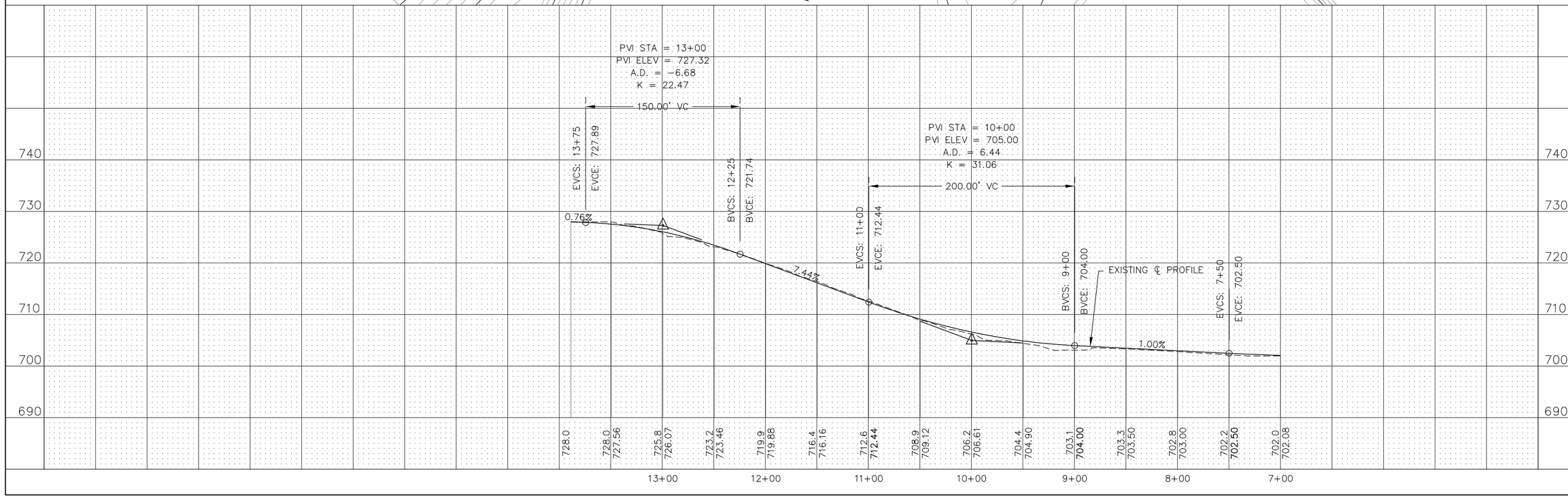
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

EXSISTING ROADWAY PROFILE 30 SCALE

SHEET NUMBER

C6.02





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TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

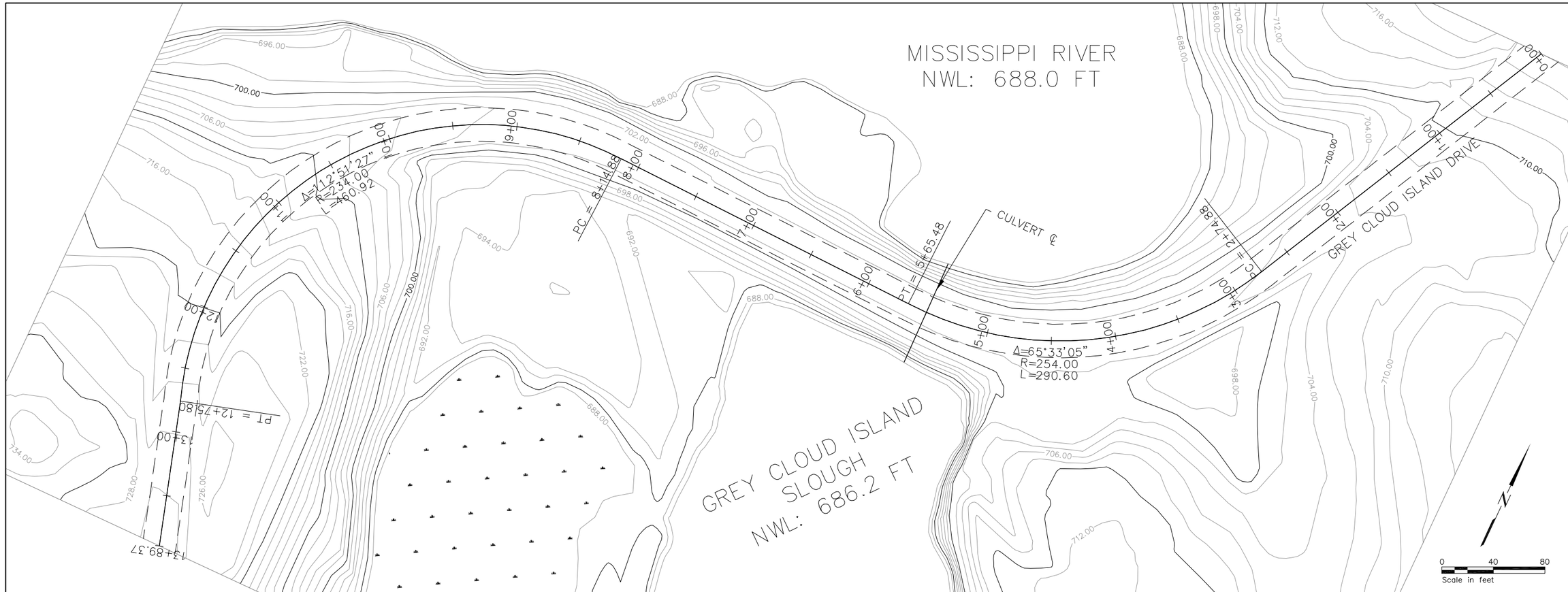
GREY CLOUD TOWNSHIP, MINNESOTA

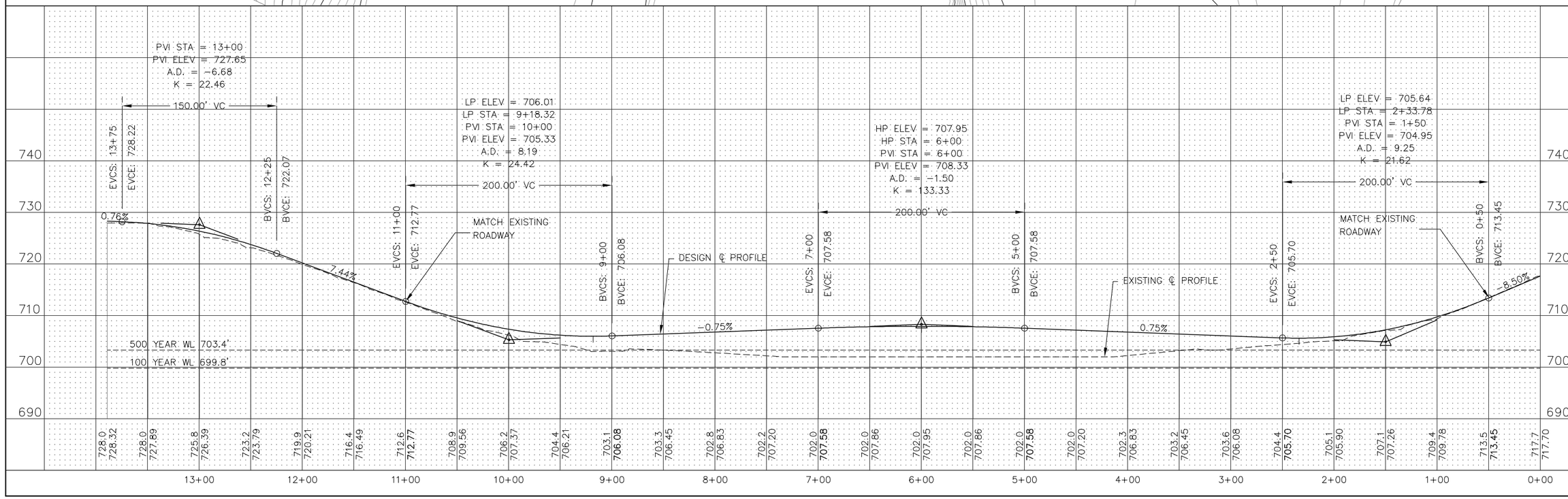
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

EXISTING ROADWAY PROFILE 30 SCALE

SHEET NUMBER

C6.03





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SIGNATURE: _____

DATE: _____

SURVEY

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DATE

PROJ. NO. 101-06-001

MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

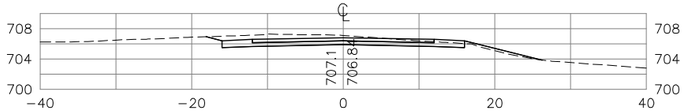
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

DESIGN ROADWAY PROFILE

SHEET NUMBER

C6.04

1+50



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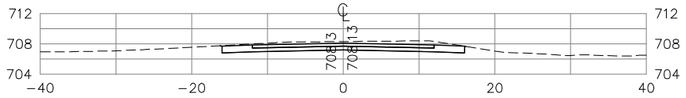

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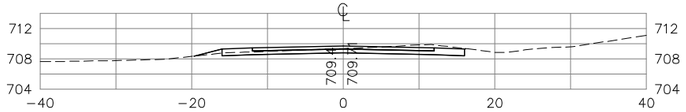

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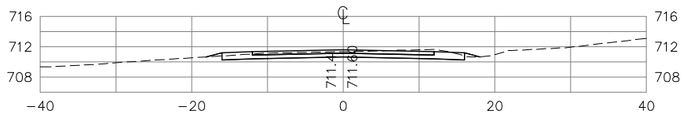

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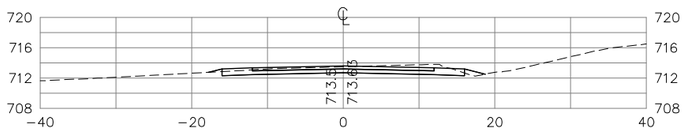

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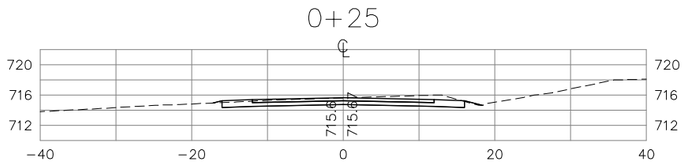

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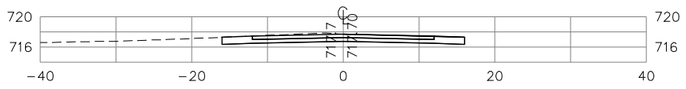

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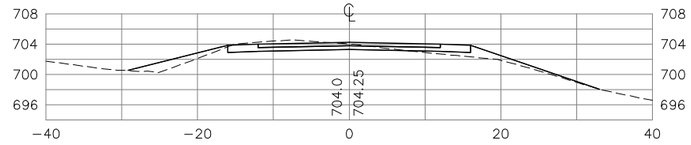

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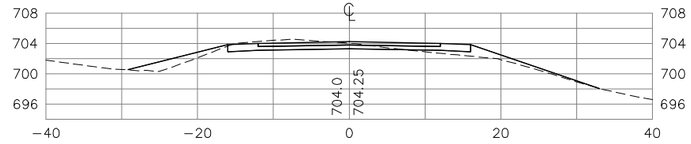

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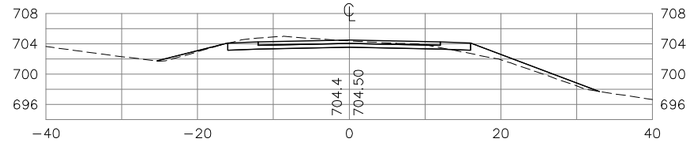

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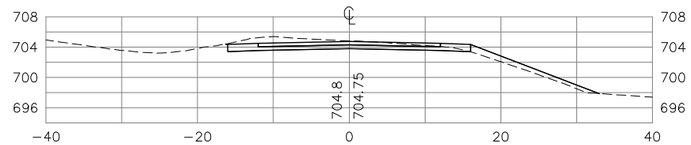

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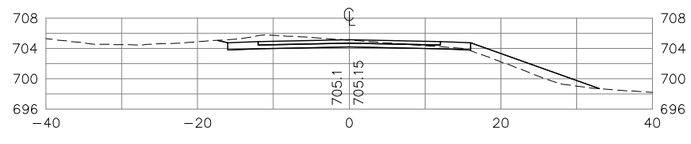

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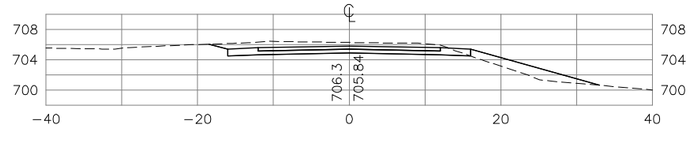

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TIM DAVIS
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BEN KRAUSE
DEREK NEWBAUER

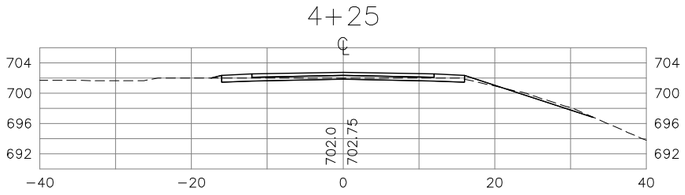
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

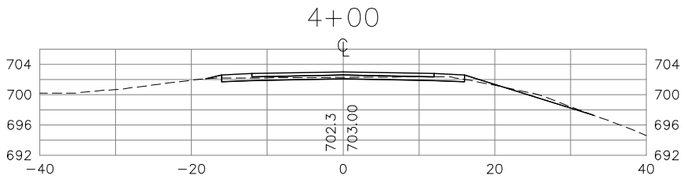
GREY CLOUD ISLAND SLOUGH IMPROVEMENTS

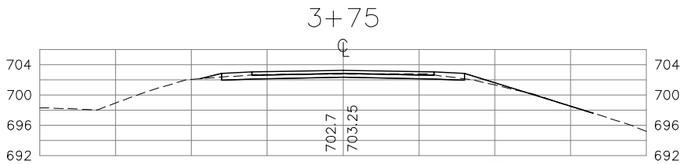
100 YEAR ROADWAY CROSS SECTIONS

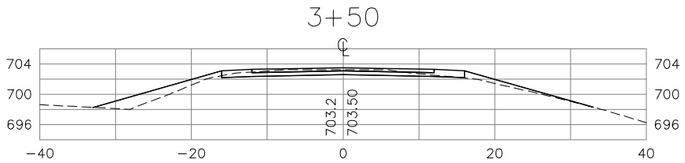
SHEET NUMBER

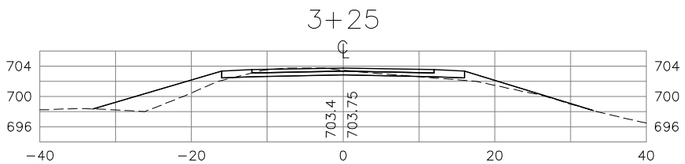
C7.01

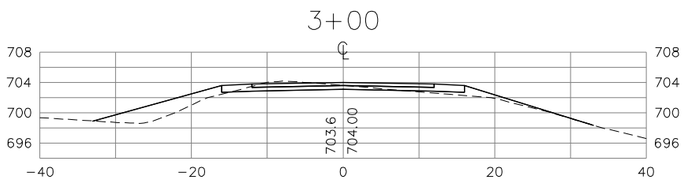


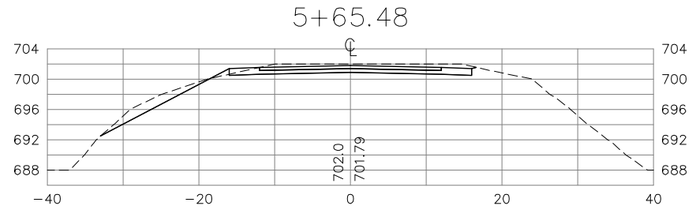


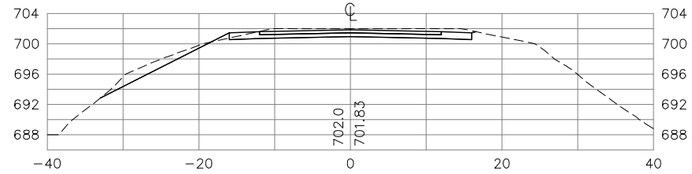


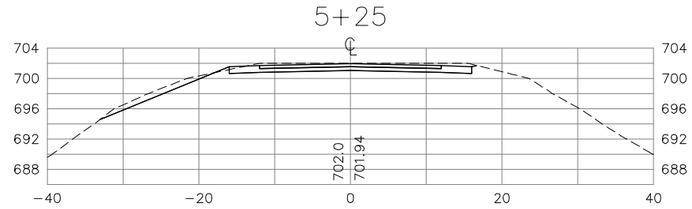


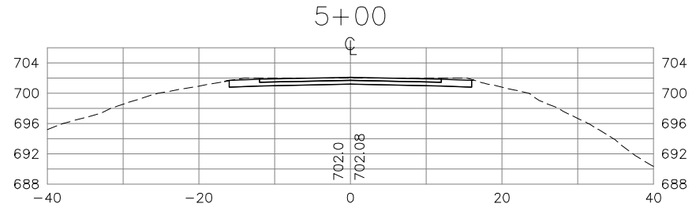


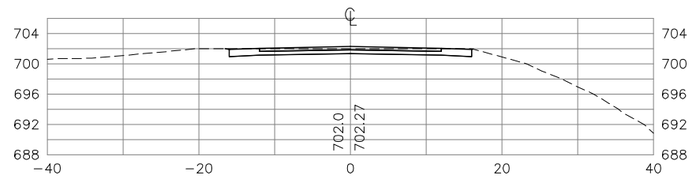


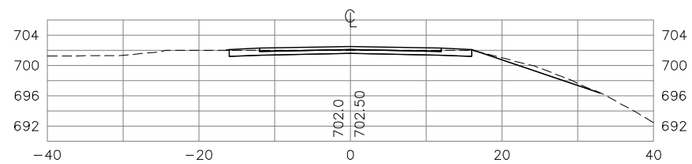












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TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

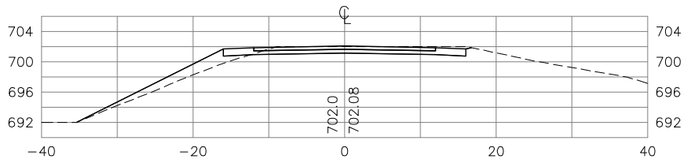
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

100 YEAR ROADWAY CROSS SECTIONS

SHEET NUMBER

C7.02

7+00



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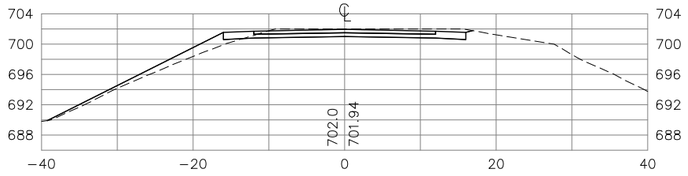

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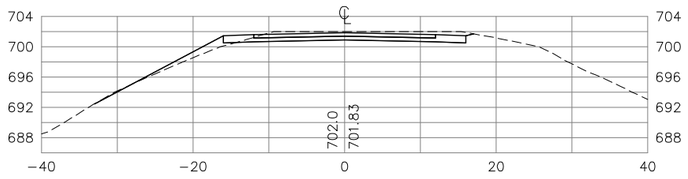

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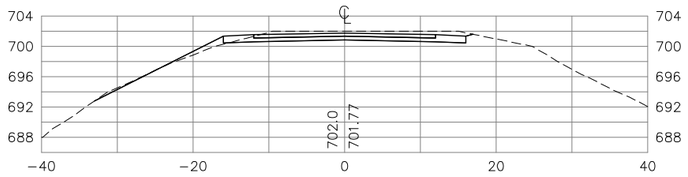

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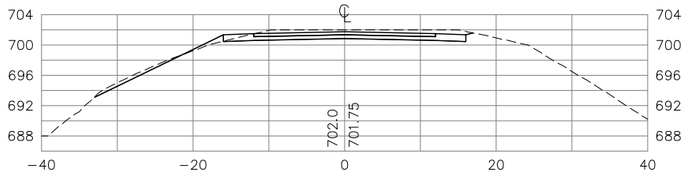

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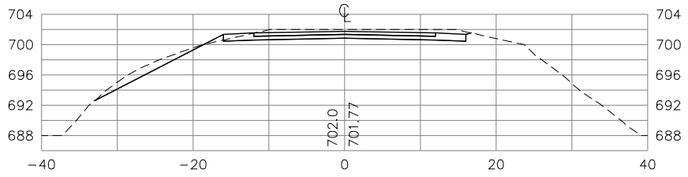

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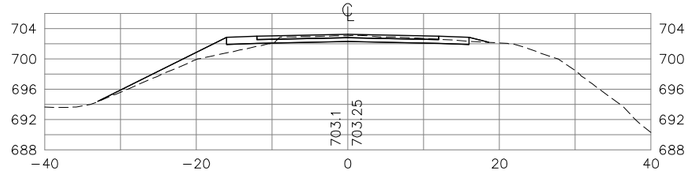

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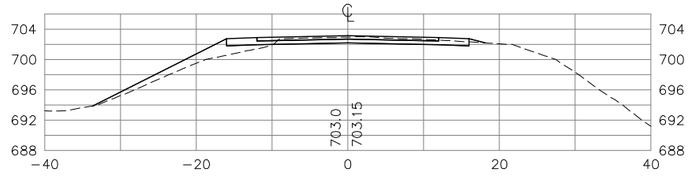

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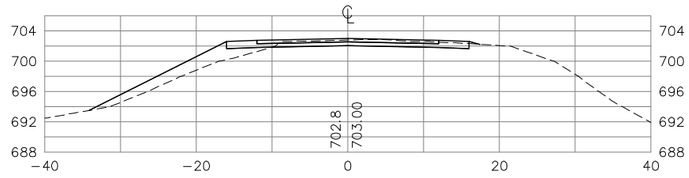

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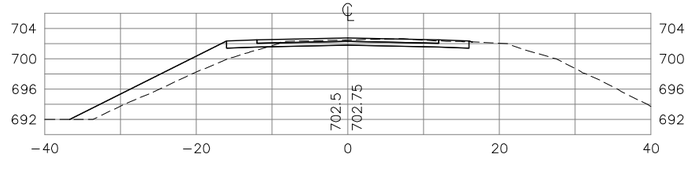

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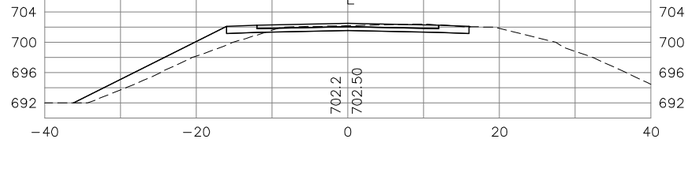

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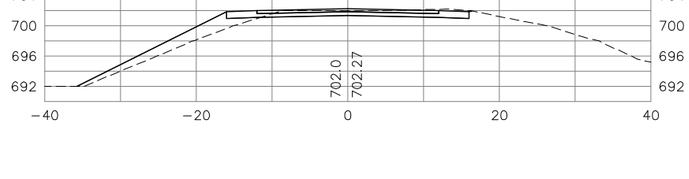

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GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

GREY CLOUD ISLAND SLOUGH IMPROVEMENT
100 YEAR ROADWAY CROSS SECTIONS

SHEET NUMBER
C7.03

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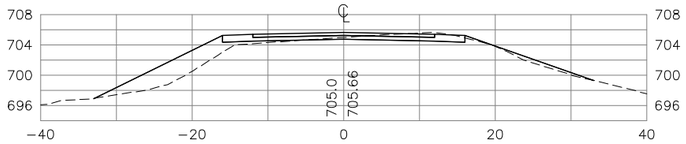

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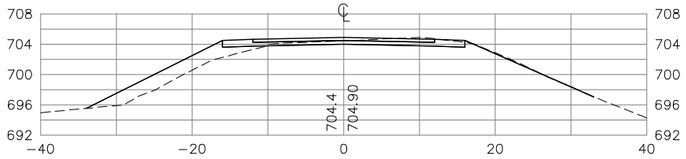

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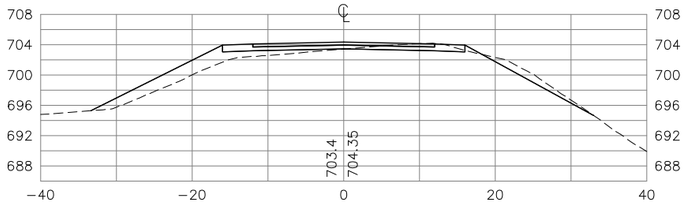

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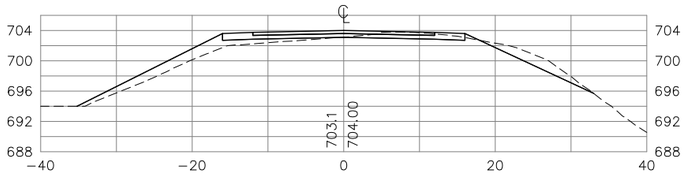

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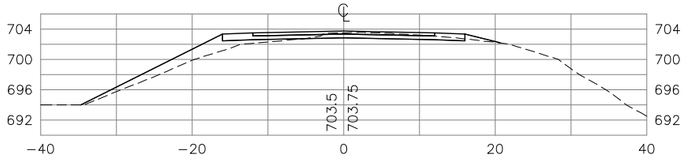

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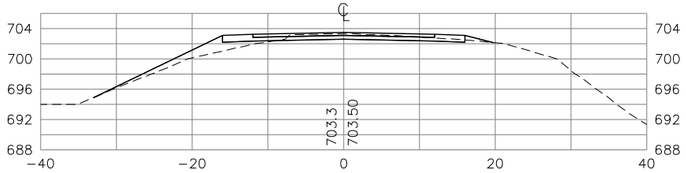

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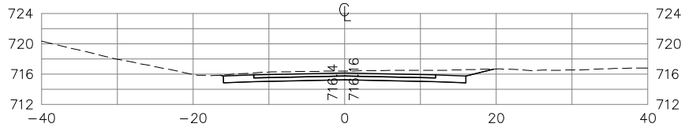

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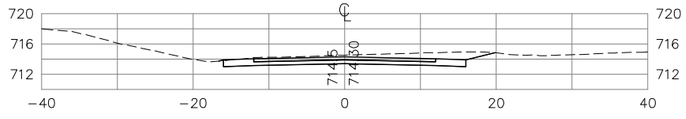

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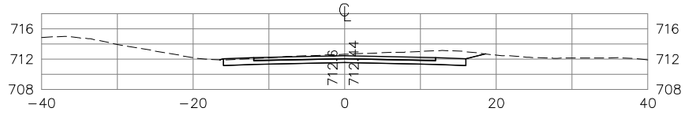

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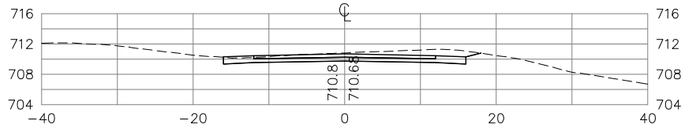

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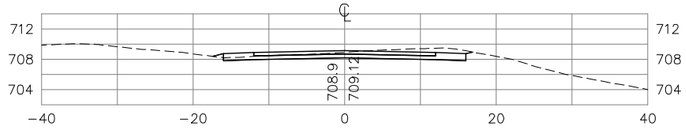

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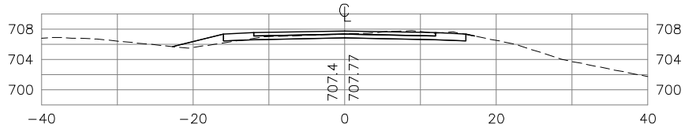

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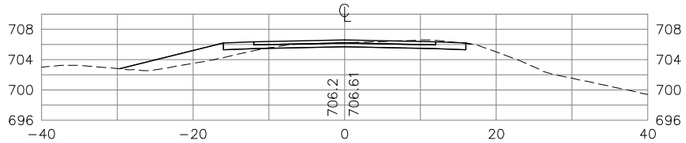

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SHEET NUMBER

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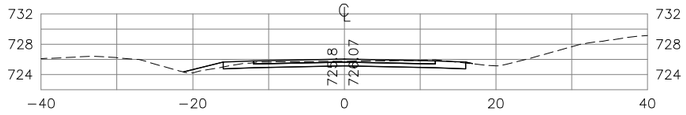
13+00



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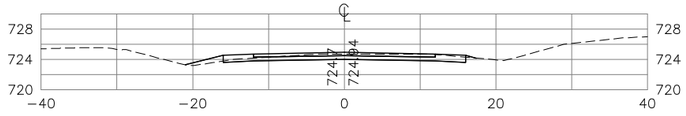

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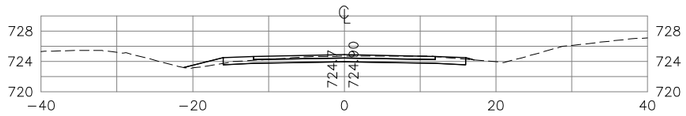

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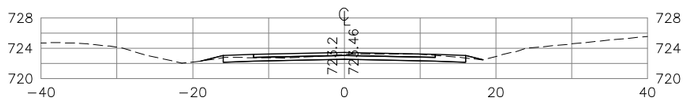

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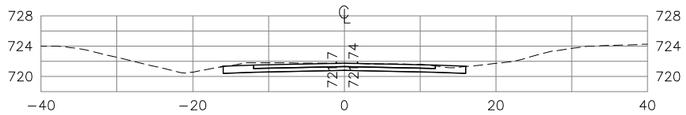

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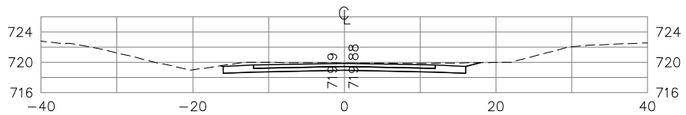

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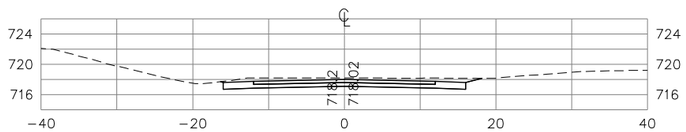

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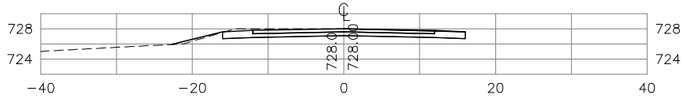

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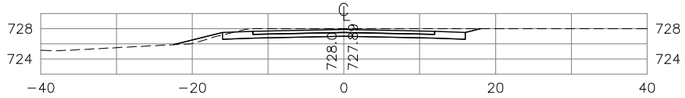

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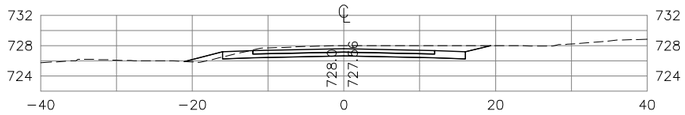

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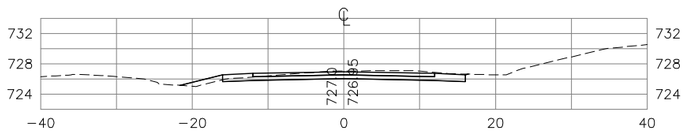

MATT BEYER
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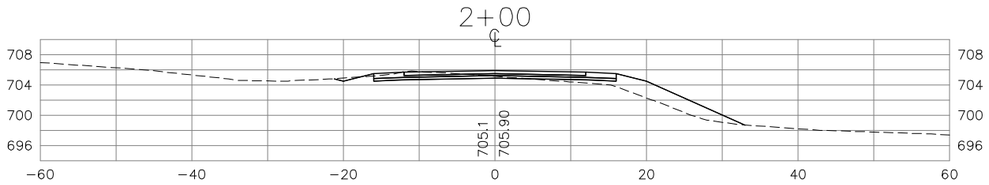
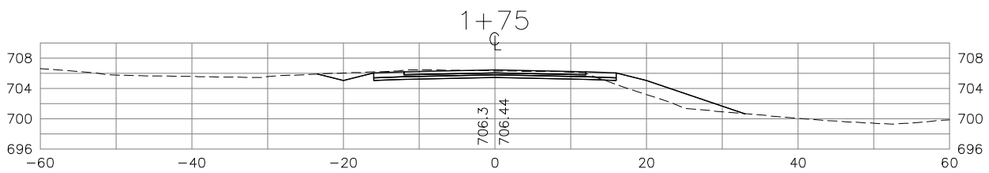
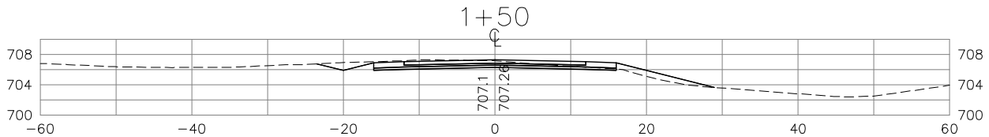
PROJ. NO. 101-06-001

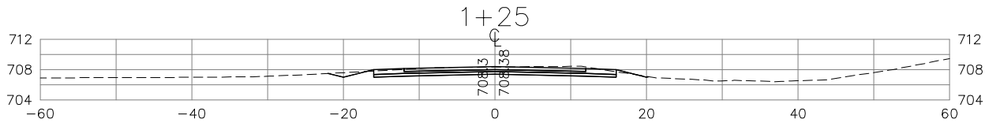
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
100 YEAR ROADWAY CROSS SECTIONS
DESIGN ROADWAY PROFILE

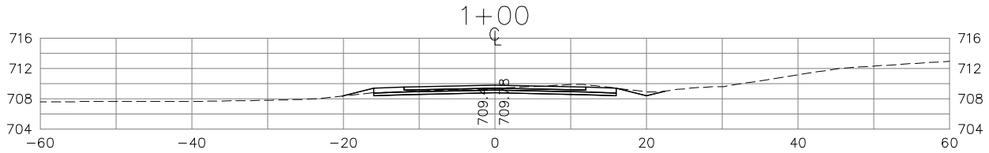
SHEET NUMBER
C7.05

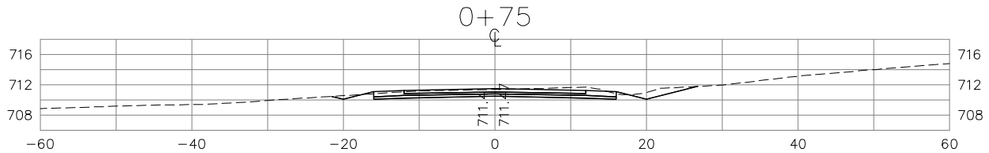


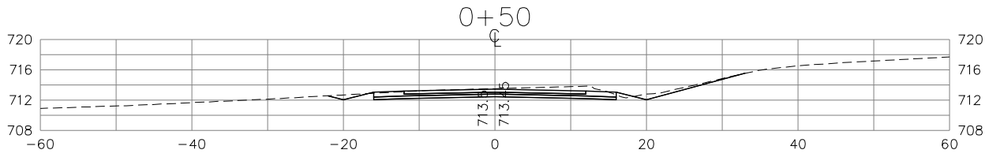


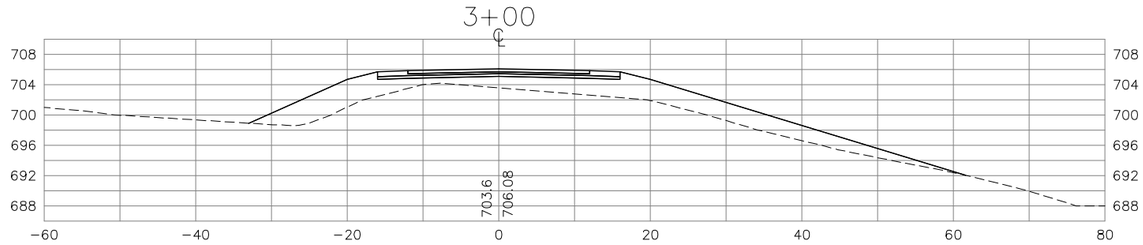


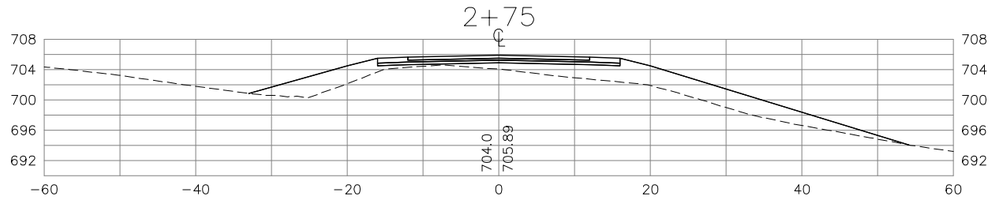


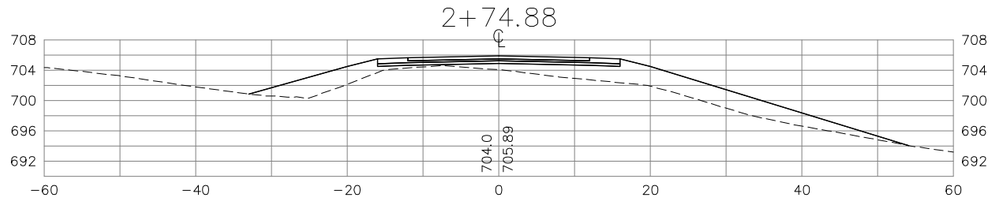


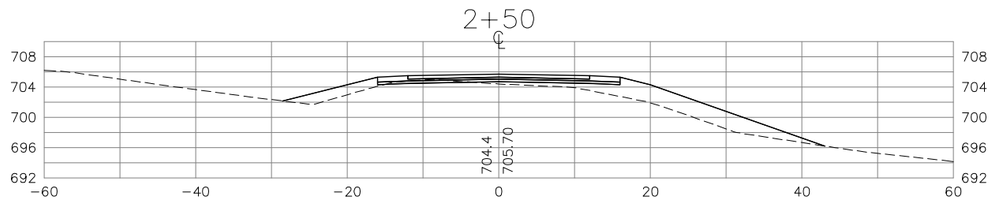


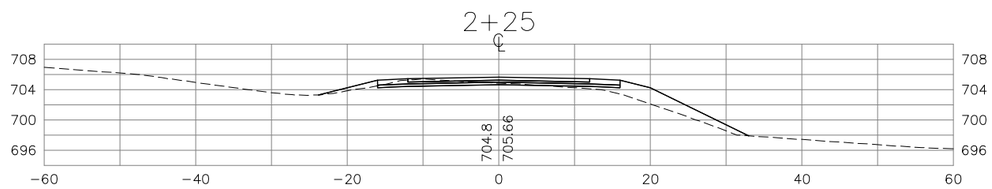












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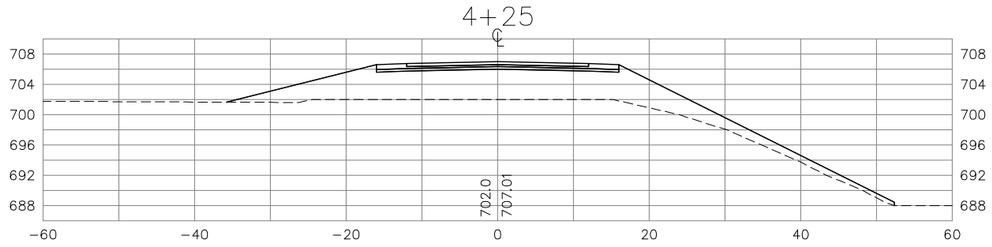
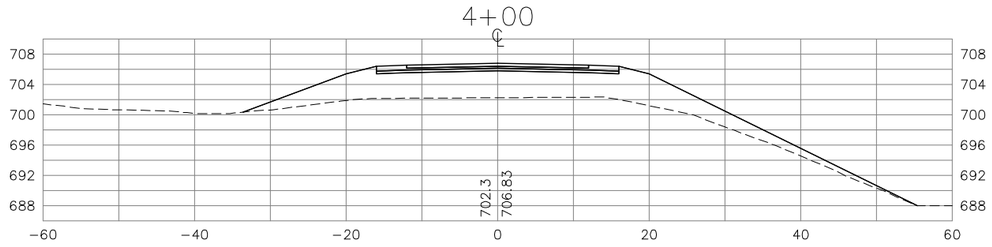
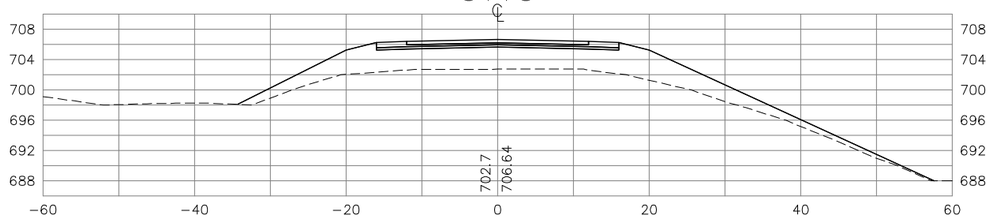
DEREK NEWBAUER

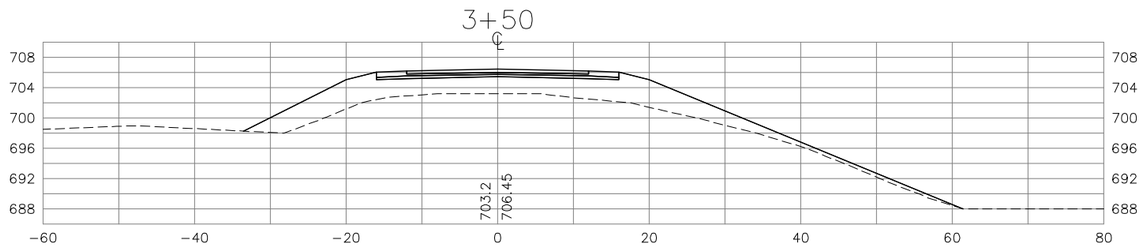
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
500 YEAR ROADWAY CROSS SECTIONS

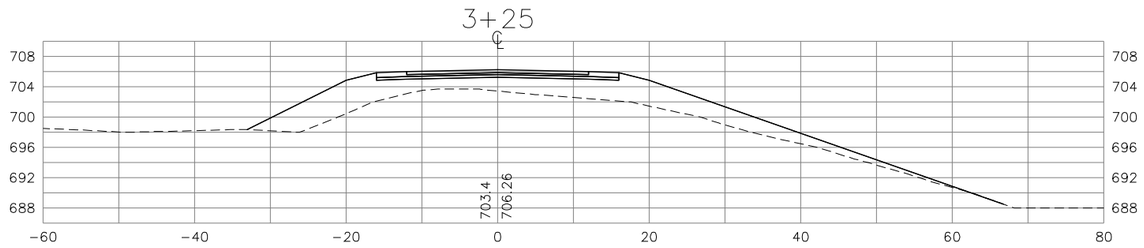
SHEET NUMBER
C7.06

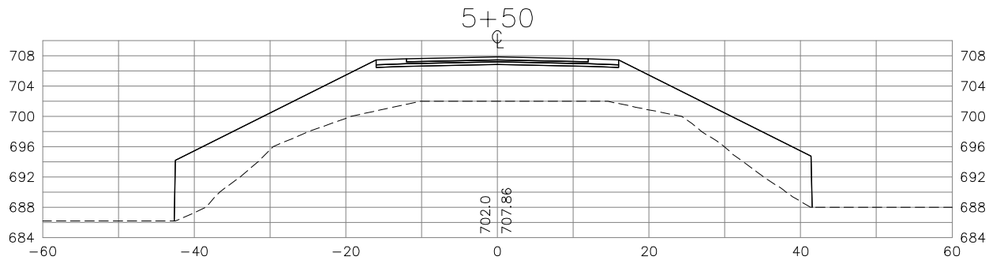


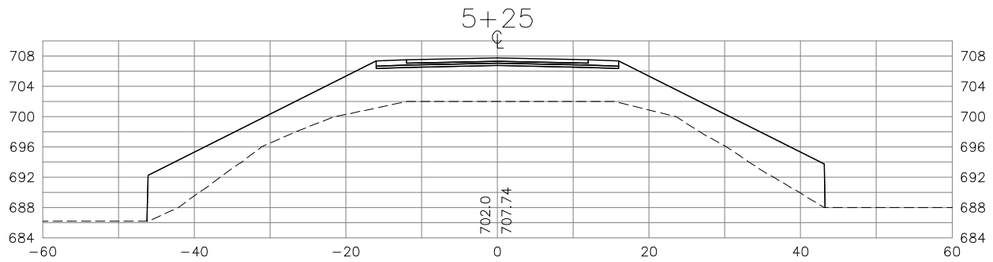


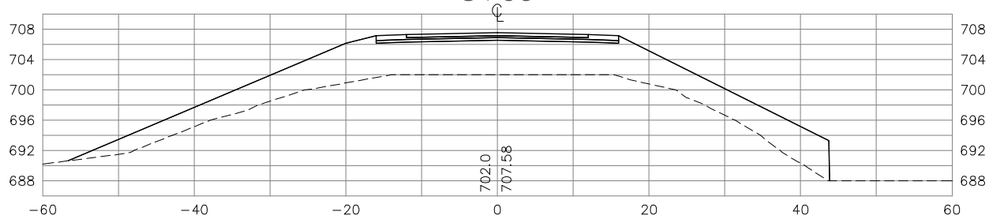


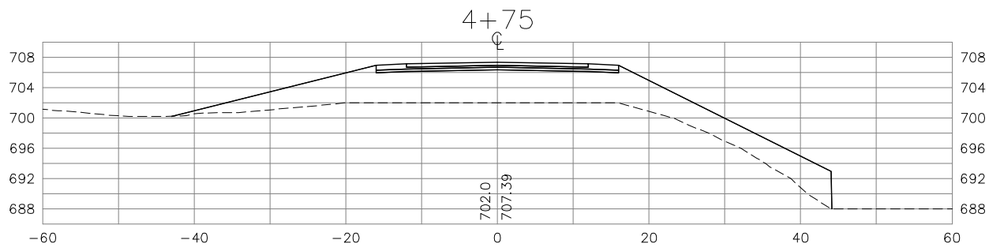


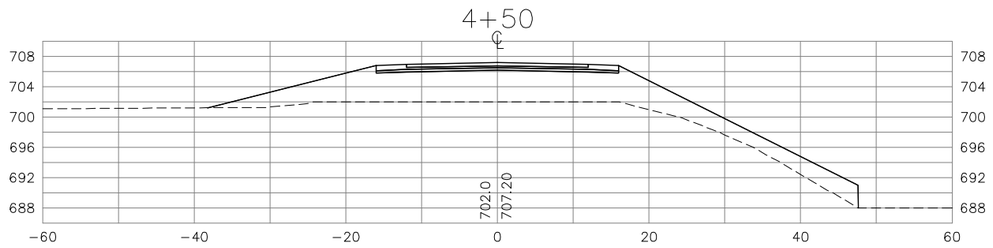












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TIM DAVIS
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BEN KRAUSE
DEREK NEWBAUER

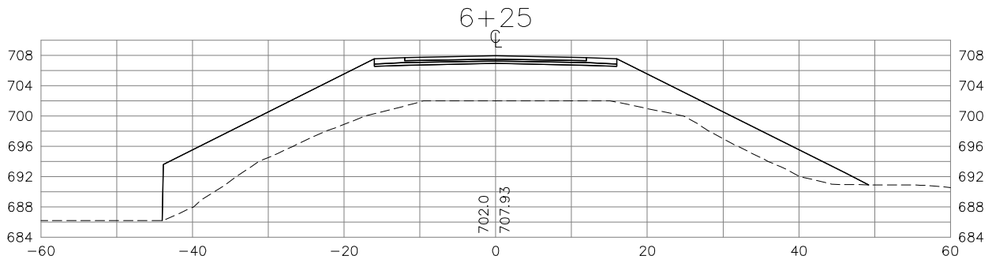
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

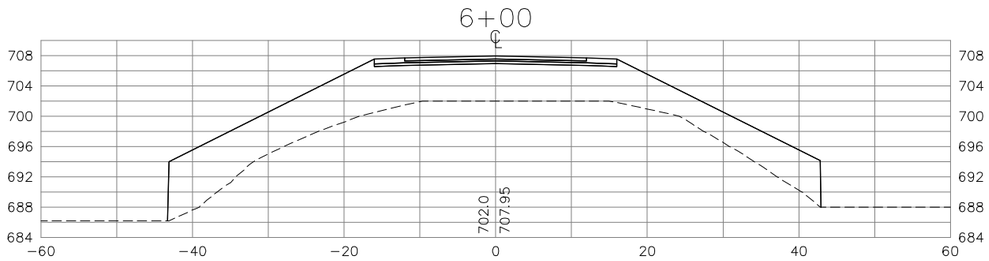
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

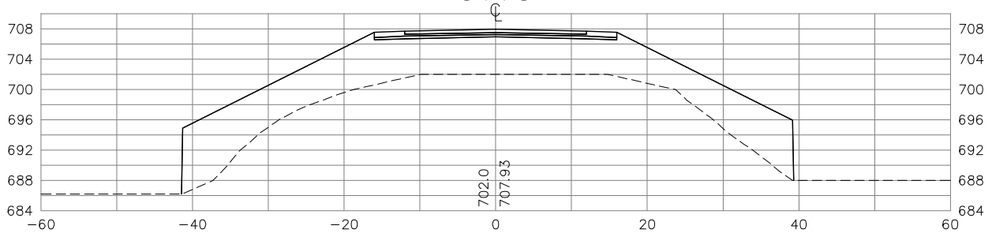
500 YEAR ROADWAY CROSS SECTIONS

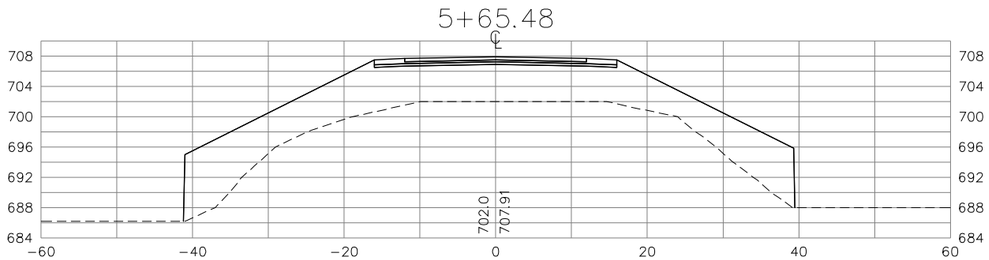
SHEET NUMBER

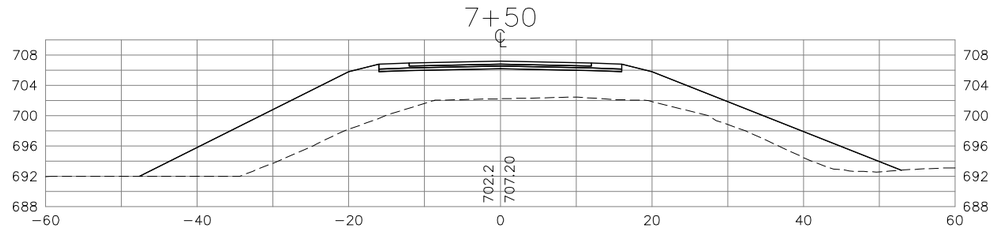
C7.07

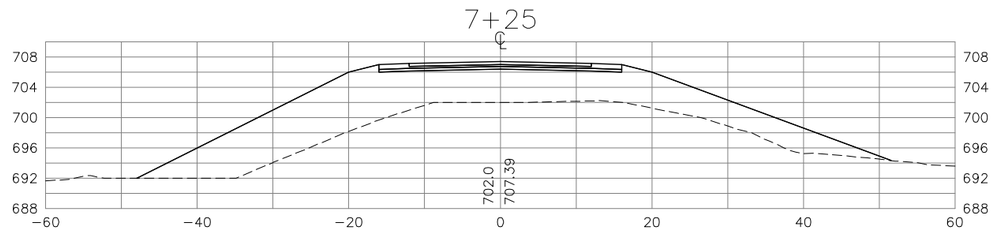


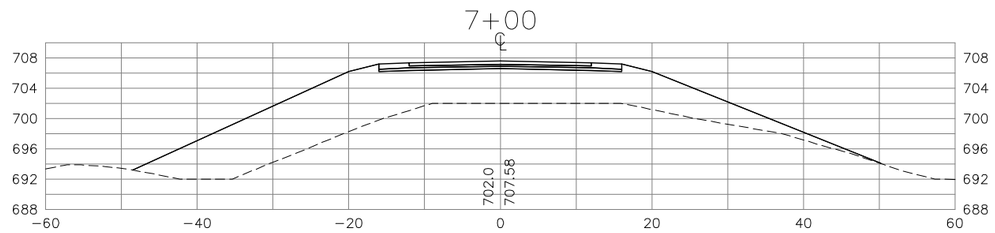


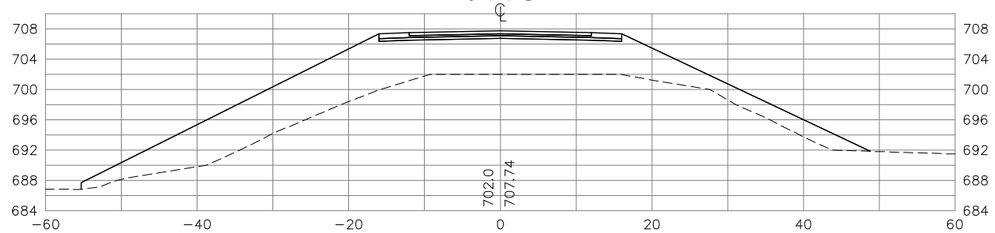


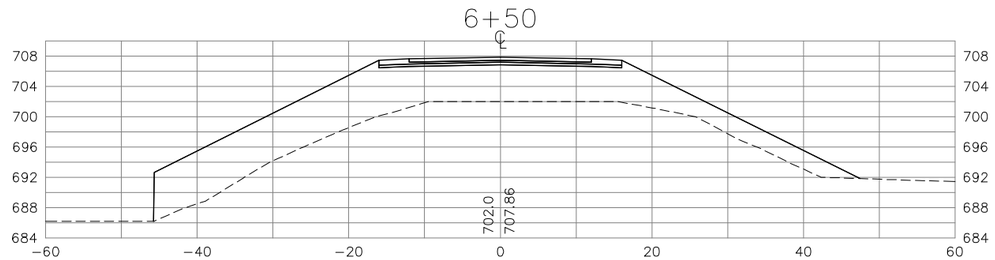












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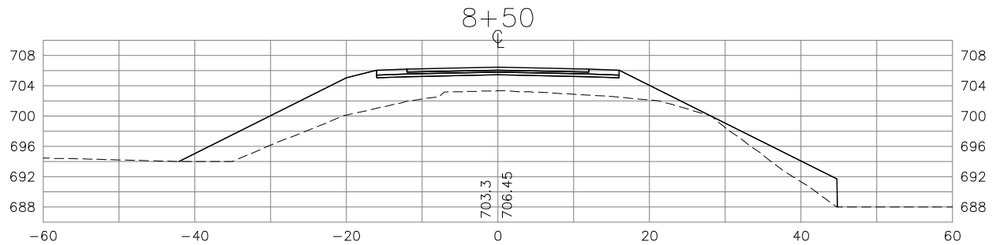
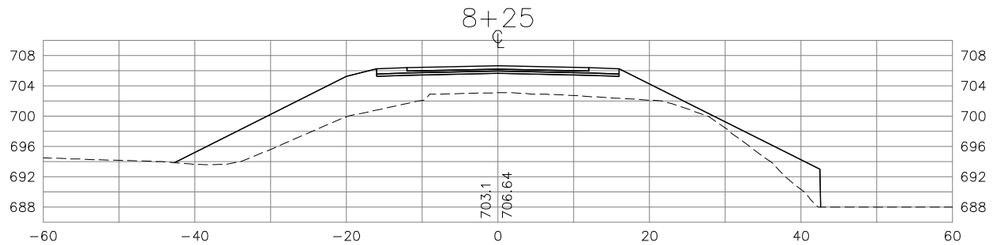
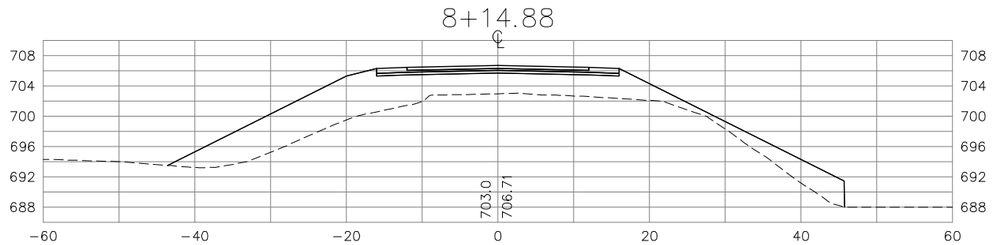
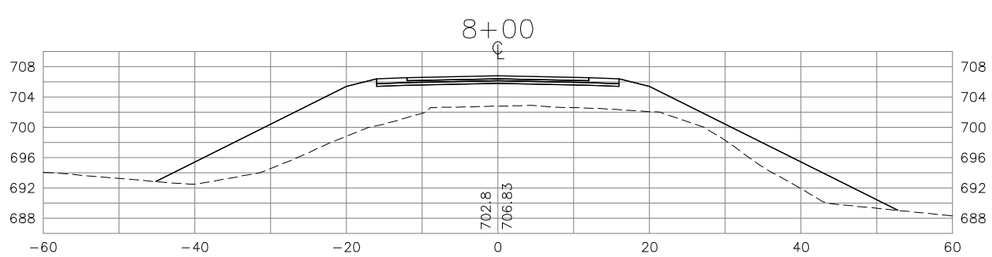
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
500 YEAR ROADWAY CROSS SECTIONS

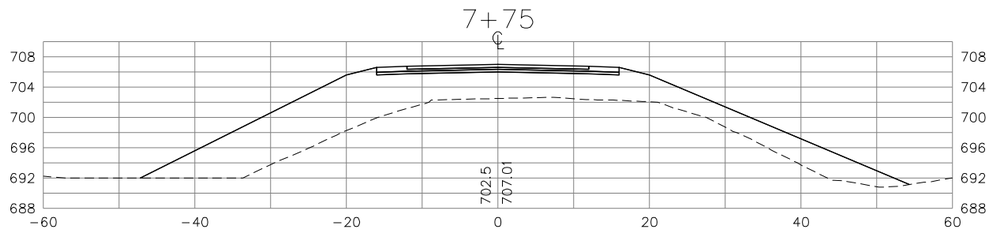
SHEET NUMBER
C7.08

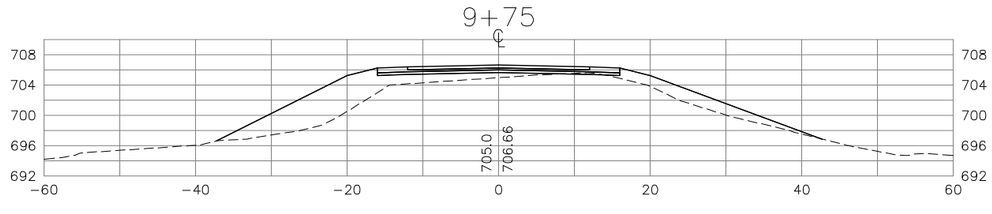


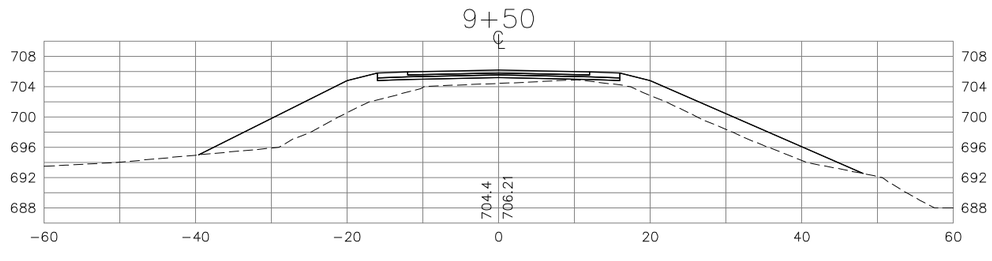


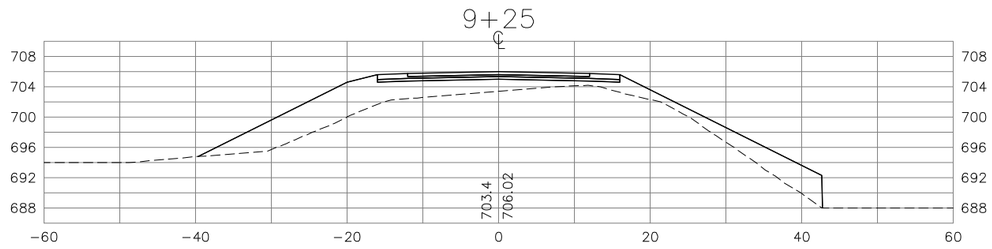


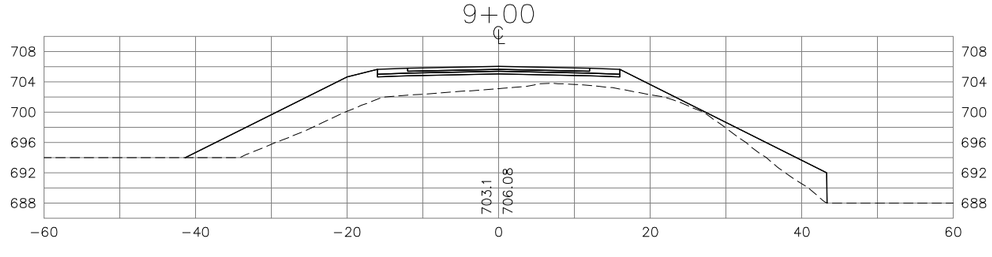


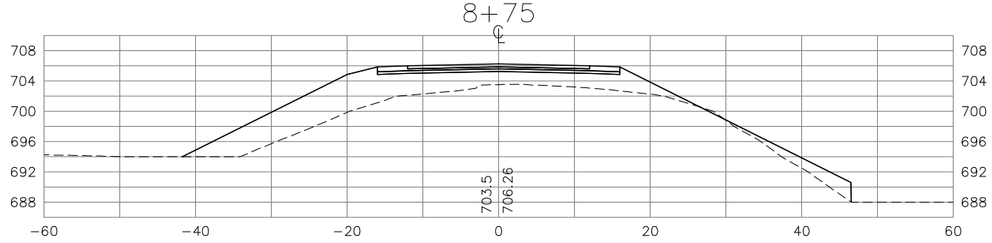












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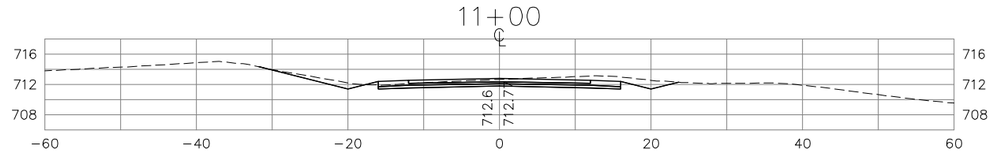
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

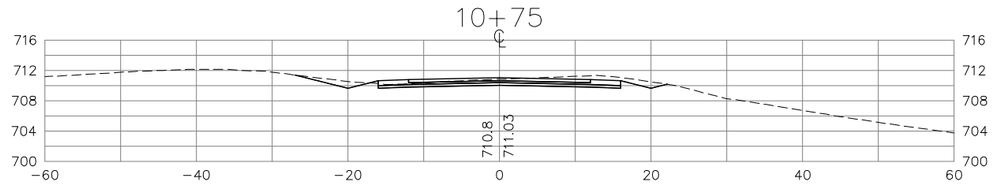
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

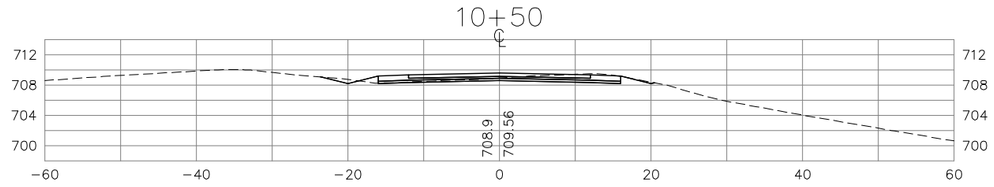
500 YEAR ROADWAY CROSS SECTIONS

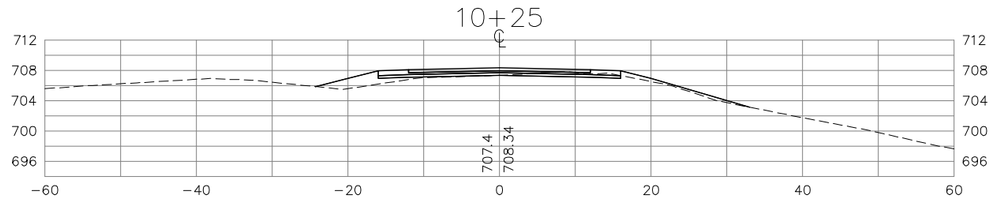
SHEET NUMBER

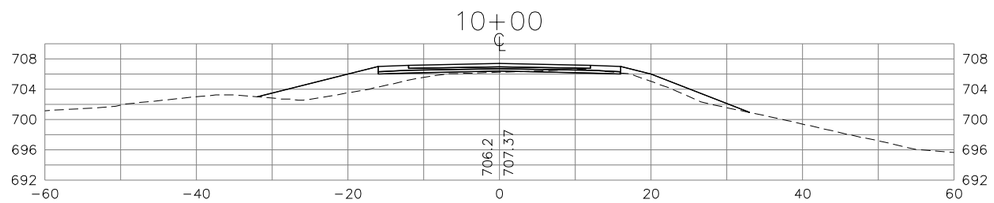
C7.09











STATION	AREAS Square Feet		VOLUMES Cubic Yards		CUMULATIVE VOLUMES Cubic Yards	
	CUT	FILL	CUT	FILL	CUT	FILL
0+50	42.0820	0.8683	37.5943	0.6102	37.5943	0.6102
0+75	39.1216	0.4497	30.2419	0.7746	67.8362	1.3848
1+00	26.2009	1.2235	28.0860	0.7803	95.9221	2.1651
1+25	34.4647	0.4619	29.8456	3.7440	125.7677	5.9091
1+50	30.0018	7.6252	29.2895	14.8589	155.0573	20.7680
1+75	33.2636	24.4699	21.5418	25.8934	176.5990	46.6614
2+00	13.2667	31.4598	10.9225	28.5830	187.5215	75.2444
2+25	10.3259	30.2794	6.3289	49.0461	193.8504	124.2905
2+50	3.3446	75.6601	1.5413	96.6747	195.3916	220.9651
2+74.88	0.0000	134.1273	0.0000	0.5486	195.3916	221.5138
2+75	0.0000	134.3408	0.0000	140.3467	195.3916	361.8605
3+00	0.0000	182.0449	0.0205	169.5112	195.4121	531.3717
3+25	0.0506	195.6911	0.0205	174.2158	195.4326	705.5876
3+50	0.0000	187.7178	0.0000	174.8988	195.4326	880.4864
3+75	0.0000	196.6454	0.0000	188.3479	195.4326	1068.8343
4+00	0.0000	218.1396	0.0000	204.9614	195.4326	1273.7957
4+25	0.0000	231.1661	0.0000	227.4599	195.4326	1501.2556
4+50	0.0000	267.9601	0.0000	259.5850	195.4326	1760.8406
4+75	0.0000	303.9790	0.0000	314.3775	195.4326	2075.2181
5+00	0.0000	380.4243	0.0000	374.6841	195.4326	2449.9021
5+25	0.0000	423.8327	0.0000	405.6931	195.4326	2855.5952
5+50	0.0000	443.9565	0.0000	258.0807	195.4326	3113.6759
5+65.48	0.0000	446.5537	0.0000	158.2959	195.4326	3271.9718
5+75	0.0000	451.6193	0.0000	419.9736	195.4326	3691.9454
6+00	0.0000	455.5236	0.0000	420.6388	195.4326	4112.5841
6+25	0.0000	453.0562	0.0000	415.2701	195.4326	4527.8543
6+50	0.0000	443.9272	0.0000	408.1627	195.4326	4936.0170
6+75	0.0000	437.7043	0.0000	401.1813	195.4326	5337.1983
7+00	0.0000	428.8472	0.0000	398.4985	195.4326	5735.6967
7+25	0.0000	431.9095	0.0000	394.1352	195.4326	6129.8319
7+50	0.0000	419.4225	0.0000	378.7312	195.4326	6508.5631
7+75	0.0000	398.6369	0.0000	343.7273	195.4326	6852.2904
8+00	0.0000	343.8141	0.0000	172.2832	195.4326	7024.5736
8+14.88	0.0000	281.2235	0.0000	98.4785	195.4326	7123.0520
8+25	0.0000	255.7534	0.0027	218.3903	195.4353	7341.4424
8+50	0.0055	225.7374	0.2385	192.1097	195.6738	7533.5521
8+75	0.4543	200.3027	0.2230	177.1331	195.8968	7710.6852
9+00	0.0000	193.3250	0.0000	174.0989	195.8968	7884.7841
9+25	0.0000	188.3007	0.0000	158.3676	195.8968	8043.1517
9+50	0.0000	157.0851	0.3463	125.8525	196.2431	8169.0042
9+75	0.7301	121.3824	2.1204	77.5635	198.3635	8246.5678
10+00	3.6451	52.4238	5.0160	31.5917	203.3794	8278.1595
10+25	6.7463	17.8926	12.3053	8.4413	215.6847	8286.6007
10+50	19.0431	1.2223	26.5559	0.6245	242.2407	8287.2252
10+75	37.4701	0.2284	37.9616	0.2665	280.2023	8287.4918
11+00	43.7852	0.3910	0.0000	0.0000	280.2023	8287.4918

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 UNDER THE LAWS OF THE STATE OF
PRINT NAME:
SIGNATURE: LIC. NO.
DATE:

SURVEY:
DRAWN
DESIGNED
APPROVED
DATE
PROJ. NO. 101-06-001

MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

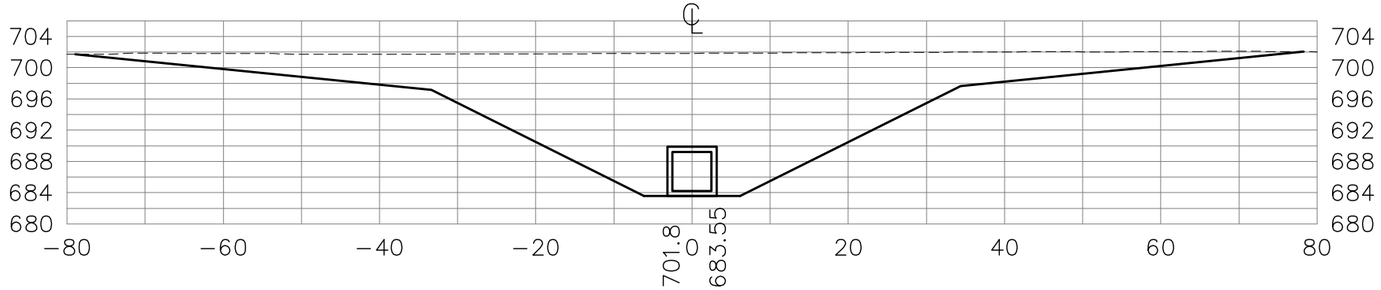
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

500 YEAR ROADWAY CROSS SECTIONS

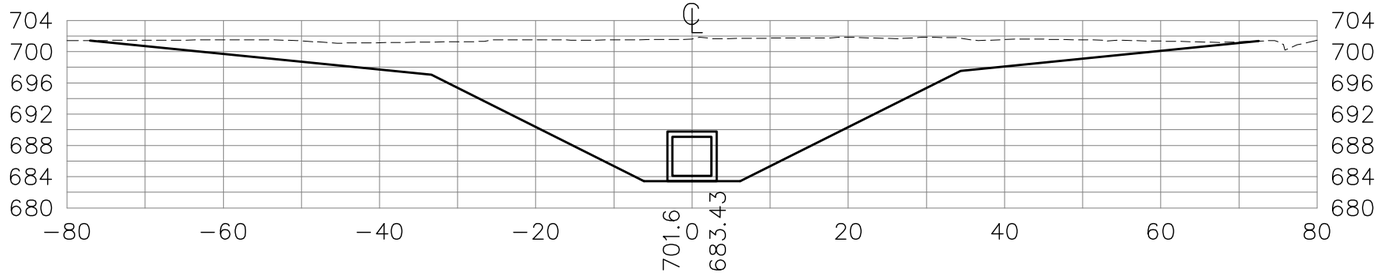
SHEET NUMBER

C7.10

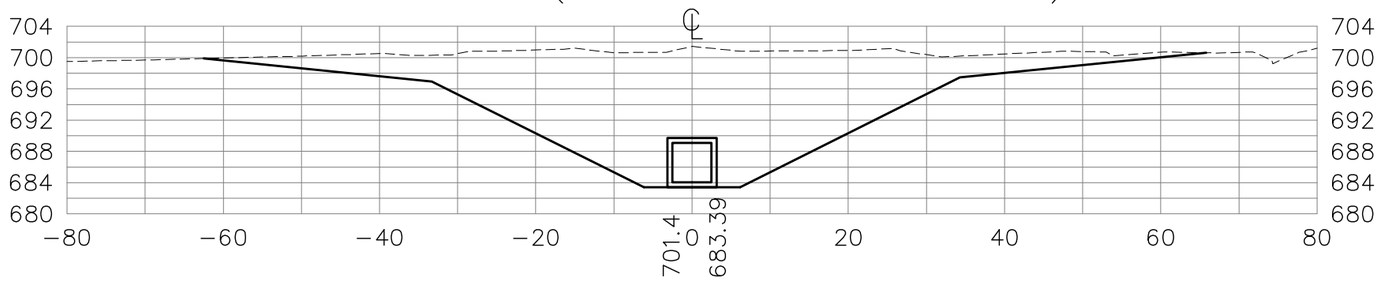
0+42.49 (ROADWAY CL)



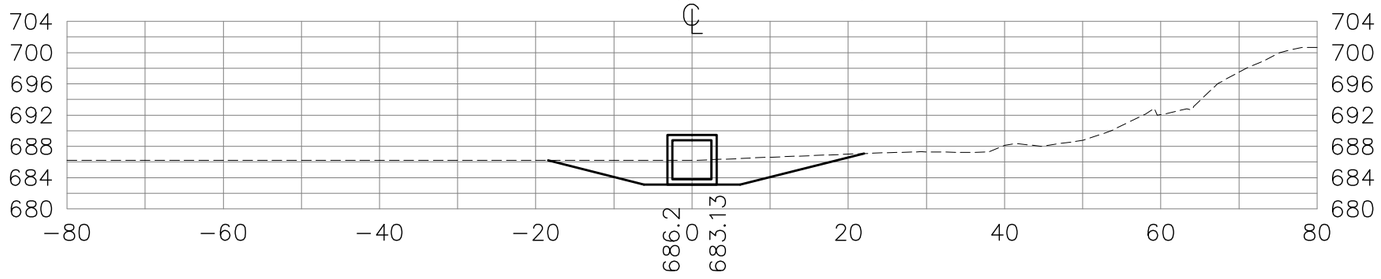
0+30.49 (EDGE OF PAVEMENT)



0+26.49 (EDGE OF SHOULDER)



0+00 (OUTLET)



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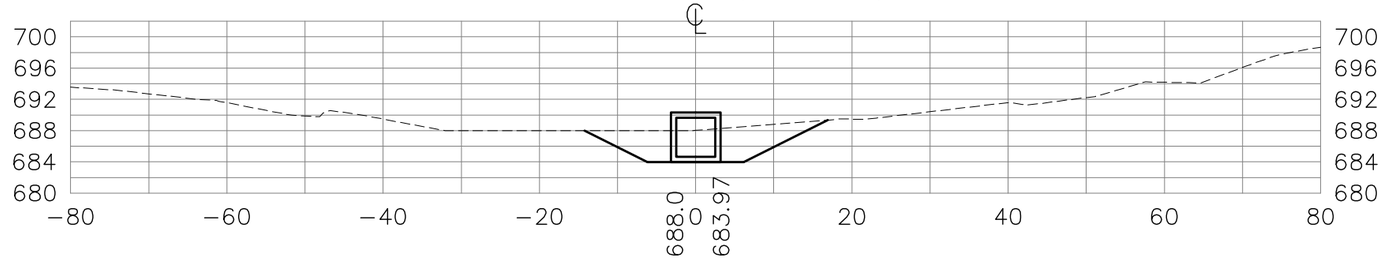
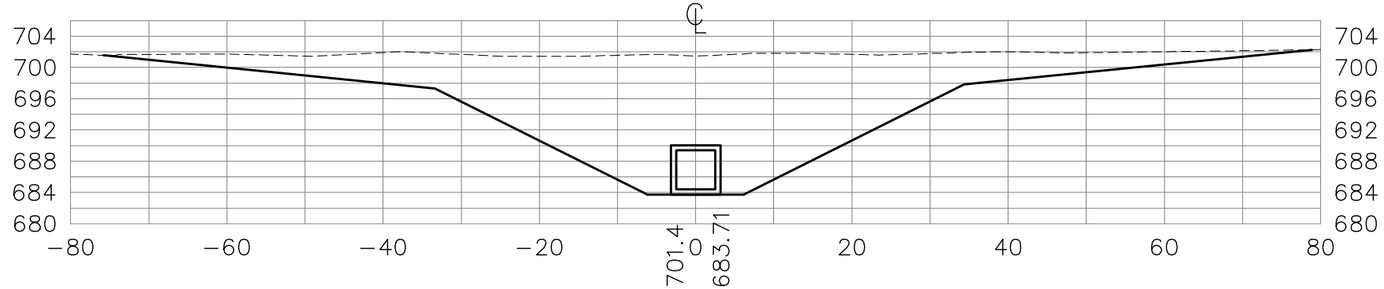
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
100 YR CULVERT CROSS SECTIONS

SHEET NUMBER
C8.01

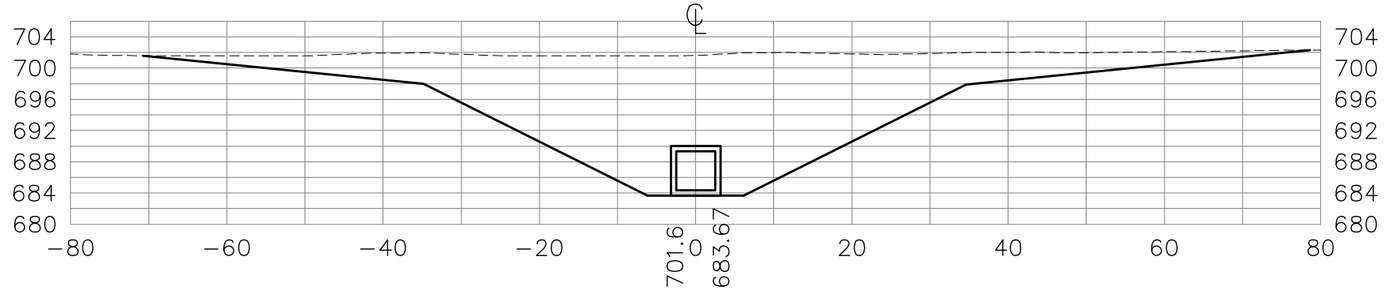
0+83.80 (INLET)



0+58.49 (EDGE OF SHOULDER)



0+54.49 (EDGE OF PAVEMENT)



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SURVEY

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APPROVED

DATE

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MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

GREY CLOUD ISLAND SLOUGH IMPROVEMENT

100 YR CULVERT CROSS SECTIONS

SHEET NUMBER

C8.02

STATION	AREAS Square Feet		VOLUMES Cubic Yards		CUMULATIVE VOLUMES Cubic Yards	
	CUT	FILL	CUT	FILL	CUT	FILL
0+00	91.23	0.00				
0+26.49	997.91	0.00	534.28	0.00	534.28	0.00
0+30.49	1010.28	0.00	148.75	0.00	683.04	0.00
0+42.49	1031.13	0.00	453.65	0.00	1136.68	0.00
0+54.49	1004.13	0.00	452.28	0.00	1588.96	0.00
0+58.49	921.99	0.00	142.68	0.00	1731.64	0.00
0+83.80	59.47	0.00	460.06	0.00	2191.70	0.00
			0.00	0.00	2191.70	0.00

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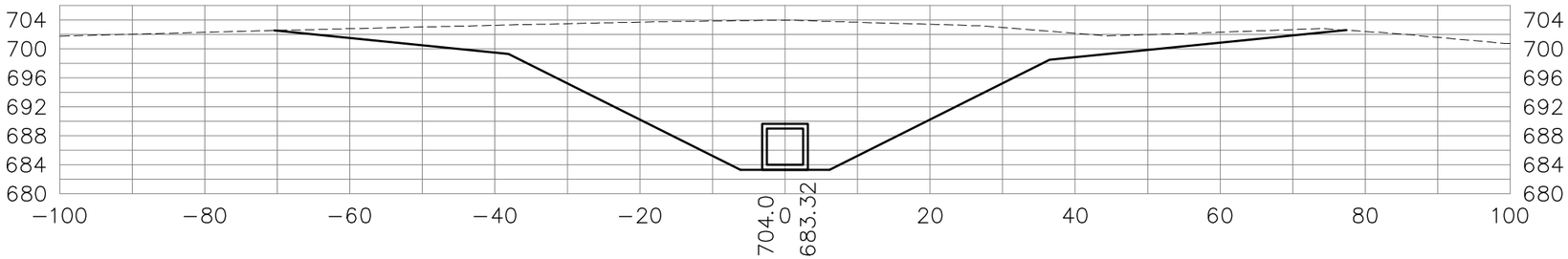
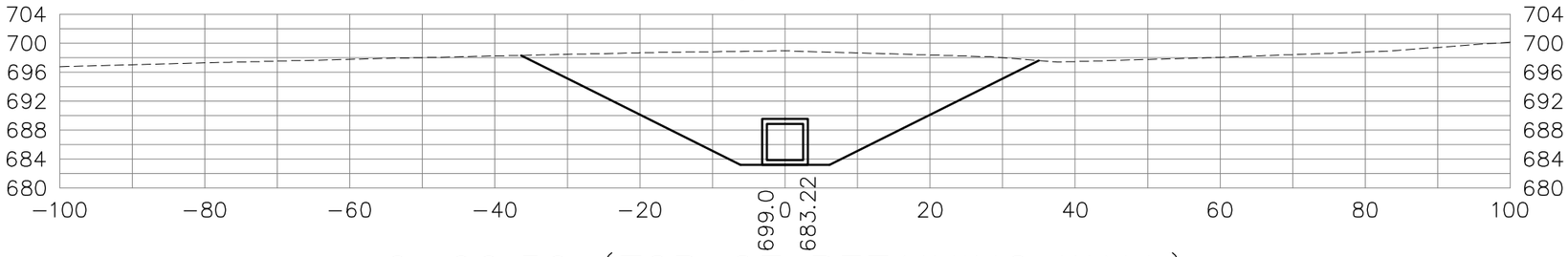
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
100 YR CULVERT CROSS SECTIONS

SHEET NUMBER
C8.03

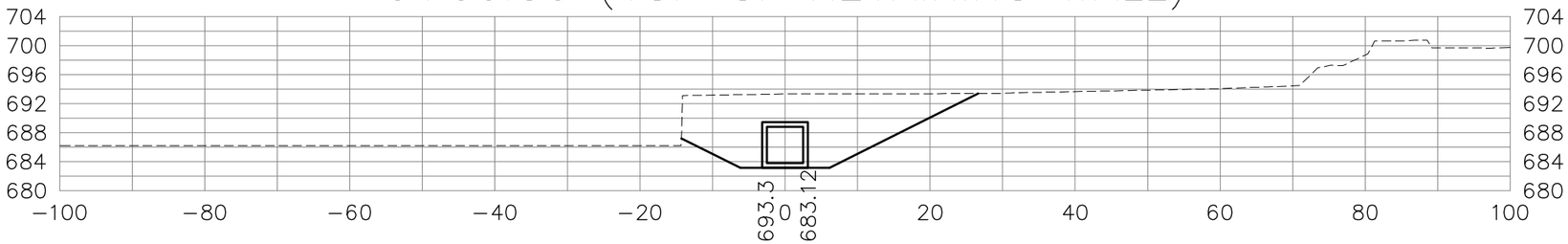
0+20



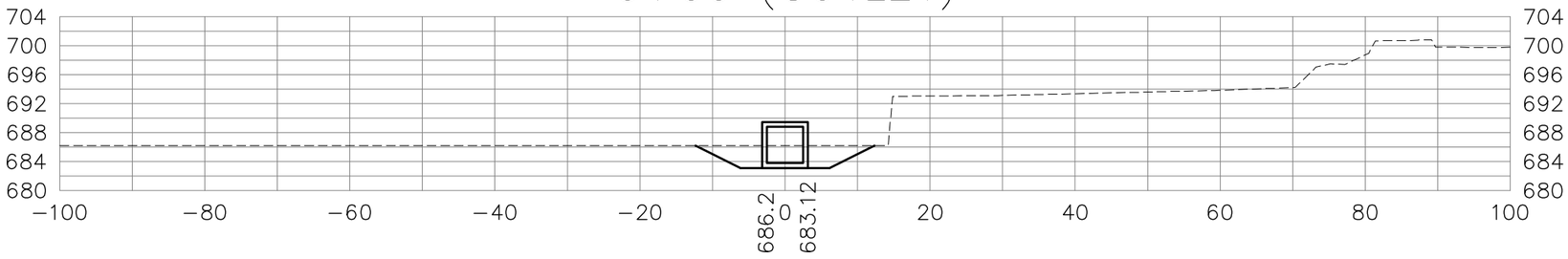
0+10



0+00.50 (TOP OF RETAINING WALL)



0+00 (OUTLET)



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BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

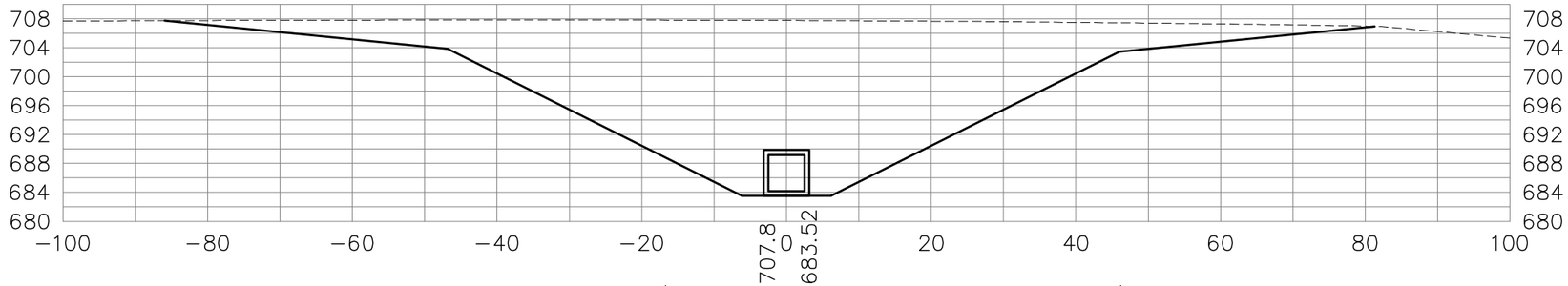
GREY CLOUD ISLAND SLOUGH IMPROVEMENTS

500 YR CULVERT CROSS SECTIONS

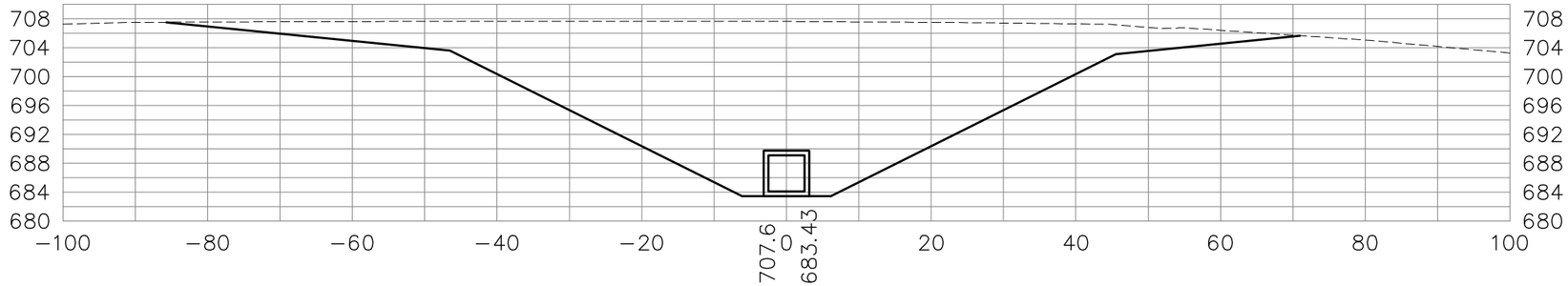
SHEET NUMBER

C8.04

0+40



0+30.99 (EDGE OF PAVEMENT)



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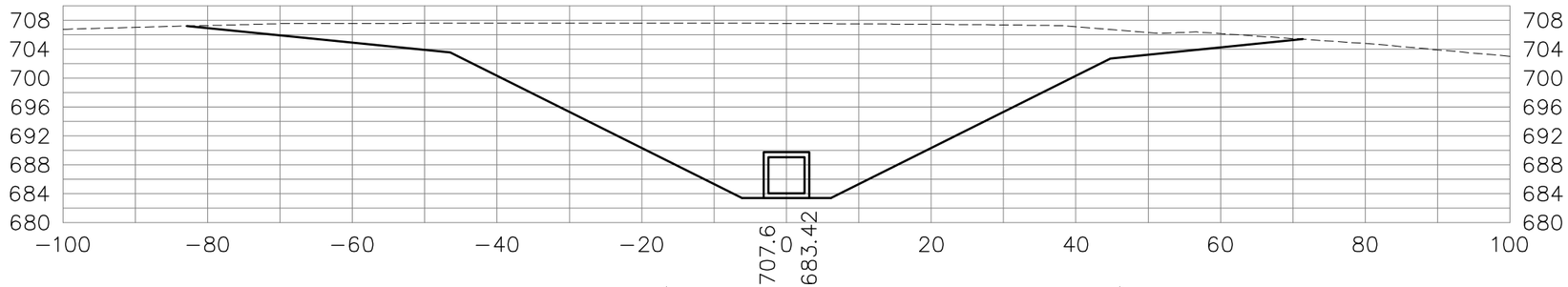
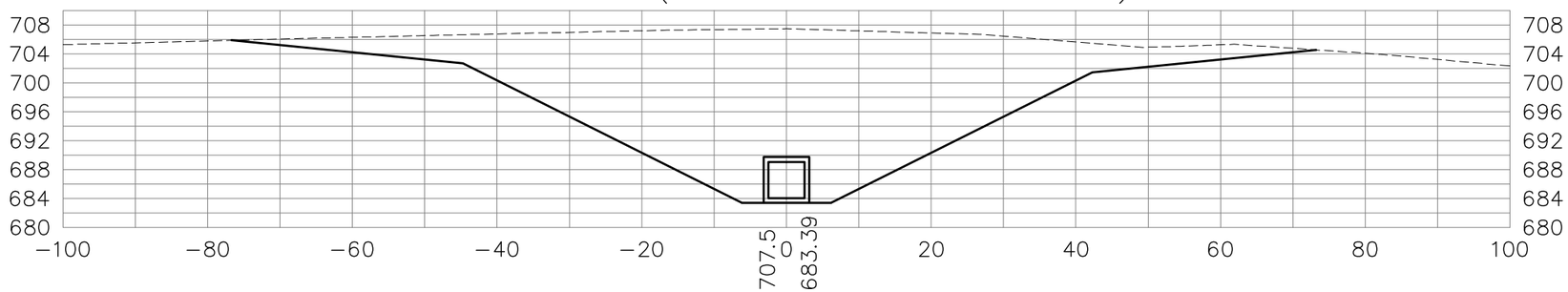


0+26.99 (EDGE OF SHOULDER)



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GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

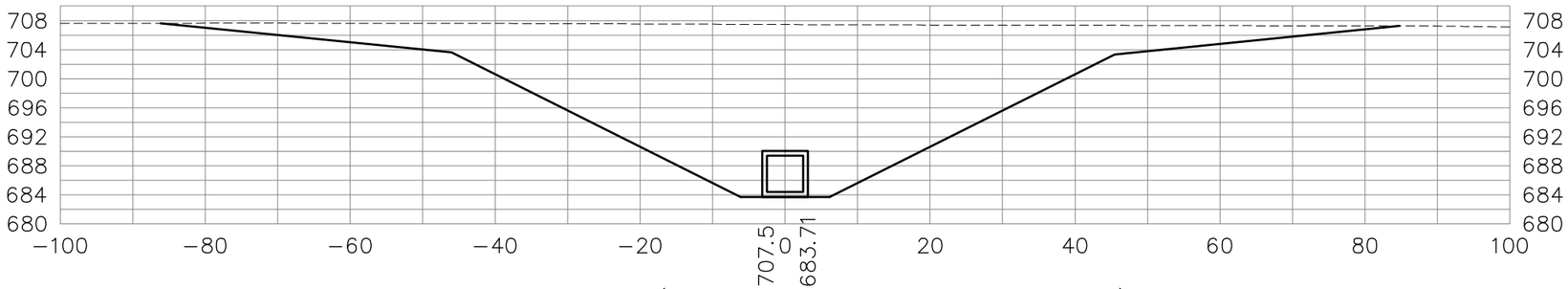
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

500 YR CULVERT CROSS SECTIONS

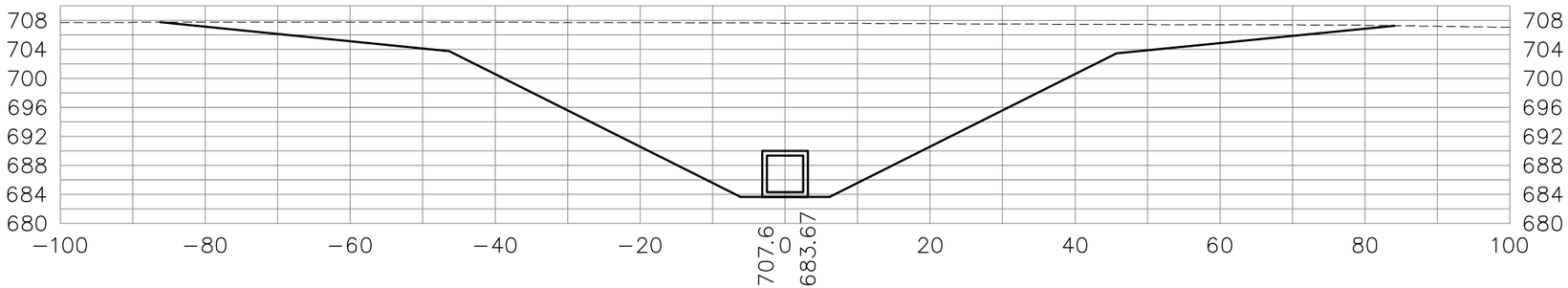
SHEET NUMBER

C8.05

0+58.99 (EDGE OF SHOULDER)



0+54.99 (EDGE OF PAVEMENT)



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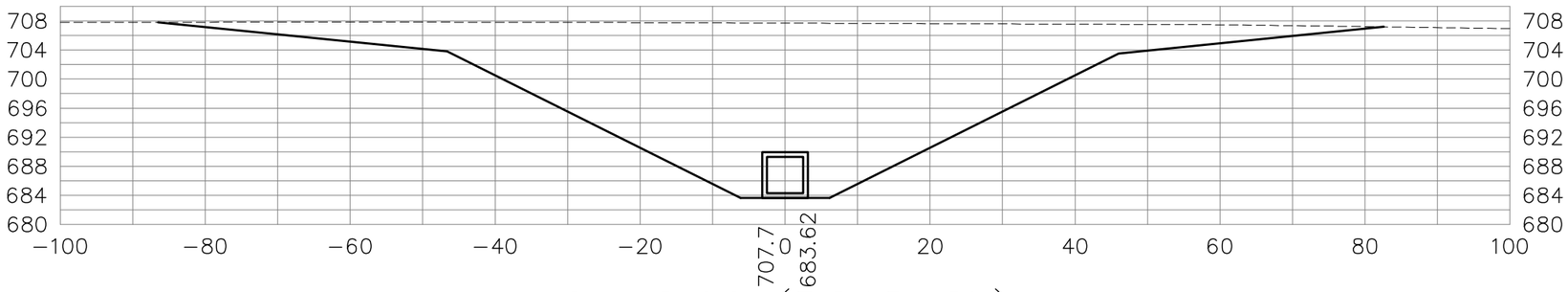
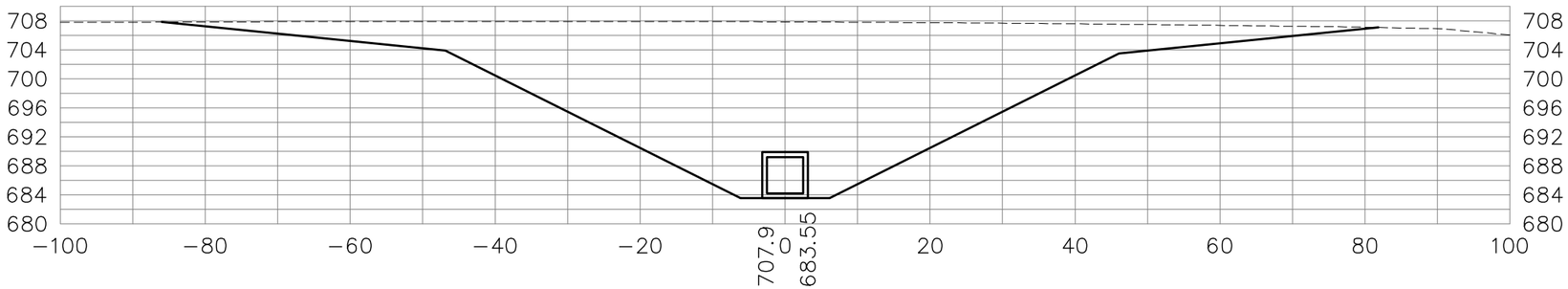


0+42.99 (ROAD CL)



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GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

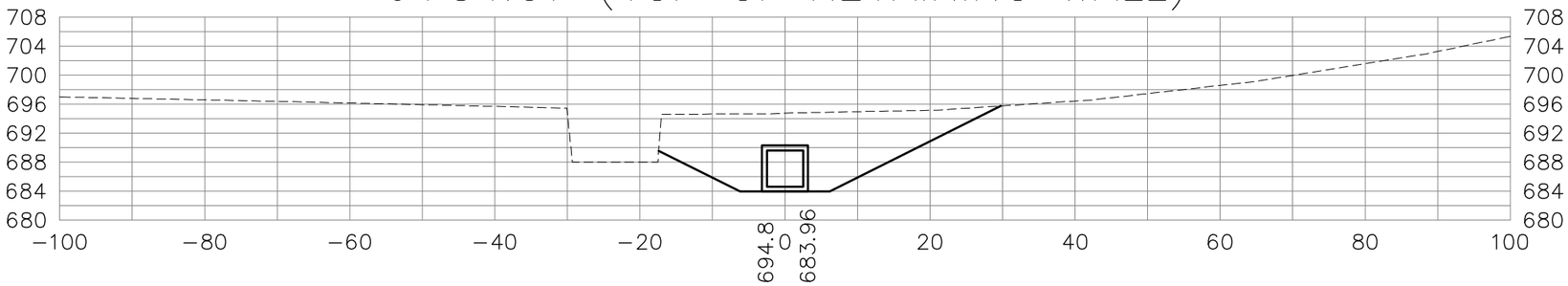
GREY CLOUD ISLAND SLOUGH IMPROVEMENT

500 YR CULVERT CROSS SECTIONS

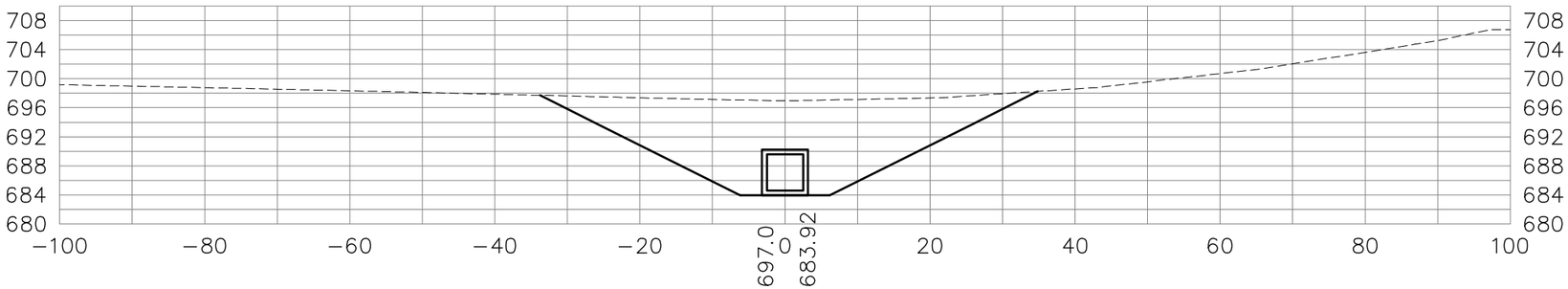
SHEET NUMBER

C8.06

0+84.37 (TOP OF RETAINING WALL)



0+80



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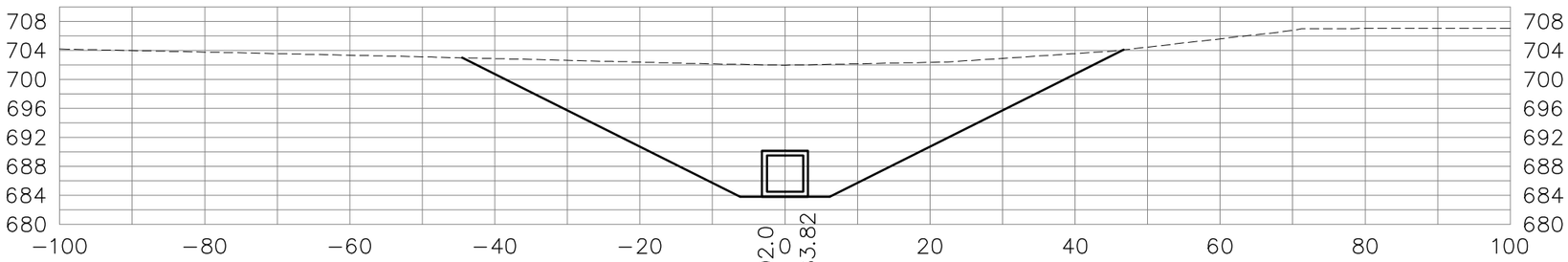

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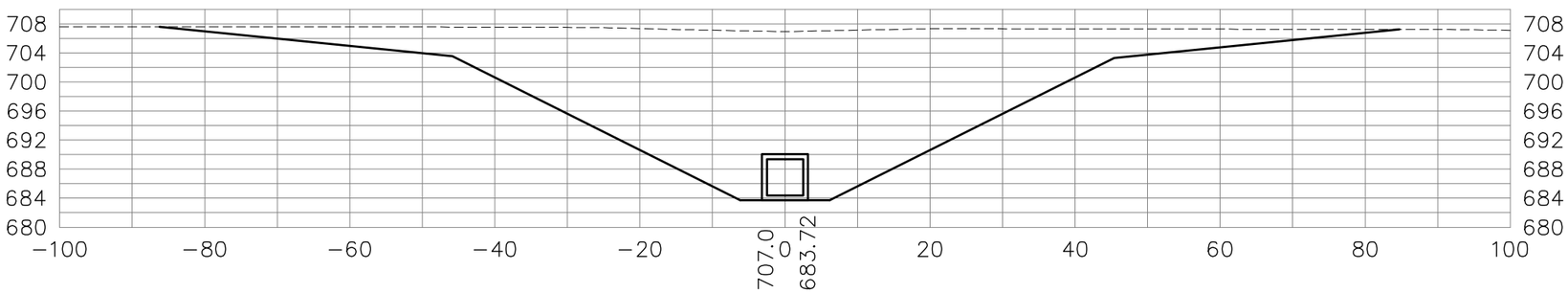

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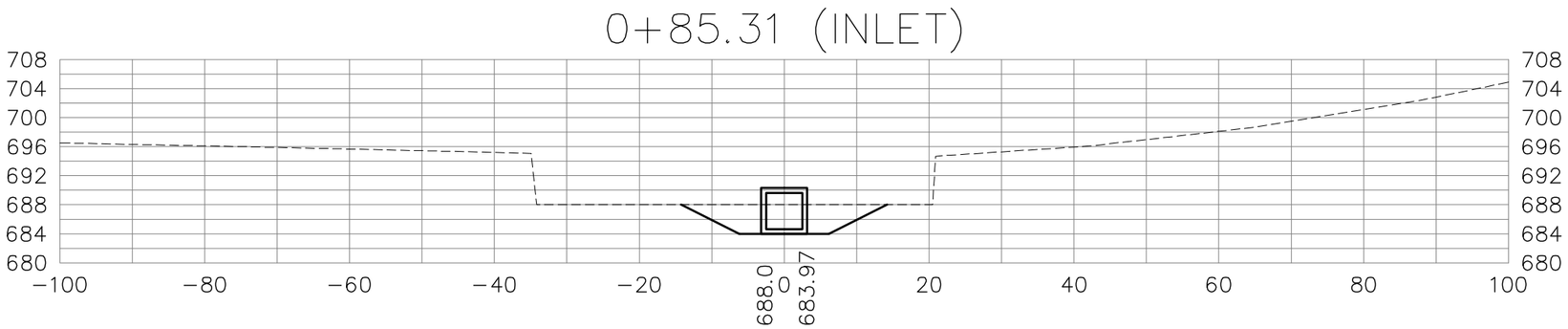
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
500 YR CULVERT CROSS SECTIONS

SHEET NUMBER
C8.07



STATION	AREAS Square Feet		VOLUMES Cubic Yards		CUMULATIVE VOLUMES Cubic Yards	
	CUT	FILL	CUT	FILL	CUT	FILL
0+00	57.04	0.00				
0+00.50	294.70	0.00	3.28	0.00	3.28	0.00
0+10	658.95	0.00	167.70	0.00	170.99	0.00
0+20	1158.81	0.00	336.62	0.00	507.61	0.00
0+27	1475.11	0.00	341.29	0.00	848.90	0.00
0+30	1548.90	0.00	168.17	0.00	1017.07	0.00
0+31	1557.05	0.00	57.35	0.00	1074.41	0.00
0+40	1589.62	0.00	524.62	0.00	1599.03	0.00
0+43	1593.25	0.00	176.65	0.00	1775.68	0.00
0+50	1580.99	0.00	411.65	0.00	2187.33	0.00
0+55	1567.74	0.00	291.37	0.00	2478.71	0.00
0+59	1549.97	0.00	230.94	0.00	2709.65	0.00
0+60	1534.18	0.00	57.29	0.00	2766.93	0.00
0+70	932.81	0.00	456.85	0.00	3223.78	0.00
0+80	526.58	0.00	270.26	0.00	3494.04	0.00
0+84.37	346.13	0.00	70.67	0.00	3564.71	0.00
0+85.31	82.19	0.00	7.47	0.00	3572.18	0.00
			0.00	0.00	3572.18	0.00

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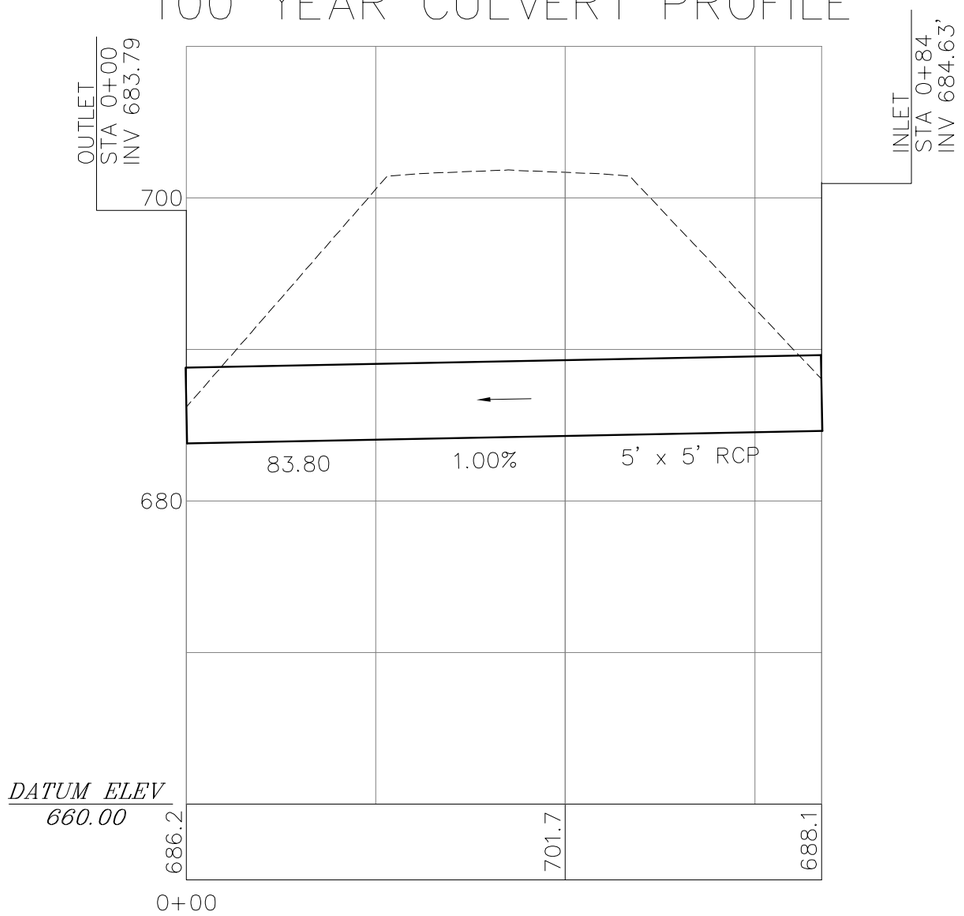
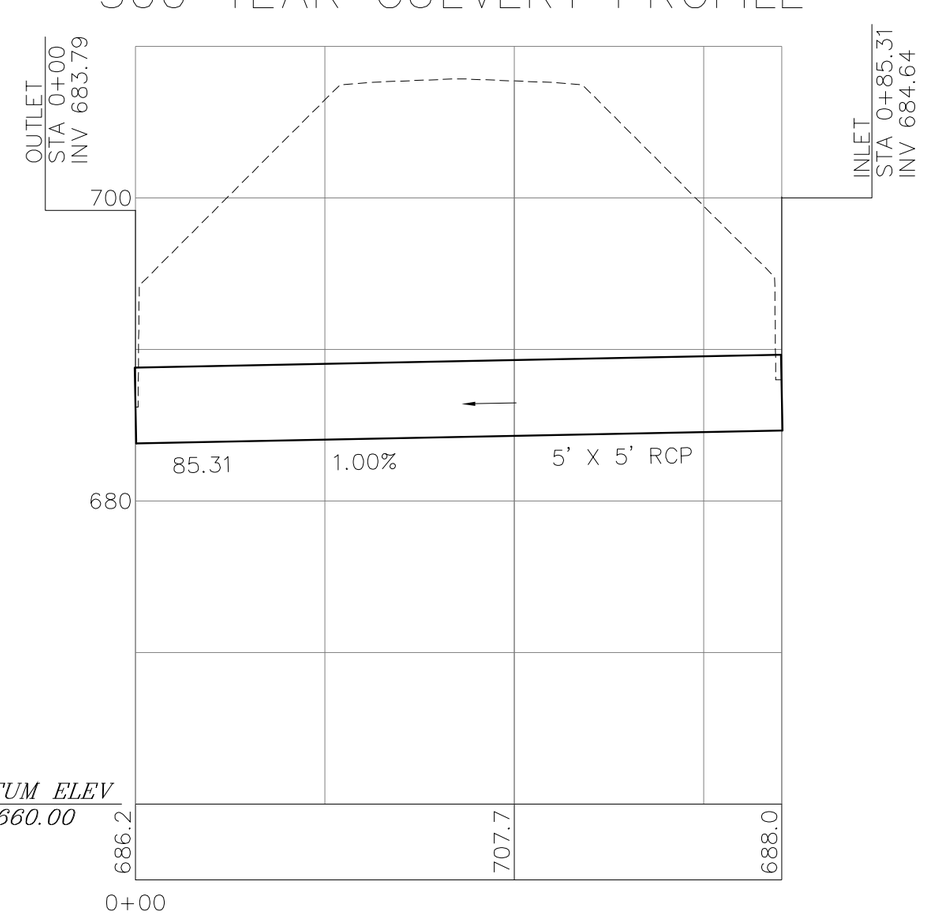
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENT
500 YR CULVERT CROSS SECTIONS

SHEET NUMBER
C8.08

100 YEAR CULVERT PROFILE



500 YEAR CULVERT PROFILE



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BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA

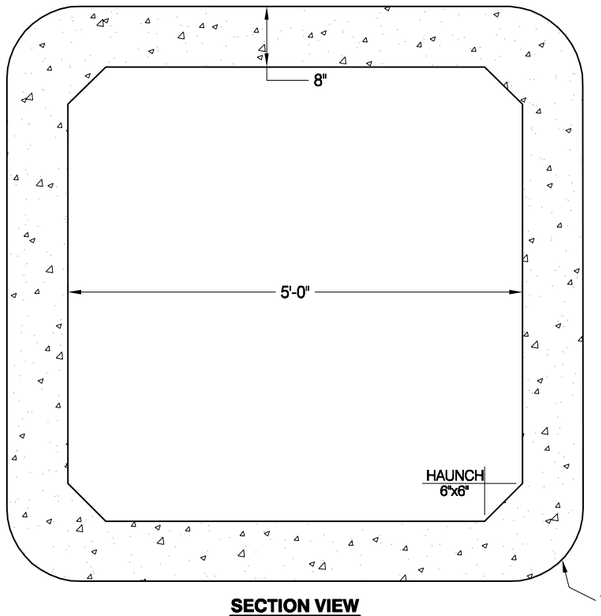
GREY CLOUD ISLAND SLOUGH IMPROVEMENTS

CULVERT PROFILES

SHEET NUMBER

C9.01

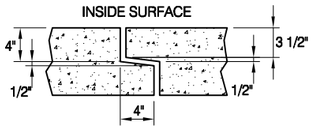
5' x 5' SINGLE CELL BOX CULVERT DESIGN DETAILS



SECTION VIEW

WEIGHT / FT. = 2,300 LBS.

LOADING, DESIGN METHODS AND
MATERIALS COMPLY WITH ASTM C1433
Standard laying length = 6'-0"
WWF ASTM A185, fy = 65 KSI
Concrete Strength, f'c = 5 KSI
Box culvert design and analysis is performed on
the BOX CAR computer program.

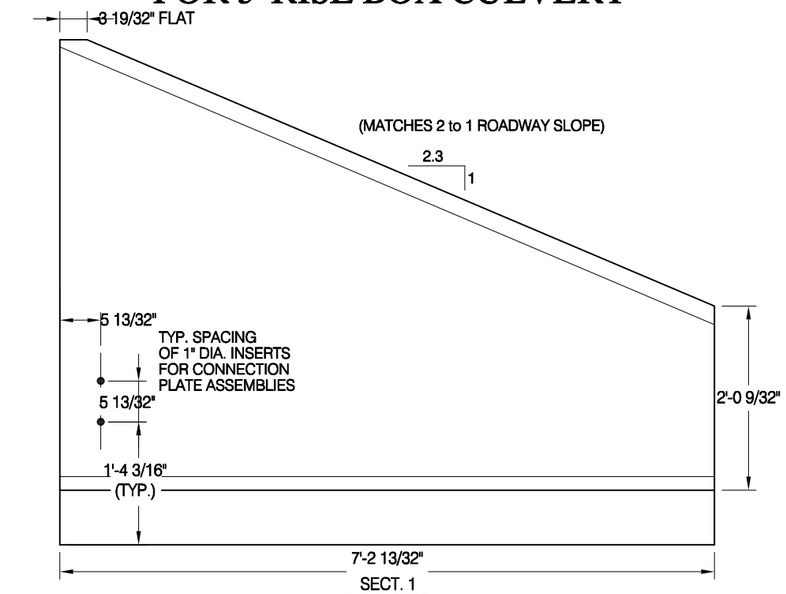


TYPICAL JOINT DETAIL

5' x 5' SINGLE CELL BOX CULVERT
DESIGN DETAILS

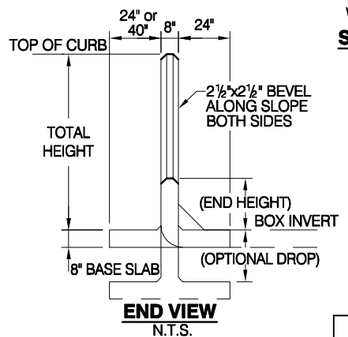
SCALE | DATE | DWG. NO. 0604SCWCSE

30° FLARED END SECTION FOR 5' RISE BOX CULVERT

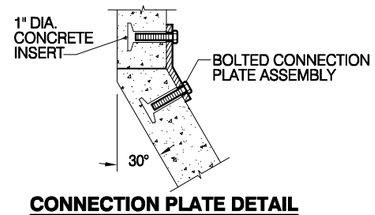


SECT. 1
WT. = 6,900

SIDE VIEW



END VIEW
N.T.S.



CONNECTION PLATE DETAIL

IOWA CONCRETE PRODUCTS CO.
WEST DES MOINES, IOWA

30° FLARED END SECTION
FOR 5' RISE BOX CULVERT

DATE AUGUST 1, 2002 | DWG. NO. ICPC04FEDE

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 UNDER THE LAWS OF THE STATE OF
PRINT NAME:
SIGNATURE: LIC. NO.
DATE:

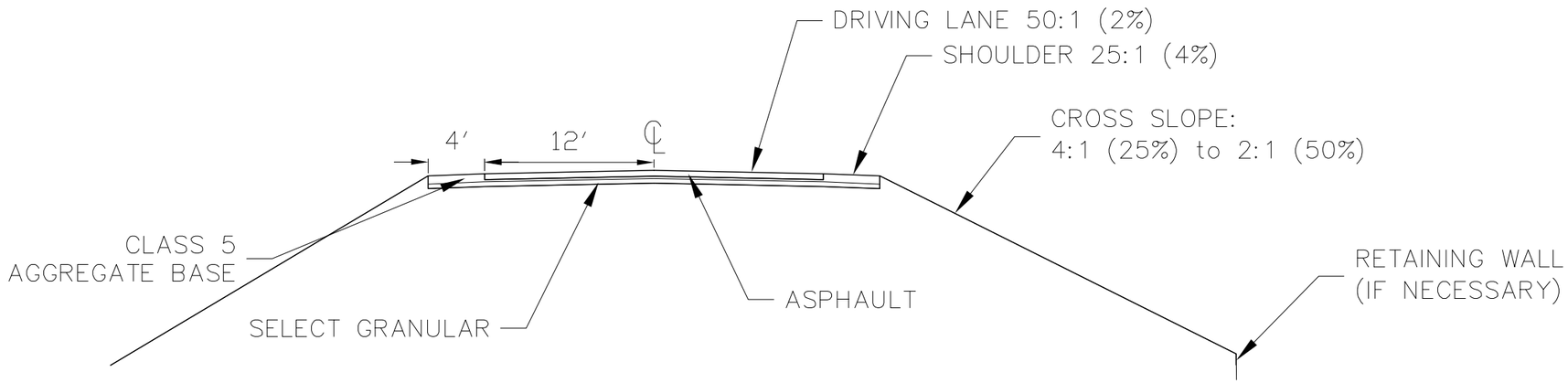
SURVEY:
DRAWN
DESIGNED
APPROVED
DATE:
PROJ. NO. 101-06-001

MATT BEYER
TIM DAVIS
MATT HOESE
BEN KRAUSE
DEREK NEWBAUER

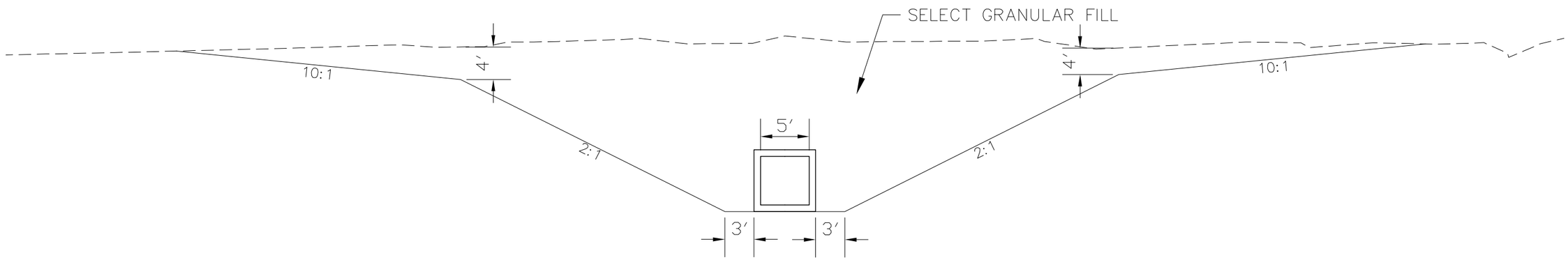
GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENTS
DETAILS

SHEET NUMBER
C10.01

TYPICAL ROADWAY SECTION



TYPICAL CULVERT CUT UNDER ROADWAY



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 UNDER THE LAWS OF THE STATE OF
PRINT NAME:
SIGNATURE: LIC. NO.
DATE

SURVEY
DRAWN
DESIGNED
APPROVED
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MATT BEYER
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BEN KRAUSE
DEREK NEWBAUER

GREY CLOUD ISLAND TOWNSHIP, MINNESOTA
GREY CLOUD ISLAND SLOUGH IMPROVEMENTS
DETAILS

SHEET NUMBER
C10.02

Pavement Design Computations

ESALS

$$ESAL = (ADT)_o (T)(T_F)(G)(D)(L)(365)(Y)$$

where:

ESAL = equivalent 18-kip single-axel-load
ADT_o= Average daily traffic = 1700 vehicles
T= percentage of trucks in the ADT = .15
T_F = the number of 18-kip single-axel load applications per truck=0.21
G = growth factor= 1.7
D = the direction distribution factor = 0.5
L= the lane distribution factor = 1
Y = design period in years = 20 years

ESAL= (1700)*(0.15)*(0.21)*(1.7)*(0.5)*(1.0)*(365)*(20)= 332,277

Granular Equivalent factor

G.E. requirement = 15.12 inches
Bituminous pavement = 2.25 = 2.25 * 5inches = 11.25 inches
Class 5 Aggregate base = 1.0 G.E. Factor = 1.0 * 3 inches = 3 inches
Select granular = 0.5 G.E. Factor = 0.5* 4inch = 2 inches
Total Granular Equivalent Factor = 11.25 in + 3 in + 2 in = 16.25 inches > 15.12 inches

Appendix C: Permitting

WASHINGTON COUNTY TRANSPORTATION & PHYSICAL DEVELOPMENT

11660 Myeron Road North ◆ Stillwater, Minnesota 55082
Phone: (651) 430-4300 ◆ Fax: (651) 430-4350

OFFICE USE ONLY

Permit No._____
County Road_____
Municipality_____
Permit Fee $_____

APPLICATION FOR RIGHT OF WAY PERMIT

Company Project No._____

Application is hereby made for permission to place, construct, and thereafter maintain a _____ along or across County Highway No._____ from _____ to _____ _____Feet from centerline on the (north, south, east, or west) side of the County Highway in accordance with the attached sketch.

I. Aerial Utility Construction	Type	Voltage
Minimum height of conductor:	ft. along highway	ft. at crossing over highway

II. Underground Utility Construction Type	Conduit Type	Casing Type
Size	Max. operating pressure	Depth / Voltage

Method of Installing Under Roadbeds ***(if open trench, explain why and complete Section IV. Excavation. If work will obstruct a traveled lane of a County Road or a County State Aid Highway, complete Section III. Obstruction of Roadway)***

☐Boring ☐Jacking ☐Open trench_____

III. Obstruction of Roadway	Type of Work	Start Date and Time	End Date and Time
IV. Excavation	Type of Work	In Roadway? ☐Yes ☐No	Start Date and End Date

V. Work to start on or after _____ and be completed on or before_____

VI. The applicant shall perform all work according to the terms of this permit, the Washington County Right of Way Ordinance and all other regulations of Washington County, and any Special Provisions which are attached to the permit. The applicant shall comply with all applicable laws and ordinances, codes, and regulations. The work performed shall be in no way detrimental to the highway or to the safety of the public. All traffic control shall comply with the provisions of the Minnesota Manual on Uniform Traffic Control Devices, including the Temporary Traffic Control Zone Layouts Field Manual. Applicant shall supply accurate electronic "as-built" drawing files in either .DWG or .DXF format. Files will be accepted in other formats and converted, at the applicant's expense, to a compatible format. If files cannot be converted by the County, the applicant must convert them to a compatible format. Conversion costs will be billed by the County at applicable billable labor rates plus material costs.

Name of Company making application: _____ Registration #:_____

Contact person: _____

Phone: _____ Date:_____

Address:_____
(include city and zip code)

Signature:_____ Title:_____

DO NOT WRITE BELOW THIS AREA

UTILITY PERMIT AUTHORIZATION

Performance Requirement

In accordance with this application, a Right of Way Permit is granted to the applicant to place, construct, and maintain said utility on or across the right of way of said County highway in the location shown on the sketch which is a part of this application, or in a location or manner specified by the County Engineer in the attached Special Provisions. A copy of this Permit must be available at the work site at all times.

Performance Bond, Cashier's Check, or Certified Check No._____ Amount_____

No interest shall be earned or paid on this deposit.

SPECIAL PROVISIONS_____

Approved_____
Washington County Transportation & Physical Development Date

Copies: ☐Applicant ☐County Engineer ☐Municipality

Revised 11/7/00

R\word\forms\right of way permit

Preparing Your Application for Mailing. To apply for both state and Federal authorization, your application must include Part I (Pages 1-4), the Federal application (Page 5) and attachments as indicated on final Checklist for Part I (Instructions, Page 4). Make three copies of the entire application and all attachments. Keep the original, and mail the three copies to the appropriate local, state, and Federal agencies (see below).

Mailing your application. Mail a complete copy of your application to each of the local state, and Federal entities listed below. Include Part I, and all attachments. If you are using the Public Road Maintenance Short Form Notice include required attachments.

LOCAL: Send to the appropriate Local Government Unit (LGU). Contact your county Soil and Water Conservation District (SWCD) office or the Board of Water and Soil Resources (BWSR) web site (www.bwsr.state.mn.us) for this information. SWCD offices are also listed on the BWSR web site.

For local road projects that qualify for wetland replacement under the BWSR Public Road Replacement Program, also send a complete copy of the application, including TEP member signatures on page 6, and attachments to the BWSR Wetland Banking Administrator at 520 Lafayette Road North, St. Paul, MN 55155, phone 651-215-1703.

STATE: Send to your area DNR Waters office, attention Area Hydrologist. Contact your county Soil and Water Conservation District (SWCD) office or the DNR web site (www.dnr.state.mn.us) for this information. Area offices can also be determined by contacting the applicable Regional DNR office:

NW Region: **2115 Birchmont Beach Road N.E.**
Bemidji, MN 56601
Phone: 218-755-3973

NE Region: **1201 East Highway 2**
Grand Rapids, MN 55744
Phone: 218-327-4416

Central Region: **1200 Warner Road**
St. Paul, MN 55106
Phone: 651-772-7910

Southern Region: **261 Highway 15 South**
New Ulm, MN 56073
Phone: 507 359-6053

FEDERAL: Send to the appropriate U.S. Army Corps of Engineers regulatory field office:

Brainerd: **U.S. Army Corps of Engineers, Regulatory Branch, 10867 E. Gull Lake Drive N.W., Brainerd, MN 56401-9051, Phone: 218-829-8402**

St. Paul: **U.S. Army Corps of Engineers, Regulatory Branch, Army Corps of Engineers Centre, 190 5th Street East, St. Paul, MN 55101-9051, Phone: 651-290-5375**

La Crescent: **U.S. Army Corps of Engineers, Regulatory Branch, 1114 South Oak Street, La Crescent, MN 55947-1338, Phone: 507-895-8059**

Two Harbors: **U.S. Army Corps of Engineers, Regulatory Branch, 1554 Highway 2, Suite 2, Two Harbors, MN 55616, Phone: 218-834-6630**

Minnesota Local/State/Federal Application Forms for Water/Wetland Projects

PUBLIC TRANSPORTATION AND LINEAR UTILITY PROJECTS

PART I - STANDARD APPLICATION

For Internal Use Only			
Application No. INV:	Field Office Code	Date Initial Application Received	Date Initial Application Deemed Complete

"**See HELP**" for important additional information and assistance in Instructions, Pages 3 – 5

IS THIS AN ORIGINAL OR AMENDED NOTICE? (check one)

This is *an original* notice ☐, dated This is an *amended* notice ☐, dated

1. APPLICANT CONTACT INFORMATION:

Name of applicant:

Contact person (name and title):

Complete mailing address:

Business phone: (___) _____ Fax: (___) _____ e-mail: _____

2. PROJECT IDENTIFICATION (See HELP 2): Also attach *PROJECT LOCATION MAP.*

3. LAND USE: Describe existing land use in project area. **(See HELP 3)** (pick one from the list)

4. PROJECT CATEGORY (check **all** that apply):

- ☐ Repair rehabilitation, reconstruction or replacement of existing roads that impact wetlands (including wetland areas of DNR Public Waters). If so, indicate size of impact (check one).
- ☐ Less than 10,000 square feet of wetlands (**see HELP 4**).
- ☐ Greater than 10,000 square feet of wetlands.
- ☐ New road or modification of an existing road solely to increase traffic capacity impacting any amount of wetland area River, lake or stream impact (excluding wetland areas of DNR Public Waters).
- ☐ Placement, maintenance or repair of linear utility projects.

5. PROPOSED TIMELINE: Approximate project start date: _____ Projected end date:_____.

6. PROJECT DESCRIPTION: Check **all** that apply. **Also include a detailed overhead view of your plan** that clearly depicts the work to be undertaken. See What To Include on Plans (Instructions, Page 4)

- ☐ Guardrail improvement
- ☐ Guardrail improvement with slope flattening
- ☐ Resurfacing
- ☐ Culvert work; repair, extension or replacement
- ☐ Stream diversion
- ☐ Shoulder work: repair widening
- ☐ Shoulder widening with ditch grading
- ☐ Other
- ☐ Slope flattening
- ☐ Turn lane: improvement of existing or new construction
- ☐ Bridge work: repair
- ☐ Bridge work: replacement
- ☐ Reconstruction (existing roads)
- ☐ Additional lanes solely for traffic capacity
- ☐ New road construction
- ☐ Linear utility Projects

7. ESTIMATED PROJECT COST: FUNDING SOURCES (%): Federal State Local

8. SEQUENCING CONSIDERATIONS: What alternatives to this proposed project have you considered that could have avoided or minimized impacts to wetlands or water? **For new construction only - list at least two alternatives** (one of which may be "no build" or "do nothing"), and explain why you chose to pursue the option described in this application over these alternatives. (If space below is not adequate, attach separate sheet labeled *SEQUENCING CONSIDERATIONS.)*

WASHINGTON COUNTY SHERIFF'S DEPARTMENT
15015 62nd Street North - Stillwater, Minnesota 55082
(651) 430-7877

WASHINGTON COUNTY
TRANSPORTATION & PHYSICAL DEVELOPMENT DEPARTMENT
11660 Myeron Road North - Stillwater, Minnesota 55082
(651) 430-4300

OFFICE USE ONLY
Permit No._____
County Road_____
Municipality_____
Permit Fee $_____

APPLICATION FOR EVENT PERMIT ON COUNTY HIGHWAY RIGHT OF WAY

I. Application is hereby made for permission to place/hold a(an) _____
on County Highway No. _____ from _____ to _____.

Description of Event:_____

Description of Route: (Attach map, if applicable)_____

II. Event to start on or after _____, 19____, _____ a.m./p.m. and to be completed on or before _____, 19____, _____ a.m./p.m.

III. Method of Traffic Control (Signs, Flaggers, etc.). If a detour or lane closure is planned, include a drawing of the detour route or lane closure plan.

IV. The applicant shall conform with the terms of this permit, the regulations of Washington County, and any Special Provisions which are attached to the permit. The applicant shall comply with all applicable laws and ordinances, codes and regulations. All detours and/or lane closures shall conform to the provisions of the Minnesota Manual on Uniform Traffic Control Devices, including all appendices. The event shall be in no way detrimental to the highway or to the safety of the public.

V. The applicant shall provide insurance which will indemnify Washington County and its employees in amounts of at least $200,000.00 per injury and $600,000.00 per occurrence.

Insurance Company_____ Policy No._____ Liability Limits_____

Dated this _____ day of _____ 19____. _____
Name of organization making application

Signature_____ ***Title***_____

Address_____ Phone_____

Do not write below this line

EVENT PERMIT AUTHORIZATION

Performance Requirement

In accordance with this application, an Event Permit is granted to the applicant to hold said event on the right of way of said County highway(s) in the location shown on the sketch which is a part of this application, or in a location or manner specified by the County Engineer in the attached Special Provisions.

Performance Bond, Cashier's Check, or Certified Check No._____ **Amount**_____
No interest shall be earned or paid on this deposit.

SPECIAL PROVISIONS_____

Copies ? Applicant
? County Engineer
? Sheriff Dept.
? Municipality

Approved_____
Washington County Sheriff's Department Date

Approved_____
Washington County Transportation & Physical Development Department Date

Appendix D: Construction

Appendix – Cost Estimate Breakdown

	100-yr flood	**500-yr flood**
Tree/Brush Removal[1]	$15,000	$15,000
Temporary Utility Re-routing[2]	$10,000	$10,000
Cofferdam Installation and Removal[3]	$265,000	$265,000
Removing existing pavement & subgrade[4]	$16,000	$105,000
Box Culvert Installation	$21,000[5]	$66,500[6]
Cut/Fill/Compaction[7]	$24,600	$35,800
New Pavement and Subgrade[8]	$64,000	$420,000
Retaining Wall[9]	$0	$70,000
Erosion Control[10]	$1,800	$2,400
Guard Rails[11]	$6,170	$6,170
Dewatering[12]	$8,000	$8,000
SUBTOTAL	**$431,570**	**$1,003,870**
added costs[13]	30%	40%
	$129,471	*$401,548*
Engineering Costs (estimated 15%)	*$64,736*	*$150,581*
TOTAL COST ESTIMATE	***$630,000***	***$1,560,000***

[1]estimate based on 2005 RS Means value of $7,950/acre including equipment & labor costs, approx. 2 acres needed to be removed
[2]based on costs from similar situations
[3]estimate based on 2005 RS Means calculation of $19.80/S.F of single-layer shore-driven steel sheet pile, plus contingency costs for rising steel prices
[4]based on estimated removal costs of $100/L.F. of pavement and subgrade (160' for 100-yr flood profile, 1050' for 500-yr profile)
[5]cost estimate based on average 2005 RS Means values for 6'x3' ($199 per ft incl. materials, equipment, and labor) and 6'x7' ($293 per ft incl. materials, equipment, and labor) pre-cast box culverts; cost also based on soil stabilization under culvert deemed unnecessary for 100-yr profile
[6]in addition to footnote 5, an estimated cost for steel sheet pile stabilization due to unknown soil behavior was added
[7]number based on "industry average costs" for moving/removing/compacting soil
[8]based on an estimated cost of $400/L.F. of pavement and subgrade construction
[9]retaining wall in 500-yr profile cost based on 2005 RS Means value of $200/yd^3 with 525' of retaining wall 6' high and 1' thick
[10]estimate based on 2005 RS Means value of $1.20/yd^2 (incl. materials, equipment, and labor) of Jute Mesh soil erosion control plus an estimated cost of $300 for culvert rip-rap at outlet
[11]estimate based on 2005 RS Means cost of $19.10/ft of guard rail and $110 per end section (incl. materials, equipment, and labor) with 300' and four end section required
[12]costs based on an estimated value of $200 per day to dewater for 40 continuous days
[13]added costs could be the following but not limited to: unknown soil conditions, permitting costs, project delays of any kind including weather-related, rising costs of materials, etc.; value is higher for 500-year due to probably soil compaction issues