

Upper Turtle River Watershed Dam #9, Larimore Dam

Geotechnical Engineering Report

Grand Forks County Water Resource District
USDA - NRCS

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Abbreviations

ASTM	American Society for Testing Materials
bgs	Below Ground Surface
Bpf	Blows per Foot
ft	Feet
ft/s	Feet per Second
GSD	Grain Size Distribution
HDR	HDR Engineering, Inc.
LL	Liquid Limit
NRCS	Natural Resources Conservation Service
PI	Plasticity Index
PL	Plastic Limit
SPT	Standard Penetration Tests
USCS	Unified Soil Classification System
USGS	United States Geological Survey
VWP	Vibrating Wire Piezometer
WRD	Water Resource District

1 Introduction

This Geotechnical Engineering Report (GER) has been prepared for the Grand Forks County Water Resource District (WRD) by HDR Engineering, Inc. for the Upper Turtle River Watershed Dam #9, Larimore Dam.

This report summarizes the findings of the preliminary geological investigation at Larimore Dam. Data presented in the report include exploration methods, borehole data, field and laboratory testing results, and description of the subsurface conditions encountered during the investigation. The investigation included geotechnical drilling and sampling, collection of soil samples for laboratory testing, and installation of vibrating wire piezometers (VWP). The report also includes recommendations for future investigations for completion of the final design of the selected structural alternative.

The purpose of the geological investigation is to collect soil data for subsequent laboratory testing (including soil mechanics tests for SITES and WinDAM inputs), and to develop a profile along the existing dam embankment and auxiliary spillway cross-section for use in analysis of the foundation conditions, seepage, and slope stability to determine feasibility of the structural alternatives being considered for completion of a Preliminary Supplemental Watershed Plan-Environmental Assessment (EA) for Larimore Dam.

Structural alternatives from the dam assessment work in 2015 include (all elevations in alternatives shown in National Geodetic Vertical Datum of 1929 (NGVD29) unless otherwise noted):

Alternative 1 – Modify Principal and Auxiliary Spillways

Remove top of existing principal spillway riser to elevation 1067.7, raise auxiliary spillway 1 foot to elevation 1090.3, and raise dam 4.5 feet to elevation1104.1.

Alternative 2 – Modify Principal Spillway and Install Structural Spillway

Remove top of existing principal spillway riser to elevation 1071, raise auxiliary spillway 1.2 feet to elevation 1090.5, raise top of dam 4.2 feet to elevation 1103.8, install 150-foot-wide structural spillway with a crest elevation of 1089.3, and raise the top of dam 4.2 feet to 1103.8.

Alternative 3 – Modify Principal Spillway and Replace Vegetated Spillway

Remove top of existing principal spillway riser to elevation 1071.0, abandon existing auxiliary spillway, raise top of dam 5 feet to elevation 1104.6, install 300-foot-wide structural spillway with a crest elevation of 1089.3, and raise the top of dam 5.0 feet to 1104.6.

Additional hydrologic modeling since the 2015 dam assessment work suggest potential raises of the dam could be as much as 7.1 feet to elevation 1106.7.

2 Objectives and Scope

HDR was scoped to complete the geologic investigations and this resulting report under the requirements of NEM Part 531 and NEH Part 631 for Group A Structures, and TR210-60

(NRCS 2019), including: conducting subsurface investigations, obtaining samples for laboratory testing, soil mechanics tests for SITES and WinDAM inputs and for use in analysis of foundation conditions and slope stability of the current structure. The primary objective of the geological investigation is to characterize the subsurface to better understand the foundation conditions at the site and to assess feasibility of structural alternatives being considered.

The geological investigation consisted of the following tasks:

- Drill and log five (5) exploratory borings in the overburden soil of the dam embankment and auxiliary spillway using hollow-stem augers to advance the borings. Borings were advanced up to 111.0 feet to collect soil samples representative of the subsurface strata.
- Perform standard penetration test (SPT) sampling tests concurrent with drilling to provide insight of the in-situ subsurface conditions and allow for sample collection of soil for laboratory testing. Other sampling methods such as thin-walled sampling was utilized to collect relatively undisturbed samples of the soils.
- Perform laboratory testing on select representative soil samples. Laboratory testing of the soil verifies field observations and identifies the distribution and variability of soil types and grain size in the project area. Laboratory testing also serves to characterize encountered soils and to allow estimates of the material parameters.
- Install VWPs in borings 601 and 602 to monitor groundwater flow through the dam embankment.

The original drilling plan did include three borings through the embankment cross-section- one at the crest, one at the stability berm and one at the dam toe. Due to issues with accessing the dam toe during the investigation, the toe boring was eliminated as part of this scope.

Following the August 2020 investigation, it was noted that the VWPs installed in borings 601 and 602 were installed incorrectly. As a result, two (2) additional borings were drilled to re-install VWPs in the embankment at approximately 15-foot offsets from 601 and 602. In April of 2021, TH 31 and TH 32 were drilled to 111 and 101.5 feet, respectively and nested piezometers were installed. The VWPs installed in 601 and 602 were abandoned. Split spoon and undisturbed samples were collected from boring TH 31 and TH 32 for additional laboratory samples.

3 Site Description

The dam was constructed starting in 1977 and is a multi-purpose structure which provides flood control benefits to agricultural land and infrastructure downstream as well as water-based recreation benefits to the area. Larimore Dam consists of the following components: earthen embankment, reinforced concrete principal spillway riser and conduit, vegetated auxiliary spillway, and St. Anthony Falls (SAF) stilling basin. Information provided in this section (Section 3) is taken from the 1977 as-built drawings (Appendix B). Key project elevation data is summarized in Table 3-1. All elevations noted in this report are in National Geodetic Vertical Datum of 1929 (NGVD29) unless otherwise noted.

According to the as-built drawings (Appendix B), the earthen embankment is approximately 1,040 feet long, 66 feet high and has a top width of 20 feet. The upstream face of the dam embankment has a 30-foot-wide berm located at elevation 1065.0. The slope upstream of the berm is 3.5H:1V and below the berm, the slope is 4H:1V. The downstream face of the dam embankment has a slope of 2.5H:1V with a 50-foot stability berm between elevations of 1065.0 and 1067.0. Both the upstream and downstream slopes are vegetated.

The 1977 as-built drawings called out 'top of dam after settlement' at elevation 1099.6 feet and show an as-built top of dam elevation of 1101.6 feet (resulting in a 1-foot allowance for settlement). The survey completed by HDR in April 2021 shows elevations along the top of dam ranging from 1100.9 to 1101.1 feet (NGVD29) showing that the dam has settled approximately 0.5 to 0.7 feet since 1977.

The principal spillway consists of a two-stage reinforced concrete riser. The first stage has two orifices, both of 4.5-feet width by 2.5-feet height. The upstream orifice is at elevation 1067.2. The upstream orifice can be closed with a stop log. The downstream orifice is at elevation 1067.7. The second stage of the riser has an inlet with a weir length of 12 feet on the two sides for a total weir length of 24 feet. All inlets are protected by trash racks.

The outlet conduit is a six-foot by six-foot cast-in-place reinforced concrete pipe. Reinforced concrete anti-seepage collars were placed at approximately 24-foot intervals along the conduit. The pipe discharges into a St. Anthony Falls (SAF) stilling basin. The basin is riprap lined with side slopes of 2H:1V. The basin overflows to a 20-foot-wide outlet channel with side slopes of 3H:1V.

A foundation drain, to collect seepage, outlets through two 6-inch pipes. One outlet pipe is located on each side of the principal spillway outlet. Each outlet has a fabricated animal guard installed.

A 300-foot wide broad-crested auxiliary spillway is located to the north of the dam with a crest elevation of 1089.3. The spillway is excavated into natural ground with side slopes at 3H:1V. The outlet of the auxiliary spillway is very long at approximately 1,600 feet in length from the upstream end of the level section to the natural valley outlet. During 2000 flooding from an extreme summer rainfall event, the auxiliary spillway was activated and experienced erosion at the outlet end of the constructed auxiliary spillway. The auxiliary spillway outlet at that point in time exited into the very steep natural bank. A repair of that erosion included re-grading the outlet slope to 15 percent and selectively placed Turf Reinforcement Matrix installed along stretches of the repaired auxiliary spillway. The earthen spillway is vegetated. Figure 3-1 presents a plan view of the project site.

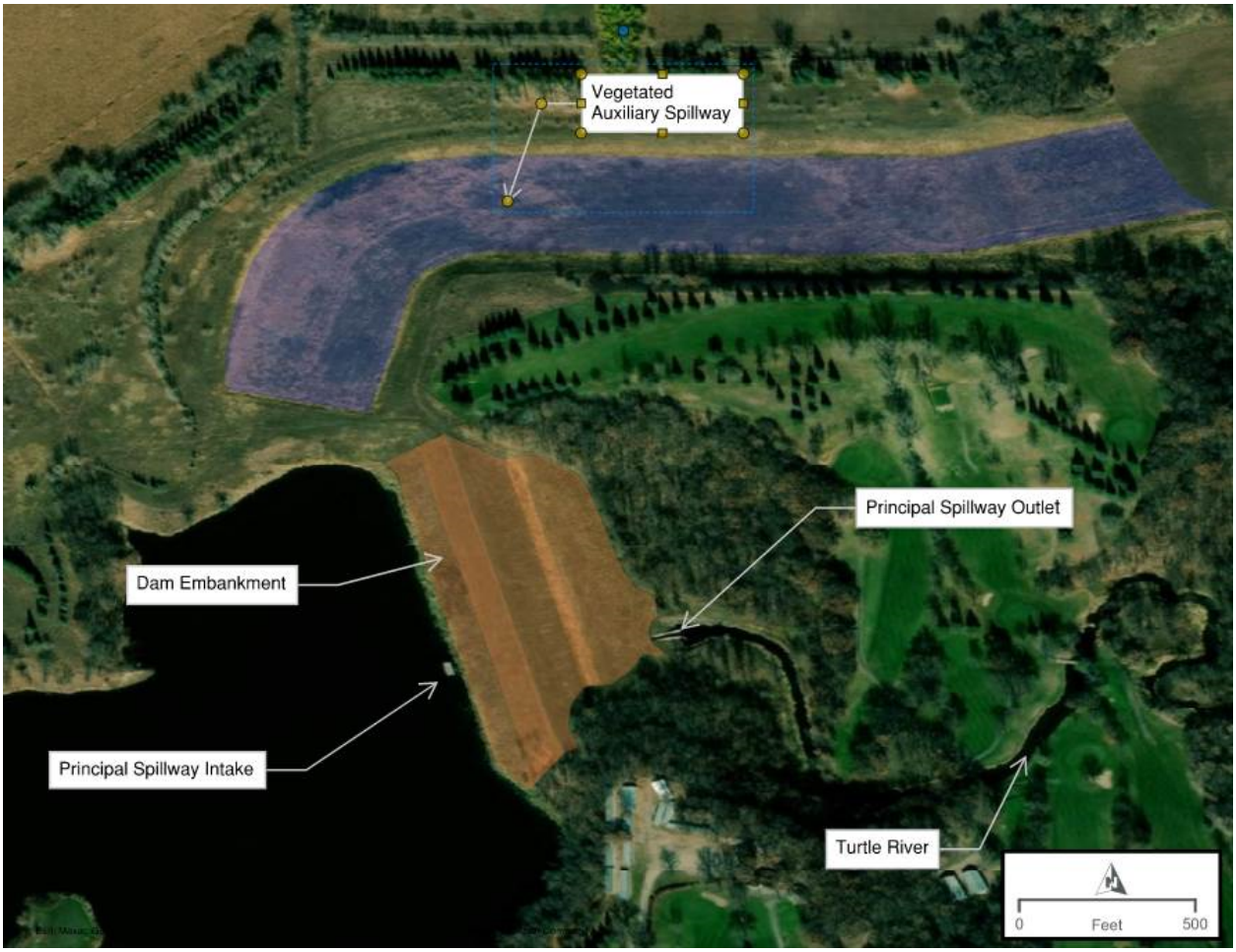


Figure 3-1: Site Map

Table 3-1 Key Project Elevations From 1977 As-Built Drawings (Appendix B)

Feature	Elevation [ft] NGVD29
Top of Dam	1101 .6
Design High Water (DHW)	1099.6
Auxiliary Spillway Crest	1089.3
Second Stage Riser Crest	1082.0
First Stage Riser Crest	1067.2
Permanent Pool	1067.2
Outlet Pipe Intake Invert	1043.0
Pipe Downstream Invert	1033.0

Note: Conversion from NGVD29 to NAVD88 is +1.18 feet

4 Geologic Setting

4.1 Data Sources

The following data sources were reviewed in preparation of this section of the report:

- Hansen, Dan E. and Kume, Jack, Bulletin 53, Geology and Ground Water Resources of Grand Forks County, North Dakota State Water Commission, 1970.
- Laird, Wilson M., The Geology of the Turtle River State Park, North Dakota Geological Survey, 1959.
- NRCS, Detailed Geologic Investigation of Dam Sites, Upper Turtle River, 1972.

4.2 Site Geology

The previous geologic review completed prior to the dam construction and performed by the NRCS classified the general geology of the site as Late Wisconsin glacial till that is mantled by glacial lake sediments (SCS, 1972). This review describes encountering buried end moraine deposits (Edinburg Moraine) that are exposed in cut banks along the stream. Elk Valley delta sediments and glacial Lake Agassiz beach deposits mantle the moraine. It is unclear where the exposed deposits described above were encountered at the site and it is presumed that the end moraine deposits could be contributing to the current seepage being experienced along the right abutment.

Other geologic data for the site include Bulletin 53: Geology and Groundwater Resources of Grand Forks County (Hansen and Kume, 1970). This report prepared by the North Dakota Geological Survey (in cooperation with the North Dakota State Water Commission, the United

States Geological Survey and the Grand Forks Water Management District) provides an interpretive summary of the geology of Grand Forks County. It includes maps of the glacial and associated deposits, as well as bedrock geology. Exhibit 1 is a sub-section of the Geologic and Landform Map of Grand Forks County. This figure identifies the predominant surficial deposits at and around the project site (identified by the red circle). In the immediate vicinity of the dam, the valley bottom consists of alluvium (grey, “AF”) with ridged beach deposits (yellow “B”) occurring on the side slopes to the north. Immediately to the south is a waterworn end moraine ridged beach deposit (green, “Ew”). A regional geologic cross-section (Exhibit 2) shows that the upper alluvium consists of clay and silt and the underlying alluvium consists of sand and gravel and that glacial till underlies the alluvium deposits and that bedrock underlies the till (cross-section C-C of Plate 4, Hansen and Kume, 1970). The thickness of the underlying till in the project area is between 250 feet and 300 feet (Figure 8, Hansen and Kume, 1970).

A test hole one mile south of the site encountered bedrock at 337 feet below ground surface. This is consistent with regional bedrock maps which estimate the elevation of bedrock to be between Elevation 800 and 750 feet; bedrock is identified as Carlile Formation Shale (Hansen and Kume, 1970).

5 Previous Investigation and Construction Records

5.1 Previous Subsurface Exploration

The preliminary investigation for the dam was completed in March 1972 by the NRCS. The borings drilled in the 1972 investigation were used to understand the thickness and contact elevation of the various geologic subsurface materials; these borings include eleven (11) borings along and offset from the dam centerline; eight (8) borings along the centerline of dam; three (3) borings along the centerline of the principal spillway; four (4) borings along the auxiliary (emergency) spillway and thirteen (13) borings in the proposed borrow area. The as-built drawings (Appendix B) provide graphic logs of soils and borings completed during the previous field investigation. As-built drawings also provides a profile along the centerline of the dam and through the auxiliary spillway. The as-built Drawings provide no written logs of the test pits.

5.1.1 Foundation Material

The 1972 investigation concluded that the contact elevation between the recent surficial alluvial deposits and the underlying glacial till (referred to as glacial drift in the 1972 report, but referred to as glacial till herein) is generally uniform and ranged from elevation 1030 on the north side of the valley but rises to elevation 1034 as you move toward the right abutment, upstream of the centerline. The general alluvium-till contact surface slopes downstream.

The surficial alluvium deposit varied from non-plastic silty sand (SM) to low-plasticity clayey sand, silt, and lean clay material. Material at the left side and center of the floodplain was

logged as sandy and gravelly material while the material at the base of the right abutment was logged as silty and sandy material. Average blow counts for the saturated sands in this deposit were 7 to 10 blows per foot (bpf). Boulders and cobbles were occasionally encountered in this deposit, generally at the contact between the alluvium and glacial till. The alluvium deposit was removed under the dam footprint as part of the embankment dam construction (as shown in Figure 6-2in Section 6.4).

The glacial till immediately under the alluvium is described as stratified and varied from sandy silt (ML) to silty lean clay (CL). Blow counts averaged 10 to 12 bpf. This deposit was generally encountered between elevation 1030 and 1000 feet. This deposit is underlain by an older glacial till deposit that was interpreted to be a pre-consolidated till. The blow counts jumped to 40 bpf or greater when pre-consolidated till was encountered at approximately at elevation 1000.

5.1.2 Auxiliary (Emergency) Spillway Foundation

The 1972 auxiliary spillway investigation encountered surficial lacustrine sediments consisting of non-plastic silty sand (SM) over low-plasticity silt (ML) that become finer with depth. Glacial till consisting of predominately low-plasticity lean clay (CL) underlies the lacustrine sediments and is the existing surface deposit of the current auxiliary spillway as the surficial lacustrine native material was removed for dam construction.

5.1.3 Borrow Area

A 15-acre borrow area upstream of the dam and on the left abutment was drilled on a 200-foot grid. The 1972 borrow area investigation encountered shallow (0 to 6 feet) lacustrine sediments overlying the glacial till (drift). The lacustrine sediments were predominantly non-plastic silty sand (SM) and clayey sand (SC) materials and the glacial till was predominantly a low plasticity lean clay (CL) material. The borrow area was drilled to a depth of 20 feet.

5.2 Previous Laboratory Testing

5.2.1 Foundation Material

From the 1972 field investigation, eleven samples were collected of the foundation material. As previously described, the foundation material includes a sand and gravel surficial alluvium overlying a silty and sandy stratified glacial till that was predominantly a lean clay (CL). It also includes silty sand (SM) and silt (ML) lacustrine and beach deposits, which is the surficial material overlying the glacial till in the uplands and high abutments of the flood plain.

Index, consolidation, permeability, and shear strength testing was completed on the foundation materials. The following sections summarize the results reported in the 1972 Investigation Report (SCS, 1972).

5.2.1.1 DRY UNIT WEIGHT

The dry density of the sand and gravel alluvial deposit varied from 75.5 pcf to 88 pcf. The dry density of the glacial till ranged from 89.9 pcf to 98.6 pcf.

5.2.1.2 CONSOLIDATION

One-dimensional consolidation tests were completed on four undisturbed samples (one alluvium and three glacial till samples). The test results indicated that the material was pre-consolidated compared to the pre-dam in-situ stresses. The shallow alluvium sample had a pre-consolidation pressure of approximately 3,000 psf. The three glacial till samples had a pre-consolidation pressure ranging from 4,500 psf for the upper sample to 7,500 psf for the deeper sample. At the time of design, the anticipated loading of the dam on the glacial till layer (which includes 58-foot-high embankment dam and overburden loads) ranged from 6,500 psf to 8,000 psf; as a result, consolidation potential for the alluvium was estimated to be 7% and consolidation potential for the glacial till above elevation 1015 was estimated to be 4%. Consolidation potential for the glacial till below elevation 1015 was expected to be negligible for the anticipated loading.

5.2.1.3 PERMEABILITY

Falling head permeability testing was completed on glacial till samples and permeability ranged of $3.53x10^{-6}$ cm/s to $2.12x10^{-6}$ cm/s.

5.2.1.4 SHEAR STRENGTH

Shear strength testing was completed on the surficial alluvial samples as well as the underlying glacial till samples.

Shear strength testing of the surficial alluvial samples included both triaxial and direct shear tests. The shear strength envelope from the direct shear test on a silty sand sample obtained from the upper portion of the alluvial material was a phi of 26.5 degrees and a cohesion of 375 psf. The total shear strength envelope from the triaxial test on a silt sample obtained from the lower portion of the alluvial material was a phi of 6.5 degrees and a cohesion of 600 psf.

Shear strength testing of the glacial till included triaxial shear and unconfined compression testing. The total shear strength envelope from the triaxial test on a silt sample the glacial till was a phi of 14 degrees and cohesion of 750 psf. The unconfined compression test results for the same glacial till sample and another sample resulted in a cohesion of 1,720 psf and 2,490 psf for test specimens that were 96 and 98 percent of theoretical saturation, respectively.

5.2.2 Proposed Embankment Fill (1972)

Based on the 1972 investigation report, the proposed borrow sources for the embankment dam was the surficial silty and sandy lacustrine materials from the emergency spillway excavation and silty glacial till from the borrow area. The lacustrine samples were described as non-plastic silty sand (SM) to low-plasticity silt (ML). The glacial till borrow is described as low-plasticity lean clay (CL) material.

Index, proctor, permeability, shear strength and consolidation testing were completed on the proposed embankment fill.

5.2.2.1 STANDARD PROCTOR TESTING

Eleven standard Proctor tests were completed on proposed borrow materials. The maximum dry density of the lacustrine borrow materials varied from 100.0 pcf to 107.0 pcf. Maximum dry density of the glacial till borrow material varied from 110.5 pcf to 114.0 pcf. Optimum moisture contents varied from 15 to 21.5 percent.

5.2.2.2 PERMEABILITY

Constant head permeability testing was completed on the silty sand (SM) and silt (ML) lacustrine borrow material and lean clay (CL) glacial till borrow material. The material was compacted wet of optimum to approximately 95 percent of standard Proctor maximum dry density at confining loads of 1,000 psf, 2,000 psf, 4,000 psf, and 8,000 psf.

The permeability for samples at a confining load of 2,000 psf ranged from 7.06E-08 cm/s to 2.12E-07 cm/s. The permeability for samples at a confining load of 8000 psf ranged from 1.06E-07 cm/s to zero.

5.2.2.3 SHEAR STRENGTH

Shear strength testing was completed on the non-plastic silty sand (SM) and the silt (SM) lacustrine borrow material and the lean clay (CL) glacial till borrow material. Shear strength testing included consolidated undrained triaxial shear tests for the silt (ML) and lean clay (CL) materials and a direct shear test for the non-plastic silty sand (SM) material.

The silt (ML) and lean clay (CL) samples were remolded to slightly wet of optimum and compacted to 95 percent of standard Proctor maximum dry density. The effective and total shear strength envelopes from triaxial testing of the silt (ML) lacustrine borrow material were a phi of 33.5 degrees and a cohesion of zero and a phi of 18 degrees and a cohesion of 425 psf, respectively. The effective and total shear strength envelopes from triaxial testing of the lean clay (CL) glacial till borrow material was a phi of 33.5 degrees and a cohesion of zero and a phi of 16 degrees and a cohesion of 375 psf.

The non-plastic silty sand (SM) samples were remolded by compacting to 95% of the standard Procter maximum dry density and flooded with water at the start of the shear test. The total shear strength envelope from direct shear testing of the SM lacustrine borrow material was a phi of 33.5 degrees and a cohesion of 250 psf.

5.2.2.4 CONSOLIDATION

Based on the consolidation of the remolded samples during the permeability and direct shear testing, the permeability samples consolidated between 3.2 and 6.9% under the 8,000 psf loading and direct shear sample consolidated 5% under the 5,760 psf normal load. The average embankment consolidation at the time of design for the anticipated loading of the dam (which includes 58-foot-high embankment dam and overburden loads) was estimated to be 2 to 3%.

5.3 1972 Stability Analysis

Table 5-1 provides the shear strength parameters that were used to evaluate slope stability in the 1972 Stability Analysis.

Table 5-1 1972 Slope Stability Modeling Parameters

Material	Shear Strength Parameters			
	Total Stress Envelope		Effective Stress Envelope	
	c (psf)	ϕ (deg)	c' (psf)	ϕ' (deg)
Lean Clay (CL) Embankment Fill	375	16	0	33.5
Silty Sand (SM) Alluvium	375	26.5	-	-
Silt (ML) Alluvium	600	6.5	-	-
Lean Clay (CL)Glacial Till	750	14	200	32

The stability analysis required 3.5H:1V to achieve a safety factor greater than 1 for undrained slopes and 2.5H:1V to achieve a safety factor greater than 1 for undrained slopes using infinite slope analysis.

The stability analysis required the upstream slope to consists of 3.5H:1V above a 29-foot-wide berm at Elevation 1067.2 and 4H:1V slope below the berm to achieve a safety factor of 1.30 for the full drawdown analysis.

The stability analysis required the downstream slope to consist of 2.5H:1V above a 50-foot-wide berm at Elevation 1065 and 4H:1V slope below the berm to achieve a safety factor of 1.30 for the steady seepage analysis for a full reservoir condition.

It should be noted that the method of analysis, minimum required factors of safety, and shear strength test methods have been updated since the 1972 stability analysis. The analysis described in Section 7.4 reflects these changes.

5.4 1972 Settlement Analysis

The settlement analysis was completed as part of the 1972 dam design. Differential settlement was not anticipated to be an issue at the site. The consolidation potential was estimated to be 3 feet across the flood plain and the total settlement at the end of construction was estimated to be 2 feet across the flood plain.

5.5 Foundation Treatment

The as-built drawings show that 5 feet of material was removed from under the entire foundation below the embankment. Furthermore, along the dam centerline, material was excavated to

approximately elevation 1030 to remove the sandy alluvium and construct a cutoff trench that extends down into the glacial till. The cutoff trench is 12 feet wide at its base and has excavation slopes of 1H:1V or flatter. The grade of the cut-off trench is illustrated in Exhibit 3.

In cut areas of the auxiliary spillway, the as-built drawings indicate the contractor was required to over-excavate 0.5 feet and backfill with topsoil. The constructed grade of the auxiliary spillway along the centerline is illustrated in Exhibit 4.

5.6 Zoned Embankment Construction

The as-built drawings show that the embankment was zoned. Zone I is located at the dam centerline. The top is located at elevation 1090 and is 8 feet wide. Below elevation 1090, Zone I slopes at 1H:1V to the foundation excavation line. Zone I fill is indicated to consist of lean clay material compacted to 95% standard Proctor at a water content above optimum.

A foundation blanket is identified to be located at the right abutment, right of Station 12+00. The foundation blanket fill is indicated to consist of Zone I fill that is 6 feet thick and is located below elevation 1062.

All other embankment is identified to consist of Zone II fill. Zone II fill is indicated to consist of silty sand (SM) or silt (ML) material compacted to 95% standard Proctor at a water content above optimum.

5.7 Drains

The as-built drawings show a shallow foundation trench drain from STA 5+10 to 11+40 and from STA 11+60 to STA 13+47. The drain is located below the permanent pool elevation and 100 feet offset downstream from the dam centerline. The purpose of the foundation drain, according to the 1972 investigation report, is to “provide embankment stability for the downstream slope and to provide a controlled outlet for foundation seepage that by-passes the centerline cutoff trench” (SCS, 1972). The foundation drain consists of sand and gravel drain fill that is a minimum of 6.0 feet in depth and 3.5 feet in width. Except for at the dam abutments, the drain includes a 6-inch diameter perforated asbestos cement pipe.

The foundation drain outlet is through two perpendicular drains that outlets at the downstream toe of the dam. A drain is on each side of the principal spillway outlet. The perpendicular drains consist of sand and gravel drain fill that is a minimum of 6.0 feet in depth and 3.5 feet in width. The drain includes a 6-inch diameter nonperforated asbestos cement pipe and they have a fabricated animal guard installed at the outlet.

A design memo from the Soil Conservation Service (now the NRCS) outlines the design considerations for the filter and the recommended filter criteria (SCS, 1977). This memo notes that:

> *The alluvium in the foundation where the drain will be placed contains CL, ML, and SM soils. The CL will not pipe and therefore does not need to be considered in the filter design. The ML and SM are potentially pipeable. A filter designed to prevent particle*

movement in the ML would be so fine it would be very low permeability and would also be subject to plugging with the silt size particles... the best approach in this case is to provide a filter with higher permeability and about three times normal thickness, which is two feet… The filter can then be designed to fit the SM materials.

It should be noted that this memo was written in response to original design drain fill filter gradation recommendations that were outlined in the 1972 geologic investigation report. The as-built drawings confirm that the drain fill filter material placed follows the guidance from the 1977 design memo. The constructed filter gradations, as reported in the as-built drawings, are provided in Table 5-2.

Table 5-2: Drain Fill Gradation

Size (inches)	Size (mm)	Percent Passing	
		Upper Bound	Lower Bound
2	50.8	100	
1	25.4	90	100
0.5	12.7	75	90
No. 4	4.75	50	75
No. 8	2.36	35	55
No. 16	1.18	15	35
No. 30	0.6	0	10
No. 40	0.425	0	5

6 2020 and 2021 Site Geotechnical Investigation

The site investigation program that was performed in August of 2020 consisted of five (5) geotechnical borings and accompanied by laboratory testing of selected soil samples to investigate the geotechnical and geological conditions at the site for the Project.

Following the 2020 investigation, it was noted that the VWPs were installed incorrectly so the two (2) instrumented embankment borings were re-drilled at approximately 15-foot offsets from the original borings. Nested VWPs were installed in these borings and the original VWPs were disconnected. Additional samples were collected and tested.

6.1 Geotechnical Borings

A total of seven (7) borings were advanced as part of the investigation, three (3) in the auxiliary spillway channel, and four (4) through the dam embankment as shown on the boring location

map in Figure 6-1. A summary of the borings is shown in Table 6-1. At the time of drilling, a boring originally planned at the landside toe was not accessible and was not drilled.

The borings were drilled by Terracon Consultants, Inc. using a tracked ATV drill rig. Samples were collected at approximate 5.0-foot intervals and consisted of split-spoon and thin-wall samples. 3.25-inch diameter hollow-stem augers were used to advance the borings to termination depths, as directed by HDR. Logging of the borings was completed in general conformance with 210-NEH-631. Logging was performed by Terracon's exploration team and logs were reviewed and finalized by a Terracon geotechnical engineer for the August 2020 investigation; logging was performed by HDR geologist for the April 2021 investigation. Boring logs are included in Appendix A-1 and A-2 of this report. Borings TH-31 and TH-32 were completed with nested vibrating wire piezometers (VWP). Boring 601 and 602 were also completed with nested vibrating wire piezometers, but after discrepancies were noted in the VWP construction logging, these VWPs were abandoned-in-place. Further details about VWP installation are included in Section 6.2Borings 201, 202, and 203 were backfilled with bentonite grout upon completion of drilling.



Figure 6-1: Boring Location Map

Table 6-1. Summary of Geotechnical Borings

Boring	Investigation	Location	Type	Latitude	Longitude	Surface Elevation (feet) NGVD 29	Boring Termination Depth (feet BGS)	Boring Termination Elevation (feet) NGVD 29
601	Aug 2020	Embankment Crest, Right of Principal Spillway	Geotech boring w/ VWP (abandoned)	47.9369	-97.5922	1100.65	106.0	994.65
602	Aug 2020	Embankment Stability Berm, Right of Principal Spillway	Geotech boring w/ VWP (abandoned)	47.9369	-97.5918	1067.37	101.0	966.37
201	Aug 2020	Auxiliary Spillway Centerline	Geotech boring	47.9408	-97.592	1090.9	41.0	1049.9
202	Aug 2020	Auxiliary Spillway Centerline	Geotech Boring	47.9408	-97.5904	1081.6	41.0	1040.6
203	Aug 2020	Auxiliary Spillway Centerline	Geotech Boring	47.9408	-97.5888	1080.6	41.0	1076.6
TH-31	Apr 2021	Embankment Crest, Right of Principal Spillway	Geotech boring w/ VWP	47.9365	-97.5923	1100.65	111.0	989.65
TH-32	Apr 2021	Embankment Stability Berm, Right of Principal Spillway	Geotech boring w/ VWP	47.9369	-097.5918	1067.47	101.5	965.97

Note: Conversion from NGVD29 to NAVD88 is +1.18 feet

6.1.1 Standard Penetration Test (SPT)

Standard penetration tests (SPT) were performed in general accordance with ASTM D1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils. An 18-inch-long, 2-inch-outside-diameter, 1.375-inch-inside-diameter, split-spoon sampler is driven with an automatic 140-pound hammer, falling freely from a height of 30 inches. The number of blows required to achieve each of three, 6-inch increments of sampler penetration is recorded. The number of blows required to advance the last 12 inches of penetration is termed the Standard Penetration Resistance, or N-value. When penetration resistances exceed 50 blows for 6 inches or less of penetration (refusal), the test is terminated and the number of blows along with the penetration distance is recorded on the borehole log. The N-value is indicative of the relative density of granular soils and the consistency of fine-grained soils. A table showing N-values for each of the SPT is presented in Appendix A-4. Photos of each split-spoon sample were captured and are included in Appendix A-2 of this report.

6.1.2 Thin Wall Samples

Eighteen (18) thin wall samples were collected using 24-inch-long Shelby tubes at intervals selected by HDR. The samples contained enough undisturbed sample to complete the proposed testing program and results are provided in Appendix A-4. Shelby tubes were collected in accordance with ASTM D1587. Shelby tubes were attached to the tip of the drilling rods and slowly pushed using down pressure generated by the drilling rig. The tubes were left in the ground for approximately 10 minutes prior to being brought to the surface to improve recovery of the sample. Upon returning to the surface, the sample recovery was measured and the material visible at the ends of the tubes was described. The tubes were then capped and taped at both ends, labeled, and stored in an upright position inside of the heated campground facility overnight to avoid exposure to freezing temperatures.

6.1.3 Modified California Samples

Five (5) modified California samples were collected in place of Shelby tubes to obtain recovery in the very stiff to hard glacial till deposits. The modified California sampling was performed in general accordance with ASTM D3550 using a 24-inch long, 2.5-inch outer diameter sampler containing four 6-inch-long brass liners. The sampler is driven with an automatic 140-pound hammer falling freely from a height of 30 inches and blow counts are recorder for each 6-inch interval. If sufficient amount of sample was recovered, 2 of the sample liners were capped, taped, labeled, and stored in an upright position for laboratory testing. For each sample, the topmost “waste” liner was discarded. Photos of the modified California samples were captured and are included in Appendix A-2.

6.2 VWP Installation

Model 4500S, unvented, vibrating wire pressure transducer piezometers (VWPs) from Geokon were installed by HDR to monitor pore water pressures within the embankment and foundation strata using the fully-grouted method as per manufacturers specifications (Geokon, 2020). Locations of borings with VWP installations are shown in Figure 6-1. The abandoned piezometer details are not included in this section.

Three (3) VWP transducers were installed in boring TH 31 at depths of 50.14, 65.14, and 106.14 feet bgs and three (3) VWP transducers were installed in boring TH 32 at depths of 15.38, 30.38, and 95.38 feet bgs.

Upon completion of drilling, each piezometer boring was cleared of any remaining downhole drill cuttings. Each pre-saturated VWP sensor was secured to the outside of a 1-inch diameter PVC carrier pipe at the desired depth using electrical tape. The VWP cable was taped to the carrier pipe at approximate five-foot intervals to prevent cable snagging while being lowered down the hole. Once the VWP was in place, the boring was tremie-grouted to the surface while remaining auger segments were brought to the surface. In conformance with the Geokon 4500S Instruction Manual, a light-weight grout mixture using field proportions of 94 pounds of Portland cement to 30 gallons of water to 25 pounds of bentonite (as needed for a pumpable consistency) was used. Once the augers were removed and the boring was fully grouted, PVC pipe stickup was measured to determine the final depth of the VWP sensors. The dataloggers

associated with the abandoned VWPs in borings 601 and 602 were detached and reconnected to newly installed VWPs in borings TH-31 and TH-32. Table 6-2 presents a summary of the six VWPs installed.

Table 6-2. VWP Installation Summary

Boring No.	VWP ID	VWP Sensor Depth (ft bgs)	VWP Sensor Elevation (ft) NGVD 29	Average Elevation of Groundwater (ft) NGVD 29
TH 31	TH-31-T	50.14	1049.31	1055.87
	TH-31-M	65.14	1034.31	1054.43
	TH-31-B	106.14	993.31	1064.69
TH 32	TH-32-T	15.38	1052.09	1047.32
	TH-32-M	30.38	1037.09	1047.67
	TH-32-B	95.38	972.09	1052.44

Note: Conversion from NGVD29 to NAVD88 is +1.18 feet

6.3 Laboratory Testing

Soil from the 2020 investigation was logged in the field and the collected samples were transported to Terracon testing laboratories in Grand Forks, ND and Denver, CO for further testing. Soil from the 2021 investigation was logged in the field and the collected samples were transported by HDR to Braun Intec of Bloomington, MN for laboratory testing. Geotechnical laboratory testing was performed on selected split spoon, modified California and thin-wall samples to aid in classification and determine the index and engineering properties of the soil. A summary of the laboratory testing performed is shown in

Table 6-3 below. Laboratory testing results are included in Appendix A-4 of this report.

Table 6-3. Laboratory Testing Quantities

Laboratory Test	Quantity
Water Content Test (ASTM D2216)	56
Dry Density Determination (ASTM D7263)	14
#200 Sieve Only (ASTM D1140)	9
Grain Size Analysis (sieve/hydro) (ASTM D6913/D7928)	18
Atterberg Limits (ASTM D4318)	25
Consolidated-Undrained Tri-axial Testing (ASTM D4767)	6
Hydraulic Conductivity Using Flexible Wall Permeameter (ASTM D5084)	6
One-dimensional Consolidation (ASTM D2435)	2
Organic Content (ASTM D2974)	1
Crumb Test (ASTM D6572)	15

6.3.1 Moisture Content, Dry Density and Void Ratio

Tests to determine the weight-volume relationships for soils were used to assist with soil classification. The results of the moisture content (*MC*), Dry Density (*DD*) and the Void Ratio, *e*. Results are summarized in Appendix A-4.

6.3.2 Grain Size Distribution Analysis (Sieve and Hydrometer)

Grain size distribution of a soil is valuable in providing initial estimates of a soil's engineering properties and assists in classification of soils to better understand the depositional environments in which the soils were deposited.

Results of the sieve and hydrometer particle size distribution testing are provided for each of the sieve samples (test through Sieve No. 200) and hydrometer samples (includes particles passing No. 200 sieve) Appendix A-4.

The results are presented in terms of the measured gravel content defined as particles greater than 4.75mm (retained in the No. 4 sieve), measured sand content defined as particles passing the No. 4 sieve but greater than 7 µm (retained in the No. 200 sieve), and fines content defined as particles passing the No. 200 sieve. The hydrometer samples were further presented in terms of the measured silt content defined as particles passing the No. 200 sieve, but greater than 2 µm and clay content defined as particles less than 2 µm.

6.3.3 Atterberg Limit Testing

Atterberg Limit testing was completed to characterize the fine-grained behavior of the soil. Results of the Atterberg Limit testing are summarized in Appendix A-4 in terms of the liquid limit (LL), plastic limit (PL), and plasticity index (PI) of the materials.

6.3.4 Shear Strength Testing

Shear strength testing was completed on undisturbed cohesive soil samples. Shear strength of a soil is controlled primarily by its resistance due to interlocking particles, frictional resistance between the individual soil grains, and adhesion between soil particles or cohesion.

Results from shear strength testing were used to develop stability parameters for the preliminary slope stability analysis, described in Section 7.4.

6.3.5 Permeability Testing

Permeability (Hydraulic Conductivity) tests were performed on samples collected in the embankment fill and in the upper glacial till. Tested samples were undisturbed (i.e., thin wall). The detailed results of the permeability testing are included in Appendix A-4.

Results from permeability testing were used to develop hydraulic parameters used as part of the preliminary slope stability analysis, described in Section 7.3.

6.3.6 Dispersion Testing

TR210-60 (NRCS 2019) states that soils containing dispersive clays are extremely erosive and that dams constructed using dispersive clays are vulnerable to internal erosion failures and require special design considerations. Consequently, several Dispersion tests were completed as part of the 2021 investigation. Soil Dispersion testing was performed using the Crumb test (ASTM D6572). Results from dispersion testing are summarized in

Table 6-4.

Results from dispersion testing varied for all soil units tested (soil layers are defined in greater detail in the next section). Results from dispersion testing was used in the filter assessment described in Section 7.2. It is recommended that double hydrometer testing (ASTM D4221) be performed in the next phase of investigation because this test quantifies the dispersion potential.

Table 6-4. Dispersion Test Results

Boring	Sample Depth (ft)	Soil Layer	Test Results	Crumb Test Grade
TH-31	14.5-16.0	Embankment Fill	Intermediate	2
TH-31	19.5-21.0	Embankment Fill	Non-Dispersive	1
TH-31	29.5-31.0	Embankment Fill	Dispersive	3
TH-31	39.5-41.0	Embankment Fill	Non-Dispersive	1
TH-31	44.5-46.0	Embankment Fill	Intermediate	2
TH-31	59.5-61.0	Embankment Fill	Intermediate	2
TH-31	69.5-71.0	Upper Glacial Till	Non-Dispersive	1
TH-31	79.5-81.0	Upper Glacial Till	Non-Dispersive	1
TH-32	4.5-6.0	Embankment Fill	Intermediate	2
TH-32	24.5-26.0	Embankment Fill	Intermediate	2
TH-32	34.5-36.0	Embankment Fill	Intermediate	2
TH-32	44.5-46.0	Upper Glacial Till	Non-Dispersive	1
TH-32	49.5-51.0	Upper Glacial Till	Non-Dispersive	1
TH-32	59.5-61.0	Upper Glacial Till	Non-Dispersive	1
TH-32	69.5-71.0	Pre-consolidated Till	Dispersive	3

6.3.7 Consolidation Testing

The potential for settlement of the dam due to changes in loading of the dam embankment (e.g., to determine future settlement if the dam is raised) through consolidation of cohesive layers is addressed using consolidation testing performed on undisturbed samples. Consolidation tests were performed on samples collected in the embankment fill material and upper till. Both the embankment fill and upper till material have over consolidation ratios greater than 1.0 (meaning the soil is over consolidated). Results are summarized in Table 6-5 and included in Appendix A-4.

Table 6-5 Summary of Consolidation Test Results

Material	Sample	Effective Overburden[1] (psf)	P_c (psf)	Approx. Depth to Ground-water (ft BGS) NGVD 29	OCR	C_c (void ratio/log stress)	C_r (void ratio/log stress)	Initial Void Ratio
Embankment Fill	601 (21-23)	2865	4696	45 ft (Elev. 1055.7 ft)	1.63	0.088	0.007	0.488
Upper Till	602 (41-43)	3752	6169	26 ft (Elev. 1040.8ft)	1.64	0.189	0.012	0.783

Note: Conversion from NGVD29 to NAVD88 is +1.18 feet

[1]Estimated assuming a unit weight of 130 psf for the embankment fill and 120 psf for the upper glacial till and water table as indicated in Table 6-1

6.4 Investigation Summary

This 2020 and 2021 geotechnical investigations were performed to collect soil data for subsequent laboratory testing (including soil mechanics tests for SITES inputs), and to develop a profile along the existing dam embankment cross-section for use in analysis of the foundation conditions, seepage, and slope stability to determine feasibility of the structural alternatives being considered.

6.4.1 Subsurface Conditions

Overall, the subsurface conditions encountered in the 2020 and 2021 geotechnical investigation coincide closely with the results of previous investigations performed at the site. Generally, the dam embankment consists of approximately 70 feet of fill underlain by 30 feet of glacial till which is underlain by a harder pre-consolidated glacial till. Stratigraphy of the auxiliary spillway consists of a thin layer of topsoil at the surface underlain by glacial till. Surficial sandy alluvial deposits were removed at the boring locations drilled through the embankment dam and surficial lacustrine deposits were removed at the boring locations drilled in the auxiliary spillway; this agrees with the dam construction plan drawings as shown in Exhibit 3 and 4.

6.4.1.1 TOPSOIL

Approximately the top 0.5 to 1.0 feet of each boring consisted of topsoil. The topsoil is described as brown to black sandy lean clay.

6.4.1.2 EMBANKMENT FILL

Fill was encountered in borings 601, 602, TH-31 and TH-32 and generally consists of light brown to dark brownish-gray sandy lean clay (CL) and trace gravel. The fill directly underlies the topsoil layer and continues to an approximate elevation of 1030 feet. This is consistent with the as-built drawings that show maximum excavation in the valley at the cutoff trench to be between elevations of 1027 and 1031. An illustration of the embankment section from as-built drawings is provided in Figure 6-2.

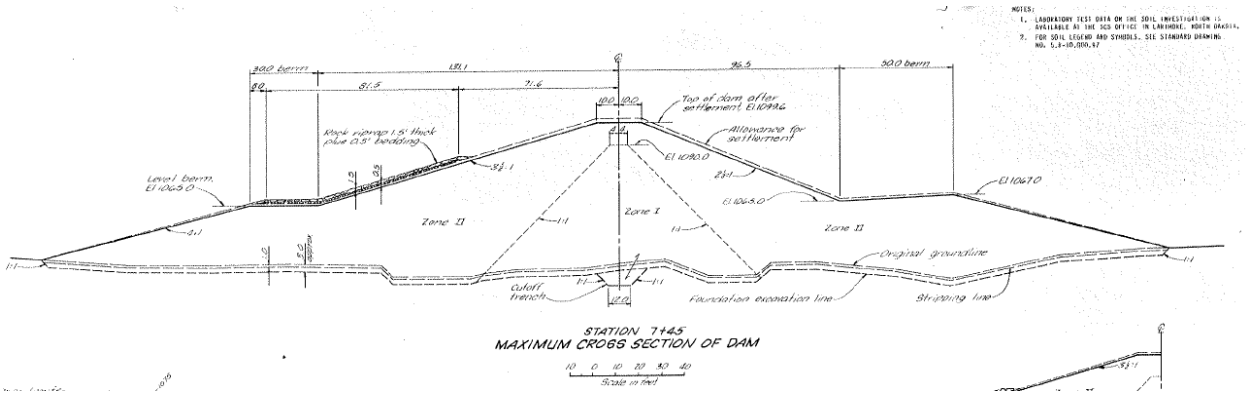


Figure 6-2 Typical Embankment Section from as-built Drawings

The stratigraphic thickness of the fill layer in boring 601 and TH-31 (drilled near the crest of the dam) is 69.5 and 69.0 feet, respectively which aligns closely with the reported height of the dam

(66 feet). It is 39.5 and 38.5 feet at boring 602 and TH-32, respectively (drilled on the downstream stability berm), which is also in agreement with design drawings for the dam.

From the 2020 and 2021 investigation, the material has N-value ranging from 28 to bpf with an average N-value of 16. Average dry density and moisture content of the embankment fill is 109.9 pcf and 15.6 percent. Based on grain-size data from the geotechnical borings, on average this layer is comprised of 1.2 percent gravel, 32 percent sand, and 64.9 percent fines. The average liquid limit is 31 and average plasticity index is 13. Dispersion testing of the embankment soils varied from non-dispersive, intermediately dispersive to dispersive. Permeability testing of the embankment fill yielded an average hydraulic conductivity of 4.14×10^{-8} cm/s. Shear strength testing of embankment fill indicated drained friction angle of 33 degrees and cohesion of 2200 psf. Shear strength test results, along with literature and typical values for embankment fill were used to develop the shear strength parameters described in Section 7.4.

The 1972 geotechnical investigation report recommended to:

> *Selectively place the fine-grained ML and CL lacustrine and glacial drift in the center zone and coarse-grained SM and SC materials in the outer zones.*

Based on the geometry defined in the as-built drawings, Zone I and Zone II materials were assessed separately to see if a distinction could be made based on field and laboratory testing. The laboratory results for the two materials did not show that the Zone II material was coarser in nature. Furthermore, all samples for the fill material (both in Zone I and Zone II) were classified as a sandy lean clay (CL) material. As a result, the embankment fill is considered a single soil unit for the stability analysis; it was treated as two different materials for the seepage analysis.

6.4.1.3 ALLUVIUM AND LACUSTRINE DEPOSITS

As noted in Section 5, a surficial native sandy alluvium deposit was present at the dam embankment footprint prior to dam construction and overlies the upper glacial till, however this layer was removed along the dam centerline as part of dam construction. Based on the materials encountered during the 2020 and 2021 investigations, it does appear that at boring location 601, 602, TH-31, and TH-32 this material was removed. Outside the dam centerline footprint, this layer may still be present, at least to the extents indicated in Figure 6-2.

Similarly, a surficial lacustrine deposit was present at the auxiliary spillway footprint prior to dam construction and overlies the upper glacial till, however it was also removed as part of auxiliary spillway construction. The materials encountered in boring 201, 202 and 203 indicate that this material was removed. Outside the auxiliary spillway footprint, this deposit may still be present.

6.4.1.4 UPPER GLACIAL TILL

Glacial till underlies the dam embankment fill in borings 601, 602, TH-31, and TH-32 and lies beneath the topsoil layer in borings 201, 202, and 203 in the auxiliary spillway. In the dam embankment, the contact between the till and overlying fill is at an approximate elevation of 1030 feet. The upper glacial till layer generally consists of gray and dark gray medium stiff to stiff sandy lean clay, trace gravel, and occasional cobbles and boulders.

From the 2020 and 2021 investigation, the upper glacial till material has N-value ranging from 15 to 4 bpf with an average N-value of 8. Average dry density and moisture content of the upper glacial till is 104.1 pcf and 21.6 percent. Based on grain-size data from the geotechnical borings, on average this layer is comprised of 0.3 percent gravel, 29 percent sand, and 66.8 percent fines. The average liquid limit is 38 and average plasticity index is 18. Dispersion testing of the upper glacial till are non-dispersive. Permeability testing of the upper glacial till yielded an average hydraulic conductivity of $2.10x10^{-7}$ cm/s. Shear strength testing of this material indicated drained friction angles of 32 degrees and cohesion of 200 psf.

6.4.1.5 PRE-CONSOLIDATED GLACIAL TILL

Pre-consolidated glacial till lies beneath the upper glacial till stratum and was encountered in borings 601, 602, TH-31, and TH-32. The material is described as gray to dark gray very stiff to hard sandy lean clay, trace gravel, and occasional cobbles and boulders. The pre-consolidated glacial till is similar to the overlying layer in grain size distribution but is much denser. The contact of the glacial till and pre-consolidated glacial till occurs at elevation 1001.0 and 1005.2 for the borings drilled at the crest (601 and TH-31) and at elevation 998.5 and 999.0 for borings drilled in the downstream stability berm (602 and TH-32). This agrees with findings from the 1972 investigation.

From the 2020 and 2021 investigation, the pre-consolidated glacial till material has N-value ranging from over 50 blows per 6 inches to 7 bpf with an average N-value of 42 bpf. Average dry density and moisture content of the pre-consolidated till is 96.9 pcf and 23.5 percent. Based on grain-size data from the geotechnical borings, on average this layer is comprised of 1.7 percent gravel, 31 percent sand, and 67 percent fines. The average liquid limit is 45 and average plasticity index is 20. The dispersion testing of the pre-consolidated till is dispersive. Permeability testing of the upper glacial till yielded an average hydraulic conductivity of $4.70x10^{-8}$ cm/s. Shear strength testing of this material indicated drained friction angles of 33 degrees and cohesion of 250 psf.

6.4.1.6 BEDROCK

Bedrock was not encountered at the site during the investigation however previously published geologic maps and a previous investigation south of the dam site suggest that bedrock underlies the site at an approximate depth of between 250 and 300 feet bgs and consists of rock belonging to the Carlile Shale Formation from the Late Cretaceous time period.

6.4.2 Groundwater

Groundwater levels were observed during drilling as well as prior to hole abandonment. During drilling, groundwater was initially noted in the samples at a depth of 88.0 feet in TH-31 and persisted until a depth of 104.5 feet. This is noted on the boring log and seen in the sample photos, both provided in Appendix A2. In boring TH-32, groundwater was first encountered at at a depth of 73.0 feet and persisted to the boring termination depth at 101.5 feet.. Terracon reported that groundwater was not encountered during drilling and borings 601, 602, 201, 202, and 203 were dry prior to backfilling. Nested VWPs were installed in borings 601,602, TH-31, and TH-32 to monitor porewater pressures in the dam embankment. VWPs installed in borings

601 and 602 during the 2020 investigation were abandoned and their associated dataloggers were detached and reconnected to the VWPs installed in borings TH-31 and TH-32 in 2021. Readings are recorded every two hours and stored in the VWP datalogger at borings TH-31 and TH-32. Readings have been retrieved from the dataloggers on a monthly basis since installation and are shown on the hydrographs presented as Figure 6-3 and Figure 6-4.

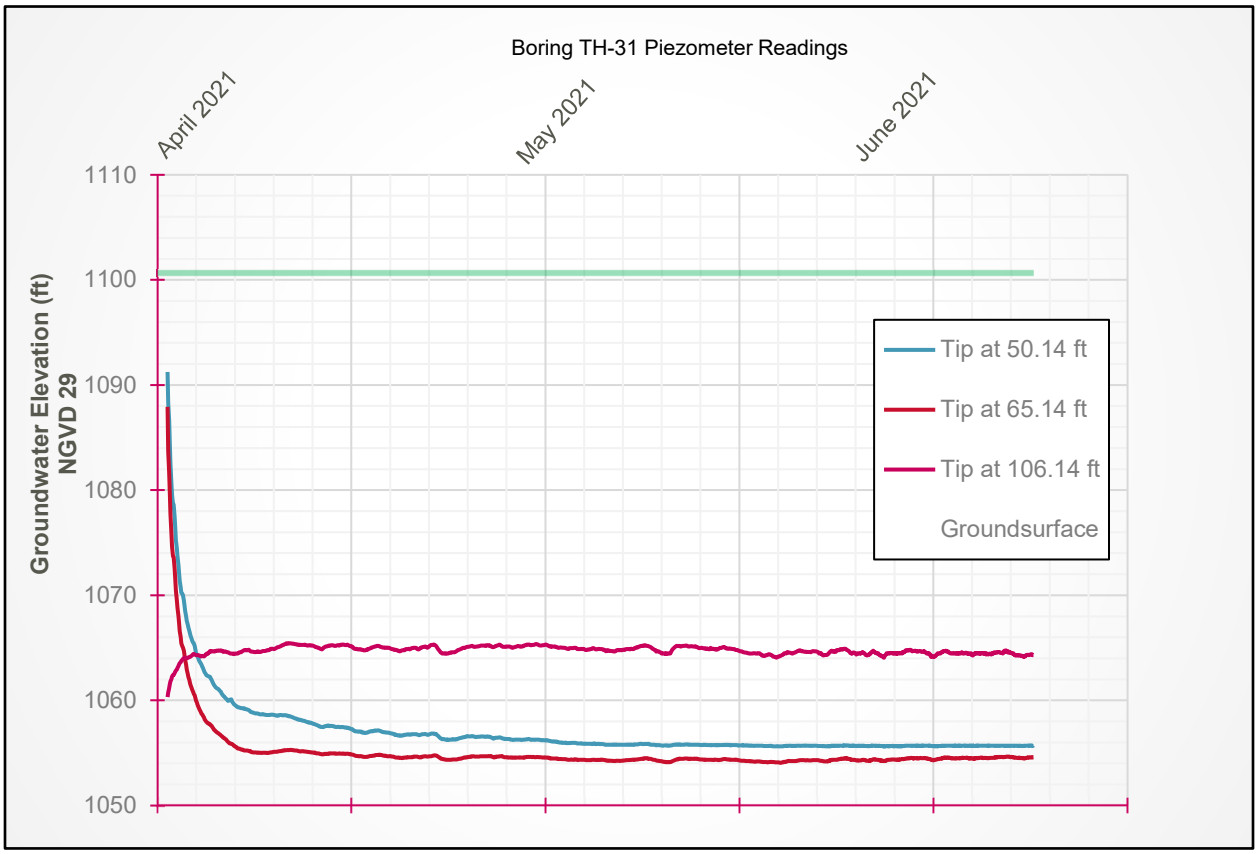


Figure 6-3: Boring TH-31 Hydrograph

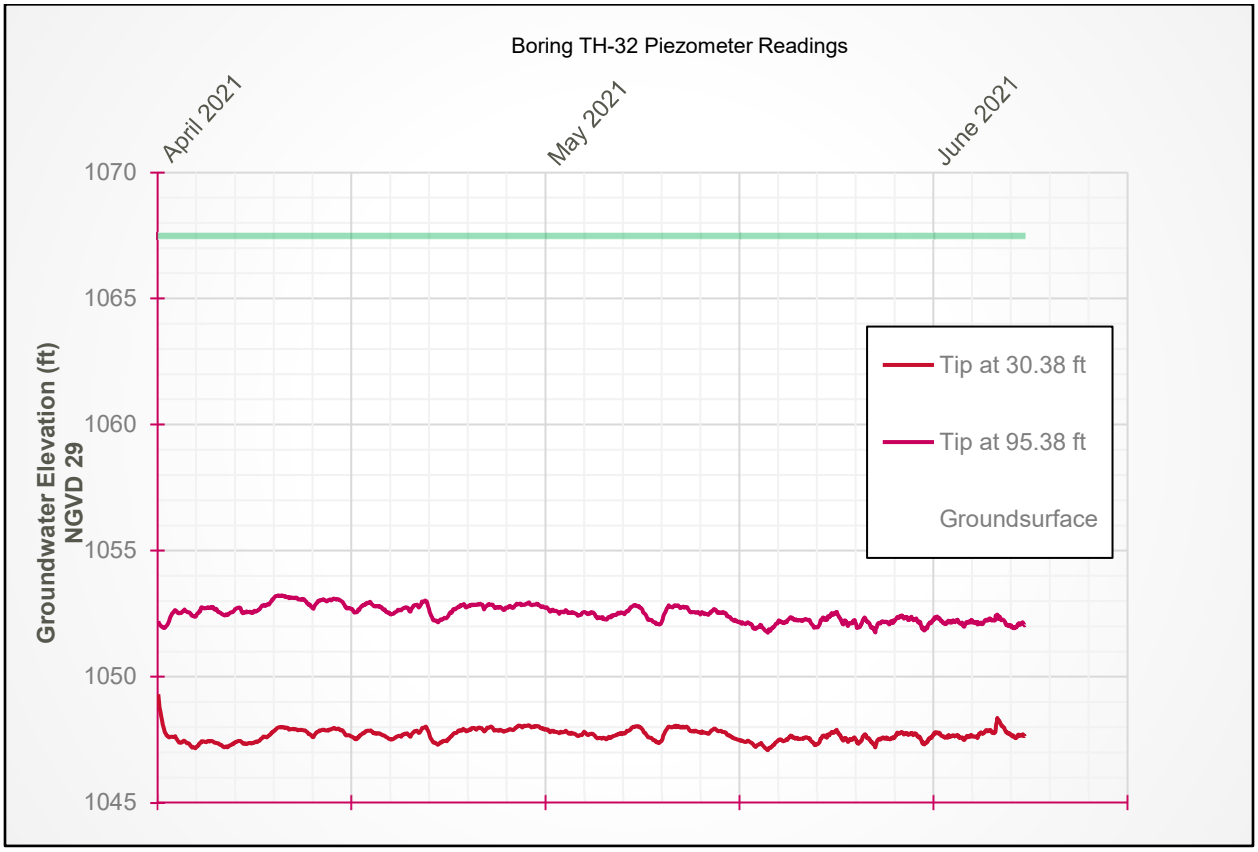


Figure 6-4: TH-32 Hydrograph

VWPs TH-31-T, TH-31-M, TH-32-T, and TH-32-M were installed within the dam embankment fill material and VWPs TH-31-B and TH-32-B were installed within the Pre-consolidated Glacial Till material. Upon installation, the VWP sensors took approximately one week for readings to stabilize, shown by the drastic change in readings in early April. It should be noted that the top piezometer at TH-32 (TH-32T) was installed above the water table and as a result is not included in Figure 6-4.

Reaction to changes in groundwater flow is generally consistent among the six VWPs installed in borings TH-31 and TH-32 as shown by the close alignment of peaks and valleys in the data. The hydrographs show an approximate 10 to 12-foot change in groundwater elevation from boring TH-31 at the dam crest to boring TH-32 on the downstream stability berm suggesting that pore water pressure decreases downstream through the embankment cross-section.

The groundwater readings recorded to date indicate that in both borings TH-31 and TH-32, the VWPs located within the dam embankment material are recording similar pressures with average readings of 1056.22 ft and 1053.58 ft for VWPs TH-31-T and TH-31-M, respectively, and an average reading of 1046.53 ft for VWP TH-32-M. VWP TH-32-T was installed above the water table and therefore the readings are not included in the hydrograph figures above. In both borings, VWPs TH-31-B and TH-32-B report groundwater elevation readings within the pre-

consolidated glacial till that are approximately 5 to10 feet higher than the shallower VWPs located within the dam embankment.

The groundwater readings recorded since piezometer installation indicate that the water pressure decreases downstream through the embankment cross-section in the embankment fill, as would be expected. There is also a pressure decrease in the deeper preconsolidated glacial till, which indicates that a downward gradient also exists in the native material.

7 Geotechnical Analyses

7.1 Auxiliary Spillway SITES Analysis

The following geotechnical engineering parameters (Table 7-1) were developed for use in the auxiliary spillway integrity analysis (SITES). Headcut erodibility index was determined following guidelines given in National Engineering Handbook, Chapter 52, Field Procedures for Headcut Erodibility Index. Other parameters were developed from laboratory test data and correlated with published values for the upper glacial till as this is the only material present in the auxiliary spillway (except for topsoil). Appendix C-1 contains the calculations for the recommendations. Three geotechnical borings (201, 202 and 203) were drilled along the centerline of the existing auxiliary spillway as shown on Figure 6-1. The SITES analysis will be completed at a later date and the results will be presented in a separate report.

Table 7-1. Auxiliary Spillway Soil Parameters

Layer	Dry Unit Weight, γ_d (pcf)	% Clay	K_h	D_{75} (mm)	PI
Upper Glacial Till	104.13	29.48	0.035	0.17	18.12

7.2 Drain Fill Compatibility Analysis

A filter analysis was completed as part of the original dam design. Details are provided in Appendix C-2. The filter design was based on proposed silty sand (SM) borrow material that was expected to be placed in Zone II of the embankment. A designed filter is intended to protect against seepage-induced particle migration of embankment material. An engineered filter, by definition, will “act as a separator to hold the soil in place and allow the free escape of water” (Cedergren, 1989) and is therefore designed to allow free release of pressure while minimizing the loss of fines. To better understand if the designed and constructed filter satisfies current filter design criteria, a filter compatibility analysis was completed using the criteria outlined in Chapter 26 of the National Engineering Handbook Part 633 (NRCS, 2017).

7.2.1 Filter Design Procedure

One of the first steps outlined in NRCS's filter design procedure is to determine the base gradation of the material that requires filtering (the embankment fill material). The available gradation curves from the 2020/2021 investigation for the embankment fill all are classified as Base Soil Category 2, which is defined as material with 40 to 85 percent finer than the No. 200 sieve (0.075mm), or sands, silts, clays and silty sands. Comparatively, the SM borrow material that was used as the basis for the original filter design is classified as Base Soil Category 4, which is defined as material with less than 15 percent finer than the No. 200 sieve, or sands and gravels. The upper and lower bound gradations for the SM material from the original filter design is presented in Figure 7-1 (brown curves). As summarized in Section 5.4, the original filter was designed for the silty sand (SM) Embankment fill because, at the time of design, it was believed that a filter designed for the silt (ML) fill would be too fine and subject to plugging and the lean clay (CL) material is not prone to piping and does not need to be considered in the filter design.

Gradational data obtained from the 2020/2021 is also presented in this Figure 7-1. This includes samples from Zone 1 and Zone 2. The fill tested from the 2020/2021 investigation is a potentially dispersive lean clay (CL) material and the boring logs from the investigation also suggest that there is not a lot of variability in the fill material, however, only one cross-section through the dam embankment was tested. Not all dispersion test results for the embankment fill tested as dispersive, but for the filter design procedure, it was considered dispersive because a portion of the results for this material did test as dispersive.

The filter requirements for the embankment fill material based on the 2020/2021 gradation data and the current NRCS requirements are presented in Figure 7-2 in red. The as-built upper and lower bound gradations for the filter is also presented in this figure in green. The results from the filter compatibility analysis indicate that the placed filter does not meet the NRCS filter design requirements because the embankment material is much finer than the material the original filter was designed for. Additional investigation is recommended to identify the presence of silt (ML), silty sand (SM), and determine whether the Embankment Fill is dispersive. A two-stage filter should be designed to accommodate the variable soil conditions that could be present in the embankment fill.

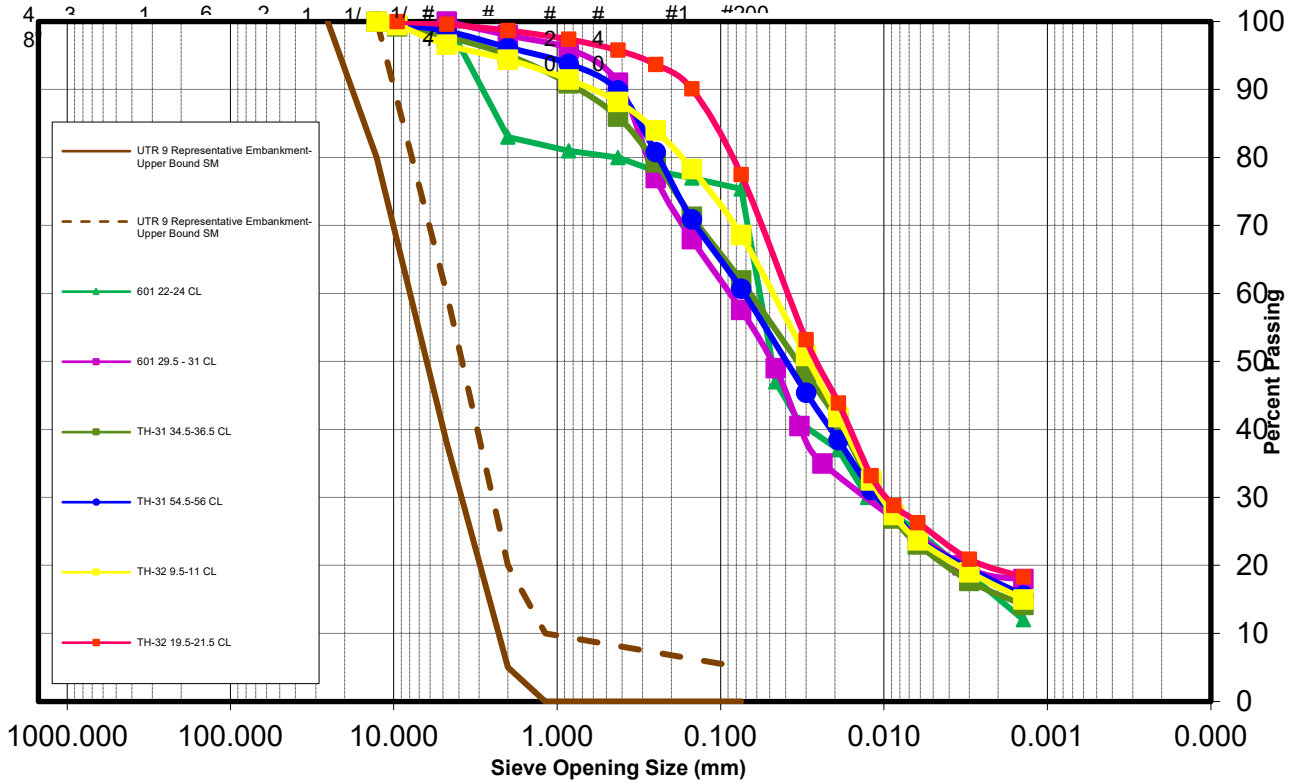


Figure 7-1: Embankment Fill Gradations- Proposed SM Borrow used as basis for original filter design and embankment fill samples from 2020/2021 Investigation

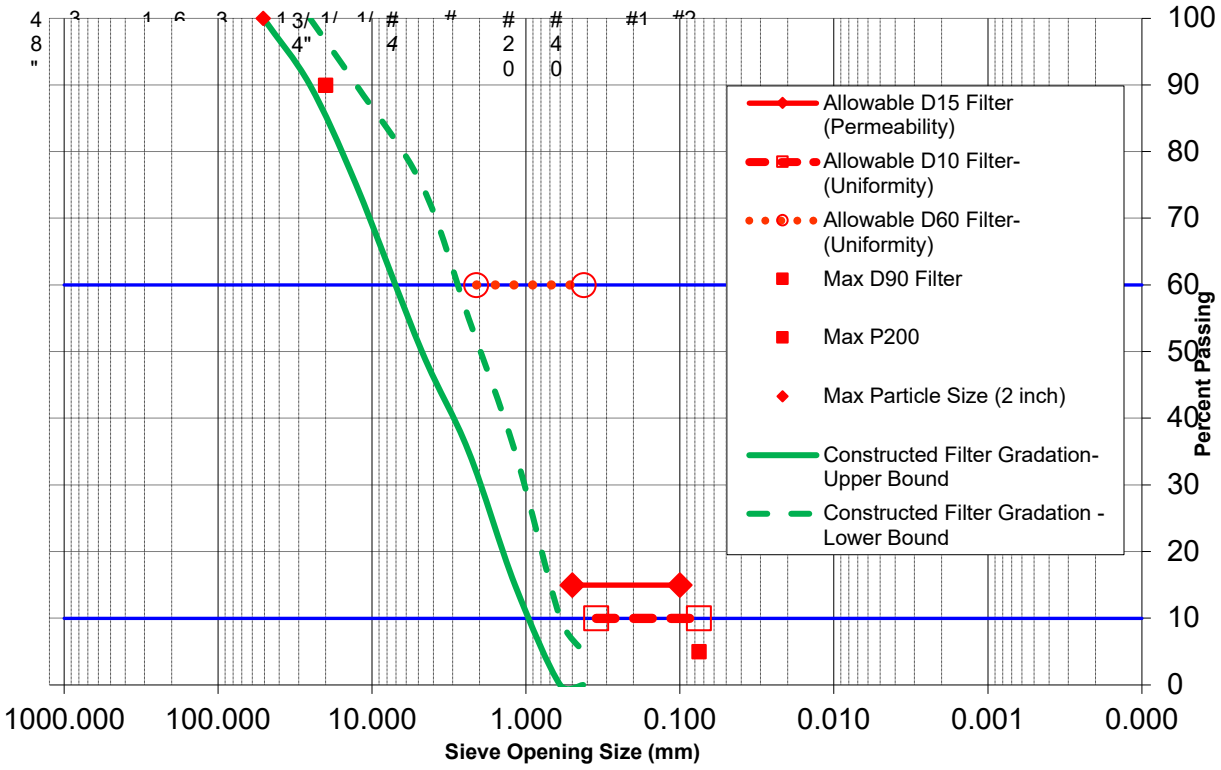


Figure 7-2: As-built filter gradation (green) and current NRCS filter design recommendations (red)

7.3 Seepage Analyses

The seepage analyses were conducted using GeoStudio's SEEP/W module, which uses the finite-element analysis technique to model water movement and pore water pressure distribution within porous materials, such as soil and rock. This program can analyze both simple and highly complex seepage problems, including saturated and unsaturated flow, steady-state and transient conditions, and various boundary conditions. SEEP/W is one of the most widely utilized software packages on the market for evaluating seepage conditions and is commonly used by organizations like the United States Army Corps of Engineers (USACE) for evaluating critical infrastructures.

A seepage analysis was completed to assess the seepage forces and pore water pressures at the embankment section investigated (STA 12+00) during normal pool and flood surcharge pool levels, and the results of the seepage analyses were imported into the slope stability models. The modeled cross-section was developed from 2021 survey data collected at the site.

The primary input parameter in seepage analyses is saturated hydraulic conductivity (or permeability) of the materials that comprise the dam and foundation. Initial permeability values used for the Embankment Fill and foundation soils were obtained from laboratory test results. A seepage model was created to calibrate hydraulic input parameters, specifically the hydraulic conductivity, using observed piezometer data from June 2021. Calibration process involved manually adjusting permeability and anisotropy values until good agreement was achieved

between measured and modeled total head values at the piezometer locations; good agreement was considered to be within two feet of the measured head. Sensitivity to permeability and anisotropy, as well as material extent and applied boundary conditions, were evaluated to calibrate the models. The comparison of modeled and measured total head at the VWP locations and elevations is summarized in Table 7-2: Seepage Calibration Details. VWP TH-32T was installed above the water table so it was not used as part of the calibration process.

Table 7-2: Seepage Calibration Details

Piezometer	Material	Measured Head- 6/11/2021 (ft) NGVD 29	Modeled Head (ft)	Difference
TH-31T	Embankment Fill- Zone 1	1055.65	1058.36	-2.71
TH-31M	Embankment Fill- Zone 1, near Trench Drain/native cay transition	1054.23	1060.64	-6.41
TH-31B	Pre-consolidated Glacial Till	1064.34	1063.17	1.16
TH-32M	Embankment Fill- Zone 2	1047.35	1046.38	0.97
TH-32B	Pre-consolidated Glacial Till	1051.95	1050.84	1.11

The calibrated model includes an upstream far-field groundwater boundary condition, a constant head reservoir boundary condition (equal to the surveyed pond elevation) applied to the upstream face of the dam, a drain boundary condition at the approximate elevation and location as what is shown in the as-built drawings at Station 12+00, and an open seepage face on the downstream ground surface. The hydraulic conductivity of the Embankment Fill was varied; the best calibration was achieved when the horizontal hydraulic conductivity of the Embankment Fill in Zone 1 was adjusted to be less permeable than the average hydraulic conductivity from laboratory testing. Anisotropy of all materials, except for the drain fill, were also adjusted, but values were within published values for similar soil material. The seepage parameters are presented in Table 7-3.

In general, the measured head from VWPs installed at TH-31 and TH-32 are in good agreement with the calibrated model. Except for TH-31M, all modeled head nodes were within two feet of the measured VWP total heads. TH-31M is located near the trench drain as well as the transition between the embankment fill and the native upper glacial till. Given the variability of measured total heads with respect to depth at TH-31, there is a factor that is influencing the pore-pressures at the elevation of TH-31M that is not accounted for in the calibrated 2D model. Additional investigation and instrumentation is recommended to investigation this variability.

Table 7-3: Seepage Modeling Parameters

Material	Model Anisotropy	SEEP Input, k_h [ft/s]	Coefficient of Volume Compressibility M_v	Sat. Vol Water Content
	k_v/k_h	ft/s	(/psf)	--
Embankment Fill-Zone 1	0.1	5.44e-10	4.79e-07	0.4
Embankment Fill-Zone 2	0.33	5.44e-09	4.79e-07	0.4
Upper Glacial Till	0.1	2.08E-08	4.79e-07	0.4
Pre-consolidated Till	0.2	4.67e-09	4.79e-07	0.4
Drain Material	1	0.116	4.79e-07	0.3

Following calibration, seepage models were created to estimate the steady-state phreatic surface at normal pool and flood surcharge pool for evaluation of slope stability as described in Section 7.4. The hydraulic boundary conditions for the seepage models are provided in Table 7-4. Prior to the 2020/2021 investigation, the reservoir elevation had not been measured. As a result, it is assumed that the surveyed water elevation is typical normal pool conditions.

Table 7-4: Seepage Modeling Cases and Hydraulic Boundary Conditions

Loading Case	Analysis Type	Far-Field Upstream Groundwater [feet] NGVD 29	Headwater [feet] NGVD 29	Drain	Downstream Ground surface
Calibration	Steady-State	1064	1067.7	Zero Pressure Boundary Condition applied at El. 1042 ft, 100 ft downstream of dam centerline	Open Seepage Face
I	Normal Pool		1067.7		
II	Surcharge Pool (PMF)		1099.6		
I	Normal Pool – Plugged Drain		1067.7	No Drain boundary condition or drain material included in model	
II	Surcharge Pool (PMF)- Plugged Drain		1099.6		

A third loading case was evaluated for the stability analysis - the rapid drawdown (RDD) stability of existing upstream slope. This analysis follows the staged undrained strength method (Duncan, 1990), which requires input of two piezometric surfaces, one representing highest normal pool conditions (reservoir set to 1067.7 feet), and one with the reservoir set to the lowest gated outlet. Stability models with defined piezometric surfaces do not require a corresponding seepage model to define the pore water pressures and phreatic surface for that loading scenario. Seepage modeling outputs are provided in Appendix C-4.

7.4 Slope Stability Analyses

The embankment slope stability modeling was conducted using GeoStudio's SLOPE/W module, which uses limit-equilibrium theory to compute the factor of safety (FOS) of earth and rock slopes. Like SEEP/W, SLOPE/W has an established track record for analyzing critical infrastructure within the geotechnical profession. In the limit equilibrium approach, the geologic material is assumed to be at the state of limiting equilibrium and a FOS is computed. SLOPE/W is capable of using a variety of methods to compute the FOS of a slope while analyzing complex geometry, stratigraphy, and loading conditions.

Analyses were performed to assess the FOS for slope stability at the cross-section along the embankment right of the principal spillway at Larimore Dam. The primary focus of the stability analyses was to assess the normal and surcharge stability of the embankments at the cross-sections analyzed; RDD from the normal pool to lowest gated outlet was also analyzed. GeoStudio allows for integration of SEEP/W and SLOPE/W, such that the pore water pressures, and phreatic surface computed in SEEP/W can be automatically imported and used in the SLOPE/W analysis. This allows for a more realistic stability analysis than can be obtained by drawing in a phreatic surface. For any node on the ground surface line where the pore water pressure is positive (i.e., surface ponding condition), SLOPE/W automatically computes the equivalent weight of the water above the ground surface. As described in Section 7.3, piezometric surfaces were defined within the stability model for the RDD analysis.

Spencer's method was used to calculate the FOS of the embankment in this stability analysis. This method is considered an adequate limit equilibrium method because it satisfies conditions of static equilibrium and provides a FOS based on both force and moment equilibrium. The critical potential failure surface was obtained using the entry-exit search function. Entry-exit search functions were employed through a consistent framework in which multiple search patterns were used for a given embankment slope to review for global and local/shallow slip surfaces. This framework allows for slip surfaces with the minimum FOS values to be captured, while also providing a regular method for delivering larger "global" slip surfaces that may be considered more critical to dam safety.

Embankment slope stability modeling requires shear strength parameters for Effective and total stress conditions. Shear strength parameters for soils were obtained using the results of laboratory testing on site soil, from correlations with SPT blow counts and from published values for similar soils if no site-specific information was available (see Appendix A-4 for the laboratory reports). Input parameters for SLOPE/W modeling are summarized in

Table 7-5. The shear strength parameters applied to each type of material for the modeling cases analyzed, as well as the slope face analyzed, is summarized in Table 7-6.

The effective stress condition generally applies to long-term, steady-state groundwater flow conditions for which no excess pore water pressure exists. The total stress condition typically applies to short-term conditions, for example during or immediately after construction, where the excess pore water pressures have not had time to dissipate. Construction stability was not analyzed for this report. For the flood surcharge and RDD stability loading cases, stability is assessed using shear strength parameters determined from the composite envelope (bilinear strength) as per TR 210-60. SLOPE/W requires the input of both effective and total stress parameters as well as the normal stress of the intersection of the two failure envelopes to perform a bilinear strength analysis (Table 7-4). Figure 7-3 shows the Bilinear Composite Envelope.

Figure 5–2: Mohr-Coulomb Envelope for Upstream Drawdown

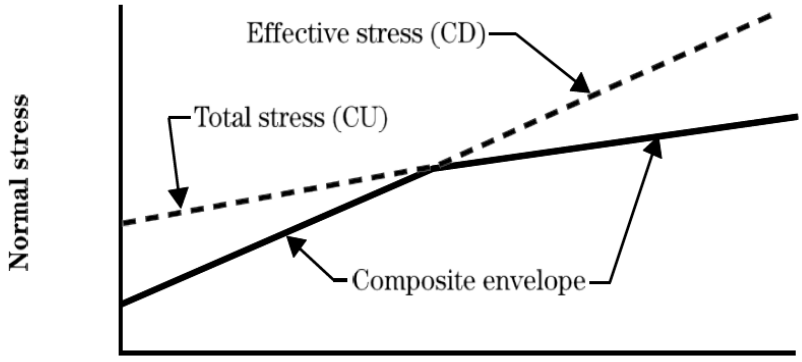


Figure 7-3 Bilinear Composite Envelope

As discussed in Section **Error! Reference source not found.** above, the embankment fill is considered a single soil unit for this phase of analysis. The shear strength parameters of the Embankment Fill, Upper Glacial Till, and Pre-consolidated Till were determined from detailed analysis of the CU triaxial testing. The CU test results were plotted to establish soil strength envelopes for the total stress and effective stress conditions (see Appendix C-3 for details and figures). In EM 1110-2-1902, guidance suggest that a design strength envelope could be created assuming that two-thirds of the strength data exist above and one-third the data fall below an acceptable strength envelope. This methodology was considered and the effective and total strength envelopes for the 33rd percentile were calculated. These values were compared to the 33rd percentile strength values determined from the CU testing, and the lower value was selected to be used in analysis.

Table 7-5 Slope Stability Modeling Parameters

Material	Moist Unit Weight (pcf)	Saturated Unit Weight (pcf)	Shear Strength Parameters				
			Total Stress Envelope		Effective Stress Envelope		Bilinear Stress
			c (psf)	ϕ (deg)	c' (psf)	ϕ' (deg)	Normal Stress[1] (psf)
Embankment Fill	129	133	900	23	200	33	3112
Upper Glacial Till	126	128	700	17	200	32	1566
Pre-consolidated Till	122	126	2000	22	250	33	7131
Drain Material	128	135	N/A	N/A	28	0	N/A

1. The normal stress, σ_N, is the normal stress coordinate of the intersection of the effective stress and total stress failure envelope (TR210-60 Figure 5-2 is replicated as **Error! Reference source not found.**) and is calculated with the equation: $\sigma_N = (c - c')/(\tan \phi' - \tan \phi)$

Table 7-6. Shear Strength Parameter Applied to Stability Loading Cases

Stability Loading Case	Slope Analyzed	Applicable Shear Strength Parameters	
		Free Draining Materials	Low-Permeability Materials
Case I: Normal Pool Steady-State Seepage	Downstream	Effective Stress Parameters	Effective Stress Parameters
Case II: Flood Surcharge Steady-State Seepage	Downstream	Effective Stress Parameters	Composite Bilinear Shear Strength Envelope
Case III: RDD	Upstream	Effective Stress Parameters	Composite Bilinear Shear Strength Envelope

Minimum factors of safety were determined from Table 5-3 of TR 210-60. A minimum slip surface depth of 3 feet was set for all stability analyses. Slope stability analysis results are summarized in Table 7-7 and slope stability modeling outputs are provided in Appendix C-5. Slope stability analysis results indicate that for the cases analyzed, the existing slopes are stable with respect to TR 210-60's stability criteria.

Table 7-7: Embankment Slope Stability Results

Analysis	Slope Analyzed	NRCS Recommended Minimum Factor of Safety	Calculated Minimum Factor of Safety
Case I: Normal Pool-Steady State	Downstream	1.5	2.5
Case I: Normal Pool-Steady State (Clogged Drain)	Downstream		2.5
Case II: Flood Surcharge Pool-Steady State	Downstream	1.4	1.8
Case II: Flood Surcharge Pool-Steady State (Clogged Drain)	Downstream		1.7
Case III: Rapid Drawdown	Upstream	1.2	2.3

The geotechnical modeling indicates the embankment slope stability FOS results are above NRCS recommended minimum values for all cases analyzed. Only one section was analyzed and not all NRCS loading cases were evaluated for this phase of analysis. If additional material will be placed on the dam, construction loading will need to be evaluated. Additionally, seismic stability was not evaluated, and it may not be necessary as local PGA values may be below the threshold for required evaluation, but this will need to be confirmed. Additional embankment cross-sections should be investigated and modeled with respect to seepage and slope stability to verify that they are consistent to STA 12+00.

Based on the results of the stability analysis, it is reasonable to conclude that as long as the upstream and downstream slope angels are maintained, the proposed construction alternatives appear to be feasible. Additional stability modeling will be required prior to constructing the preferred construction alternative to verify this.

8 Consideration for Future Work

Based on the findings from the 2020 and 2021 geotechnical investigation, HDR recommends the following for the subsequent investigation for final design of the dam:

- It is recommended that a geologic field survey be completed before final design so that mapped outcrop deposits can help support the findings from the subsurface

investigation. It is recommended that this field survey would be completed by a professional geologist. The 2020 investigation did not include a field survey as it was not part of the scope and it is unclear on the exact location of the geologic outcrops described in the 1972 investigation.

- Generally, the findings from the 2020 and 2021 investigation were in good agreement with the 1972 investigation. The subsurface descriptions and profiles developed from the 1972 investigation should be used as a tool to plan future investigations and borings should be concentrated where variability in subsurface conditions was noted, specifically, the right abutment. In particular, the future investigation plan should include borings at the dam abutments. It would also be good to switch to continuous sampling at the approximate contact elevation of the Embankment Fill and Upper Glacial Till to verify that the sandy alluvial deposits were removed.
- Relatively high pore pressures recorded in the deeper pre-consolidated till (TH-31B and TH-32B) suggests that their pore pressures are influenced by a source other than the reservoir pool. Additional VWPs at variable depths through the embankment fill and native foundation material is recommended to better understand the seepage regime through these soil layers. A VWP installed at the abutment foundation soils is recommended to determine if high pore pressures are coming from the abutment soils.
- Additional VWPs are recommended along the dam centerline and through the dam cross-section, preferably on both sides of the control structure to better understand the phreatic surface through the dam. As the current foundation drain outlets may have a significant effect on the phreatic surface (at least in the near field), phreatic surface profiles should be developed both near the drain outlet sections and further away, as they might be different.
- For future piezometer installation, it is recommended that the installation depth of instruments be set and recorded to the hundredth of a foot to allow for water level measurements to also be within that accuracy.
- Install an automated system to measure the pool elevation in the reservoir.
- 2021 Laboratory dispersion test results indicate that the embankment fill and native material is dispersive. Complete additional laboratory dispersion testing to better understand the extent of the dispersive materials in the project site
- Laboratory data was consistent with the material types encountered and generally in agreement with the laboratory results from 1972; however, there were slight variations in the index and material property values reported. Variability within materials is expected, especially native deposits, but additional index, strength, consolidation, and permeability testing is recommended for all materials encountered in the 2020 and 2021 investigation (embankment fill, Upper Glacial Till, Pre-consolidated Glacial Till).
- Consolidation test results indicate that the embankment fill and upper glacial till are over-consolidated and that the material is expected to behave as an over-consolidated material nature if loaded.
- Slope stability results indicate the existing embankment is stable for the loading cases evaluated. Future slope stability modeling should consider construction loading (if additional material will be placed and/or removed from the existing embankment), and possibly seismic loading. Additional cross-sections through the dam embankment should also be investigated and modeled to verify that the conditions encountered in STA 12+00 are representative across the dam.

- The filter compatibility analysis results indicate the constructed filter is not compatible with the material it is meant to filter (the embankment fill). Removal and replacement of existing drain fill with a two-stage seepage collection system compatible with the embankment fill around the filter is recommended. Additionally, the embankment fill material tested as dispersive. Future embankment fill placed should not be dispersive.
- The SITEs parameters developed for this report indicate that the material in the auxiliary spillway is erosive. Additional erosional testing is recommended.

9 Limitations

Recommendations and findings provided in this report are based on limited subsurface explorations, laboratory testing, and field observations for the purposes of the Larimore Dam Investigation. Soil conditions may vary between or beyond the points explored or observed. Groundwater conditions may vary from the conditions observed at the time of data collection. The investigation did not include environmental investigation of project site soils or groundwater. If soil or groundwater conditions are identified that differ from those described herein, or the project configuration is altered, HDR should be notified immediately so that a review and supplemental recommendations can be provided by HDR. HDR may request that additional work be performed and that an updated report be issued. Information and recommendations presented in this report should not be used for other projects on this site, should not be extrapolated to other areas, and should not be used for projects in other locations without HDR's review and approval.

10 References

ASTM D2488, Standard Practice for Description and Identification of Soils (Visual Manual).

HDR|Kleinfelder JV, 2015. North Dakota Dam Assessment for Upper Turtle River Dam No. 9. May, 2015.

Hansen, D. E. and Jack Kume. Bulletin 53: Geology and Ground Water Resources of Grand Forks County, Part 1 (Geology). North Dakota Geological Survey, 1970.

Instruction Manual: Model 4500 Series. Geokon, 2020, <www.geokon.com/content/manuals/4500_Piezometer.pdf>.

SCS (United States Department of Agriculture Soil Conservation Service), 1972. Detailed Geologic Investigation of Dam Sites, Upper Turtle River. March, 1972

SCS (United States Department of Agriculture Soil Conservation Service), 1975. Upper Turtle River Watershed Multiple-purpose Structure No. 9: Emergency Spillway Dewatering. April, 1975.

DCS (United States Department of Agriculture Soil Conservation Service), 1977. Upper Turtle River Watershed Multiple-purpose Structure No. 9: As-Built. February, 1977.

NRCS (United States Department of Agriculture Natural Resources Conservation Service), 2001. Emergency Watershed Protection: Upper Turtle River Watershed Floodwater Retarding Structures No. 9, Emergency Spillway Repair. June, 2001.

NRCS (United States Department of Agriculture Natural Resources Conservation Service), Technical Release 210-60: Earth Dams and Reservoirs, March 2019.

NRCS (United States Department of Agriculture Natural Resources Conservation Service), 210-NEM-Part 531: Geology, June 2013.

NRCS (United States Department of Agriculture Natural Resources Conservation Service), 210-NEH-631: Geology, January 2012.

NRCS (United States Department of Agriculture Natural Resources Conservation Service), Part 633 Soils Engineering National Engineering Handbook: Chapter 26 Gradation Design of Sand and Gravel Filters, August 2017.

United States Army Corps of Engineers, 2014. ER 1110-1-1807: Drilling in Earth Embankment Dams and Levees. Dec 31, 2014.

United States Bureau of Reclamation (USBR), 2014. DSO-98-17: Standard Penetration Test: Driller's/Operator's Guide. July, 2014.

Exhibit 1

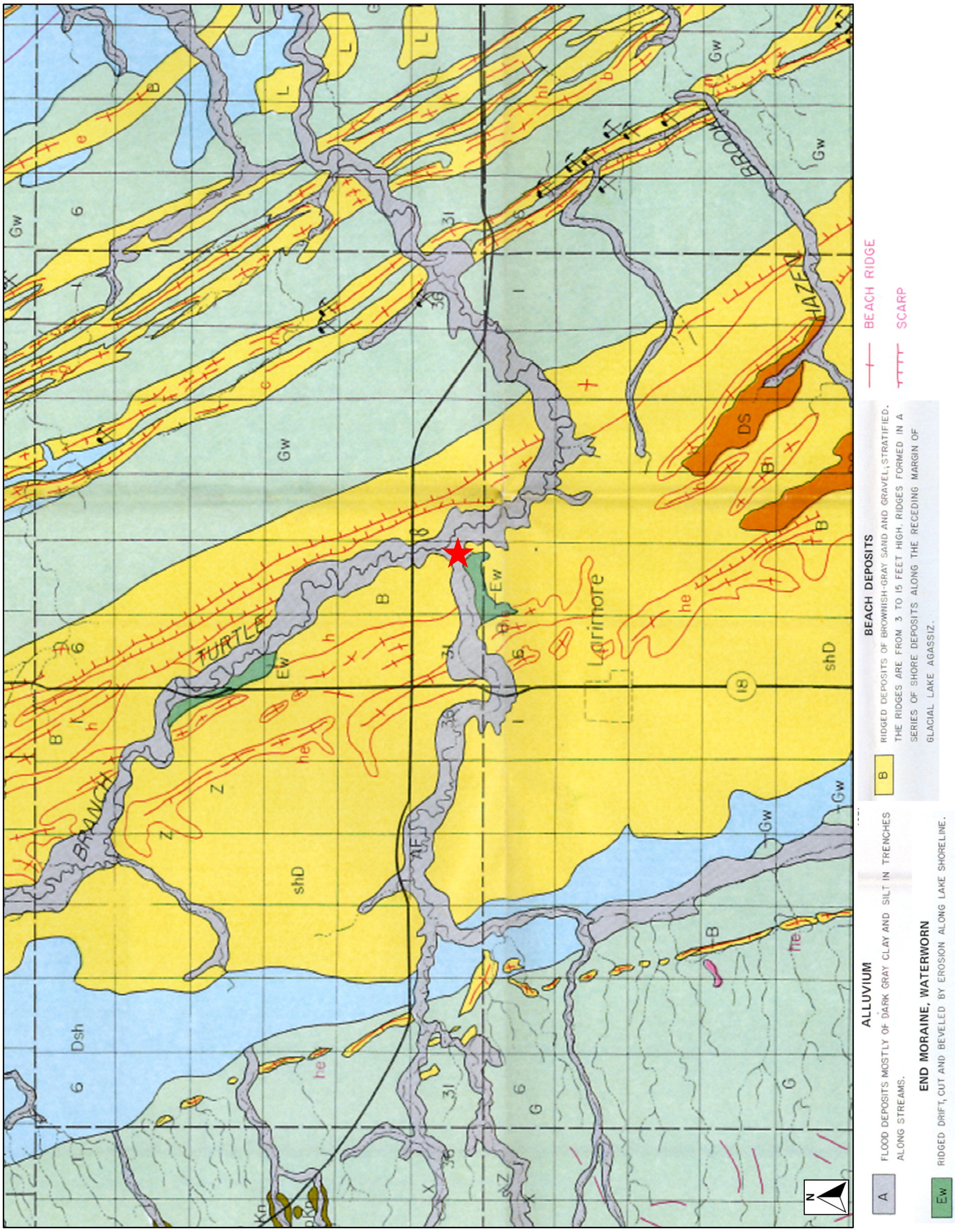


Exhibit 1: Excerpt from Geologic and Landforms Map of Grand Forks County (Hansen and Kume,1970); site location noted by red star

Exhibit 2

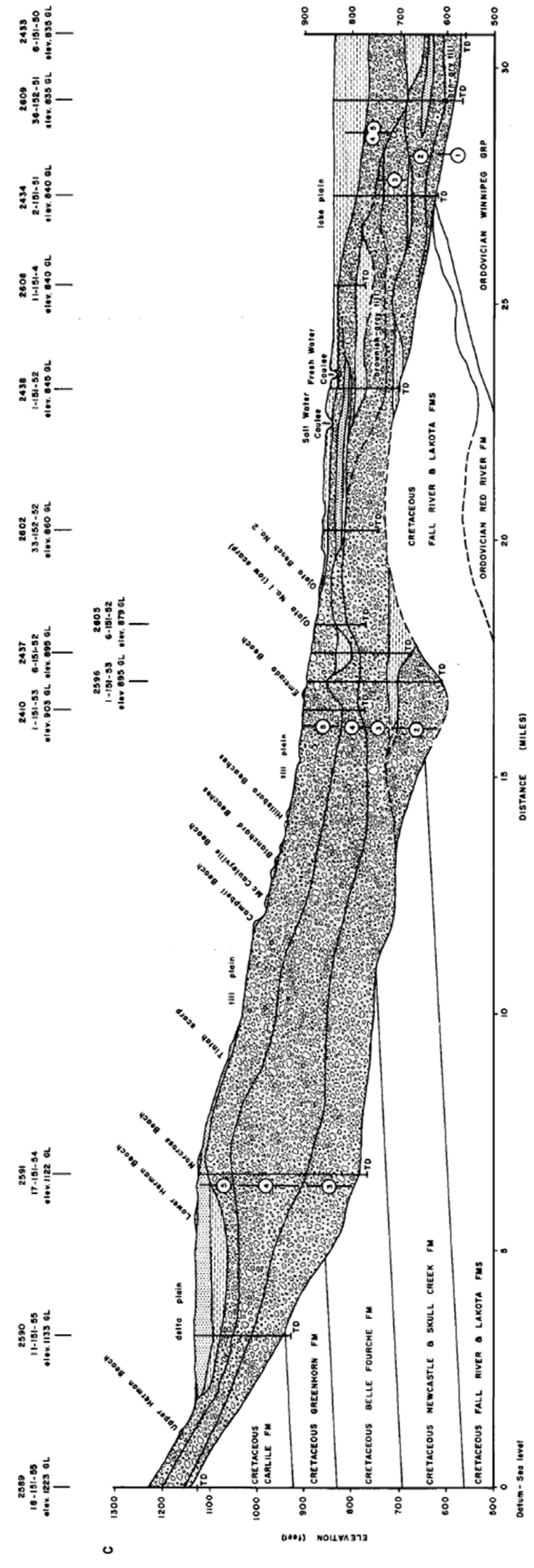


Exhibit 2: Stratigraphic Cross-Section of Glacial Drift in Grand Forks County (Hansen and Kume, 1970)

Exhibit 3

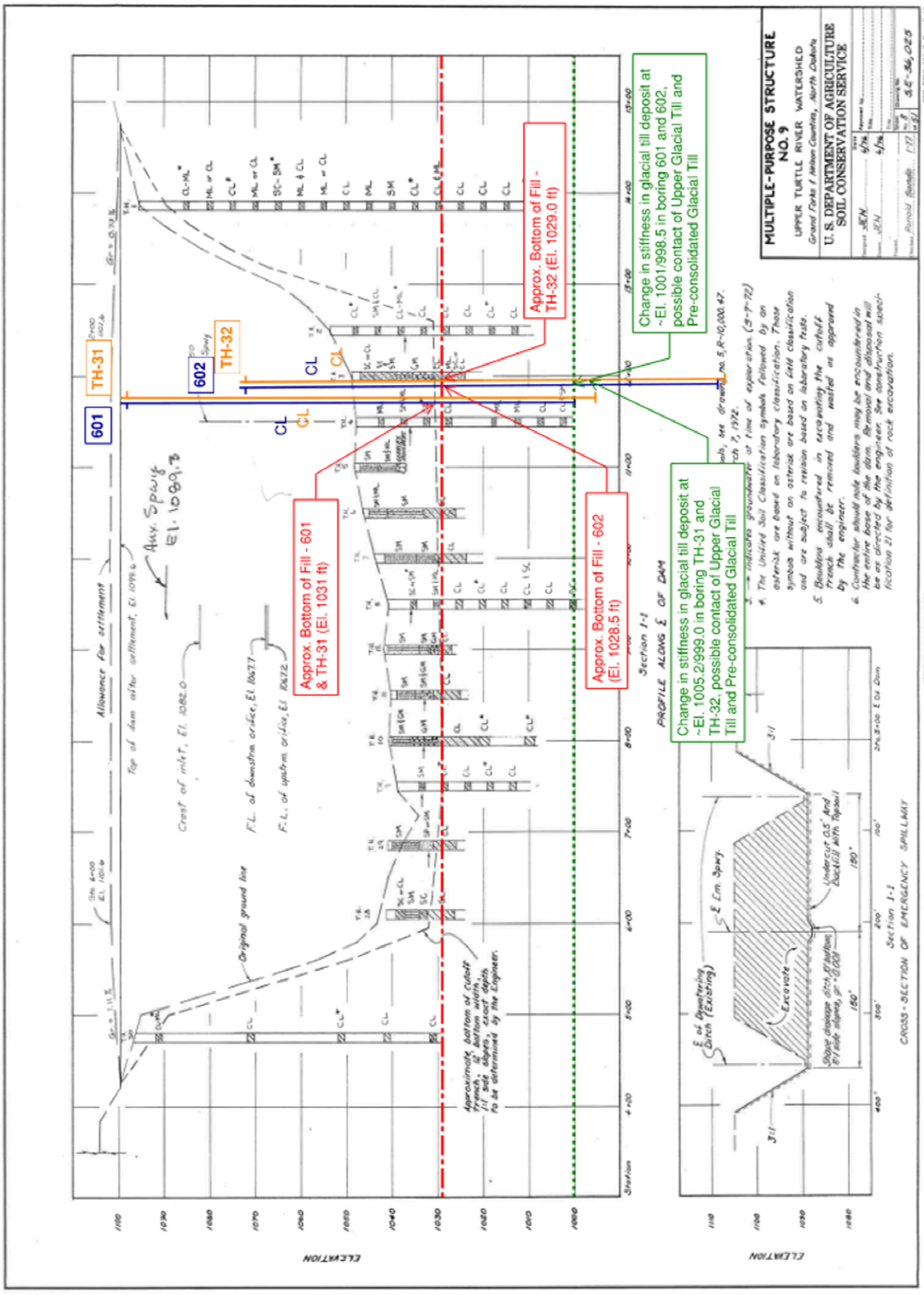


Exhibit 3: Dam Profile with approximate boring location and contact elevations encountered in the 2020 and 2021 investigations

Exhibit 4

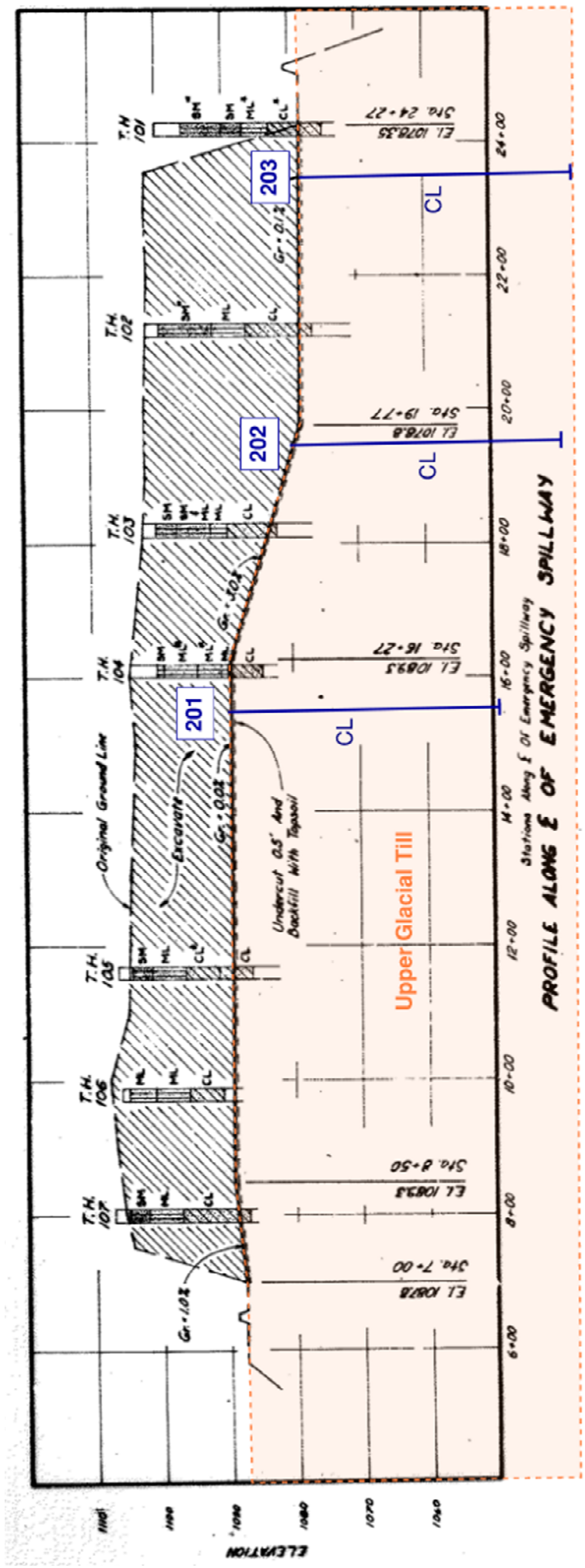


Exhibit 4: Emergency Spillway Profile with approximate boring location and contact elevations encountered in the 2020 investigation

APPENDIX A: 2020/2021 Geotechnical Investigation Results

A-1: 2020 Terracon Geotechnical Investigation Report

Geotechnical Exploration Report

Larimore Dam
Larimore, North Dakota
December 2, 2020
Terracon Project No. M5205031

Prepared for:
HDR Engineering, Inc.
Minneapolis, Minnesota

Prepared by:
Terracon Consultants, Inc.
Grand Forks, North Dakota

December 2, 2020

HDR Engineering, Inc.
701 Xenia Avenue S, Ste 600
Minneapolis, Minnesota 55416-3636

Attn: Ms. Greta Backman, PE
P: (763) 591 6637
E: Greta.Backman@hdrinc.com

Re: Geotechnical Exploration Report
Larimore Dam
Larimore, North Dakota
Terracon Project No. M5205031

Dear Ms. Backman:

We have completed the Geotechnical Exploration services for the above referenced project. This study was performed in general accordance with the Terracon Proposal No. PM5205031 and Task Order dated August 13, 2020. This report presents the findings of the subsurface exploration for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Jonathan J. Malaterre, EI
Staff Engineer

William R. Olson, PE
Geotechnical Department Manager

REPORT TOPICS

INTRODUCTION 1
SITE CONDITIONS 1
PROJECT DESCRIPTION 2
GEOTECHNICAL CHARACTERIZATION 2
GENERAL COMMENTS 2

Note: This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the ***GeoReport*** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES
PHOTOGRAPHY LOG
SITE LOCATION AND EXPLORATION PLANS
EXPLORATION RESULTS
SUPPORTING INFORMATION

Note: Refer to each individual Attachment for a listing of contents.

Geotechnical Exploration Report

Larimore Dam

Larimore, North Dakota

Terracon Project No. M5205031

December 2, 2020

INTRODUCTION

This report presents the results of our subsurface exploration services performed for the proposed to be located near the South Branch Turtle River near Larimore, North Dakota. The purpose of these services is to provide the following:

- Subsurface soil conditions
- Groundwater conditions

The geotechnical engineering Scope of Services for this project included the advancement of five test borings to depths ranging from approximately 40 to 105 feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs and as separate graphs in the **Exploration Results** section.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project is in Grand Forks County approximately 2 ½ miles northeast of Larimore, North Dakota. Approximate coordinates: 47.93732, -97.59223
Existing Improvements	Existing Dam embankment and spillway
Current Ground Cover	Vegetation
Existing Topography	Gently rolling topography surrounding the dam site.

We also collected photographs at the time of our field exploration program. Representative photos are provided in our **Photography Log**.

PROJECT DESCRIPTION

Our understanding of the project conditions is as follows:

Item	Description
Information Provided	Our proposal is based on the information provided in the Larimore Dam Geotechnical Investigation Work Plan dated August 10, 2020.
Project Description	Our scope of services will include drilling and sampling of geotechnical borings, installation of vibrating wire piezometers and laboratory testing.

GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. Conditions encountered at each boring location are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section.

Our borings advanced on the top of the embankment encountered approximately 1 ½ feet of topsoil fill underlain by clay fill to depths on the order of 39 ½ to 69 ½ feet. The clay fill is underlain by lean clay with varying amounts of sand to the termination depth of our borings. Our borings advanced in the spillway encountered 1 ½ feet of topsoil fill underlain by sandy lean clay to the termination depth of our 41-foot borings.

Groundwater Conditions

The boreholes were observed while drilling and after completion for the presence and level of groundwater. Groundwater was not observed in the borings while drilling, or for the short duration the borings could remain open. However, this does not necessarily mean the borings terminated above groundwater. Borings 601 and 602 were completed as piezometers to obtain groundwater information.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur

between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet)	Location
2	100[1]	Embankment instrumented borings
3	40	Auxiliary spillway centerline

1. Borings 601 and 602 were completed as piezometers with vibrating wires installed at the depths indicated on the boring logs.

Boring Layout and Elevations: Borings were staked by HDR prior to our field exploration with elevations and coordinates provided.

Subsurface Exploration Procedures: We advanced the borings with a rubber-tired drill rig using hollow stem augers. We obtained representative samples by the split-barrel and Shelby tube sampling procedures. In the split-barrel sampling procedure, a standard, 2-inch O.D., split-barrel sampling spoon is driven into the boring with a 140-pound automatic SPT (Standard Penetration Test) hammer falling 30 inches. We recorded the number of blows required to advance the sampling spoon the last 12 inches of an 18-inch sampling interval as the standard penetration resistance value, N. In the Shelby tube sampling procedure, a thin wall seamless steel tube with a sharp cutting edge is pushed into the soil by hydraulic pressure to obtain a relatively undisturbed sample of cohesive soil. The samples were placed in appropriate containers, taken to our soil laboratory for testing, and classified by a geotechnical engineer.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed at this site. A greater efficiency is typically achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between the SPT values and soil properties are based on the lower efficiency cathead and rope method. This higher efficiency affects the standard penetration resistance blow count (N) value by increasing the penetration per hammer blow over what would be obtained using the cathead and rope method.

Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the geotechnical engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

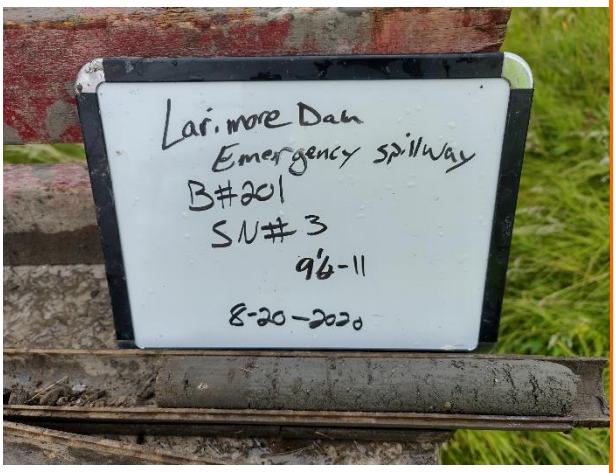
- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D7928-17 Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis
- ASTM D2435/D2435M Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
- ASTM D5084-16A Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
- ASTM D4767-11(2020) Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils

The laboratory testing program included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance

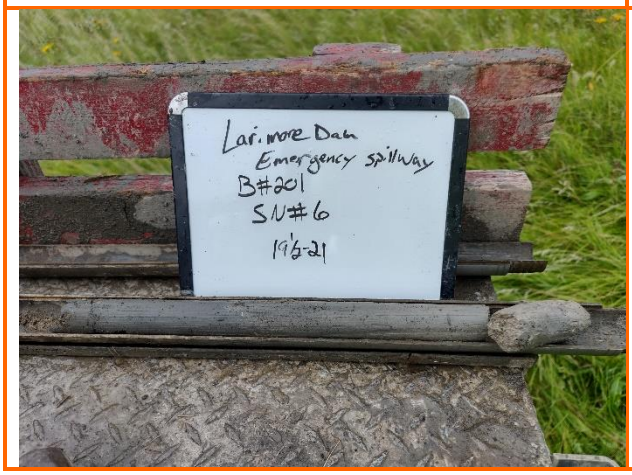
PHOTOGRAPHY LOG

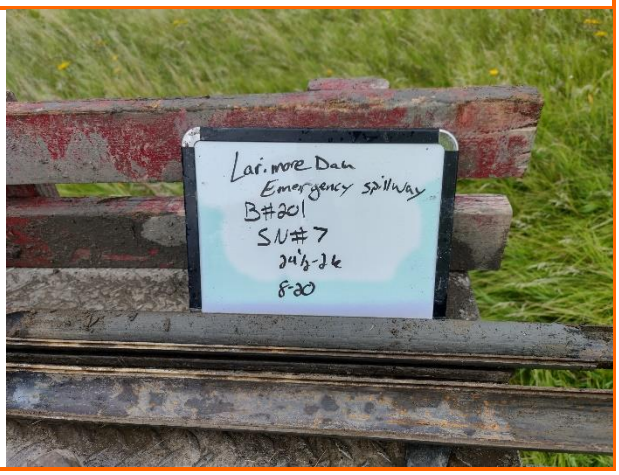












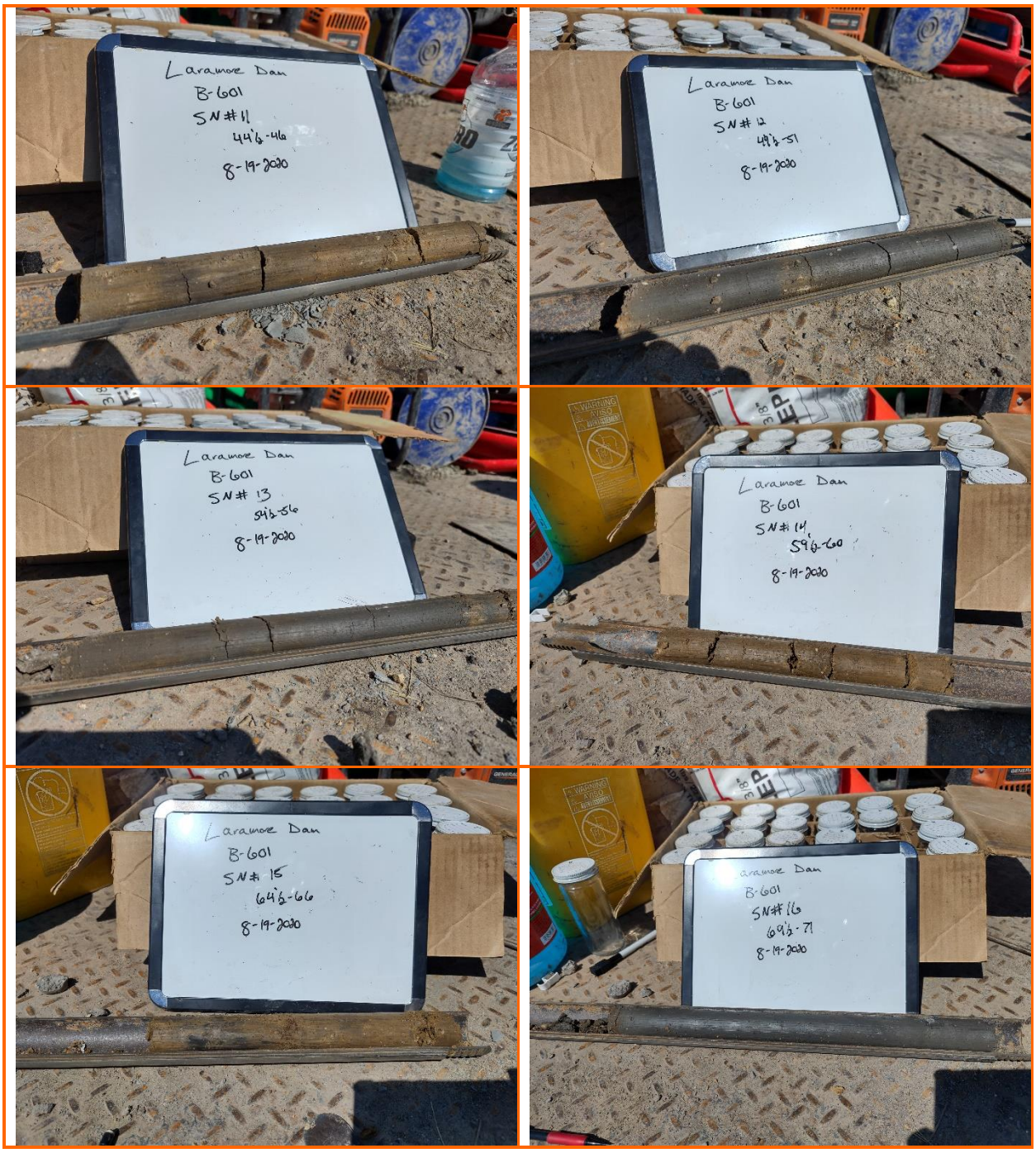

Lar. more Dam
Emergency spillway
B#201
SN# 8
29½-31
8-20
Lar. more Dam
Emergency spillway
B#201
SN# 9
34½-36
8-20
Lar. more Dam
Emergency spillway
B#201
SN# 10
39½-41
8-20
Lar. more Dam
Emergency spillway
B# 202
SN# 1
0-1½
8-20
Lar. more Dam
Emergency spillway
B#202
SN# 2
4½-6
8-20
Lar. more Dam
Emergency spillway
B#202
SN# 3
9½-11
8-20


Larimore Dam
Emergency spillway
B#202
SN# 4
14½-16
8-20
Larimore Dam
Emergency spillway
B#202
SN# 5
19½-21
8-20
Larimore Dam
Emergency spillway
B#202
SN# 7
24½-26
8-20
Larimore Dam
Energency spill way
B#202
SN# 8
29½-31
8-80
Larimore Dam
Energency spill way
B#202
SN# 9
34½-36
8-80
Larimore Dam
Energency spill way
B#202
SN# 10
39½-41
8-80

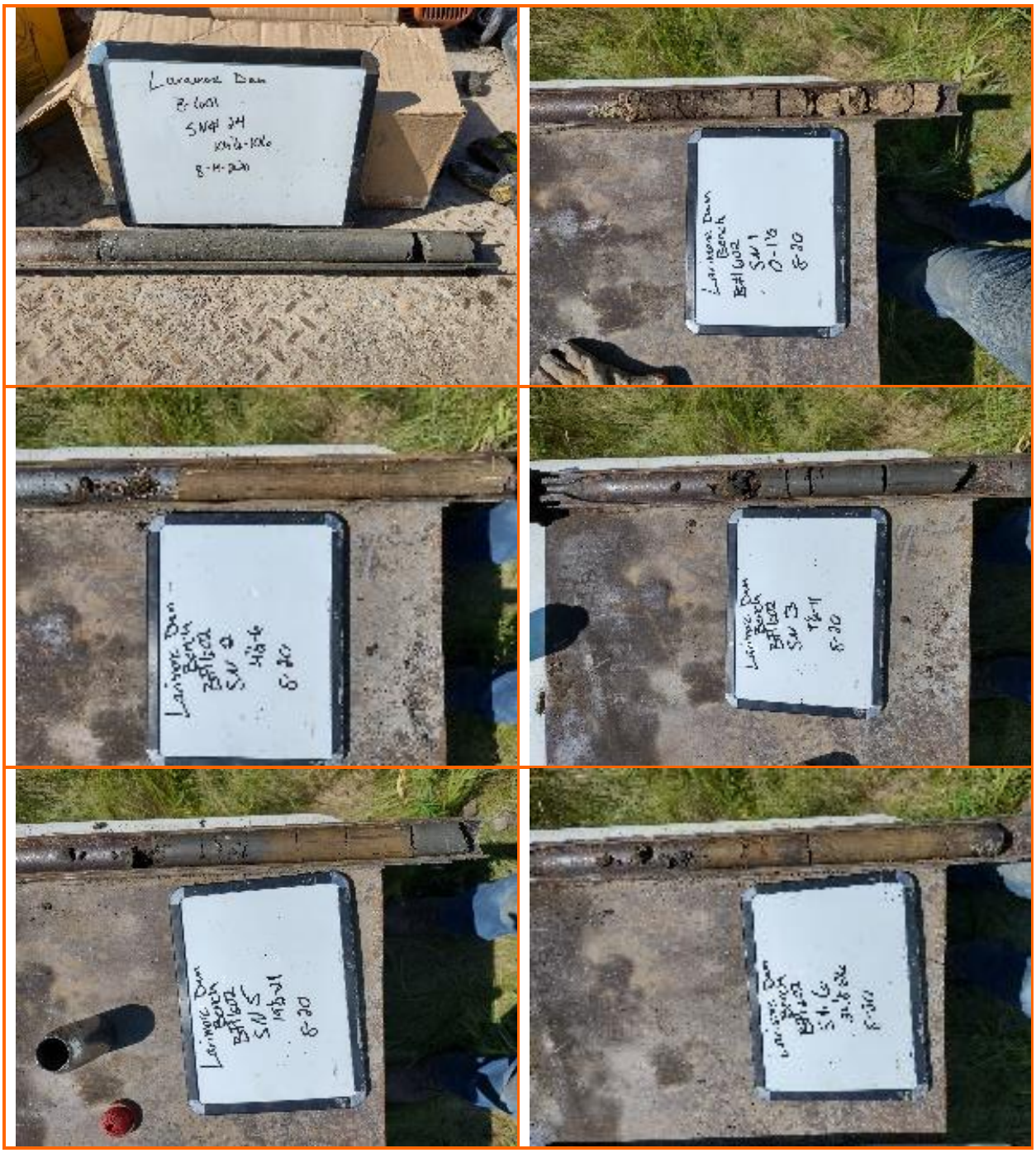

Larimore Dam
Emergency Spillway
B# 203
SN# 1
0-1½
E-20
Larimore Dam
Emergency Spillway
B# 203
SN# 2
4½-6
E-20
Larimore Dam
Emergency Spillway
B# 203
SN# 3
9½-11
E-20
Larimore Dam
Emergency Spillway
B# 203
SN# 4
14½-16
E-20
Larimore Dam
Emergency Spillway
B# 203
SN# 5
19½-21
E-20
Larimore Dam
Emergency Spillway
B# 203
SN# 6
24½-26
E-20

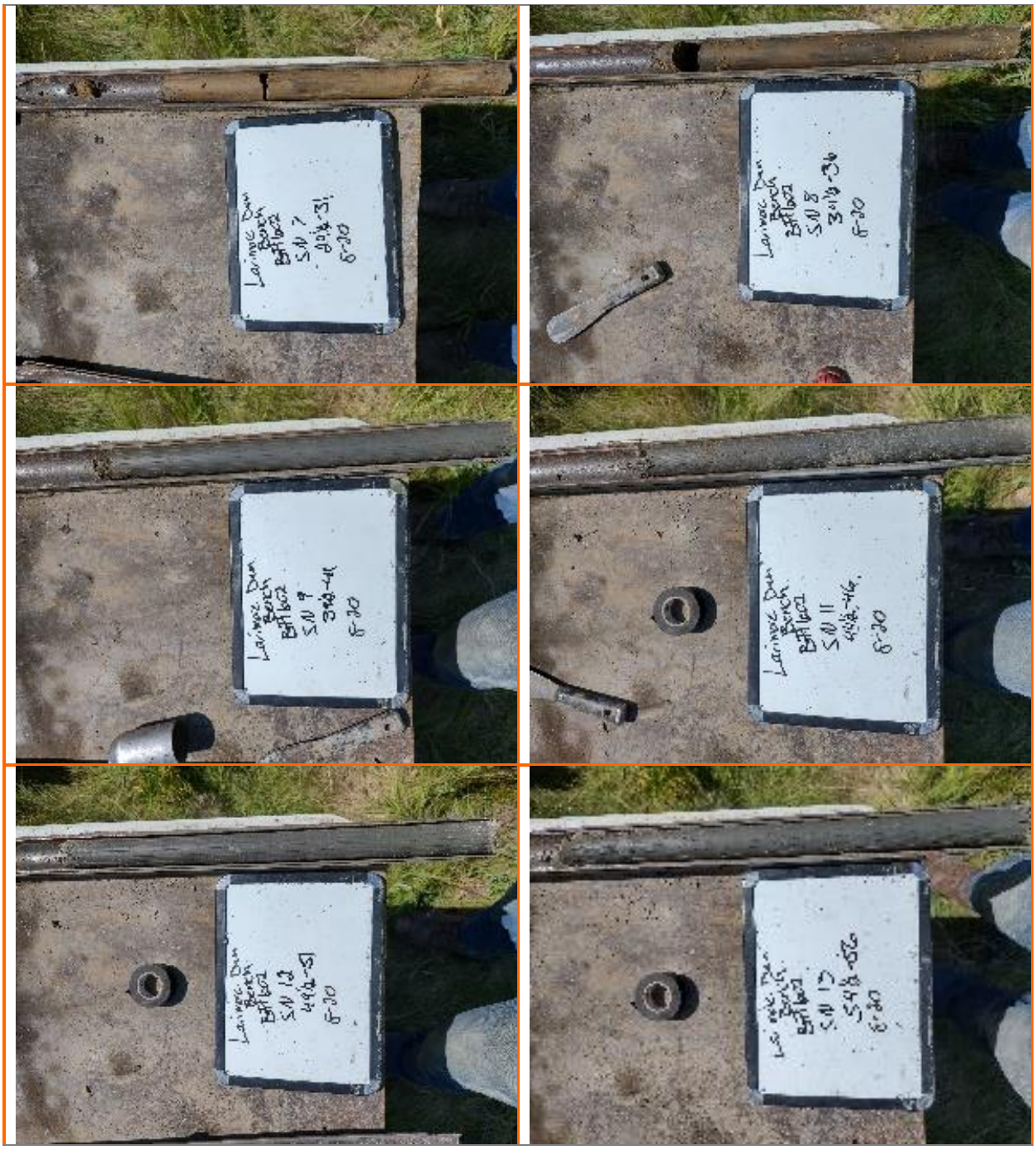

Larimore Dam
Energency Spill way
B# 203
SN# 7
29½-31
8-20
Larimore Dam
Energency Spill
B# 203
SN# 9
34½-36
8-20
Larimore Dam
Energency Spill
B# 203
SN# 10
39½-41
8-20
Laramore Dam
B-602
SN#1
0-1½'
8-19-2020
Laramore Dam
B-602
SN#2
4½-6
8-19-2020
Laramore Dam
B-602
SN#3
9½-11
8-19-2020

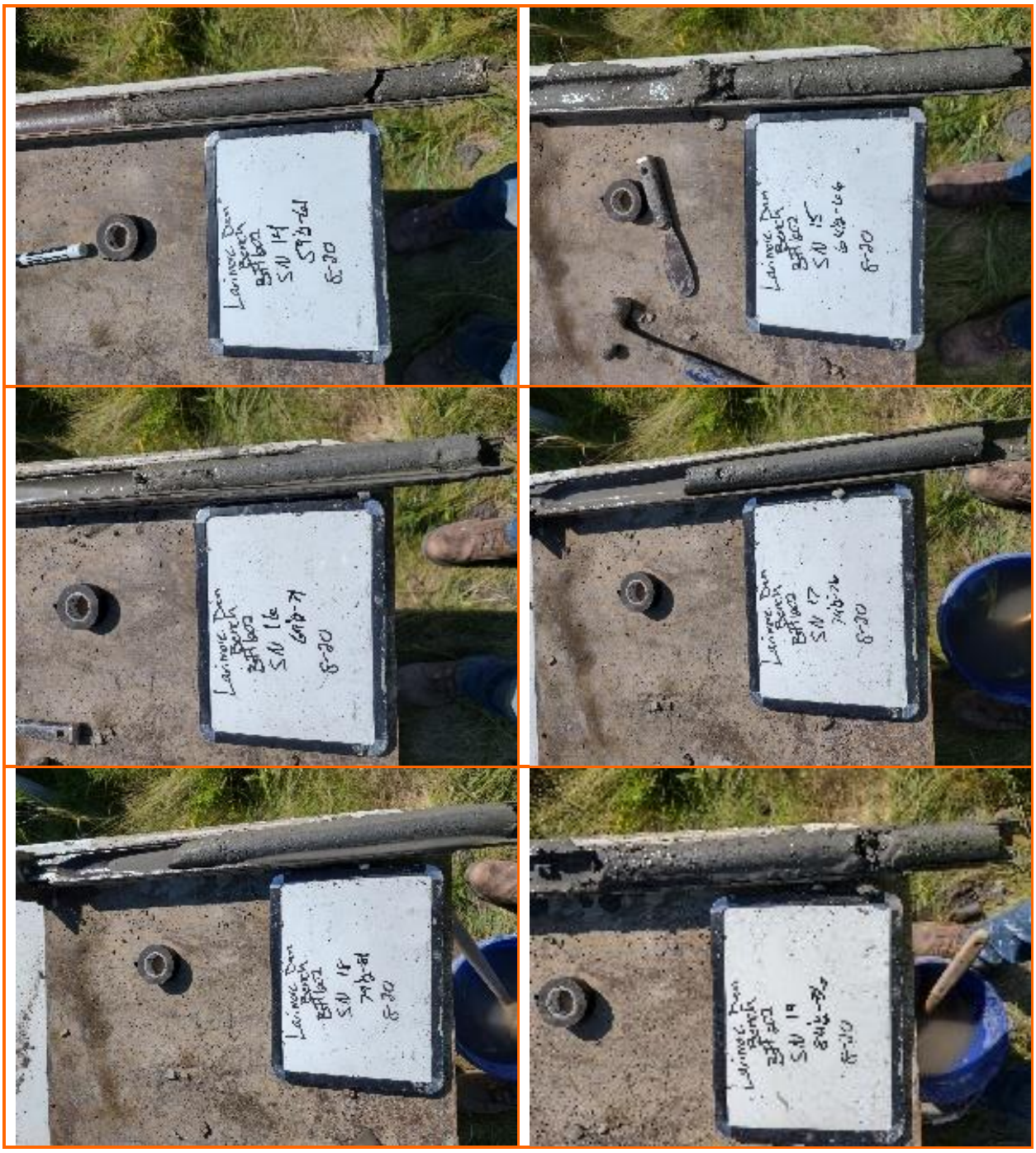

Laramore Dam
B-602
SN#4
12½-16
8-19-2020
Laramore Dam
B-601
SN#5
19½-21
8-19-2020
Laramore Dam
B-601
SN#7
24½-26
8-19-2020
Laramore Dam
B-601
SN#8
29½-31
8-19-2020
Laramore Dam
B-601
SN#9
34½-36
8-19-2020
Laramore Dam
B-601
SN#10
39½-41
8-19-2020


Laramore Dam
B-601
SN#11
44½-46
8-19-2020
Laramore Dam
B-601
SN# 12
49½-51
8-19-2020
Laramore Dam
B-601
SN# 13
54½-56
8-19-2020
Laramore Dam
B-601
SN# 14
59½-60
8-19-2020
Laramore Dam
B-601
SN# 15
64½-66
8-19-2020
Laramore Dam
B-601
SN# 16
69½-71
8-19-2020


Laramore Dam
B-601
SN# 18
74½-76
8-19-2020
Laramore Dam
B-601
SN# 19
79½-81
8-19-2020
Laramore Dam
B-601
SN# 20
84½-86
8-19-2020
Laramore Dam
B-601
SN# 21
89½-91
8-19-2020
Laramore Dam
B-601
SN# 22
94½-96
8-19-2020
Laramore Dam
B-601
SN# 23
99½-101
8-19-2020









SITE LOCATION AND EXPLORATION PLANS

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted above.

SITE LOCATION

Larimore Dam ■ Larimore, North Dakota
December 2, 2020 ■ Terracon Project No. M5205031

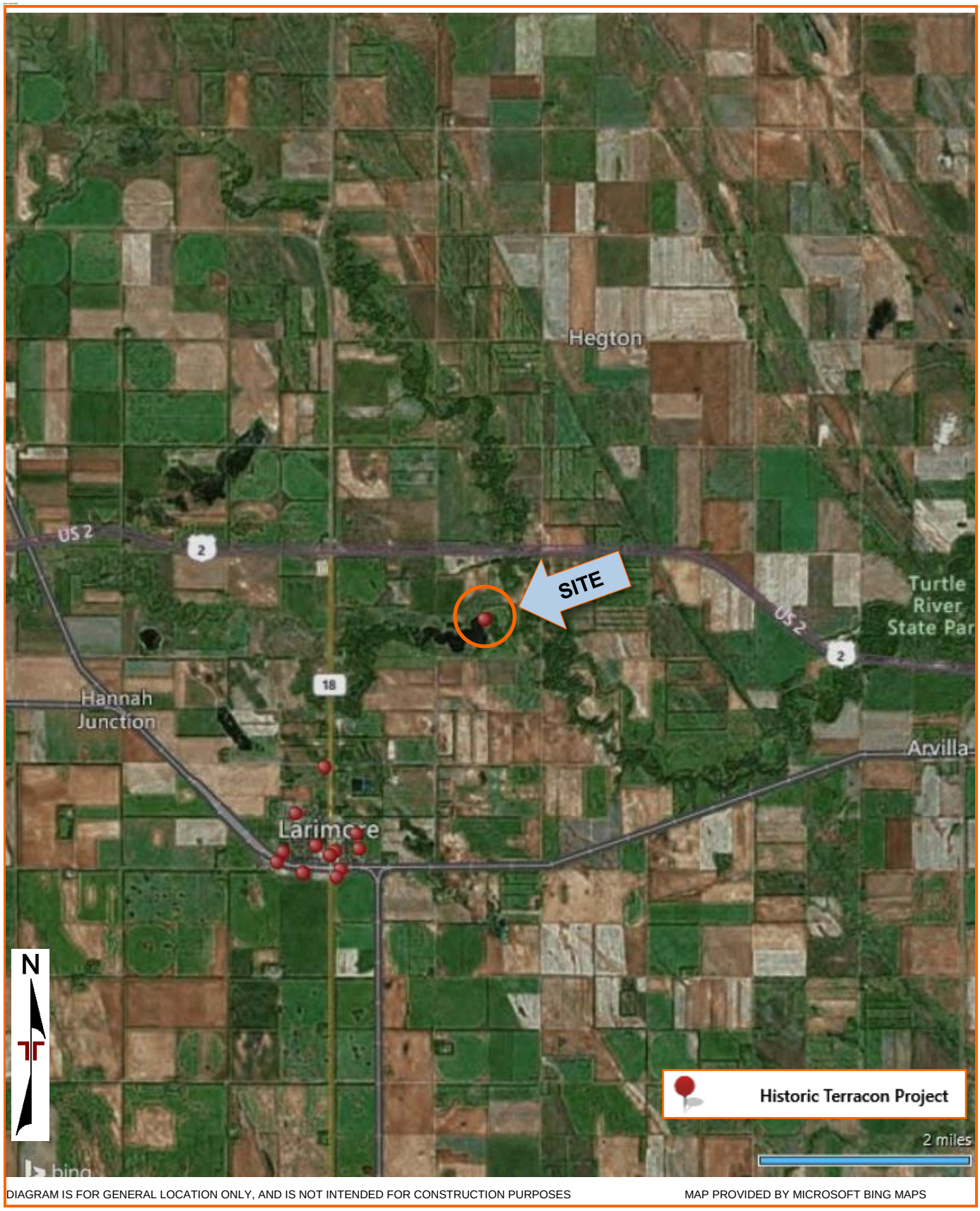


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

Larimore Dam ■ Larimore, North Dakota
December 2, 2020 ■ Terracon Project No. M5205031



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Boring Logs (B-601 through B-203)
Atterberg Limits
Grain Size Distribution (2 pages)
One-Dimensional Consolidation (18 pages)
Hydraulic Conductivity (2 pages)
Consolidation Undrained Triaxial Compression (2 pages)

Note: All attachments are one page unless noted above.

Re-surveyed by HDR (4/15/21) and surface elevation for BH 601 is 1100.67' (NGVD29)

BORING LOG NO. 601

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9369° Longitude: -97.5922°

NAVD 88

See Note Surface Elev.: 1100.44 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	ORGANIC CONTENT %	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1.5	1099								
FILL - TOPSOIL - SANDY LEAN CLAY, dark brown and black									
FILL - SANDY LEAN CLAY, trace gravel, light brown to dark brown									
				12	2-3-5 N=8				
		5		14	5-11-17 N=28		17.6		
9.5	1091								
FILL - LEAN CLAY WITH SAND, trace gravel, dark brownish gray		10		12	4-5-7 N=12				
		15		12	4-6-9 N=15		15.0		
		20		13	3-5-7 N=12				
							14.8	33-18-15	75
24.5	1076								
FILL - SANDY LEAN CLAY, trace gravel, dark brownish gray		25		14	8-8-10 N=18	1.5	25.8 16.8	33-19-14	53
		30		13	5-8-11 N=19		15.4 14.6	36-19-17 34-20-14	62 58
		35		14	4-7-8 N=15				
		40		14	6-7-11 N=18		15.9		
		45		14	8-10-14 N=24				
		50		13	4-8-11 N=19		14.6	32-18-14	66

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

Vibrating Wire Piezometer installed. Wires installed at depths of 50', 65' and 100'

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-19-2020 | Boring Completed: 08-20-2020

Drill Rig: Tracked ATV Drill Rig | Driller: MR

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

BORING LOG NO. 601

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan
Latitude: 47.9369° Longitude: -97.5922°
NAVD 88
See Note Surface Elev.: 1100.44 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	ORGANIC CONTENT %	LABORATORY HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		55											
	FILL - SANDY LEAN CLAY, trace gravel, dark brownish gray *(continued)*				16	6-9-16 N=25				14.4			
		60			11	5-8-11 N=19							
		65			12	6-7-10 N=17				16.9			
69.5	1031												
	SANDY LEAN CLAY (CL), trace gravel, gray, medium stiff to very stiff to hard, occasional cobbles/boulders	70			14	4-5-6 N=11				22.7			
										24.1			
		75			17	3-4-6 N=10							
		80			18	1-3-4 N=7				21.6			73
86.0	1014.5	85			8	2-3-5 N=8							
	LEAN CLAY WITH SAND (CL), trace gravel, gray, medium stiff									25.2		44-21-23	77
		90			18	1-2-3 N=5							
		95			18	2-3-5 N=8				17.9		34-19-15	
99.5	1001												
	SANDY LEAN CLAY (CL), trace gravel, gray, very stiff to hard, occasional cobbles/boulders	100			15	6-9-17 N=26							
106.0	994.5	105				14-24-31 N=55				21.6		40-26-14	93
	Boring Terminated at 106 Feet												

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-19-2020 | Boring Completed: 08-20-2020
Drill Rig: Tracked ATV Drill Rig | Driller: MR
Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

Re-surveyed by HDR (4/15/21) and surface elevation for BH 602 is 1067.39' (NGVD29)

BORING LOG NO. 602

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9369° Longitude: -97.5918°

NAVD 88

See Note Surface Elev.: 1068.15 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
1.5	1066.5	**FILL - TOPSOIL - SANDY LEAN CLAY**, dark brown and black
		FILL - SANDY LEAN CLAY, trace gravel, dark brown
39.5	1028.5	**LEAN CLAY (CL)**, trace sand and gravel, gray, medium stiff
44.5	1023.5	**LEAN CLAY WITH SAND (CL)**, trace gravel, dark gray, medium stiff to stiff to very stiff

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		11	2-5-10 N=15			
5		10	4-5-7 N=12	14.8		
10		10	3-5-8 N=13			
15		12	3-6-8 N=14	15.4	32-22-10	66
20		13	4-6-9 N=15			
25		13	6-8-11 N=19	14.3		
30		14	5-7-10 N=17			
35		12	4-5-8 N=13	24.7	43-26-17	
40		14	1-2-3 N=5	22.2	48-21-27	96
45		15	1-1-3 N=4			
50		16	1-1-3 N=4			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

Vibrating Wire Piezometer installed. Wires installed at depths of 15', 30' and 110'

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-20-2020 | Boring Completed: 08-21-2020

Drill Rig: Tracked ATV Drill Rig | Driller: MR

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

BORING LOG NO. 602

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9369° Longitude: -97.5918°

NAVD 88

See Note Surface Elev.: 1068.15 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (Inch)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	LEAN CLAY WITH SAND (CL), trace gravel, dark gray, medium stiff to stiff to very stiff *(continued)*	55	15	1-2-2 N=4			
		60	13	1-3-4 N=7			
	-sand seam at 64.5'	65	12	4-5-6 N=11			8 71
		70	13	9-14-23 N=37			
		75	14	9-12-22 N=34			
79.5	988.5						
	SANDY LEAN CLAY (CL), trace gravel, dark gray, very stiff, occasional cobbles/boulders	80	12	5-13-19 N=32	24.3	45-25-20	55
		85	16	9-22-22 N=44			
		90	15	7-19-19 N=38			
		95	18	6-9-9 N=18	25.1	48-19-29	62
101.0	967	100	16	4-11-11 N=22			
	Boring Terminated at 101 Feet						

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-20-2020 | Boring Completed: 08-21-2020

Drill Rig: Tracked ATV Drill Rig | Driller: MR

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

Surveyed by Pribula Engineering & Surveying (2020) and surface elevation for BH 201 is 1089.74' (NGVD29)

BORING LOG NO. 201

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9408° Longitude: -97.592°

NAVD 88

See Note Surface Elev.: 1090.92 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1.5	1089.5								
FILL - TOPSOIL - SANDY LEAN CLAY, dark brown									
SANDY LEAN CLAY (CL), trace gravel, gray to dark gray, medium stiff to very stiff			X	5	2-3-5 N=8				
		5	X	10	4-5-6 N=11	19.8		33-19-14	67
		10	X	10	3-3-4 N=7				
		15	X	7	1-2-3 N=5				
			■			17.3	110		
		20	X	17	0-2-2 N=4				
-sand seam @ 30.5'		25	X	18	2-3-3 N=6				
		30	X	15	3-5-7 N=12				
		35	X	16	1-3-5 N=8				
41.0	1050	40	X	16	1-4-4 N=8				
Boring Terminated at 41 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-20-2020 | Boring Completed: 08-20-2020

Drill Rig: CME 750X | Driller: CN

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

Surveyed by Pribula Engineering & Surveying (2020) and surface elevation for BH 202 is 1080.39' (NGVD29)

BORING LOG NO. 202

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9408° Longitude: -97.5904°

NAVD 88

See Note Surface Elev.: 1081.57 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1.5	1080								
FILL - TOPSOIL - SANDY LEAN CLAY, trace sand, dark brown and black									
SANDY LEAN CLAY (CL), trace gravel, gray, medium stiff to stiff		5		12	1-2-3 N=5				
				16	2-3-4 N=7				
		10		17	1-3-4 N=7	19.9		32-18-14	57
		15		16	2-3-4 N=7				
		20		14	1-3-5 N=8				
						18.0	112		
-sand seam @ 26'		25		14	3-4-7 N=11				
		30		16	1-3-4 N=7				
		35		14	2-3-12 N=15				
41.0	1040.5	40		17	2-4-5 N=9				
Boring Terminated at 41 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-20-2020 | Boring Completed: 08-20-2020

Drill Rig: CME 750X | Driller: CN

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

Surveyed by Pribula Engineering & Surveying (2020) and surface elevation for BH 203 is 1079.40' (NGVD29)

BORING LOG NO. 203

PROJECT: Larimore Dam

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

SITE: Larimore Dam
Larimore, North Dakota

LOCATION See Exploration Plan

Latitude: 47.9408° Longitude: -97.5888°

NAVD 88

See Note Surface Elev.: 1080.58 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (Inch)	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1.5	1079								
FILL - TOPSOIL - SANDY LEAN CLAY, dark brown									
SANDY LEAN CLAY (CL), trace gravel, dark brown, stiff to medium stiff									
		5		16	3-7-12 N=19				
				12	5-7-6 N=13				
9.5	1071								
SANDY LEAN CLAY (CL), trace gravel, dark gray, medium stiff to stiff		10		8	2-2-4 N=6				
		15		10	2-2-4 N=6	17.6		34-19-15	55
		20		12	0-2-2 N=4				
		25		16	0-2-3 N=5				
		30		17	1-3-4 N=7				
						15.4	112		
		35		16	9-5-6 N=11				
41.0	1039.5	40		8	4-5-6 N=11				
Boring Terminated at 41 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 ¼ inch hollow stem auger

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations provided by HDR

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

Boring Started: 08-20-2020 Boring Completed: 08-20-2020

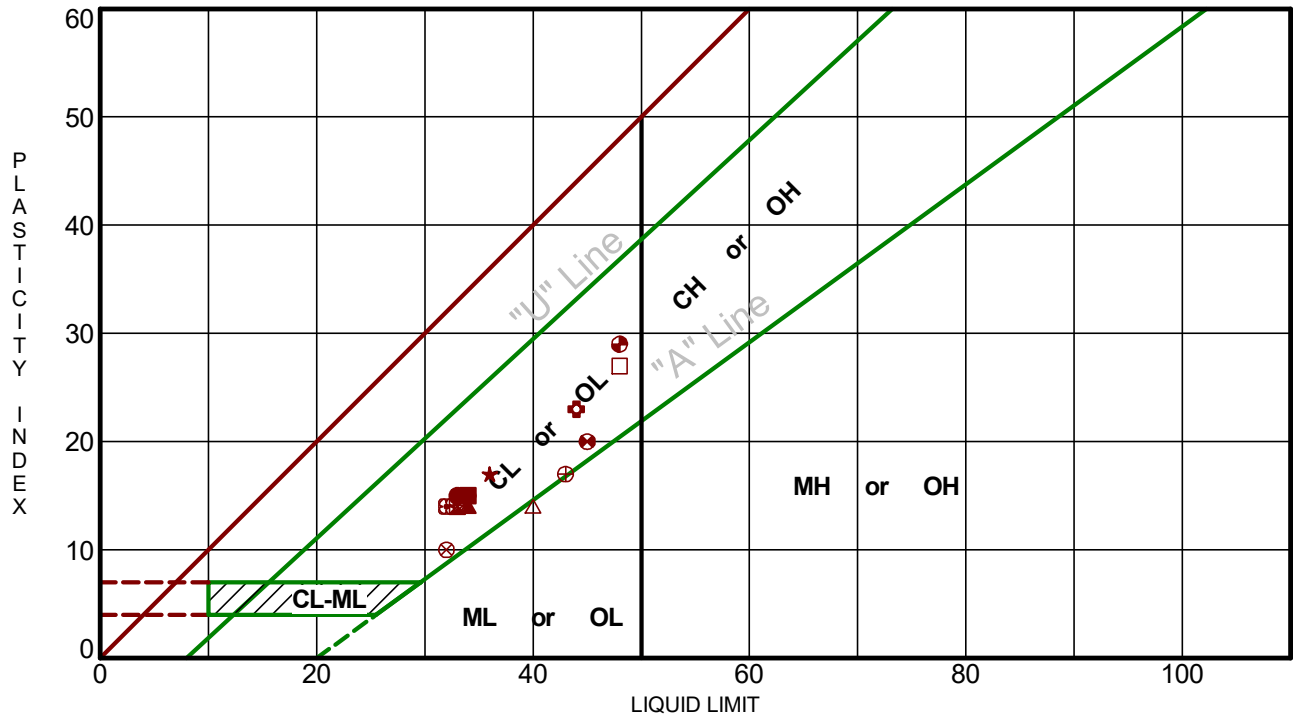
Drill Rig: CME 750X Driller: CN

Project No.: M5205031

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 12/1/20

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth	LL	PL	PI	Fines	USCS	Description
●	601	22 - 24	33	18	15	75.4	CL	LEAN CLAY with SAND
⊠	601	25	33	19	14	53.0	CL	SANDY LEAN CLAY
▲	601	29.5 - 31	34	20	14	57.6	CL	SANDY LEAN CLAY
★	601	30	36	19	17	61.8	CL	SANDY LEAN CLAY
⊙	601	49.5 - 51	32	18	14	65.6	CL	SANDY LEAN CLAY
✿	601	86 - 88	44	21	23	77.3	CL	LEAN CLAY with SAND
○	601	94.5 - 96	34	19	15		CL	LEAN CLAY
△	601	104.5 - 106	40	26	14	93.4	ML	SILT
⊗	602	14.5 - 16	32	22	10	65.8	CL	SANDY LEAN CLAY
⊕	602	34.5 - 36	43	26	17		CL	SANDY LEAN CLAY
□	602	41 - 43	48	21	27	95.9	CL	LEAN CLAY
⊠	602	79.5 - 81	45	25	20	54.6	CL	SANDY LEAN CLAY
◕	602	94.5 - 96	48	19	29	61.7	CL	SANDY LEAN CLAY
☆	201	4.5 - 6	33	19	14	66.8	CL	SANDY LEAN CLAY
✿	202	9.5 - 11	32	18	14	57.3	CL	SANDY LEAN CLAY
■	203	14.5 - 16	34	19	15	55.2	CL	SANDY LEAN CLAY

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

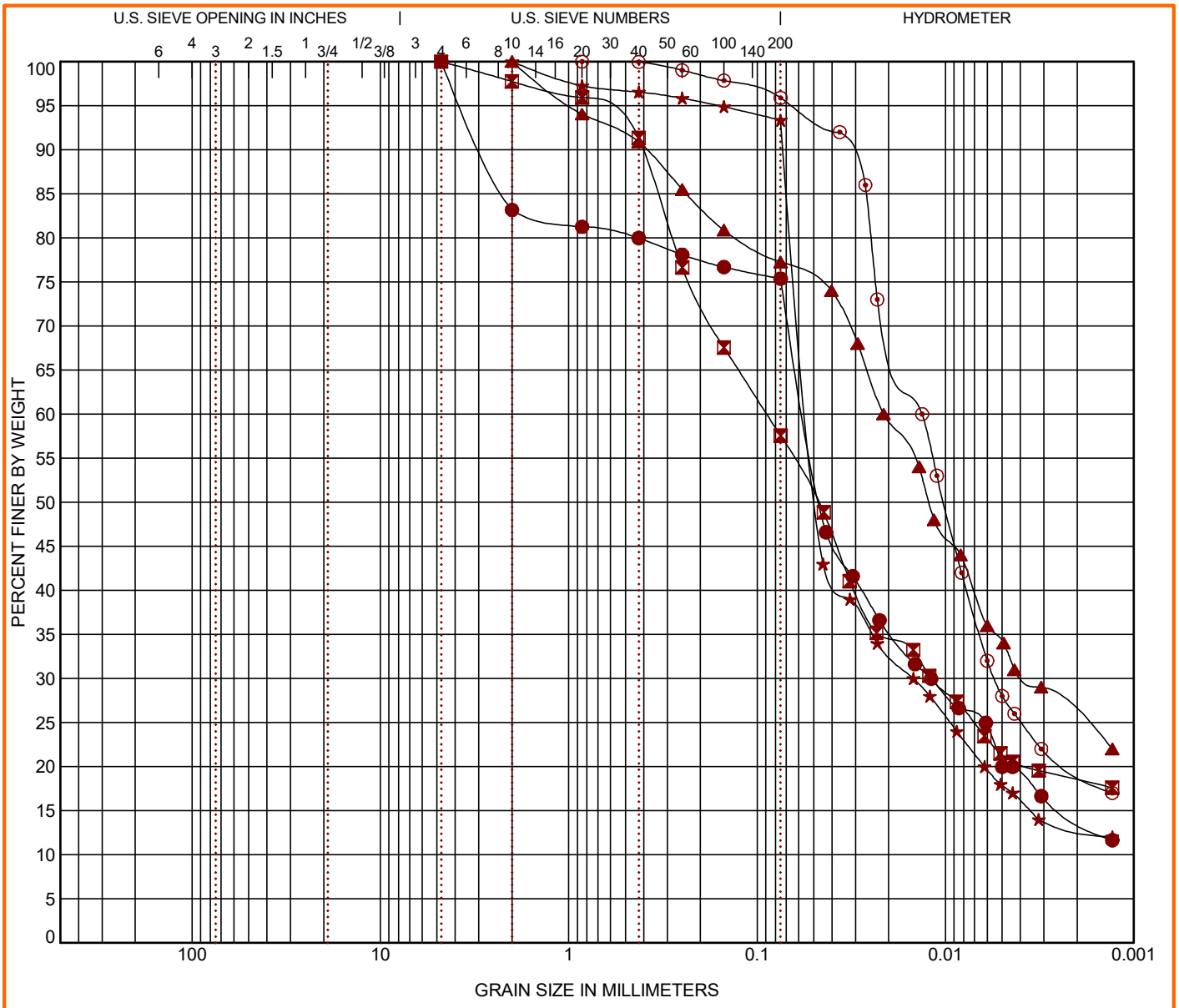
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. ATTERBERG LIMITS M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 11/24/20

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	601	22 - 24	LEAN CLAY with SAND (CL)	14.8	33	18	15		
⊠	601	29.5 - 31	SANDY LEAN CLAY (CL)	14.6	34	20	14		
▲	601	86 - 88	LEAN CLAY with SAND (CL)	25.2	44	21	23		
★	601	104.5 - 106	SILT (ML)	21.6	40	26	14		
⊙	602	41 - 43	LEAN CLAY (CL)	22.2	48	21	27		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	601	22 - 24	4.75	0.056	0.012		0.0	0.0	24.6	55.4		20.0
⊠	601	29.5 - 31	4.75	0.089	0.012		0.0	0.0	42.4	36.2		21.4
▲	601	86 - 88	2	0.021	0.004		0.0	0.0	22.7	43.1		34.2
★	601	104.5 - 106	2	0.053	0.015		0.0	0.0	6.6	75.5		17.9
⊙	602	41 - 43	0.85	0.013	0.005		0.0	0.0	4.1	67.9		28.0

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

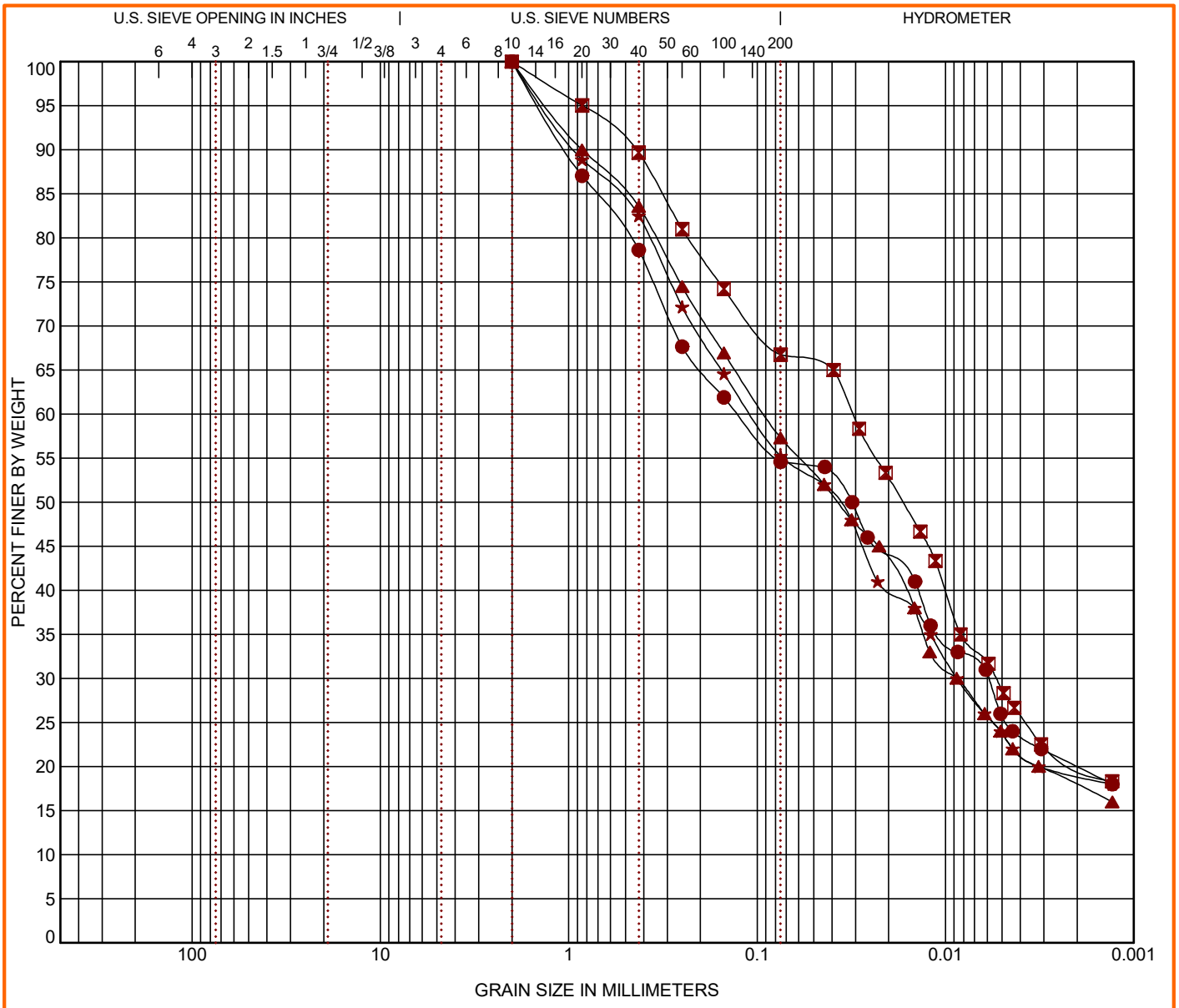
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 11/24/20

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	602	79.5 - 81	SANDY LEAN CLAY (CL)	24.3	45	25	20		
⊠	201	4.5 - 6	SANDY LEAN CLAY (CL)	19.8	33	19	14		
▲	202	9.5 - 11	SANDY LEAN CLAY (CL)	19.9	32	18	14		
★	203	14.5 - 16	SANDY LEAN CLAY (CL)	17.6	34	19	15		

Boring ID		Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	602	79.5 - 81	2	0.125	0.006		0.0	0.0	45.4	28.9		25.7
⊠	201	4.5 - 6	2	0.031	0.005		0.0	0.0	33.2	38.1		28.7
▲	202	9.5 - 11	2	0.091	0.009		0.0	0.0	42.7	33.6		23.7
★	203	14.5 - 16	2	0.107	0.009		0.0	0.0	44.8	31.5		23.7

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

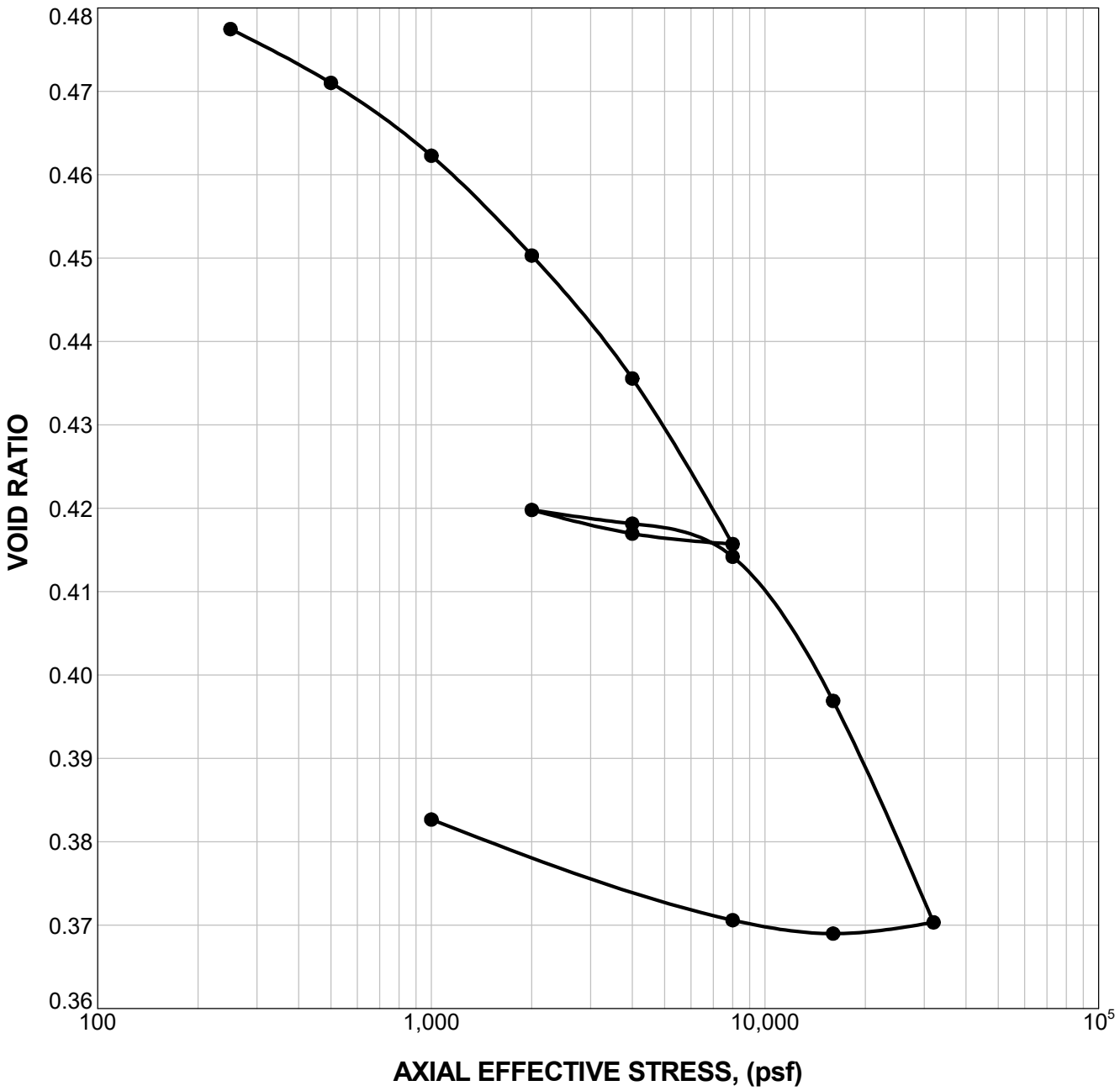
SITE: Larimore Dam
Larimore, North Dakota

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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CONSOLIDATION TEST (D2435)



Natural		Initial Dry Density (pcf)	LL	PI	Sp. Gr.	Overburden (psf)	P_c (psf)	C_c (vr / log stress)	C_r (vr / log stress)	Initial Void Ratio
Saturation	Moisture									
87.4 %	15.9 %	112.4	33	15	2.68		4,696	0.088	0.007	0.488

MATERIAL DESCRIPTION	USCS	AASHTO
LEAN CLAY with SAND	CL	A-6

NOTES:

Borehole: 601 Depth: 22 ft Specimen #: 6

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

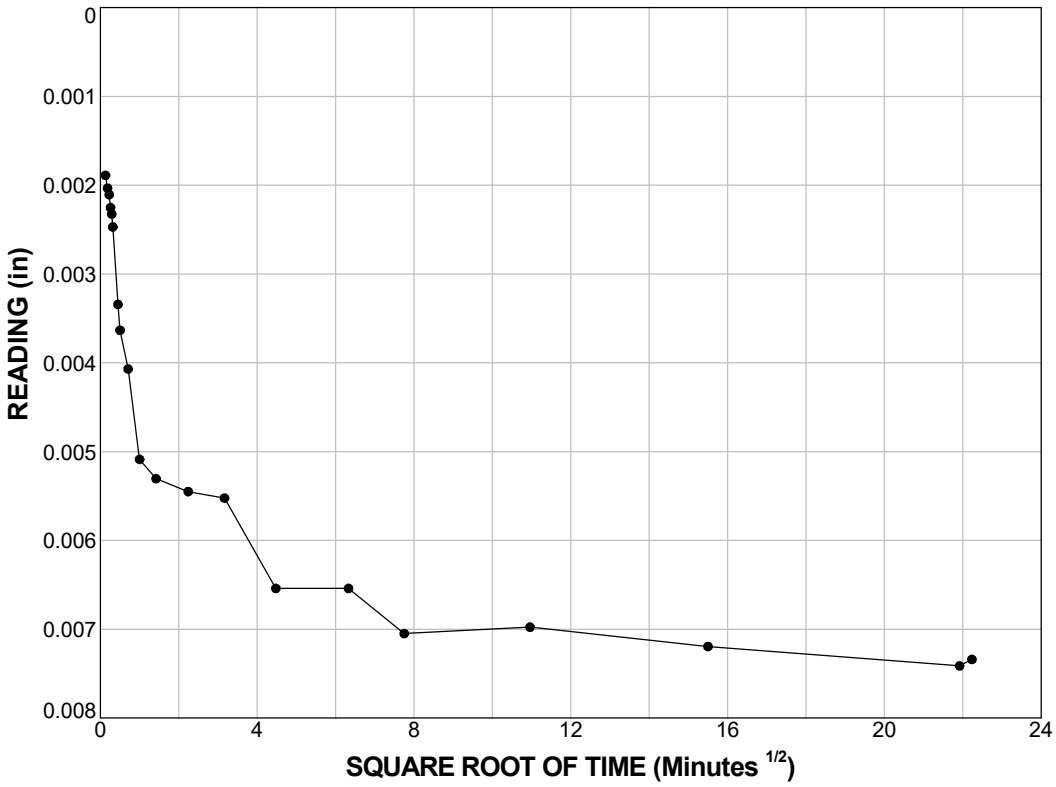
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CONS_LOAD-DEF_PROP_STRESS-VOIDRATIO M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 10/30/20

Per ASTM D2435/D2435M, Fig. 2

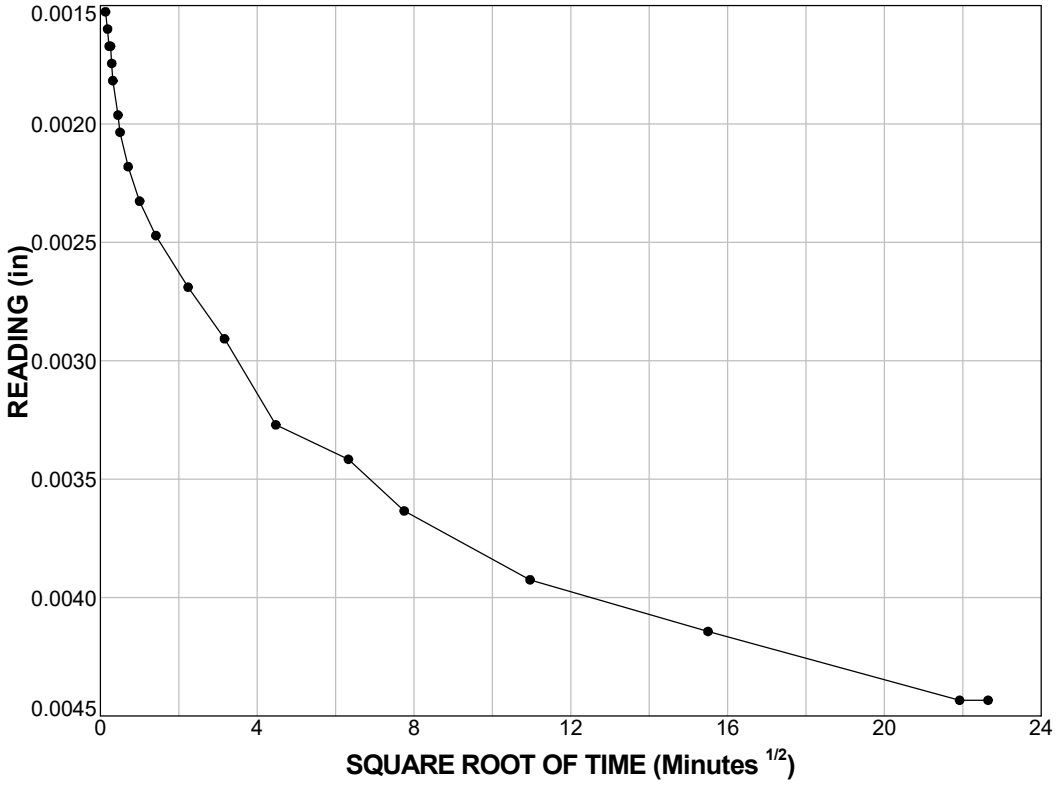
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 1
Load = 250 psf
D_0 = 0.0015
D_{90} = 0.0040
D_{100} = 0.0043
t_{90} = 0.38 min.

C_V @ t_{90}
5.549 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 2
Load = 500 psf
D_0 = 0.0014
D_{90} = 0.0021
D_{100} = 0.0022
t_{90} = 0.32 min.

C_V @ t_{90}
6.649 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

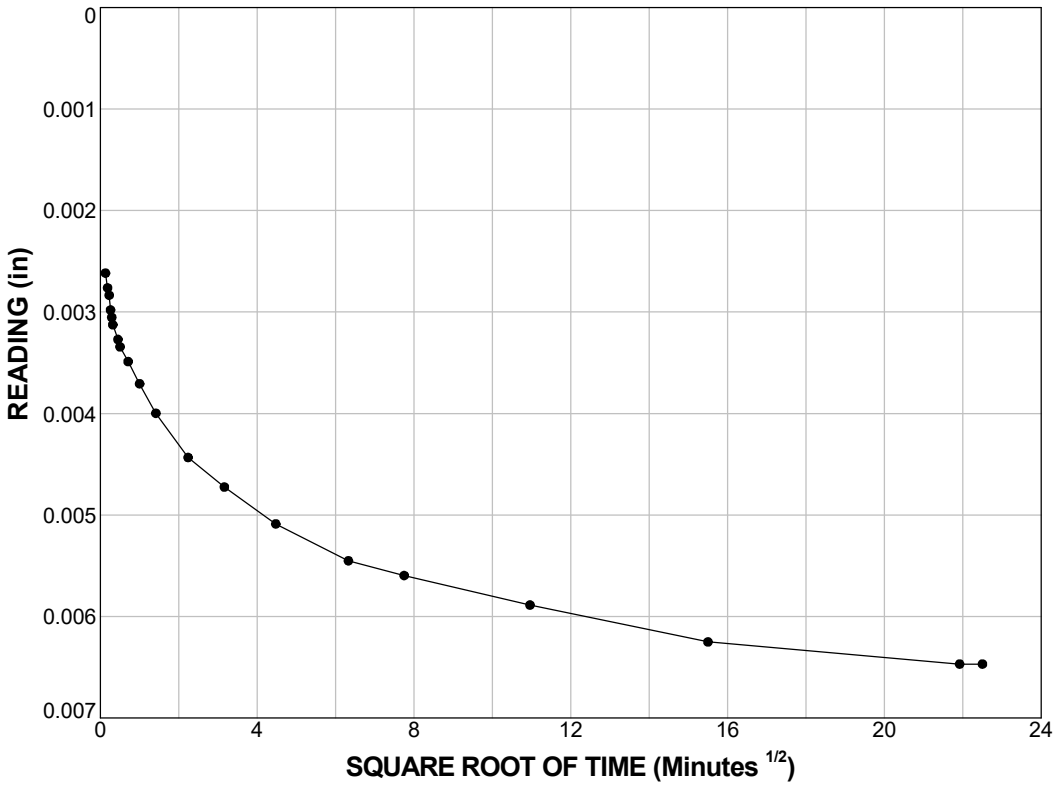
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CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CONS_TIME-DEF_PROP_SQRT-TIME M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 10/30/20

Per ASTM D2435/D2435M, Fig. 2

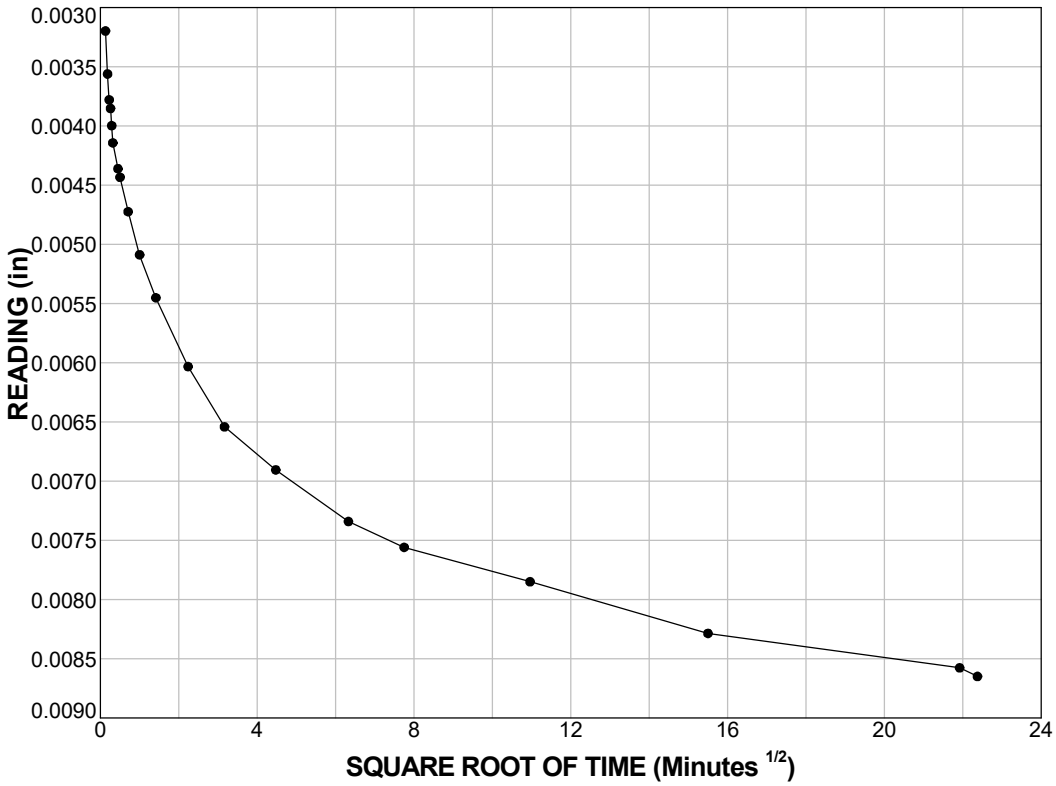
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 3
Load = 1000 psf
D_0 = 0.0023
D_{90} = 0.0032
D_{100} = 0.0033
t_{90} = 0.15 min.

C_V @ t_{90}
13.818 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 4
Load = 2000 psf
D_0 = 0.0029
D_{90} = 0.0043
D_{100} = 0.0044
t_{90} = 0.14 min.

C_V @ t_{90}
15.541 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

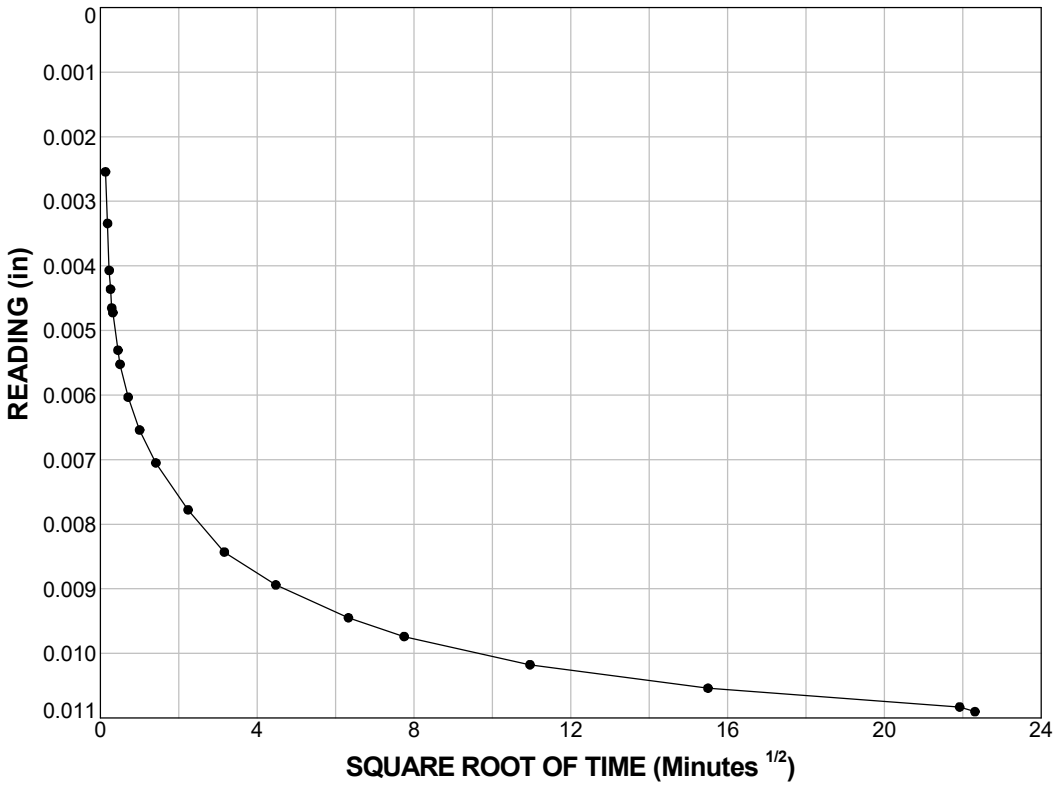
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Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

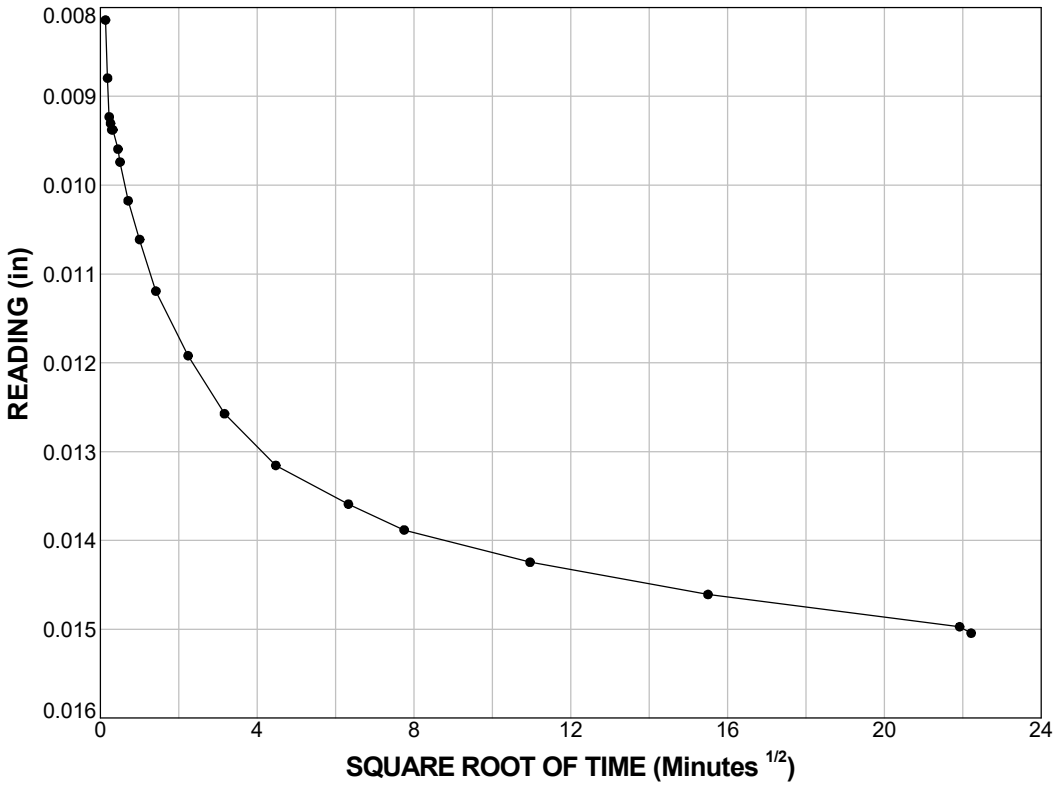
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 5
Load = 4000 psf
D_0 = 0.0007
D_{90} = 0.0047
D_{100} = 0.0052
t_{90} = 0.10 min.

C_V @ t_{90}
20.570 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 6
Load = 8000 psf
D_0 = 0.0070
D_{90} = 0.0094
D_{100} = 0.0096
t_{90} = 0.08 min.

C_V @ t_{90}
24.687 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

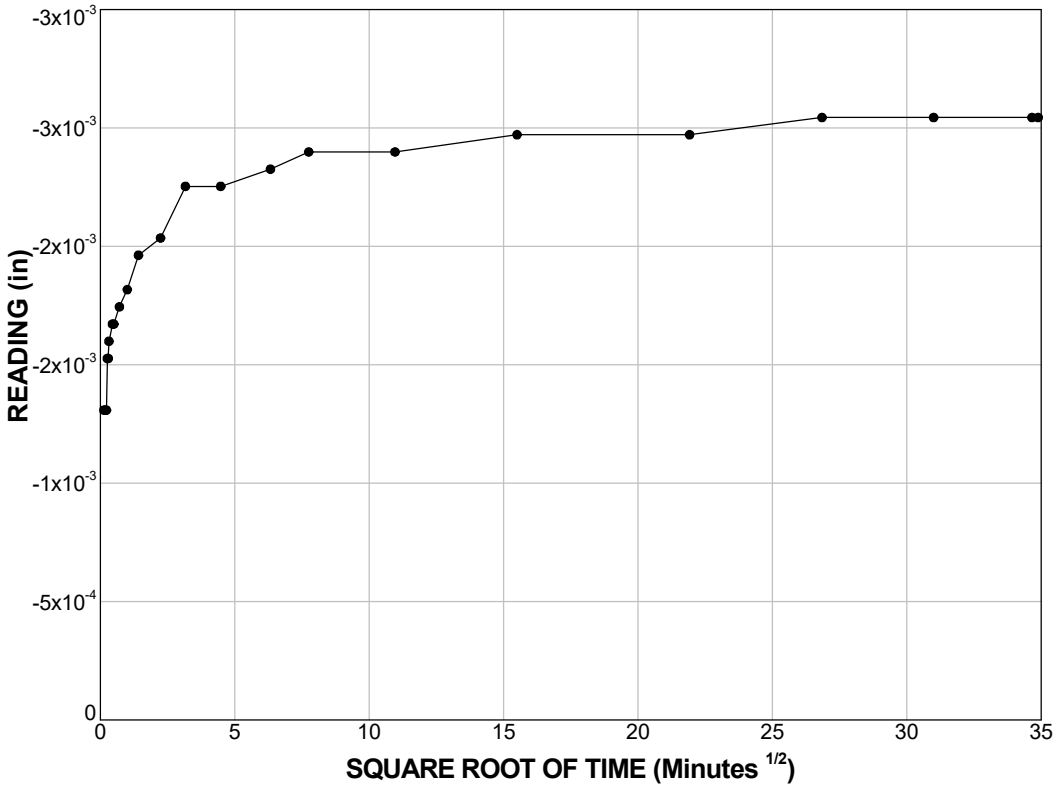
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1555 N 42nd St, Unit B
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Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

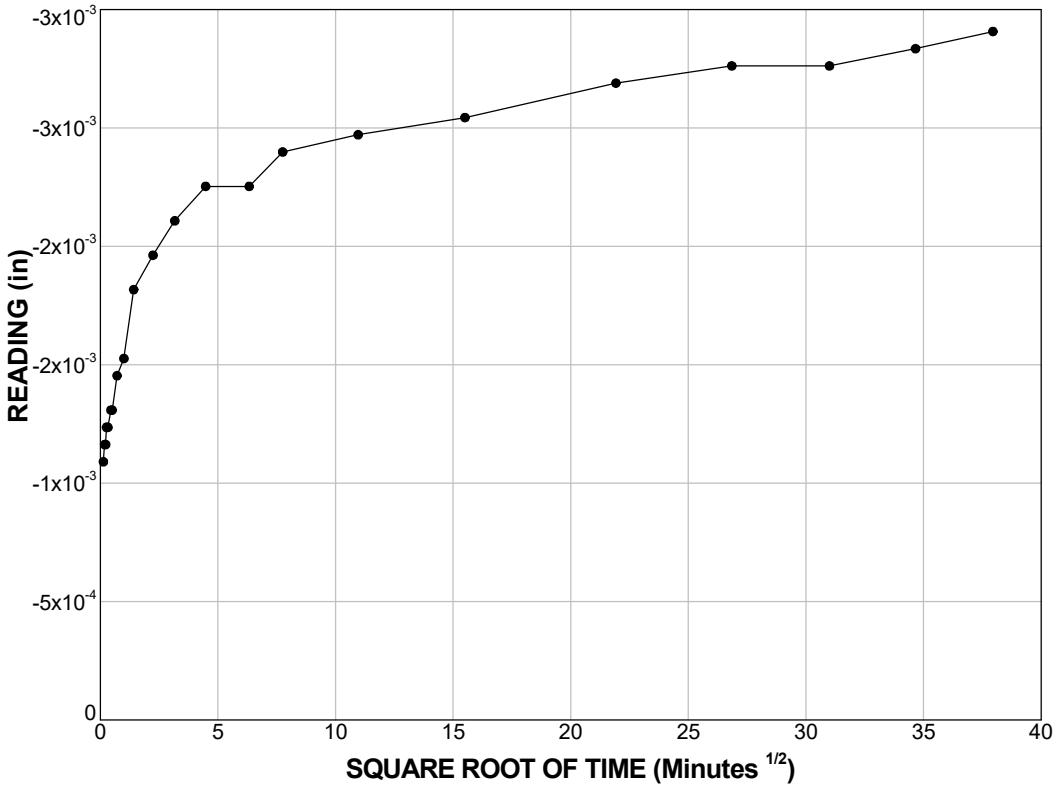
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 7
Load = 4000 psf
D_0 = -0.0008
D_{90} = -0.0016
D_{100} = -0.0017
t_{90} = 0.13 min.

C_V @ t_{90}
15.754 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 8
Load = 2000 psf
D_0 = -0.0010
D_{90} = -0.0012
D_{100} = -0.0013
t_{90} = 0.10 min.

C_V @ t_{90}
22.017 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

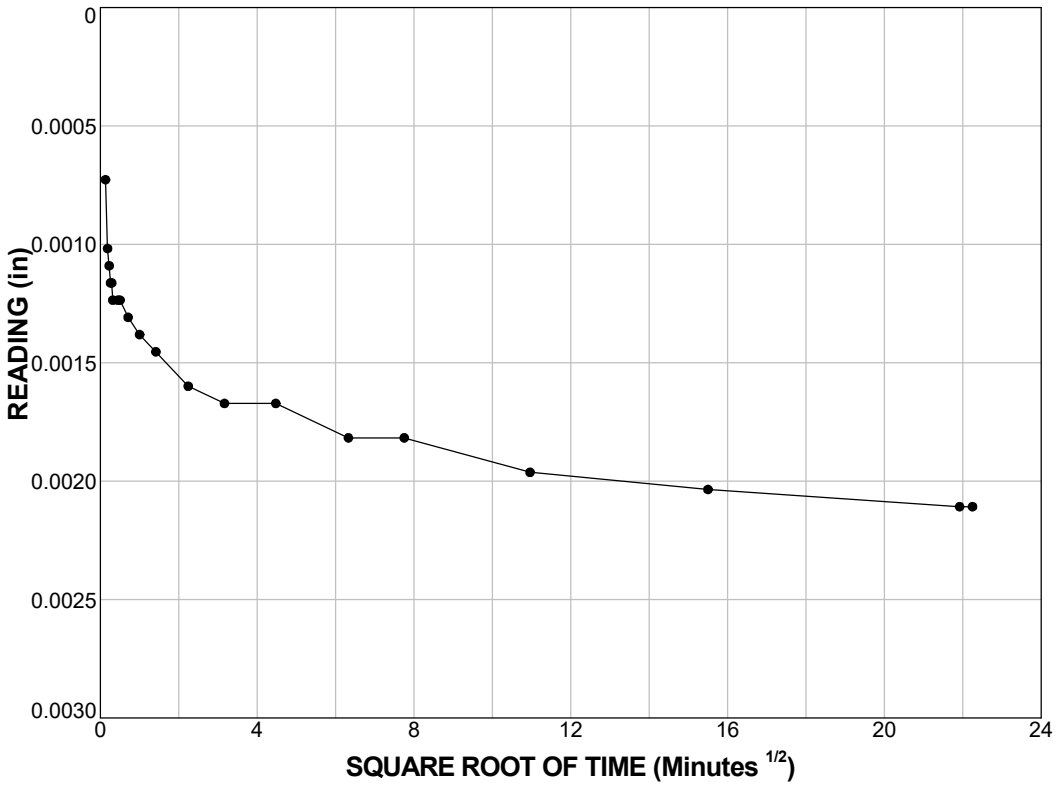
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

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Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

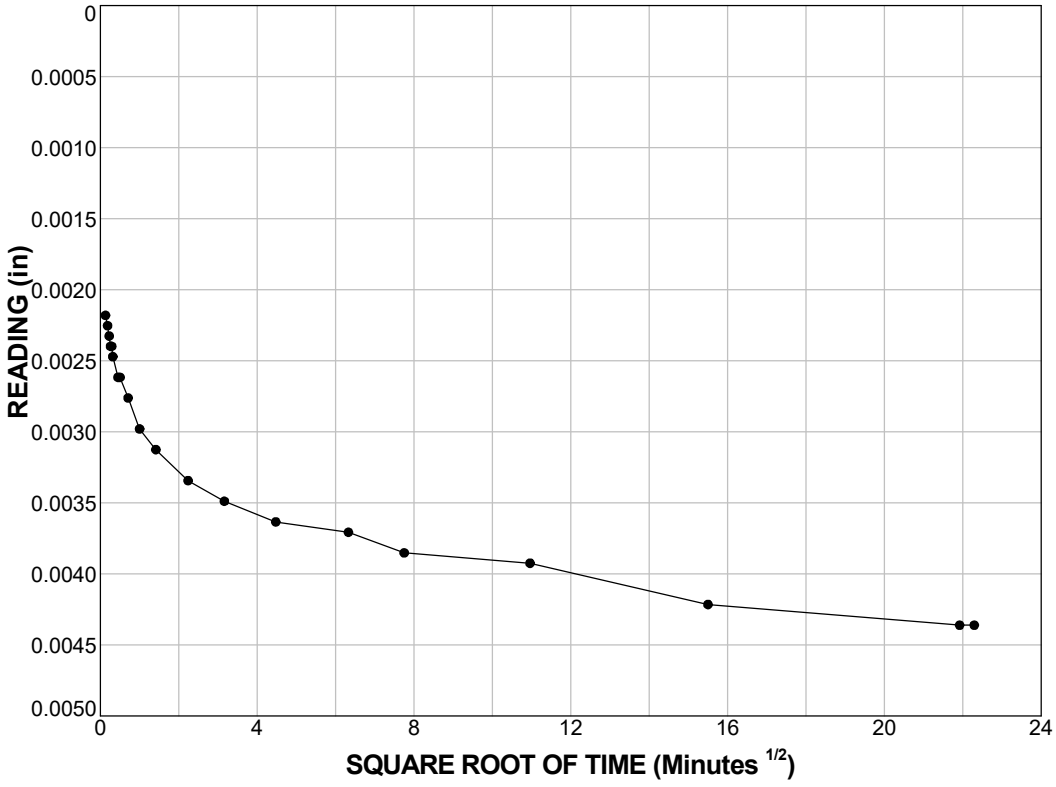
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 9
Load = 4000 psf
D_0 = 0.0007
D_{90} = 0.0012
D_{100} = 0.0013
t_{90} = 0.08 min.

C_V @ t_{90}
26.070 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 10
Load = 8000 psf
D_0 = 0.0007
D_{90} = 0.0031
D_{100} = 0.0034
t_{90} = 2.21 min.

C_V @ t_{90}
0.956 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

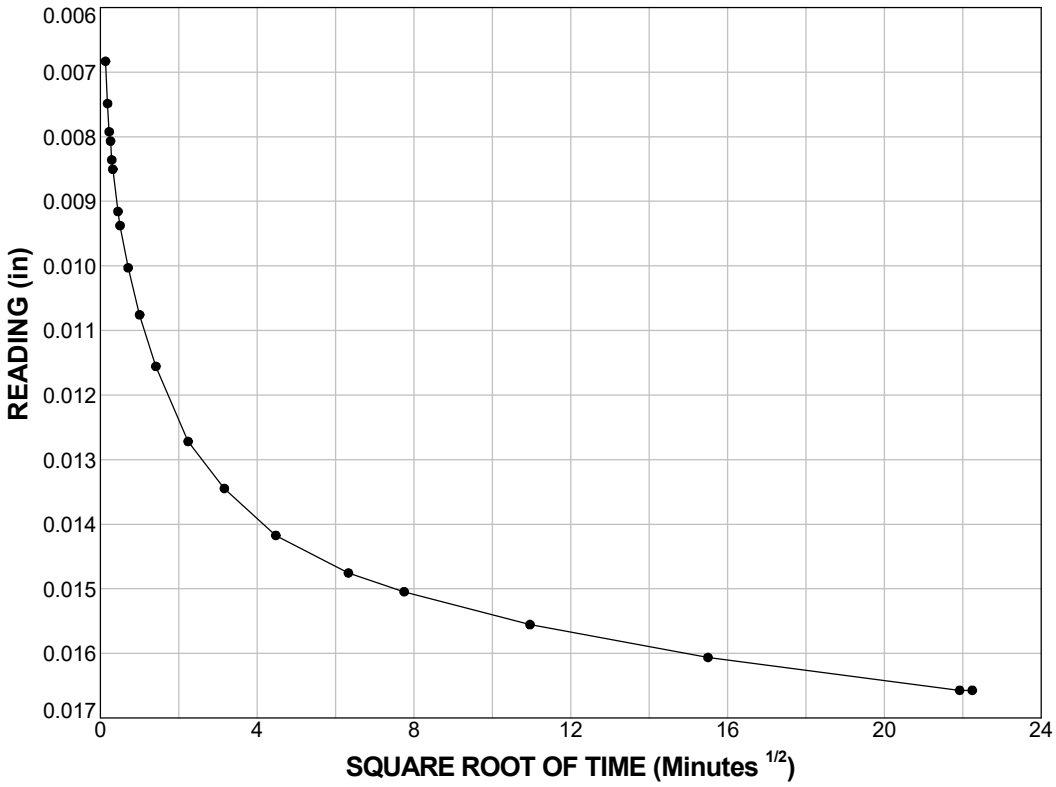
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Per ASTM D2435/D2435M, Fig. 2

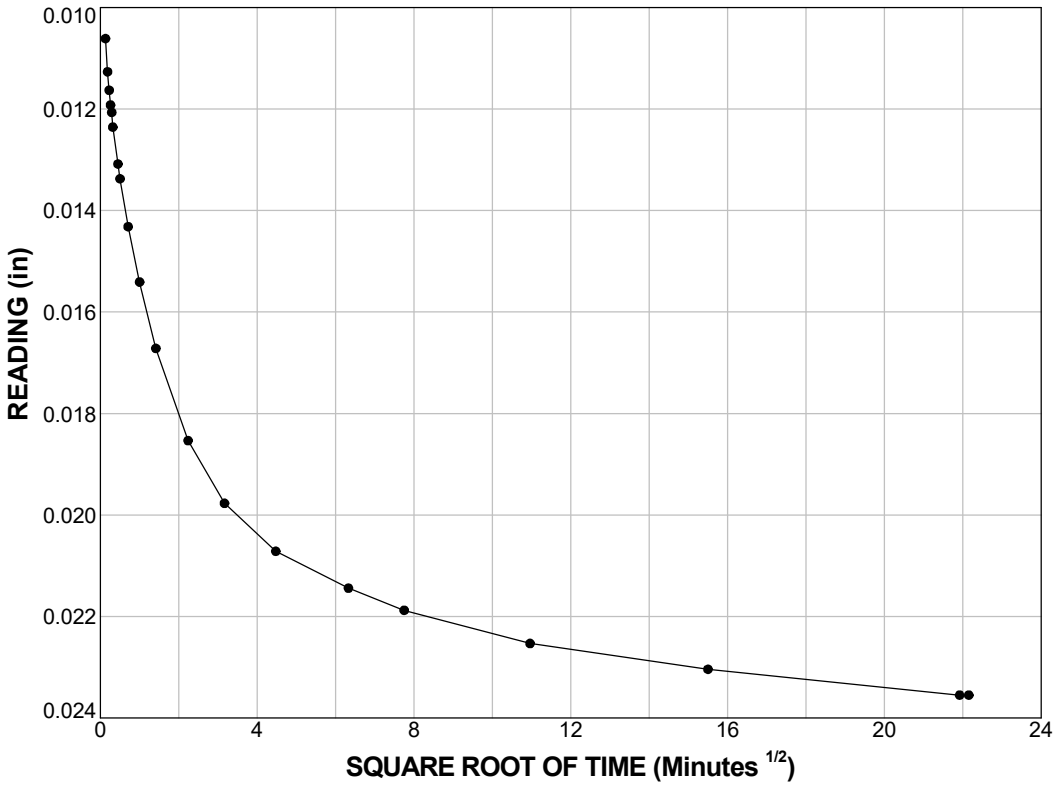
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 11
Load = 16000 psf
D_0 = 0.0057
D_{90} = 0.0088
D_{100} = 0.0091
t_{90} = 0.13 min.

C_V @ t_{90}
15.685 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 12
Load = 32000 psf
D_0 = 0.0097
D_{90} = 0.0128
D_{100} = 0.0131
t_{90} = 0.15 min.

C_V @ t_{90}
13.927 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

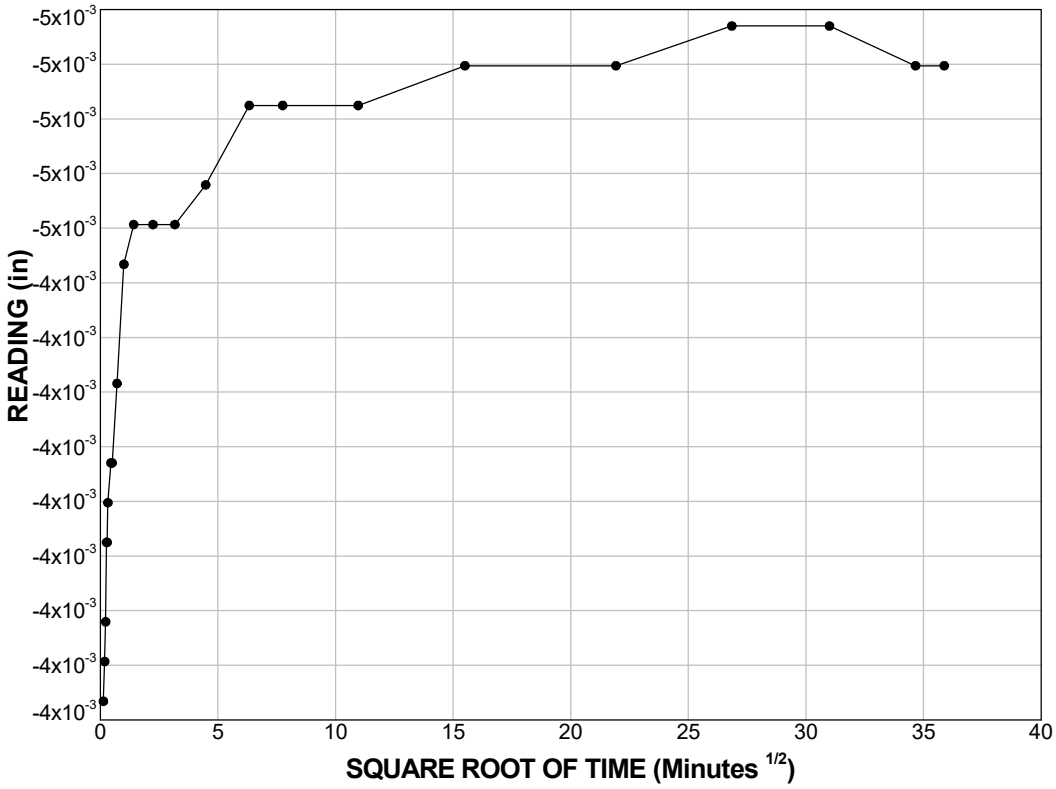
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Per ASTM D2435/D2435M, Fig. 2

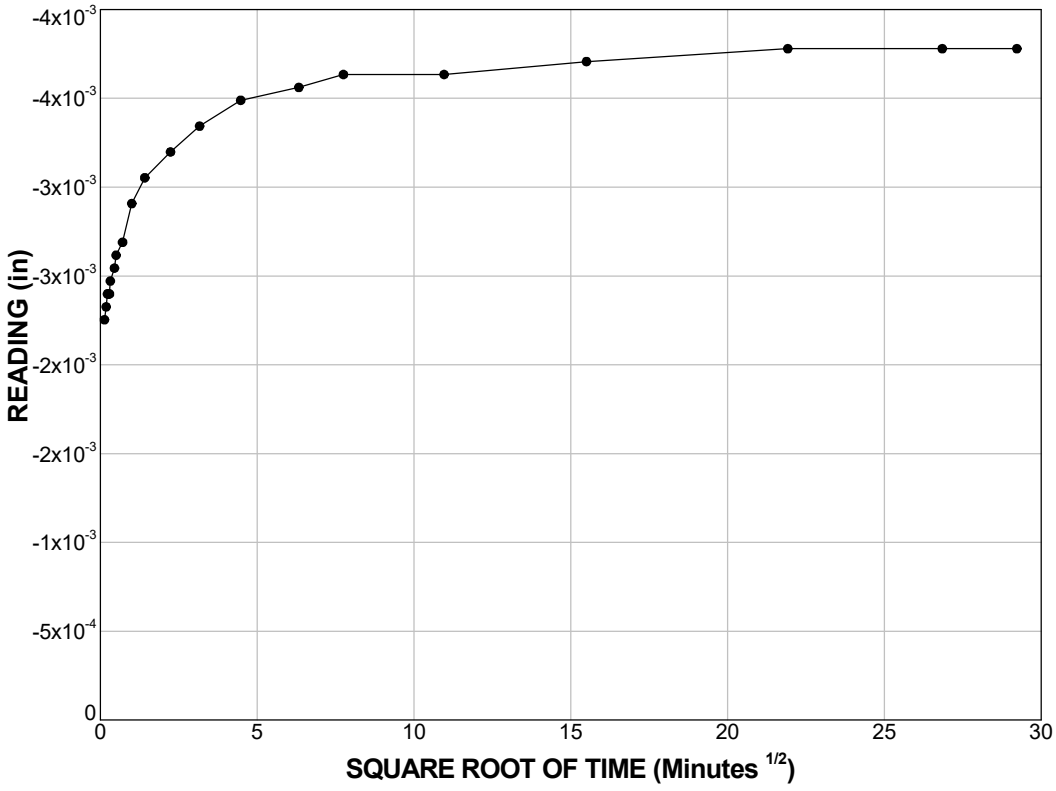
Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 13
Load = 16000 psf
D_0 = -0.0034
D_{90} = -0.0040
D_{100} = -0.0041
t_{90} = 0.14 min.

C_V @ t_{90}
15.438 ft^2/day

Borehole: 601 Depth: 22 Specimen #: 6



Load No. = 14
Load = 8000 psf
D_0 = -0.0021
D_{90} = -0.0025
D_{100} = -0.0026
t_{90} = 0.15 min.

C_V @ t_{90}
14.342 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

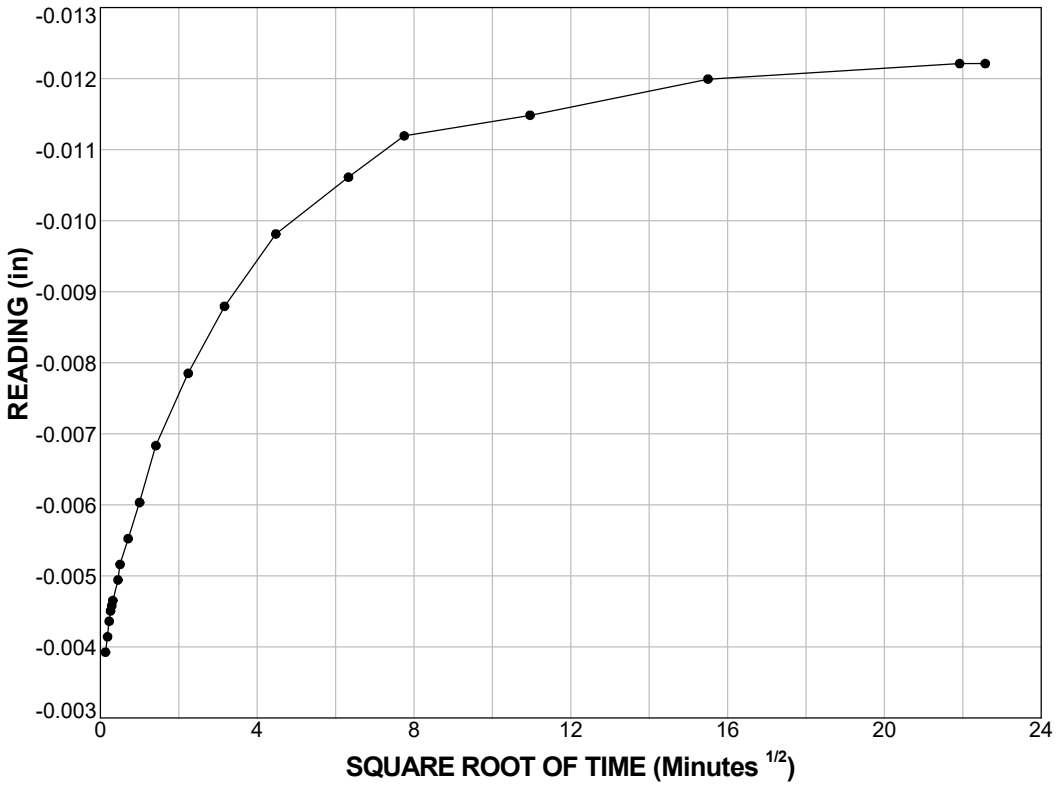
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CONS_TIME-DEF_PROP_SQRT-TIME M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 10/30/20

Borehole: 601 Depth: 22 Specimen #: 6

Per ASTM D2435/D2435M, Fig. 2



Load No. = 15
Load = 1000 psf
D_0 = -0.0033
D_{90} = -0.0047
D_{100} = -0.0049
t_{90} = 0.13 min.

C_V @ t_{90}
16.982 ft^2/day

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PROJECT: Larimore Dam

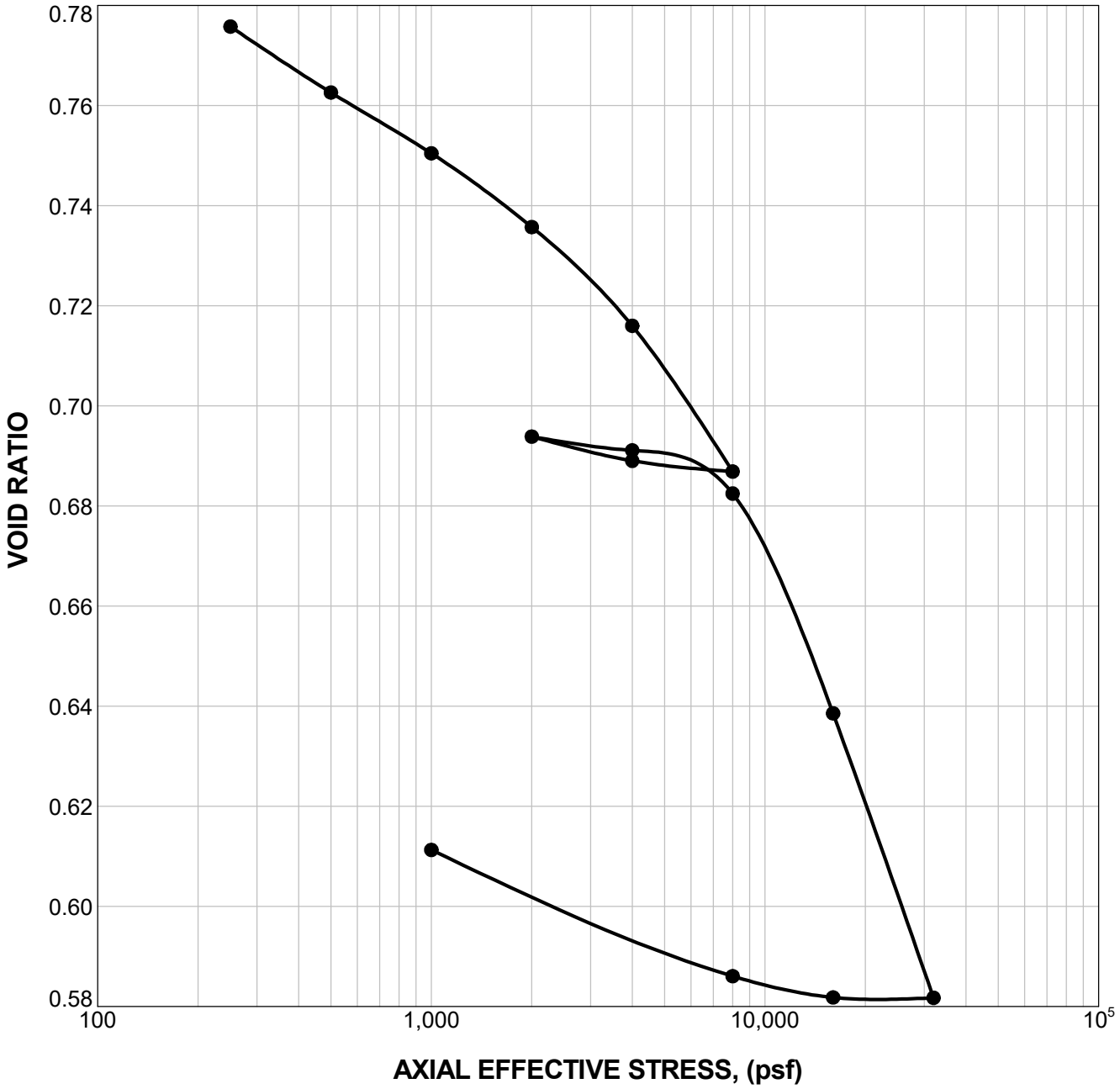
PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

CONSOLIDATION TEST (D2435)



Natural		Initial Dry Density (pcf)	LL	PI	Sp. Gr.	Overburden (psf)	P_c (psf)	C_c (vr / log stress)	C_r (vr / log stress)	Initial Void Ratio
Saturation	Moisture									
75.9 %	22.2 %	93.8	48	27	2.68		6,169	0.189	0.012	0.783

MATERIAL DESCRIPTION	USCS	AASHTO
LEAN CLAY	CL	A-7-6

NOTES:

Borehole: 602 Depth: 41 ft Specimen #: 10

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

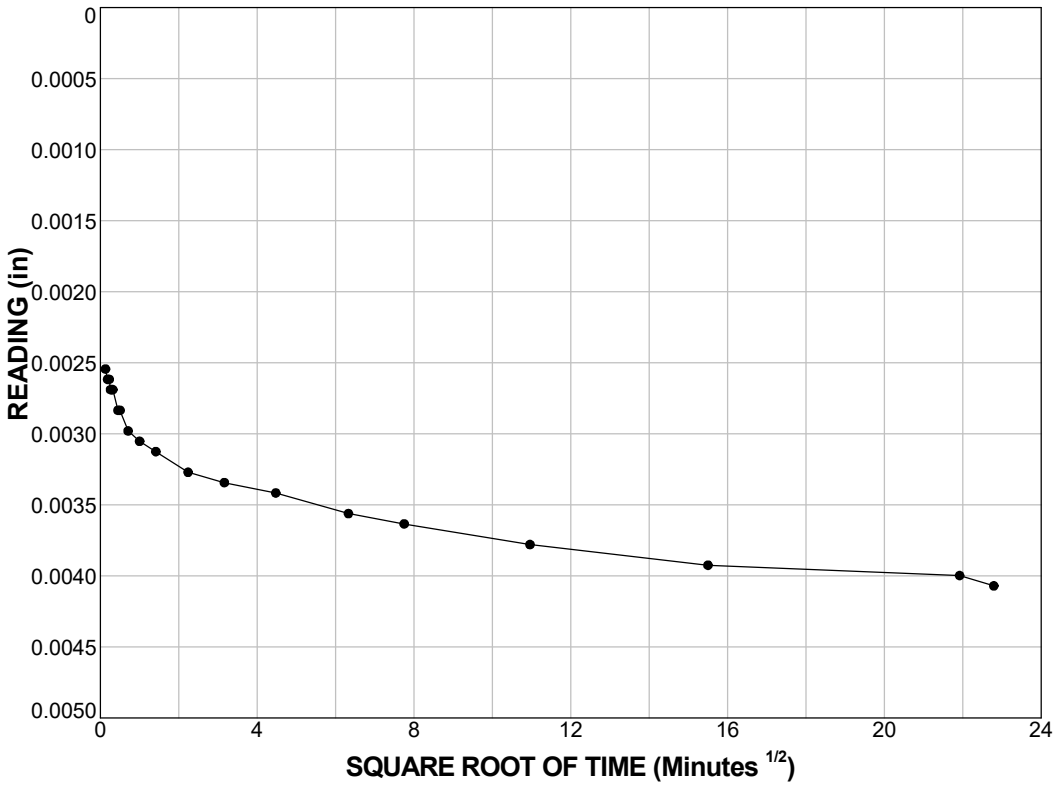
Terracon
1555 N 42nd St, Unit B
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CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CONS_LOAD-DEF_PROP_STRESS-VOIDRATIO M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 10/30/20

Per ASTM D2435/D2435M, Fig. 2

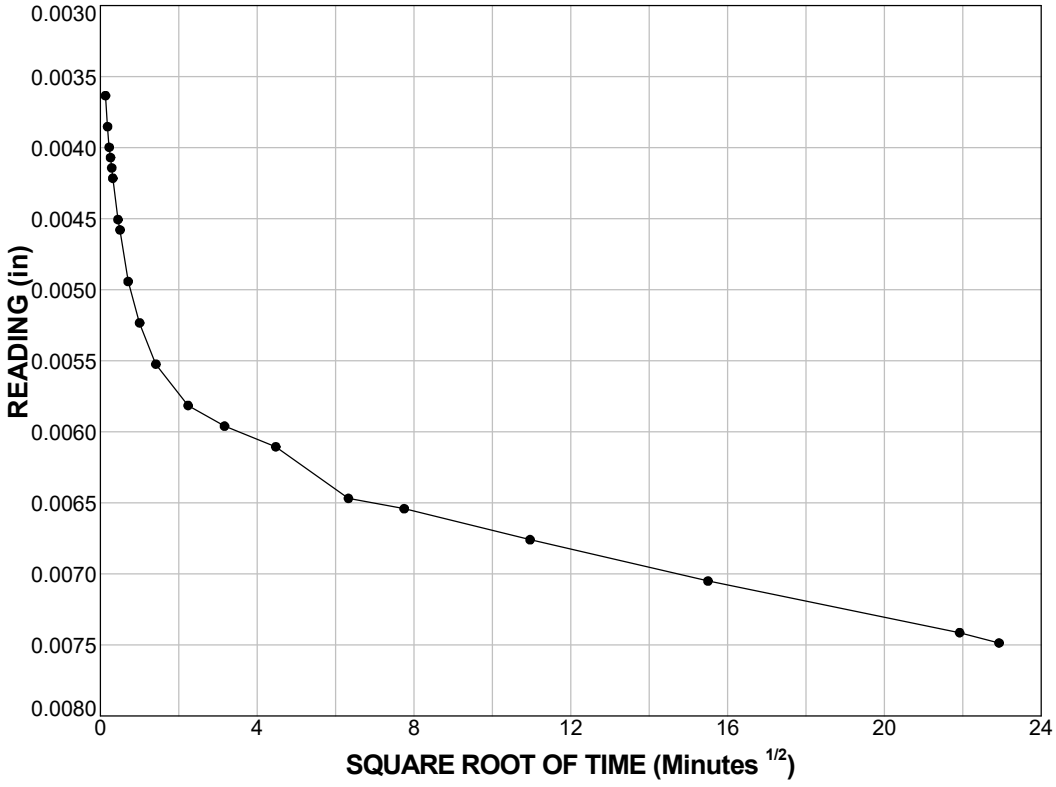
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 1
Load = 250 psf
D_0 = 0.0024
D_{90} = 0.0028
D_{100} = 0.0029
t_{90} = 0.23 min.

C_V @ t_{90}
9.316 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 2
Load = 500 psf
D_0 = 0.0032
D_{90} = 0.0044
D_{100} = 0.0045
t_{90} = 0.16 min.

C_V @ t_{90}
13.171 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

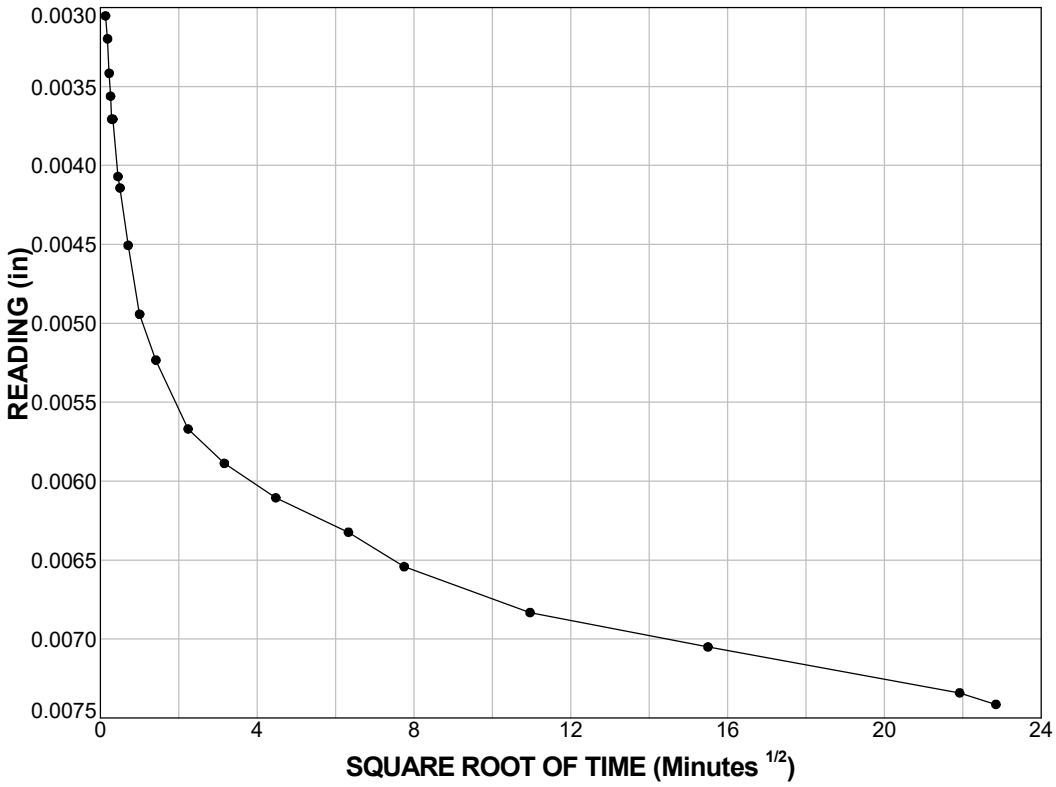
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

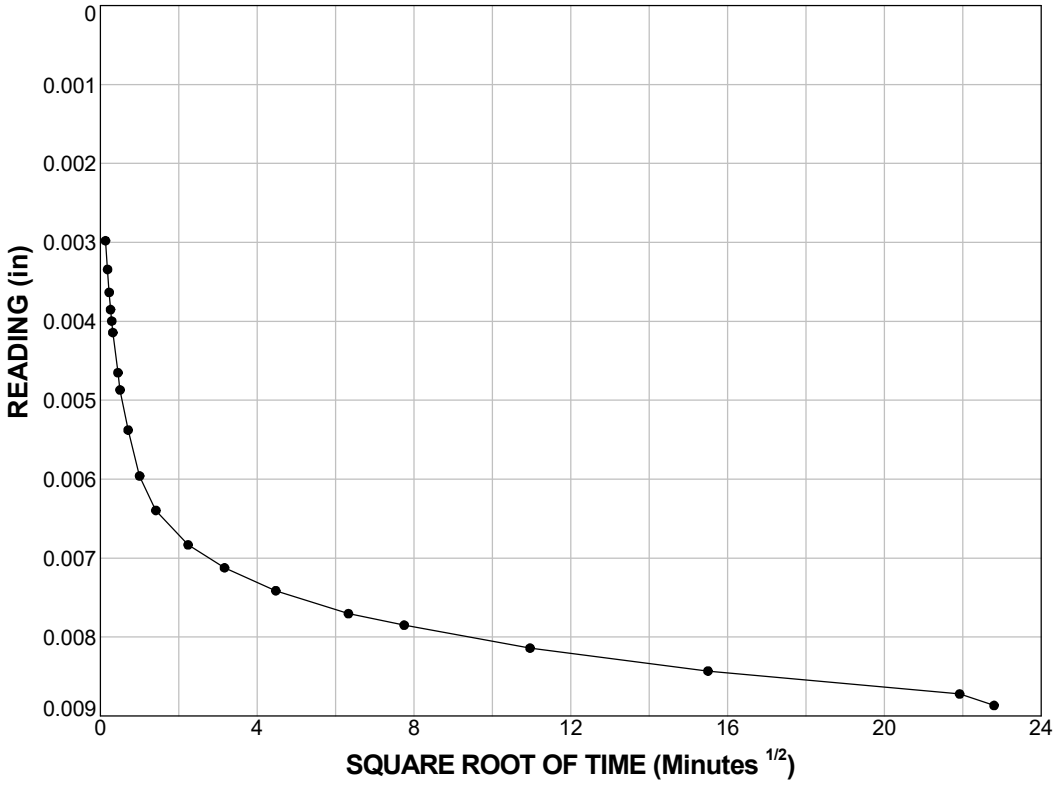
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 3
Load = 1000 psf
D_0 = 0.0023
D_{90} = 0.0038
D_{100} = 0.0040
t_{90} = 0.13 min.

C_V @ t_{90}
16.083 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 4
Load = 2000 psf
D_0 = 0.0021
D_{90} = 0.0045
D_{100} = 0.0047
t_{90} = 0.16 min.

C_V @ t_{90}
13.149 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

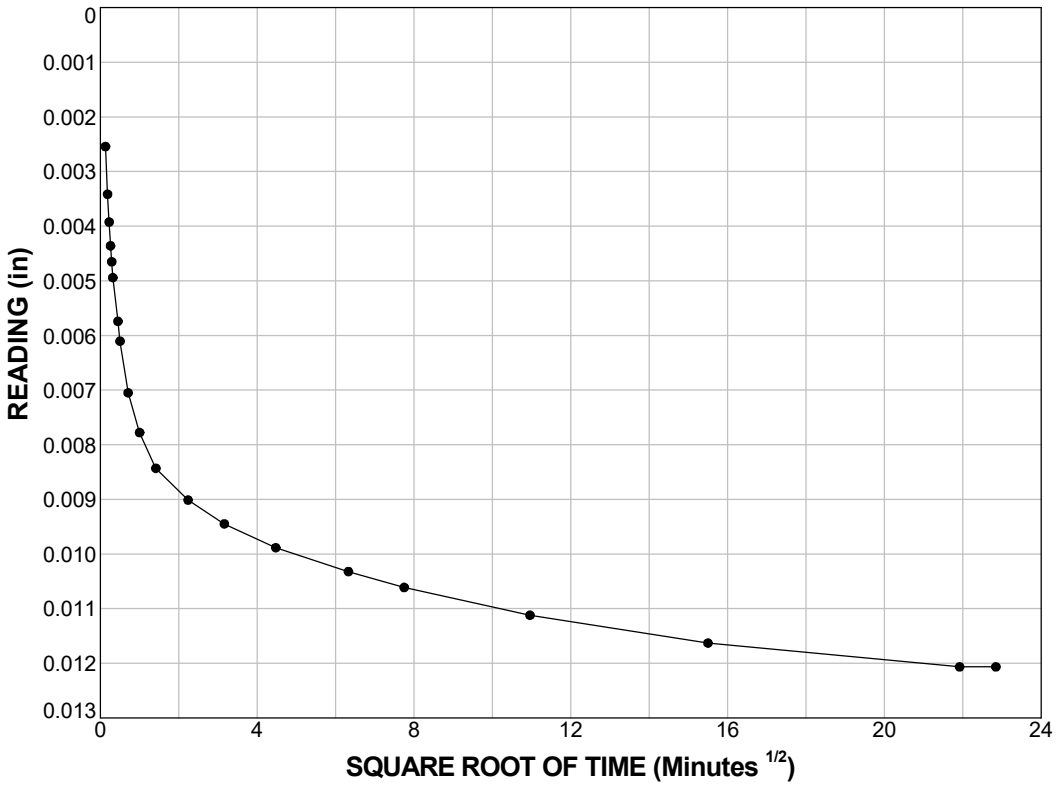
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

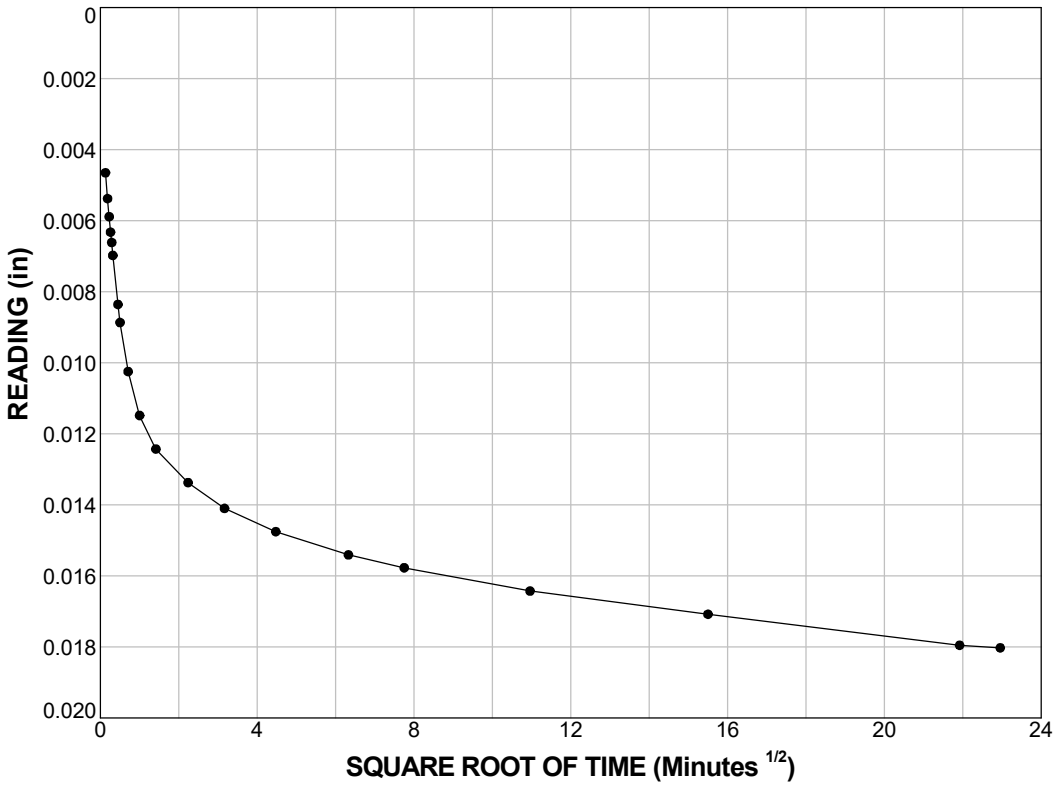
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 5
Load = 4000 psf
D_0 = 0.0008
D_{90} = 0.0053
D_{100} = 0.0057
t_{90} = 0.13 min.

C_V @ t_{90}
15.650 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 6
Load = 8000 psf
D_0 = 0.0030
D_{90} = 0.0092
D_{100} = 0.0099
t_{90} = 0.31 min.

C_V @ t_{90}
6.791 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

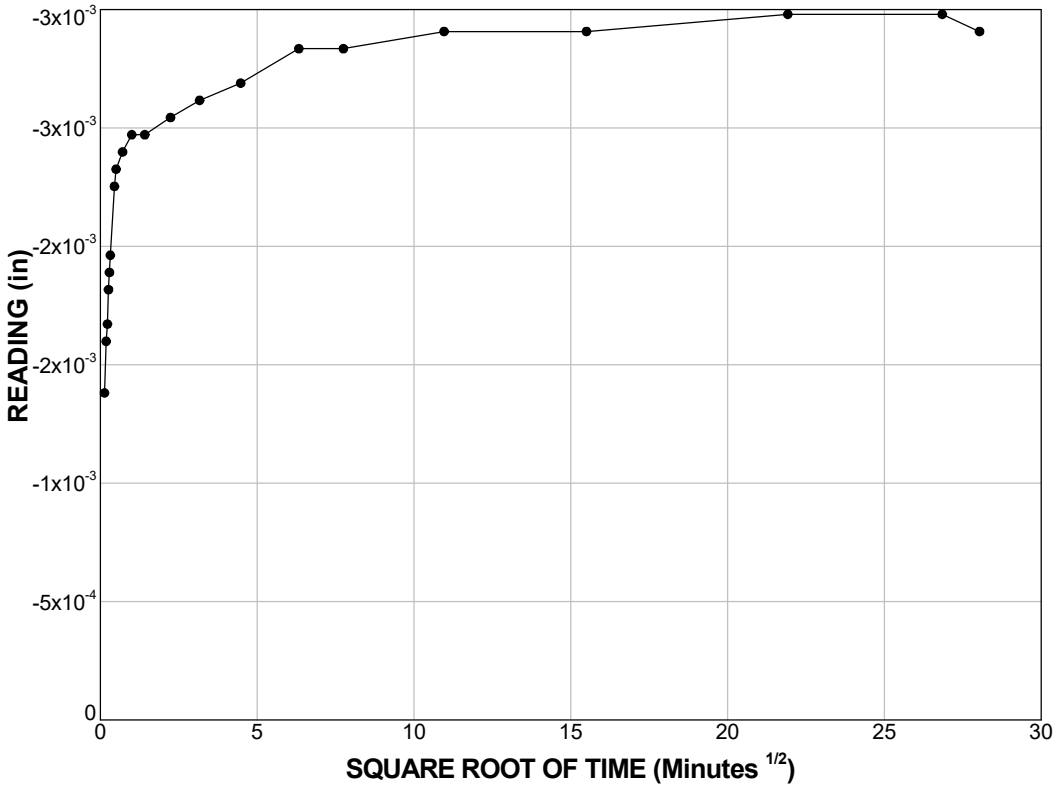
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CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

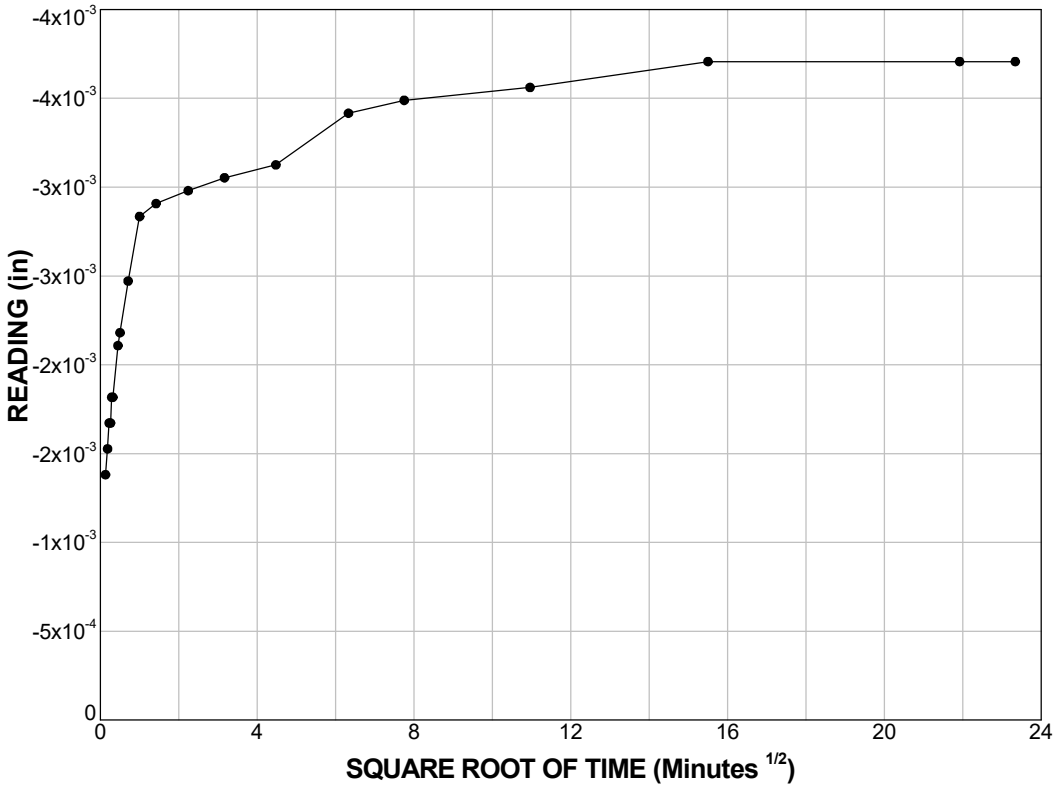
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 7
Load = 4000 psf
D_0 = -0.0010
D_{90} = -0.0023
D_{100} = -0.0024
t_{90} = 0.21 min.

C_V @ t_{90}
10.022 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 8
Load = 2000 psf
D_0 = -0.0011
D_{90} = -0.0022
D_{100} = -0.0024
t_{90} = 0.28 min.

C_V @ t_{90}
7.494 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

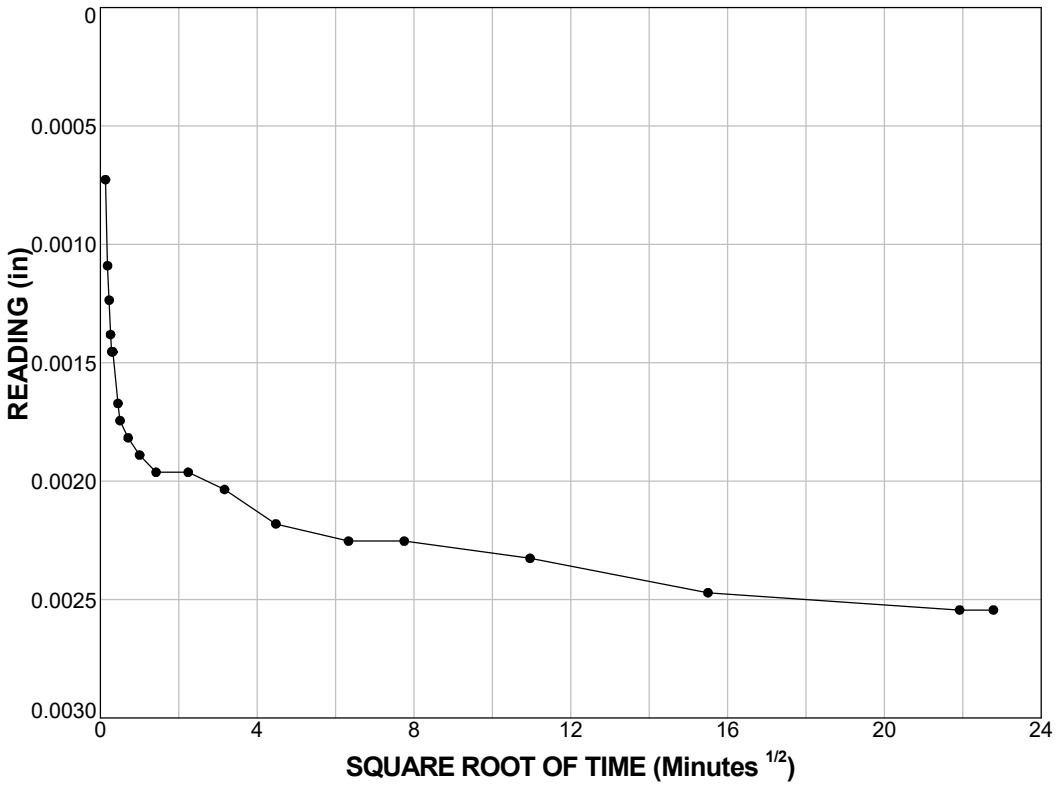
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Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

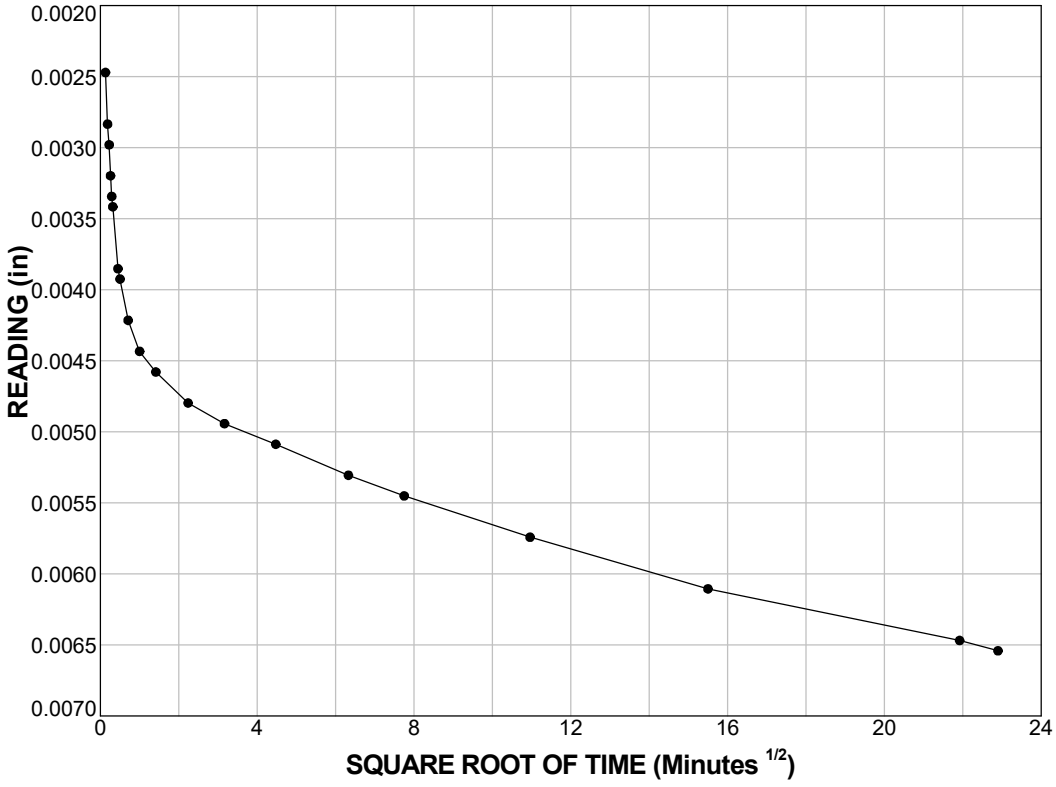
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 9
Load = 4000 psf
D_0 = 0.0001
D_{90} = 0.0015
D_{100} = 0.0016
t_{90} = 0.09 min.

C_V @ t_{90}
22.356 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 10
Load = 8000 psf
D_0 = 0.0018
D_{90} = 0.0037
D_{100} = 0.0039
t_{90} = 0.16 min.

C_V @ t_{90}
12.807 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

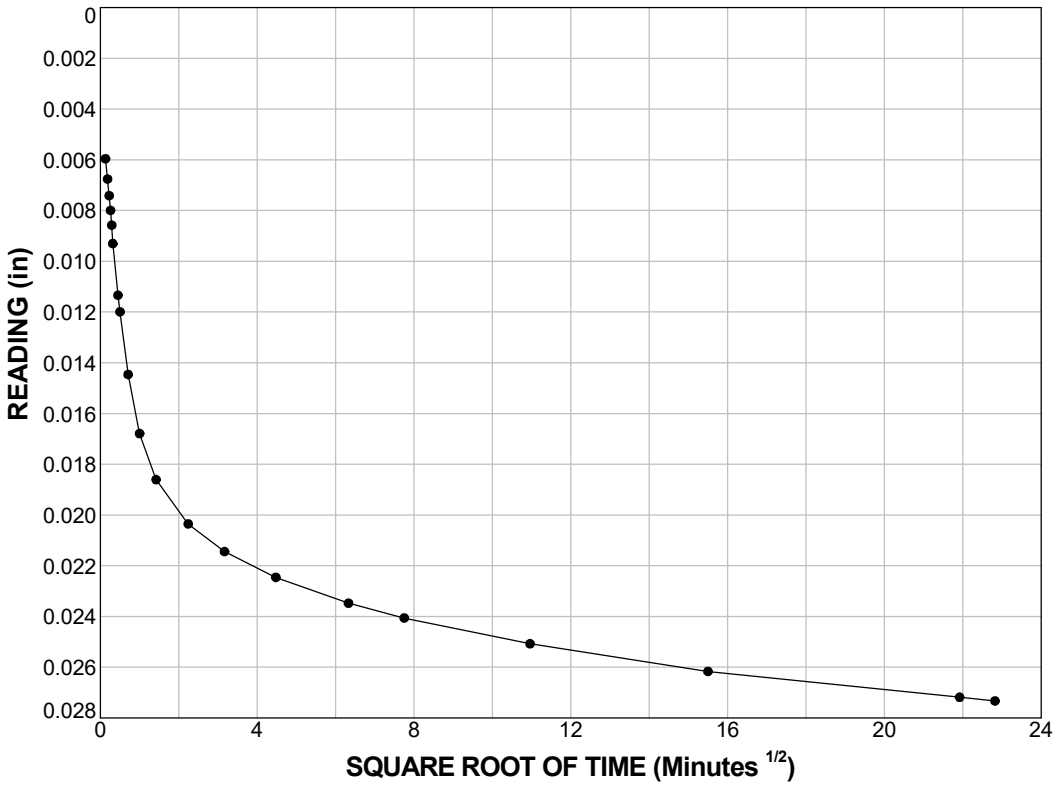
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Grand Forks, ND

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Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

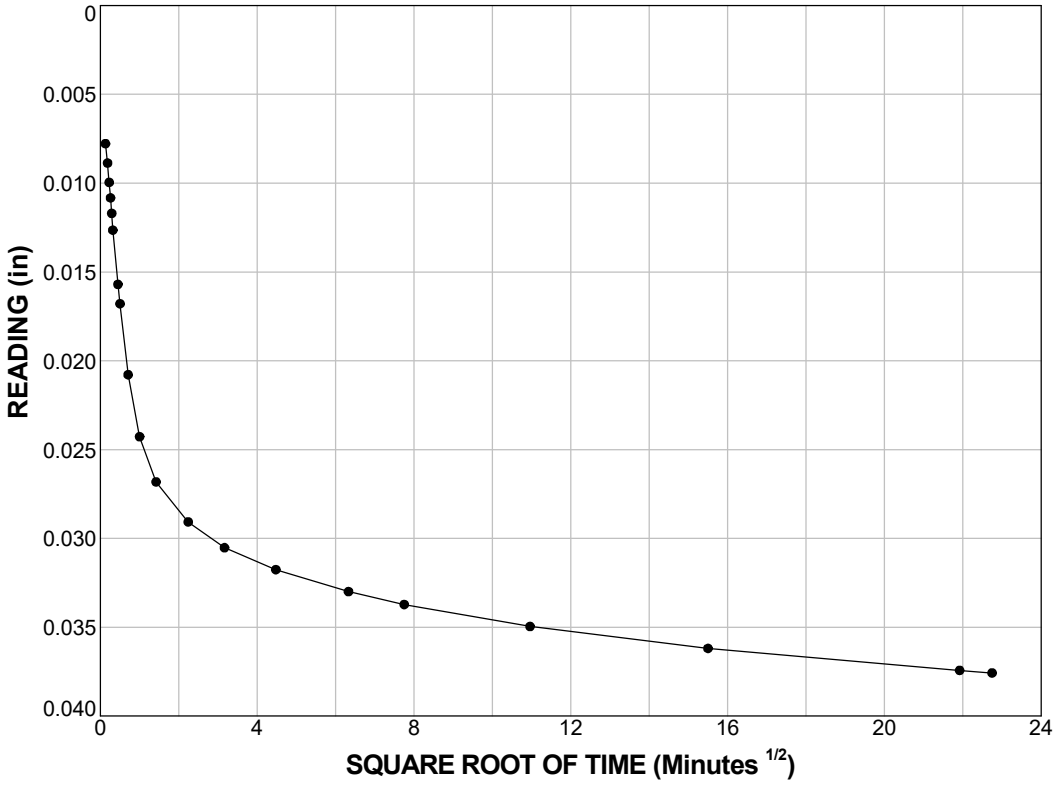
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 11
Load = 16000 psf
D_0 = 0.0028
D_{90} = 0.0128
D_{100} = 0.0139
t_{90} = 0.32 min.

C_V @ t_{90}
6.462 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 12
Load = 32000 psf
D_0 = 0.0034
D_{90} = 0.0194
D_{100} = 0.0212
t_{90} = 0.40 min.

C_V @ t_{90}
5.109 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

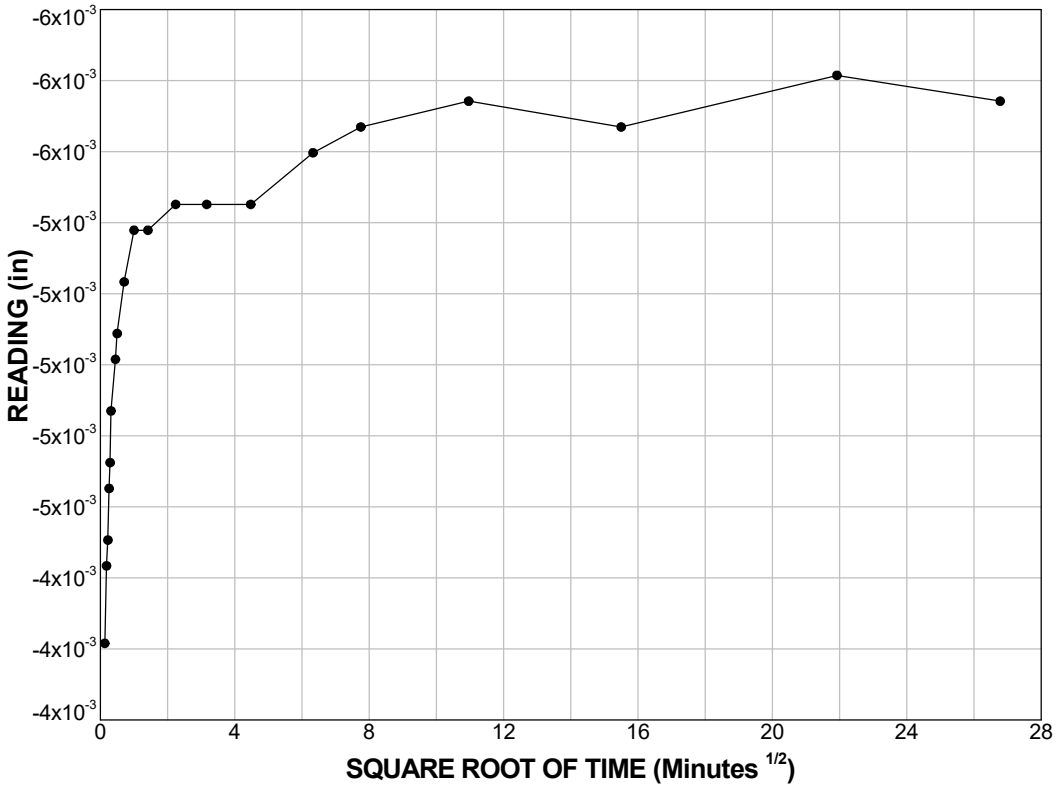
Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

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Per ASTM D2435/D2435M, Fig. 2

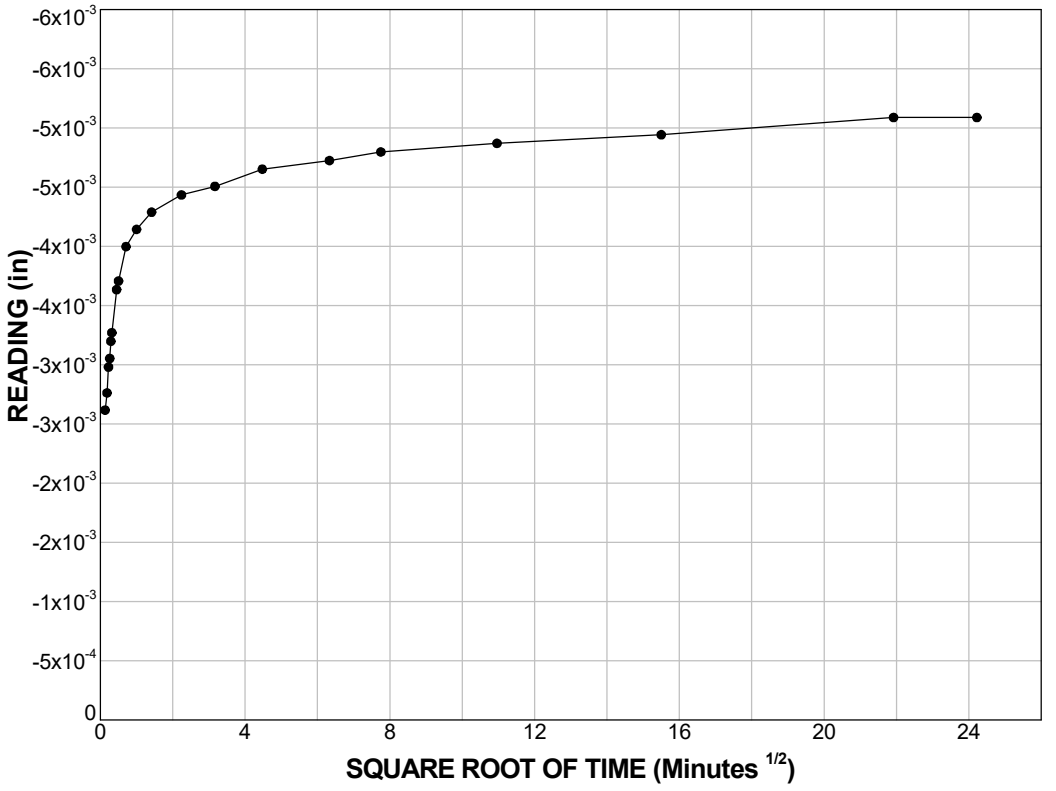
Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 13
Load = 16000 psf
D_0 = -0.0037
D_{90} = -0.0050
D_{100} = -0.0051
t_{90} = 0.16 min.

C_V @ t_{90}
13.741 ft^2/day

Borehole: 602 Depth: 41 Specimen #: 10



Load No. = 14
Load = 8000 psf
D_0 = -0.0021
D_{90} = -0.0037
D_{100} = -0.0038
t_{90} = 0.22 min.

C_V @ t_{90}
9.708 ft^2/day

PROJECT: Larimore Dam

PROJECT NUMBER: M5205031

SITE: Larimore Dam
Larimore, North Dakota

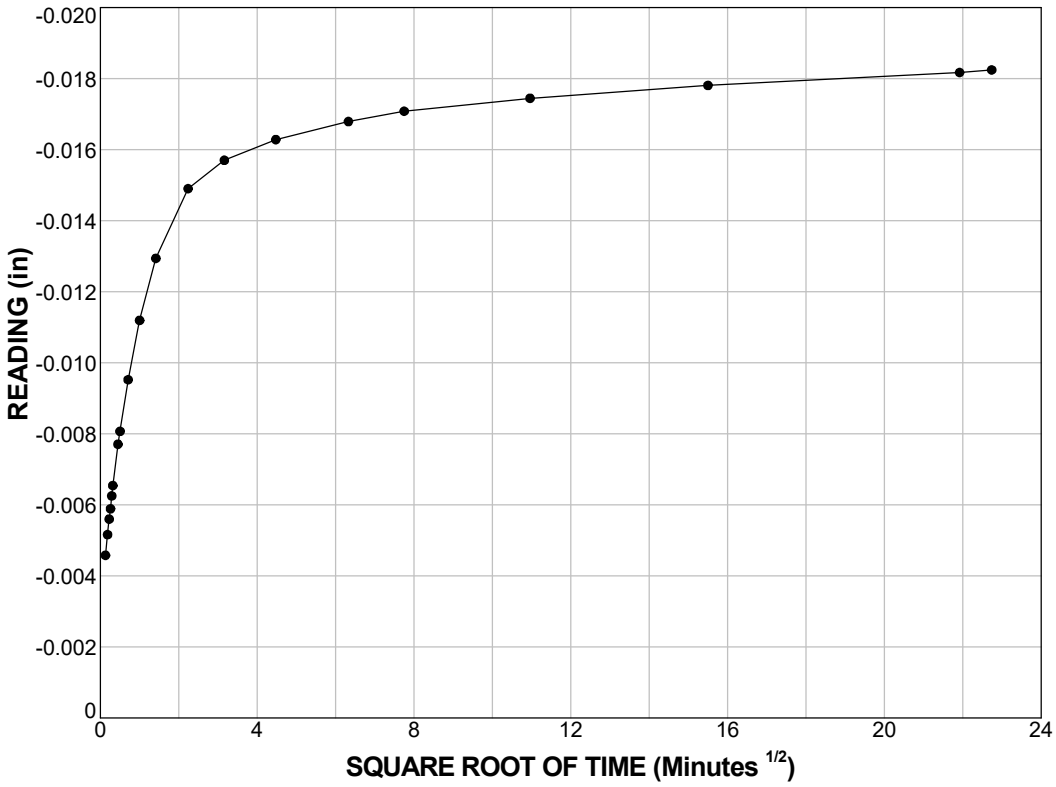
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1555 N 42nd St, Unit B
Grand Forks, ND

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Minneapolis, Minnesota

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Borehole: 602 Depth: 41 Specimen #: 10

Per ASTM D2435/D2435M, Fig. 2



Load No. = 15
Load = 1000 psf
D_0 = -0.0033
D_{90} = -0.0092
D_{100} = -0.0098
t_{90} = 0.43 min.

C_V @ t_{90}
4.963 ft^2/day

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CONS_TIME-DEF_PROP_SQRT-TIME M5205031 LARIMORE DAM.GPJ TERRACON_DATATEMPLATE.GDT 10/30/20

PROJECT: Larimore Dam

SITE: Larimore Dam
Larimore, North Dakota

Terracon
1555 N 42nd St, Unit B
Grand Forks, ND

PROJECT NUMBER: M5205031

CLIENT: HDR Engineering, Inc.
Minneapolis, Minnesota

HYDRAULIC CONDUCTIVITY REPORT

Terracon
1555 N. 42nd St., Unit B
Grand Forks, ND 58203
701-772-2832

Service Date: 10/14/2020
Report Date: 10/30/2020

Client

HDR Engineering, Inc.
Minneapolis, Minnesota

Project

Larimore Dam
Larimore, North Dakota

Project Number: M5205031

Test Method:	ASTM D5084 - Method C	Sample No.:	B601
Sample Type:	3-inch Shelby tube	Location :	22 to 24
Date Sampled :	8/19/2020	Operator :	wro
Soil Type :	LEAN CLAY with SAND		

Initial Sample Parameters

Wet Wt. (g)	677.86	Diameter (in)	2.869	Height (in)	2.963	Water Content Pan No.:	3
Dry Wt. (g)	584.87		2.867		2.943	Wet Wt.	88.49
Area (cm^2)	41.718		2.872		2.995	Dry Wt.	78.48
Area (in^2)	6.466	Average (in)	2.869	Average(in)	2.967	Pan Wt.	15.52
Density (pcf)	116.0					W.C. (%)	15.9
Assumed Sp.G.	2.685		Void Ratio:	0.443		% Saturation	96.0
Vol Wet (cc)	314.39	Vol. Solids Vs(cc)	217.83	Porosity n (%):	31		

Final Sample Parameters

Wet Wt. (g)	682.03	Diameter (in)	2.874	Height (in)	2.975	Water Content Pan No.:	12
Dry Wt. (g)	584.89		2.880		2.965	Wet Wt.	765.19
Area (cm^2)	41.766		2.859		2.969	Dry Wt.	668.08
Area (in^2)	6.474	Average (in)	2.871	Average(in)	2.970	Pan Wt.	83.38
Density (pcf)	115.8					W.C. (%)	16.6
						% Saturation	99.6

Panel No.:	2	Chamber No.:	3			Hydraulic Gradient:	20.2
Cell Press.(psi)	72.9	Back Press.(psi)	68.1	Tail Press. (psi)	66.0		
		○ Pipette	◉ Burette	Pipe Area (cm^2)	0.894	Fluid:	De-aired tap water

Date and Time	Temp	Head (h1)	Tail (h2)	Elapsed Time (S)	Total Head	k (cm / s)	k_{20} (cm/sec)	dt / dh
10/14/20 7:56	22.8	5.90	43.20		193.95			
10/14/20 18:18	22.8	8.10	41.00	37320	189.02	5.57E-08	5.21E-08	1.00
10/15/20 7:36	22.4	10.70	38.40	47880	183.20	5.28E-08	4.98E-08	1.00
10/15/20 18:25	22.2	12.60	36.40	38940	178.83	5.00E-08	4.75E-08	1.05
10/16/20 7:38	21.0	15.10	34.00	47580	173.34	5.29E-08	5.16E-08	0.96

HYDRAULIC CONDUCTIVITY (k_{20}) = AVERAGE 5.03E-08 cm/sec

HYDRAULIC CONDUCTIVITY REPORT

Service Date: 10/27/2020
Report Date: 12/1/2020

Terracon
1555 N. 42nd St., Unit B
Grand Forks, ND 58203
701-772-2832

Client

HDR Engineering, Inc.
Minneapolis, Minnesota

Project

Larimore Dam
Larimore, North Dakota

Project Number: M5205031

Test Method:	ASTM D5084 - Method C	Sample No.:	B-602
Sample Type:	3-inch Shelby tube	Location :	41 to 43
Date Sampled :	8/19/2020	Operator :	wro
Soil Type :	LEAN CLAY (CL)		

Initial Sample Parameters

Wet Wt. (g)	297.79	Diameter (in)	2.848	Height (in)	1.453	Water Content Pan No.:	152
Dry Wt. (g)	240.75		2.841		1.456	Wet Wt.	62.37
Area (cm^2)	41.003		2.845		1.442	Dry Wt.	53.07
Area (in^2)	6.356	Average (in)	2.845	Average(in)	1.450	Pan Wt.	13.82
Density (pcf)	99.4					W.C. (%)	23.7
Assumed Sp.G.	2.68		Void Ratio:	0.681		% Saturation	93.0
Vol Wet (cc)	151.05	Vol. Solids Vs(cc)	89.83	Porosity n (%):	41		

Final Sample Parameters

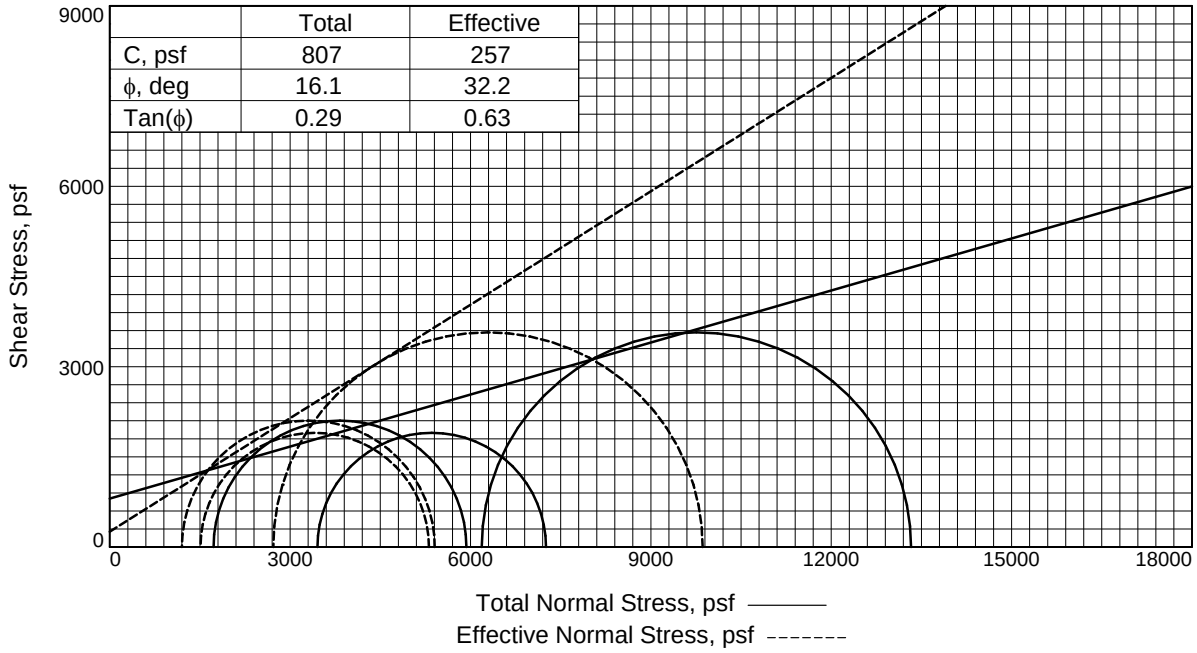
Wet Wt. (g)	302.17	Diameter (in)	2.852	Height (in)	1.467	Water Content Pan No.:	13
Dry Wt. (g)	238.15		2.832		1.452	Wet Wt.	366.23
Area (cm^2)	40.975		2.847		1.455	Dry Wt.	302.31
Area (in^2)	6.351	Average (in)	2.844	Average(in)	1.458	Pan Wt.	64.52
Density (pcf)	97.9					W.C. (%)	26.9
						% Saturation	101.6

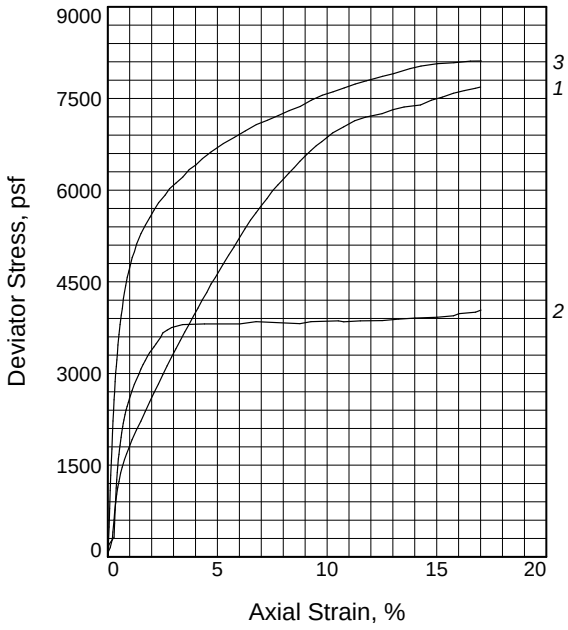
Panel No.:	1	Chamber No.:	1	Hydraulic Gradient:	47.2
Cell Press.(psi)	67.9	Back Press.(psi)	62.6	Tail Press. (psi)	60.1
	(●) Pipette	( ) Burette		Pipe Area (cm^2)	0.079

Fluid: De-aired tap water

Date and Time	Temp	Head (h1)	Tail (h2)	Elapsed Time (S)	Total Head	k (cm / s)	k_{20} (cm/sec)	dt / dh
10/27/20 11:00	23.3	2.30	46.60		223.63			
10/27/20 11:15	23.3	11.90	37.10	900	202.24	3.96E-07	3.67E-07	0.99
10/27/20 11:30	23.3	20.50	29.00	900	183.53	3.83E-07	3.54E-07	0.94
10/27/20 11:45	23.3	28.20	21.60	900	166.62	3.81E-07	3.52E-07	0.96
10/27/20 12:00	23.3	34.80	15.10	900	151.95	3.63E-07	3.36E-07	0.98

HYDRAULIC CONDUCTIVITY (k_{20}) = AVERAGE 3.52E-07 cm/sec





Sample No.		1	2	3
Initial	Water Content, %	28.2	25.9	27.0
	Dry Density, pcf	95.4	99.2	95.8
	Saturation, %	100.3	101.1	97.0
	Void Ratio	0.7535	0.6860	0.7469
	Diameter, in.	2.81	2.80	2.84
	Height, in.	5.38	5.37	5.56
At Test	Water Content, %	26.8	23.1	24.8
	Dry Density, pcf	97.4	103.4	100.5
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7175	0.6188	0.6648
	Diameter, in.	2.79	2.76	2.80
	Height, in.	5.34	5.30	5.47
Strain rate, in./min.		0.001	0.001	0.001
Back Pressure, tsf		3.600	3.600	3.600
Cell Pressure, tsf		4.463	5.327	6.693
Fail. Stress, psf		4205	3801	7142
Total Pore Pr., psf		7727	9146	10667
Ult. Stress, psf		7689	4038	8114
Total Pore Pr., psf		6106	8703	9982
$\bar{\sigma}_1$ Failure, psf		5405	5309	9861
$\bar{\sigma}_3$ Failure, psf		1200	1508	2719

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: Lean Clay (CL)

LL= 48 **PL=** 21 **PI=** 27

Specific Gravity= 2.68

Remarks:

Figure _____

Client: HDR Engineering, Inc.

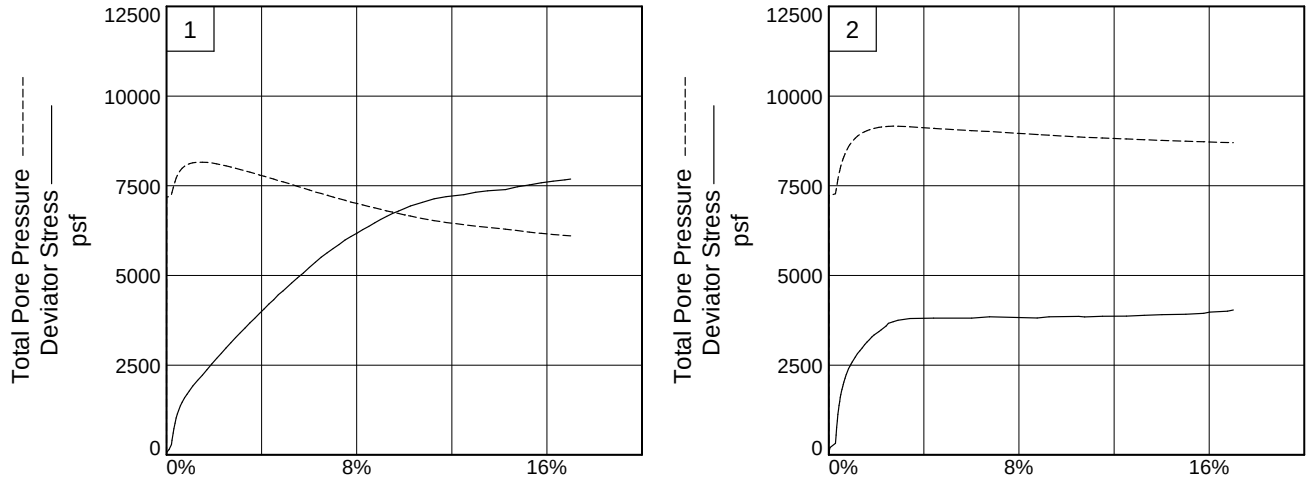
Project: Larimore Dam

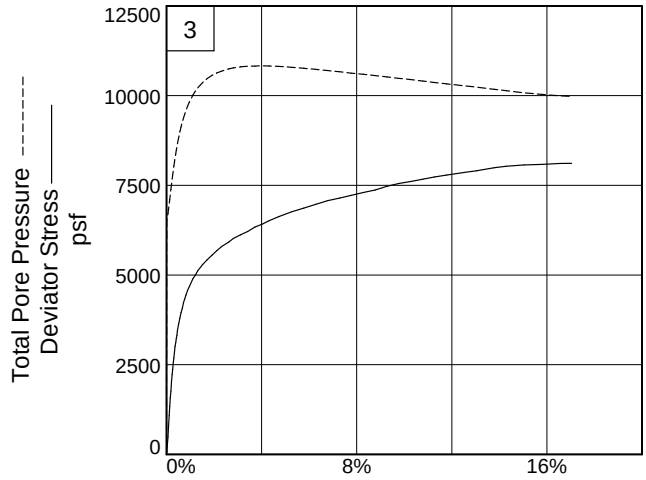
Source of Sample: 602 **Depth:** 41-43'

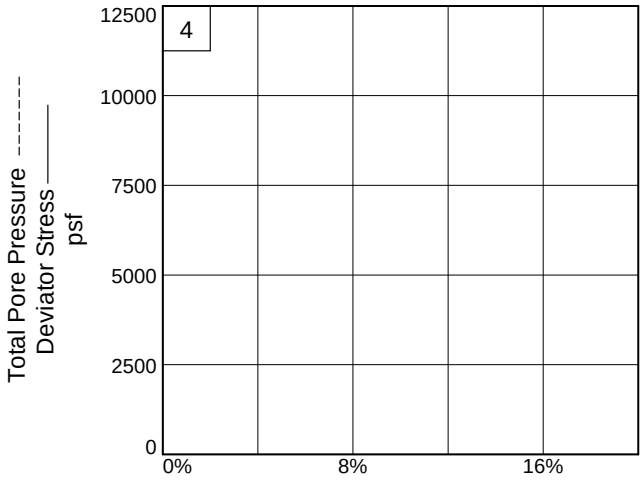
Sample Number: 10

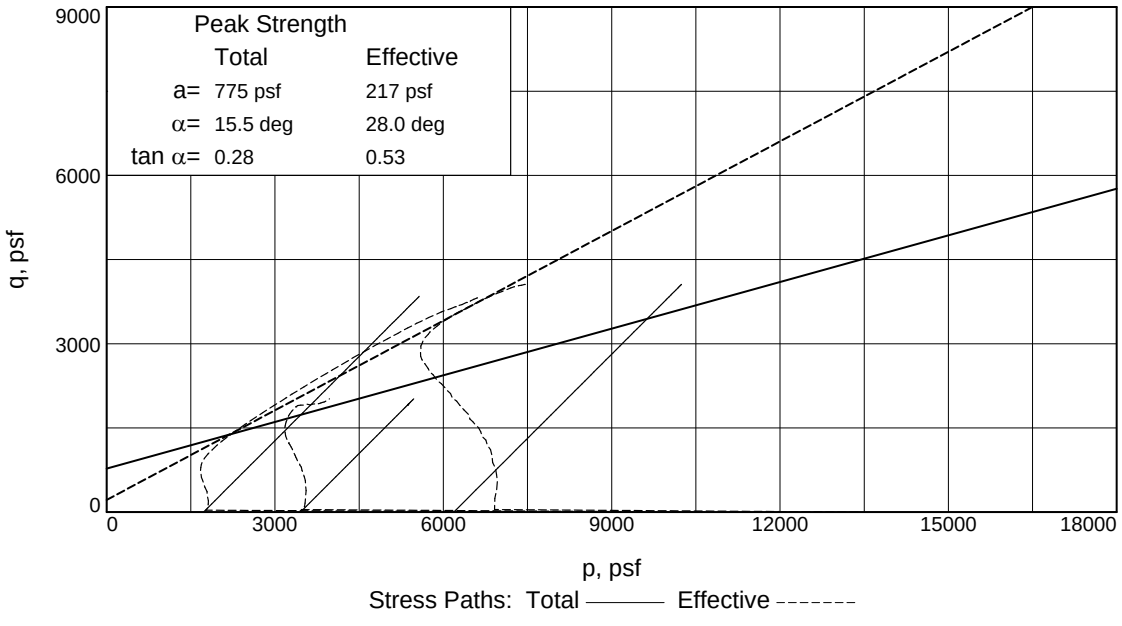
Proj. No.: M5205031 **Date Sampled:** 8/20/2021

TRIAXIAL SHEAR TEST REPORT
Terracon Consultants, Inc.
Wheat Ridge, Colorado









Client: HDR Engineering, Inc.

Project: Larimore Dam

Source of Sample: 602 **Depth:** 41-43' **Sample Number:** 10

Project No.: M5205031 **Figure** _____

Terracon Consultants, Inc.

SUPPORTING INFORMATION

Contents:

General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Larimore Dam ■ Larimore, North Dakota

Terracon Project No. M5205031

Terracon GeoReport

SAMPLING



WATER LEVEL



Water Initially Encountered



Water Level After a Specified Period of Time



Water Level After a Specified Period of Time



Cave In Encountered

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

N	**Standard Penetration Test Resistance (Blows/Ft.)**
(HP)	**Hand Penetrometer**
(T)	**Torvane**
(DCP)	**Dynamic Cone Penetrometer**
UC	**Unconfined Compressive Strength**
(PID)	**Photo-Ionization Detector**
(OVA)	**Organic Vapor Analyzer**

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

LOCATION AND ELEVATION NOTES

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		**CONSISTENCY OF FINE-GRAINED SOILS** (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (psf)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 500	0 - 1
Loose	4 - 9	Soft	500 to 1,000	2 - 4
Medium Dense	10 - 29	Medium Stiff	1,000 to 2,000	4 - 8
Dense	30 - 50	Stiff	2,000 to 4,000	8 - 15
Very Dense	> 50	Very Stiff	4,000 to 8,000	15 - 30
		Hard	> 8,000	> 30

RELEVANCE OF SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.

UNIFIED SOIL CLASSIFICATION SYSTEM

Terracon GeoReport

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ≥ 4 and 1 ≤ Cc ≤ 3 [E]		GW	Well-graded gravel [F]
			Cu < 4 and/or [Cc<1 or Cc>3.0] [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F, G, H]
			Fines classify as CL or CH		GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu ≥ 6 and 1 ≤ Cc ≤ 3 [E]		SW	Well-graded sand [I]
			Cu < 6 and/or [Cc<1 or Cc>3.0] [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G, H, I]
			Fines classify as CL or CH		SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A"		CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K, L, M, N]
			Liquid limit - not dried			Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K, L, M]
			PI plots below "A" line		MH	Elastic Silt [K, L, M]
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay [K, L, M, P]
			Liquid limit - not dried			Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

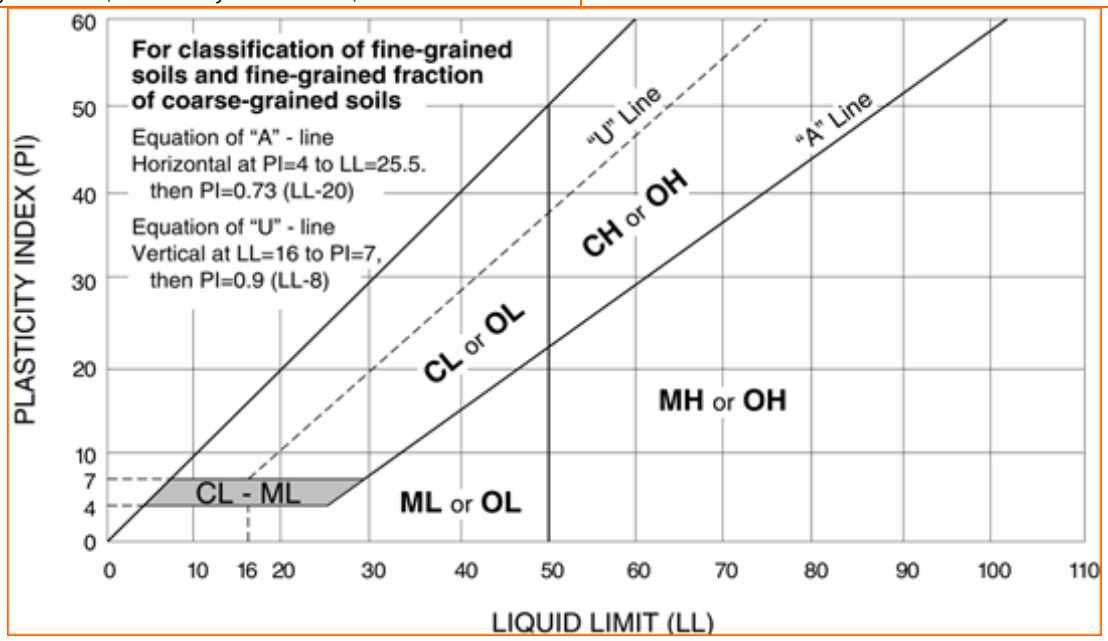
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



A-2: 2021 Boring/Piezometer Logs with Sample Photos

BORING LOG LEGEND

HDR

CLIENT Grand Forks Water Resource District **PROJECT NAME** Larimore Dam

PROJECT NUMBER **PROJECT LOCATION** Larimore, ND

SOIL GRAPHIC SYMBOLS

(Unified Soil Classification System)

CL - Low Plasticity Clay

TOPSOIL - Topsoil

WELL CONSTRUCTION SYMBOLS

Cement Bentonite

VWP Sensor

Water Levels During Drilling

End of Drilling

After Drilling

ABBREVIATIONS

GW	-Groundwater	%	-Percent
JRC	-Joint Roughness Coeffecient	mm	-Millimeters
SPT	-Standard Penetration Test	psi	-Pounds Per Square Inch
PI	-Plasticity Index	pcf	-Pounds Per Cubic Foot
MC	-Moisture Content	deg	-Degrees
LL	-Liquid Limit	cm/s	-Centimeters Per Second

SAMPLER SYMBOLS

Modified California Sampler

Split Spoon

Thin-walled sampler

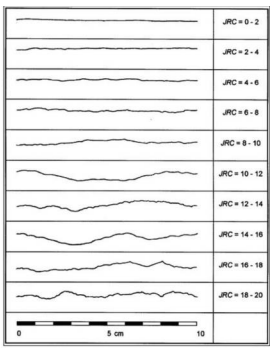
LABORATORY TEST RESULTS KEY

DD - Dry Density
%G - Percent Gravel
%S - Percent Sand
% Si - Percent Silt (from hydrometer)
% C - Percent Clay (from hydrometer)
D_{100} - Size which 100% of soil particles are smaller than
D_{60} - Size which 60% of soil particles are smaller than
D_{30} - Size which 30% of soil particles are smaller than
D_{10} - Size which 10% of soil particles are smaller than
C_c - Coeffecient of Curvature
C_u - Coeffecient of Uniformity
⊛ - Unconfined Compressive Strength - Soil
UU-c - Triaxial Compressive Test - Unconsolidated Undrained - total cohesion
UU-ϕ - Triaxial Compressive Test - Unconsolidated Undrained - total friction angle
CU-c - Triaxial Compressive Test - Consolidated Undrained - total cohesion
CU-ϕ - Triaxial Compressive Test - Consolidated Undrained - total friction angle
CU-c' - Triaxial Compressive Test - Consolidated Undrained - effective cohesion
CU-ϕ' - Triaxial Compressive Test - Consolidated Undrained - effective friction angle
DSS-c' - Direct Shear Test - Soil - effective cohesion
DSS-ϕ' - Direct Shear Test - Soil - effective friction angle
Opt MC - Optimum Moisture Content (Modified Proctor Test)
Max DD - Maximum Dry Density (Modified Proctor Test)
CHP - Constant Head Permeability Tetst
FHP - Falling Head Permeability Tetst
• - Pinhole Dispersion Test
  D1,D2: Dispersive Soils
  ND4,ND3: Intermediate Soils
  ND2,ND1: Nondispersive Soils
◎ - Crumb Test
  Grade 1: No Reaction
  Grade 2: Slight Reaction
  Grade 3: Moderate Reaction
  Grade 4: Strong Reaction
GCM - Geochemical Testing
✳ - Unconfined Compressive Strength - Rock
DSR-c - Direct Shear Test - Rock - cohesion
DSR-ϕ - Direct Shear Test - Rock - friction angle

DISCONTINUITY DATA KEY

SYMBOL	TYPE	SPACING	INFILLING
	J: Joint	1: >20'	Ca: Calcite
	B: Bedding	2: 6' - 20'	Cl: Clay
	Fo: Foliation	3: 2' - 6'	Ch: Chlorite
	V: Vein	4: 8" - 2'	Fe: Iron Oxide
	S: Shear	5: 2.4" - 8"	Gr: Gravel
	SG: Shear Gouge	6: 0.75" - 2.4"	Qz: Quartz
	SB: Shear Breccia	7: 0.25" - 0.75"	Sd: Sand
	MB: Mechanical Break	8: 0.1" - 0.25"	- : None
		9: <0.1"	O: Other

JOINT ROUGHNESS COEFFECIENT (JRC)



SURFACE ROUGHNESS	SURFACE WEATHERING
Slk: Slickensided	F: Fresh
S: Smooth	SW: Slightly Weathered
SR: Slightly Rough	MW: Moderately Weathered
R: Rough	HW: Highly Weathered
VR: Very Rough	D: Decomposed
	RS: Residual Soil

KEY TO SYMBOLS-VWP-HDR LOG - HDR BORING LOG TEMPLATE.GDT - 6/28/21 15:50 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No.

TH-31

Sheet 1 of 3

Angle from H: 90°	Start Date: 3/31/2021	Drilling Co.: Terracon	**Drilling**	**Soil**	**Rock**	Logged by: SWM	Total Depth: 111 ft
Azimuth: N/A°	End Date: 4/1/2021	Rig Type: Mobil B-52 Track Rig	**Method**	HSA	N/A	Checked by:	Refusal Depth: ft
North: 2681065.768	H Datum:	Driller: Mike Roberts	Bit Type		N/A	Date:	Casing Depth: ft
East: 355186.529	V Datum: NGVD29	Helper: Eric	Bit Diam.	5.5"	N/A	Hammer Type: Auto	GW Depth: 88 ft
Elevation: 1100.651 ft	Crd System:		Fluid	N/A	N/A	Weather:	

Boring Location: Crest

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION
0		0 to 0.2 feet: Topsoil
		0.2 to 9.5 feet: sandy lean clay (cl), light brown to gray, dry, very stiff, homogeneous (embankment fill)
5	1105	
	1110	9.5 to 49.5 feet: sandy lean clay with angular to subangular gravel (cl), light brown to gray, dry, stiff, lensed with pockets of displaced till, low to medium plasticity (embankment fill)
10		
	1115	
15		14.5 ft: decreased sand content in SS-3
	1120	
20		
	1125	
25		24.5 ft: color change to dark gray, resembles till
	1130	
30		29.5 ft: color returns to light brown
	1135	
35		

PIEZOMETER | GRAPHIC LOG

SAMPLES

NUMBER - TYPE SYMBOL (RECOVERY) INTERVAL (FT)		LABORATORY TEST RESULTS	POCKET PEN. (tsf)
1-SS	4.5 – 6		
2-SS	9.5 – 11		
3-SS	14.5 – 16	◎ = 2	
4-SS	19.5 – 21	◎ = 1	
5-SS	24.5 – 26		
6-SS	29.5 – 31	◎ = 3	
	34.5	%G = 2% %S = 36%	

ROCK DISCONTINUITY DATA

SYMBOL | NUMBER | TYPE | ANGLE | SPACING | APERTURE (mm) | INFILLING TYPE | INFILLING AMOUNT (mm/in) | JRC | SURFACE ROUGHNESS | SURFACE WEATHERING

SPT Data, N in blows/ft ⊙

PI MC LL

FINES CONTENT (%) ☐

RECOVERY (%) ▨

RQD (%) ▩

20 40 60 80

26 11 12 9 10 11

HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

(Continued Next Page)

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No.

TH-31

Sheet 2 of 3

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	PIEZOMETER	GRAPHIC LOG	SAMPLES: NUMBER - TYPE SYMBOL (RECOVERY) INTERVAL (FT)	SAMPLES: LABORATORY TEST RESULTS	POCKET PEN. (tsf)	ROCK DISCONTINUITY DATA: SYMBOL, NUMBER, TYPE, ANGLE, SPACING, APERTURE (mm), INFILLING TYPE, INFILLING AMOUNT (mm/in), JRC, SURFACE ROUGHNESS, SURFACE WEATHERING	SPT Data, N in blows/ft
35									PI MC LL; FINES CONTENT (%) ☐; RECOVERY (%) ▨; RQD (%) ▩ 20 40 60 80
	1140	37.5-40.5 ft: dark gray lean clay and gravel, resembles till			1-TW 36.5	% Si = 41% % C = 21% D_{60} = 68.9mm D_{30} = 10.8mm			
40					7-SS 39.5 – 41	◎ = 1			15
	1145				8-SS 44.5 – 46	◎ = 2			14
45		VWP TH-31-T Sensor Depth: 50.14 ft							
	1150	49.5 to 59.5 feet: lean clay with subangular gravel, trace fine sand (cl), gray, dry, medium plasticity, stiff, homogeneous (embankment fill)			9-SS 49.5 – 51				14
50									
	1155	54.5 ft: TW-2 only pushed 18 inches due to tube bending			2-TW 54.5 – 56.5	DD = 108pcf %G = 1% %S = 38% % Si = 38% % C = 22% D_{60} = 73mm D_{30} = 11.1mm FHP = 4.10E-08cm/s			
55									
	1160	59.5 to 69 feet: sandy lean clay and gravel (cl), brown, dry, low plasticity, gravel up to 1 inch in diameter, subangular to subrounded, fine to medium grained sand, stiff to very stiff, homogeneous (embankment fill)			10-SS 59.5 – 61	◎ = 2			22
60									
	1165	VWP TH-31-M Sensor Depth: 65.14 ft			11-SS 64.5 – 66				15
65									
	1170	69 to 95.5 feet: lean clay and subangular to rounded gravel, trace sand (cl), gray to dark gray, slight moisture, medium stiff to stiff, homogeneous (upper glacial till)			12-SS 69.5 – 71	◎ = 1			11
70									

HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

(Continued Next Page)

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No.

TH-31

Sheet 3 of 3

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	PIEZOMETER	GRAPHIC LOG	SAMPLES: NUMBER - TYPE SYMBOL (RECOVERY) INTERVAL (FT)	SAMPLES: LABORATORY TEST RESULTS	POCKET PEN. (tsf)	ROCK DISCONTINUITY DATA: SYMBOL / NUMBER / TYPE / ANGLE / SPACING / APERTURE (mm) / INFILLING TYPE / INFILLING AMOUNT (mm/in) / JRC / SURFACE ROUGHNESS / SURFACE WEATHERING	SPT Data, N in blows/ft ⊙ PI MC LL; FINES CONTENT (%) □; RECOVERY (%) ▨; RQD (%) ▩ 20 40 60 80
75					3-TW 74.5–76.5	DD = 98pcf %G = 1% %S = 15% % Si = 51% % C = 34% D_{60} = 15.9mm D_{30} = 3.8mm FHP = 6.70E-08cm/s			
80		79.5: trace gravel - pebble sized			13-SS 79.5–81	◎ = 1			5
85					4-TW 84.5–86.5	%G = 1% %S = 15% % Si = 51% % C = 33% D_{60} = 16.6mm D_{30} = 4mm			
90		88.0 ft: groundwater encountered and sustained until depth of 104.5 ft 89.5 ft: MC-1 sample: wet			1-MC 89.5–91				13
95		95.5 to 111 feet: sandy lean clay with gravel (cl), dark gray, wet, lensed with pockets of increased sand and gravel content, gravel is angular to subrounded, low to medium plasticity (preconsolidated till) 95.8 ft: TW-5: driller indicated much greater down pressure needed to push tube from 95.5-96.5 ft			5-TW 94.5–96.5				
100					14-SS 99.5–101				24
105		104.5 ft: slight moisture in MC-2 VWP TH-31-B Sensor Depth: 106.14 ft			2-MC 104.5–106				70
110		109.5 ft: decreased sand content in MC-3			3-MC 109.5–111				97

Bottom of borehole at 111.0 feet.

HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

TH-31


LABIMORE DAM
BORING: TH-31
DEPTH: 4.5-6.0
SAMPLE: SS-1
DATE: 3-31-21

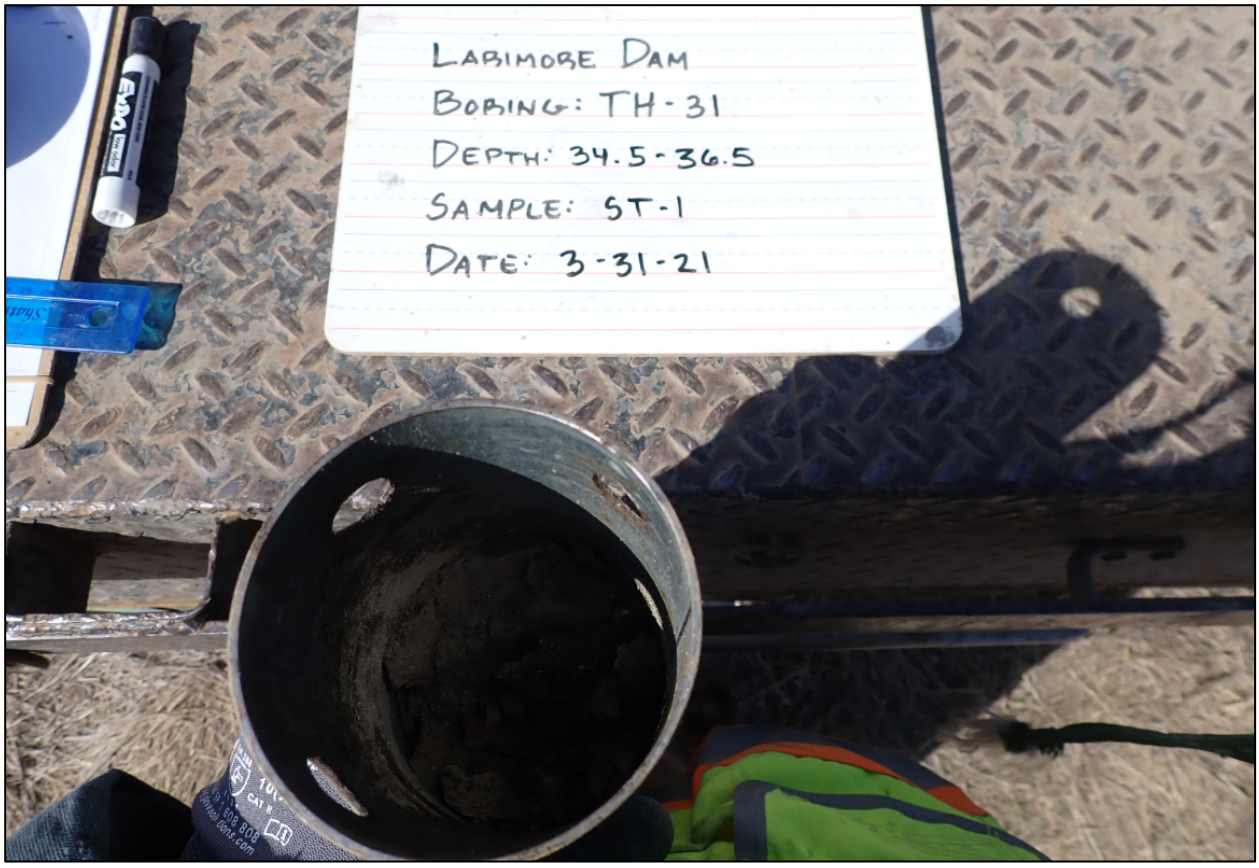

LABIMORE DAM
BORING: TH-31
DEPTH: 9.5-11.0
SAMPLE: SS-2
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 14.5-16.0
SAMPLE: SS-3
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 19.5-21.0
SAMPLE: SS-4
DATE: 3-31-21

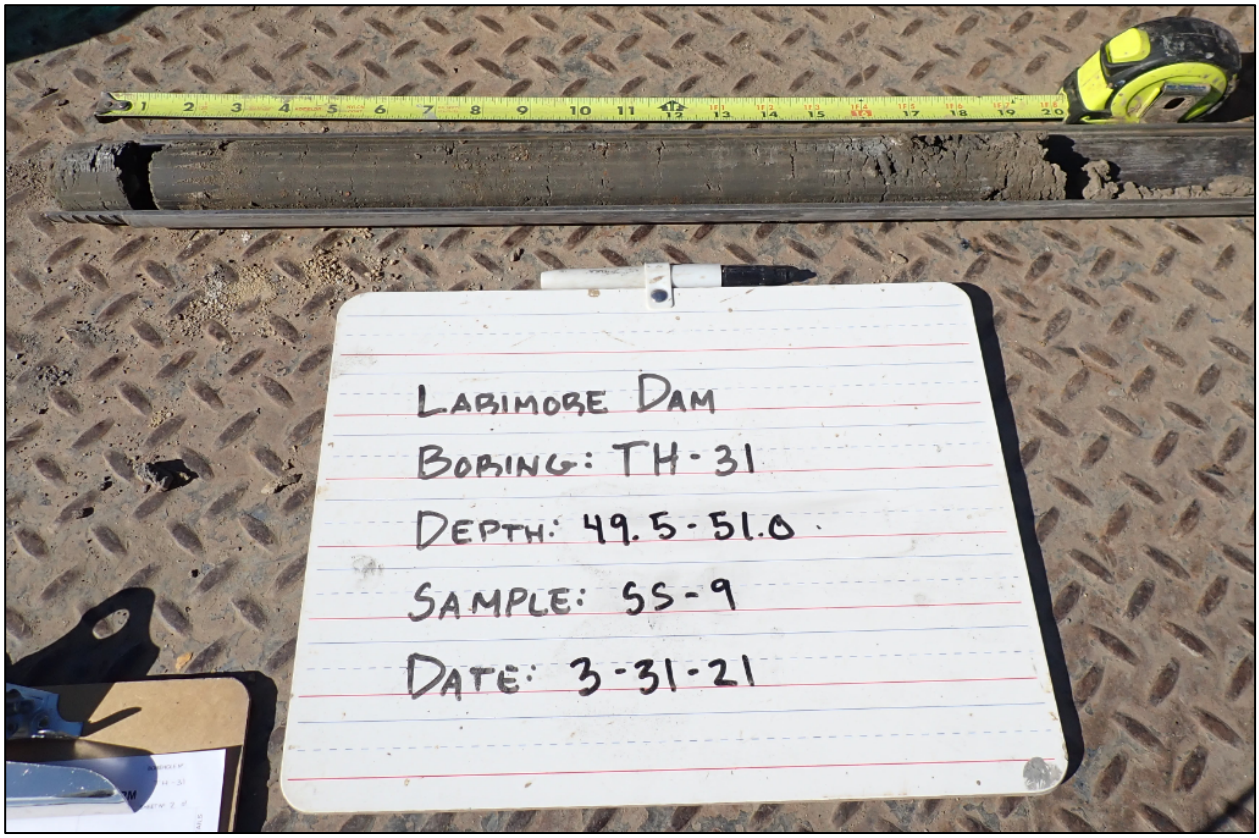

LABIMORE DAM
BORING: TH-31
DEPTH: 24.5-26.0
SAMPLE: SS-5
DATE: 3-31-21

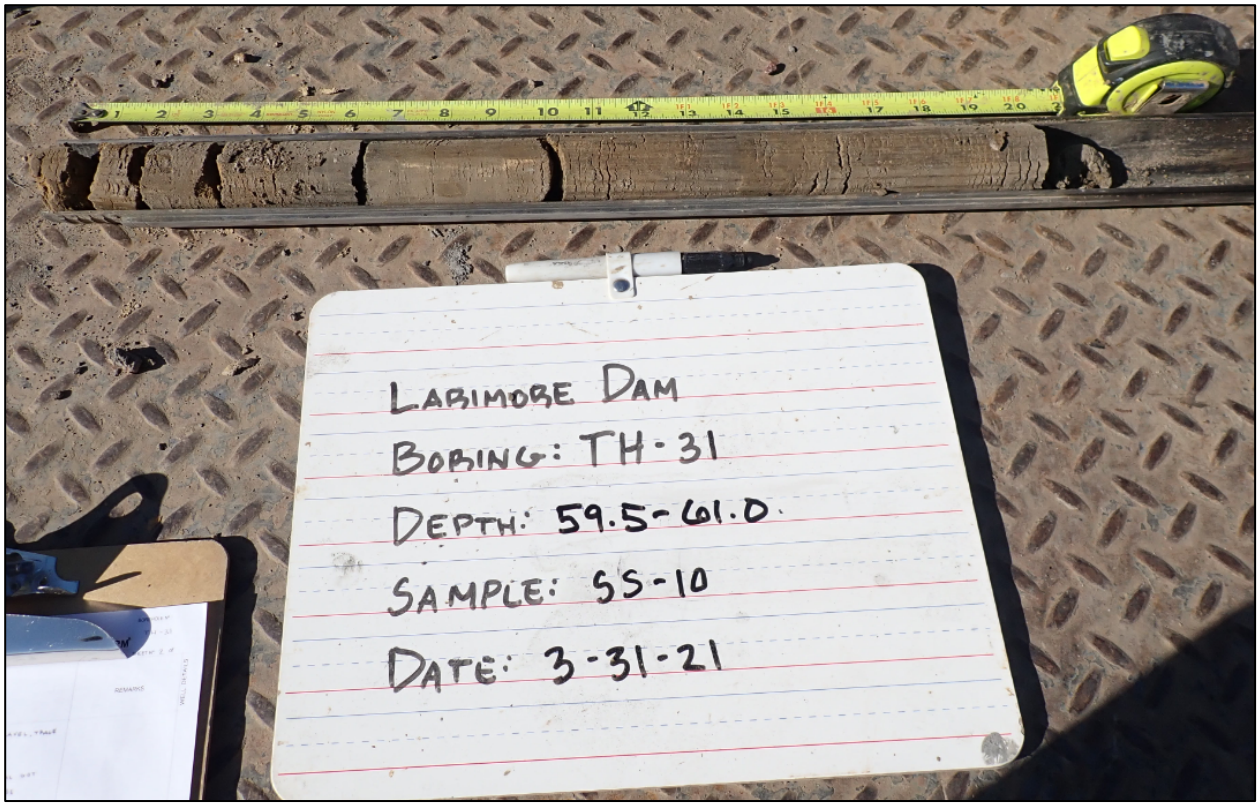

LABIMORE DAM
BORING: TH-31
DEPTH: 29.5-31.0
SAMPLE: SS-6
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 34.5-36.5
SAMPLE: ST-1
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 39.5-41.0
SAMPLE: SS-7
DATE: 3-31-21

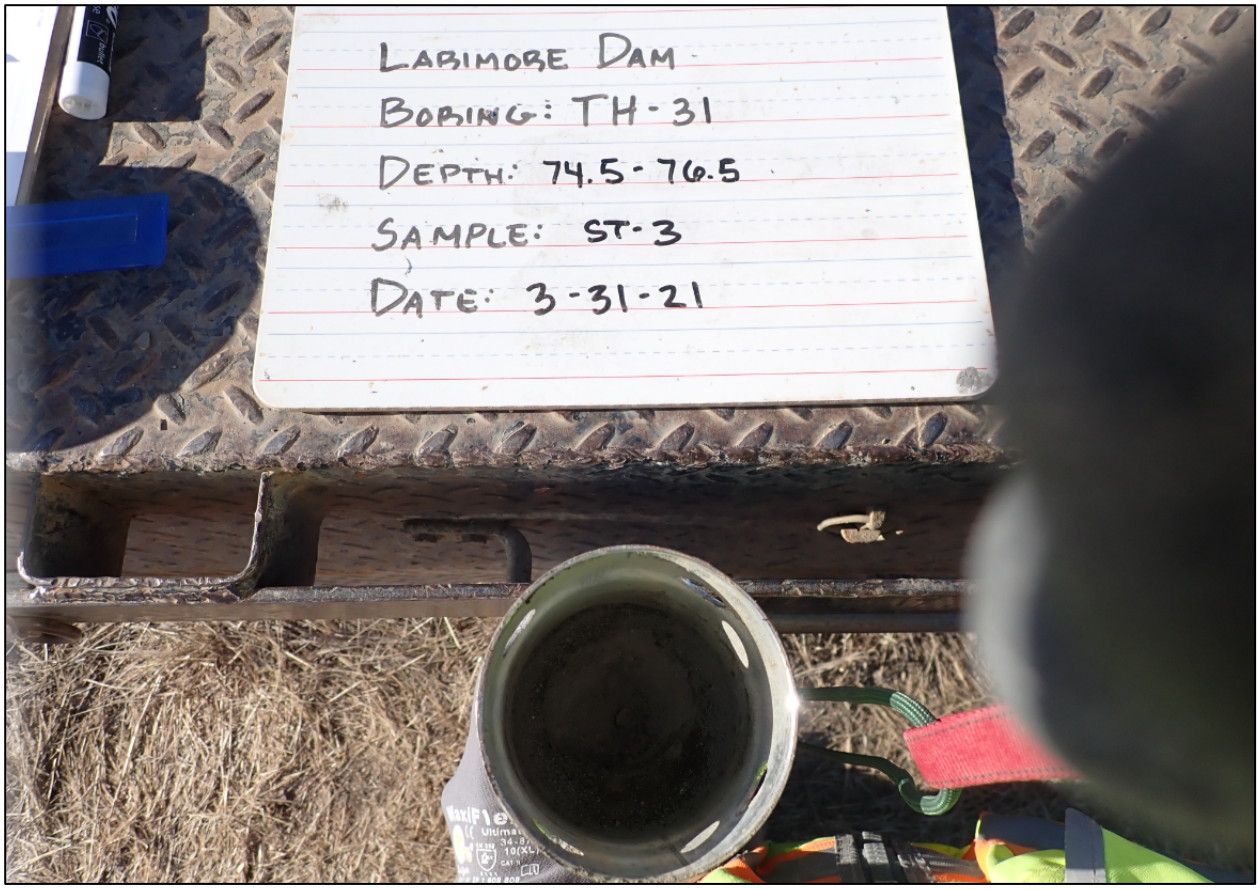

LABIMORE DAM
BORING: TH-31
DEPTH: 44.5-46.0
SAMPLE: SS-8
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 49.5-51.0
SAMPLE: SS-9
DATE: 3-31-21

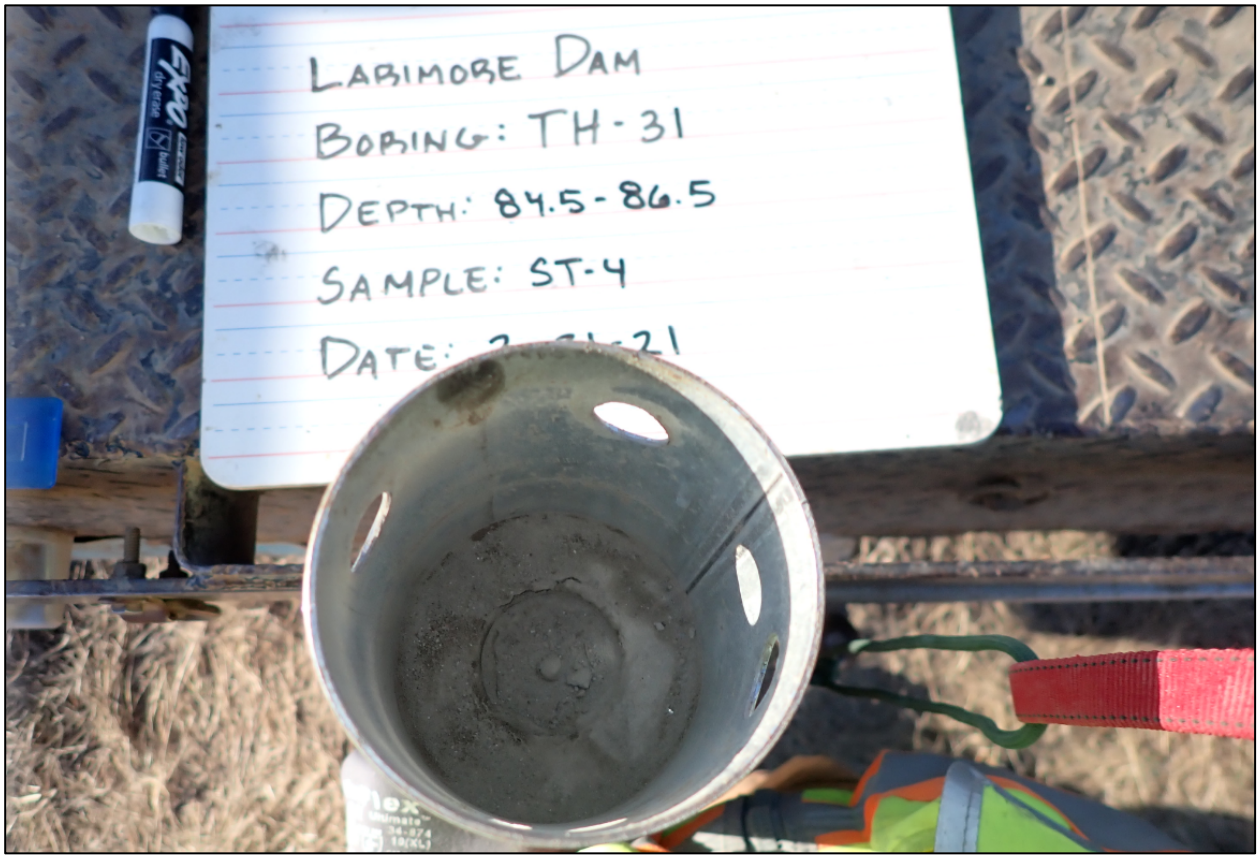

LABIMORE DAM
BORING: TH-31
DEPTH: 59.5-61.0
SAMPLE: SS-10
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 64.5-66.0
SAMPLE: SS-11
DATE: 3-31-21

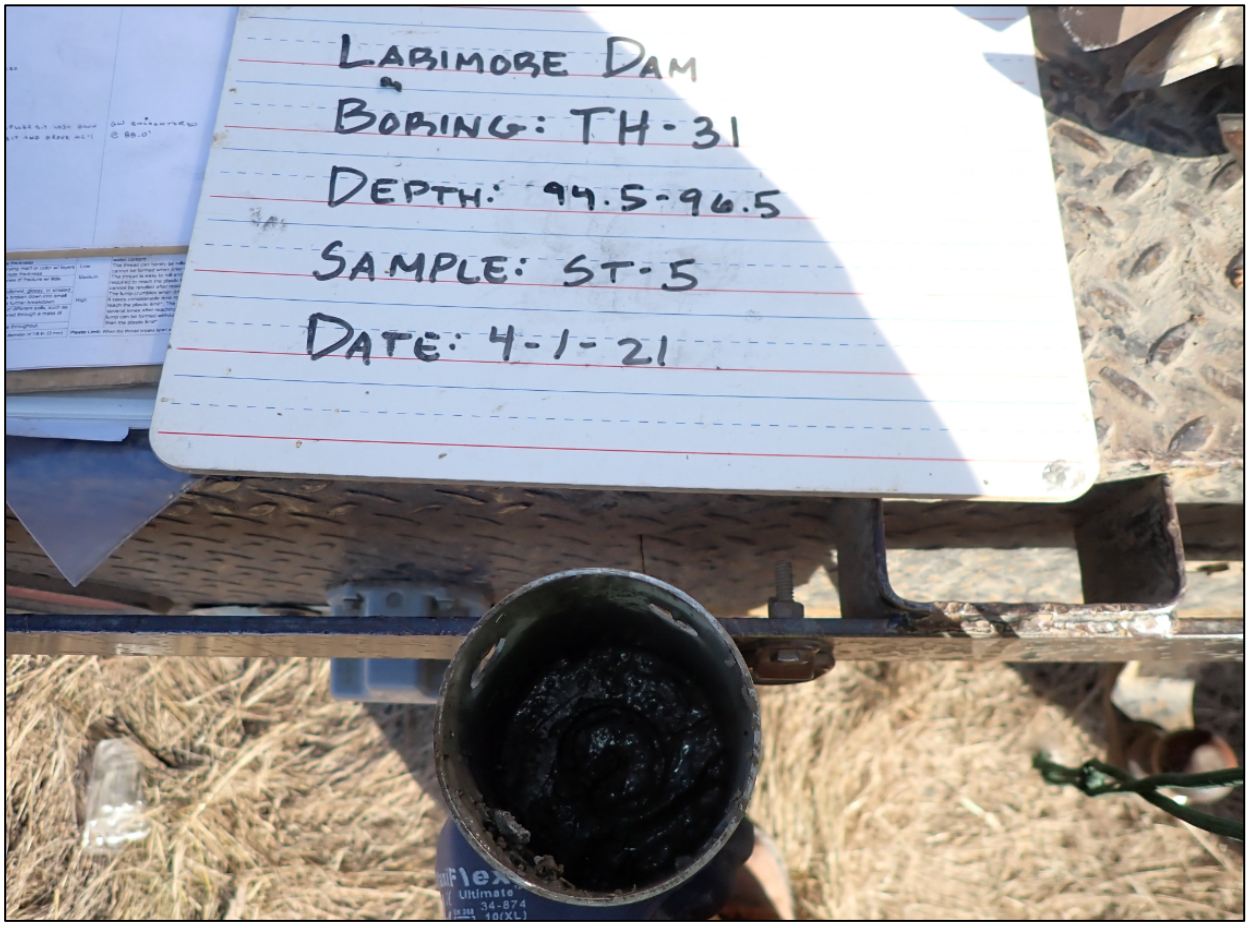

LABIMORE DAM
BORING: TH-31
DEPTH: 69.5-71.0
SAMPLE: SS-12
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 74.5-76.5
SAMPLE: ST-3
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 79.5-81.0
SAMPLE: SS-13
DATE: 3-31-21


LABIMORE DAM
BORING: TH-31
DEPTH: 84.5-86.5
SAMPLE: ST-4


LABIMORE DAM
BORING: TH-31
DEPTH: 89.5-91.0
SAMPLE: MC-1
DATE: 4-1-21


LABIMORE DAM
BORING: TH-31
DEPTH: 94.5-96.5
SAMPLE: ST-5
DATE: 4-1-21


LABIMORE DAM
BORING: TH-31
DEPTH: 99.5-101.0
SAMPLE: SS-14
DATE: 4-1-21


LABIMORE DAM
BORING: TH-31
DEPTH: 104.5-106.0
SAMPLE: MC-2
DATE: 4-1-21


LABIMORE DAM
BOBING: TH-31
DEPTH: 109.5-111.0
SAMPLE: MC-3
DATE: 4-1-21

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No. **TH-32**

Sheet 1 of 3

Angle from H: 90°	Start Date: 3/30/2021	Drilling Co.: Terracon	**Drilling**	**Soil**	**Rock**	Logged by: SWM	Total Depth: 101.5 ft
Azimuth: N/A°	End Date: 3/31/2021	Rig Type: Mobil B-52 Track Rig	**Method**	HSA	N/A	Checked by:	Refusal Depth: ft
North: 2681185.411	H Datum:	Driller: Mike Roberts	Bit Type		N/A	Date:	Casing Depth: ft
East: 355226.223	V Datum: NGVD29	Helper: Eric	Bit Diam.	5.5"	N/A	Hammer Type: Auto	GW Depth: 73 ft
Elevation: 1067.471 ft	Crd System:		Fluid	N/A	N/A	Weather:	

Boring Location: DS Bench

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	PIEZOMETER	GRAPHIC LOG	SAMPLES: NUMBER - TYPE SYMBOL (RECOVERY) INTERVAL (FT)	SAMPLES: LABORATORY TEST RESULTS	POCKET PEN. (tsf)	ROCK DISCONTINUITY DATA: SYMBOL / NUMBER / TYPE / ANGLE / SPACING / APERTURE (mm) / INFILLING TYPE / INFILLING AMOUNT (mm/in) / JRC / SURFACE ROUGHNESS / SURFACE WEATHERING	SPT Data, N in blows/ft ⊙
0		0 to 0.5 feet: Topsoil							
		0.5 to 14.5 feet: sandy lean clay with angular to subangular gravel (cl) light brown, dry, stiff to very stiff, homogeneous (embankment fill)							
	1070								
5					1-SS 4.5 – 6	◎ = 2			15
	1075								
10					1-TW 9.5 – 11.5	DD = 113pcf %G = 3% %S = 28% % Si = 47% % C = 22% D_{60} = 53.7mm D_{30} = 10.5mm FHP = 3.30E-08cm/s			
	1080								
15		14.5 to 30 feet: lean clay with sand, trace gravel (cl), brown and gray, dry, stiff to very stiff, low plasticity, homogeneous (embankment fill)			2-SS 14.5 – 16				9
	1085	VWP TH-32-T Sensor Depth: 15.38 ft							
20					2-TW 19.5 – 21.5	%G = 0% %S = 22% % Si = 53% % C = 25% D_{60} = 43.3mm D_{30} = 9.8mm			
	1090								
25		24.5 ft: increased sand content in SS-3			3-SS 24.5 – 26	◎ = 2			17
	1095								
30		30 to 38.5 feet: lean clay, trace sand and gravel (cl), brown, dry, stiff to very stiff, homogeneous (embankment fill)			4-SS 29.5 – 31				15
	1100	VWP TH-32-M Sensor Depth: 30.38 ft							
35		34.5 ft: trace organics (root fragments) in SS-5, slight moisture			34.5	◎ = 2			

PI MC LL

FINES CONTENT (%) ☐

RECOVERY (%) ▨

RQD (%) ▩ 20 40 60 80

(Continued Next Page)

HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No. **TH-32**

Sheet 2 of 3

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	PIEZOMETER	GRAPHIC LOG	SAMPLES: NUMBER - TYPE SYMBOL (RECOVERY)	SAMPLES: INTERVAL (FT)	SAMPLES: LABORATORY TEST RESULTS	POCKET PEN. (tsf)	ROCK DISCONTINUITY DATA: SYMBOL / NUMBER / TYPE / ANGLE / SPACING / APERTURE (mm) / INFILLING TYPE / INFILLING AMOUNT (mm/in) / JRC / SURFACE ROUGHNESS / SURFACE WEATHERING	SPT Data, N in blows/ft ⊙
35										PI MC LL; FINES CONTENT (%) ☐; RECOVERY (%) ▨; RQD (%) ▩ 20 40 60 80
	1105				5-SS	36				10
40		38.5 to 54.5 feet: lean clay, trace gravel (cl), gray, soft to medium stiff, dry, medium plasticity, homogeneous, gravel is pebble sized and includes various rock types (upper glacial till)			6-SS	39.5 41				
	1110				7-SS	44.5 46	◎ = 1			4
45										
	1115				3-TW	49.5 51.5	◎ = 1			
50					4-TW	52 54				
	1120				8-SS	54.5 56				9
55		54.5 to 68.5 feet: sandy lean clay, trace gravel (cl), gray, dry, medium stiff to stif, homogeneous (upper glacial till)								
	1125				5-TW	59.5 61.5	◎ = 1			
60										
	1130									
65		64.5 ft: decreased sand content in SS-9			9-SS	64.5 66				7
	1135									
70		68.5 to 101.5 feet: sandy lean clay, trace gravel (cl), gray, dry to wet, stiff to hard, low to medium plasticity, homogeneous, gravel is angular to subrounded ranging to 0.5-inch diameter (preconsolidated glacial till)			10-SS	69.5 71	%G = 2% %S = 35% % Si = 42% % C = 21% D_{60} = 66.3mm D_{30} = 11.3mm ◎ = 3			35
	1140		▽							

(Continued Next Page)

HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

CLIENT: Grand Forks Water Resource District

PROJECT: Larimore Dam **NUMBER:**

LOCATION: Larimore, ND

Boring No.

TH-32

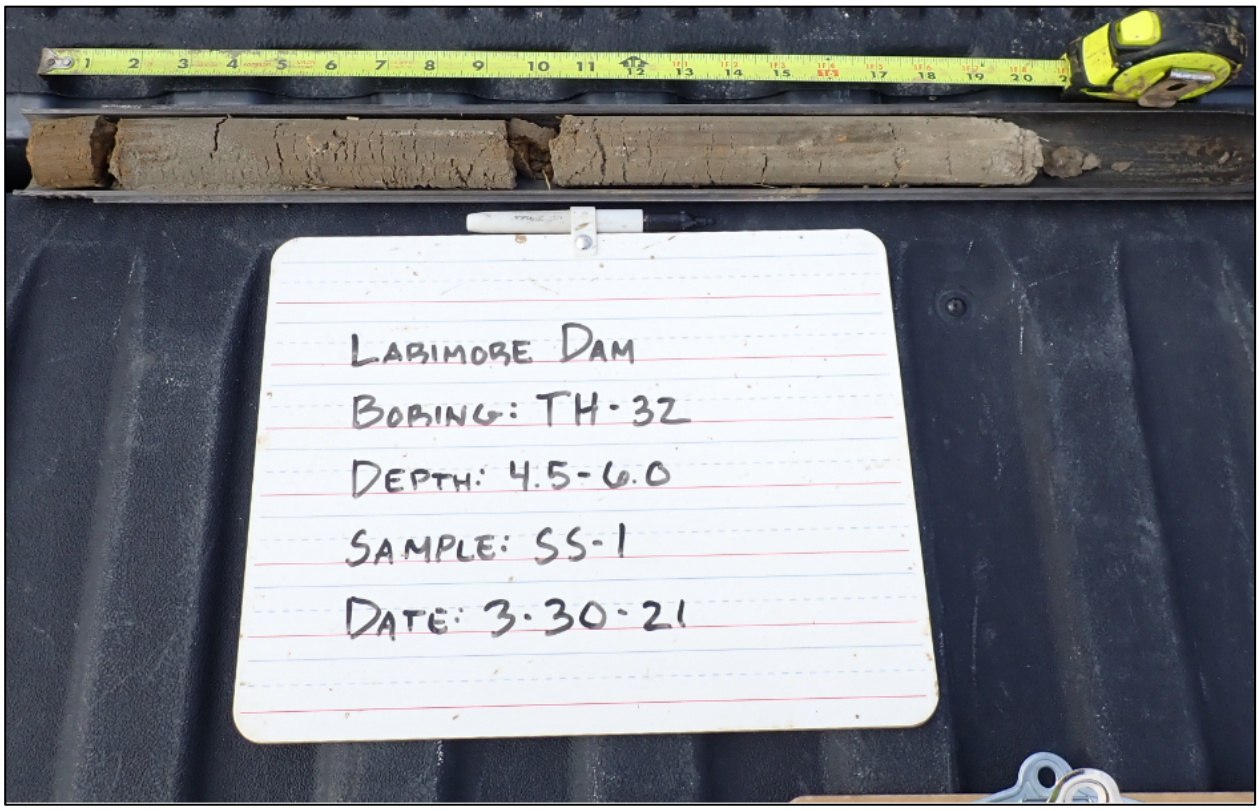
Sheet 3 of 3

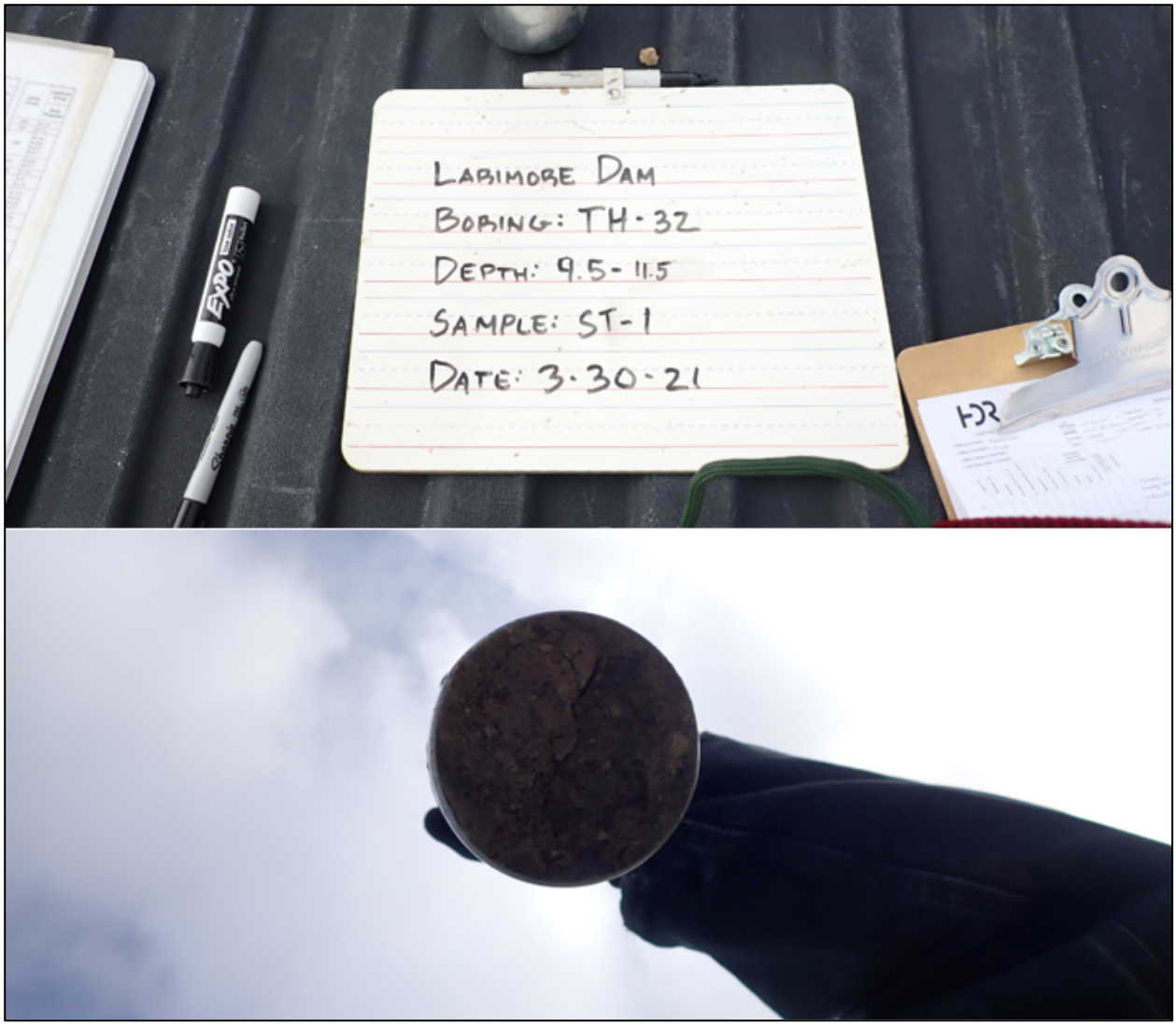
DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	PIEZOMETER	GRAPHIC LOG	SAMPLES: NUMBER - TYPE SYMBOL (RECOVERY) INTERVAL (FT)	SAMPLES: LABORATORY TEST RESULTS	POCKET PEN. (tsf)	ROCK DISCONTINUITY DATA: SYMBOL / NUMBER / TYPE / ANGLE / SPACING / APERTURE (mm) / INFILLING TYPE / INFILLING AMOUNT (mm/in) / JRC / SURFACE ROUGHNESS / SURFACE WEATHERING	SPT Data, N in blows/ft ⊙ / PI MC LL / FINES CONTENT (%) ☐ / RECOVERY (%) ▨ / RQD (%) ▩
75		73.0: groundwater encountered, subsequent samples wet 74.5 ft: MC-1 sample: wet 74.5 ft: thin wall sample attempted at 74.5 ft, could only be pushed 4 inches - no sample recovered			1-MC 74.5 – 76.5	%G = 3% %S = 33% % Si = 35% % C = 28% D_{60} = 62.2mm D_{30} = 5.9mm			95
80		79.5 ft: MC-2 sample: wet			2-MC 79.5 – 81	DD = 96pcf %G = 2% %S = 34% % Si = 36% % C = 29% D_{60} = 57.5mm D_{30} = 5.6mm FHP = 4.70E-08cm/s			62
85		84.5 ft: MC-3 sample: wet			3-MC 84.5 – 86	%G = 3% %S = 35% % Si = 35% % C = 28% D_{60} = 66.9mm D_{30} = 6.2mm			46
90		89.5-101.5: increased plasticity			11-SS 89.5 – 91				13
95		VWP TH-32-B Sensor Depth: 95.38 ft			12-SS 94.5 – 96	%G = 1% %S = 35% % Si = 36% % C = 28% D_{60} = 60.5mm D_{30} = 6.2mm			14
100					6-TW 99.5 – 101.5				

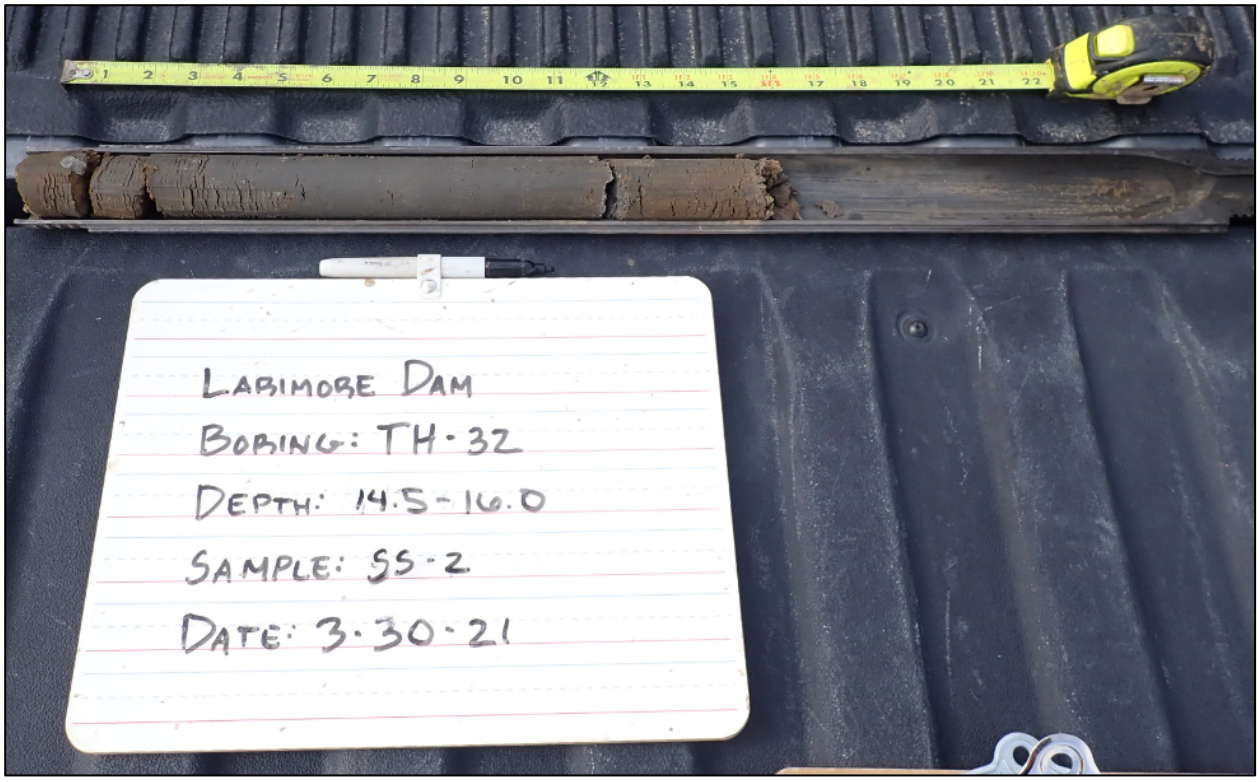
Bottom of borehole at 101.5 feet.

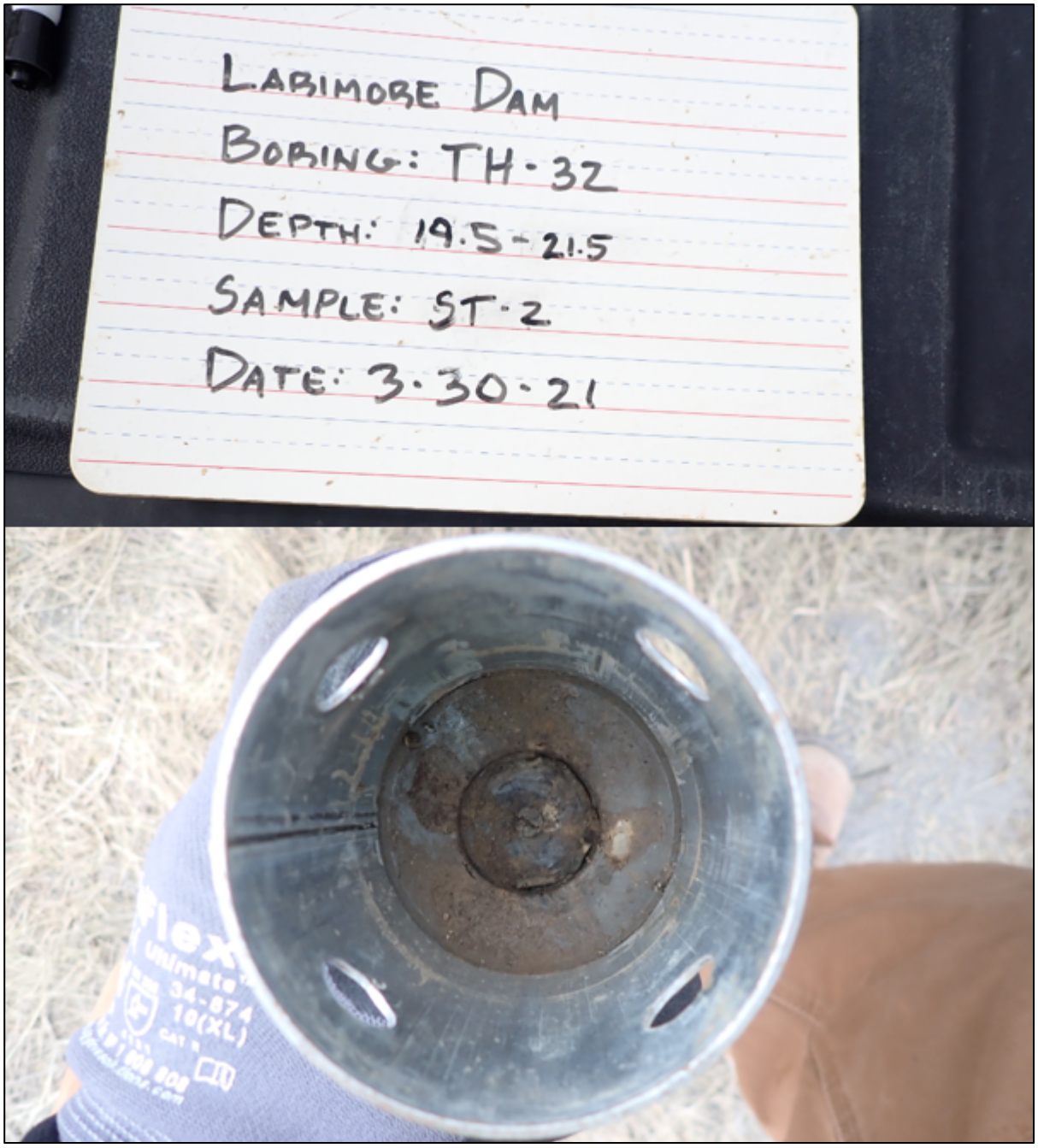
HDR LOG TEMPLATE - HDR BORING LOG TEMPLATE.GDT - 6/28/21 16:17 - C:\USERS\SMCWILLIAM\DESKTOP\PROJECTS\LARIMORE DAM\GINT\LARIMORE_DAM.GPJ

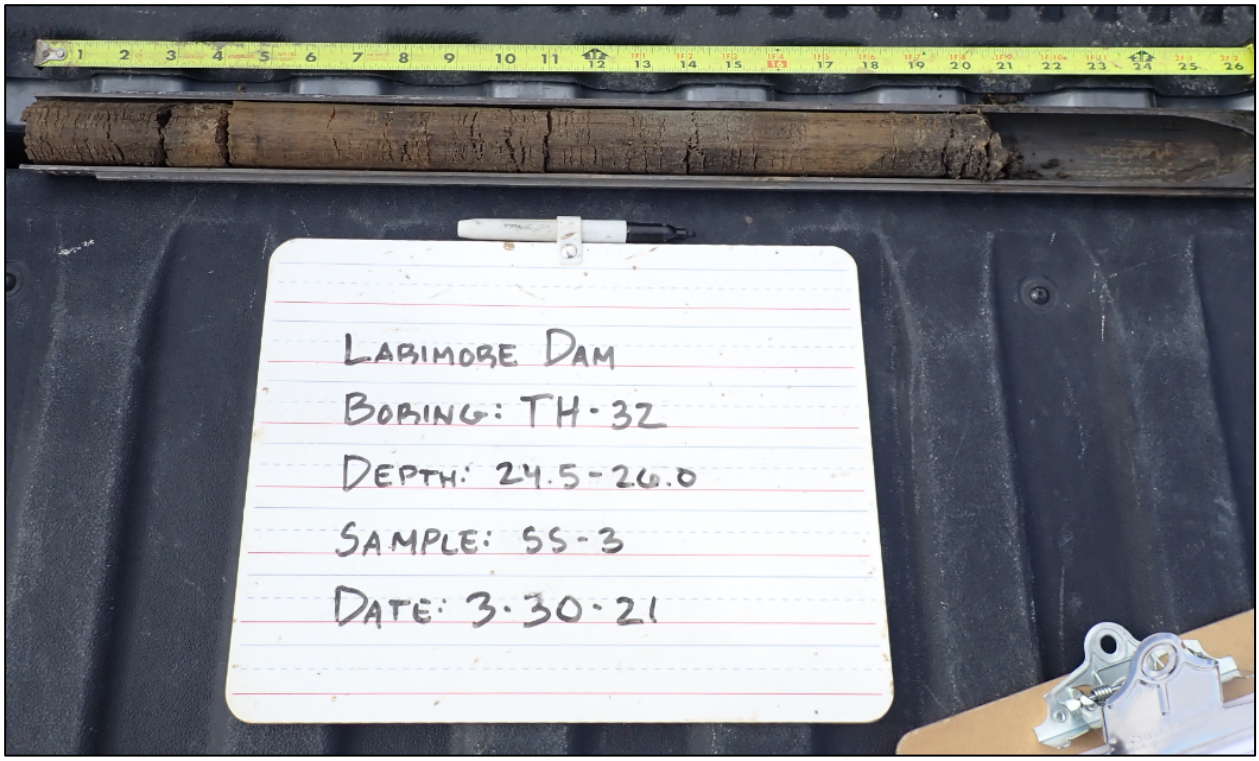
TH-32

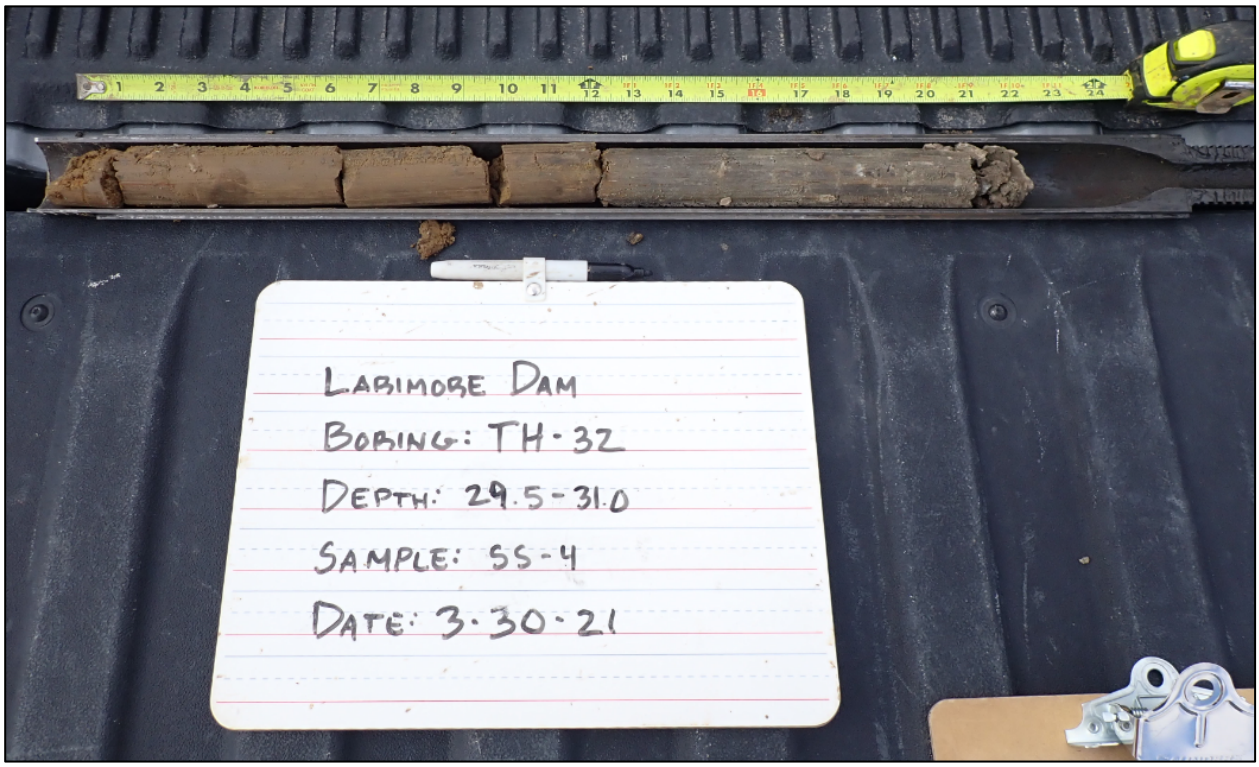


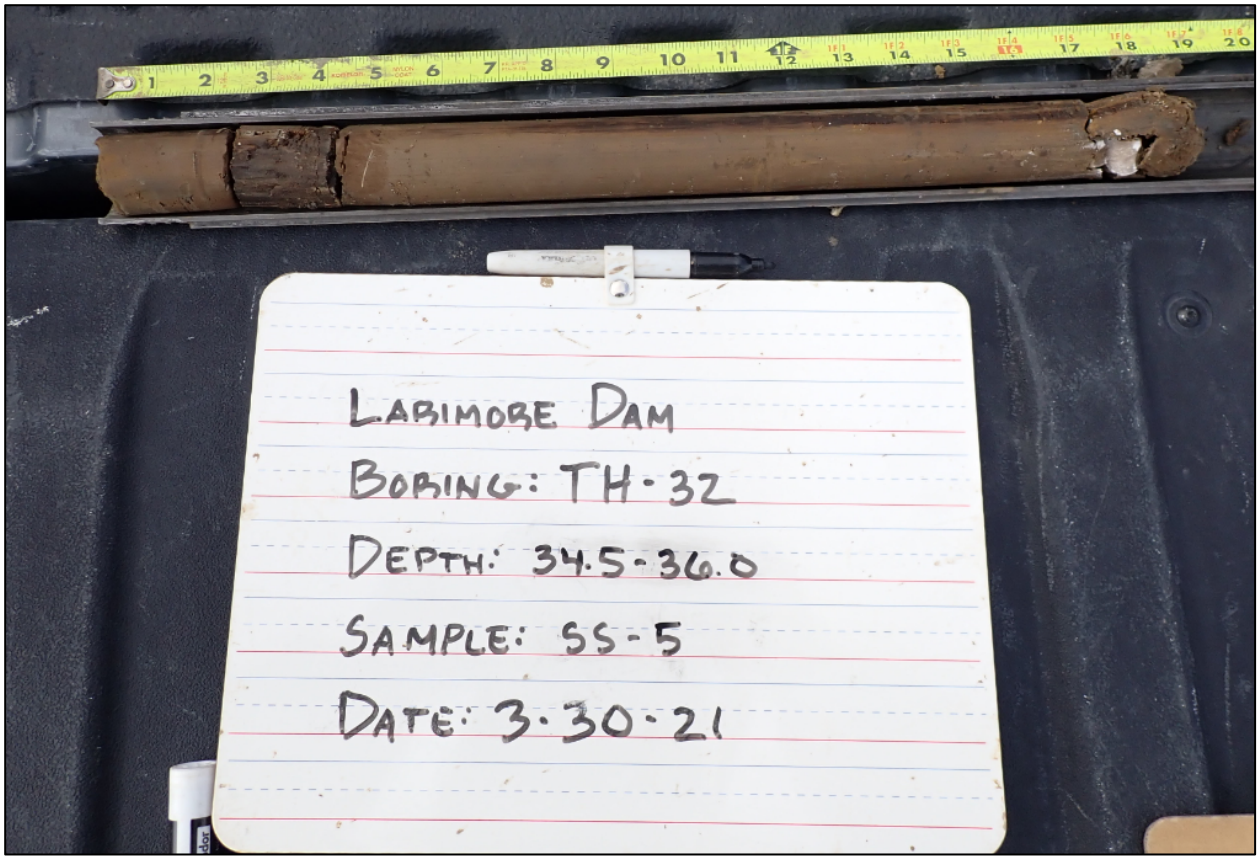

LABIMORE DAM
BORING: TH-32
DEPTH: 9.5-11.5
SAMPLE: ST-1
DATE: 3.30.21
HDR

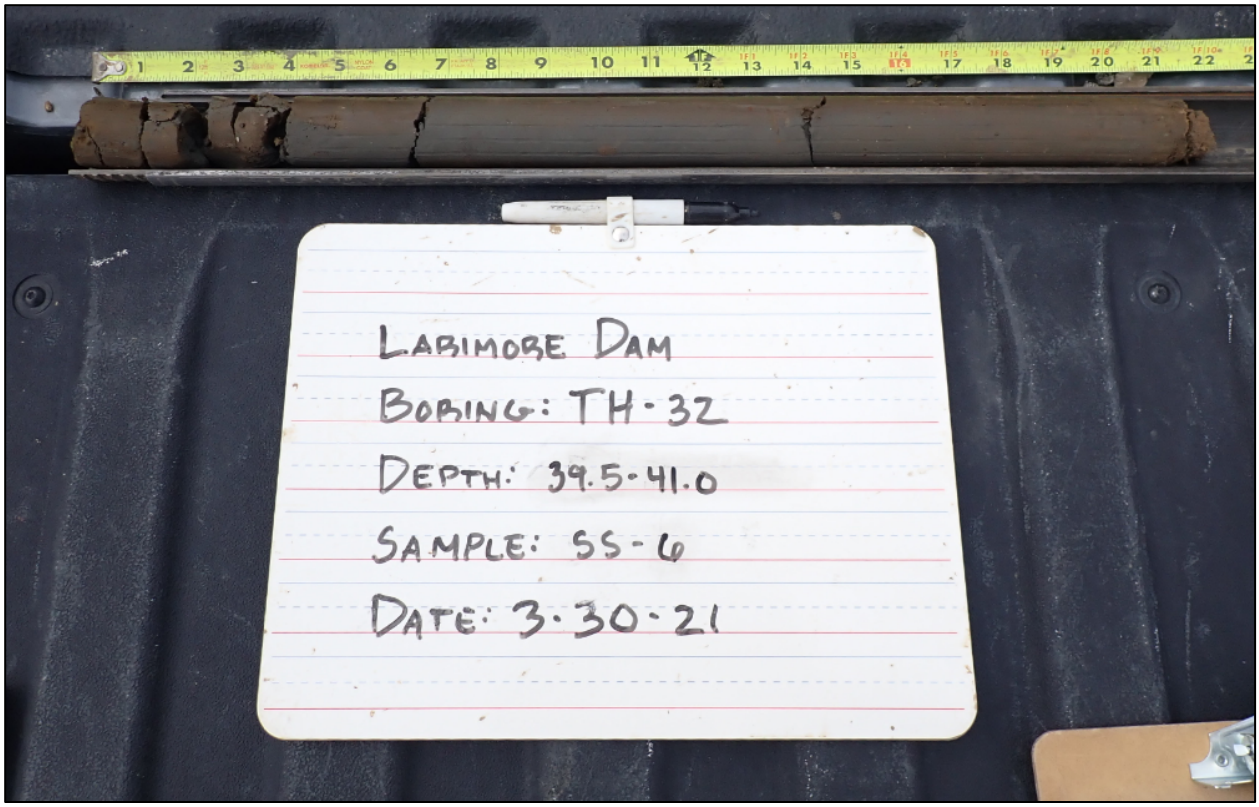

LABIMORE DAM
BORING: TH-32
DEPTH: 14.5-16.0
SAMPLE: SS-2
DATE: 3-30-21

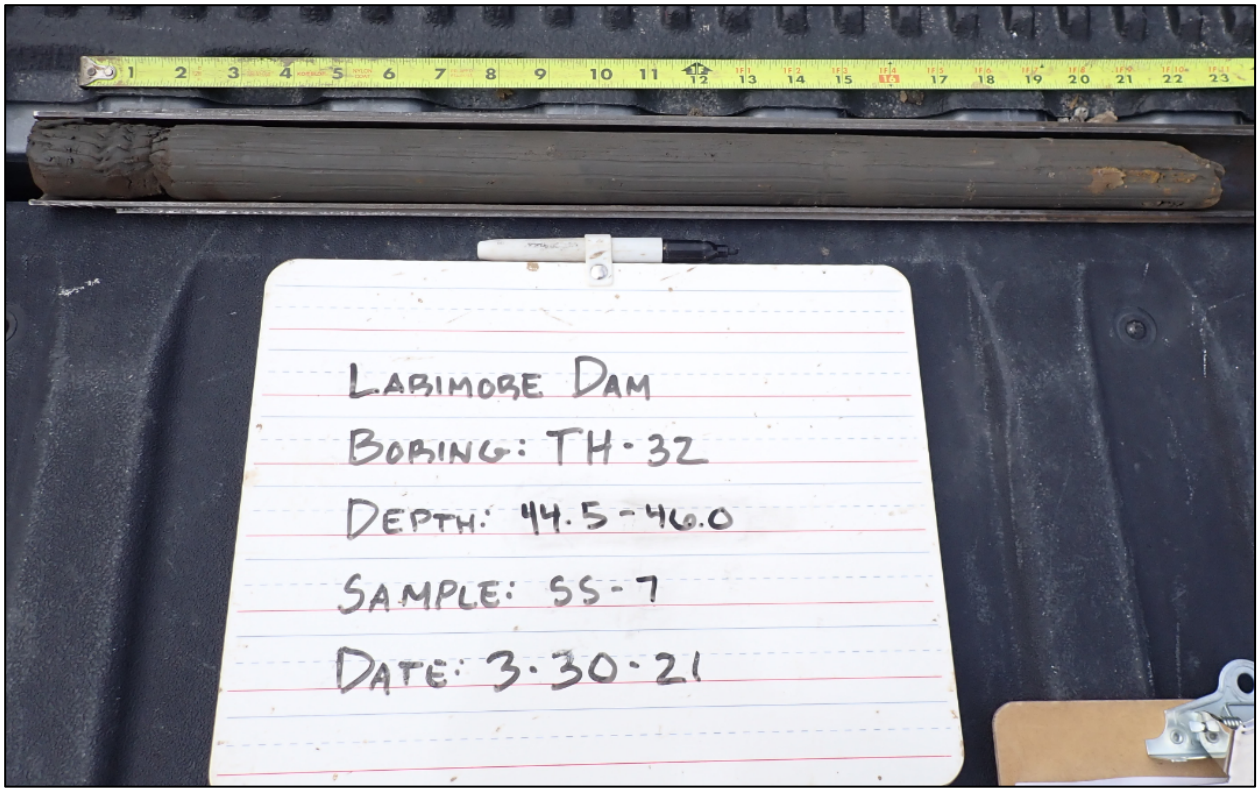

LABIMORE DAM
BORING: TH-32
DEPTH: 19.5-21.5
SAMPLE: ST-2
DATE: 3-30-21

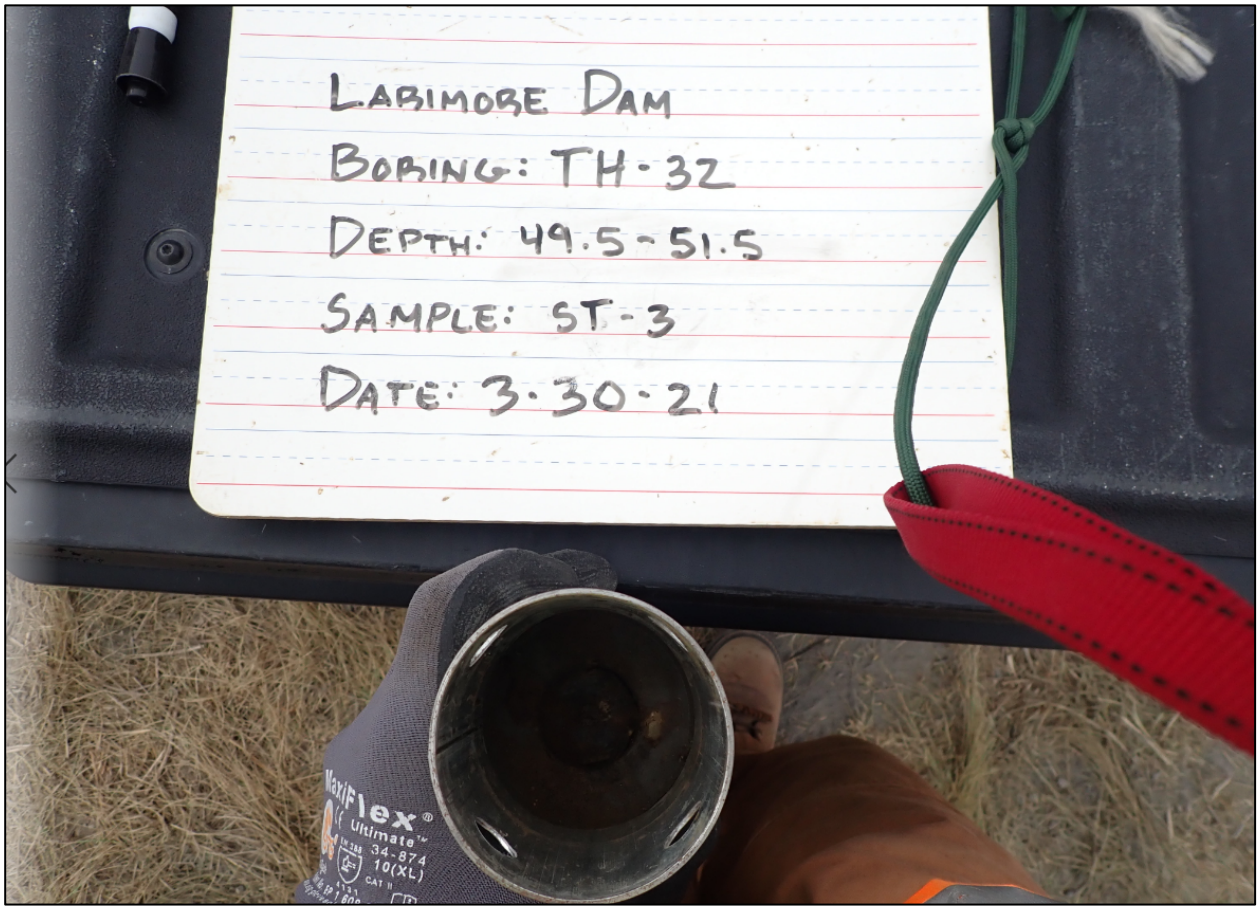

LABIMORE DAM
BORING: TH-32
DEPTH: 24.5-26.0
SAMPLE: SS-3
DATE: 3-30-21

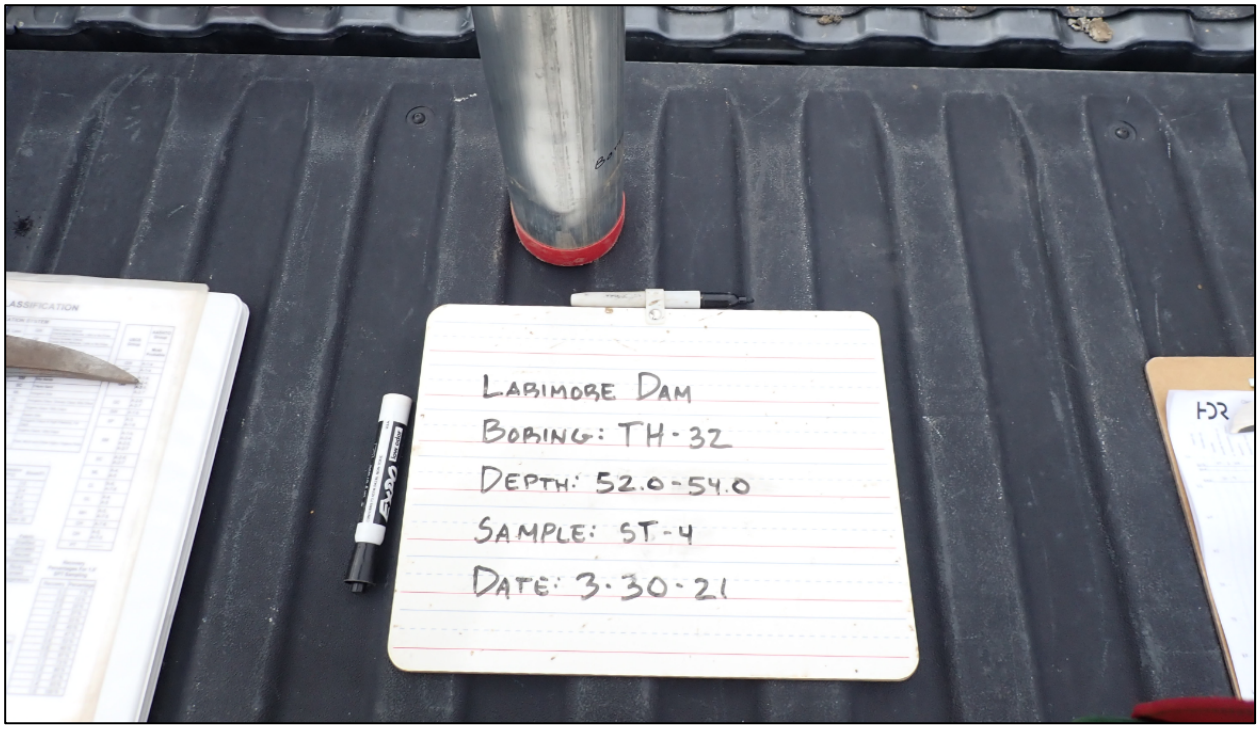

LABIMORE DAM
BORING: TH-32
DEPTH: 29.5-31.0
SAMPLE: SS-4
DATE: 3-30-21

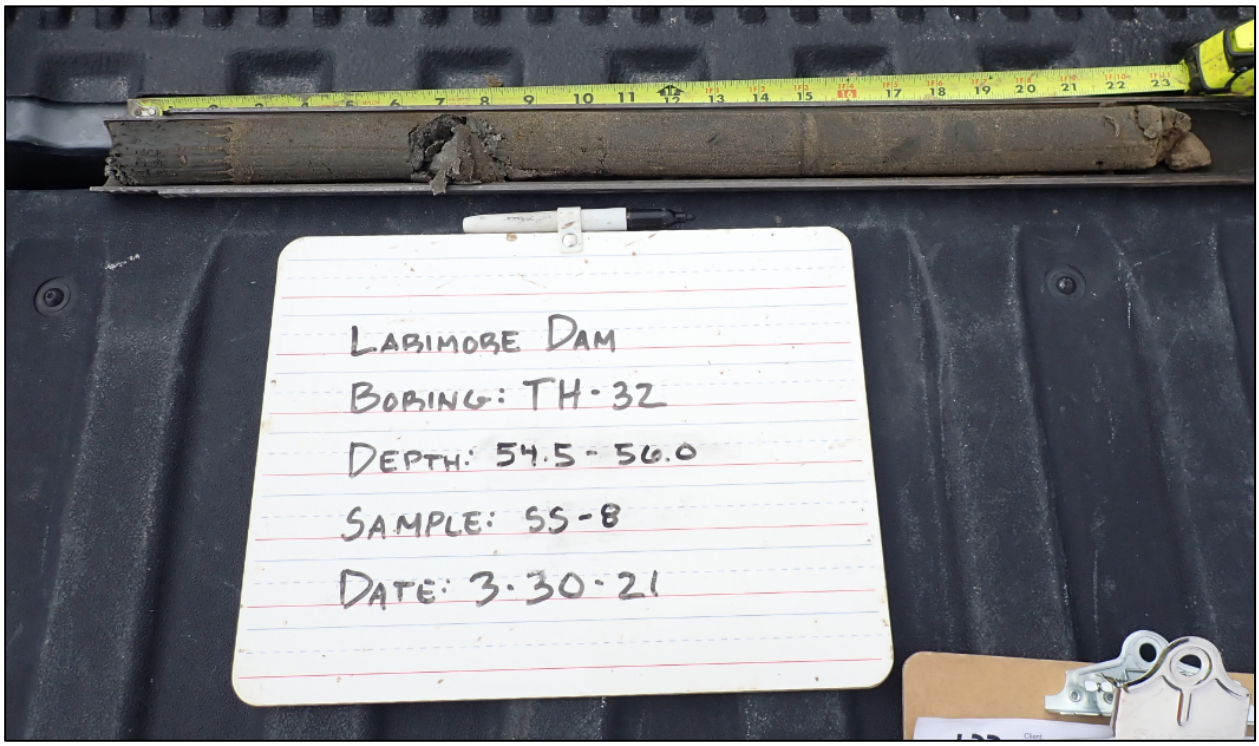

LABIMORE DAM
BORING: TH-32
DEPTH: 34.5-36.0
SAMPLE: SS-5
DATE: 3-30-21

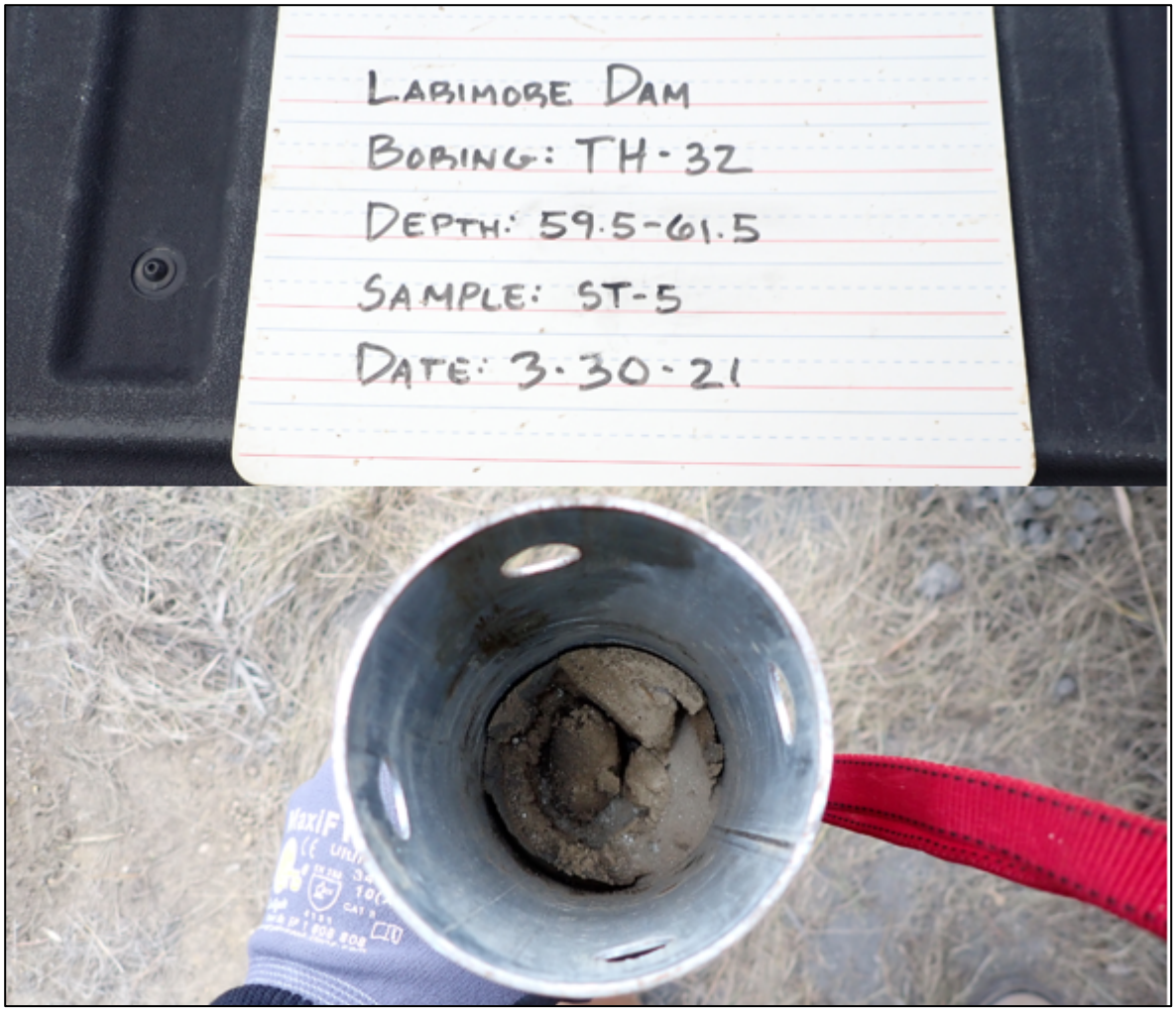

LABIMORE DAM
BORING: TH-32
DEPTH: 39.5-41.0
SAMPLE: SS-6
DATE: 3-30-21

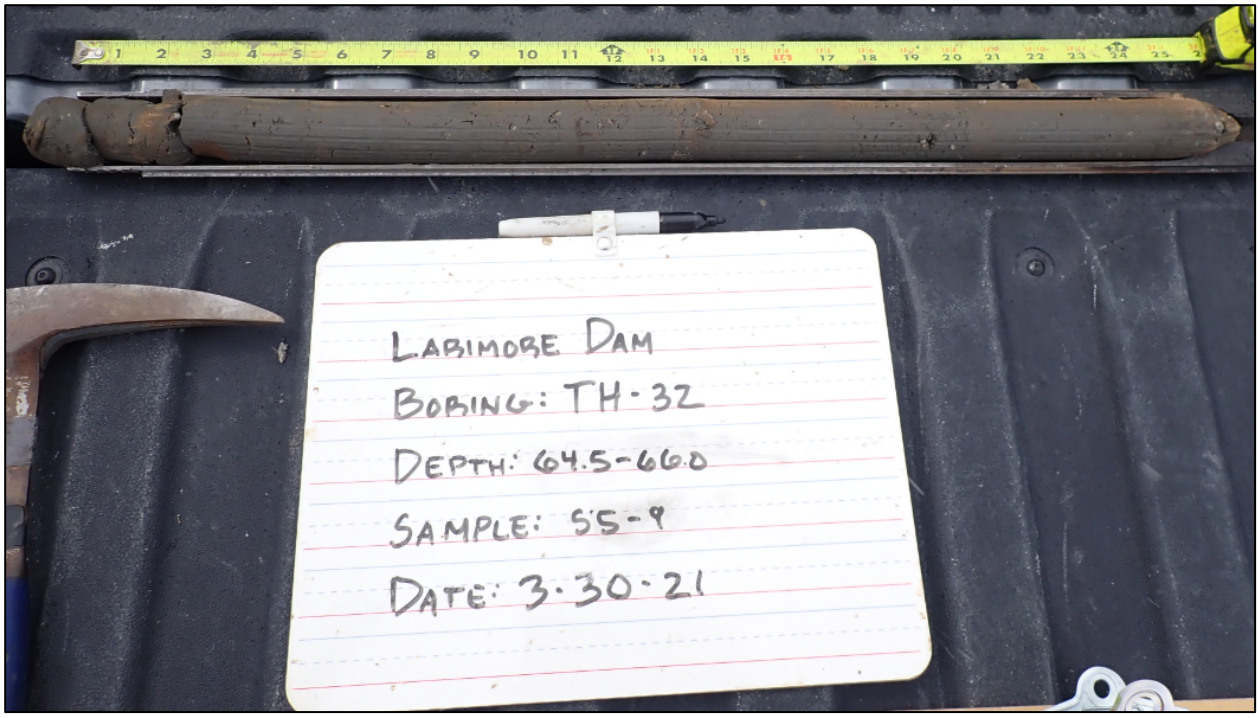

LABIMORE DAM
BORING: TH-32
DEPTH: 44.5-46.0
SAMPLE: SS-7
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 49.5-51.5
SAMPLE: ST-3
DATE: 3-30-21
MaxiFlex
Ultimate
34-874
10(XL)

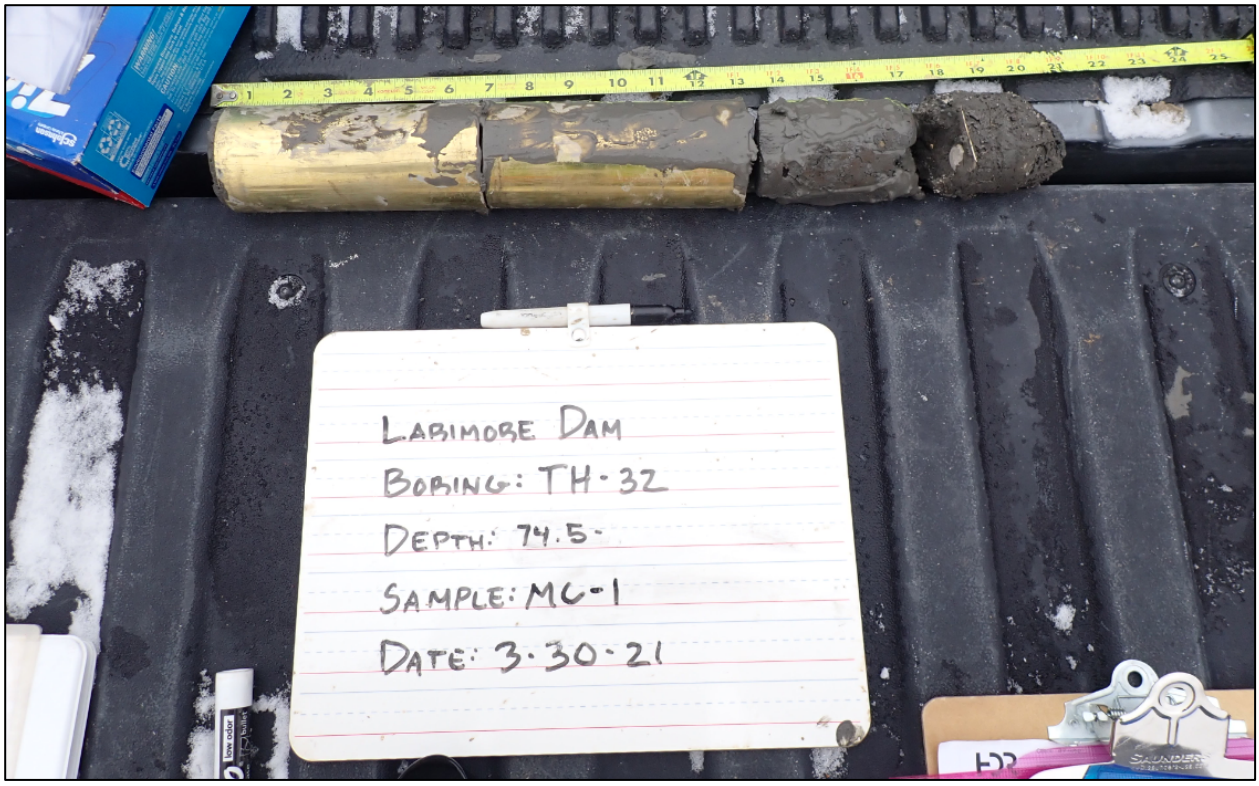

LABIMORE DAM
BORING: TH-32
DEPTH: 52.0-54.0
SAMPLE: ST-4
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 54.5-56.0
SAMPLE: SS-8
DATE: 3-30-21

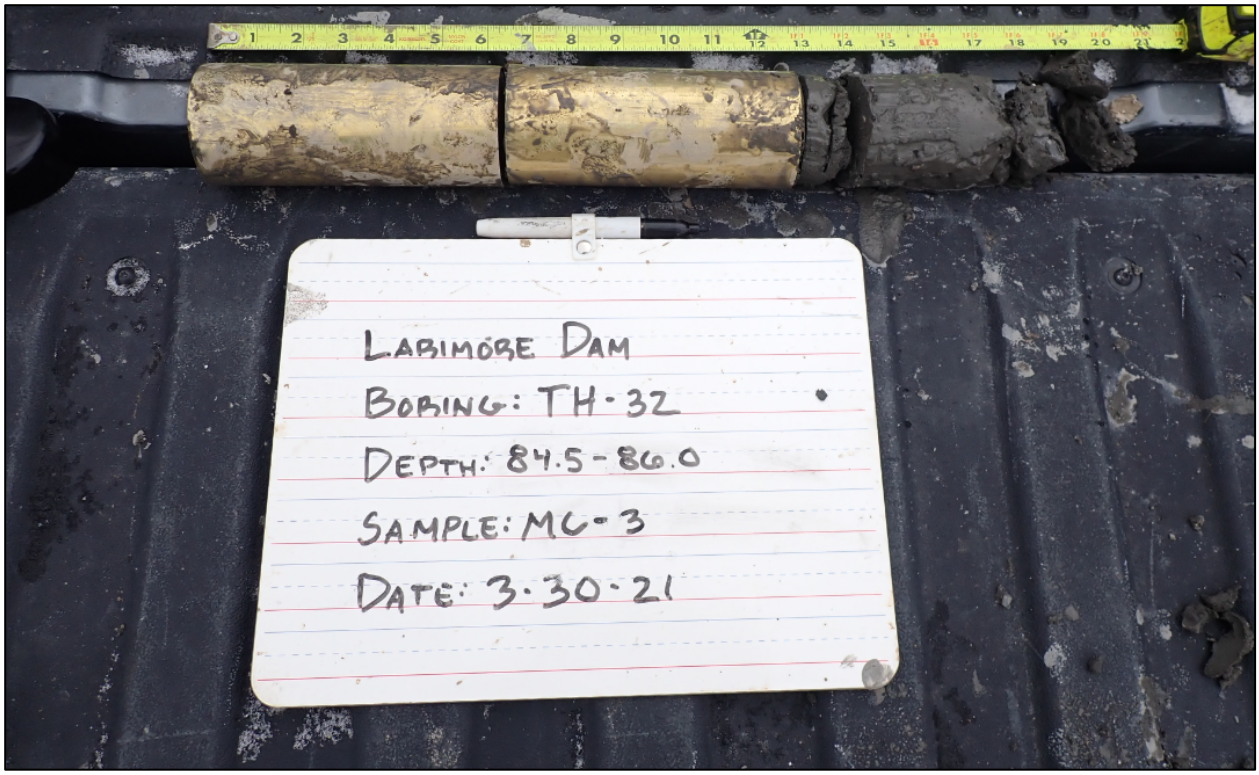

LABIMORE DAM
BORING: TH-32
DEPTH: 59.5-61.5
SAMPLE: ST-5
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 64.5-66.0
SAMPLE: SS-9
DATE: 3-30-21

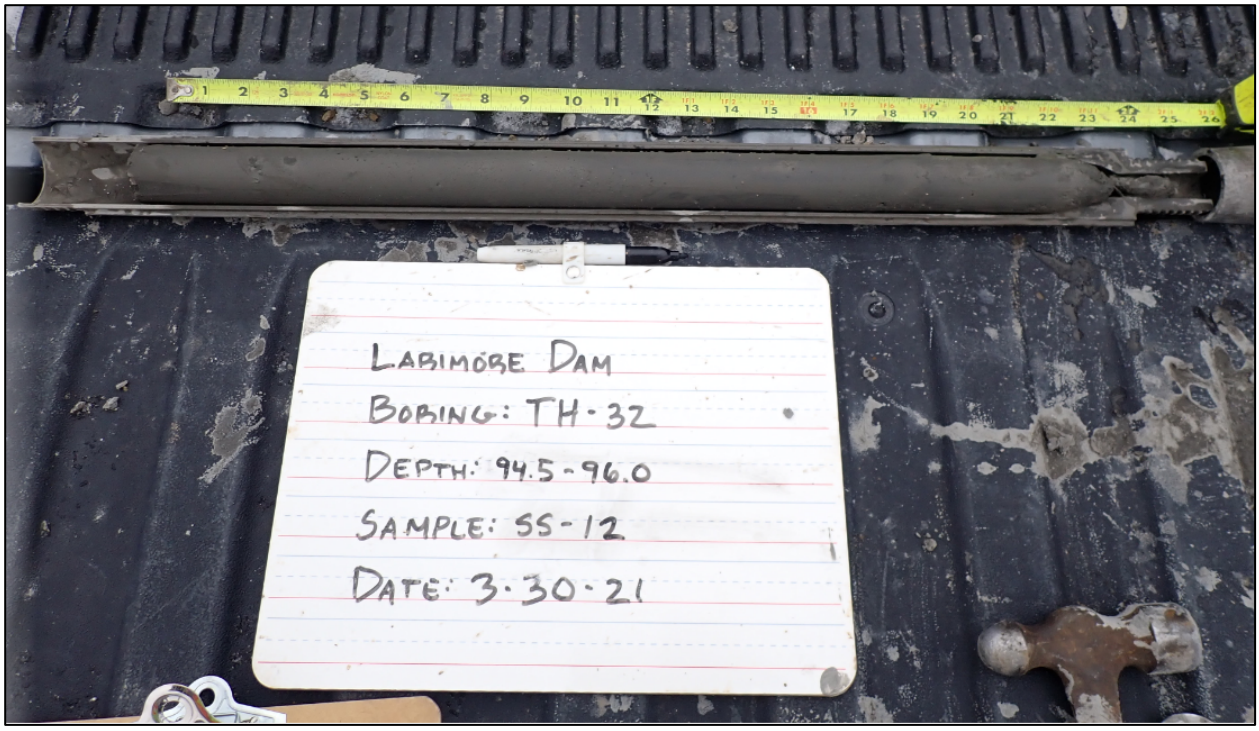

LABIMORE DAM
BORING: TH-32
DEPTH: 69.5-71.0
SAMPLE: SS-10
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 74.5-
SAMPLE: MC-1
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 79.5-81.0
SAMPLE: MC-2
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 84.5-86.0
SAMPLE: MC-3
DATE: 3-30-21


LABIMORE DAM
BORING: TH-32
DEPTH: 89.5-91.0
SAMPLE: SS-11
DATE: 3-30-21


LABIMÓRE DAM
BORING: TH-32
DEPTH: 94.5-96.0
SAMPLE: SS-12
DATE: 3-30-21


LABIMÓRE DAM
BORING: TH-32
DEPTH: 99.5-101.5
SAMPLE: ST-6
DATE: 3-30-21

A-3: 2021 Vibrating Wire Piezometer Calibration Records

GEOKON TH-31-T

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: March 17, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2113175

Temperature: 21.30 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1000.3 mbar

Cable Length: 65 feet

Technician:

FINAL TIP DEPTH: 50.14 FT

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8983	8984	8984	-0.053	-0.02	-0.033	-0.01
70.0	8327	8328	8328	70.08	0.03	70.09	0.03
140.0	7675	7675	7675	139.8	-0.03	139.8	-0.03
210.0	7019	7019	7019	210.0	0.01	210.0	0.01
279.9	6364	6365	6365	280.0	0.00	280.0	0.01
350.0	5709	5710	5710	350.0	-0.01	350.0	0.00

(kPa) Linear Gauge Factor (G): -0.1069 **(kPa/ digit)**

Polynomial Gauge factors: **A:** 8.682E-09 **B:** -0.1070 **C:**

Thermal Factor (K): -0.09051 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.01551 **(psi/ digit)**

Polynomial Gauge Factors: **A:** 1.259E-09 **B:** -0.01553 **C:**

Thermal Factor (K): -0.01313 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)$*

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$*

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8982 **Temperature:** 21.4 °C **Barometer:** 1002.8 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

This report shall not be reproduced except in full without written permission of Geokon.

INITIAL ZERO PRESSURE: 9027.852 INITIAL TEMP: 16.6°C INITIAL BAROM: 29.3 INHg

GEOKON® TH-31-M

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: March 17, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2113173

Temperature: 21.30 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1000.3 mbar

Cable Length: 80 feet

Technician:

FINAL TIP DEPTH: 605.14 FT

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8984	8986	8985	0.000	0.00	0.001	0.00
70.0	8318	8318	8318	70.01	0.01	69.98	0.00
140.0	7651	7651	7651	140.0	0.02	140.0	0.00
210.0	6984	6985	6985	210.0	0.01	209.9	-0.01
279.9	6317	6318	6318	280.0	0.02	280.0	0.01
350.0	5650	5651	5651	350.0	0.00	350.0	0.00

(kPa) Linear Gauge Factor (G): -0.1050 **(kPa/ digit)**

Polynomial Gauge factors: **A:** 2.12E-08 **B:** -0.1053 **C:**

Thermal Factor (K): -0.04500 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.01522 **(psi/ digit)**

Polynomial Gauge Factors: **A:** 3.075E-09 **B:** -0.01527 **C:**

Thermal Factor (K): -0.006527 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)^*$

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)^*$

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8986 **Temperature:** 20.9 °C **Barometer:** 1002.8 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

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INITIAL ZERO PRESSURE: 9031.433 INITIAL TEMP: 16.1°C INITIAL BAROM: 29.3 INHg

GEOKON® TH-31-B

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-700 kPa

Date of Calibration: March 10, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2111215

Temperature: 22.40 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1009.1 mbar

Cable Length: 110 feet

Technician: Kelly Rogers

FINAL TIP DEPTH: 106.14 FT

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8739	8740	8740	0.779	0.11	0.021	0.00
140.0	7936	7937	7937	139.8	-0.02	139.9	-0.01
279.9	7129	7130	7130	279.5	-0.06	280.0	0.01
419.9	6321	6321	6321	419.5	-0.06	420.0	0.01
560.1	5510	5510	5510	559.9	-0.03	560.0	-0.02
700.1	4695	4696	4696	700.9	0.12	700.1	0.01

(kPa) Linear Gauge Factor (G): -0.1731 **(kPa/ digit)**

Polynomial Gauge factors: **A:** -3.231E-07 **B:** -0.1688 **C:**

Thermal Factor (K): -0.03591 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.02511 **(psi/ digit)**

Polynomial Gauge Factors: **A:** -4.687E-08 **B:** -0.02448 **C:**

Thermal Factor (K): -0.005209 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)^*$

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)^*$

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8753 **Temperature:** 22.3 °C **Barometer:** 996.6 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

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INITIAL ZERO PRESSURE: 8773.042 INITIAL TEMP: 16.3°C INITIAL BAROM: 29.3 inHg

GEOKON® TH-32-T

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: March 17, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2113176

Temperature: 21.30 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1000.3 mbar

Cable Length: 30 feet

Technician:

FINAL TIP DEPTH: 15.38 FT

105 FT OF PVC - 4.62' STICK UP

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8932	8932	8932	0.236	0.07	0.049	0.01
70.0	8341	8342	8342	69.87	-0.03	69.86	-0.04
140.0	7747	7747	7747	140.0	0.00	140.0	0.02
210.0	7154	7154	7154	209.9	-0.02	210.0	0.00
279.9	6560	6560	6560	279.9	0.00	279.9	-0.01
350.0	5964	5964	5964	350.2	0.05	350.0	0.00

(kPa) Linear Gauge Factor (G): -0.1179 **(kPa/ digit)**

Polynomial Gauge factors: **A:** -1.255E-07 **B:** -0.1160 **C:**

Thermal Factor (K): -0.05833 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.01710 **(psi/ digit)**

Polynomial Gauge Factors: **A:** -1.82E-08 **B:** -0.01683 **C:**

Thermal Factor (K): -0.008460 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)^*$

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)^*$

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8931 **Temperature:** 21.2 °C **Barometer:** 1002.8 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

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INITIAL ZERO PRESSURE: 8971.110 INITIAL TEMP: 16.1°C INITIAL BAROM: 29.3 inHg

GEOKON® TH-32-M

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: March 17, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2113174

Temperature: 21.30 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1000.3 mbar

Cable Length: 45 feet

Technician:

FINAL TIP DEPTH: 30.38 FT

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	9143	9144	9144	-0.055	-0.02	-0.030	-0.01
70.0	8501	8501	8501	70.14	0.05	70.09	0.03
140.0	7862	7863	7863	139.9	-0.02	139.8	-0.04
210.0	7220	7220	7220	210.1	0.04	210.0	0.02
279.9	6580	6580	6580	280.0	0.02	280.0	0.01
350.0	5939	5940	5940	350.0	-0.01	350.0	0.00

(kPa) Linear Gauge Factor (G): -0.1093 **(kPa/ digit)**

Polynomial Gauge factors: **A:** 4.203E-08 **B:** -0.1099 **C:**

Thermal Factor (K): -0.08495 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.01585 **(psi/ digit)**

Polynomial Gauge Factors: **A:** 6.096E-09 **B:** -0.01594 **C:**

Thermal Factor (K): -0.01232 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)^*$

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)^*$

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 9139 **Temperature:** 21.1 °C **Barometer:** 1002.8 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

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INITIAL ZERO PRESSURE: 9185.309 INITIAL TEMP: 16.5° C INITIAL BAROM: 29.3 INHg

GEOKON TH-32-B

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-700 kPa

Date of Calibration: March 10, 2021

This calibration has been verified/validated as of 03/25/2021

Serial Number: 2111214

Temperature: 22.10 °C

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Barometric Pressure: 1011.6 mbar

Cable Length: 110 feet

Technician: Kelly Rogers

FINAL TIP DEPTH: 95.38 FT

Applied Pressure (kPa)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	9009	9010	9010	1.106	0.16	0.037	0.01
140.0	8195	8196	8196	139.6	-0.05	139.9	-0.01
279.9	7376	7377	7377	279.0	-0.13	279.9	0.00
419.9	6554	6554	6554	419.0	-0.13	419.9	0.00
560.1	5726	5727	5727	559.8	-0.03	560.1	0.01
700.1	4896	4897	4897	701.1	0.15	700.0	0.00

(kPa) Linear Gauge Factor (G): -0.1702 **(kPa/ digit)**

Polynomial Gauge factors: **A:** -4.887E-07 **B:** -0.1634 **C:**

Thermal Factor (K): 0.05897 **(kPa/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gauge Factor (G): -0.02468 **(psi/ digit)**

Polynomial Gauge Factors: **A:** -7.088E-08 **B:** -0.02370 **C:**

Thermal Factor (K): 0.008553 **(psi/ °C)**

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)$*

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$*

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 9030 **Temperature:** 22.3 °C **Barometer:** 996.6 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

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INITIAL ZERO PRESSURE: 4048.828 INITIAL TEMP: 16.3°C INITIAL BAROM: 29.3 inHg

A-4: 2021 Laboratory Data

BRAUN INTERTEC
The Science You Build On.

1502 Grumman Lane
Bismarck, ND 58504
Phone: 701-255-7180

Geotechnical Testing

Various ASTM

5/10/2021

Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

Sample Information

Metafield ID: 373941

Completed Date: 05/10/2021 **Prepared By:** Tschida, Simone T.

Laboratory Results Summary

Boring	Sample	Depth (ft)	MC (%)	Wash Loss (%)	LL	PL	PI	Organic Content %	Dry Density (pcf)	Resistivity (ohm-cm)	Q_u (tsf)	Specific Gravity
TH-31	2	9.5	16.3									
TH-31	5	24.5	16.3									
TH-32	10	69.5	14.7									
TH-32	12	94.5	26.0									
TH-31	1	34.5			29	19	10					
TH-31	2	54.5			31	19	12					
TH-31	3	74.5			40	21	19					
TH-31	4	84.5			39	21	18					
TH-32	1	9.5			29	20	9					
TH-32	2	19.5			37	24	13					
TH-32	1	74.5			45	24	21					
TH-32	2	79.5			44	26	18					
TH-32	3	84.5			45	26	19					

General

Notes: hydrometer-sieve, hydraulic conductivity, C-U triaxial compression, and crumb testing results were provided separately.

The results included in this report relate only to the items inspected or tested. Additionally, this report is for the exclusive use of the addressed parties. We assume no responsibility to other parties regarding this report. The information indicated in this report shall not be reproduced, except in full, without the prior written approval.

2020/2021 Laboratory Lab Summary

Larimore Dam

North Dakota

Boring	Sample	Sample	Top Depth	Bottom Depth	Middle Depth	Middle Elevation (NGVD29)	USCS Lab/Log			Moisture Content	Dry Density	Atterberg Limits			Grain Size Analysis					Consolidated Undrained Triaxial Compression				One-Dimensional Consolidation				Hydraulic Conductivity (cm/s)
#	#	Type	(feet)	(feet)	(feet)		Class.	Description	N Value			LL	PL	PI	%Gravel	%Sand	%Fines	% Silt	% Clay	Φ' (deg)	c' (psf)	Φ (deg)	c (psf)	Pc (psf)	Cc	Cr	e_o	
	1	SS	0	1.5	0.75	1098.49	CL	Fill- Topsoil- Sandy Lean Clay	8																			
	2	SS	4.5	6	5.25	1093.99	CL	Fill- Sandy Lean Clay	28	17.6																		
	3	SS	9.5	11	10.25	1088.99	CL	Fill- Sandy Lean Clay	12																			
	4	SS	14.5	16	15.25	1083.99	CL	Fill- Lean Clay with Sand	15	15																		
	5	SS	19.5	21	20.25	1078.99	CL	Fill- Lean Clay with Sand	12																			
	6	**TW**	**22**	**24**	**23**	1076.24	**CL**	**Fill- Lean Clay with Sand**		**14.8**	**112.4**	**33**	**18**	**15**	**0**	**24.6**	**75.4**	**55.4**	**20**					**4696**	**0.088**	**0.007**	**0.488**	**5.03E-08**
	7A	SS	24.5	26	25.25	1073.99	CL	Fill- Lean Clay with Sand	18	25.8		33	19	14			53											
	7B						CL	Fill- Sandy Lean Clay		16.8		1																
	8A	SS	29.5	31	30.25	1068.99	CL	Fill- Sandy Lean Clay	19	15.4		36	19	17	0	42.4	62	26.2	21.4								
	8B						CL	Fill- Sandy Lean Clay		14.6		34	20	14			58											
	9	SS	34.5	36	35.25	1063.99	CL	Fill- Sandy Lean Clay	15																			
	10	SS	39.5	41	40.25	1058.99	CL	Fill- Sandy Lean Clay	18	15.9																		
	11	SS	44.5	46	45.25	1053.99	CL	Fill- Sandy Lean Clay	24																			
601	12	SS	49.5	51	50.25	1048.99	CL	Fill- Sandy Lean Clay	19	14.6		32	18	14			66											
	13	SS	54.5	56	55.25	1043.99	CL	Fill- Sandy Lean Clay	25	14.4																		
	14	SS	59.5	61	60.25	1038.99	CL	Fill- Sandy Lean Clay	19																			
	15	SS	64.5	66	65.25	1033.99	CL	Fill- Sandy Lean Clay	17	16.9																		
	16	SS	69.5	71	70.25	1028.99	CL	Sandy Lean Clay (CL)	11	22.7																		
	17	**TW**	**71**	**73**	**72**	1027.24	CL	Sandy Lean Clay (CL)		**24.1**																		
	18	SS	74.5	76	75.25	1023.99	CL	Sandy Lean Clay (CL)	10																			
	19	SS	79.5	81	80.25	1018.99	CL	Sandy Lean Clay (CL)	7	21.6							73											
	20	SS	84.5	86	85.25	1013.99	CL	Sandy Lean Clay (CL)	8																			
	21*	**TW**	**86**	**88**	**87**	1012.24	**CL**	**Lean Clay with Sand (CL)**		**25.2**		**44**	**21**	**23**	**0**	**22.7**	**77**	**43.1**	**34.2**								
	22*	SS	89.5	91	90.25	1008.99	CL	Lean Clay with Sand (CL)	5																			
	23*	SS	94.5	96	95.25	1003.99	CL	Lean Clay with Sand (CL)	8	17.9		34	19	15														
	24A*	SS	99.5	101	100.25	998.99	CL	Lean Clay with Sand (CL)	26																			
	24B*						CL	Sandy Lean Clay (CL)																				
	25*	SS	104.5	106	105.25	993.99	CL	Sandy Lean Clay (CL)	55	21.6		40	26	14	0	4.1	93	67.9	28								
	1	SS	0	1.5	0.75	1066.20	CL	Fill- Topsoil- Sandy Lean Clay	15																			
	2	SS	4.5	6	5.25	1061.70	CL	Fill- Sandy Lean Clay	12	14.8																		

2020/2021 Laboratory Lab Summary

Larimore Dam

North Dakota

Boring	Sample	Sample	Top Depth	Bottom Depth	Middle Depth	Middle Elevation (NGVD29)	USCS Lab/Log			Moisture Content	Dry Density	Atterberg Limits			Grain Size Analysis					Consolidated Undrained Triaxial Compression				One-Dimensional Consolidation				Hydraulic Conductivity (cm/s)
#	#	Type	(feet)	(feet)	(feet)		Class.	Description	N Value			LL	PL	PI	%Gravel	%Sand	%Fines	% Silt	% Clay	Φ' (deg)	c' (psf)	Φ (deg)	c (psf)	Pc (psf)	Cc	Cr	e_o	
602	3	SS	9.5	11	10.25	1056.70	CL	Fill- Sandy Lean Clay	13																			
	4	SS	14.5	16	15.25	1051.70	CL	Fill- Sandy Lean Clay	14	15.4		32	22	10			66											
	5	SS	19.5	21	20.25	1046.70	CL	Fill- Sandy Lean Clay	15																			
	6	SS	24.5	26	25.25	1041.70	CL	Fill- Sandy Lean Clay	19	14.3																		
	7	SS	29.5	31	30.25	1036.70	CL	Fill- Sandy Lean Clay	17																			
	8	SS	34.5	36	35.25	1031.70	CL	Fill- Sandy Lean Clay	13	24.7		43	26	17														
	9	SS	39.5	41	40.25	1026.70	CL	Lean Clay (CL)	5																			
	10	**TW**	**41**	**43**	42	1024.95	**CL**	**Lean Clay (CL)**		**22.2**	**93.8**	**48**	**21**	**27**			**96**			**32.2**	**257**	**16.1**	**807**	**6196**	**0.189**	**0.012**	**0.783**	**3.52E-07**
	11	SS	44.5	46	45.25	1021.70	CL	Lean Clay with Sand (CL)	4																			
	12	SS	49.5	51	50.25	1016.70	CL	Lean Clay with Sand (CL)	5																			
	13	SS	54.5	56	55.25	1011.70	CL	Lean Clay with Sand (CL)	4																			
	14	SS	59.5	61	60.25	1006.70	CL	Lean Clay with Sand (CL)	7																			
	15A	SS	64.5	66	65.25	1001.70	SP	[sand seam]	11								8											
	15B						CL	Lean Clay with Sand (CL)									71											
	16	SS	69.5	71	70.25	996.70	CL	Lean Clay with Sand (CL)	37																			
	17	SS	74.5	76	75.25	991.70	CL	Lean Clay with Sand (CL)	34																			
	18	SS	79.5	81	80.25	986.70	CL	Sandy Lean Clay (CL)	32	24.3		45	25	20	0	45.4	55	28.9	25.7									
	19	SS	84.5	86	85.25	981.70	CL	Sandy Lean Clay (CL)	44																			
	20	SS	89.5	91	90.25	976.70	CL	Sandy Lean Clay (CL)	38																			
	21	SS	94.5	96	95.25	971.70	CL	Sandy Lean Clay (CL)	18	25.1		48	19	29			62											
	22	SS	99.5	101	100.25	966.70	CL	Sandy Lean Clay (CL)	22																			
201	1	SS	0	1.5	0.75		CL	Fill- Topsoil- Sandy Lean Clay	8																			
	2	SS	4.5	6	5.25	1084.47	CL	Sandy Lean Clay (CL)	11	19.8		33	19	14	0	33.2	67	38.1	28.7									
	3	SS	9.5	11	10.25	1079.47	CL	Sandy Lean Clay (CL)	7																			
	4	SS	14.5	16	15.25	1074.47	CL	Sandy Lean Clay (CL)	5																			
	5	**TW**	**16**	**18**	17.00	1072.72	**CL**	**Sandy Lean Clay (CL)**		**17.3**	**110**																	
	6A	SS	19.5	21	20.25	1069.47	CL	Sandy Lean Clay (CL)	4																			
	6B					1089.72	CL	Sandy Lean Clay (CL)																				
	7	SS	24.5	26	25.25	1064.47	CL	Sandy Lean Clay (CL)	6																			
	8	SS	29.5	31	30.25	1059.47	SP	[sand seam @ 30.5]	12																			
	9	SS	34.5	36	35.25	1054.47	CL	Sandy Lean Clay (CL)	8																			

2020/2021 Laboratory Lab Summary

Larimore Dam

North Dakota

Boring	Sample	Sample	Top Depth	Bottom Depth	Middle Depth	Middle Elevation (NGVD29)	USCS Lab/Log			Moisture Content	Dry Density	Atterberg Limits			Grain Size Analysis					Consolidated Undrained Triaxial Compression				One-Dimensional Consolidation				Hydraulic Conductivity (cm/s)
#	#	Type	(feet)	(feet)	(feet)		Class.	Description	N Value			LL	PL	PI	%Gravel	%Sand	%Fines	% Silt	% Clay	Φ' (deg)	c' (psf)	Φ (deg)	c (psf)	Pc (psf)	Cc	Cr	e_o	
	10	SS	39.5	41	40.25	1049.47	CL	Sandy Lean Clay (CL)	8																			
202	1	SS	0	1.5	0.75		CL	Fill- Topsoil- Sandy Lean Clay	5																			
	2	SS	4.5	6	5.25	1075.12	CL	Sandy Lean Clay (CL)	7																			
	3	SS	9.5	11	10.25	1070.12	CL	Sandy Lean Clay (CL)	7	19.9		32	18	14	0	42.7	57	33.6	23.7									
	4	SS	14.5	16	15.25	1065.12	CL	Sandy Lean Clay (CL)	7																			
	5	SS	19.5	21	20.25	1060.12	CL	Sandy Lean Clay (CL)	8																			
	6	**TW**	**21**	**23**	22.00	1058.37	**CL**	**Sandy Lean Clay (CL)**		**18**	**112**																	
	7A	SS	24.5	26	25.25	1055.12	CL	Sandy Lean Clay (CL)	11																			
	7B					1080.37	SP	[sand seam @ 26']																				
	8	SS	29.5	31	30.25	1050.12	CL	Sandy Lean Clay (CL)	7																			
	9	SS	34.5	36	35.25	1045.12	CL	Sandy Lean Clay (CL)	15																			
	10	SS	39.5	41	40.25	1040.12	CL	Sandy Lean Clay (CL)	9																			
203	1	SS	0	1.5	0.75		CL	Fill- Topsoil- Sandy Lean Clay	19																			
	2	SS	4.5	6	5.25	1074.13	CL	Sandy Lean Clay (CL)	13																			
	3	SS	9.5	11	10.25	1069.13	CL	Sandy Lean Clay (CL)	6																			
	4	SS	14.5	16	15.25	1064.13	CL	Sandy Lean Clay (CL)	6	17.6		34	19	15	0	44.8	55	31.5	23.7									
	5	SS	19.5	21	20.25	1059.13	CL	Sandy Lean Clay (CL)	4																			
	6	SS	24.5	26	25.25	1054.13	CL	Sandy Lean Clay (CL)	5																			
	7	SS	29.5	31	30.25	1049.13	CL	Sandy Lean Clay (CL)	7																			
	8	**TW**	**31**	**33**	32.00	1047.38	**CL**	**Sandy Lean Clay (CL)**		**15.4**	**112**																	
	9	SS	34.5	36	35.25	1044.13	CL	Sandy Lean Clay (CL)	11																			
	10	SS	39.5	41	40.25	1039.13	CL	Sandy Lean Clay (CL)	11																			
	0	SS	0	0.5	0.25			Fill - Topsoil																				
	1	SS	4.5	6	5.25	1095.40	CL	Fill - Sandy Lean Clay with gravel	26																			
	2	SS	9.5	11	10.25	1090.40	CL	Fill - Sandy Lean Clay with gravel	11	16.3																		
	3	SS	14.5	16	15.25	1085.40	CL	Fill - Sandy Lean Clay with gravel	12	15.6																		

2020/2021 Laboratory Lab Summary

Larimore Dam

North Dakota

Boring	Sample	Sample	Top Depth	Bottom Depth	Middle Depth	Middle Elevation (NGVD29)	USCS Lab/Log			Moisture Content	Dry Density	Atterberg Limits			Grain Size Analysis					Consolidated Undrained Triaxial Compression				One-Dimensional Consolidation				Hydraulic Conductivity (cm/s)
#	#	Type	(feet)	(feet)	(feet)		Class.	Description	N Value			LL	PL	PI	%Gravel	%Sand	%Fines	% Silt	% Clay	Φ' (deg)	c' (psf)	Φ (deg)	c (psf)	Pc (psf)	Cc	Cr	e_o	
	4	SS	19.5	21	20.25	1080.40	CL	Fill - Sandy Lean Clay with gravel	9	19.6																		
	5	SS	24.5	26	25.25	1075.40	CL	Fill - Sandy Lean Clay with gravel	13	16.3																		
	6	SS	29.5	31	30.25	1070.40	CL	Fill - Sandy Lean Clay with gravel	11	19..1																		
	1	**ST**	34.5	36.5	35.50	1065.15	CL	Fill - Sandy Lean Clay with gravel		17.4333	112.2	29	19	10	2.2	35.9	61.9	40.6	21.3	33.40	211.60	23.20	2205.60					
	7	SS	39.5	41	40.25	1060.40	CL	Fill - Lean Clay and gravel	15	18.3																		
	8	SS	44.5	46	45.25	1055.40	CL	Fill - Lean Clay and gravel	14	14.9																		
TH 31	9	SS	49.5	51	50.25	1048.99	CL	Fill - Lean Clay (CL) with gravel	14																			
	2	ST	54.5	56	55.25	1043.99	CL	Fill - CL Sandy Lean Clay		16.8	108	31	19	12	1.4	37.9	60.7	38.3	22.4									4.10E-08
	10	SS	59.5	61	60.25	1038.99	CL	Fill- Sandy Lean Clay and Gravel	22	13.7																		
	11	SS	64.5	66	65.25	1033.99	CL	Fill- Sandy Lean Clay and Gravel	15																			
	14	SS	69.5	71	70.25	1028.99	CL	Lean Clay (CL) and Gravel	11	18.8																		
	3	ST	74.5	76.5	75.5	1023.74	CL	CL Lean Clay		26.8	97.6	40	21	19	1	14.7	84.3	50.6	33.7									0.000000067
	13	SS	79.5	81	80.25	1018.99	CL	Lean Clay (CL) and Gravel	5	26																		
	4	**ST**	**84.5**	**86.5**	**85.5**	1013.74	CL	Lean Clay (CL) and Gravel		25.3	99.4	39	21	18	0.7	15.2	84.1	51.2	32.9	31.90	194.20	17.60	748.40					
	1	MC	89.5	90.5	91.5	1007.74	CL	Lean Clay (CL) and Gravel	13																			
	5	ST	94.5	95.5	96.5	1002.74	CL	Lean Clay (CL) with Gravel	0																			
	14	SS	100	101.5	100.75	998.49	CL	Lean Clay (CL) with Gravel	24																			
	2	**MC**	**104.5**	**106**	**105.25**	993.99	**CL**	Lean Clay (CL) with Gravel	115																			
	3	MC	109.5	111	110.25	988.99	CL	Lean Clay (CL) with Gravel	97																			
	0	SS	0	0.5	0.25			Fill - Topsoil																				
	1	SS	4.5	6	5.25	1062.22	CL	Fill - Sandy Lean Clay with gravel	15	16.3																		
	1	ST	9.5	11.5	10.50	1056.97	CL	Fill - Sandy Lean Clay with gravel		16.1	113	29	20	9	3.4	28	68.6	46.5	22.1									0.000000033
	2	SS	14.5	16	15.25	1052.22	CL	Fill - Lean Clay with sand	9																			
	2	ST	19.5	21.5	20.50	1046.97	CL	Fill - Lean Clay with sand		21	103.93	37	24	13	0.4	22.1	77.5	53	24.5	24.30	2410.00	16.40	4904.80					
	3	SS	24.5	26	25.25	1042.22	CL	Fill - Lean Clay with sand	17	16.6																		
	4	SS	29.5	31	30.25	1037.22	CL	Fill - Lean Clay trace sand/gravel	15																			

2020/2021 Laboratory Lab Summary

Larimore Dam

North Dakota

Boring	Sample	Sample	Top Depth	Bottom Depth	Middle Depth	Middle Elevation (NGVD29)	USCS Lab/Log			Moisture Content	Dry Density	Atterberg Limits			Grain Size Analysis					Consolidated Undrained Triaxial Compression				One-Dimensional Consolidation				Hydraulic Conductivity (cm/s)
#	#	Type	(feet)	(feet)	(feet)		Class.	Description	N Value			LL	PL	PI	%Gravel	%Sand	%Fines	% Silt	% Clay	Φ' (deg)	c' (psf)	Φ (deg)	c (psf)	Pc (psf)	Cc	Cr	e_o	
TH 32	**5**	**SS**	34.5	36	35.25	1032.22	CL	Fill - Lean Clay trace sand/gravel	11	25.4																		
	6	SS	39.5	41	40.25	1027.22	CL	Fill - Lean Clay trace gravel	10																			
	7	SS	44.5	46	45.25	1022.22	CL	Fill - Lean Clay and gravel	4	27																		
	3	ST	49.5	51.5	50.5	1016.97	CL	Fill - Lean Clay (CL) with gravel		25.4																		
	4	ST	54	54.5	54.25	1013.22	CL	Fill - Lean Clay (CL) with gravel																				
	8	SS	54.5	56	55.25	1012.22	CL	Fill- Sandy Lean Clay and Gravel	9																			
	5	ST	59.5	61.5	60.5	1006.97	CL	Fill- Sandy Lean Clay and Gravel		19.5																		
	9	SS	64.5	66	65.25	1002.22	CL	Lean Clay (CL) and Gravel	7																			
	10	SS	69.5	71	70.25	997.22	CL	Lean Clay (CL) and Gravel	35	14.7					2.4	34.9	62.7	42.1	20.6									
	1	MC	74.5	76.5	75.5	991.97	CL	Lean Clay (CL) and Gravel	95	24.6667	99.467	45	24	21	3.3	33.4	63.3	35.1	28.2	33.20	208.00	22.10	2798.80					
	2	**MC**	**79.5**	**81**	**80.25**	987.22	CL	Lean Clay (CL) and Gravel	52	25.1	96.1	44	26	18	1.5	34	64.5	35.8	28.7									0.000000047
	3	MC	84.5	86	91.5	975.97	CL	Lean Clay (CL) and Gravel	46	26.6667	95.133	45	26	19	3	34.7	62.3	34.8	27.5	32.70	453.60	21.80	1760.20					
	11	SS	89.5	91	96.5	970.97	CL	Lean Clay (CL) with Gravel	13																			
	12	SS	94.5	96	95.25	972.22	CL	Lean Clay (CL) with Gravel	14	26																		
	6	**ST**	**99.5**	**101.5**	**100.5**	966.97	**CL**	Lean Clay (CL) with Gravel																				

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Hydrometer And Sieve Analysis

ASTM D422

5/11/2021

1502 Grumman Lane
Bismarck, ND 58504
Phone: 701-255-7180

Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

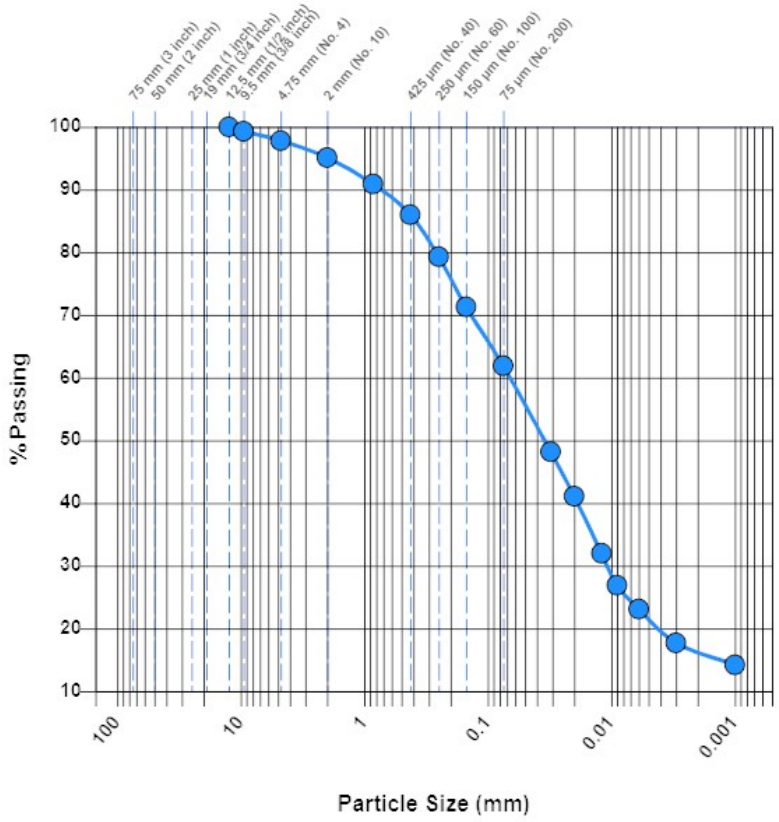
Sample Information

Sample Number:	373944	**Depth (ft):**	34.5-36
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.3	-
4.75 mm (No. 4)	97.8	-
2 mm (No. 10)	95.1	-
850 µm (No. 20)	90.9	-
425 µm (No. 40)	86.0	-
250 µm (No. 60)	79.3	-
150 µm (No. 100)	71.3	-
75 µm (No. 200)	61.9	-
31.0 (µm)	48.2	-
20.2 (µm)	41.1	-
12.0 (µm)	32.0	-
8.7 (µm)	26.9	-
6.2 (µm)	23.1	-
3.1 (µm)	17.7	-
1.4 (µm)	14.2	-



Soil Classification: CL Sandy lean clay

Gravel (%):	2.2	**Sand (%):**	35.9	**Silt (%):**	40.6	**Clay (%):**	21.3
D_{60} (µm):	68.9	**D_{30} (µm):**	10.8				

General

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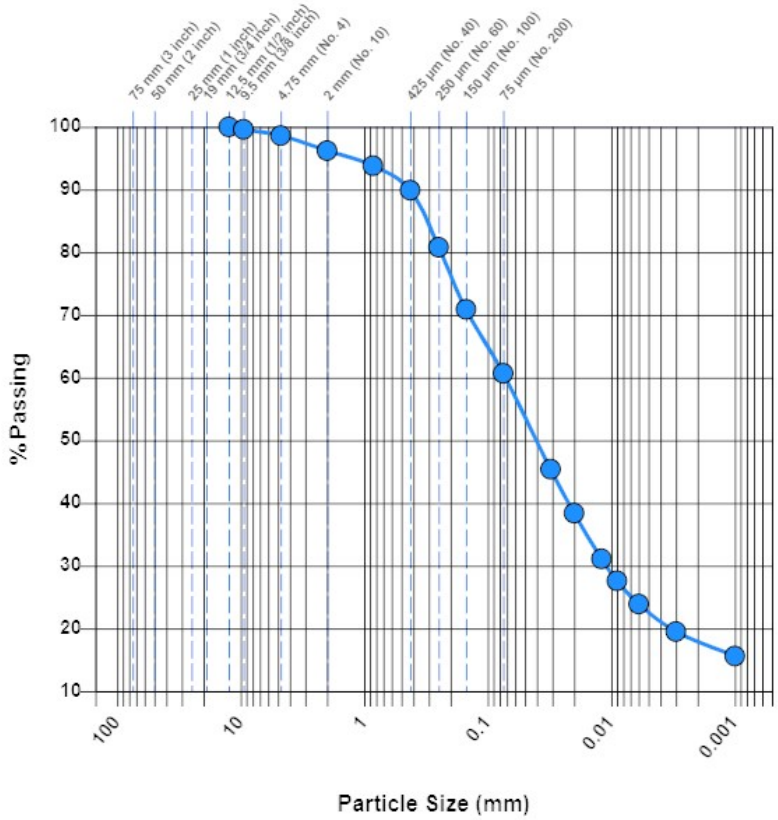
Sample Information

Sample Number:	373945	**Depth (ft):**	54.5-56
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.6	-
4.75 mm (No. 4)	98.6	-
2 mm (No. 10)	96.2	-
850 µm (No. 20)	93.8	-
425 µm (No. 40)	89.9	-
250 µm (No. 60)	80.8	-
150 µm (No. 100)	70.9	-
75 µm (No. 200)	60.7	-
31.2 (µm)	45.4	-
20.3 (µm)	38.4	-
12.0 (µm)	31.1	-
8.6 (µm)	27.6	-
6.2 (µm)	23.9	-
3.0 (µm)	19.5	-
1.4 (µm)	15.6	-



Soil Classification: CL Sandy lean clay

Gravel (%):	1.4	**Sand (%):**	37.9	**Silt (%):**	38.3	**Clay (%):**	22.4
D_{60} (µm):	73.0	**D_{30} (µm):**	11.1				

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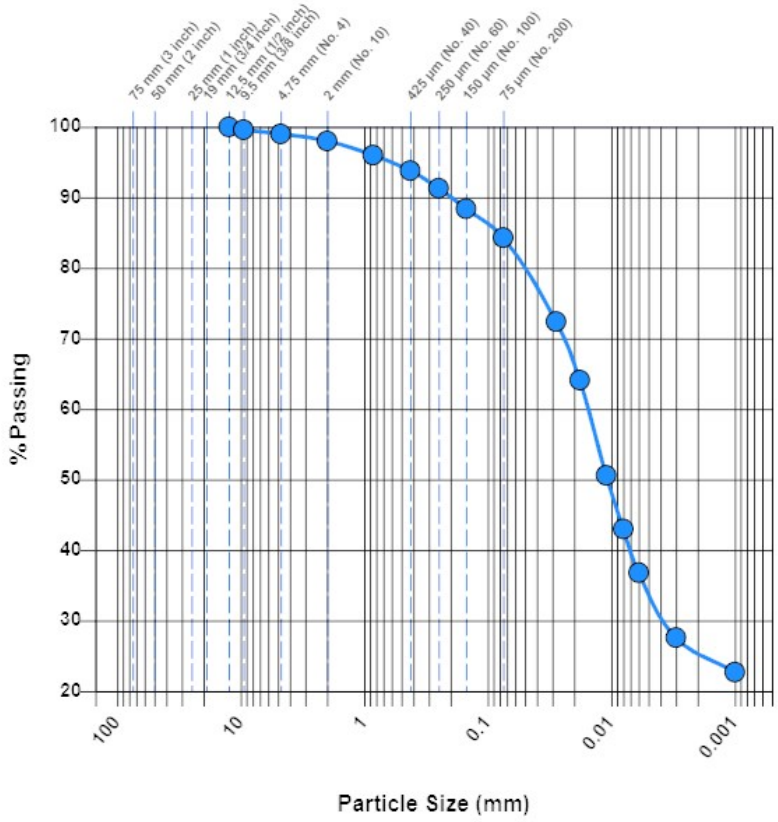
Sample Information

Sample Number:	373946	**Depth (ft):**	74.5-76
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.6	-
4.75 mm (No. 4)	99.0	-
2 mm (No. 10)	98.0	-
850 µm (No. 20)	96.0	-
425 µm (No. 40)	93.8	-
250 µm (No. 60)	91.3	-
150 µm (No. 100)	88.4	-
75 µm (No. 200)	84.3	-
28.0 (µm)	72.4	-
18.4 (µm)	64.1	-
11.2 (µm)	50.6	-
8.2 (µm)	43.0	-
5.9 (µm)	36.8	-
3.0 (µm)	27.6	-
1.3 (µm)	22.7	-



Soil Classification: CL Lean clay

Gravel (%):	1.0	**Sand (%):**	14.7	**Silt (%):**	50.6	**Clay (%):**	33.7
D_{60} (µm):	15.9	**D_{30} (µm):**	3.8				

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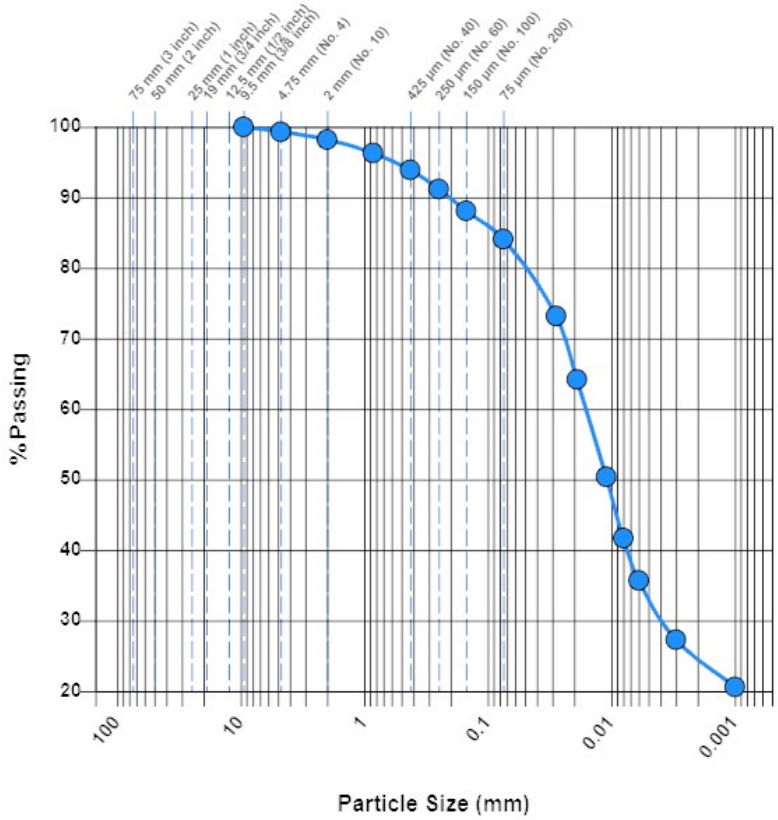
Sample Information

Sample Number:	373947	**Depth (ft):**	84.5-86
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
9.5 mm (3/8 inch)	100.0	-
4.75 mm (No. 4)	99.3	-
2 mm (No. 10)	98.2	-
850 µm (No. 20)	96.3	-
425 µm (No. 40)	93.9	-
250 µm (No. 60)	91.2	-
150 µm (No. 100)	88.1	-
75 µm (No. 200)	84.1	-
28.1 (µm)	73.2	-
18.5 (µm)	64.2	-
11.3 (µm)	50.4	-
8.3 (µm)	41.7	-
5.9 (µm)	35.7	-
3.0 (µm)	27.3	-
1.4 (µm)	20.6	-



Soil Classification: CL Lean clay with sand

Gravel (%):	0.7	**Sand (%):**	15.2	**Silt (%):**	51.2	**Clay (%):**	32.9
D_{60} (µm):	16.6	**D_{30} (µm):**	4.0				

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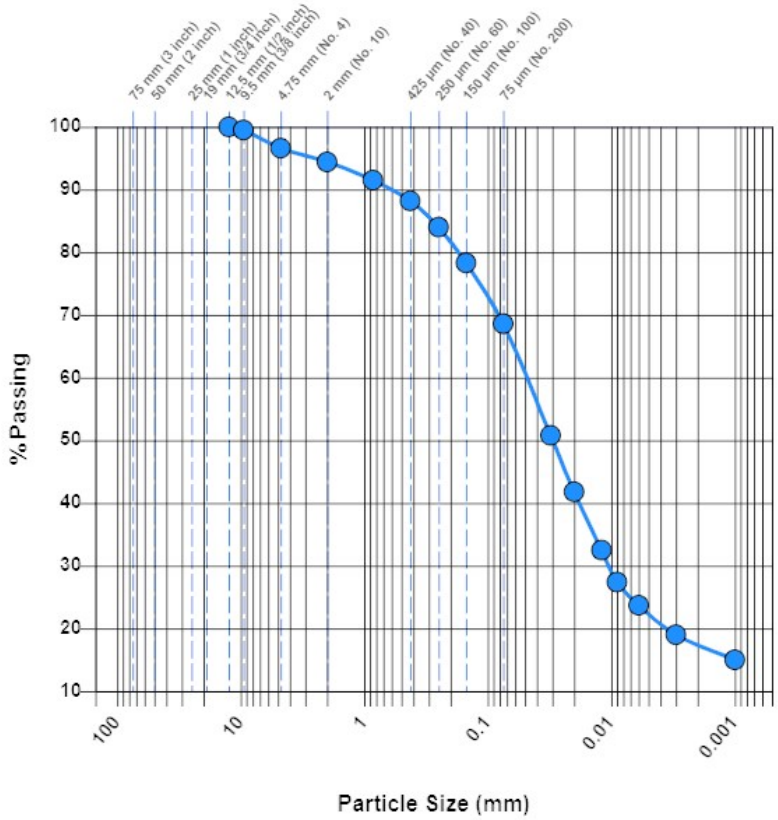
Sample Information

Sample Number:	373948	**Depth (ft):**	9.5-11
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.5	-
4.75 mm (No. 4)	96.6	-
2 mm (No. 10)	94.4	-
850 µm (No. 20)	91.5	-
425 µm (No. 40)	88.2	-
250 µm (No. 60)	84.0	-
150 µm (No. 100)	78.3	-
75 µm (No. 200)	68.6	-
30.7 (µm)	50.8	-
20.1 (µm)	41.8	-
12.0 (µm)	32.5	-
8.5 (µm)	27.4	-
6.2 (µm)	23.7	-
3.1 (µm)	19.0	-
1.4 (µm)	15.0	-



Soil Classification: CL Sandy lean clay

Gravel (%):	3.4	**Sand (%):**	28.0	**Silt (%):**	46.5	**Clay (%):**	22.1
D_{60} (µm):	53.7	**D_{30} (µm):**	10.5				

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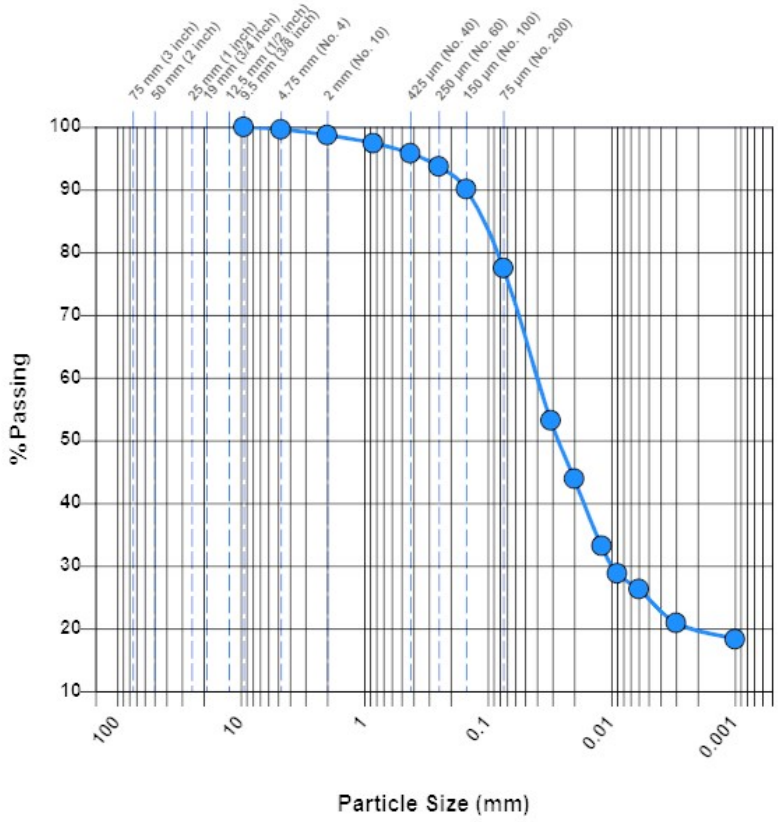
Sample Information

Sample Number:	373949	**Depth (ft):**	19.5-21
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
9.5 mm (3/8 inch)	100.0	-
4.75 mm (No. 4)	99.6	-
2 mm (No. 10)	98.7	-
850 µm (No. 20)	97.4	-
425 µm (No. 40)	95.8	-
250 µm (No. 60)	93.7	-
150 µm (No. 100)	90.1	-
75 µm (No. 200)	77.5	-
30.6 (µm)	53.2	-
20.0 (µm)	43.9	-
11.6 (µm)	33.2	-
8.6 (µm)	28.8	-
6.1 (µm)	26.3	-
3.0 (µm)	20.9	-
1.4 (µm)	18.3	-



Soil Classification: CL Lean clay with sand

Gravel (%):	0.4	**Sand (%):**	22.1	**Silt (%):**	53.0	**Clay (%):**	24.5
D_{60} (µm):	43.3	**D_{30} (µm):**	9.8				

General

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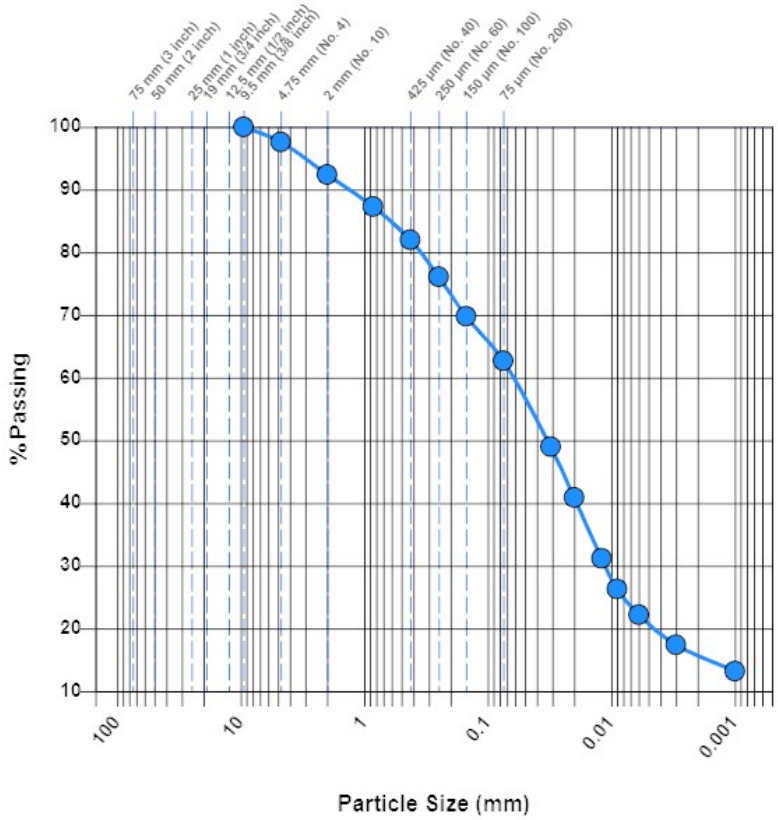
Sample Information

Sample Number:	373950	**Depth (ft):**	69.5-71
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
9.5 mm (3/8 inch)	100.0	-
4.75 mm (No. 4)	97.6	-
2 mm (No. 10)	92.4	-
850 µm (No. 20)	87.3	-
425 µm (No. 40)	82.0	-
250 µm (No. 60)	76.1	-
150 µm (No. 100)	69.8	-
75 µm (No. 200)	62.7	-
31.3 (µm)	49.0	-
20.4 (µm)	40.9	-
12.2 (µm)	31.2	-
8.5 (µm)	26.3	-
6.3 (µm)	22.2	-
3.0 (µm)	17.4	-
1.4 (µm)	13.2	-



Soil Classification: CL Sandy lean clay

Gravel (%):	2.4	**Sand (%):**	34.9	**Silt (%):**	42.1	**Clay (%):**	20.6
D_{60} (µm):	66.3	**D_{30} (µm):**	11.3				

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Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

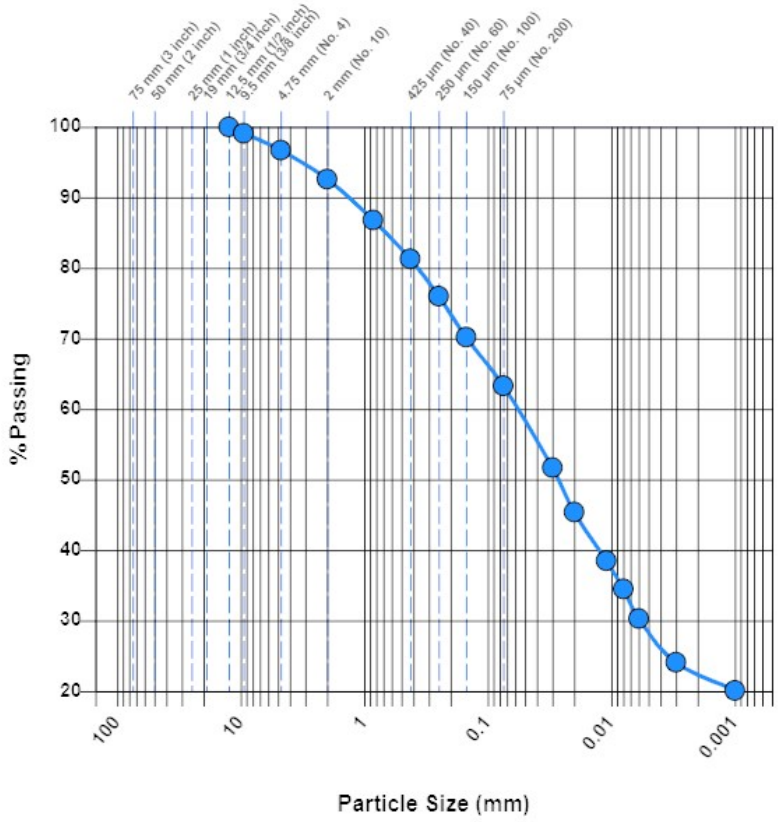
Sample Information

Sample Number:	373951	**Depth (ft):**	74.5-76
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.1	-
4.75 mm (No. 4)	96.7	-
2 mm (No. 10)	92.6	-
850 µm (No. 20)	86.8	-
425 µm (No. 40)	81.3	-
250 µm (No. 60)	76.0	-
150 µm (No. 100)	70.2	-
75 µm (No. 200)	63.3	-
30.4 (µm)	51.7	-
19.7 (µm)	45.4	-
11.3 (µm)	38.5	-
8.4 (µm)	34.5	-
6.0 (µm)	30.3	-
3.0 (µm)	24.1	-
1.4 (µm)	20.1	-



Soil Classification: CL Sandy lean clay

Gravel (%):	3.3	**Sand (%):**	33.4	**Silt (%):**	35.1	**Clay (%):**	28.2
D_{60} (µm):	62.2	**D_{30} (µm):**	5.9				

General

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Hydrometer And Sieve Analysis

ASTM D422

5/11/2021

1502 Grumman Lane
Bismarck, ND 58504
Phone: 701-255-7180

Client:

HDR, Inc.
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St Louis Park, MN 55416

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Grand Forks, ND

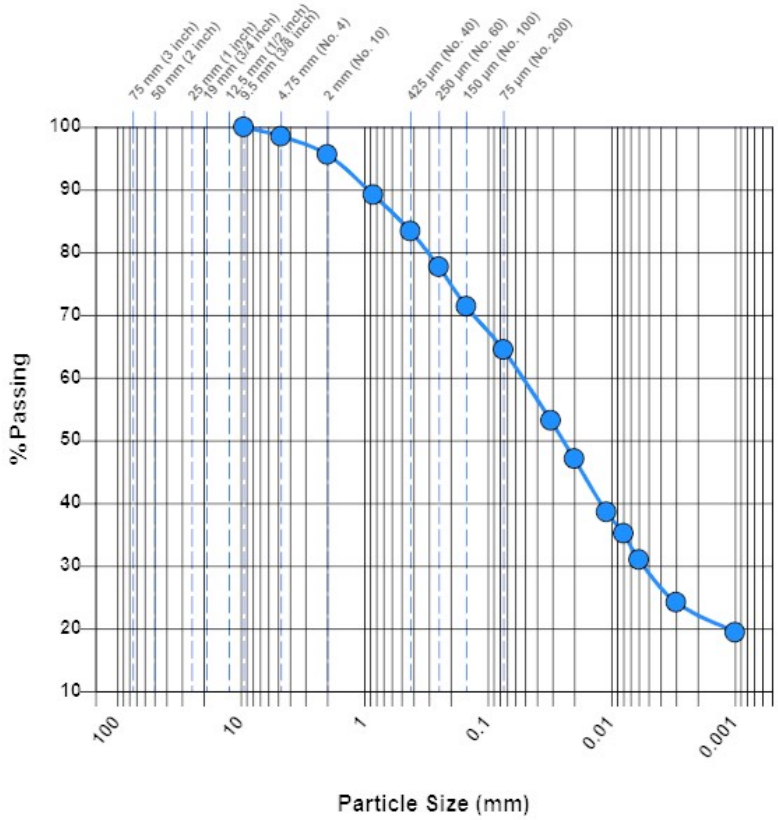
Sample Information

Sample Number:	373952	**Depth (ft):**	79.5-81
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
9.5 mm (3/8 inch)	100.0	-
4.75 mm (No. 4)	98.5	-
2 mm (No. 10)	95.6	-
850 µm (No. 20)	89.2	-
425 µm (No. 40)	83.4	-
250 µm (No. 60)	77.7	-
150 µm (No. 100)	71.4	-
75 µm (No. 200)	64.5	-
30.6 (µm)	53.2	-
19.8 (µm)	47.1	-
11.4 (µm)	38.6	-
8.4 (µm)	35.2	-
6.0 (µm)	31.0	-
3.0 (µm)	24.2	-
1.4 (µm)	19.4	-



Soil Classification: CL Sandy lean clay

Gravel (%):	1.5	**Sand (%):**	34.0	**Silt (%):**	35.8	**Clay (%):**	28.7
D_{60} (µm):	57.5	**D_{30} (µm):**	5.6				

General

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Grand Forks, ND

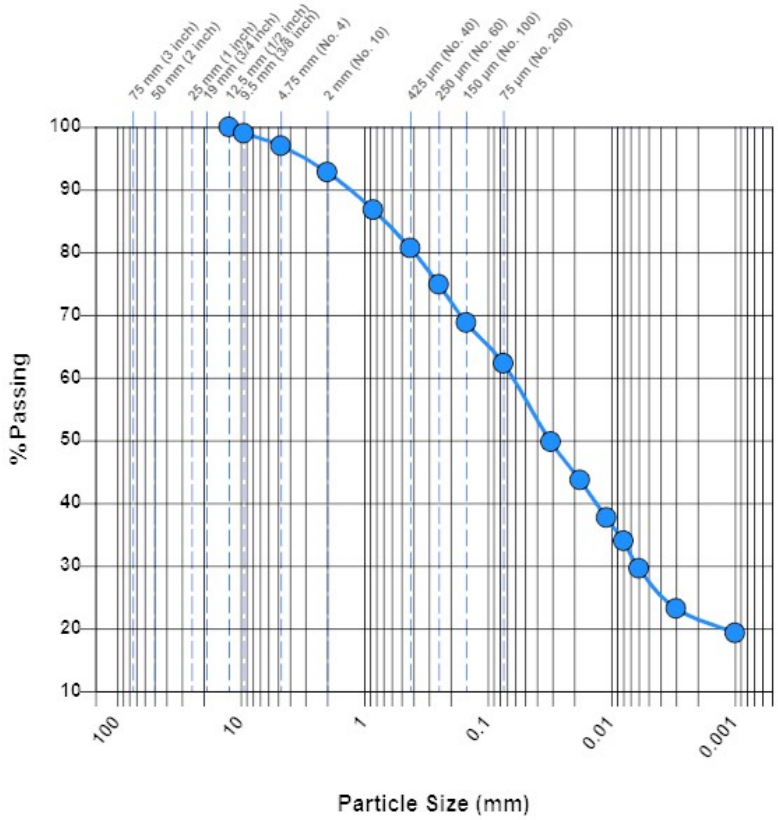
Sample Information

Sample Number:	373953	**Depth (ft):**	84.5-86
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	99.0	-
4.75 mm (No. 4)	97.0	-
2 mm (No. 10)	92.8	-
850 µm (No. 20)	86.8	-
425 µm (No. 40)	80.7	-
250 µm (No. 60)	74.9	-
150 µm (No. 100)	68.8	-
75 µm (No. 200)	62.3	-
30.7 (µm)	49.8	-
18.2 (µm)	43.7	-
11.4 (µm)	37.7	-
8.4 (µm)	34.0	-
6.0 (µm)	29.6	-
3.0 (µm)	23.2	-
1.3 (µm)	19.3	-



Soil Classification: CL Sandy lean clay

Gravel (%):	3.0	**Sand (%):**	34.7	**Silt (%):**	34.8	**Clay (%):**	27.5
D_{60} (µm):	66.9	**D_{30} (µm):**	6.2				

General

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Hydrometer And Sieve Analysis

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Grand Forks, ND

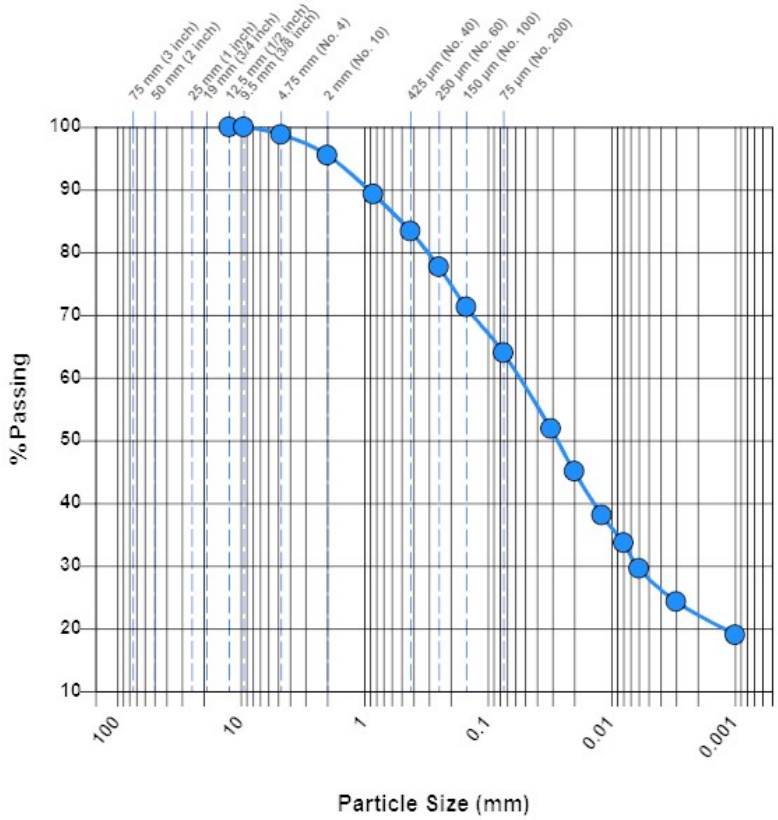
Sample Information

Sample Number:	373954	**Depth (ft):**	94.5-96
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/10/2021	**Tested By:**	Tschida, Simone T.

Laboratory Data

Sieve-Hydrometer Analysis

Particle Size	% Passing	Specification
12.5 mm (1/2 inch)	100.0	-
9.5 mm (3/8 inch)	100.0	-
4.75 mm (No. 4)	98.8	-
2 mm (No. 10)	95.5	-
850 µm (No. 20)	89.3	-
425 µm (No. 40)	83.4	-
250 µm (No. 60)	77.7	-
150 µm (No. 100)	71.3	-
75 µm (No. 200)	64.0	-
31.1 (µm)	51.9	-
20.1 (µm)	45.1	-
11.9 (µm)	38.1	-
8.4 (µm)	33.7	-
6.1 (µm)	29.6	-
3.0 (µm)	24.3	-
1.3 (µm)	19.0	-



Soil Classification: CL Sandy lean clay

Gravel (%):	1.2	**Sand (%):**	34.8	**Silt (%):**	36.2	**Clay (%):**	27.8
D_{60} (µm):	60.5	**D_{30} (µm):**	6.2				

General

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Hydraulic Conductivity

ASTM D5084

1502 Grumman Lane
Bismarck, ND 58504
Phone: 701-255-7180

Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

Sample Information

Sample Number:	373955	**Depth (ft):**	54.5-56
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/11/2021	**Tested By:**	Seokaran, Kanhai

Laboratory Data

Type Of Specimen:	Intact	**Back Pressure (psi):**	91.00	
Permeant Liquid:	Water	**Specific Gravity:**	2.70	(Assumed)
Saturation B Coefficient:	1.00	**Effective Pressure (psi):**	8.00	

Method: Method C Falling Head Rising Tailwater

Elapsed Time (sec)	Average Test Temp. (°C)	Influent Reading Initial (cm)	Influent Reading Final (cm)	Effluent Reading Initial (cm)	Effluent Reading Final (cm)	Average Head Loss (cm)	Hydraulic Gradient	Hydraulic Conductivity @ 20 °C (cm/sec)
32580	22.0	12.90	12.40	11.20	11.70	212.2	29.77	4.4E-08
14460	22.0	12.40	12.20	11.80	12.00	211.4	29.66	4.0E-08
5940	22.0	12.20	12.10	12.00	12.10	211.1	29.61	4.9E-08
66360	22.0	12.10	11.40	12.10	12.80	210.3	29.50	3.1E-08

Average Of Last Four Hydraulic Conductivity (cm/sec): 4.1E-08

	Initial	Final
Saturation (%)	80.7	97.5
Moisture Content (%):	16.8	17.7
Dry Density Of Specimen (pcf):	108.0	113.1

Soil Classification: CL Sandy lean clay

General

Remarks: Control parameters meet the testing requirements.

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Hydraulic Conductivity

ASTM D5084

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Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

Sample Information

Sample Number:	373956	**Depth (ft):**	74.5-76
Boring Number:	TH-31	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/11/2021	**Tested By:**	Seokaran, Kanhai

Laboratory Data

Type Of Specimen:	Intact	**Back Pressure (psi):**	91.00	
Permeant Liquid:	Water	**Specific Gravity:**	2.70	(Assumed)
Saturation B Coefficient:	1.00	**Effective Pressure (psi):**	8.00	

Method: Method C Falling Head Rising Tailwater

Elapsed Time (sec)	Average Test Temp. (^{o}C)	Influent Reading Initial (cm)	Influent Reading Final (cm)	Effluent Reading Initial (cm)	Effluent Reading Final (cm)	Average Head Loss (cm)	Hydraulic Gradient	Hydraulic Conductivity @ 20 ^{o}C (cm/sec)
14160	22.0	15.00	14.60	9.70	10.00	216.0	30.34	7.5E-08
14280	22.0	15.30	15.00	9.30	9.60	216.7	30.45	6.4E-08
9540	22.0	15.50	15.30	9.10	9.30	217.2	30.52	6.3E-08
66420	22.0	17.00	15.50	7.60	9.10	218.9	30.76	6.8E-08

Average Of Last Four Hydraulic Conductivity (cm/sec): 6.7E-08

	Initial	Final
Saturation (%)	99.5	100.2
Moisture Content (%):	26.8	27.4
Dry Density Of Specimen (pcf):	97.6	97.0

Soil Classification: CL Lean clay

General

Remarks: Control parameters meet the testing requirements.

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Phone: 701-255-7180

Client:

HDR, Inc.
1601 Utica Avenue SouthSuite 600
St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

Sample Information

Sample Number:	373957	**Depth (ft):**	9.5-11
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/11/2021	**Tested By:**	Seokaran, Kanhai

Laboratory Data

Type Of Specimen:	Intact	**Back Pressure (psi):**	91.00	
Permeant Liquid:	Water	**Specific Gravity:**	2.70	(Assumed)
Saturation B Coefficient:	1.00	**Effective Pressure (psi):**	8.00	

Method: Method C Falling Head Rising Tailwater

Elapsed Time (sec)	Average Test Temp. (^{o}C)	Influent Reading Initial (cm)	Influent Reading Final (cm)	Effluent Reading Initial (cm)	Effluent Reading Final (cm)	Average Head Loss (cm)	Hydraulic Gradient	Hydraulic Conductivity @ 20 ^{o}C (cm/sec)
7140	22.0	13.90	13.80	11.10	11.20	213.7	34.71	3.5E-08
6420	22.0	13.80	13.70	11.20	11.30	213.5	34.67	3.9E-08
7380	22.0	13.80	13.70	11.30	11.40	213.4	34.66	3.4E-08
44160	22.0	13.70	13.30	11.30	11.80	213.0	34.58	2.6E-08

Average Of Last Four Hydraulic Conductivity (cm/sec): 3.3E-08

	Initial	Final
Saturation (%)	88.5	94.8
Moisture Content (%):	16.1	17.3
Dry Density Of Specimen (pcf):	113.0	112.9

Soil Classification: CL Sandy lean clay

General

Remarks: Control parameters meet the testing requirements.

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St Louis Park, MN 55416

Project:

B2102974
Triaxial Compressive Strength Testing
Grand Forks, ND

Sample Information

Sample Number:	373959	**Depth (ft):**	79.5-81
Boring Number:	TH-32	**Sampled By:**	Drill Crew
Sample Date:	04/09/2021		
Received Date:	05/10/2021	**Lab:**	11001 Hampshire Ave S, Bloomington, MN
Tested Date:	05/11/2021	**Tested By:**	Seokaran, Kanhai

Laboratory Data

Type Of Specimen:	Intact	**Back Pressure (psi):**	91.00	
Permeant Liquid:	Water	**Specific Gravity:**	2.70	(Assumed)
Saturation B Coefficient:	1.00	**Effective Pressure (psi):**	8.00	

Method: Method C Falling Head Rising Tailwater

Elapsed Time (sec)	Average Test Temp. (°C)	Influent Reading Initial (cm)	Influent Reading Final (cm)	Effluent Reading Initial (cm)	Effluent Reading Final (cm)	Average Head Loss (cm)	Hydraulic Gradient	Hydraulic Conductivity @ 20 °C (cm/sec)
6000	22.0	14.60	14.50	14.60	14.70	210.9	29.64	4.8E-08
5460	22.0	14.60	14.50	14.60	14.70	210.9	29.64	5.3E-08
6360	22.0	14.50	14.40	14.70	14.80	210.7	29.62	4.6E-08
7380	22.0	14.50	14.40	14.70	14.80	210.7	29.62	3.9E-08

Average Of Last Four Hydraulic Conductivity (cm/sec): 4.7E-08

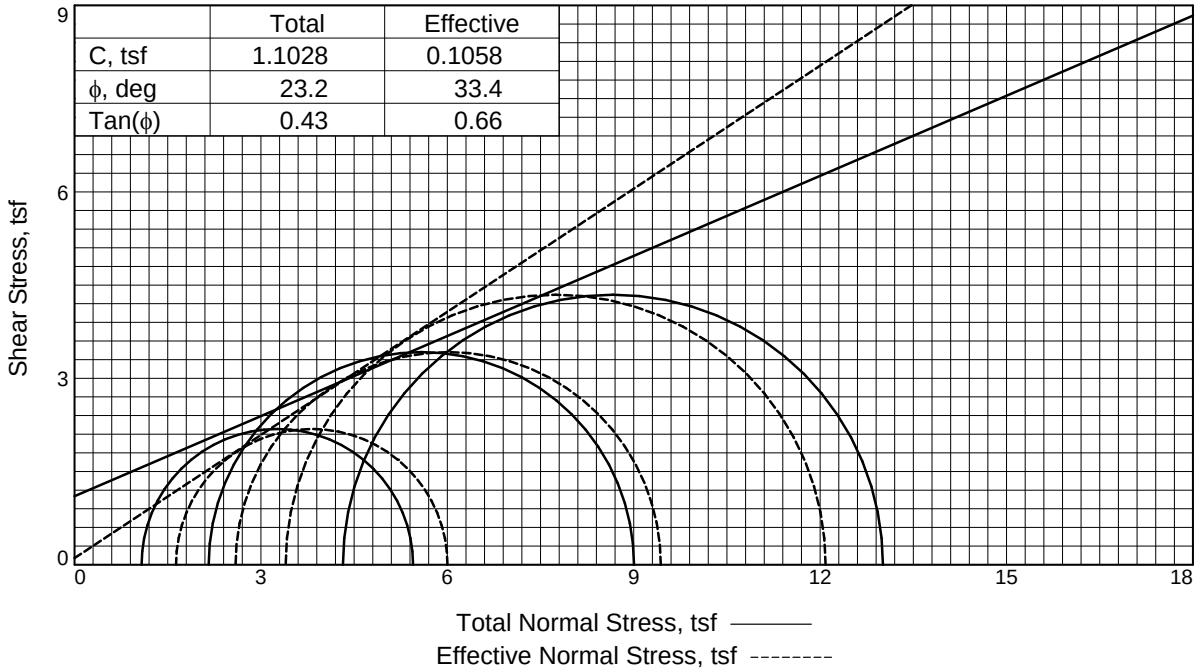
	Initial	Final
Saturation (%)	89.9	95.4
Moisture Content (%):	25.1	25.5
Dry Density Of Specimen (pcf):	96.1	97.9

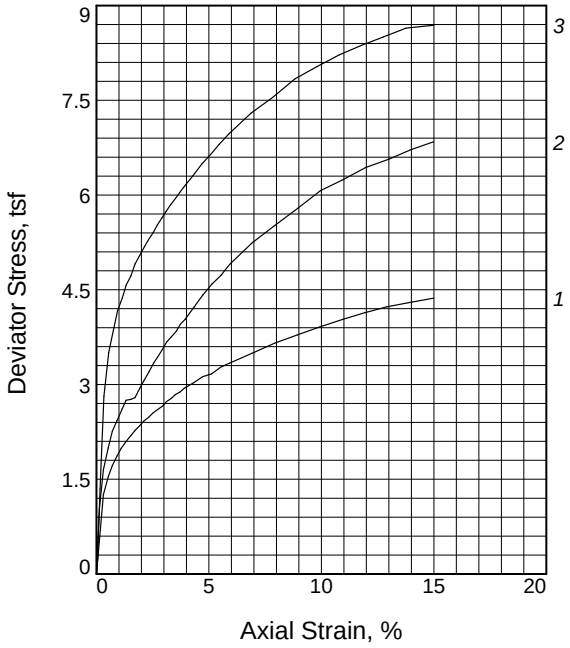
Soil Classification: CL Sandy lean clay

General

Remarks: Control parameters meet the testing requirements.

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Sample No.		1	2	3
Initial	Water Content, %	17.3	16.7	18.3
	Dry Density, pcf	110.1	112.9	110.7
	Saturation, %	87.8	91.8	94.6
	Void Ratio	0.5304	0.4928	0.5226
	Diameter, in.	1.400	1.418	1.400
	Height, in.	2.788	2.790	2.841
At Test	Water Content, %	19.5	17.6	18.7
	Dry Density, pcf	110.4	114.4	112.1
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5268	0.4739	0.5040
	Diameter, in.	1.399	1.412	1.394
	Height, in.	2.785	2.778	2.829
Strain rate, %/min.				
Back Pressure, tsf		6.05	4.97	2.81
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		4.37	6.84	8.69
Total Pore Pr., tsf		5.49	4.54	3.73
Ult. Stress, tsf		4.37	6.84	8.69
Total Pore Pr., tsf		5.49	4.54	3.73
$\bar{\sigma}_1$ Failure, tsf		6.00	9.44	12.09
$\bar{\sigma}_3$ Failure, tsf		1.63	2.59	3.40

Type of Test:
CU with Pore Pressures
Sample Type: Shelby Tube
Description: SANDY LEAN CLAY (CL), brown

LL= 29 **PL=** 19 **PI=** 10
Assumed Specific Gravity= 2.70
Remarks: CU Triax ASTM D 4767

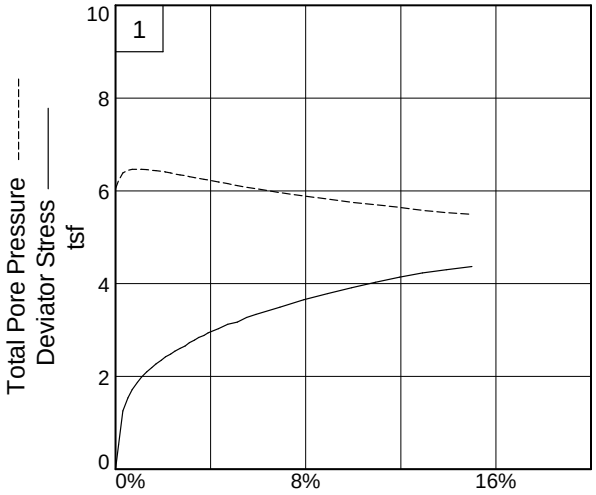
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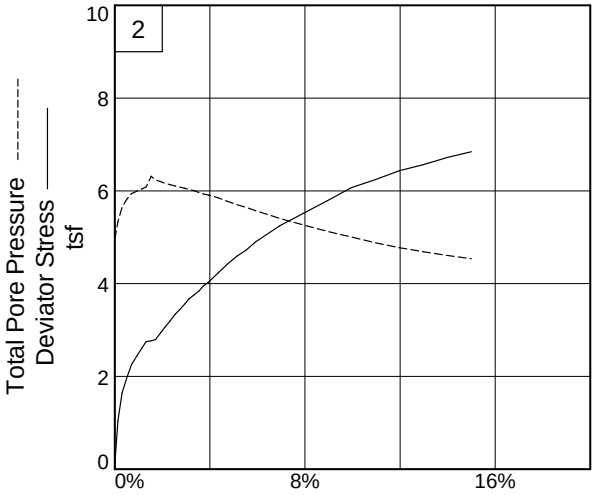
Client: HDR, Inc.

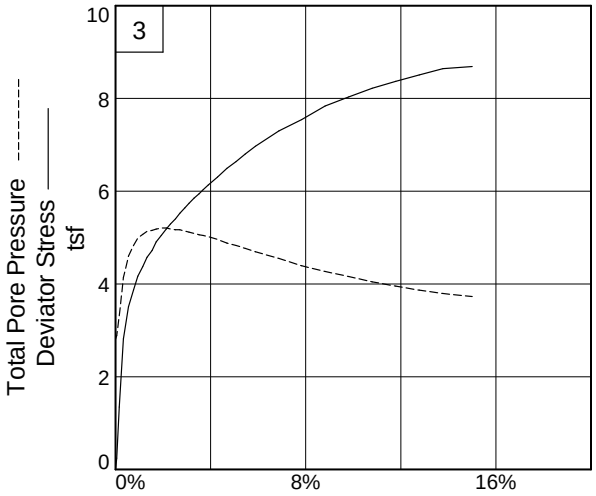
Project: Triaxial Compressive Strength Testing
Grand Forks, ND
Source of Sample: TH-31 **Depth:** 34.5-36'

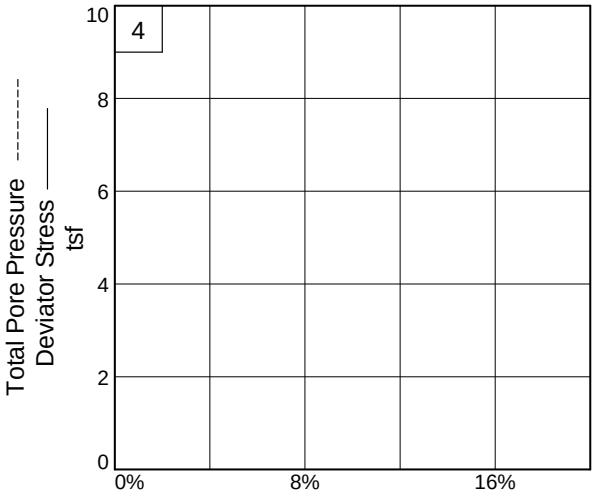
Proj. No.: B2102974 **Date Sampled:**

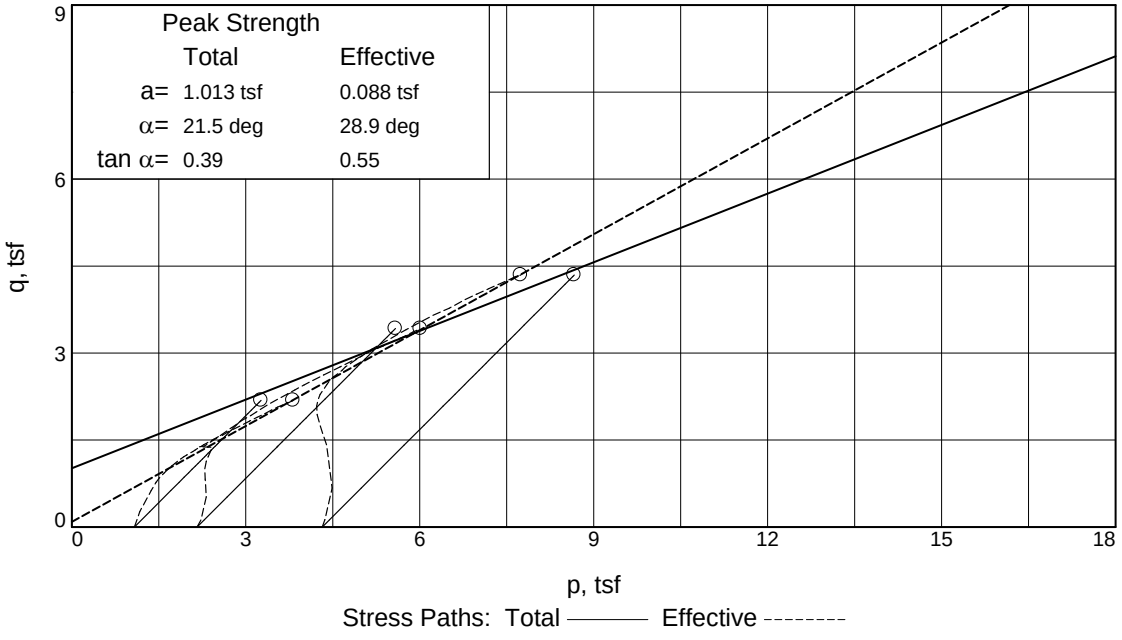
BRAUN INTERTEC











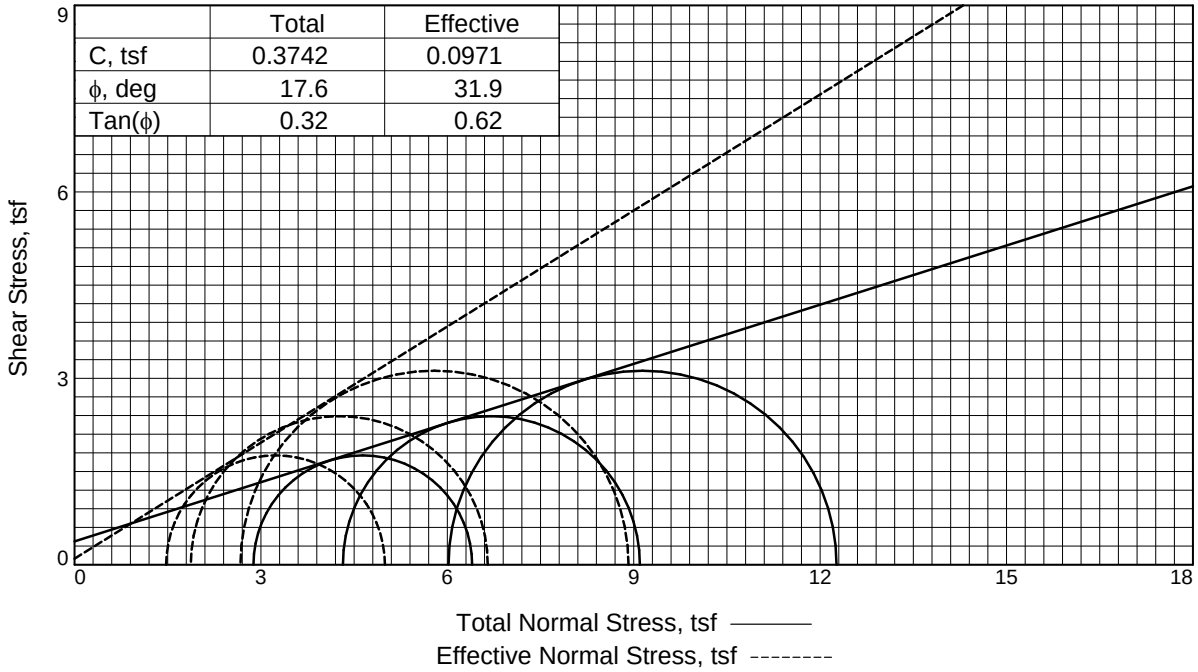
Client: HDR, Inc.

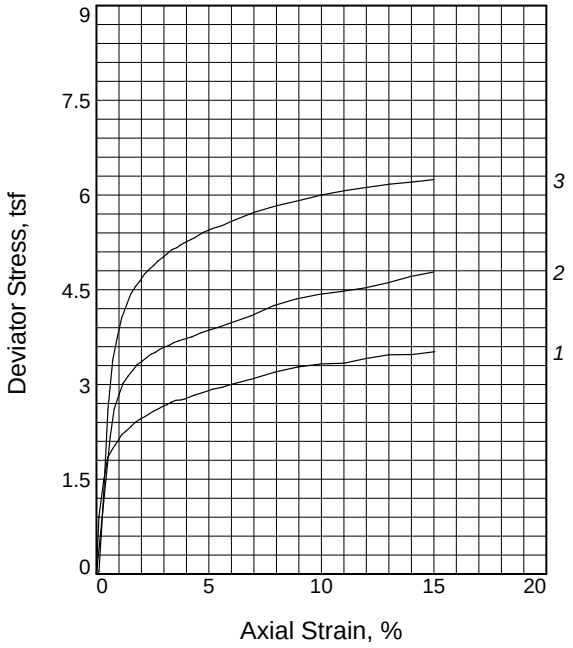
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-31 **Depth:** 34.5-36'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	24.9	25.3	25.7
	Dry Density, pcf	98.5	100.1	99.6
	Saturation, %	94.4	99.9	100.0
	Void Ratio	0.7120	0.6836	0.6929
	Diameter, in.	1.395	1.405	1.403
	Height, in.	2.821	2.812	2.806
At Test	Water Content, %	25.1	23.1	23.6
	Dry Density, pcf	100.5	103.7	102.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6765	0.6249	0.6379
	Diameter, in.	1.385	1.388	1.388
	Height, in.	2.801	2.779	2.775
Strain rate, %/min.				
Back Pressure, tsf		4.248	2.808	1.109
Cell Pressure, tsf		7.128	7.128	7.128
Fail. Stress, tsf		3.519	4.779	6.245
Total Pore Pr., tsf		5.652	5.256	4.457
Ult. Stress, tsf		3.519	4.779	6.245
Total Pore Pr., tsf		5.652	5.256	4.457
$\bar{\sigma}_1$ Failure, tsf		4.995	6.651	8.916
$\bar{\sigma}_3$ Failure, tsf		1.476	1.872	2.671

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: LEAN CLAY with SAND (CL), brown

LL= 39 **PL=** 21 **PI=** 18

Assumed Specific Gravity= 2.70

Remarks: CU Triax ASTM D 4767

Figure _____

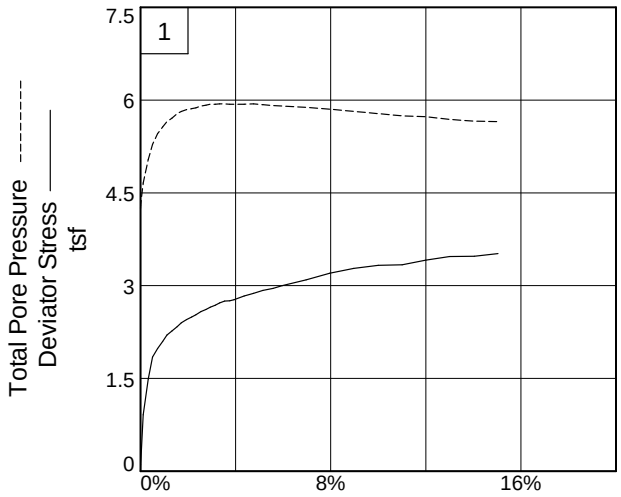
Client: HDR, Inc.

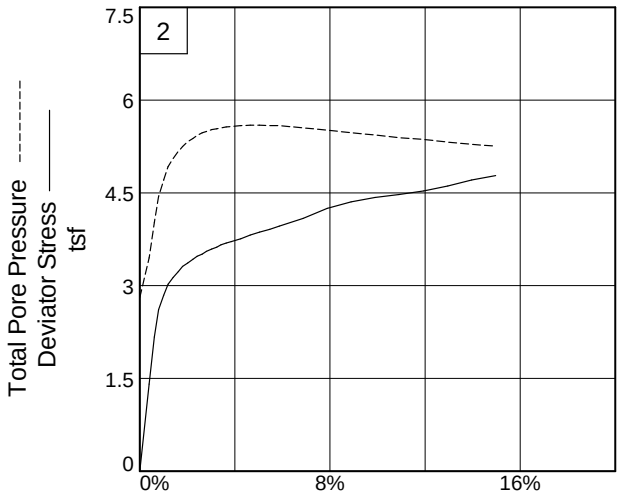
Project: Triaxial Compressive Strength Testing
Grand Forks, ND

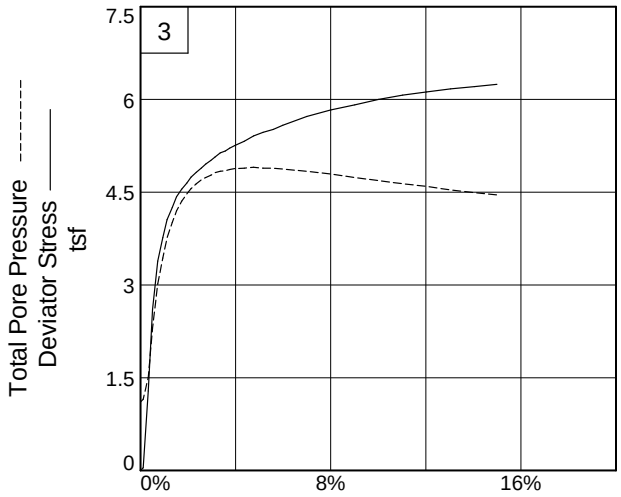
Source of Sample: TH-31 **Depth:** 84.5-86'

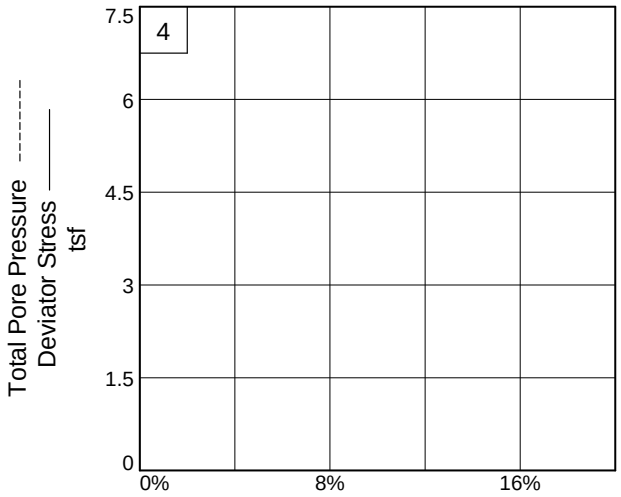
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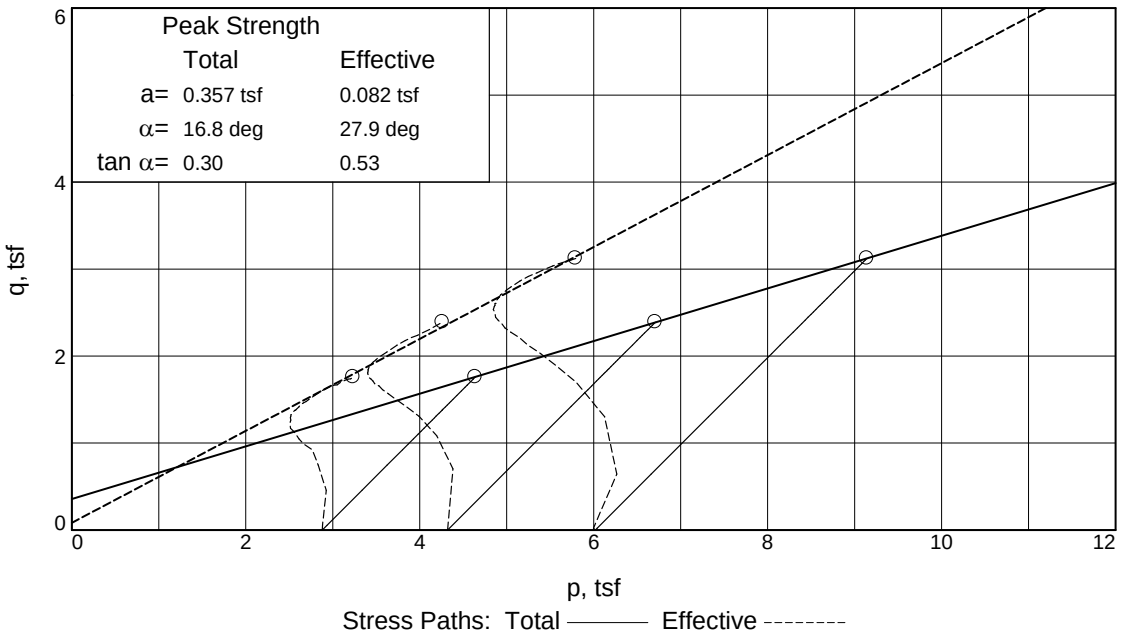
BRAUN INTERTEC











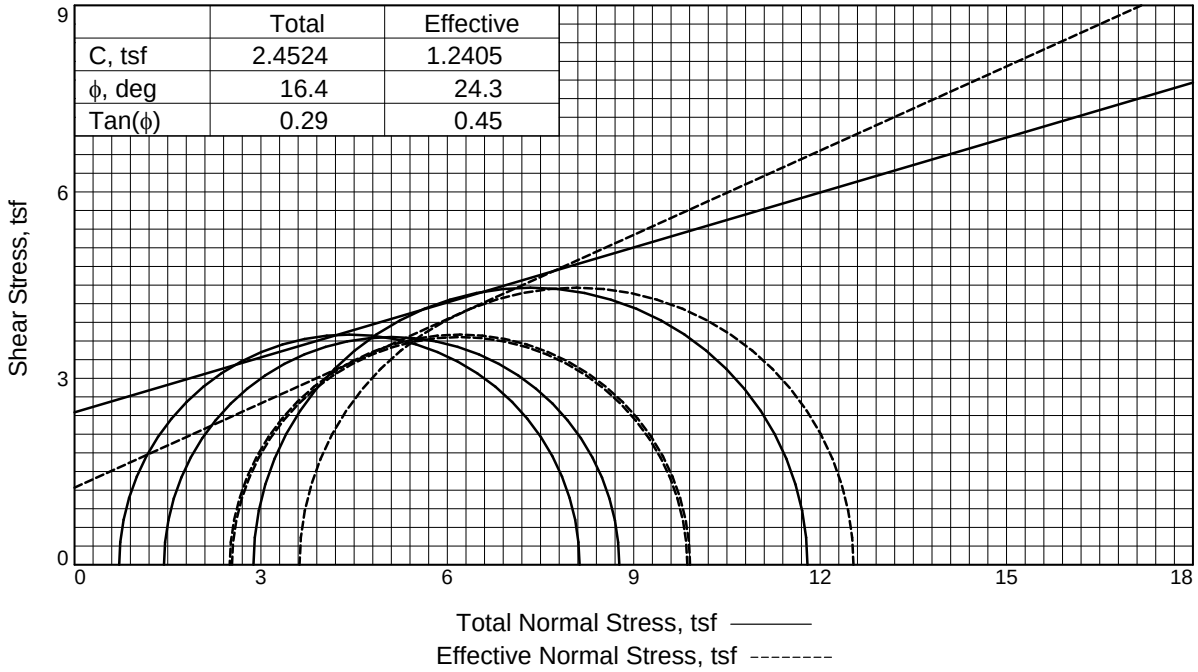
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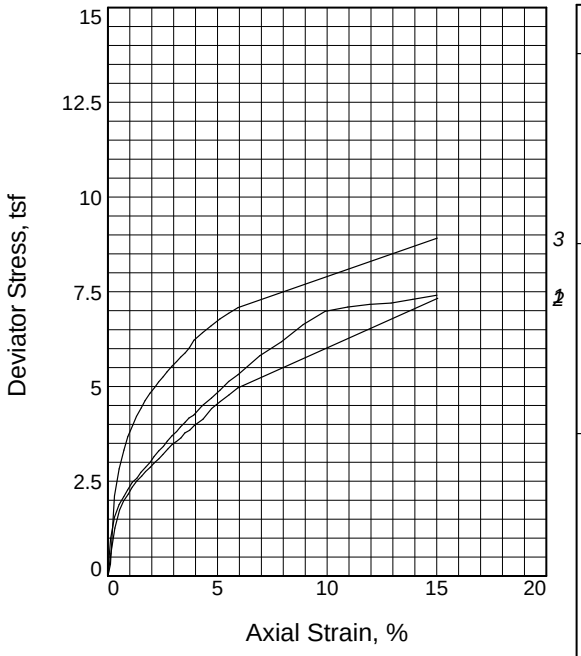
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-31 **Depth:** 84.5-86'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	22.7	22.8	17.5
	Dry Density, pcf	100.0	101.3	110.5
	Saturation, %	89.3	92.8	90.1
	Void Ratio	0.6858	0.6641	0.5249
	Diameter, in.	1.407	1.405	1.405
	Height, in.	2.821	2.789	2.788
At Test	Water Content, %	25.3	24.2	19.2
	Dry Density, pcf	100.1	101.9	110.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6840	0.6543	0.5196
	Diameter, in.	1.407	1.402	1.403
	Height, in.	2.821	2.784	2.784
Strain rate, %/min.				
Back Pressure, tsf		6.41	5.69	4.25
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		7.41	7.33	8.92
Total Pore Pr., tsf		4.63	4.59	3.51
Ult. Stress, tsf		7.41	7.33	8.92
Total Pore Pr., tsf		4.63	4.59	3.51
$\bar{\sigma}_1$ Failure, tsf		9.91	9.86	12.54
$\bar{\sigma}_3$ Failure, tsf		2.50	2.53	3.62

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: LEAN CLAY with SAND (CL), brown

LL= 37 **PL=** 24 **PI=** 13

Assumed Specific Gravity= 2.70

Remarks: CU Triax ASTM D 4767

Figure _____

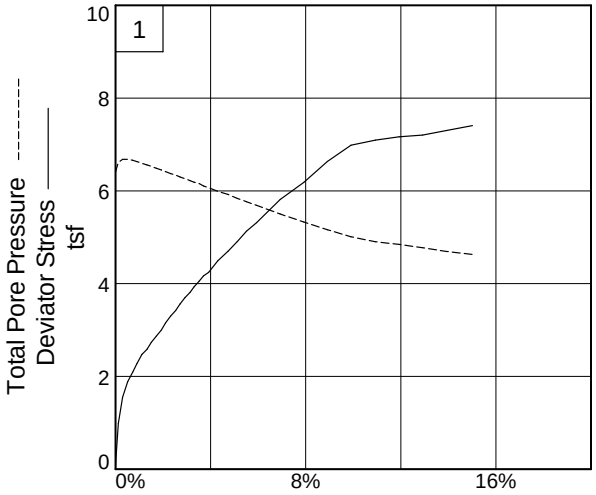
Client: HDR, Inc.

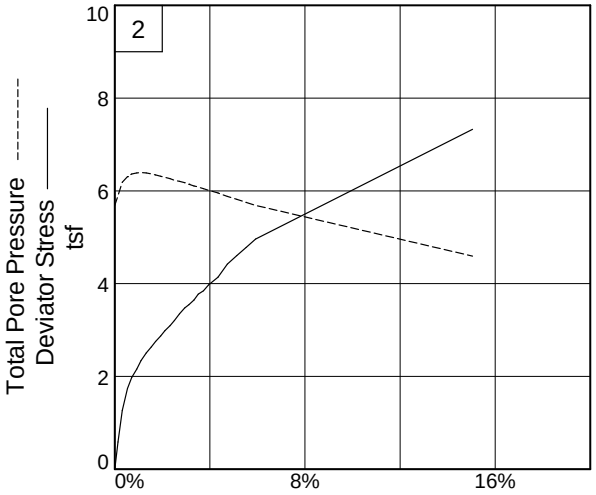
Project: Triaxial Compressive Strength Testing
Grand Forks, ND

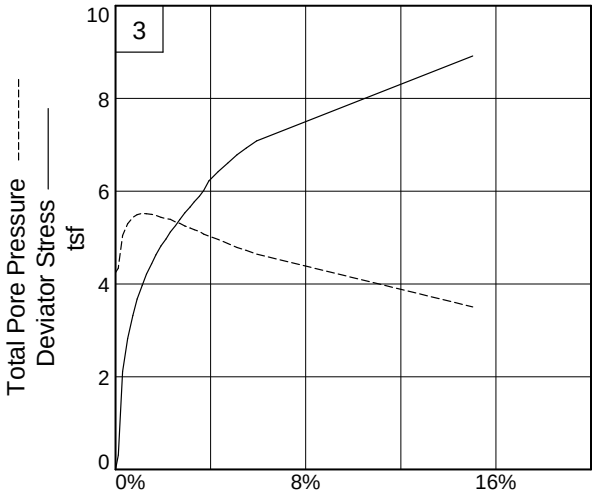
Source of Sample: TH-32 **Depth:** 19.5-21'

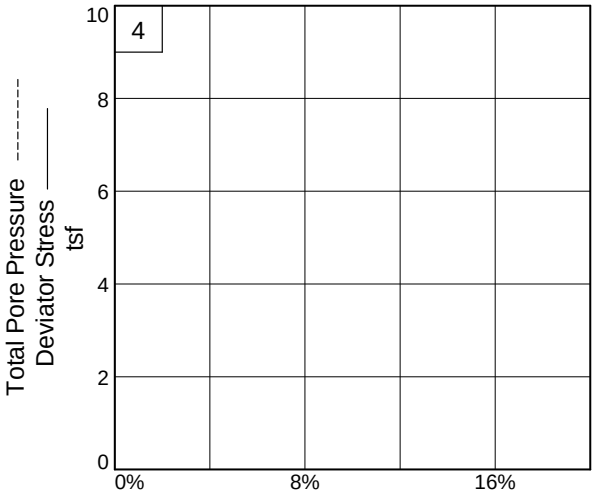
Proj. No.: B2102974 **Date Sampled:**

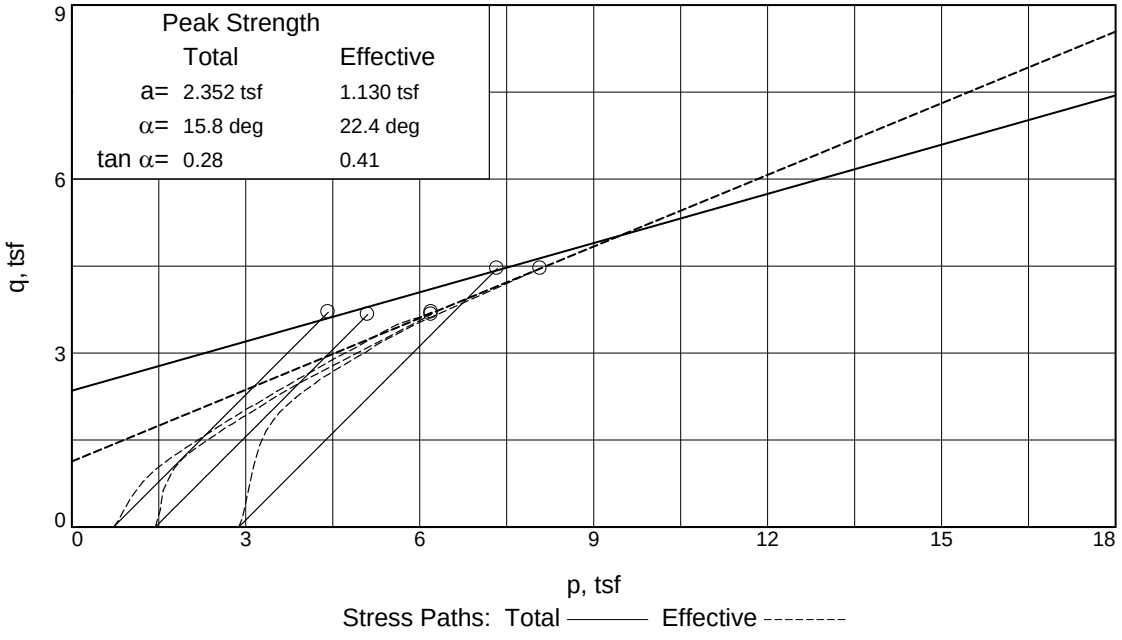
BRAUN INTERTEC











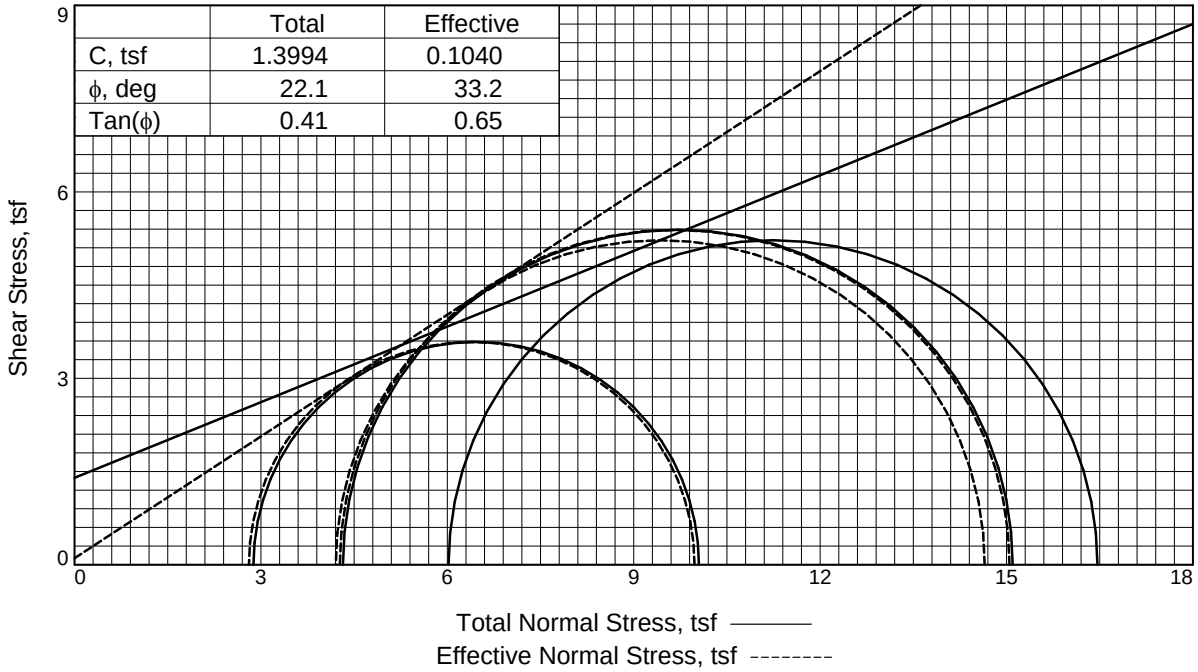
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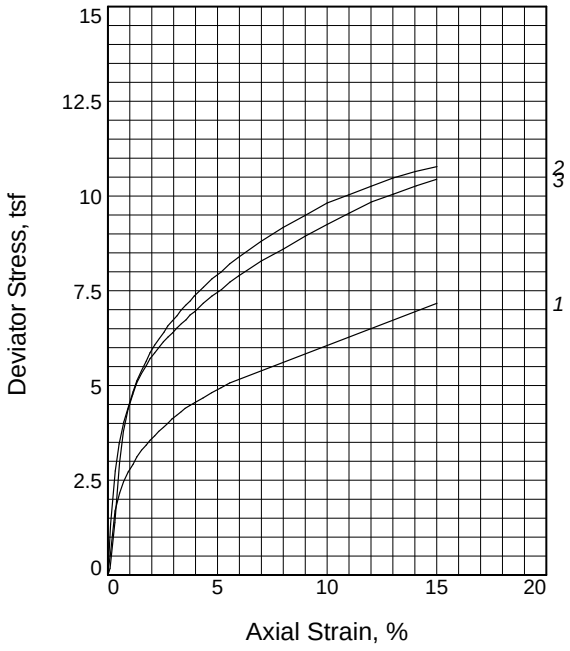
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-32 **Depth:** 19.5-21'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	25.2	24.0	24.8
	Dry Density, pcf	99.7	100.4	98.3
	Saturation, %	98.5	95.7	93.6
	Void Ratio	0.6902	0.6783	0.7146
	Diameter, in.	1.420	1.418	1.420
	Height, in.	2.829	2.852	2.827
At Test	Water Content, %	24.4	24.0	24.6
	Dry Density, pcf	101.7	102.3	101.4
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6579	0.6481	0.6631
	Diameter, in.	1.411	1.409	1.406
	Height, in.	2.811	2.835	2.798
Strain rate, %/min.				
Back Pressure, tsf		4.25	2.81	1.11
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		7.17	10.78	10.44
Total Pore Pr., tsf		4.32	2.86	2.92
Ult. Stress, tsf		7.17	10.78	10.44
Total Pore Pr., tsf		4.32	2.86	2.92
$\bar{\sigma}_1$ Failure, tsf		9.98	15.05	14.65
$\bar{\sigma}_3$ Failure, tsf		2.81	4.27	4.20

Type of Test:
CU with Pore Pressures
Sample Type: Shelby Tube
Description: SANDY LEAN CLAY (CL), brown

LL= 45 **PL=** 24 **PI=** 21
Assumed Specific Gravity= 2.70
Remarks: CU Triax ASTM D 4767

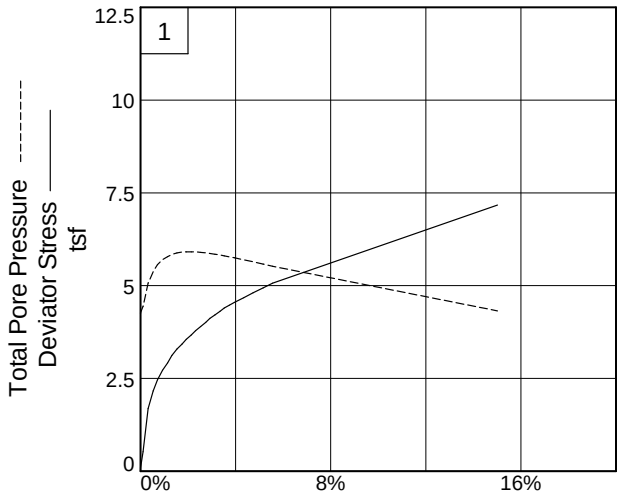
Figure _____

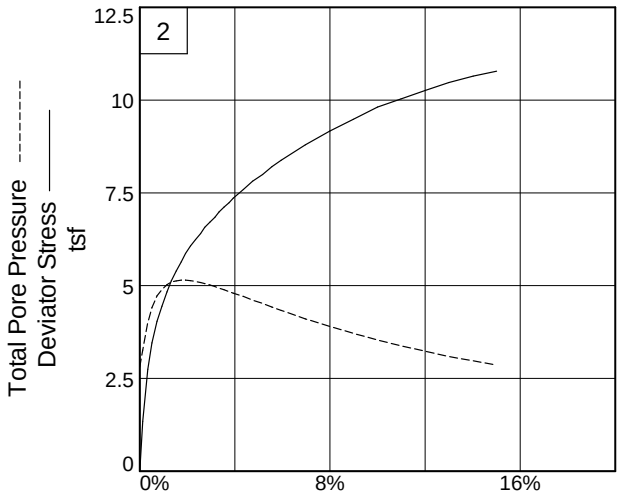
Client: HDR, Inc.

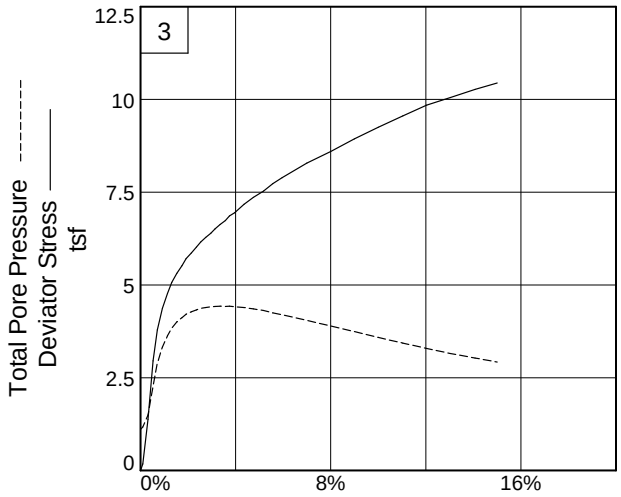
Project: Triaxial Compressive Strength Testing
Grand Forks, ND
Source of Sample: TH-32 **Depth:** 74.5-76'

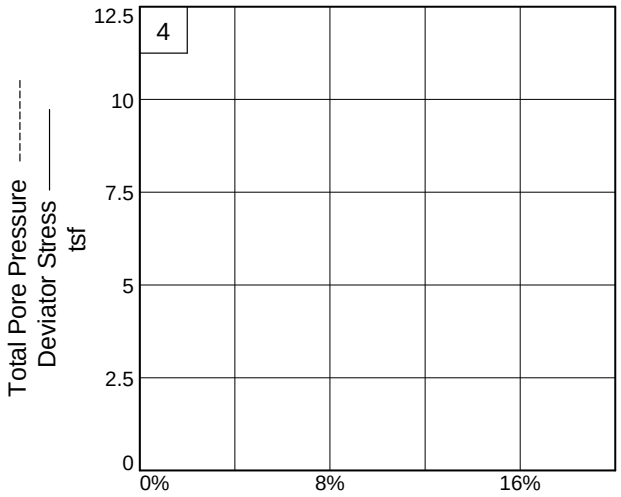
Proj. No.: B2102974 **Date Sampled:**

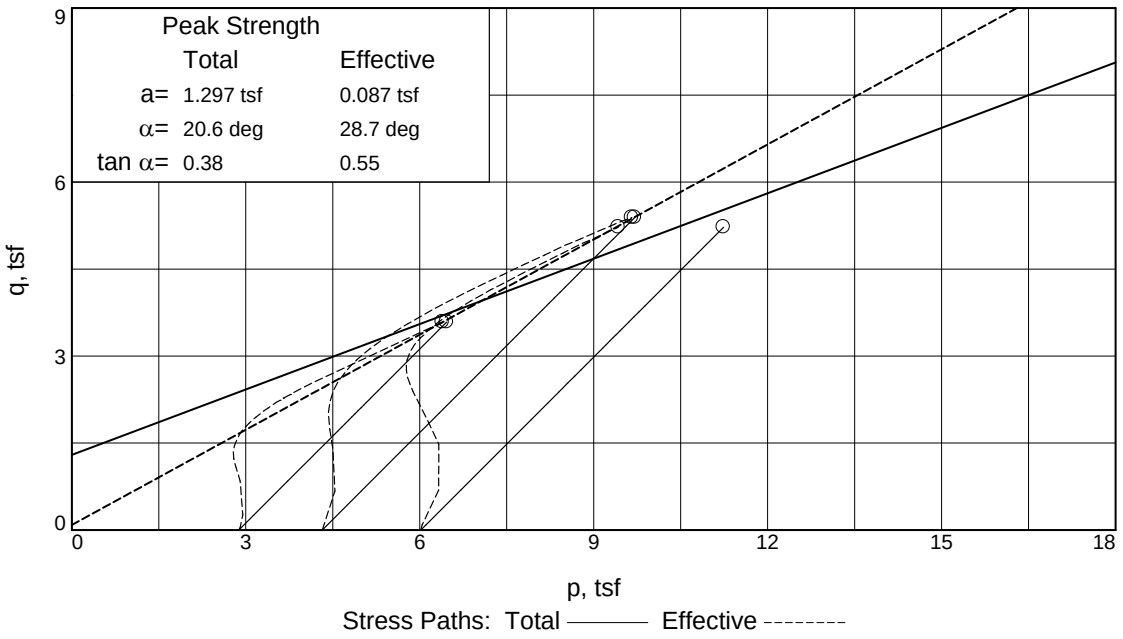
BRAUN INTERTEC











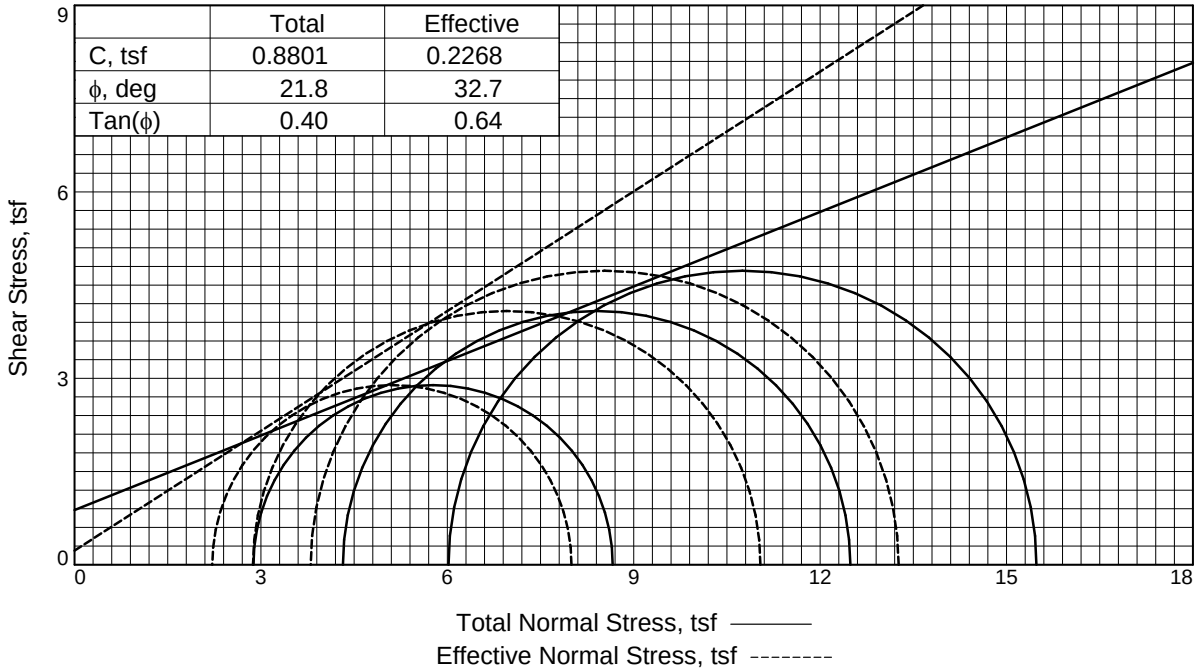
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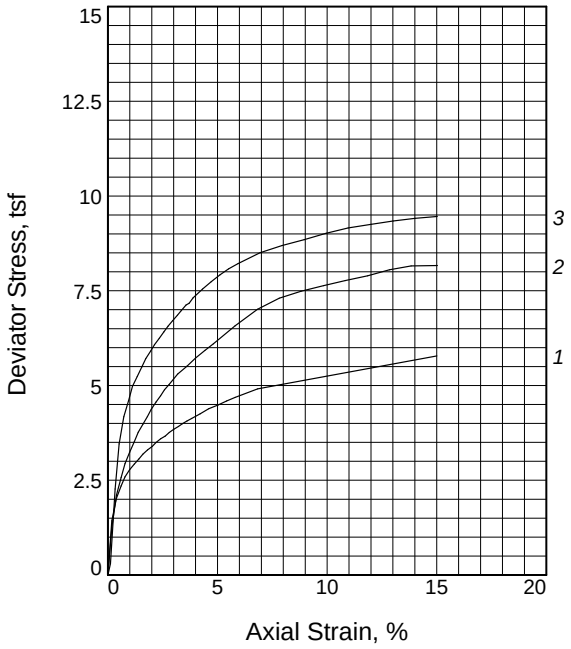
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-32 **Depth:** 74.5-76'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	27.4	26.6	26.0
	Dry Density, pcf	95.5	95.3	94.6
	Saturation, %	96.7	93.6	89.7
	Void Ratio	0.7653	0.7685	0.7818
	Diameter, in.	1.415	1.397	1.406
	Height, in.	2.840	2.839	2.816
At Test	Water Content, %	27.3	27.6	26.8
	Dry Density, pcf	97.0	96.5	97.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7376	0.7465	0.7223
	Diameter, in.	1.408	1.391	1.390
	Height, in.	2.825	2.827	2.784
Strain rate, %/min.				
Back Pressure, tsf		4.25	2.81	1.11
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		5.78	8.17	9.46
Total Pore Pr., tsf		4.91	4.26	3.33
Ult. Stress, tsf		5.78	8.17	9.46
Total Pore Pr., tsf		4.91	4.26	3.33
$\bar{\sigma}_1$ Failure, tsf		8.00	11.04	13.26
$\bar{\sigma}_3$ Failure, tsf		2.22	2.87	3.80

Type of Test:
CU with Pore Pressures
Sample Type: Shelby Tube
Description: SANDY LEAN CLAY (CL), brown

LL= 45 **PL=** 26 **PI=** 19
Assumed Specific Gravity= 2.70
Remarks: CU Triax ASTM D 4767

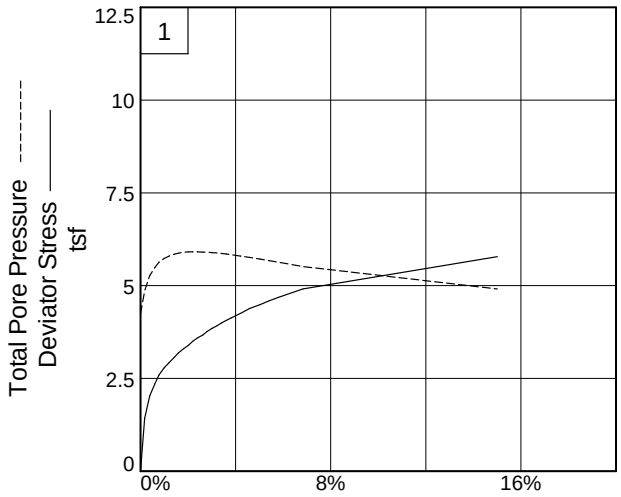
Client: HDR, Inc.

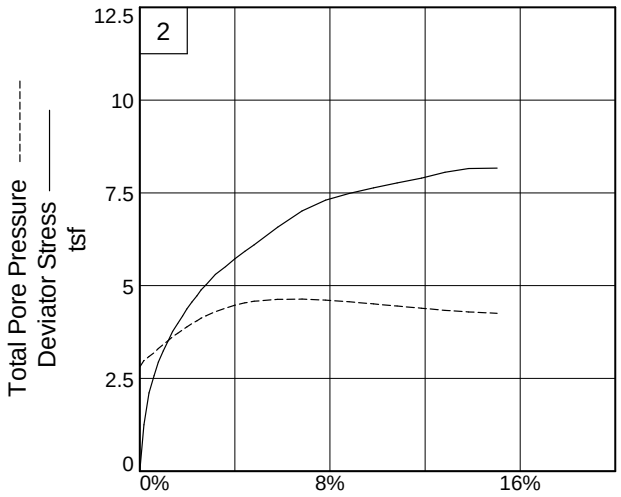
Project: Triaxial Compressive Strength Testing
Grand Forks, ND
Source of Sample: TH-32 **Depth:** 84.5-86'

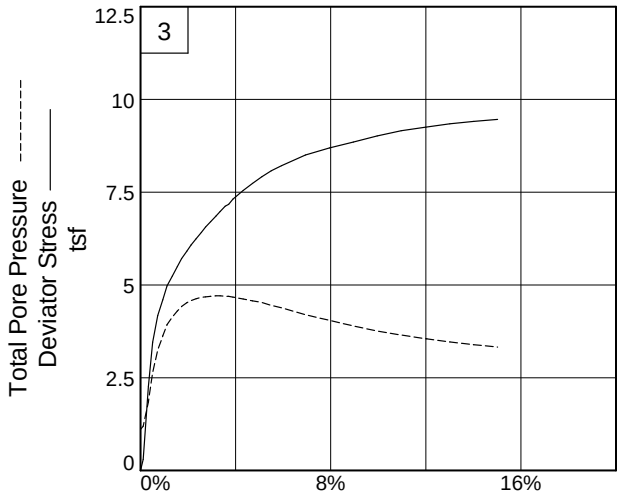
Proj. No.: B2102974 **Date Sampled:**

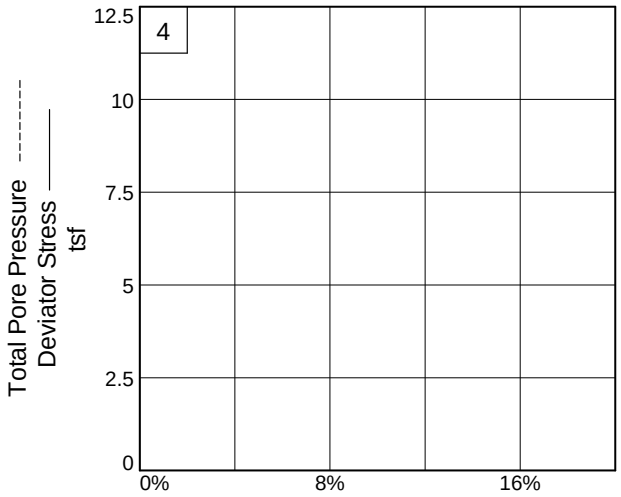
BRAUN INTERTEC

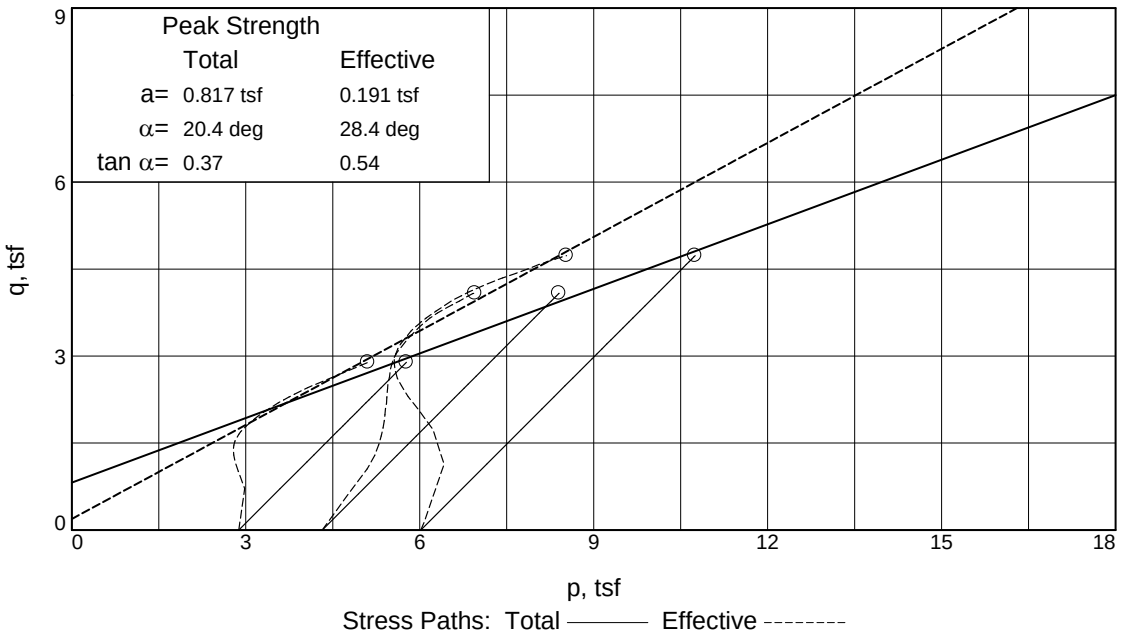
Figure _____











Client: HDR, Inc.

Project: Triaxial Compressive Strength Testing

Source of Sample: TH-32 **Depth:** 84.5-86'

Project No.: B2102974 **Figure** _____

Braun Intertec

Crumb Test
ASTM D6572

Sample MC		Sample	TH-31	Time Started:	9:59A		
tare number	MT95	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	67.64	Water Type	DISTILLED	2 min ± 15 s	10:01A	1	21.5
dry + tare (g)	61.31	Initial Water Temp °C	21.7	1 hr ± 8 min	10:58A	2	20.6
tare (g)	20.83			6 hr ± 45 min	4:00P	2	20.6
% Moisture	15.6%						

SAMPLE TH-31 at 14.5-16.0'

Overall Dispersive Classification: **2**

Bowl # CR-1

Sample MC		Sample	TH-31	Time Started:	9:59A		
tare number	CC24	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	59.29	Water Type	DISTILLED	2 min ± 15 s	10:01A	1	21.3
dry + tare (g)	52.87	Initial Water Temp °C	21.5	1 hr ± 8 min	10:58A	1	20.5
tare (g)	20.18			6 hr ± 45 min	4:00P	1	20.5
	19.6%						

SAMPLE TH-31 at 19.5-21.0'

Overall Dispersive Classification: **1**

Bowl # CR-2

Sample MC		Sample	TH-31	Time Started:	9:59A		
tare number	MT79	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	65.46	Water Type	DISTILLED	2 min ± 15 s	10:01A	2	21.3
dry + tare (g)	58.31	Initial Water Temp °C	21.5	1 hr ± 8 min	10:58A	2	20.6
tare (g)	20.84			6 hr ± 45 min	4:00P	3	20.6
	19.1%						

SAMPLE TH-31 at 29.5-31.0'

Overall Dispersive Classification: **3**

Bowl # CR-3

Sample MC		Sample	TH-31	Time Started:	9:59A		
tare number	MT15	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	57.34	Water Type	DISTILLED	2 min ± 15 s	10:01A	1	21.4
dry + tare (g)	51.67	Initial Water Temp °C	21.7	1 hr ± 8 min	10:58A	1	20.5
tare (g)	20.76			6 hr ± 45 min	4:00P	1	20.5
	18.3%						

SAMPLE TH-31 at 39.5-41.0'

Overall Dispersive Classification: **1**

Bowl # CR-4

PROJECT NO. B2102974
PROJECT: HDR LARIMORE DAM PROJECT

Grading

Grade 1 - Nondispersive. No reaction, sample may crumble but there is no turbid water or anything in suspension.

Grade 2 - Intermediate. Slight reaction, a faint barely visible suspension near sample.

Grade 3 - Dispersive. Moderate reaction, easily visible cloud is seen around the sample and may extend 10 mm away.

Grade 4 - Highly dispersive. Strong reaction, a dense cloud will appear and will extend around the dish.

Overall Dispersive Classification

If the dispersive grade changed during the test, the 1 hour reading is normally used for the overall test evaluation.

However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 hour reading and the 6 hour reading, use the 6 hour reading for the overall test evaluation.

Crumb Test
ASTM D6572

Sample MC		Sample	TH-31	Time Started:	10:07A		
tare number	MT74	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	71.49	Water Type	DISTILLED	2 min ± 15 s	10:09A	1	21.3
dry + tare (g)	63.47	Initial Water Temp °C	21.4	1 hr ± 8 min	11:01A	1	20.5
tare (g)	20.77			6 hr ± 45 min	4:07P	1	20.5
% Moisture	18.8%						

SAMPLE TH-31 at 69.5-71.0'

Overall Dispersive Classification: **1**

Bowl #: CR-5

Sample MC		Sample	TH-31	Time Started:	10:07A		
tare number	T19	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	60.31	Water Type	DISTILLED	2 min ± 15 s	10:09A	1	21.3
dry + tare (g)	55.07	Initial Water Temp °C	21.4	1 hr ± 8 min	11:01A	2	20.5
tare (g)	19.94			6 hr ± 45 min	4:07P	2	20.5
	14.9%						

SAMPLE TH-31 at 44.5-46.0'

Overall Dispersive Classification: **2**

Bowl #: CR-6

Sample MC		Sample	TH-31	Time Started:	10:07A		
tare number	MT30	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	62.94	Water Type	DISTILLED	2 min ± 15 s	10:09A	1	21.3
dry + tare (g)	57.87	Initial Water Temp °C	21.5	1 hr ± 8 min	11:01A	2	20.6
tare (g)	20.80			6 hr ± 45 min	4:07P	2	20.6
	13.7%						

SAMPLE TH-31 at 59.5-61.0'

Overall Dispersive Classification: **2**

Bowl #: CR-7

Sample MC		Sample	TH-31	Time Started:	10:07A		
tare number	MT18	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	61.93	Water Type	DISTILLED	2 min ± 15 s	10:09A	1	21.4
dry + tare (g)	53.42	Initial Water Temp °C	21.4	1 hr ± 8 min	11:01A	1	20.5
tare (g)	20.72			6 hr ± 45 min	4:07P	1	20.5
	26.0%						

SAMPLE TH-31 at 79.5-81.0'

Overall Dispersive Classification: **1**

Bowl #: CR-8

PROJECT NO. B2102974 TESTING
PROJECT: HDR LARIMORE DAM PROJECT

Grading

Grade 1 - Nondispersive. No reaction, sample may crumble but there is no turbid water or anything in suspension.

Grade 2 - Intermediate. Slight reaction, a faint barely visible suspension near sample.

Grade 3 - Dispersive. Moderate reaction, easily visible cloud is seen around the sample and may extend 10 mm away.

Grade 4 - Highly dispersive. Strong reaction, a dense cloud will appear and will extend around the dish.

Overall Dispersive Classification

If the dispersive grade changed during the test, the 1 hour reading is normally used for the overall test evaluation.

However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 hour reading and the 6 hour reading, use the 6 hour reading for the overall test evaluation.

Crumb Test
ASTM D6572

Sample MC		Sample	TH-32	Time Started:	11:39A		
tare number	MT52	Method	B-REMOLDED	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	70.22	Water Type	DISTILLED	2 min ± 15 s	11:41A	1	21.5
dry + tare (g)	63.29	Initial Water Temp °C	21.9	1 hr ± 8 min	12:39P	1	21.1
tare (g)	20.71			6 hr ± 45 min	5:30P	1	21.4
% Moisture	16.3%						

SAMPLE TH-32 at 4.5-6'

Overall Dispersive Classification: **2**

Bowl #: CR-9

Sample MC		Sample	TH-32	Time Started:	11:40A		
tare number	MT86	Method	B-REMOLDED	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	63.60	Water Type	DISTILLED	2 min ± 15 s	11:42A	1	21.8
dry + tare (g)	57.51	Initial Water Temp °C	21.9	1 hr ± 8 min	12:40P	2	20.7
tare (g)	20.85			6 hr ± 45 min	5:30P	2	21.4
	16.6%						

SAMPLE TH-32 at 24.5-26'

Overall Dispersive Classification: **2**

Bowl #: CR-10

Sample MC		Sample	TH-32	Time Started:	11:40A		
tare number	MT78	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	69.63	Water Type	DISTILLED	2 min ± 15 s	11:43	1	21.8
dry + tare (g)	59.73	Initial Water Temp °C	21.9	1 hr ± 8 min	12:41P	2	20.9
tare (g)	20.80			6 hr ± 45 min	5:30P	2	21.4
	25.4%						

SAMPLE TH-32 at 34.5-36'

Overall Dispersive Classification: **2**

Bowl #: CR-11

Sample MC		Sample	TH-32	Time Started:	11:41A		
tare number	MT43	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	63.43	Water Type	DISTILLED	2 min ± 15 s	11:44A	1	21.8
dry + tare (g)	54.37	Initial Water Temp °C	21.9	1 hr ± 8 min	12:41P	1	20.9
tare (g)	20.87			6 hr ± 45 min	5:30P	1	21.4
	27.0%						

SAMPLE TH-32 at 44.5-46'

Overall Dispersive Classification: **1**

Bowl #: CR-12

PROJECT NO. B2102974 TESTING
PROJECT: HDR LARIMORE DAM PROJECT

Grading

Grade 1 - Nondispersive. No reaction, sample may crumble but there is no turbid water or anything in suspension.

Grade 2 - Intermediate. Slight reaction, a faint barely visible suspension near sample.

Grade 3 - Dispersive. Moderate reaction, easily visible cloud is seen around the sample and may extend 10 mm away.

Grade 4 - Highly dispersive. Strong reaction, a dense cloud will appear and will extend around the dish.

Overall Dispersive Classification

If the dispersive grade changed during the test, the 1 hour reading is normally used for the overall test evaluation.

However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 hour reading and the 6 hour reading, use the 6 hour reading for the overall test evaluation.

Crumb Test
ASTM D6572

Sample MC		Sample	TH-32	Time Started:	11:47A		
tare number	T7	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	63.48	Water Type	DISTILLED	2 min ± 15 s	11:49A	1	21.7
dry + tare (g)	54.67	Initial Water Temp °C	21.8	1 hr ± 8 min	12:47P	1	20.9
tare (g)	20.01			6 hr ± 45 min	5:30P	1	20.9
% Moisture	25.4%						

SAMPLE TH-32 at 49.5-51'

Overall Dispersive Classification: **1**

Bowl #: CR-13

Sample MC		Sample	TH-32	Time Started:	11:48A		
tare number	MT71	Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	62.90	Water Type	DISTILLED	2 min ± 15 s	11:50A	1	21.8
dry + tare (g)	56.02	Initial Water Temp °C	21.8	1 hr ± 8 min	12:48P	1	20.9
tare (g)	20.73			6 hr ± 45 min	5:30P	1	20.9
	19.5%						

SAMPLE TH-32 at 59.5-61'

Overall Dispersive Classification: **1**

Bowl #: CR-14

Sample MC		Sample	TH-32	Time Started:	11:52A		
tare number	MT70	Method	B-REMOLDED	Target Reading	Time	Grade	Temp °C
Wet + tare (g)	65.90	Water Type	DISTILLED	2 min ± 15 s	11:54A	1	21.7
dry + tare (g)	59.41	Initial Water Temp °C	21.8	1 hr ± 8 min	12:49P	2	20.9
tare (g)	20.68			6 hr ± 45 min	5:30P	3	20.9
	16.8%						

SAMPLE TH-32 at 69.5-71'

Overall Dispersive Classification: **3**

Bowl #: CR-15

Sample MC		Sample		Time Started:			
tare number		Method	A	Target Reading	Time	Grade	Temp °C
Wet + tare (g)		Water Type		2 min ± 15 s			
dry + tare (g)		Initial Water Temp °C		1 hr ± 8 min			
tare (g)				6 hr ± 45 min			
	#DIV/0!						

Overall Dispersive Classification:

Bowl #:

PROJECT NO. B2102974 TESTING
PROJECT: HDR LARIMORE DAM PROJECT

Grading

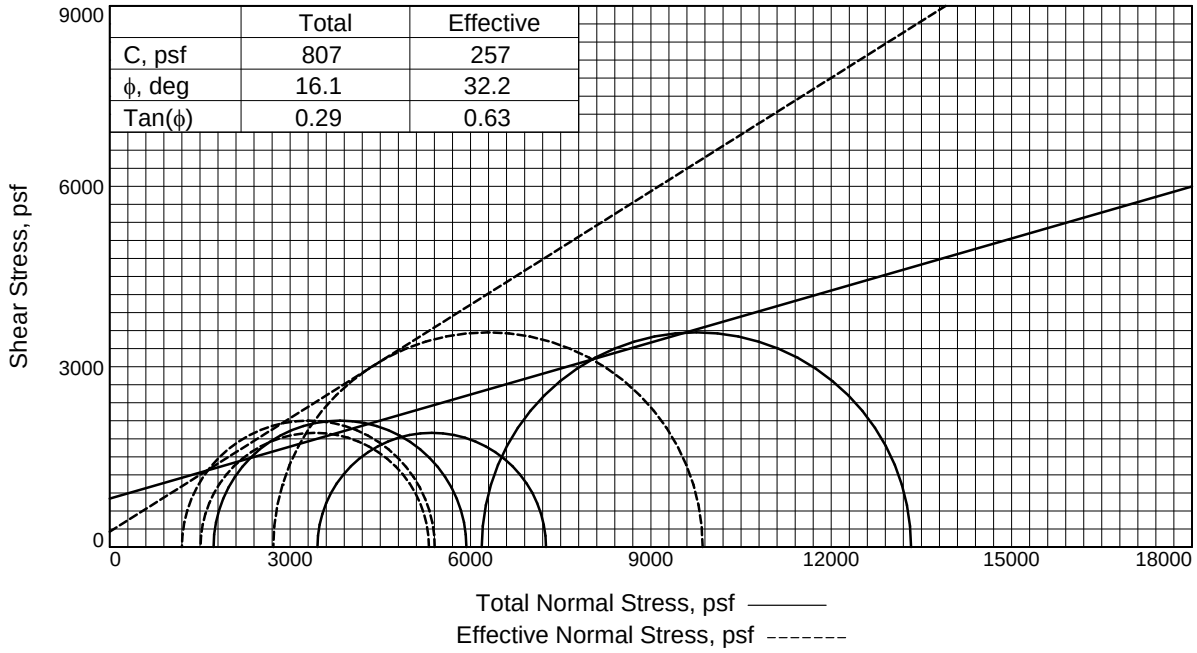
Grade 1 - Nondispersive. No reaction, sample may crumble but there is no turbid water or anything in suspension.

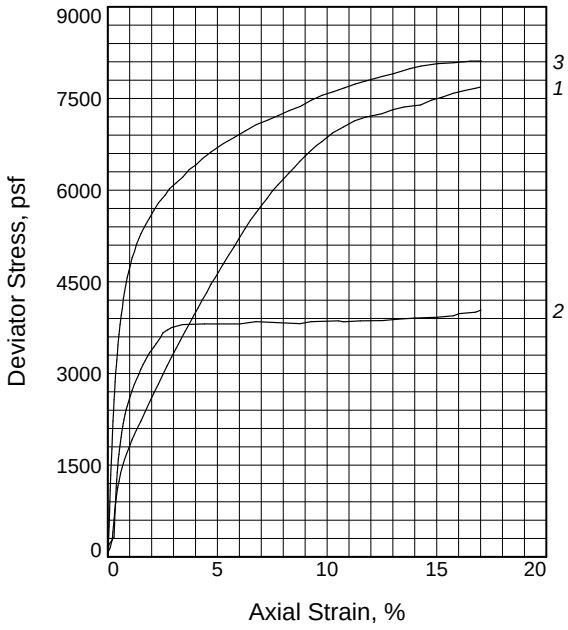
Grade 2 - Intermediate. Slight reaction, a faint barely visible suspension near sample.

Grade 3 - Dispersive. Moderate reaction, easily visible cloud is seen around the sample and may extend 10 mm away. Grade 4 - Highly dispersive. Strong reaction, a dense cloud will appear and will extend around the dish.

Overall Dispersive Classification

If the dispersive grade changed during the test, the 1 hour reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 hour reading and the 6 hour reading, use the 6 hour reading for the overall test evaluation.





Sample No.		1	2	3
Initial	Water Content, %	28.2	25.9	27.0
	Dry Density, pcf	95.4	99.2	95.8
	Saturation, %	100.3	101.1	97.0
	Void Ratio	0.7535	0.6860	0.7469
	Diameter, in.	2.81	2.80	2.84
	Height, in.	5.38	5.37	5.56
At Test	Water Content, %	26.8	23.1	24.8
	Dry Density, pcf	97.4	103.4	100.5
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7175	0.6188	0.6648
	Diameter, in.	2.79	2.76	2.80
	Height, in.	5.34	5.30	5.47
Strain rate, in./min.		0.001	0.001	0.001
Back Pressure, tsf		3.600	3.600	3.600
Cell Pressure, tsf		4.463	5.327	6.693
Fail. Stress, psf		4205	3801	7142
Total Pore Pr., psf		7727	9146	10667
Ult. Stress, psf		7689	4038	8114
Total Pore Pr., psf		6106	8703	9982
$\bar{\sigma}_1$ Failure, psf		5405	5309	9861
$\bar{\sigma}_3$ Failure, psf		1200	1508	2719

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: Lean Clay (CL)

LL= 48 **PL=** 21 **PI=** 27

Specific Gravity= 2.68

Remarks:

Upper Glacial Till CL

Figure _____

Client: HDR Engineering, Inc.

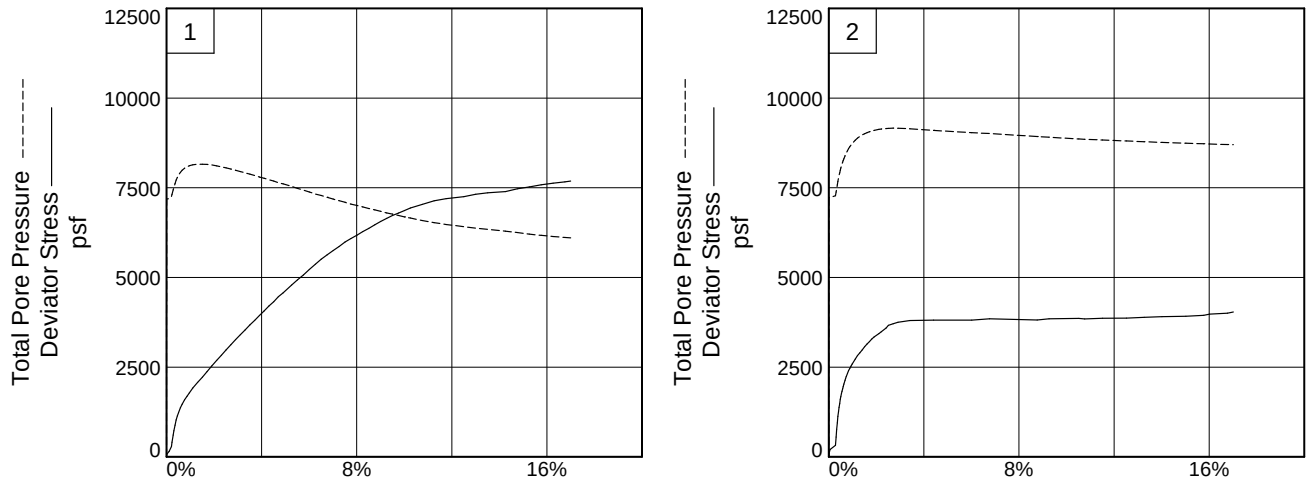
Project: Larimore Dam

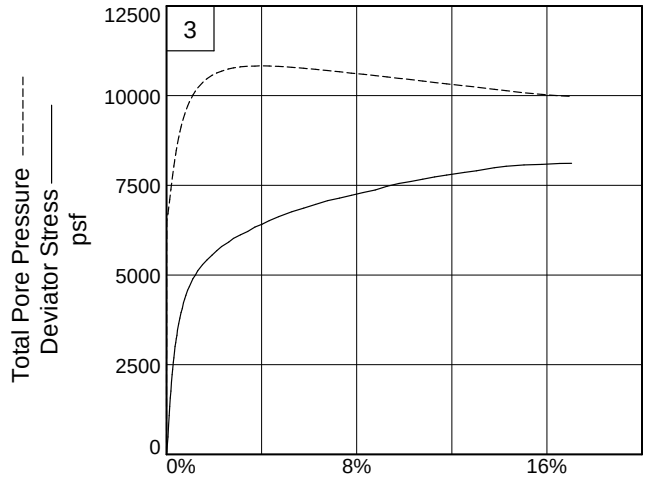
Source of Sample: 602 **Depth:** 41-43'

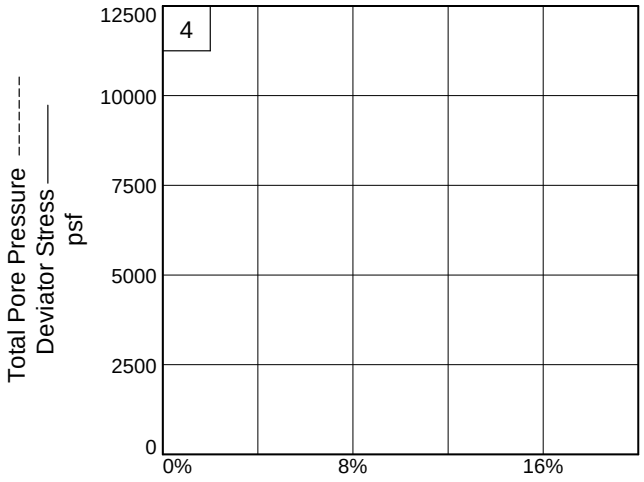
Sample Number: 10

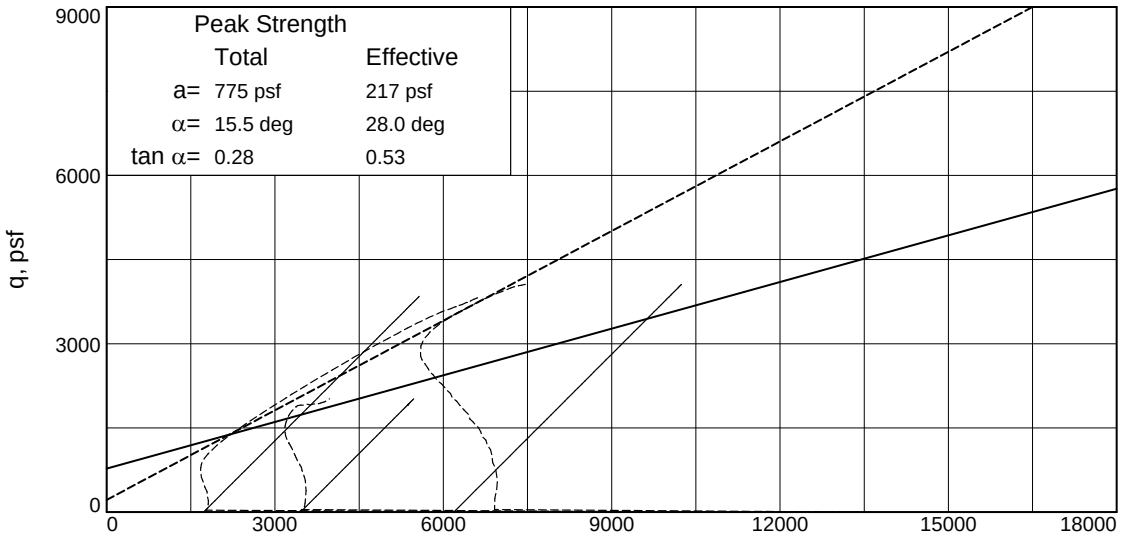
Proj. No.: M5205031 **Date Sampled:** 8/20/2021

TRIAXIAL SHEAR TEST REPORT
Terracon Consultants, Inc.
Wheat Ridge, Colorado







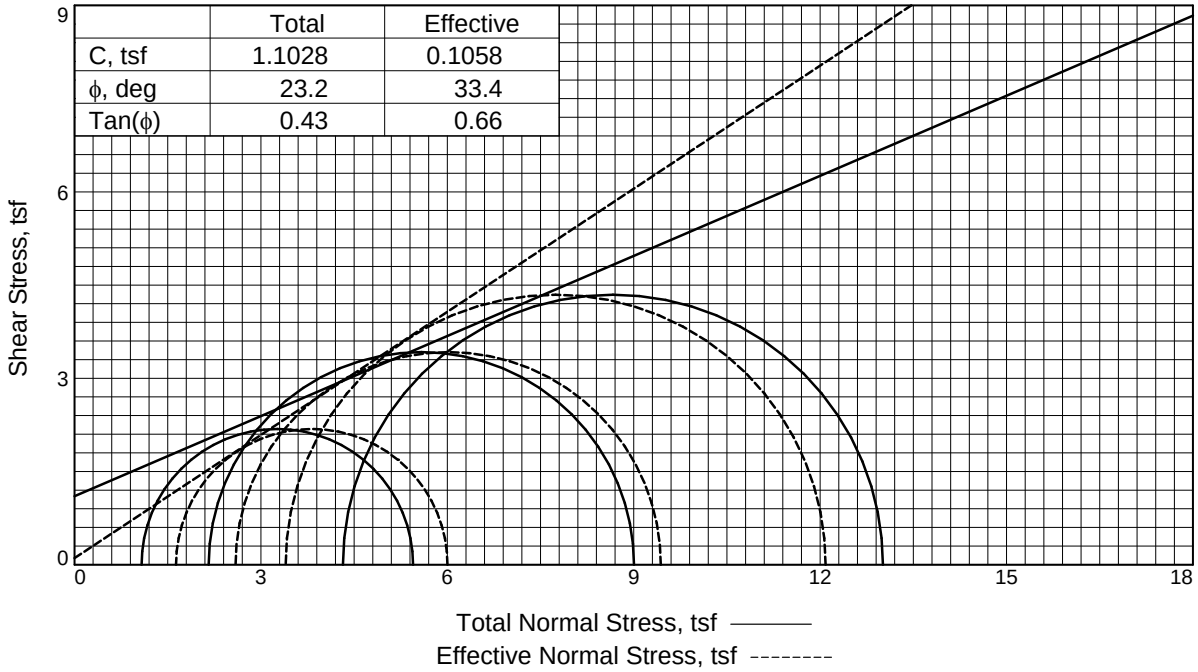


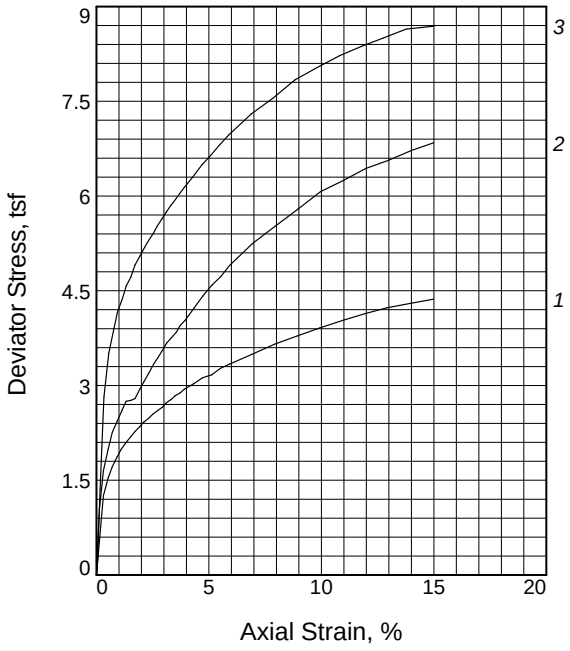
Upper Glacial Till CL

Client: HDR Engineering, Inc.
Project: Larimore Dam
Source of Sample: 602 **Depth:** 41-43' **Sample Number:** 10
Project No.: M5205031 **Figure** _____

Terracon Consultants, Inc.

	Total	Effective
C, tsf	1.1028	0.1058
ϕ, deg	23.2	33.4
Tan(ϕ)	0.43	0.66





Sample No.		1	2	3
Initial	Water Content, %	17.3	16.7	18.3
	Dry Density, pcf	110.1	112.9	110.7
	Saturation, %	87.8	91.8	94.6
	Void Ratio	0.5304	0.4928	0.5226
	Diameter, in.	1.400	1.418	1.400
	Height, in.	2.788	2.790	2.841
At Test	Water Content, %	19.5	17.6	18.7
	Dry Density, pcf	110.4	114.4	112.1
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5268	0.4739	0.5040
	Diameter, in.	1.399	1.412	1.394
	Height, in.	2.785	2.778	2.829
Strain rate, %/min.				
Back Pressure, tsf		6.05	4.97	2.81
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		4.37	6.84	8.69
Total Pore Pr., tsf		5.49	4.54	3.73
Ult. Stress, tsf		4.37	6.84	8.69
Total Pore Pr., tsf		5.49	4.54	3.73
$\bar{\sigma}_1$ Failure, tsf		6.00	9.44	12.09
$\bar{\sigma}_3$ Failure, tsf		1.63	2.59	3.40

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: SANDY LEAN CLAY (CL), brown

LL= 29 **PL=** 19 **PI=** 10

Assumed Specific Gravity= 2.70

Remarks: CU Triax ASTM D 4767

Dam Embankment Fill CL

Figure _____

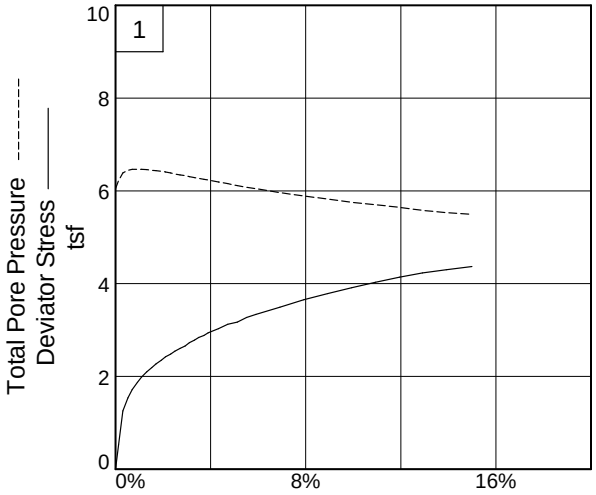
Client: HDR, Inc.

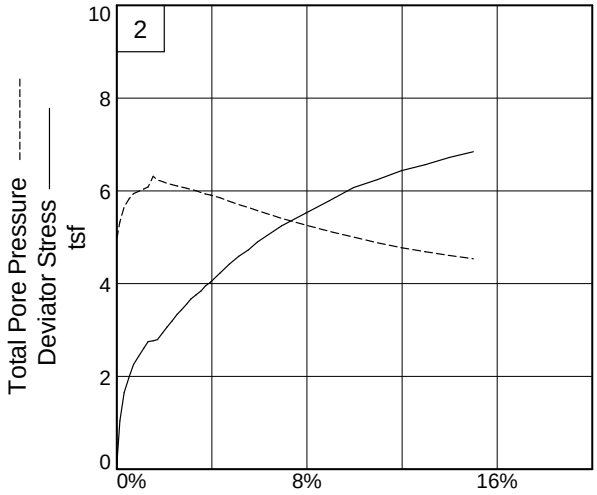
Project: Triaxial Compressive Strength Testing
Grand Forks, ND

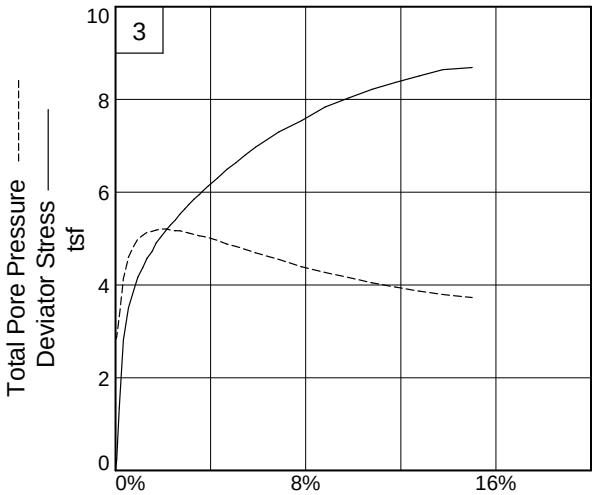
Source of Sample: TH-31 **Depth:** 34.5-36'

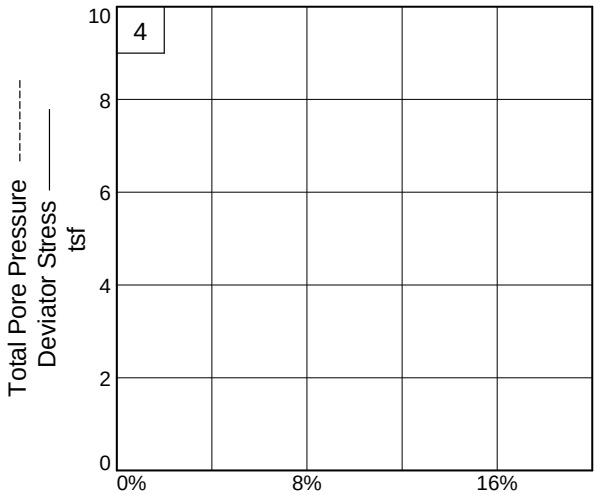
Proj. No.: B2102974 **Date Sampled:**

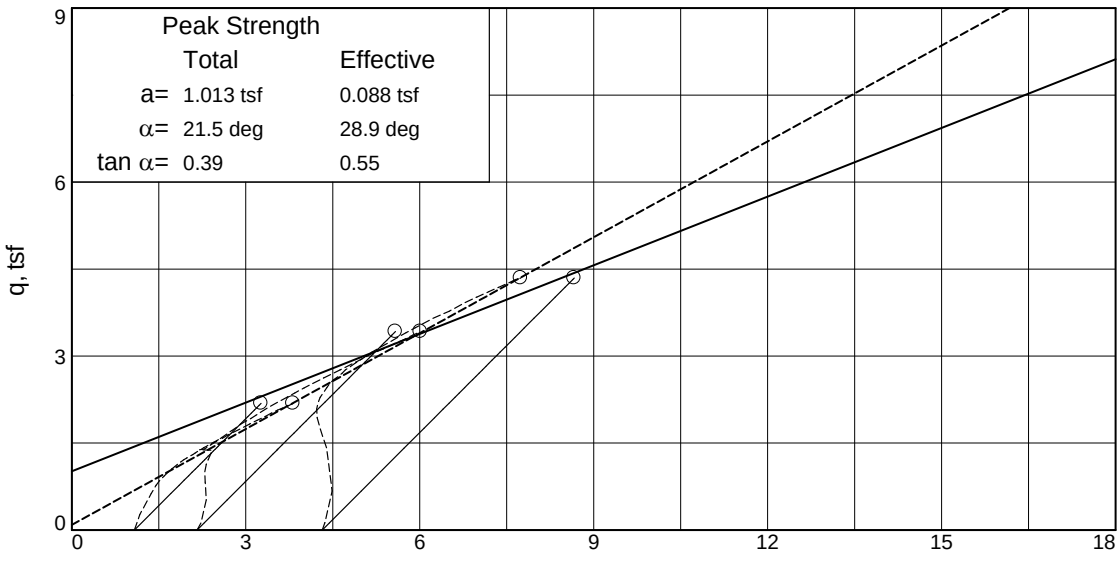
BRAUN℠ INTERTEC











Dam Embankment Fill CL

Stress Paths: Total ——— Effective --------

Client: HDR, Inc.

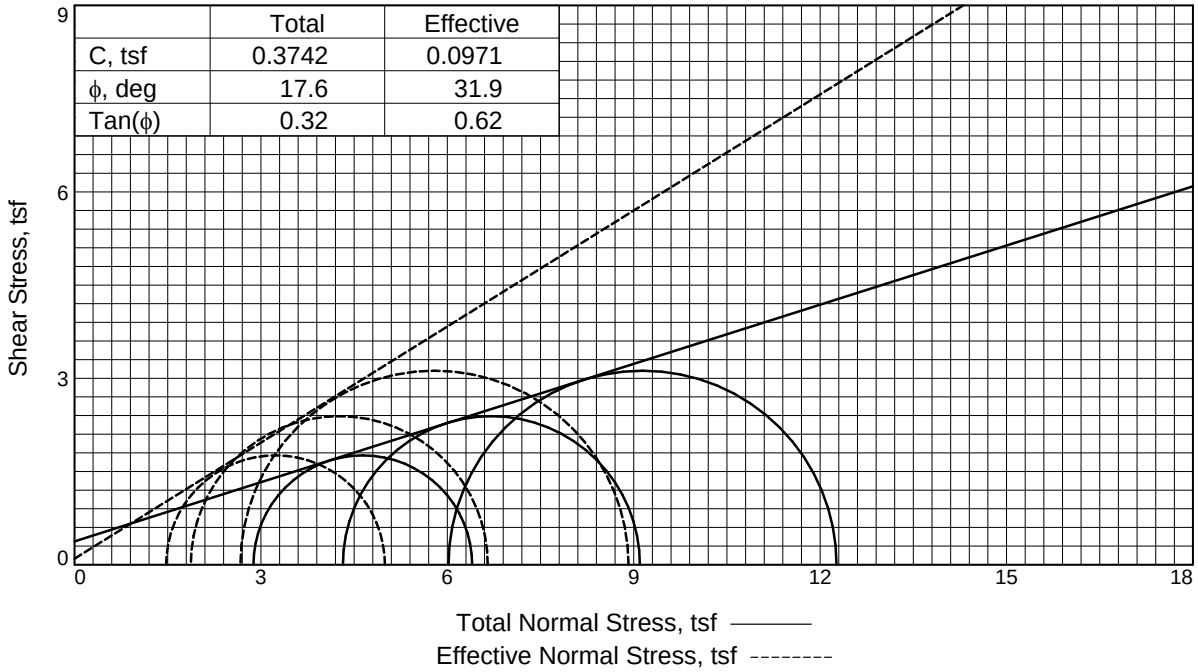
Project: Triaxial Compressive Strength Testing

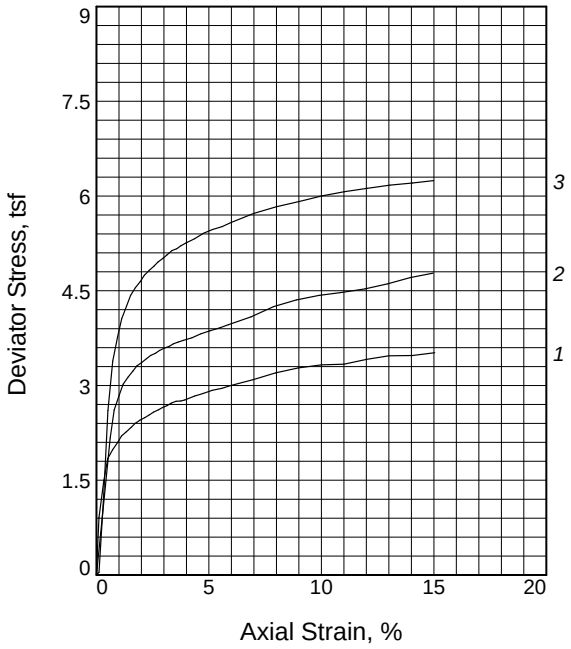
Source of Sample: TH-31 **Depth:** 34.5-36'

Project No.: B2102974 **Figure** _____

Braun Intertec

	Total	Effective
C, tsf	0.3742	0.0971
ϕ, deg	17.6	31.9
Tan(ϕ)	0.32	0.62





Sample No.		1	2	3
Initial	Water Content, %	24.9	25.3	25.7
	Dry Density, pcf	98.5	100.1	99.6
	Saturation, %	94.4	99.9	100.0
	Void Ratio	0.7120	0.6836	0.6929
	Diameter, in.	1.395	1.405	1.403
	Height, in.	2.821	2.812	2.806
At Test	Water Content, %	25.1	23.1	23.6
	Dry Density, pcf	100.5	103.7	102.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6765	0.6249	0.6379
	Diameter, in.	1.385	1.388	1.388
	Height, in.	2.801	2.779	2.775
Strain rate, %/min.				
Back Pressure, tsf		4.248	2.808	1.109
Cell Pressure, tsf		7.128	7.128	7.128
Fail. Stress, tsf		3.519	4.779	6.245
Total Pore Pr., tsf		5.652	5.256	4.457
Ult. Stress, tsf		3.519	4.779	6.245
Total Pore Pr., tsf		5.652	5.256	4.457
$\bar{\sigma}_1$ Failure, tsf		4.995	6.651	8.916
$\bar{\sigma}_3$ Failure, tsf		1.476	1.872	2.671

Type of Test:
CU with Pore Pressures
Sample Type: Shelby Tube
Description: LEAN CLAY with SAND (CL), brown
LL= 39 **PL=** 21 **PI=** 18
Assumed Specific Gravity= 2.70
Remarks: CU Triax ASTM D 4767

Upper Glacial Till CL

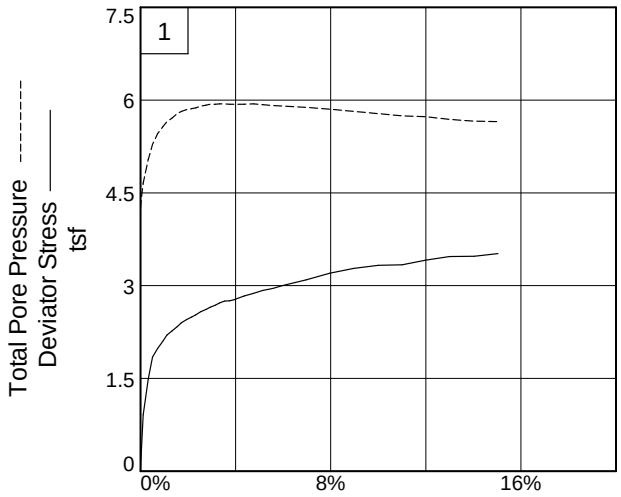
Figure _____

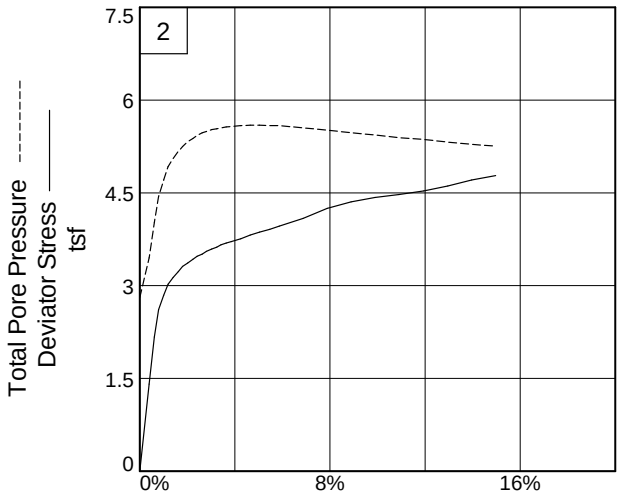
Client: HDR, Inc.

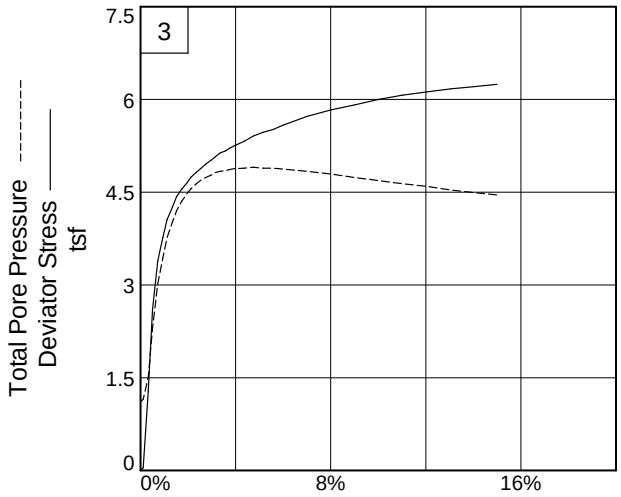
Project: Triaxial Compressive Strength Testing
Grand Forks, ND
Source of Sample: TH-31 **Depth:** 84.5-86'

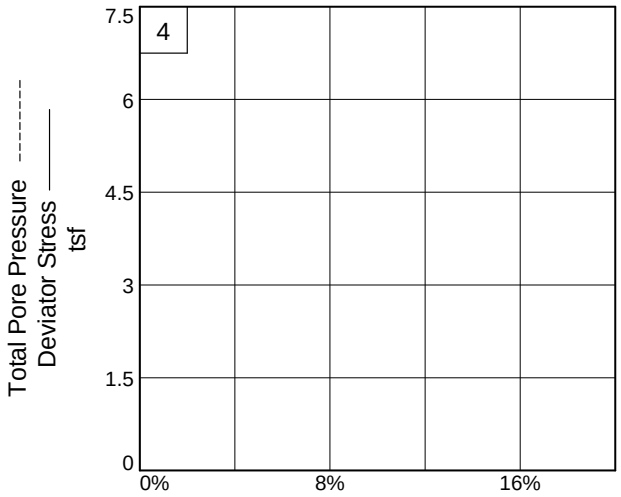
Proj. No.: B2102974 **Date Sampled:**

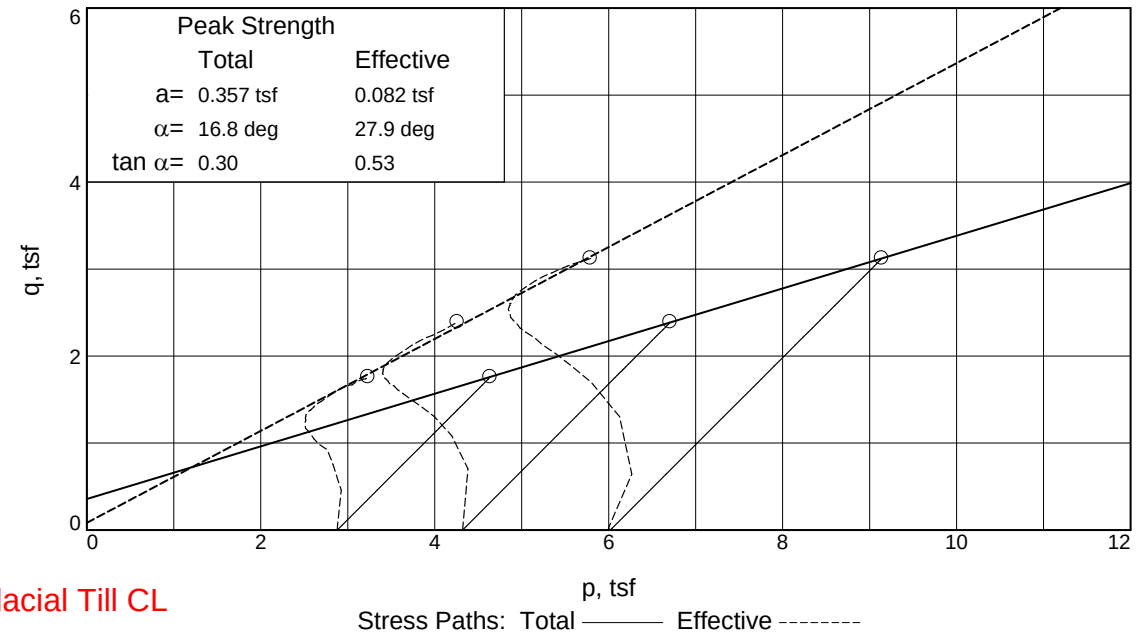
BRAUN INTERTEC











Upper Glacial Till CL

Stress Paths: Total ——— Effective --------

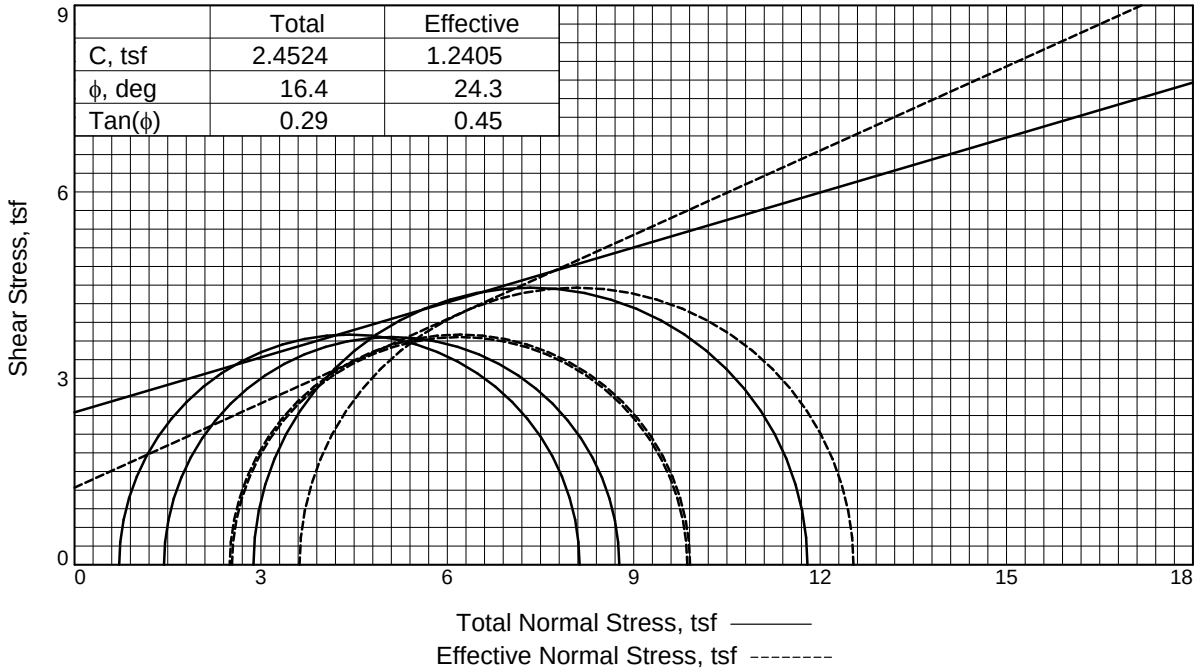
Client: HDR, Inc.

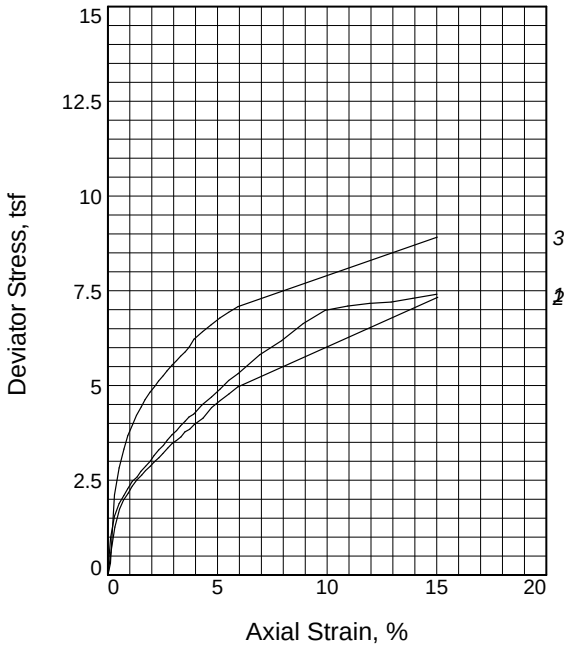
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-31 **Depth:** 84.5-86'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	22.7	22.8	17.5
	Dry Density, pcf	100.0	101.3	110.5
	Saturation, %	89.3	92.8	90.1
	Void Ratio	0.6858	0.6641	0.5249
	Diameter, in.	1.407	1.405	1.405
	Height, in.	2.821	2.789	2.788
At Test	Water Content, %	25.3	24.2	19.2
	Dry Density, pcf	100.1	101.9	110.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6840	0.6543	0.5196
	Diameter, in.	1.407	1.402	1.403
	Height, in.	2.821	2.784	2.784
Strain rate, %/min.				
Back Pressure, tsf		6.41	5.69	4.25
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		7.41	7.33	8.92
Total Pore Pr., tsf		4.63	4.59	3.51
Ult. Stress, tsf		7.41	7.33	8.92
Total Pore Pr., tsf		4.63	4.59	3.51
$\bar{\sigma}_1$ Failure, tsf		9.91	9.86	12.54
$\bar{\sigma}_3$ Failure, tsf		2.50	2.53	3.62

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: LEAN CLAY with SAND (CL), brown

LL= 37 **PL=** 24 **PI=** 13

Assumed Specific Gravity= 2.70

Remarks: CU Triax ASTM D 4767

Dam Embankment Fill CL

Figure _____

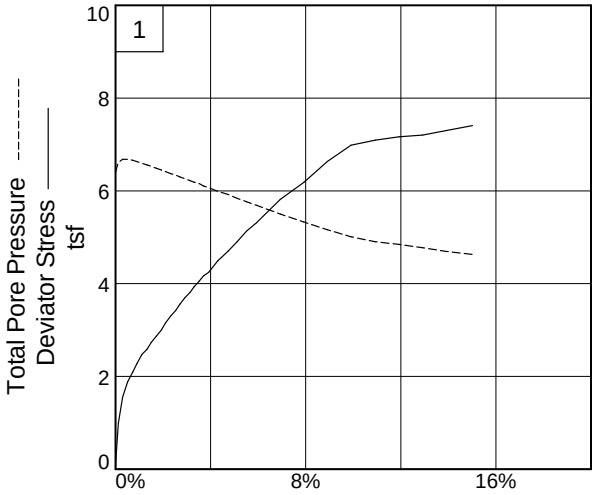
Client: HDR, Inc.

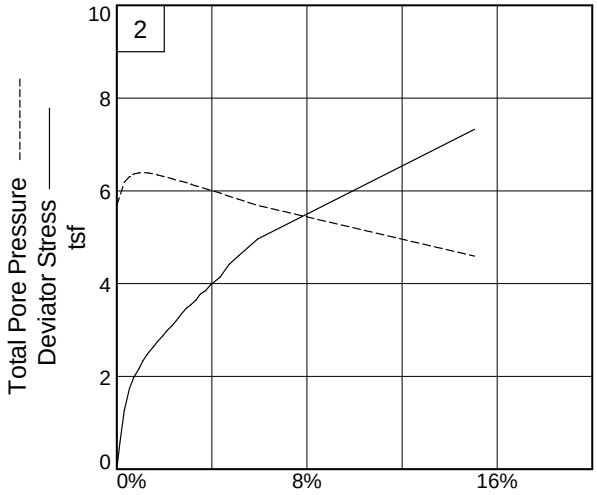
Project: Triaxial Compressive Strength Testing
Grand Forks, ND

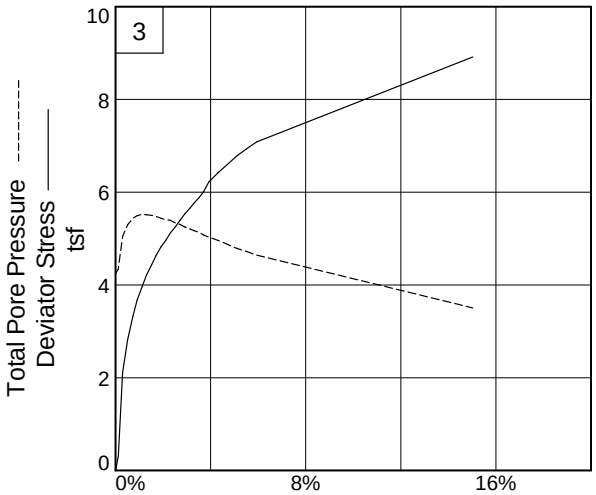
Source of Sample: TH-32 **Depth:** 19.5-21'

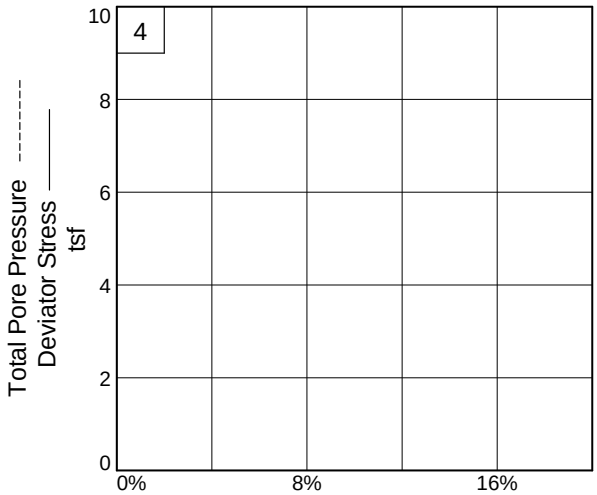
Proj. No.: B2102974 **Date Sampled:**

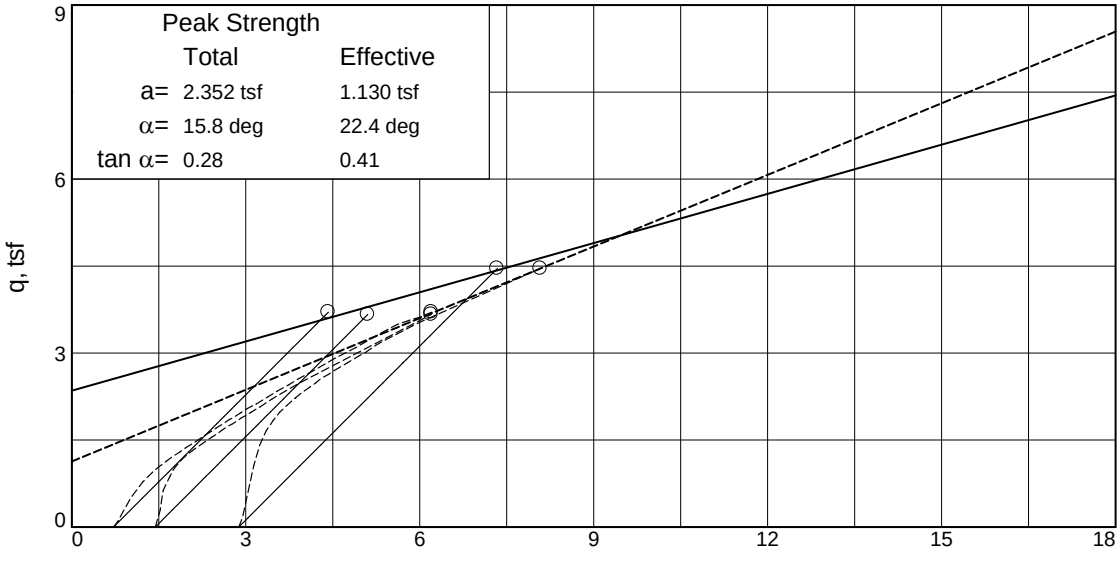
BRAUN INTERTEC











Dam Embankment Fill CL

Stress Paths: Total ——— Effective --------

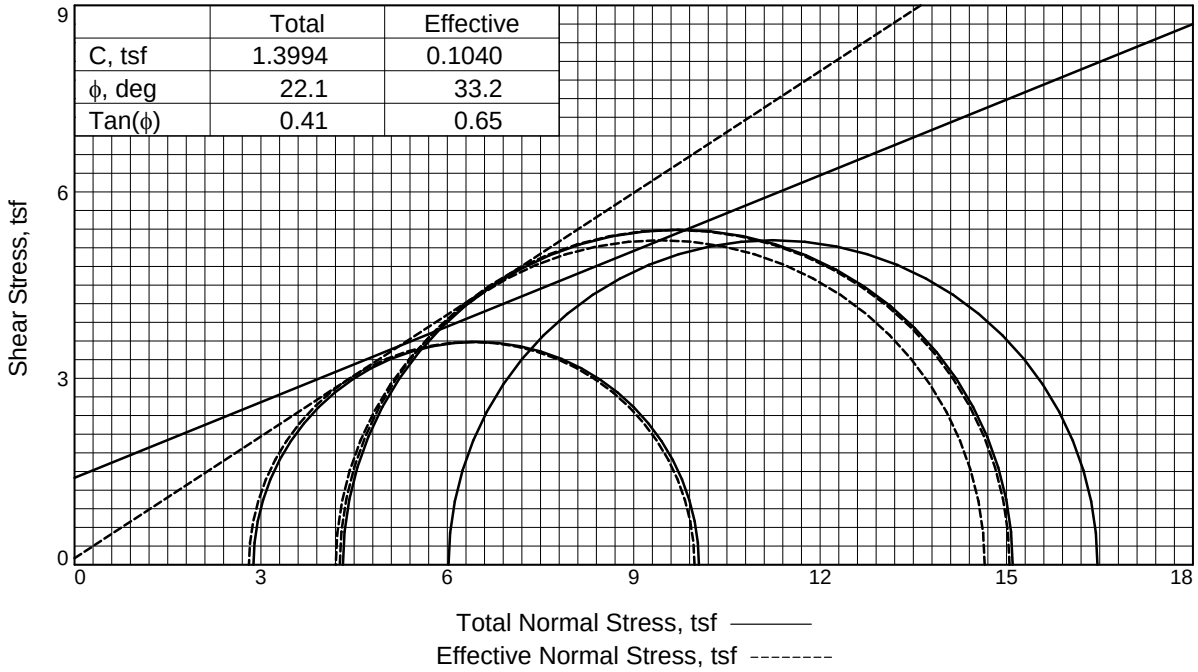
Client: HDR, Inc.

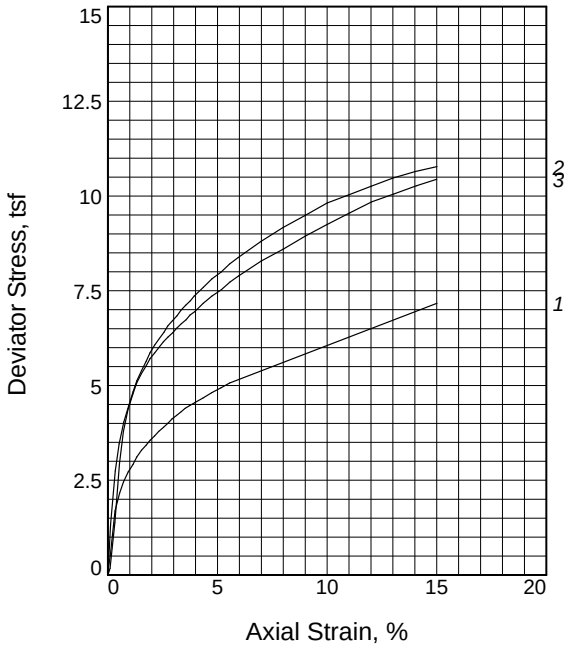
Project: Triaxial Compressive Strength Testing

Source of Sample: TH-32 **Depth:** 19.5-21'

Project No.: B2102974 **Figure** _____

Braun Intertec





Sample No.		1	2	3
Initial	Water Content, %	25.2	24.0	24.8
	Dry Density, pcf	99.7	100.4	98.3
	Saturation, %	98.5	95.7	93.6
	Void Ratio	0.6902	0.6783	0.7146
	Diameter, in.	1.420	1.418	1.420
	Height, in.	2.829	2.852	2.827
At Test	Water Content, %	24.4	24.0	24.6
	Dry Density, pcf	101.7	102.3	101.4
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6579	0.6481	0.6631
	Diameter, in.	1.411	1.409	1.406
	Height, in.	2.811	2.835	2.798
Strain rate, %/min.				
Back Pressure, tsf		4.25	2.81	1.11
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		7.17	10.78	10.44
Total Pore Pr., tsf		4.32	2.86	2.92
Ult. Stress, tsf		7.17	10.78	10.44
Total Pore Pr., tsf		4.32	2.86	2.92
$\bar{\sigma}_1$ Failure, tsf		9.98	15.05	14.65
$\bar{\sigma}_3$ Failure, tsf		2.81	4.27	4.20

Type of Test:
CU with Pore Pressures
Sample Type: Shelby Tube
Description: SANDY LEAN CLAY (CL), brown

LL= 45 **PL=** 24 **PI=** 21
Assumed Specific Gravity= 2.70
Remarks: CU Triax ASTM D 4767

Pre-consolidated Glacial Till CL

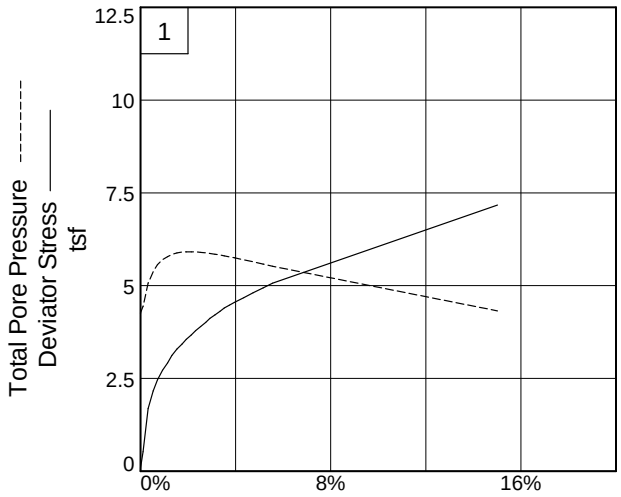
Figure _____

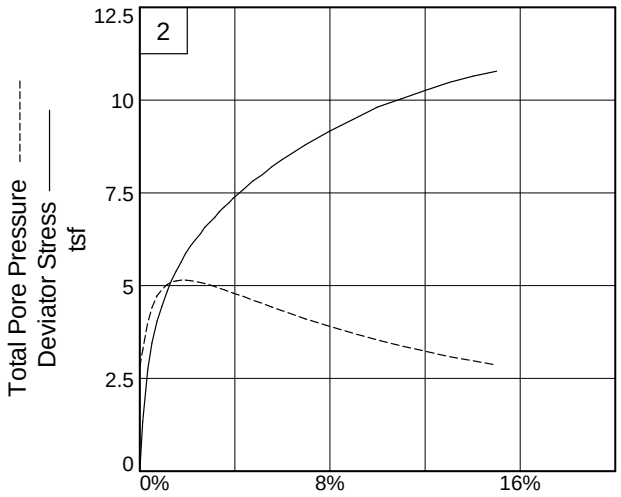
Client: HDR, Inc.

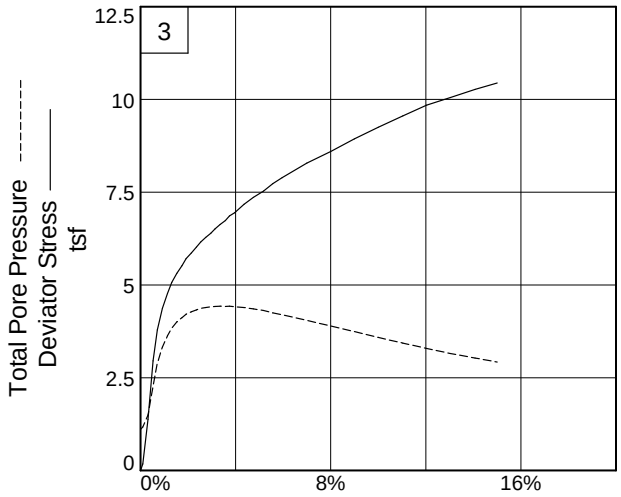
Project: Triaxial Compressive Strength Testing
Grand Forks, ND
Source of Sample: TH-32 **Depth:** 74.5-76'

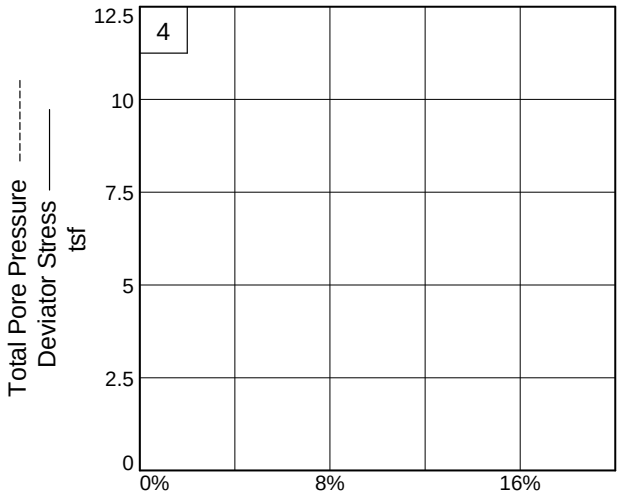
Proj. No.: B2102974 **Date Sampled:**

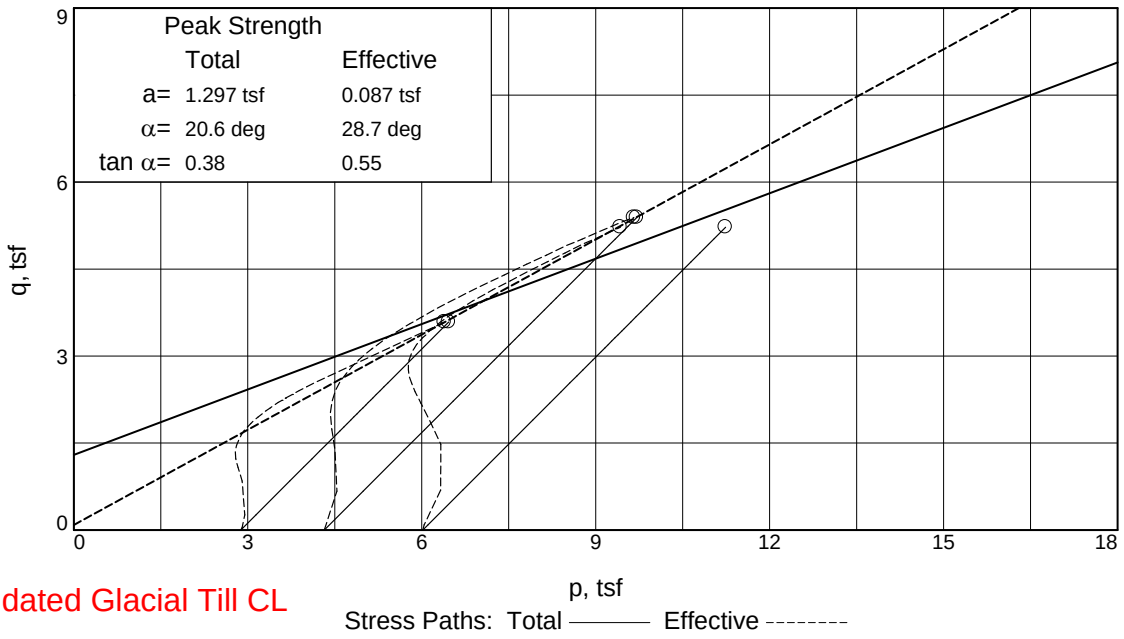
BRAUN℠ INTERTEC











Pre-consolidated Glacial Till CL

Client: HDR, Inc.

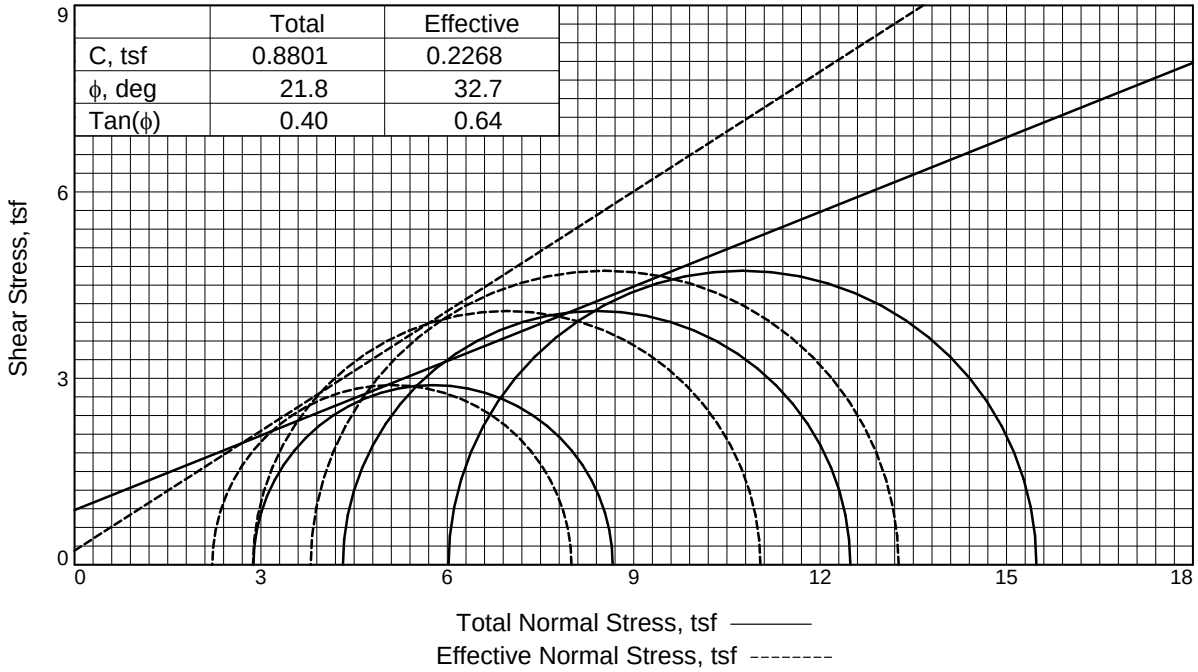
Project: Triaxial Compressive Strength Testing

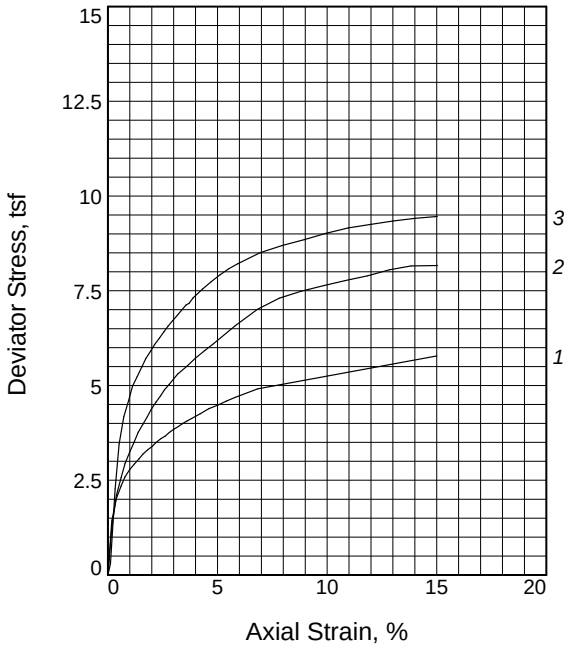
Source of Sample: TH-32 **Depth:** 74.5-76'

Project No.: B2102974 **Figure** _____

Braun Intertec

	Total	Effective
C, tsf	0.8801	0.2268
ϕ, deg	21.8	32.7
Tan(ϕ)	0.40	0.64





Sample No.		1	2	3
Initial	Water Content, %	27.4	26.6	26.0
	Dry Density, pcf	95.5	95.3	94.6
	Saturation, %	96.7	93.6	89.7
	Void Ratio	0.7653	0.7685	0.7818
	Diameter, in.	1.415	1.397	1.406
	Height, in.	2.840	2.839	2.816
At Test	Water Content, %	27.3	27.6	26.8
	Dry Density, pcf	97.0	96.5	97.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7376	0.7465	0.7223
	Diameter, in.	1.408	1.391	1.390
	Height, in.	2.825	2.827	2.784
Strain rate, %/min.				
Back Pressure, tsf		4.25	2.81	1.11
Cell Pressure, tsf		7.13	7.13	7.13
Fail. Stress, tsf		5.78	8.17	9.46
Total Pore Pr., tsf		4.91	4.26	3.33
Ult. Stress, tsf		5.78	8.17	9.46
Total Pore Pr., tsf		4.91	4.26	3.33
$\bar{\sigma}_1$ Failure, tsf		8.00	11.04	13.26
$\bar{\sigma}_3$ Failure, tsf		2.22	2.87	3.80

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: SANDY LEAN CLAY (CL), brown

LL= 45 **PL=** 26 **PI=** 19

Assumed Specific Gravity= 2.70

Remarks: CU Triax ASTM D 4767

Pre-consolidated Glacial Till CL

Figure _____

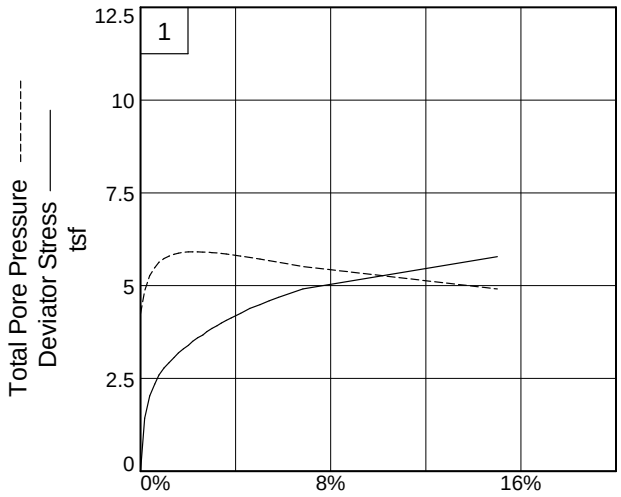
Client: HDR, Inc.

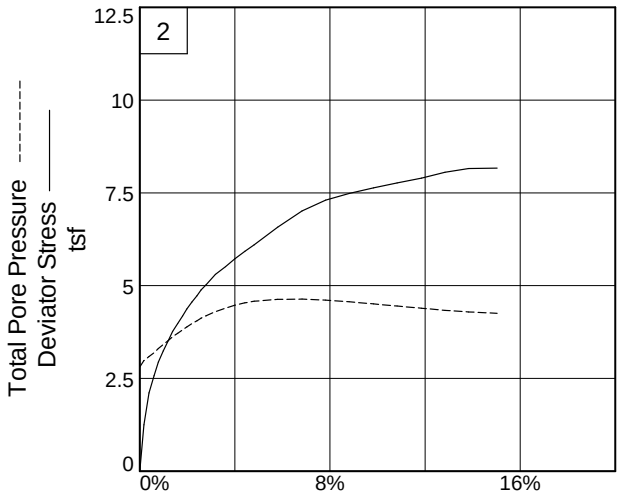
Project: Triaxial Compressive Strength Testing
Grand Forks, ND

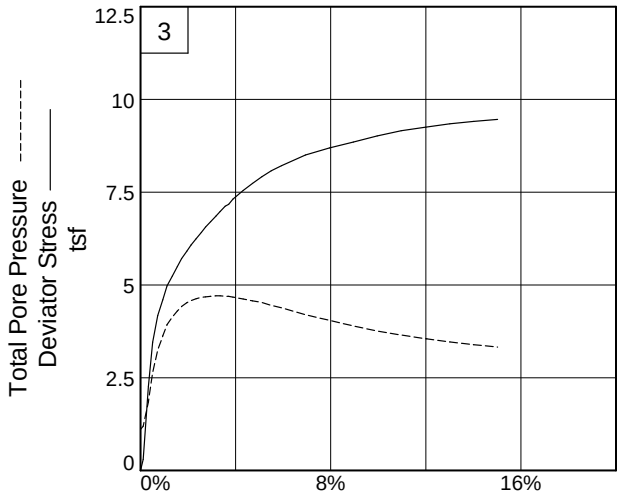
Source of Sample: TH-32 **Depth:** 84.5-86'

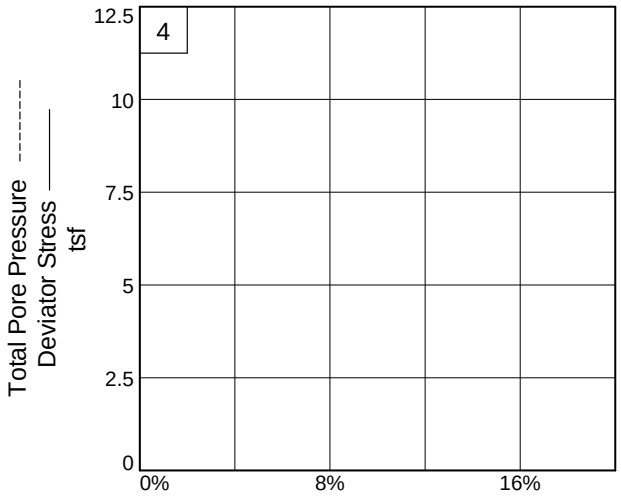
Proj. No.: B2102974 **Date Sampled:**

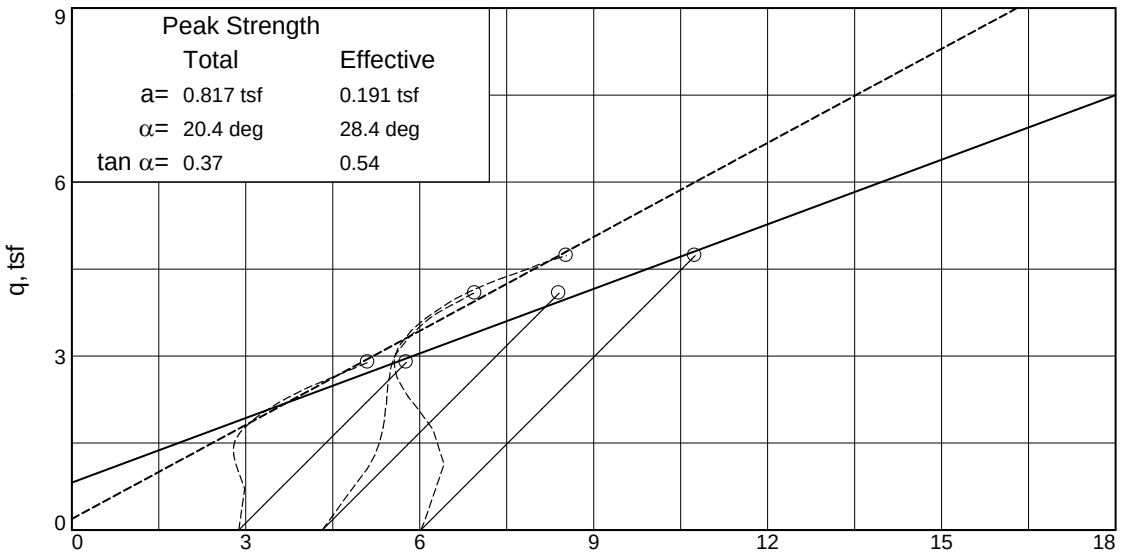
BRAUN℠ INTERTEC











Pre-consolidated Glacial Till CL

Client: HDR, Inc.

Project: Triaxial Compressive Strength Testing

Source of Sample: TH-32 **Depth:** 84.5-86'

Project No.: B2102974 **Figure** _____

Braun Intertec

APPENDIX B: As-Built Drawings

UPPER TURTLE RIVER WATERSHED

GRAND FORKS AND NELSON COUNTIES, NORTH DAKOTA

MULTIPLE-PURPOSE STRUCTURE NO. 9

CONSTRUCTION STARTED: 6-8-77
CONSTRUCTION COMPLETED: 11-2-79
CONTRACTOR: P.N. STREMICK CONST. CO. WALHALLA, N.D.
PROJECT ENGINEER: LARRY KUSESKE
PROJECT INSPECTORS: ELMER BITTNER, BOB VAUDRIN, JOHN SUCHOR
BENCH MARK— 100' NORTH OF PI. STA. 13+88.9
ELEV. BRASS CAP IN CONCRETE POST

SPONSORING AGENCIES:

NELSON COUNTY SOIL CONSERVATION DISTRICT
WEST GRAND FORKS COUNTY SOIL CONSERVATION DISTRICT
NELSON COUNTY WATER MANAGEMENT DISTRICT
GRAND FORKS COUNTY WATER MANAGEMENT DISTRICT

WITH ASSISTANCE BY

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

DRAWING INDEX

SHEET NO.	CONTENTS
1	COVER SHEET
2	TABLE OF QUANTITIES LOCATION MAPS RESERVOIR CAPACITY TABLE PLAN VIEW - JUNCTION PIPE & CUTOFF TRENCH
3	TOPOGRAPHIC MAP RESERVOIR AREA LOCATION BORROW AREA, WASTE AREAS, WORK LIMITS AND CLEARING LIMITS
4	TOPOGRAPHIC MAP OF DAM SITE AREA LOCATION DEBRIS BASIN, SOD CHUTE & CLEARING & GRUBBING LIMITS
5 & 6	TOPOGRAPHIC MAP OF EMERGENCY SPILLWAY
7	PRINCIPAL SPILLWAY OUTLET CHANNEL DETAILS
8 & 9	PROFILE ALONG CENTERLINE OF DAM AND EMERGENCY SPILLWAY LOG OF ADDITIONAL SOIL BORINGS
10	MAXIMUM CROSS SECTION OF DAM, EMBANKMENT MATERIAL SOURCES & PLACEMENT REQUIREMENTS, LABORATORY TEST INFORMATION ON TYPICAL MATERIALS DETAIL OF FOUNDATION BLANKET
11 & 12	DETAILS OF FOUNDATION DRAIN
13 & 14	DETAILS OF CONDUIT BACKFILL, PRINCIPAL SPILLWAY LAYOUT
15 THRU 18	DETAILS OF SAF OUTLET
19 THRU 24	DETAILS OF CHUTE
25 THRU 27	DETAILS OF TRANSITION
28 THRU 32	DETAILS OF CONDUIT
33	DETAILS OF ANTISEEP COLLARS
34 THRU 43	DETAILS OF R/C INLET
44	DETAILS OF STOPLOG INSTALLATION
45 & 46	TRASH RACK DETAILS
47	DETAILS GATE STEM CAGE DETAILS WELL GRATINGS
48	DETAILS OF LADDER
49	DETAILS OF COVER SLAB RAILINGS
50	CONDUIT DETAILS
51	DETAILS OF DRAWDOWN INLET
ATTACHMENTS:	STRUCTURE DATA SHEET STANDARD DRAWING 5,R-10,000.N7

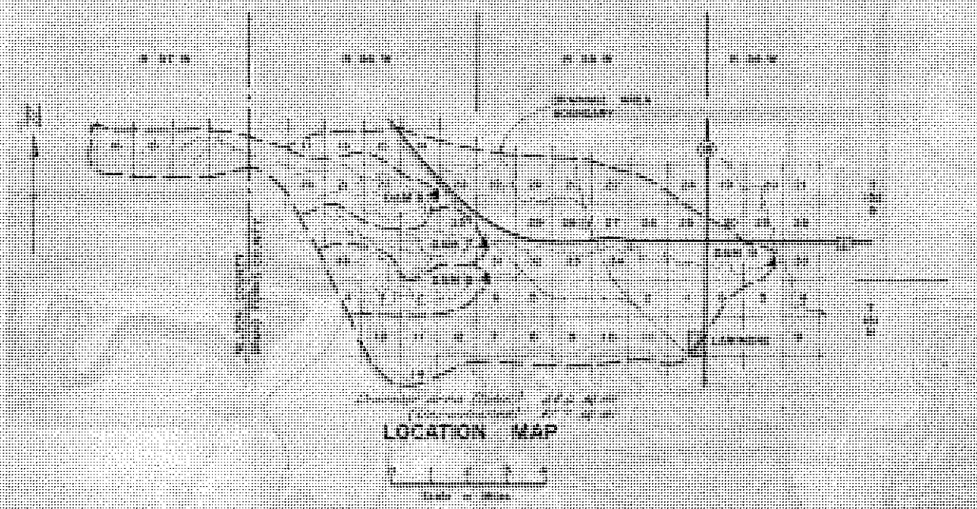
AS BUILT
FEB. 6 1979

SOIL CONSERVATION SERVICE

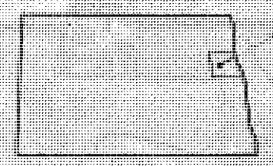
I CERTIFY THAT THE PLANS AND DETAILED SPECIFICATIONS FOR THIS PROJECT WERE DEVELOPED BY THE SOIL CONSERVATION SERVICE AND ARE APPROVED.

Richard Moum — 2-14-77
STATE CONSERVATION ENGINEER — DATE

Bruce M. Ferguson — 2-17-77
HEAD, ENGINEERING AND WATERSHED PLANNING UNIT — DATE



LOCATION MAP



LOCATION IN GRAND FORKS COUNTY, NORTH DAKOTA

RESERVOIR CAPACITY TABLE

TABLE OF QUANTITIES*

Curve Data
Δ = 77° 00' D = 20°
R = 287.34' T = 229.0'
L = 385.0' P.I. = Sta. 12+40.6
P.C. = Sta. 10+11.6 P.T. = Sta. 13+96.6

Approx. limits existing stockpile Zone I material

Waste will be placed as directed by the engineer in this general area

Notes:
1. Contour lines shown are those existing before construction of the dewatering ditches. Excavated material from the ditches is stockpiled within the limits of the emergency spillway.
2. Topsoil stripped from the emergency spillway has been stockpiled at the location shown on the drawings.
3. Care will be taken to minimize disturbance of the completed sections of the emergency spillway upstream from Sta. 7+00 and downstream from Sta 24+27.
4. A copy of the plans for the existing dewatering ditches may be seen at the SCS office in Larimore, N.Dak.
5. Observation wells are set on both sides of the emergency spillway. Contractor will use care to avoid damage to the observation wells.
6. See sheet 8 of 51, section 1-1 for cross section view of dewatering ditches.
7. Provide drainage ditch starting at Sta. 7+50 and proceeding along ℄ of emergency spillway to Sta. 14+00. The ditch will have a 10' bottom and 8:1 side slopes with a grade of 0.001.

Spillway Diversion
Bottom Width - 8.0
Side Slopes - 6:1 SS
Grade - .004

Dike - Minimum Height 2.0

Level Section El. 1087.8 (Existing)
Dike (Existing)
El. 1087.8
T.H. 107
T.H. 106
Sta. 0+00
Approximate Work Limit Boundary
T.H. 105
Gr. = 1.0%
El. 1089.3
E-Dewatering Ditch (Existing)
Approx limits of existing stockpile Zone II material
Diversion
Sta 7+50
Sta. 7+00
Sta. 8+50
Provide drainage ditch (see note 7)
Existing C.M. Pipe
Sta 10+11.6 = P.C.
Sta 12+40.6 = P.I.
Dike
Sta. 3+50
4:1
30' Berm
3½:1
Top of dam
20'
2½:1
50' Berm
4:1
E-Dewatering Ditch (Existing)
Sta. 0+00 ℄ of dam
Level Section El. 1089.3
Temporary fence to be installed by contractor
Approximate Work Limit Boundary
Sta. 14+00
Sta. 13+96.6 = P.T.
150.0'
150.0'
3:1
3:1
Approximate Location of Topsoil Stockpile from Emergency Spillway.
AS BUILT FEB. 1979
Match Line See Sheet 4.
Golf course "Keep Out"
Match Line, See Sheet 6.
El. 1089.3
T.H. 104
Sta. 16+27

TOPOGRAPHIC MAP OF DAMSITE

50 0 50 100 150
Scale in feet

MULTIPLE-PURPOSE STRUCTURE NO. 9

UPPER TURTLE RIVER WATERSHED
Grand Forks & Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed RDS & JEN	Date 6/76	Approved by:	
Drawn JEN	6/76	Title:	
Traced		Title:	
Checked Ronald Sando	1-77	Sheet No. 5 of 51	Drawing No. SE-36025

SCS-ENG-313-B Rev. 7-69

800'

Approximate Work Limit Boundary

Approximate Location of Topsoil Stockpile from Emergency Spillway.

Approx. limits of existing stockpile Zone I material

Approx. limits existing stockpile of Zone II material

N

Diversion
SEC. 32-T152N-R54W

Sta. 1+40

Sod Chute
See Typical Cross-Section

Dike (Existing)

See notes on sheet 5.

10.0'
1.5'
Bottom Width

Note:
Snagging & clearing:
Designated trees & deadfalls at the outlet of the emergency spillway that are dead or designated by the engineer shall be removed.

B

1105

Gr. = 3.0%

Gr. = 0.1%

300'

700'

Sta. 14+27

1103

El. 1089.3

Assumed Quarter Line

T.H. 103

Sta. 19+77

T.H. 102

T.H. 101

Sta. 24+27

℄ of Emergency Spillway

℄ - Dewatering Ditch (Existing)

El. 1078.8

Level Section
El. 1078.35
(Existing)

℄ Outlet Ditch (Existing)

C.M. Pipe (Existing)

AS BUILT
FEB. 8 1978

1105

Approximate Work Limit Boundary

1342'

1102

Match Line
See Sheet 5.

B

Golf course
"Keep Out"

1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
950
945
940
935
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TOPOGRAPHIC MAP OF DAMSITE

60 0 50 100 150

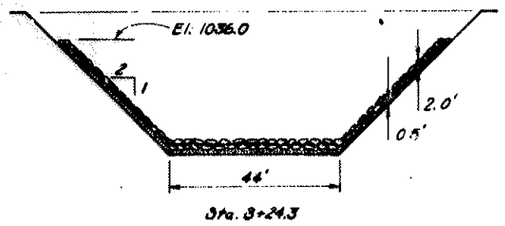
Scale in feet

MULTIPLE-PURPOSE STRUCTURE
NO. 3
UPPER TURTLE RIVER WATERSHED
Grand Forks & McHenry Counties North Dakota.

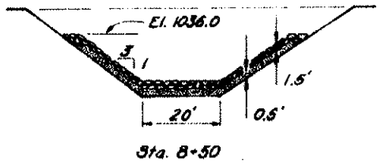
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed RDS, JEN	Date 4/76	Approved by	
Drawn Ronald Sands	3/77	Title	
Traced		Title	
Checked J.E.N.	1-77	Sheet No 6 of 51	Drawing No SE-36,025

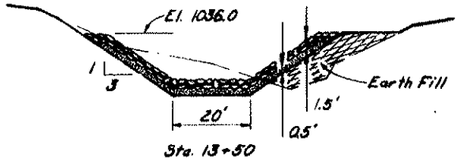
SCS-ENG-313-B Rev. 7-69



Sta. 3+24.3



Sta. 8+50

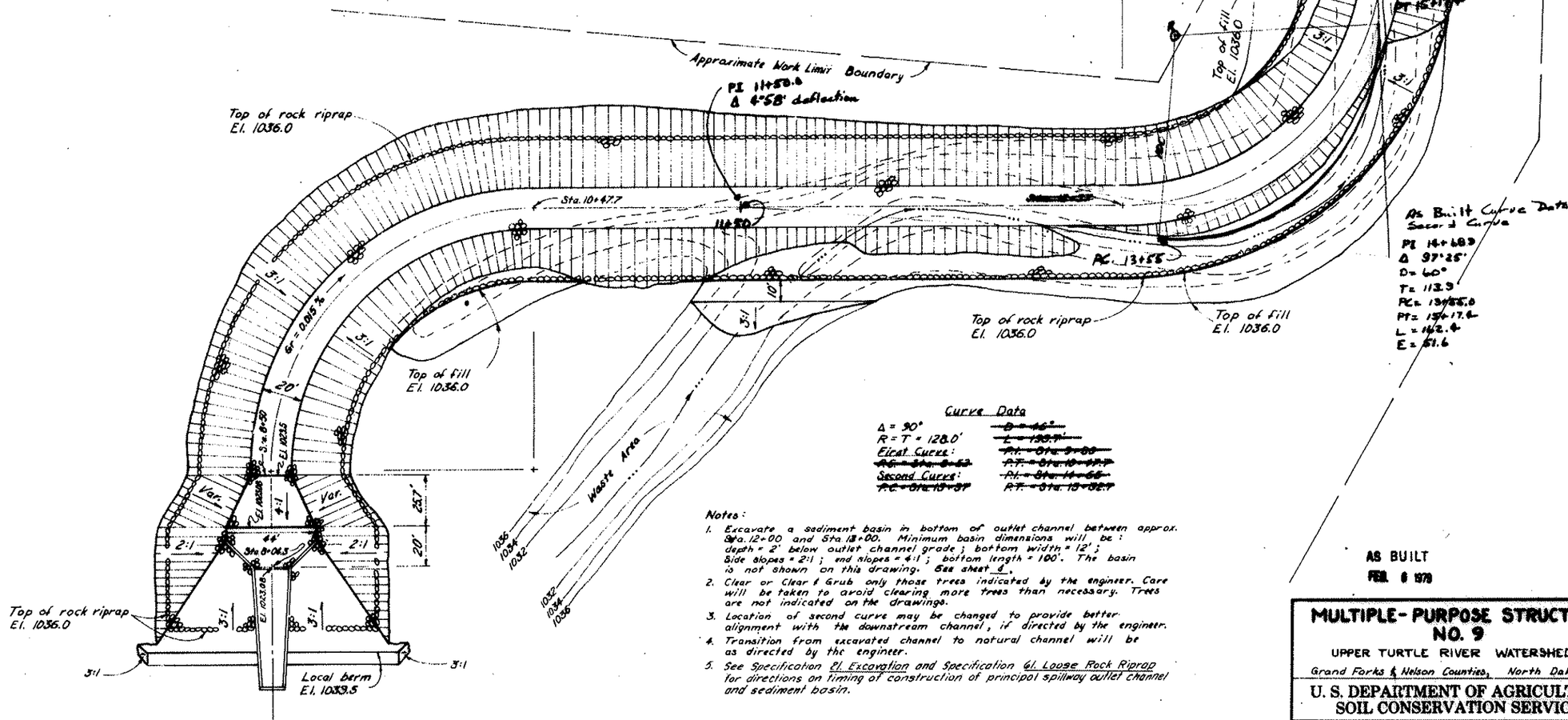


Sta. 13+50

1. Thickness of rock riprap and bedding is measured vertically.
2. Upstream from outlet channel Sta. 8+50, rock riprap will be 2.0' thick plus 0.5' bedding.
3. Between Sta. 8+50 and Sta. 15+32.7, rock riprap will be 1.5' thick plus 0.5' bedding.

TYPICAL SECTIONS OF PRINCIPAL SPILLWAY OUTLET CHANNEL

(Not to scale)



Curve Data

Δ = 30°
R = T = 128.0'
~~D = 16°~~
~~L = 139.7'~~
First Curve:
~~PC = Sta. 8+50~~
~~PT = Sta. 9+89~~
Second Curve:
~~PC = Sta. 10+97~~
~~PT = Sta. 11+65~~
~~PC = Sta. 13+37~~
~~PT = Sta. 13+82.7~~

Notes:

1. Excavate a sediment basin in bottom of outlet channel between approx. Sta. 12+00 and Sta. 13+00. Minimum basin dimensions will be: depth = 2' below outlet channel grade; bottom width = 12'; side slopes = 2:1; end slopes = 4:1; bottom length = 100'. The basin is not shown on this drawing. See sheet 4.
2. Clear or Clear & Grub only those trees indicated by the engineer. Care will be taken to avoid clearing more trees than necessary. Trees are not indicated on the drawings.
3. Location of second curve may be changed to provide better alignment with the downstream channel, if directed by the engineer.
4. Transition from excavated channel to natural channel will be as directed by the engineer.
5. See Specification El. Excavation and Specification 61. Loose Rock Riprap for directions on timing of construction of principal spillway outlet channel and sediment basin.

PLAN VIEW OF PRINCIPAL SPILLWAY OUTLET CHANNEL

100 75 50 25 0 100

(Scale in feet)

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FEB. 6 1978

MULTIPLE-PURPOSE STRUCTURE NO. 9

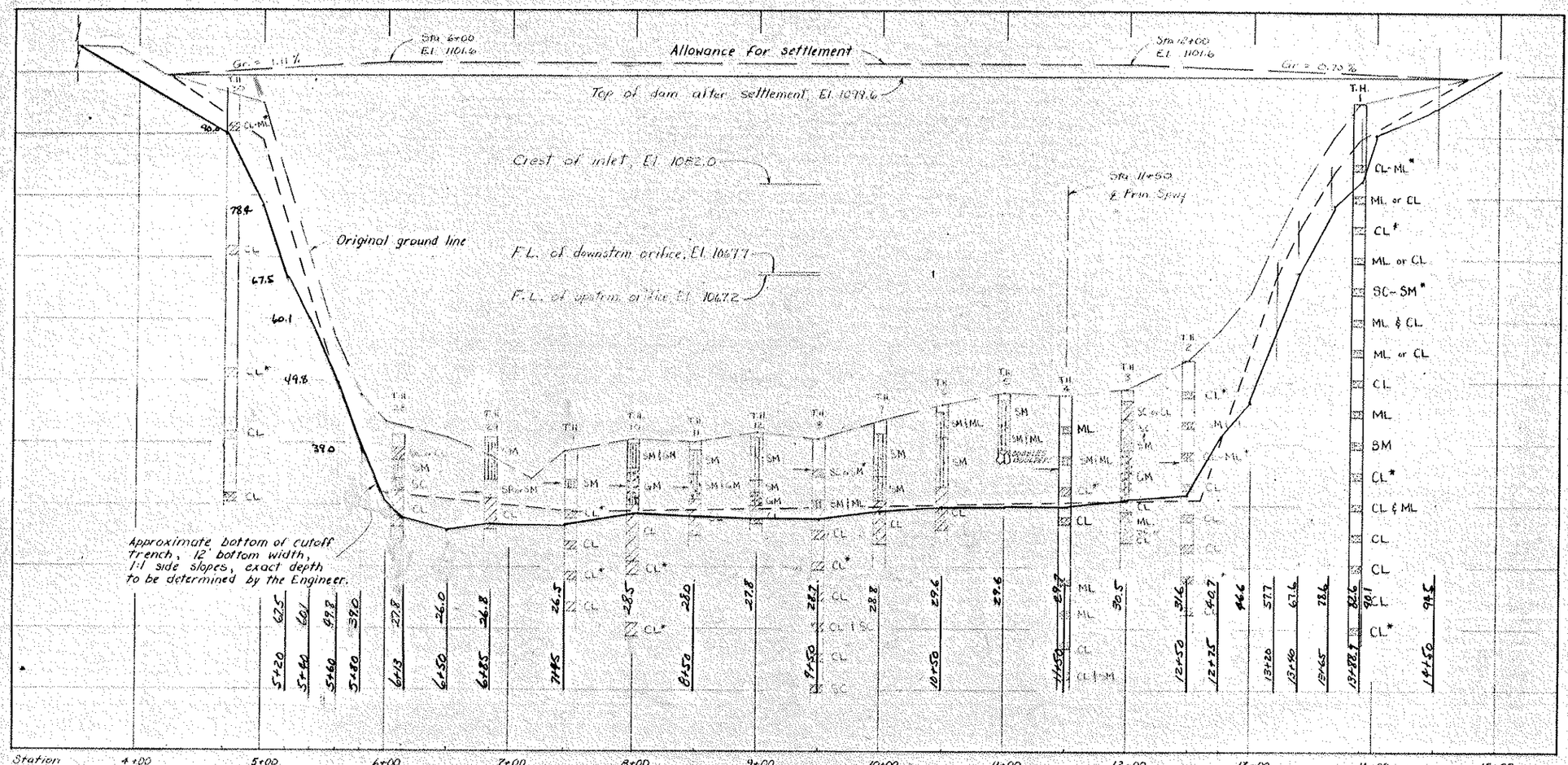
UPPER TURTLE RIVER WATERSHED

Grand Forks & Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

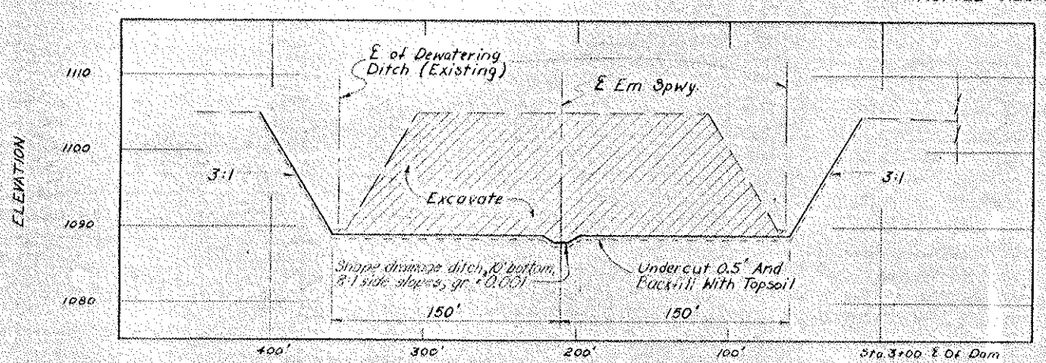
Designed JEN	Date 6/76	Approved by	
Drawn JEN	7/76	Title	
Traced		Sheet No. 7 of 51	Drawing No. SE-36,025
Checked Ronald Sando	1-77		

SCS-ENG-313-B Rev. 7-69



Section 1-1

PROFILE ALONG ℄ OF DAM



Section 1-1

CROSS-SECTION OF EMERGENCY SPILLWAY

Notes:

1. For soils legend and symbols, see drawing no. 5,R-10,000.47.
2. Soil exploration date - March 7, 1972.
3. → indicates groundwater at time of exploration. (3-7-72)
4. The Unified Soil Classification symbols followed by an asterisk are based on laboratory classification. Those symbols without an asterisk are based on field classification and are subject to revision based on laboratory tests.
5. Boulders encountered in excavating the cutoff trench shall be removed and wasted as approved by the engineer.
6. Contractor should note boulders may be encountered in the entire base of the dam. Removal and disposal will be as directed by the engineer. See construction specification 21 for definition of rock excavation.

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FEB. 6 1979

MULTIPLE-PURPOSE STRUCTURE NO. 9

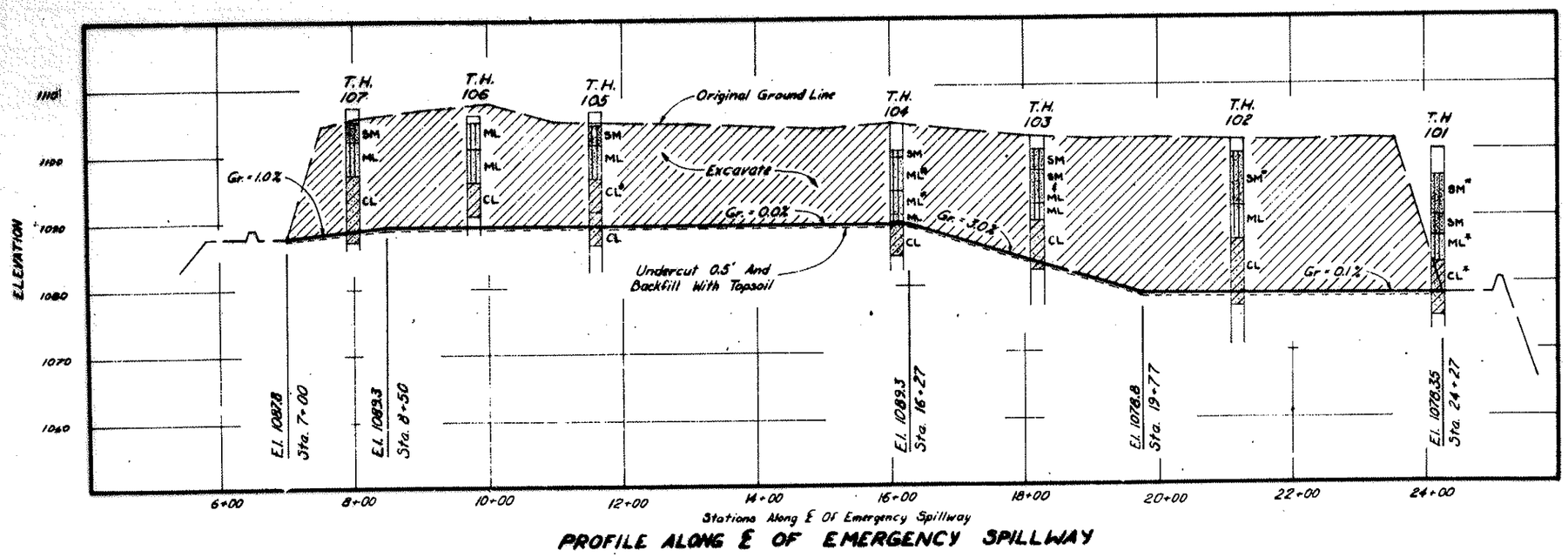
UPPER TURTLE RIVER WATERSHED

Grand Forks & Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
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	Date		
Designed JEN	4/76	Approved by	
Drawn JEN	4/76	Title	
Traced		Title	
Checked Ronald Sando	1-77	Sheet No. 8 of 51	Drawing No. 5,E-36,025

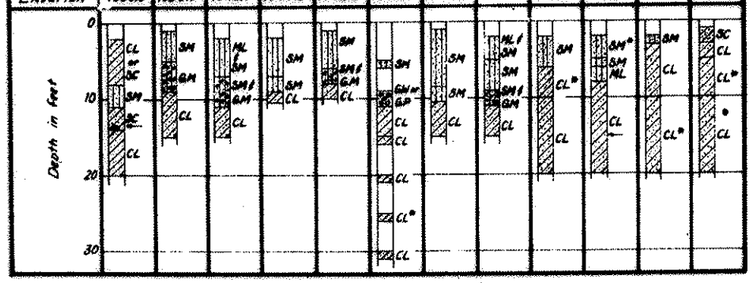
SCS-ENG-313-B Rev. 7-69



PROFILE ALONG ℄ OF EMERGENCY SPILLWAY

LOG OF SOIL BORINGS

Location	Foundation								Borrow Area			
Test Hole No.	14	18	19	20	22	25	26	27	109	110	112	122
Elevation	1058.8	1039.3	1042.7	1040.3	1042.2	1040.0	1041.8	1040.0	1109.7	1109.6	1107.0	1109.8



Notes:

1. Test holes 105, 106, and 107 are superimposed on centerline of Emergency Spillway.
2. For additional notes concerning test hole logs, see sheet 8 .

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FEB. 6 1978

MULTIPLE-PURPOSE STRUCTURE NO. 9

UPPER TURTLE RIVER WATERSHED

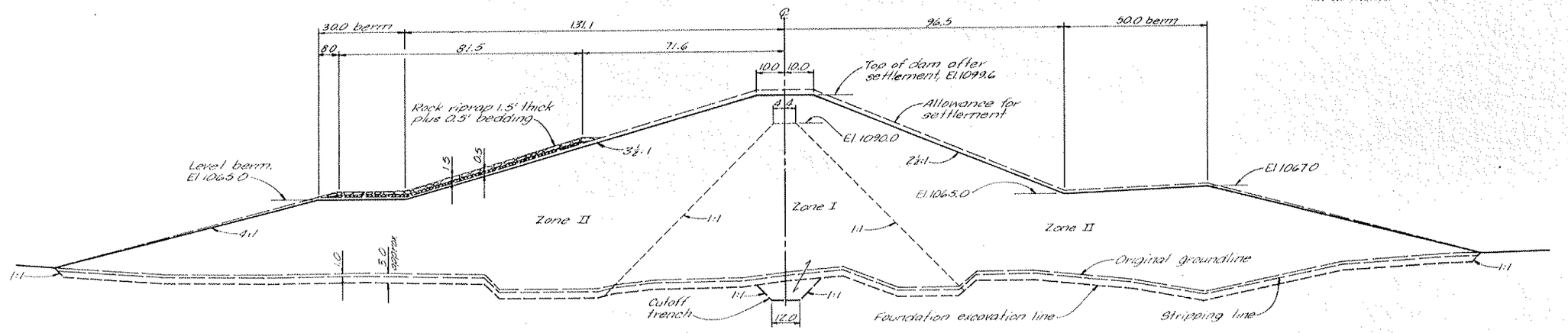
Grand Forks & Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

Designed JEN, RDS	Date 6/76	Approved by	
Drawn JEN	7/76	Title	
Traced		Title	
Checked Ronald Sando	1-77	Sheet No 9 of 51	Drawing No SE-36025

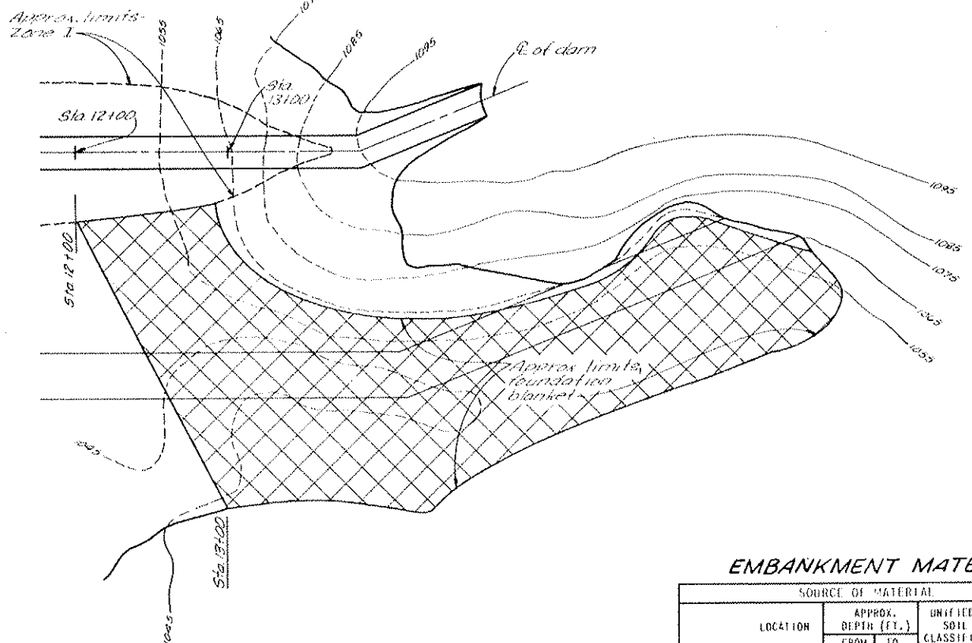
SCS-ENG-313-B Rev. 7-69

NOTES:
1. LABORATORY TEST DATA ON THE SOIL INVESTIGATION IS AVAILABLE AT THE SCS OFFICE IN FARGO, NORTH DAKOTA.
2. FOR SOIL LEGEND AND SYMBOLS, SEE STANDARD DRAWING NO. 5-R-10,000.47



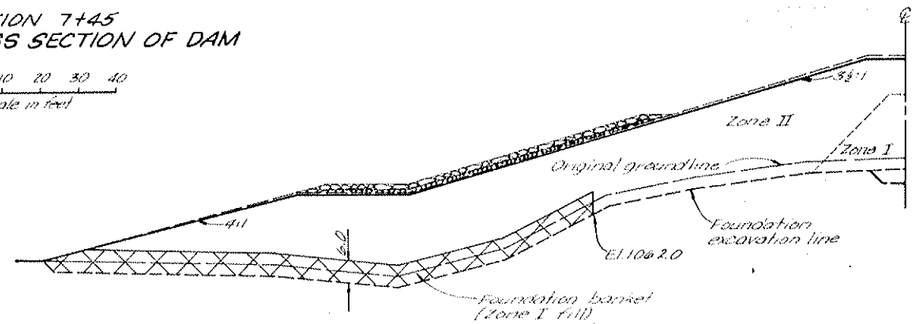
STATION 7+45
MAXIMUM CROSS SECTION OF DAM

10 0 10 20 30 40
Scale in feet



PLAN VIEW OF FOUNDATION BLANKET

50 25 0 50 100 150
Scale in feet



TYPICAL SECTION OF FOUNDATION BLANKET

10 0 10 20 30 40
Scale in feet

LABORATORY TEST INFORMATION ON TYPICAL MATERIALS

UNIFIED SOIL CLASSIFICATION	TEST HOLE 101 CL	TEST HOLE 104 ML	TEST HOLE 102 SM	TEST HOLE 122 CL
REFERENCE TEST METHOD	METHOD A ASTM D-698	METHOD A ASTM D-698	METHOD A ASTM D-698	METHOD A ASTM D-698
MAXIMUM DRY DENSITY	110.5 P.C.F.	101.0 P.C.F.	107.0 P.C.F.	112.0 P.C.F.
OPTIMUM MOISTURE	16.5%	21.5%	17.5%	16.5%
DESCRIPTION	GLACIAL DRIFT	LACUSTRINE SEDIMENTS	LACUSTRINE SEDIMENTS	GLACIAL DRIFT

EMBANKMENT MATERIAL SOURCES AND PLACEMENT REQUIREMENT

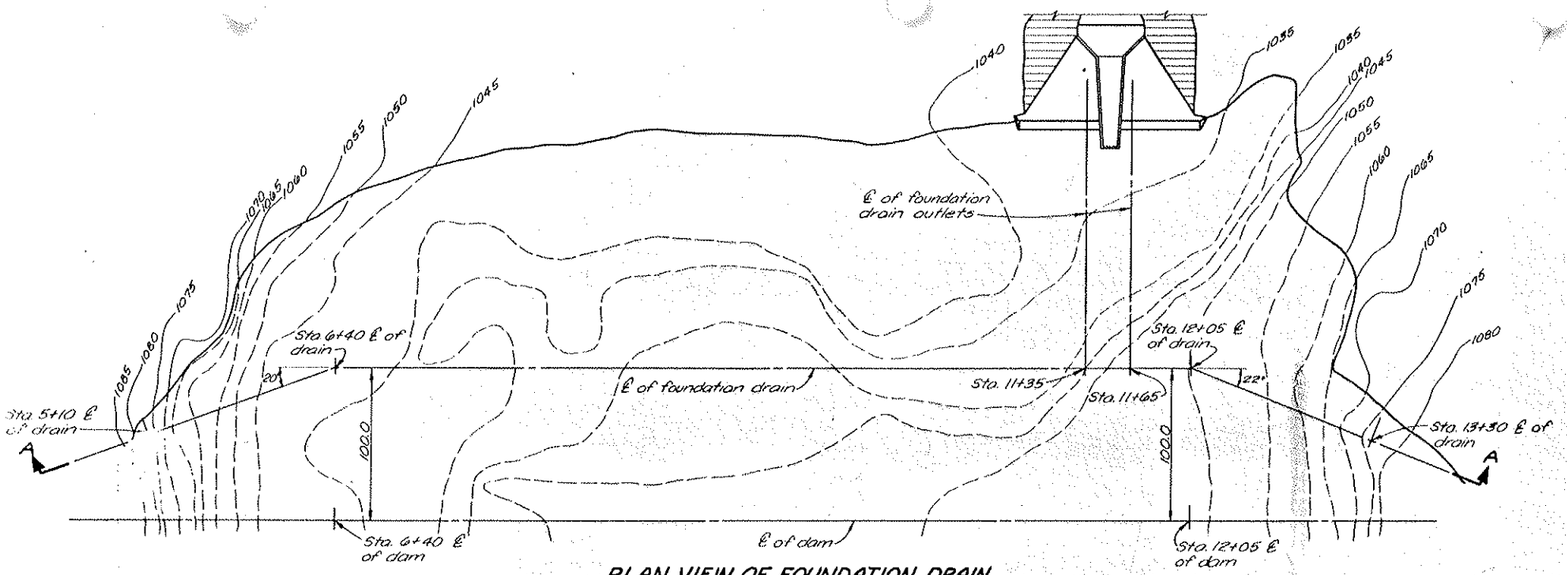
SOURCE OF MATERIAL					PLACEMENT AND MOISTURE DENSITY REQUIREMENT							
LOCATION		APPROX. DEPTH (FT.) FROM	TO	UNIFIED SOIL CLASSIFICATION	DEPTH OF LIFT	MAX. SIZE ROCK FRAGMENTS	FILL MATRIX SIZE TESTED	COMPACTION CLASS	REFERENCE TEST METHOD	REQ'D. (%) COMPACTION	ALLOWABLE MOISTURE RANGE FROM OPTIMUM(%)	FILL LOCATION
TEST HOLE 102	EMERGENCY SPILLWAY	2	10	SM	9"	6"	<#4	A	METHOD A ASTM D-698	95	0 AND ABOVE	ZONE II
TEST HOLE 104	EMERGENCY SPILLWAY	5	14	ML	9"	6"	<#4	A	METHOD A ASTM D-698	95	0 AND ABOVE	ZONE II
TEST HOLE 105	EMERGENCY SPILLWAY	10	18	CL	9"	6"	<#4	A	METHOD A ASTM D-698	95	0 AND ABOVE	ZONE I
TEST HOLE 110	BORROW AREA	2	5	SM	9"	6"	<#4	A	METHOD A ASTM D-698	95	0 AND ABOVE	ZONE II
TEST HOLE 122	BORROW AREA	5	10	CL	9"	6"	<#4	A	METHOD A ASTM D-698	95	0 AND ABOVE	ZONE I

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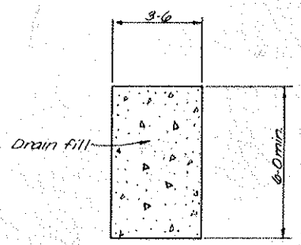
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

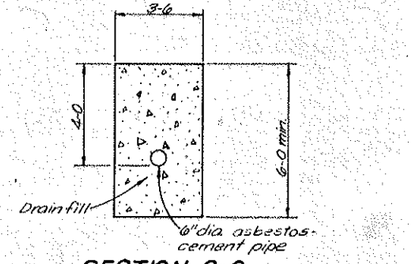
	Date		
Designed J.E.N.	8-76	Approved by	
Drawn J.E.N.	8-76	Title	
Traced		Title	
Checked Donald Simdo	1-77	Sheet No. 10 of 51	Drawing No. 5-E-36,025



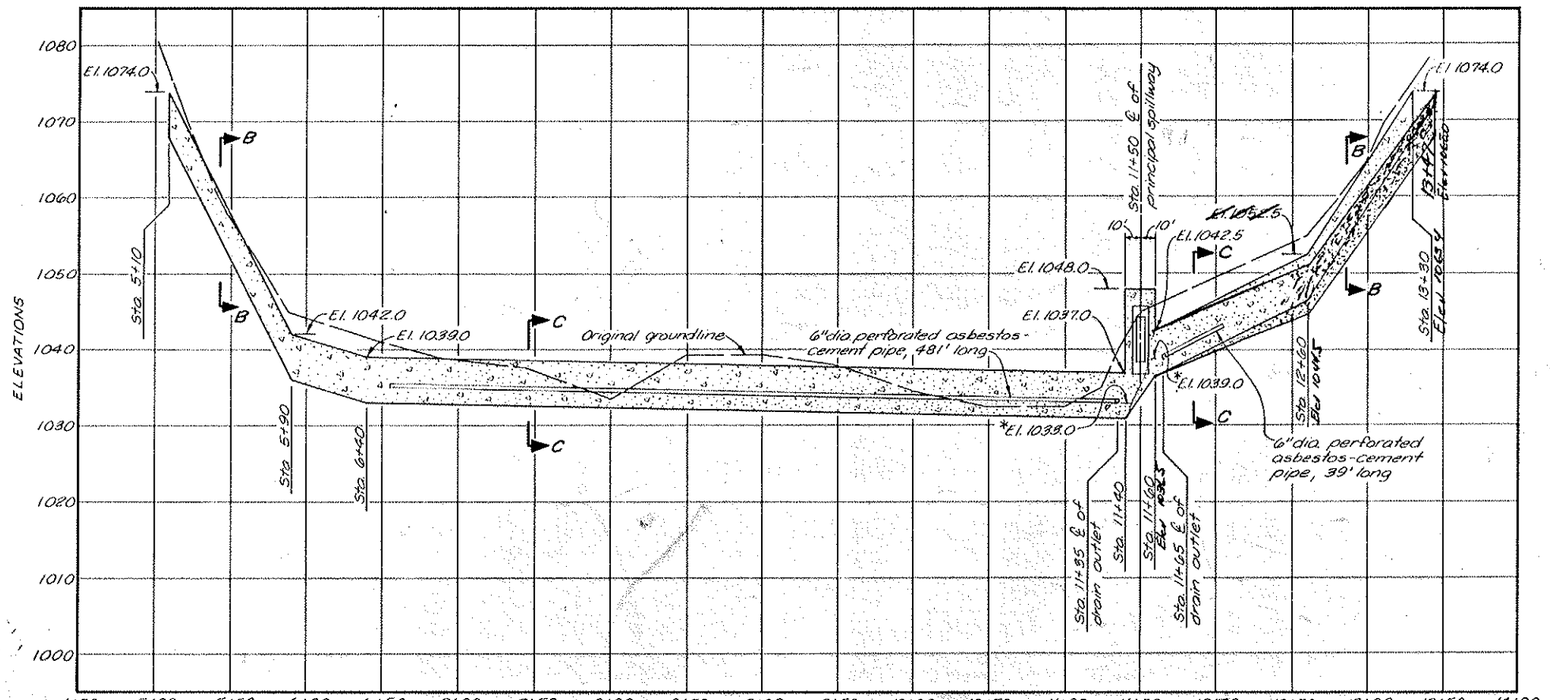
PLAN VIEW OF FOUNDATION DRAIN



SECTION B-B



SECTION C-C



SECTION A-A

PROFILE ALONG ℄ OF FOUNDATION DRAIN

NOTES:

1. THE FOUNDATION DRAIN FROM STA. 5+10 TO STA. 11+40 AND FROM STA. 11+60 TO STA. 13+30 WILL HAVE A MINIMUM DEPTH OF 6', THE EXACT DEPTH WILL BE DETERMINED BY THE ENGINEER.
2. PLACE DRAIN FILL AROUND PRINCIPAL SPILLWAY CONDUIT AS INDICATED.
3. *INDICATES PIPE INVERT ELEVATIONS.
4. FOR DRAIN FILL GRADATION, SEE SHEET 12.
5. PLUG UPPER END OF PIPES WITH 6" OF CONCRETE OR PREFABRICATED CAP.
6. THE DEPTH OF FILL OVER THE DRAIN PIPE SHALL BE AT LEAST 2' BEFORE PASSING HEAVY EQUIPMENT OVER THE PIPE.
7. WHERE THE FOUNDATION DRAIN AND DRAIN OUTLETS ARE ABOVE THE GROUNDLINE, PLACE COMPACTED EARTH FILL TO ELEVATION AT TOP OF DRAIN AND EXCAVATE DRAIN IN COMPACTED FILL.

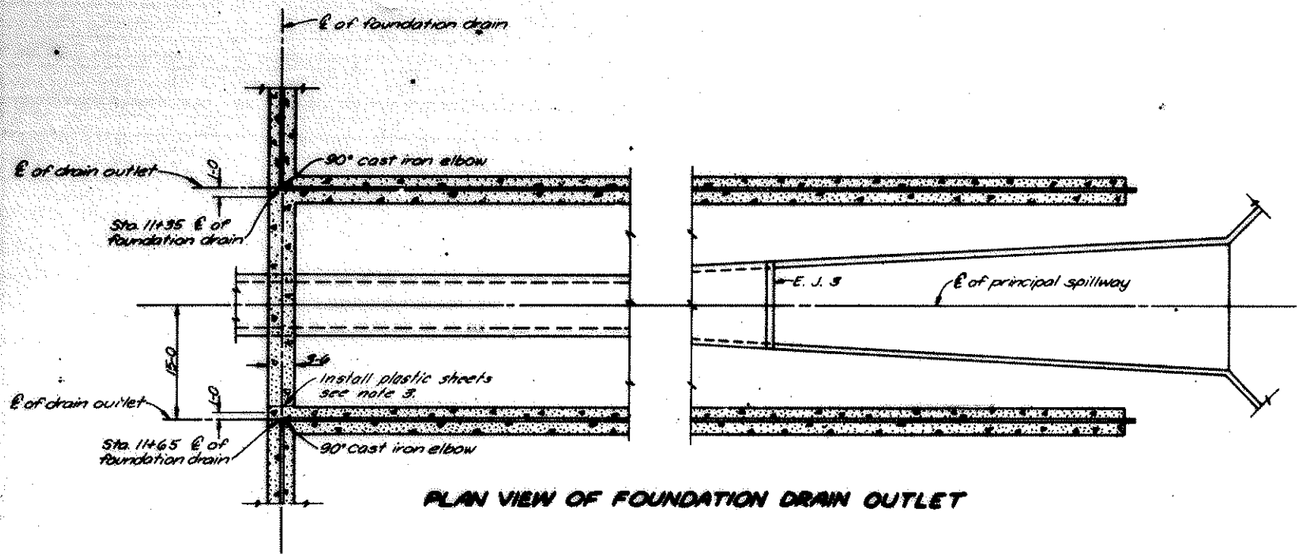
AS BUILT
FEB. 8 1979

DETAILS OF FOUNDATION DRAIN

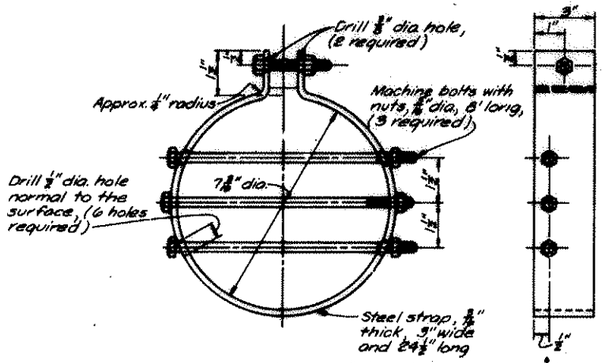
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

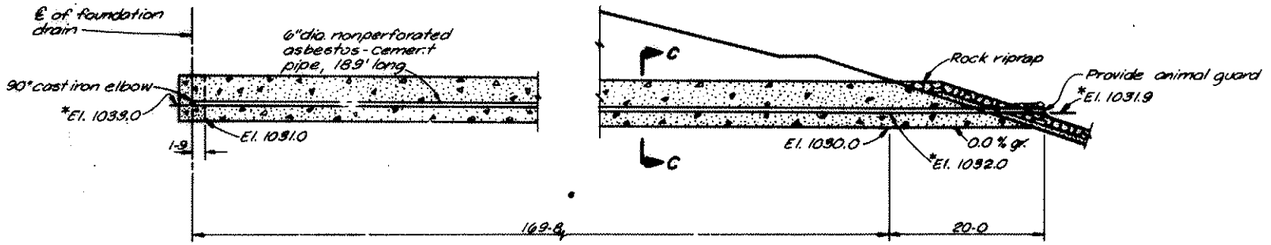
	Date		
Designed J.E.N, H.W.H.	8-76	Approved by	
Drawn		Title	
Traced		Sheet No. 11 of 51	Drawing No. SE-36,025
Checked H.W.H, G.E.M.	8-76		



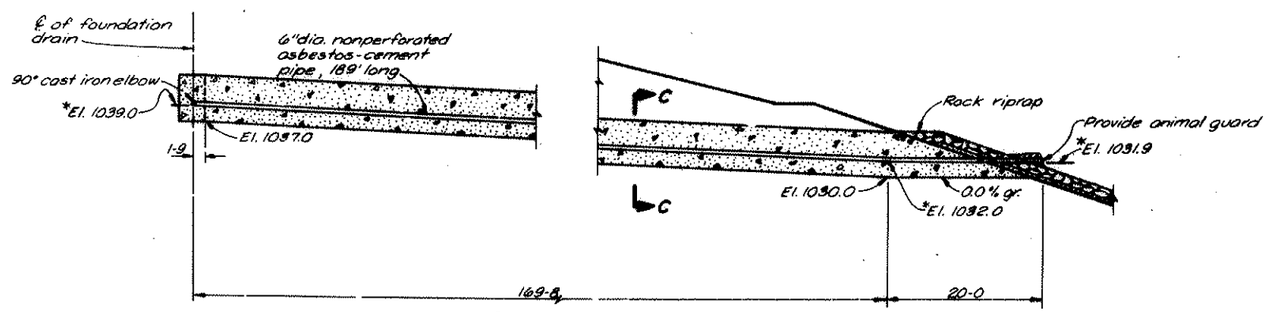
PLAN VIEW OF FOUNDATION DRAIN OUTLET



ANIMAL GUARD FOR 6" DIA. ASBESTOS-CEMENT DRAIN OUTLET PIPE



PROFILE ALONG ℄ OF DRAIN OUTLET AT STA. 11+35



PROFILE ALONG ℄ OF DRAIN OUTLET AT STA. 11+65

DRAIN FILL GRADATION

SIEVE SIZE	PERCENT PASSING
2"	100
1"	90 - 100
1/2"	75 - 90
#4	50 - 75
#8	35 - 55
#16	15 - 35
#30	0 - 10
#40	0 - 5

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
DRAIN FILL	CU.YD.	926
6" DIA. PERFORATED ASBESTOS CEMENT PIPE, CLASS 150	LIN.FT.	520
6" DIA. NONPERFORATED ASBESTOS CEMENT PIPE, CLASS 150	LIN.FT.	378
6" DIA. 90° CAST IRON ELBOW	EACH	2
ANIMAL GUARD, PER DETAIL	EACH	2

NOTES:
1. FOR DETAILS OF SECTION C-C, SEE SHEET 11.
2. *INDICATES PIPE INVERT ELEVATION.
3. INSTALL TWO SHEETS OF 8 MIL. PLASTIC IN THE FOUNDATION DRAIN AT THE LOCATION SHOWN IN PLAN VIEW. THE PLASTIC SHEETS WILL BE USED TO PREVENT WATER FROM THE SOUTH ABUTEMENT TO FLOW BELOW PRINCIPAL SPILLWAY CONDUIT. INSTALLATION SHALL BE AS AS DIRECTED BY THE ENGINEER.

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DETAILS OF FOUNDATION DRAIN

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J.E.N. H.W.H.	Date 8-76	Approved by	
Drawn		Title	
Traced		Title	
Checked H.W.H. C.E.M.	8-76	Sheet No. 12 of 51	Drawing No. 5-E-36,025

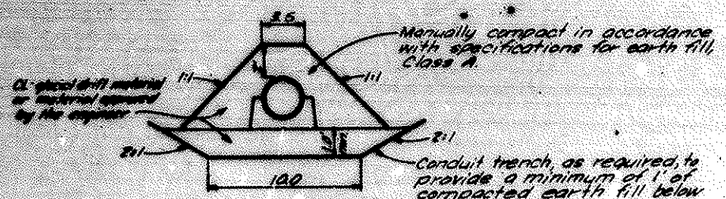
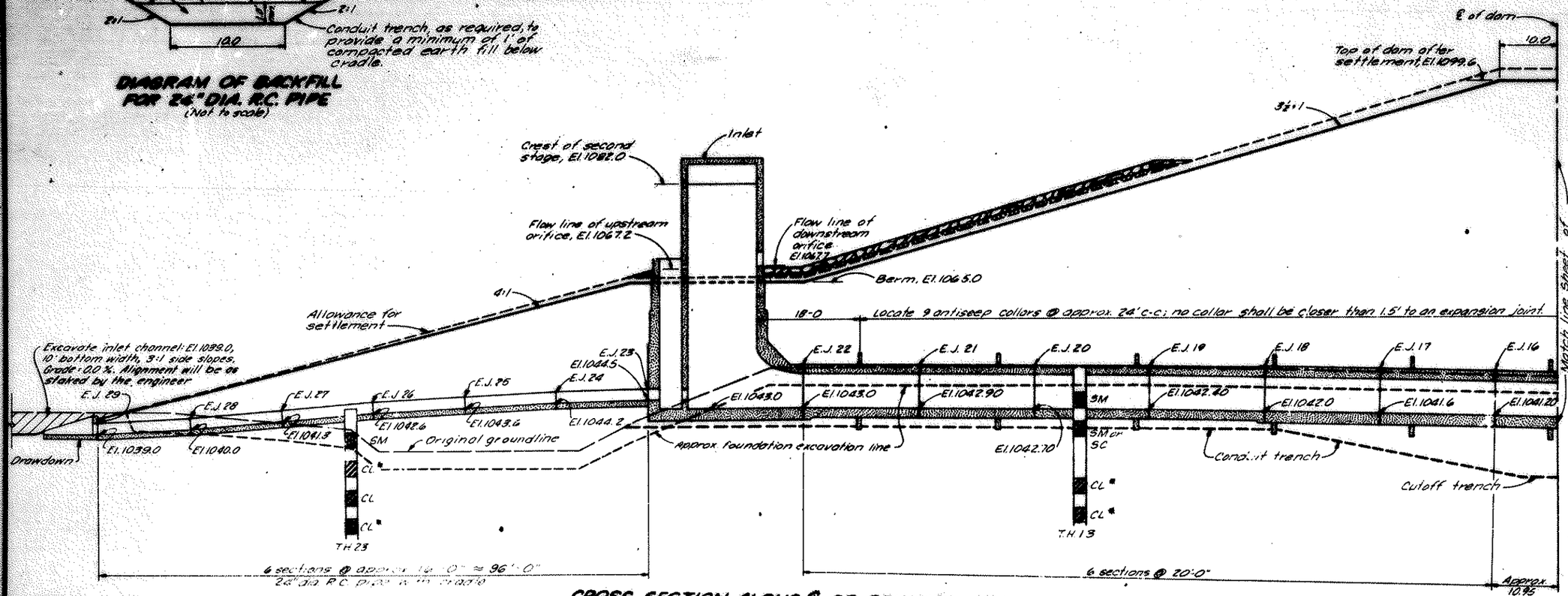
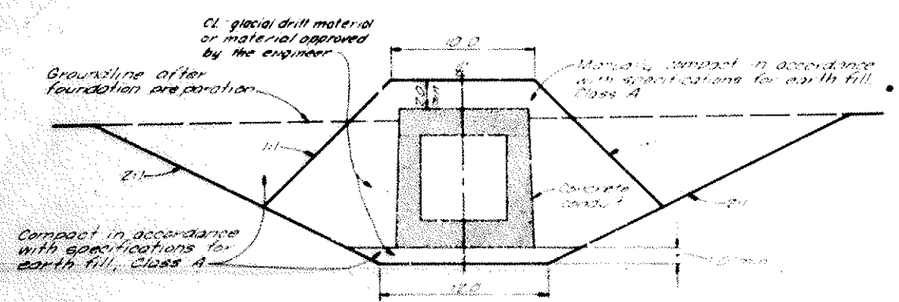


DIAGRAM OF BACKFILL FOR 24" DIA. R.C. PIPE
(Not to scale)



CROSS SECTION ALONG ℄ OF PRINCIPAL SPILLWAY



DETAILS OF PRINCIPAL SPILLWAY CONDUIT TRENCH
(Not to scale)

NOTES:
1. TEST HOLES 13 AND 23 ARE SUPERIMPOSED ON CENTERLINE OF PRINCIPAL SPILLWAY.
2. FOR ADDITIONAL NOTES CONCERNING TEST HOLE LOGS, SEE SHEET
3. FOR DETAILS OF INLET STRUCTURE, SEE SHEET 44 TO 48
4. FOR DETAILS OF DRAWDOWN WORKS, SEE SHEETS 32 TO 34
5. TRASH RACKS, LADDER, COVER SLAB RAILINGS, AND SLIDE GATE ARE NOT SHOWN.

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FEB 6 1980

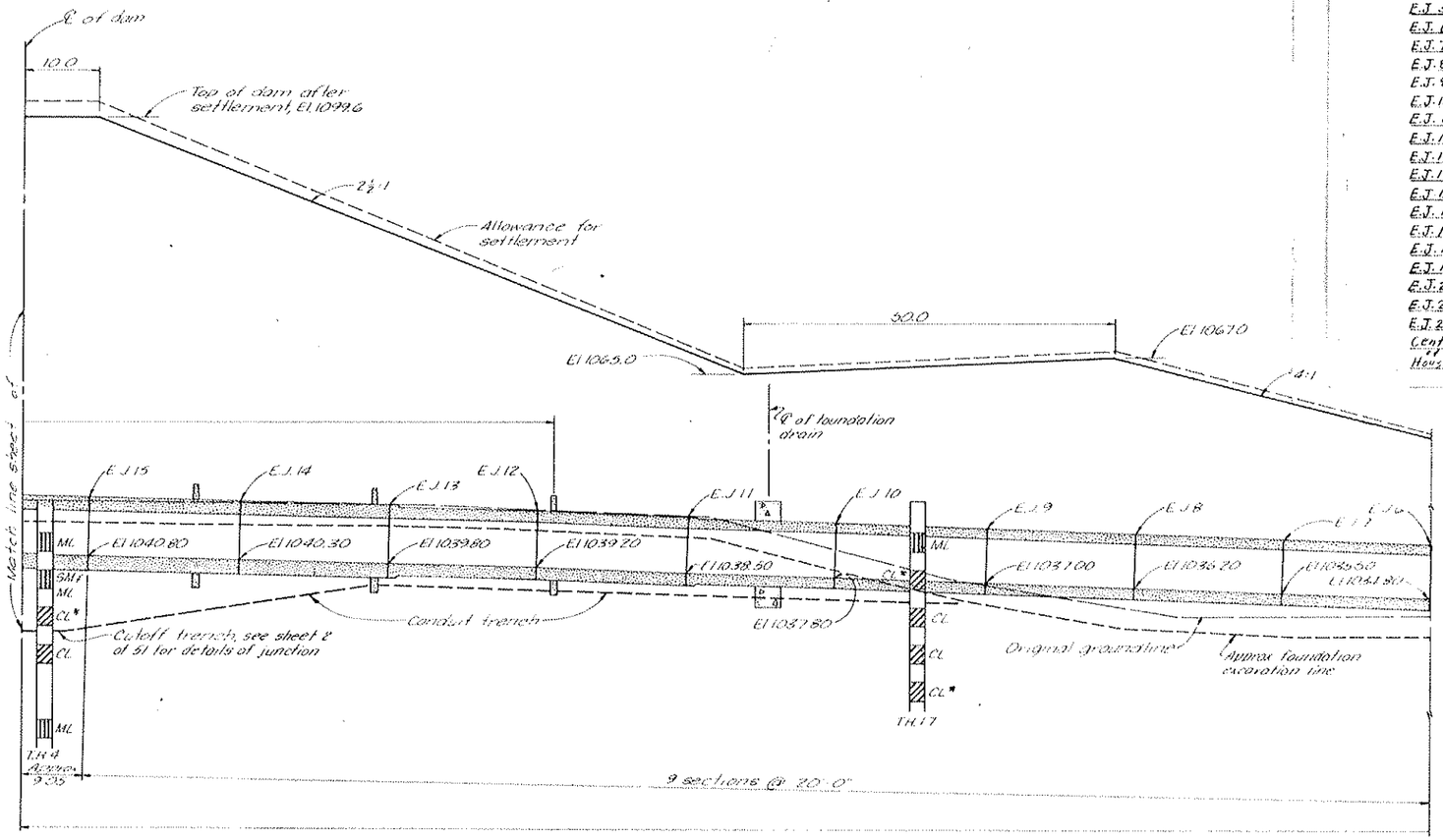
0 10 20 30
Scale in feet

PRINCIPAL SPILLWAY LAYOUT

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

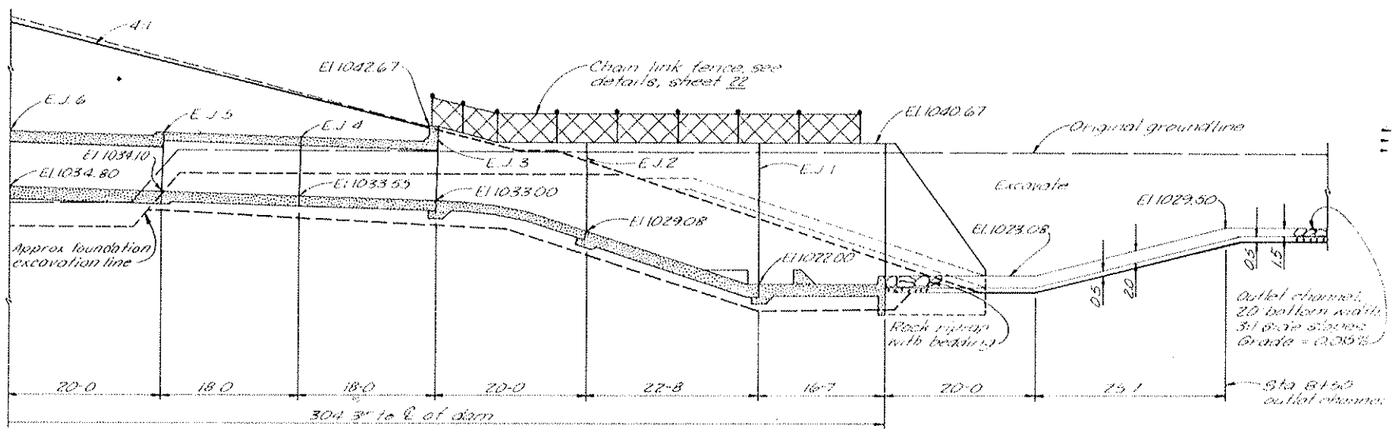
Designed J.E.N.	Date 4-76	Approved by	
Drawn		Title	
Traced		Title	
Checked C.C.N.C.	9-76	Sheet No. 13 of 51	Drawing No. S.E-36,025



Station	PLANNED ELEVATIONS	SOUTH SIDE	℄ OUTLET	NORTH SIDE
E.J. 3	1033.00	1032.92		1032.88
E.J. 4	1033.55	1033.45		1033.40
E.J. 5	1034.10	1033.94		1033.92
E.J. 6	1034.80	1034.54		1034.63
E.J. 7	1035.50	1035.24		1035.22
E.J. 8	1036.20	1035.94		1036.92
E.J. 9	1037.00	1036.78		1036.80
E.J. 10	1037.50	1037.64		1037.64
E.J. 11	1038.50	1038.23		1038.24
E.J. 12	1039.20	1038.96		1038.96
E.J. 13	1039.80	1039.51		1038.50
E.J. 14	1040.30	1039.81		1038.84
E.J. 15	1040.80	1040.19		1040.20
E.J. 16	1041.20	1040.64		1040.64
E.J. 17	1041.60	1041.22		1041.21
E.J. 18	1042.00	1041.72		1041.71
E.J. 19	1042.20	1042.06		1042.03
E.J. 20	1042.70	1042.41		1042.41
E.J. 21	1043.20	1042.65		1042.65
E.J. 22	1043.00	1042.84		1042.85
Center of House	1043.00		1042.84	

Shots Taken looking upstream

NOTES:
1. TEST HOLE 17 IS SUPERIMPOSED ON CENTERLINE OF PRINCIPAL SPILLWAY.
2. FOR ADDITIONAL NOTES CONCERNING TEST HOLE LOGS, SEE SHEET 8.
3. E.J. = EXPANSION JOINT.
4. FOR DETAILS OF PRINCIPAL SPILLWAY OUTLET WORKS, SEE SHEETS 19 TO 24.
5. FOR DETAILS OF PRINCIPAL SPILLWAY CONDUIT, SEE SHEETS 32 TO 35.



CROSS SECTION ALONG ℄ OF PRINCIPAL SPILLWAY

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0 10 20 30
Scale in feet

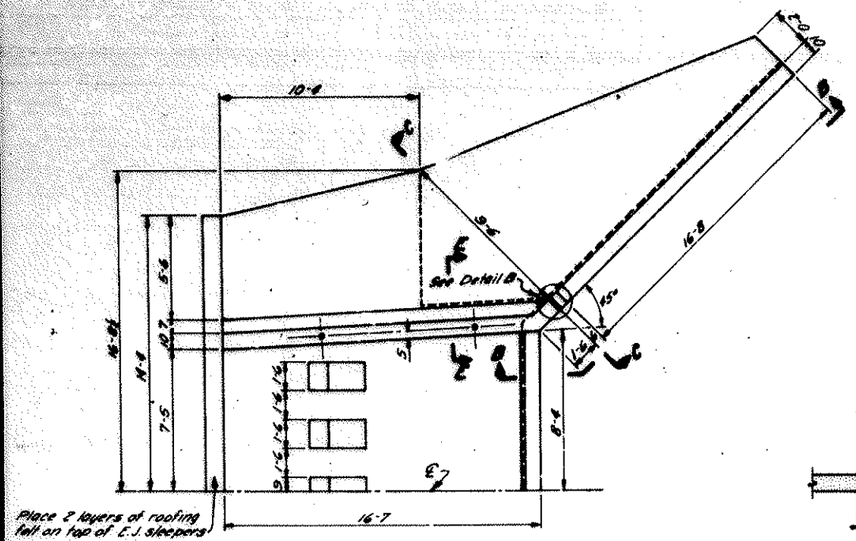
PRINCIPAL SPILLWAY LAYOUT

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED

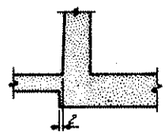
Grand Forks and Nelson Counties, North Dakota

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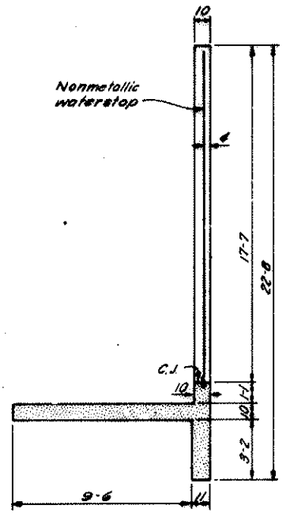
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Designed J.S.N.	4-30	Approved by
Drawn		Title
Traced		Title
Checked C.E.M.	4-30	Sheet No. 14 of 51 — Drawing No. 5,E-36,025



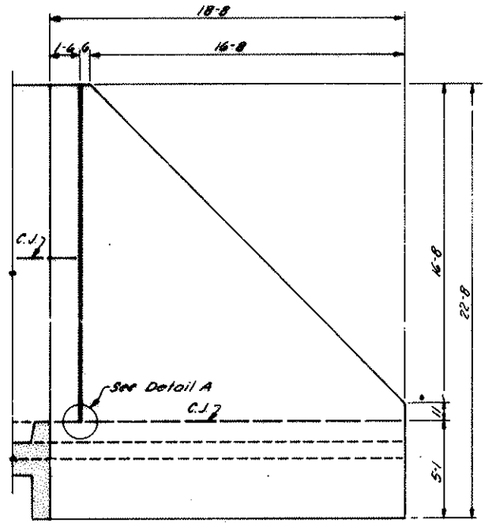
HALF PLAN



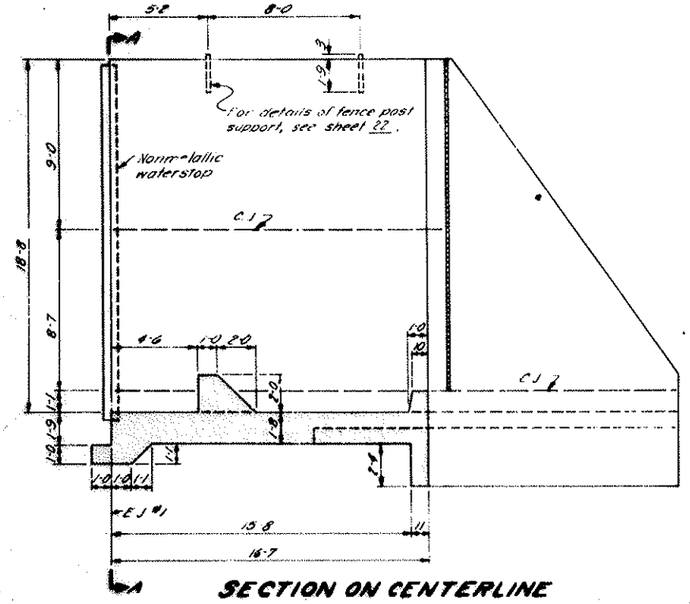
SECTION E-E



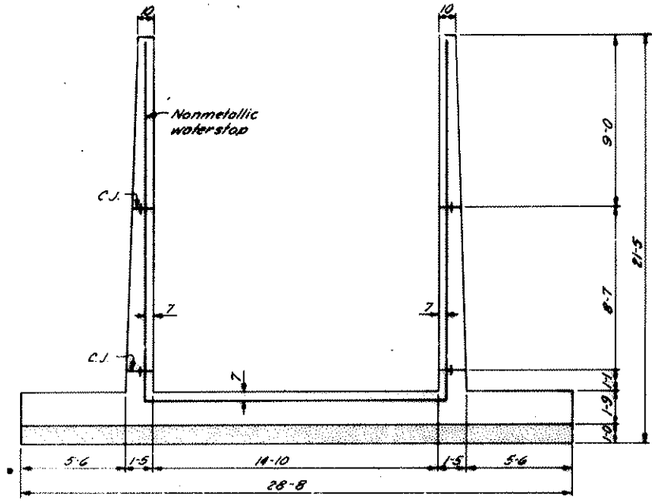
SECTION C-C



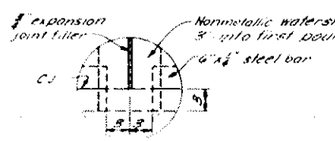
SECTION B-B



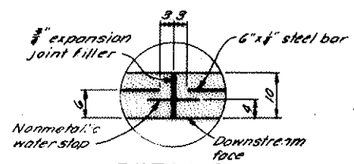
SECTION ON CENTERLINE



SECTION A-A



DETAIL A
(Not to scale)



DETAIL B
(Not to scale)

NOTES:
1. E.J. = EXPANSION JOINT
2. C.J. = CONSTRUCTION JOINT
3. FOR DETAILS OF WATERSTOP AND DOWEL BARS, SEE SHEET 23.
4. FOR DETAILS OF PLATE CONSTRUCTION JOINT, SEE SHEET 16.

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
CONCRETE (CLASS 4000)	CU.YD.	84.0
REINFORCING STEEL	LB.	11,741
NONMETALLIC WATERSTOP	LIN.FT.	89
STEEL BAR, 6" X 1/4" (CONSTRUCTION JOINT)	LIN.FT.	103

NOTE:
THE SAF FLOOR BLOCKS AND THE CHUTE FLOOR BLOCKS CAN BE POURED SEPARATELY FROM THE BASE AT THE CONTRACTOR'S OPTION. IF POURED SEPARATELY TWO SHEAR PLATES PER BLOCK WILL BE PROVIDED. THE SHEAR PLATES WILL BE SET TRANSVERSE TO THE CENTERLINE OF THE STRUCTURE AND AS DIRECTED BY THE ENGINEER. THE BLOCKS WILL BE POURED WITHIN 36 HOURS OF THE BASE POUR. THE BASE OF THE BLOCKS WILL BE KEPT CLEAR AND DAMP AND FREE OF CURING COMPOUND.

AS BUILT
FEB. 8 [illegible]

0 2 4 6
Scale in feet

SAF OUTLET
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed J.E.N.	4-76	Approved by
Drawn J.E.N., D.L.R.	7-76	Title
Traced		Title
Checked C.E.M.	5-76	Sheet No. 15 of 51 — Drawing No. SE-36,025

R BENDS

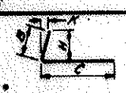
Straight — TYPE 1



TYPE 19



TYPE 21



TYPE 22



TYPE 24



TYPE 25

STEEL SCHEDULE

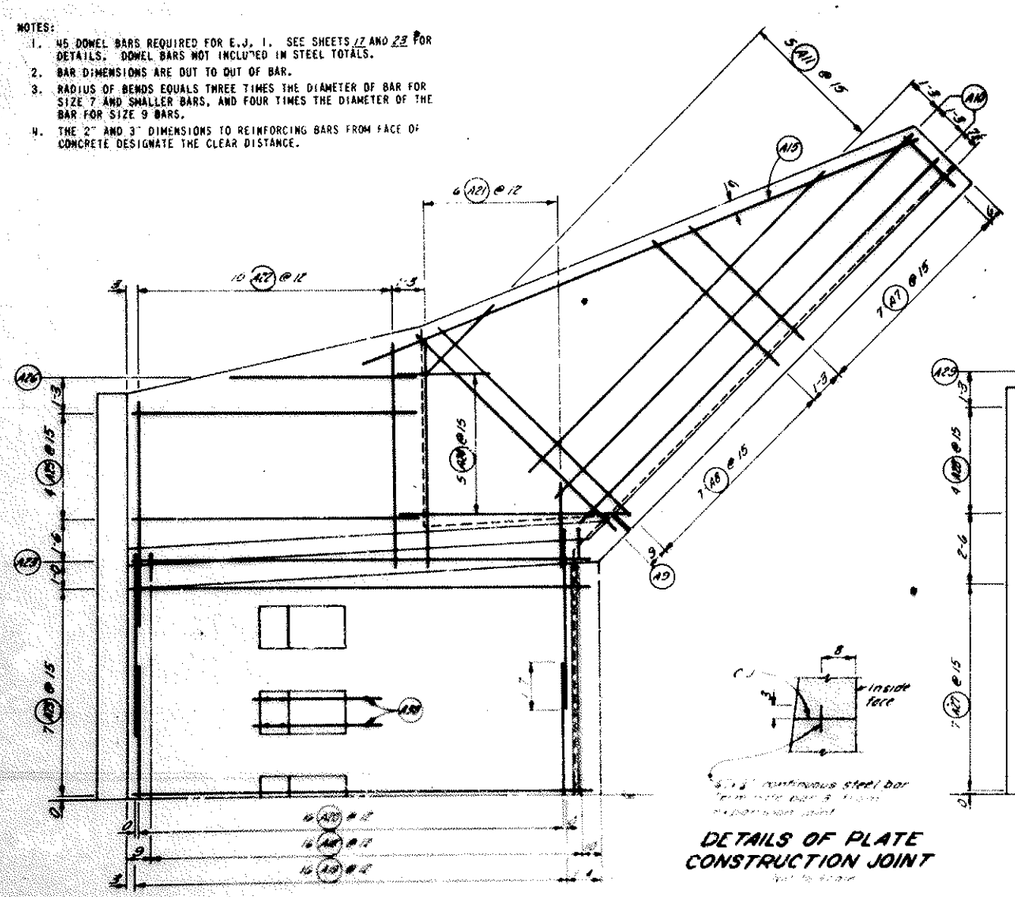
MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	A	B	C
A1	5	10	20-8	205-0	19		2-0	18-6
A2	5	4 SETS OF 3 BARS	6-0 TO 8-6 @ 1-3 INC	87-0	1			
A3	5	48	6-5	312-0	1			
A4	5	10	20-9	207-6	19		2-3	18-6
A5	5	10	17-0	170-0	1			
A6	5	28	4-9	133-0	1			
A7	4	2 SETS OF 7 BARS	2-6 TO 5-6 @ 6" INC	56-0	1			
A8	4	2 SETS OF 7 BARS	6-3 TO 9-3 @ 6" INC	108-6	1			
A9	4	2	9-9	19-6	1			
A10	4	8	18-0	144-0	1			
A11	4	4 SETS OF 5 BARS	3-3 TO 15-3 @ 3-0" INC	105-0	1			
A12	4	2 SETS OF 4 BARS	3-3 TO 5-6 @ 9" INC	35-0	21		1-0	2-3 TO 4-6 @ 9" INC
A13	6	2 SETS OF 6 BARS	5-6 TO 8-0 @ 6" INC	81-0	21		1-0	4-6 TO 7-0 @ 6" INC
A14	6	2 SETS OF 13 BARS	8-0 TO 11-0 @ 3" INC	247-0	21		1-0	7-0 TO 10-0 @ 3" INC
A15	7	4	21-0	84-0	1			

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	A	B	C	D	E	F	G	H	J	K
A16	5	6	15-3	91-6	1										
A17	5	29	4-3	123-3	24	0-7	2-2	1-6						0-5	
A18	9	32	7-3	232-0	22		1-0	6-3					1-0		0-3/8
A19	9	32	12-6	400-0	22		6-3	6-3					6-3		0-2 3/8
A20	5	16	10-0	160-0	1										
A21	5	2 SETS OF 6 BARS	3-0 TO 8-0 @ 1-0" INC	66-0	1										
A22	5	20	8-0	160-0	1										
A23	5	15	16-0	240-0	1										
A24	4	2 SETS OF 5 BARS	3-3 TO 8-3 @ 1-3" INC	57-6	1										
A25	5	8	9-9	78-0	1										
A26	5	2	6-6	13-0	1										
A27	7	13	16-0	208-0	1										
A28	5	2 SETS OF 4 BARS	13-3 TO 17-0 @ 1-3" INC	121-0	1										
A29	5	2	9-0	18-0	1										
A30	7	5	20-0	100-0	1										
A31	7	11	19-0	209-0	1										
A32	5	2 SETS OF 5 BARS	3-0 TO 7-0 @ 1-0" INC	50-0	1										
A33	6	10	9-0	90-0	1										

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	D	E	F
A34	6	12	7-9	93-0	1					
A35	6	34	4-0	136-0	1					
A36	4	2	16-0	32-0	1					
A37	6	2	16-0	32-0	1					
A38	5	10	9-3	92-6	25	0-6	3-2	0-7	4-6	0-6
C1	6	36	10-3	389-6	1					
C2	6	18	17-3	310-6	19	1-0	16-3			
C3	6	64	8-6	544-0	1					
C4	4	10	16-6	165-0	1					
C5	6	8	16-6	132-0	1					
D1	5	72	8-9	630-0	1					
D2	5	18	17-3	310-6	19	1-0	16-3			
D3	5	18	16-6	297-0	1					
E1	5	4 SETS OF 11 BARS	4-9 TO 17-3 @ 1-3" INC	484-0	1					
E2	5	4	16-9	67-0	1					
E3	5	4 SETS OF 13 BARS	0-9 TO 15-9 @ 1-3" INC	429-0	1					

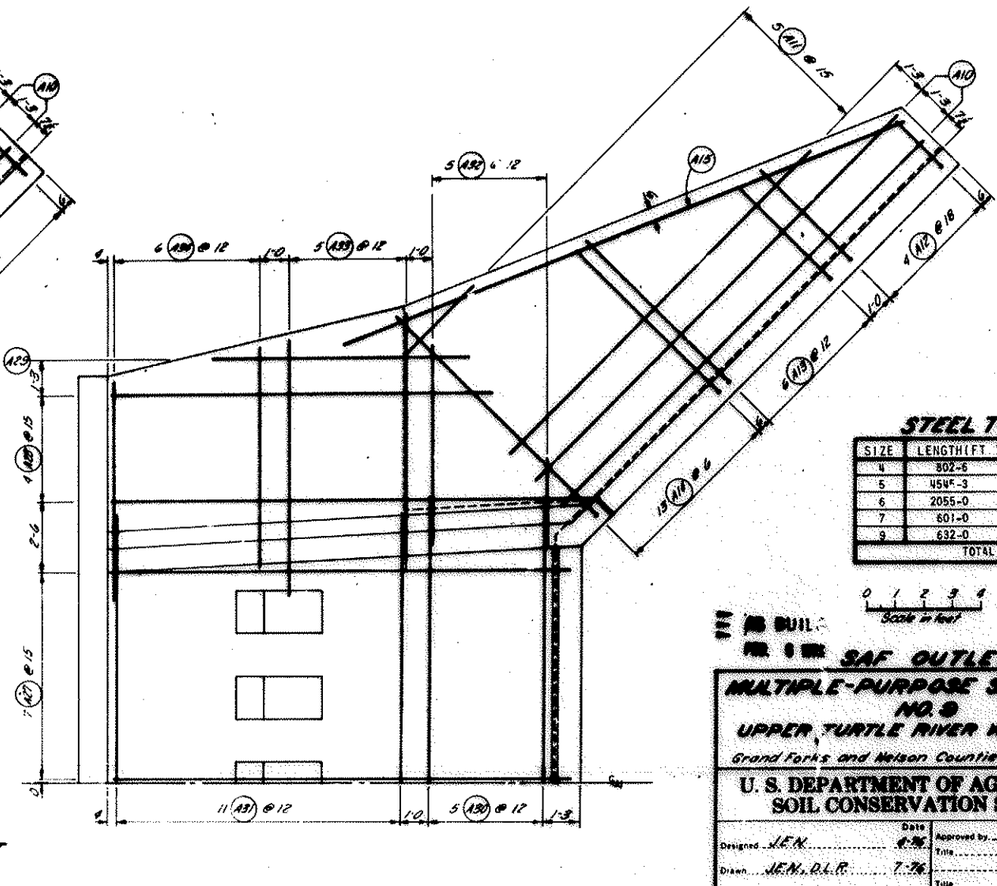
NOTES:

1. 45 DOWEL BARS REQUIRED FOR E.J. 1. SEE SHEETS 17 AND 23 FOR DETAILS. DOWEL BARS NOT INCLUDED IN STEEL TOTALS.
2. BAR DIMENSIONS ARE OUT TO OUT OF BAR.
3. RADIUS OF BENDS EQUALS THREE TIMES THE DIAMETER OF BAR FOR SIZE 7 AND SMALLER BARS, AND FOUR TIMES THE DIAMETER OF THE BAR FOR SIZE 9 BARS.
4. THE 2" AND 3" DIMENSIONS TO REINFORCING BARS FROM FACE OF CONCRETE DESIGNATE THE CLEAR DISTANCE.



STEEL IN BOTTOM FACE
HALF PLAN

DETAILS OF PLATE CONSTRUCTION JOINT



STEEL IN TOP FACE
HALF PLAN

STEEL TOTALS

SIZE	LENGTH(FT.)	WEIGHT(LB.)
4	802-6	536
5	4545-3	4,741
6	2055-0	3,087
7	601-0	1,228
9	632-0	2,149
	TOTAL	11,741

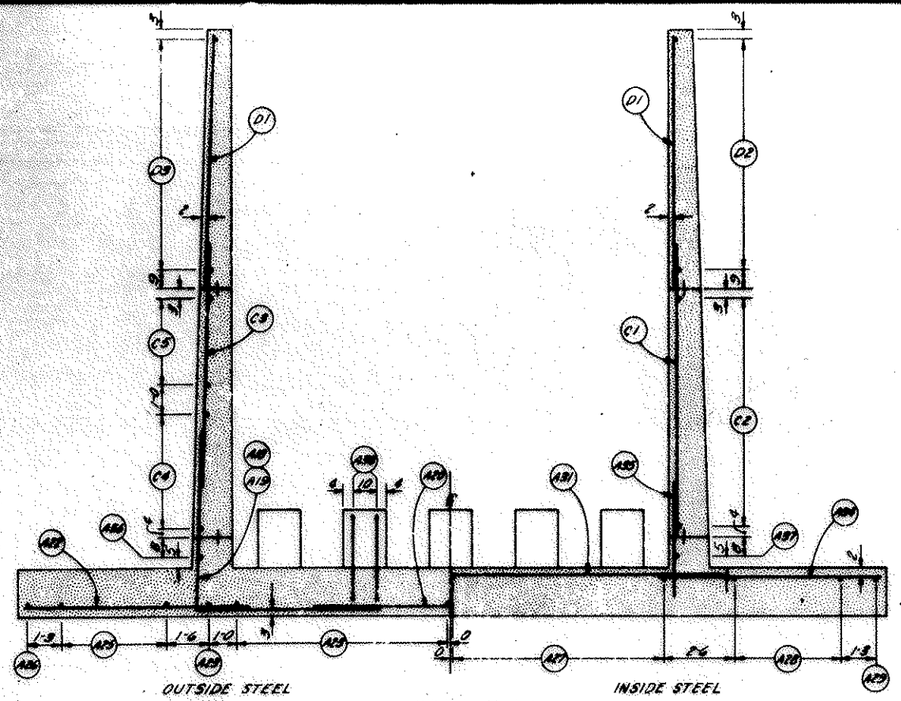
0 1 2 3 4
Scale in feet

FOR BUILDING NO. 9 SAF OUTLET

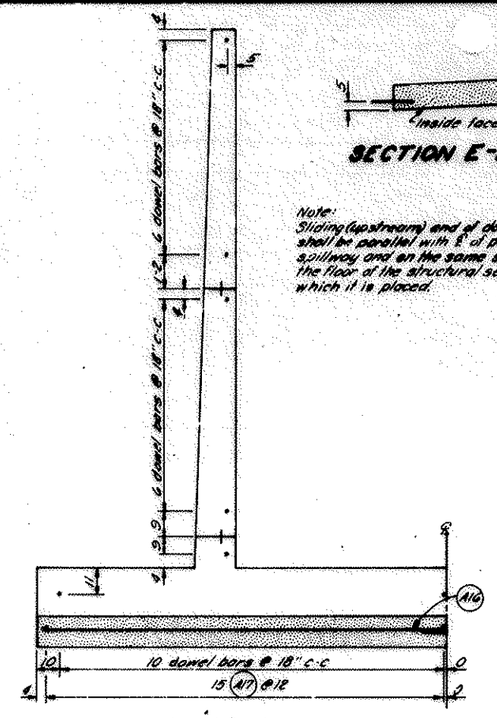
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed JEN	Date 6-76	Approved by	
Drawn JEN, D.L.P.	7-76	Title	
Traced		Title	
Checked GEM	8-76	Sheet No. 16 of 51	Drawing No. SE-36,025



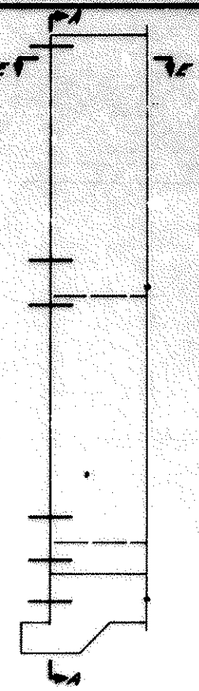
SECTION D-D



HALF SECTION A-A

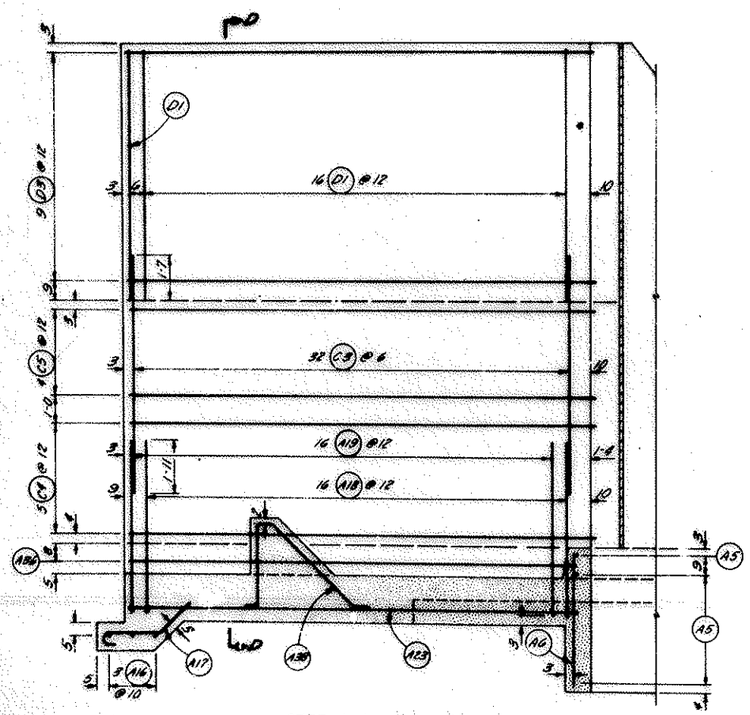
SECTION E-E

Note:
Sliding (upstream) end of dowel bar shall be parallel with ℄ of principal spillway and on the same slope as the floor of the structural section in which it is placed.

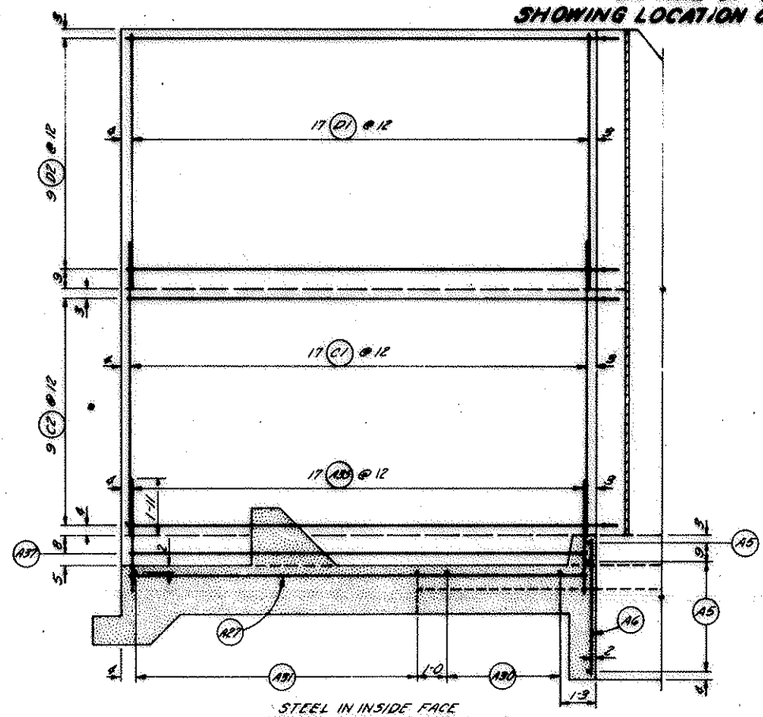


PARTIAL SIDEWALL ELEVATION

DETAIL OF JOINT I
SHOWING LOCATION OF DOWEL BARS



STEEL IN OUTSIDE FACE
SECTION ON CENTERLINE



STEEL IN INSIDE FACE
SECTION ON CENTERLINE



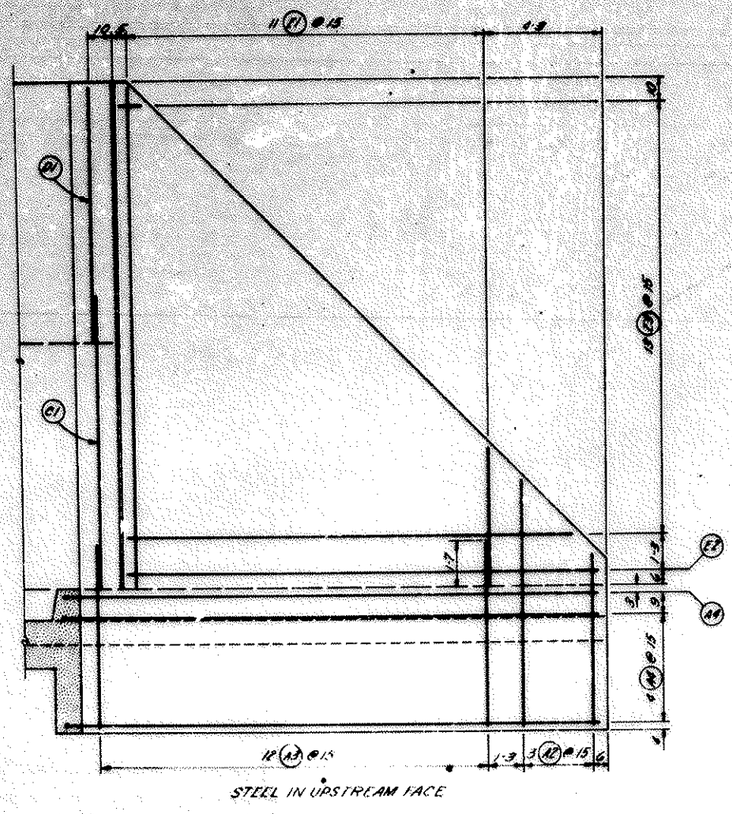
AS BUI..
AS BUILT
FEB 1 [illegible]

SAF OUTLET

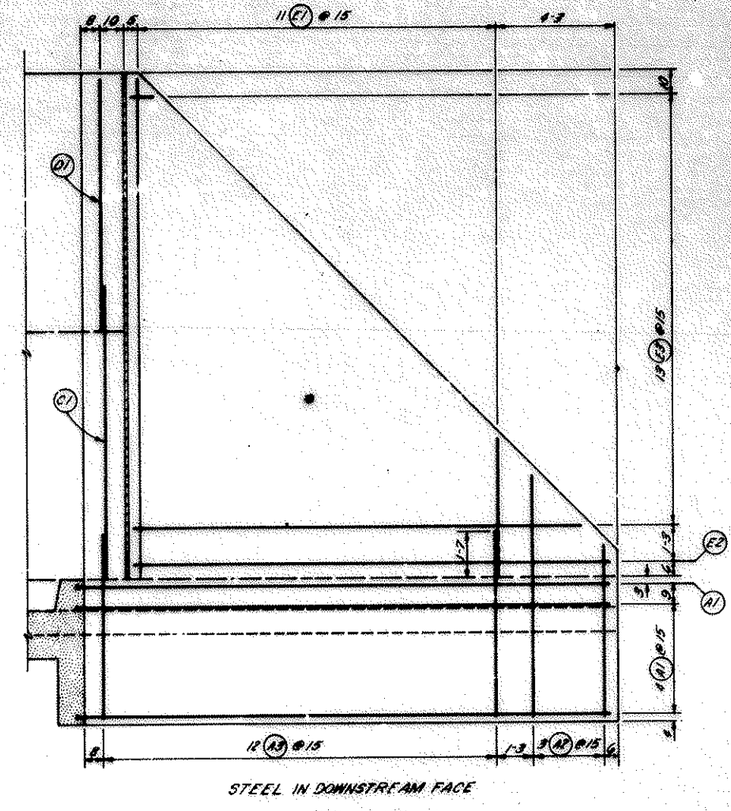
MULTIPLE-PURPOSE STRUCTURE NO.9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

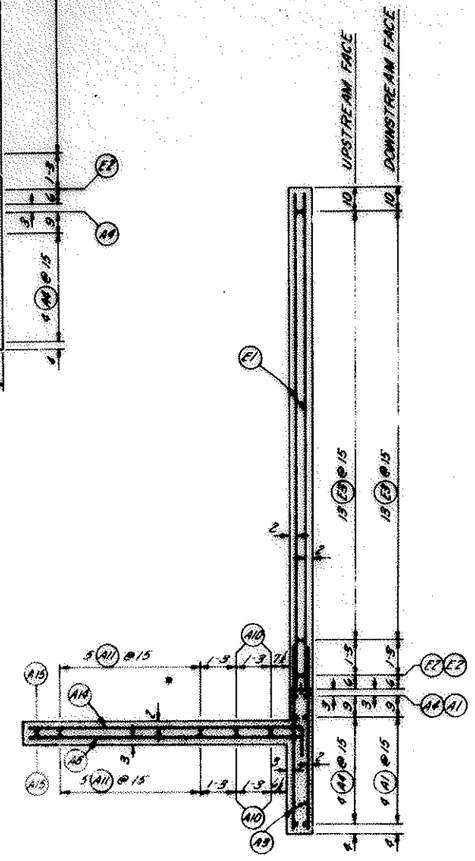
Designed J.E.N.	Date 6-76	Approved by	
Drawn J.E.N., D.L.R.	7-76	Title	
Traced		Title	
Checked C.E.M.	8-76	Sheet No. 17 of 51	Drawing No. S.E-36,025



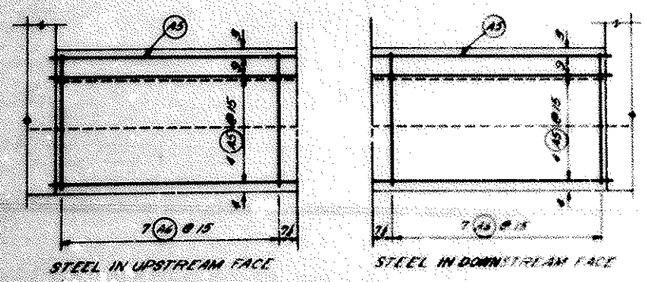
SECTION B-B



SECTION B-B



SECTION C-C



TOEWALL ELEVATION

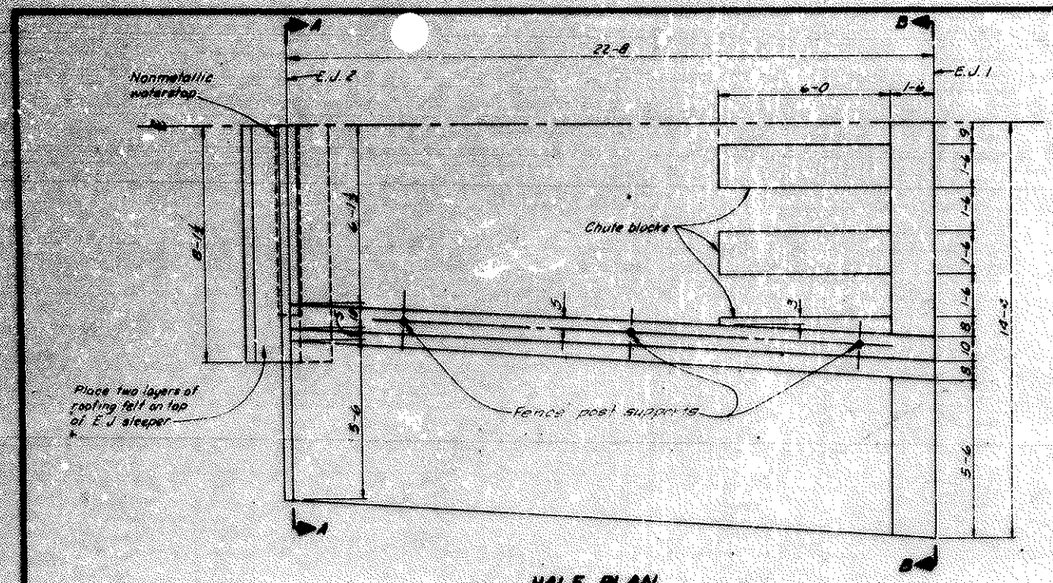
AS BUILT
FEB 8 1980

0 1 2 3 4
Scale in feet

SAF OUTLET
MULTIPLE-PURPOSE STRUCTURE
NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

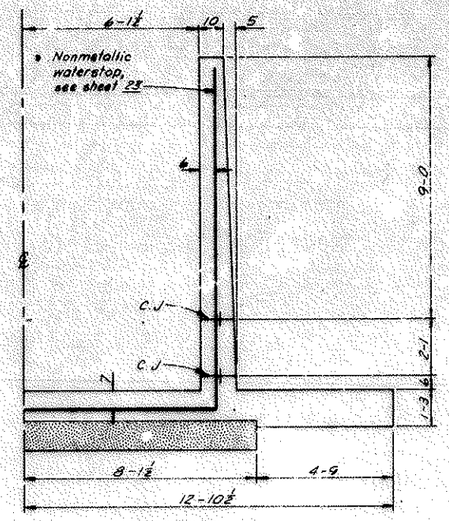
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed J.E.N.	7-78	Approved by
Drawn J.E.N., D.L.R.	7-78	Title
Traced		Title
Checked C.E.M.	5-78	Sheet No. 19 of 51
		Drawing No. SE-36,025



HALF PLAN

Structure symmetrical about ℄



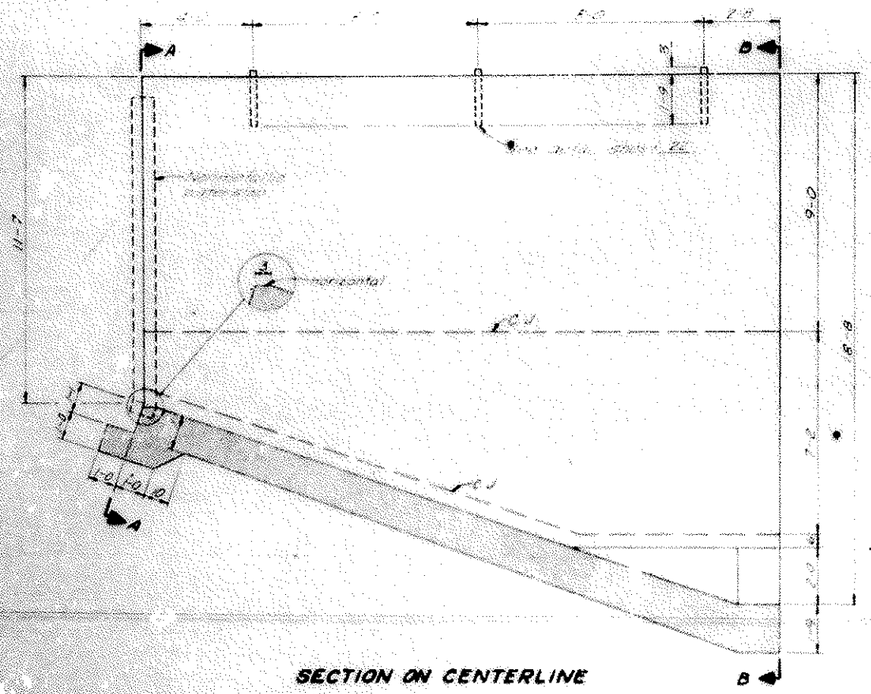
SECTION A-A

TABLE OF QUANTITIES

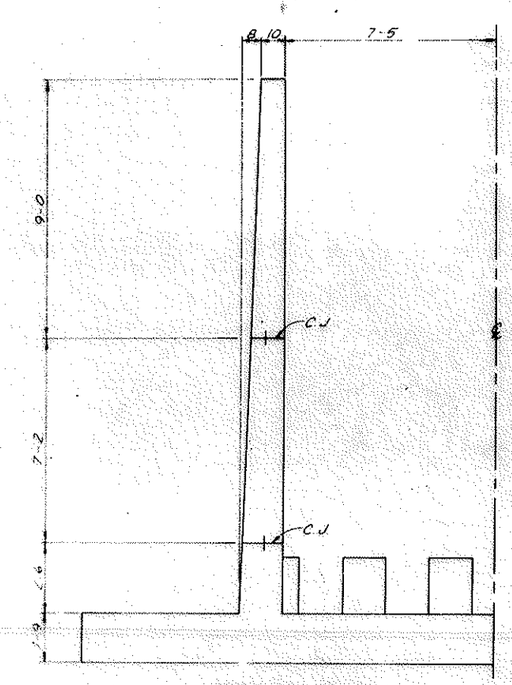
ITEM	UNIT	QUANTITY
CONCRETE (CLASS 4000)	CU.YD.	67.5
REINFORCING STEEL	LB.	10,964
NONMETALLIC WATERSTOP	LIN.FT.	35
STEEL BAR, 6" X 1/4" (CONSTRUCTION JOINT)	LIN.FT.	91

NOTES:

1. E.J. = EXPANSION JOINT.
2. C.J. = CONSTRUCTION JOINT.
3. FOR DETAILS OF WATERSTOP AND DOWEL BARS, SEE SHEET 23.
4. FOR DETAILS OF PLATE CONSTRUCTION JOINT, SEE SHEET 21.



SECTION ON CENTERLINE



SECTION B-B

0 1 2 3 4
Scale in feet

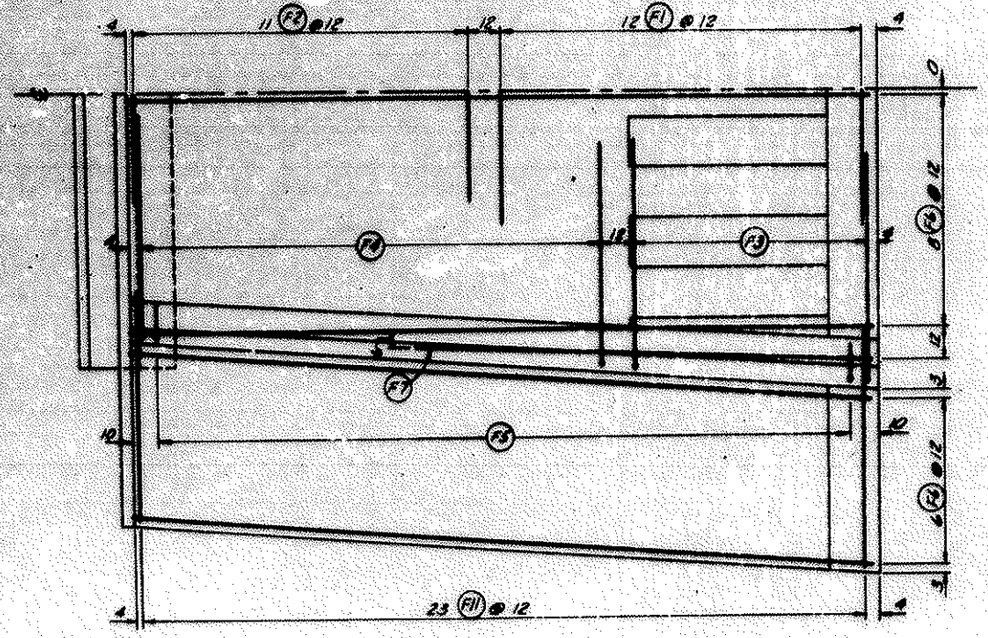
AS BUILT
FEB. 1 978

DETAILS OF CHUTE (E.J.1-E.J.2)

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

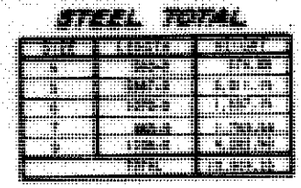
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

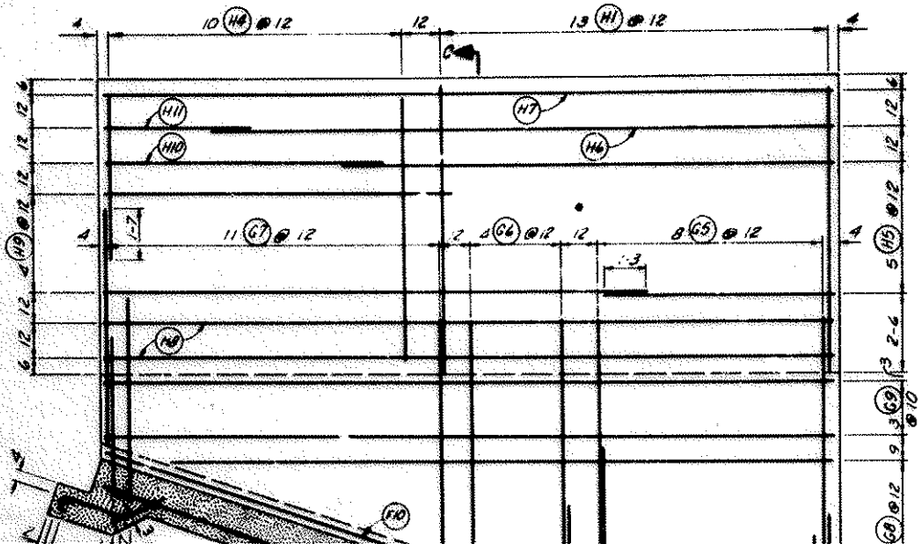
	Date	Approved by
Designed J.F.N.	4-76	Title
Drawn D.L.J.	5-76	
Traced		Title
Checked C.E.M.	5-76	Sheet No. 19 of 51 — SE-36,025

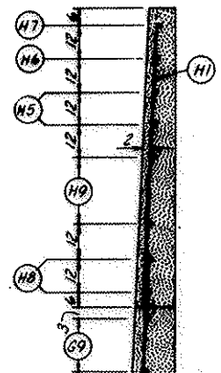


STEEL IN BOTTOM FACE

HALF PLAN

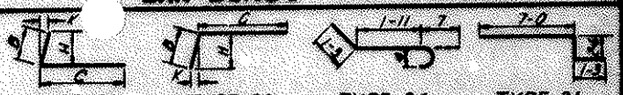






BAR BENDS

Straight

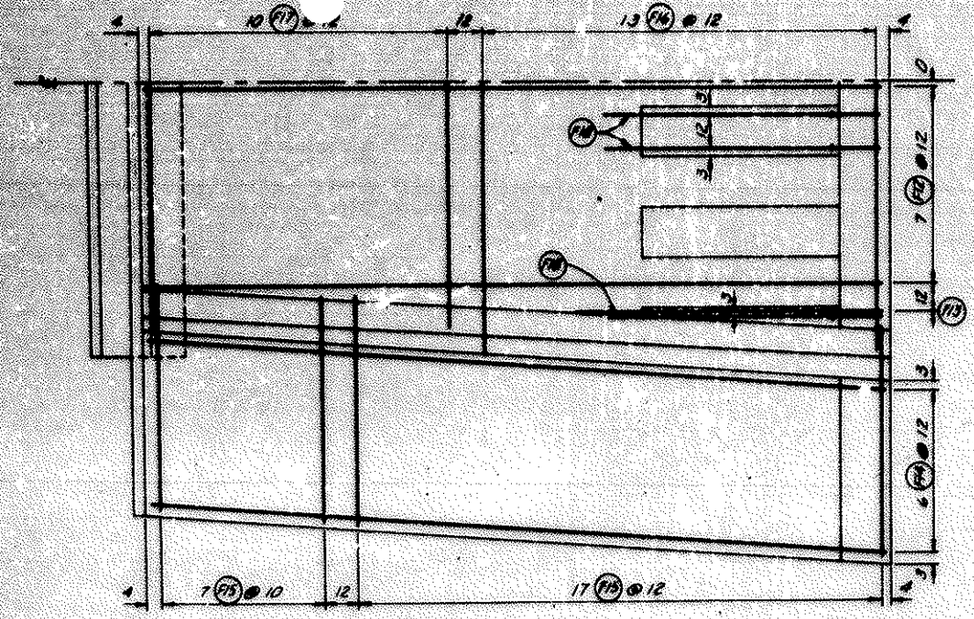


TYPE 1 TYPE 22 TYPE 23 TYPE 24 TYPE 31

BAR SCHEDULE

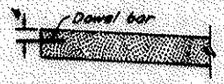
MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	H	X
F1	5	12	8-0	96-0	1				
F2	5	11	6-6	71-6	1				
F3	9	16	13-6	216-0	22	6-9	5-9	6-9	0-2 3/4
F4	9	30	11-3	337-6	22	4-9	6-6	4-9	0-2
F5	9	44	7-3	319-0	22	6-3	1-0	6-3	0-2 3/4
F6	5	27	23-6	634-6	23	1-0	22-6	0-4	0-11
F7	5	2	14-9	29-6	23	1-0	13-9	0-4	0-11
F8	4	2	3-0	6-0	1				
F9	4	2	5-9	11-6	1				
F10	4	2	23-0	46-0	28	7-0	16-0	2-2 1/2	6-8
F11	5	46	7-0	322-0	1				
F12	7	13	23-3	302-3	23	1-3	22-0	0-4 1/2	1-2 1/2
F13	7	2	9-9	19-6	23	1-3	8-6	0-4 1/2	1-2 1/2
F14	5	12	23-3	279-0	23	1-3	22-0	0-4 1/2	1-2 1/2
F15	7	48	7-0	336-0	1				
F16	7	13	16-0	208-0	1				
F17	6	10	14-6	145-0	1				
F18	6	10	10-9	107-6	31	*	SEE BAR BENDS		
F19	6	16	5-0	80-0	1				
F20	6	22	3-0	66-0	1				
F21	6	12	6-0	72-0	1				
F22	6	2	23-0	46-0	23	7-0	16-0	2-2 1/2	6-8
F23	5	16	3-9	60-0	24		SEE BAR BENDS		
F24	5	3	15-6	46-6	1				
G1	6	16	8-9	140-0	1				
G2	6	2 SETS OF 10 BARS	5-6 TO 8-6 @ 4" INC.	140-0	1				
G3	6	2 SETS OF 5 BARS	8-0 TO 20-0 @ 3-0 INC.	140-0	1				
G4	6	6	22-3	133-6	1				
G5	9	16	8-9	140-0	1				
G6	9	2 SETS OF 4 BARS	7-6 TO 8-6 @ 4" INC.	64-0	1				
G7	9	22	7-3	159-6	1				
G8	4	2 SETS OF 5 BARS	8-0 TO 20-0 @ 3-0 INC.	140-0	1				
G9	4	6	22-3	133-6	1				
H1	5	62	8-9	542-6	1				
H2	5	2 SETS OF 5 BARS	7-9 TO 8-9 @ 3" INC.	82-6	1				
H3	5	18	22-3	400-6	1				
H4	5	2 SETS OF 10 BARS	5-0 TO 8-0 @ 4" INC.	130-0	1				
H5	5	2 SETS OF 5 BARS	7-0 TO 15-0 @ 2-0 INC.	110-0	1				
H6	5	2	19-0	38-0	1				
H7	5	2	22-3	44-6	1				
H8	4	4	22-3	89-0	1				
H9	4	2 SETS OF 4 BARS	10-6 TO 16-6 @ 2-0 INC.	188-0	1				
H10	4	2	8-6	17-0	1				
H11	4	2	4-6	9-0	1				

0 1 2 3 4

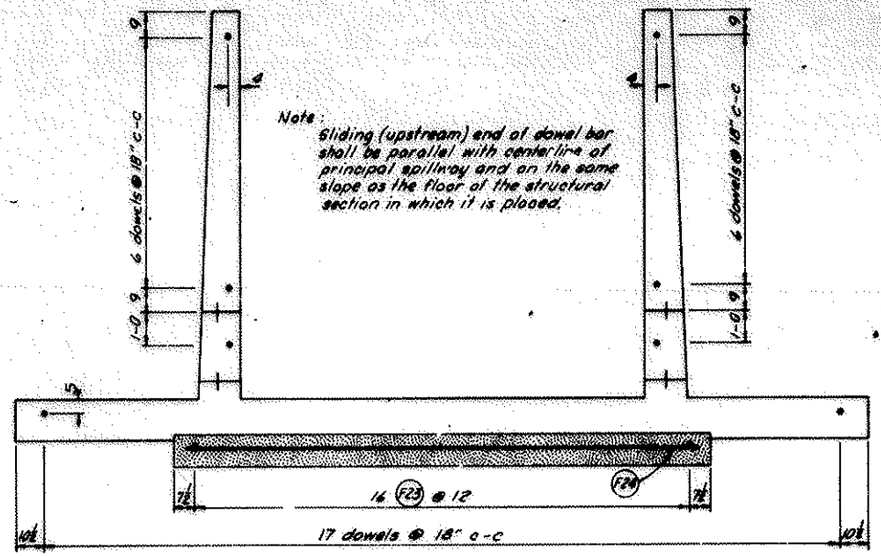


STEEL IN TOP FACE

HALF PLAN

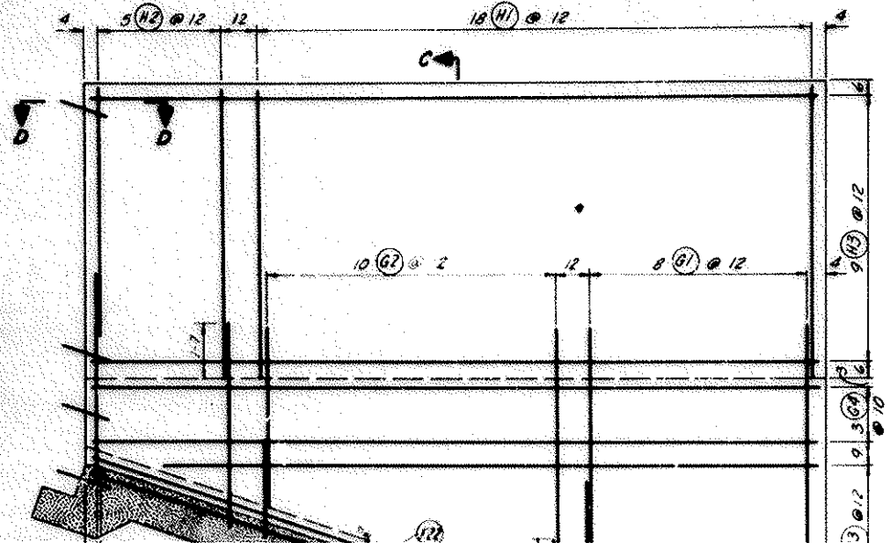


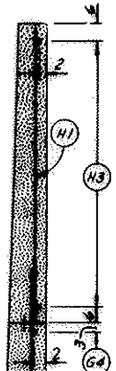
SECTION D-D

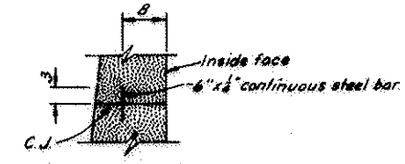


SECTION A-A

DETAILS OF E.J.2







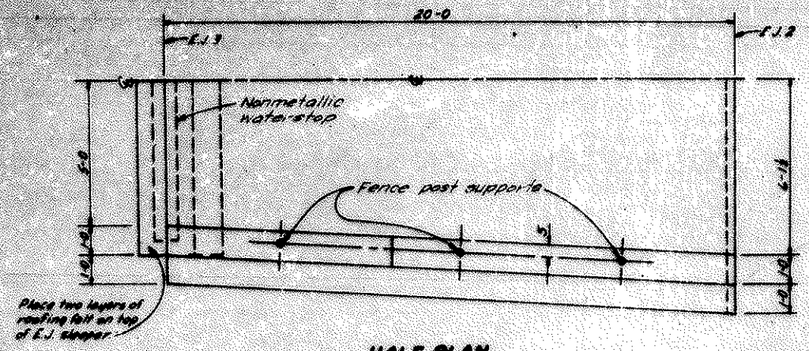
DETAILS OF PLATE CONSTRUCTION JOINT

Not to scale

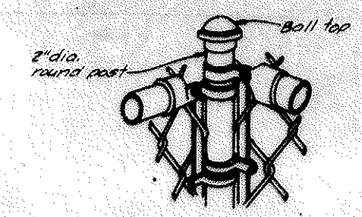
0 1 2 3 4

TABLE F QUANTITIES FOR CHAIN LINK FENCE

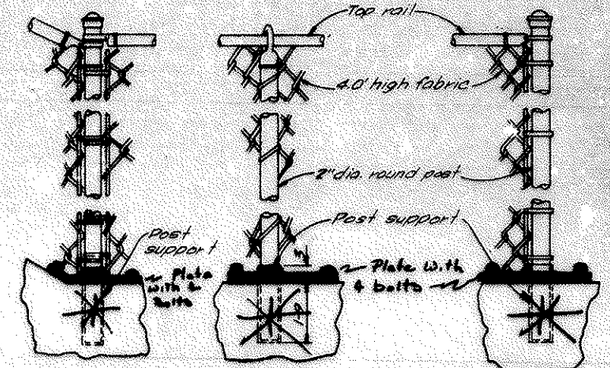
ITEM	UNIT	QUANTITY
4.0' HIGH, 9 GAUGE FABRIC AND HARDWARE	LIN.FT.	129-6
2" DIA. O.D. STEEL POSTS, GALV.	EACH	19
2 1/2" DIA. STD. GALV. PIPE AS PER DETAIL	EACH	18



HALF PLAN
STRUCTURE SYMMETRICAL ABOUT ℄



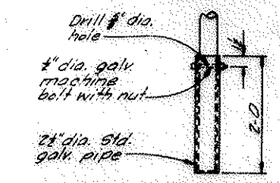
CORNER POST DETAIL



LINE POSTS **END POST**



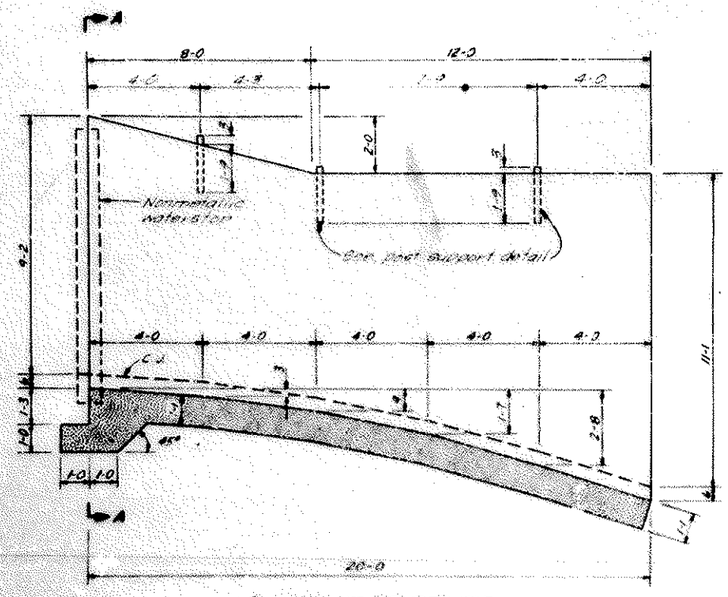
DETAILS OF PLATE CONSTRUCTION JOINT E.J 2 TO E.J 3
Not to scale



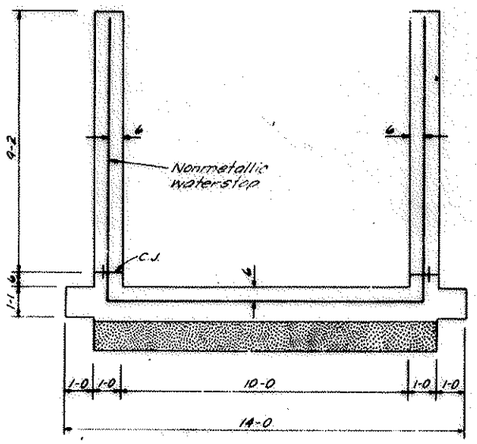
POST SUPPORT DETAIL
N.T.S.

NOTES:
1. POST SUPPORTS ARE 2 1/2" DIA. STANDARD GALV. PIPE 2.0' LONG. SUPPORTS WILL BE EMBEDDED 21" IN CONCRETE. EMBEDDED ENDS SHALL BE CAPPED TO PREVENT CONCRETE FROM ENTERING PIPE.
2. FENCE POSTS SHALL BE BOLTED TO POST SUPPORTS WITH 0.5" DIA. GALV. MACHINE BOLTS 3" LONG.
3. FABRIC SHALL BE 9 GAUGE, GALVANIZED, 4.0' HIGH
4. POSTS SHALL BE 2" DIA., GALVANIZED.
5. FABRIC TO BE INSTALLED TOWARDS OUTSIDE FACE OF CONCRETE WALL WITH POST ON THE INSIDE.

DETAILS OF CHAIN LINK FENCE



SECTION ON CENTERLINE



SECTION A-A

TABLE OF QUANTITIES FOR CHUTE

ITEM	UNIT	QUANTITY
CONCRETE (CLASS 4000)	CU.YD.	27.66
REINFORCING STEEL	LB.	5,389
NONMETALLIC WATERSTOP	LIN.FT.	29.3
STEEL BAR, 6" X 1/4" (CONSTRUCTION JOINT)	LIN.FT.	40

NOTES:
1. E.J.= EXPANSION JOINT.
2. C.J.= CONSTRUCTION JOINT.
3. FOR DETAILS OF WATERSTOP AND DOWEL BARS, SEE SHEET 29.

0 1 2 3 4
Scale in feet

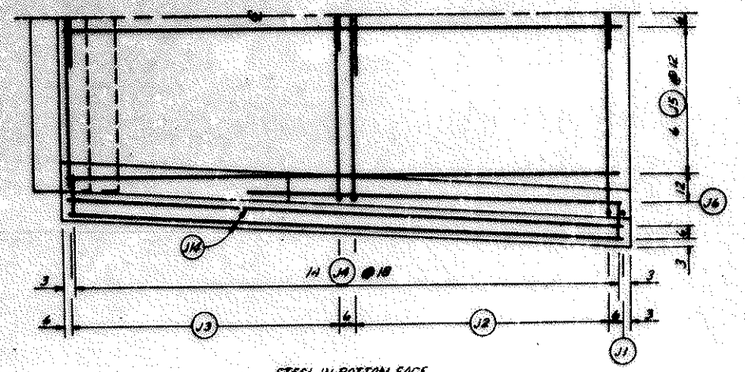
AS BUILT
FEB. 8 1978

DETAILS OF CHUTE (E.J 2-E.J 3)

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

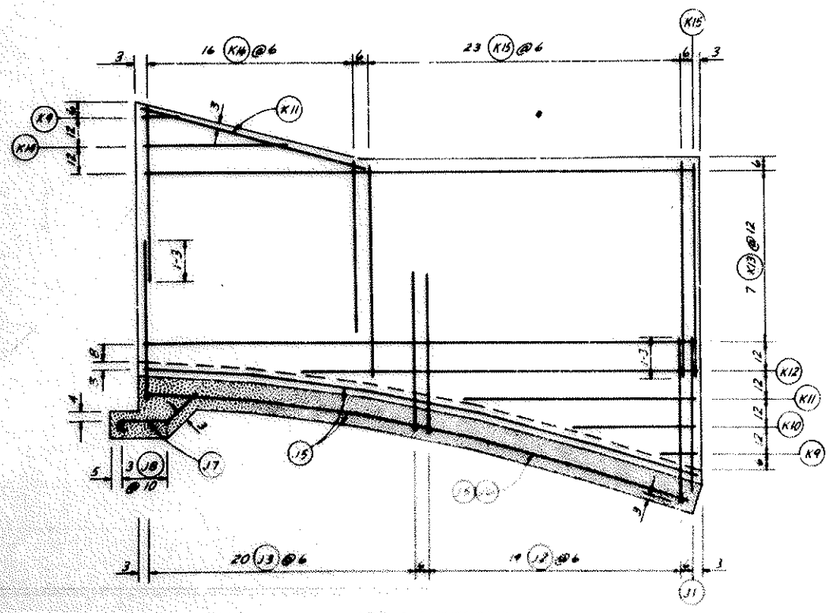
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date		
Designed J.E.N.	4-76	Approved by	
Drawn D.L.J.	5-76	Title	
Traced		Title	
Checked C.E.M.	6-76	Sheet No. 28 of 37	Drawing No. SC-36,025



STEEL IN BOTTOM FACE

HALF PLAN



STEEL IN OUTSIDE FACE

SECTION ON CENTERLINE

BAR BENDS

Straight — TYPE 1



TYPE 21

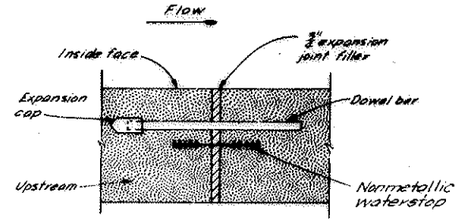


TYPE 24

BAR SCHEDULE

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C
J1	8	2	5-6	11-0	1		
J2	8	38	14-0	532-0	21	5-9	8-3
J3	8	40	13-6	540-0	21	5-9	7-9
J4	4	28	1-3	35-0	1		
J5	4	14	20-0	280-0	FIELD BEND		
J6	4	2	13-9	27-6	FIELD BEND		
J7	5	12	3-9	45-0	24	SEE BAR BENDS	
J8	5	3	11-6	34-6	1		
J9	5	12	20-0	240-0	FIELD BEND		
J10	5	2	10-0	20-0	FIELD BEND		
J11	5	20	8-9	175-0	1		
J12	5	20	8-3	165-0	1		
J13	5	40	2-9	110-0	1		
J14	3	8	20-0	160-0	FIELD BEND		
K1	5	2 SETS OF 12 BARS	7-8 TO 10-5 @ 3" INC.	217-0	1		
K2	5	2 SETS OF 8 BARS	7-8 TO 8-10 @ 2" INC.	132-0	1		
K3	5	4	1-3	5-0	1		
K4	5	2	4-6	9-0	1		
K5	5	4	8-3	33-0	1		
K6	5	2	14-0	28-0	1		
K7	5	14	19-6	273-0	1		
K8	5	2	5-0	10-0	1		
K9	4	4	1-3	5-0	1		
K10	4	2	4-6	9-0	1		
K11	4	4	8-3	33-0	1		
K12	4	2	14-0	28-0	1		
K13	4	14	19-6	273-0	1		
K14	4	2	5-0	10-0	1		
K15	4	48	7-6	360-0	1		
K16	4	32	6-0	192-0	1		

STEEL TOTAL



DETAIL OF JOINTS 1, 2 AND 3

(DOWEL BAR AND WATERSTOP)
Not to scale

0 1 2 3 4
Scale in feet

DETAILS OF CHUTE (E.J 2-E.J 3)

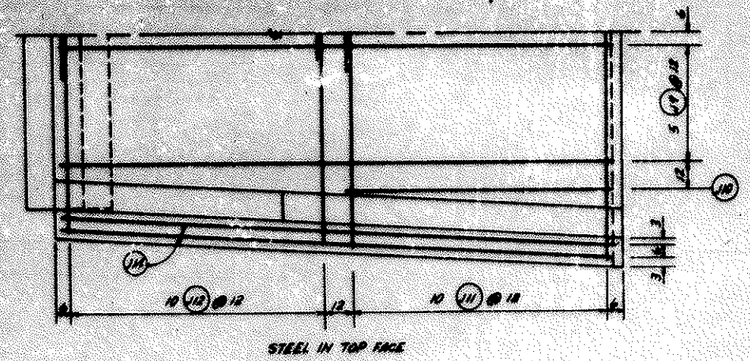
MULTIPLE-PURPOSE STRUCTURE NO. 9

UPPER TURTLE RIVER WATERSHED

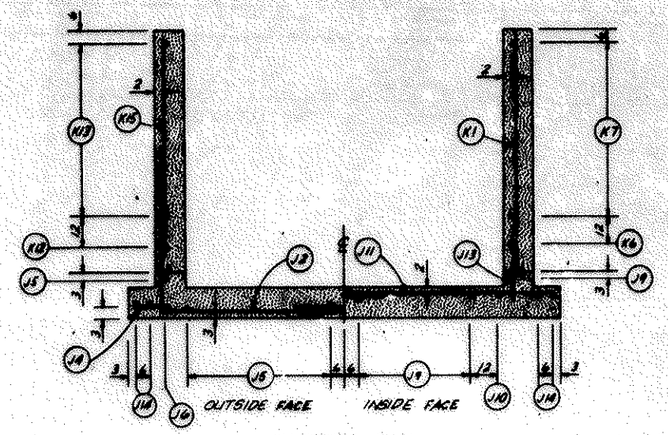
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed J.E.N.	4-76	Approved by
Drawn C.L.J.	5-76	Title
Traced		Title
Checked C.E.M.	5-76	Sheet No. 13 of 21 — Drawing No. S.E-36,025



HALF PLAN

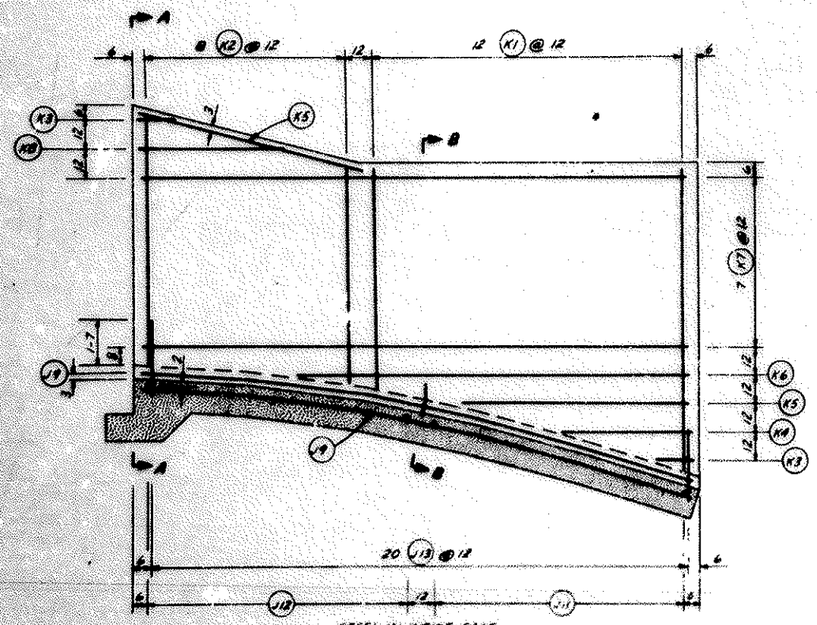


SECTION B-B

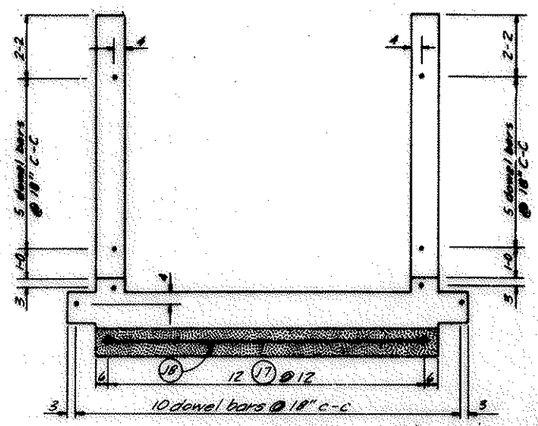
NOTE:
SLIDING (UPSTREAM) END OF DOWEL BAR SHALL BE PARALLEL WITH THE CENTERLINE OF THE PRINCIPAL SPILLWAY AND ON THE SAME SLOPE AS THE FLOOR OF THE STRUCTURAL SECTION IN WHICH IT IS PLACED. FOR DETAIL OF DOWEL BAR SEE SHEET 28.



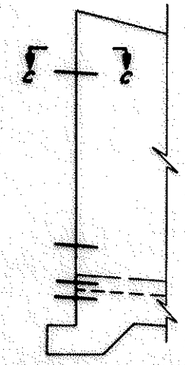
SECTION C-C
(Not to Scale)



SECTION ON CENTERLINE



SECTION A-A



PARTIAL SIDEWALL ELEVATION

0 1 2 3 4
Scale in Feet

DETAIL OF JOINT 3

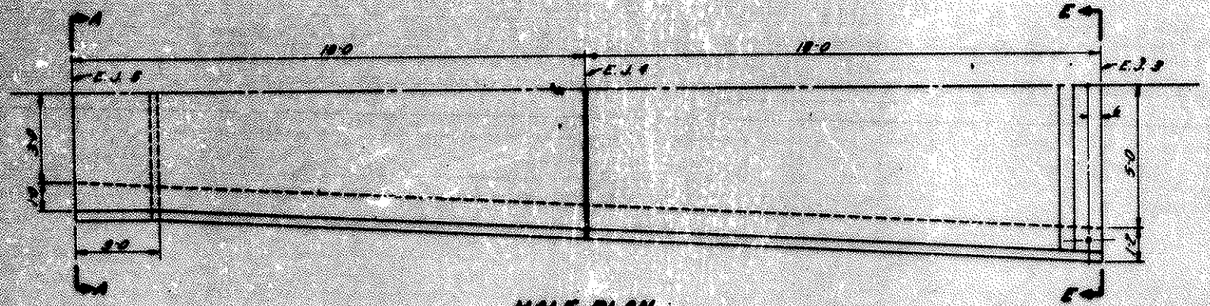
AS BUILT FEB 8 1978

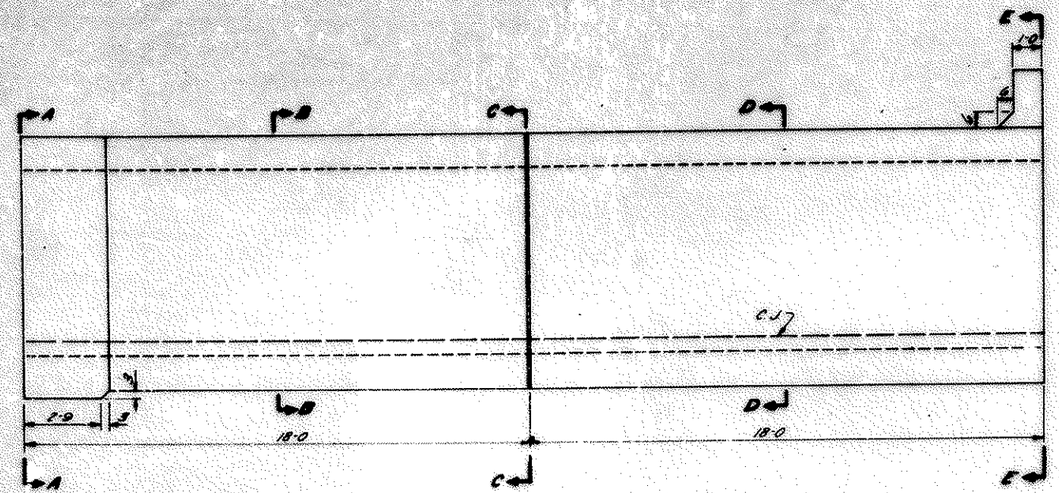
DETAILS OF CHUTE (E.J 2-E.J 3)

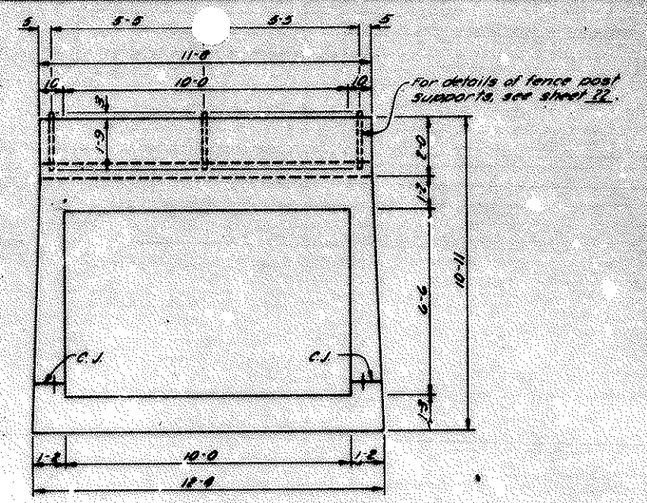
MULTIPLE-PURPOSE STRUCTURE
NO 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J.E.N.	Date 4-76	Approved by	
Drawn D.L.J.	5-76	Title	
Traced		Title	
Checked C.E.M.	5-76	Sheet No. 27 of 51	Drawing No. S.C-56.025



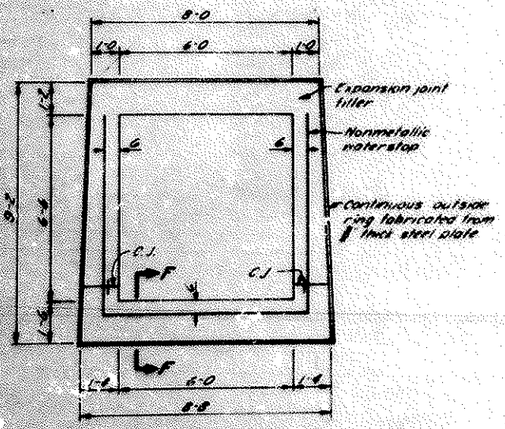


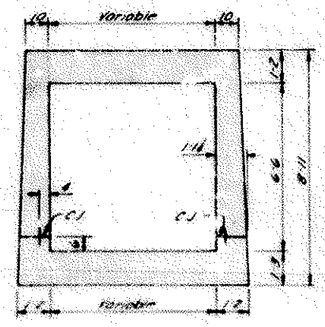


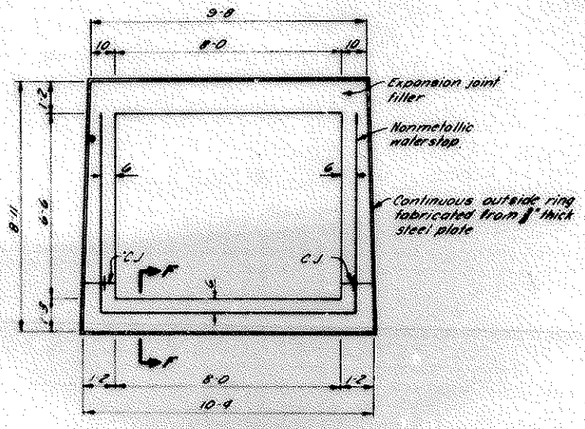
NOTES:
1. E.J.= EXPANSION JOINT
2. C.J.= CONSTRUCTION JOINT
3. FOR DETAILS OF PLATE CONSTRUCTION JOINT, SEE SHEET 27.
4. FOR DETAILS OF SECTION F-F, SEE SHEET 27.

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
CONCRETE (CLASS 4000)	CU.YD.	50.9
REINFORCING STEEL	LB.	9,134
NONMETALLIC WATERSTOP	LIN.FT.	43
STEEL BAR, 6" X 3/4" CONSTRUCTION JOINT	LIN.FT.	70
STEEL PLATE, PER DETAIL, EXPANSION JOINT OUTSIDE	LIN.FT.	73







AS BUILT

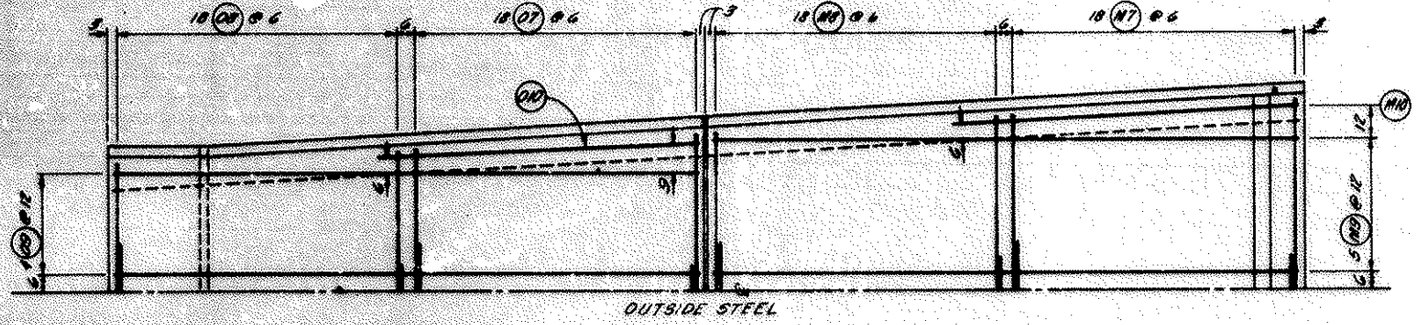
0 1 2 3 4
Scale in feet

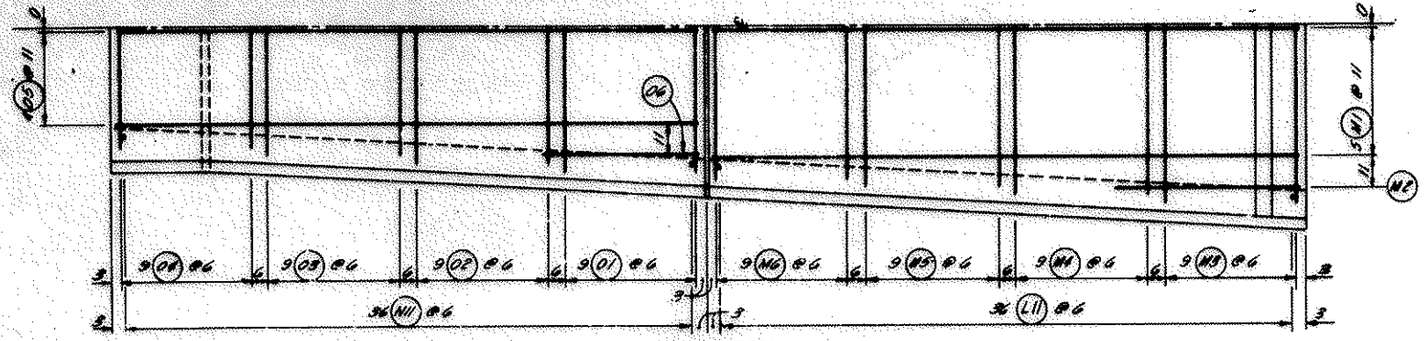
DETAILS OF TRANSITION

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

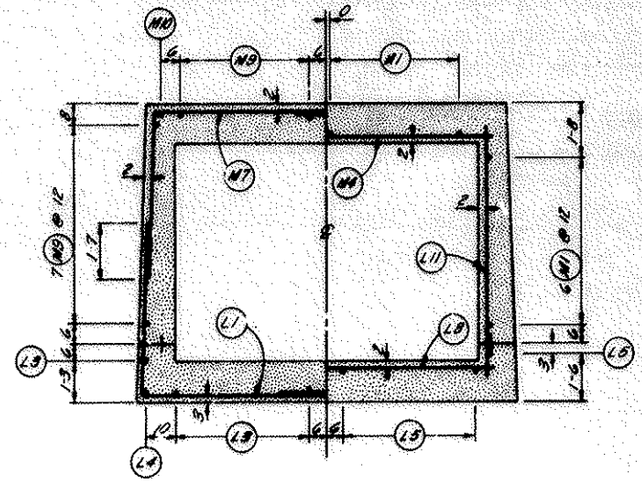
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date		
Designed	M.F.N.	6-58	Approved by	
Drawn	W.M.S., O.L.P.	7-58	Title	
Traced			Title	
Checked	C.K.M.	6-58	Sheet No. 25 of 51	Drawing No. SE-36,025

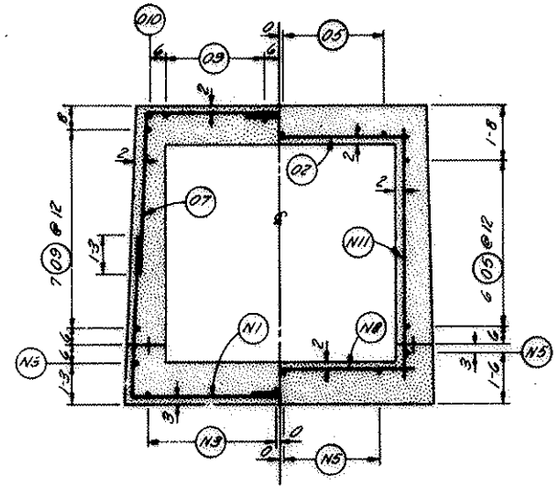




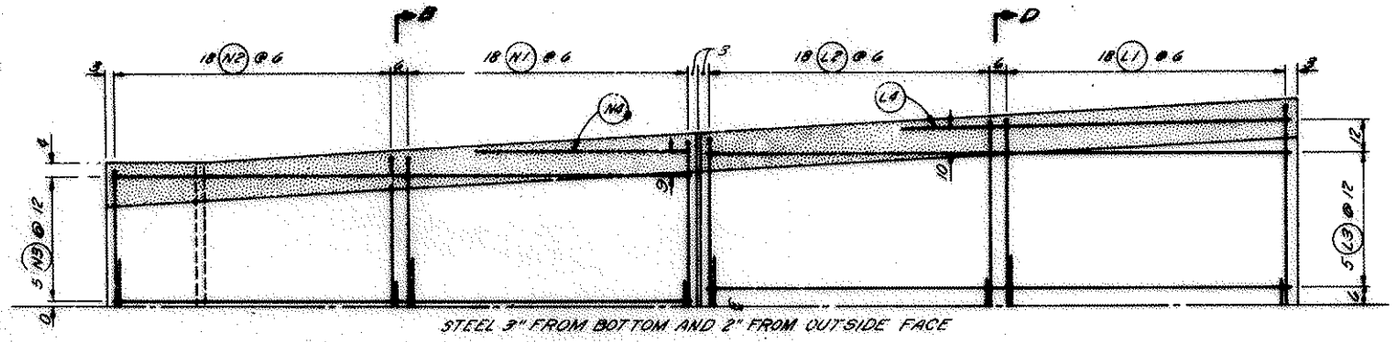
PLAN - TOP



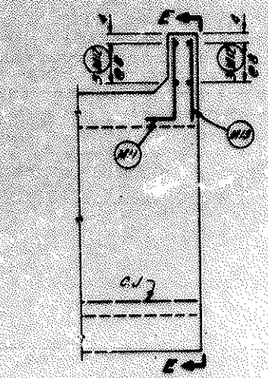
SECTION D-D



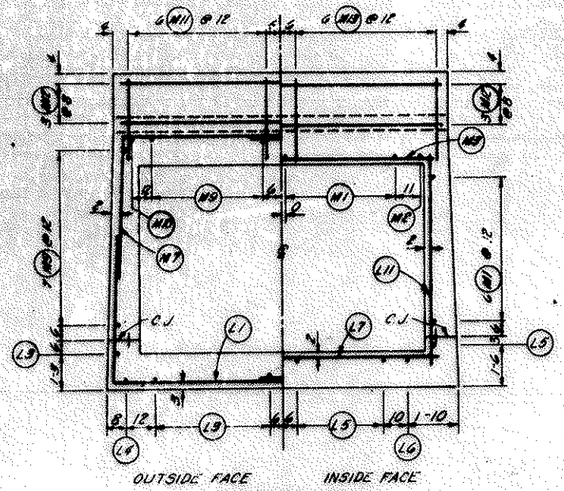
SECTION B-B







PARTIAL SIDEWALL ELEVATION

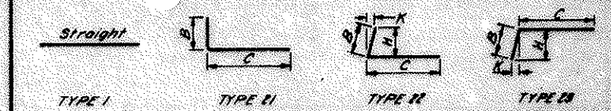


SECTION E-E

STEEL TOTALS

SIZE	LENGTH (FT.)	WEIGHT (LB.)
4	3188-0	2,130
5	3009-6	3,139
6	1907-6	2,865
	TOTAL	8,134

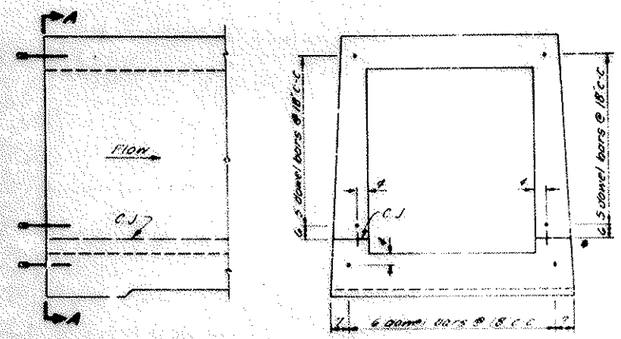
BAR BENDS



TYPE 1 TYPE 21 TYPE 22 TYPE 28

STEEL SCHEDULE

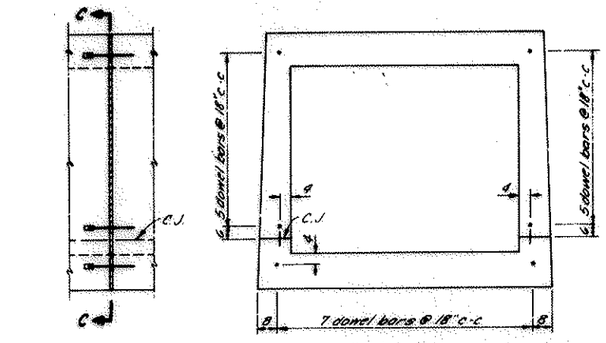
MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	'	K
L1	5	36	12-3	441-0	22	5-3	7-0	5-3	0-2 1/4
L2	5	36	11-9	428-0	22	5-3	6-6	5-3	0-2 1/4
L3	4	12	17-6	210-0	1				
L4	4	2	11-9	23-6	1				
L5	6	10	17-6	175-0	1				
L6	5	2	7-6	15-0	1				
L7	6	9	11-0	99-0	1				
L8	6	9	10-6	94-6	1				
L9	6	9	10-0	90-0	1				
L10	6	9	9-6	85-6	1				
L11	4	72	7-6	540-0	1				
M1	5	21	17-6	367-6	1				
M2	5	2	5-6	11-0	1				
M3	6	9	10-9	96-9	1				
M4	6	9	10-3	92-3	1				
M5	6	9	9-9	87-9	1				
M6	6	9	9-3	83-3	1				
M7	6	36	12-0	432-0	23	5-3	6-9	5-3	0-2 1/4
M8	6	36	11-6	414-0	23	5-3	6-3	5-3	0-2 1/4
M9	4	24	17-6	420-0	1				
M10	4	2	10-6	21-0	1				
M11	5	12	3-9	45-0	21	1-0	2-9		
M12	4	6	11-3	67-6	1				
M13	5	12	2-9	33-0	1				
N1	4	36	10-9	387-0	22	5-0	5-9	5-0	0-2 1/8
N2	4	36	10-3	369-0	22	5-0	5-3	5-0	0-2 1/8
N3	4	11	17-6	192-6	1				
N4	4	2	6-6	13-0	1				
N5	6	9	17-6	157-6	1				
N6	5	2	4-9	9-6	1				
N7	5	9	9-0	81-0	1				
N8	5	9	8-6	76-6	1				
N9	5	9	8-0	72-0	1				
N10	5	9	7-6	67-6	1				
N11	4	72	7-6	540-0	1				
O1	5	9	8-9	78-9	1				
O2	5	9	8-3	74-3	1				
O3	5	9	7-9	69-9	1				
O4	5	9	7-3	65-3	1				
O5	5	19	17-6	332-6	1				
O6	5	2	4-6	9-0	1				
O7	5	36	10-6	378-0	23	5-0	5-6	5-0	0-2 1/8
O8	5	36	10-0	360-0	23	5-0	5-0	5-0	0-2 1/8
O9	4	22	17-6	385-0	1				
O10	4	2	9-9	19-6	1				



PARTIAL SIDEWALL ELEVATION

SECTION A-A

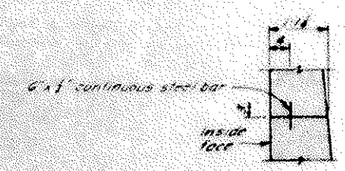
DETAILS OF JOINT 5 SHOWING LOCATION OF DOWEL BARS



PARTIAL SIDEWALL ELEVATION

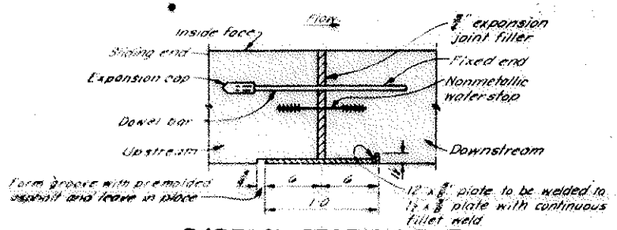
SECTION C-C

DETAILS OF JOINT 4 SHOWING LOCATION OF DOWEL BARS



DETAILS OF PLATE CONSTRUCTION JOINT E.J 3 TO E.J 5

Not to scale



PARTIAL SECTION F-F

Not to scale

Note:
Dowel bars shall be 3/4" dia x 18" long smooth steel bars, coated on sliding end to prevent bond. Coating shall be oil, asphalt or other method accepted by the engineer.

AS BUILT

0 1 2 3 4
Scale in feet

FOR 9 MM

DETAILS OF TRANSITION

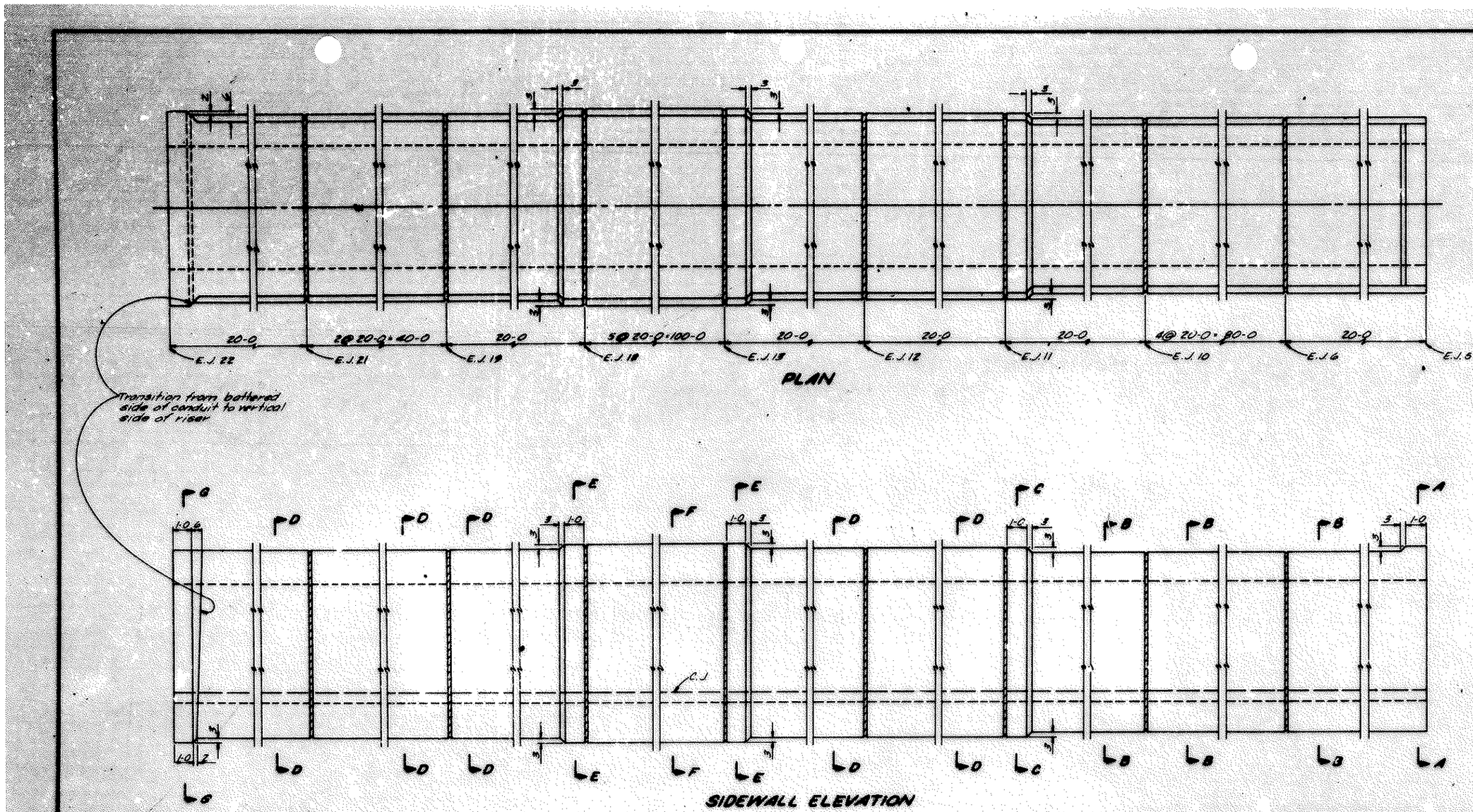
MULTIPLE-PURPOSE STRUCTURE NO. 9

UPPER TURTLE RIVER WATERSHED

Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

		Date	
Designed	J.E.N.	6-76	Approved by
Drawn	D.L.J., D.L.R.	7-76	Title
Traced			Title
Checked	J.E.N.	6-76	Sheet No. 27 of 51 — Drawing No. S.E-36,025



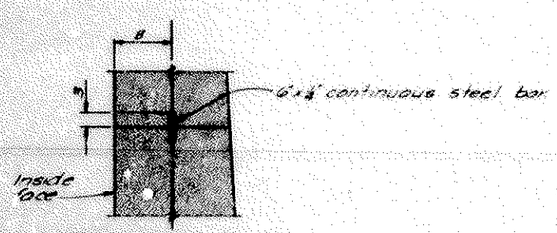
PLAN

SIDEWALL ELEVATION

NOTES:
1. C.J. = CONSTRUCTION JOINT.
2. E.J. = EXPANSION JOINT
3. FOR DETAILS OF EXPANSION JOINTS, SEE SHEETS 29 AND 32.
4. FOR SECTIONS A-A THROUGH G-G, SEE SHEET 29.

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
CONCRETE (CLASS 4000)	CU.YD.	591.1
REINFORCING STEEL	LB.	59,166
NONMETALLIC WATERSTOP	LIN.FT.	465
STEEL BAR, 6" x 1/4" (CONSTRUCTION JOINT)	LIN.FT.	669
3/8" X 10" STEEL PLATE, EXPANSION JOINT (INSIDE) E.J. 6-22	LIN.FT.	408
STEEL PLATE, PER DETAIL, EXPANSION JOINT (OUTSIDE) E.J. 6-22	LIN.FT.	625



DETAILS OF PLATE CONSTRUCTION JOINT
E.J. 5-E.J. 22
(Not to scale)

0 1 2 3 4
Scale in feet

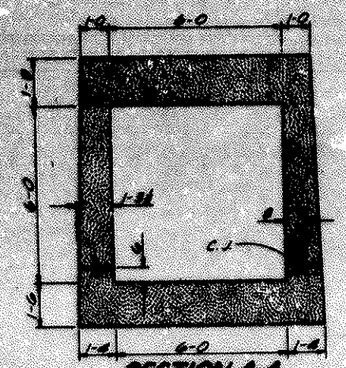
AS BUILT FEB 8 1979

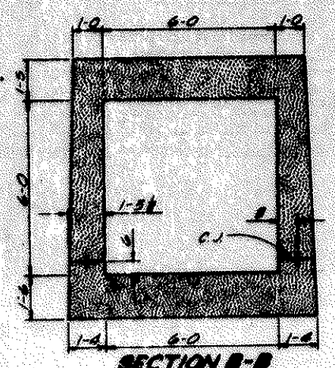
DETAILS OF CONDUIT

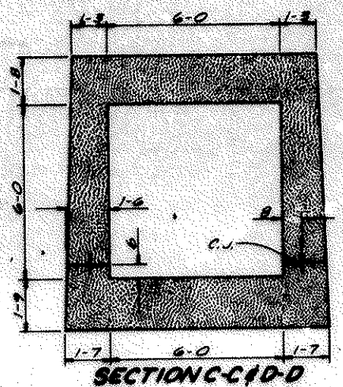
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

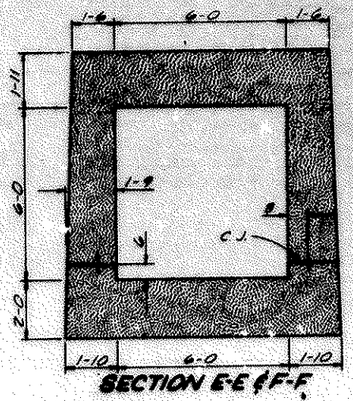
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

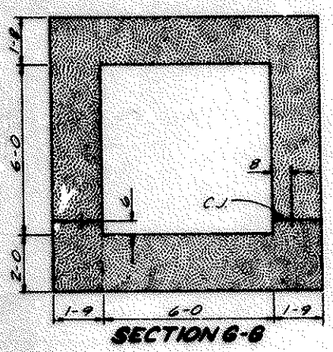
Designed J.E.N.	Date 6-76	Approved by	
Drawn N.S.	7-76	Title	
Traced		Date	
Checked C.E.M.	8-76	Sheet No. 27 of 37	Drawing No. GE-54025

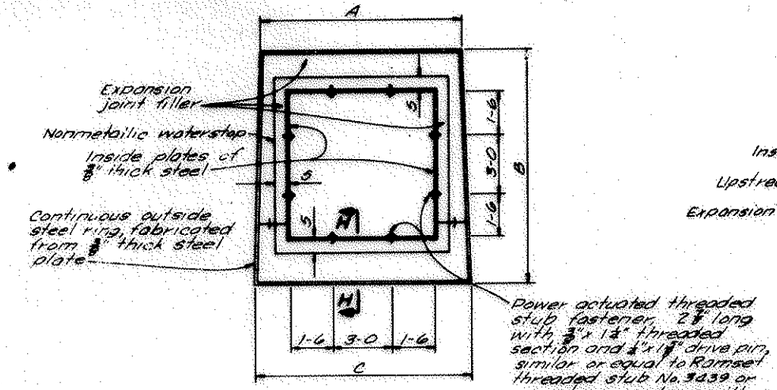






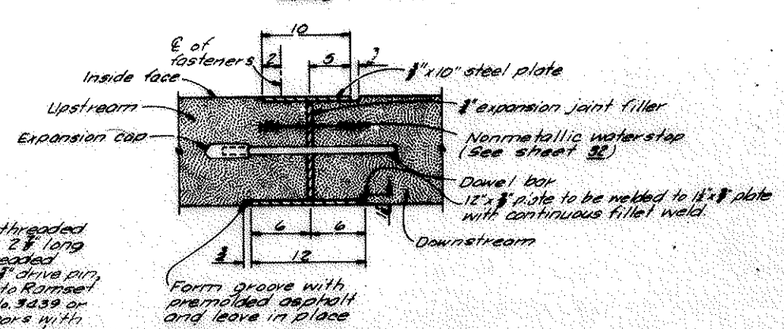






DETAILS OF EXPANSION JOINTS 6 THROUGH 22
(Not to scale)

NOTE:
DOWEL BARS SHALL BE 3/4" DIA. X 18" LONG SMOOTH STEEL BARS COATED ON UPSTREAM END TO PREVENT BOND. COATING SHALL BE OIL, ASPHALT OR OTHER METHOD APPROVED BY THE ENGINEER.



PARTIAL SECTION H-H
(Not to scale)

Scale in feet: 0 1 2 3 4

AS BUILT
FOR 1 STR

DETAILS OF CONDUIT

EXPANSION JOINT DIMENSIONS

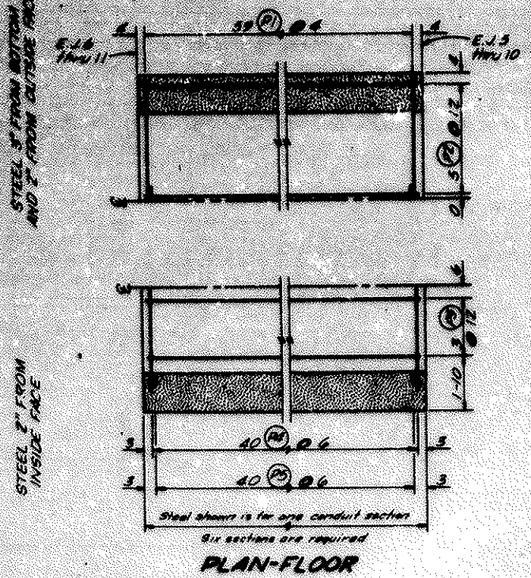
SECTION	A	B	C
SECTION B-B	8-11	8-11	8-8
SECTION C-C & D-D	8-6	9-5	9-2
SECTION E-E & F-F	9-0	9-11	9-8
SECTION 6-6	9-6	9-5	9-6

NOTES:
1. C.J. = CONSTRUCTION JOINT.
2. FOR LOCATIONS OF SECTIONS, SEE SHEET 22.

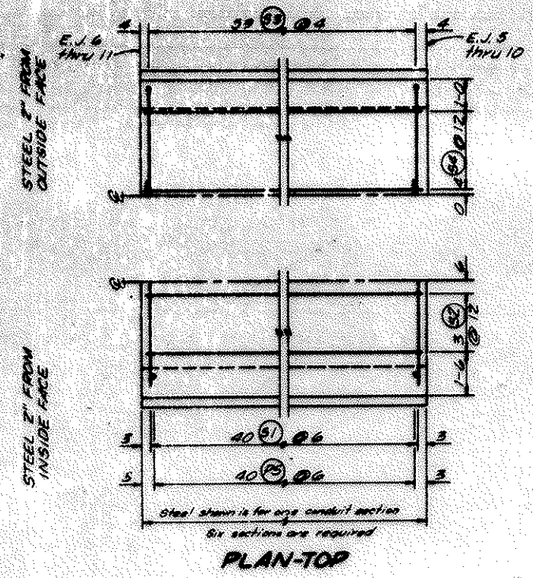
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J.E.N.	Date 6-76	Approved by	
Drawn N.S.	7-76	Title	
Traced		Title	
Checked C.E.M.	8-76	Sheet No. 29 of 31 sheets	Drawing No. S.E-36,025

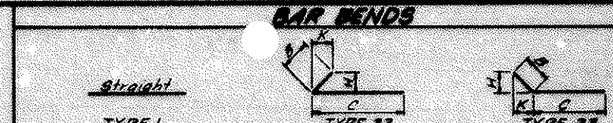


PLAN-FLOOR



PLAN-TOP

BAR BENDS



STEEL SCHEDULE

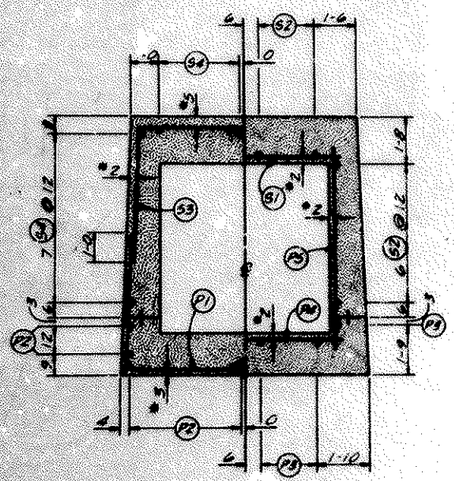
MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	H	K
P1	3	708	9-6	6726-0	22	4-9	4-9	4-9	0-2 7/8
P2	4	78	19-6	1521-0	1				
P3	6	48	19-6	936-0	1				
P4	6	240	7-0	1680-0	1				
P5	4	480	7-0	3360-0	1				
S1	6	240	7-0	1680-0	1				
S2	6	108	19-6	2106-0	1				
S3	3	708	9-6	6726-0	22	4-9	4-9	4-9	0-2 7/8
S4	4	126	19-6	2457-0	1				

STEEL TOTAL

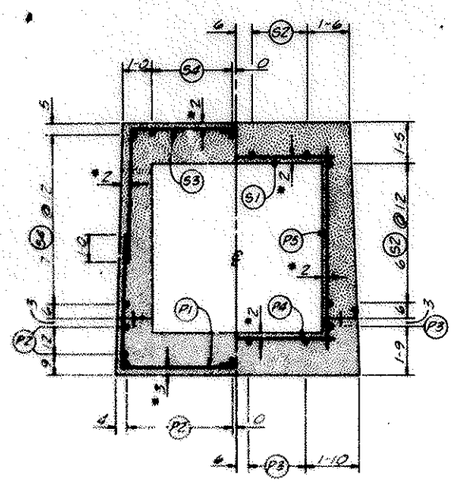
SIZE	LENGTH (FT.)	WEIGHT (LB.)
3	13452-0	5058
4	7338-0	4902
6	6432-0	9616
	TOTAL	19576

NOTES:

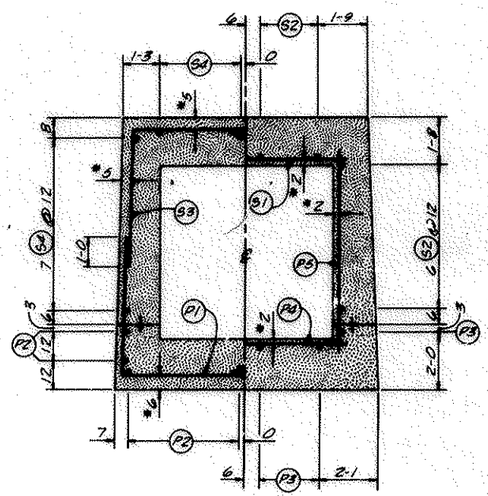
1. 120 DOWEL BARS REQUIRED FOR E.J. 6 THRU E.J. 11. DOWEL BARS NOT INCLUDED IN STEEL TOTALS.
2. BAR DIMENSIONS ARE OUT TO OUT OF BAR.
3. RADIUS OF BENDS EQUALS THREE TIMES THE DIAMETER OF THE BAR.
4. BAR MARKS (P4) (P5) AND (S1) NEAREST JOINTS SHALL BE CUT TO CLEAR WATERSTOP.
5. SEE SHEET 08 FOR LOCATION OF SECTIONS.
6. # INDICATES CLEAR COVER OVER STEEL REINFORCEMENT.



SECTION A-A



SECTION B-B



SECTION C-C

0 1 2 3 4
Scale in feet

AS BUILT

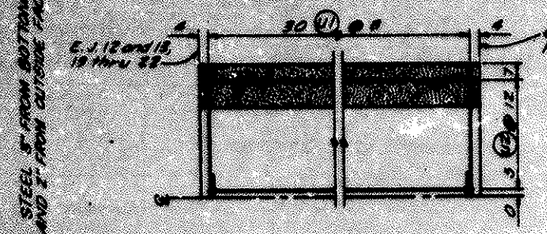
DETAILS OF CONDUIT (E.J.5-E.J.11)

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

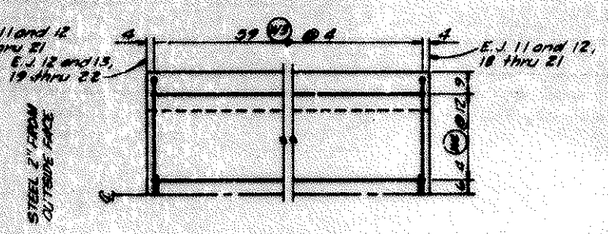
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed J.E.N.	6-76	Approved by
Drawn N.S.	7-76	Title
Traced		Title
Checked C.E.M.	8-76	Sheet No. 30 of 51

Drawing No. SE-96,025



PLAN-FLOOR



PLAN-TOP

BAR BENDS



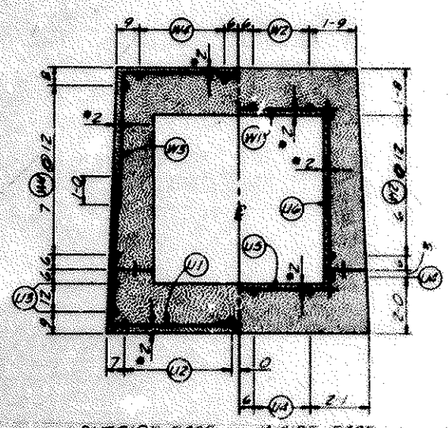
STEEL SCHEDULE

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	H	K
U1	4	380	10-6	3780-0	22	5-3	5-3	5-3	0-2 1/8
U2	4	54	19-6	1053-0	1				
U3	4	24	19-6	468-0	1				
U4	4	48	19-6	936-0	1				
U5	6	240	7-0	1680-0	1				
U6	6	252	7-0	1764-0	1				
W1	6	240	7-0	1680-0	1				
W2	6	108	19-6	2106-0	1				
W3	3	708	9-6	6726-0	23	4-9	4-9	4-9	0-2 1/8
W4	4	192	10-5	2574-0	1				

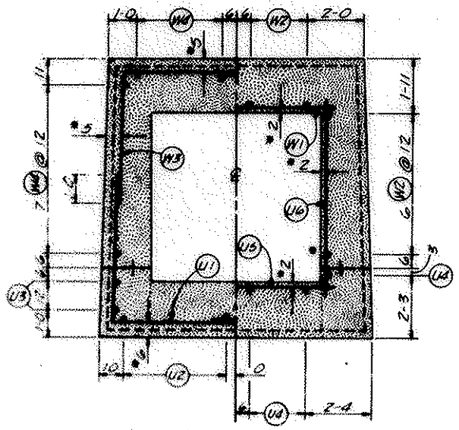
STEEL TOTAL

SIZE	LENGTH (FT.)	WEIGHT (LBS.)
3	6726-0	2,529
4	7907-0	5,998
6	8634-0	12,368
	TOTAL	20,895

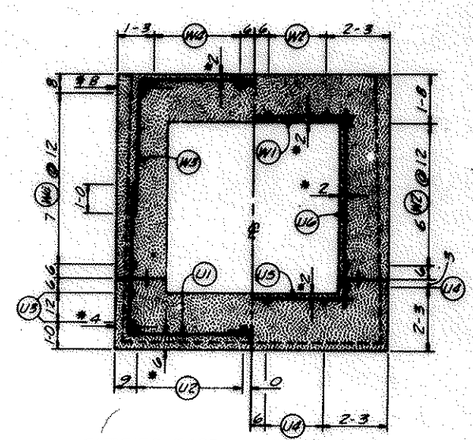
NOTES:
1. 120 DOWEL BARS REQUIRED FOR E.J. 12 AND 13 AND E.J. 19 THRU 22. DOWEL BARS NOT INCLUDED IN STEEL TOTALS.
2. BAR DIMENSIONS ARE OUT TO OUT OF BAR.
3. RADIUS OF BENDS EQUALS THREE TIMES THE DIAMETER OF THE BAR.
4. BAR MARKS (U5), (U6) AND (W1) NEAREST JOINTS SHALL BE CUT TO CLEAR WATERSTOP.
5. SEE SHEET 22 FOR LOCATION OF SECTIONS.
6. * INDICATES CLEAR COVER OVER STEEL REINFORCEMENT.



SECTION D-D



SECTION E-E



SECTION 3-G

Scale in feet

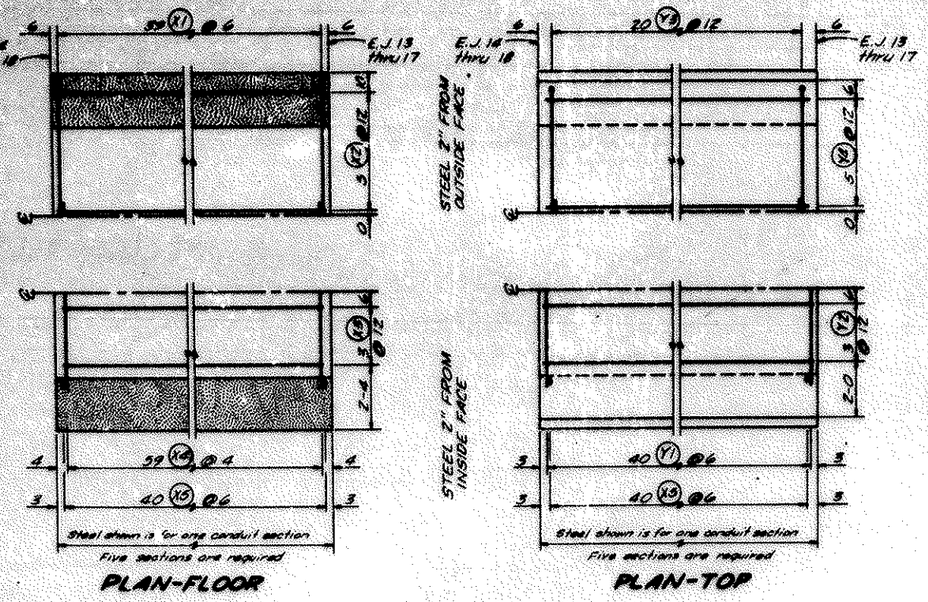
AS BUILT

DETAILS OF CONDUIT (E.J. 11 THRU 13 AND E.J. 18 THRU 22)

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J.E.N.	Date 6-76	Approved by	
Drawn N.S.	7-76	Title	
Traced		Title	
Checked C.E.M.	8-76	Sheet No. 21 of 41	Drawing No. SE-54,023



BAR BENDS

Straight — TYPE 1



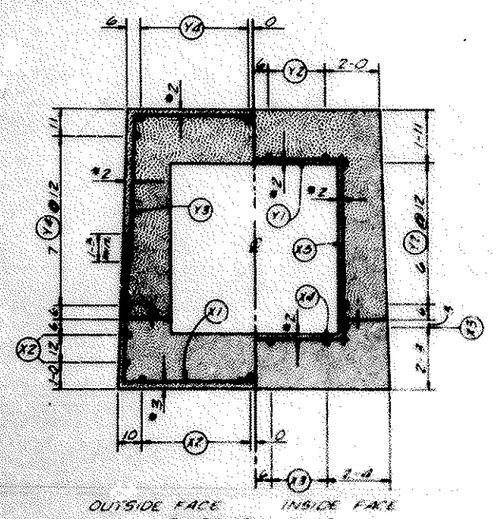
STEEL SCHEDULE

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C	H	K
X1	4	390	11-0	4290-0	22	5-6	5-6	5-6	0-2 1/8
X2	4	65	19-6	1267-6	1				
X3	6	40	19-6	780-0	1				
X4	5	295	7-0	2065-0	1				
X5	5	400	7-0	2800-0	1				
Y1	7	200	7-0	1400-0	1				
Y2	6	90	19-6	1755-0	1				
Y3	5	200	10-6	2100-0	22	5-3	5-3	5-3	0-2 1/8
Y4	4	115	19-6	2242-6	1				

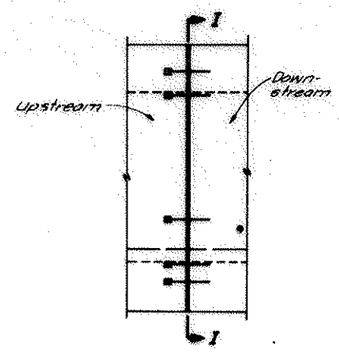
STEEL TOTALS

NOTES:

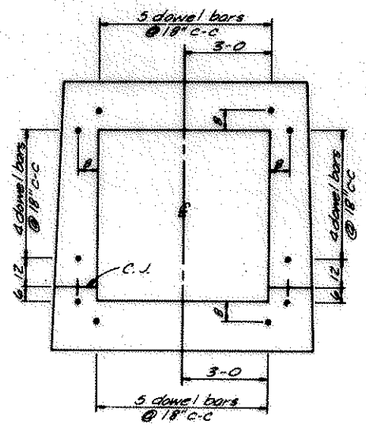
1. 100 DOWEL BARS REQUIRED FOR E.J. 14 THRU E.J. 18. DOWEL BARS NOT INCLUDED IN STEEL TOTALS.
2. BAR DIMENSIONS ARE OUT TO OUT OF BAR.
3. RADIUS OF BENDS EQUALS THREE TIMES THE DIAMETER OF THE BAR.
4. BAR MARKS (X4) (X5) AND (Y1) NEAREST JOINTS SHALL BE CUT TO CLEAR WATERSTOP.
5. SEE SHEET 20 FOR LOCATION OF SECTIONS E-E AND F-F.
6. # INDICATES CLEAR COVER OVER STEEL REINFORCEMENT.



SECTION C-F

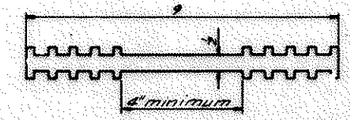


PARTIAL SIDEWALL ELEVATION



SECTION I-I

DETAILS OF EXPANSION JOINTS 6 THROUGH 22 SHOWING LOCATION OF DOWEL BARS



DETAIL OF NONMETALLIC WATERSTOP
(Not to scale)

AS BUILT REV. 1 9/77

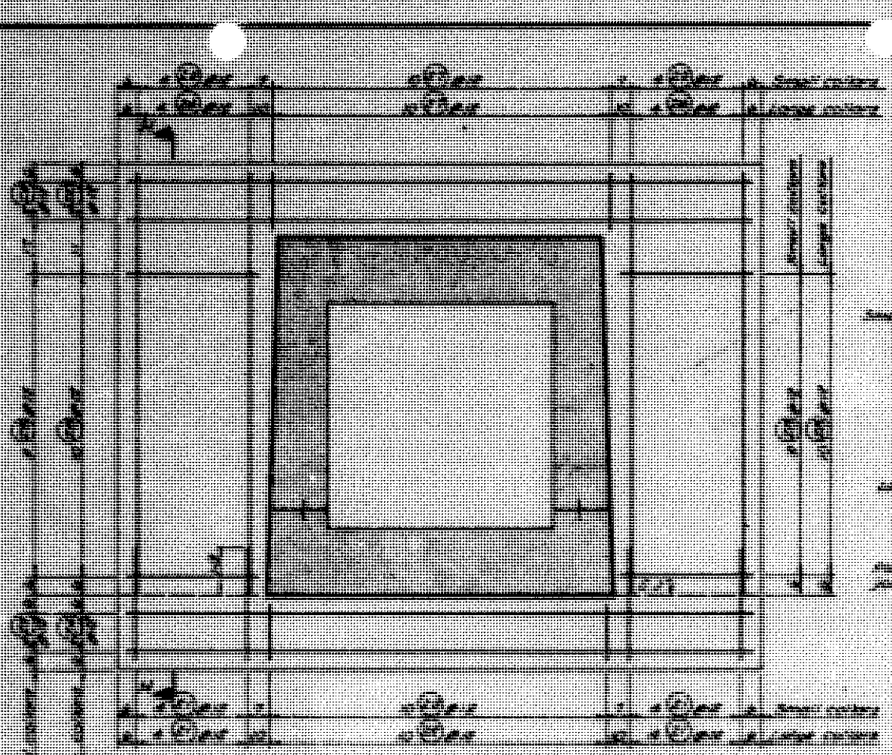
0 1 2 3 4
Scale in feet

DETAILS OF CONDUIT (E.J. 13 - E.J. 18)

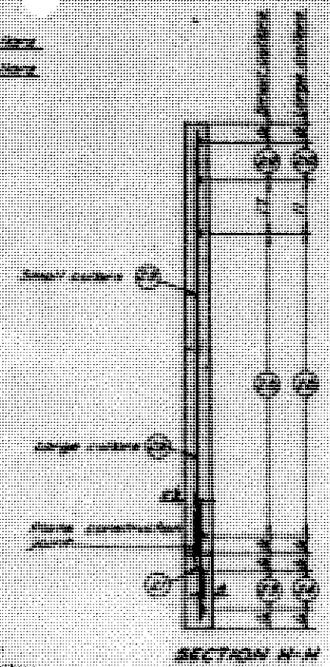
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J.E.N.	Date 6-76	Approved by	
Drawn N.S.	7-76	Title	
Traced		Title	
Checked C.E.M.	8-76	Sheet No. 57 of 82	Drawing No. SE-54 085

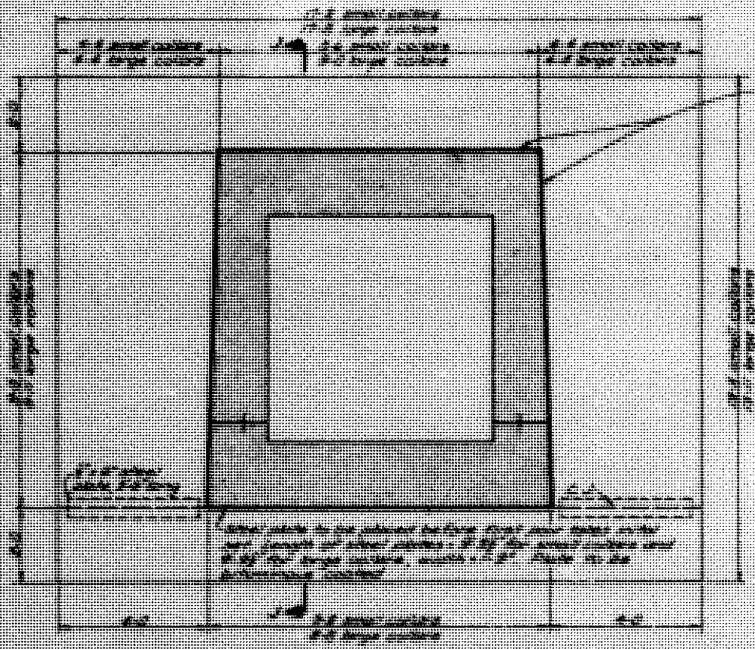


TRANSVERSE SECTION

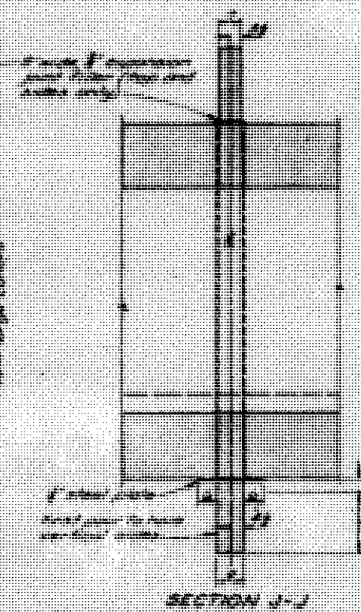


SECTION H-H

REINFORCING STEEL DETAILS OF ANTISEEP COLLARS



ELEVATION OF ANTISEEP COLLARS



SECTION J-J

BAR BENDS

STEEL SCHEDULE

MARK	SIZE	SHAPE	LENGTH	TOTAL LENGTH	CLASS
A1	5	1	14'-0"	14'-0"	
A2	5	1	14'-0"	14'-0"	
A3	5	1	14'-0"	14'-0"	
A4	5	1	14'-0"	14'-0"	
A5	5	1	14'-0"	14'-0"	
A6	5	1	14'-0"	14'-0"	
A7	5	1	14'-0"	14'-0"	
A8	5	1	14'-0"	14'-0"	
A9	5	1	14'-0"	14'-0"	
A10	5	1	14'-0"	14'-0"	
A11	5	1	14'-0"	14'-0"	
A12	5	1	14'-0"	14'-0"	

STEEL TOTALS

SIZE	LENGTH	WEIGHT
5	2,912 ft	7,280 lbs

TABLE OF QUANTITIES

CONCRETE (CLASS A)	30.1 cu. yds.	30.1
REINFORCING STEEL	7,280 lbs.	7.28
STRUCTURAL STEEL PLATE (1/4" THICK)	1,200 lbs.	1.2
STRUCTURAL STEEL ANGLES	1,200 lbs.	1.2
STRUCTURAL STEEL PLATE (1/2" THICK)	1,200 lbs.	1.2

NOTES

1. ALL CONCRETE SHALL BE CLASS A.
2. ALL REINFORCING STEEL SHALL BE GRADE 40 DEFORMED BARS.
3. ALL STRUCTURAL STEEL SHALL BE GRADE 36.

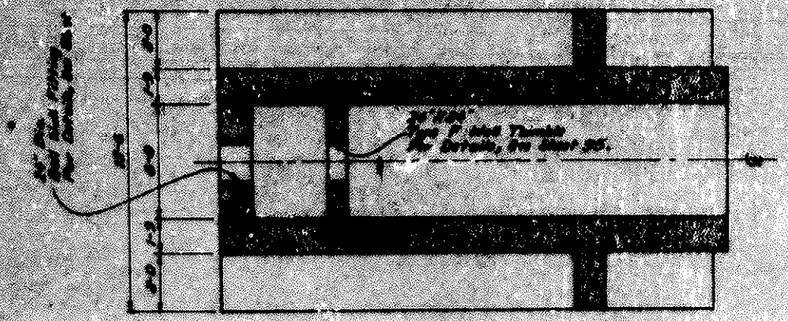
DETAILS OF ANTISEEP COLLARS

MULTIPLE-PURPOSE STRUCTURE NO. 8

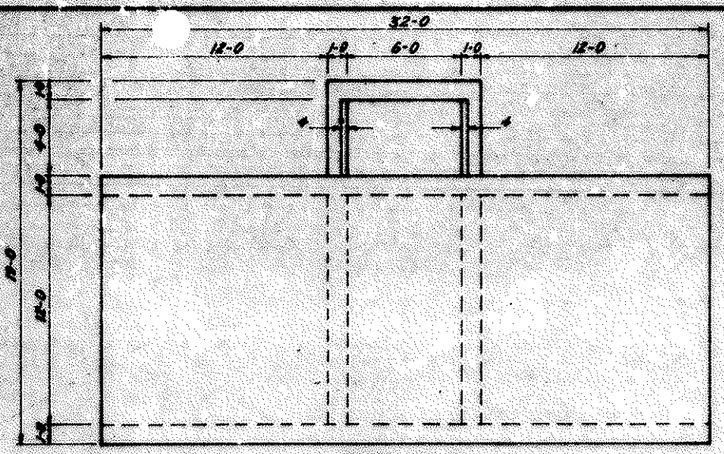
UPPER TURTLE RIVER WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

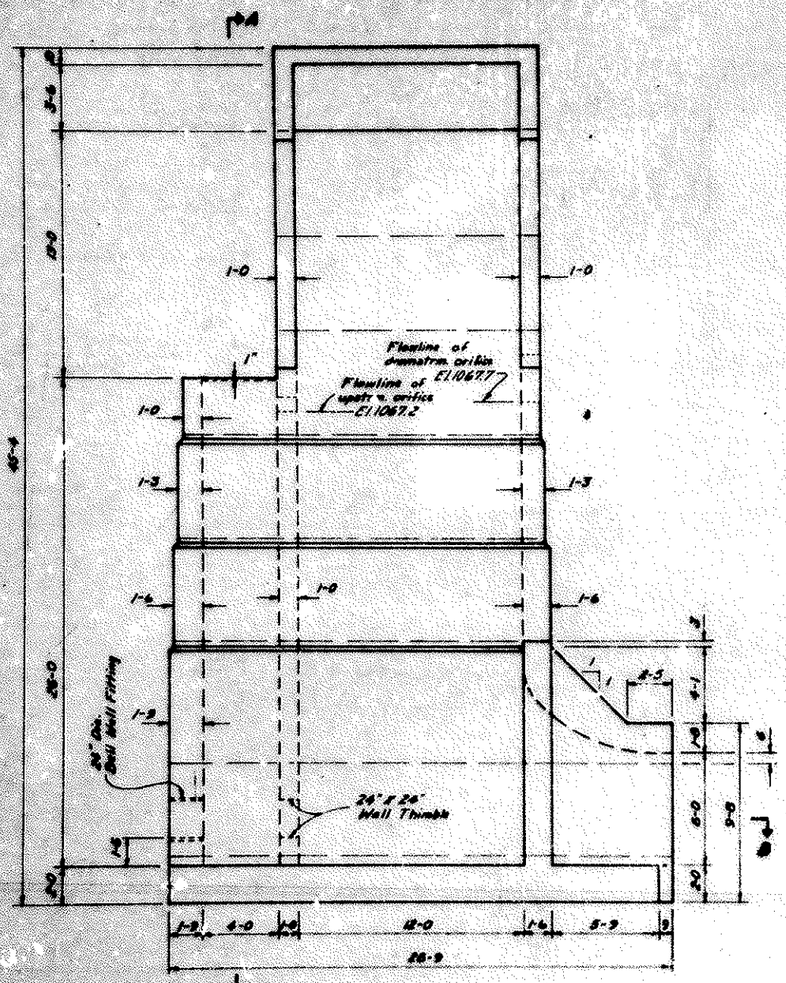
DESIGNED			
DRAWN			
TRACED			
CHECKED			SHEET NO. 8 OF 8 SHEETS



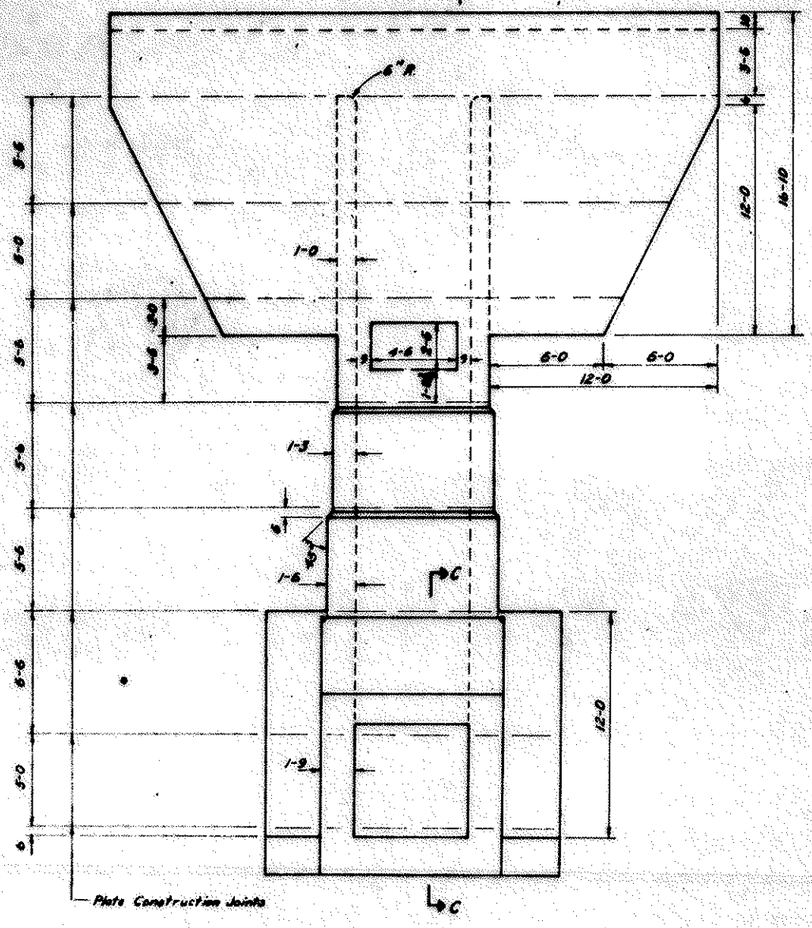
SECTION B-B



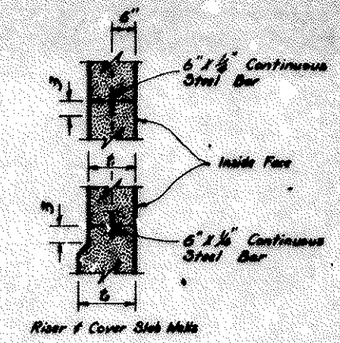
TOP PLAN



SIDEWALL ELEVATION



DOWNSTREAM ELEVATION



DETAILS OF
PLATE CONSTRUCTION JOINTS

TABLE OF QUANTITIES

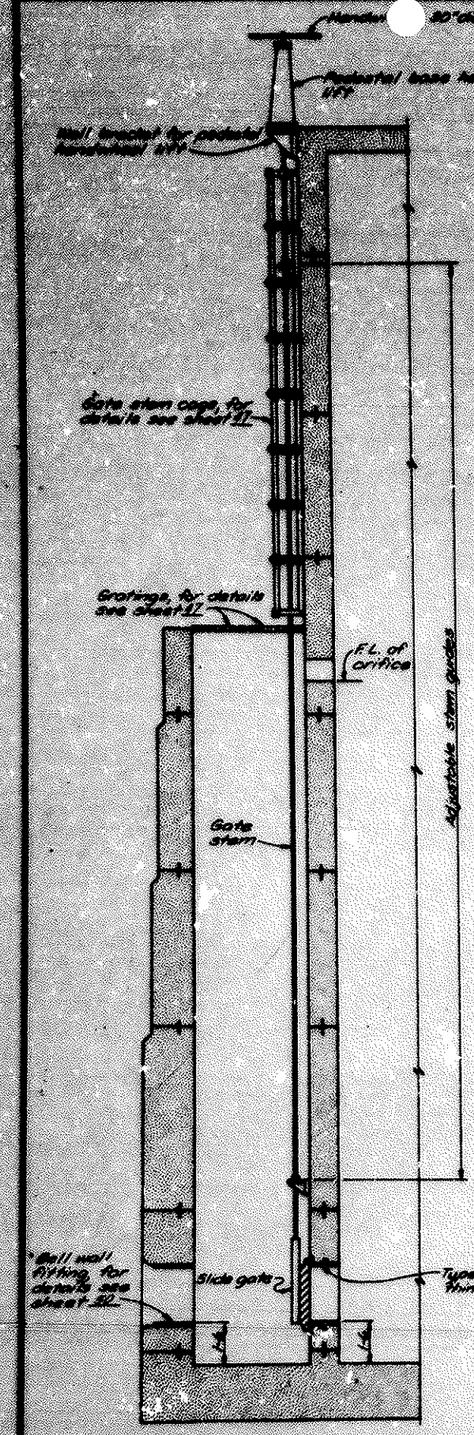
ITEM	UNIT	QUANTITY
CONCRETE, CLASS 4000	CU. YD.	190.8
STEEL REINFORCEMENT	LB.	25,090
1/8" X 6" STEEL PLATE	LIN. FT.	166

0 1 2 3 4 5 6
SCALE IN FEET
FOR 1 IN.
DETAILS OF S.S. INLET

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks & Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

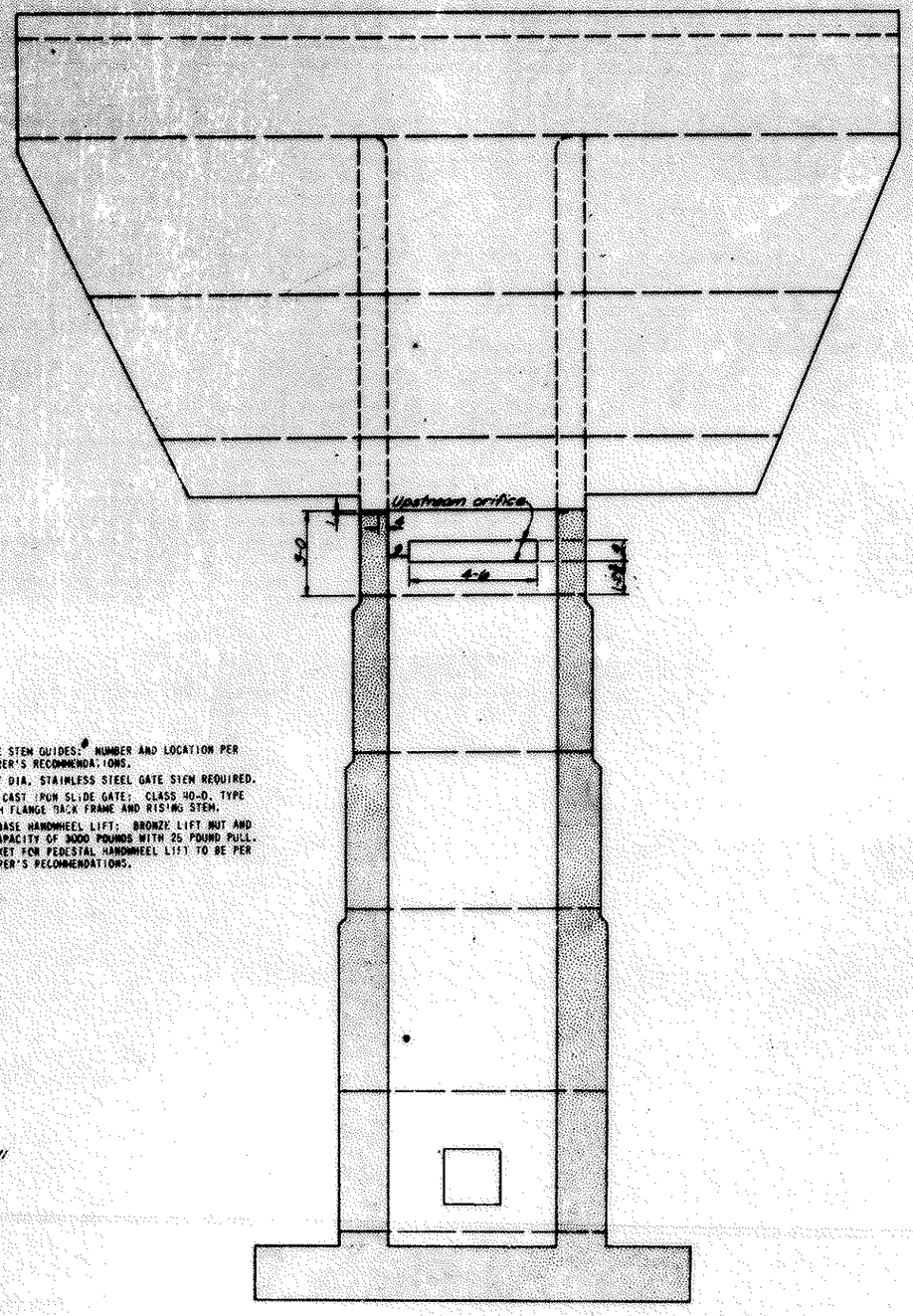
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Drawn JEN	7/58	Title	
Traced		Date	
Checked C.E.M	7/58	Sheet No. 24 of 27 sheets	Drawing No. SE-36,025



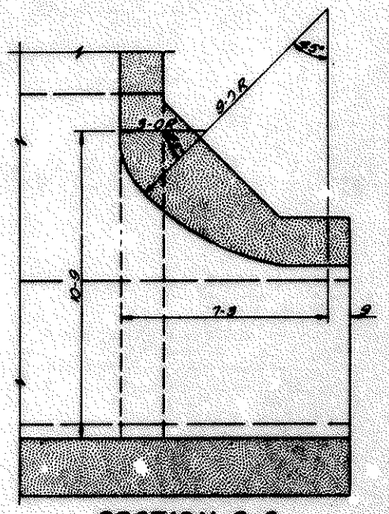
DETAILS OF SLIDE GATE

NO. 25:

1. ADJUSTABLE STEM GUIDES: NUMBER AND LOCATION PER MANUFACTURER'S RECOMMENDATIONS.
2. ONE 1 1/8" DIA. STAINLESS STEEL GATE STEM REQUIRED.
3. 24" X 24" CAST IRON SLIDE GATE: CLASS 40-D, TYPE WHS-2 WITH FLANGE BACK FRAME AND RISING STEM.
4. PEDESTAL BASE HANDWHEEL LIFT: BRONZE LIFT NUT AND MINIMUM CAPACITY OF 3000 POUNDS WITH 25 POUND PULL. WALL BRACKET FOR PEDESTAL HANDWHEEL LIFT TO BE PER MANUFACTURER'S RECOMMENDATIONS.



SECTION A-A



SECTION C-C

0 1 2 3 4
Scale in feet

AS BUILT
FOR 6 UN

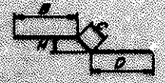
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

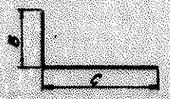
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

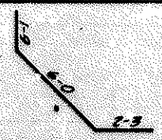
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Drawn G.W.W.	9-76	Title	
Traced		Title	
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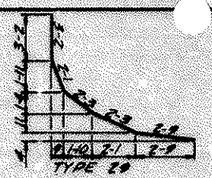
LEGENDS

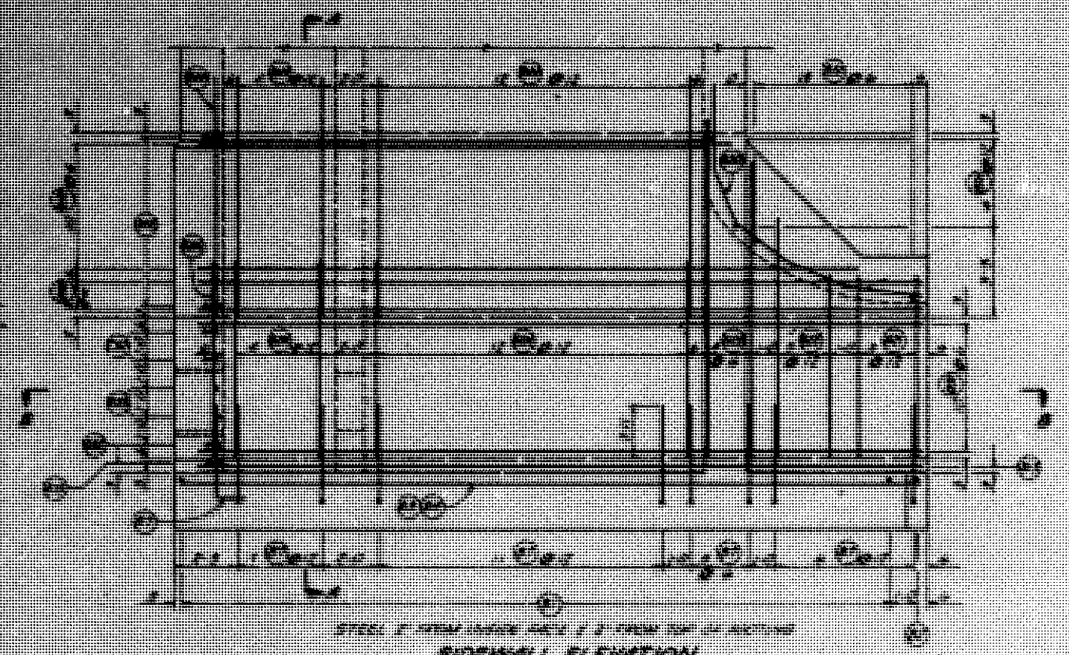




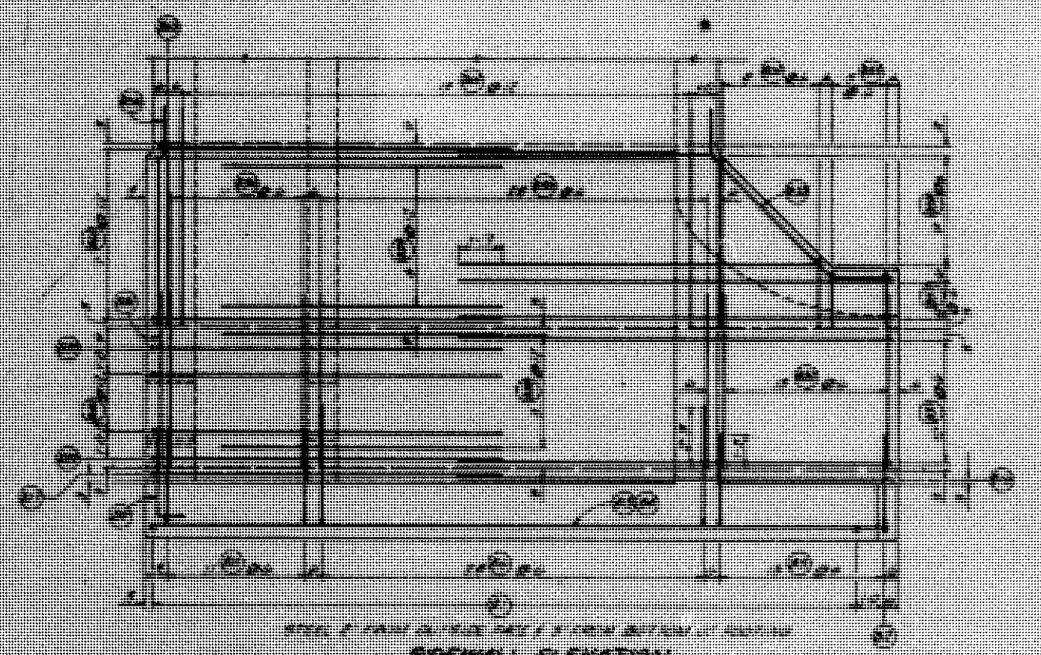




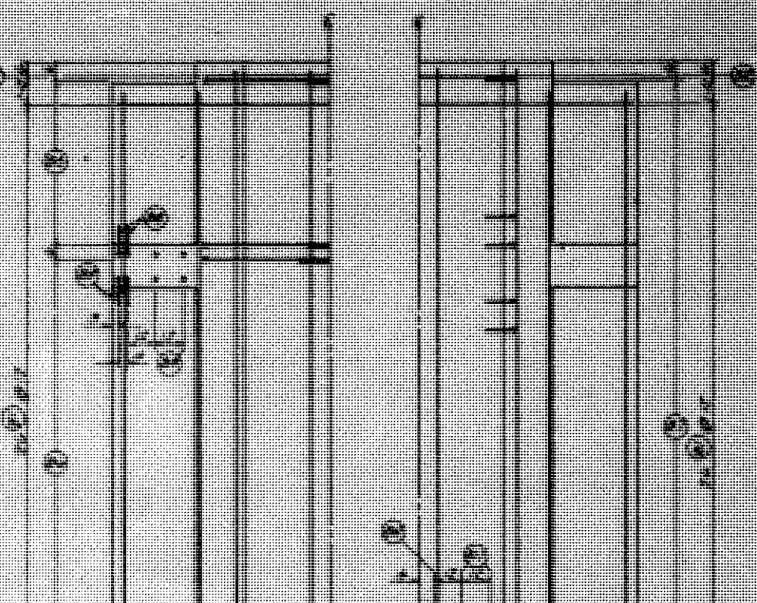

2-3
2-3
2-3



SIDEWALL ELEVATION



SIDEWALL ELEVATION

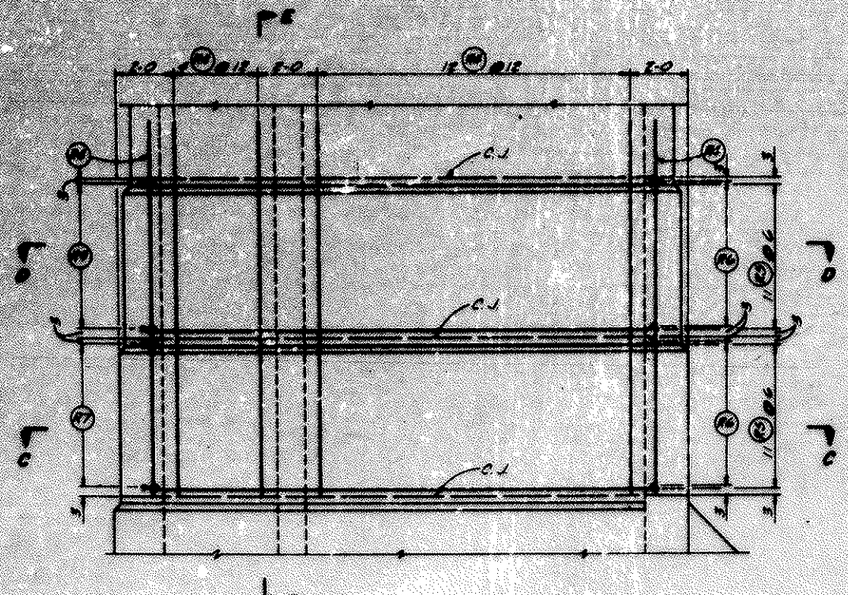


PLAN - FOOTING

DETAILS OF R/C INLET

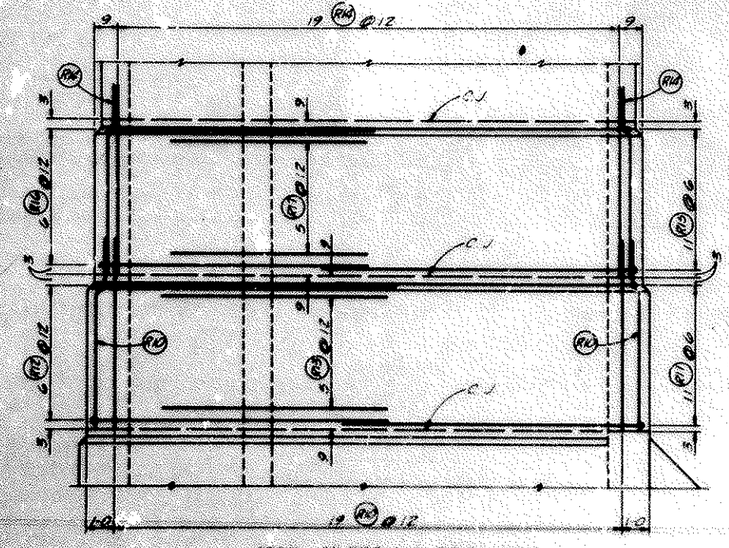
MULTIPLE - PURPOSE STRUCTURE
NO. 8
UPPER TURTLE RIVER WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE



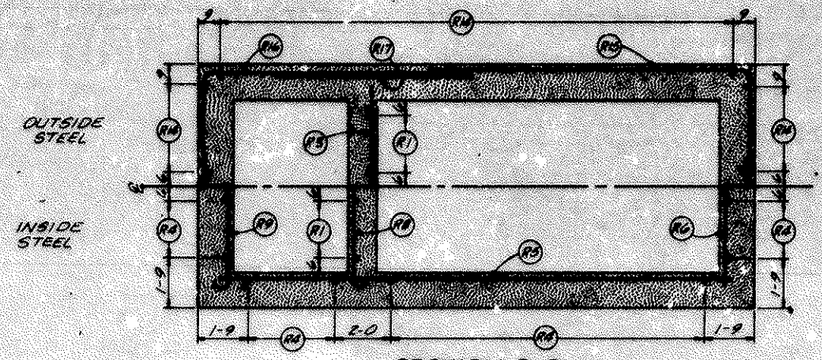
STEEL 7" FROM INSIDE FACE

SIDEWALL ELEVATION

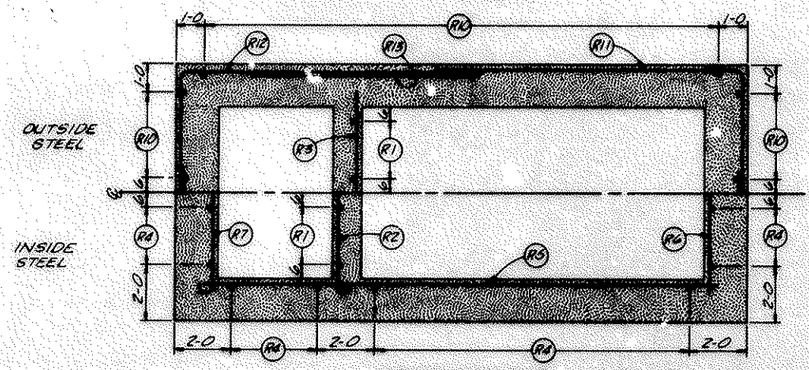


STEEL 2" FROM OUTSIDE FACE

SIDEWALL ELEVATION



SECTION D-D



SECTION C-C

AS BUILT FOR 1 YEAR

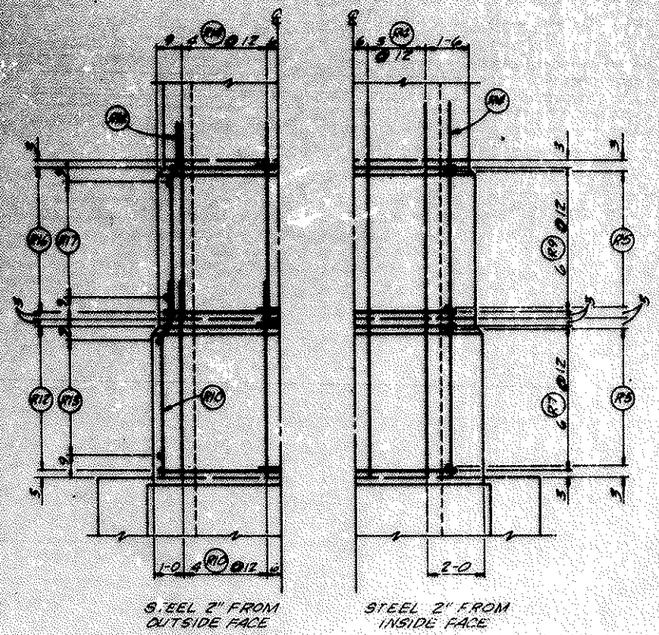
1 2 3 4
Scale in feet

DETAILS OF R/C INLET

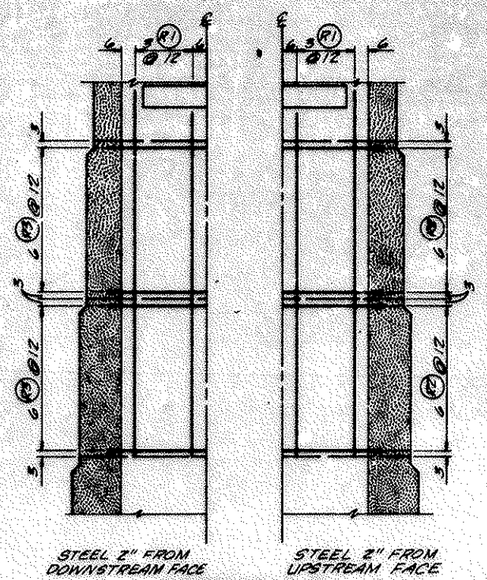
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

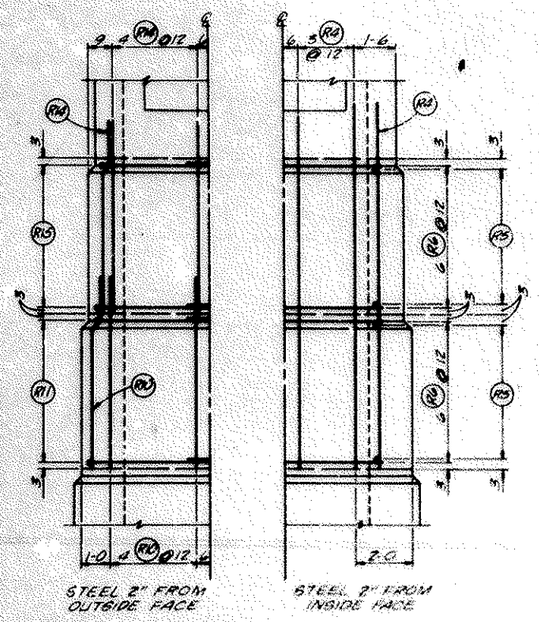
Designed J.E.N.	Date 9-76	Approved by	
Drawn N.S.	7-76	Title	
Traced			
Checked C.E.M.	9-76	Sheet No. 39 of 51 sheets	Drawing No. S.E-36,025



UPSTREAM ELEVATION



SECTION E-E



DOWNSTREAM ELEVATION

NOTE:
BAR MARKS R1 AND R4 WILL BE FIELD CUT TO CLEAR THE ORIFICES BY 2".

AS BUILT
FEB. 6 1979

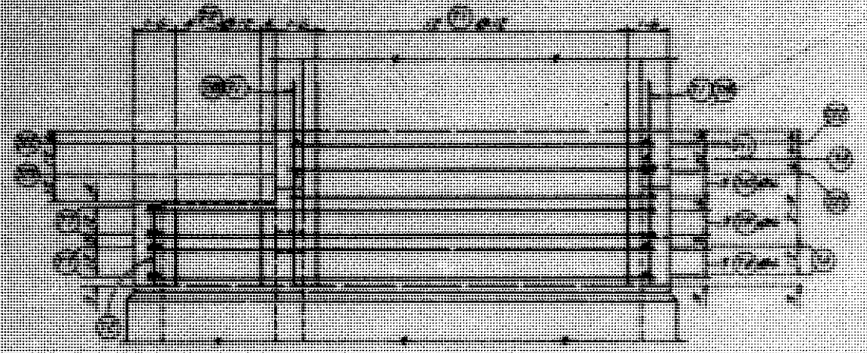
0 1 2 3 4
Scale in feet

DETAILS OF R/C INLET

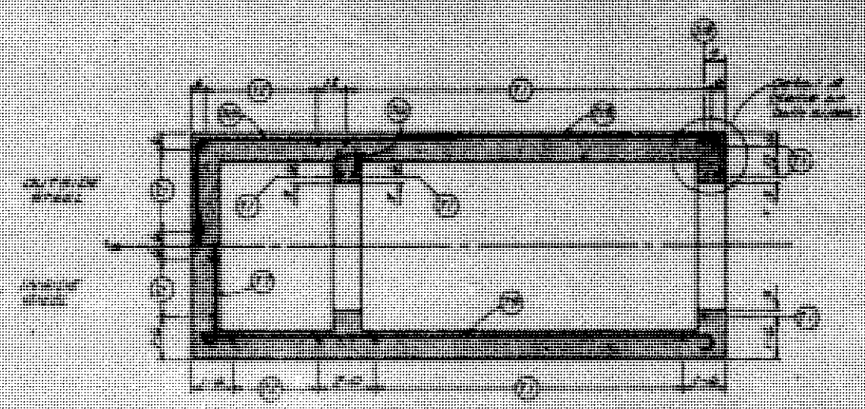
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

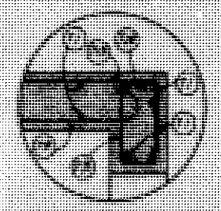
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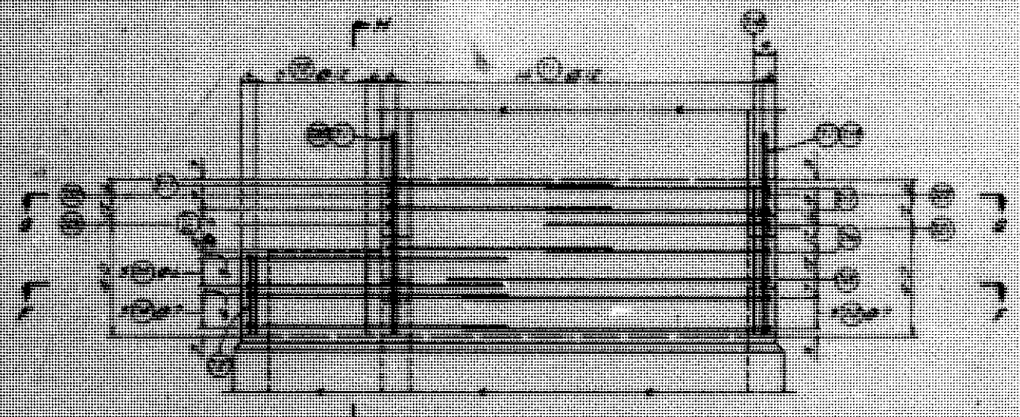
SIDEWALL ELEVATION



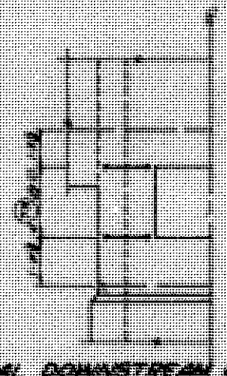
SECTION F-F



DETAIL A



SIDEWALL ELEVATION

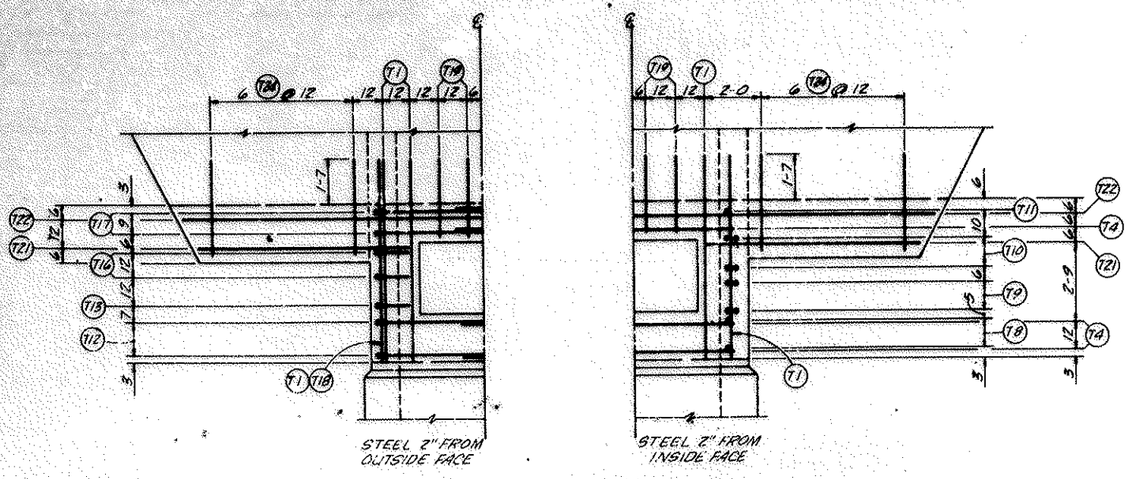


PARTIAL DOWNSTREAM SIDEWALL ELEVATION SHOWING ADDITIONAL STEEL AROUND ORIFICE

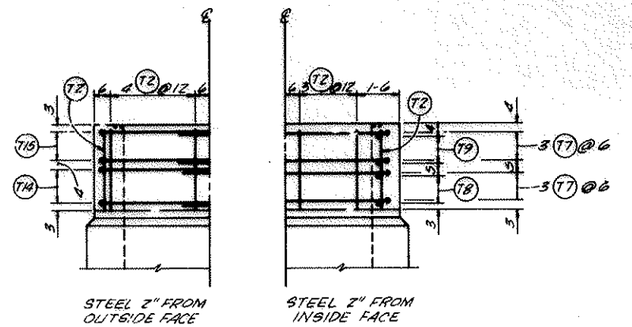
DETAILS OF RISER INLET

MULTIPLE-PURPOSE STRUCTURE NO. 2
UPPER TURTLE CREEK WATERSHED

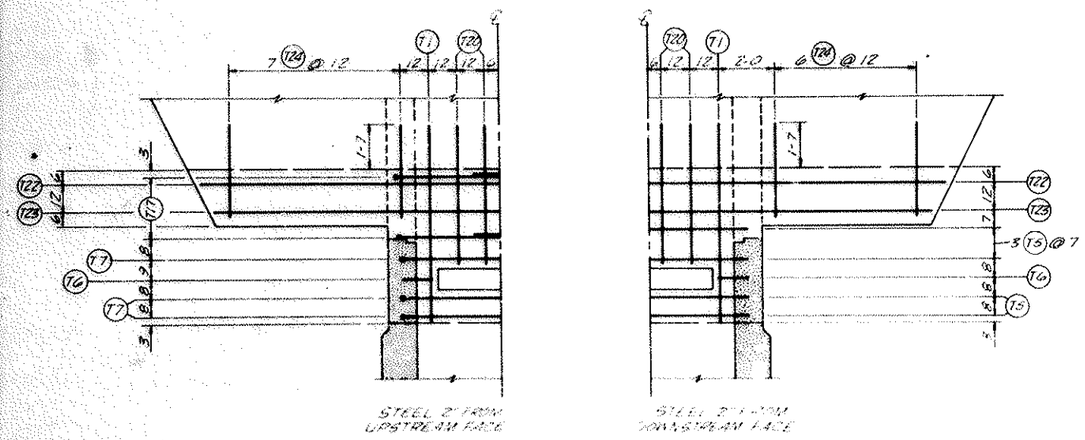
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE



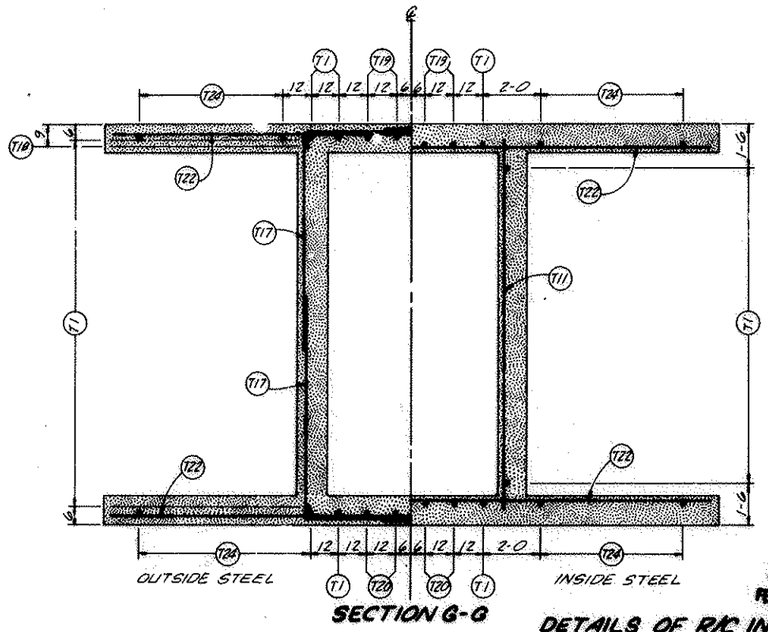
DOWNSTREAM ENDWALL



UPSTREAM ENDWALL



SECTION H-H



SECTION G-G

AS BUILT FEB 8 '77

DETAILS OF R/C INLET

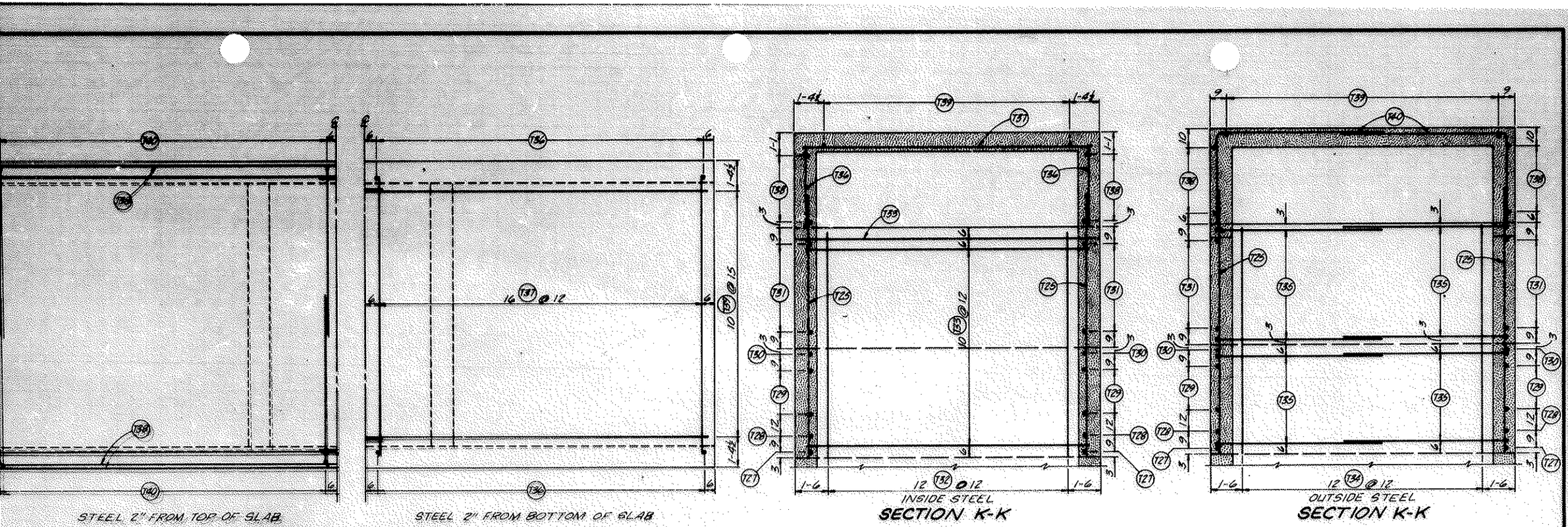
0 1 2 3 4
Scale in feet

NOTE:
BAR MARKS R1 AND R4 . FROM THE PREVIOUS RISER SECTION, SHALL BE FIELD CUT TO CLEAR THE ORIFICES BY 2".

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

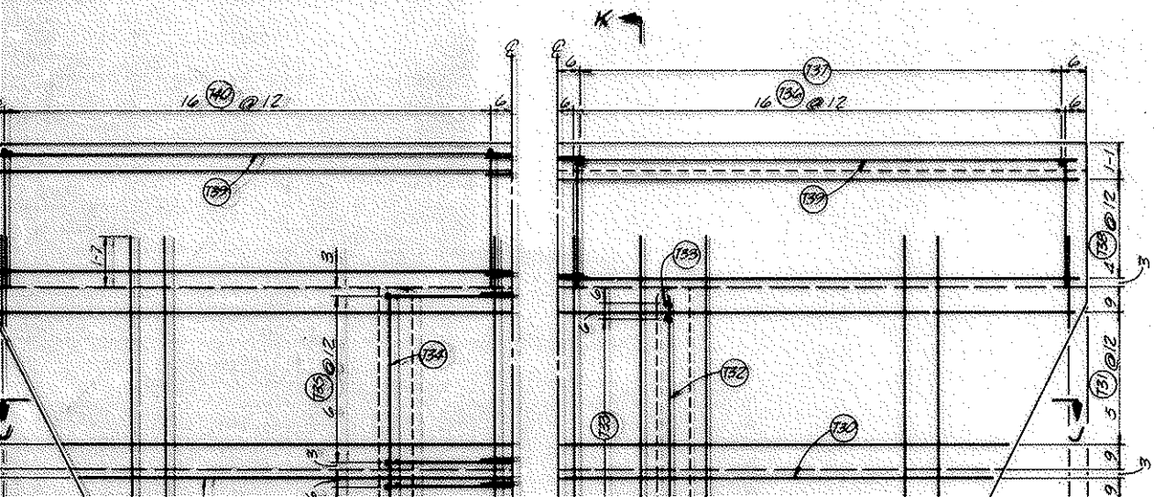
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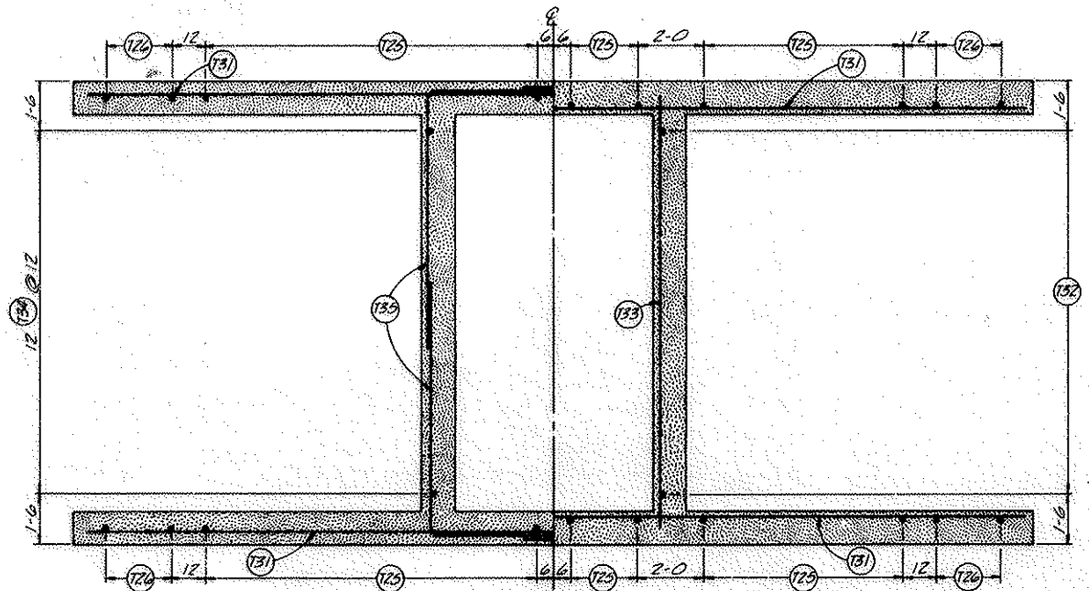


COVER SLAB PLAN

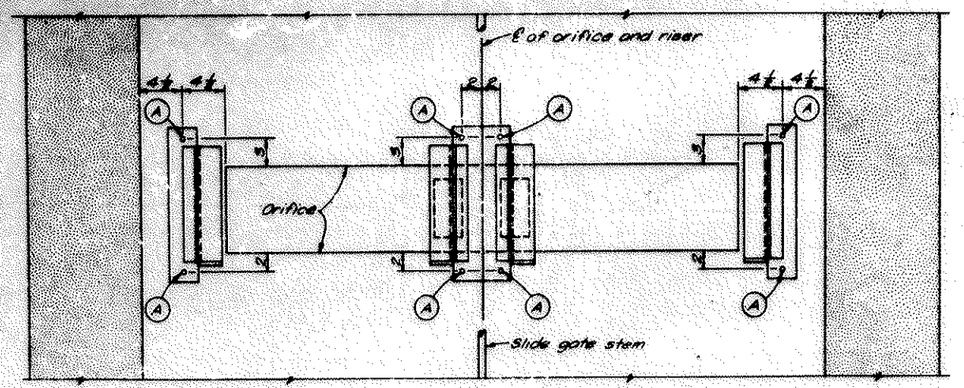
SECTION K-K

SECTION K-K

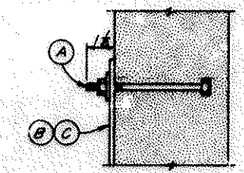




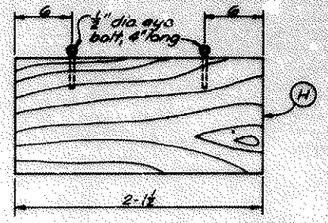
SECTION J-J



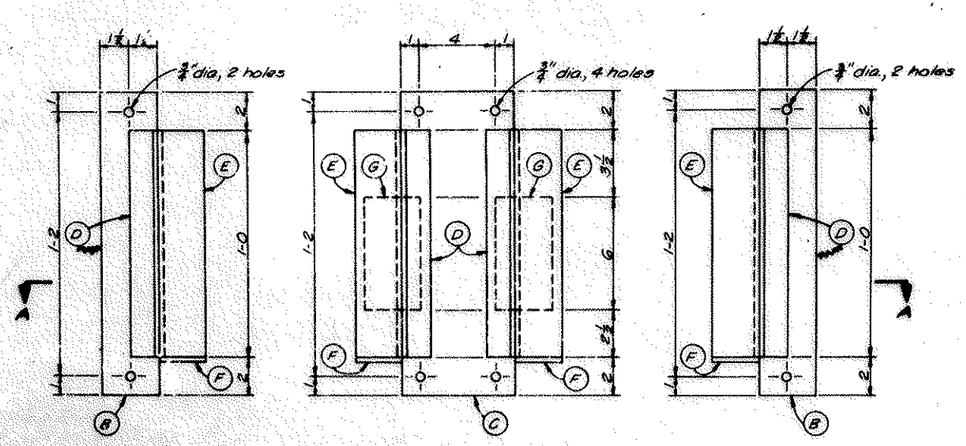
ELEVATION OF UPSTREAM ORIFICE SHOWING LOCATIONS OF ANCHOR BOLTS



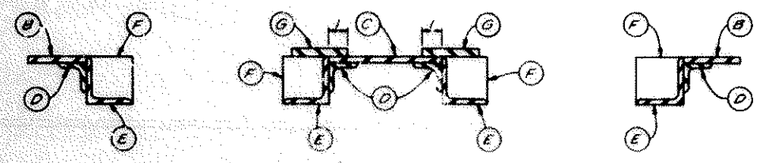
DETAIL OF ANCHOR BOLT



DETAIL OF STOPLOG



DETAILS OF GUIDES



SECTION A-A

MATERIAL LIST FOR STOPLOG INSTALLATION

MARK	ITEM	QUANTITY
A	5/8" DIA. GALV. BOLT WITH NUT & WASHER, 8" LONG	8
B	1/4" X 3" STEEL PLATE, 1'-4" LONG	2
C	1/4" X 6" STEEL PLATE, 1'-4" LONG	1
D	1 1/2" X 1 1/2 X 1/4" ANGLE, 1'-0" LONG	4
E	2 1/2" X 2 1/2 X 1/4" ANGLE, 1'-0" LONG	4
F	1/4" X 2 1/2" X 2 1/2" STEEL PLATE	4
G	1/4" X 3" STEEL PLATE, 6" LONG	2
H	2" X 12" LUMBER WITH EYE BOLTS, PER DETAIL	2

TOTAL WEIGHT OF STRUCTURAL STEEL = 93 LB.

NOTES:

1. ALL STRUCTURAL STEEL MEMBERS TO BE SECURELY WELDED ALONG ALL JUNCTIONS.
2. ALL STRUCTURAL STEEL MEMBERS TO BE GALVANIZED.
3. LUMBER FOR STOPLOGS WILL BE SOUND WOOD FREE OF DECAY AND KNOT CLUSTERS. THE MINIMUM STRESS GRADE WILL BE 1000 PSI.
4. LUMBER WILL BE PRESSURE TREATED WITH CREOSOTE OR OTHER APPROVED PRESERVATIVE. CUT EDGES WILL BE COATED WITH NOT LESS THAN THREE BRUSH COATS OF THE SAME PRESERVATIVE USED IN THE ORIGINAL TREATMENT.

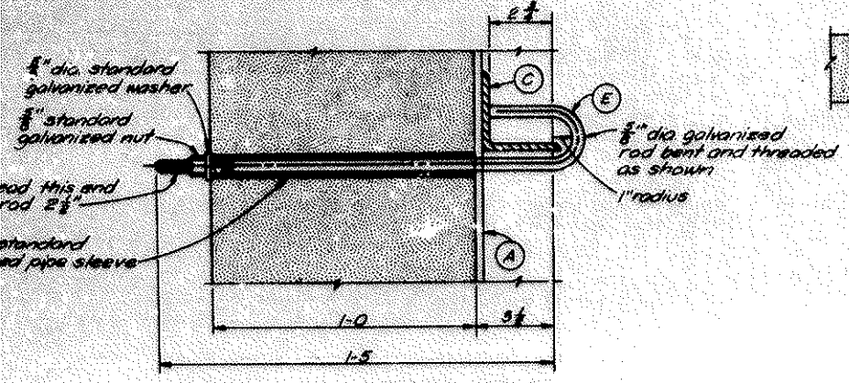
AS BUILT
FEB 8 '77

DETAILS OF STOPLOG INSTALLATION

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

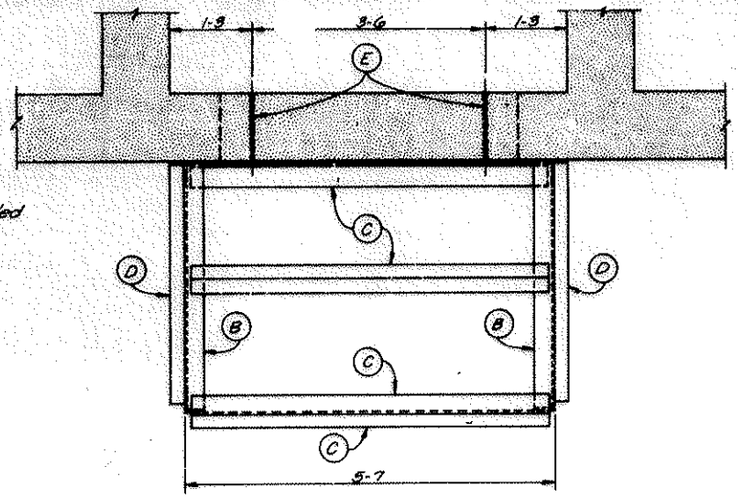
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Drawn		Title	
Traced		Title	
Checked C.E.M.	9-76	Sheet No. 41 of 51	Drawing No. 5,E-36,025



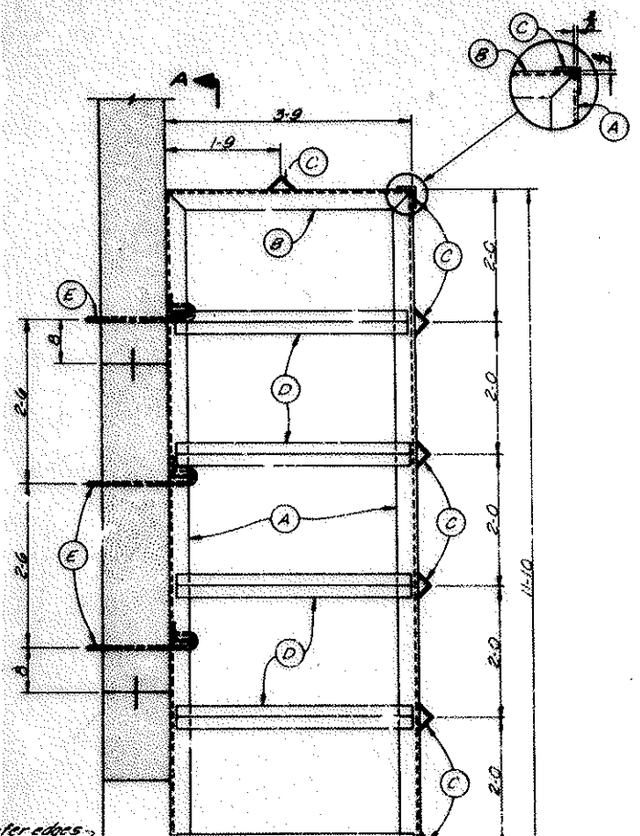
DETAIL OF ANCHOR BOLT

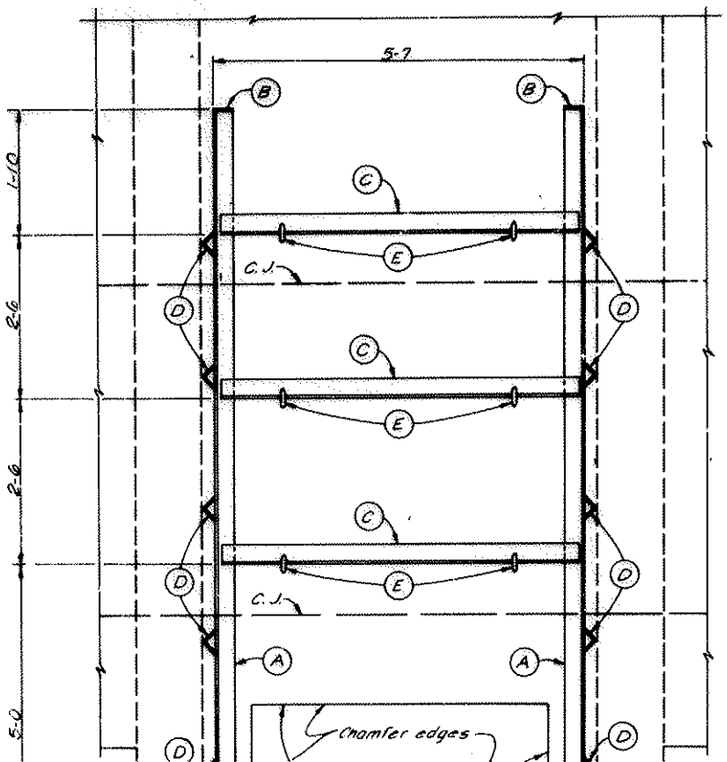
0 1 2 3 4

Scale in inches



PLAN





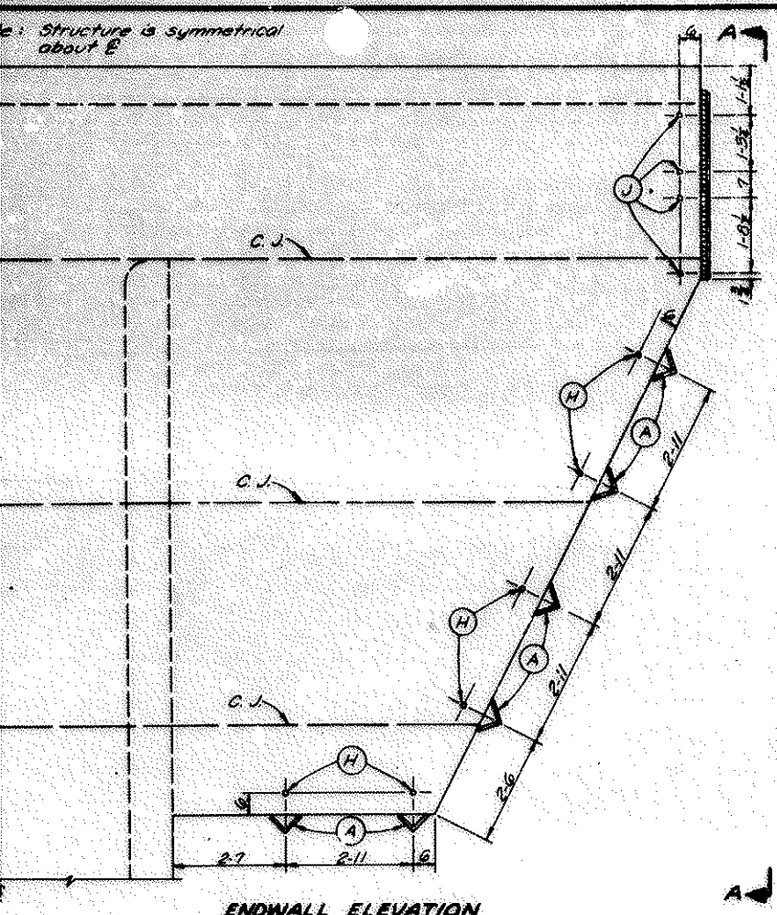
MATERIAL LIST FOR LOW STAGE ORIFICE TRASH RACK

MARK	ITEM	QUANTITY
A	ANGLE 3 1/2 X 3 1/2 X 3/8. 11-10 LONG	4
B	ANGLE 3 1/2 X 3 1/2 X 3/8. 3-9 LONG	2
C	ANGLE 3 1/2 X 3 1/2 X 3/8. 5-5 LONG	10
D	ANGLE 3 X 3 X 1/4. 3-7 LONG	10
E	5/8" DIA. GALV. ROD (SEE DETAIL)	6

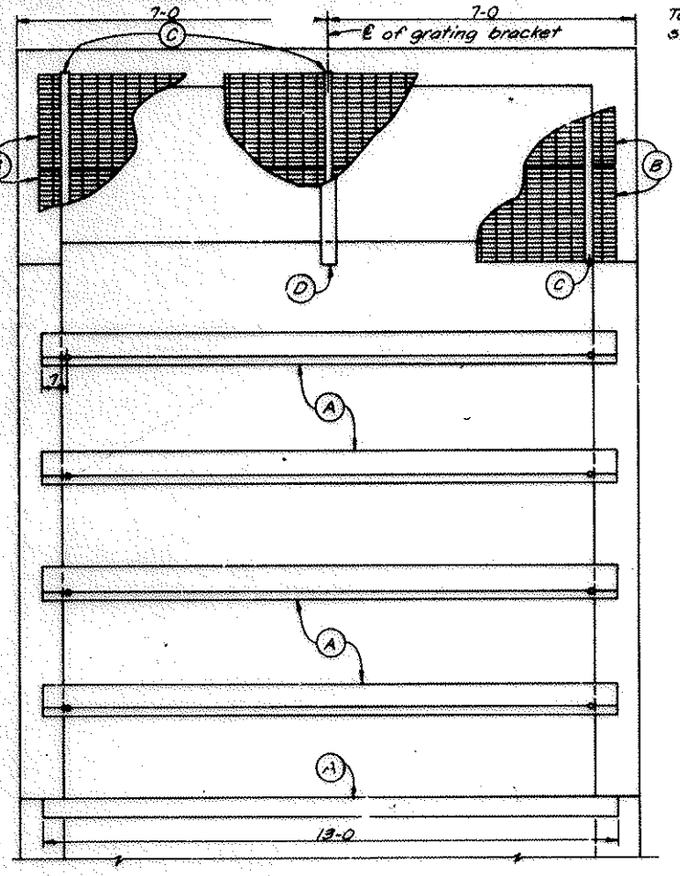
WEIGHT OF STRUCTURAL STEEL = 1102 LB.

NOTES:

1. CLIP ENDS OF MEMBERS (A) AND (B) AS SHOWN.
2. ALL ANGLES TO BE SECURELY WELDED AT ALL JUNCTIONS.
3. ALL STRUCTURAL STEEL MEMBERS TO BE GALVANIZED.



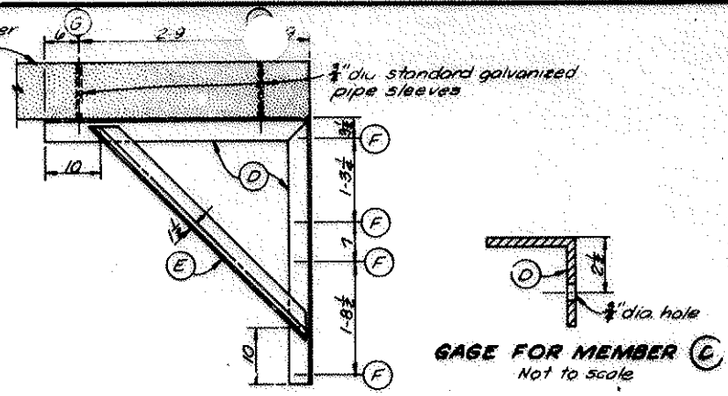
ENDWALL ELEVATION



ELEVATION A-A

DETAILS OF SECOND STAGE TRASH RACK

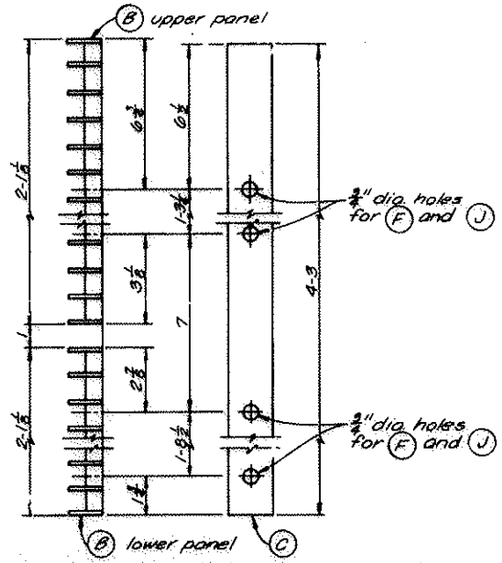
Scale in feet



GAGE FOR MEMBER (C)
Not to scale

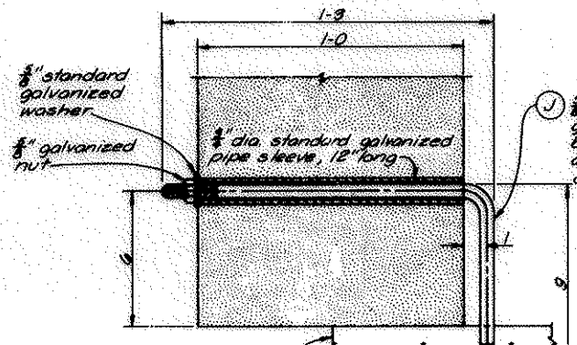
DETAIL OF GRATING BRACE

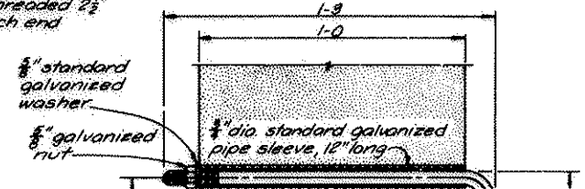
Scale in feet

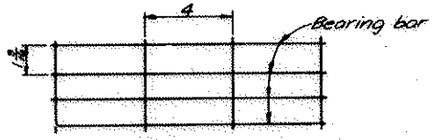


PLACEMENT DIAGRAM FOR MEMBER (B) AND (C)

CLIP ENDS OF MEMBERS (D) AND (E) AS SHOWN.
SECURELY WELD MEMBERS (D) AND (E) AT ALL JUNCTIONS.
STRUCTURAL STEEL ANGLES, BARS, AND GRATING TO BE GALVANIZED.

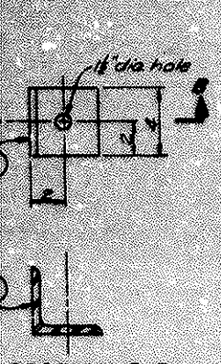


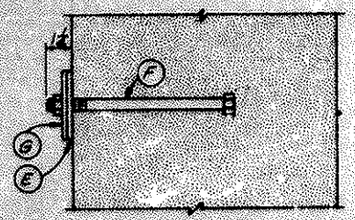




DETAIL OF GRATING SHOWING BEARING BAR SPACING

Scale in feet





DETAIL OF ANCHORAGE FOR GATE STEM CAGE
(Not to scale)

SECTION B-B

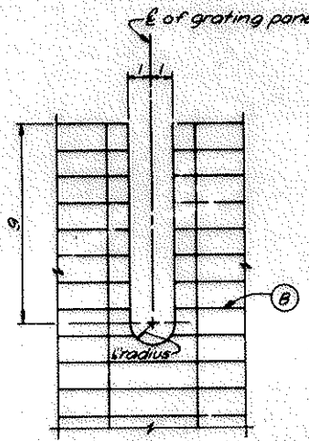
...IL OF MEMBER (E)
(Not to scale)

MATERIAL LIST FOR GATE STEM CAGE

MARK	ITEM	QUANTITY
A	2" X 2" X 1/4" ANGLE, 15'-4" LONG	4
B	2" X 2" X 1/4" ANGLE, 1'-0" LONG	4
C	2" X 2" X 1/4" ANGLE, 1'-5" LONG	9
D	2" X 2" X 1/4" ANGLE, 0'-11" LONG	14
E	4" X 4" X 1/4" ANGLE, 0'-4" LONG	4
F	5/8" DIA. GALV. BOLT WITH NUT, 9" LONG	4
G	2" X 4" X 1/4" STEEL BAR WITH 3/4" HOLE IN CENTER, GALVANIZED	4

WEIGHT OF STRUCTURAL STEEL = 299 LB.

NOTES:
1. CLIP END OF MEMBERS (A) AND (B) AS SHOWN.
2. ALL ANGLES TO BE SECURELY WELDED AT ALL JUNCTIONS.
3. GATE STEM CAGE TO BE GALVANIZED.



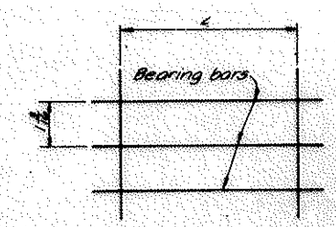
DETAIL OF GATE STEM OPENING
(Not to scale)

MATERIAL LIST FOR GATE WELL GRATINGS

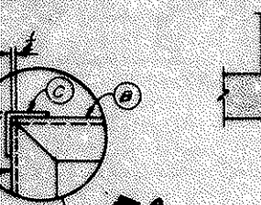
MARK	ITEM	QUANTITY
A	GRATING: 6'-6" LONG X 1'-10 3/4" WIDE WITH 1 1/2" X 3/16" BEARING BARS, GALVANIZED STEEL	1
B	GRATING: 6'-6" LONG X 1'-10 3/4" WIDE WITH 1 1/2" X 3/16" BEARING BARS AND GATE STEM OPENING, GALVANIZED STEEL	1
C	5/8" DIA. GALVANIZED ROD, PER DETAIL	4
D	2" X 4" X 1/4" STEEL BAR WITH 3/4" HOLE IN CENTER, GALVANIZED	4

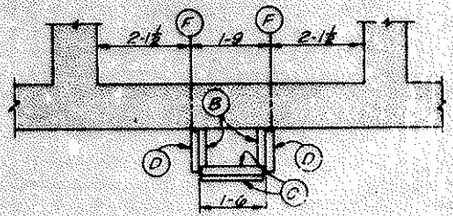
WEIGHT OF STEEL GRATINGS = 275 LB.

NOTE:
GATE STEM OPENING TO BE FABRICATED ACCORDING TO MANUFACTURERS RECOMMENDATION.

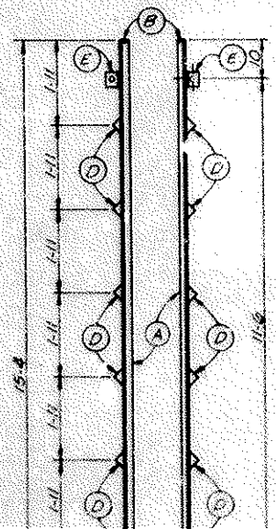


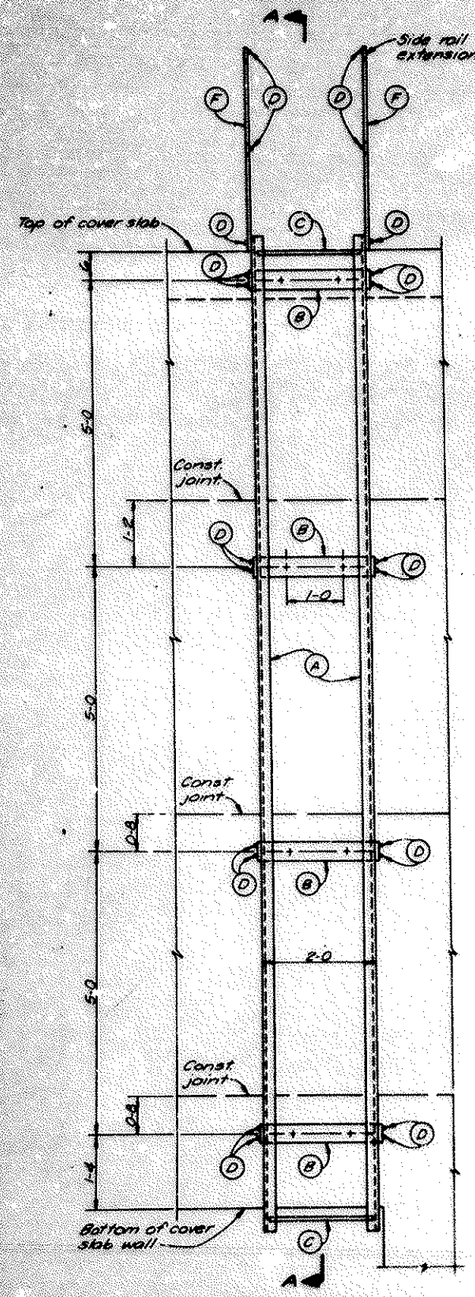
DETAIL OF GRATING SHOWING BEARING BAR SPACING
(Not to scale)



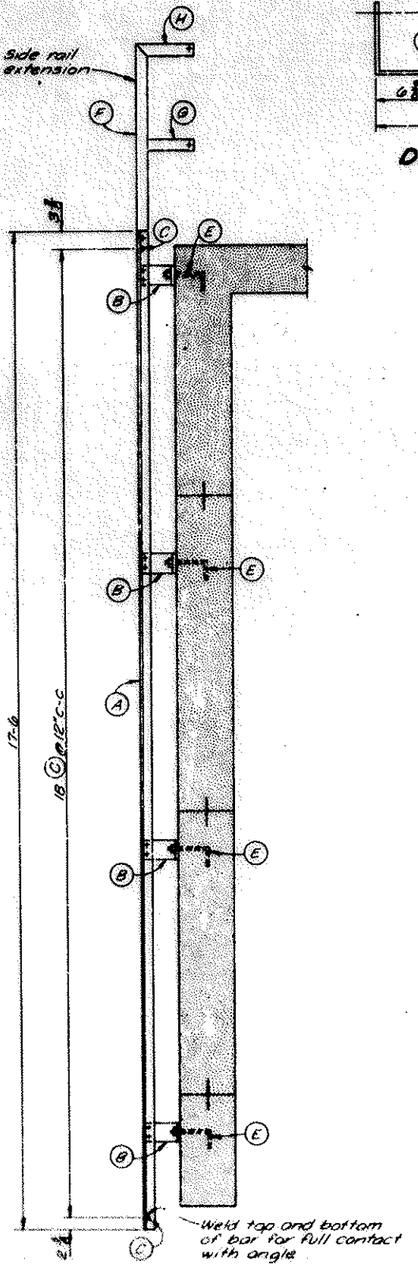


PLAN

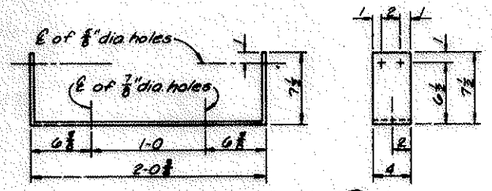

B
E
E
C
D
D
A
D
D
F
15-4
1-11
1-11
1-11



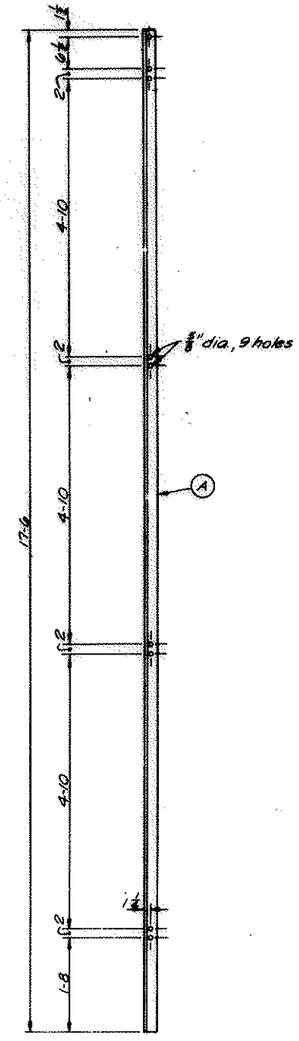
FRONT ELEVATION



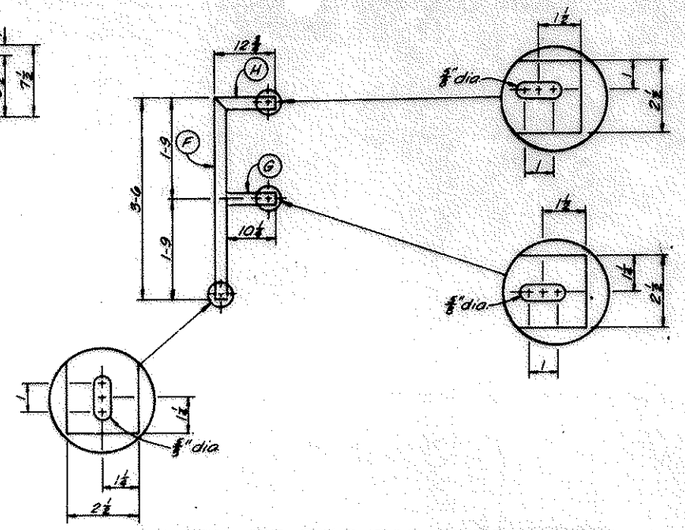
SECTION A-A



DETAILS OF MEMBER (B)
Not to scale



DETAIL OF MEMBER (A)



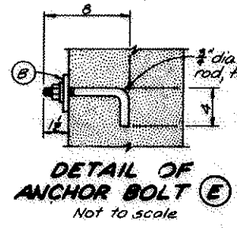
DETAILS OF SIDE RAIL EXTENSIONS
Not to scale

MATERIAL LIST FOR LADDER

MARK	ITEM	QUANTITY
A	2 1/2" X 2 1/2" X 3/8" ANGLE, 17'-6" LONG	2
B	4" X 3/8" STEEL BAR, 3'-3 3/4" LONG	4
C	3/4" X 3/4" STEEL BAR, 1'-10 1/2" LONG	18
D	1/2" DIA. GALV. BOLT WITH NUT AND WASHER, 1 1/2" LONG	22
E	3/4" DIA. GALV. ANCHOR BOLT WITH NUT AND WASHER	8
F	2 1/2" X 3/8" STEEL BAR, 3'-6" LONG	2
G	2 1/2" X 3/8" STEEL BAR, 10 1/4" LONG	2
H	2 1/2" X 3/8" STEEL BAR, 12 3/4" LONG	2

WEIGHT OF STRUCTURAL STEEL = 373 LB.

NOTES:
1. LADDER AND APPURTENANCES WILL BE GALVANIZED.
2. CLIP ENDS OF MEMBERS (F) AND (H) AS SHOWN.
3. SECURELY WELD MEMBERS (F), (J), AND (H) AT JUNCTIONS AND GRIND WELDS SMOOTH.
4. BOLT SIDE RAIL EXTENSIONS TO COVER SLAB RAILINGS.
5. FOR LOCATION OF LADDER, SEE SHEET 49.



DETAIL OF ANCHOR BOLT (E)
Not to scale

0 1 2
Scale in feet

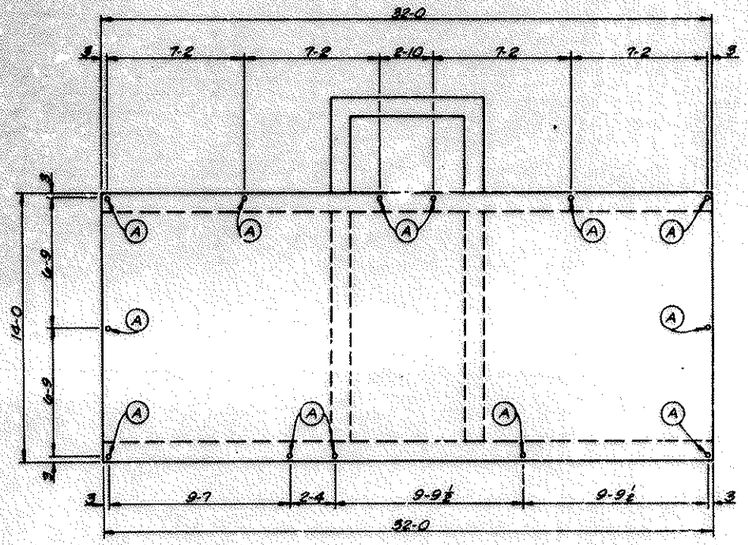
AS BUILT
FEB. 8 1978

DETAILS OF LADDER

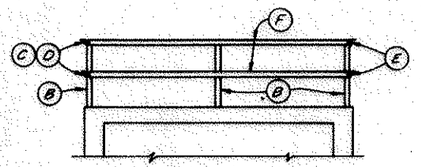
MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

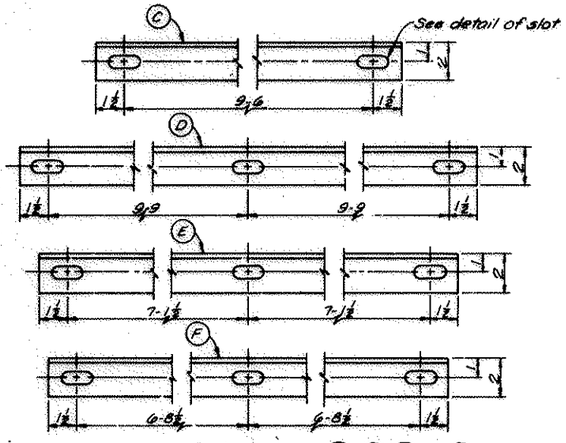
Designed J.E.N	Date 9-76	Approved by	
Drawn J.E.N	9-76	Title	
Traced		Title	
Checked C.E.M	9-76	Sheet No 48 of 51	Drawing No SE-36025



TOP PLAN SHOWING ANCHOR BOLT LOCATIONS



SIDE ELEVATION



DETAILS OF MEMBERS (C) (D) (E) & (F) SHOWING LOCATION OF SLOTS

Not to scale

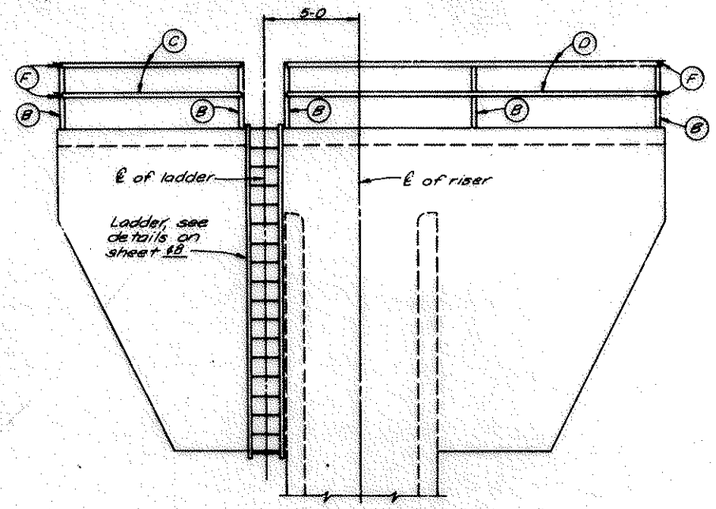
MATERIAL LIST FOR COVER SLAB RAILINGS

MARK	ITEM	QUANTITY
A	3/4" DIA. GALV. ANCHOR BOLT WITH NUT AND WASHER, PER DETAIL	13
B	3" X 3" X 1/4" ANGLE WITH 3 1/2" X 3 1/2" X 1/4" STEEL PLATE, PER DETAIL	13
C	2" X 2" X 1/4" ANGLE, 9'-9" LONG, PER DETAIL	2
D	2" X 2" X 1/4" ANGLE, 19'-9" LONG, PER DETAIL	2
E	2" X 2" X 1/4" ANGLE, 14'-6" LONG, PER DETAIL	4
F	2" X 2" X 1/4" ANGLE, 13'-8" LONG, PER DETAIL	4
G	1/2" DIA. GLAV. BOLT WITH NUT AND WASHER, 1 1/2" LONG	34

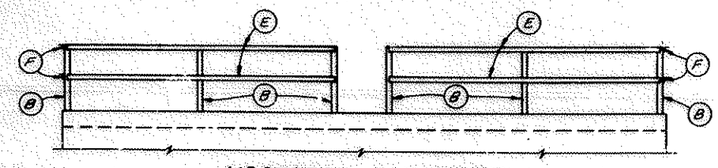
WEIGHT OF STRUCTURAL STEEL = 782 LB.

NOTES:

1. ALL STRUCTURAL STEEL ANGLES AND BARS WILL BE GALVANIZED.
2. GRIND TOP EDGE OF MEMBERS (B) TO REMOVE SHARP EDGES BEFORE GALVANIZING.
3. SECURELY BOLT MEMBERS (C) THRU (F) TO MEMBER (B).



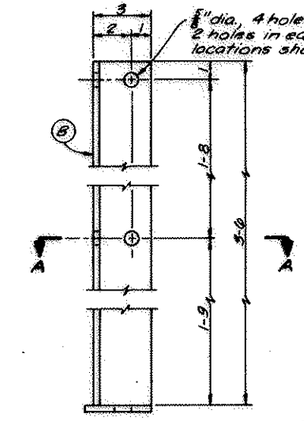
DOWNSTREAM ELEVATION



UPSTREAM ELEVATION

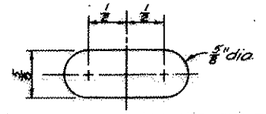
0 1 2 3 4 5

Scale in feet



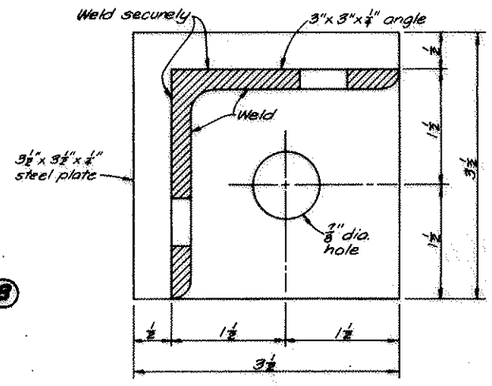
DETAIL OF MEMBER (B)

Not to scale



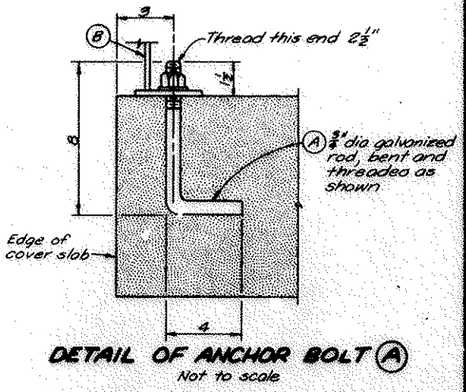
DETAIL OF SLOT FOR MEMBERS (C) (D) (E) & (F)

Not to scale



SECTION A-A

Not to scale



DETAIL OF ANCHOR BOLT (A)

Not to scale

AS BUILT

FEB 8 1977

DETAILS OF COVER SLAB RAILINGS

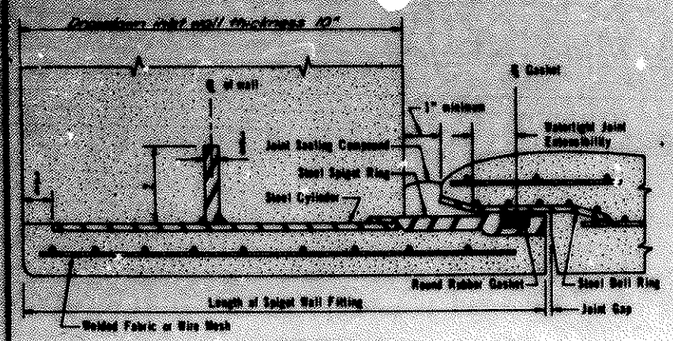
MULTIPLE-PURPOSE STRUCTURE NO. 9

UPPER TURTLE RIVER WATERSHED

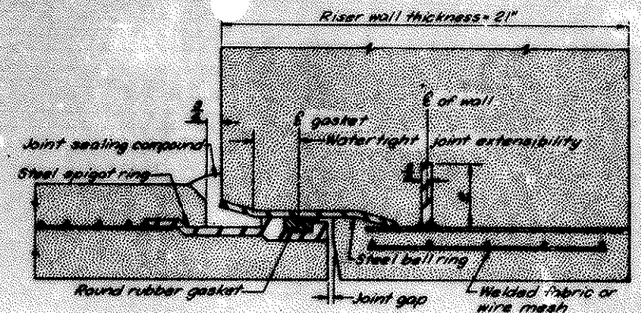
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date		
Designed J.E.N.	8-76	Approved by	
Drawn J.E.N.	8-76	Title	
Traced		Sheet No. 19 of 21	Drawing No. S.E-36,025
Checked C.E.M.	8-76		



DETAIL A



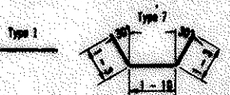
DETAIL C

STEEL SCHEDULE						
Cradle						
Mark	Size	Total Quantity	Length	Type		Total Length
C1	4	24	4 - 4	7		416-0
C2	8	48	15- 6	1		744-0

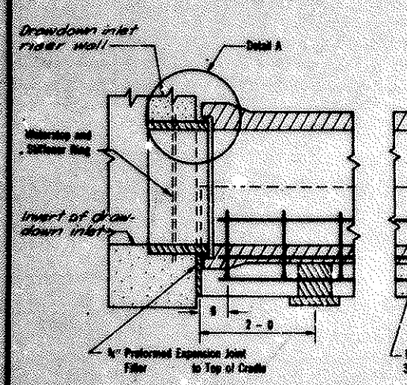
QUANTITIES	
Concrete	Cu. Yd.
Cradle	
** Per Lineal Foot of Cradle	0.212
Total	20.4
Steel	Pounds
Cradle	1395

Concrete quantities are based on an outside diameter of pipe of 26 5/8 inches
Steel quantities do not change with outside diameter of pipe.

** This quantity is given by
$0.1923 - 0.000918\,(D_f - 32)\,(D_f - 32)$ cu. yds.
D_f = outside diameter of pipe furnished, inches.

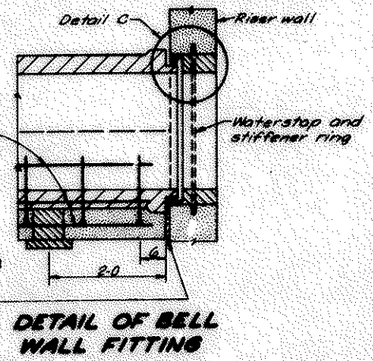


BAR TYPES

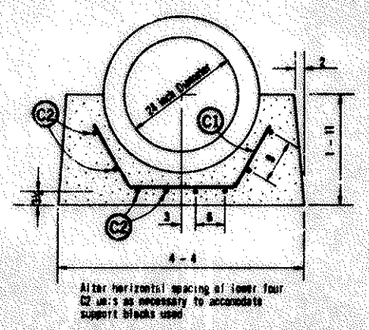


DETAIL OF SPIGOT WALL FITTING

DETAIL OF PIPE JOINT

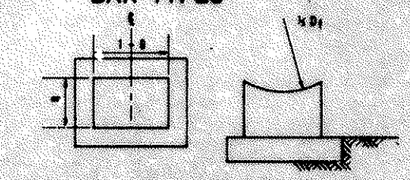


DETAIL OF BELL WALL FITTING



After horizontal spacing of lower four C2 units as necessary to accomodate support blocks used

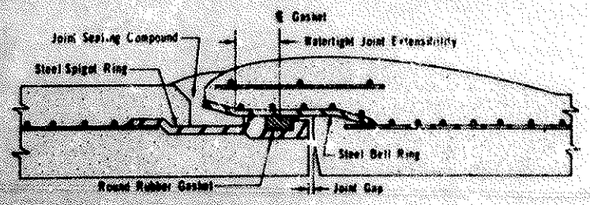
DETAIL OF CRADLE



SUGGESTED SUPPORT BLOCKS

Sufficient blocks shall be provided to support the pipe to the required line and grade. The Contractor shall determine the number and size of blocks required. Wedges may be used as an alternate.

AS BUILT
FEB. 8 1980



DETAIL B

JOINT REQUIREMENTS			
Length of Pipe Section	Minimum Joint Length	Minimum Joint Limiting Angle	
feet	inches	radians	degrees
16	2 1/2		1° 00

For pipe length other than shown, joint requirements will be determined by the Engineer.

Where pipes of different length are connected, adjoining pipes shall meet the requirements of the longer pipe.

Prior to delivery of pipe, the pipe joint detail proposed for use shall be submitted to the Engineer for approval.

STRENGTH REQUIREMENTS			
Inside Diameter of Pipe	Internal Load	External Load	
	Hydrostatic Pressure	Minimum 3-Edge Bearing Strength in Pounds per Lineal Foot of Pipe	
		Applicable Standard Specification	
		AWWA C-301	AWWA C-300
	Head of Water	Load to produce 0.001 inch crack one foot long	Load to produce 0.01 inch crack one foot long
inches	feet		
24	55	2900	3800

The outside diameter of pipe assumed in design is 30 1/8 inches. Where the pipe furnished has an outside diameter greater than assumed in design, the three-edge bearing strength of the pipe furnished must not be less than the specified three-edge bearing strength multiplied by the ratio of the outside diameter of the pipe furnished to the outside diameter assumed in design.

REVISED 8-79 BY MTSC

STANDARD CURRENT DETAILS
FOR
REINFORCED CONCRETE PRESSURE PIPE
PRINCIPAL SPILLWAY

DRAWING NO. ES- 5024-CE

DATE 2-79 REV. 2-79 SHEET 1 OF 1

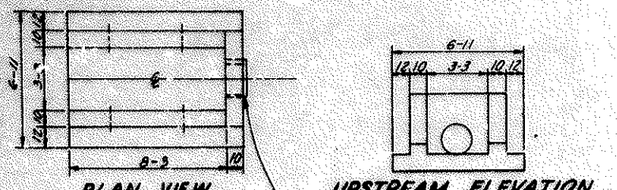
Joint length equals watertight joint extensibility plus joint gap

The pipe shall be drawn together so that the maximum joint gap does not exceed 3/8 inch for pipe laid on a straight line. For mitered pipe or pipe laid on a curved line, the joint gap at the narrowest point shall not exceed 3/8 inch.

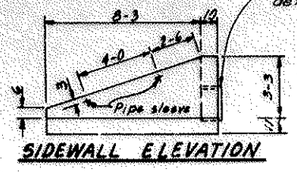
MULTIPLE-PURPOSE STRUCTURE
NO. 8
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

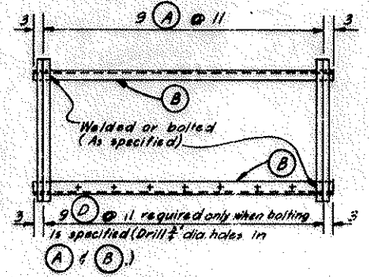
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

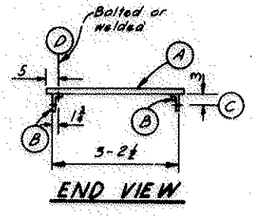
Designed	Date	Approved by
J.E.N.	8-79	Title
Drawn		Title
Traced		Title
Checked C.E.M.	8-79	Sheet No. 50 of 51 Drawing No. ES-54,025

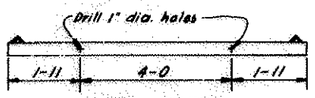


Spigot wall fitting, for detail see sheet 50

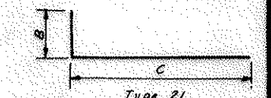








BAR BENDS



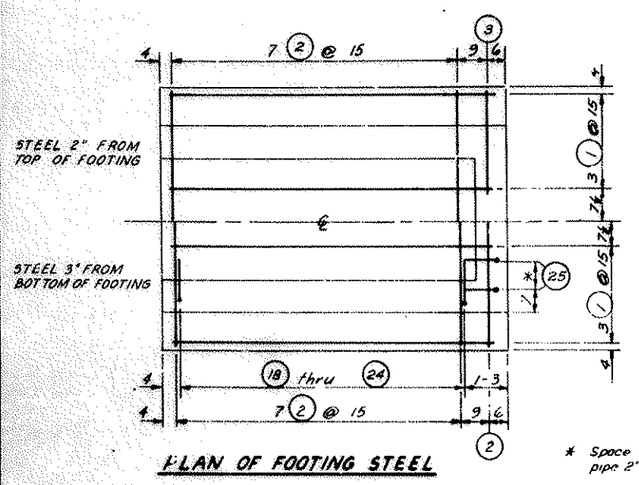
STEEL SCHEDULE

MARK	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	B	C
1	5	12	8-6	102-0	1		
2	5	15	6-6	97-6	1		
3	5	2	2-9	5-6	1		
4	5	2	0-9	1-6	1		
5	5	2	1-0	2-0	1		
6	5	2	1-6	3-0	1		
7	5	2	2-0	4-0	1		
8	5	2	2-3	4-6	1		
9	5	2	2-9	5-6	1		
10	5	2	3-3	6-6	1		
11	5	2	8-0	16-0	1		
12	5	4	4-0	16-0	1		
13	5	4	8-9	35-0	1		
14	5	2	0-9	1-6	1		
15	5	2	0-9	1-6	1		
16	5	2	3-6	7-0	1		
17	5	4	0-9	3-0	1		
18	5	2	2-3	4-6	21	1-0	1-3
19	5	2	2-6	5-0	21	1-5	1-1
20	5	2	3-0	6-0	21	1-10	1-2
21	5	2	3-6	7-0	21	2-3	1-3
22	5	2	3-9	7-6	21	2-6	1-1
23	5	2	4-3	8-6	21	3-1	1-2
24	5	2	4-9	9-6	21	3-6	1-3
25	5	4	5-0	20-0	21	3-9	1-3
26	5	2	9-6	19-0	21	1-0	8-6
27	5	2	5-6	11-0	21	1-0	4-6
28	5	2	4-6	9-0	21	1-6	3-0
29	5	2	3-9	7-6	21	0-9	3-0

TRASH RACK MATERIAL LIST

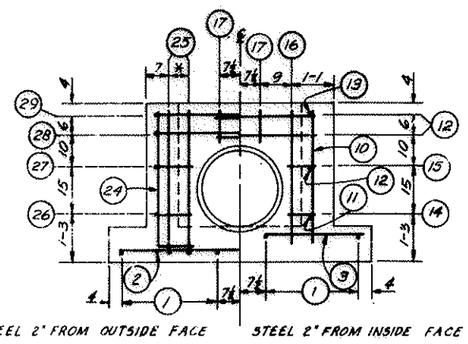
MARK	ITEM	QUANTITY
A	ANGLE 2 X 2 X 1/4 3-9 LONG	9
B	ANGLE 5 X 3 X 3/8 7-10 LONG	2
C	BOLT - 5/8" DIA.. 11 1/2" LONG	4
D (REQUIRED ONLY WHEN BOLTING IS SPECIFIED)	BOLT - 5/8" DIA., 2 3/4" LONG	18
	PIPE SLEEVE - 3/4" DIA., STD., GALV., 10" LONG	4

BOLTS SHALL BE GRADE A, GALV., WITH HEX NUT AND STANDARD WASHER

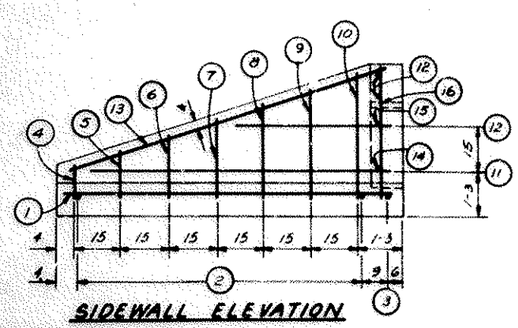


PLAN OF FOOTING STEEL

* Space to clear pipe 2".

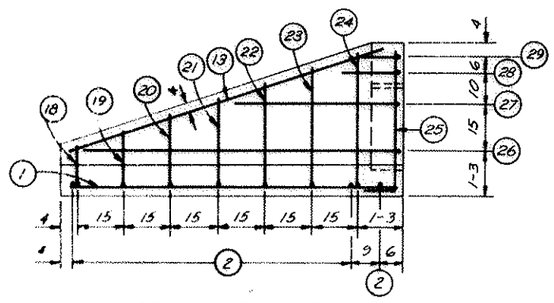


ENDWALL ELEVATION



SIDEWALL ELEVATION

STEEL 2" FROM INSIDE FACE
STEEL 2" FROM TOP OF FOOTING



SIDEWALL ELEVATION

STEEL 2" FROM OUTSIDE FACE
STEEL 3" FROM BOTTOM OF FOOTING

MATERIAL AND FABRICATION

(Check appropriate block)

1. TRASH RACK SHALL BE CONSTRUCTED FROM:
   - ☒ STRUCTURAL STEEL
   - ☐ ALUMINUM ALLOY
2. RACK SHALL BE:
   - ☐ BOLTED
   - ☒ WELDED
3. STRUCTURAL STEEL SHALL BE:
   - ☒ GALVANIZED
   - ☐ PAINTED
   - ☐ UNCOATED

GALVANIZING OR PAINTING SHALL BE IN ACCORDANCE WITH SPECIFICATIONS.

QUANTITIES

CONCRETE, CLASS MCCC _____ 3.58 CU.YDS.
STEEL REINFORCEMENT _____ 445 LBS.

(TOTAL LENGTH OF 5 BARS = 390-6+ TOTAL LENGTH OF BARS (14), (15), (17), (26), AND (27).)

AS BUILT
FEB. 8 1971

DETAILS OF DRAWDOWN INLET

MULTIPLE-PURPOSE STRUCTURE NO. 9
UPPER TURTLE RIVER WATERSHED

Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date		
Designed J.E.N.	8-70	Approved by	
Drawn		Title	
Traced		Sheet No. 51 of 51	Drawing No. 5,E-36,025
Checked C.E.M.	8-70		

E & WP UNIT - DESIGN SECTION
LINCOLN, NEBRASKA

BASE DWG. NO. 5,E-13,850.210
DATE APPROVED MARCH 31, 1969
REV. JULY, 1970

SHEET 1 OF 1

STRUCTURE DATA

Class of Structure b

Drainage Area (total) 41,350 Ac. 64.6 Sq.Mi.

(uncontrolled) 27,350 Ac. 42.7 Sq.Mi.

Time of Concentration 13.3 Hours

Soil Cover Complex Number 77 For A.M.C. II

Sediment Capacity Available 292 Ac.Ft. below Elev. ____

Total Sediment Capacity Available 292 Ac.Ft.

Capacity Equivalents (Vol.) 0.13 In.

Retarding Capacity Provided 4,180 Ac.Ft.

2027 A.F. between 1st & 2nd stage

Capacity Equivalents (Vol.) 1.84 In.

Water Supply Provided 527 Ac.Ft. - Identify Uses (Recreation)

Principal Spillway:

Maximum Capacity (low stage) 240 c.f.s.

Maximum Capacity (high stage) 1350 c.f.s.

10 Day Drawdown Elev. 1075.6

Emergency Spillway:

Percent Chance Use 2 Storm Duration 6 Hr.

Type Vegetated "n" Value Used 0.04

Emergency Spillway Hydrograph for Class b Structures

Rainfall 6.2 in.

Runoff 3.7 in.

Peak Inflow 9725 c.f.s.

Maximum Discharge - Emergency Spillway 4783 c.f.s.

Maximum Water Surface Elev. 1094.6

Velocity of Flow (V_c) 7.95 f.p.s.

Supplementary Data and Special Design Features:

Duration of flow (ESH) - 30.75 hrs.

Freeboard Hydrograph for Class b Structures

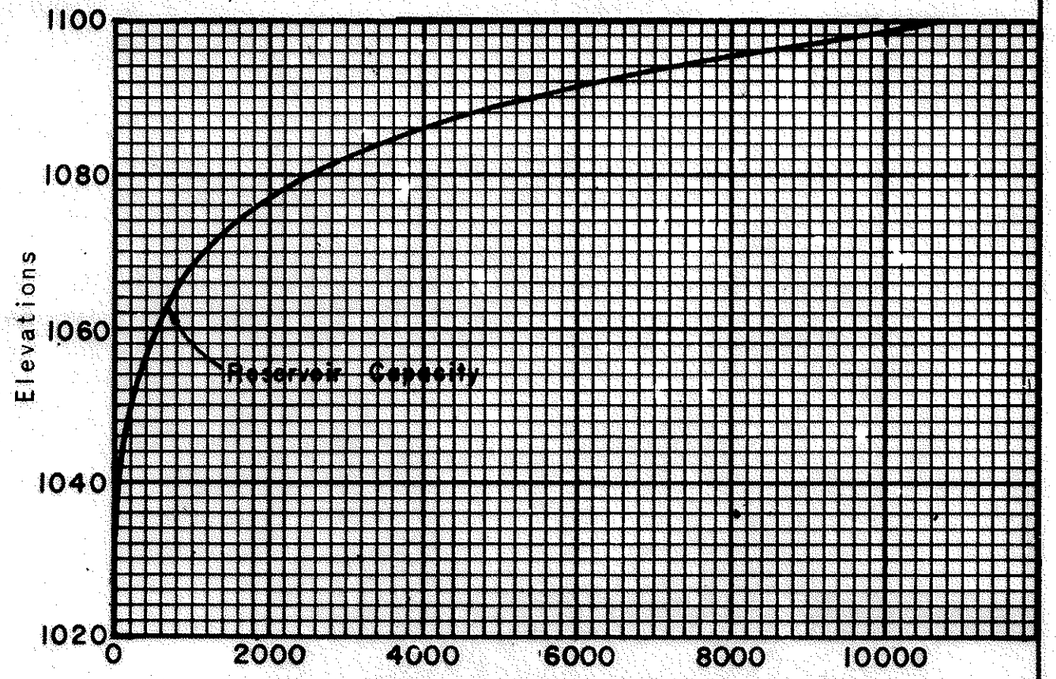
Rainfall 11.44 in.

Runoff 8.5 in.

Peak Inflow 24,047 c.f.s.

Maximum Discharge - Emergency Spillway 18,786 c.f.s.

Maximum Water Surface Elev. 1099.6



MULTIPLE-PURPOSE STRUCTURE
NO. 9
UPPER TURTLE RIVER WATERSHED
Grand Forks and Nelson Counties, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed RDS	Date 10-71	Approved by	
Drawn		Title	
Traced		Title	
Checked JEN	3-76	Sheet No. of	Drawing No. 5E-36,025

EMERGENCY WATERSHED PROTECTION

UPPER TURTLE RIVER WATERSHED

GRAND FORKS COUNTY, NORTH DAKOTA

FLOODWATER RETARDING STRUCTURE NO. 9

EMERGENCY SPILLWAY REPAIR

SPONSORING AGENCIES:

WESTERN GRAND FORKS COUNTY SOIL CONSERVATION DISTRICT
GRAND FORKS COUNTY WATER RESOURCE DISTRICT

WITH ASSISTANCE BY

U.S. DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE

INDEX TO DRAWINGS

SHEET NO.	CONTENTS
1.	Cover Sheet
2.	Table of Quantities
	Location Maps
3.	Plan View - Emergency Spillway Outlet
4.	Profile Along Centerline of Spillway
5.	Profile Along Centerline of Drain
	Typical Cross Sections of Drain
6 - 8	Typical Cross Sections of Spillway

WESLEY J. WIEDENMEYER
REGISTERED
PROFESSIONAL
P.E. 2528
ENGINEER
NORTH DAKOTA

I CERTIFY THAT THE PLANS AND DETAILED SPECIFICATIONS FOR THIS PROJECT WERE DEVELOPED BY THE NATURAL RESOURCES CONSERVATION SERVICE AND ARE APPROVED.

STATE CONSERVATION ENGINEER — DATE 6/12/01

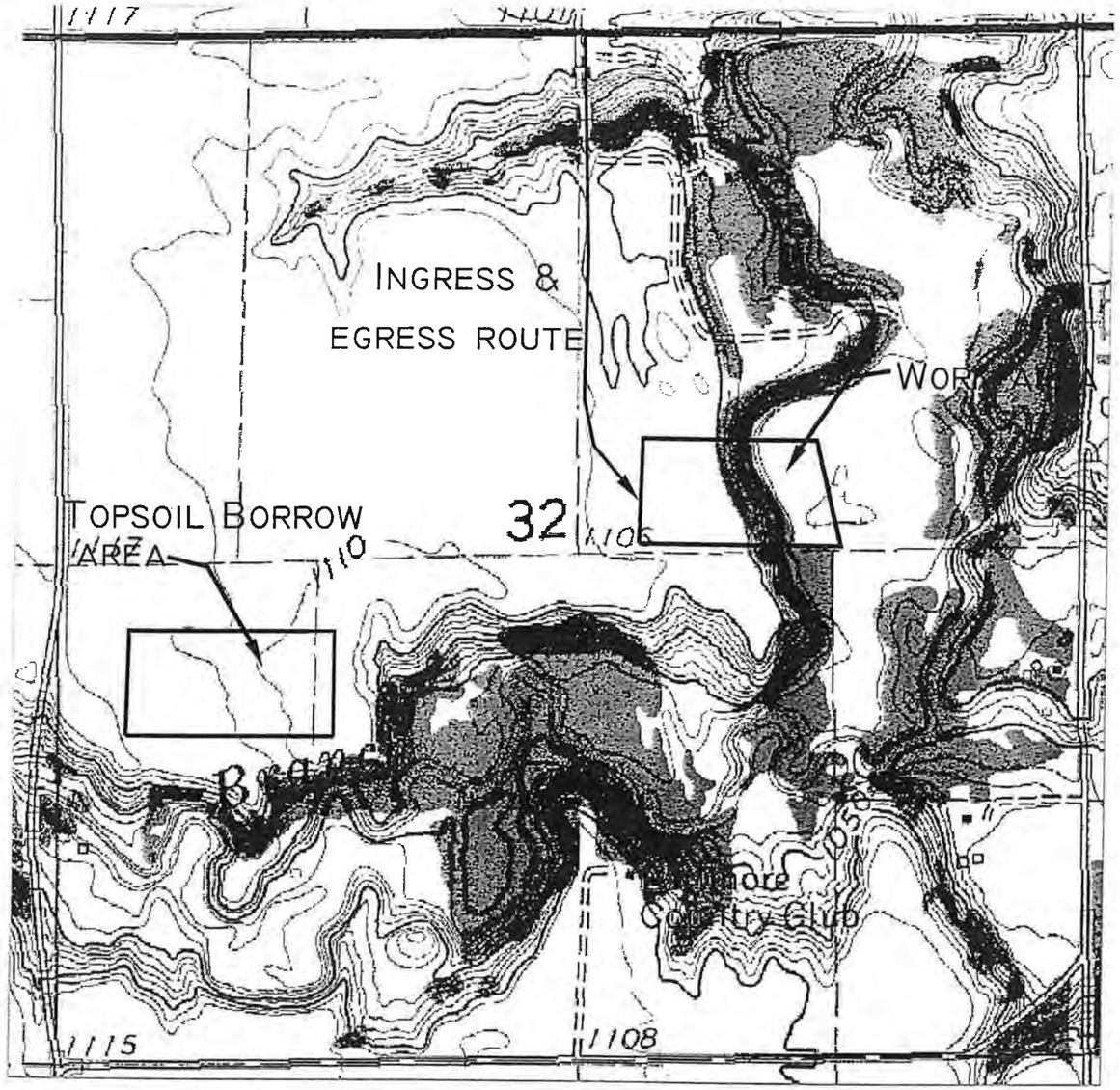
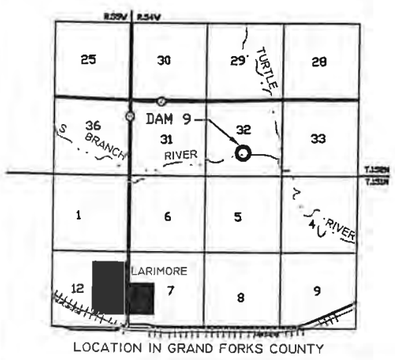


TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
Clearing and Grubbing	Ac.	1.6
Seeding and Mulching	Ac.	12.9
Turf Reinforcement Matrix	SY	1,016
Excavation, Common	CY	23,487
Earthfill, Class A	CY	13,494
Topsoiling	SY	33,050

All quantites are estimated



LOCATION IN GRAND FORKS COUNTY



LOCATION IN NORTH DAKOTA

Designed J. Nestoss Date
Drawn J. Ramirez
Checked D. Reep 06-30
Approved

DAM No 9
UPPER TURTLE RIVER WATERSHED
GRAND FORKS COUNTY, NORTH DAKOTA

USDA NRCS Natural Resources Conservation Service

File No.

Drawing No. 216-01-055

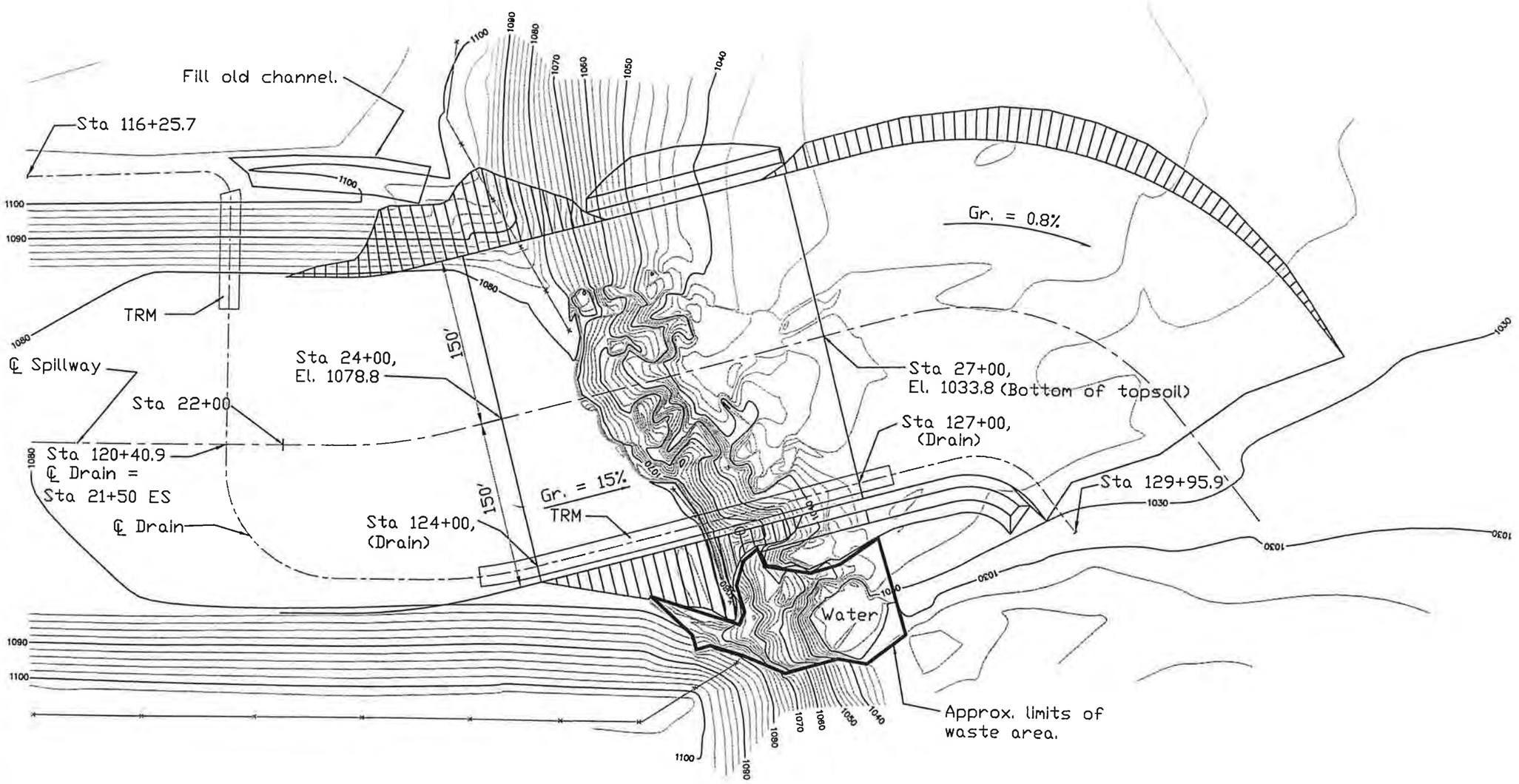
Sheet 2 of 8

NOTES

1. Dimensions of the emergency spillway shall be: Bottom width = 300 ft. and 3:1 side slopes, except that the north side slope shall be flattened to 10:1 downstream of Sta. 27+00.
2. Dikes adjacent to the spillway (approx. Sta 25+20 to Sta 27+00 on north and Sta 26+00 to Sta 30+30 on south) shall have a 12 ft. top and 3:1 side slopes. Top of the dikes shall be 3.5 ft. above spillway grade.
3. The south waste area shall be filled to El. 1080 upstream of Sta 25+60 and sloped to the east no steeper than 3:1. With the approval of the engineer, the east limit of the waste area may be extended to the end of the south dike.
4. TRM = Turf Reinforcement Matrix

CENTERLINE COORDINATES								
SPILLWAY			DRAIN			DRAIN		
STATION	NORTH	EAST	STATION	NORTH	EAST	STATION	NORTH	EAST
19+77.00	1000.00	1977.00	116+25.68	1237.80	1969.25	122+97.21(PC)	881.23	2330.50
22+52.82 (PC)	1000.00	2252.82	117+83.59(PC)	1243.81	2127.02	132+47.21(PT)	881.23	2380.50
23+00.00 (PI)	1000.00	2300.00	118+06.59(PI)	1244.68	2150.00	123+98.84(PT)	894.11	2428.81
23+46.84 (PT)	1012.16	2345.58	118+19.18(PT)	1221.69	2150.00	127+89.01(PC)	995.21	2807.93
27+77.44 (PC)	1123.16	2761.84	120+59.63(PC)	981.23	2150.00	128+39.01(PI)	1008.10	2856.24
29+27.44 (PI)	1161.81	2906.77	121+59.63(PI)	881.23	2150.00	128+77.61(PT)	999.06	2887.48
30+43.24 (PT)	1044.69	3000.50	122+16.71(PT)	881.23	2250.00	129+95.94	876.67	2981.42
31+73.51	942.99	3081.90						

CURVE DATA						
PI STATION	23+00.00	29+27.44	118+06.56	121+59.63	132+47.21	128+39.01
RADIUS	360.00ft	229.83ft	22.14ft	100.00ft	381.55ft	76.61ft
DELTA	14 55'53"	86 15'38"	92 10'52"	90 00'00"	14 55'53"	86 15'38"
DEG OF CURVATURE (ARC DEFINITION)	15 54'56"	24 55'45"	258 46'51"	57 17'45"	15 00'59"	74 47'16"
ARC LENGTH	93.82ft	285.79ft	35.62ft	157.08ft	99.43ft	88.60ft
CHORD LENGTH	93.55ft	251.23ft	31.90ft	141.42ft	99.15ft	83.74ft
TANGENT LENGTH	47.18ft	150.00ft	23.00ft	100.00ft	50.00ft	50.00ft
MIDDLE ORDINATE	3.05ft	37.36ft	6.79ft	29.29ft	3.23ft	12.45ft
EXTERNAL	3.08ft	44.62ft	9.78ft	41.42ft	3.26ft	14.87ft



PLAN VIEW — EMERGENCY SPILLWAY OUTLET

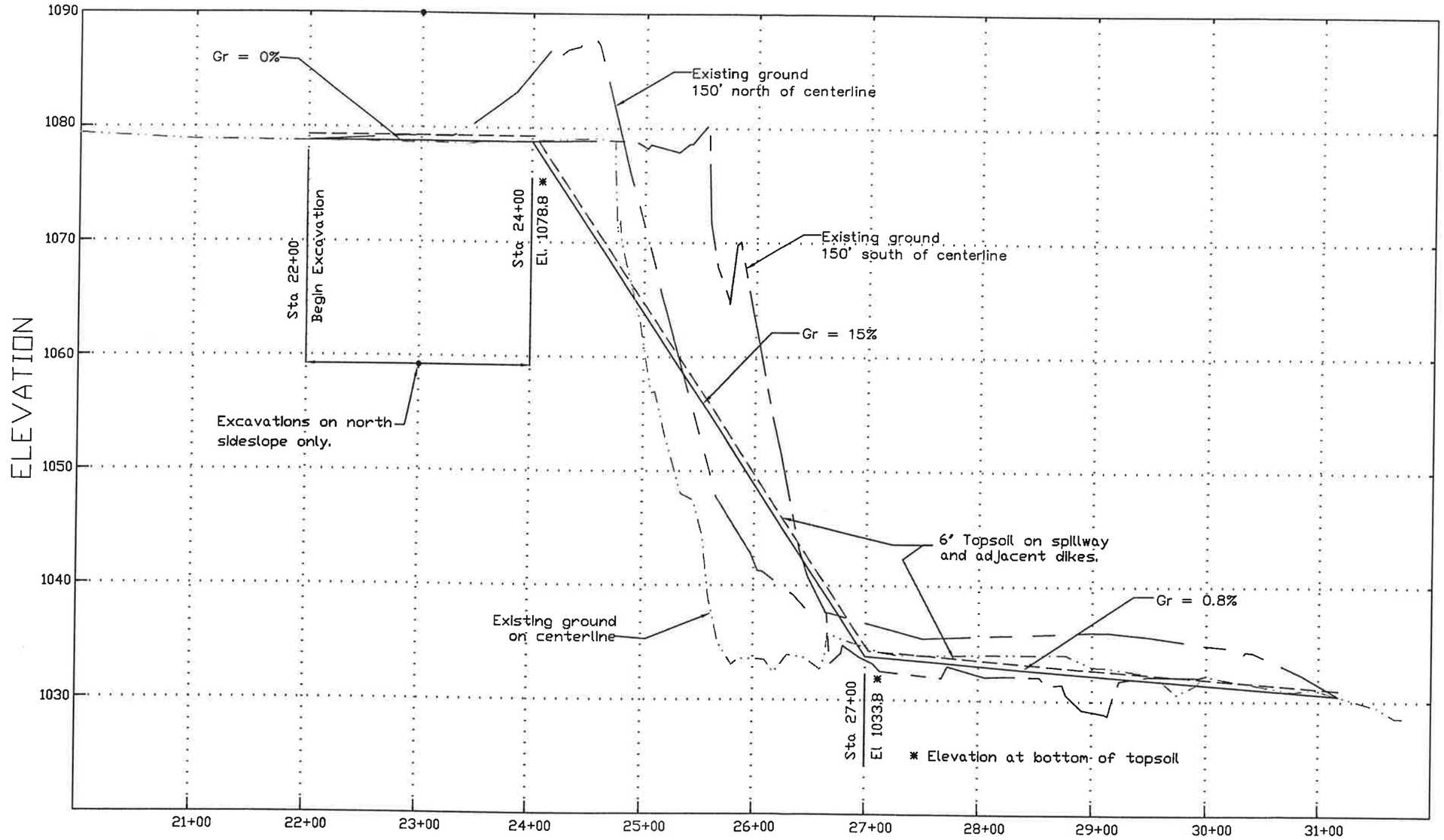
0 50 100 150
SCALE IN FEET
Contour Interval = 2 feet

Date
Designed J. Nestoss 05-01
Drawn J. Ramirez 05-01
Checked D. Reep 06-01
Approved

DAM No 9
UPPER TURTLE RIVER WATERSHED
GRAND FORKS COUNTY, NORTH DAKOTA

USDA NRCS Natural Resources Conservation Service

File No.
Drawing No. 216-01-055
Sheet 3 of 8



PROFILE ALONG CENTERLINE
OF EMERGENCY SPILLWAY

	Date
Designed J. Nystoss	05-01
Drawn J. Ramirez	05-01
Checked D. Reep	06-01
Approved	

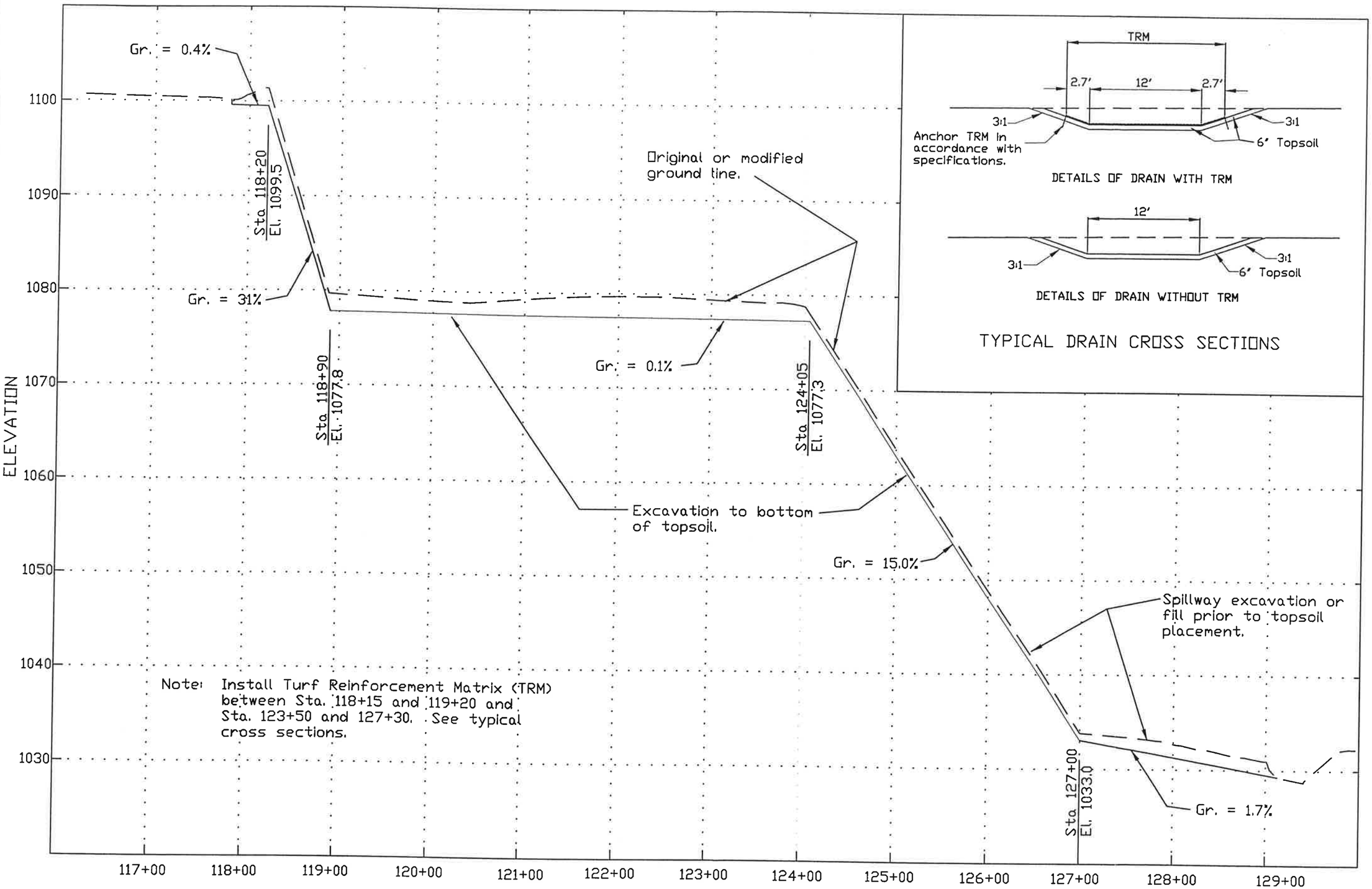
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Drawing No. 216-01-055

Sheet 4 of 8



PROFILE ALONG CENTERLINE OF DRAIN

TYPICAL DRAIN CROSS SECTIONS

Date 05-01
Designed J. Negoss 05-01
Drawn J. Ramirez 05-01
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Approved

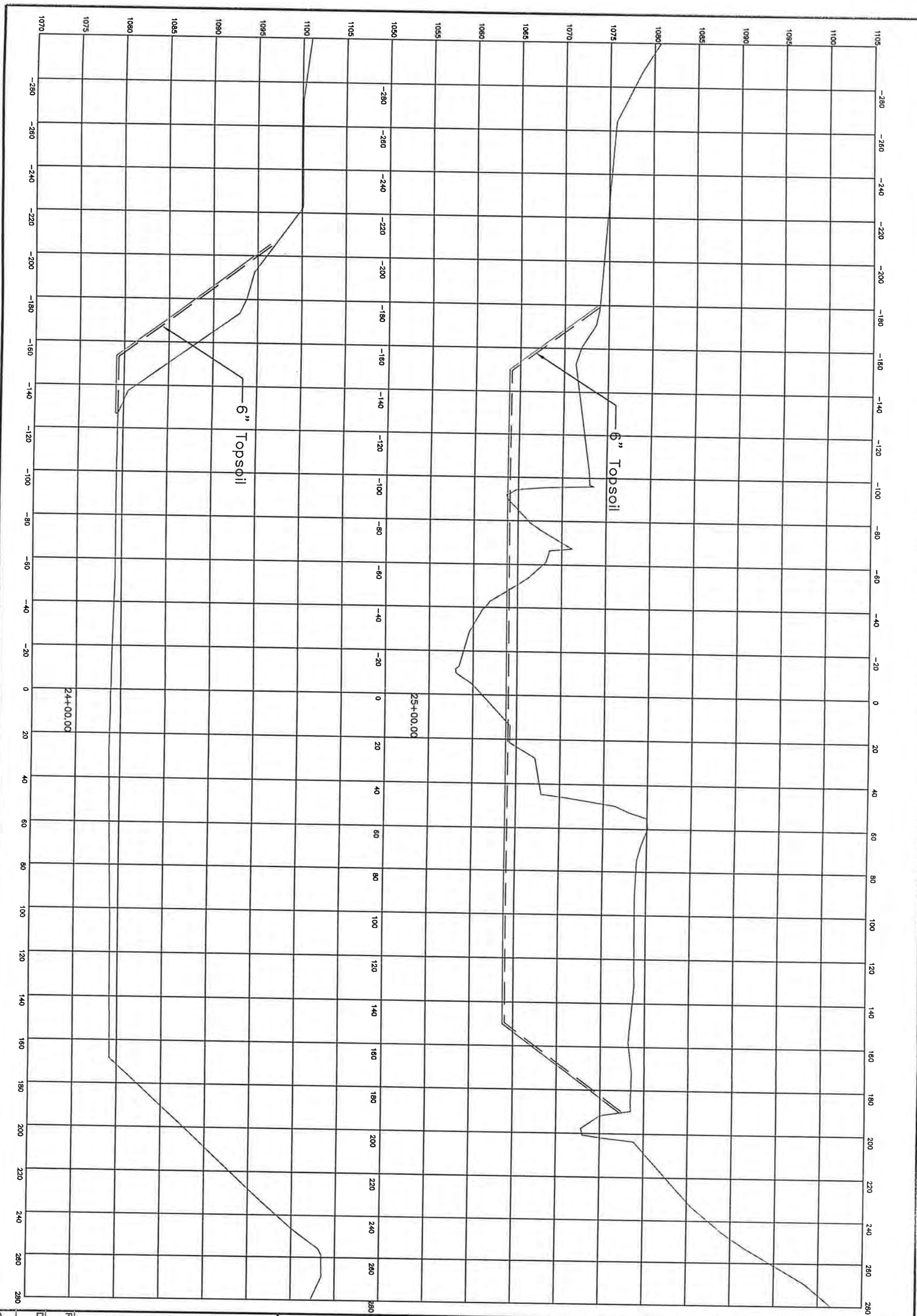
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Drawing No. 216-01-055

Sheet 5 of 8



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UPPER TURTLE RIVER WATERSHED
GRAND FORKS COUNTY, NORTH DAKOTA

		Date
Designed	J. Nestass	05-01
Drawn	J. Ramirez	05-01
Checked	D. Reep	06-01
Approved		

File No.
Drawing No. 216-01-055
Sheet 6 of 8

Date
Designed J. Nestoss 05-01
Drawn J. Ramirez 05-01
Checked D. Reep 06-01
Approved

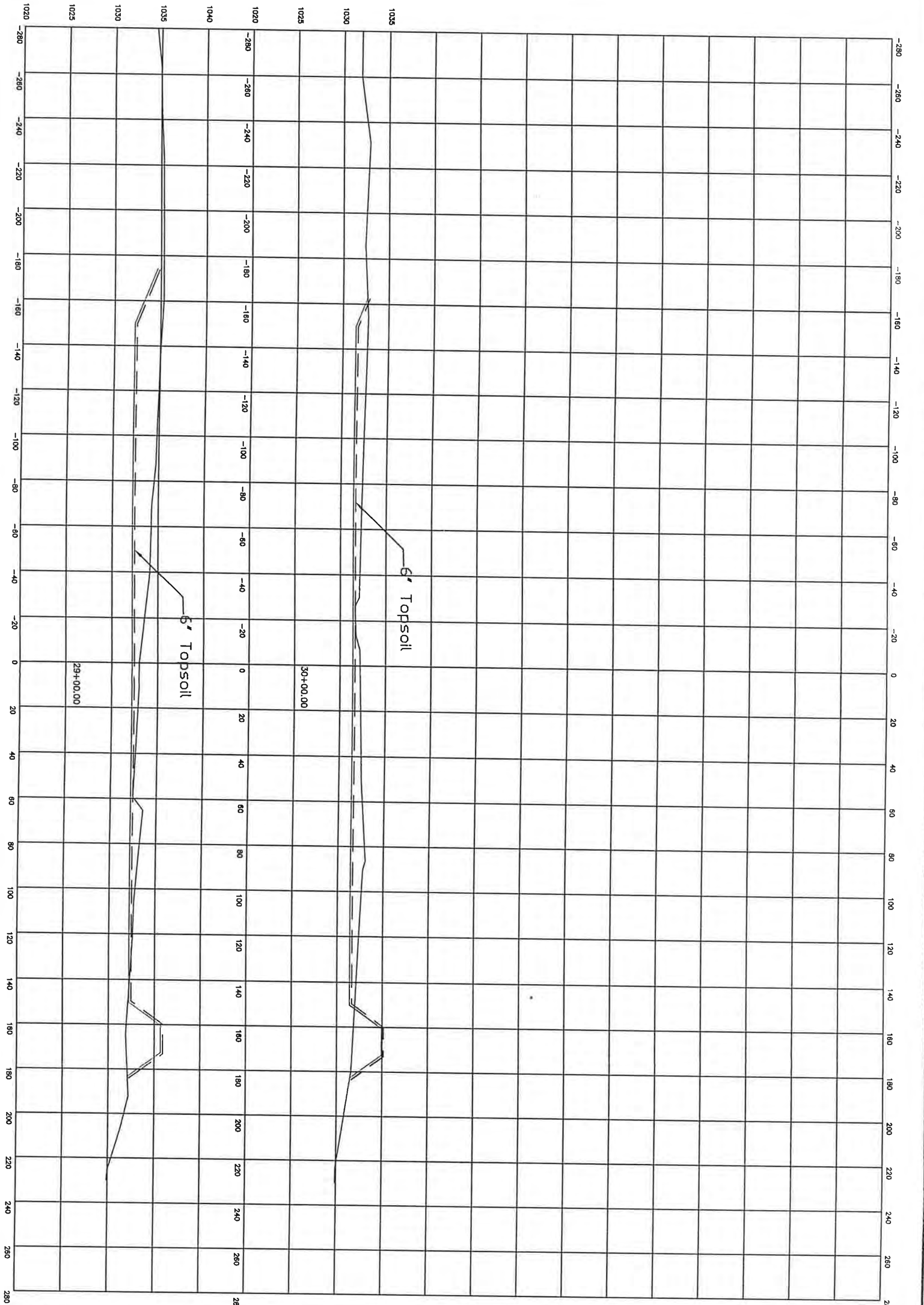
DAM No 9
UPPER TURTLE RIVER WATERSHED
GRAND FORKS COUNTY, NORTH DAKOTA

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File No.

Drawing No. 216-01-055

Sheet 7 of 8



Natural Resources Conservation Service

DAM No 9
UPPER TURTLE RIVER WATERSHED
GRAND FORKS COUNTY, NORTH DAKOTA

	Date
Designed J. Nestoss	05 01
Drawn J. Ramirez	05 0
Checked D. Reep	06 01
Approved	

Sheet 8 of 8

Drawing No. 216-01-055

File No.

Appendix C: Calculations

Appendix C1: Calc Package for SITES Analysis Parameters

Reference: **NRCS, 2001. NEH Chapter 52. Field Procedures Guide for the Headcut Erodibility Index.**

Headcut Erodibility, Kh = Ms x Kb x Kd x Js

Ms = material strength number of the earth material
Kb = block or particle size number
Kd = discontinuity or interparticle bond shear strength number
Js = relative ground structure number

Predominant Layer in Auxiliary Spillway - Upper Glacial Till

Upper Glacial Till in Auxilary Spillway

201	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam
202	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam
203	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam

Upper Glaciall Till also Present in the following borings:

601	67.0'-98.0'	Sandy Lean Clay (CL) and Lean Clay with Sand (CL)
602	36.0'-65.25'	Lean Clay (CL) and Lean Clay with Sand with sand seam

Lab data for upper glacial till encountered in all borings was used for parameter development

Determine soil strength parameter, Ms:

Boring	Sample Top Depth	N (bpf)	Density Description	USCS
	69.5	11	Stiff	CL
	74.5	10	Stiff	CL
	79.5	7	Medium	CL
	84.5	8	Medium	CL
	89.5	5	Medium	CL
601	94.5	8	Medum	CL/SP
	39.5	5	Medium	CL
	44.5	4	Soft	CL
	49.5	5	Medium	CL
	54.5	4	Soft	CL
	59.5	7	Medium	CL
602	64.5	11	Stiff	CL/SP
	4.5	11	Stiff	CL
	9.5	7	Medium	CL
	14.5	5	Medium	CL
	19.5	4	Soft	CL
	24.5	6	Medium	CL
	29.5	12	Stiff	CL/SP

	34.5	8	Medium	CL
201	39.5	8	Medium	CL
	4.5	7	Medium	CL
	9.5	7	Medium	CL
	14.5	7	Medium	CL
	19.5	8	Medium	CL
	24.5	11	Stiff	CL/SP
	29.5	7	Medium	CL
	34.5	15	Stiff	CL
202	39.5	9	Stiff	CL
	4.5	13	Stiff	CL
	9.5	6	Medium	CL
	14.5	6	Medium	CL
	19.5	4	Soft	CL
	24.5	5	Medium	CL
	29.5	7	Medium	CL
	34.5	11	Stiff	CL
203	39.5	11	Stiff	CL

Table 52–3 Material strength number, M_s, for cohesive soil

Consistency	Field identification tests	SPT (blows/0.3 m)	Unconfined compressive strength (UCS) (kPa)	M_s
Very soft	Exudes between fingers when squeezed in hand.	< 2	< 40	< 0.02
Soft	Easily molded with fingers. Point of geologic pick easily pushed into shaft of handle.	2 - 4	40 - 80	0.02 - 0.05
Firm	Penetrated several centimeters by thumb with moderate pressure. Molded by fingers with some pressure.	4 - 8	80 - 150	0.05 - 0.10
Stiff	Indented by thumb with great effort. Point of geologic pick can be pushed in up to 1 centimeter. Very difficult to mold with fingers. Just penetrated with hand spade.	8 - 15	150 - 300	0.10 - 0.20
Very stiff	Indented only by thumbnail. Slight indentation by pushing point of geologic pick. Requires hand pick for excavation.	15 - 30	300 - 625	0.20 - 0.45

Aux borings	8.125
All data	7.777778

For Upper Glacial Till use:

Ms **0.075**

Determine block size, Kb

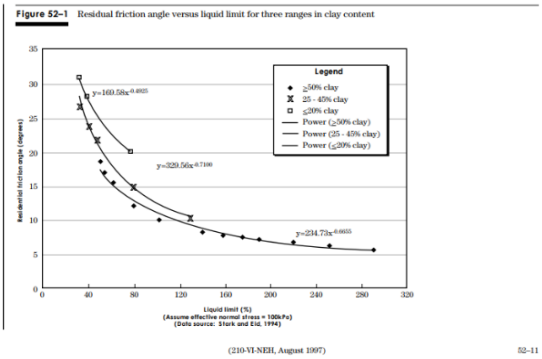
NRCS (2001) setion 628.5203.b.2 recommends Kb-1.0 for intact cohesive soils and gravels

For Upper Glacial Till

Kb **1**

Determine discontinuity or interparticle bond shear strength number, Kd

Because residual shear testing was not completed, utlize empirical relationship from NRCS, 2001



Layer	USCS	% clay	LL
Upper Glacial Till	CL	27.575	37.5

ϕr **25.14040641**

Kd **0.469294487**

Determine relative ground structure number, Js

Section 628.5203.d, Js equals 1.0 for intact soil

Js **1**

Computation of Headcut Index

Kh **0.035197087**

Estimate dry unit weight of soil (Upper Glacial Till)

Ɣd **104.1333333 pcf** (Average from lab data, 4 tests total)

Determine representatieve particle diameter

Upper Glacial Till D75

601	21*	0.075
201	4.5	0.16
202	9.5	0.25
203	14.5	0.3

D75 **0.173205081** mm

(geomean of the gradation data presented above)

Determine plasticity index for Upper Glacial Till

PI **18.125** (based on lab from 8 test results)

Summary Table of Soil Parameters for SITES Analysis

Layer	Dry Unit Weight, Yd (pcf)	% Clay	Kh	D75 (mm)	PI
Upper Glacial Till	104.1333333	29.48333	0.03519709	0.17320508	18.125

C-1: SITES Parameter Development

Appendix C1: Calc Package for SITES Analysis Parameters

Reference: **NRCS, 2001. NEH Chapter 52. Field Procedures Guide for the Headcut Erodibility Index.**

Headcut Erodibility, Kh = Ms x Kb x Kd x Js

Ms = material strength number of the earth material
Kb = block or particle size number
Kd = discontinuity or interparticle bond shear strength number
Js = relative ground structure number

Predominant Layer in Auxiliary Spillway - Upper Glacial Till

Upper Glacial Till in Auxilary Spillway

201	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam
202	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam
203	3.0'-41.0'	Sandy Lean Clay (CL) with occasional sand seam

Upper Glaciall Till also Present in the following borings:

601	67.0'-98.0'	Sandy Lean Clay (CL) and Lean Clay with Sand (CL)
602	36.0'-65.25'	Lean Clay (CL) and Lean Clay with Sand with sand seam

Lab data for upper glacial till encountered in all borings was used for parameter development

Determine soil strength parameter, Ms:

Boring	Sample Top Depth	N (bpf)	Density Description	USCS
	69.5	11	Stiff	CL
	74.5	10	Stiff	CL
	79.5	7	Medium	CL
	84.5	8	Medium	CL
	89.5	5	Medium	CL
601	94.5	8	Medum	CL/SP
	39.5	5	Medium	CL
	44.5	4	Soft	CL
	49.5	5	Medium	CL
	54.5	4	Soft	CL
	59.5	7	Medium	CL
602	64.5	11	Stiff	CL/SP
	4.5	11	Stiff	CL
	9.5	7	Medium	CL
	14.5	5	Medium	CL
	19.5	4	Soft	CL
	24.5	6	Medium	CL
	29.5	12	Stiff	CL/SP

	34.5	8	Medium	CL
201	39.5	8	Medium	CL
	4.5	7	Medium	CL
	9.5	7	Medium	CL
	14.5	7	Medium	CL
	19.5	8	Medium	CL
	24.5	11	Stiff	CL/SP
	29.5	7	Medium	CL
	34.5	15	Stiff	CL
202	39.5	9	Stiff	CL
	4.5	13	Stiff	CL
	9.5	6	Medium	CL
	14.5	6	Medium	CL
	19.5	4	Soft	CL
	24.5	5	Medium	CL
	29.5	7	Medium	CL
	34.5	11	Stiff	CL
203	39.5	11	Stiff	CL

Table 52–3 Material strength number, M_s, for cohesive soil

Consistency	Field identification tests	SPT (blows/0.3 m)	Unconfined compressive strength (UCS) (kPa)	M_s
Very soft	Exudes between fingers when squeezed in hand.	< 2	< 40	< 0.02
Soft	Easily molded with fingers. Point of geologic pick easily pushed into shaft of handle.	2 - 4	40 - 80	0.02 - 0.05
Firm	Penetrated several centimeters by thumb with moderate pressure. Molded by fingers with some pressure.	4 - 8	80 - 150	0.05 - 0.10
Stiff	Indented by thumb with great effort. Point of geologic pick can be pushed in up to 1 centimeter. Very difficult to mold with fingers. Just penetrated with hand spade.	8 - 15	150 - 300	0.10 - 0.20
Very stiff	Indented only by thumbnail. Slight indentation by pushing point of geologic pick. Requires hand pick for excavation.	15 - 30	300 - 625	0.20 - 0.45

Aux borings	8.125
All data	7.777778

For Upper Glacial Till use:

Ms **0.075**

Determine block size, Kb

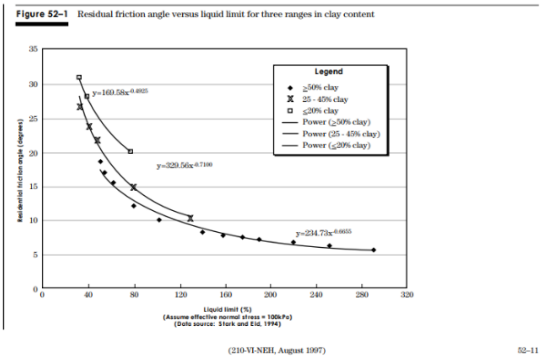
NRCS (2001) setion 628.5203.b.2 recommends Kb-1.0 for intact cohesive soils and gravels

For Upper Glacial Till

Kb **1**

Determine discontinuity or interparticle bond shear strength number, Kd

Because residual shear testing was not completed, utlize empirical relationship from NRCS, 2001



Layer	USCS	% clay	LL
Upper Glacial Till	CL	27.575	37.5

ϕr **25.14040641**

Kd **0.469294487**

Determine relative ground structure number, Js

Section 628.5203.d, Js equals 1.0 for intact soil

Js **1**

Computation of Headcut Index

Kh **0.035197087**

Estimate dry unit weight of soil (Upper Glacial Till)

Ɣd **104.1333333 pcf** (Average from lab data, 4 tests total)

Determine representatieve particle diameter

Upper Glacial Till D75

601	21*	0.075
201	4.5	0.16
202	9.5	0.25
203	14.5	0.3

D75 **0.173205081** mm

(geomean of the gradation data presented above)

Determine plasticity index for Upper Glacial Till

PI **18.125** (based on lab from 8 test results)

Summary Table of Soil Parameters for SITES Analysis

Layer	Dry Unit Weight, Yd (pcf)	% Clay	Kh	D75 (mm)	PI
Upper Glacial Till	104.1333333	29.48333	0.03519709	0.17320508	18.125

C-2: Filter Compatibility Analysis

Project: **Larimore Dam** Analysis Performed By: GFB

Client: Date:

Analysis Checked By:

Date: BK

FILTER ANALYSIS

Method: Chapter 26: Gradation Design of Sand and Gravel Filters (210-633-H, 1st Ed., Amend. 61, Aug 2017)

Purpose: Check if filter meets current design criteria for base soil.

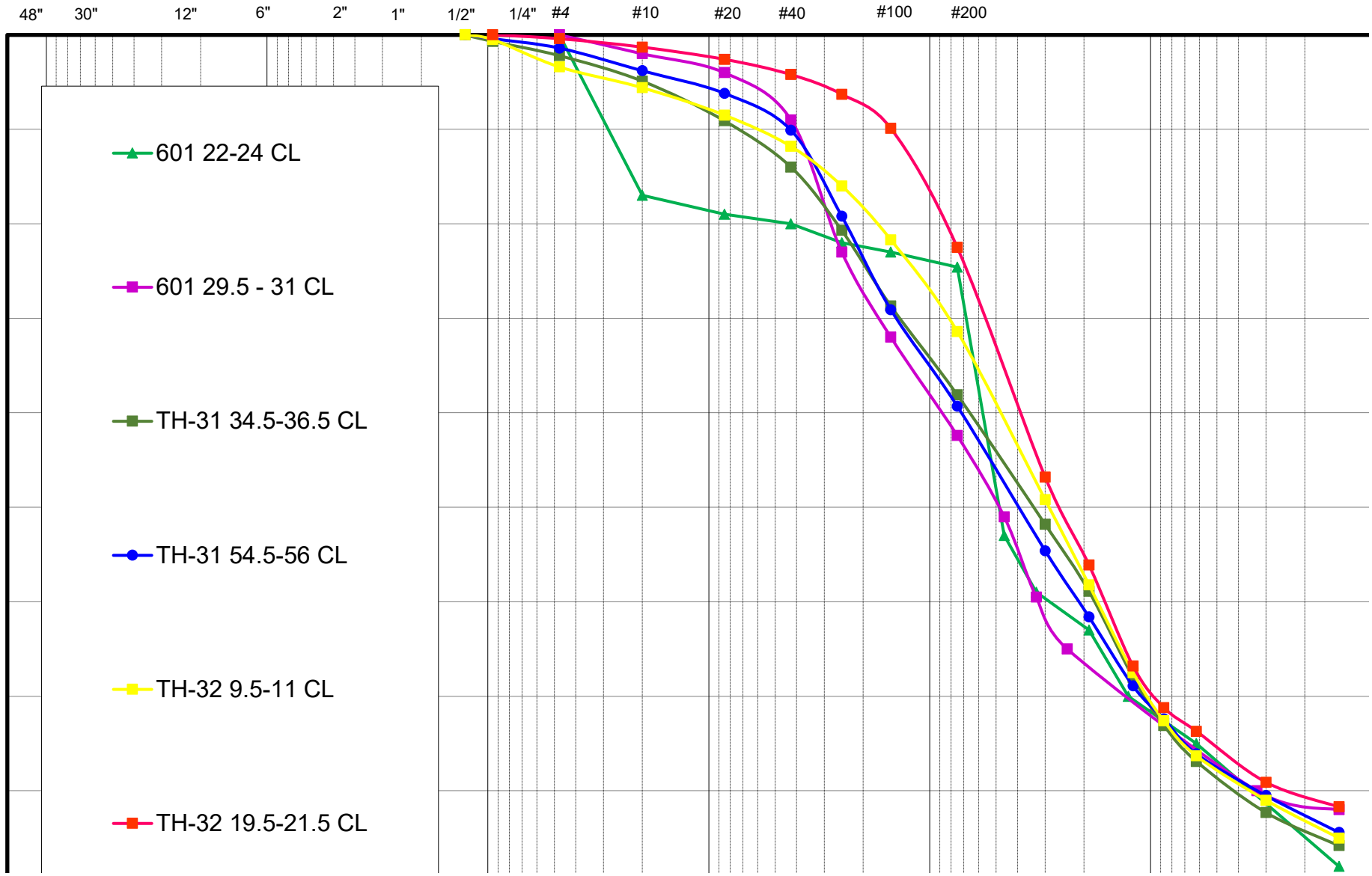
Step 1 - Plot gradation data for materail that requires a filter (base soil materials)- for this analysis, we used the gradational curves from the embankmnet fill material collected during the 2020/2021 invstigagiton

Gradation Data				Data Collected from 2020/2021 Investigation					
			Sample ID:	601	601	TH-31	TH-31	TH-32	TH-32
	Sieve	**Grain**	**Depth:**	22-24	29.5 - 31	34.5-36.5	54.5-56	9.5-11	19.5-21.5
	No.	**Size (mm)**	**USCS:**	CL	CL	CL	CL	CL	CL
Size (inches)	48	1219.2	48 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	45	1143.0	45 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	42	1066.8	42 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	39	990.6	39 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	36	914.4	36 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	33	838.2	33 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	30	762.0	30 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	27	685.8	27 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	24	609.6	24 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	21	533.4	21 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	18	457.2	18 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	15	381.0	15 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	12	304.8	12 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	9	228.6	9 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	6	152.4	6 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	4	101.6	4 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3	76.2	3 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2	50.8	2 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	1.5	38.1	1.5 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	1	25.4	1 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	0.75	19.1	3/4 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	.625	15.9	5/8 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	.5	12.7	1/2 inch	#N/A	#N/A	100	100	100	#N/A
	0.375	9.5	3/8 inch	#N/A	#N/A	99.3	99.6	99.5	100
	0.25	6.4	1/4 inch	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Sieve No.	4	4.75		100	100	97.8	98.6	96.6	99.6
	6	3.35		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	8	2.36		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	10	2		83	98	95.1	96.2	94.4	98.7
	14	1.4		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	16	1.18		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	20	0.85		81	96	90.9	93.8	91.5	97.4
	30	0.6		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	40	0.425		80	91	86	89.9	88.2	95.8
	50	0.3		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	60	0.25		78	77	79.3	80.8	84	93.7
	80	0.18		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	100	0.15		77	68	71.3	70.9	78.3	90.1
	140	0.104		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	200	0.075		75.4	57.6	61.9	60.7	68.6	77.5
Hydrometer		0.0627		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.054		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.046		47	49	#N/A	#N/A	#N/A	#N/A
		0.04		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.035		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0329		41	40.5	#N/A	#N/A	#N/A	#N/A
		0.03		#N/A	#N/A	48.2	45.4	50.8	53.2
		0.029		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0238		#N/A	35	#N/A	#N/A	#N/A	#N/A
		0.019		37	#N/A	41.1	38.4	41.8	43.9
		0.0126		30	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0122		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.012		#N/A	#N/A	32	31.1	32.5	33.2
		0.011		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.009		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0087		#N/A	#N/A	26.9	27.6	27.4	28.8
		0.0081		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0071		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0065		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0062		25	#N/A	23.1	23.9	23.7	26.3
		0.0058		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.005		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0047		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0042		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0033		#N/A	20	#N/A	#N/A	#N/A	#N/A

		0.003
		0.0023
		0.0014
		0.001
		0.0007
		0.0005

	#N/A	#N/A	17.7	19.5	19	20.9
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	12	18	14.2	15.6	15	18.3
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
% Gravel:	0	0	2.2	1.4	3.4	0.4
% Sand:	24.6	42.4	35.9	37.9	28	22.1
% Fines:	75.4	57.6	61.9	60.7	68.6	77.5

Uncorrected Gradation



\\omapi-fs03\Geotech\Projects\10202148- Larimore\Filter Analysis\Filter Design_OriginalDesignRecords_2.xlsxOrig Grad Plot

Project: Larimore Dam Analysis Performed By: GFB

Client: Date:

Page 2 Analysis Checked By: BK

Date:

Method: Chapter 26: Gradation Design of Sand and Gravel Filters (210-633-H, 1st Ed., Amend. 61, Aug 2017)

Step 2 - Correct original gradation data to exclude gravel

Corrected Gradation Data

	Sieve No.	Grain Size (mm)		Sample ID:	601	601	TH-31	TH-31	TH-32	TH-32
					(Corrected)	(Corrected)	(Corrected)	(Corrected)	(Corrected)	(Corrected)
				Depth:	22-24	29.5 - 31	34.5-36.5	54.5-56	9.5-11	19.5-21.5
				USCS:	CL	CL	CL	CL	CL	CL
Size (inches)	48	1219.2	48 inch							
	45	1143.0	45 inch							
	42	1066.8	42 inch							
	39	990.6	39 inch							
	36	914.4	36 inch							
	33	838.2	33 inch							
	30	762.0	30 inch							
	27	685.8	27 inch							
	24	609.6	24 inch							
	21	533.4	21 inch							
	18	457.2	18 inch							
	15	381.0	15 inch							
	12	304.8	12 inch							
	9	228.6	9 inch							
	6	152.4	6 inch							
	4	101.6	4 inch							
	3	76.2	3 inch							
	2	50.8	2 inch							
	1.5	38.1	1.5 inch							
	1	25.4	1 inch							
	0.75	19.1	0.75 inch							
	.625	15.9	0.625 inch							
	.5	12.7	0.5 inch							
	0.375	9.5	0.375 inch							
	0.25	6.4	0.25 inch							
Sieve No.	4	4.75			100	100	100	100	100	100
	6	3.35			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	8	2.36			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	10	2			83	98	97.2	97.6	97.7	99.1
	14	1.4			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	16	1.18			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	20	0.85			81	96	92.9	95.1	94.7	97.8
	30	0.6			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	40	0.425			80	91	87.9	91.2	91.3	96.2
	50	0.3			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	60	0.25			78	77	81.1	81.9	87.0	94.1
	80	0.18			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	100	0.15			77	68	72.9	71.9	81.1	90.5
	140	0.104			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	200	0.075			75.4	57.6	63.3	61.6	71.0	77.8
Hydrometer		0.0627			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.054			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.046			47	49	#N/A	#N/A	#N/A	#N/A
		0.04			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.035			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0329			41	40.5	#N/A	#N/A	#N/A	#N/A
		0.03			#N/A	#N/A	49.3	46.0	52.6	53.4
		0.029			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.021			#N/A	35	#N/A	#N/A	#N/A	#N/A
		0.019			37	#N/A	42.0	38.9	43.3	44.1
		0.0128			30	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0122			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.012			#N/A	#N/A	32.7	31.5	33.6	33.3
		0.011			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.009			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0087			#N/A	#N/A	27.5	28.0	28.4	28.9
		0.0081			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0071			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0066			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0062			25	#N/A	23.6	24.2	24.5	26.4
		0.0058			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.005			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0044			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0042			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0032			#N/A	20	#N/A	#N/A	#N/A	#N/A
		0.003			#N/A	#N/A	18.1	19.8	19.7	21.0
		0.002			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.0013			12	18	14.5	15.8	15.5	18.4
		0.001			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.00074			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		0.00045			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Plotted as Step 3 on Corr Grad Plot tab				Corrected % Gravel:	0	0	0	0	0	0
				Corrected % Sand:	24.6	42.4	36.7	38.4	29.0	22.2
CONTROLLING DESIGN VALUES				Corrected % Fines:	75.4	57.6	63.3	61.6	71.0	77.8
				Dispersive?	YES	YES	YES	YES	YES	YES

Step 2 Determine if the base soils have particles larger than the No. 4 sieve. At the same time, determine if the base soils are gap-graded and potentially subject to internal instability (see app. 26A, A–2 for further explanation).

(a) If the base soil has no gravel particles and is not gap-graded, proceed to step 4.

(b) If a base soil contains any particles larger than the No. 4 (4.75 mm) sieve, the soil should be regraded on the No. 4 sieve; proceed to step 3, with the following exceptions.

(1) Sands and gravels with less than 15 percent passing the No. 200 (0.075 mm) sieve that are not gap-graded and not broadly graded do not require regrading; proceed to step 4.

Step 4 - Determine base soil category

Base soil category:		2	2	2	2	2	2
enter manually based on Corr Grad Plot	**$D_{85\text{-Base}}$:**	1.15	0.33	0.33	0.33	0.33	0.33
enter manually based on Orig Grad Plot	**$D_{15\text{-Base}}$:**	0.002	0.001	0.001	0.001	0.001	0.001

Step 5 - Determine filter design point for particle retention (internal stability)

Reviewing max $D_{15\text{-Filter}}$:		0.7	0.7	0.7	0.7	0.7	0.7
Dispersive soils override?		0.5	0.5	0.5	0.5	0.5	0.5
Max $D_{15\text{-Filter}}$:	**0.5**						

Step 6 - Determine filter design point for permeability (controls in difficult design)

Reviewing min $D_{15\text{-Filter}}$ (Rec):	0.01	0.005	0.005	0.005	0.005	0.005	**$_{\text{-Filter}}$ Range**
Reviewing min $D_{15\text{-Filter}}$ (USACE):	0.006	0.003	0.003	0.003	0.003	0.003	0.5
Fine soils override?	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Min $D_{15\text{-Filter}}$:	0.1						

See $D_{15\text{-Filter}}$ controlling design range on Corr Grad Plot tab

Analysis Performed By: GFB
Date:
Analysis Checked By:
Date: BK

Method: Chapter 26: Gradation Design of Sand and Gravel Filters (210-633-H, 1st Ed., Amend. 61, Aug 2017)

Step 7 - Design filter material

7.1 check for segregation

$D_{15\text{-Filter}}$ Range Check: 5.0 **must be < 5, or need to tighten range for $D_{15\text{-Filter}}$**

7.1 check for uniformity coefficient

	Max	Min	
$D_{60\text{-Filter}}$:	2.10	0.42	
$D_{10\text{-Filter}}$:	0.35	0.0750	
C_U:	6.0	5.6	**must be between 2 and 6**
	ok	*ok*	**or need to modify filter to be more uniform**

STEP 8 (NRCS) Max particle size for 2 inch and No. 200 Sieve

50.8 **2 inch** **100** **percent**
0.075 **No. 200 max** **5** **percent**

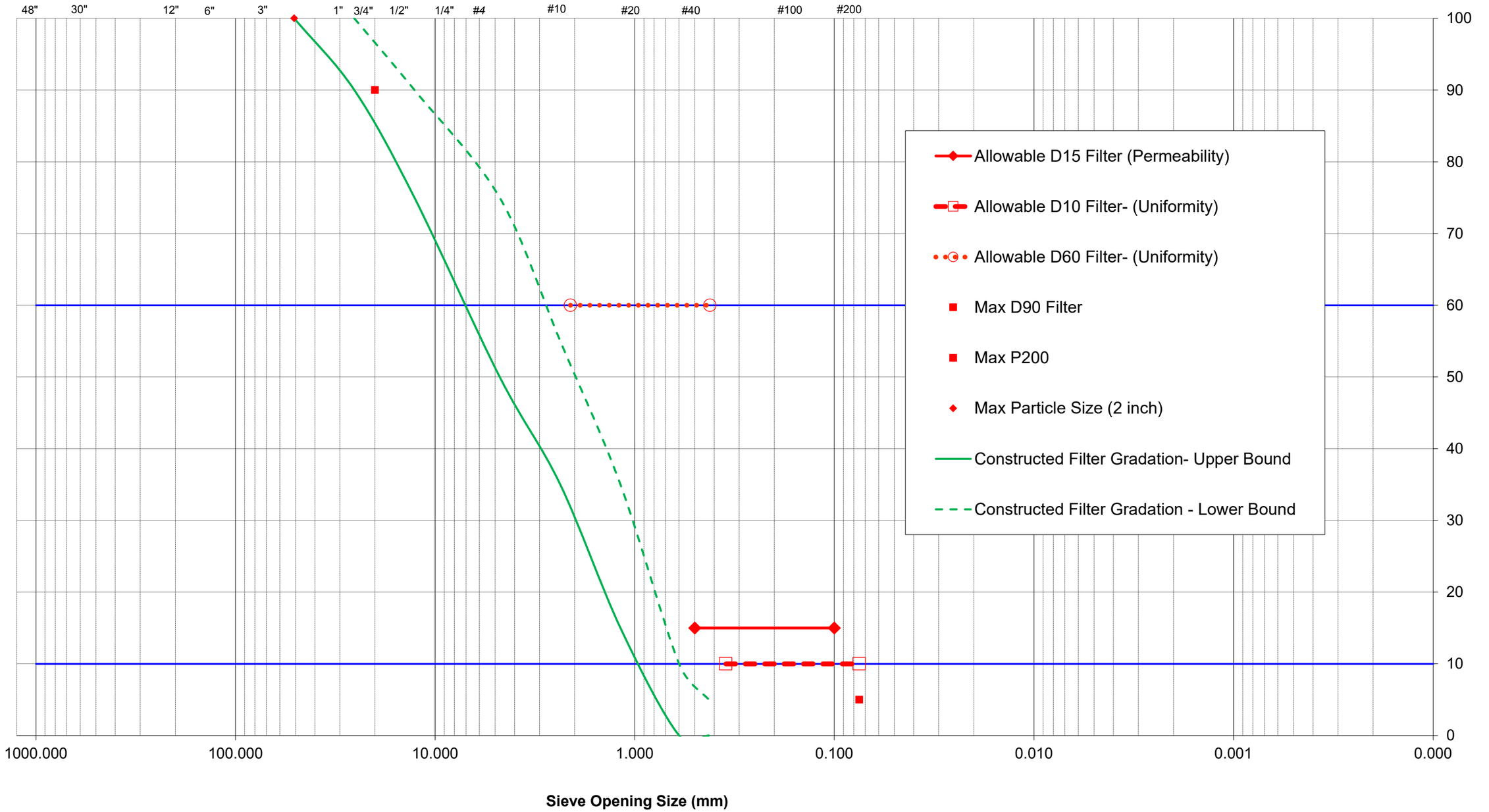
STEP 9 (NRCS) Max D90 and Min D10 (for segregation during construction)

Min $D_{10\text{-Filter}}$ **0.0750** **mm**
Max $D_{90\text{-Filter}}$ **20** **mm**

Table 26–3 Segregation criteria

Base soil category	If D_{10} is: (mm)	Then, maximum D_{90} is: (mm)
ALL categories	< 0.5	20
	0.5-1.0	25
	1.0-2.0	30
	2.0-5.0	40
	5.0-10	50
	> 10	60

Step 10- Filter Design
Filter Specifications



C-3: Shear Strength Calc Package

Appendix C3

Date:	Tuesday, June 29, 2021
Project:	Larimore Dam
To:	Greta Backman, PE
From:	Kerrie Berg, PE
Subject:	Selection of Soil Strength Design Parameters

Objectives

This memo details the selection of the soil strength design parameters. The more specifically, details include:

- Soil Shear Strength from Laboratory Testing
- Simplified Undrained Shear Strength for Cohesive Soils
- Simplified Drained Shear Strength for Cohesive Soils

Soil Shear Strength from Laboratory Testing

The shear strengths of the soils obtained during HDR's 2020 and 2021 geotechnical investigations were measured in the laboratory through the use of Consolidated Undrained (CU) Triaxial testing (ASTM D4767) with pore water pressure measurements, which provides drained and undrained soil strengths. Two CU tests were performed in each soil layer (embankment fill, upper glacial till, and pre-consolidated till).

Detailed analysis of the CU triaxial test results were performed by plotting the individual test results for each soil layer to establish soil strength envelopes for the Undrained Strength Stability Analysis (USSA) and Effective Stress Stability Analysis (ESSA). The EM 1110-2-1902 (USACE 2003) 33rd percentile design strength envelope guidance was considered and design strengths for the 33rd percentile were calculated.

Figure 1 through Figure 6 present the design strength envelopes from the CU testing. The drained and undrained strength parameters determined from the soil strength envelopes were compared to the 33rd percentile strength values determined from the CU testing, and the lower value was selected to be used in analysis. These values are presented in Table C3-1.

Table C3-1: 33rd Percentile Data

Soil Layer		c (psf)	ϕ (deg)	c' (psf)	ϕ' (deg)
Embankment Fill	33rd Percentile (graph)	2206	23	212	33
	33rd Percentile (lab data)	2206	23	212	33
Upper Glacial Till	33rd Percentile (graph)	805	17	235	32
	33rd Percentile (lab data)	768	17	208	32
Pre-consolidated Till	33rd Percentile (graph)	2105	22	380	33
	33rd Percentile (lab data)	2103	22	289	33

The drained and undrained strength parameters selected for each soil layer are presented in Table C3-2. These values are generally based on the 33rd percentile data. For the embankment fill, the effective cohesion was adjusted to 900 psf based on literature and typical values used for compacted clay fill. Table C3-2 also presents a summary of the soil strengths for use in the design. Design unit weight values were selected based on average laboratory tests completed in each soil layer.

Material	Moist Unit Weight (pcf)	Saturated Unit Weight (pcf)	Shear Strength Parameters				
			USSA		ESSA		Bilinear Stress
			c (psf)	ϕ (deg)	c' (psf)	ϕ' (deg)	Normal Stress (psf)
Embankment Fill	129	133	900	23	200	33	3112
Upper Glacial Till	126	128	700	17	200	32	1566
Pre-consolidated Till	122	126	2000	22	250	33	7131
Drain Material	128	135	N/A	N/A	--	28	N/A

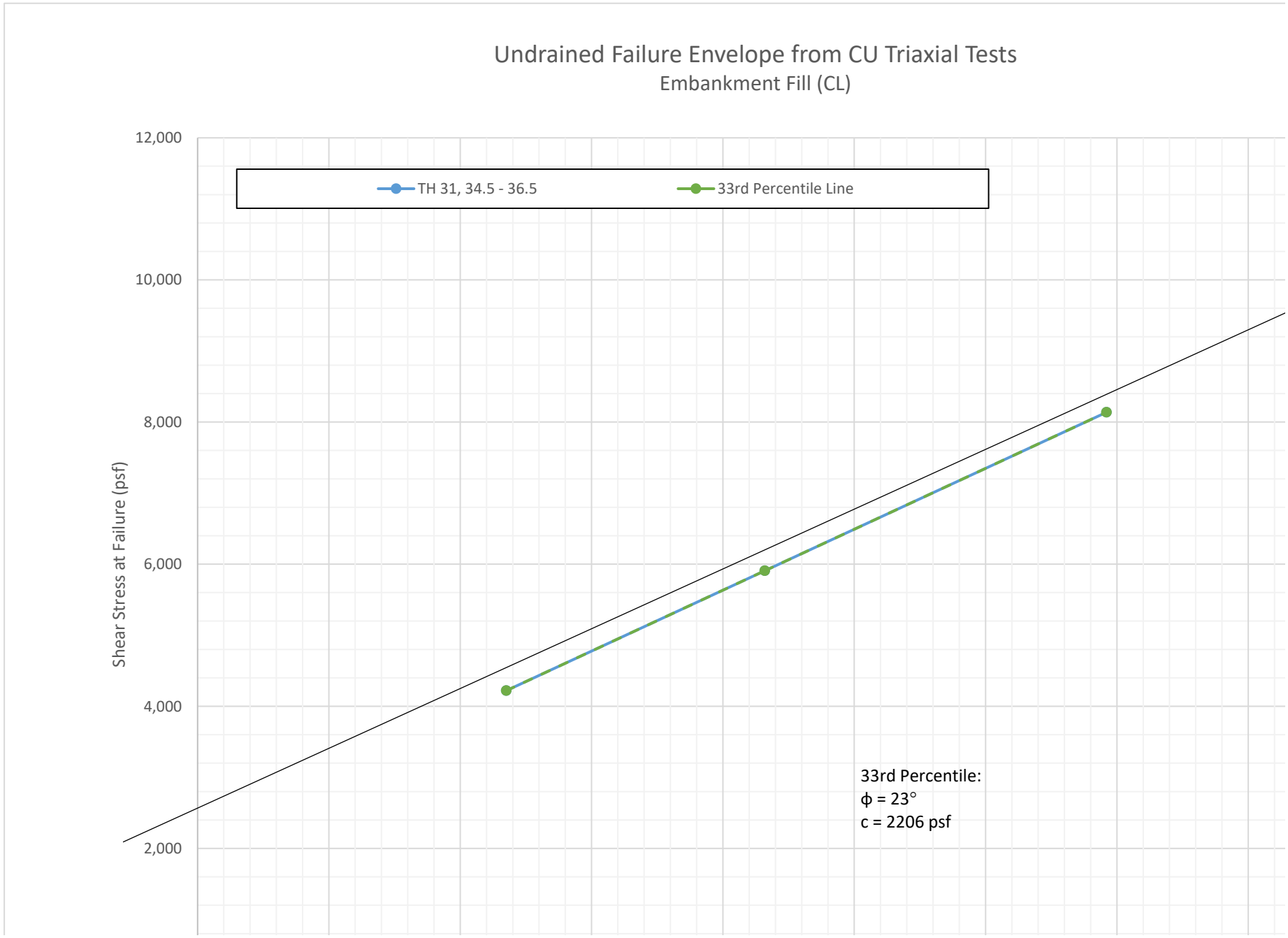
Rapid Drawdown Strength Selection (Composite Curves)

In the case of a rapid drawdown (RDD) event and flood surcharge event, TR 210-60 recommends using the lowest of effective or consolidated total stress parameters for low permeability material – strength parameters are presented as a bilinear shear strength envelope where the envelope represents the lower bound of the total and effective stress envelopes.

The effective stress parameters c' and φ' and the total stress parameters c and φ are plotted in Figure 7 through Figure 9, for the embankment fill, upper glacial till, and pre-consolidated till layers. The graphs also identify the point of intersection. The bilinear stress selected for each soil layer is presented in Table C3-2.

References

United States Army Corps of Engineers, 2003 Engineering and Design, Slope Stability, EM 1110-2-1902. October 31, 2003.


Undrained Failure Envelope from CU Triaxial Tests
Embankment Fill (CL)
TH 31, 34.5 - 36.5
33rd Percentile Line
Shear Stress at Failure (psf)
12,000
10,000
8,000
6,000
4,000
2,000
33rd Percentile:
ϕ = 23°
c = 2206 psf

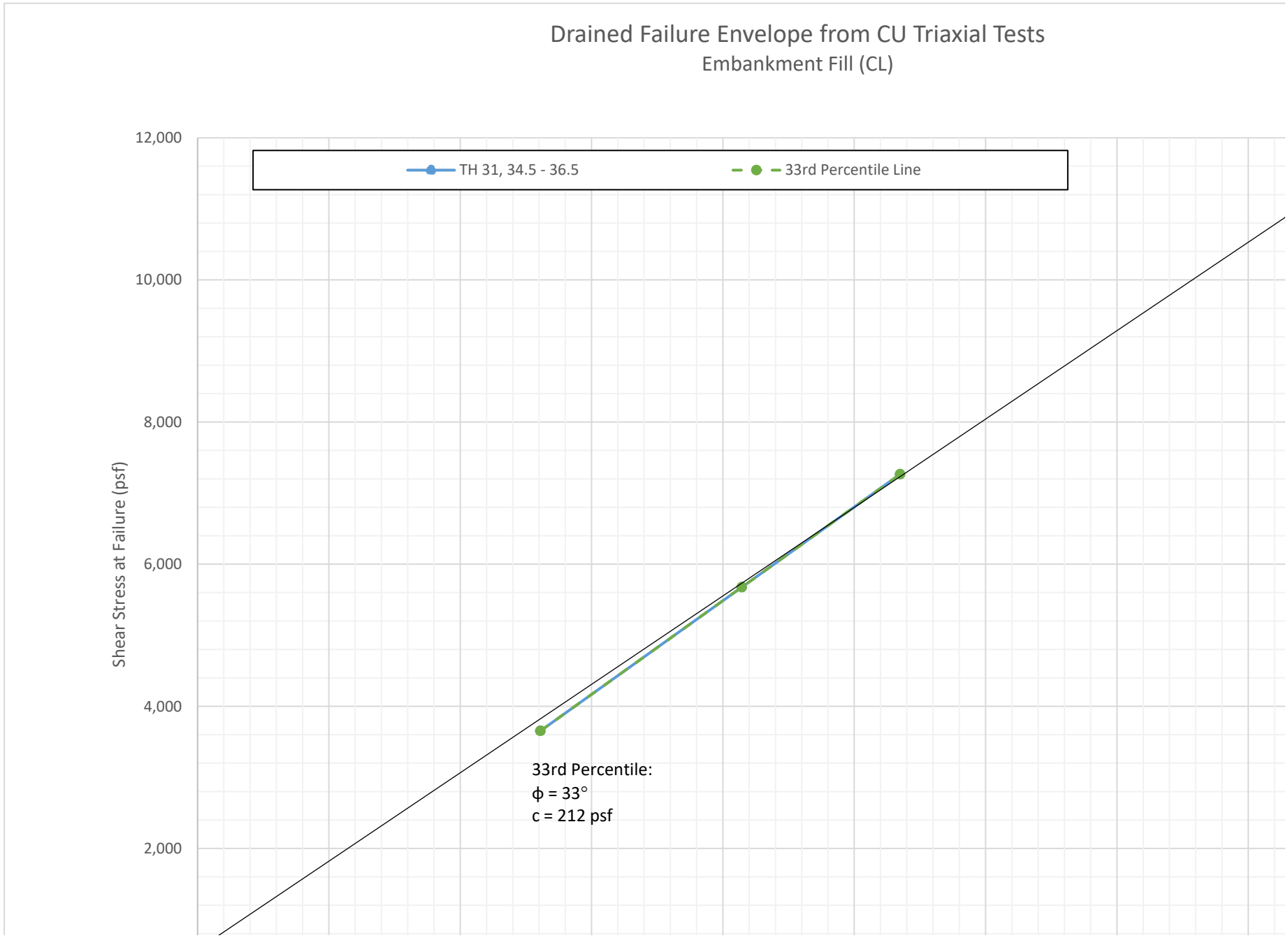

Drained Failure Envelope from CU Triaxial Tests
Embankment Fill (CL)
TH 31, 34.5 - 36.5
33rd Percentile Line
Shear Stress at Failure (psf)
12,000
10,000
8,000
6,000
4,000
2,000
33rd Percentile:
ϕ = 33°
c = 212 psf

Figure 3. Drained Failure Envelope from CU Triaxial Tests for Upper Glacial Till

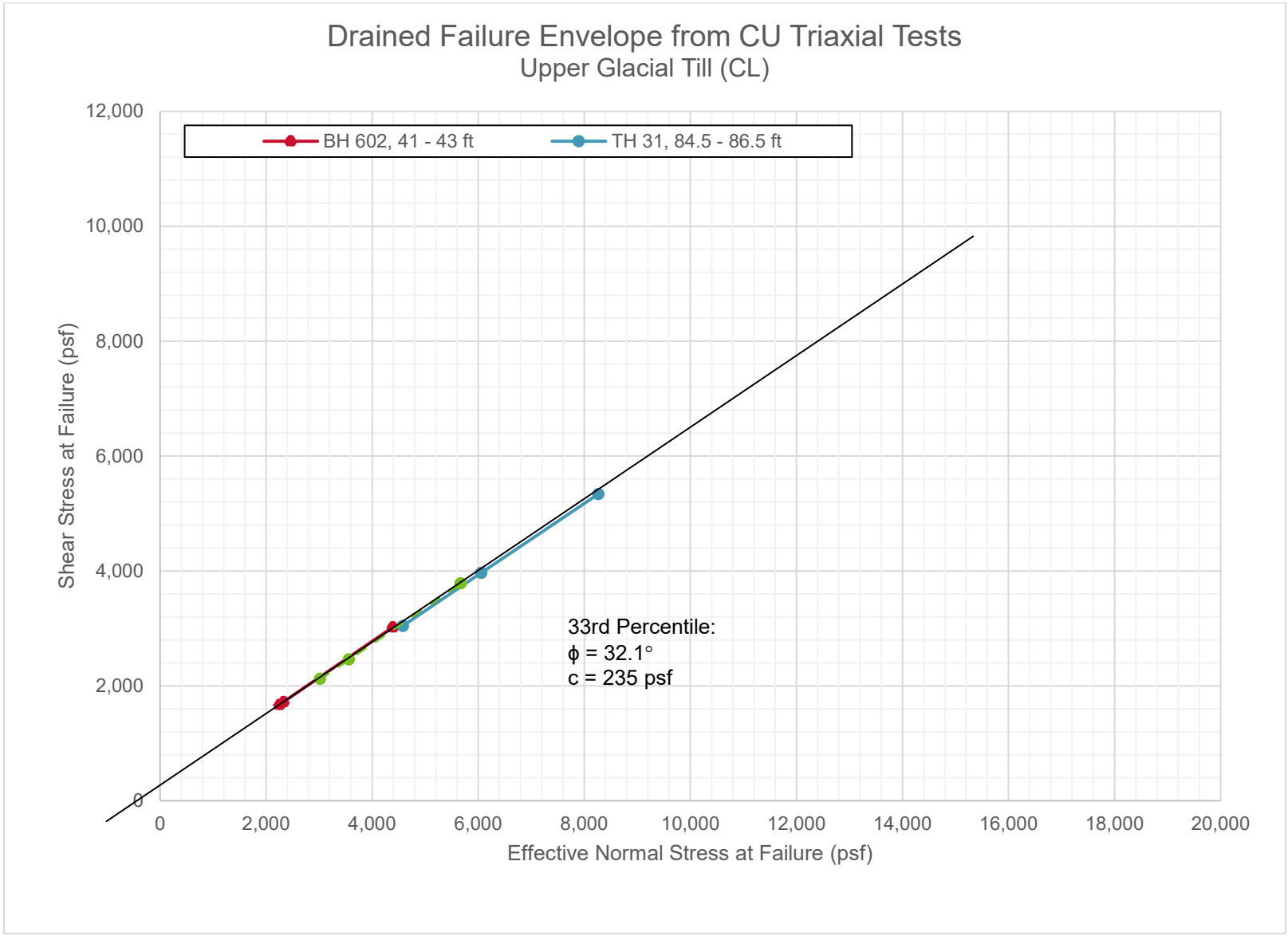


Figure 4. Undrained Failure Envelope from CU Triaxial Tests for Upper Glacial Till

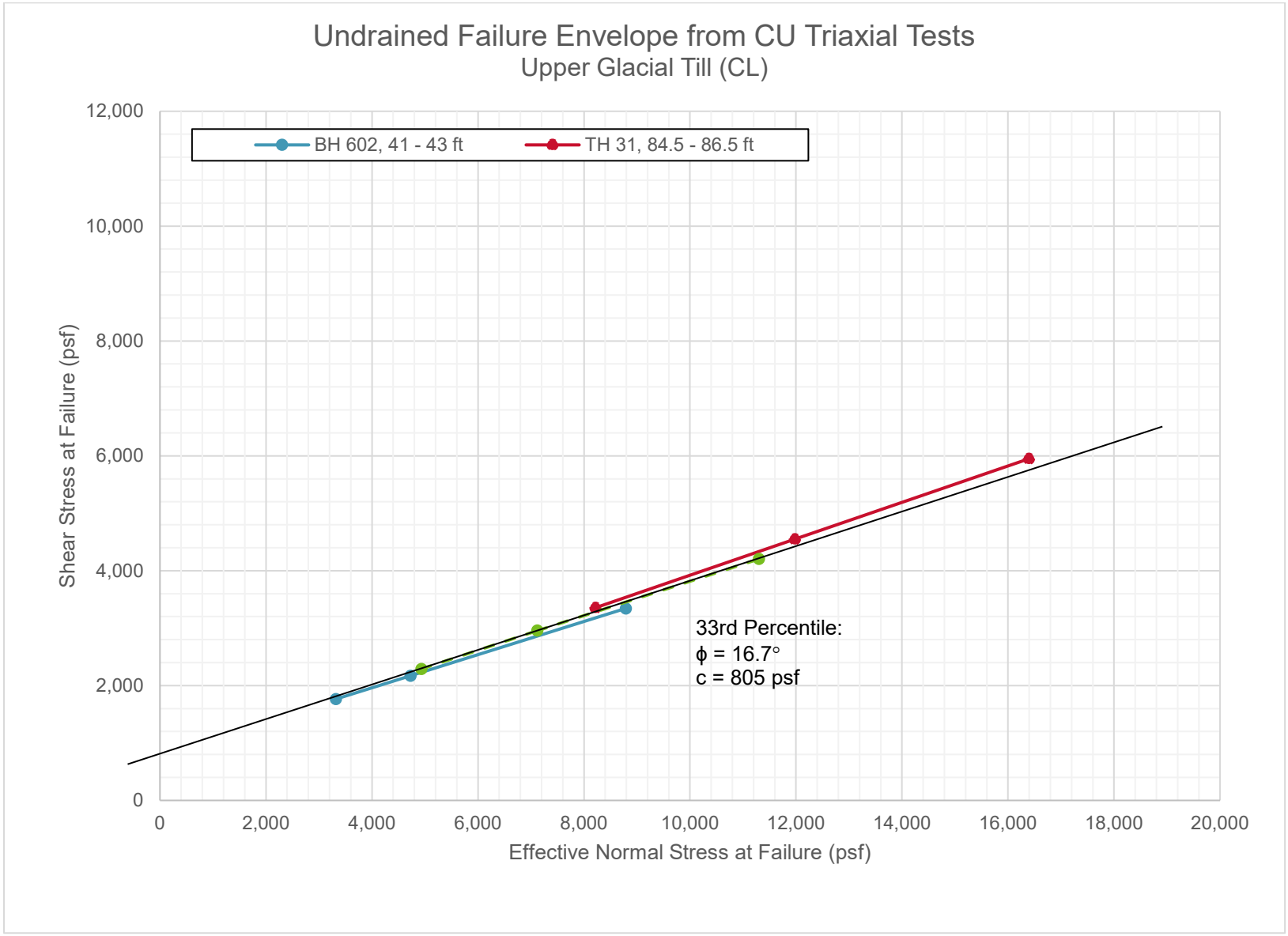


Figure 5. Drained Failure Envelope from CU Triaxial Tests for Pre-consolidated Till

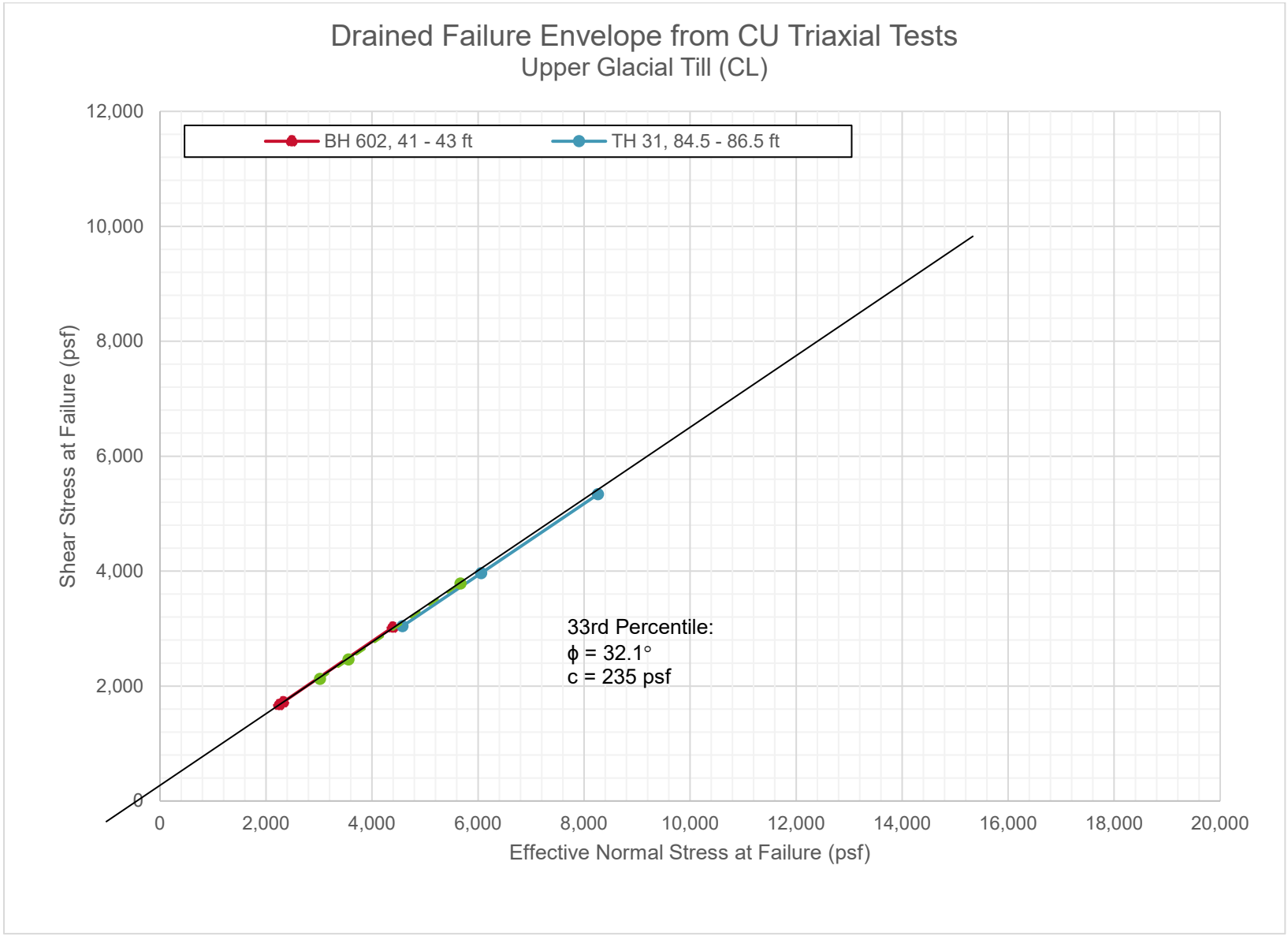


Figure 6. Undrained Failure Envelope from CU Triaxial Tests for Pre-consolidated Till

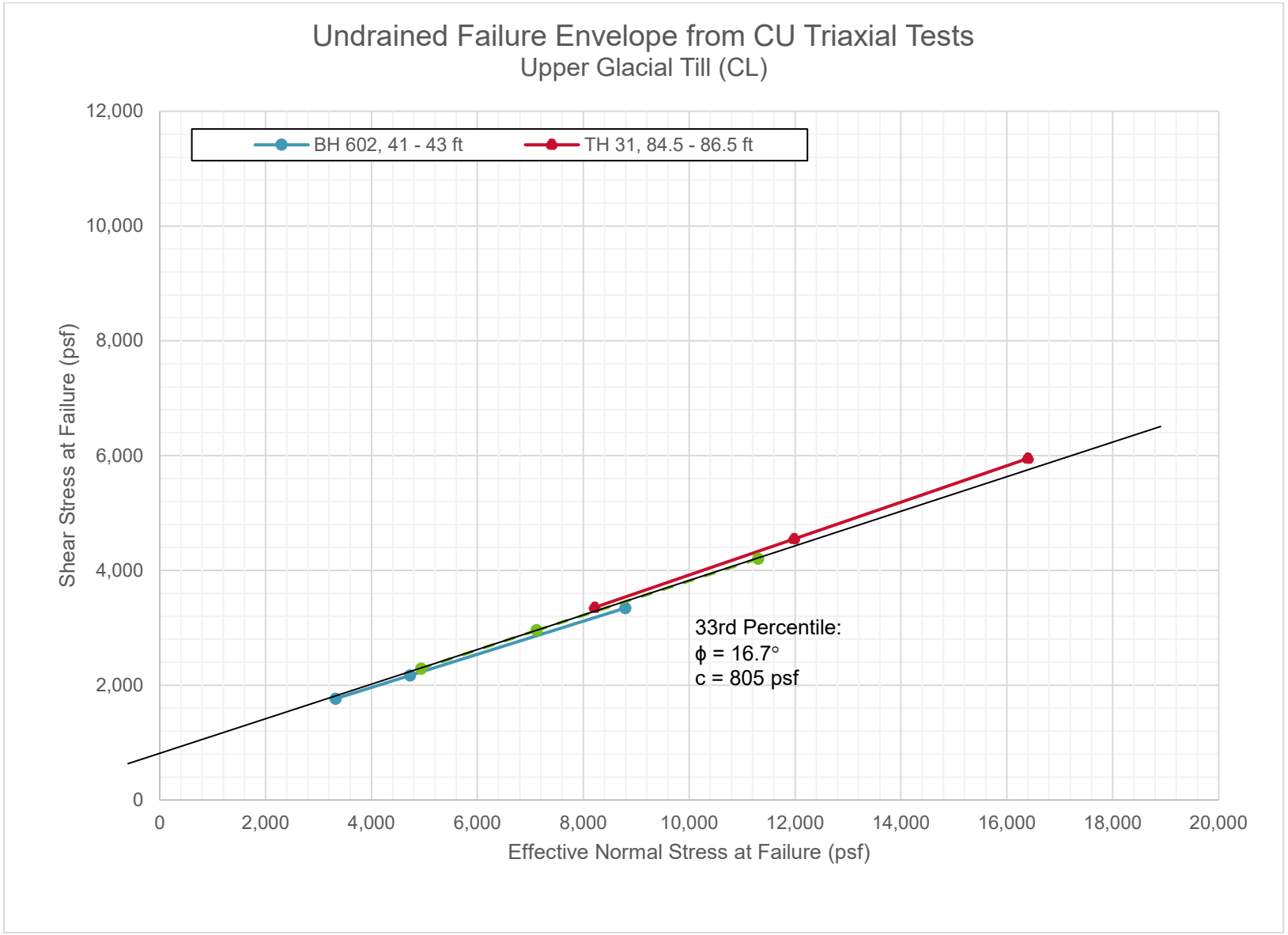


Figure 7. Composite Envelope, Embankment Fill

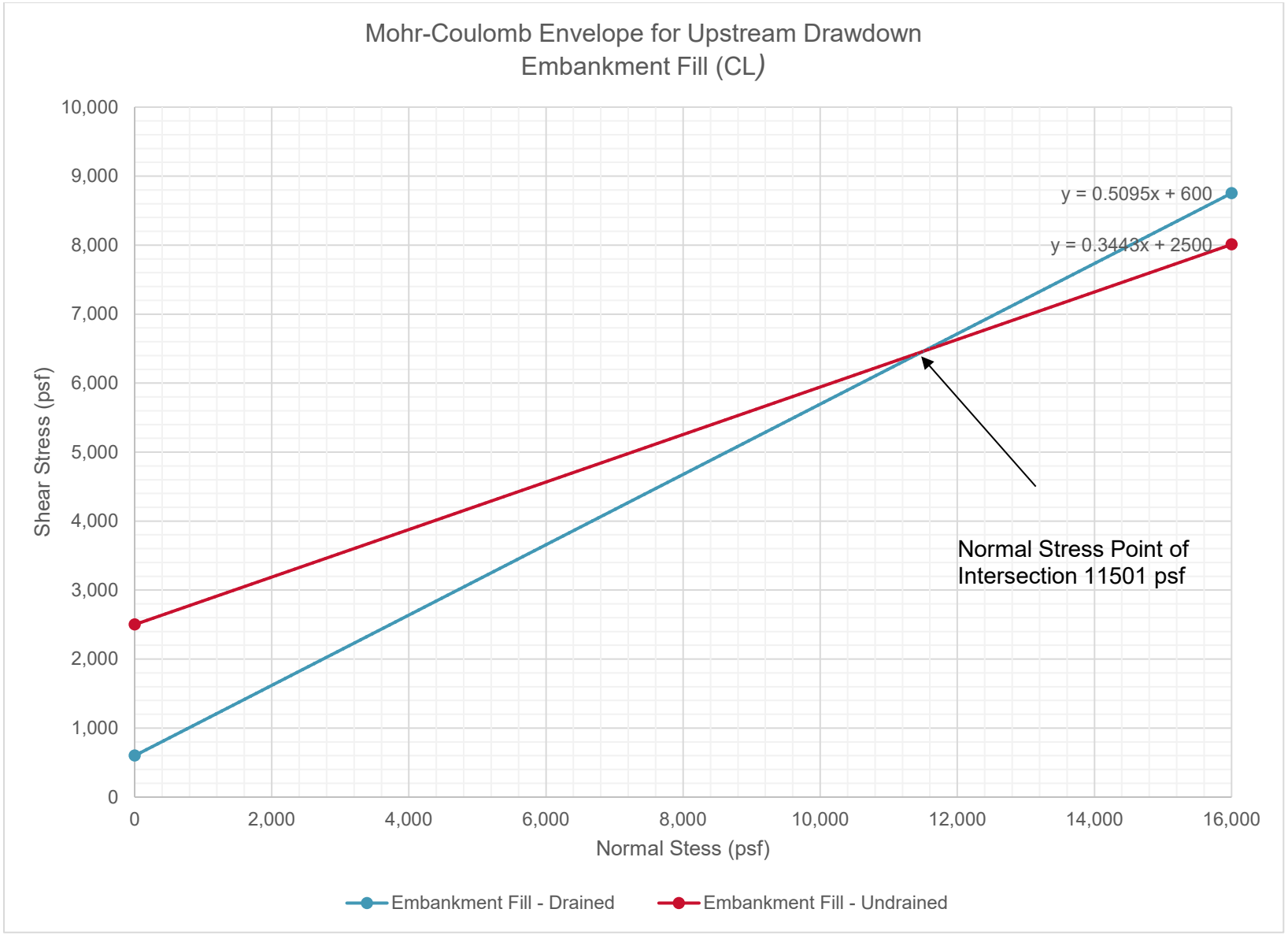


Figure 8. Composite Envelope, Upper Glacial Till

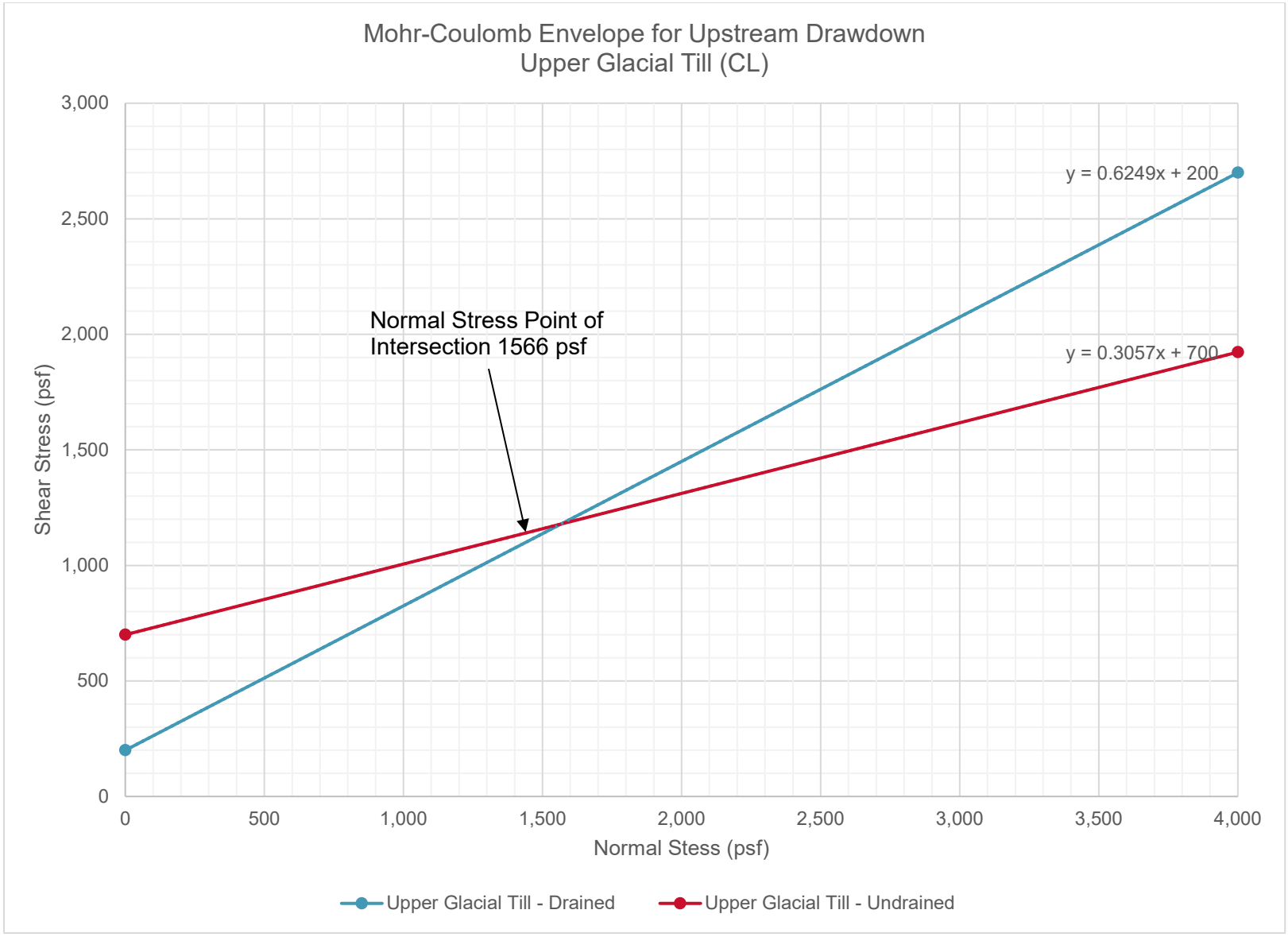
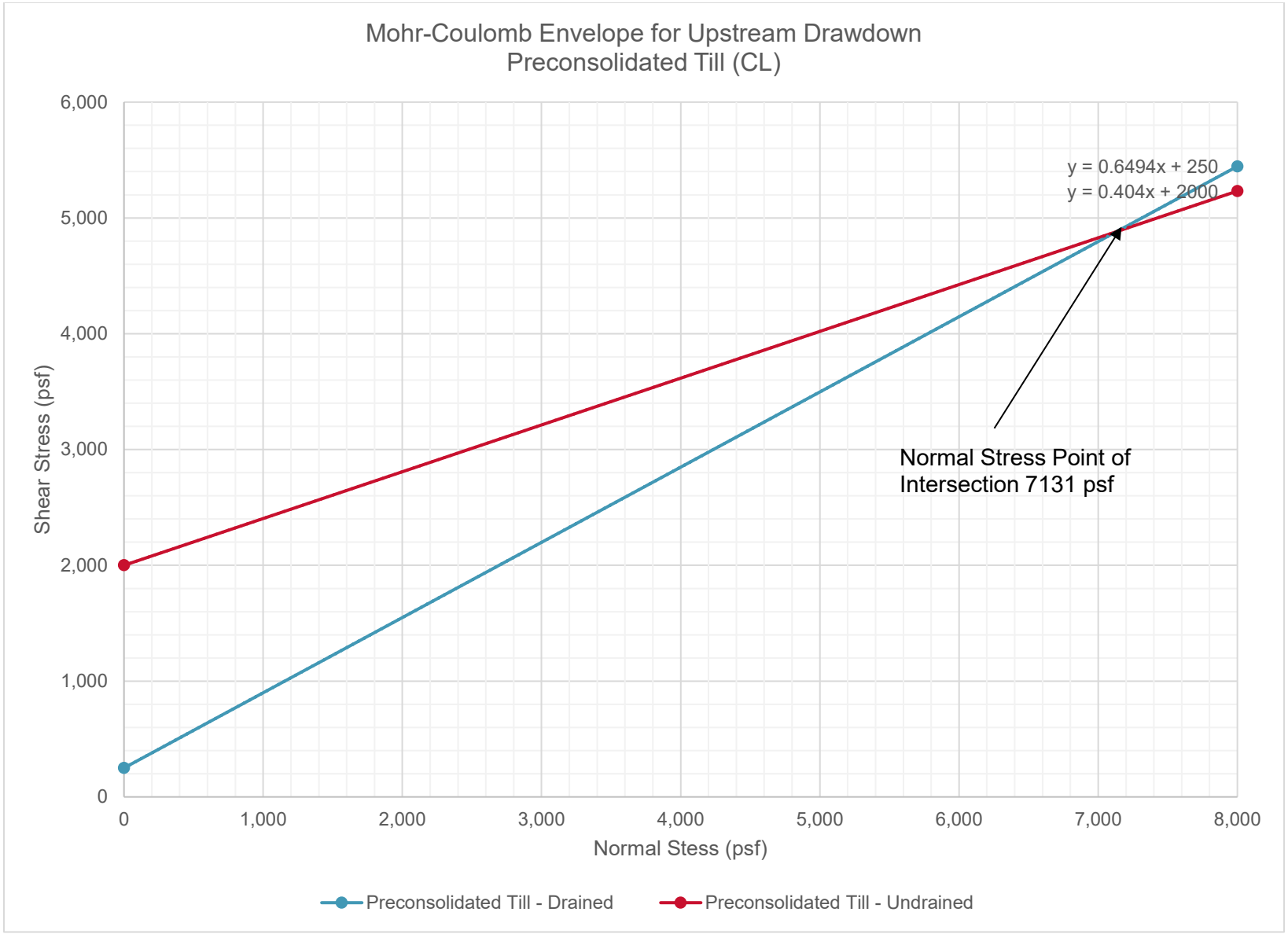


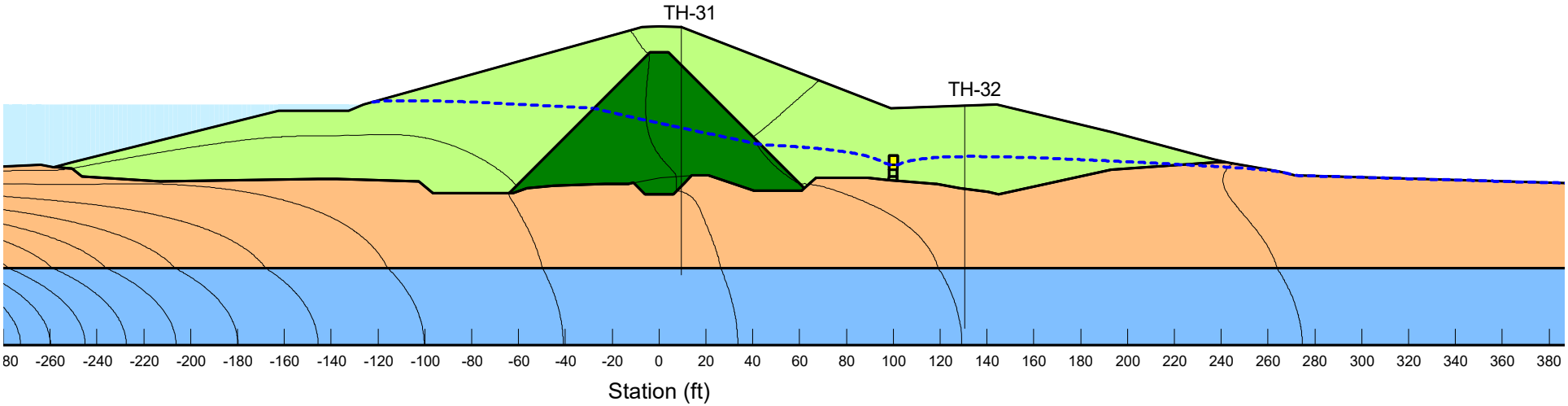
Figure 9. Composite Envelope, Pre-consolidated Till



C-4: Embankment Seepage Model Output

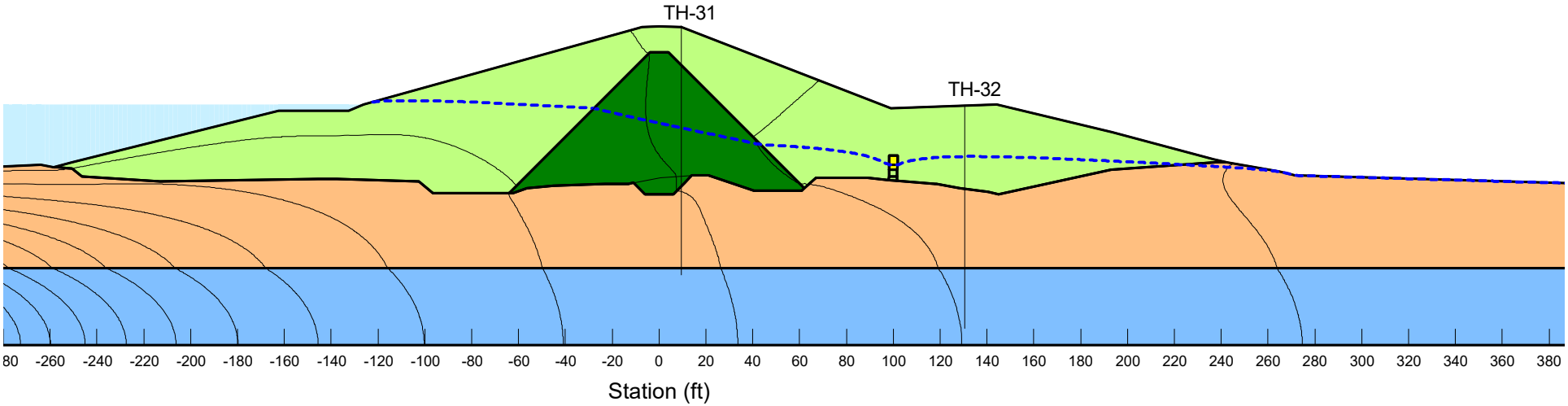
Name: Steady State Seepage (Calibration)
File Name: STA_12+00_Larimore.gsz
Kind: SEEP/W
Method: Steady-State
Date: 06/30/2021

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/psf)
	Drain Material (SP)	Saturated Only	0.116	1	0.3	4.79e-07
	Embankment Fill- Zone I	Saturated Only	5.44e-10	0.1	0.4	4.79e-07
	Embankment Fill- Zone II	Saturated Only	5.44e-09	0.33	0.4	4.79e-07
	Pre-consolidated Till	Saturated Only	4.67e-09	0.2	0.4	4.79e-07
	Upper Glacial Till	Saturated Only	2.08e-08	0.1	0.4	4.79e-07



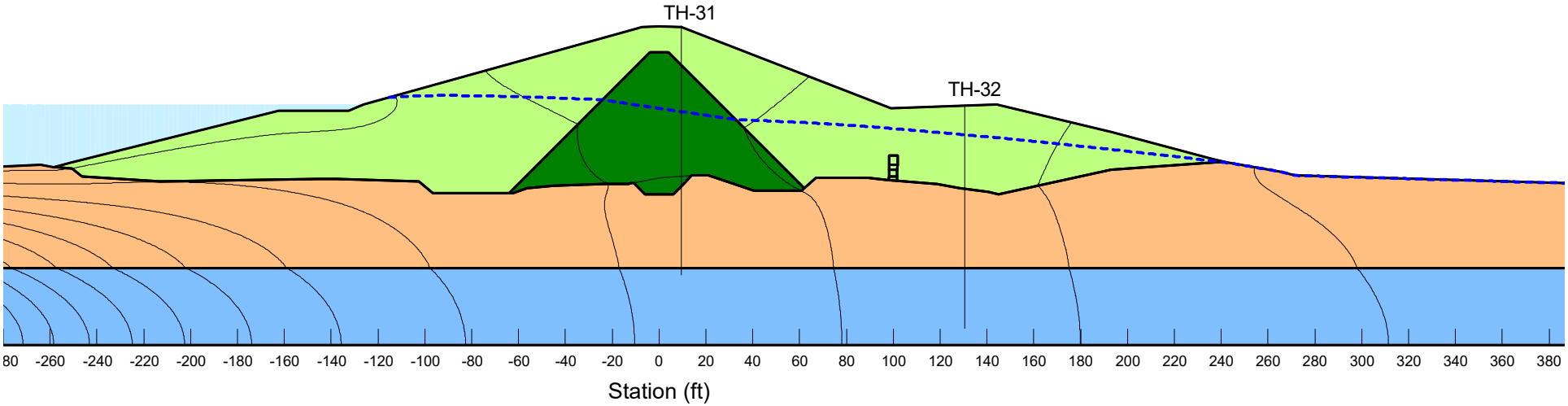
Name: 1.0 Steady State Seepage - Normal Pool (1067.7)
File Name: STA_12+00_Larimore.gsz
Kind: SEEP/W
Method: Steady-State
Date: 06/30/2021

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/psf)
	Drain Material (SP)	Saturated Only	0.116	1	0.3	4.79e-07
	Embankment Fill- Zone I	Saturated Only	5.44e-10	0.1	0.4	4.79e-07
	Embankment Fill- Zone II	Saturated Only	5.44e-09	0.33	0.4	4.79e-07
	Pre-consolidated Till	Saturated Only	4.67e-09	0.2	0.4	4.79e-07
	Upper Glacial Till	Saturated Only	2.08e-08	0.1	0.4	4.79e-07



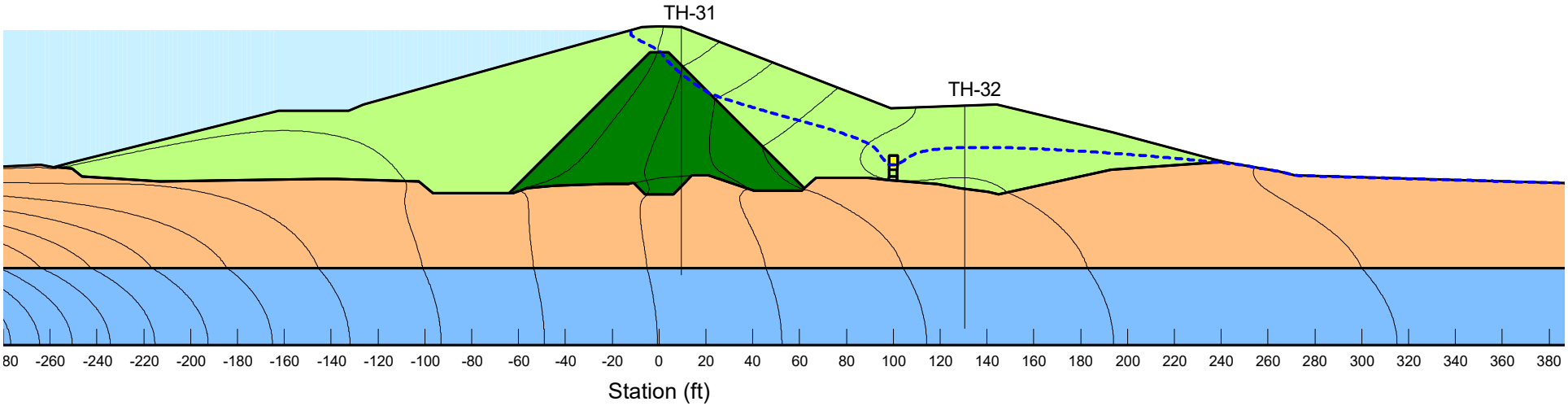
Name: 1.0 Steady State Seepage - Normal Pool (1067.7) (Clogged Drain)
File Name: STA_12+00_Larimore.gsz
Kind: SEEP/W
Method: Steady-State
Date: 06/30/2021

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/psf)
	Embankment Fill- Zone I	Saturated Only	5.44e-10	0.1	0.4	4.79e-07
	Embankment Fill- Zone II	Saturated Only	5.44e-09	0.33	0.4	4.79e-07
	Pre-consolidated Till	Saturated Only	4.67e-09	0.2	0.4	4.79e-07
	Upper Glacial Till	Saturated Only	2.08e-08	0.1	0.4	4.79e-07



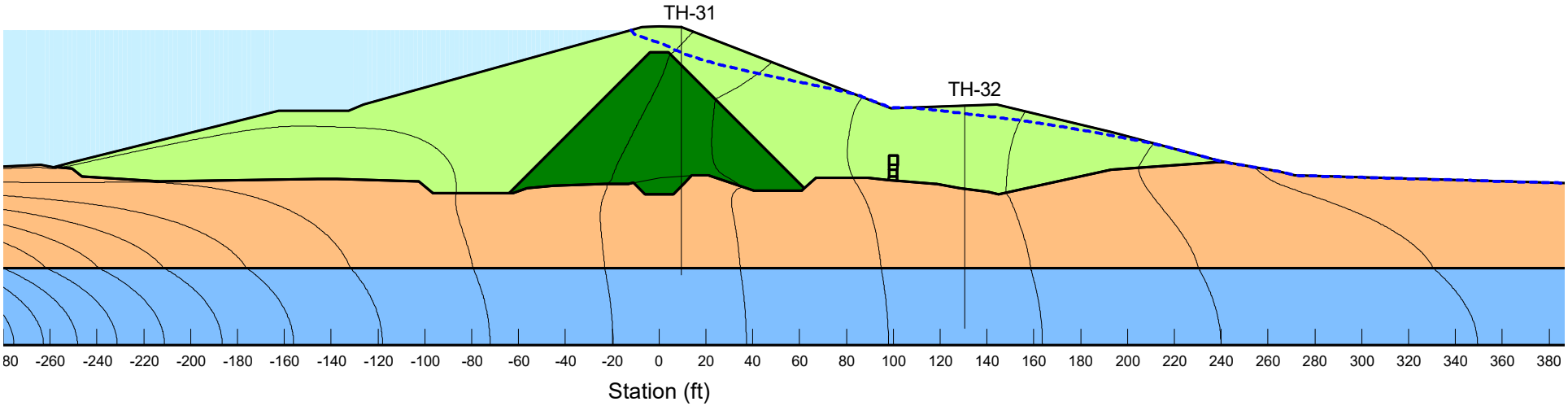
Name: 2.0 Steady State Seepage - Flood Surcharge (1099.6)
File Name: STA_12+00_Larimore.gsz
Kind: SEEP/W
Method: Steady-State
Date: 06/30/2021

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/psf)
	Drain Material (SP)	Saturated Only	0.116	1	0.3	4.79e-07
	Embankment Fill- Zone I	Saturated Only	5.44e-10	0.1	0.4	4.79e-07
	Embankment Fill- Zone II	Saturated Only	5.44e-09	0.33	0.4	4.79e-07
	Pre-consolidated Till	Saturated Only	4.67e-09	0.2	0.4	4.79e-07
	Upper Glacial Till	Saturated Only	2.08e-08	0.1	0.4	4.79e-07



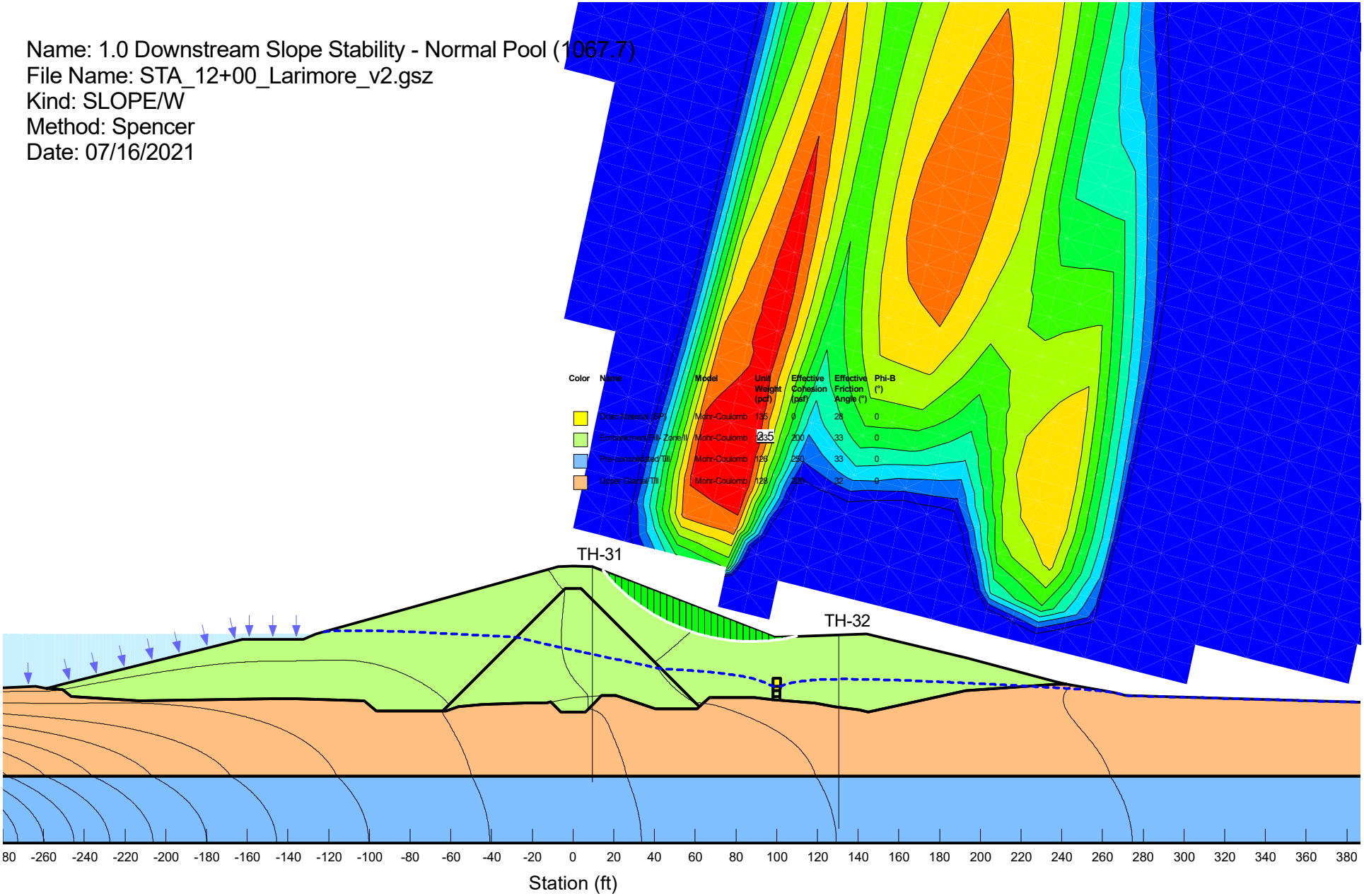
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File Name: STA_12+00_Larimore.gsz
Kind: SEEP/W
Method: Steady-State
Date: 06/30/2021

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/psf)
	Embankment Fill- Zone I	Saturated Only	5.44e-10	0.1	0.4	4.79e-07
	Embankment Fill- Zone II	Saturated Only	5.44e-09	0.33	0.4	4.79e-07
	Pre-consolidated Till	Saturated Only	4.67e-09	0.2	0.4	4.79e-07
	Upper Glacial Till	Saturated Only	2.08e-08	0.1	0.4	4.79e-07

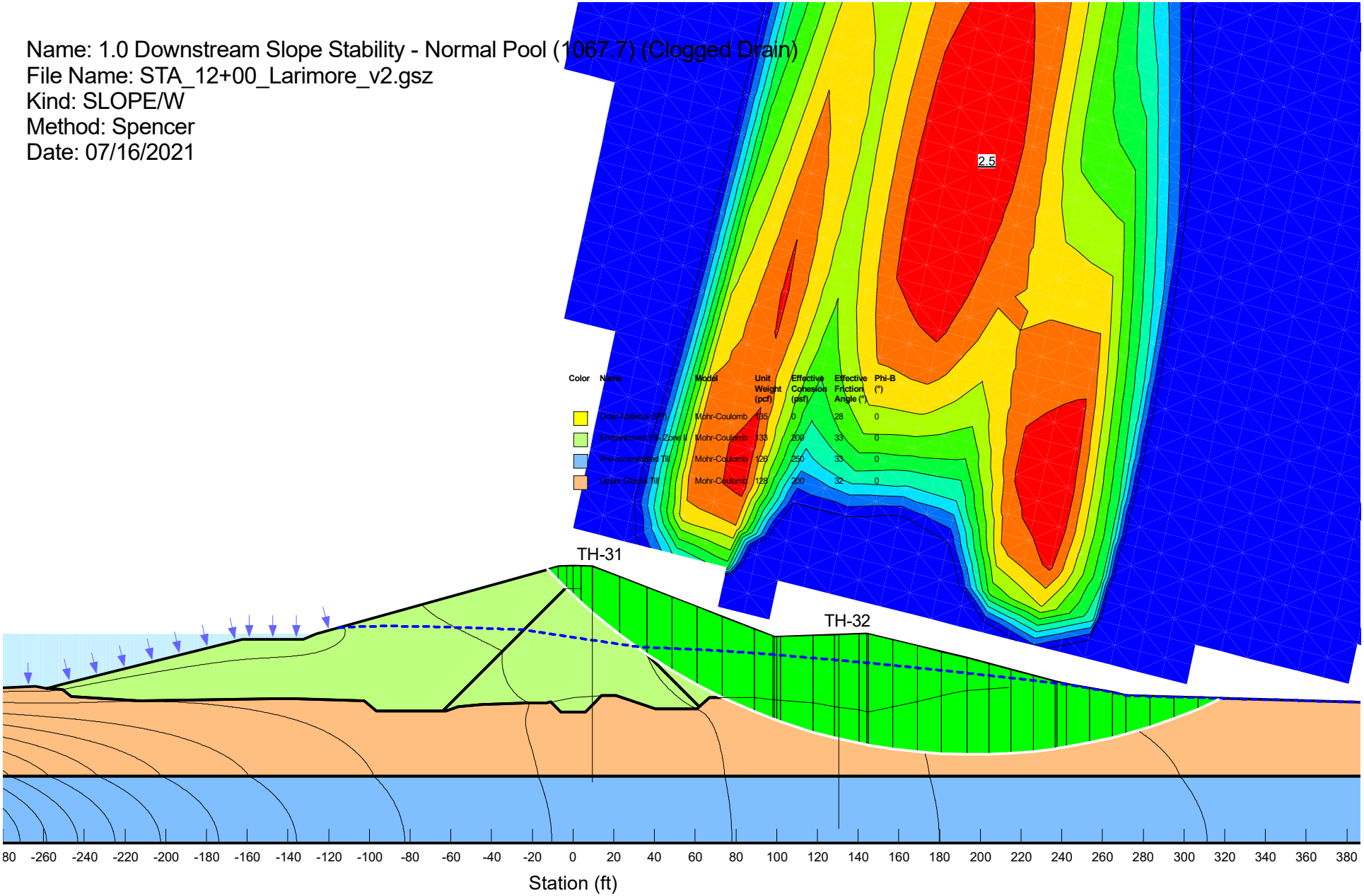


C-5: Embankment Stability Model Output

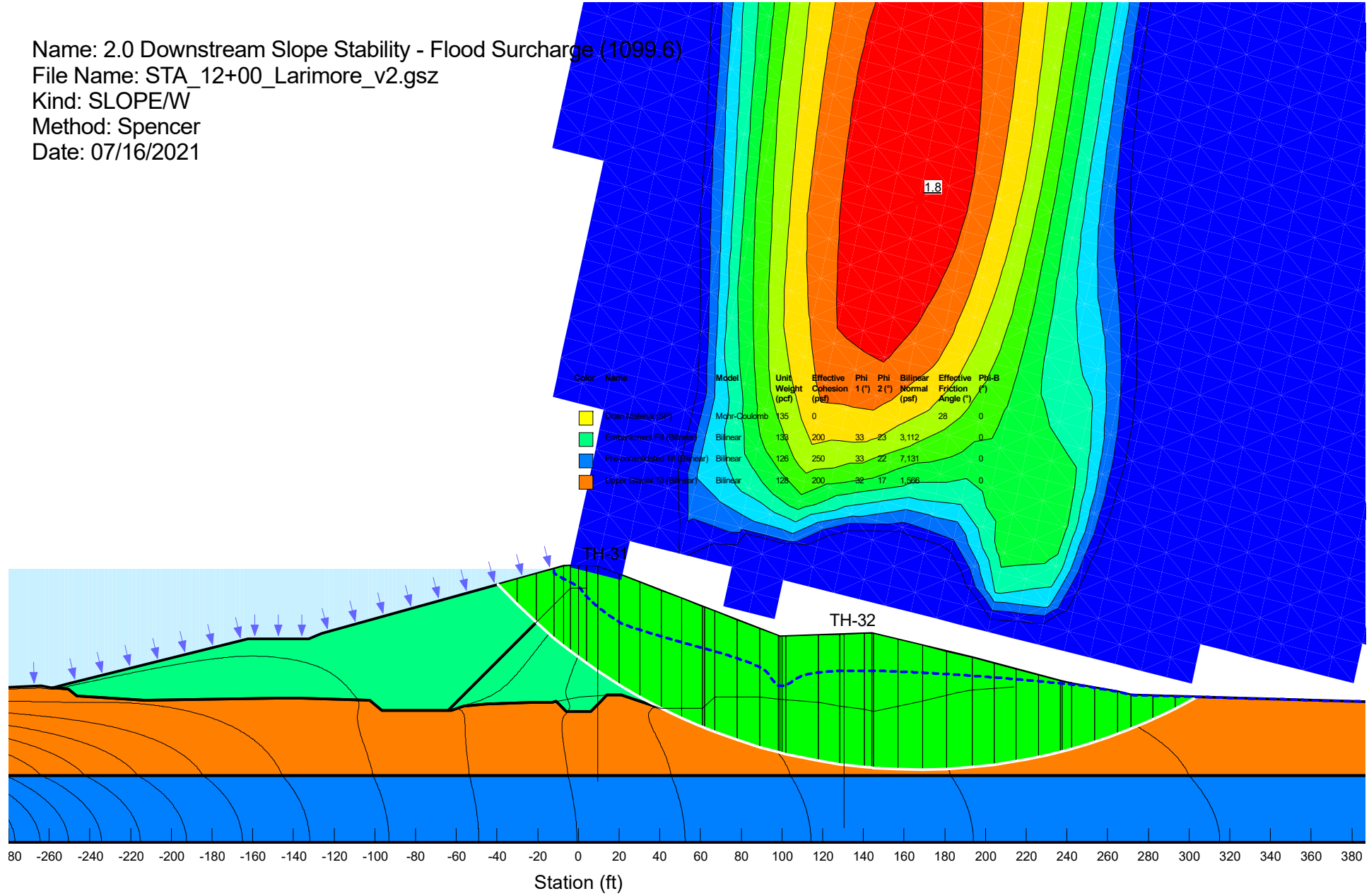
Name: 1.0 Downstream Slope Stability - Normal Pool (1067.7)
File Name: STA_12+00_Larimore_v2.gsz
Kind: SLOPE/W
Method: Spencer
Date: 07/16/2021



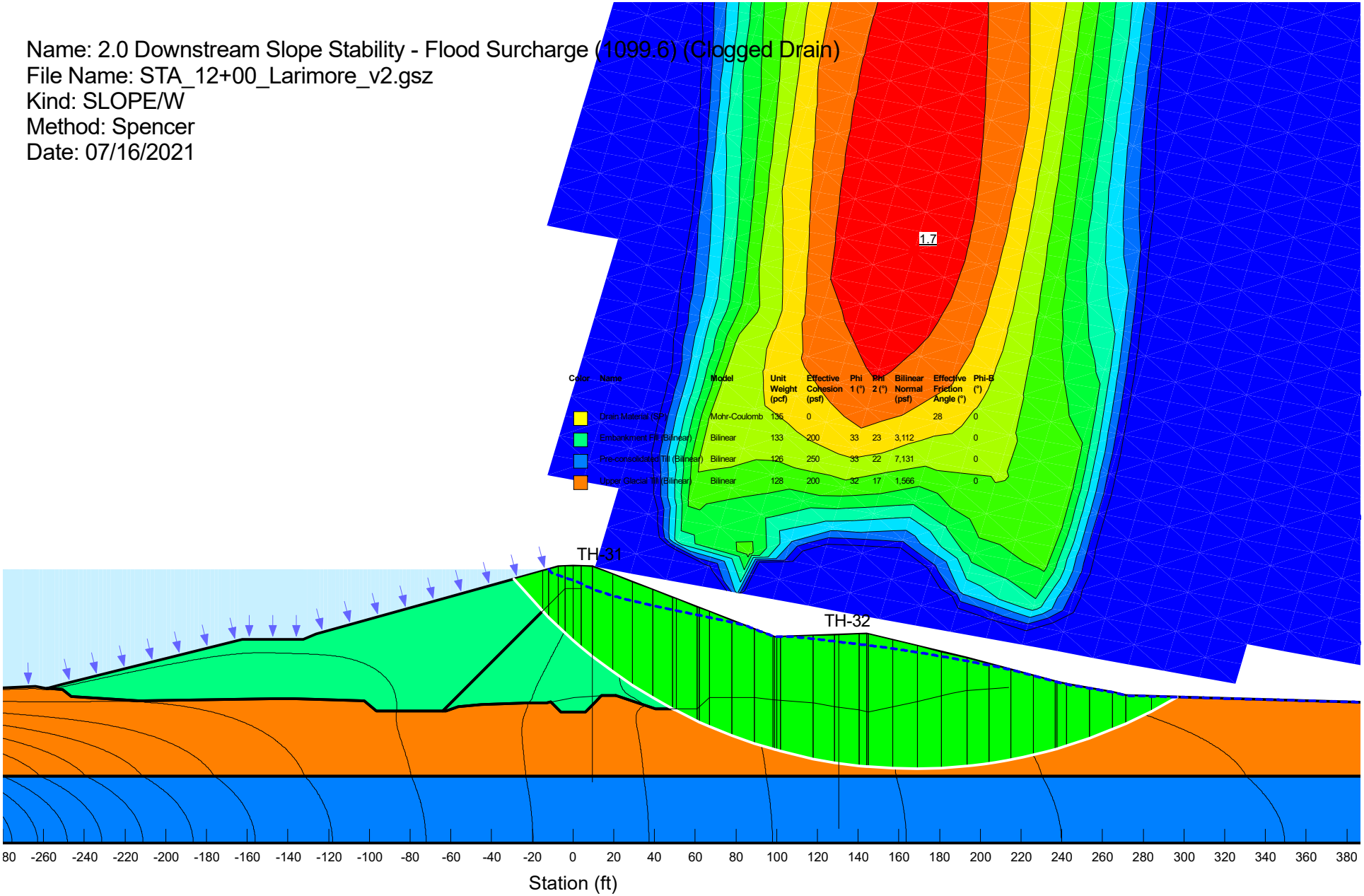
Name: 1.0 Downstream Slope Stability - Normal Pool (1067.7) (Clogged Drain)
File Name: STA_12+00_Larimore_v2.gsz
Kind: SLOPE/W
Method: Spencer
Date: 07/16/2021



Name: 2.0 Downstream Slope Stability - Flood Surcharge (1099.6)
File Name: STA_12+00_Larimore_v2.gsz
Kind: SLOPE/W
Method: Spencer
Date: 07/16/2021

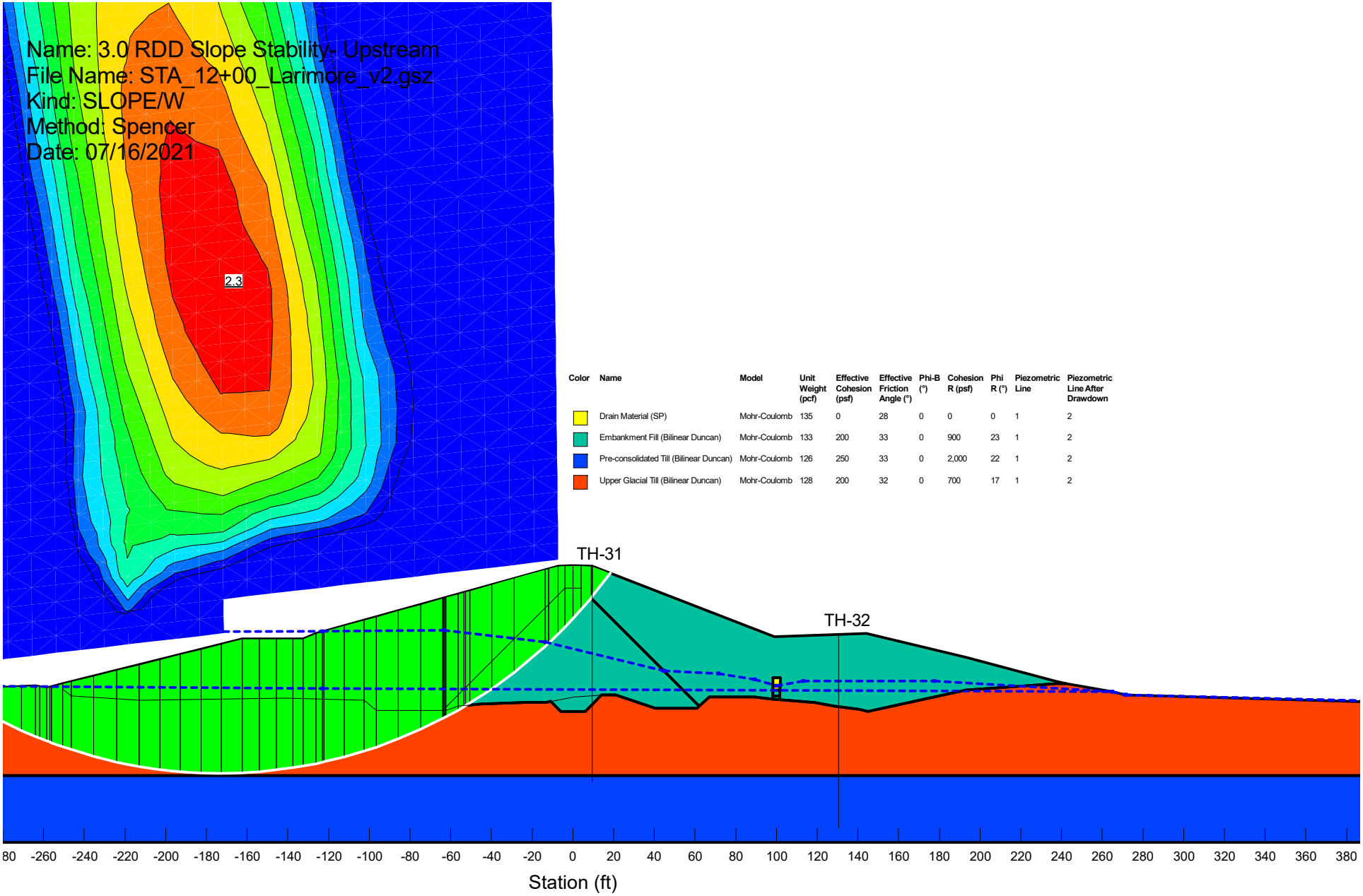


Name: 2.0 Downstream Slope Stability - Flood Surcharge (1099.6) (Clogged Drain)
File Name: STA_12+00_Larimore_v2.gsz
Kind: SLOPE/W
Method: Spencer
Date: 07/16/2021



Color	Name	Model	Unit Weight (pcf)	Effective Cohesion (psf)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (psf)	Effective Friction Angle (°)	Phi-B (°)
	Drain Material (SP)	Mohr-Coulomb	135	0				28	0
	Embankment Fill (Bilinear)	Bilinear	133	200	33	23	3,112		0
	Pre-consolidated Till (Bilinear)	Bilinear	126	250	33	22	7,131		0
	Upper Glacial Till (Bilinear)	Bilinear	128	200	32	17	1,566		0

80 -260 -240 -220 -200 -180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380



Color	Name	Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	Drain Material (SP)	Mohr-Coulomb	135	0	28	0	0	0	1	2
	Embankment Fill (Bilinear Duncan)	Mohr-Coulomb	133	200	33	0	900	23	1	2
	Pre-consolidated Till (Bilinear Duncan)	Mohr-Coulomb	126	250	33	0	2,000	22	1	2
	Upper Glacial Till (Bilinear Duncan)	Mohr-Coulomb	128	200	32	0	700	17	1	2

August 13, 2024 Addendum #1 to Larimore Dam Rehab Geotechnical Engineering Report

Geotechnical Engineering Report, prepared February 28, 2022 by HDR Engineering, Inc., evaluated the geotechnical properties of the Upper Turtle River Dam #9 (Larimore Dam), including the head cut erodibility index (Kh) calculated value of 0.035 for auxiliary spillway SITES analysis. Table 1 is screen capture from HDR Engineering, Inc. 2022. HDR Engineering, Inc. (2022) Report states that the SITES analysis will be completed at later date. However, the values presented in HDR (2022) are based on laboratory test results from all of the borings advanced in 2020 and 2021 rather than just the borings completed for the auxiliary spillway. As such, the percent clay used is higher than the soils encountered in the auxiliary spillway. The three samples sieved in borings 201, 202, and 203 have a percent clay of 28.7, 23.7, and 23.7 and percent fines of 67, 57, and 47. The Liquid Limit (LL) is 33, 32, and 34, the Plastic Limit (PL) is 19, 18, and 19, and the Plasticity Index (PI) is 14, 14, 15. Using the LL and PL for the three samples, all the samples classify as a CLAY (CL). Therefore, the values in this Table 1 from HDR Engineering, Inc. 2022 are not accurate for the soils in the auxiliary spillway.

Table 1. Auxiliary Spillway Soil Parameters from HDR Engineering, Inc. (2022)

Layer	Dry Unit Weight, Y_d (pcf)	% Clay	K_h	D_{75} (mm)	PI
Upper Glacial Till	104.13	29.48	0.035	0.17	18.12

The auxiliary spillway material properties were adjusted based on the laboratory test results on the soil obtained from the 2020 borings, boring numbers 201, 202 and 203. These results, as summarized above result in an average PI of 14, and average percent clay of 25.4 for the gray Sandy Lean Clays encountered in the auxiliary spillway. The dry density of this strata are reported as 110 pounds per cubic foot (pcf) at a depth of 16 feet below grade, 112 pcf at a depth of 21 feet below grade, and 112 31 feet below grade. A dry density of 110 pcf was used as to best reflect the density of the soils closest to the surface. The representative particle diameter, D_{75} in millimeters, is reported for the auxiliary spillway borings as 0.16 mm, 0.25 mm, and 0.30 mm resulting in an average D_{75} of 0.24 mm or approximately 0.009 inches.

During existing conditions and alternatives development by NRCS North Dakota, it was determined that the June 2000 flood should be used for calibration of the SITES model, including auxiliary spillway erosion. During the June 2000 flood event the auxiliary spillway eroded about 150 feet from the EWP drawings, and Figure 1 show the location of the erosional event within the auxiliary spillway. Figure 1 is aerial photography from Google Earth of the auxiliary prior to June 2000 flood. The aerial photo dated September 16, 1997, shows the auxiliary had trees on a hill slope. The June 2000 flood eroded at the location of trees. In 2001, an Emergency Watershed Protection (EWP) project was completed to remove the trees within the auxiliary spillway and re-grade erosion that occurred during the flood event. Figure 2 shows aerial photography from Google Earth after the EWP regrading was completed. The date of the aerial photography is June 27, 2003.



Figure 1. Google earth aerial photography dated September 16, 1997. The Pale yellow polygon represents the location of auxiliary spillway erosion and the EWP tree removal and grading repair.

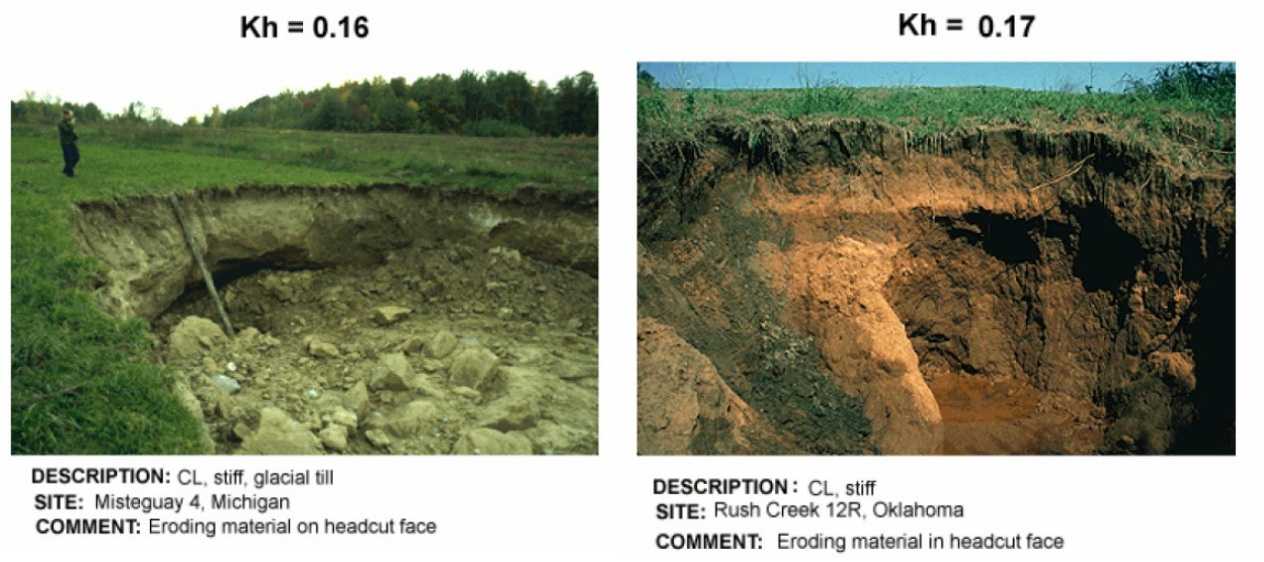


Figure 2. Google earth aerial photography dated June 27, 2003. The Pale yellow polygon represents the location of auxiliary spillway erosion and the EWP tree removal and grading repair.

The maximum point precipitation for the June 2000 event in the watershed measured 20.0 inches. The June event was used for H&H modeling calibration, and peak reservoir level results of 4.5 feet of depth over auxiliary spillway level section matched local testimonials that peak depth was between 4 and 5 feet. The head cut advance shown on EWP design drawings was ~150 feet. Adjustment of the head cut erodibility index to match ~150 feet of head cut advance, resulted in a value of 1.3. With originally

assumed head cut erodibility index of 0.035, the 2000 flood event SITES model result would breach the auxiliary spillway; therefore, the head cut erodibility index will need adjusted from the HDR Engineering, Inc. (2022) Report.

. The findings of boring logs along the auxiliary spillway are considered to be glacial till with classification of "CL" and description of "gray and dark gray medium stiff to stiff sandy lean clay, trace gravels, and occasional cobles and boulders". NRCS examples with calculated head cut erodibility value for "stiff CL" is 0.16 or 0.17.



With the adoption of head cut erodibility index of 0.16 based on geology here considered glacial till, the 2000 flood auxiliary spillway erosion is greater than ~150' noted in EWP plans; however, the 2000 flood did not fully breach the auxiliary spillway. Furthermore, the 0.16 value aligns better with NRCS guidance and still considers calibration results. Therefore, the head cut erodibility index to be used for existing conditions and alternative development is 0.16. Head cut erodibility index for in-situ soils has high sensitivity and uncertainty. The following table, Table 2, summarizes the revised soil parameters as discussed and used for SITES analyses.

Soil Classification	Dry Density (pcf)	% Clay	Plasticity Index	D_{75} (inches)	Kh
Sandy Lean Clay	110	25.4	14	0.009	0.16

Table 2. Revised Auxiliary Spillway Soil Parameters based on 2020 Borings 201, 202 and 203

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Ana Vargo, NRCS Geologist

March 3, 2025 Addendum #2 to Larimore Dam Rehab Geotechnical Engineering Report

HDR prepared a Geotechnical Engineering Report, dated February 28, 2022 in which they provided soil boring logs, presented and summarized laboratory test results, provided narratives on the approaches used for modeling seepage and slope stability for the existing condition of Upper Turtle River Dam No. 9 (Larimore Dam), and discussed the results of those analyses.

For purposes of seepage and slope stability models, HDR utilized two different approaches. For the seepage modeling, a zoned-construction of Larimore Dam as shown in as-built drawings was assumed. However, for slope stability modeling, HDR assumed the embankment was homogenous. As discussed in Section 7.3 Seepage Analyses, HDR adjusted the permeability (hydraulic conductivity) of the soils based on piezometer data from June of 2021.

Review of the soil boring logs and soil property test results – unit weight, Atterberg Limits, gradations, triaxial compression, and hydraulic conductivity tests – support that the dam was constructed with a homogeneous fill, comprised of Lean Clay with varying amounts of sand and gravel (see Table 1, following page). Additionally, blow counts from the soil boring logs do not show greater compactive effort where the anticipated impervious zone was expected. Therefore, a new seepage model was created under the assumption that the embankment is a homogeneous structure. For this model, laboratory hydraulic conductivities were used (highlighted green in Table 1) for each soil layer, and the anisotropic ratio was adjusted for each soil layer to roughly match the measured head in the vibrating wire piezometers. Boundary conditions were also set to match the total head on the reservoir/upstream side of the embankment, a drainage condition on the downstream side, and an estimated groundwater head downstream from the dam.

Upon reviewing available laboratory test results, HDR omitted triaxial test results for boring TH-32 at a depth of 19.5-21.5 feet for slope stability analyses. New slope stability analyses were created from the seepage models discussed above, using the lower effective angle of internal friction, phi, of 24 degrees. One of the slope stability models was created with cohesion set to zero, and another with a reduced effective cohesion of 200 psf. The new slope stability analyses show the existing conditions are stable for all slope stability criteria.

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USDA

United States Department of Agriculture

Table 1: Summary of Soil Laboratory Test Results from borings 601, 602, TH-31, TH-32

Boring	Depth	USCS	Dry unit wt (pcf)	MC	Unit wt (pcf)	LL-PL-PI	%Fines	Hyd Con (cm/s)	Hyd Con (ft/s)	c (psf)	phi (deg)	c' (psf)	phi' (deg)
Embankment Fill (as defined by HDR)													
601	22-24	CLwS	112.4	14.8	129.0	33-18-15	75.4	5.03E-08	1.65E-09				
	24.5-26	CLwS		25.8		33-19-14	53						
	29.5-31	S(CL)		15.4		36-19-17	62						
	49.5-51	S(CL)		14.6		32-18-14	66						
TH-31	34.5-36.5	S(CL)wG	112.2	17.43	131.8	29-19-10	61.9			2205.6	23.2	211.6	33.4
	54.5-56	S(CL)	108.0	16.8	126.1	31-19-12	60.7	5.10E-08	1.67E-09				
TH-32	9.5-11.5	S(CL)wG	113.0	16.1	131.2	29-20-9	68.6	3.30E-08	1.08E-09				
	19.5-21.5	CLwS	103.9	21	125.8	37-24-13	77.5			4904.8	16.4	2410	24.3
Upper Glacial Till (as defined by HDR)													
602	41-43	CL	93.8	22.2	114.6	48-21-27	96	3.52E-07	1.15E-08	807	16.1	257	32.2
TH-31	74.5-76.5	CL	97.6	26.8	123.8	40-21-19	87.3	6.70E-08	2.20E-09				
Pre-consolidated Till (as defined by HDR)													
601	86-88	CLwS		25.2		44-21-23	77						
	104.5-106	S(CL)		21.6		40-26-14	67.9						
602	79.5-81	S(CL)		24.3		45-25-20	55						
	94.5-96	S(CL)		25.1		48-19-29	62						
TH-31	84.5-86.5	CL	99.4	25.3	124.5	39-21-18	84.1			748.4	17.6	197.2	31.9
TH-32	69.5-71	CL&G		14.7			62.7						
	74.5-76.5	CL&G	99.5	24.67	124.0	45-24-21				2798.8	22.1	208	33.2
	79.5-81	CL&G	96.4	25.1	120.6	44-26-18		4.70E-08	1.54E-09				
	84.5-86	CL&G	95.1	26.67	120.5	45-26-19	62.3						