Preliminary Foundation Investigation and Design Report

High Fill Embankments and Deep Cut Sections
Highway 35/115 Interchange Improvements, Orono, Ontario
MTO Agreement No. 4016-E-0034

Submitted to:

WSP Canada Group Ltd.
610 Chartwell Road, Suite 300
Oakville, Ontario
L6J 4A5 Canada

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada
+1 905 567 4444

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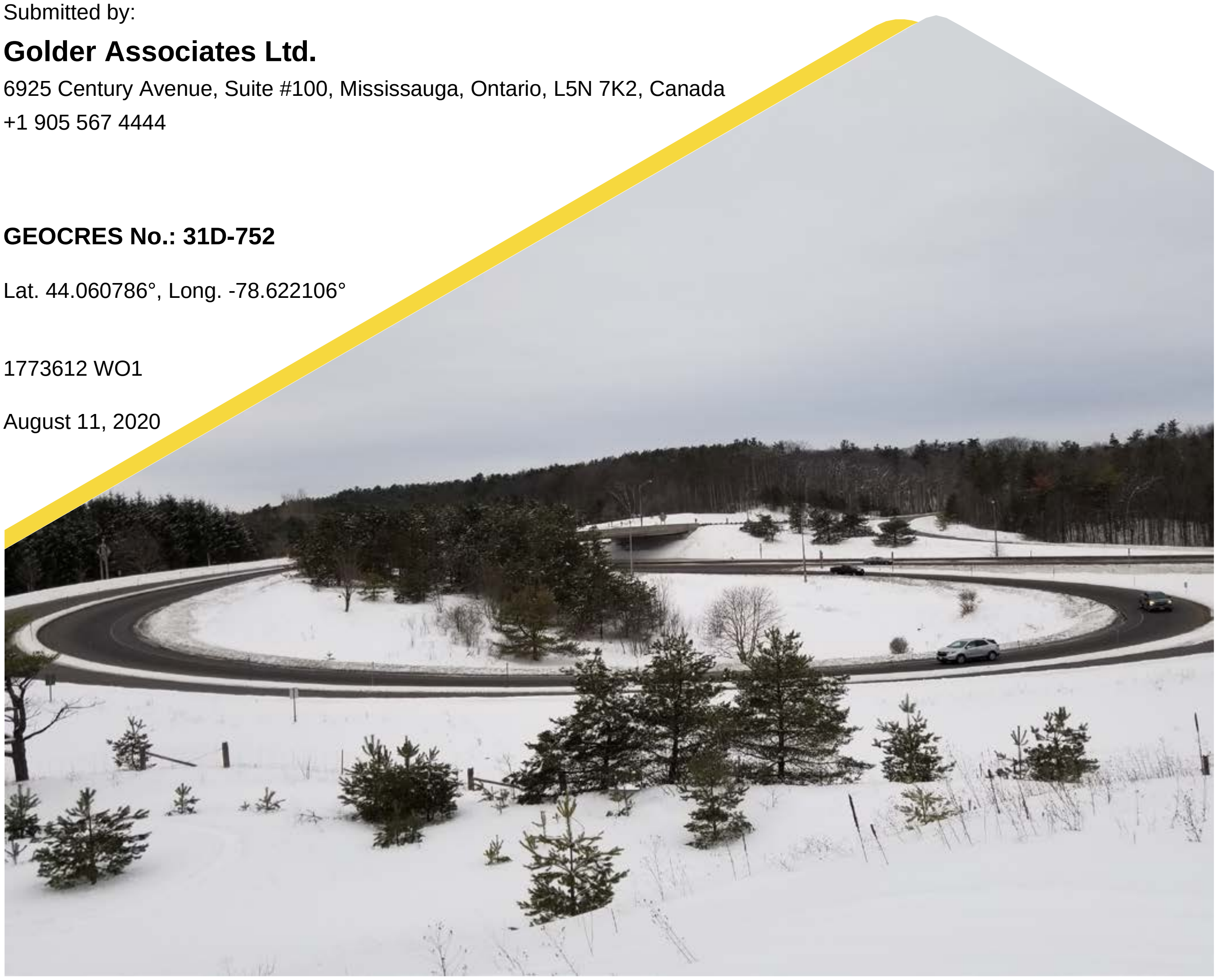

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PRELIMINARY FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the preliminary design of high fill embankments and deep cuts sections associated with the proposed Highway 35/115 interchange improvements in Orono, Ontario, located approximately as shown on the Key Plan on Drawing 1.

This report addresses the results of the foundation investigation carried out at five high fill embankment and three deep cut areas for ramps adjacent to the highway alignment that will be constructed as part of the interchange improvements. The purpose of this investigation is to establish the subsurface soil and groundwater conditions in the general vicinity of the high fill embankment and deep cut areas by borehole drilling, in situ testing and geotechnical laboratory testing on selected soil samples.

The scope of work for the preliminary foundation engineering services are outlined in Golder's revised scope letter for Work Order #1, dated February 3, 2020, which forms part of the Consultant's Assignment for the Eastern Region Large Value Retainer under Agreement No. 4016-E-0034.

2.0 SITE DESCRIPTION

The existing Highway 35/115 interchange and associated new highway ramps are located approximately 12 km east of Regional Road 57 and approximately 1.5 km south of Boundary Road in Orono, Ontario. For the purposes of this report, Highway 35 is taken as oriented in a north-south direction and Highway 35/115 is taken as oriented in an east-west direction. The natural terrain is rolling to undulating, with the existing ground surface varying from approximately Elevation 330 m to 354 m in the vicinity of the interchange. Residential land is present in the southeast, northeast and northwest quadrants of the interchange and an undeveloped vegetated area is present in the southwest quadrant.

Based on the design drawings for the proposed Highway 35/115 interchange provided by WSP, new ramps will be constructed in the vicinity of the interchange as part of the proposed interchange improvements. The high fill and deep cut areas are located along the proposed interchange ramps. The approximate locations, extent and depths/heights of the high fill and deep cut sections are shown on Drawings 1 and 2.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between February 5 and February 12, 2020. During this time a total of ten boreholes (designated as Boreholes HF1-1 to HF1-4, HF2-1, HF4-1, HF5-1, DC1-1, DC2-1 and DC3-1) were advanced at the site. The boreholes were advanced at the locations shown on Drawing 1 to provide broad coverage of the high fill embankment and deep cut section areas.

Boreholes HF1-1 to HF1-4, HF4-1, DC1-1 and DC3-1 were drilled using 210 mm outer diameter hollow stem augers, and Boreholes HF2-1, HF5-1 and DC2-1 were drilled using 150 mm outer diameter solid stem augers, using a limited access D-25 track-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) [1].

[1] ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

The groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. The boreholes were backfilled in accordance with Ontario Regulation 903 (i.e., with cuttings and/or bentonite) and the ground surface was restored to near original condition as practical.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the sampling and in situ testing operations, logged the boreholes and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Whitby for further visual review and geotechnical laboratory testing on selected samples, consisting of natural moisture content, Atterberg limits and grain size distribution conducted in accordance with MTO and/or ASTM Standards as applicable.

The borehole locations and elevations were surveyed by WSP using survey equipment with a horizontal and vertical accuracy of 0.05 m. The locations given on the borehole records and shown on Drawings 1 and 2 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, including geographic (latitude/longitude) coordinates, ground surface elevations and borehole depths are summarized below.

Borehole No.	MTM NAD83		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
HF1-1	4,880,753.4 (44.063394)	375,268.9 (-78.620382)	331.9	9.8
HF1-2	4,880,685.0 (44.062783)	375,215.5 (-78.621058)	331.1	6.6
HF1-3	4,880,659.5 (44.062563)	375,116.2 (-78.622301)	335.8	6.7
HF1-4	4,880,691.7 (44.062863)	375,010.0 (-78.623623)	346.4	9.8
HF2-1	4,880,544.0 (44.061510)	375,266.2 (-78.620444)	329.6	8.1
HF4-1	4,880,277.7 (44.059121)	375,179.7 (-78.621560)	336.6	9.3
HF5-1	4,880,317.5 (44.059473)	375,251.1 (-78.620663)	336.0	8.2
DC1-1	4,880,413.4 (44.060323)	375,379.5 (-78.619047)	346.4	12.4
DC2-1	4,880,397.0 (44.060181)	375,331.0 (-78.619655)	346.2	8.2
DC3-1	4,880,494.4 (44.061084)	375,052.9 (-78.623113)	348.6	12.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The Highway 35/115 interchange lies at the transition between the physiographic regions known as the South Slope and the Oak Ridges Moraine, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)[2].

The Oak Ridges Moraine is a ridge of land that runs roughly parallel to and north of Lake Ontario, extending from the Niagara Escarpment near Caledon in the west to the Trent River in the east. It ranges from 1 km to 15 km in width, and has an undulating topography made of up gravel, sand and some silt. The Moraine is an important source of groundwater from rainwater percolation into this ridge of generally porous soils, and it forms the watershed divide between Lake Ontario and Lake Simcoe. The South Slope lies south of and at the base of the Oak Ridges Moraine. Drainage in the area of this site is generally toward the south; streams and intermittent drainage channels have generally cut steep valleys and gulley's into the soil, the majority of which have a north-south orientation.

The overburden soils in these physiographic regions consist of thick glacial till and glaciofluvial deposits: the till deposits are present in both kame and ground moraines as well as drumlins, and the glaciofluvial deposits occur as coarse-grained outwash and ice contact sediments deposited by meltwater flowing off the ice front into the former glacial Lake Iroquois, which occupied the area to the south during the last glacial recession. The bedrock in this area consists of the Trenton and Black River formations, which include limestone, dolomite, and shale. The surface of the bedrock is generally more than 50 m below natural ground surface in this area.

4.2 General Overview of Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced during the current investigation, together with the results of the laboratory tests and in-situ testing carried out, are presented on the borehole records and geotechnical laboratory test sheets in Appendices A and B, respectively.

The stratigraphic boundaries shown on the borehole records and on the stratigraphic profiles on Drawings 1 and 2 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change; moreover, the interpreted stratigraphy shown on Drawings 1 and 2 represents a simplification of the subsurface conditions. Furthermore, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the site consist of surficial layers of topsoil and fill, underlain by extensive non-cohesive silty sand and sand deposits. Localized interlayers or lenses of clayey silt, silty clay, sandy silt or gravel were also encountered at the site. A more detailed description of the subsurface conditions encountered at the site is provided in the following sub-sections.

4.2.1 Topsoil

An approximately 30 mm to 250 mm thick layer of topsoil was encountered from ground surface in all boreholes except Borehole HF5-1.

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[2] Chapman, L.J. and Putnam, D,F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

4.2.2 Silty Sand (SM) (Fill)

A 0.7 m to 1.5 m thick non-cohesive deposit of fill, comprised of silty sand, was encountered in Boreholes HF1-2, HF1-3 and HF5-1 at ground surface or beneath the topsoil between Elevations 336.0 m and 331.1 m. Organic inclusions were observed in Borehole HF1-2 and extend to a depth of 0.7 m below ground surface (mbgs). A 25 mm layer of crushed gravel was observed at ground surface in Borehole HF5-1.

The SPT "N"-values measured within the fill deposit range from 5 blows to 39 blows per 0.3 m of penetration, indicating a loose to dense compactness condition. The higher "N"-value of 39 blows may be attributed to frozen ground conditions. Grain size distribution analysis was carried out on one sample of the silty sand fill and the result is presented on Figure B-1 in Appendix B. The in-situ moisture content measured on one sample of the silty sand fill deposit is about 10 per cent.

4.2.3 Gravelly Sand (SW-SM) to Sand (SW/SP-SM)

A 2.8 m and 5.6 m thick deposit of non-cohesive gravelly sand to sand was encountered in Boreholes DC1-1 and DC3-1 beneath the topsoil at Elevations 346.3 m and 348.6 m, respectively. Rootlets were observed in the upper portion of the deposit in Borehole DC1-1. Cobbles and boulders are inferred to be present within the gravelly sand to sand deposit based on auger grinding observed during drilling in Borehole DC3-1.

The SPT "N"-values measured within the gravelly sand to sand range from 3 blows to 60 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition.

Grain size distribution analysis was carried out on four samples of the gravelly sand to sand deposit and the results are presented on Figure B-2 in Appendix B. The natural moisture content measured on samples of the gravelly sand to sand range from about 1 per cent to 7 per cent.

4.2.4 Gravel (GW-GM)

A 1.9 m thick deposit of non-cohesive gravel and sand was encountered in Borehole HF1-4 interlaid within the silty sand to sand deposit at Elevation 342.7 m. Cobbles and boulders are inferred to be present within the gravelly sand to sand deposit based on auger grinding observed during drilling.

Two SPT "N"-values measured within the gravel are 39 and 45 blows per 0.3 m of penetration, indicating a dense compactness condition. Grain size distribution analysis was carried out on one sample of the gravel deposit and the results are presented on Figure B-3 in Appendix B. The natural moisture content measured on one sample gravel and sand deposit is about 1 per cent.

4.2.5 Silty Sand (SM) to Sand (SP/SP-SM)

A non-cohesive deposit of silty sand to sand was encountered in all boreholes at the site. The surface of the deposit was encountered between Elevations 346.3 m and 329.5 m, and the deposit is between 3.8 m to 9.7 m in thickness, with its base at approximately Elevation 338.0 m to 321.5 m. Rootlets and organic inclusions were observed in the upper 0.7 m to 1.5 m of the deposit in Boreholes DC2-1, HF1-4, HF2-1 and HF4-1. Cobbles and boulders are inferred to be present within the silty sand to sand deposit based on auger grinding observed during drilling in Borehole HF2-1. Several boreholes were terminated in this deposit.

The SPT "N"-values measured within the silty sand to sand deposit range from 2 blows per 0.3 m of penetration to greater than 100 blows per 0.05 m of penetration, indicating a very loose to very dense, but typically compact to very dense compactness condition. The lower "N"-values were typically encountered in the upper portions of the deposit.

Grain size distribution testing carried out on twenty-three samples of this deposit are shown on Figures B-4A, B-4B, B-4C and B-4D in Appendix B. Atterberg limits tests were carried out on ten samples of the deposit and returned non-plastic results. The natural water content measured on selected samples of this deposit range from about 2 per cent to 21 per cent.

4.2.6 Clayey Silt (CL) to Silty Clay (CI)

A cohesive deposit of clayey silt to silty clay was encountered in Boreholes DC1-1, HF1-2 and HF4-1 beneath the silty sand or sandy silt deposits. The surface of the clayey silt to silty clay deposit was encountered between Elevations 336.2 m and 326.6 m. The clayey silt to silty clay deposit was not fully penetrated in Borehole HF1-2 after exploring the deposit for a depth of 2.1 m.

The SPT “N”-values measured within the clayey silt to silty clay deposit are 4 blows per 0.3 m of penetration in Borehole HF4-1 where this deposit was encountered near ground surface, indicating a firm consistency. In Boreholes DC1-1 and HF1-2, the SPT “N”-values are between 43 blows to 95 blows per 0.3 m of penetration where the deposit was near the base of the borehole, indicating a hard consistency.

Grain size distribution analysis was carried out on two samples of the clayey silt to silty clay deposit and the results are presented on Figure B-5 in Appendix B. Atterberg limits tests was carried out on two samples of the deposit. The results, presented on Figure B-6 in Appendix B, indicate plastic limits of about 19 per cent and 17 per cent, liquid limits of about 27 per cent and 36 per cent and plasticity indices of about 8 per cent and 19 per cent. The natural moisture content measured on two samples of the deposit are about 21 per cent and 29 per cent.

4.2.7 Silt to Sandy Silt (ML)

Approximately two 1.5 m thick layers of non-cohesive silt to sandy silt were encountered in Borehole DC1-1 beneath the gravelly sand to sand and silty sand at Elevations 343.5 m and 337.7 m, respectively. In Borehole HF4-1, the sandy silt was encountered at Elevation 328.4 m below the silty sand deposit. Cobbles and boulders are inferred to be present within the gravelly sand to sand deposit based on auger grinding observed during drilling in Borehole HF4-1. The silt deposit was not fully penetrated in Borehole HF4-1 after exploring the deposit for a depth of 1.1 m.

The SPT “N”-values measured within the silt to sandy silt deposit range from 18 blows per 0.3 m of penetration to greater than 100 blows per 0.13 m of penetration, indicating a compact to very dense compactness condition.

Grain size distribution analysis was carried out on two samples of the silt deposit and the results are presented on Figure B-7 in Appendix B. Atterberg limits tests were carried out on two samples of the deposit and returned a non-plastic result. The natural moisture content measured on samples of the silt to sandy silt range from about 7 per cent to 17 per cent.

4.3 Groundwater Conditions

The overburden samples obtained from the boreholes during the current investigation were generally moist. The groundwater conditions in the open boreholes were measured upon completion of drilling operations as shown on the borehole records in Appendix A and in the table below.

Borehole No.	Ground Surface Elevation (m)	Depth to Groundwater (m)	Estimated Groundwater Elevation (m)	Date
HF1-1	331.9	Dry	Below 322.2	February 5, 2020
HF1-2	331.1	Dry	Below 324.5 (but potential for groundwater perched above clayey silt)	February 6, 2020
HF1-3	335.8	Dry	Below 329.1	February 6, 2020
HF1-4	346.4	Dry	Below 336.7	February 6, 2020
HF2-1	329.6	Borehole caved to 6.1	Near or below 323.5	February 11, 2020
HF4-1	336.6	Dry	Below 327.3	February 10, 2020
HF5-1	336.0	Borehole caved to 6.4	Below 329.6	February 10, 2020
DC1-1	346.4	Borehole caved to 7.9	Near or below 338.5	February 11, 2020
DC2-1	346.2	Dry	Below 338.0	February 12, 2020
DC3-1	348.6	Dry	Below 335.8	February 7, 2020

As the water levels were measured during or immediately after completion of drilling, they may not represent the stabilized groundwater level at the site. However, as the soils were generally relatively coarse-grained, the groundwater level at the site is anticipated to be below the elevations shown in the table above. The groundwater level will be subject to seasonal fluctuations and should be expected to be higher during the spring season or during and following periods of heavy precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Mo'oud Nasr, P.Eng., a geotechnical engineer with Golder. The technical aspects were reviewed by Ms. Sarah Poot, P.Eng., Associate of Golder and the Senior/Lead Foundation Engineer for this project. Ms. Lisa Coyne, P.Eng., a Principal and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Signature Page

Golder Associates Ltd.

Mo’oud Nasr, P.Eng.
Geotechnical Engineer

Sarah E. M. Poot, P.Eng.
Associate, Senior Geotechnical Engineer

Lisa Coyne, P. Eng.
Principal, MTO Designated Foundations Contact

MJB/MN/SEMP/LCC/ljv

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
HIGH FILL EMBANKMENTS AND DEEP CUT SECTIONS
HIGHWAY 35/115 INTERCHANGE IMPROVEMENTS, ORONO, ONTARIO
MTO AGREEMENT NO. 4016-E-0034

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the high fill embankments and deep cut sections associated with the proposed Highway 35/115 interchange improvements in Orono, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation at this site. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the requirements for stability and settlement of the high fill embankments, and stability of the deep cut sections.

The discussions and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and their designers, and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. Contractors must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

Based on the profiles and cross-sections for the project, improvements to the Highway 35/115 interchange will involve construction of high fill embankments between approximately 4.5 m and 7.5 m in height and deep cut sections between approximately 4.5 m and 8.5 m deep.

6.2 Consequence and Degree of Understanding Factors

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* CAN/CSA S6-19 (*CHBDC (2019))* and its *Commentary*, the proposed embankments are expected to carry medium to high traffic volumes and their performance may have potential impacts on other transportation corridors; hence, the proposed high fill embankment works have been assessed as having a “typical consequence level” associated with exceeding limits states design.

In addition, given the project-specific foundation investigation carried out across the site (although preliminary, the conditions encountered in the boreholes are reasonably consistent), in comparison to the degree of site understanding in Section 6.5 of *CHBDC (2019)*, the level of confidence for design is considered to be a “typical degree of site and prediction model understanding”. Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, Ψ, and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs}, from Tables 6.1 and 6.2 of the *CHBDC (2019)* have been used for the design.

For a “typical degree of understanding”, *CHBDC (2019)* requires a minimum Factor of Safety of 1.3 for short-term/temporary condition and 1.5 for the long-term/permanent condition for global stability of embankments. In accordance with MTO’s Materials Engineering Research Office (MERO) Provincial Engineering Memorandum 2020-01, dated March 23, 2020, a geotechnical resistance factor of 1.0 has been applied for preliminary assessment of the settlement of high fill embankments.

6.3 Seismic Design

6.3.1 Seismic Hazard Assessment and Liquefaction Potential

A preliminary screening for liquefaction potential was undertaken in consideration of the predominantly granular materials present, age of the deposits, relative density/consistency, groundwater depth and the historically low regional seismicity. The screening indicates a very low potential for seismic liquefaction, particularly due to the depth of groundwater, and as such a detailed evaluation of the liquefaction potential of the foundation soils and the impact of seismic forces on embankment stability is not considered warranted at this site.

6.3.2 Seismic Site Classification

The subsurface conditions for seismic site characterization were assessed based on the results of the field investigation and in situ testing. Based on the energy corrected average penetration resistance, $\overline{N}_{60}$ below the founding level, the site may be classified as Site Class D in accordance with Table 4.1 of the 2019 CHBDC, in the absence of any geophysical testing.

The 2019 CHBDC states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 5th generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015.

6.4 High Fill Embankments

High fill embankments are proposed in five segments in three general areas associated with the planned interchange improvements. The following table provides further details on the proposed high fill embankments.

Location	High Fill ID	Extent	Approximate Horizontal Distance (m)	Approximate Maximum Height (m)	Relevant Boreholes
Ramp E-N	HF-1	Sta. 10+040 to 10+360	320	8.5	HF1-1, HF1-2, HF1-3, HF1-4
Ramp S-N	HF-2	Sta. 10+110 to 10+180	70	7.5	HF2-1
Wilcox Road	HF-3	Sta. 0+100 to 0+200	100	7.0	HF4-1
Highway 35	HF-4	Sta. 9+800 to 9+860	60	7.1	HF5-1
Highway 35 S-Wilcox Road	HF-5	Sta. 10+400 to 10+450	50	6.7	HF5-1

6.4.1 Global Stability

6.4.1.1 Methodology

The preliminary stability analyses have been completed for representative critical sections based on the highest embankment section proposed within each high fill embankment area and the worst-case soil conditions. The embankment geometry is based on the typical cross sections provided by WSP. The embankment side slopes have been analyzed for a maximum (i.e., steepest) side slope orientation of 2 horizontal to 1 vertical (2H:1V) with the incorporation of mid-height benches where embankments are equal to or greater than 8 m in height (as in High Fill Area 1, where the embankments will be up to 8.5 m in height). It is assumed for analysis that topsoil and other organic/unsuitable fill material will be removed from the footprint of the embankments during foundation preparation.

Two-dimensional limit equilibrium global slope stability analyses were carried out for the proposed embankments using the commercially available program Slide 2018, developed by RocScience Inc., employing the Morgenstern-Price method of analysis. The Factors of Safety of numerous potential failure surfaces were computed to establish the minimum Factor of Safety. The Factor of Safety is equal to the inverse of the product of the consequence factor, ψ, and the geotechnical resistance factor ϕ_{gu} (i.e. FoS = $1/(\psi * \phi_{gu})$). Accordingly, minimum Factors of Safety of 1.3 and 1.5 have been used for the design of the proposed embankments for the short-term (temporary) and long-term (permanent) conditions, as per Table 6.2 of *CHBDC (2019)* and the MERO Provincial Engineering Memorandum 2020-01.

6.4.1.2 Parameter Selection

For the cohesive deposits, total stress parameters were employed in the analyses of the short-term, undrained conditions (i.e., temporary conditions). The total stress parameters (i.e., average mobilized undrained shear strength – s_u) for the cohesive soils were estimated from correlations with the SPT results and other laboratory test data (i.e., natural water content, liquid limit etc.), where appropriate.

Effective stress parameters were also assigned to the cohesive and non-cohesive deposits to evaluate the stability based on long-term, drained conditions (i.e., permanent conditions). The effective stress parameters (i.e., effective friction angle (φ')) for the cohesive deposits were estimated from empirical correlations based on the plasticity indices and the results were adjusted using engineering judgement based on precedent experience in similar soil conditions. For the non-cohesive soils present at this site, the effective stress parameters were estimated from empirical correlations based on the results of the corrected Standard Penetration Test (SPT) “N”-values. The correlations proposed by Peck et al (1974) and U.S. Navy (1986) were employed and the results were adjusted by engineering judgment based on precedent experience in similar soil conditions.

The simplified stratigraphy together with the preliminary geotechnical parameters for the different soil types encountered in the proposed high fill embankment areas are summarized below. For the purpose of the preliminary global stability analyses, the groundwater level was assumed to be below the base of the boreholes, based on the observations during the field investigation program.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m^3)	Effective Friction Angle, φ' (°)	Cohesion, c’ (kPa)	Undrained Shear Strength, s_u (kPa)
New Embankment Fill – Assumed to be Select Subgrade Material (SSM) or Engineered Earth Fill	20	32	---	---
Very loose to loose SILTY SAND (SM)	20	30	---	---
Compact to very dense SILTY SAND (SM)	20	33	---	---
Firm SILTY CLAY (CI) (at HF-3 area)	19	31	---	75
Hard CLAYEY SILT (CL)	20	32	---	400
Very dense Sandy SILT (ML)	20	33	---	---

6.4.1.3 Analysis Results

The preliminary global stability analyses indicate that during and immediately after completion of construction, high fill embankments up to 8.5 m high with side slope orientation of 2 horizontal to 1 vertical (2H:1V) for the various soil conditions at the borehole locations will have a Factor of Safety of greater than 1.3 in the short-term/temporary (undrained) conditions for deep-seated, global failure surfaces that would impact the operation of the roadway. For most high fill embankment areas, a minimum factor of safety of 1.5 is achieved in the long-term/permanent (drained) condition; some surficial instability and slumping may occur depending on the material selected for use in embankment construction, although this is not anticipated to affect the ramp pavements and shoulders.

However, the presence of near-surface layers of very loose to loose silty sand and firm silty clay in Borehole HF4-1 in High Fill Area 3, at the Wilcox Road connection to Highway 35, requires a flatter side slope of 2.5H:1V to achieve a Factor of Safety of greater than 1.5 for global stability in long-term/permanent conditions, at this preliminary stage. It is recommended that further investigation and testing be completed during detailed design to confirm and refine the geotechnical parameters for the soils in this area, and to confirm whether flatter side slopes are indeed required for this section of high fill embankment. If property constraints or other geometric constraints are present in this area, stability mitigation measures could be employed to allow 2H:1V side slopes. For the shallow depth of very loose to loose and firm soils (approximately 2.9 m per Borehole HF4-1), it is anticipated that localized subexcavation or shallow ground improvement measures (aggregate columns or beams, or shallow soil mixing) would be feasible.

Figures 1 and 2 in Appendix C illustrate the results of these static global stability analyses. These analyses and factors of safety assume the embankment is constructed of SSM following sub-excavation of topsoil and any surficial organic/deleterious material.

6.4.2 Settlement

The construction of the proposed high fill embankments will result in placement of up to approximately 6.5 m to 8.5 m of new fill on top of the existing ground surface. To estimate the magnitude of expected settlement of the high fill embankments, preliminary settlement analyses were carried out at critical sections of the proposed high fill areas using the commercially available program Settle3 (Version 5.0), developed by Rocscience Inc. A geotechnical resistance factor of 1.0 has been used for the settlement analysis as per the MERO Provincial Engineering Memorandum 2020-01.Based on the results of the settlement analyses, the total settlement of the foundation soils under the loading imposed by 6.5 m to 8.5 m high embankments is estimated to be less than approximately 25 mm. The majority of the total settlement is expected to occur during construction (i.e., immediate, elastic), and therefore settlement mitigation measures are not required. However, in the vicinity of Borehole HF4-1 in High Fill Area 3, at the Wilcox Road connection to Highway 35, the estimated total settlement is in the order of 45 mm, and there is some potential for about 15 mm of this settlement (within the near-surface, firm silty clay layer) to extend a few months beyond completion of construction. The extent, thickness and settlement properties of this layer should be further assessed in detail design, to determine if settlement mitigation measures are required associated with embankment construction in High Fill Area 3.

It is noted that the settlement analysis assumes that any topsoil, organics or other deleterious materials have been removed and replaced with SSM or granular fill prior to construction of the high fill embankments.

6.4.3 Construction Considerations

6.4.3.1 Removal of Topsoil and Organic Materials

Based on the information from the boreholes advanced during the field investigation, the thickness of organic deposits (mainly topsoil) generally ranges between about 30 mm and 250 mm. To improve settlement performance, it is recommended that all surficial layers of topsoil, organic soils, and any other deleterious materials should be stripped from the plan limits of the proposed high fill embankment footprints, regardless of the embankment height, in accordance with OPSS.PROV 206 (*Grading*).

6.4.3.2 Embankment Construction

Placement of Select Subgrade Material (SSM) or granular fill (satisfying OPSS.PROV 1010 (*Aggregates*) Granular 'B' Type I or Type II requirements) is recommended for construction of the new embankments to minimize the potential for slumping and surficial failures. Engineered earth fill from a local source may also be considered for embankment construction; however, an evaluation of the potential source material, including its plasticity and water content, should be made in detail design to confirm the suitability in terms of surficial stability.

Embankment construction should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (*Grading*) and any amendments, and the fill should be compacted in accordance with OPSS.PROV 501 (*Compacting*) and any amendments. The embankment side slopes should be no steeper than 2H:1V, except at High Fill Area 3 as described above where 2.5H:1V side slopes are recommended at this preliminary stage, unless stability mitigation such as subexcavation or shallow ground improvement are employed to enable support of 2H:1V side slopes. The embankment side slopes should also include a minimum 2 m wide bench at mid-height for all fill heights greater than 8 m per OPSD 202.010 (*Slope Flattening*), which is anticipated to be applicable for HF-1 Ramp E-N. In addition, benching of new fill into any existing embankment side slopes should be carried out to "key in" the new fill materials for the realigned roadway and ramp fills, in accordance with OPSD 208.010 (*Benching of Earth Slopes*).

6.4.3.3 Erosion Protection

To reduce erosion of the embankment side slopes due to surface water runoff, it is a best practice that placement of topsoil and seeding or pegged sod be carried out as soon as practicable after construction of the embankments. In the short-term, if placement of cover material cannot be carried out soon after the construction of the embankments, erosion control blankets are recommended to minimize erosion of the embankment slopes. The erosion protection should be in accordance with OPSS.PROV 804 (*Seed and Cover*).

6.4.3.4 Groundwater and Surface Water Control

Excavations within the footprint of the high fill embankments will be required to remove topsoil, organic soils and/or deleterious materials prior to embankment fill placement. Based on the groundwater information obtained at the time of the investigation, it is expected that such excavations will be maintained above the groundwater table. However, if construction operations are carried out during the wet season or periods of heavy or sustained precipitation, some limited groundwater seepage may occur from zones where groundwater is perched on top of lenses or layers of clayey silt to silty clay; it is anticipated that such seepage could be handled by pumping from properly filtered sumps within the excavation footprint. Surface water flow may occur into sub-excavation areas, and such surface water should be directed away from the excavations.

6.5 Deep Cut Sections

Earth cuts are proposed at three locations associated with the planned interchange improvements. The following table provides further details on the proposed cut sections.

Location	Deep Cut ID	Extent	Approximate Horizontal Distance (m)	Approximate Maximum Depth (m)	Relevant Boreholes
Ramp N-E	DC-1	Sta. 9+520 to 9+640	120	8.4	DC1-1
Ramp S-N	DC-2	Sta. 10+280 to 10+370	85	5.8	DC2-1
Ramp N-S	DC-3	Sta. 10+040 to 10+120	80	6.5	DC3-1

6.5.1 Global Stability

6.5.1.1 Methodology

The preliminary stability analyses have been completed for representative critical sections based on the deepest cut slope and the various soil types encountered within the deep cut areas. The cut slope geometry is based on the typical cross sections provided by WSP. The deep cut side slopes have been analyzed for a maximum (i.e., steepest) side slope orientation of 2 horizontal to 1 vertical (2H:1V). Where cut slopes are deeper than 6 m (such as for Deep Cut Area 1, DC-1), a 2 m wide mid-height bench has been incorporated in the analyzed cross-section, consistent with best practices and MTO standard requirements to reduce erosion on the slope face.

Similar to the slope stability analysis for the High Fill areas, two-dimensional limit equilibrium global slope stability analyses were carried out for the proposed deep cut sections with the same software and approach to Factors of Safety described earlier, in accordance with *CHBDC (2019)* and the MERO Provincial Engineering Memorandum 2020-01.

6.5.1.2 Parameter Selection

The total stress and effective stress parameters employed in the analyses were determined in the same manner as described in Section 6.3.1.2. The simplified stratigraphy together with the preliminary geotechnical parameters for the different soil types encountered in the proposed deep cut sections are summarized below. For the purpose of the stability analyses, the groundwater level was assumed to be below the base of the boreholes, based on the observations during the field investigation program.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m^3)	Effective Friction Angle, φ' (°)	Cohesion, c' (kPa)	Undrained Shear Strength, s_u (kPa)
Very loose to loose Gravelly SAND (SW-SM) to SAND (SP-SM)	20	30	---	---
Compact to dense gravelly SAND (SW-SM) to SAND (SP-SM)	20	35	---	---
Compact to dense SILT (ML) and sand	20	32	---	---
Very dense Sandy SILT (ML)	20	33	---	---
Hard CLAYEY SILT (CL)	20	32	---	400
Very dense SILTY SAND (SM)	20	34	---	---

6.5.1.3 Analysis Results

The preliminary slope stability analysis results depicting the factors of safety for the selected critical deep cut section are shown on Figure 3 provided in Appendix C. The analysis indicates that cut sections constructed with side slopes oriented at 2H:1V or shallower will have Factors of Safety that are greater than the target factor of safety of 1.3 in short-term/temporary (undrained) conditions and greater than 1.5 in the long-term/permanent (effective stress) conditions.

6.5.2 Construction Considerations

6.5.2.1 Surficial Stability and Erosion Protection

As described above, where cut slopes are deeper than 6 m (such as for Deep Cut Area 1, DC-1), a 2 m wide mid-height bench must be included in the design to reduce erosion on the slope face. The bench should extend for the length through which the cut section height exceeds 6 m, be at least 2 m wide, and have 2 per cent positive drainage to shed run-off water.

All of the cut slopes will be carried out through granular soils. The groundwater observations made during the time of drilling (as presented in Section 4.3) indicate that the groundwater table is generally below the proposed ramp roadway grades. However, in Borehole DC1-1 within Deep Cut Area 1 on the N-E Ramp, is estimated to be near or below Elevation 338.5 m, near the proposed roadway cut grade. It is recommended that further investigation and assessment of the water level be completed in this area during detail design to confirm the water level and any specific pavement drainage measures that may be required.

Although the groundwater level is generally anticipated to be below the proposed cut depth except in the vicinity of Borehole DC1-1, there is potential for perched groundwater to be encountered above lenses or interlayer of less permeable cohesive soil, which may be distributed randomly throughout the soils at the site, and which may not be encountered even with additional borehole drilling during detail design. Such perched groundwater is anticipated to be localized/of limited extent, and any seepage and associated sloughing upon exposure in the cut face may be of limited duration; however, there may be a need for treatment of such areas on the cut face with granular blankets, if encountered during construction. The need for such treatment should be further assessed through additional investigation in detail design, with a provision for drainage blankets included in the future contract documents if necessary.

Proper erosion control measures should be implemented both during construction and for the permanent condition. Aside from the mid-height bench discussed above for slopes greater than 6 m in height, it is recommended that the cut slope design consider other measures to minimize surface water runoff from flowing down the face of the slope, such as interceptor ditches along the crest where space permits. Vegetation cover should be established on all permanent cut slope faces following construction to protect against surficial erosion, as per OPSS 803 (*Sodding*) and/or OPSS 804 (*Seed and Cover*).

6.6 Hydraulic Conductivity Estimates for Potential Future Stormwater Management (SWM) Pond Planning

As requested by WSP, a total of eight native silty sand soil samples and one native clayey silt soil sample obtained from two borehole locations (i.e., Boreholes HF1-2 and HF2-1) were submitted to Golder's Whitby laboratory for grain size distribution analysis. This testing has been completed to provide a preliminary assessment of the hydraulic conductivity of the soils in the vicinity of potential future stormwater management (SWM) ponds.

The hydraulic conductivity of the soil samples was estimated based on the size of particles at which 90% is coarser and 10% is finer (i.e., Hazen's method).

Based on Hazen's method, the hydraulic conductivity values of the silty sand soil samples were estimated to range from 3 x 10^{-7} m/s to 6 x 10^{-5} m/s, with a geometric mean of 2 x 10^{-5} m/s (n=8). For the clayey silt soil sample, the hydraulic conductivity was estimated to be 1 x 10^{-8} m/s. The individual results of the analysis are presented in the table below.

Borehole ID	Sample Number	Depth Range (m)	Tested Soil Unit	D_{10} (mm)	Estimated Hydraulic Conductivity, k (m/s)
HF1-2	3	1.5 - 2.1	(SM) Silty Sand	0.0580	3 x 10^{-5}
HF1-2	4	2.3 - 2.9	(SM) Silty Sand	0.0600	4 x 10^{-5}
HF1-2	5	3.1 - 3.7	(SM) Silty Sand	0.0055	3 x 10^{-7}
HF1-2	7	4.6 - 5.2	(CL) Clayey Silt	0.0010	1 x 10^{-8} (1)
HF2-1	2	0.8 - 1.4	(SM) Silty Sand	0.0600	4 x 10^{-5}
HF2-1	3	1.5 - 2.1	(SM) Silty Sand	0.0800	6 x 10^{-5}
HF2-1	4	2.3 - 2.9	(SM) Silty Sand	0.0650	4 x 10^{-5}
HF2-1	6	3.8 - 4.4	(SM) Silty Sand	0.0500	3 x 10^{-5}
HF2-1	7	4.6 - 5.2	(SM) Silty Sand	0.0300	9 x 10^{-6}

Note:

1. It is noted that the grain size distribution curve did not reach 10% passing for the clayey silt soil sample; therefore, the estimated hydraulic conductivity value should be considered approximate. However, it is noted that the estimated hydraulic conductivity is within the expected range for this soil type.

6.7 Recommendations for Future Work During Detail Design

Additional geotechnical investigation is recommended during the detail design phase for the proposed works to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report. The additional boreholes should be placed along the proposed deep cut and high fill embankment alignment at a maximum spacing of 50 m per MTO's May 2019 *Guideline for Foundation Engineering Services*, with one borehole at each end of the proposed embankment or cut slope alignment. It is recommended that the detailed geotechnical investigation include the following:

- Given the presence of the near-surface layer of very loose to loose silts/sands and firm silty clay in Borehole HF4-1 in High Fill Area 3, at the Wilcox Road connection to Highway 35, the detailed design investigation should target this area to allow for a more specific stability and settlement assessment of the subsurface conditions at this location, to confirm or optimize the currently recommended 2.5H:1V embankment side slope configuration and to further examine and develop stability mitigation such as subexcavation or ground improvement. The investigation should assess how the surface elevation, depth and strength parameters for the very loose cohesionless, and firm cohesive deposits vary at this location.

- Confirm stabilized groundwater elevations within the footprint of the deep cut sections (particularly within Deep Cut Area 1 where Borehole DC1-1 suggests the groundwater table may be near the proposed ramp cut grade) and perform long-term groundwater monitoring to assess seasonally high water table conditions.
- Perform field slug testing to better assess the hydraulic conductivity values of the soils in support of the detailed design of any infiltration features proposed in the vicinity of the interchange (e.g., stormwater management ponds).

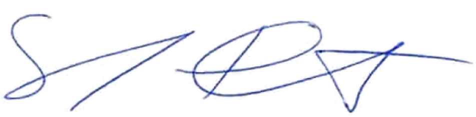
7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Mo'oud Nasr, P.Eng., a geotechnical engineer with Golder. The technical aspects were reviewed by Ms. Sarah Poot, P.Eng., Associate of Golder and the Senior/Lead Foundation Engineer for this project. Ms. Lisa Coyne, P.Eng., a Principal and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Signature Page

Golder Associates Ltd.

Mo'oud Nasr, P.Eng.
Geotechnical Engineer



Sarah E. M. Poot, P.Eng.
Associate, Senior Geotechnical Engineer

Lisa Coyne, P. Eng.
Principal, MTO Designated Foundations Contact

MN/SEMP/LCC/ljv

https://golderassociates.sharepoint.com/sites/11407g/wo1 hwy 35115/5. reporting/final/1773612-wo1 fidr 2020'8'11 hwy 35 high fills & deep cuts final.docx

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Unified Facilities Criteria, U.S. Navy. 1986*. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures*. Alexandria, Virginia.

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Commercial Software:

Slide (Version 2018) by RocScience Inc.

Ontario Provisional Standard Drawing:

OPSD 202.010 Slope Flattening

OPSD 208.010 Benching of Earth Slopes

Ontario Provincial Standard Specification:

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 803 Construction Specification for Sodding

OPSS.PROV 804 Construction Specification for Seed and Cover

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act:

Ontario Regulation 903/90 Wells (as amended)

Ontario Regulation 213/91 Construction Projects (as amended)

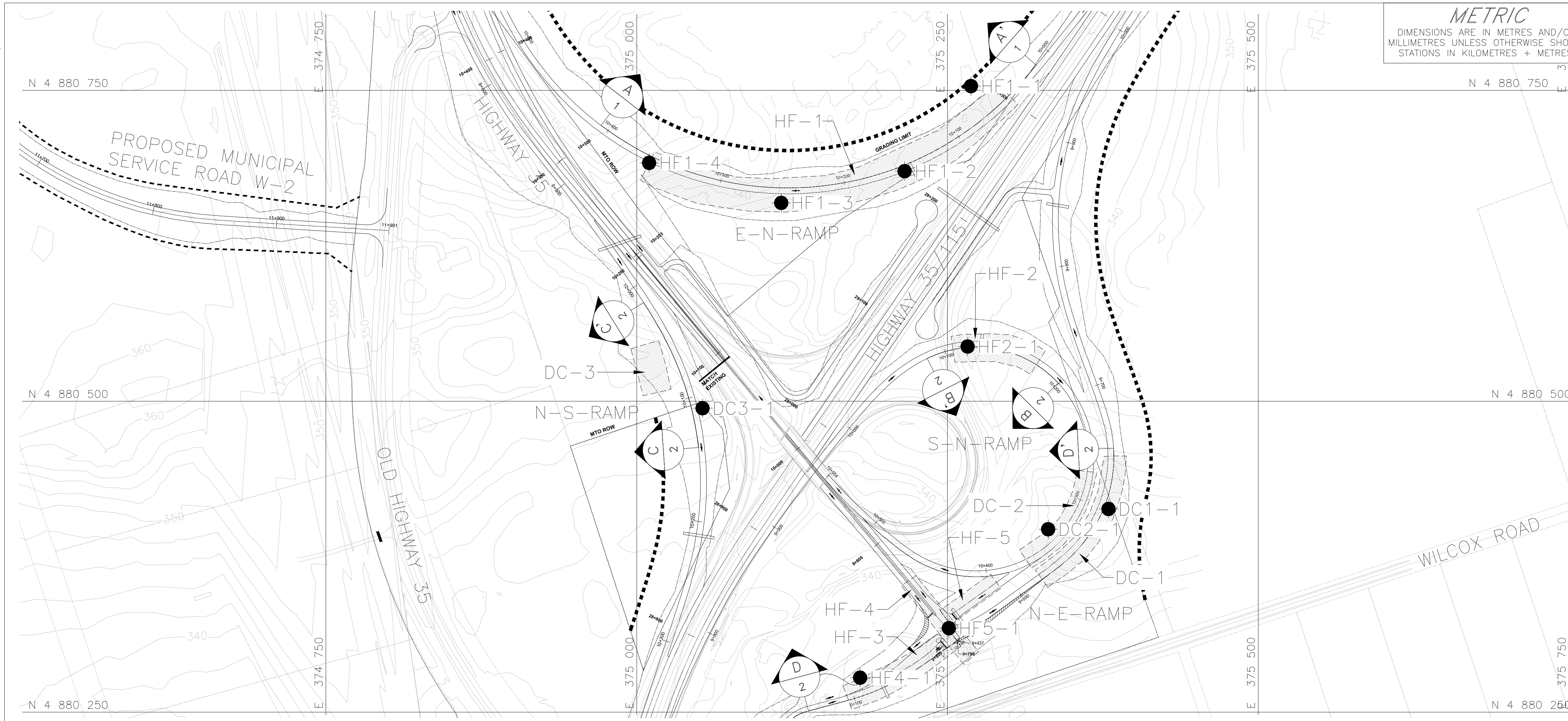
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

HIGHWAY 35/115
INTERCHANGE IMPROVEMENTS
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



PLAN
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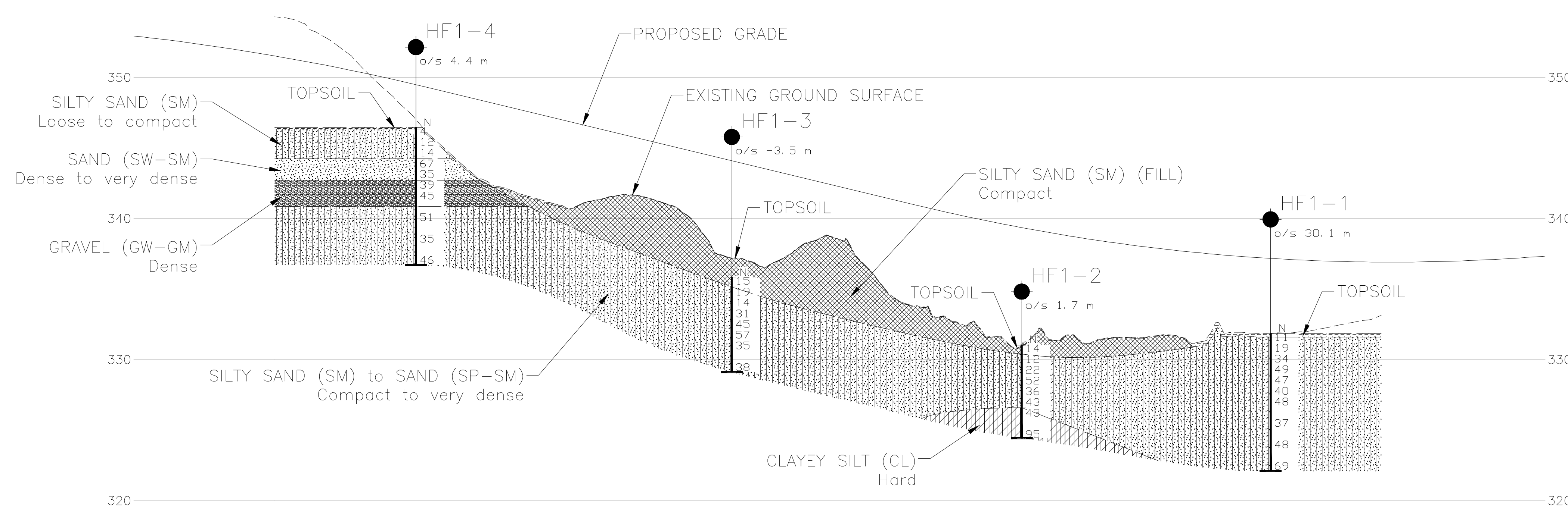


A-A 1 E-N-RAMP PROFILE
SCALE
20 0 20 40 m
4 0 4 8 m

KEY PLAN
SCALE
1 0 1 2 km

LEGEND

●	Borehole – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
DC1-1	346.4	4880413.4	375379.5
DC2-1	346.2	4880397.0	375331.0
DC3-1	348.6	4880494.4	375052.9
HF1-1	331.9	4880753.4	375268.9
HF1-2	331.1	4880685.0	375215.5
HF1-3	335.8	4880659.5	375116.2
HF1-4	346.4	4880691.7	375010.0
HF2-1	329.6	4880544.0	375266.2
HF4-1	336.6	4880277.7	375179.7
HF5-1	336.0	4880317.5	375251.1

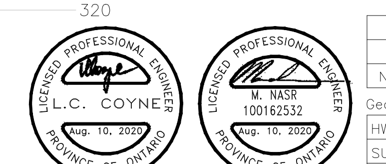
NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by WSP, drawing file no. HWY 35-115 Interchange_ALT-4_Recommended _ Plan & Profile.dwg, received December 17, 2019.



NO.	DATE	BY	REVISION

Geocres No. 31D-752

HWY. 35/115	PROJECT NO. 1773612		DIST.
SUBM'D. MN	CHKD. MN	DATE: 8/10/2020	SITE:
DRAWN: DD/JM	CHKD. SEMP	APPD. LCC	DWG. 1

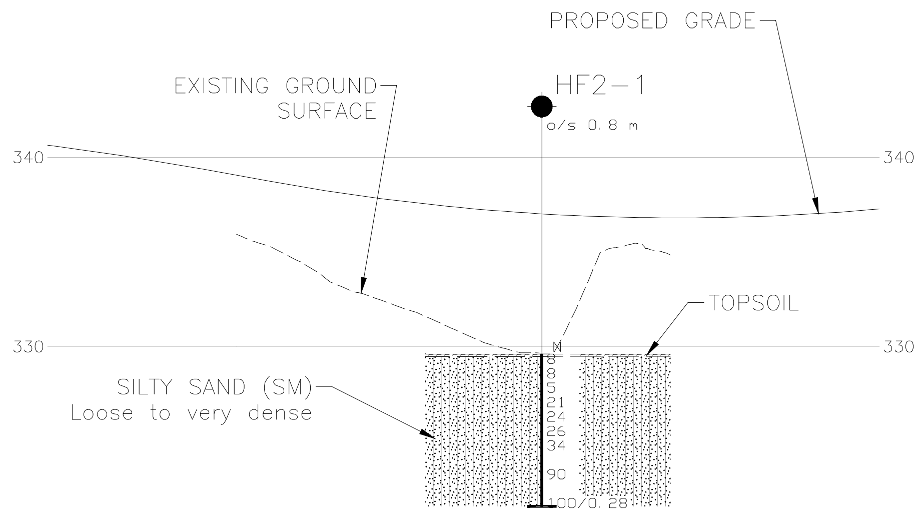
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

HIGHWAY 35/115
INTERCHANGE IMPROVEMENTS
SOIL STRATA

SHEET

GOLDER



B-B 1 S-N-RAMP PROFILE

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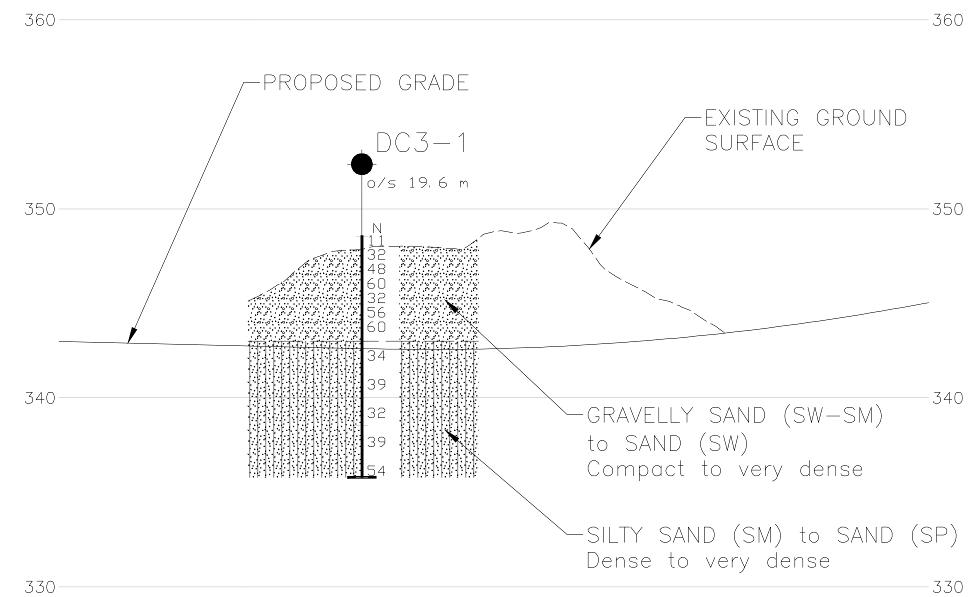

C-C 1 N-S-RAMP PROFILE

SCALE
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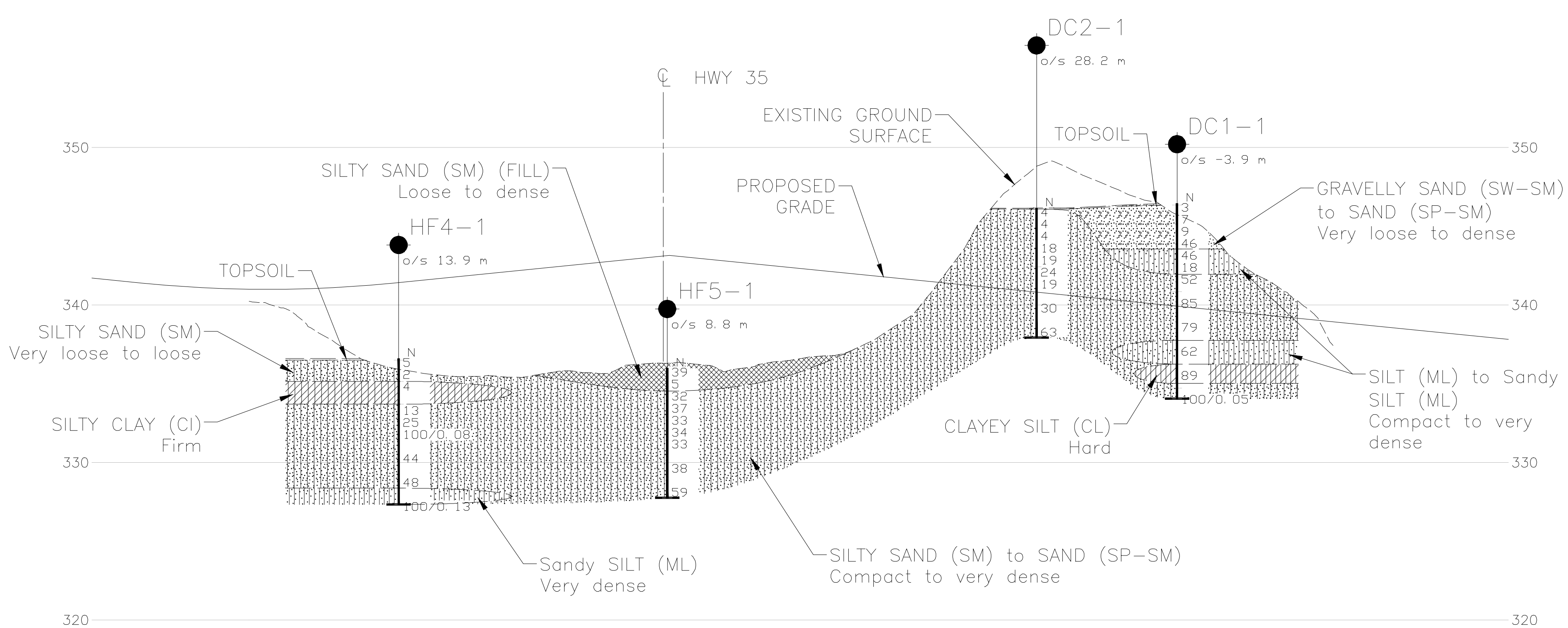
4 0 4 8 m



D-D 1 N-E-RAMP, WILCOX ROAD AND HWY 35 PROFILE

SCALE
20 0 20 40 m
4 0 4 8 m

KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- ● Borehole – Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
DC1-1	346.4	4880413.4	375379.5
DC2-1	346.2	4880397.0	375331.0
DC3-1	348.6	4880494.4	375052.9
HF1-1	331.9	4880753.4	375268.9
HF1-2	331.1	4880685.0	375215.5
HF1-3	335.8	4880659.5	375116.2
HF1-4	346.4	4880691.7	375010.0
HF2-1	329.6	4880544.0	375266.2
HF4-1	336.6	4880277.7	375179.7
HF5-1	336.0	4880317.5	375251.1

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LICENSED PROFESSIONAL ENGINEER L.C. COYNE Aug. 10, 2020 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER M. NASR 100162532 Aug. 10, 2020 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31D-752

HWY. 35/115	PROJECT NO. 1773612		DIST.
SUBM'D. MN	CHKD. MN	DATE: 8/10/2020	SITE:
DRAWN: DD/JM	CHKD. SEMP	APPD. LCC	DWG. 2

PLOT DATE: August 10, 2020
FILENAME: S:\Clients\MTO\Hwy_35_and_Hwy_115\99_PROJ\1773612\40_PROD\0001_Interchange_Preliminary_FDR\1773612-0001-BD-0002.dwg

APPENDIX A

Borehole Records

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS
MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS[1,2]

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (*i.e.,* SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (*i.e.,* some sand)
≤ 10	trace (*i.e.,* trace fines)

1. Only applicable to components not described by Primary Group Name.
2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	➢ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
E	void ratio
N	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

GOLDER

Foundation Design

RECORD OF BOREHOLE No DC1-1

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
DIST Central HWY 35/115
DATUM Geodetic
LOCATION N 4880413.4; E 375379.5 MTM NAD 83 ZONE 10 (LAT. 44.060323; LONG. -78.619047)
BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger
DATE February 11, 2020
ORIGINATED BY YS
COMPILED BY MN
CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT (kN/m³)	GR	SA	SI	CL
346.4	GROUND SURFACE									
0.0	TOPSOIL (100 mm)									
0.1	Gravelly SAND (SW-SM) to SAND (SP-SM), some fines, trace rootlets in upper portion; Very loose to dense; Brown; Moist	1	SS	3						
		2	SS	7	o		24	65	8	3
		3	SS	9						
		4	SS	46	o		0	88	11	1
343.5 / 2.9	SILT (ML) and sand; Compact to dense; Brown; Moist	5	SS	46	o	NP	0	47	53	0
		6	SS	18						
341.9 / 4.5	SAND (SP-SM), some fines; Very dense; Brown; Moist	7	SS	52	o					
340.8 / 5.6	SILTY SAND (SM); Very dense; Brown; Moist	8	SS	85						
		9	SS	79	o					
337.7 / 8.7	Sandy SILT (ML); Very dense; Brown; Wet	10	SS	62	o	NP	0	39	58	3
336.2 / 10.2	CLAYEY SILT (CL); Hard; Brown; Moist	11	SS	89						
334.7 / 11.7	SILTY SAND (SM); Very dense; Brown; Moist	12	SS	100/0.05						
334.0 / 12.4	END OF BOREHOLE									

NOTES:

1. Borehole caved to a depth of 7.9 m (Elev. 338.5 m) upon completion of drilling.

2. Borehole dry upon completion of drilling.

Elevation scale: 346, 345, 344, 343, 342, 341, 340, 339, 338, 337, 336, 335

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED — 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTO\HWY_35_AND_HWY_115\02_DATA\GINT\HWY_35_AND_HWY_115.GPJ GAL-GTA.GDT 6/12/20

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RECORD OF BOREHOLE No DC2-1

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
LOCATION N 4880397.0; E 375331.0 MTM NAD 83 ZONE 10 (LAT. 44.060181; LONG. -78.619655)
ORIGINATED BY YS
DIST Central HWY 35/115
BOREHOLE TYPE Power Auger; 150 mm O.D. Solid Stem Auger
COMPILED BY MN
DATUM Geodetic
DATE February 12, 2020
CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
346.2	GROUND SURFACE										
0.0 / 0.1	TOPSOIL (70 mm)				346						
	SAND (SP-SM), some fines; Loose to compact; Brown; Moist; - Rootlets to 0.7 m	1	SS	4							
		2	SS	4	345	~5		0	88	12	0
		3	SS	4	344						
		4	SS	18		~5					
		5	SS	19	343						
342.5 / 3.7	SILTY SAND (SM); Compact to very dense; Brown; Moist	6	SS	24	342	~4	NP	0	74	26	0
		7	SS	19	341						
		8	SS	30	340						
					339						
338.0 / 8.2		9	SS	63	338						
	END OF BOREHOLE										
	NOTE:										
	1. Borehole dry upon completion of drilling.										

Column headings also include: GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%).

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No DC3-1

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
DIST Central HWY 35/115
DATUM Geodetic
LOCATION N 4880494.4; E 375052.9 MTM NAD 83 ZONE 10 (LAT. 44.061084; LONG. -78.623113)
BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger
DATE February 7, 2020
ORIGINATED BY YS
COMPILED BY MN
CHECKED BY

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
348.6	GROUND SURFACE
0.0 / 0.1	TOPSOIL (50 mm)
	Gravelly SAND (SW-SM) to SAND (SW) and gravel, trace fines Compact to very dense Brown Moist - Auger grinding from 2.7 m to 2.9 m depth
343.0 / 5.6	SILTY SAND (SM) Dense Brown Moist
338.5 / 10.1	SAND (SP) Dense to very dense Brown Moist
335.8 / 12.8	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	WATER CONTENT	UNIT WEIGHT	GR	SA	SI	CL
1	SS	11						
2	SS	32	o		32	59	8	1
3	SS	48						
4	SS	60						
5	SS	32	o					
6	SS	56						
7	SS	60	o		47	48	4	1
8	SS	34						
9	SS	39	o	NP	0	57	43	0
10	SS	32	o					
11	SS	39						
12	SS	54	o					

ELEVATION SCALE: 348, 347, 346, 345, 344, 343, 342, 341, 340, 339, 338, 337, 336

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+3, ×3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No HF1-1

SHEET 1 OF 1

METRIC

PROJECT 1773612/W01

W.P.

LOCATION N 4880753.4; E 375268.9 MTM NAD 83 ZONE 10 (LAT. 44.063394; LONG. -78.620382)

ORIGINATED BY YS

DIST Central HWY 35/115

BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger

COMPILED BY MN

DATUM Geodetic

DATE February 5, 2020

CHECKED BY

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
331.9	GROUND SURFACE						
0.0	TOPSOIL (250 mm)						
0.3	SAND (SP-SM), trace to some fines Compact to very dense Brown Moist	1	SS	11			
		2	SS	19	331	o	
		3	SS	34	330	o	0 91 9 0
		4	SS	49	329		
		5	SS	47	328	o	
		6	SS	40			
		7	SS	48	327	o	0 83 17 0
					326		
		8	SS	37	325		
		9	SS	48	324	o	0 91 (9)
					323		
322.2		10	SS	69			
9.8	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No HF1-2

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
LOCATION N 4880685.0; E 375215.5 MTM NAD 83 ZONE 10 (LAT. 44.062783; LONG. -78.621058)
ORIGINATED BY YS
DIST Central HWY 35/115
BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger
COMPILED BY MN
DATUM Geodetic
DATE February 5 and 6, 2020
CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
331.1	GROUND SURFACE										
0.0	TOPSOIL (50 mm)										
0.1	SILTY SAND (SM), containing organic inclusions, rootlets (FILL) Compact Brown Moist	1	SS	14							
330.4 / 0.7	SILTY SAND (SM), some gravel to gravelly, trace clay Compact to very dense Brown Moist	2	SS	12							
		3	SS	22				23	62	15	0
		4	SS	52				22	66	11	1
		5	SS	36			NP	17	39	41	3
		6	SS	43							
326.6 / 4.5	CLAYEY SILT (CL) Hard Brown Moist	7	SS	43				0	0	75	25
		8	SS	95							
324.5 / 6.6	END OF BOREHOLE										

NOTE:

1. Borehole dry upon completion of drilling.

Elevation scale: 330, 329, 328, 327, 326, 325

Dynamic cone penetration resistance plot: 20 40 60 80 100
Shear strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED — 20 40 60 80 100
Plastic limit W_P, natural moisture content W, liquid limit W_L; water content (%) 10 20 30

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

GOLDER

Foundation Design

RECORD OF BOREHOLE No HF1-3

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01

W.P.

DIST Central HWY 35/115

DATUM Geodetic

LOCATION N 4880659.5; E 375116.2 MTM NAD 83 ZONE 10 (LAT. 44.062563; LONG. -78.622301)

BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger

DATE February 6, 2020

ORIGINATED BY YS

COMPILED BY MN

CHECKED BY

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
335.8	GROUND SURFACE										
0.0	TOPSOIL (30 mm)										
	SILTY SAND (SM) (FILL) Compact Brown Moist	1	SS	15							
335.1 / 0.7	SILTY SAND (SM), trace gravel Compact to very dense Brown Moist				335						
		2	SS	19		~10					
		3	SS	14	334						
		4	SS	31	333	~7		0	75	23	2
		5	SS	45	332						
		6	SS	57		~3					
		7	SS	35	331						
					330						
		8	SS	38		~6	NP	1	67	31	1
329.1 / 6.7	END OF BOREHOLE										

NOTE:

1. Borehole dry upon completion of drilling.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%); GROUND WATER CONDITIONS; STRAT PLOT

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No HF1-4

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
DIST Central HWY 35/115
DATUM Geodetic

LOCATION N 4880691.7; E 375010.0 MTM NAD 83 ZONE 10 (LAT. 44.062863; LONG. -78.623623)
BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger
DATE February 6, 2020

ORIGINATED BY YS
COMPILED BY MN
CHECKED BY

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
346.4	GROUND SURFACE									
0.0	TOPSOIL (100 mm)									
0.1	SILTY SAND (SM); Loose to compact; Brown; Moist; - Rootlets to 0.7 m depth	1	SS	4						
		2	SS	12	o					
		3	SS	14						
344.2 / 2.2	SAND (SW-SM), some gravel, trace fines; Very dense to dense; Brown; Moist	4	SS	67	o		16	74	8	2
		5	SS	35						
342.7 / 3.7	GRAVEL (GW-GM) and sand, trace fines; Dense; Brown; Moist; - Augers grinding from 5.2 m to 5.5 m depth	6	SS	39	o		49	43	6	2
		7	SS	45						
340.8 / 5.6	SILTY SAND (SM); Dense to very dense; Brown; Moist	8	SS	51						
		9	SS	35	o	NP	0	69	31	0
		10	SS	46	o					
336.7 / 9.8	END OF BOREHOLE									

Elevation scale: 346, 345, 344, 343, 342, 341, 340, 339, 338, 337

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTE:

1. Borehole dry upon completion of drilling.

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Foundation Design

RECORD OF BOREHOLE No HF2-1

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01

W.P.

LOCATION N 4880544.0; E 375266.2 MTM NAD 83 ZONE 10 (LAT. 44.061510; LONG. -78.620444)

ORIGINATED BY YS

DIST Central HWY 35/115

BOREHOLE TYPE Power Auger; 150 mm O.D. Solid Stem Auger

COMPILED BY MN

DATUM Geodetic

DATE February 11, 2020

CHECKED BY

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
329.6	GROUND SURFACE										
0.0	TOPSOIL (130 mm)										
0.1	SILTY SAND (SM), trace gravel Loose to very dense Brown Moist - Rootlets to 0.7 m	1	SS	8	329						
		2	SS	8		o		6	79	15	0
		3	SS	5	328	o	NP	0	62	33	5
		4	SS	21	327	o		0	86	14	0
		5	SS	24	326						
		6	SS	26		o	NP	0	76	21	3
		7	SS	34	325	o		0	77	18	5
	- Augers grinding from 5.8 m to 5.9 m depth				324						
		8	SS	90	323						
		9	SS	100/0.28	322	o		1	79	20	0
321.6 8.1	END OF BOREHOLE										

NOTES:

1. Borehole dry during drilling and upon completion of drilling.

2. Borehole caved to a depth of 6.1 m (Elev. 323.5 m) upon completion of drilling.

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100. Shear Strength kPa: O Unconfined, + Field Vane, ● Quick Triaxial, × Remoulded. Plastic Limit W_P, Natural Moisture Content W, Liquid Limit W_L. Water Content (%) 10 20 30. Remarks & Grain Size Distribution (%).

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

GOLDER

Foundation Design

RECORD OF BOREHOLE No HF4-1

SHEET 1 OF 1 — METRIC

PROJECT 1773612/W01
W.P.
DIST Central HWY 35/115
DATUM Geodetic
LOCATION N 4880277.7; E 375179.7 MTM NAD 83 ZONE 10 (LAT. 44.059121; LONG. -78.621560)
BOREHOLE TYPE Power Auger; 200 mm O.D. Hollow Stem Auger
DATE February 10, 2020
ORIGINATED BY YS
COMPILED BY MN
CHECKED BY

ELEV DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT (kN/m³)	GR	SA	SI	CL
336.6	GROUND SURFACE									
0.0	TOPSOIL (100 mm)									
0.1	SILTY SAND (SM), containing organic inclusions, rootlets; Loose to very loose; Brown; Moist	1	SS	5						
		2	SS	2						
335.2 / 1.5	SILTY CLAY (CI), trace sand; Firm; Brown; w>PL	3	SS	4	(wP, w, wL plotted)		0	4	69	27
333.7 / 2.9	SILTY SAND (SM), trace gravel; Compact to very dense; Brown; Moist	4	SS	13	(plotted)		7	64	26	3
		5	SS	25	(plotted)	NP	0	74	26	0
		6	SS	100/0.08						
		7	SS	44						
		8	SS	48	(plotted)					
328.4 / 8.2	Sandy SILT (ML), trace gravel; Very dense; Brown; Moist									
327.3 / 9.3	- Augers grinding from 8.2 m to 8.5 m depth; END OF BOREHOLE	9	SS	100/0.13						

Elevation scale: 336, 335, 334, 333, 332, 331, 330, 329, 328

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT wP — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wL; WATER CONTENT (%): 10 20 30
REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTE:

1. Borehole dry upon completion of drilling.

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

GOLDER

Foundation Design

RECORD OF BOREHOLE No HF5-1

SHEET 1 OF 1 **METRIC**

PROJECT 1773612/W01
W.P.
DIST Central HWY 35/115
DATUM Geodetic

LOCATION N 4880317.5; E 375251.1 MTM NAD 83 ZONE 10 (LAT. 44.059473; LONG. -78.620663)
BOREHOLE TYPE Power Auger; 150 mm O.D. Solid Stem Auger
DATE February 10, 2020

ORIGINATED BY YS
COMPILED BY MN
CHECKED BY

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
336.0	GROUND SURFACE											
0.0	SILTY SAND (SM) (FILL) Dense to loose Brown Moist - 25 mm of crushed granular at ground surface		1	SS	39				0	74	25	1
			2	SS	5		335					
334.6 1.5	SILTY SAND (SM), trace gravel Dense to very dense Brown Moist - becomes grey below 4.57 m		3	SS	32		334					
			4	SS	37		333					
			5	SS	33			NP	0	73	27	0
			6	SS	34		332					
			7	SS	33		331					
							330					
			8	SS	38		329					
			9	SS	59		328	NP	2	83	13	2
327.8 8.2	END OF BOREHOLE											

NOTES:

1. Borehole dry upon completion of drilling.
2. Borehole caved to a depth of 6.4 m (Elev. 329.6 m) upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

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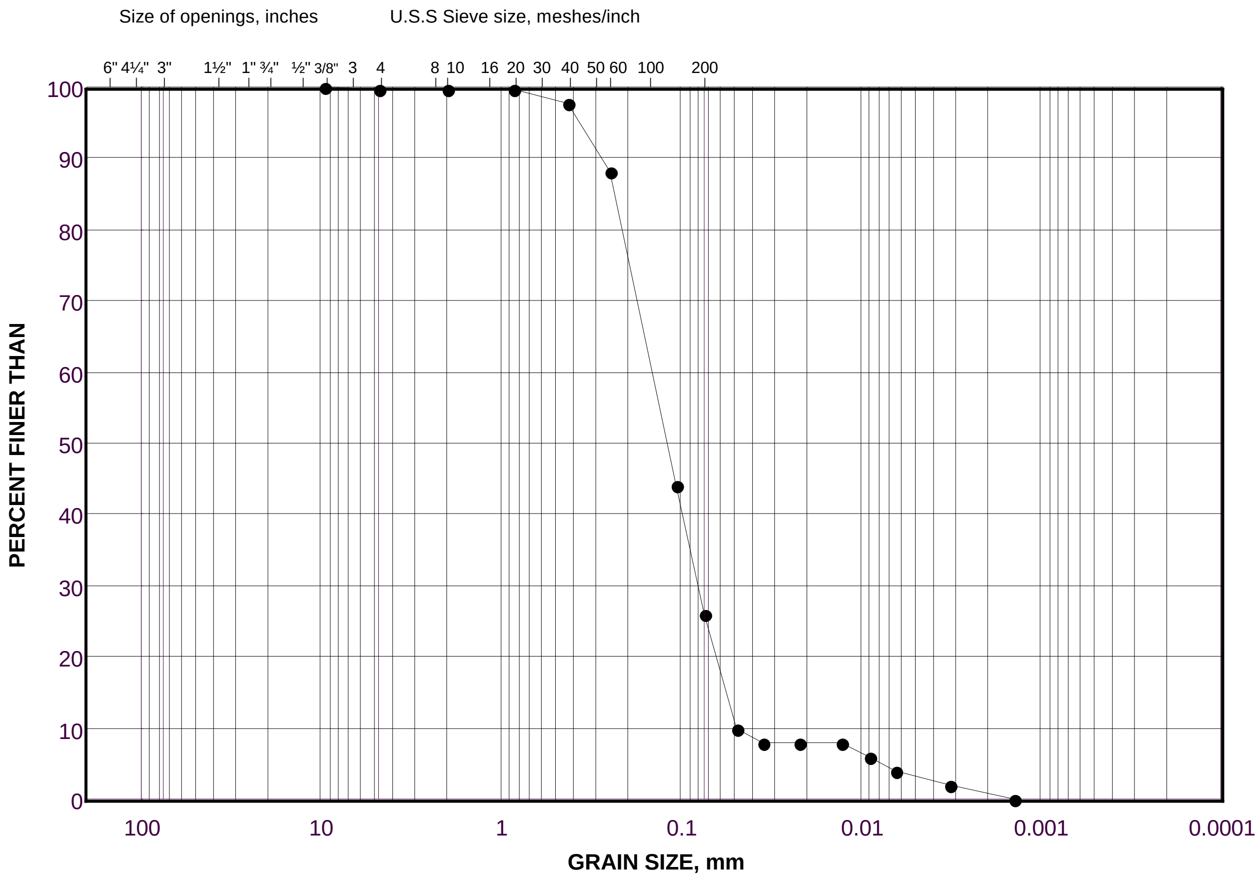
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM) (FILL)

FIGURE B-1



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF5-1	1	336.0 - 335.4

Project Number: 1773612 (W01)

Checked By: SEMP

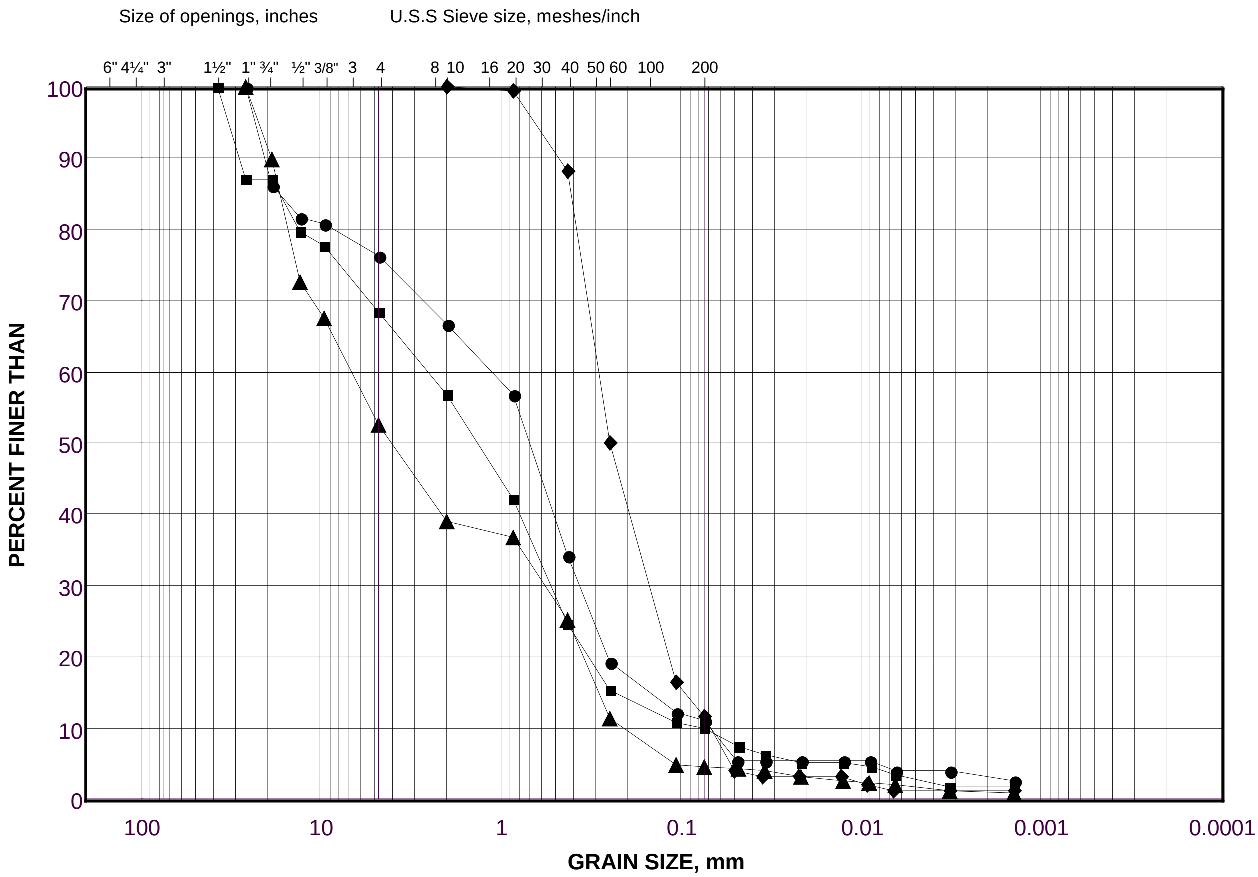
Golder Associates

Date: 08-Jun-20

GRAIN SIZE DISTRIBUTION

Gravelly SAND (SW-SM) to SAND (SW/SP-SM)

FIGURE B-2



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	DC1-1	2	345.6 - 345.0
■	DC3-1	2	347.8 - 347.2
◆	DC1-1	4	344.1 - 343.5
▲	DC3-1	7	344.0 - 343.4

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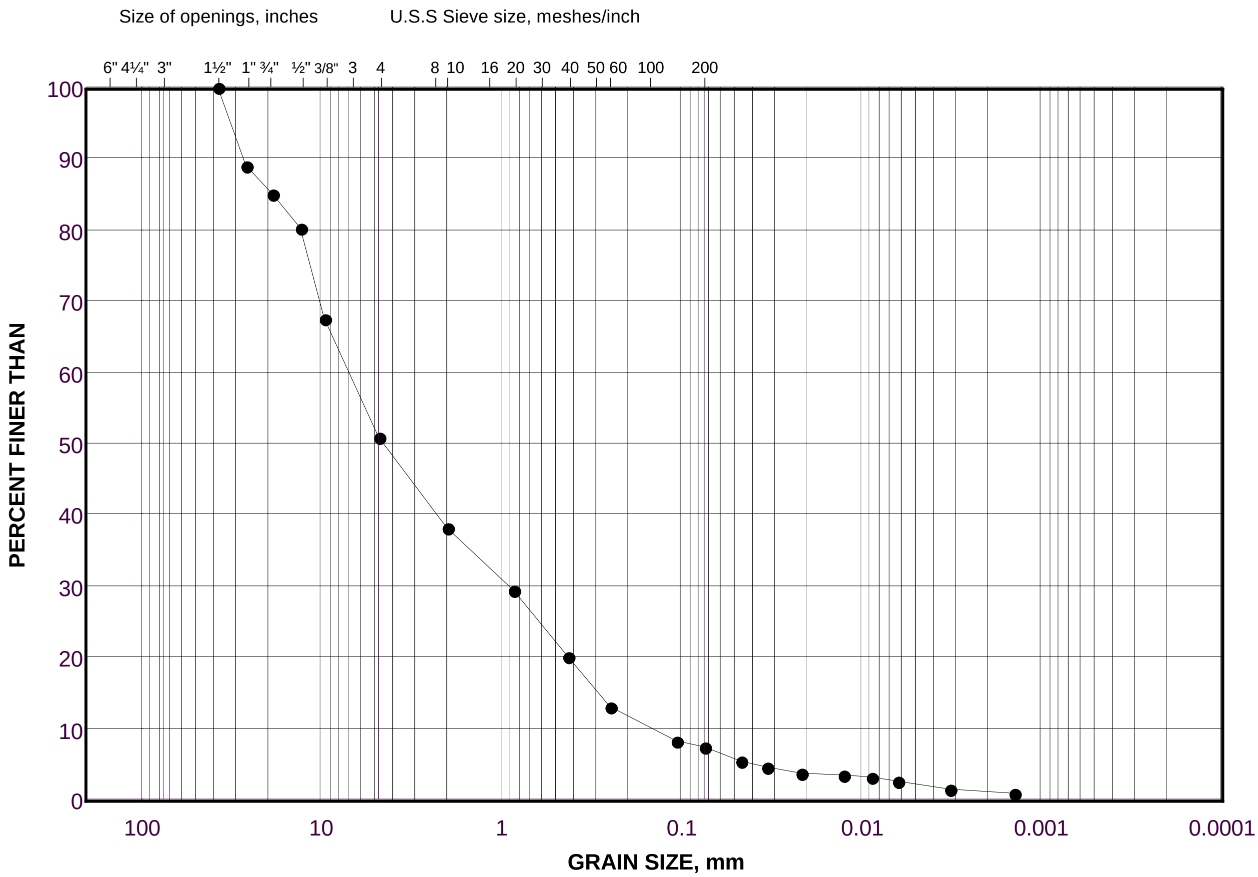
GRAIN SIZE DISTRIBUTION

GRAVEL (GW-GM)

FIGURE B-3



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF1-4	6	342.6 - 342.0

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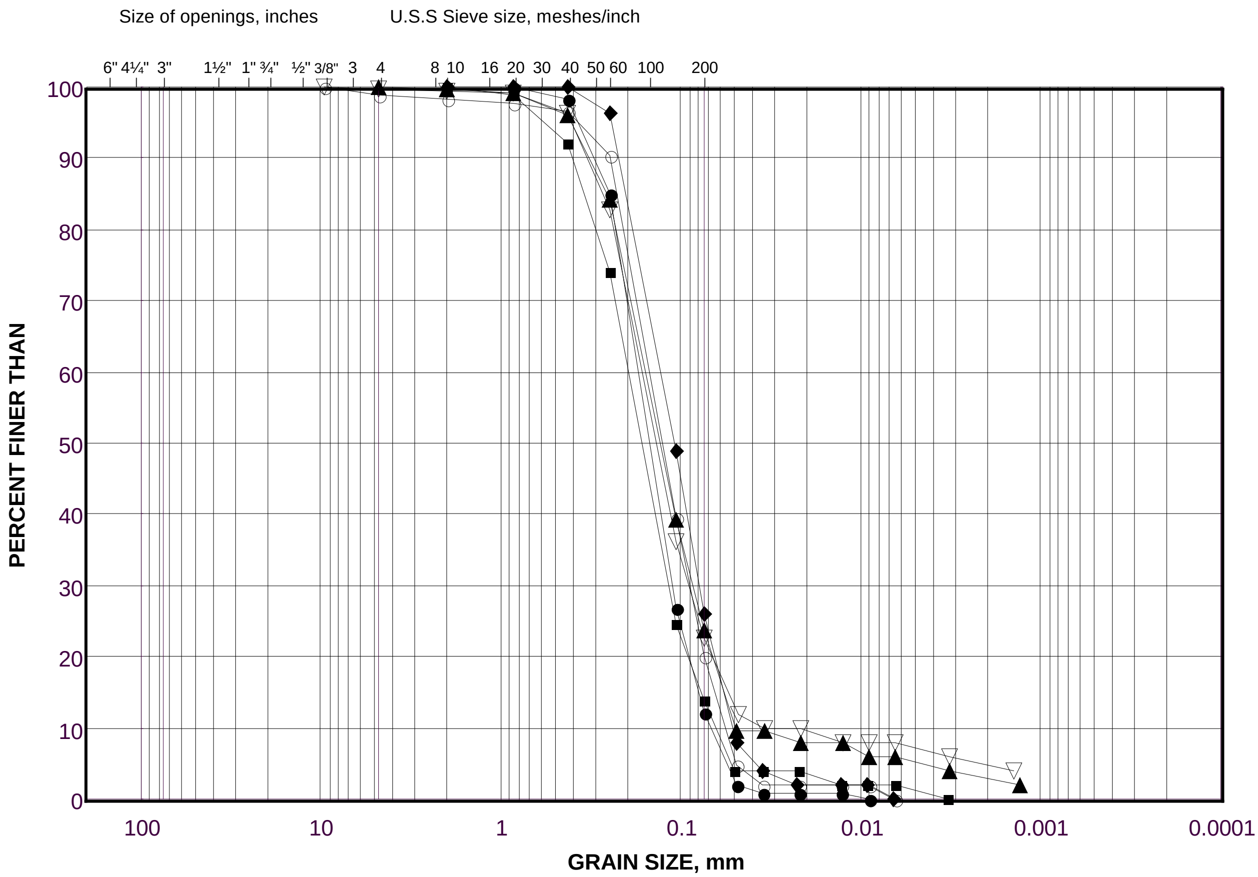
GRAIN SIZE DISTRIBUTION

SILTY SAND (SM) to SAND (SP/SP-SM)

FIGURE B4-A



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	DC2-1	2	345.4 - 344.8
■	HF2-1	4	327.3 - 326.7
◆	DC2-1	6	342.4 - 341.8
▲	HF2-1	6	325.8 - 352.2
▽	HF2-1	7	325.0 - 324.4
❍	HF2-1	9	322.0 - 321.7

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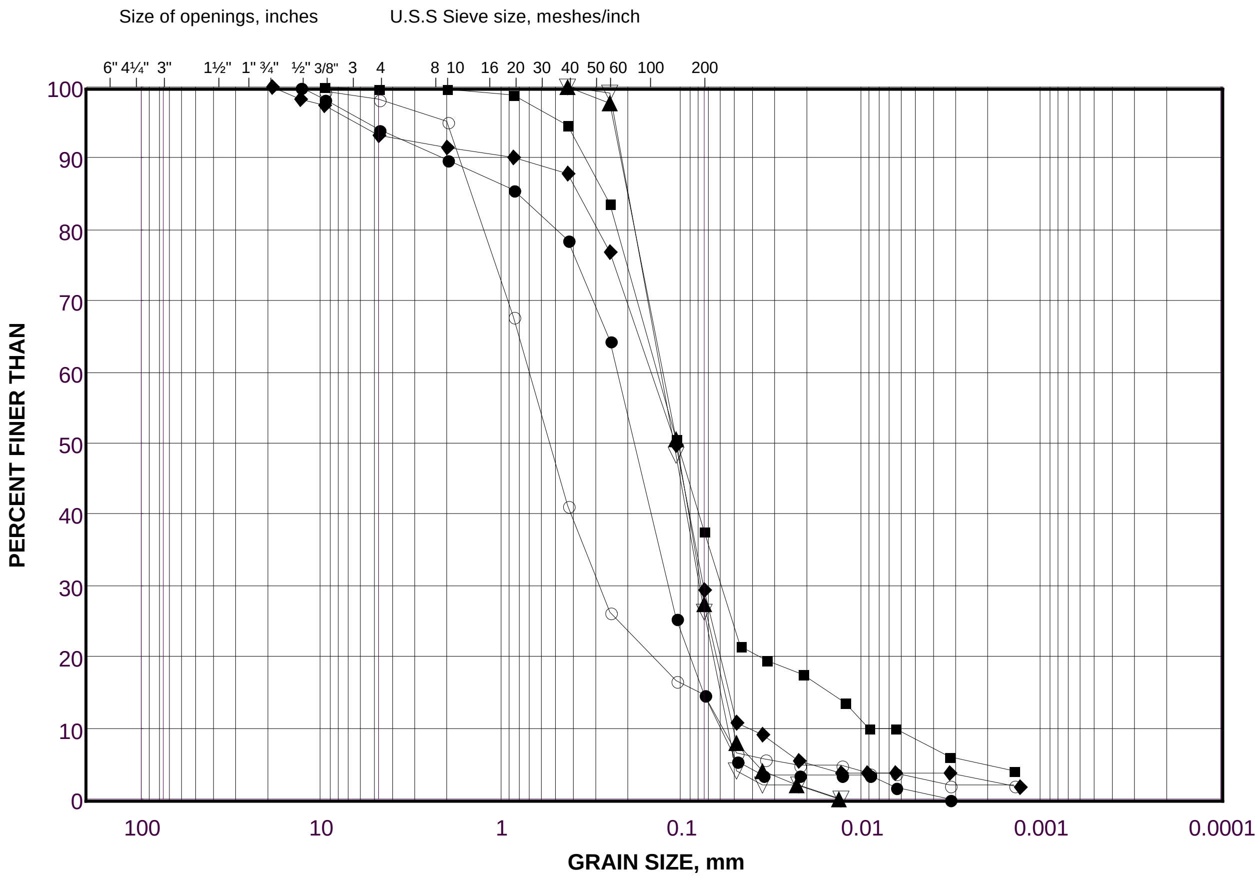
GRAIN SIZE DISTRIBUTION
SILTY SAND (SM) to SAND (SP/SP-SM)

FIGURE B-4B



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF2-1	2	328.8 - 328.3
■	HF2-1	3	328.1 - 327.5
◆	HF4-1	4	334.3 - 333.7
▲	HF5-1	5	333.0 - 332.3
▽	HF4-1	5	333.6 - 332.9
❍	HF5-1	9	328.4 - 327.7

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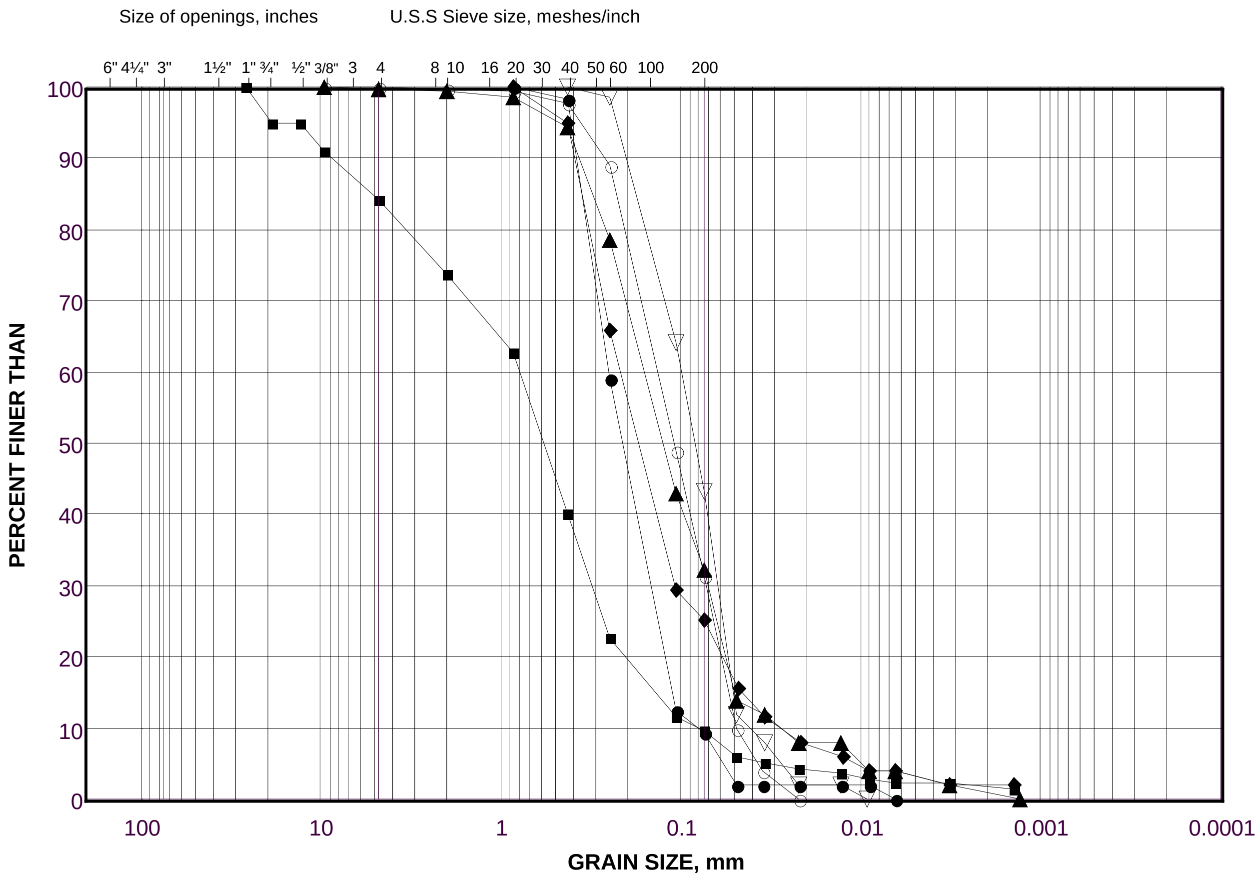
GRAIN SIZE DISTRIBUTION
SILTY SAND (SM) to SAND (SP/SP-SM)

FIGURE B4-C



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF1-1	3	330.4 - 329.8
■	HF1-4	4	344.1 - 343.5
◆	HF1-3	4	333.5 - 332.9
▲	HF1-3	8	329.7 - 329.1
▽	DC3-1	9	341.0 - 340.4
❍	HF1-4	9	338.8 - 338.2

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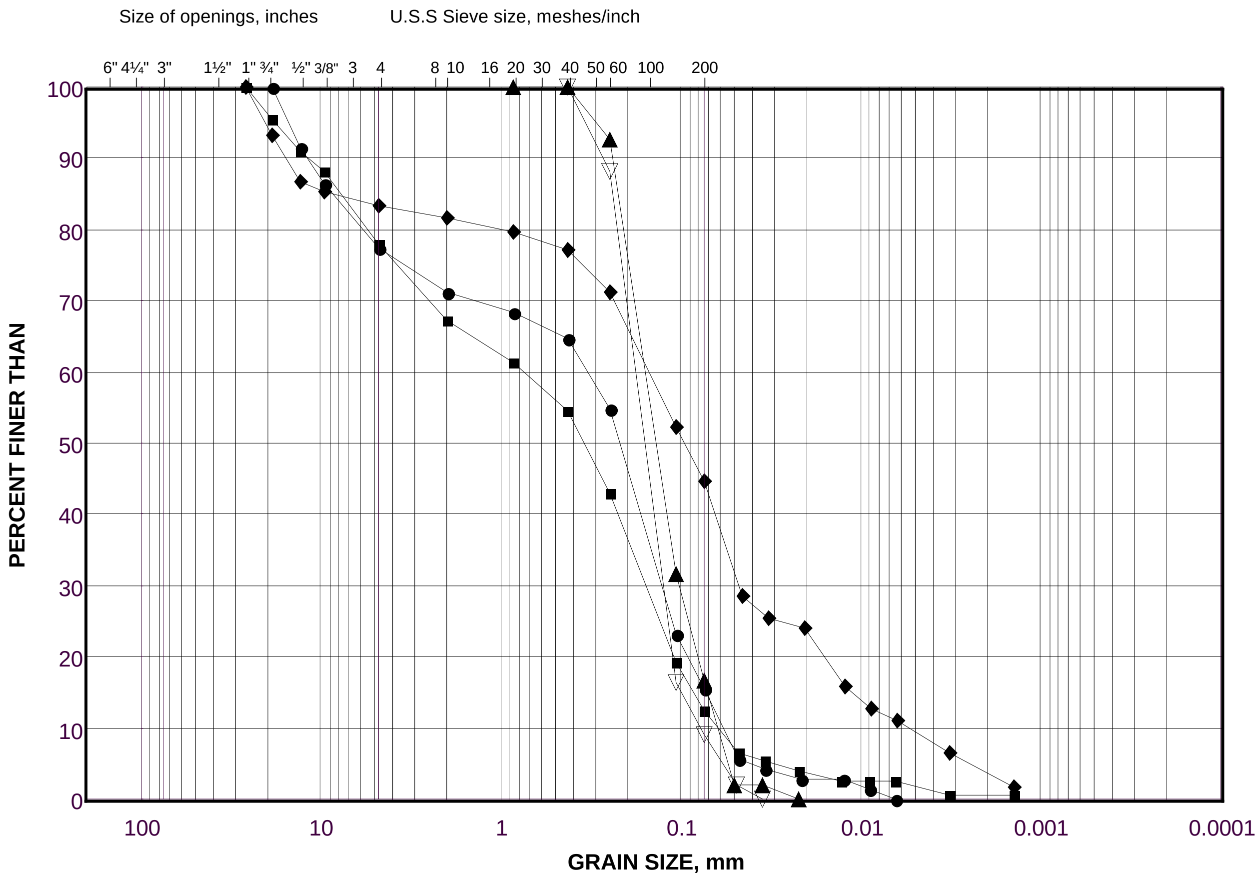
GRAIN SIZE DISTRIBUTION

SILTY SAND (SM) to SAND (SP/SP-SM)

FIGURE B-4D



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF1-2	3	329.6 - 329.0
■	HF1-2	4	328.8 - 328.2
◆	HF1-2	5	328.1 - 327.4
▲	HF1-1	7	327.3 - 326.7
▽	HF1-1	9	324.3 - 323.7

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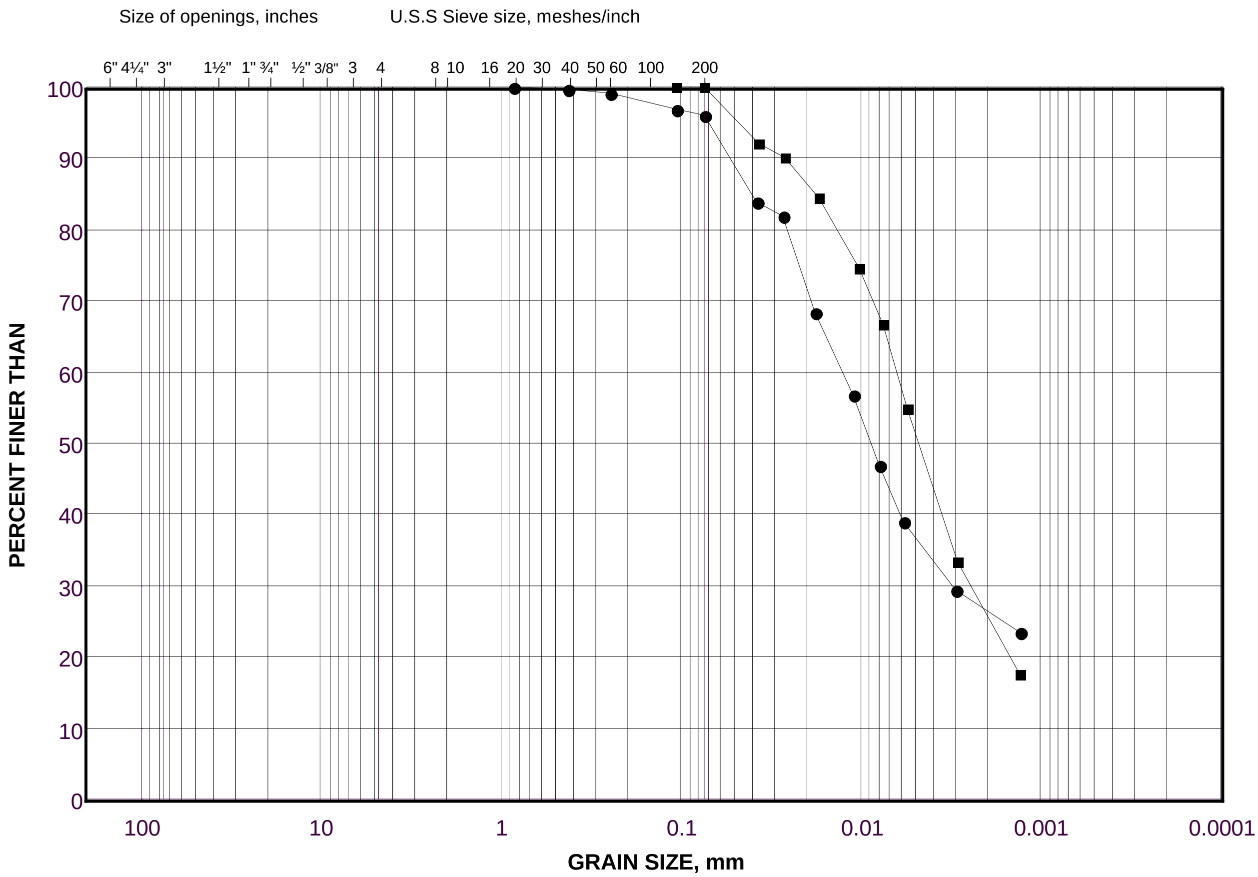
GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) To SILTY CLAY (CI)

FIGURE B-5



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	**GRAVEL SIZE**		**SAND SIZE**			**FINE GRAINED**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HF4-1	3	335.1 - 334.5
■	HF1-2	7	326.6 - 325.9

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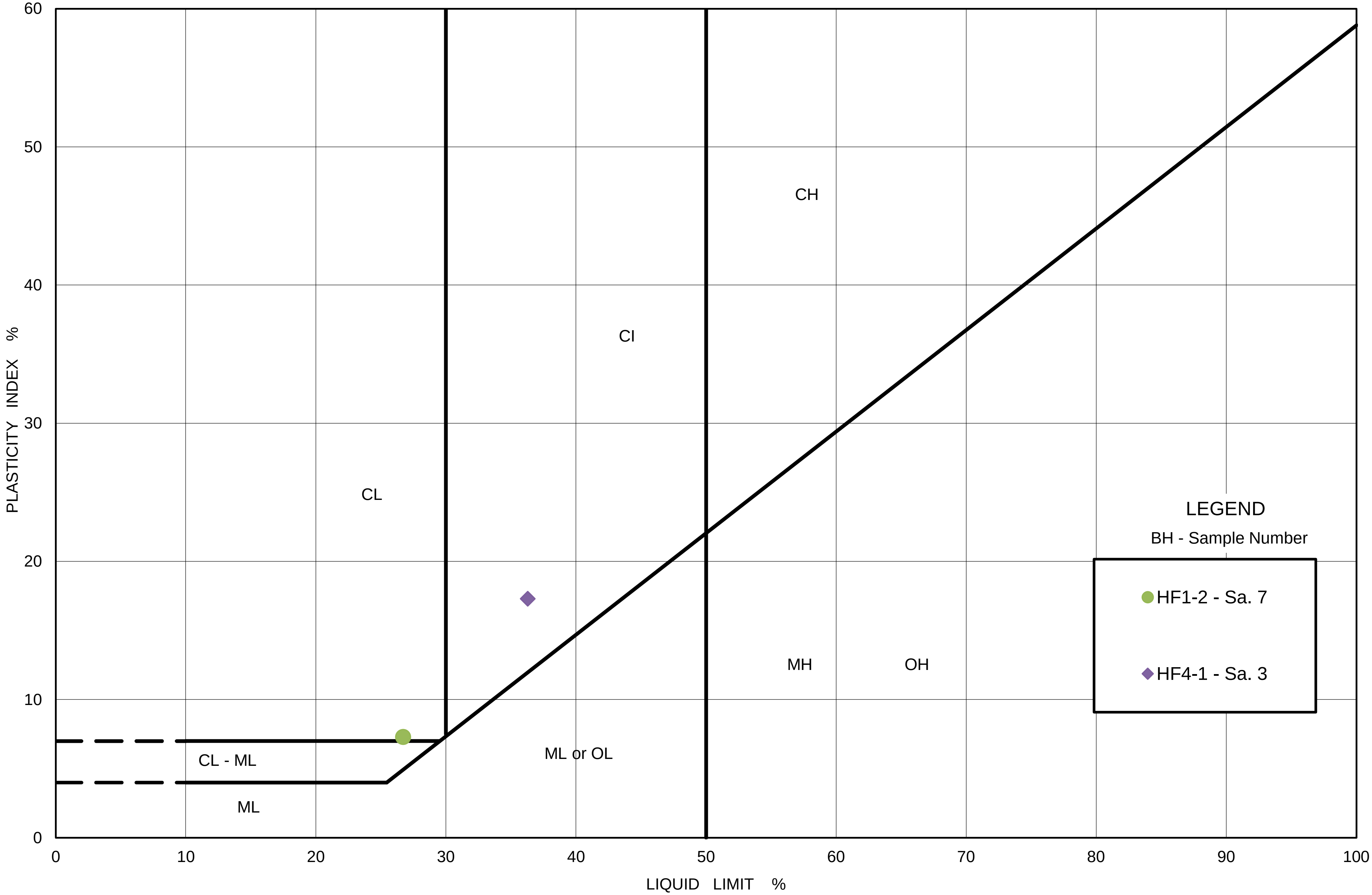
LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ASTM D4318)



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PLASTICITY CHART

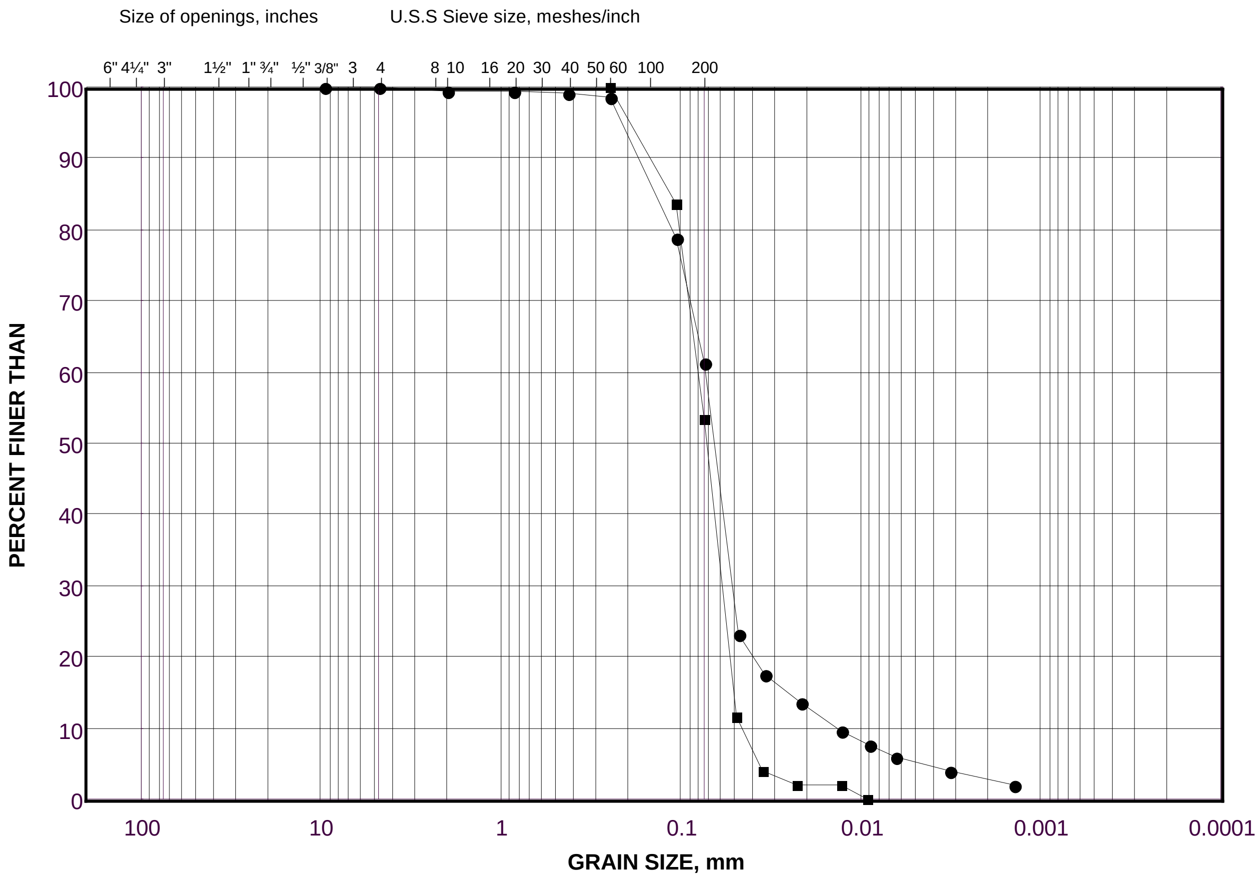
CLAYEY SILT (CL) to SILTY CLAY (CI)

Figure No.:	B-6
Project No.:	1773612 - W01
Checked By:	SEMP

GRAIN SIZE DISTRIBUTION

SILT (ML)

FIGURE B-7



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	DC1-1	10	337.3 - 336.6
■	DC1-1	5	343.4 - 342.7

Project Number: 1773612 (W01)

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Date: 08-Jun-20

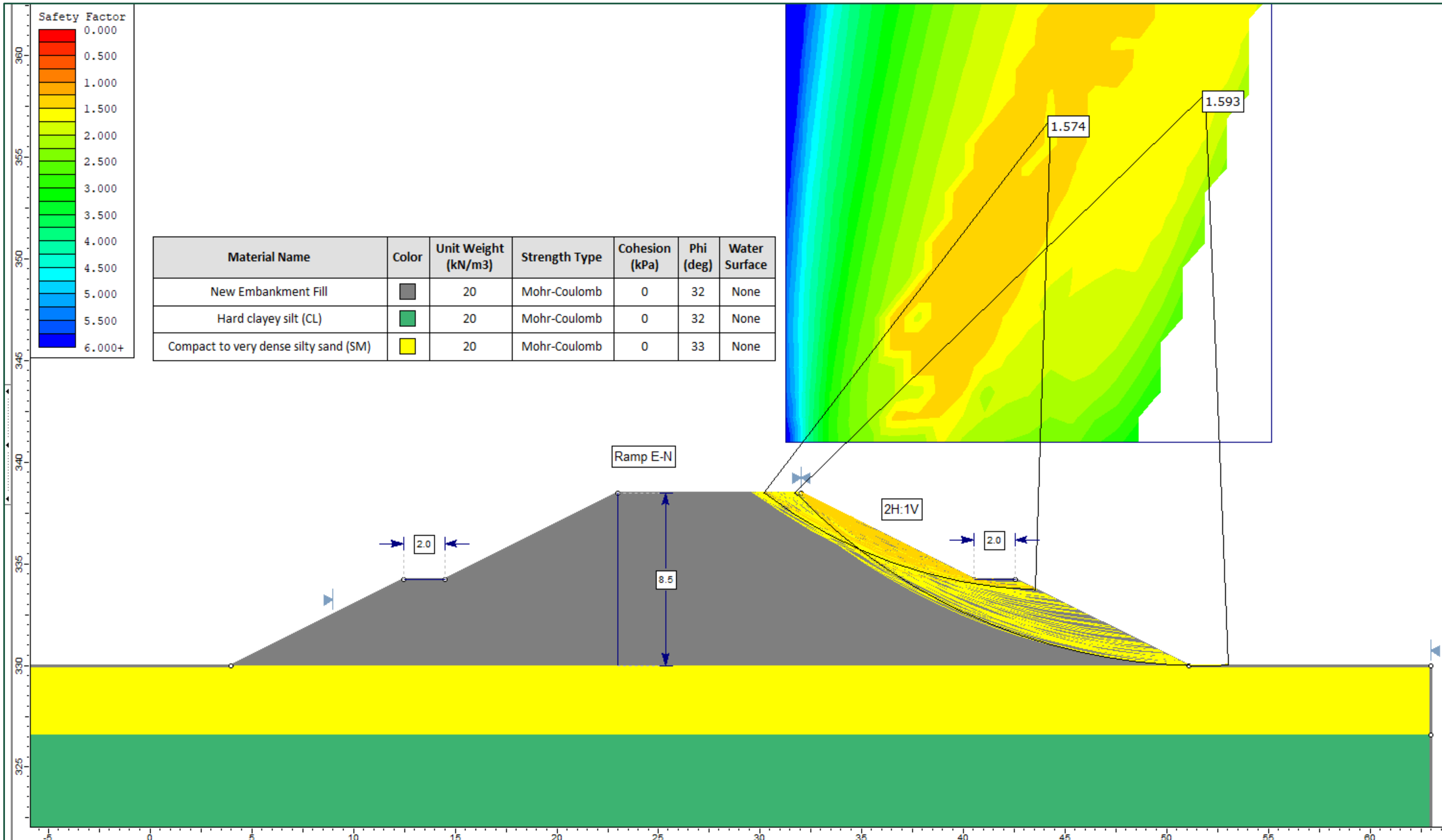
APPENDIX C

Global Stability Analysis Results

Global Stability Analysis

Figure 1

Highway 35/115 Interchange Improvements
E-N Ramp HF-1 (Sta. 10+140)
Long-Term (Drained) Analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
New Embankment Fill		20	Mohr-Coulomb	0	32	None
Hard clayey silt (CL)		20	Mohr-Coulomb	0	32	None
Compact to very dense silty sand (SM)		20	Mohr-Coulomb	0	33	None

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Analysis By: MN
Reviewed By: SEMP

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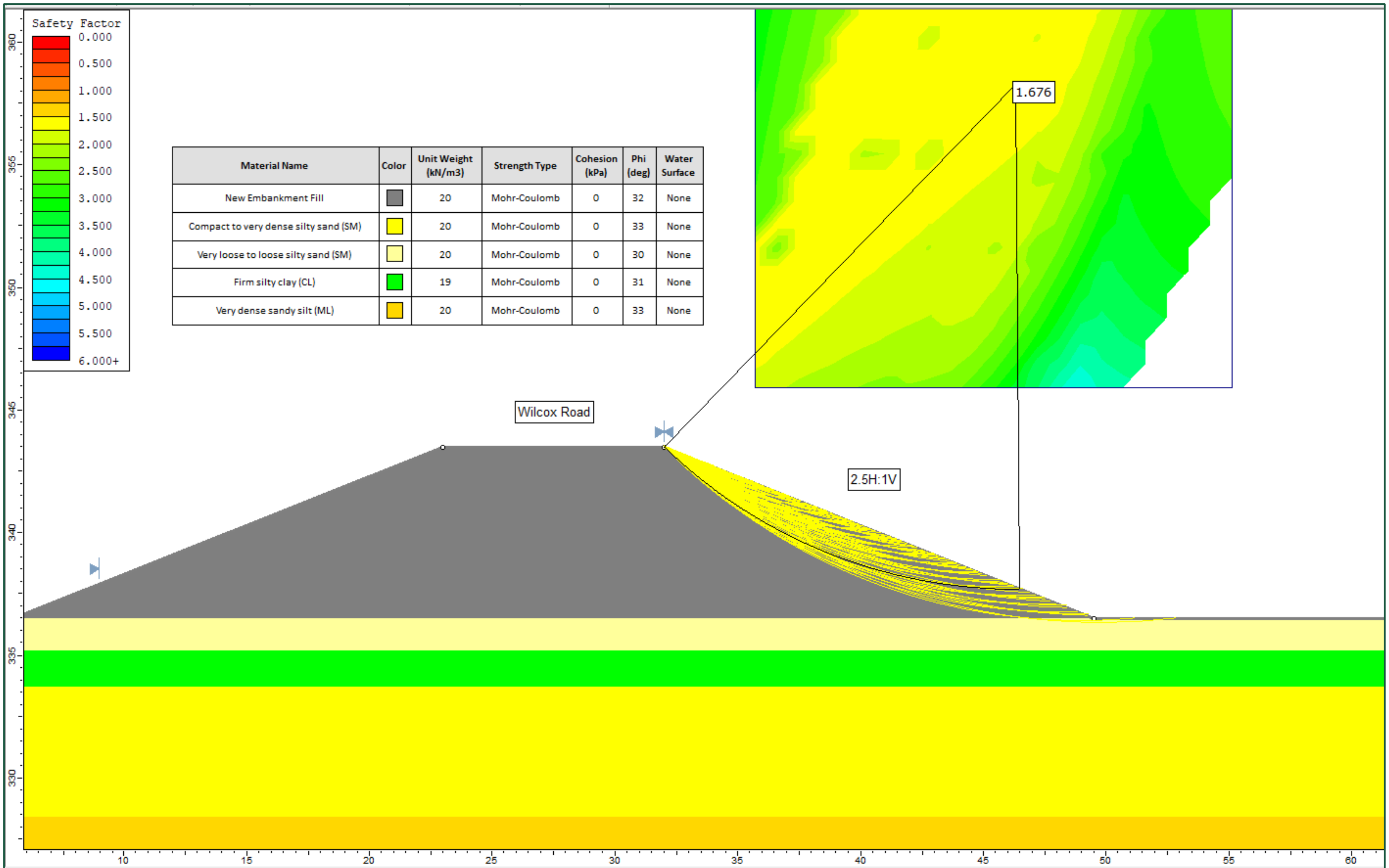
Global Stability Analysis

Figure 2

Highway 35/115 Interchange Improvements
Wilcox Road HF-3 (Sta. 0+110)
Short-Term (Undrained) Analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
New Embankment Fill		20	Mohr-Coulomb	0	32	None
Compact to very dense silty sand (SM)		20	Mohr-Coulomb	0	33	None
Very loose to loose silty sand (SM)		20	Mohr-Coulomb	0	30	None
Firm silty clay (CL)		19	Mohr-Coulomb	0	31	None
Very dense sandy silt (ML)		20	Mohr-Coulomb	0	33	None

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Analysis By: MN
Reviewed By: SEMP

Global Stability Analysis

Figure 3

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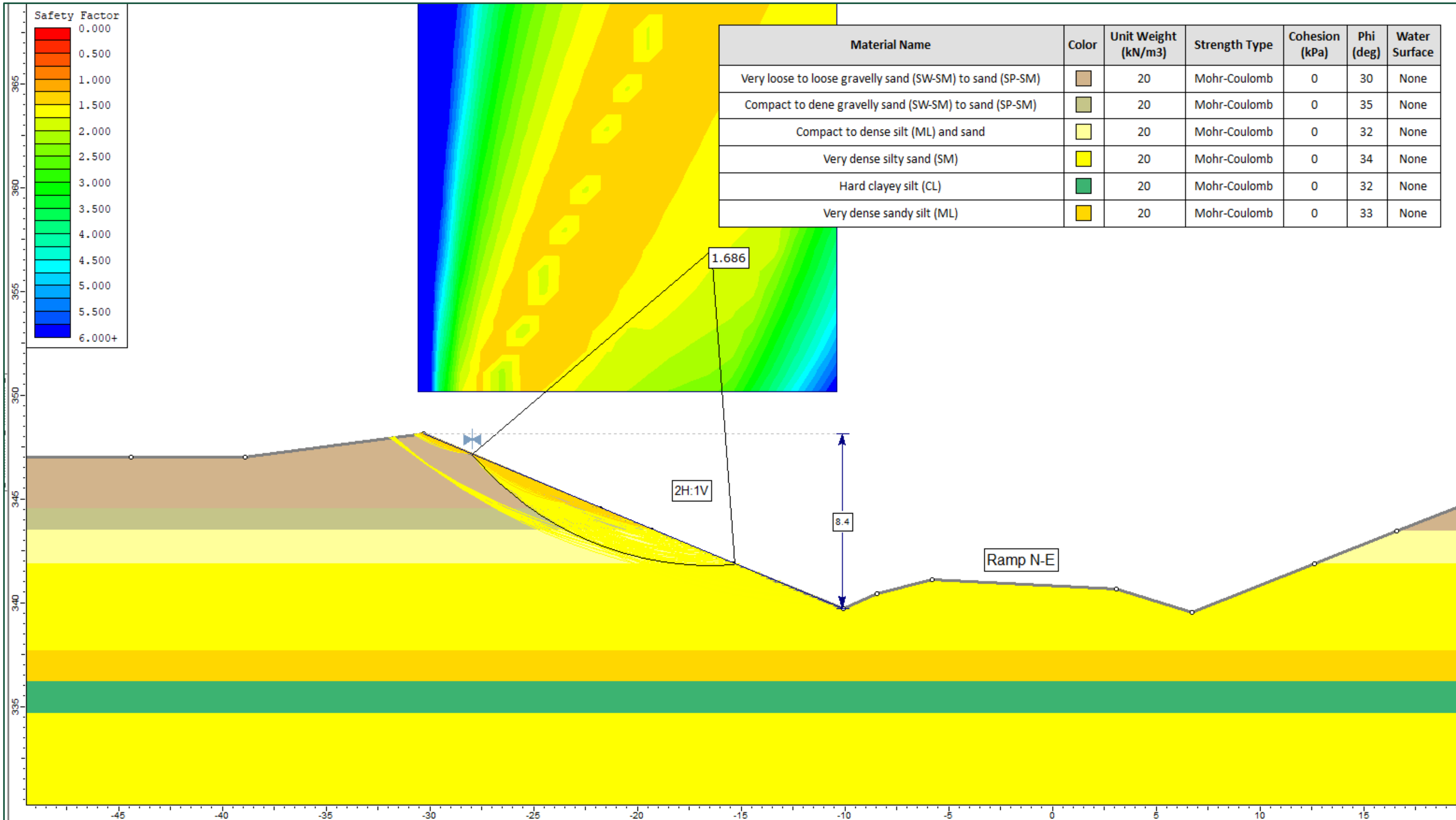
Highway 35/115 Interchange Improvements
N-E Ramp DC-1 (Sta. 9+560)
Long-Term (Drained) Analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Very loose to loose gravelly sand (SW-SM) to sand (SP-SM)		20	Mohr-Coulomb	0	30	None
Compact to dene gravelly sand (SW-SM) to sand (SP-SM)		20	Mohr-Coulomb	0	35	None
Compact to dense silt (ML) and sand		20	Mohr-Coulomb	0	32	None
Very dense silty sand (SM)		20	Mohr-Coulomb	0	34	None
Hard clayey silt (CL)		20	Mohr-Coulomb	0	32	None
Very dense sandy silt (ML)		20	Mohr-Coulomb	0	33	None

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Analysis By: MN
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