HMG
Houston-Moore Group

FLOOD DIVERSION AUTHORITY

TECHNICAL MEMORANDUM

OXBOW, HICKSON, BAKKE RING LEVEE

March 12, 2013

TABLE OF CONTENTS

Figures

Appendices

1 OBJECTIVE

Operation of the Fargo Moorhead Diversion results in the staging of flood water upstream of the Cities of Fargo and Moorhead, including the City of Oxbow, the Village of Hickson, and Bakke Subdivision. The feasibility study and subsequent cost estimate related to a value engineering proposal include costs to purchase all structure in the staging area resulting in a total buyout of the Oxbow, Hickson, and Bakke (OHB) area.

The United States Army Corps of Engineers (USACE), at the request of the local sponsors, has determined that constructing a ring levee around the OHB area is a viable alternative to a total buyout. This technical memorandum outlines a feasibility level design and cost estimate for constructing a ring levee for the OHB area which is intended to maintain the community at its current size.

2 DESIGN

The OHB ring levee project outlined in this technical memorandum includes a ring levee designed to provide flood damage reduction for the OHB area, transportation improvements intended to maintain access to the community, and infrastructure to replace public and private infrastructure destroyed by the construction of the ring levee.

2.1 LEVEE DESIGN

2.1.1 EMBANKMENT DESIGN GUIDELINES

The embankment design follows guidelines similar to what was used in the Post-Feasibility Southern Alignment Analysis (PFSAA) report, including typical cross sections, freeboard, and geotechnical factors of safety. The embankment design includes 5H:1V slopes and a 10’ top width. An inspection trench is also included as well as adequate clear space, topsoil, and seeding.

Two geotechnical analyses are included in the embankment design. The first analysis included in Appendix A, used soil boring information from the original Red River Control Structure location which is approximately one mile north of Oxbow and concluded that the embankment, as designed, meets necessary geotechnical criteria. The second analysis, using soil boring data from within Oxbow and provided by the City of Oxbow, confirms the results of the first analysis.

The top of the embankment for this analysis has been set at 926’, which is approximately 4 feet above both the 1% and 0.2% water surface elevations associated with the operation fo the project . The project HEC-RAS models have

been updated to include the OHB ring levee. The resulting peak water surface profiles are included in Appendix B. The addition of the OHB ring levee raises the water surface elevation at Oxbow by approximately 0.1' for the 1% event with no change in the 0.2% water surface elevation.

2.1.2 EMBANKMENT LOCATIONS

The OHB levee used for preliminary design and cost estimating surrounds the Village of Hickson, the Bakke Subdivision, and a portion of the City of Oxbow. Oxbow is located along the banks of the Red River and generally consists of residential lots surrounding the Oxbow Country Club. A number of residential lots as well as the Country Club are impacted by the levee alignment. The alignment generally follows parallel to the Red River through residential areas in both the north and south portions of Oxbow and crosses directly through the Oxbow Country Club. The alignment runs parallel to the north edge of Bakke Subdivision and southward along the westerly edge of Bakke Subdivision and Hickson. From the southeast edge of Oxbow and the southwest edge of Hickson, the levee encompasses a previously agricultural area surrounding residential lots and golf holes. Refer to Figure 1 for the Proposed Oxbow, Bakke, and Hickson Levee Option Map.

After input and feedback from the area residents, local sponsors, and the USACE, three additional conceptual embankment levee options were developed in addition to Option 1. Option 2 is similar to Option 1 except that, rather than surrounding Bakke Subdivision, it surrounds only Oxbow and Hickson. A conceptual map is shown in Figure 2 for the Proposed Oxbow and Hickson Levee Option Map.

Option 3 would surround only the City of Oxbow and the replacement area for impacts within Oxbow. The embankment would follow the corridor between Cass County Highway 25 and Sunset Drive of Oxbow until it reaches the southern edge of Hickson. The embankment will then continue straight west and make a slightly larger loop than the first two options for the proposed Oxbow replacement area. The replacement area for this option is of similar size to the other options. A conceptual map is shown in Figure 3 for the Proposed Oxbow Levee Option Map.

Option 4 is an alternative option to option 1. This embankment footprint would protect the same properties as option 1, which is the Village of Hickson, The Bakke Subdivision, and part of the City of Oxbow. The biggest change to this embankment footprint is that the proposed Oxbow replacement area would be shifted west and the levee would run parallel to US highway 81 and 18. Refer to Figure 4 for the Proposed Oxbow, Bakke, and Hickson Levee Alternative Option Map.

In all instances where levees are adjacent to existing residential lots, the embankment is located a sufficient distance from the edge of residential lots to allow for clear space needed for levee maintenance, drainage features, and a vegetative buffer. The embankment is also located a satisfactory distance from the Red River to ensure geotechnical

stability. Options 2, 3, and 4 are preliminary and conceptual with their designs. For the purpose of this technical memorandum all sections in this memorandum refer to option 1 unless stated otherwise.

2.2 TRANSPORTATION IMPROVEMENTS

2.2.1 CASS HIGHWAY 81

Cass Highway 81 is raised over the levee in two different locations where the highway intersects the proposed OHB ring levee. Both north and south crossings need to be gradually raised so the reconstructed road will be above the minimum elevation of the levee in order to maintain a safe line of sight for travel and meet the minimum height requirement for the proposed levee. This will include all road work, subgrade, earthwork, and any other items asscociated with the road located above the proposed levee elevation. The preliminary design includes a 1% roadway slope on both sides of the levee for both intersections. In addition to the road raises over the proposed levee, Cass Highway 81 will be raised from the southern extent of the levee project to Cass Highway 18 to allow access even during times of flooding. The road surface will be raised to an approximate elevation of 923 feet. This elevation will extend through the intersection of Cass Highway 81 and Cass County Highway 18 to allow residents to access their homes in a time of flood. South of Cass Highway 18, the road will gradually slope until it ties into the existing Cass Highway 81 road south of the previous mentioned intersection. The project HEC-RAS models have been updated to include all road raises that are necessary to the OHB levee.

2.2.2 CASS HIGHWAY 18

Cass County Highway 18 between Cass Highway 81 and Interstate 29 will be raised to a minimum shoulder elevation of 922.5 feet. East of Cass Highway 81the road will be graded to meet the existing road elevation. Raising the road to this elevation allows the residents of the Oxbow, Hickson, and Bakke communities to access their homes and business during events up to a 0.2% (500-year) event.

2.2.3 CASS HIGHWAY 25

Cass Highway 25 will be raised to be above the minimum levee elevation of 926 feet where it intersects the proposed OHB ring levee in the southern end of the proposed project. The change in road grade will begin at the intersection of Cass Highway 25 and 18 intersections until it reaches its minimum elevation height as it crosses the proposed ring levee, and then gradually be graded back until it ties into the existing roadway elevations.

2.3 INFRASTRUCTURE REPLACEMENT

The construction of the ring levee results in the removal of approximately 40 homes as well as disruptions to the Oxbow Country Club including several golf holes and the club house. The ring levee plan includes replacement of lost infrastructure, including residential lots and associated infrastructure and reconfiguration of the Oxbow Country Club. All replacement infrastructure described in this memorandum is conceptual and will be subject to modifications through consultation with the City of Oxbow and the Oxbow Country Club during final design. The plan included in this memorandum is intended to produce an overall footprint and cost estimate for the purpose of determining impacts of the proposed action. The following sections include a more detailed description of infrastructure replaced as part of the ring levee plan.

2.3.1 URBAN INFRASTRUCTURE

The proposed OHB ring levee creates a need to alter some of the infrastructure within the protected communities. Most of the alterations occur in the community of Oxbow, where a significant portion of the existing infrastructure is located under the embankment or outside of the protected area and will need to be removed and replaced. The proposed Oxbow addition, as conceptualized for this memorandum, will extend the existing Sunset Drive south and shift the alignment along Cass Highway 25, where it will cross the ring levee above the minimum elevation of 926' to meet levee height requirements and tie into Cass Highway 25. The proposed road includes one intersection that services two cul-de-sacs, where the proposed residential lots will be located for the Oxbow addition. In addition to residential lots, the Oxbow Country Club will be relocated along Sunset Drive that allows for easy access to the clubhouse from either Highway 81 or County Road 18. All proposed roadways will be paved in the Oxbow addition. Modifications will also be necessary to the community's infrastructure to accommodate the proposed layout. As noted above, this proposed layout is a concept and may be altered in the future based on input from the local communities, the country club, the golf course architect, and other local authorities. The existing sanitary sewer system serving the Oxbow Drive and Oxbow Circle area generally flows west to east to a lift station located outside of the proposed ring levee area. This lift station will be abandoned and removed. A new lift station located near Oxbow Drive within the protected area of the levee will be installed to maintain sewer service to that portion of the City. The proposed Oxbow addition requires a new sanitary collection system which ties into an existing regional sanitary system located near the intersection of Sunset Drive and Riverbend Road. The system will be gravity fed into the existing system. The sanitary sewer collection system in Oxbow and Bakke is tied into a regional system which conveys sewage to the City of Fargo for treatment. The portion of this system that will be under the proposed levee will be replaced with high density polyethylene (HDPE) pipe. This pipe will include a shut off valve will be located on each side of the levee per the Corps guidance.

The existing water main for the City of Oxbow has a connecting loop that would be located on the non protected side of the levee through the Country Club. To maintain the loop, a pipe running parallel to the levee along the golf course which ties the waterline at Riverbend Road and Oxbow Drive together is included. The waterline will be located a safe distance away from the levee footprint so it does not disturb the integrity of the. The proposed Oxbow addition ties into the existing water main located near the intersection of Sunset Drive and Riverbend Road. Service hookups are also being provided for each proposed lot in the new addition. Like the sewer main, the portion of the water transmission lines serving the area that are located under the levee will be replaced with HDPE pipe. Shut off valves will also be located on each side of the levee to accommodate the Corps guidance.

The existing storm system generally slopes from west to east and ultimately outfalls into the Red River. The proposed modified system would reduce the number of pipes which cross the levee. To achieve this, two separate pipe network systems are being proposed. One intercepts the existing storm pipe network and the other will be for the proposed Oxbow addition. Both of the systems discharge into a proposed stormwater detention pond within the levee. Please refer to section 2.4, Internal Drainage for a more detailed description of the pipe network systems.

The proposed ring levee does not create any conflicts with the sanitary, water, or transportation infrastructure for the Hickson or Bakke communities. A more detailed description on the alterations needed for drainage within the respected communities is included in section 2.4, Internal Drainage.

2.3.2 OXBOW COUNTRY CLUB

The proposed OHB ring levee will create a need to re-configure the golf course as well as relocate the clubhouse and other facilities provided by the Oxbow Country Club. As the golf course exists, holes one thru six will be located outside of the OHB protected area and holes 9,13,18, and the practice area will have the proposed levee footprint encroaching each hole and will need to be altered. Generally, the existing golf course today sheet flows from west to east into the Red River of the North. To accommodate this, there will be a proposed storm system along the ring levee that will have inlets placed in areas of lower elevation along the golf course to collect the storm water and convey it to a proposed retention basin. A more detailed description of drainage is included in section 2.4, Internal Drainage. The golf holes in the proposed Oxbow addition will also have inlets placed in low points to gather and convey the water as part of the proposed pipe network system that ultimately outfalls into the proposed detention basin for the ring levee. All sanitary sewer, storm sewer, water lines, and parking lots needed to service the proposed Oxbow Country Club, the golf course, and the other amenities offered by the country club will be tied into the new urban infrastructure along the proposed sunset drive alignment.

2.4 INTERNAL DRAINAGE

The internal drainage for the OHB ring levee includes a combination of open channels, storm sewer, a stormwater detention pond, and a storm sewer pump station. The storm sewer system is designed to local standards. The storm sewer and open channel system will collect storm water and convey it to the onsite detention pond, where there will be a storm water pump station is included. The combination of the available storage and pumping capacity of the lift station are adequate to prevent internal flooding during a river flood event when the gravity outfall is inoperable. The proposed detention basin is located east of the Bakke addition and northwest of the U.S. Highway 81. There will be a redundant power source running to the pump station to serve as a backup to the main power supply.

The existing conditions in the Oxbow development include a storm sewer network within the development and overland drainage on the golf course. These systems both ultimately outfall into the Red River of the North and will need to be altered to accommodate the proposed ring levee. The proposed storm sewer system begins in the southern end of the Oxbow development and collects the storm water from the golf course and neighborhood streets with various types of catch basin inlets. The system continues east along the southern edge of the existing Oxbow property until it turns north and runs parallel with the proposed ring levee. This storm system will be located an adequate distance from the levee to ensure that the integrity of the levee is not compromised. The storm system ties into the existing storm system along Oxbow drive, continues northwest along the golf course, and crosses highway 81 discharging into the proposed detention basin.

The drainage in the proposed Oxbow addition will be part of a separate storm sewer system that also outfalls into the proposed detention basin. This pipe network will be made up of a system that collects the runoff from the golf course, neighborhoods, and streets. The water will be captured using various types of catch basin inlets along the roads and golf course and use a pipe system that travels along a corridor paralleling Sunset Drive in Oxbow, crossing highway 81 near the Cass Highway 25 intersection and outfalling into the proposed retention basin.

Storm water currently runs off of the Bakke addition and the Hickson areas through open ditches. Both areas will use the existing channels to accommodate runoff to the proposed detention basin. The proposed levee near Bakke includes a parallel ditch designed to collect storm water from the existing drainage systems in and around Hickson and Bakke subdivision and convey it into the proposed detention basin.

As a part of the storm water detention system, there will be a storm pump station located on the north end of the proposed pond, which, during times of flooding, will pump water out of the detention basin and into the Red River of the North. This storm pump station includes a sluice gate that will allow the gravity system to be positively closed during periods of flooding preventing back flow of floodwaters to the Red River.

3 COST ESTIMATE

3.1 LAND ACQUISITION

The land acquisition costs include the purchase of all residential structures in Oxbow and Bakke that are either under or outside the proposed levee. The cost for acquisition of residential properties is based on a multiple of the assessed values plus relocation, removal, and administrative costs. The value multiplier and additional costs are based on similar recent regional buyouts.

The construction of the OHB levee and the associated infrastructure replacement may require purchase of approximately 260 acres of agricultural land. The cost for acquisition of agricultural property is based on recent land purchases in the area. A contingency of 25% is included for all land acquisition costs. The costs for land acquisition are included in the cost estimate located in Appendix C.

3.2 CONSTRUCTION COST

Construction costs for the Oxbow, Hickson, Bakke ring levee are determined using multiple sources. Where applicable, unit costs developed during the FR/FEIS and subsequent PFSAAS VE13 are used as a basis of costs for the Levee Earthwork and Drainage items. The PFSAA VE13 unit pricing for this work has been modified for this cost estimate to account for likely contracting methods. Because of the size of the construction contract(s), the construction cost estimate assumes a single contractor markup rather than the double markup that was used for the FR/FEIS. Markups by both prime and subcontractors of 22% and 20% respectively were assumed in the PFSAA VE13A cost estimate. Using the assumption that the work will be completed by the prime, the prices are reduced by approximately 17% from the FR/FEIS and VE13 prices.

The FR/FEIS and VE13A cost estimates do not include unit costs for the infrastructure necessary to replace the residential lots and golf course. A compilation of project bid tabs and cost estimates from local projects similar in size and scope is used to determine the construction cost for the remaining line items of the cost estimate. The region is experiencing significant growth resulting in consistent, ongoing development that is of similar scope to the replacement infrastructure in Oxbow. The ongoing regional development results in a large pool of recently bid and constructed projects from which unit costs have been determined. All construction costs include a 25% contingency and a midpoint of contstruction escalation factor derived from the FR/FEIS earlier conducted by the Corps. A detailed cost estimate is included in Appendix C.

3.3 COST SUMMARY

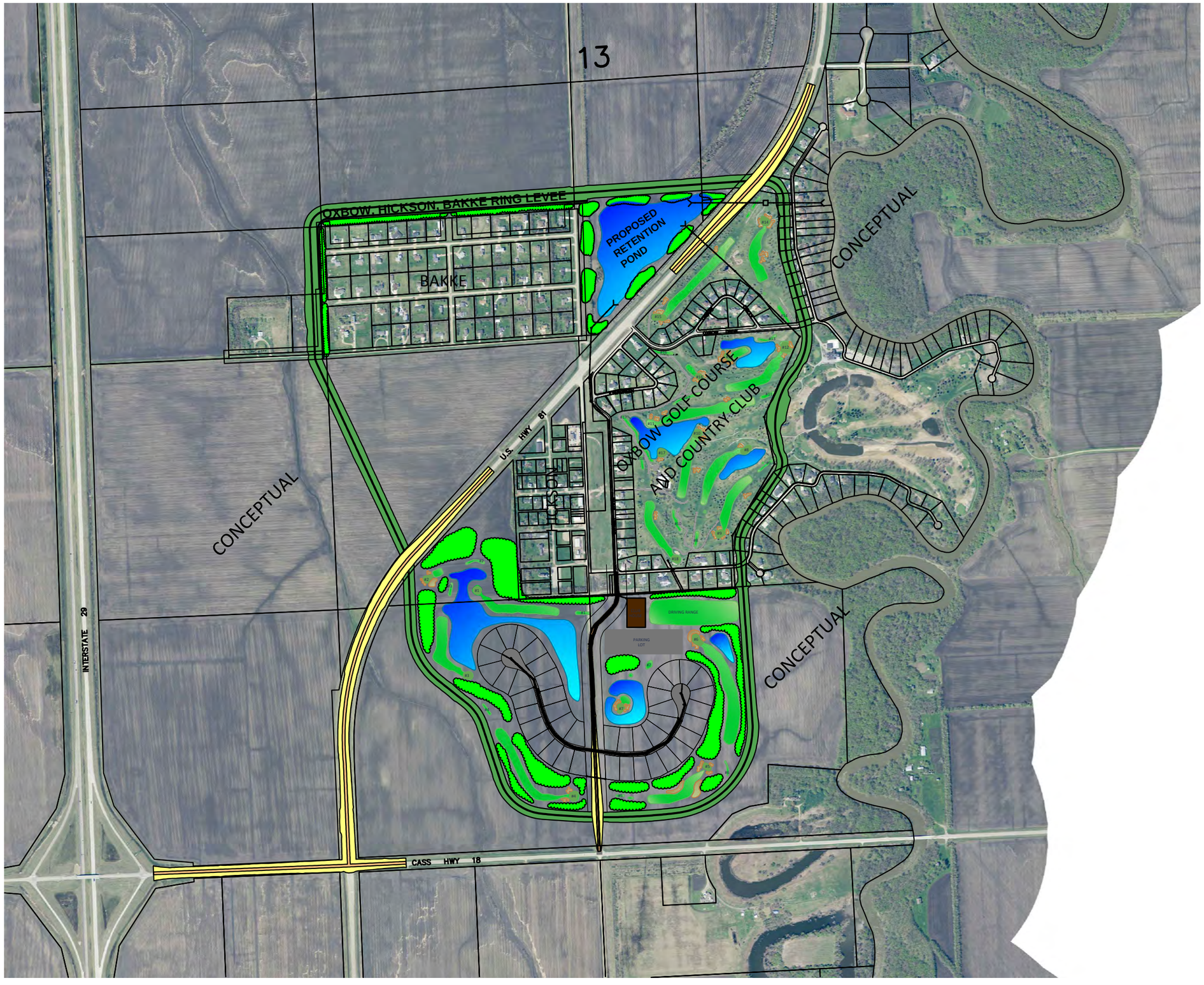
Below is table 3.1, which provides a cost estimate summary for the Oxbow, Hickson, Bakke Ring Levee.

Table 3.1 Cost Estimate Summary – Oxbow, Hickson, Bakke Ring Levee

Cost Category	Base Cost	Contingency Costs (25%)	Combined Costs
Levee Earthwork and Drainage	$7.51M	$1.88M	$9.39M
Sanitary Sewer Items	$0.56M	$0.14M	$0.70M
Water main Items	$0.44M	$0.11M	$0.55M
Storm Sewer Items	$2.13M	$0.53M	$2.66M
Detention Pond Items	$6.10M	$1.53M	$7.63M
Transportation – Highway 81 and 18 Items	$1.70M	$0.43M	$2.13M
Transportation – Oxbow Addition Items	$1.11M	$0.28M	$1.39M
General Items	$0.11M	$0.03M	$0.14M
Street Lighting Items	$0.11M	$0.03M	$0.14M
Golfcourse Items	$6.70M	$1.68M	$8.38M
Land Acquisitions Items	$18.98M	$4.74M	$23.72M
Planning and Engineering Design	$4.96M	-	$4.96M
Construction Management	$2.32M		$2.32M
Total Estimated Project Cost	-	-	$64.10M

Although this is the total estimate for the project cost, not all of it may be eligible for Federal Cost Share. For a more detailed breakdown of estimated costs, please refer to Appendix C, Cost Estimate.

FIGURES



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Scale in Feet

PRELIMINARY

100-YR WSE = ± 922
TOP OF LEVEE = ± 926
LEVEE LENGTH = 3.9 MILES

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Oxbow, Hickson, Bakke Project Map

Flood Risk Management Evaluation
Land Management Evaluation
Proposed Oxbow, Bakke, and Hickson Levee Option

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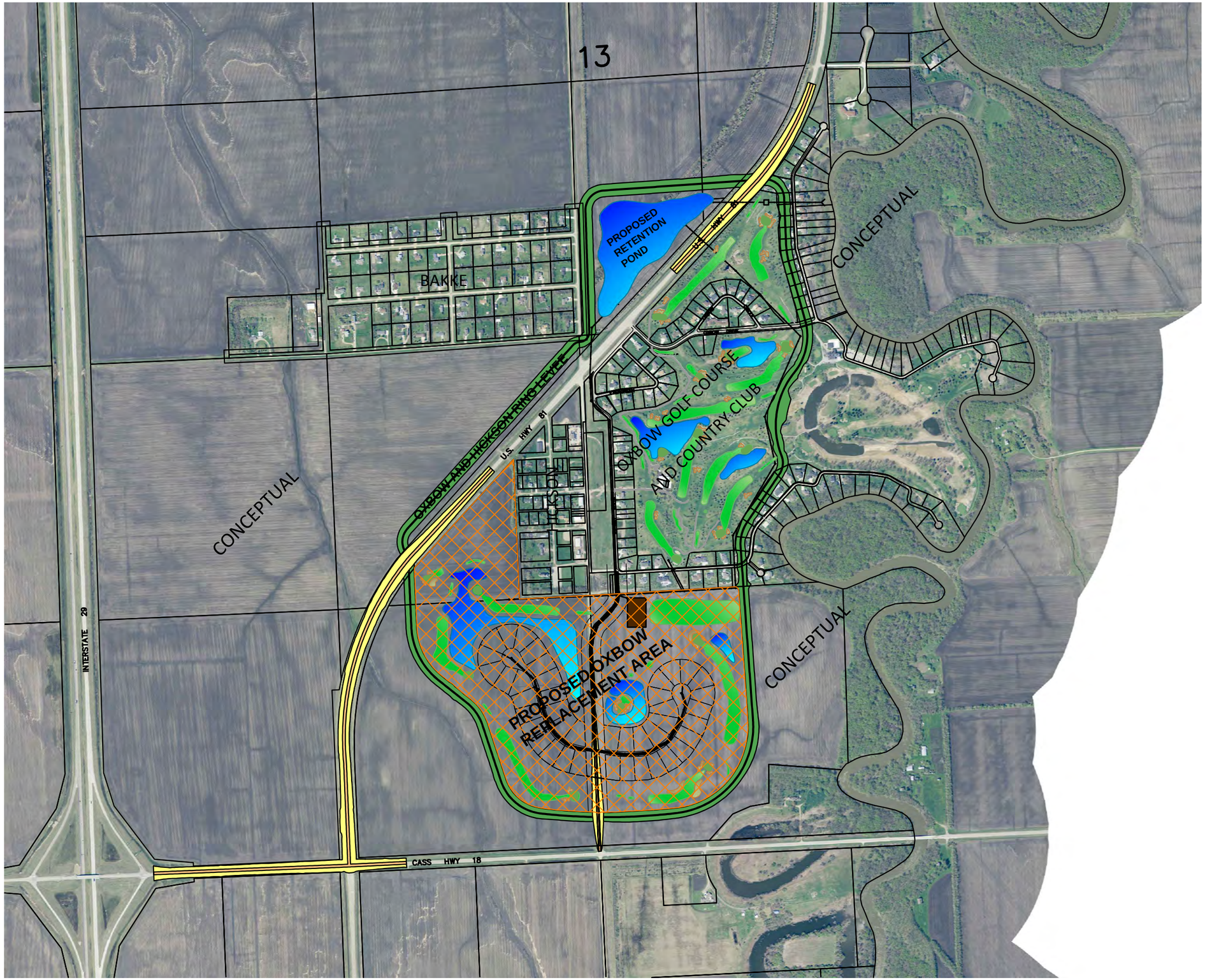
FIG. 1

SHEET 1 OF 1



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Scale in Feet

PRELIMINARY

100-YR WSE = ± 922
TOP OF LEVEE = ± 926
LEVEE LENGTH = 3.5 MILES

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Oxbow, Hickson, Bakke Project Map

Flood Risk Management Evaluation
Land Management Evaluation
Proposed Oxbow and Hickson Levee Option

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FIG. 2

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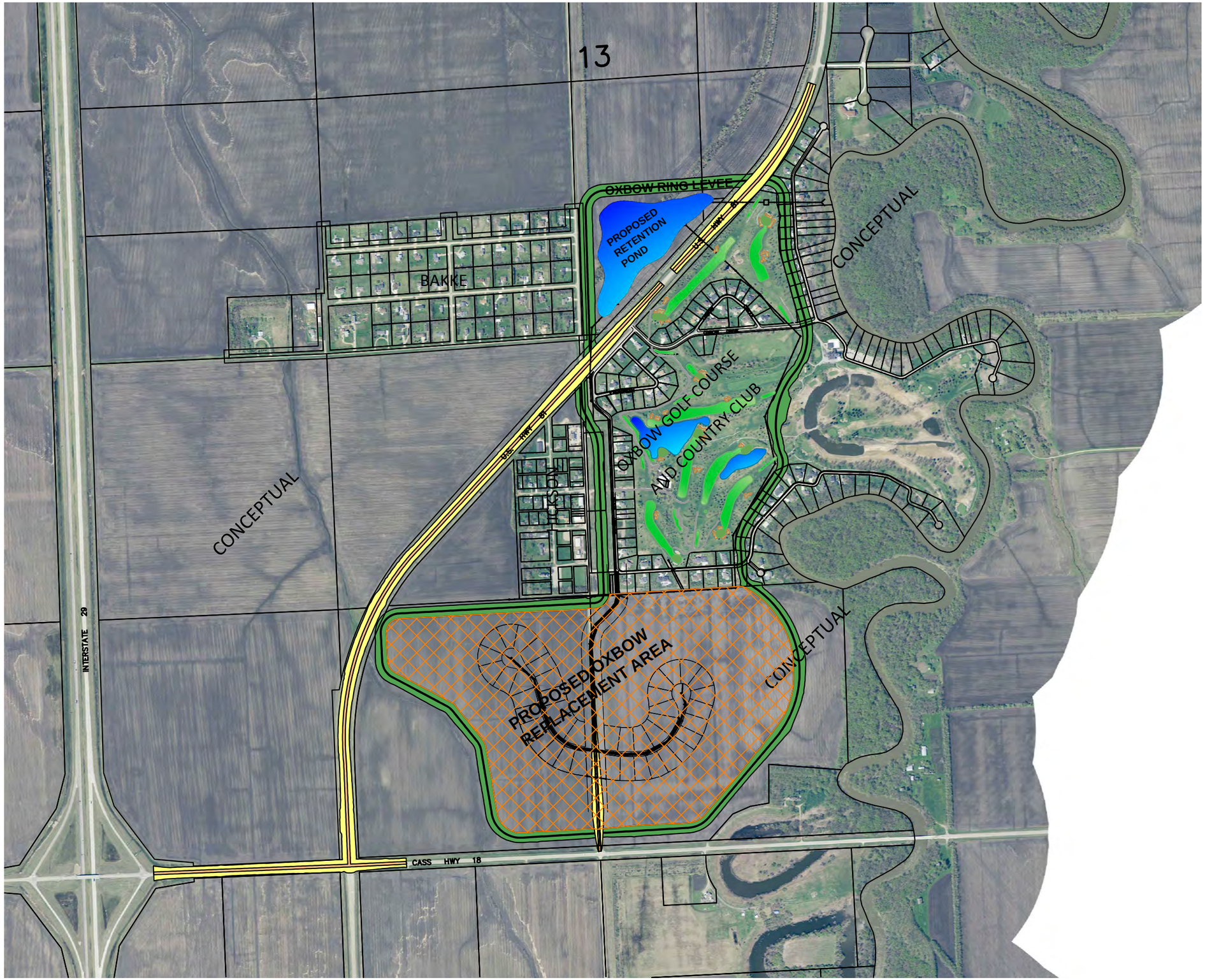

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Scale in Feet

PRELIMINARY

100-YR WSE = ± 922
TOP OF LEVEE = ± 926
LEVEE LENGTH = 3.9 MILES

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Oxbow, Hickson, Bakke Project Map

Flood Risk Management Evaluation
Land Management Evaluation
Proposed Oxbow Levee Option

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FIG. 3

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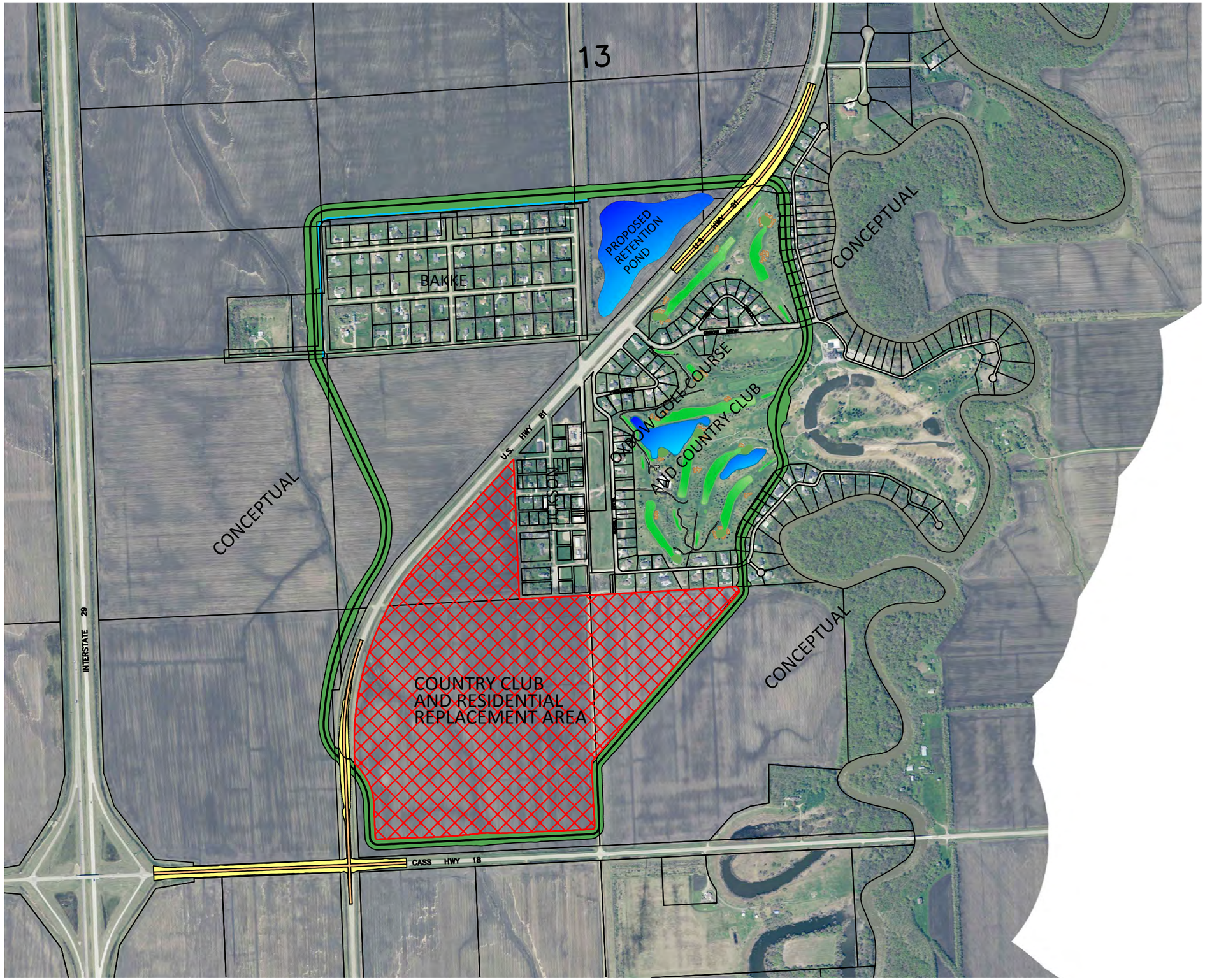

PRELIMINARY

100-YR WSE = ± 922
TOP OF LEVEE = ± 926
LEVEE LENGTH =3.9 MILES

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Oxbow, Hickson, Bakke Project Map

Flood Risk Management Evaluation
Land Management Evaluation
Proposed Oxbow, Bakke, Hickson Alt. Levee Option

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FIG. 4

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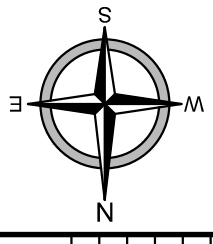

PRELIMINARY

FIG. 5

SHEET 1 OF 1

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FARGO - MOORHEAD AREA
FLOOD RISK MANAGEMENT PROJECT
LAND MANAGEMENT EVALUATION NO. 1
OXBOW, HICKSON, BAKKE LEVEE
EXISTING AND PROPOSED SANITARY SEWER UTILITY MAP

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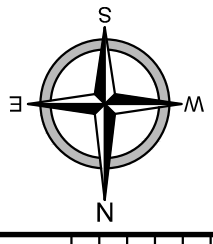

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FIG. 6

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FARGO - MOORHEAD AREA
FLOOD RISK MANAGEMENT PROJECT
LAND MANAGEMENT EVALUATION NO. 1
OXBOW, HICKSON, BAKKE LEVEE
EXISTING AND PROPOSED WATER UTILITY MAP

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PROJ. ENGINEER:	LTB

FARGO - MOORHEAD AREA
FLOOD RISK MANAGEMENT PROJECT
LAND MANAGEMENT EVALUATION NO. 1
OXBOW, HICKSON, BAKKE LEVEE
EXISTING AND PROPOSED STORM SEWER UTILITY MAP

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FIG. 7

SHEET 1 OF 1

FIGURE 8 - LAND ACQUISTION MAP
OXBOW, NORTH DAKOTA

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1 in = 600 feet

moore engineering, inc.

Created By: KMV Date Created: 12/12/2012 Date Saved: 03/05/2013 Date Printed: 12/11/2012 Date Exported: 03/06/2013
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Horizontal Datum: NAD 1983 StatePlane North Dakota South FIPS 3302 Feet Vertical Datum: NAVD1988
T:\Numbered Projects\16474\16474_100\Land Acquisition Map.mxd

APPENDIX A

GEOTECHNICAL REPORTS

resourceful. naturally.
engineering and environmental consultants

BARR

Technical Memorandum

To: Mr. Kyle Volk, Moore Engineering, Inc.
From: Eric Brandner and Aaron Grosser, P.E.
Subject: Oxbow Levee Slope Stability Analysis
Date: December 7th, 2012
Project: 34091004

At the request of Moore Engineering, Inc. (Moore), Barr Engineering Company (Barr) has performed a revised slope stability analysis for the Fargo-Moorhead Flood Diversion Project. The stability analysis was performed for levees near the town of Oxbow, located in North Dakota along the Red River, south of the proposed Fargo-Moorhead diversion channel alignment. This memo discusses the revised approach, based on updated site-specific data analysis, and results of the Oxbow levee analysis and supersedes the report titled "Oxbow Levee Slope Stability Analysis" dated July 31st, 2012.

Geotechnical Data

A previous geotechnical analysis was completed by Northern Technologies, Inc. (NTI) for Moore in 2010 titled "Stability Evaluation of Flood Protection Levee Flood Protection Levees – City of Oxbow, North Dakota" dated April 30th, 2010. This analysis was recently provided to Barr. It incorporated four site-specific soil borings, a minimal amount of laboratory testing, and slope stability analyses. Laboratory testing included water content and dry density. No laboratory shear strength testing was completed. Because only minimal laboratory testing was completed, this evaluation utilizes geotechnical parameters developed for the main portion of the Fargo-Moorhead Flood Diversion Project. Stratigraphy was estimated using the four soil borings included in **Attachment A**. Surficial geometry for the proposed levees was provided by Moore and reviewed by Barr to determine critical sections of the levee alignment. This modeling methodology is generally consistent with the US Army Corp of Engineers (USACE) guidelines used for the main portion of the Fargo-Moorhead Flood Diversion Project.

Stability Analysis

The slope stability analysis was conducted using SLOPE/W, part of the GeoStudio 2007 Version 7.20 software package. SLOPE/W uses the limit equilibrium theory to compute the factor of safety of earth and rock slopes. In the limit equilibrium approach, the geologic material is assumed to be at the state of limiting equilibrium and a factor of safety is computed. Spencer's method was used to calculate the factor of safety of the levee cross-sections in this stability analysis using a 5-foot minimum slip surface depth.

This method is considered an adequate limit equilibrium method because it satisfies all conditions of static equilibrium and provides a factor of safety based on both force and moment equilibrium.

In SLOPE/W, the critical failure surface was modeled using the entry and exit method. This allows the location of the trial slip surfaces to be chosen manually, or rather where slip surfaces will enter and exit the ground surface, with a chosen number of entry and exit points. The entry range was defined between approximately 100 feet landward from the landward levee toe to the riverward toe of the levee. The exit range extended across the width of the river and river banks.

The pore pressures used in the SLOPE/W model were modeled using SEEP/W analysis which is a finite element modeling program and also part of the GeoStudio 2007 version 7.20 software package. Boundary conditions were set in the seepage model to simulate pore water pressures which are incorporated into the slope stability models. A far field hydraulic boundary condition is assumed for all seepage models and consists of groundwater 10 feet below the ground surface based on USACE guidelines. The 2011 annual low and average Red River water elevations at Oxbow are 887.34 feet and 889.11 feet, respectively. The nominal oxbow lake elevation is 893 feet. The Red River and oxbow lake elevations were provided to Barr by Moore (transmitted on 7/3/2012).

The proposed levees will have 5H:1V side slopes and a crest width of 10 feet. The crest of the levee is at an elevation of 926 feet or approximately 10 feet above surrounding ground surface. Levees are assumed to have the material properties of Semi-Compacted Excavated Material, which was developed for the main portion of the Fargo-Moorhead Flood Diversion Project. This material is expected to consist primarily of Sherack Formation taken from shallow borrow areas in the region.

Two types of stability analyses are typically performed for slopes: the Undrained Strength Stability Analysis (USSA) and the Effective Stress Stability Analysis (ESSA). The USSA is performed to analyze the case in which loading or unloading is applied rapidly and excess pore-water pressures do not have time to dissipate during shearing. This approach is often referred to as the end-of-construction case. The ESSA is performed to account for much slower loading or unloading, or no external loading, in which the drained shear strength of the materials is mobilized and no excess pore-water pressures are allowed to develop. The shear strength used in these analyses is the drained (long-term) strength. The shear strengths in Lake Agassiz clays can be especially low under drained (long-term) conditions because of the mineralogical composition of the material, and the drained strength of the material typically controls the design of stable slopes in the Red River Valley. Thus, the ESSA was the controlling case for slope stability.

Slope stability was examined at three locations (cross-sections A, B, and C) along the proposed levee, as shown in **Attachment B** provided by Moore (transmitted on 7/3/2012). The Red River channel is incorporated into cross-sections A and C as shown on **Figure 1**. Cross-section B intersects an oxbow lake of the Red River. An oxbow lake is a curved stretch of a river channel cut off from the main channel. Fluctuations in water elevation are expected to occur in the Red River while the water level in the oxbow

lake is expected to stay at a fixed elevation. Surficial relief along each cross-section is also illustrated in **Attachment A**.

For typical long-term conditions, the minimum recommended factor of safety for levees and embankments is 1.40, while 1.30 is recommended for the end-of-construction case according to USACE standard EM 1110-2-1913, Table 6-1b (USACE, 2003).

Stability Model Input Parameters

The assumed stratigraphy near the town of Oxbow consists of the four soil units shown in Table 1. The contacts of the four units are based on boring logs from NTI's 2010 field investigation. The location of the borings are shown in **Figure 1** and included in **Attachment A**. The elevation of the contact between the Argusville and Sherack Formations increased from 877 feet at cross-section A to 883 feet at cross-section C. Because no borings were conducted at cross-section B, the contact elevation of the two units was interpolated to be 879 feet. Stratigraphy for each cross-section is shown in the model output figures in **Attachment C**. The stratigraphic sequencing from the top down includes: Semi-Compacted Excavated Material, Sherack Formation, Argusville Formation, and Unit "A" glacial till. The Brenna Formation becomes thinner from north to south in the Red River Valley. The presences of the Brenna Formation was not reflected on any boring logs, and thus concluded not to be present at the site.

The permeability values used in the SEEP/W analysis are included below in **Table 1**. These values are the established USACE parameters.

Table 1. Permeability Parameters Summary

Material	Material Model Type	Sample Material	Vertical Permeability		Horizontal Permeability	
			k_y [cm/sec]	k_y [ft/day]	k_y/k_x ratio	k_x [ft/day]
Semi-Compacted Excavated Material	Sat / Unsaturated	Silty Clay	1.0E-06	2.8E-03	0.25	0.0113
Sherack	Sat / Unsaturated	Silty Clay	1.0E-06	2.8E-03	0.25	0.0113
Argusville	Sat / Unsaturated	N/A	1.0E-07	2.8E-04	1	0.00028
Glacial Till	Sat / Unsaturated	N/A	5.0E-06	1.4E-02	0.25	0.057

Material index and strength properties are based on information provided by the USACE St. Paul District Office in March and April 2012. **Table 2** summarizes the unit weight and shear strength properties used in the SLOPE/W analysis.

Table 2. Unit Weight and Shear Strength Parameter Summary

Material	Unit Weight	Shear Strength Parameters			
	γ_{sat}	Drained (ESSA)		Undrained (USSA)	
	[pcf]	ϕ' [deg.]	c' [psf]	ϕ_{cu} [deg.]	c (psf)
Semi-Compacted Excavated Material	123	31	0	0	900
Sherack	115	Note 1		0	900
Argusville	110	See curvilinear envelope in Table 3		0	Note 2
Glacial Till	Impenetrable				

1. The ultimate bi-linear effective stress curve for the Sherack is ϕ'=28 deg, c'=0 psf and then at 2,000 psf, ϕ'=11 deg.
2. The Argusville Formation ultimate undrained shear strength was assumed to be linearly increasing with depth. Initial cohesion was assumed to be 575 psf, with an increase with depth of 10 psf/ft.

The curvilinear drained strength envelope for the Argusville Formation used in the SLOPE/W analysis are included below in **Table 3**. These values are the established USACE parameters.

Table 3. Curvilinear Properties Summary

Argusville Formation	
Effective Normal Stress	Shear Strength
σ' [psf]	τ' [psf]
0	50
200	127
1000	413
200	653
3000	893
4000	1093
6000	1460
8000	1740

Stability Model Results

The limit equilibrium slope stability analyses are summarized in **Table 4**. The seepage and slope stability analysis outputs are included in **Attachment C**.

Table 4. Results of Stability Analysis

River Elevation	Model	Section A	Section B	Section B - 5 ft offset	Section C
Low Flow El. 887.34	Global Long Term (ESSA)	1.54	-	-	1.51
	End of Construction (USSA)	1.68	-	-	1.78
Average Flow El. 889.11	Global Long Term (ESSA)	1.58	-	-	1.55
	End of Construction (USSA)	1.71	-	-	1.78
Oxbow Pond El 893	Global Long Term (ESSA)	-	1.38	1.40	-
	End of Construction (USSA)	-	1.42	1.44	-
Oxbow Pond El 894	Global Long Term (ESSA)	-	1.40	-	-
	End of Construction (USSA)	-	1.44	-	-

As shown in Table 4, the factors of safety for cross-sections A and C exceed the minimum requirement of 1.40 (ESSA) and 1.30 (USSA). However, the factor of safety for the global long-term (ESSA) cross-section B resulted in a factor of safety of 1.38, which is below the 1.40 required factor of safety value.

The factor of safety at cross-section B can be increased to the recommended value by either offsetting the centerline of the levee 5 feet in the landward direction, approximately west or left on the model outputs shown in Attachment C, from the proposed alignment at this location or maintaining the water level in the oxbow lake at an elevation of 894 feet. It may be difficult in the long term to maintain water levels in the oxbow lake, therefore the 5-foot levee offset is recommended.

Limitations of Analysis

The analysis and conclusions provided are based on the limited dataset available at the time of this analysis. Using generally accepted engineering methods and practices, analyses have been performed using reasonable effort to characterize the site. However, the analyses represent a large area, and variations in stratigraphy, strength, and groundwater conditions may occur. As with any project of this nature with limited data, we recommend site specific investigations to confirm our assumptions and develop site specific parameters for use in modeling.

Reviewed By

Jedediah D. Greenwood — December 7, 2012 (Date)

Certification

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

Aaron T. Grosser (Reg. #PE-6221) — December 7, 2012 (Date)

REGISTERED PROFESSIONAL ENGINEER — AARON THOMAS GROSSER — 6221 — DATE 12/7/12 — NORTH DAKOTA

References

- Northern Technologies, Inc. "Stability Evaluation of Flood Protection Levee Flood Protection Levees – City of Oxbow, North Dakota" dated April 30th, 2010.
- Barr Engineering Co. "Oxbow Levee Slope Stability Analysis" dated July 31st, 2012.
- US Army Corp of Engineers "Fargo-Moorhead Metropolitan Area Flood Risk Management, Final Feasibility Report and Environmental Impact Statement, Appendix I: Geotechnical Design and Geology", July 2011.

Attachments

- Attachment A – Site-Specific Soil Borings
- Attachment B – Cross-Section Locations and Profiles
- Attachment C – GeoStudio Model Output

Figures

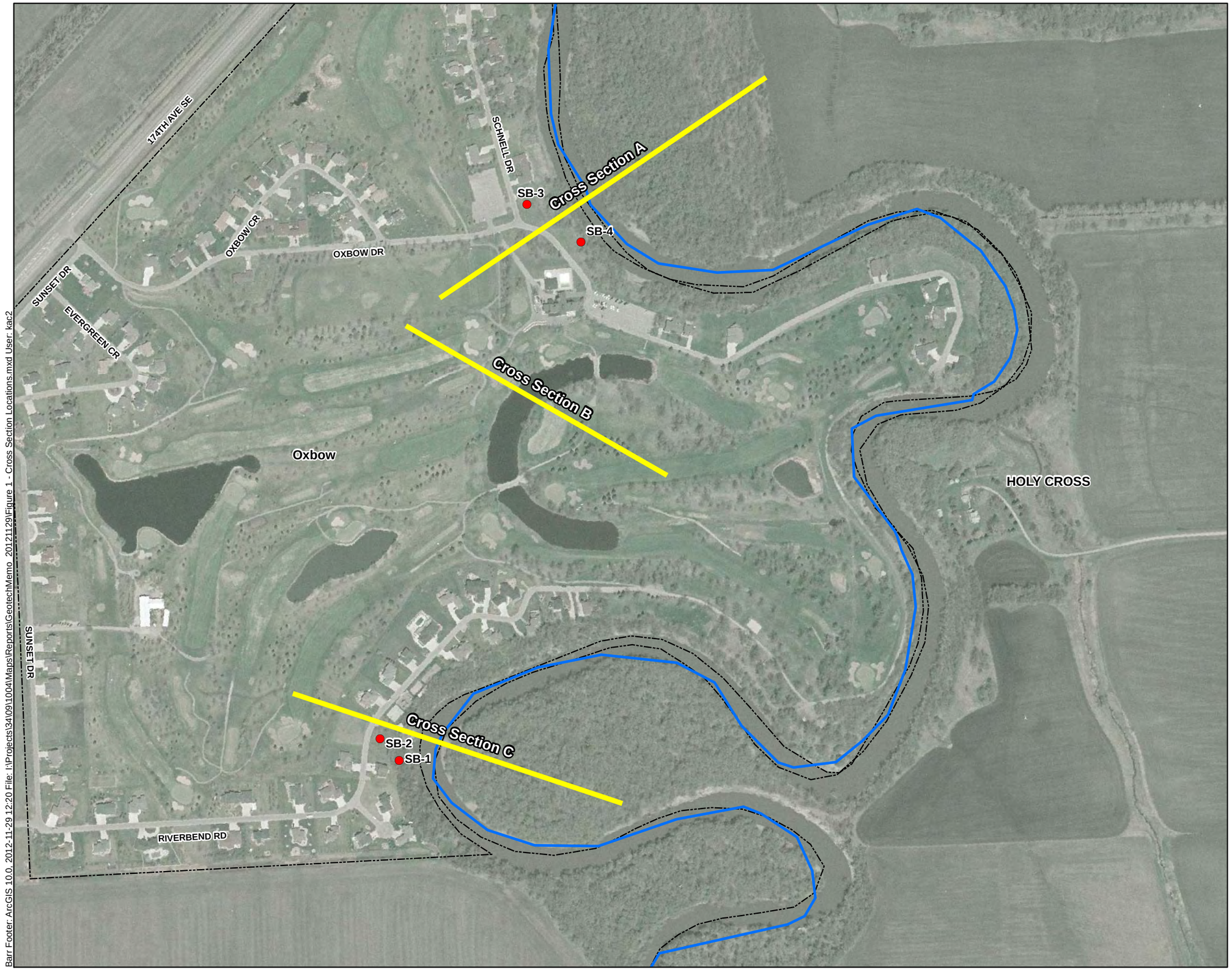

Figure 1

CROSS SECTION LOCATIONS
Fargo - Moorhead Area

Barr Footer: ArcGIS 10.0, 2012-11-29 12:20 File: I:\Projects\34\09\1004\Maps\Reports\GeotechMemo_20121129\Figure 1 - Cross Section Locations.mxd User: kac2

Attachment A

GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-1

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
	TOPSOIL, ORGANIC SILTY FAT CLAY, BLACK (OH)	**TOPSOIL**			1	FA				
2 1/2	SILTY FAT CLAY, LIGHT BROWN TO LIGHT GRAY, SOFT TO MEDIUM TO SOFT (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		4	2	SS	42	77		- / 0.8
				5	3	SS	34	89		- / 1.8
				3	4	SS	46	77		- / 1.0
9	SILTY FAT CLAY, LIGHT BROWN TO LIGHT GRAY WITH VERTICAL SEAMS OF WHITE PRECIPITATE, SOFT (CH)			4	5	SS	40	85		- / 1.2
11 1/2	SILTY FAT CLAY, LIGHT BROWN TO LIGHT GRAY, SOFT TO MEDIUM TO SOFT (CH)			5	6	SS	38	83		- / 1.6
				7	7	SS	38	83		- / 1.5
				7	8	SS	42	81		- / 1.3
24 1/2	SILTY FAT CLAY, DARK GRAY, SOFT (CH)			4	9	SS	40	81		- / 1.4
27	FAT CLAY, DARK GRAY, SOFT (CH)									
				4	10	SS	43	77		- / 1.0
				4	11	SS	42	81		- / 1.0

Boring continued on next page

GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100 BORING NUMBER: SB-1

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
40	FAT CLAY (continued), DARK GRAY, SOFT (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		4	12	SS	41	81		- / 0.9
				3	13	SS	42	81		- / 0.9
46	**END OF BORING**									
	Boring terminated at 46 feet. Bore hole filled with soil cuttings after retrieval of hollow stem auger. Cave-in Depth: 14 feet. Depth of Frost: 1.5 feet.									

DATE:	WATER TABLE MEASUREMENTS	DATE:	2/22/2010
2/22/10	No measurable groundwater encountered during or at completion of boring.	METHOD OF DRILLING:	3¼" H.S.A. 0 to 44 1/2 ft
		CREW CHIEF:	J. BROOKS

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GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-2

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pg
	FILL, ORGANIC FAT CLAY, BLACK TO GRAY TO BROWN	**FILL**			1	FA				
				8	2	SS				- /
3	**BURIED TOPSOIL,** ORGANIC SILTY FAT CLAY, BLACK (OL)	**BURIED TOPSOIL**								
5	SILTY FAT CLAY, GRAY TO LIGHT BROWN, MEDIUM (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		6	3	SS				- /
6 1/2				7	4	SS	38	86		- / 1.7
				7	5	SS	36	89		- / 1.7
				6	6	SS	38	87		- / 1.8
				6	7	SS	37	88		- / 1.8
				5	8	SS	38	86		- / 2.0
				5	9	SS	38	88		- / 1.7
29	SILTY FAT CLAY, LIGHT GRAY TO LIGHT BROWN, SOFT (CH)			3	10	SS	45	78		- / 0.6
32	FAT CLAY, DARK GRAY, SOFT (CH)			4	11	SS	36	88		- / 0.7

Boring continued on next page

GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-2

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
40	FAT CLAY (continued), DARK GRAY, SOFT (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		3	12	SS	38	86		- / 0.9
				3	13	SS				- / 0.9
46	**END OF BORING**									
	Boring terminated at 46 feet. Bore hole filled with soil cuttings after retrieval of hollow stem auger. Cave-in Depth: 14 feet. Depth of Frost: 2 feet.									

DATE:	WATER TABLE MEASUREMENTS	DATE:	2/22/2010
2/22/10	No measurable groundwater encountered during or at completion of boring.	METHOD OF DRILLING:	3¼" H.S.A. 0 to 44 1/2 ft
		CREW CHIEF:	J. BROOKS

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GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-3

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
	FILL, ORGANIC FAT CLAY, TRACE OF SAND AND GRAVEL, BLACK TO GRAY TO BROWN	**FILL**			1	FA				
				7	2	SS				- /
5	FAT CLAY, LIGHT GRAY TO LIGHT BROWN, MEDIUM (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		8	3	SS				- / 2.0
				7	4	SS	39	85		- / 1.9
				5	5	SS	40	84		- / 1.8
				5	6	SS	40	84		- / 1.7
				5	7	SS	43	81		- / 1.9
				5	8	SS	41	80		- / 1.9
				5	9	SS	39	84		- / 1.5
29	SILTY FAT CLAY, GRAY TO LIGHT BROWN, MEDIUM (CH)			6	10	SS	37	89		- / 1.3
32	SILTY FAT CLAY, DARK GRAY, MEDIUM (CH)			5	11	SS	41	81		- / 1.8
38	FAT CLAY, DARK GRAY, SOFT TO MEDIUM (CH)									

Boring continued on next page

GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-3

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
40	FAT CLAY, DARK GRAY, SOFT TO MEDIUM (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		4	12	SS	42	83		- / 1.6
				4	13	SS	41	84		- / 1.0
					14	3T				- / 1.6
				6	15	SS	41	83		- / 1.0
				7	16	SS	36	90		- / 0.8
				7	17	SS	40	83		- / 1.0
70	SAND, FINE TO COARSE GRAINED, LITTLE GRAVEL, DARK GRAY, WET, VERY DENSE (SP-SM)	COARSE ALLUVIUM	▼	5	18	SS	35	88		- / 1.1
72	SANDY LEAN CLAY, TRACE OF GRAVEL, DARK GRAY, VERY STIFF (CL)	GLACIAL TILL		109	19	SS	16	116		- / >6
76	**END OF BORING** Boring terminated at 76 feet. Bore hole filled with soil cuttings after retrieval of hollow stem auger. Cave-in Depth: 28 feet. Depth of Frost: 2.5 feet.									

DATE:	WATER TABLE MEASUREMENTS	DATE:	3/3/2010
3/3/10	Measurable groundwater encountered at 70 feet at completion of boring.	METHOD OF DRILLING:	3¼" H.S.A. 0 to 74 1/2 ft
		CREW CHIEF:	J. BROOKS

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GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-4

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
	TOPSOIL, ORGANIC SILTY FAT CLAY, BLACK (OH)	**TOPSOIL**			1	FA				
1 1/2	SILTY FAT CLAY, LIGHT BROWN, MEDIUM (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		5	2	SS	35	89		- / 1.8
				5	3	SS	38	84		- / 1.5
				6	4	SS	40	85		- / 1.6
				7	5	SS	39	85		- / 1.7
				7	6	SS	36	90		- / 2.1
				7	7	SS	37	86		- / 2.0
20 1/2	SILTY FAT CLAY, LIGHT BROWN, WITH VERTICAL SEAMS OF WHITE PRECIPITATE, MEDIUM (CH)			7	8	SS	37	87		- / 1.7
				6	9	SS	40	84		- / 1.8
28	FAT CLAY, DARK GRAY, MEDIUM TO SOFT TO MEDIUM (CH)			5	10	SS	39	87		- / 1.8
				5	11	SS	42	82		- / 1.8

Boring continued on next page

GEOTECHNICAL BORING LOG

PROJECT TITLE: PROPOSED OXBOW FLOOD PROTECTION - OXBOW, NORTH DAKOTA
PROJ. NUMBER: 10-10639.100

BORING NUMBER: SB-4

DEPTH (feet)	DESCRIPTION OF MATERIAL surface elevation:	GEOLOGIC ORIGIN	SAMPLE DATA				LABORATORY TESTS			
			WL	N	NO	TYPE	W	D	LL PL	Qu Pq
40	FAT CLAY (continued), DARK GRAY, MEDIUM TO SOFT TO MEDIUM (CH)	GLACIAL LAKE AGASSIZ DEPOSIT		4	12	SS	40	85		- / 1.8
				5	13	SS	41	82		- / 1.8
				5	14	SS	40	83		- / 1.8
51	**END OF BORING**									
	Boring terminated at 51 feet. Bore hole filled with soil cuttings after retrieval of hollow stem auger. Cave-in Depth: 18 feet. Depth of Frost: 1.5 feet.									

DATE:	WATER TABLE MEASUREMENTS	DATE:	3/1/2010
3/1/10	No measurable groundwater encountered during or at completion of boring.	METHOD OF DRILLING:	3¼" H.S.A. 0 to 49 1/2 ft
		CREW CHIEF:	C. CULP

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N

Base drawing provided by Moore Eng. Inc.
NTI Project 10-10639.100
April 30, 2010

moore engineering, inc.
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50 Years of Service

Attachment B

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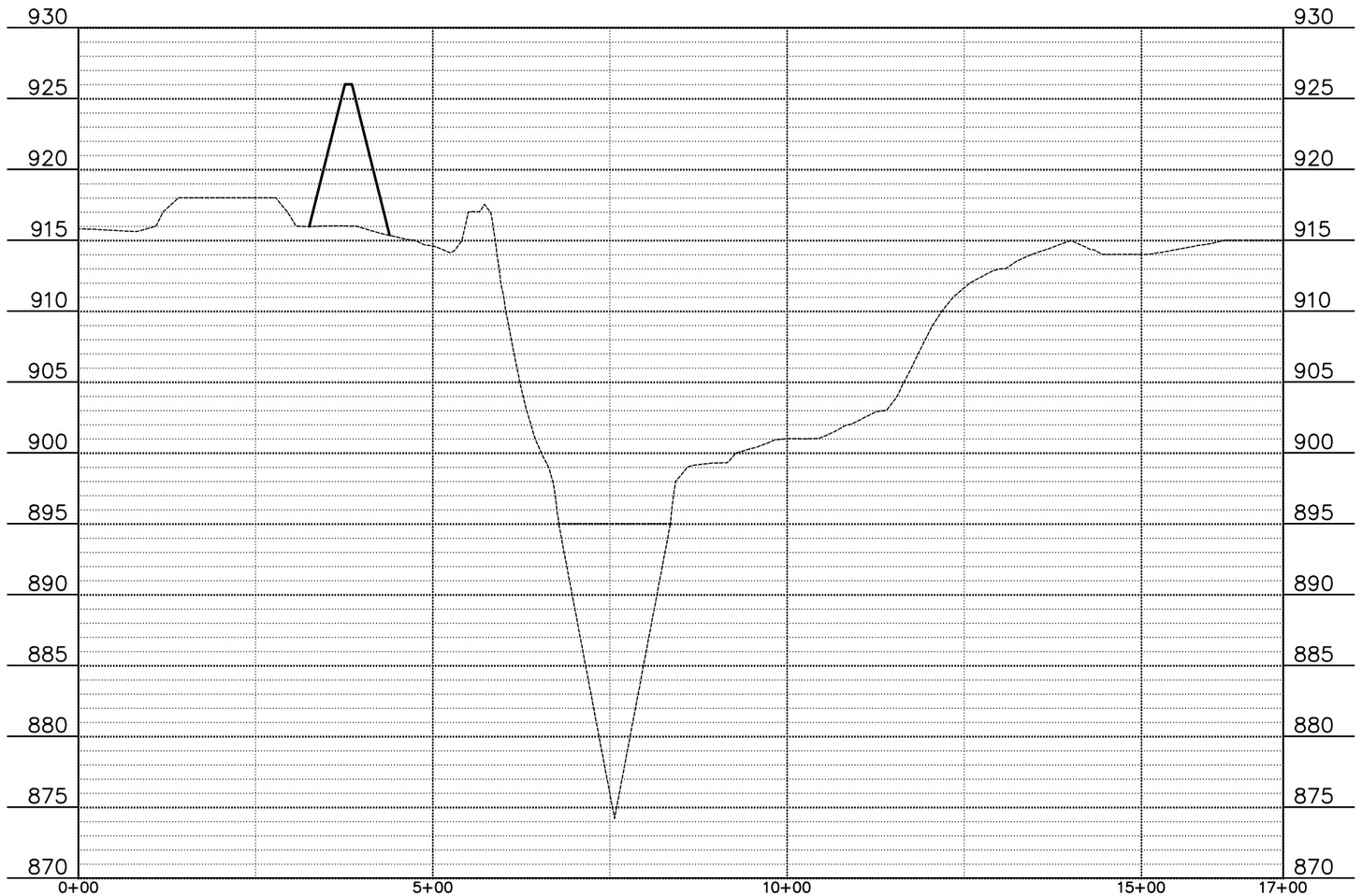
West Fargo, ND • Fergus Falls, MN • Minot, ND
www.mooreengineeringinc.com

OXBOW CROSS SECTION LOCATION
OXBOW LEVEE EVALUATION
FM METRO DIVERSION
CASS COUNTY, NORTH DAKOTA

DATE	REVISED	PROJECT NO.
06/13/12	07/03/12	16474
CH'D BY	DRAWN BY	SHEET
KMV	KMV	1 OF 1



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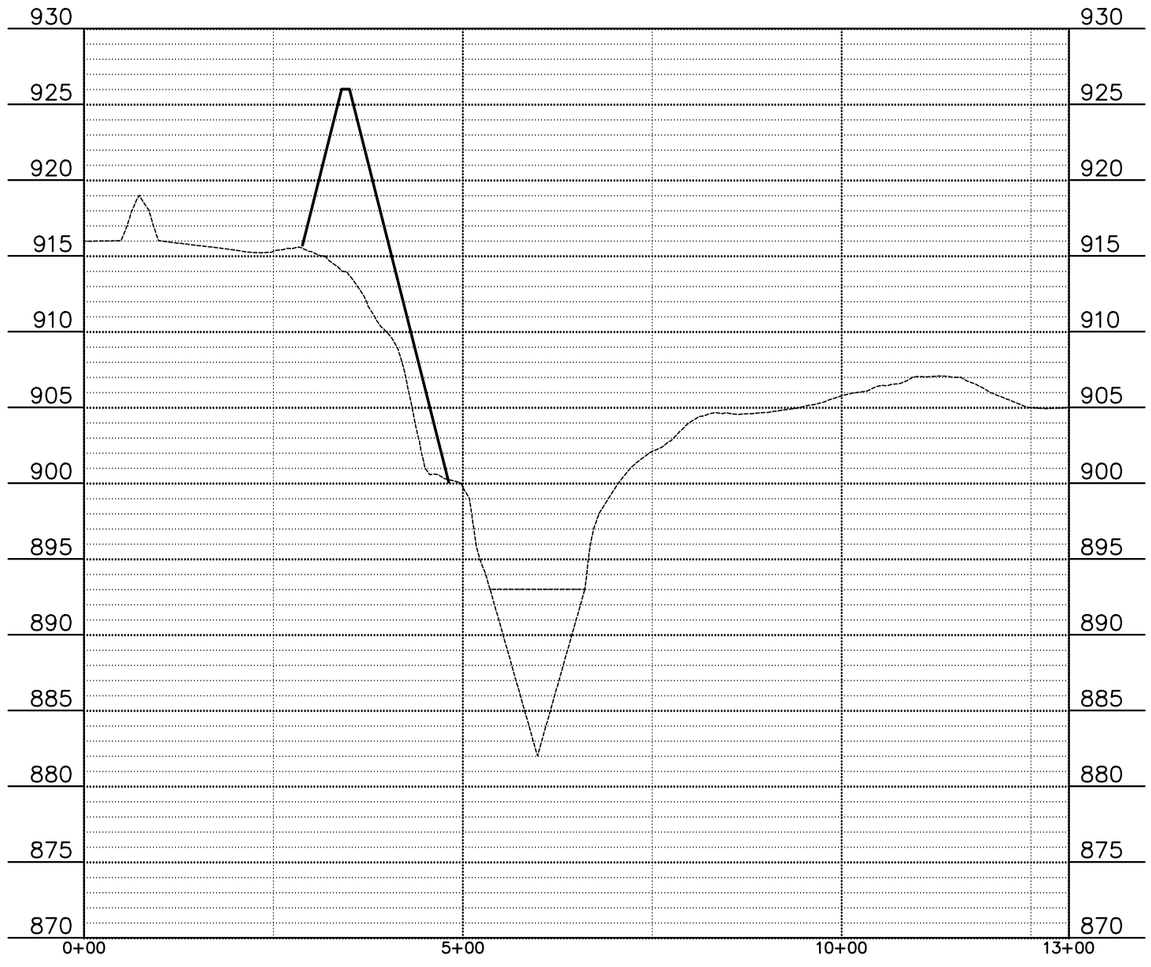
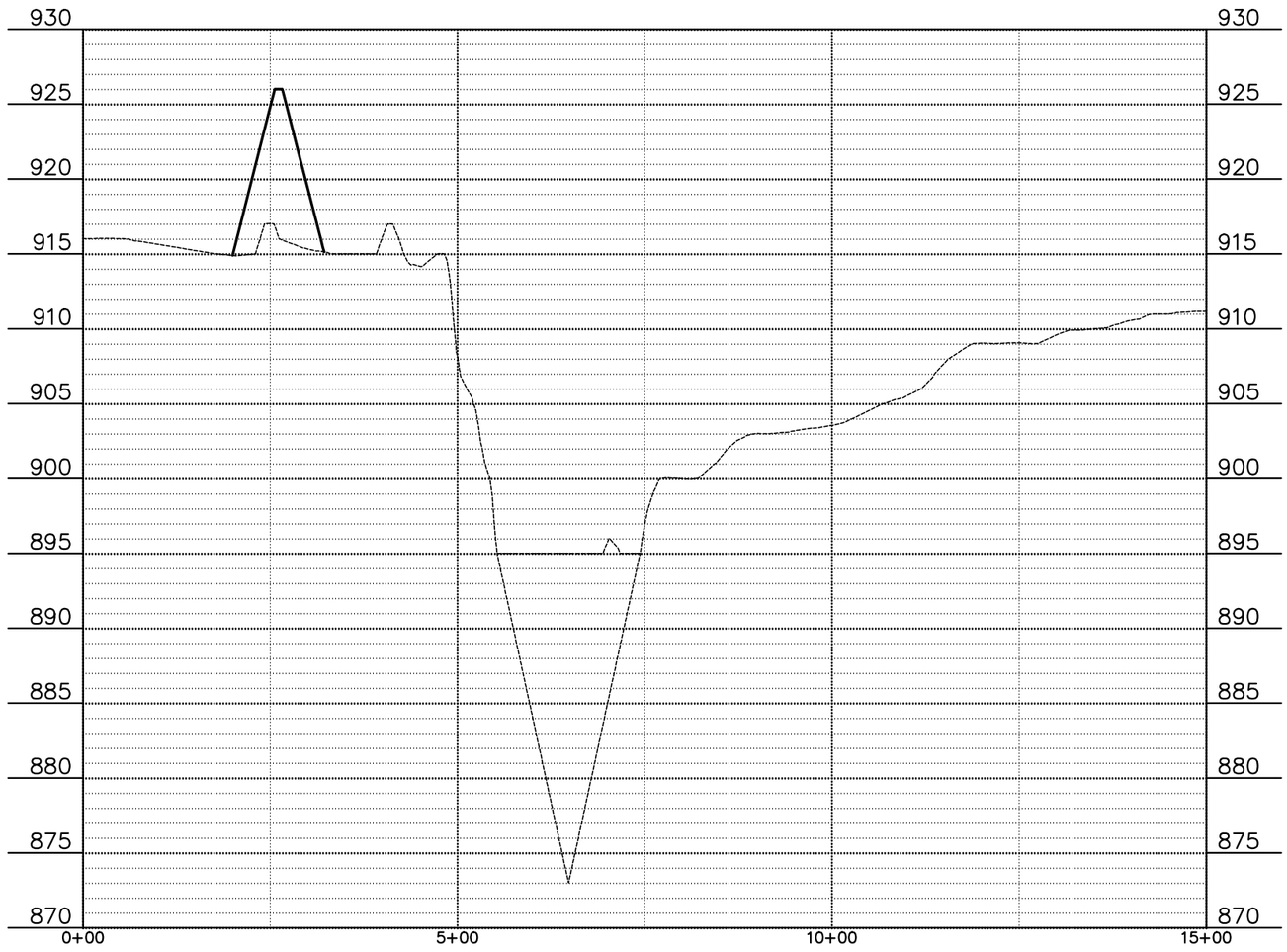
CROSS SECTION A
OXBOW LEVEE EVALUATION
FM METRO DIVERSION
CASS COUNTY, NORTH DAKOTA

DATE	REVISED	PROJECT NO.
06/13/12		16474
SCALE	DRAWN BY	SHEET
H: 1"=200' V: 1"=5'	KMV	1 OF 1



moore engineering, inc. Consulting Engineering • Land Surveying West Fargo, ND • Fergus Falls, MN • Minot, ND www.mooreengineeringinc.com	CROSS SECTION B OXBOW LEVEE EVALUATION FM METRO DIVERSION CASS COUNTY, NORTH DAKOTA	DATE: 06/13/12 SCALE: H: 1"=200' V: 1"=5'	REVISED: DRAWN BY: KMV	PROJECT NO.: 16474 SHEET: 1 OF 1



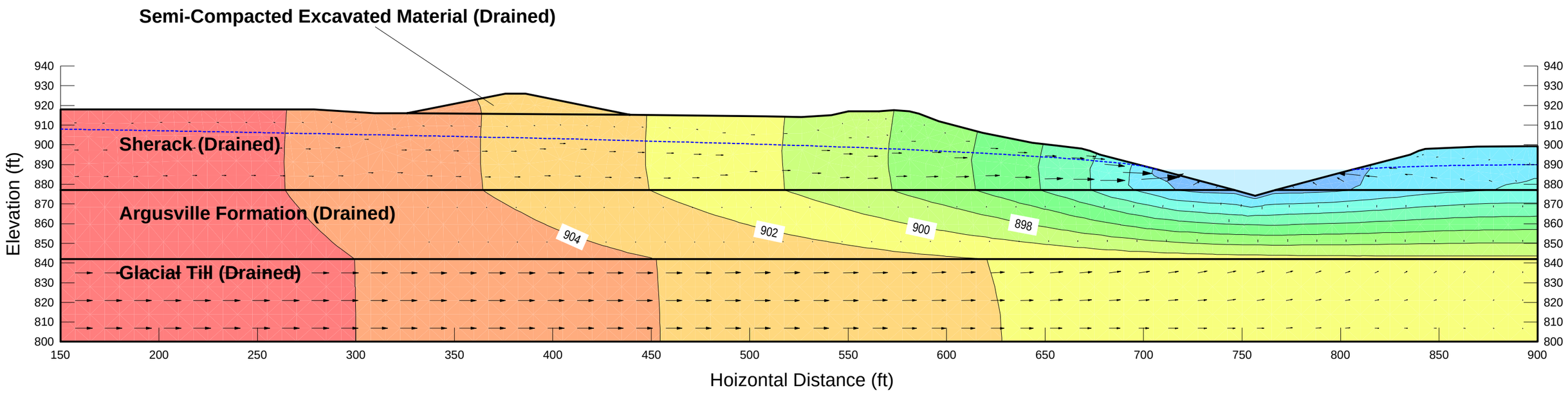
moore engineering, inc. Consulting Engineering • Land Surveying West Fargo, ND • Fergus Falls, MN • Minot, ND www.mooreengineeringinc.com	CROSS SECTION C OXBOW LEVEE EVALUATION FM METRO DIVERSION CASS COUNTY, NORTH DAKOTA	DATE: 06/13/12 SCALE: H: 1"=200' V: 1"=5'	REVISED: DRAWN BY: KMV	PROJECT NO.: 16474 SHEET: 1 OF 1

Attachment C

Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

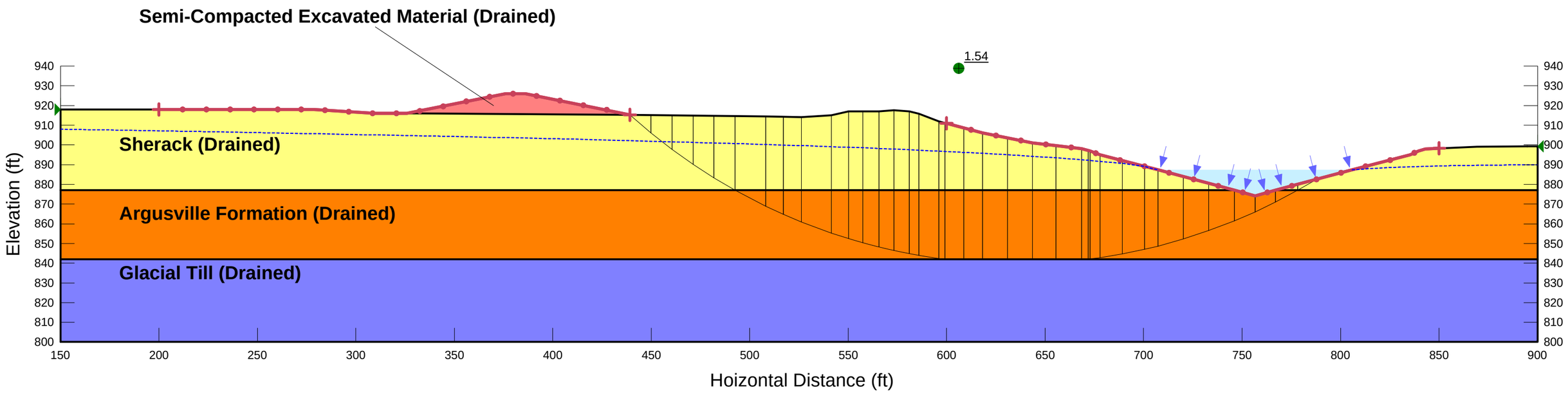
Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



\\barr.com\projects\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_afterPhase4\General\Geotech Oxbow\Dec 2012 Re-analysis\Models\Cross Section A.gsz

Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.54

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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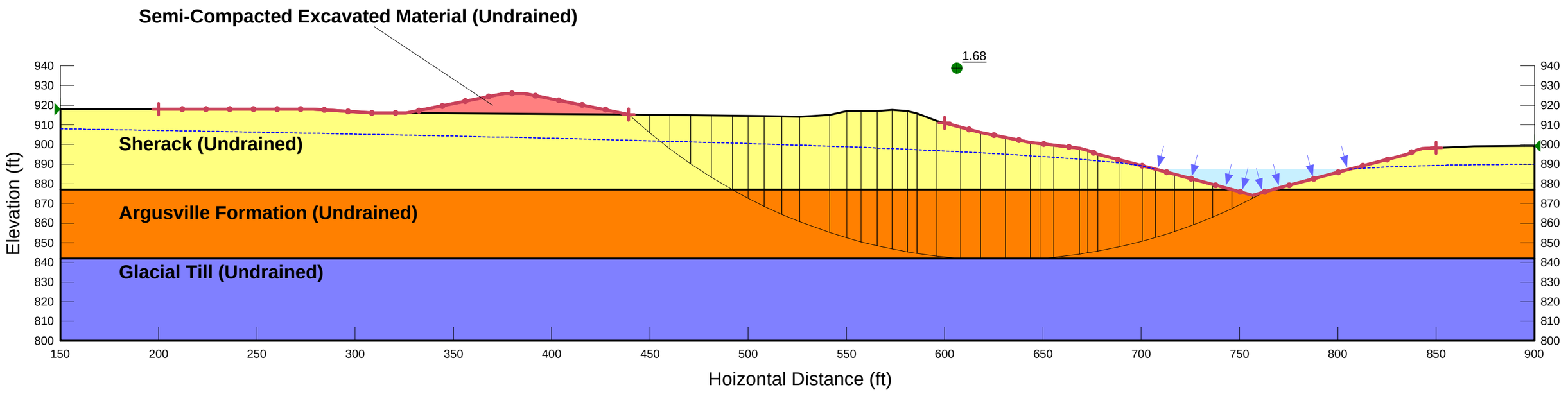
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA -River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.68

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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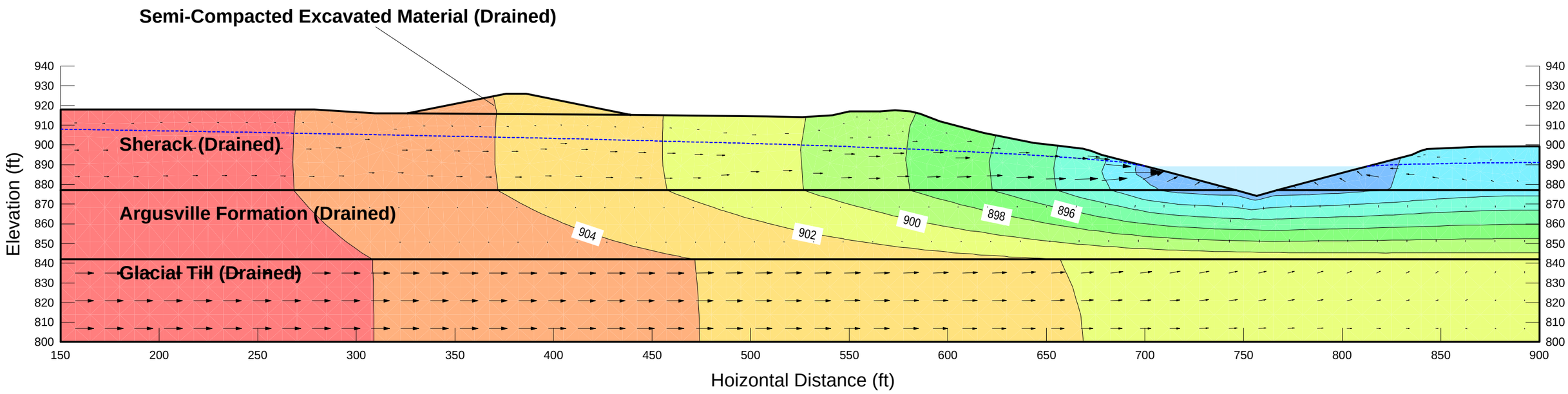
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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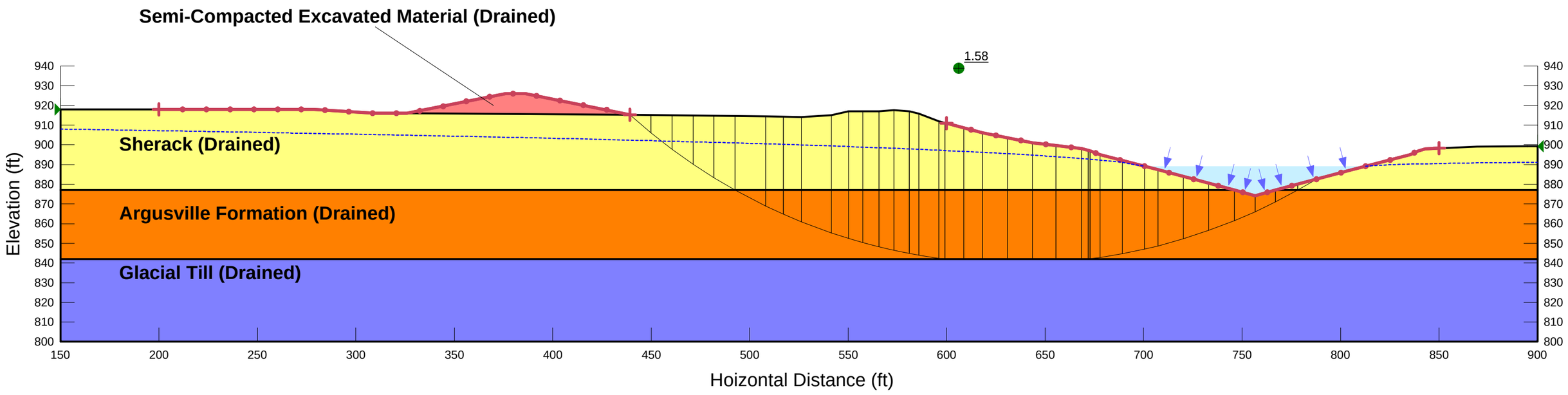
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.58

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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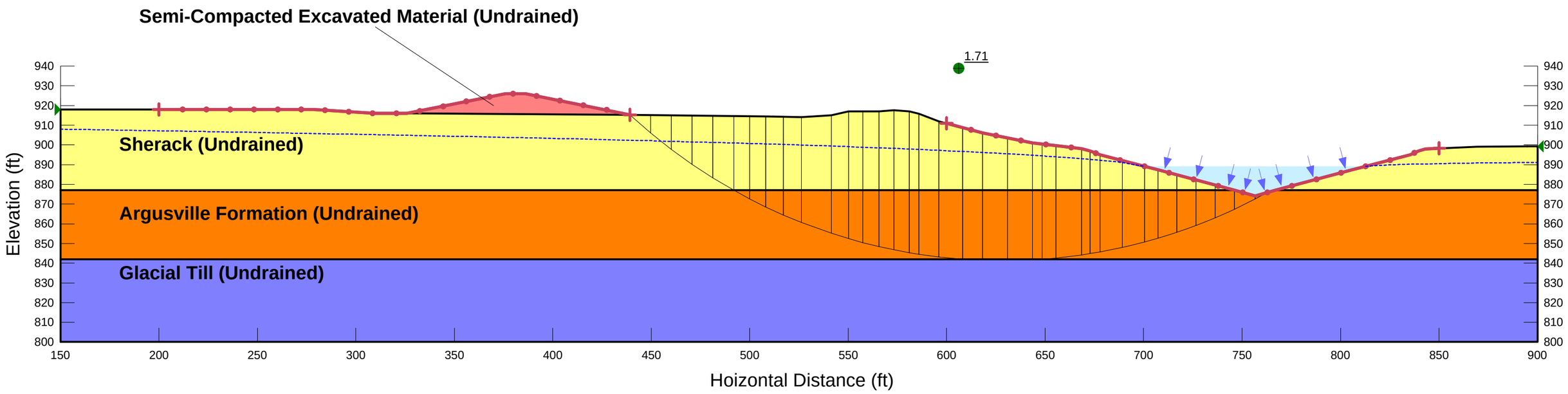
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.71

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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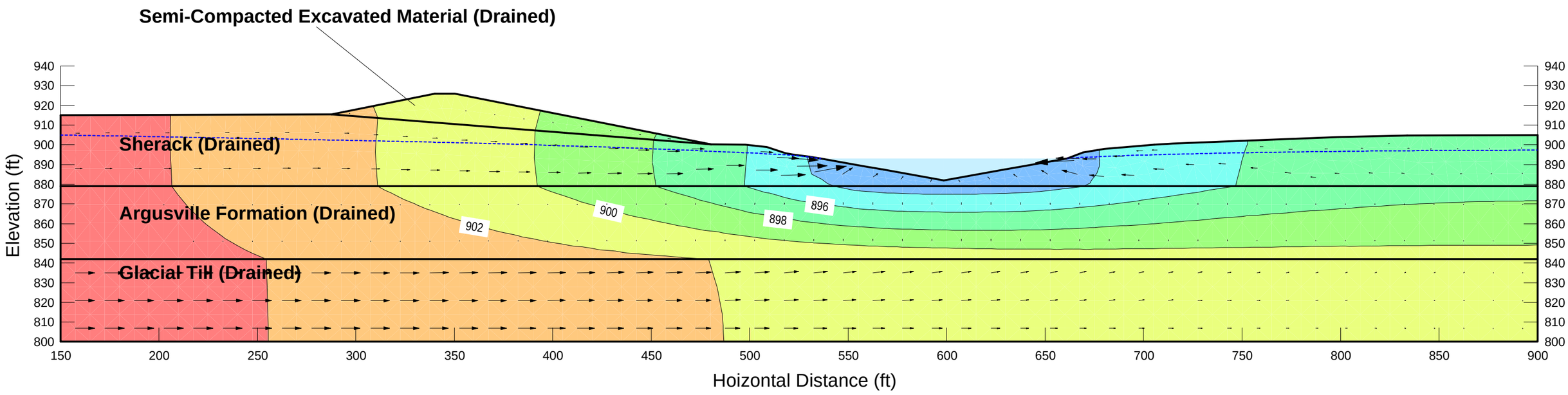
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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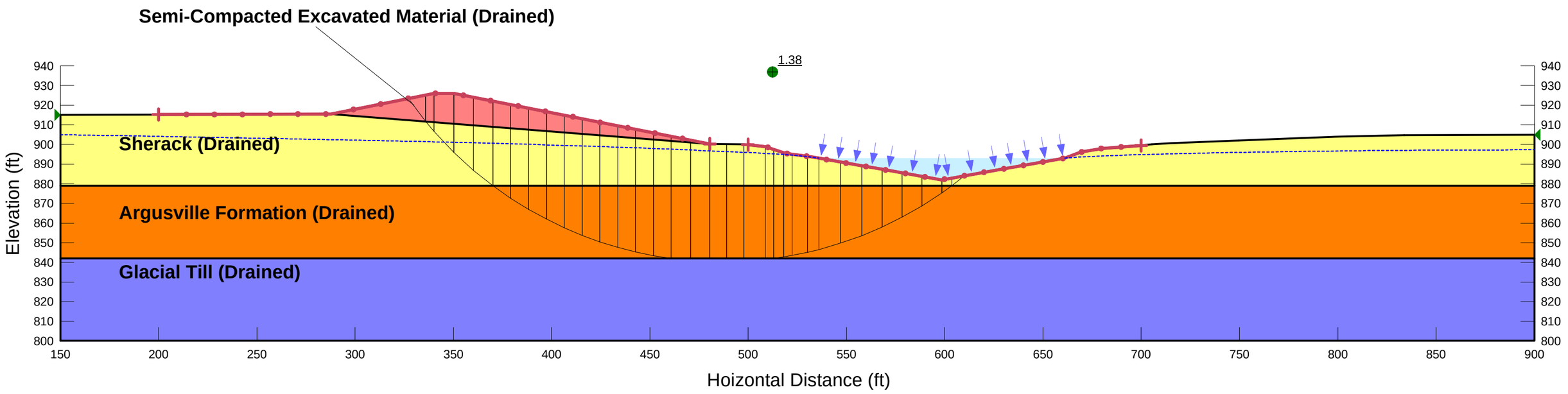
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.38

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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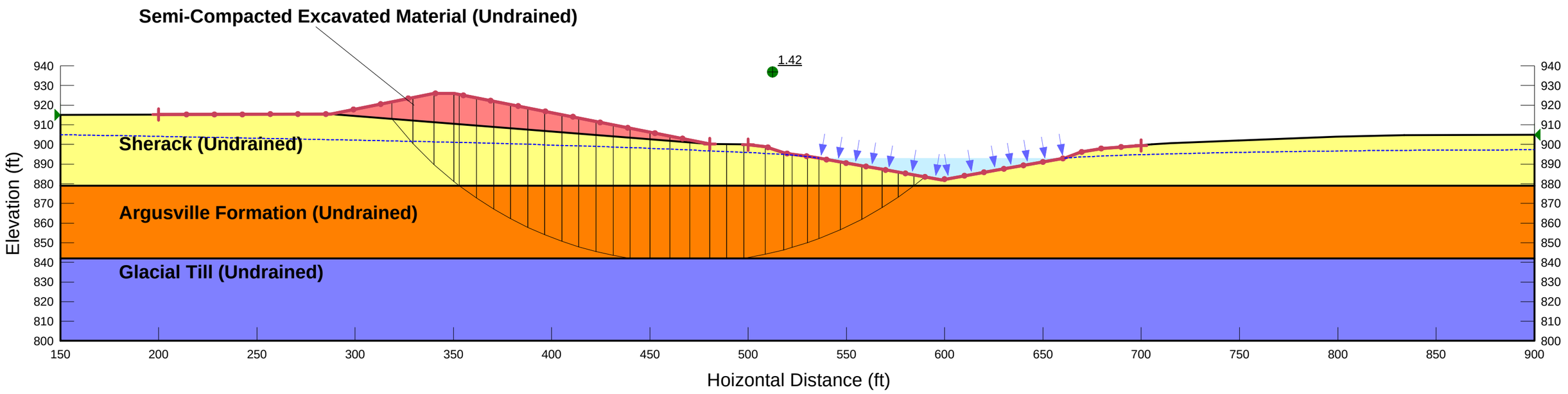
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.42

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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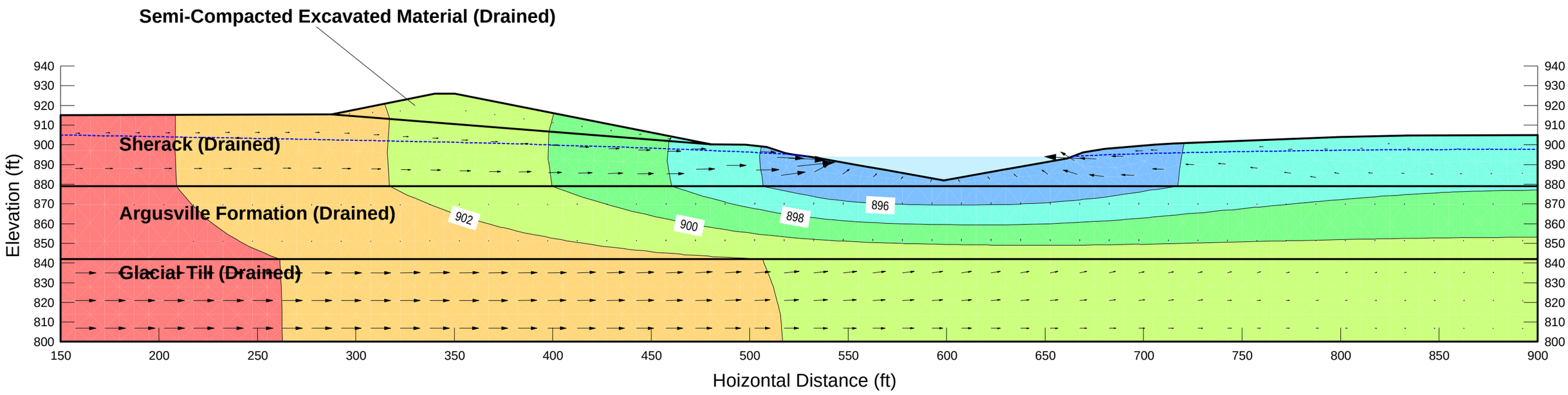
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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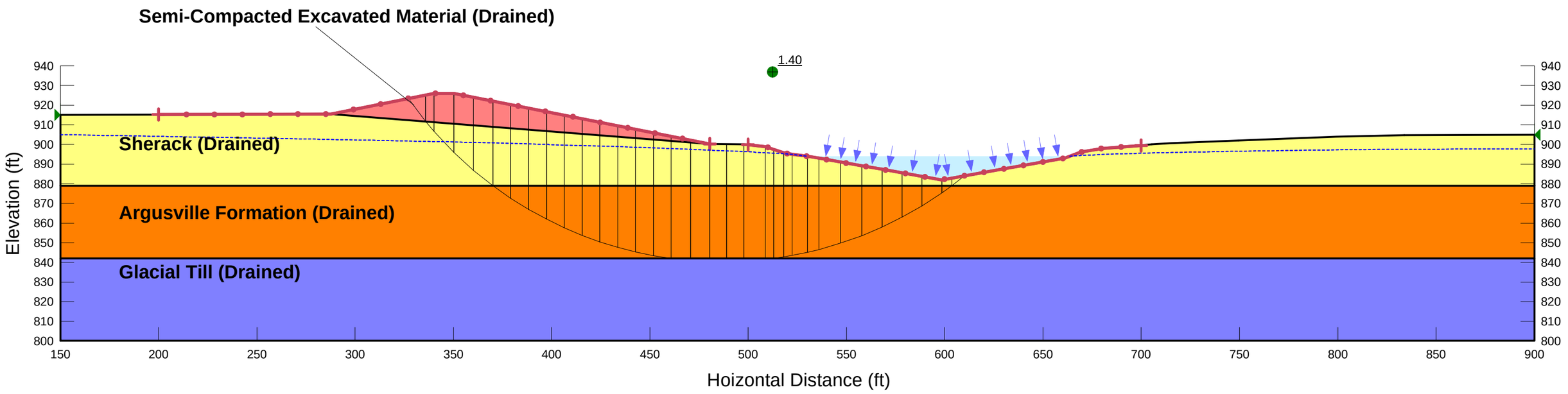
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.40

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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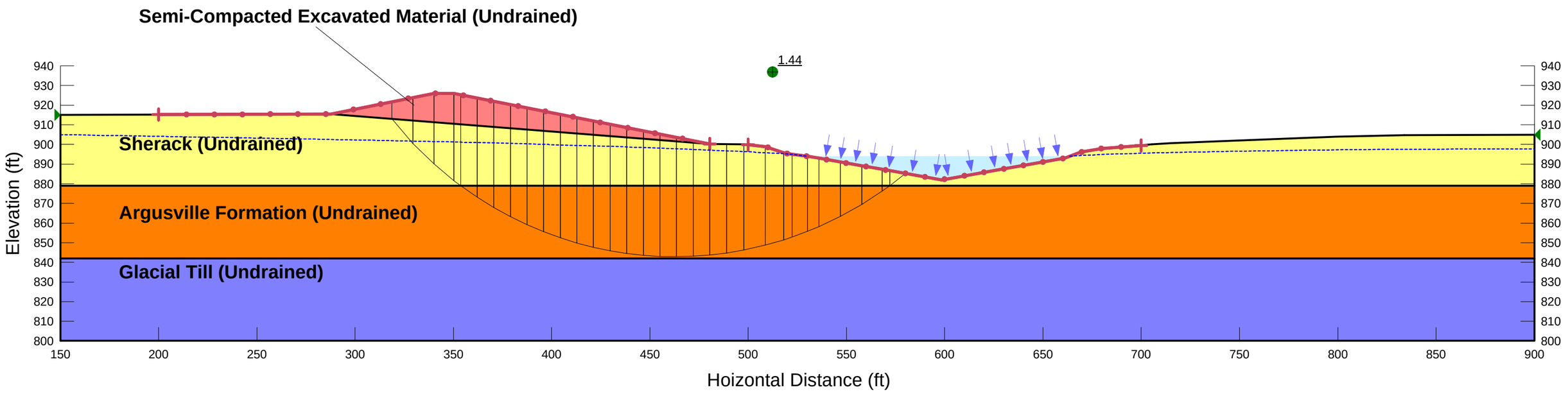
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.44

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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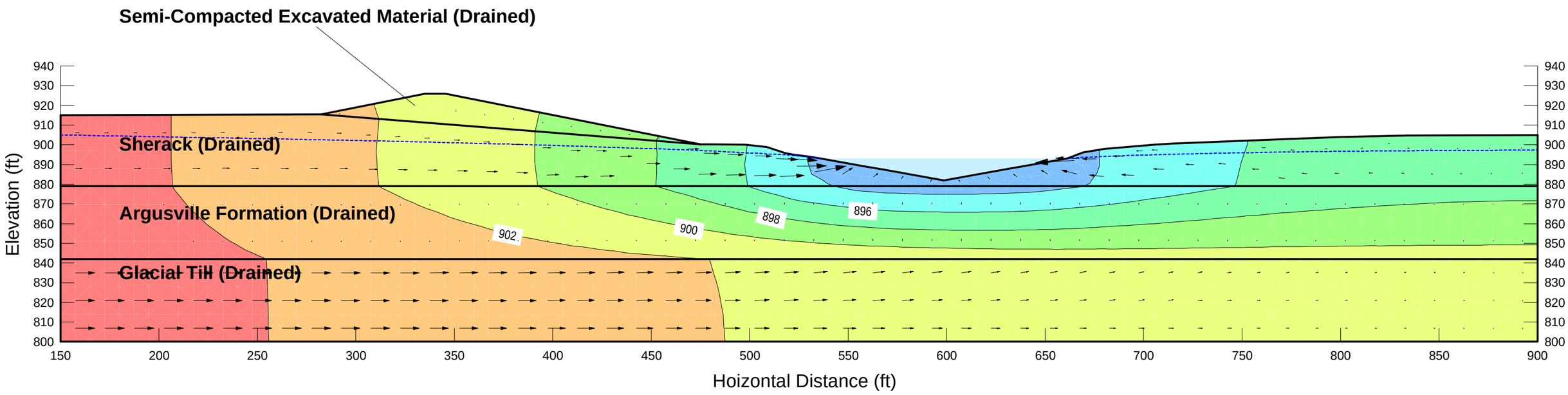
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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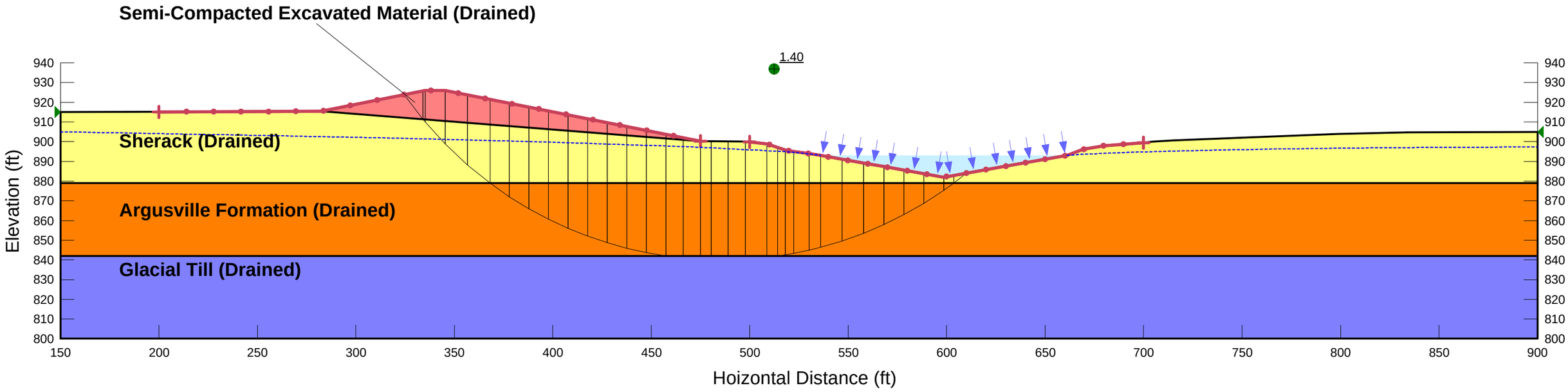
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.40

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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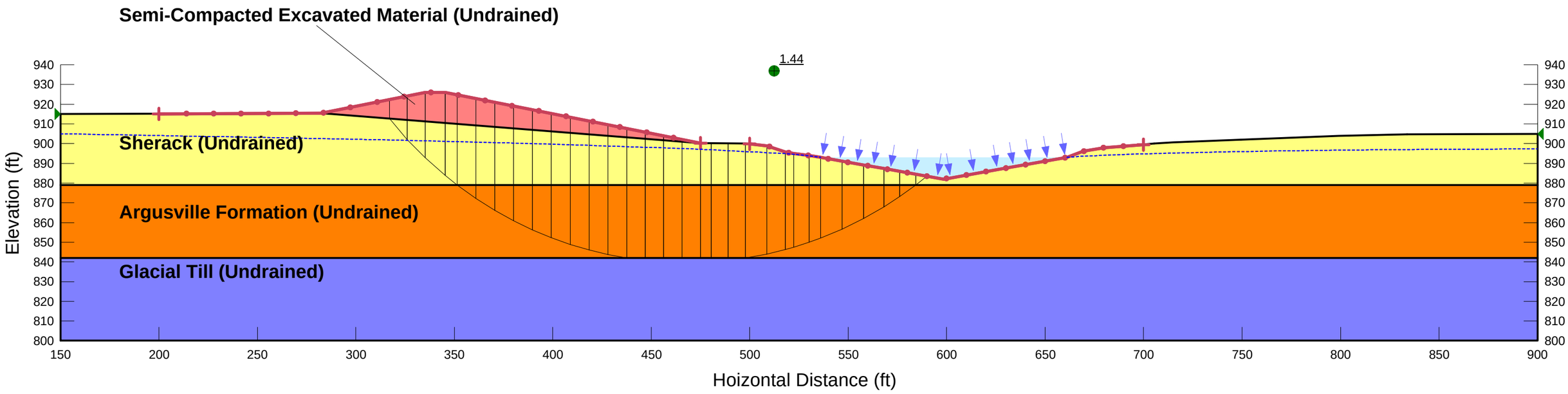
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.44

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf



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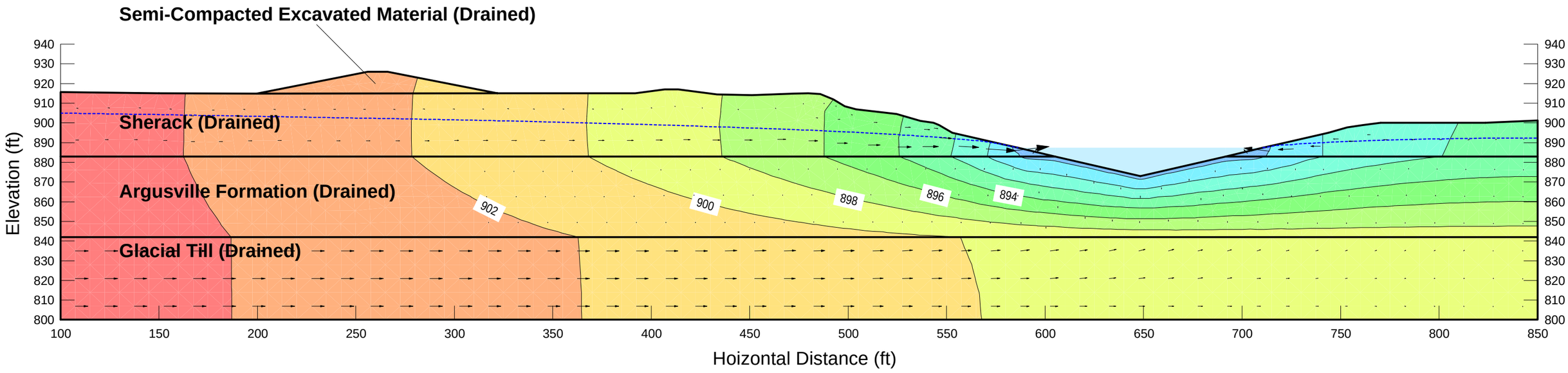
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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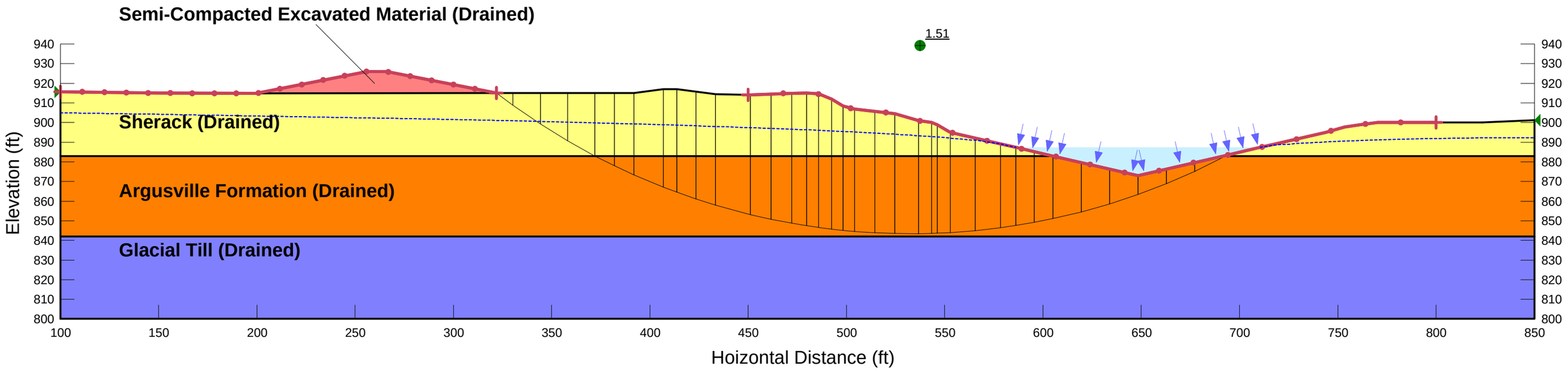
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.51

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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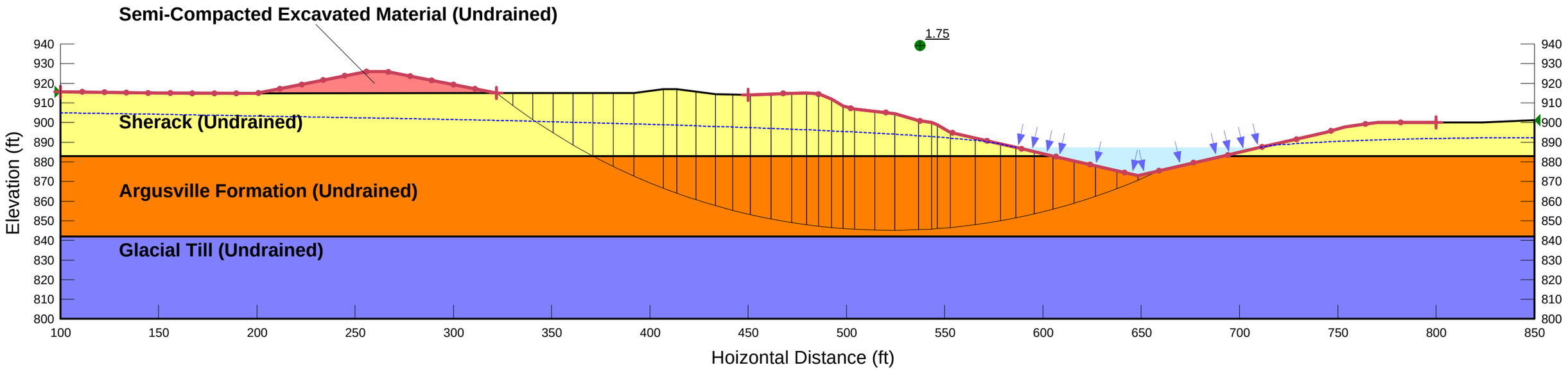
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.75

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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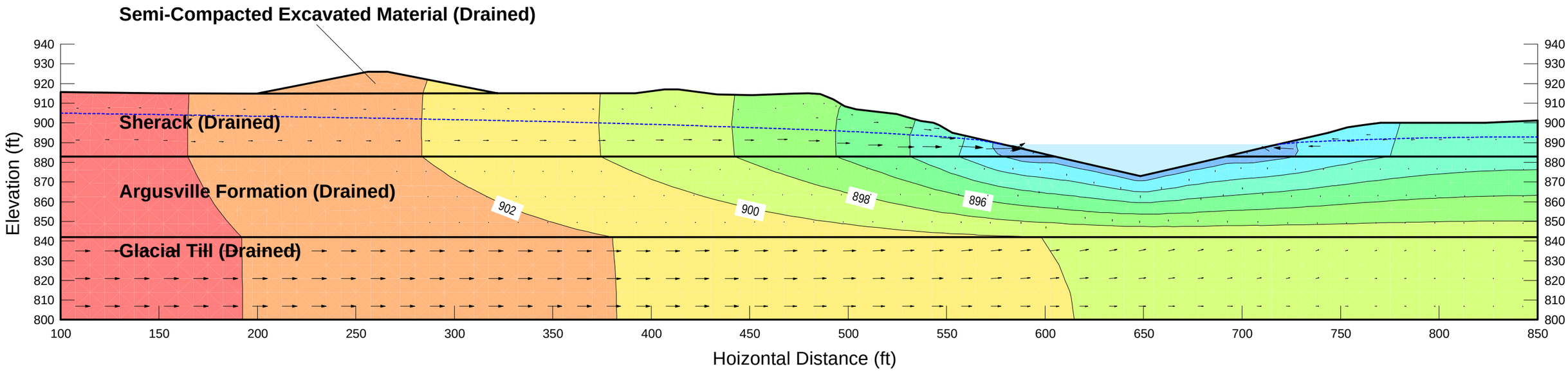
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012

Contours are Total Head in Feet

Name: Sherack (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °
Name: Semi-Compacted Excavated Material (Drained) Model: Saturated / Unsaturated K-Function: Sherack_Formation (k=1.13E-2 ft/day) Vol. WC. Function: Sherack_Formation K-Ratio: 0.25 K-Direction: 0 °



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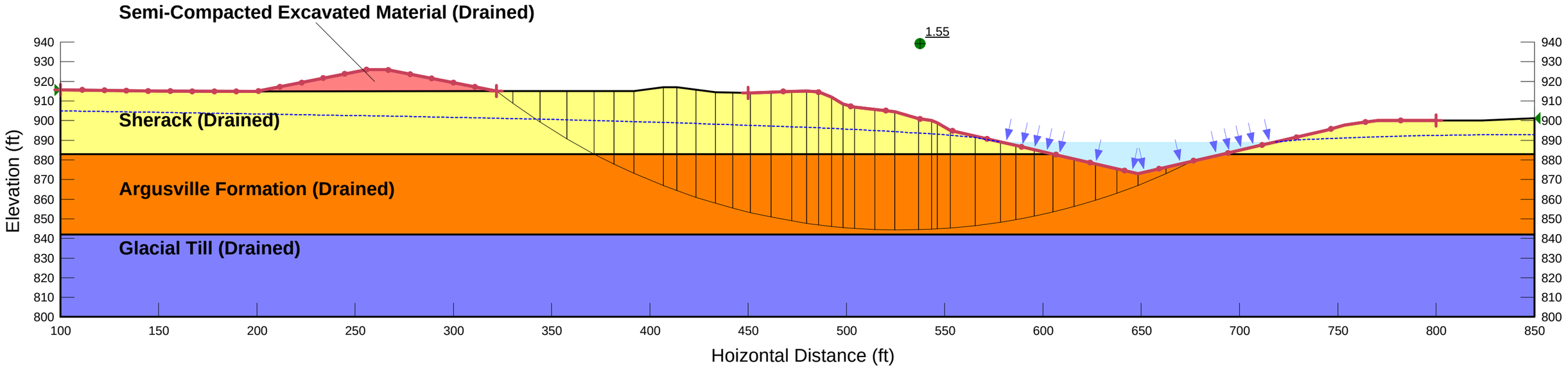
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.55

Name: Sherack (Drained) Model: Bilinear Unit Weight: 115 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Drained) Model: Bilinear Unit Weight: 123 pcf Cohesion: 0 psf Phi 1: 28 ° Phi 2: 11 ° Bilinear Normal: 2000 psf



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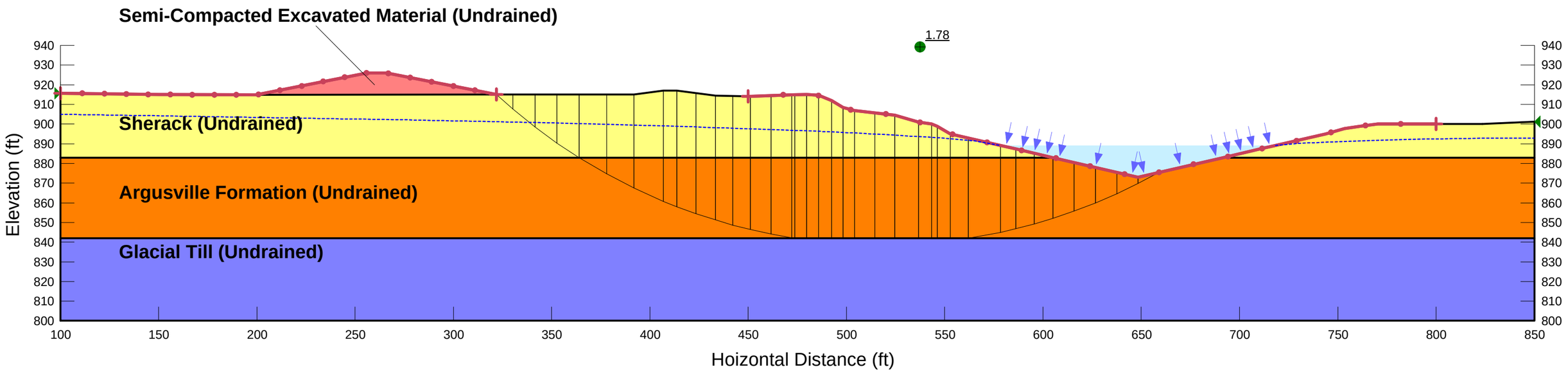
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 11/29/2012
Factor of Safety: 1.78

Name: Sherack (Undrained) Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 900 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)
Name: Semi-Compacted Excavated Material (Undrained) Model: Mohr-Coulomb Unit Weight: 123 pcf Cohesion: 900 psf Phi: 0 °



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Technical Memorandum

To: Mr. Kyle Volk, Moore Engineering, Inc.
From: Eric Brandner and Michael Haggerty, P.E.
Subject: Oxbow Levee Slope Stability Analysis
Date: July 31st, 2012
Project: 34091004

At the request of Moore Engineering (Moore), Barr Engineering Company (Barr) has performed a slope stability analysis for the Fargo-Moorhead Flood Diversion Project. The stability analysis was performed for levees near the town of Oxbow, located in North Dakota along the Red River, south of the proposed Fargo-Moorhead diversion channel alignment. This memo discusses the approach, analysis, and results of the Oxbow levee analysis.

Geotechnical Data

This project utilizes geotechnical parameters developed for the main portion of the Fargo-Moorhead Flood Diversion Project. A site-specific investigation was not conducted. Stratigraphy was estimated from available borings and cone penetration test (CPT) soundings in the general vicinity. Surficial geometry for the proposed levees was provided by Moore and reviewed by Barr to determine critical sections of the levee alignment.

Stability Analysis

The slope stability analysis was conducted using SLOPE/W, part of the GeoStudio 2007 Version 7.19 software package. SLOPE/W uses the limit equilibrium theory to compute the factor of safety of earth and rock slopes. In the limit equilibrium approach, the geologic material is assumed to be at the state of limiting equilibrium and a factor of safety is computed. Spencer's method was used to calculate the factor of safety of the levee cross-sections in this stability analysis using a 5-foot minimum slip surface depth. This method is considered an adequate limit equilibrium method because it satisfies all conditions of static equilibrium and provides a factor of safety based on both force and moment equilibrium.

In SLOPE/W, the critical failure surface was modeled using the entry and exit method. This allows the location of the trial slip surfaces to be chosen manually, or rather where slip surfaces will enter and exit the ground surface, with a chosen number of entry and exit points. The entry point of the potential failure surface was defined to occur at the toe of the proposed levee or farther from the river. The exit point of the potential failure surface was defined to occur in the immediate area of the river or banks of the river.

The pore pressures used in the SLOPE/W model were modeled using SEEP/W analysis which is a finite element modeling program and also part of the GeoStudio 2007 version 7.19 software package. Boundary conditions were set in the seepage model to simulate pore water pressures which are incorporated into the slope stability models. A far field hydraulic boundary condition is assumed for all seepage models and consists of groundwater 10 feet below the ground surface. The 2011 annual low and average Red River water elevations at Oxbow are 887.34 feet and 889.11 feet, respectively. The nominal oxbow lake elevation is 893 feet. The Red River and oxbow lake elevations were provided to Barr by Moore (transmitted on 7/3/2012).

The proposed levees will have 5H:1V side slopes and a crest width of 10 feet. The crest of the levee is approximately 10 feet above surrounding ground surface. Levees are assumed to have the same material properties as Alluvium since they would likely be constructed of shallow borrow materials consisting primarily of Alluvium found in the region.

Two types of stability analyses are typically performed for slopes: the Undrained Strength Stability Analysis (USSA) and the Effective Stress Stability Analysis (ESSA). The USSA is performed to analyze the case in which loading or unloading is applied rapidly and excess pore-water pressures do not have time to dissipate during shearing. This approach is often referred to as the end-of-construction case. The ESSA is performed to account for much slower loading or unloading, or no external loading, in which the drained shear strength of the materials is mobilized and no excess pore-water pressures are allowed to develop. The shear strength used in these analyses is the drained (long-term) strength. The shear strengths in Lake Agassiz clays can be especially low under drained (long-term) conditions because of the mineralogical composition of the material, and the drained strength of the material typically controls the design of stable slopes in the Red River Valley. Thus, the ESSA was the controlling case for slope stability.

Slope stability was examined at three locations (cross-sections A, B, and C) along the proposed levee, as shown in **Attachment A** provided by Moore (transmitted on 7/3/2012). The Red River channel is incorporated into cross-sections A and C as shown on **Figure 1**. Cross-section B intersects an oxbow lake of the Red River. An oxbow lake is a curved stretch of a river channel cut off from the main channel. Fluctuations in water elevation are expected to occur in the Red River while the water level in oxbow lake is expected to stay at a fixed elevation. Surficial relief along each cross-section is also illustrated in **Attachment A**.

For typical long-term conditions, the minimum recommended factor of safety for levees and embankments is 1.40 while 1.30 is recommended for the end-of-construction case according to USACE standard EM 1110-2-1913, Table 6-1b (USACE, 2003).

Stability Model Input Parameters

The assumed stratigraphy near Oxbow consists of the four soil units shown in Table 1. The contacts of these units are based on observations during regional drilling such as changes in color and sand content. These layers are shown in the model output figures in **Attachment B**. Stratigraphy was based on conventional borings and CPT soundings approximately two miles to the north of the project, as shown in **Figure 1** and included in **Attachment C**. The stratigraphic sequencing top down includes: Alluvium, Argusville Formation, Brenna, and unit "A" glacial till. A thin layer of the Brenna Formation was present in one boring log and occurs above the Argusville Formation. Stability modeling performed for all cross sections included modeling both with and without the Brenna to document the effect the formation has on levee stability.

The permeability values used in the SEEP/W analysis are included below in **Table 1**. These values are the established USACE parameters.

Table 1. Material Permeability Properties Summary

Material	Material Model Type	Sample Material	Vertical Permeability		Horizontal Permeability	
			k_y [cm/sec]	k_y [ft/day]	k_y/k_x ratio	k_x [ft/day]
Alluvium	Sat / Unsaturated	Silty Clay	1.0E-06	2.8E-03	0.25	0.0113
Brenna	Sat / Unsaturated	N/A	1.0E-07	2.8E-04	1	0.00028
Argusville	Sat / Unsaturated	N/A	1.0E-07	2.8E-04	1	0.00028
Glacial Till	Sat / Unsaturated	N/A	5.0E-06	1.4E-02	0.25	0.057

Material index and strength properties are based on information provided by the USACE St. Paul District Office in March and April 2012. . **Table 2** summarizes the unit weight and strength properties used in the SLOPE/W analysis.

Table 2. Material Strength Properties Summary

Material	Unit Weight	Shear Strength Parameters			
	γ_{sat}	Drained (ESSA)		Undrained (USSA)	
	[pcf]	ϕ' [deg.]	c' [psf]	ϕ_{cu} [deg.]	c (psf)
Alluvium	120	31	0	0	900
Brenna	106	See curvilinear envelope in Table 3*		0	575
Argusville	110	See curvilinear envelope in Table 3*		0	^
Glacial Till	Impenetrable				

^The Argusville formation ultimate undrained shear strength was assumed to be linearly increasing with depth. Initial cohesion was assumed to be 575 psf, with an increase of 10 psf/FT.

The curvilinear properties for drained strength used in the SLOPE/W analysis are included below in **Table 3**. These values are the established USACE parameters.

Table 3. Curvilinear Properties Summary

Brenna Formation		Argusville Formation	
Effective Normal Stress	Shear Stress	Effective Normal Stress	Shear Stress
σ' [psf]	τ' [psf]	σ' [psf]	τ' [psf]
0	50	0	50
200	120	200	127
1000	333	1000	413
2000	540	200	653
3000	673	3000	893
4000	807	4000	1093
6000	1033	6000	1460
-	-	8000	1740

Stability Model Results

The limit equilibrium slope stability analyses are summarized in **Table 4**. The seepage and slope stability analysis outputs are included in **Attachment B**.

Table 4. Results of Stability Analysis

River Elevation	Model	Section A	Section B	Section B - 5 ft offset	Section C
Low Flow El. 887.34	Global Long Term (ESSA)	1.61	-	-	1.66
	End of Construction (USSA)	1.95	-	-	1.95
	Global Long Term (ESSA) w/ Brenna	1.55	-	-	1.60
	End of Construction (USSA) w/ Brenna	1.92	-	-	1.91
Average Flow El. 889.11	Global Long Term (ESSA)	1.65	-	-	1.70
	End of Construction (USSA)	1.98	-	-	1.99
	Global Long Term (ESSA) w/ Brenna	1.59	-	-	1.64
	End of Construction (USSA) w/ Brenna	1.96	-	-	1.95
Oxbow Pond El 893	Global Long Term (ESSA)	-	1.45	1.48	-
	End of Construction (USSA)	-	1.63	1.66	-
	Global Long Term (ESSA) w/ Brenna	-	1.39	1.42	-
	End of Construction (USSA) w/ Brenna	-	1.58	1.61	-
Oxbow Pond El 894	Global Long Term (ESSA)	-	1.48	-	-
	End of Construction (USSA)	-	1.65	-	-
	Global Long Term (ESSA) w/ Brenna	-	1.42	-	-
	End of Construction (USSA) w/ Brenna	-	1.60	-	-

As shown in Table 4, the factors of safety for cross-sections A and C exceed the minimum requirement of 1.40 (ESSA) and 1.30 (USSA). However, the factor of safety for the global long term (ESSA) w/ Brenna cross-section B resulted in a factor of safety of 1.39 which is below the 1.40 required factor of safety value.

Predicting the presence and thickness of the Brenna Formation is difficult at the project location due to the distance between the project and previous geotechnical investigation sites. The Brenna Formation was only documented in a single boring, so the actual thickness of this formation at the project site is difficult to predict. Further geotechnical exploration in this area is warranted to determine if the Brenna Formation is present. In the event that Brenna is not present at the site, models containing this unit can be disregarded resulting in a stable global long term (ESSA) condition meeting the required factor of safety. Alternatively, the levee could be offset 5 feet to the west from the proposed alignment at this location to account for the possibility of the presence of Brenna Formation below the site. A second option would be maintaining the water level in the oxbow lake at an elevation of 894 feet.

Limitations of Analysis

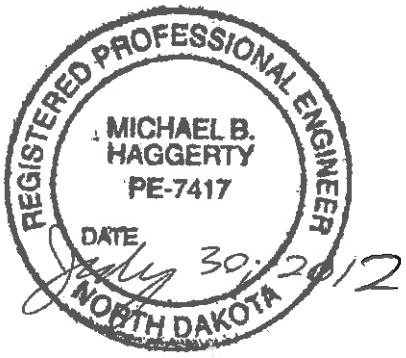
The analysis and conclusions provided are based on the limited dataset available at the time of this analysis. Using generally accepted engineering methods and practices, analyses have been performed using reasonable effort to characterize the site. However, the analyses represent a large area, and variations in stratigraphy, strength, and groundwater conditions may occur. As with any project of this nature with limited data, we recommend site specific investigations to confirm our assumptions and develop site specific parameters for use in modeling.

Certification

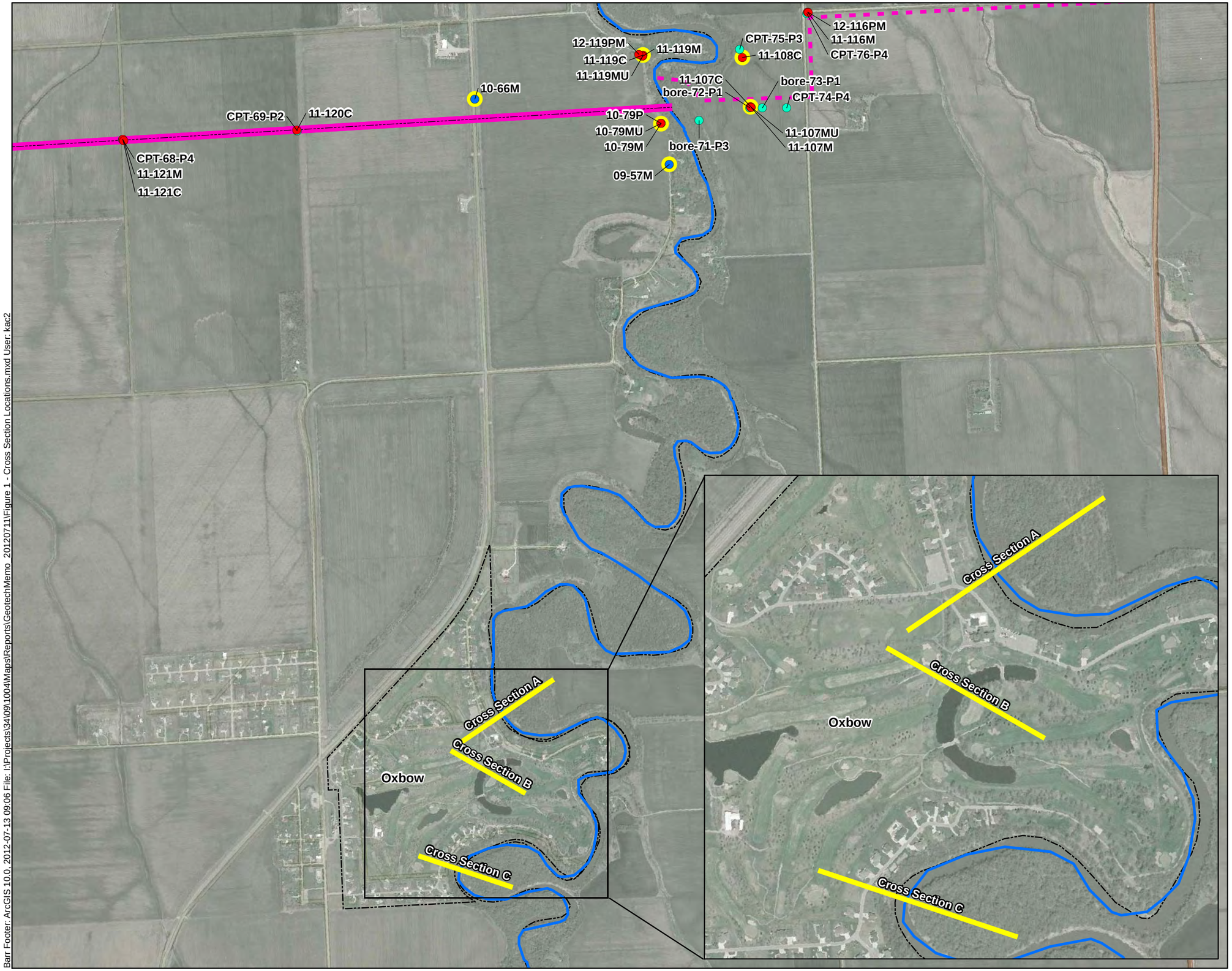
I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of North Dakota.

Michael B. Haggerty (Reg. #PE-7417)

July 30, 2012
Date



Figures



Cross Section Locations
Phase 3 USACE Borings/CPT Soundings
Phase 4 USACE Borings/CPT Soundings
Additional USACE Borings / CPT Soundings
Boring/Sounding Used for Stratigraphy
North Dakota Diversion
Locally Preferred Plan (LPP)
LPP Tieback
South of Oxbow Alignment
South of Oxbow Tieback
Storage Area 1

N

0 700 1,400 2,800
Feet

Figure 1

CROSS SECTION LOCATIONS
Fargo - Moorhead Area

Barr Footer: ArcGIS 10.0, 2012-07-13 09:06 File: I:\Projects\34\09\1004\Maps\Reports\GeotechMemo_20120711\Figure 1 - Cross Section Locations.mxd User: kac2

Appendix A

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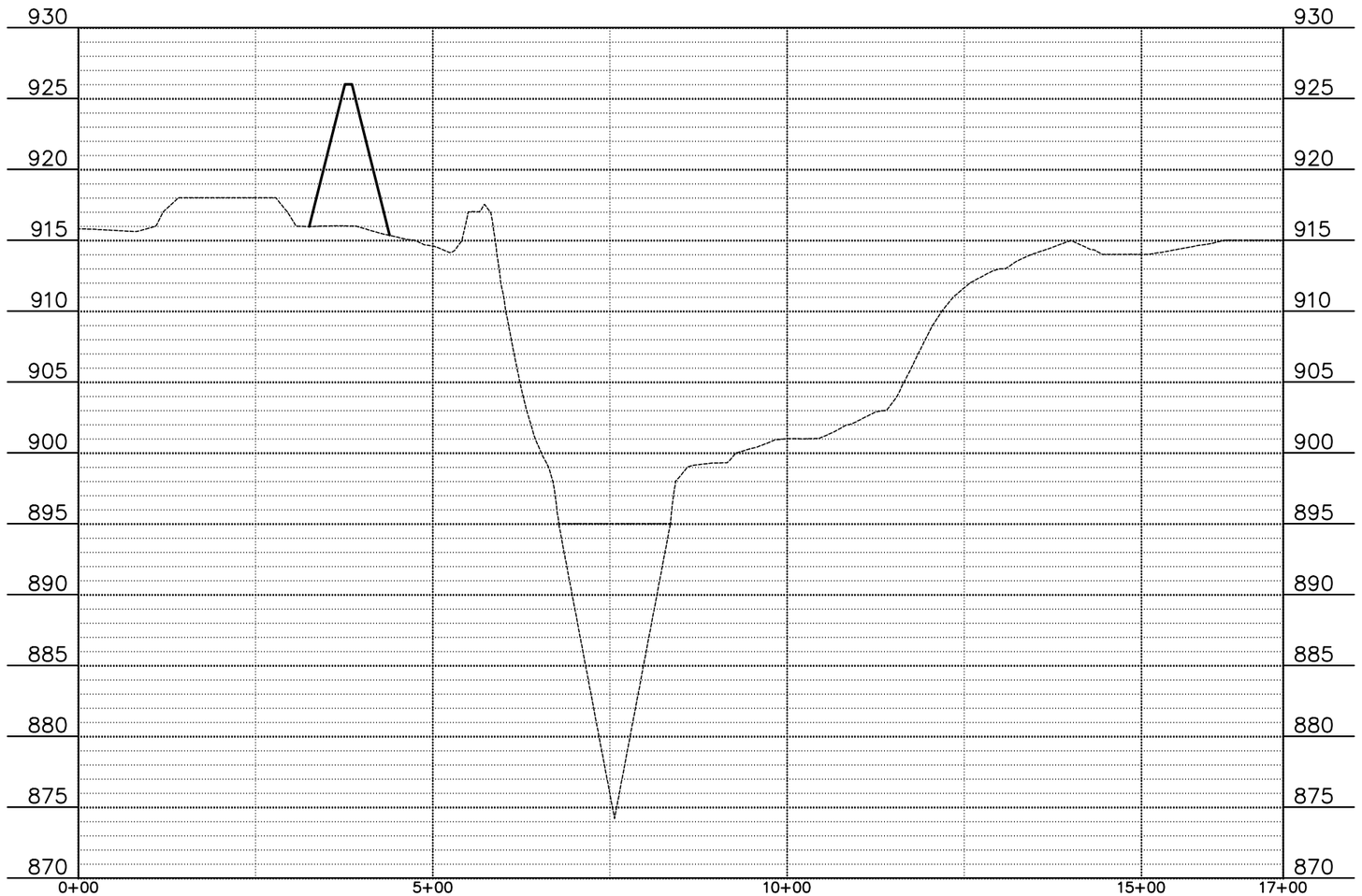
OXBOW CROSS SECTION LOCATION
OXBOW LEVEE EVALUATION
FM METRO DIVERSION
CASS COUNTY, NORTH DAKOTA

DATE	REVISED	PROJECT NO.
06/13/12	07/03/12	16474
CH'D BY	DRAWN BY	SHEET
KMV	KMV	1 OF 1



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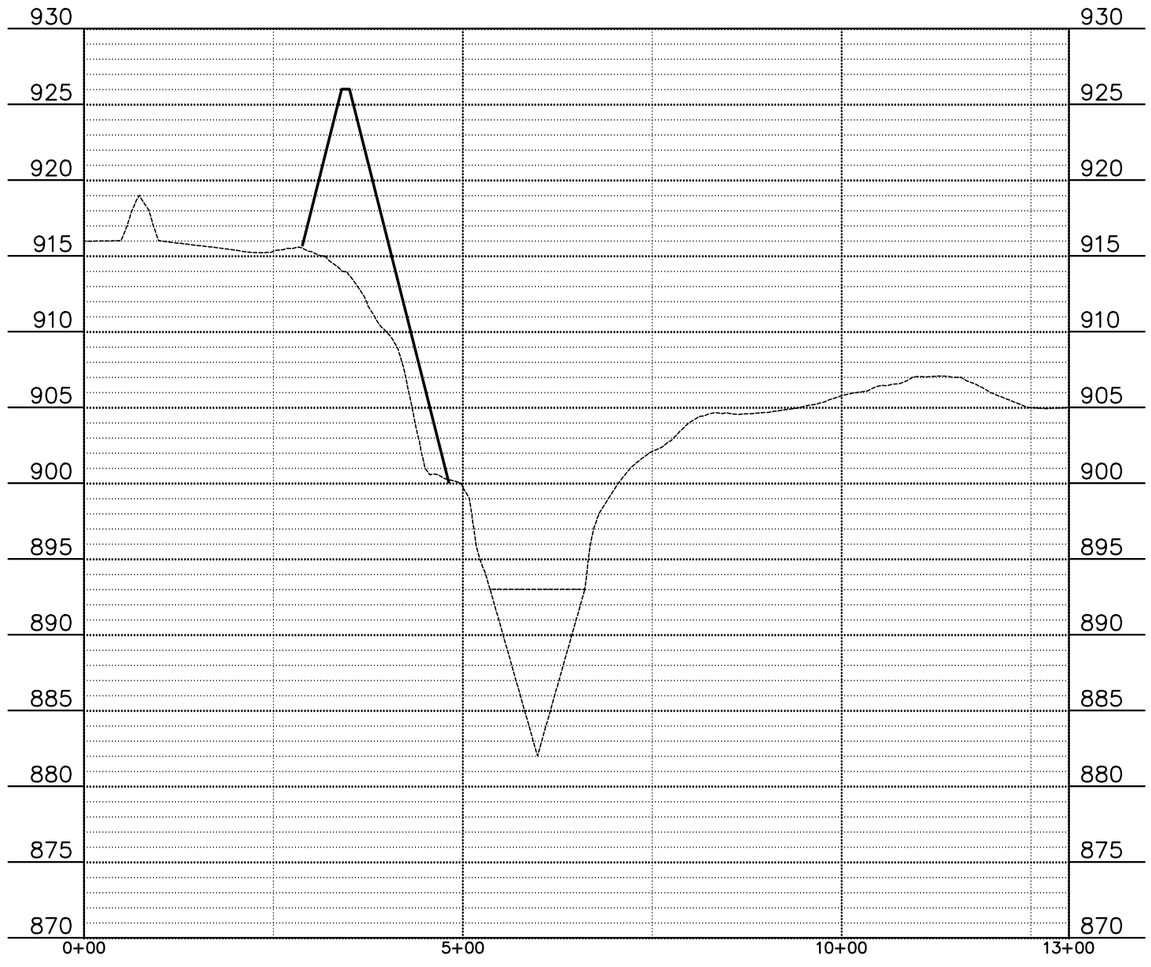
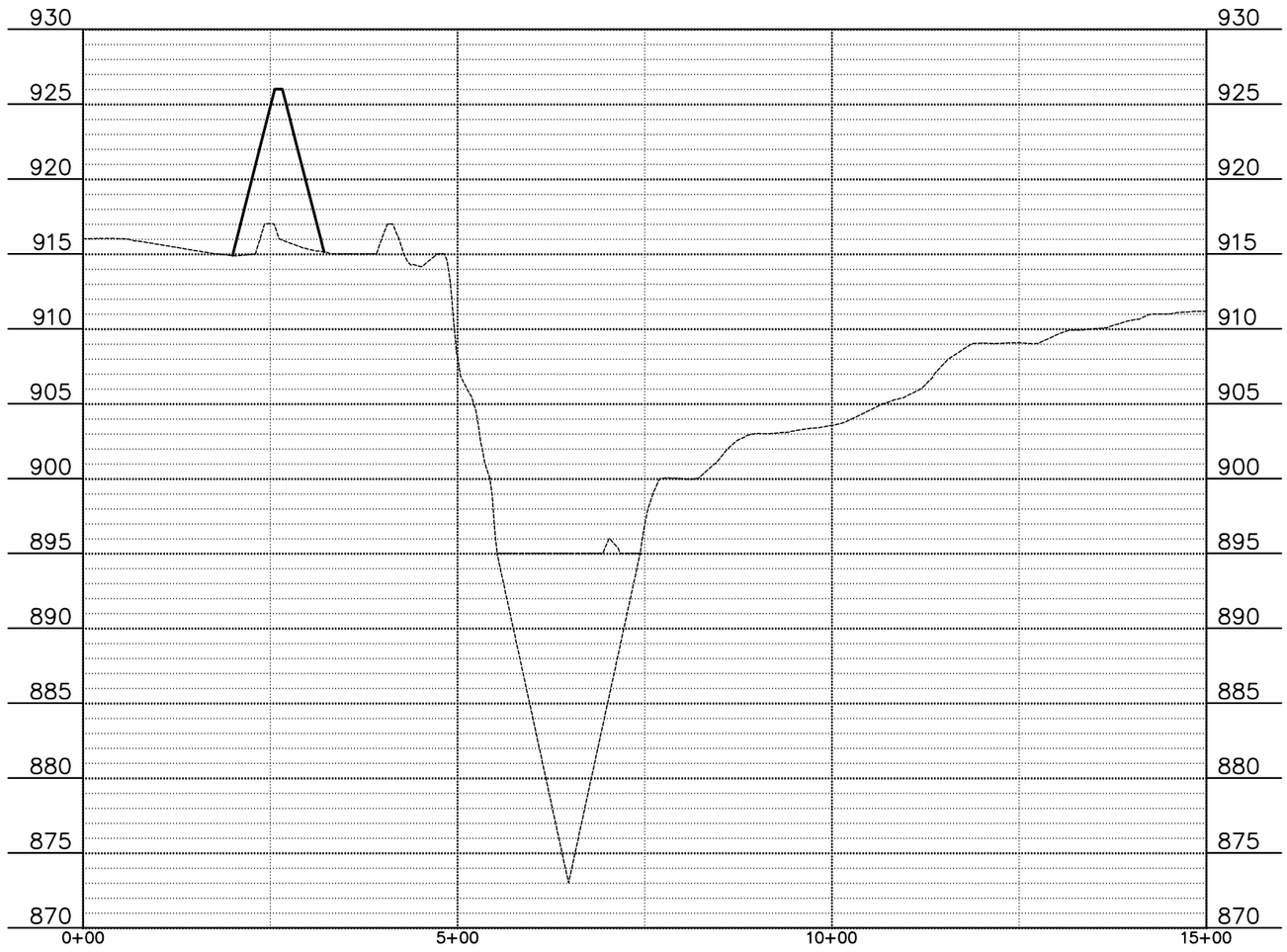
CROSS SECTION A
OXBOW LEVEE EVALUATION
FM METRO DIVERSION
CASS COUNTY, NORTH DAKOTA

DATE	REVISED	PROJECT NO.
06/13/12		16474
SCALE	DRAWN BY	SHEET
H: 1"=200' V: 1"=5'	KMV	1 OF 1



moore engineering, inc. Consulting Engineering • Land Surveying West Fargo, ND • Fergus Falls, MN • Minot, ND www.mooreengineeringinc.com	CROSS SECTION B OXBOW LEVEE EVALUATION FM METRO DIVERSION CASS COUNTY, NORTH DAKOTA	DATE: 06/13/12 SCALE: H: 1"=200' V: 1"=5'	REVISED: DRAWN BY: KMV	PROJECT NO.: 16474 SHEET: 1 OF 1



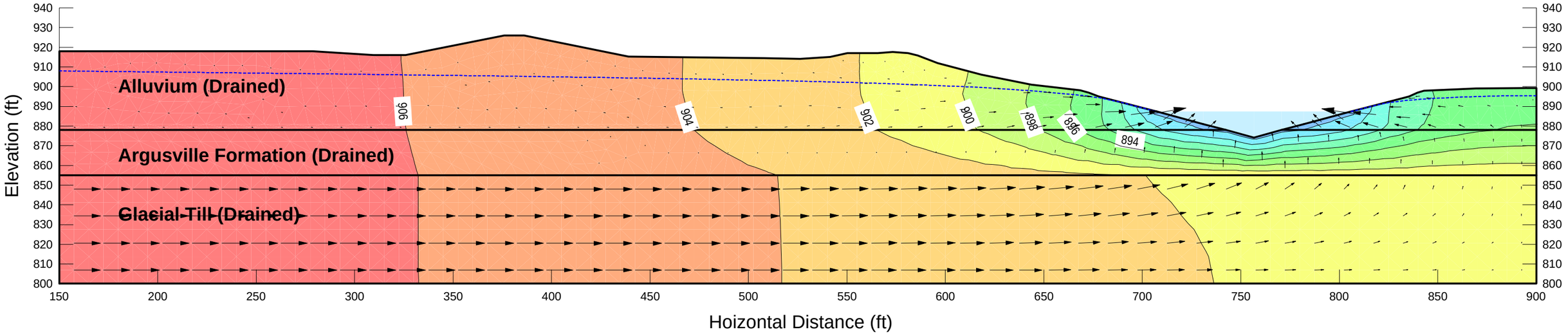
moore engineering, inc. Consulting Engineering • Land Surveying West Fargo, ND • Fergus Falls, MN • Minot, ND www.mooreengineeringinc.com	CROSS SECTION C OXBOW LEVEE EVALUATION FM METRO DIVERSION CASS COUNTY, NORTH DAKOTA	DATE: 06/13/12 SCALE: H: 1"=200' V: 1"=5'	REVISED: DRAWN BY: KMV	PROJECT NO.: 16474 SHEET: 1 OF 1

Appendix B

Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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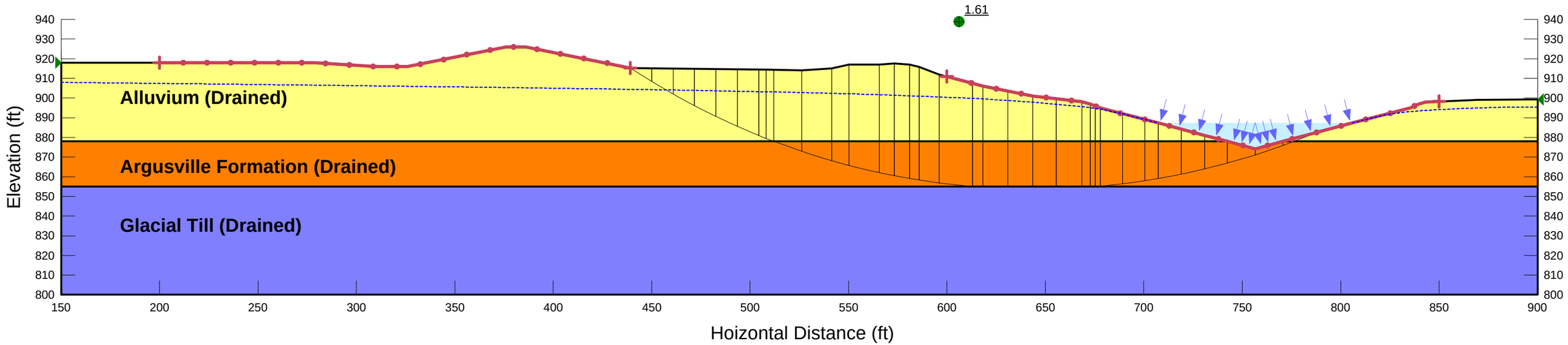
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.61

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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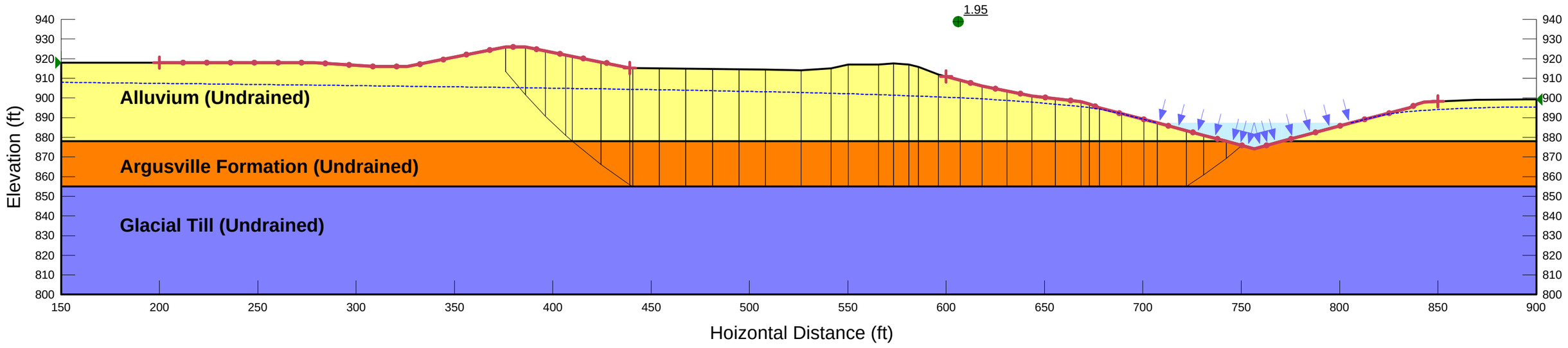
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA -River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.95

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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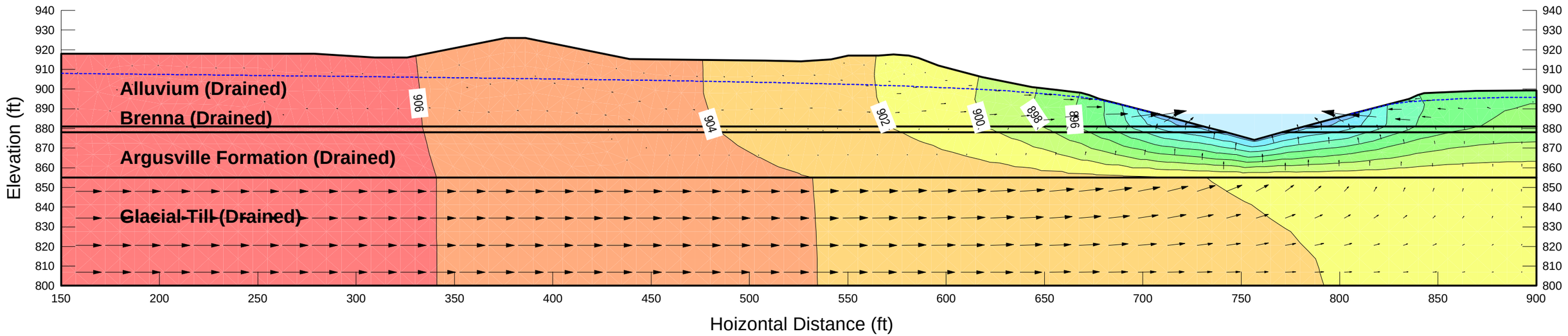
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 887.34 ft (Low Flow) w/ Brenna
File Name: Cross Section A.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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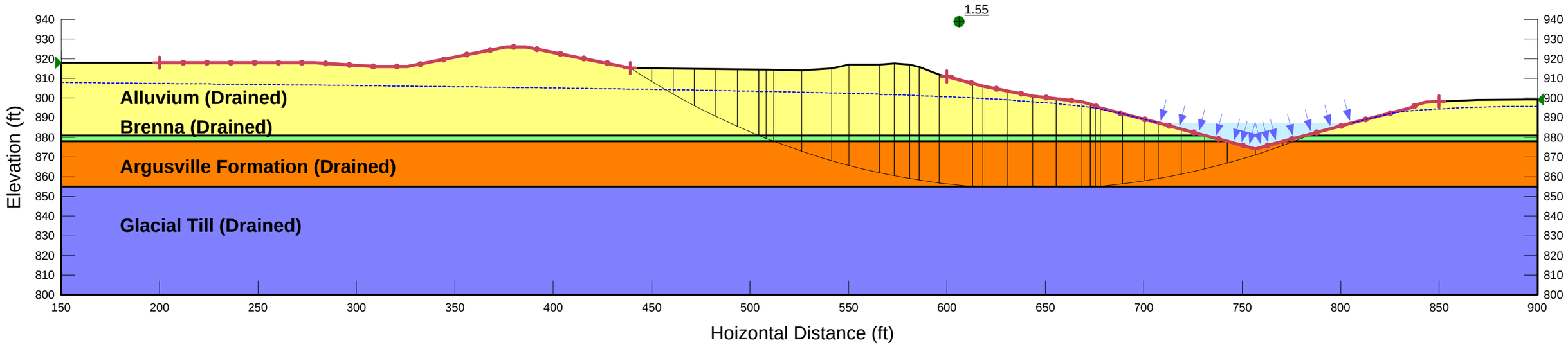
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA w/ Brenna - River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.55

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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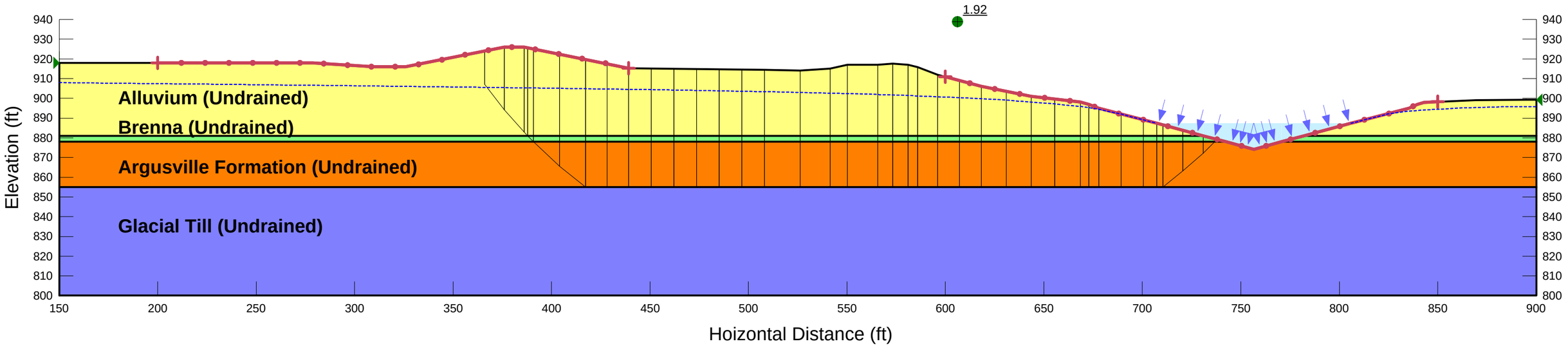
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA w/ Brenna - River El. 887.34 ft (Low Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.92

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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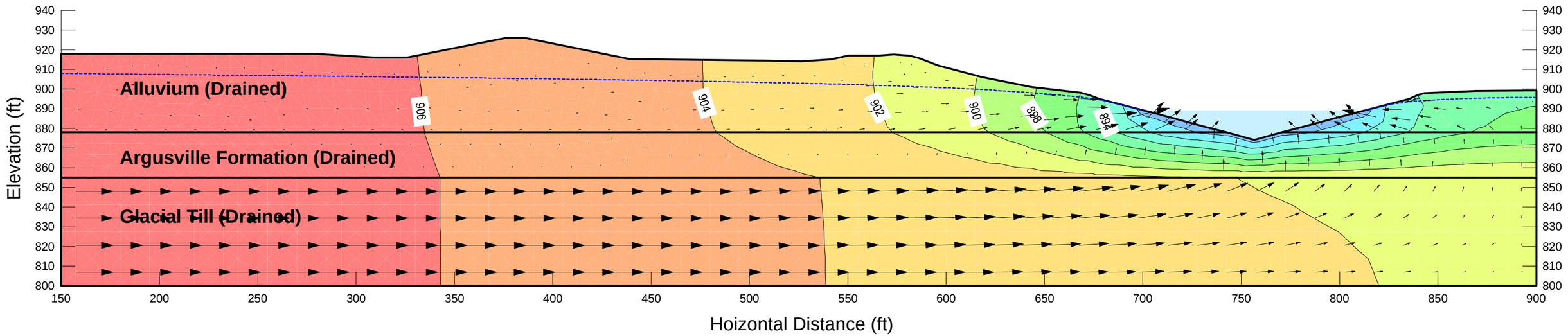
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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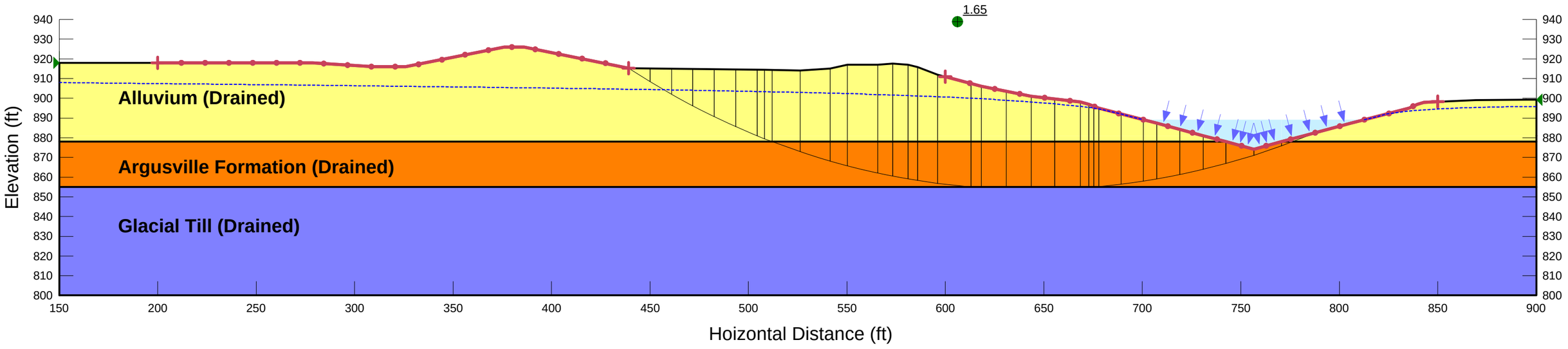
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.65

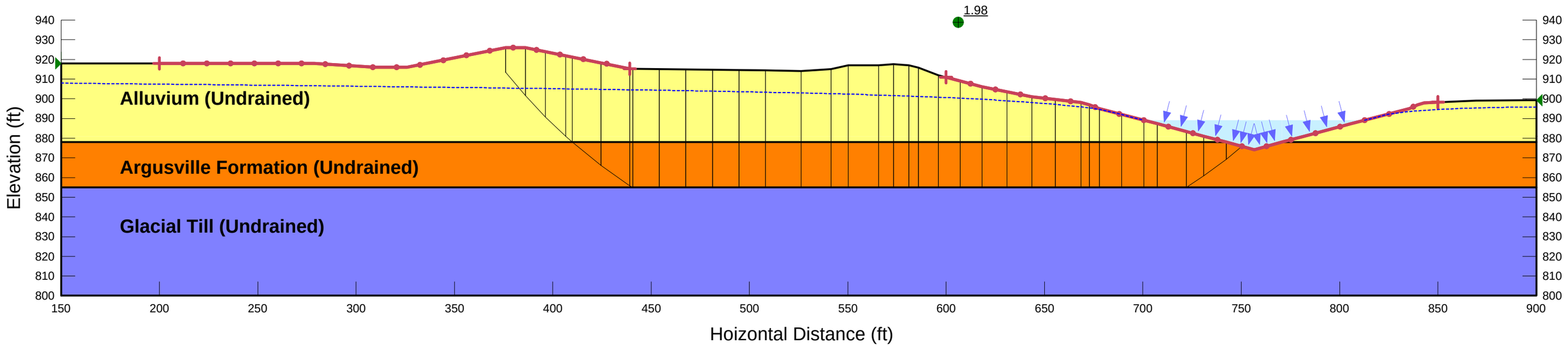
Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_afterPhase4\General\Geotech Oxbow\Models\Cross Section A.gsz

Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.98

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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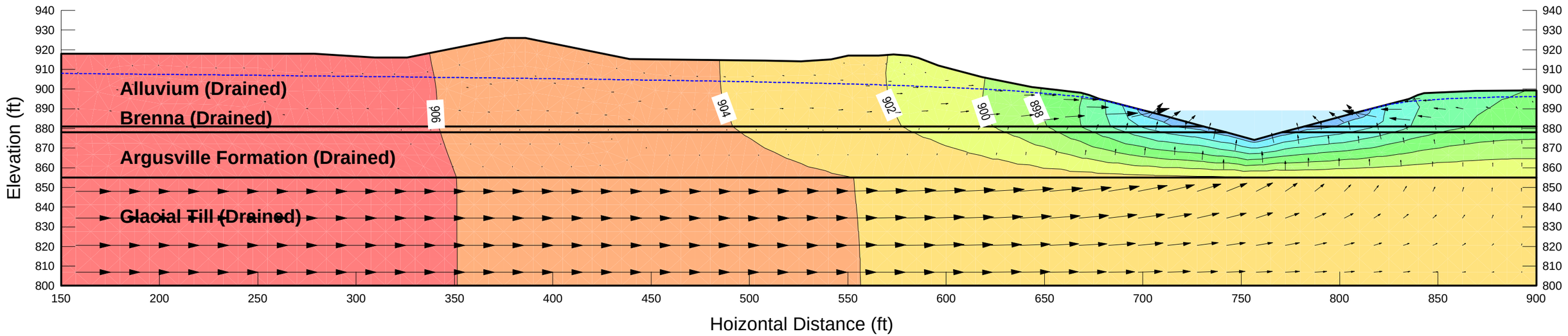
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: River El. 889.11 ft (Average Flow) w/ Brenna
File Name: Cross Section A.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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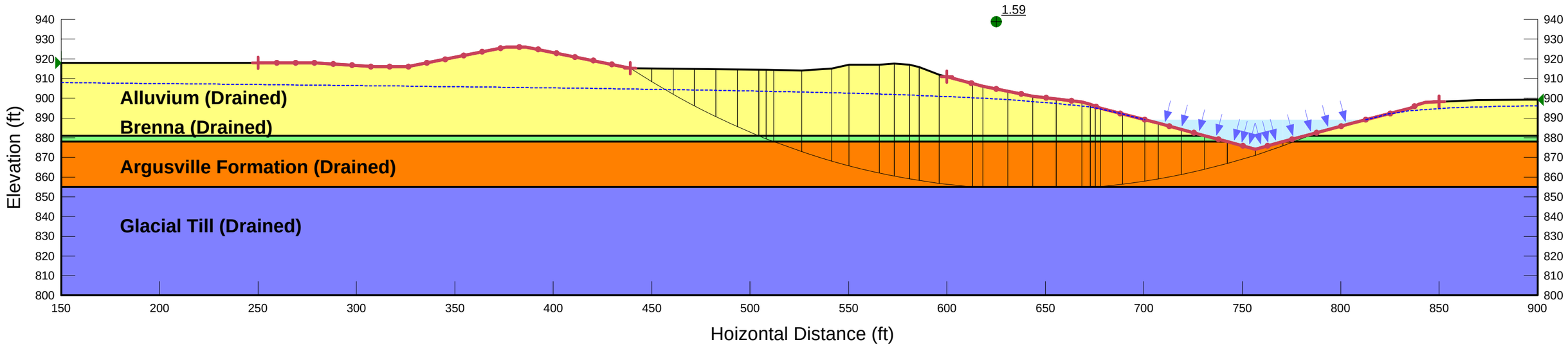
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: ESSA w/ Brenna - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.59

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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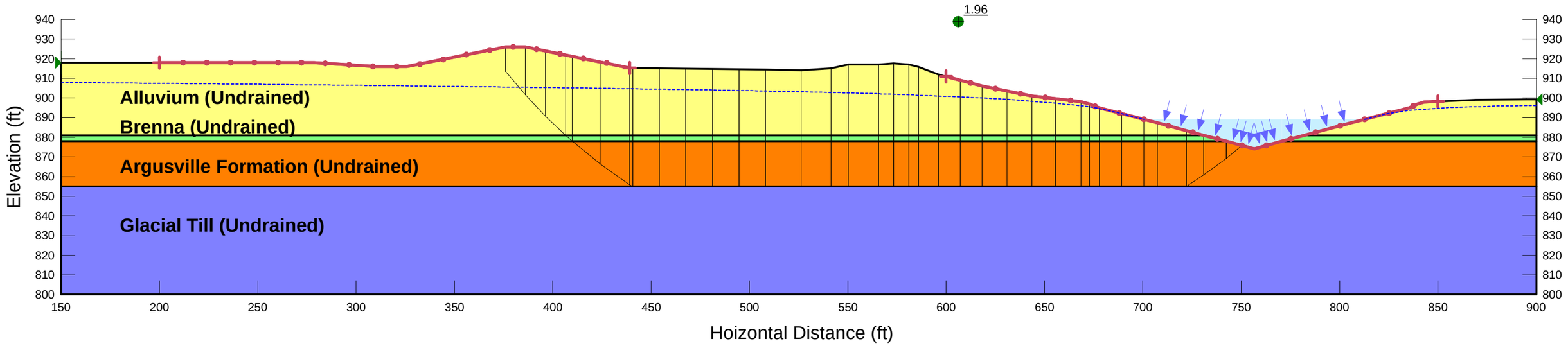
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section A Stability Analysis: USSA w/ Brenna - River El. 889.11 ft (Average Flow)
File Name: Cross Section A.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.96

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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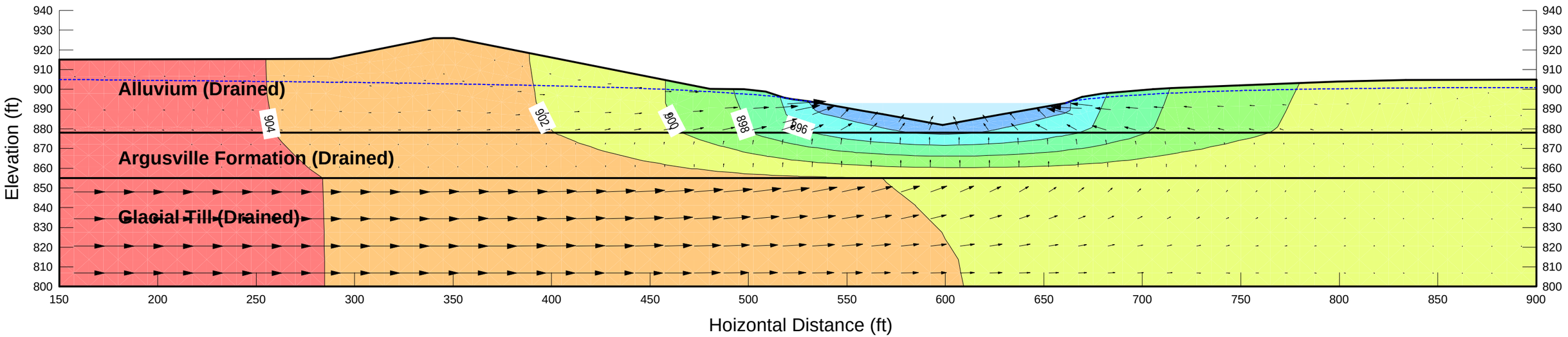
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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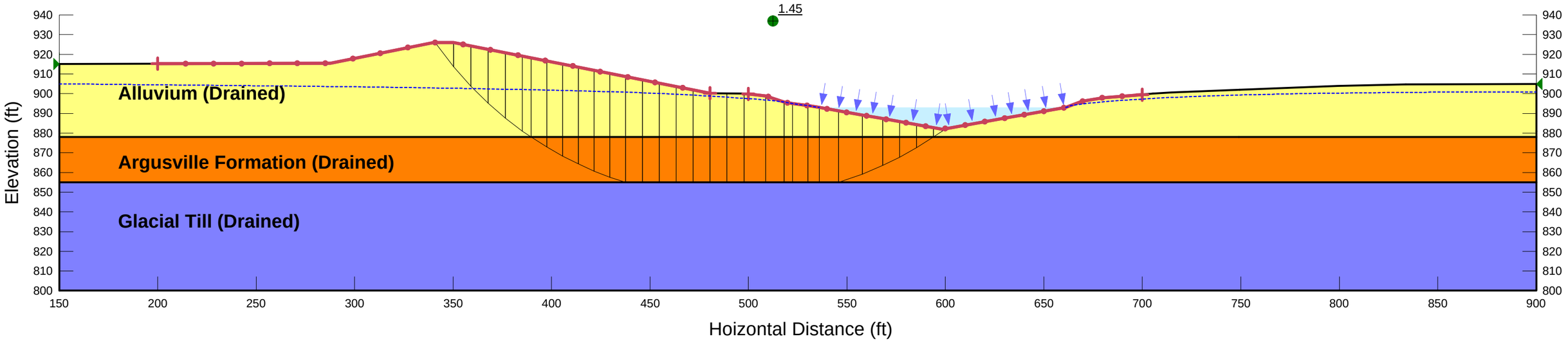
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.45

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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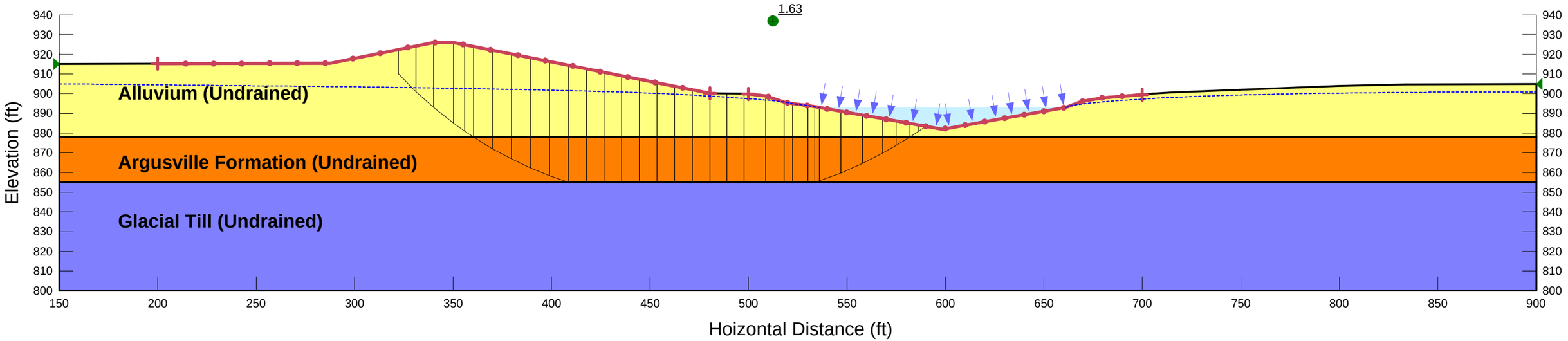
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.63

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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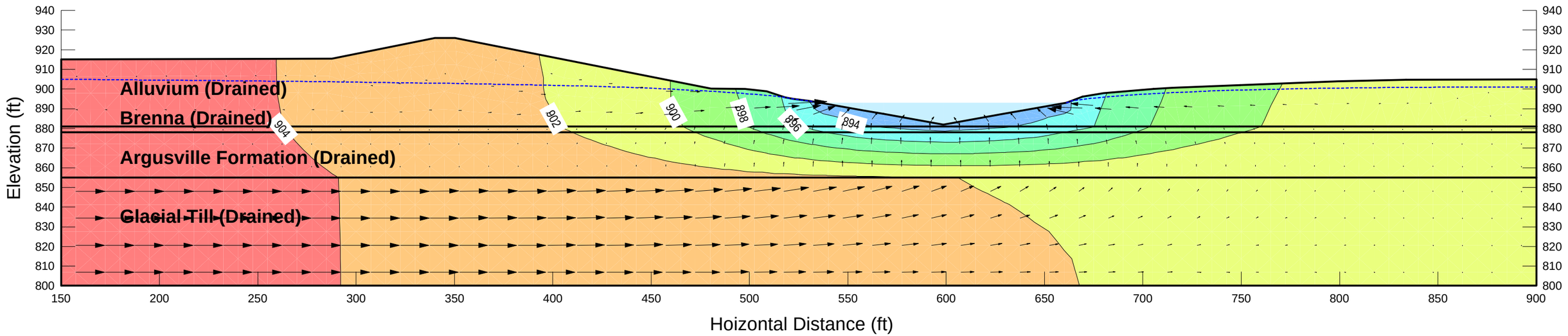
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft w/ Brenna
File Name: Cross Section B.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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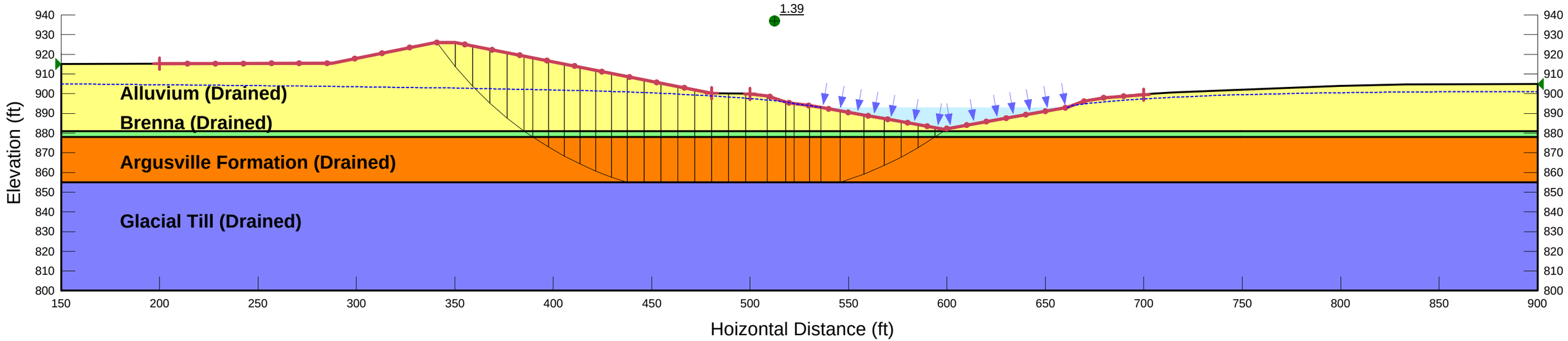
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA w/ Brenna - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.39

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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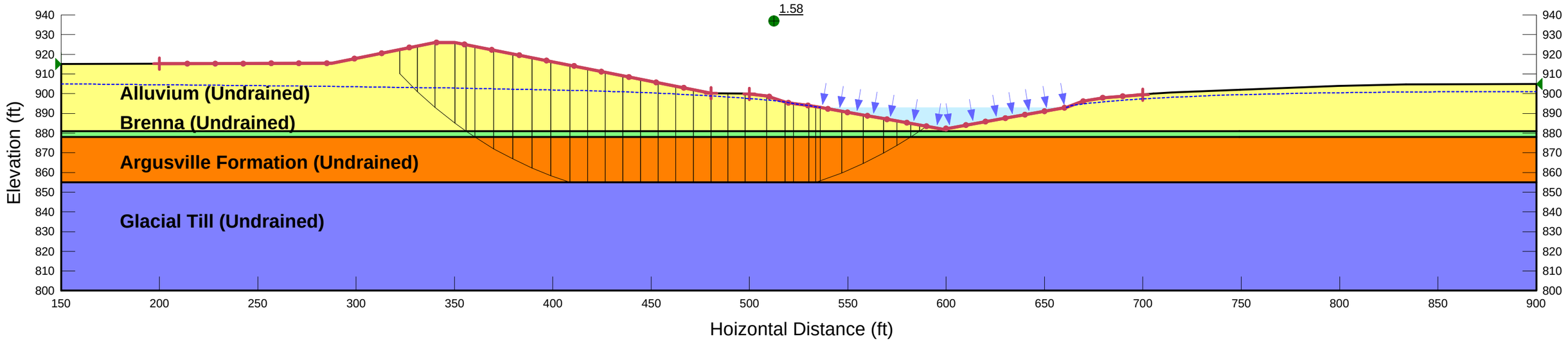
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA w/ Brenna - Oxbow Pond El. 893 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.58

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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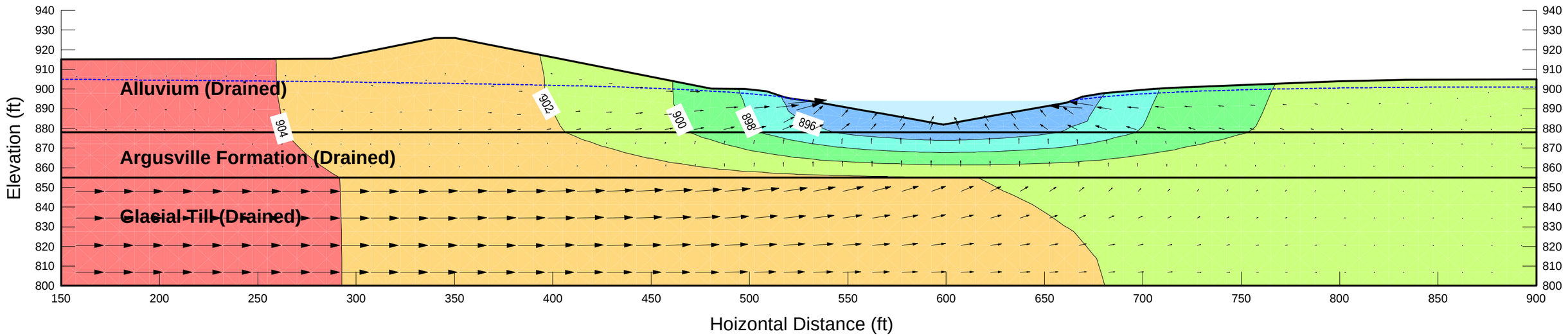
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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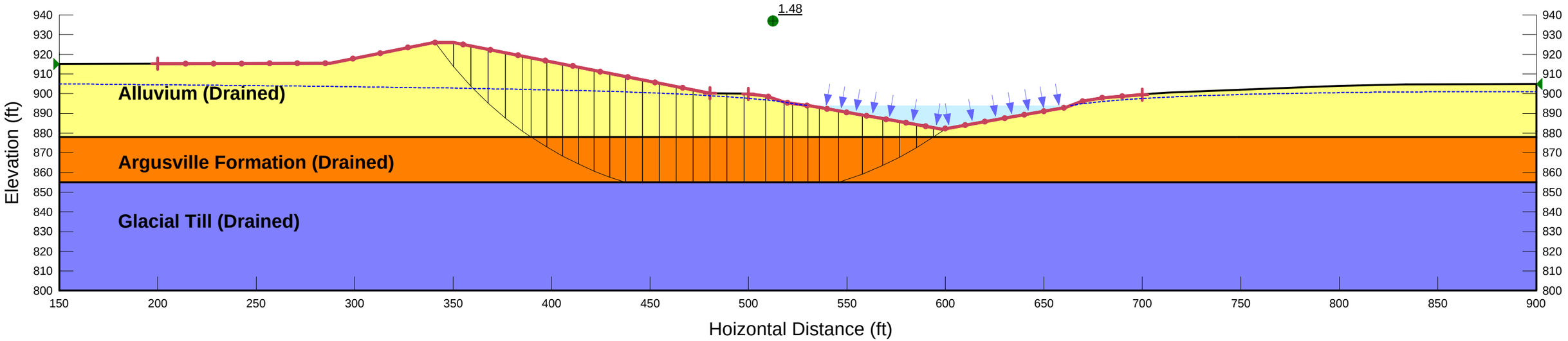
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.48

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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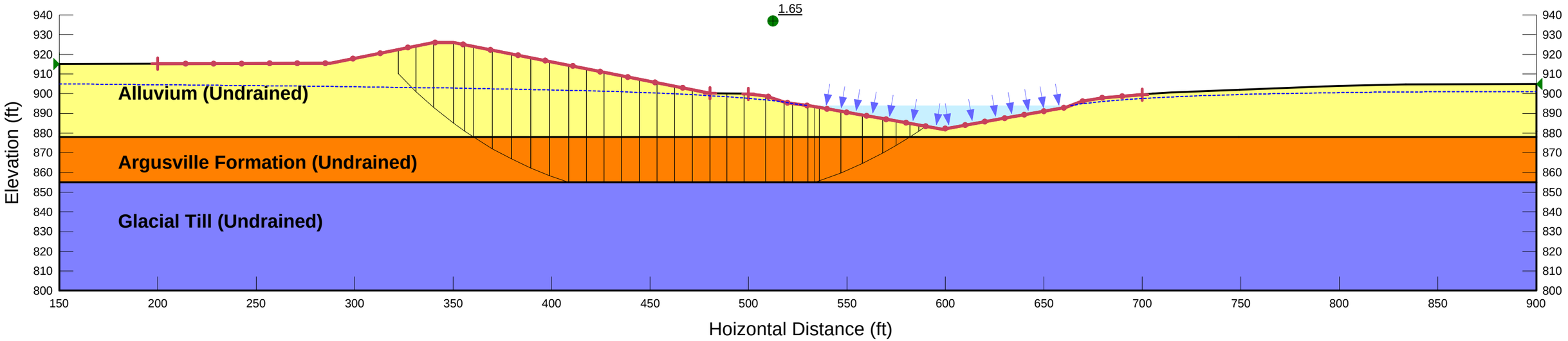
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.65

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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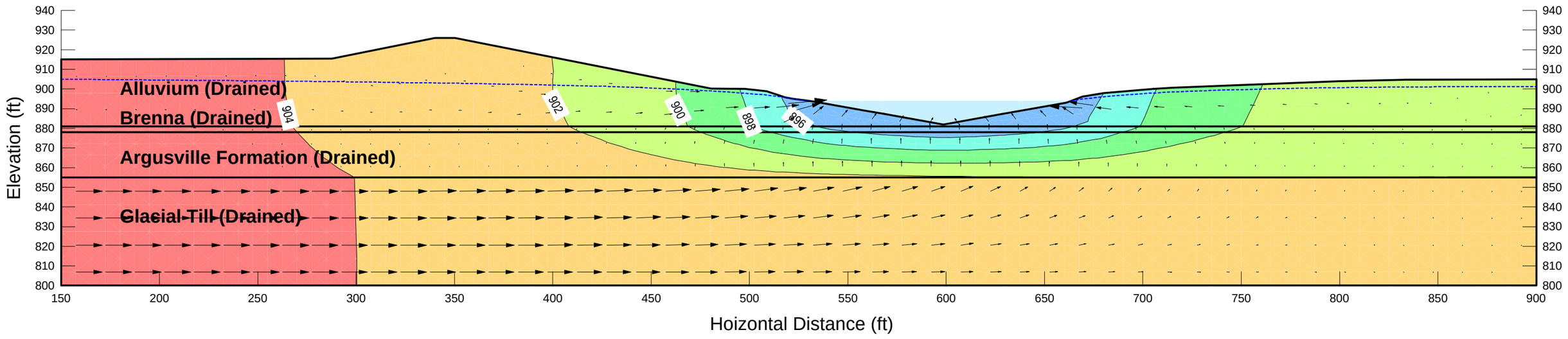
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 894 ft w/ Brenna
File Name: Cross Section B.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

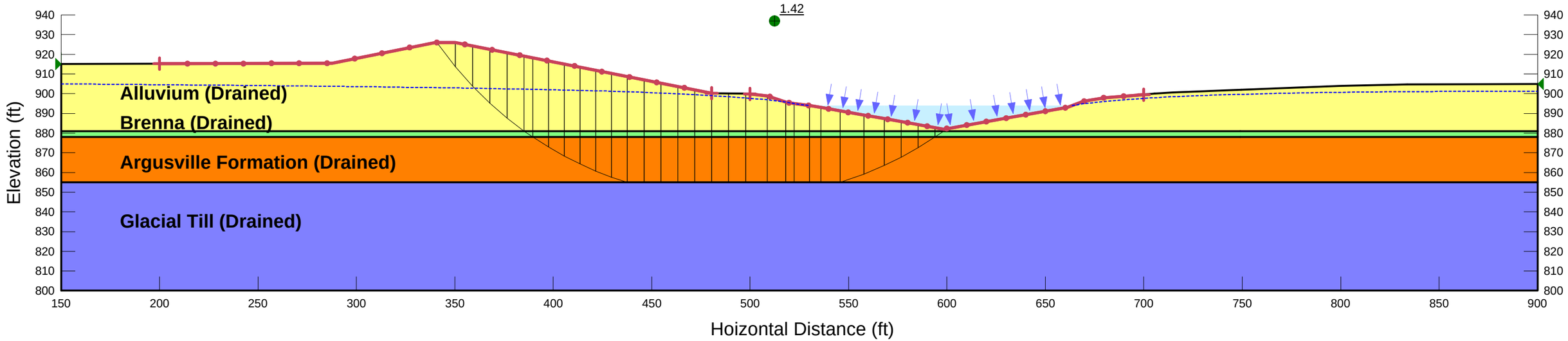
Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_afterPhase4\General\Geotech Oxbow\Models\Cross Section B.gsz

Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA w/ Brenna - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.42

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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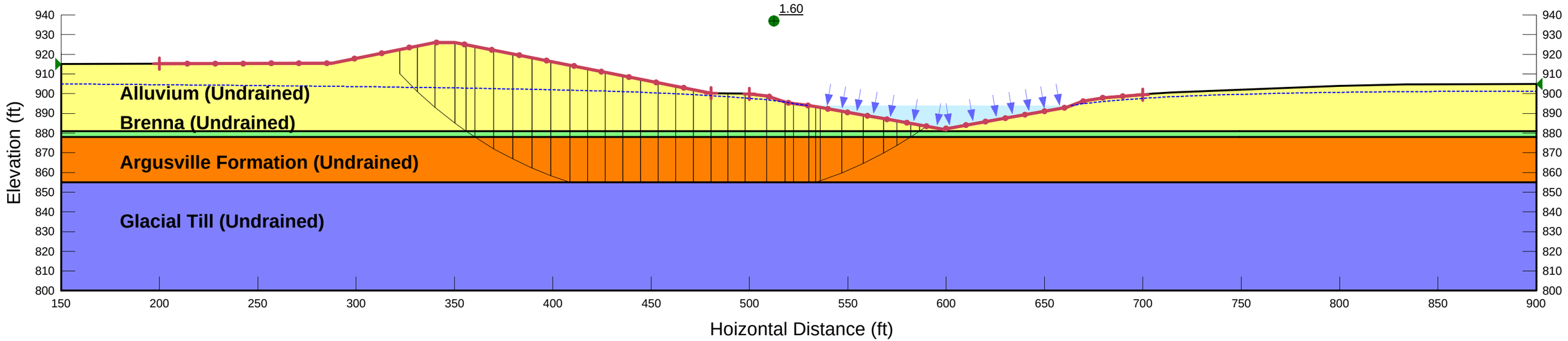
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA w/ Brenna - Oxbow Pond El. 894 ft
File Name: Cross Section B.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.60

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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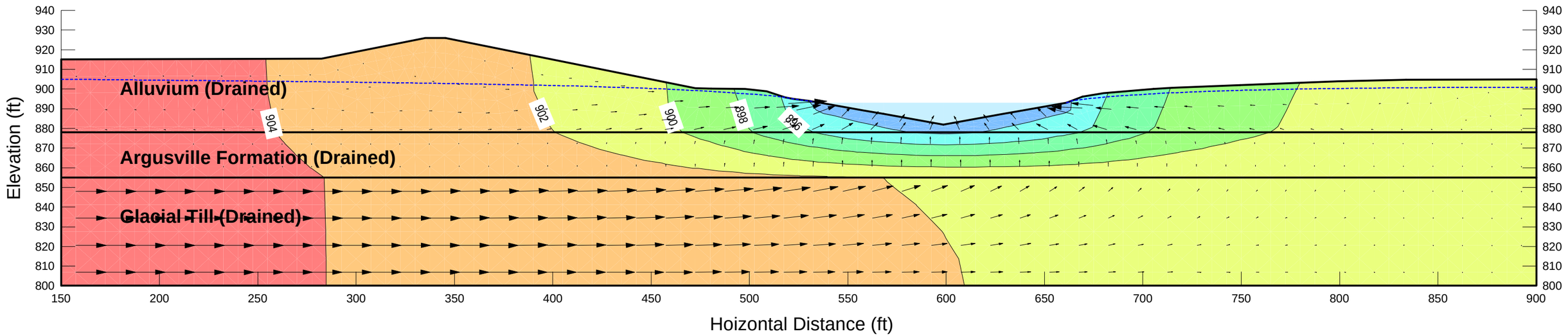
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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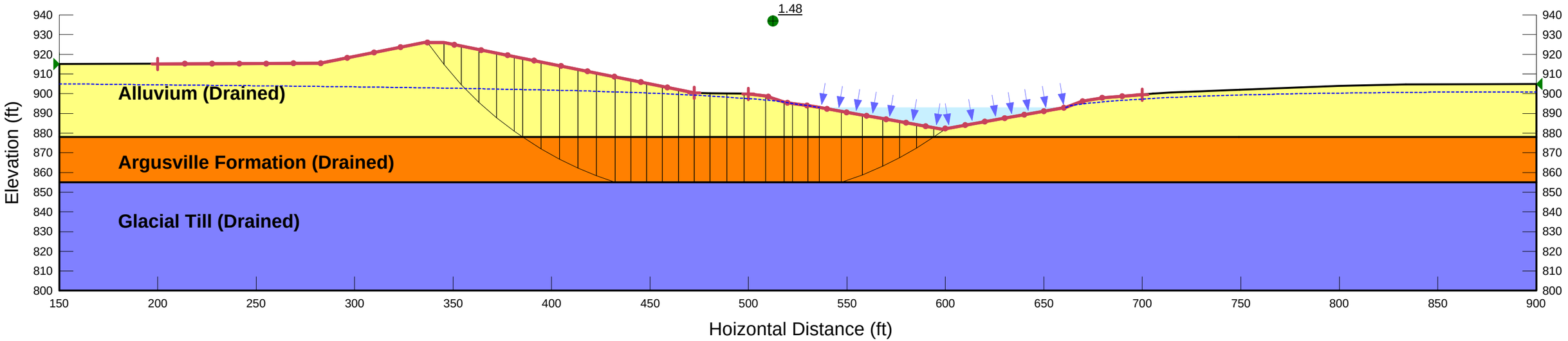
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.48

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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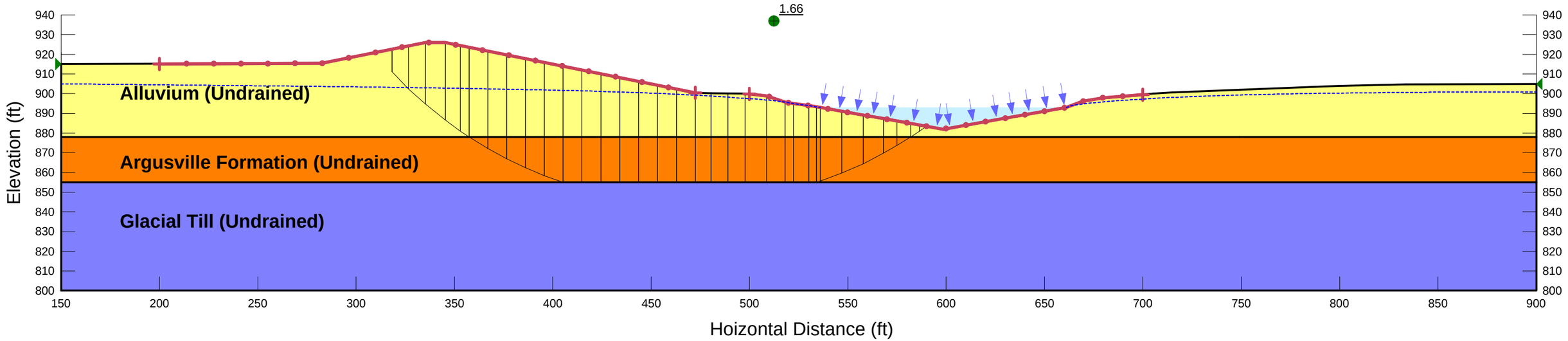
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.66

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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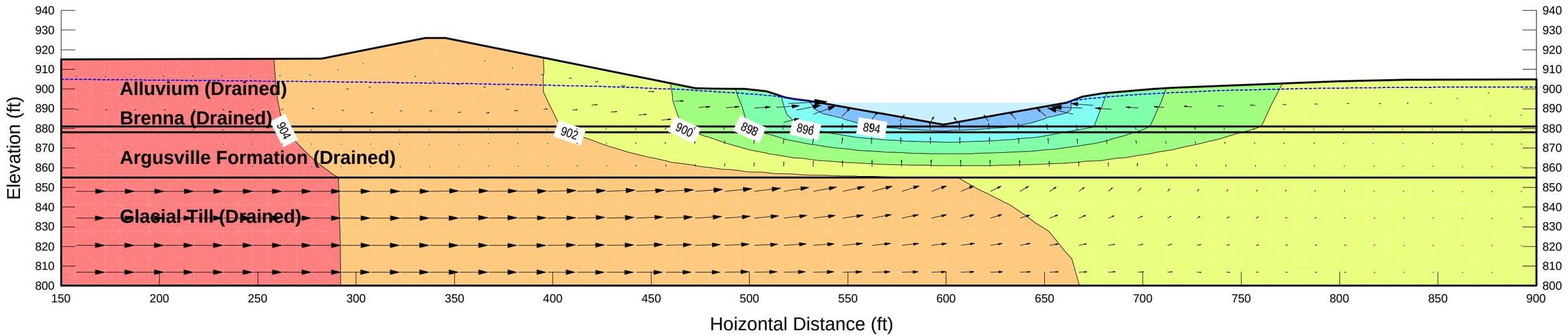
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: Oxbow Pond El. 893 ft w/ Brenna
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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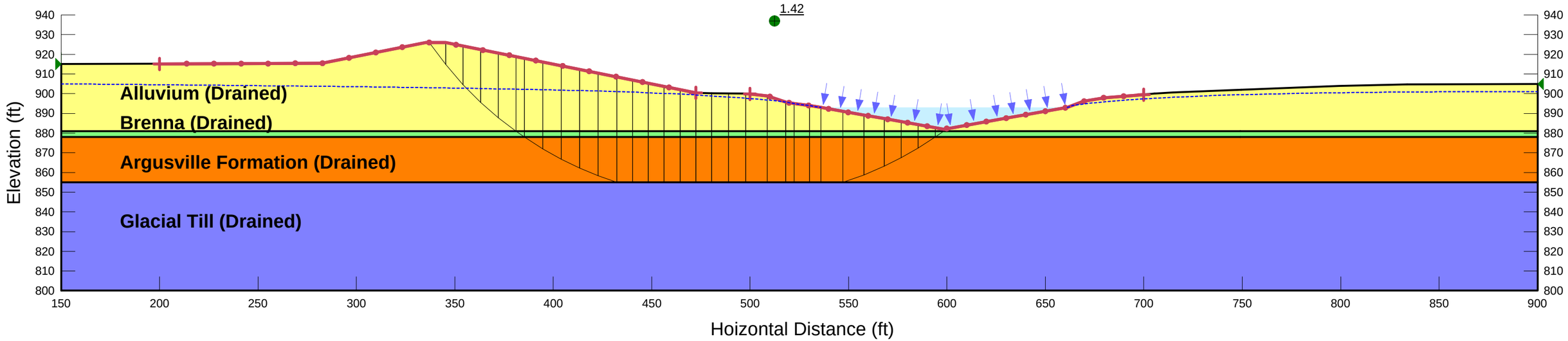
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: ESSA w/ Brenna - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.42

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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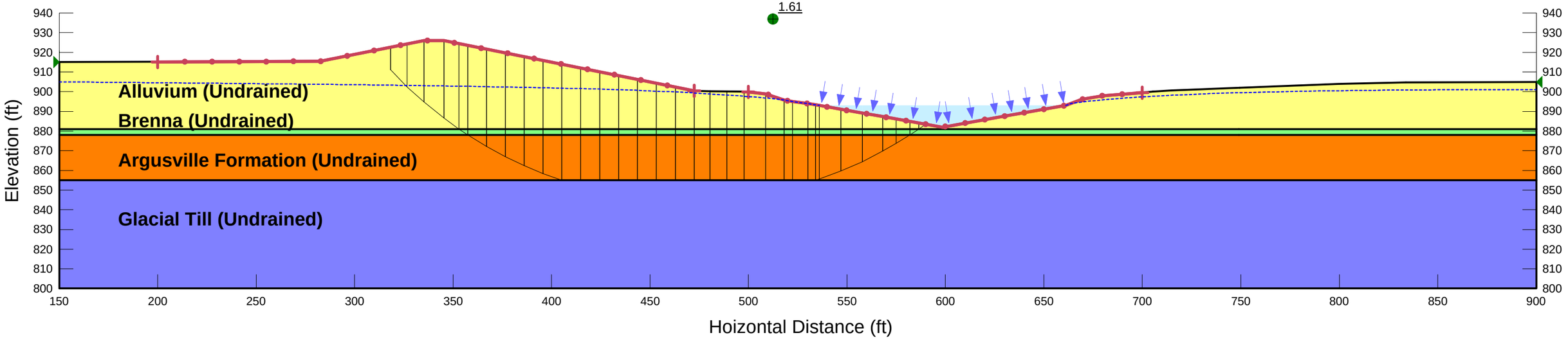
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section B Stability Analysis: USSA w/ Brenna - Oxbow Pond El. 893 ft
File Name: Cross Section B - 5 ft offset.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.61

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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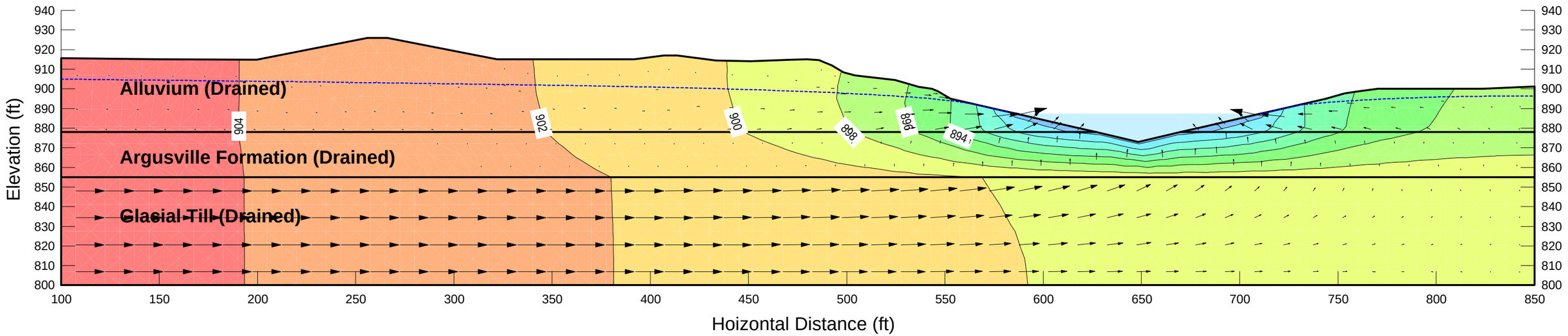
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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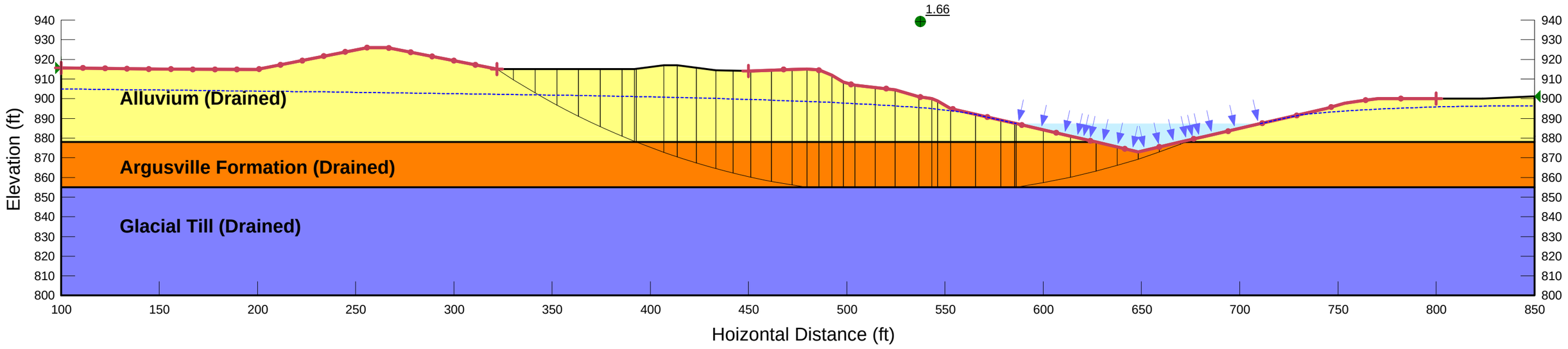
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.66

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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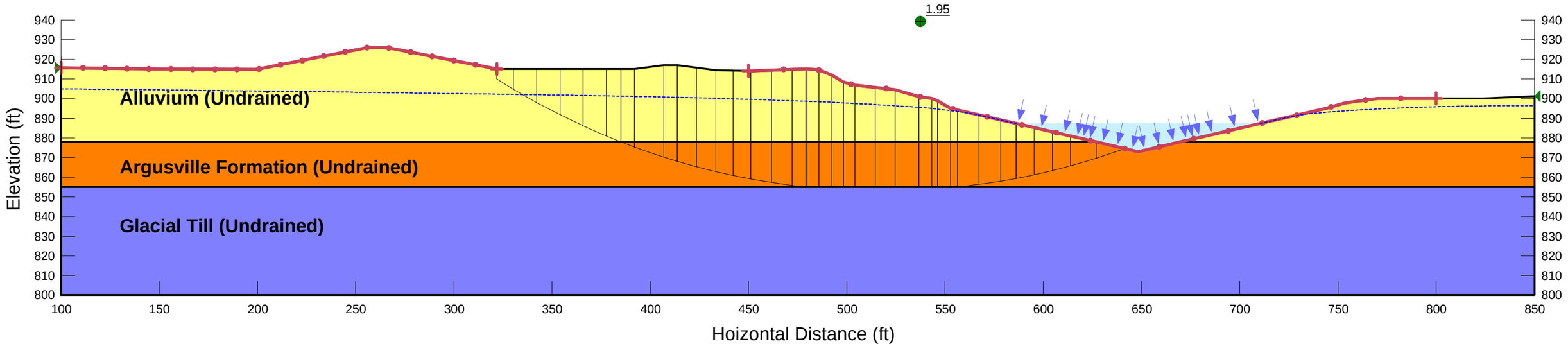
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.95

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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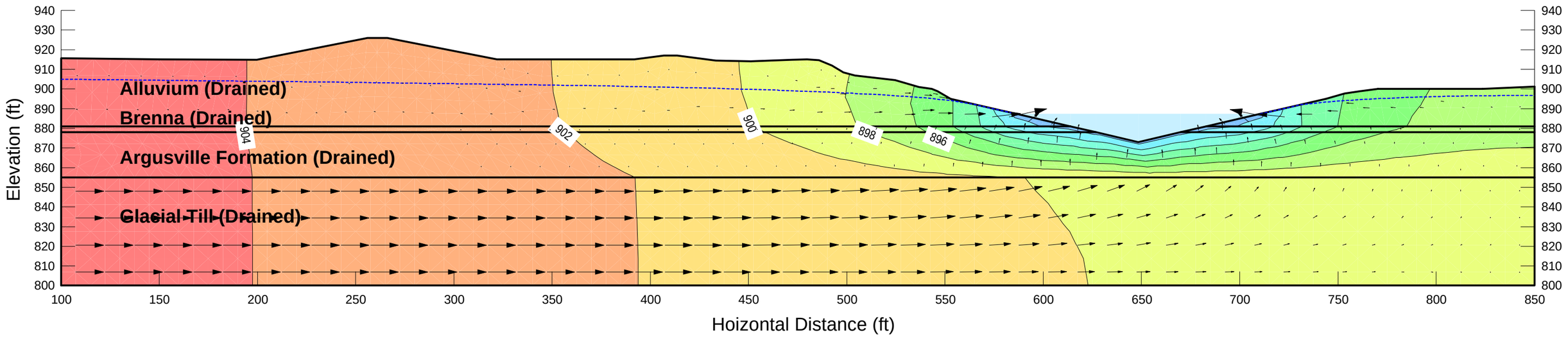
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 887.34 ft (Low Flow) w/ Brenna
File Name: Cross Section C.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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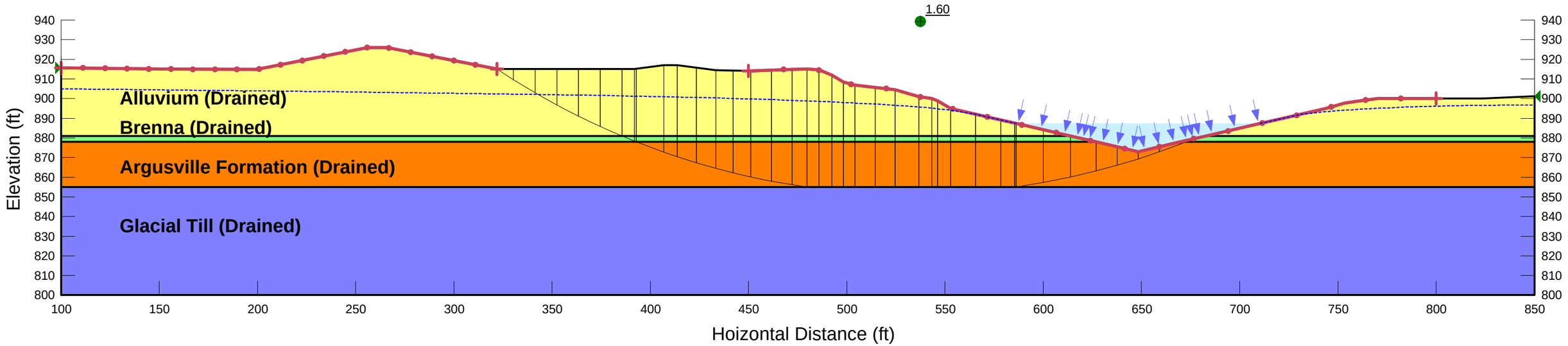
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA w/ Brenna - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.60

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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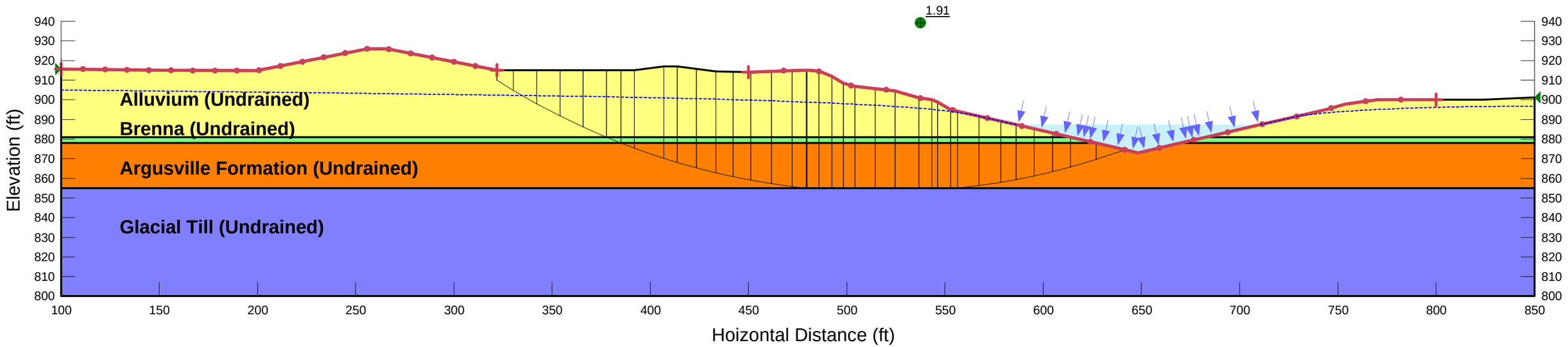
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA w/ Brenna - River El. 887.34 ft (Low Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.91

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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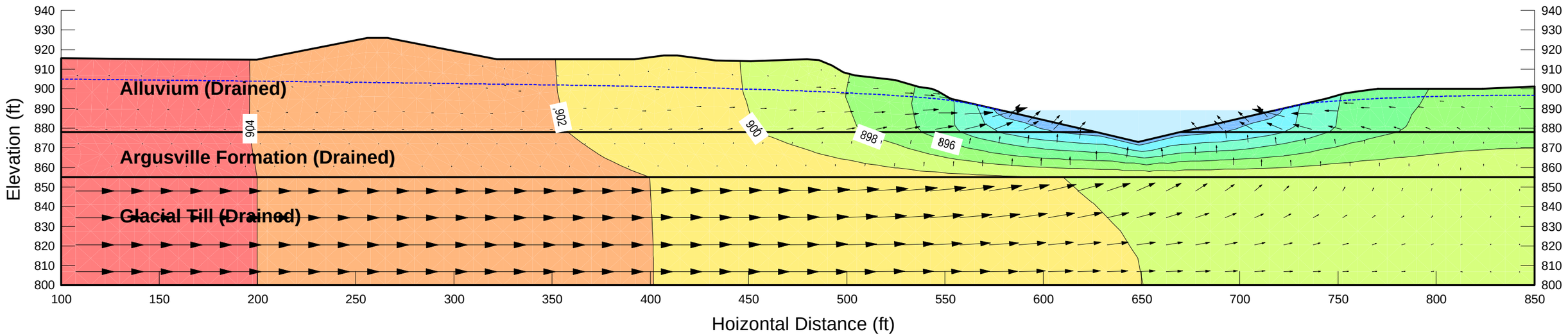
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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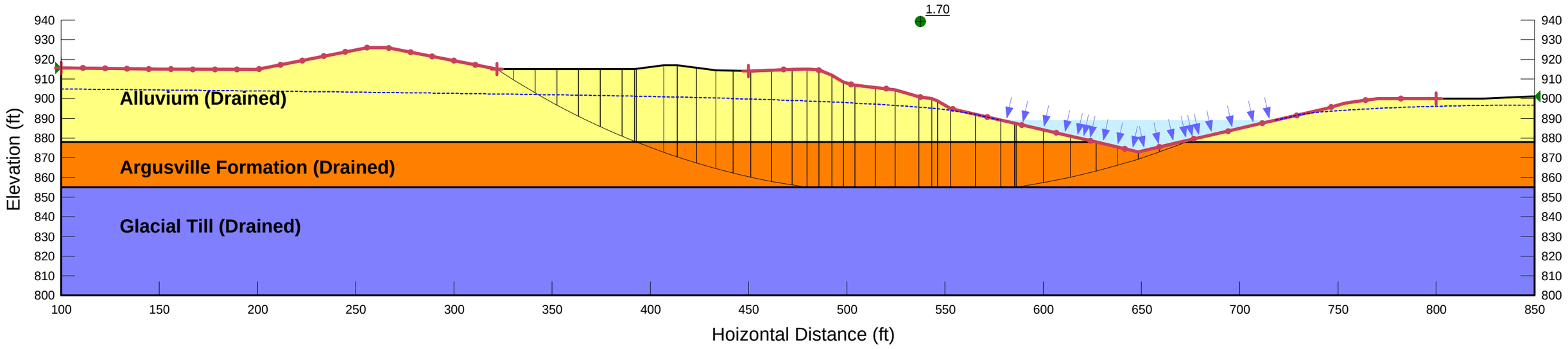
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.70

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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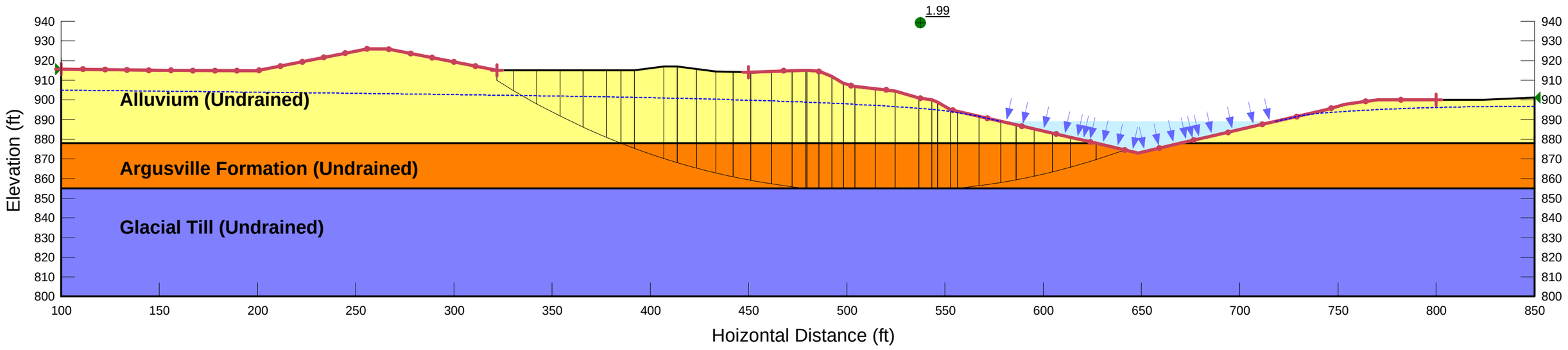
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.99

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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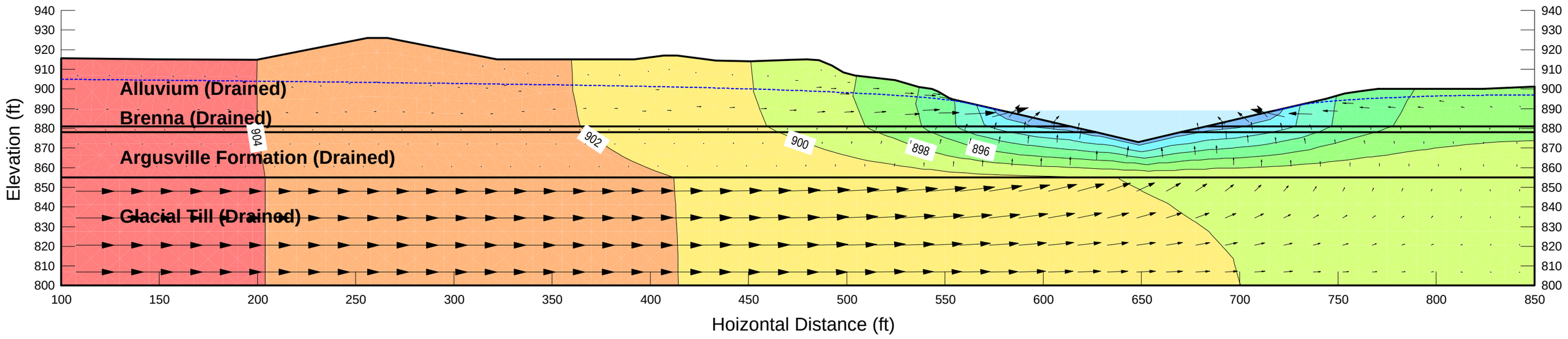
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: River El. 889.11 ft (Average Flow) w/ Brenna
File Name: Cross Section C.gsz
Last Saved Date: 7/10/2012

Contours are Total Head in feet

Name: Alluvium (Drained) Model: Saturated / Unsaturated K-Function: Alluvium_Formation (k=2.8E-3 ft/day) Vol. WC. Function: Alluvium_Formation K-Ratio: 0.25 K-Direction: 0 °
Name: Brenna (Drained) Model: Saturated / Unsaturated K-Function: Brenna_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Brenna_Formation K-Ratio: 1 K-Direction: 0 °
Name: Argusville Formation (Drained) Model: Saturated / Unsaturated K-Function: Argusville_Formation (k=2.8E-4 ft/day) Vol. WC. Function: Argusville_Formation K-Ratio: 1 K-Direction: 0 °
Name: Glacial Till (Drained) Model: Saturated / Unsaturated K-Function: Glacial_Till (k=5.7E-2 ft/day) Vol. WC. Function: Glacial_Till K-Ratio: 0.25 K-Direction: 0 °



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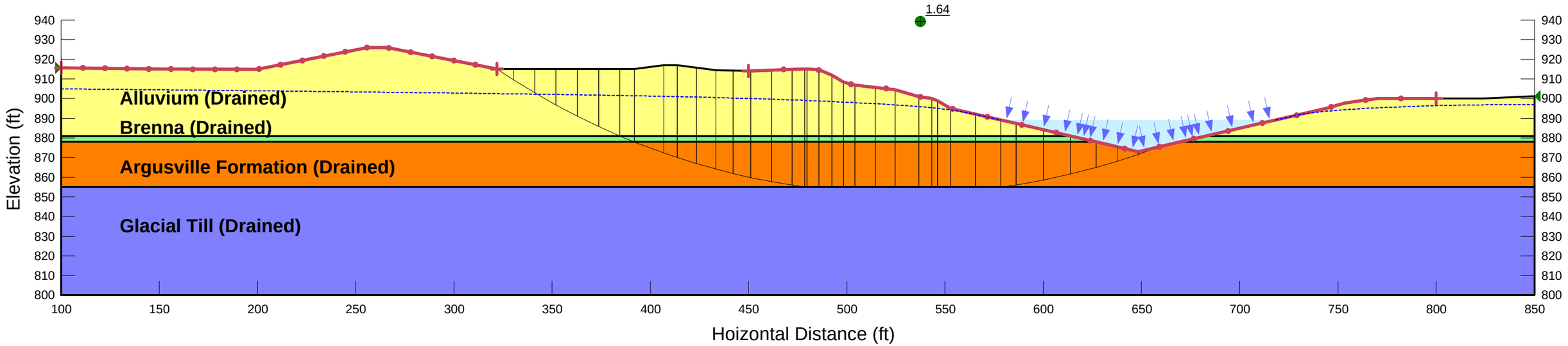
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: ESSA w/ Brenna - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.64

Name: Alluvium (Drained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 31 °
Name: Brenna (Drained) Model: Shear/Normal Fn. Unit Weight: 106 pcf Strength Function: Brenna (ESSA)
Name: Argusville Formation (Drained) Model: Shear/Normal Fn. Unit Weight: 110 pcf Strength Function: Argusville (ESSA)
Name: Glacial Till (Drained) Model: Bedrock (Impenetrable)



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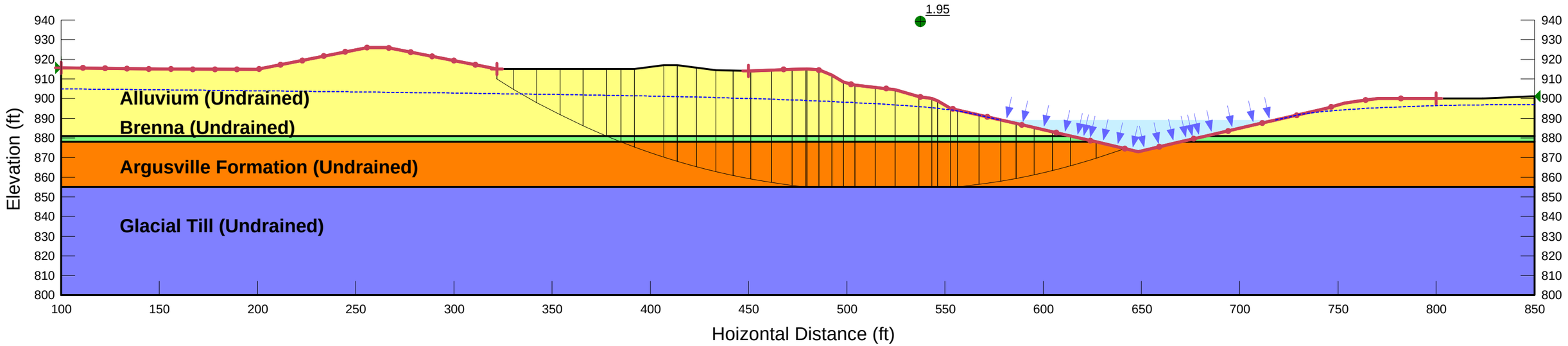
Fargo-Moorhead Flood Diversion Project: Oxbow Levee
Section C Stability Analysis: USSA w/ Brenna - River El. 889.11 ft (Average Flow)
File Name: Cross Section C.gsz
Last Saved Date: 7/30/2012
Factor of Safety: 1.95

Name: Alluvium (Undrained) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 1400 psf Phi: 0 °
Name: Brenna (Undrained) Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 650 psf Phi: 0 °
Name: Argusville Formation (Undrained) Model: S=f(depth) Unit Weight: 110 pcf C-Top of Layer: 575 psf C-Rate of Change: 10 psf/ft
Name: Glacial Till (Undrained) Model: Bedrock (Impenetrable)



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Appendix C

09-57M

SPT	D10	MC		LL	PL	
		G.S. 908.9				
			CL			0' TO 0.5' (CL) SANDY LEAN CLAY
10		28		65	23	
10		30		59	24	
16		26	CH	58	23	0.5' TO 24' (CH) FAT CLAY, MEDIUM STIFF, MOIST, WITH SILT STRATA OR LENSES, IRON OXIDE STAINING, WITH WHITE SILT WORMS, BROWN. (ALLUVIUM)
16		28		65	22	
15		33	ML & CH	59	20	24' TO 27.6' (ML & CH) SILT, MEDIUM STIFF, MOIST, RIBBONED/MARBLED TO LAMINATED, TAN AND BROWN. (SHERACK FORMATION)
6		47	CH	87	23	27.6' TO 30' (CH) FAT CLAY, SOFT, MOIST, IRON OXIDE STAINING, DARK GRAY WITH ORANGE. (BRENNA FORMATION)
6		40		65	23	
4		43		65	25	
5		40		69	28	
5		33	CH	49	22	30' TO 58' (CH) FAT CLAY, SOFT, MOIST, VARVED TO LAMINATED, WITH DROP STONES, AND TILL INCLUSIONS, AND SAND STRATA OR LENSES, DARK GRAY. (ARGUSVILLE FORMATION)
29		13		20	16	
	850.9					

NOTES:
1. WATER LEVEL NOT DETERMINED
2. HOLE STABILIZED WITH 4" CASING TO EL. 898.9
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

09-58M

SPT	D10	MC		LL	PL	
		G.S. 882.3				
			GC			0' TO 0.6' (GC) CLAYEY GRAVEL SANDY, GRAVEL FINE SAND FINE TO MEDIUM, DENSE, MOIST, ROAD FILL, BROWN. (FILL)
9		W. L. 876.7	CL	75	28	0.6' TO 2.5' (TOPSOIL)
13		28		68	30	2.5' TO 6.3' (CL) LEAN CLAY SILTY, MEDIUM STIFF, MOIST TO WET, LITTLE ROOTS, BROWN. (ALLUVIUM)
9		44	CH	76	32	6.3' TO 18' (CH) FAT CLAY SILTY, MEDIUM STIFF, WET TO SATURATED, VARVED, SILT SEAMS, IRON OXIDE STAINING, BROWN. (SHERACK FORMATION) (GLACIO-LACUSTRINE)
12		36		64	31	
11		60	CH	102	40	18' TO 26.3' (CH) FAT CLAY SILTY, MEDIUM STIFF, WET, BLOCKY, MEALLY, BROWN. (POPLER RIVER F./ HARWOOD MEMBER) (ALLUVIUM)
8		67		106	36	
6		63		97	36	
5		72		114	36	
4		59		97	35	
3			CH			26.3' TO 70' (CH) FAT CLAY, SOFT, MOIST TO WET, BREAKS ON OCCASIONAL BEDDING PLANE, DARK GRAY. (BRENNA FORMATION) (GLACIO-LACUSTRINE)
5		55		85	32	
4						
4		66		116	32	
4		61		103	31	
3		62		97	30	
3		53		86	30	
5			CH/ CL			70' TO 93' (CH/CL) FAT CLAY/LEAN CLAY SILTY, GRAVEL FINE SAND FINE TO COARSE, SOFT TO MEDIUM STIFF, MOIST TO WET, DROP STONES, AND TILL INCLUSIONS, DARK GRAY. (ARGUSVILLE FORMATION) (GLACIO-LACUSTRINE)
5		50		64	27	
10		18		30	17	
46			CL			93' TO 107' (CL) LEAN CLAY WITH SAND SILTY, GRAVEL FINE TO COARSE SAND FINE TO COARSE, STIFF, MOIST TO SATURATED, HOMOGENEOUS, SAND SEAMS OR POCKETS, GRAY. (UNIT "A" TILL)
21	775.3	20		34	16	

NOTES:
1. WATER LEVEL DETERMINED AFTER 24 HOURS IN OPEN HOLE BOTTOM OF HOLE EL. 857.3
2. HOLE STABILIZED WITH 4" CASING TO EL. 872.3
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

09-59M

03 DEC 09

SPT	D10	MC		LL	PL	
		G.S. 916.2				
7		33	CH	71	22	0' TO 7.7' (CH) FAT CLAY, MEDIUM STIFF, MOIST, BLACK TO GRAYISH BROWN
7		36		81	26	
5		W. L. 901.8 47		83	26	
7		49	CH	76	24	7.7' TO 30' (CH) FAT CLAY, MEDIUM STIFF, MOIST, BLOCKY TO VARED, WITH GYPSUM CRYSTALS, AND FE NODULES, IRON OXIDE STAINING, ORANGEISH BROWN AND DARK GRAY. (DESSICATED BRENNA FORMATION)
7		44		78	28	
6		42		82	29	
4		44	CH	78	31	30' TO 38' (CH) FAT CLAY, SOFT, MOIST, VARVED, DROP STONES, AND TILL INCLUSIONS, GRITTY, DARK GRAY. (ARGUSVILLE FORMATION)
4		38	CH	59	25	38' TO 41.8' (CH) FAT CLAY, SOFT, MOIST, VARVED TO LAMINATED, SILT STRATA OR LENSES, DARK GRAY. (ARGUSVILLE FORMATION)
4		45		76	27	
5		49		92	29	
5		35		56	25	
7		45	CH-CL	67	28	41.8' TO 69.6' (CH-CL) FAT CLAY, SOFT, MOIST, VARVED, DROP STONES, AND TILL INCLUSIONS, GRITTY, DARK GRAY. (ARGUSVILLE FORMATION)
6		47		78	23	
12		28		52	17	
49	841.2	18	CL	26	15	69.6' TO 75' (CL) SANDY LEAN CLAY WITH GRAVEL, HARD, MOIST, GRAY. (UNIT "A" TILL)

NOTES:
1. WATER LEVEL DETERMINED AFTER 24 HOURS IN OPEN HOLE
2. HOLE STABILIZED WITH 4" CASING TO EL. 906.2
3. UNDISTURBED SAMPLES TAKEN IN OFFSET HOLE
4. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

09-60M

03 DEC 09

SPT	D10	MC		LL	PL	
		G.S. 887.3				
						0' TO 3.1' ROAD FILL
7		38		80	28	3.1' TO 5.2' (TOPSOIL)
5		32	CL	69	24	5.2' TO 10' (CL) LEAN CLAY SILTY, MEDIUM STIFF, MOIST TO WET, LITTLE ROOTS, BROWN. (ALLUVIUM)
7		52		108	40	
7		52		100	37	
6		54	CH	89	37	10' TO 36' (CH) FAT CLAY SILTY, MEDIUM STIFF, WET TO SATURATED, VARVED, IRON OXIDE STAINING, REDDISH BROWN. (SHERACK FORMATION) (GLACIO-LACUSTRINE)
5		51		95	37	
6		59		95	37	
6		62		106	36	
6			CH			36' TO 58' (CH) FAT CLAY SILTY, MEDIUM STIFF, MOIST TO WET, VARVED, SLICKS IN ZONES, LAMINATED IN ZONES, GRADATIONAL WITH SHERACK FM., IRON OXIDE STAINING, REDDISH BROWN TO DARK GRAY. (BRENNA FORMATION) (GLACIO-LACUSTRINE)
4		50		88	29	
6		49	CH/ CL	72	28	58' TO 65' (CH/CL) FAT CLAY/LEAN CLAY SILTY, GRAVEL FINE SAND FINE TO COARSE, MEDIUM STIFF TO STIFF, VERY MOIST TO SATURATED, STRATIFIED, SOME VARVED, TILL INCLUSIONS, DROP STONES, DARK GRAY. (LACUSTRINE)
9						
12		19	CL			65' TO 75.2' (CL) SANDY LEAN CLAY WITH GRAVEL SILTY, GRAVEL FINE TO COARSE SAND FINE TO COARSE, MEDIUM STIFF TO STIFF, VERY MOIST TO WET, HOMOGENEOUS, DARK GRAY. (ARGUSVILLE FORMATION) (TILL)
14		20		30	16	
45			SP-SM			75.2' TO 76.1' (SP-SM) POORLY GRADED SAND WITH SILT SILTY, SAND FINE TO MEDIUM, DENSE, WET, DARK GRAY
22		17	CL	33	16	
20						76.1' TO 90' (CL) SANDY LEAN CLAY WITH GRAVEL SILTY, GRAVEL FINE TO COARSE SAND FINE TO COARSE, VERY STIFF TO HARD, VERY MOIST TO WET, HOMOGENEOUS, DARK GRAY. (ARGUSVILLE FORMATION)
	795.3	12		29	17	

NOTES:
1. WATER LEVEL NOT DETERMINED
2. HOLE STABILIZED WITH 4" CASING TO EL. 877.3
3. UNDISTURBED SAMPLES TAKEN IN OFFSET HOLE
4. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

930 920 910 900 890 880 870 860 850 840 830 820 810 800 790 780 770 760 750 740

US Army Corps of Engineers
ST. PAUL DISTRICT

MARK	APPR.	DATE	DESCRIPTION

DESIGNED BY:
DWN BY: KAH
SUBMITTED BY:
CKD BY:
PLOT SCALE:
PLOT DATE:
DATE: 2011/03/04
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
SIZE:
FILE NAME: FMMPS_FAR_B-207xxx.dgn

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

FARGO-MOORHEAD METRO FEASIBILITY STUDY
RED RIVER OF THE NORTH
FARGO NORTH DAKOTA, MOORHEAD MINNESOTA
FARGO, ND

BORING LOGS
FARGO
09-57M - 09-60M

SHEET IDENTIFICATION
B-207

09-65M

FARGO

SPT	D10	MC	LL	PL
		G.S. 902.6		
5		CL		
7	19	OL/OH	34	15
6	28	CH	42	21
10	32	CL	78	24
11	32		70	26
10	37		80	27
7	54	CH	111	38
5	64	CH	114	36
3	62		105	39
3	63		97	34
3				
4	50		87	32
4	30	CL	40	18
12	20		39	17
49	825.6			

0' TO 4.7' (CL) LEAN CLAY WITH SAND SILTY, SAND FINE, MEDIUM STIFF, MOIST, TAN. (FILL)

4.7' TO 6.5' (OL/OH) ORGANIC SOIL, MEDIUM STIFF, TOP SOIL, BLACK. (FILL)

6.5' TO 17' (CL) SANDY LEAN CLAY SILTY, SAND FINE, MEDIUM STIFF, MOIST TO SATURATED, IRON OXIDE STAINING, TANNISH BROWN. (ALLUVIUM)

17' TO 30' (CL) LEAN CLAY SILTY, MEDIUM STIFF, MOIST TO WET, MEALY, LITTLE GYPSUM CRYSTALLS, BROWN. (ALLUVIUM)

30' TO 36.5' (CH) FAT CLAY, SOFT TO MEDIUM STIFF, MOIST TO WET, DESSICATED, VARVED, PURPLEISH BROWN TO DARK GRAY. (BRENNA FORMATION) (GLACIO-LACUSTRINE)

36.5' TO 62' (CH) FAT CLAY, SOFT TO MEDIUM STIFF, WET, TRACE SILT, FORMS SLICKS WHEN SHEARED, STICKY, NO STAINING, DARK GRAY. (BRENNA FORMATION) (GLACIO-LACUSTRINE)

62' TO 75' (CL) SANDY LEAN CLAY WITH GRAVEL SILTY, GRAVEL FINE TO COARSE SAND FINE TO COARSE, VERY STIFF TO HARD, VERY MOIST TO WET, HOMOGENEOUS, DARK GRAY. (UNIT "A" TILL)

NOTES:
1. WATER LEVEL NOT DETERMINED
2. HOLE STABILIZED WITH 4" CASING TO EL. 892.6
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

10-66M

08 MAY 10

FARGO

SPT	D10	MC	LL	PL
		G.S. 915.2		
6		W.L. 909.8		
		CH	73	24
10			87	29
5			80	26
8			83	26
6		CH		
6			64	22
5			56	24
5			63	27
8			56	26
8			68	26
8			67	25
6		CH	91	28
7			27	15
34		CL	19	12
75				
95				
78	828.2			

0' TO 7.9' (CH) SANDY FAT CLAY WITH GRAVEL, MOIST, FEW SANDS AND GRAVELS TOP 1.0', BLACK. (FILL)

7.9' TO 46.5' (CH) FAT CLAY, MEDIUM STIFF, MOIST, MOTTLED, WITH GYPSUM IN FLUID FRACTURES, IRON OXIDE STAINING, VARVED. GETS SILTY BELOW 25', FEW SILT SEAMS 34.0'-37.0'. DESSICATED. OXIDIZED, DARK ORANGEISH GRAY. (BRENNA FORMATION)

46.5' TO 63.8' (CH) FAT CLAY, MEDIUM STIFF, MOIST, WITH TILL INCLUSIONS, AND SAND, VARVED. DESSICATED, GRAY. (ARGUSVILLE FORMATION)

63.8' TO 87' (CL) SANDY LEAN CLAY WITH GRAVEL, STIFF, WET TO MOIST, WITH SILT AND SAND OUTWASH LAYERS, GRAY. (UNIT "A" TILL) (TILL)

NOTES:
1. WATER LEVEL DETERMINED AFTER 48 HOURS IN OPEN HOLE
2. HOLE STABILIZED WITH 4" CASING TO EL. 905.2
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

10-67M

10 MAY 10

FARGO

SPT	D10	MC	LL	PL
		G.S. 885.7		
		CL		
16		W.L. 883.23		
37			76	25
28	32	CH	73	23
23	35		73	22
33	38	CH	92	30
12	52		100	30
13	57		104	29
10	61		116	39
12	62		99	34
13	52		98	30
9	57		96	33
8	66	CH	108	35
10	59		109	33
9	58		101	30
9	60		98	33
10	49		88	23
10	50		90	28
47	50		85	22
52	31	ML-CH	23	20
82	52		75	32
97	18		22	16
53	17		32	14
78	25	CL	32	17
100	771.4			
	11		13	10
	11			
	10	SM-ML	12	12
	9		13	12

0' TO 1.3' (CL) LEAN CLAY WITH SAND, GRAVEL FINE , STIFF, MOIST, SOME ROOTS, SOME ORGANICS, TOPSOIL/FILL, DARK BROWN. (FILL)

1.3' TO 14.7' (CH) FAT CLAY, STIFF, MOIST, LAMINATED, SOME ORGANICS, IRON OXIDE STAINING, WEATHERED. ORGANICS DECREASE WITH DEPTH. SILT LAMINATIONS GRAY AND BLACK TO BROWN. (SHERACK FORMATION)

14.7' TO 18.4' (CH) FAT CLAY, STIFF, WET, DESSICATED, SOME CALCARIOUS VEINS, WITH CALCAREOUS STRINGERS, GRAY. (DESSICATED BRENNA FORMATION)

18.4' TO 79.8' (CH) FAT CLAY, STIFF, MOIST TO WET, SLICKENSIDED, SOME CALCARIOUS VEINS, OCCASIONAL DROP STONE, SLIGHTLY OXIDIZED AT 18.4', LAMINATIONS AT 28.6'. NO FE STAINING AFTER 45'. SOME DARK GRAY MOTTLING AT 55.4', SM SEAM AT 72.1', SOME LAMINATIONS BELOW 79.4', BROWNISH GRAY. (BRENNA FORMATION)

79.8' TO 82.9' (MH) SILT, SOFT, WET, LAMINATED, TRACE FINE GRAVEL, ZONE OF GRAY AND SILTY CLAY 82' TO 82.4', SILTY APPEARANCE WHEN SHEARED, GRAY AND LIGHT GRAY

82.9' TO 98' (CL) SANDY LEAN CLAY WITH GRAVEL, GRAVEL FINE TO COARSE , HARD, MOIST, TRACE SILT, GRAY. (UNIT "A" TILL)

98' TO 114.3' (SM) SILTY SAND WITH GRAVEL, GRAVEL FINE TO COARSE SAND FINE, HARD, TRACE CLAY, GRAY

NOTES:
1. WATER LEVEL DETERMINED AFTER 28 HOURS IN OPEN HOLE
   BOTTOM OF HOLE EL. 876.53
2. HOLE STABILIZED WITH 4" CASING TO EL. 875.7
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

10-68M

10 MAY 10

FARGO

SPT	D10	MC	LL	PL
		G.S. 917.5		
5		CH	74	26
9		W.L. 908.4	71	33
6			76	27
10		CH	76	26
4			78	25
4		CH	74	26
4			91	30
5		CH	69	23
5			57	22
5			81	30
5			76	21
4		CH	71	33
4			59	27
34		CL-ML	21	16
44				
184			25	19
102	836.5			

0' TO 5.2' (CH) FAT CLAY, STIFF, MOIST, TRACE CALCARIOUS BLEBS, AND ROOTS, WITH LIGHT BROWN MOTTLING AND FEW LIGHT GRAY LAMINATIONS, BLACK WITH LIGHT GRAY. (TOPSOIL)

5.2' TO 25.2' (CH) FAT CLAY, MEDIUM STIFF, MOIST, MOTTLED, WITH GYPSUM IN FLUID FRACTURES, IRON OXIDE STAINING, VARVED. DESSICATED OXIDIZED BRENNA, DARK ORANGEISH GRAY. (BRENNA FORMATION)

25.2' TO 27.2' (CH) FAT CLAY, MEDIUM STIFF, MOIST, VARVED, GRAY. (BRENNA FORMATION)

27.2' TO 45.6' (CH) FAT CLAY, SOFT, MOIST, FORMS SLICKENSIDES WHEN SHEARED. FEW SANDS 31.2' TO 34.1', GRAY. (BRENNA FORMATION)

45.6' TO 65' (CH) FAT CLAY, SOFT, MOIST, WITH TILL INCLUSIONS, AND SAND, GRITTY AND STICKY, GRAY. (ARGUSVILLE FORMATION)

65' TO 81' (CL) SANDY LEAN CLAY WITH GRAVEL, STIFF, MOIST, WITH SILT AND SAND OUTWASH LAYERS, GRAY. (UNIT "A" TILL)

NOTES:
1. WATER LEVEL DETERMINED AFTER 24 HOURS IN OPEN HOLE
2. HOLE STABILIZED WITH 4" CASING TO EL. 907.5
3. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

US Army Corps of Engineers
ST. PAUL DISTRICT

MARK	DESCRIPTION	DATE	APPR. MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY:
DWN BY: KAH
SUBMITTED BY:
CKD BY:
PLOT SCALE:
PLOT DATE:
DATE: 2011/03/04
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
SIZE:
FILE NAME: PMMPS_FAR_B-209xxx.dgn

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

FARGO-MOORHEAD METRO FEASIBILITY STUDY
RED RIVER OF THE NORTH
FARGO NORTH DAKOTA, MOORHEAD MINNESOTA
FARGO, ND

BORING LOGS
FARGO
09-65M, 10-66M - 10-68M

SHEET IDENTIFICATION
B-209

10-77M

SPT	D10	MC		LL	PL
	G.S. 912.7				
6		28	CH	72	24
7		43	CH	85	25
6	W. L. 898.8	47	CH	79	26
5					
4		48	CH	76	25
4		39		68	21
4		42	CH	71	24
4		42		73	29
4		44	CH	63	24
4		49		74	24
5		48	CH	71	24
5		46		67	24
4		45		72	20
5		45		59	22
10		16	CL	26	15
		46			
		104			
		116	SM		
		157			
		99			
		97	SM		
		143			
97	795.7				

0' TO 3.1' (CH) FAT CLAY, MOIST, WITH ROOTS, AND ORGANICS, DARK BROWNISH BLACK. (TOPSOIL)

3.1' TO 8' (CH) FAT CLAY, MOIST, MEALY, WITH SILT NODULES, BLACK. (ALLUVIUM)

8' TO 21.7' (CH) FAT CLAY, MEDIUM STIFF, MOIST, MOTTLED, WITH GYPSUM IN FLUID FRACTURES, TRACE ROOTS, IRON OXIDE STAINING, VARVED. DESSICATED, OXIDIZED, DARK ORANGEISH GRAY. (DESSICATED BRENNA FORMATION) (GLACIO-LACUSTRINE)

21.7' TO 40' (CH) FAT CLAY, SOFT, MOIST, OCCASIONAL VARVES AND SILTY ZONES, GRAY. (BRENNA FORMATION) (GLACIO-LACUSTRINE)

40' TO 70.8' (CH) FAT CLAY, SOFT, MOIST, WITH TILL INCLUSIONS, AND SAND, GRITTY AND STICKY, GRAY. (ARGUSVILLE FORMATION) (GLACIO-LACUSTRINE)

70.8' TO 84.5' (CL) SANDY LEAN CLAY WITH GRAVEL, STIFF, MOIST, GRAY. (UNIT "A" TILL) (TILL)

84.5' TO 117' (SM) SILTY SAND, SAND FINE, VERY DENSE, SATURATED, GRAY. (OUTWASH)

NOTES:
1. WATER LEVEL DETERMINED AFTER 18 HOURS
   BOTTOM OF AUGER EL. 902.7
2. HOLE STABILIZED WITH 4" CASING TO EL. 902.7
3. INSTALL NESTED PIEZOMETER SET IN HOLE, AND BACKFILL WITH CEMENT-BENTONITE GROUT

10-78M

24 JUN 10

SPT	D10	MC		LL	PL
	G.S. 905.7				
6		31	CH	64	20
5	W.L. 898.98				
9					
8		31		67	22
4		41	CH	65	19
7		40		69	23
4		44		68	21
2		43		65	19
3		50		79	29
5		46	CH	78	23
5		45		75	20
4		51		69	21
4		48		70	15
18		32	CL-ML	18	
109		59			
60		9		15	11
195			SP-SM		
112	815.7				

0' TO 19' (CH) FAT CLAY, SOFT TO MEDIUM STIFF, MOIST, SOME SHELLS, AND ROOTS, ORGANIC, DARK BROWN GRADES TO LIGHT BROWN. (TOPSOIL/ ALLUVIUM)

19' TO 30' (CH) FAT CLAY, MEDIUM STIFF, MOIST, MOTTLED, WITH GYPSUM IN FLUID FRACTURES, TRACE ROOTS, IRON OXIDE STAINING, VARVED. DESSICATED, OXIDIZED, DARK ORANGEISH BROWN MOTTLED WITH GRAY. (DESSICATED BRENNA FORMATION) (GLACIO-LACUSTRINE)

30' TO 66.6' (CH) FAT CLAY, SOFT, MOIST, WITH TILL INCLUSIONS, AND SAND, GRITTY AND STICKY, GRAY. (ARGUSVILLE FORMATION) (GLACIO-LACUSTRINE)

66.6' TO 78' (CL-ML) SANDY LEAN CLAY WITH GRAVEL, HARD, MOIST, SOME SANDIER AND SILTIER ZONES, GRAY. (UNIT "A" TILL)

78' TO 90' (SP-SM) POORLY GRADED SAND WITH SILT, SAND FINE, SATURATED, GRAY. (OUTWASH)

NOTES:
1. WATER LEVEL DETERMINED AFTER 24 HOURS
   BOTTOM OF AUGER EL. 885.7
2. HOLE STABILIZED WITH 4" CASING TO EL. 895.7
3. UNDISTURBED SAMPLES TAKEN IN OFFSET HOLE
4. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

10-79M

25 JUNE 2010

SPT	D10	MC		LL	PL
	G.S. 905.7				
7			CH		
8	W. L. 894.98	30		56	23
9		29		58	22
14		26	CH	57	18
13		25		48	17
6		39		60	25
3		39		62	29
4		42	CH	72	24
5		61		79	21
7			SC		
82		11	CL-ML	17	13
73					
86		17		22	16
61					
46		14	CL	27	16
135			SP		
172					
153			CL		
			SP		
			GP	11	10
150	813.7	9	CL		

0' TO 6' (CH) FAT CLAY, MEDIUM STIFF, MOIST, WITH SILT ZONES , AND SILT STRINGERS, AND ROOTS, DARK BROWN. (TOPSOIL)

6' TO 30' (CH) FAT CLAY, MEDIUM STIFF, MOIST, TRACE SHELLS AND SILT STRINGERS. SANDY SEAM WITH SHELLS AND ROOTS 26.0'-27.0'. LAMINTATED WITH IRON OXIDE STAINING BELOW 27.0', TANNISH BROWN. (ALLUVIUM)

30' TO 46.3' (CH) FAT CLAY, SOFT, MOIST, WITH TILL INCLUSIONS, AND SAND, GRITTY AND STICKY, GRAY. (ARGUSVILLE FORMATION) (GLACIO-LACUSTRINE)

46.3' TO 48.2' (SC) CLAYEY SAND WITH GRAVEL, GRAVEL FINE TO COARSE SAND FINE TO COARSE, MEDIUM DENSE, WET, GRAY

48.2' TO 77' (CL-ML) SANDY LEAN CLAY WITH GRAVEL, MEDIUM STIFF TO VERY HARD, MOIST, WITH SAND SEAMS, SANDY ZONE WITH LARGE LIMESTONE GRAVELS AT 55', GRAY. (UNIT "A" TILL) (TILL)

77' TO 82' (SP) POORLY GRADED SAND, SAND FINE, SATURATED, SOME DARK ORGANIC STAINED LAYERS, GRAY. (OUTWASH)

82' TO 84.2' (CL) SANDY LEAN CLAY WITH GRAVEL, VERY HARD, MOIST, GRAY. (UNIT "A" TILL)

84.2' TO 87' (SP) POORLY GRADED SAND, SAND FINE, SATURATED, SOME DARK ORGANIC STAINED LAYERS, GRAY. (OUTWASH)

87' TO 90' (GP) POORLY GRADED GRAVEL, ASSUMED FROM DRILL ACTION AND SLUFF

90' TO 92' (CL) SANDY LEAN CLAY WITH GRAVEL, VERY HARD, MOIST, GRAY. (UNIT "A" TILL)

NOTES:
1. WATER LEVEL DETERMINED AFTER 26 HOURS
   BOTTOM OF AUGER EL. 885.68
2. HOLE STABILIZED WITH 4" CASING TO EL. 985.7
3. INSTALL NESTED PIEZOMETER SET IN HOLE, AND BACKFILL WITH CEMENT-BENTONITE GROUT

10-80M

19 JUL 10

SPT	D10	MC		LL	PL
	G.S. 921.1				
4		29	CL	48	23
2	W. L. 911.51		SP		
0			SC		
4			CL & SC		
2					
0		30	ML	35	27
49				85	27
4		52		95	25
4		50		78	27
3		61	CH	100	34
6		71		82	34
6		50		79	24
5		53	CH	78	29
6		19		26	15
14					
40		21	CL-ML	29	16
67					
60		8	CL	14	11
99		8	SC	13	11
58			SC		
54		24	CL	43	21
110		21			
63			SP-SC		
90					
117					
105			SP-SC		
98	791.1				

0' TO 5.8' (CL) LEAN CLAY WITH GRAVEL, SAND FINE, MEDIUM STIFF, MOIST, TRACE ORGANICS, DARK BROWNISH BROWN. (TOPSOIL)

5.8' TO 8.1' (SP) POORLY GRADED SAND, LOOSE, MOIST, BROWN. (ALLUVIUM)

8.1' TO 15' (SC) CLAYEY SAND, SATURATED, TRACE ORGANICS, DARK BROWN. (ALLUVIUM)

15' TO 26' (CL & SC) CLAYEY SAND, SOFT TO LOOSE, MOIST TO SATURATED, INTERBEDDED, SANDY CLAY INTERBEDDED WITH CLAYEY SAND, BROWN GRAY. (ALLUVIUM)

26' TO 30.7' (ML) SILT, SOFT, SATURATED, LAMINATED, TRACE FINE SAND, OCCASIONAL ORGANICS, GRAY. (ALLUVIUM)

30.7' TO 60' (CH) FAT CLAY, SOFT, WET, SILTY APPEARANCE WHEN SHEARED. VERY FEW SANDS BELOW 41.8', GRAY. (BRENNA FORMATION)

60' TO 66.5' (CH) FAT CLAY, MEDIUM STIFF, WET, WITH TILL INCLUSIONS, GRAY. (ARGUSVILLE FORMATION)

66.5' TO 80' (CL) SANDY LEAN CLAY WITH GRAVEL, GRAVEL FINE TO COARSE , MEDIUM STIFF, WET, GRAY. (UNIT "A" TILL) (TILL)

80' TO 88' (CL) SANDY LEAN CLAY, HARD, MOIST, GRAY. (UNIT "A" TILL) (TILL)

88' TO 96.5' (SC) CLAYEY SAND WITH GRAVEL, VERY DENSE, MOIST, GRAY

96.5' TO 106.5' (CL) SANDY LEAN CLAY WITH GRAVEL, HARD, MOIST, GRAY

106.5' TO 120' (SP-SC) POORLY GRADED SAND WITH CLAY, DENSE, WET, CL SEAM 109.1'- 109.3', GRAY. (DRIFT)

120' TO 130' (SP-SC) POORLY GRADED SAND WITH CLAY AND GRAVEL, SAND MEDIUM, DENSE, WET, GRAY

NOTES:
1. WATER LEVEL DETERMINED AFTER 14 HOURS
   BOTTOM OF AUGER EL. 911.11
2. HOLE STABILIZED WITH 4" CASING TO EL. 911.1
3. UNDISTURBED SAMPLES TAKEN IN OFFSET HOLE
4. BORING BACKFILLED WITH TREMIED HIGH SOLIDS BENTONITE GROUT.

930 920 910 900 890 880 870 860 850 840 830 820 810 800 790 780 770 760 750 740

US Army Corps of Engineers
ST. PAUL DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

DESIGNED BY:		DATE: 2011/03/04	SOLICITATION NO.:
DWN BY: KAH	CKD BY:	SUBMITTED BY:	CONTRACT NO.:
PLOT SCALE:	PLOT DATE:	FILE NUMBER:	
SIZE:	FILE NAME: FMMFS_FAR_B-212xxx.dgn		

FARGO-MOORHEAD METRO FEASIBILITY STUDY
RED RIVER OF THE NORTH
FARGO NORTH DAKOTA, MOORHEAD MINNESOTA
FARGO, ND

BORING LOGS
FARGO
10-77M - 10-80M

SHEET IDENTIFICATION
B-212

Fargo Red River Diversion

Project No: FY 2011

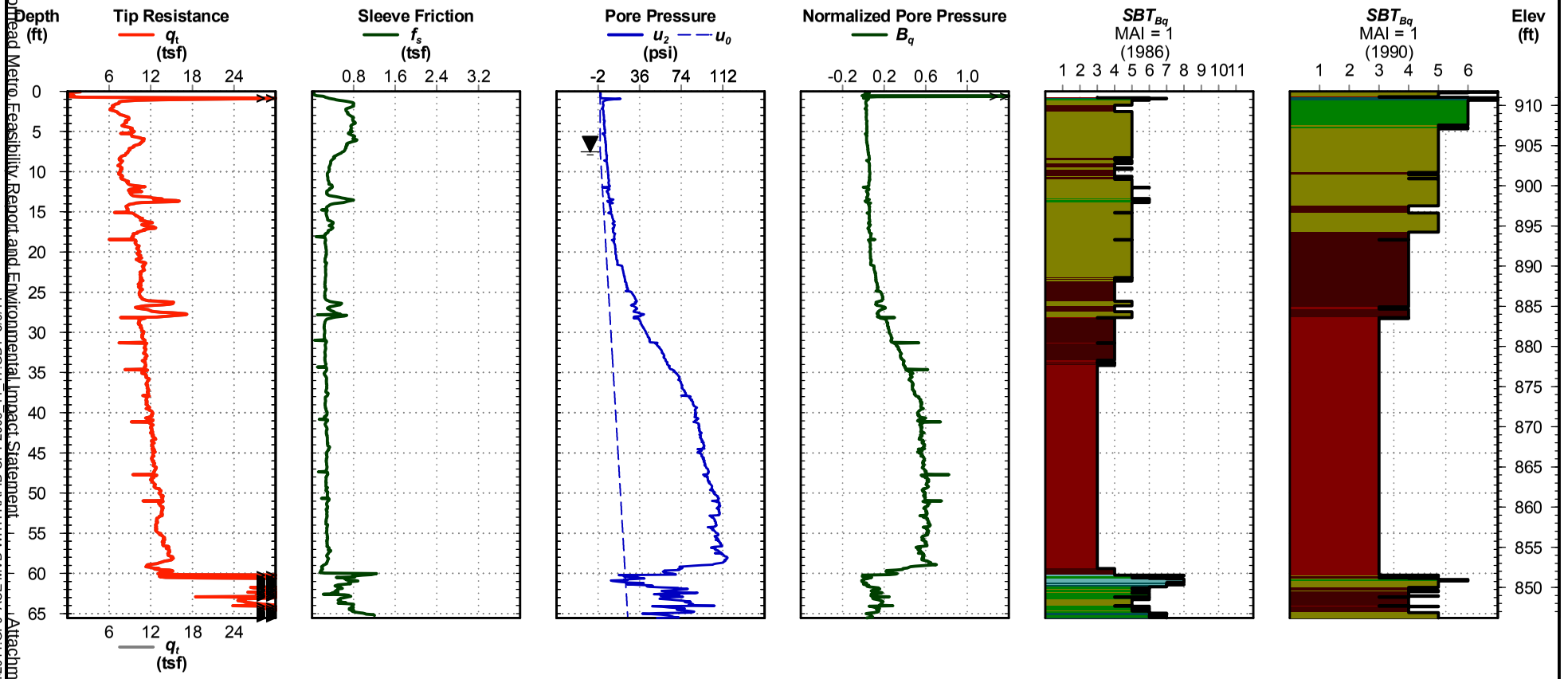
Cone Penetration Test

10-107-C

Date: Dec. 11, 2010
Operator: Johnston
Drilling Agency: USACE, Savannah District

Latitude: 46° 46' 5.124"
Longitude: -96° 55' 51.528"
Probe ID/Net Area Ratio: DDG1117 / 0.8

Elevation: 911.8
Water Depth: 7.51
Total Depth: 65.6 ft



Electronic Filename: 10-107-C.cpt

Fargo Red River Diversion

Project No: FY 2011

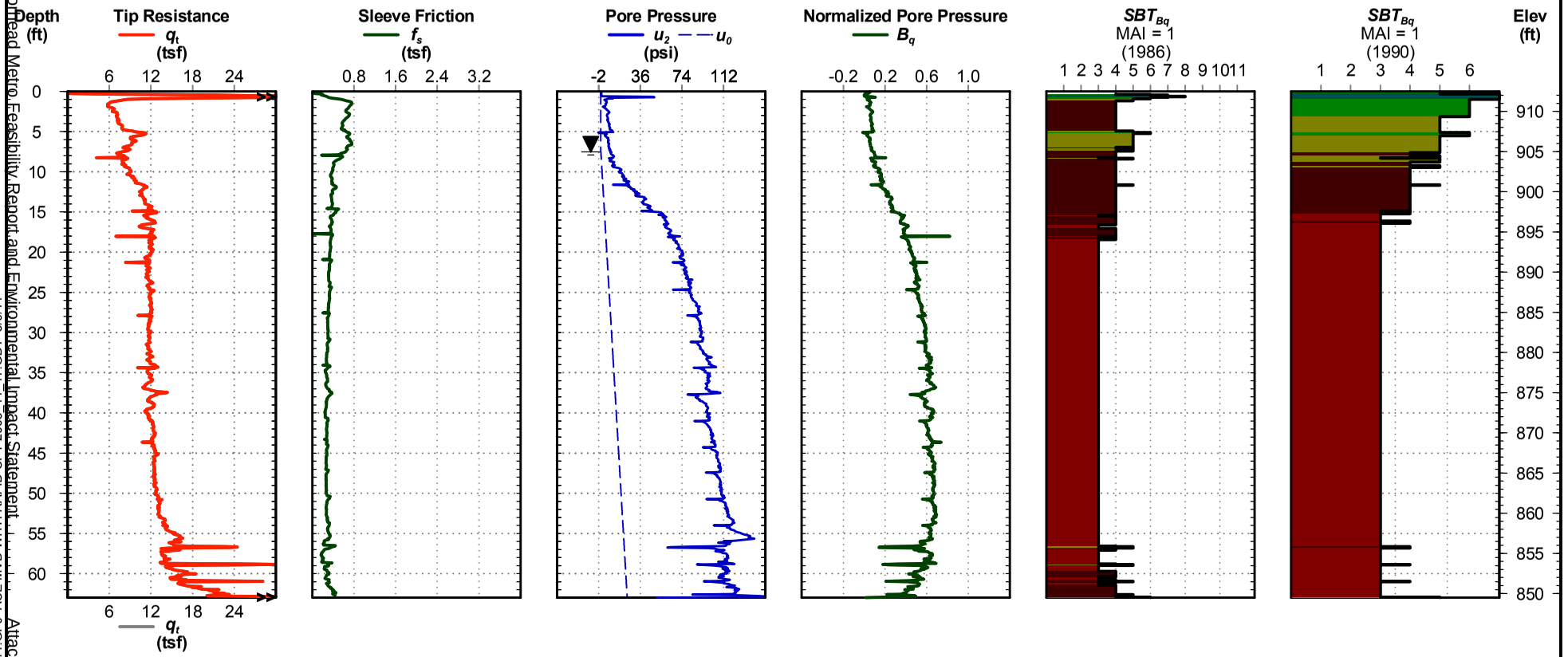
Cone Penetration Test

10-108-C

Date: Dec. 11, 2010
Operator: Johnston
Drilling Agency: USACE, Savannah District

Latitude: 46° 45' 11.448"
Longitude: -96° 56' 26.772"
Probe ID/Net Area Ratio: DDG1117 / 0.8

Elevation: 912.5
Water Depth: 7.51
Total Depth: 63.0 ft



Electronic Filename: 10-108-C.cpt

Fargo Red River Diversion

Project No: FY 2011

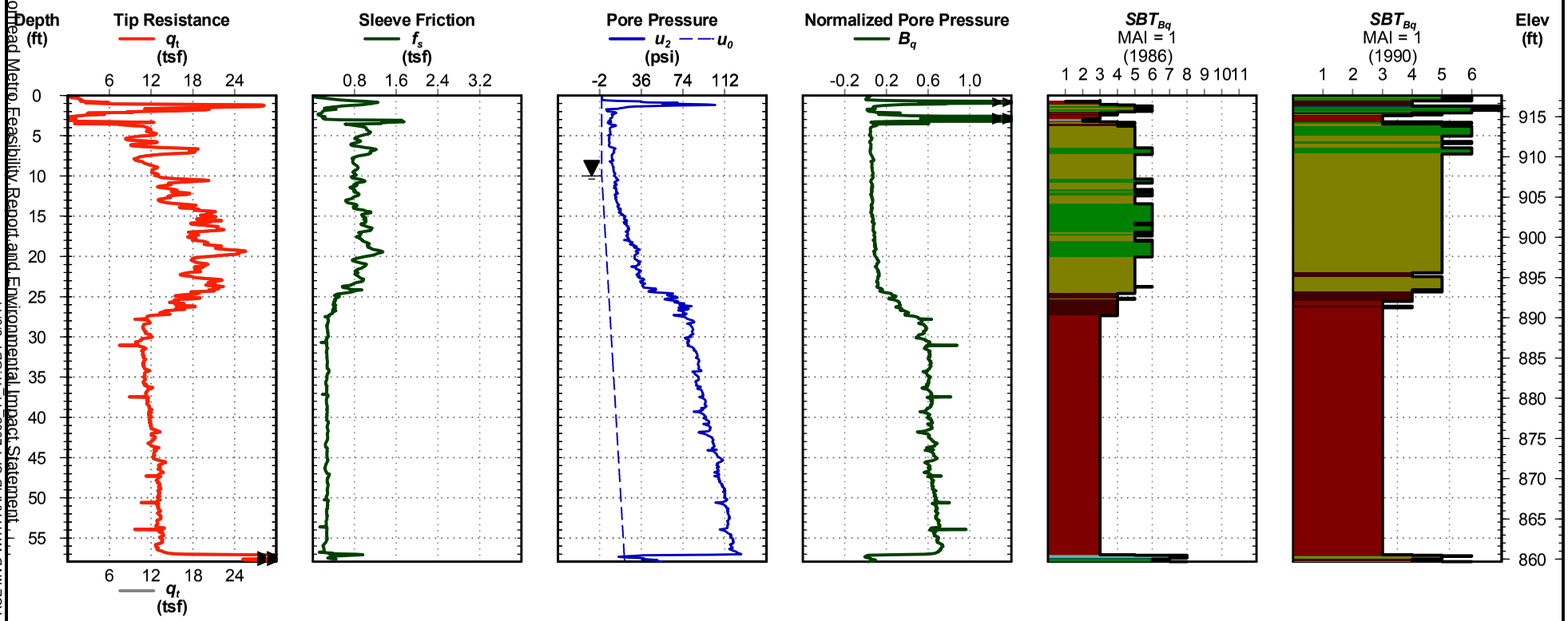
Cone Penetration Test

11-119-C

Date: Jan. 16, 2011
Operator: Johnston
Drilling Agency: USACE, Savannah District

Latitude: 46° 42' 4.5"
Longitude: -96° 47' 19.248"
Probe ID/Net Area Ratio: DDG1117 / 0.8

Elevation: 917.6
Water Depth: 10.01
Total Depth: 57.9 ft



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APPENDIX B

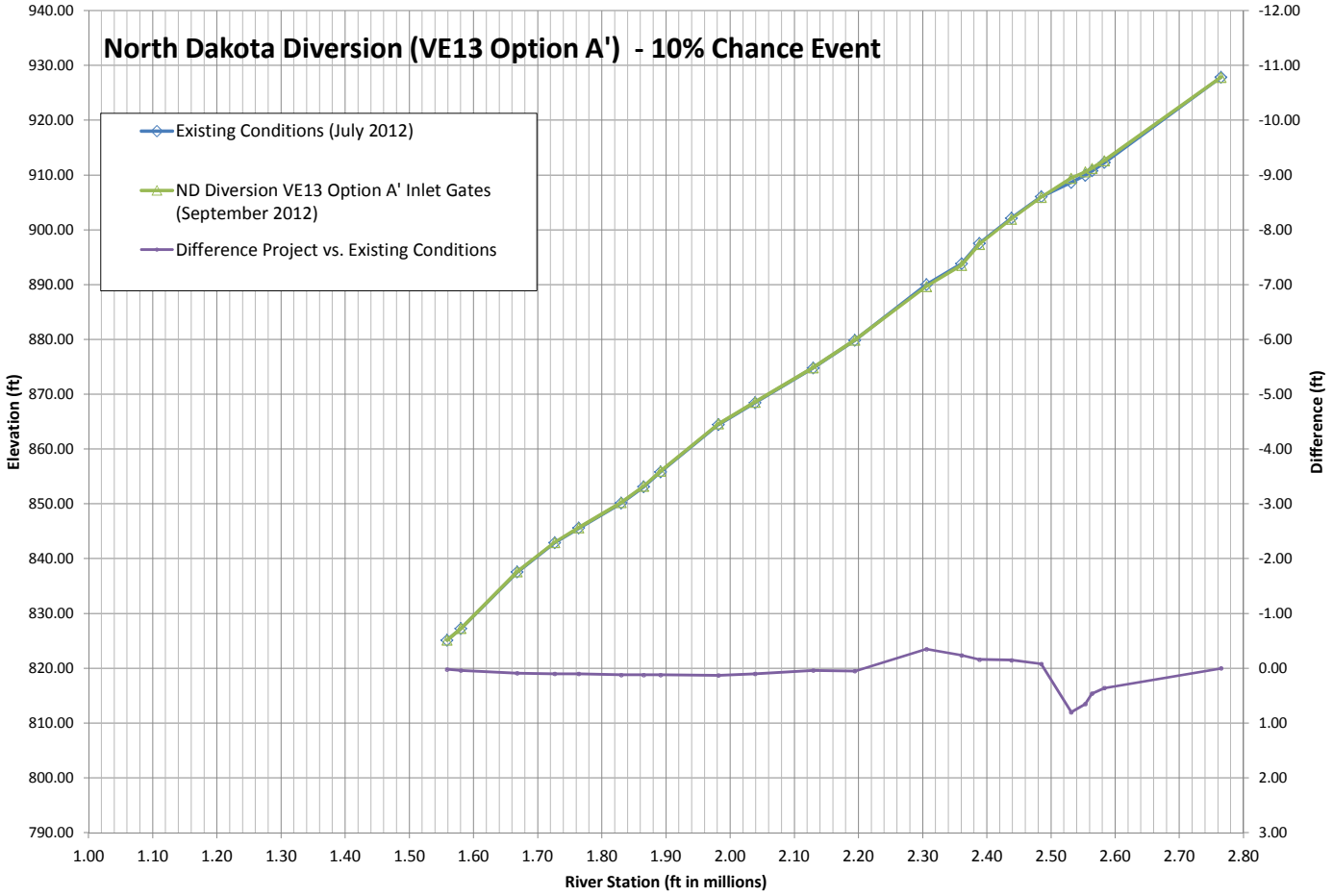
HYDRAULIC MODELING RESULTS

VE13 Option A' - 10% Chance Event

North Dakota Diversion (VE13 Option A') - 10% Chance Event

Location	Station	Existing Conditions (July 2012)	ND Diversion VE13 Option A' Inlet Gates (September 2012)	Difference Project vs. Existing Conditions	Ph. 4 LPP Impacts (April 2011)	Change in Impacts Relative to Ph.4	Ph. 6 FRP Impacts (July 2012)	Change in Impacts Relative to Ph.6
		Elevation (ft)	Elevation (ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Grand Forks Gage	1558518	825.15	825.17	0.02	0.11	-0.09	0.04	-0.02
32nd Ave, Grand Forks	1580152	827.25	827.29	0.04	0.11	-0.07	0.06	-0.02
Thompson Gage	1667877	837.58	837.67	0.09	0.04	0.05	0.05	0.04
Co. Hwy 25/ Co. Rd 221	1726274	842.90	843.00	0.10	0.04	0.06	0.05	0.05
DS Sandhill River/ Climax	1763746	845.59	845.69	0.10	0.03	0.07	0.05	0.05
Nielsville	1829877	850.14	850.26	0.12	0.03	0.09	0.06	0.06
DS Marsh River	1864960	853.13	853.25	0.12	0.04	0.08	0.06	0.06
US Goose River/ Shelly	1891054	855.86	855.98	0.12	0.03	0.09	0.05	0.07
Halstad Gage	1981580	864.50	864.63	0.13	-0.12	0.25	-0.02	0.15
Hendrum	2038409	868.48	868.58	0.10	-0.25	0.35	-0.07	0.17
Perley	2129181	874.83	874.87	0.04	-0.54	0.58	-0.24	0.28
Georgetown	2194021	879.88	879.93	0.05	-0.43	0.48	-0.23	0.28
North River/ Clay Co. Hwy 93	2305647	890.04	889.69	-0.35	-5.49	5.14	-4.18	3.83
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	893.81	893.57	-0.24	-5.36	5.12	-4.75	4.51
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.54 (34.8*)	897.38 (34.64*)	-0.16	-5.47	5.31	-5.03	4.87
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	902.15	902.00	-0.15	-5.49	5.34	-5.41	5.26
US ND Wild Rice River	2484618	906.05	905.97	-0.08	-5.15	5.07	-5.54	5.46
US Diversion	2531315	908.66	909.46	0.80	8.23	-7.43	5.74	-4.94
Oxbow	2552977	909.96	910.61	0.65	7.13	-6.48	4.90	-4.25
Hickson Gage	2563754	910.78	911.24	0.46	6.59	-6.13	4.37	-3.91
Cass/Richland County Line	2582760	912.29	912.65	0.36	5.64	-5.28	3.60	-3.24
Abercrombie	2764908	927.87	927.87	0.00	0.11	-0.11	0.06	-0.06

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

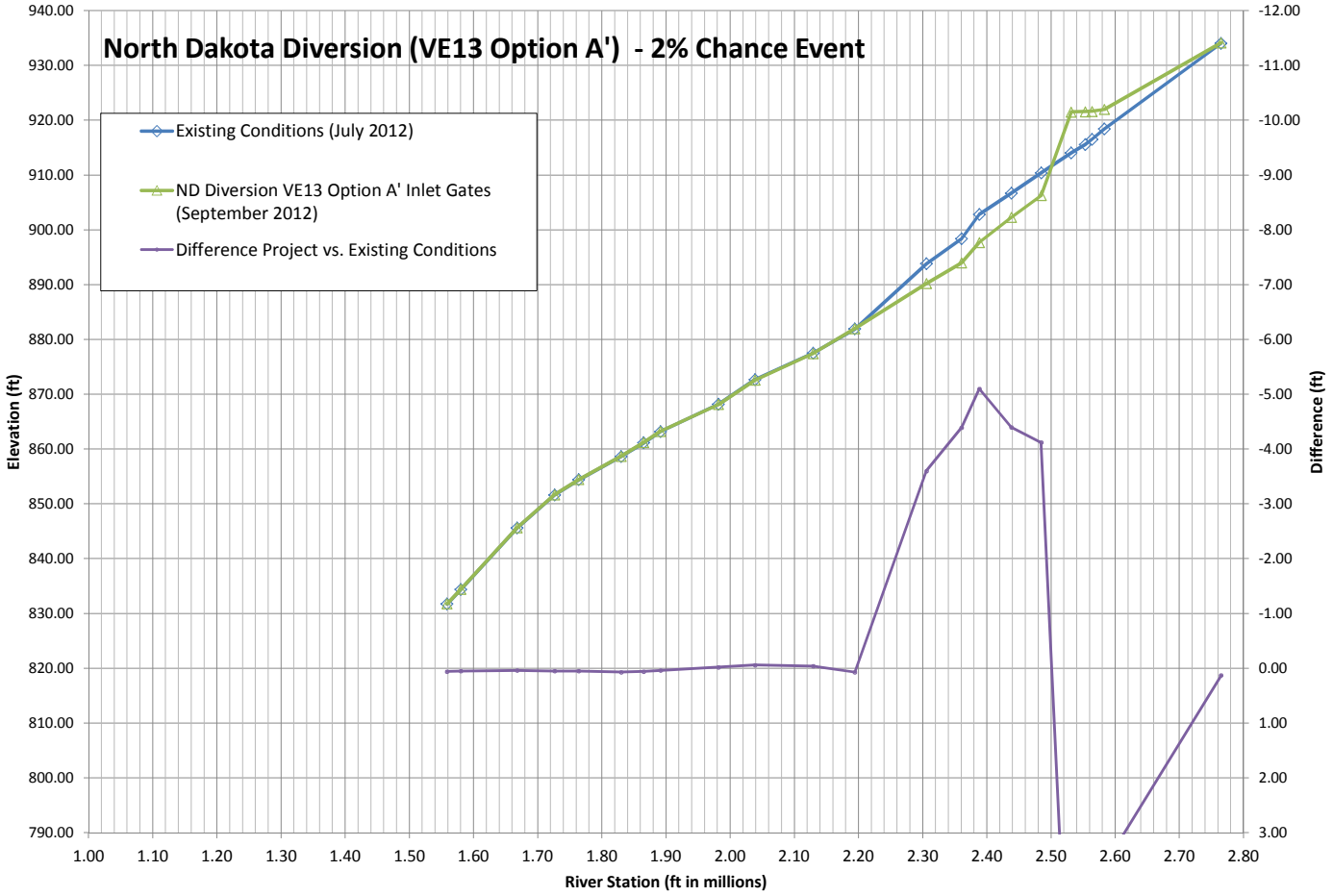


VE13 Option A' - 2% Chance Event

North Dakota Diversion (VE13 Option A') - 2% Chance Event

Location	Station	Existing Conditions (July 2012)	ND Diversion VE13 Option A' Inlet Gates (September 2012)	Difference Project vs. Existing Conditions	Ph. 4 LPP Impacts (April 2011)	Change in Impacts Relative to Ph.4	Ph. 6 FRP Impacts (July 2012)	Change in Impacts Relative to Ph.6
		Elevation (ft)	Elevation (ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Grand Forks Gage	1558518	831.74	831.80	0.06	0.18	-0.12	0.27	-0.21
32nd Ave, Grand Forks	1580152	834.40	834.45	0.05	0.28	-0.23	0.26	-0.21
Thompson Gage	1667877	845.64	845.68	0.04	0.24	-0.20	0.20	-0.16
Co. Hwy 25/ Co. Rd 221	1726274	851.65	851.70	0.05	0.21	-0.16	0.28	-0.23
DS Sandhill River/ Climax	1763746	854.41	854.46	0.05	0.21	-0.16	0.30	-0.25
Nielsville	1829877	858.65	858.72	0.07	0.18	-0.11	0.23	-0.16
DS Marsh River	1864960	861.16	861.22	0.06	0.16	-0.10	0.19	-0.13
US Goose River/ Shelly	1891054	863.20	863.24	0.04	0.12	-0.08	0.17	-0.13
Halstad Gage	1981580	868.18	868.16	-0.02	0.00	-0.02	0.04	-0.06
Hendrum	2038409	872.67	872.61	-0.06	-0.12	0.06	0.03	-0.09
Perley	2129181	877.51	877.47	-0.04	-0.32	0.28	-0.07	0.03
Georgetown	2194021	881.93	882.00	0.07	-0.23	0.30	0.03	0.04
North River/ Clay Co. Hwy 93	2305647	893.82	890.22	-3.60	-6.75	3.15	-7.45	3.85
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	898.37	893.98	-4.39	-8.35	3.96	-9.09	4.70
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.83 (40.09*)	897.73 (34.99*)	-5.10	-9.88	4.78	-10.21	5.11
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	906.71	902.31	-4.40	-10.21	5.81	-9.91	5.51
US ND Wild Rice River	2484618	910.41	906.29	-4.12	-9.41	5.29	-9.87	5.75
US Diversion	2531315	914.05	921.54	7.49	7.10	0.39	7.17	0.32
Oxbow	2552977	915.57	921.59	6.02	5.40	0.62	5.68	0.34
Hickson Gage	2563754	916.52	921.64	5.12	4.58	0.54	4.77	0.35
Cass/Richland County Line	2582760	918.40	922.00	3.60	3.52	0.08	3.30	0.30
Abercrombie	2764908	934.04	934.17	0.13	0.14	-0.01	0.25	-0.12

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

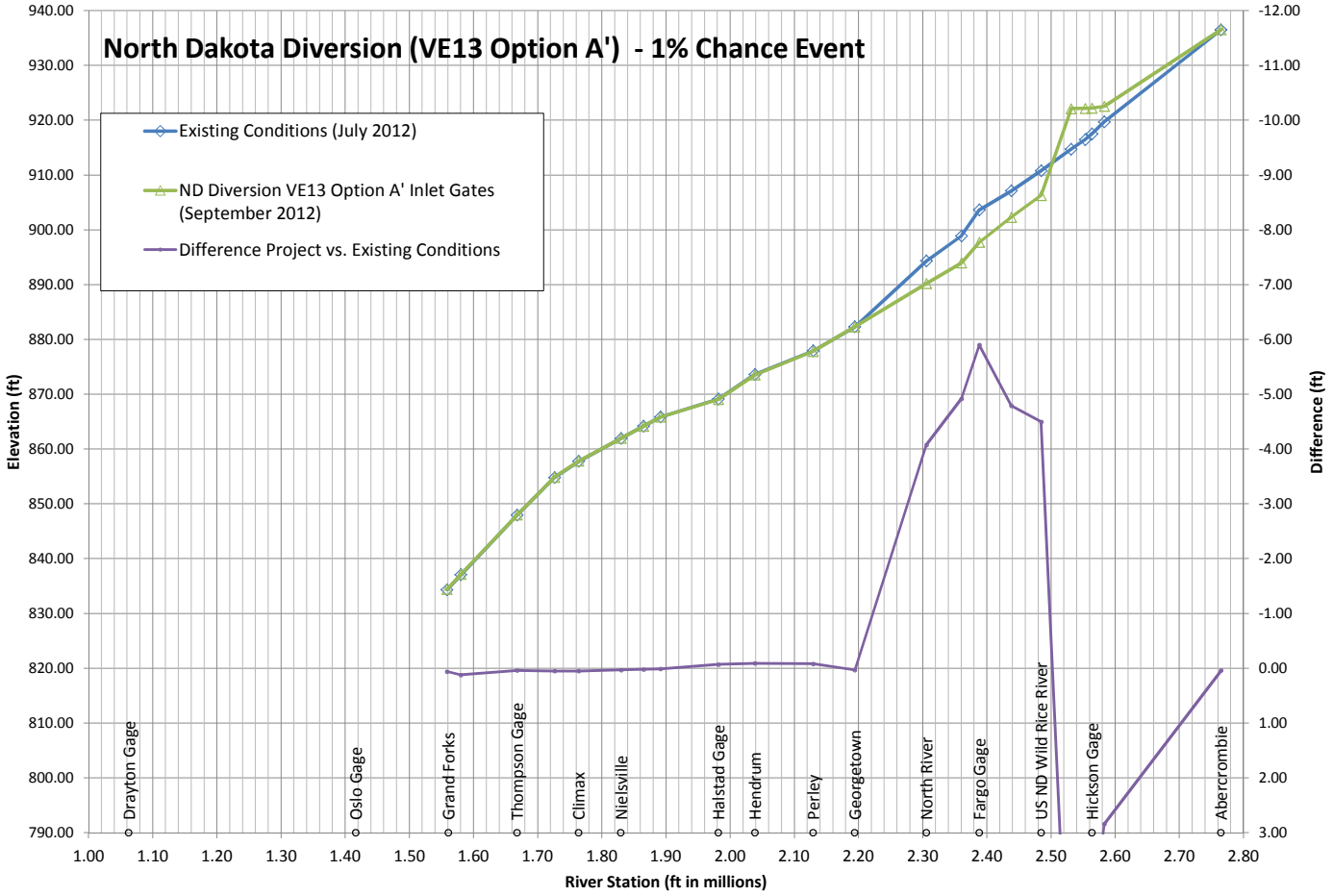


VE13 Option A' - 1% Chance Event

North Dakota Diversion (VE13 Option A') - 1% Chance Event

Location	Station	Existing Conditions (July 2012)	ND Diversion VE13 Option A' Inlet Gates (September 2012)	Difference Project vs. Existing Conditions	Ph. 4 LPP Impacts (April 2011)	Change in Impacts Relative to Ph.4	Ph. 6 FRP Impacts (July 2012)	Change in Impacts Relative to Ph.6
		Elevation (ft)	Elevation (ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Grand Forks Gage	1558518	834.36	834.42	0.06	0.24	-0.18	0.13	-0.07
32nd Ave, Grand Forks	1580152	837.06	837.18	0.12	0.28	-0.16	0.21	-0.09
Thompson Gage	1667877	847.97	848.01	0.04	0.04	0.00	0.04	0.00
Co. Hwy 25/ Co. Rd 221	1726274	854.83	854.88	0.05	-0.02	0.07	-0.03	0.08
DS Sandhill River/ Climax	1763746	857.78	857.83	0.05	-0.04	0.09	-0.04	0.09
Nielsville	1829877	861.96	861.99	0.03	-0.04	0.07	-0.09	0.12
DS Marsh River	1864960	864.20	864.22	0.02	-0.03	0.05	-0.09	0.11
US Goose River/ Shelly	1891054	865.86	865.87	0.01	-0.04	0.05	-0.10	0.11
Halstad Gage	1981580	869.15	869.08	-0.07	-0.06	-0.01	-0.24	0.17
Hendrum	2038409	873.64	873.55	-0.09	-0.06	-0.03	-0.32	0.23
Perley	2129181	877.93	877.85	-0.08	-0.28	0.20	-0.24	0.16
Georgetown	2194021	882.31	882.34	0.03	-0.25	0.28	-0.18	0.21
North River/ Clay Co. Hwy 93	2305647	894.32	890.24	-4.08	-7.25	3.17	-8.20	4.12
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	898.91	893.99	-4.92	-8.58	3.66	-8.97	4.05
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.65 (40.91*)	897.75 (35.01*)	-5.90	-10.32	4.42	-9.89	3.99
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	907.12	902.33	-4.79	-10.05	5.26	-8.78	3.99
US ND Wild Rice River	2484618	910.80	906.30	-4.50	-8.99	4.49	-8.48	3.98
US Diversion	2531315	914.74	922.13	7.39	8.23	-0.84	8.24	-0.85
Oxbow	2552977	916.47	922.18	5.71	6.30	-0.59	6.53	-0.82
Hickson Gage	2563754	917.55	922.22	4.67	5.38	-0.71	5.46	-0.79
Cass/Richland County Line	2582760	919.72	922.56	2.84	4.02	-1.18	3.42	-0.58
Abercrombie	2764908	936.52	936.56	0.04	0.11	-0.07	0.11	-0.07

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

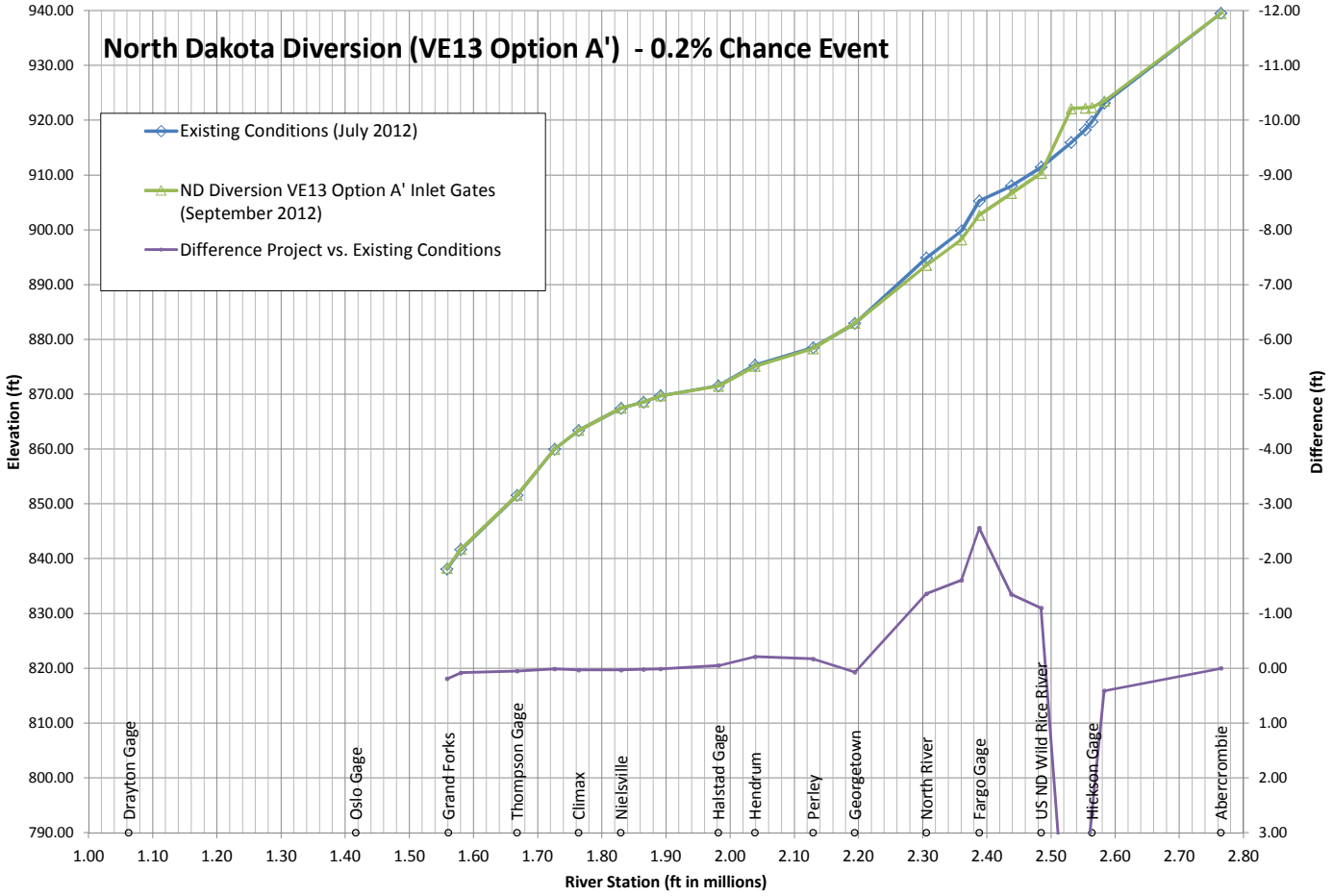


VE13 Option A' - 0.2% Chance Event

North Dakota Diversion (VE13 Option A') - 0.2% Chance Event

Location	Station	Existing Conditions (July 2012)	ND Diversion VE13 Option A' Inlet Gates (September 2012)	Difference Project vs. Existing Conditions	Ph. 4 LPP Impacts (April 2011)	Change in Impacts Relative to Ph.4	Ph. 6 FRP Impacts (July 2012)	Change in Impacts Relative to Ph.6
		Elevation (ft)	Elevation (ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Grand Forks Gage	1558518	838.09	838.28	0.19	0.22	-0.03	0.22	-0.03
32nd Ave, Grand Forks	1580152	841.66	841.74	0.08	0.27	-0.19	0.08	0.00
Thompson Gage	1667877	851.59	851.64	0.05	-0.05	0.10	-0.05	0.10
Co. Hwy 25/ Co. Rd 221	1726274	859.99	860.00	0.01	-0.12	0.13	-0.12	0.13
DS Sandhill River/ Climax	1763746	863.41	863.44	0.03	-0.15	0.18	-0.16	0.19
Nielsville	1829877	867.47	867.50	0.03	-0.16	0.19	-0.19	0.22
DS Marsh River	1864960	868.60	868.62	0.02	-0.14	0.16	-0.17	0.19
US Goose River/ Shelly	1891054	869.74	869.75	0.01	-0.13	0.14	-0.16	0.17
Halstad Gage	1981580	871.57	871.52	-0.05	-0.22	0.17	-0.21	0.16
Hendrum	2038409	875.34	875.13	-0.21	-0.30	0.09	-0.24	0.03
Perley	2129181	878.51	878.34	-0.17	-0.36	0.19	-0.19	0.02
Georgetown	2194021	882.94	883.01	0.07	-0.33	0.40	0.02	0.05
North River/ Clay Co. Hwy 93	2305647	894.89	893.53	-1.36	-2.39	1.03	-1.65	0.29
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	899.83	898.22	-1.61	-1.99	0.38	-1.87	0.26
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.29 (42.55*)	902.73 (39.99*)	-2.56	-3.03	0.47	-2.88	0.32
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	908.03	906.68	-1.35	-2.05	0.70	-1.51	0.16
US ND Wild Rice River	2484618	911.46	910.36	-1.10	-1.31	0.21	-1.24	0.14
US Diversion	2531315	915.95	922.14	6.19	6.50	-0.31	7.04	-0.85
Oxbow	2552977	918.27	922.26	3.99	3.98	0.01	4.80	-0.81
Hickson Gage	2563754	919.72	922.38	2.66	2.85	-0.19	3.40	-0.74
Cass/Richland County Line	2582760	923.12	923.53	0.41	1.13	-0.72	0.56	-0.15
Abercrombie	2764908	939.55	939.55	0.00	0.01	-0.01	0.00	0.00

* Flood stage at USGS Gaging Station 05054000, Fargo, ND



APPENDIX C

COST ESTIMATE

Fargo-Moorhead Area Flood Risk Management Project
Oxbow, Hickison, Bakke Proposed Levee
Cass County, ND

Preliminary Engineer's Opinion of Probable Cost

Date: 3/8/2013

No.	Item	Unit	Quantity	Unit Price	Total Price
LEVEE EARTHWORK AND DRAINAGE					
1.	Clearing and Grubbing	Acre	71	$1,577.00	$111,967.00
2.	Infrastructure Demolition	L. Sum	1	$200,000.00	$200,000.00
3.	Silt Fence - Furnish and Install	L.F.	20,381	$2.70	$55,028.70
4.	Topsoil Stripping	C.Y.	57,000	$3.32	$189,240.00
5.	Embankment	C.Y.	550,000	$11.25	$6,187,500.00
6.	Inspection Trench	L.F.	20,381	$10.96	$223,375.76
7.	Seeding	Acre	157	$1,833.47	$287,854.79
8.	Straw Mulch and Disk Anchoring	Acre	157	$493.85	$77,534.45
9.	Vegetation Establishment and Maintenane	Acre	157	$1,159.51	$182,043.07
				LEVEE EARTHWORK AND DRAINAGE SUBTOTAL	$7,514,543.77
				LEVEE EARTHWORK AND DRAINAGE CONTENGENCIES (25%)	$ 1,878,635.94
				TOTAL LEVEE EARTHWORK AND DRAINAGE	***$9,393,179.71***
SANITARY SEWER ITEMS					
1.	Topsoil Stripping - 6"	C.Y.	8,750	$4.00	$35,000.00
2.	Sanitary Sewer - 8" PVC SDR 35	L.F.	4,750	$40.00	$190,000.00
3.	Sanitary Sewer Manhole	Each	24	$5,000.00	$120,000.00
4.	Sanitary Sewer Service - 6" PVC SDR 26	L.F.	2,100	$22.00	$46,200.00
5.	Sanitary Sewer Connections - 6" PVC SDR 26	Each	42	$200.00	$8,400.00
6.	Televising - Sanitary Sewer Service	Each	42	$100.00	$4,200.00
7.	Sanitary Sewer - Connect to Existing	Each	1	$1,000.00	$1,000.00
8.	Sanitary Sewer Manhole - Tap Existing	Each	1	$1,500.00	$1,500.00
9.	Sanitary Sewer Lift Station	L. Sum	1	$150,000.00	$150,000.00
				SANITARY SEWER ITEMS SUBTOTAL	$556,300.00
				SANITARY SEWER ITEM CONTENGENCIES (25%)	$ 139,075.00
				TOTAL SANITARY SEWER ITEMS	***$695,375.00***
WATER MAIN ITEMS					
1.	Water Main - 8" PVC C900	L.F.	7,750	$30.00	$232,500.00
2.	Corporation - 1"	Each	42	$200.00	$8,400.00
3.	Curb Stop & Box - 1"	Each	42	$200.00	$8,400.00
4.	Water Service Line - 1" Copper	L.F.	2,100	$20.00	$42,000.00
5.	Hydrant - 6"	Each	18	$3,500.00	$63,000.00
6.	Hydrant Lead - 6" PVC C900	L.F.	500	$40.00	$20,000.00
6.	Gate Valve & Box - 8"	Each	20	$1,500.00	$30,000.00
7.	Gate Valve & Box - 6"	Each	18	$1,100.00	$19,800.00
8.	Specials	Lbs.	3,750	$4.00	$15,000.00
9.	Water Main - Connect To Existing	Each	3	$1,000.00	$3,000.00
				WATER MAIN ITEMS SUBTOTAL	$442,100.00
				WATER MAIN ITEM CONTENGENCIES (25%)	$ 110,525.00
				TOTAL WATER MAIN ITEMS	***$552,625.00***
STORM SEWER ITEMS					
1.	Storm Sewer - 15" RCP	L.F.	500	$35.00	$17,500.00
2.	Storm Sewer - 18" RCP	L.F.	1,000	$40.00	$40,000.00
3.	Storm Sewer - 21" RCP	L.F.	500	$45.00	$22,500.00
4.	Storm Sewer - 24" RCP	L.F.	3,000	$50.00	$150,000.00
5.	Storm Sewer - 27" RCP	L.F.	650	$60.00	$39,000.00
6.	Storm Sewer - 30" RCP	L.F.	800	$70.00	$56,000.00
7.	Storm Sewer - 36" RCP	L.F.	1,250	$85.00	$106,250.00
8.	Storm Sewer - 42" RCP	L.F.	2,050	$110.00	$225,500.00
9.	Storm Sewer - 48" RCP	L.F.	2,000	$130.00	$260,000.00
10.	Storm Sewer - 54" RCP	L.F.	1,000	$160.00	$160,000.00
11.	Storm Sewer - 60" RCP	L.F.	3,600	$210.00	$756,000.00
12.	Storm Sewer Manhole - 48"	Each	6	$2,500.00	$15,000.00
13.	Storm Sewer Manhole - 60"	Each	10	$3,500.00	$35,000.00
14.	Storm Sewer Manhole - 72"	Each	4	$5,500.00	$22,000.00
15.	Storm Sewer Manhole - 84"	Each	6	$7,000.00	$42,000.00
16.	Storm Sewer Manhole - 96"	Each	7	$8,500.00	$59,500.00
17.	Storm Sewer Manhole - 10' x 10'	Each	2	$12,000.00	$24,000.00
18.	Storm Sewer Manhole - Tee Inlet	Each	10	$5,000.00	$50,000.00
19.	Storm Sewer Inlet	Each	30	$1,500.00	$45,000.00
				STORM SEWER ITEMS SUBTOTAL	$2,125,250.00
				CONTENGENCIES (25%)	$ 531,312.50
				STORM SEWER ITEMS	***$2,656,562.50***

HMG

No.	Item	Unit	Quantity	Unit Price	Total Price
POND ITEMS					
1.	Excavation - Pond	C.Y.	630,000	$5.00	$3,150,000.00
2.	Control Structure	Each	1	$40,000.00	$40,000.00
3.	Storm Sewer - 60" RCP	L.F.	1,500	$210.00	$315,000.00
4.	Flared End Section - 48" RCP	Each	1	$2,500.00	$2,500.00
5.	Flared End Section - 60" RCP	Each	1	$3,000.00	$3,000.00
6.	Check Valve - 60"	Each	1	$50,000.00	$50,000.00
7.	Sluice Gate - 60"	Each	1	$30,000.00	$30,000.00
8.	Outfall Structure	L. Sum	1	$10,000.00	$10,000.00
9.	Storm Pump Station - M&E	L. Sum	1	$500,000.00	$500,000.00
10.	Storm Pump Station - Buildings, Pumps, General	L. Sum	1	$2,000,000.00	$2,000,000.00
				POND ITEMS SUBTOTAL	$6,100,500.00
				CONTENGENCIES (25%)	$ 1,525,125.00
				POND ITEMS	***$7,625,625.00***
TRANSPORTATION - HIGHWAY 81 AND 18 ITEMS					
1.	Topsoil Stripping - 6"	C.Y.	25,000	$4.00	$100,000.00
2.	Unclassified Excavation	C.Y.	12,500	$5.00	$62,500.00
3	Clay Embankment	C.Y.	78,000	$6.00	$468,000.00
4.	Subgrade Preparation	S.Y.	30,500	$2.00	$61,000.00
5.	Reinforcement Fabric	S.Y.	30,500	$1.50	$45,750.00
6.	Gravel - NDDOT Class 5 - 9"	C.Y.	7,500	$35.00	$262,500.00
7.	Asphalt Base Course - 3.5"	S.Y.	26,000	$15.00	$390,000.00
8.	Asphalt Wear Course - 2"	S.Y.	26,000	$10.00	$260,000.00
9.	Seeding	Acre	30	$1,833.47	$55,004.10
				TRANSPORTATION - HIGHWAY 81 AND 18 ITEMS SUBTOTAL	$1,704,754.10
				CONTENGENCIES (25%)	$ 426,188.53
				TRANSPORTATION - HIGHWAY 81 AND 18 ITEMS	***$2,130,942.63***
TRANSPORTATION - OXBOW ADDITION ITEMS					
1.	Topsoil Stripping - 6"	C.Y.	4,750	$4.00	$19,000.00
2.	Clay Embankment	C.Y.	14,000	$6.00	$84,000.00
3.	Subgrade Preparation	S.Y.	22,500	$2.00	$45,000.00
4.	Reinforcement Fabric	S.Y.	22,500	$1.50	$33,750.00
5.	Gravel - NDDOT Class 5 - 9"	C.Y.	5,600	$35.00	$196,000.00
6.	Pipe - 4" Perforated PVC	L.F.	12,500	$4.00	$50,000.00
7.	Curb & Gutter	L.F.	12,500	$14.00	$175,000.00
8.	Asphalt Base Course - 3.5"	S.Y.	20,000	$15.00	$300,000.00
9.	Asphalt Wear Course - 2"	S.Y.	20,000	$10.00	$200,000.00
10.	Seeding	Acre	4	$1,833.47	$7,333.88
				TRANSPORTATION - OXBOW ADDITION ITEMS SUBTOTAL	$1,110,083.88
				CONTENGENCIES (25%)	$ 277,520.97
				TRANSPORTATION - OXBOW ADDITION ITEMS	***$1,387,604.85***
GENERAL ITEMS					
1.	Tree - Large Deciduous	Each	160	$400.00	$64,000.00
2.	Cleaning	L.Sum	1	$10,000.00	$10,000.00
3.	Storm Water Management	L.Sum	1	$25,000.00	$25,000.00
4.	Traffic Control	L.Sum	1	$10,000.00	$10,000.00
				GENERAL ITEMS SUBTOTAL	$109,000.00
				CONTENGENCIES (25%)	$ 27,250.00
				GENERAL ITEMS	***$136,250.00***
STREET LIGHTING ITEMS					
1.	LED Street Light	Each	21	$5,000.00	$105,000.00
2.	Feedpoint	L. Sum	1	$7,000.00	$7,000.00
				STREET LIGHTING ITEMS SUBTOTAL	$112,000.00
				CONTENGENCIES (25%)	$ 28,000.00
				STREET LIGHTING ITEMS	***$140,000.00***
GOLFCOURSE ITEMS					
1.	Golf hole	Each	9.5	$600,000.00	$5,700,000.00
2.	Golf Clubhouse and Amenities	L.Sum	1	$1,000,000.00	$1,000,000.00
				GOLFCOURSE ITEMS SUBTOTAL	$6,700,000.00
				CONTENGENCIES (25%)	$ 1,675,000.00
				GOLFCOURSE ITEMS	***$8,375,000.00***
LAND ACQUISITIONS ITEMS					
1.	Real Estate Buyout - Home Properties	L.Sum	1	$17,418,710.00	$17,418,710.00
2.	Real Estate Buyout - Agricultural Land	Acre	260	$6,000.00	$1,560,000.00
				LAND ACQUISITIONS ITEMS SUBTOTAL	$18,978,710.00
				CONTENGENCIES (25%)	$ 4,744,677.50
				LAND ACQUISITIONS ITEMS	***$23,723,387.50***
				Subtotal Estimated Project Cost	***$56,816,553.00***
PLANNING AND ENGINEERING DESIGN (15%)		L.Sum	1	$4,963,974.70	**$4,963,974.70**
CONSTRUCTION MANAGEMENT (7%)		L.Sum	1	$2,316,521.53	**$2,316,521.53**
				Total Estimated Project Cost	***$64,097,050.00***

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