ADDENDUM NO. 1
FOUNDATION INVESTIGATION AND DESIGN REPORT
for

TEMPORARY MODULAR BRIDGE FOR SMITH CREEK BRIDGE REPLACEMENT SITE NO. 39E-0014/B0 HIGHWAY 668 – STATION 10+284 TOWN OF COCHRANE, ONTARIO G.W.P. 5284-19-00 W.P. 5368-11-01 LATITUDE AND LONGITUDE: 49.157440, -81.272080

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PML Ref.: 18TF002A
Index No.: 058FIR and 059FDR
GEOCRES No.: 42H-85
July 27, 2020

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PART A - FOUNDATION INVESTIGATION REPORT
for

TEMPORARY MODULAR BRIDGE FOR SMITH CREEK BRIDGE REPLACEMENT SITE NO. 39E-0014/B0 HIGHWAY 668 – STATION 10+284 TOWN OF COCHRANE, ONTARIO G.W.P. 5284-19-00 W.P. 5368-11-01 LATITUDE AND LONGITUDE: 49.157440, -81.272080

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TABLE OF CONTENTS

PART A - FOUNDATION INVESTIGATION REPORT

Peto MacCallum Ltd.
CONSULTING ENGINEERS

ADDENDUM NO. 1
PART A - FOUNDATION INVESTIGATION REPORT
Temporary Modular Bridge for Smith Creek Bridge Replacement
Site No. 39E-0014/B0
Highway 668 – Station 10+284
Town of Cochrane, Ontario
G.W.P. 5284-19-00, W.P. 5368-11-01

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1. INTRODUCTION

The Ministry of Transportation Ontario (MTO) has retained Parsons Corporation (Parsons) as the Prime Consultant, to provide detail design services for the replacement of two (2) bridges on Highway 668 and one (1) bridge on Highway 579. Parsons retained Peto MacCallum Ltd. (PML) on behalf of MTO to provide geotechnical engineering services for the assignment. This assignment involves two (2) contracts and the foundation investigation and design reports were submitted as follows:

Contract Package 1:

1. Replacement of Deception Creek Bridge (Site No. 39E-169) – Issued under GEOCRES No.: 42H-82, dated August 21, 2019.
2. Smith Creek Bridge (Site 39E-014) on Highway 668 – Issued under GEOCRES No.: 42H-83, dated August 19, 2019.

Contract Package 2:

1. Replacement of Gilles Creek Bridge (Site No. 39E-006) on Highway 579 - Issued under GEOCRES No.: 42H-82, dated August 21, 2019.

The foundation investigation work reported herein is part of Contract Package 1, for the detail design of the proposed Temporary Modular Bridge (TMB) at the crossing of Smith Creek along Highway 668.

Pavement investigations were also carried out in conjunction with the foundation investigation and the pavement investigation report for the proposed structure locations was issued under a separate cover.

The Terms of Reference and Scope of Work for the Foundation Engineering services are outlined in MTO Assignment No. 5017-E-0030, dated August 2017.

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BARRIE, COLLINGWOOD, HAMILTON, LONDON, KITCHENER, TORONTO

The initial scope of work for Smith Creek Bridge included the installation of a TMB. During the initial site visit on February 27 and 28, 2019, PML staff marked out the TMB boreholes, designated as Boreholes ED-1 to ED-4, along the proposed alignment. Prior to the May 2019 field investigation for the Smith Creek Bridge, in a meeting with MTO and Parsons on March 21, 2019, an alternative with full road closure of Highway 668 with detour on local roads was considered instead of the installation of the TMB. As a result, the field work for the TMB was not conducted during the initial time.

Upon completion of the initial investigations and submission of the final foundation investigation and design report, dated August 19, 2019 (GEOCRES No. 42H-83), the staging for the replacement bridge was revised to reinstate the installation of a TMB located approximately 11.5 m easterly in relation to the proposed alignment, to accommodate detour vehicular and traffic flow. The decision to revert to the original scope of work was communicated to PML by Parsons via e-mail, dated July 12, 2019. The original fieldwork for the TBM programmed consisted of four (4) boreholes, designated as Boreholes ED-1 to ED-4, located along the proposed TMB alignment. Boreholes ED-2 and ED-3 were to advanced 3.0 m into bedrock based on the Terms of Reference.

This addendum report presents the findings from the foundation investigation carried out for the proposed TMB at the crossing of Smith Creek (Station 10+284) in the Town of Cochrane, Ontario.

The purpose of the investigation was to explore the subsurface conditions to facilitate the design of the proposed TMB for the replacement Smith Creek bridge and to aid the designer in selecting the suitable type of foundation to support the TMB.

2. SITE DESCRIPTION

The location of the existing Smith Creek bridge is approximately 11 km north of Highway 11 on Highway 668. Highway 668 in the area of the bridge site is slightly elevated from the natural topography, and accommodates two (2) lanes of vehicular traffic. The site is generally a flat area, with the exception of the highway embankments. Smith Creek flows from west to east, almost perpendicular to Highway 668. The proposed bridge site is located within farm lands and are surrounded by long grass and forestation with mature trees and shrubs.

3. FIELD INVESTIGATION PROCEDURES

The field work for the foundation investigation involved advancing four (4) boreholes at the Smith Creek bridge site. The boreholes were drilled to depths ranging from 10.4 m to 22.1 m below the existing ground surface. Table 3.1 summarizes the ground surface elevation, location (northing and easting coordinates), and terminated depth and elevation of each borehole investigated for the proposed TMB.

Table 3.1: Summary of Boreholes ED1 to ED4

LOCATION	GROUND ELEVATION (m)	COORDINATES		BOREHOLE DEPTH (m)	TERMINATED ELEVATION OF BOREHOLE (m)
		Northing	Easting		
ED1	261.1	5 446 643.6	284 954.3	18.9	242.2
ED2	260.9	5 446 628.1	284 955.9	21.9	239.0
ED3	260.8	5 446 605.1	284 955.0	22.1	238.7
ED4	261.4	5 446 583.0	284 954.6	10.4	251.1

During the initial site visit on February 27 and 28, 2019, PML staff visited the site to mark out the TMB boreholes (ED-1 to ED-4). PML staff used a portable GPS device to establish the location of boreholes in the field. Subsequently, Rugged Geomatics Inc. of Timmins, Ontario, under contract to PML, carried out the survey of the as drilled borehole locations and elevations, and provided the co-ordinates for locations in MTM Northing and Easting (MTM Zone – ON12). Rugged Geomatics Inc. informed in an email dated July 21, 2020 that the absolute accuracy is 0.02 m vertically and horizontally of the survey. PML used the survey data provided by Rugged Geomatics Inc. for the preparation of this report. All elevations reported in this report are referred to Geodetic datum and expressed in meters.

The equipment used for drilling was owned and operated by Landcore Drilling of Chelmsford, Ontario and PML FS of Hamilton, Ontario. Landcore Drilling and PML FS are specialist drilling contractors and worked under the full time supervision of a PML field supervisor. Boreholes ED-1 to ED-4 were drilled on December 16 and 17, 2019 and between January 16 and 23, 2020. The boreholes were advanced using a CME 55 track-mounted drilling rig equipped with 200 mm diameter hollow stem augers and rotary coring.

Due to the existing terrain and overhead bell line along the proposed TMB alignment, the boreholes had to be relocated from the planned locations at the site to facilitate safe drilling operation.

Refer to Drawings ED-1 in Appendix A for borehole location details for the Smith Creek TMB.

Representative soil samples were recovered from the boreholes at 0.75 m intervals to a depth of 6.0 m and at 1.5 m to the depth of termination, using a conventional 51 mm OD split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. In addition, the in-situ vane shear strength of clayey soil at depths where SPT 'N' values were below about 8 blows/300 mm was measured using a N- size (MTO) vane. The field vane shear test was carried out in accordance with ASTM D2573.

The groundwater conditions at the borehole locations were observed during the drilling by visual examination of the soil samples, sampler and drill rods as the samples were retrieved. In addition, water level measurements were taken in the open boreholes upon completion of drilling. Water levels were measured using a Solinst flat tape water level reader.

The water level in Smith Creek was observed at approximate EL. 257.6 during the May 2019 fieldwork. During the January 2020 fieldwork, the surface of the creek was frozen, however, the top of the frozen creek surface was measured at approximately the same elevation (EL. 257.6).

Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and O.Reg. 903 for borehole abandonment procedures.

The recovered soil samples were returned to the PML laboratory for detailed visual examination and index tests.

4. LABORATORY TEST PROCEDURES

Laboratory tests were conducted at PML's laboratory, located in Toronto, on representative SPT samples recovered during the fieldwork. The laboratory testing program included the following:

- Natural moisture content determinations (52)
- Grain size distribution analysis (18)
- Atterberg limits tests (15)

All laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow the American Society for Testing Materials (ASTM) standards, with the exception of hydrometer tests (LS-702). The results of the grain size distribution analyses are presented on Figures ED-GS-1 to ED-GS-5. The results of the Atterberg limits tests are presented on Figures ED-PC-1 to ED-PC-3. All of the test results are summarized on the attached Record of Borehole Logs provided in Appendix A.

5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

In general, the project area is located within the Abitibi Uplands of the James physiographic region of the Canadian Shield. The Quaternary Geology map published by the Ontario Ministry of Northern Development and Mines (MNDM), indicates that the surface conditions in the area of the culvert site consist of fine grained till deposits; predominantly silty clay to silt matrix. Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the MNDM, the project area mainly consists of metasedimentary supercrustal rocks of the Superior Province.

5.2 Subsurface Conditions

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the attached Record of Borehole Sheets. The borehole locations and stratigraphic profile section are shown on Drawings ED-1. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

In general, the subsoil conditions immediately below the ground surface along the alignment of proposed TMB consists of fill 2.3 m to 3.8 m thick, composed of layers of clayey silt and sand, which is followed by firm to stiff clayey silt. The clayey silt layer is underlain by compact to very dense sand. In Boreholes ED2 and ED3, the sand deposit is underlain by bedrock by which extends to the maximum borehole termination depth of 22.1 m below the existing ground surface. For classification purposes, the subusrface stratigraphy encountered at this site can be divided into five (5) distinct zones:

a) Clayey Silt, Trace/Some Sand, Trace/Some Gravel (Fill)
b) Sand Trace/Some Silt, Trace/Some Gravel (Fill)
c) Clayey Silt/Silty Clay, Trace/Some Sand, Trace Gravel
d) Sand, Trace Silt
e) Bedrock

5.2.1 Clayey Silt, Trace/Some Sand, Trace/Some Gravel (Fill)

A 900 mm to 2.3 m thick clayey silt fill layer was encountered immediately below the ground surface in all of the boreholes (ED1 to ED4).

The SPT 'N' values in the clayey silt fill ranged from 10 blows to 30 blows, indicating stiff to hard consistency. Generally, the moisture content of the samples tested from this layer ranged from 10.3% to 26.5%, with an average value of 21.1%. However, a moisture content of one (1) sample was found to be 42.3% in Borehole ED1.

5.2.2 Sand Trace/Some Silt, Trace/Some Gravel (Fill)

A 800 mm to 1.4 m thick sand fill layer was encountered immediately below the clayey silt fill in Boreholes ED3 and ED4, located south of Smith Creek. This silty sand fill layer extends to 2.3 m (EL. 259.1 to EL. 258.5) below the existing ground surface.

The SPT 'N' values in the silty sand/sandy silt fill layer varied between 9 blows and 14 blows, indicating compactness condition ranging from loose to compact. The moisture content of the samples tested ranged from 4.0% to 9.7%, with an average value of 6.1%.

5.2.3 Clayey Silt/Silty Clay, Trace/Some Sand, Trace Gravel

The fill layer in all of the boreholes is underlain by clayey silt/silty clay deposit. This deposit extends to depths ranging from 16.8 m to 18.3 m (EL. 244.0 to EL. 242.6) below the existing ground surface, in Boreholes ED1 to ED3, where it was fully penetrated. This deposit was not fully penetrated in Borehole ED4 and extended to the termination depth of 10.4 m (EL. 251.1) below the existing ground surface.

The SPT 'N' values in this deposit vary from none to 14 blows, indicating very soft to stiff consistency, with the exception of Sample SS8 in Borehole ED1 of 25 blows, indicating very stiff consistency.

Vane shear tests were attempted at depths where low SPT 'N' values were observed. The test was performed at 21 locations within this deposit and the vane shear strength measured ranged from 28 kPa to over 120 kPa. The vane shear test results indicate firm to very stiff consistency, compared to typically very soft to stiff consistency based on SPT 'N' values.

The grain size distribution results of selected samples from this deposit are provided on Figures ED-GS-1 to ED-GS-2, and the results of Atterberg limits for the same samples are provided on Figures ED-PC-1 and ED-PC-2 in Appendix A.

The moisture content of the samples ranged from 8.5% to 45.5%, with an average value of 22.0%. However, the moisture content of two (2) samples containing organics was found to be 50.7% and 58.9%. Sieve and hydrometer tests were performed on 14 representative samples and the test results indicate that this deposit consists of none to 1% gravel, none to 16% sand, 20% to 76% silt, and 24% to 80% clay. Atterberg limits were performed on the same 14 representative samples and the test results indicate liquid limit values range from 22 to 55, plastic limit values range from 13 to 26, and corresponding plasticity index values range from 8 to 29. Based on the test results, the soil may be classified as clay of low to medium plasticity (CL/CI) in the Unified Soil Classification System (USCS), i.e., clayey silt/silty clay.

The result of the sieve analysis test performed on one (1) sample from the silty sand seam is provided on Figure ED-GS-3. The test results indicate that the soil consists of 1% gravel, 74% sand, 20% silt, and 5% clay sized particles.

The result of the sieve analysis test performed on one (1) sample from the gravelly seam is provided on Figure ED-GS-4. The test results indicate that the soil consists of 56% gravel, 29% sand, 15% silt and clay sized particles. Atterberg limits were performed on the same sample (Results shown in Figure ED-PC-3) and the test results indicate a liquid limit value of 27, a plastic limit value of 15, and a corresponding plasticity index value of 12. Based on the test results, the soil may be classified as clayey gravel (GC) in accordance with the USCS.

5.2.4 Sand, Trace Silt

A 300 mm and 1.6 m thick sand layer was encountered immediately below the clayey silt/silty clay deposit in Boreholes ED2 and ED3.

The SPT 'N' values in this deposit vary from 24 blows to 100 blows, indicating compactness condition ranging from compact to very dense.

The results of grain size distribution of selected two (2) representative samples from this deposit are provided on Figure ED-GS-5 in Appendix A. The test results indicate that this deposit consists of no gravel, 94% to 99% sand, 1% to 6% silt and clay sized particles. The moisture content of one (1) sample tested from this deposit was 14.8%.

5.2.5 Bedrock

Borehole ED1 was terminated on probable bedrock at 18.9 m, EL. 242.2. Bedrock was encountered in Boreholes ED2 and ED3, immediately below the sand deposit at approximate elevations of EL. 242.3 and EL. 242.4, respectively. The presence of bedrock was confirmed by obtaining 3.3 m and 3.7 m of rock core from Boreholes ED2 and ED3, respectively. Rock coring was advanced using an HQ sized core barrel and wash boring with a 75 mm diameter NW casing. The rock core recovery ranged from 67% to 100% and the Rock Quality Designation (RQD) of the rock cores ranged from 29% to 95%. The quality of the bedrock at this site may be described as poor to excellent based on the RQD values ranging from 29% to 95%. The bedrock was identified as Diabase. For complete description of the bedrock, refer to the Rock Core Photographs and the Rock Core Description logs provided in Appendix A.

5.2.6 Groundwater

Groundwater was encountered at 16.8 m (EL. 244.0) and 3.8 m (EL. 257.6) below the existing ground surface during drilling in Boreholes ED3 and ED4, respectively. Groundwater was not encountered in Boreholes ED1 and ED2 during drilling. Groundwater was measured at 16.8 m (EL. 244.1) and 15.2 m (EL. 245.6) below the existing ground surface upon completion of drilling in Boreholes ED2 and ED3, respectively. Boreholes ED1 and ED4 were dry upon completion of drilling. The water level in the creek was observed at approximate elevation of EL. 257.6 during the fieldwork.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal change. The groundwater levels were observed and measured prior to backfilling the boreholes. Groundwater levels are shown on the Borehole Logs in Appendix A.

6. CLOSURE

Mr. M. Mohamed and Mr. F. Meng carried out the field investigations under the supervision of Mr. N. Rahman, P.Eng., Project Engineer, and Ms. N. Leong-Sem, EIT. Landshark Drilling Ltd. of Brantford, Ontario supplied the drilling equipment for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This report was prepared by Ms. N. Leong-Sem, B.Eng., EIT, Geotechnical Services and reviewed by Mr. N. Rahman, P.Eng., Project Engineer, and Mr. G. Uwimana, MEng, P.Eng. Senior Engineer, Geotechnical Services. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

Natasha Leong-Sem
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Robert Ng, MBA, PhD, P.Eng.
Project Manager and
MTO Designated Principal Contact

NL/NR:nl-nr-nk

APPENDIX A

Borehole Locations Plan and Soil Strata Drawing ED-1

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures ED-GS-1 to ED-GS-5

Results of Atterberg Limit Tests – Figures ED-PC-1 to ED-PC-3

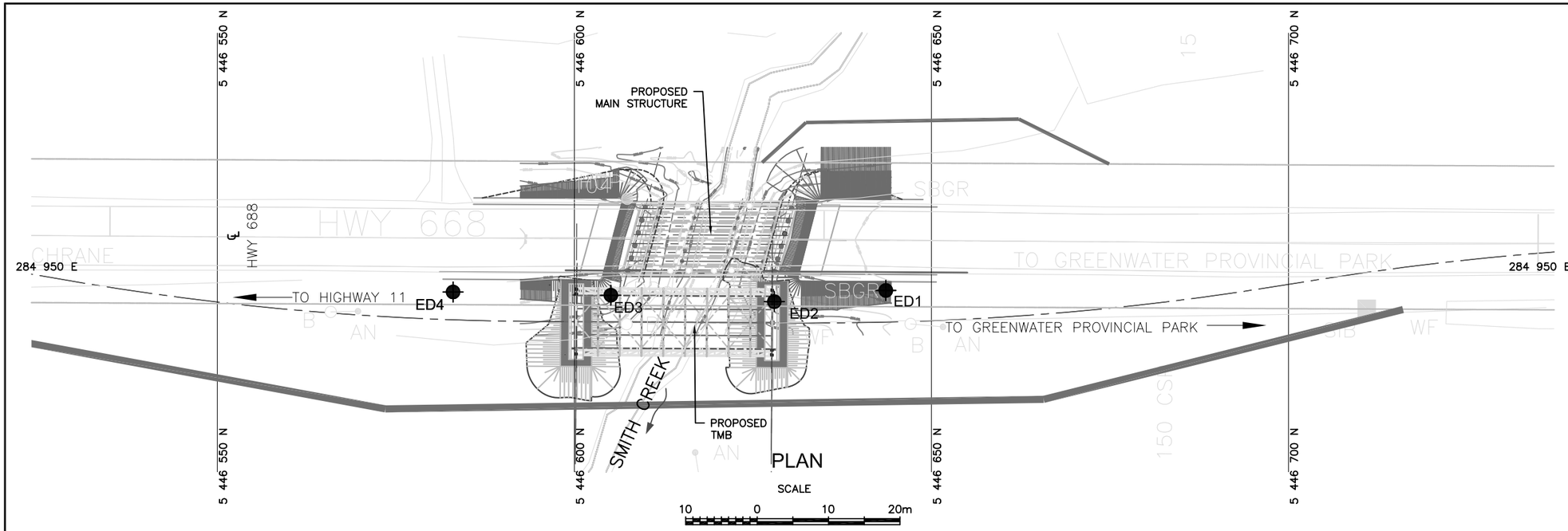
Rock Core Descriptions and Photographs

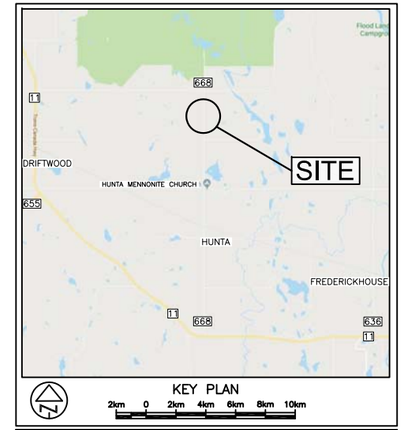
GWP No 5284-19-00
WP No 5368-11-01

SMITH CREEK TEMPORARY MODULAR BRIDGE
HIGHWAY 668
BOREHOLE LOCATIONS

SHEET

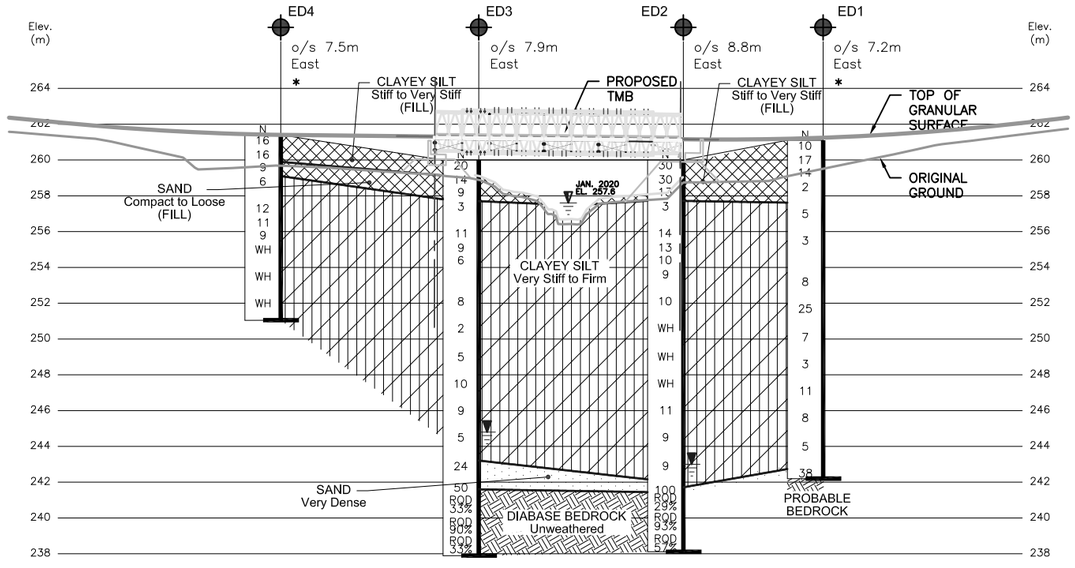
Peto MacCallum Ltd.
CONSULTING ENGINEERS





LEGEND

- Foundation Borehole for Structure
- N — Blows/0.3m (Std. Pen Test, 475 J/blow)
- WH — Penetration Due to Weight of Hammer and Rods
- * — Water Level Not Encountered Upon Completion of Drilling
- Water Level Measured Upon Completion of Drilling
- JAN. 2020 — Smith Creek Water Level



PROFILE ALONG PROPOSED TMB CENTERLINE WITH OFFSETS FROM HIGHWAY 668 CENTERLINE

HORIZONTAL SCALE
10 0 10 20m

VERTICAL SCALE
5 0 5 10m

BH No	ELEVATION	NORTHINGS	EASTINGS
ED1	261.1	5 446 643.6	284 954.3
ED2	260.9	5 446 628.1	284 955.9
ED3	260.8	5 446 605.1	284 955.0
ED4	261.4	5 446 583.0	284 954.6

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

LICENSED PROFESSIONAL ENGINEER
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PROVINCE OF ONTARIO

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REF Drawing: Smith Creek-TEMPORARY MODULAR BRIDGE-GA-GEO.dwg, Received July 2020.

NOTE
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 42H-85

HWY No 668			DIST Northern
SUBM'D NL	CHECKED NR	DATE JUL. 27, 2020	SITE 39E-0014/B0
DRAWN NL	CHECKED	APPROVED RN	DWG. ED-1

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 – 10	10 – 20	20 – 30	30 – 40	> 40
	TRACE	*SOME*	*WITH*	*ADJECTIVE (SILTY)*	*AND (AND SILT)*

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT
e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

RECORD OF BOREHOLE No ED1

1 OF 2

METRIC

G.W.P. 5284-19-00 LOCATION Coords: 5 446 643.6 N; 284 954.3 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.16 - 2020.01.17 LATITUDE 49.157580 LONGITUDE -81.272110 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
261.1	Ground Surface						261				
0.0	organics CLAYEY SILT, some sand, trace gravel Stiff to very stiff, Grey, Moist (FILL)		1	SS	10						
			2	SS	17		260				
			3	SS	14						
258.8							259				
2.3	CLAYEY SILT, trace sand, trace gravel Very stiff to stiff, Grey, Moist		4	SS	2						
				VANE			258	>>			
			5	SS	5		257				0 10 57 33
				VANE				+2			
			6	SS	3		256				0 10 57 33
				VANE			255	>>			
			7	SS	8		254				
	silty sand		8	SS	25		253				1 74 20 5
			9	SS	7		252				
				VANE			251				
			10	SS	3		250	+1			
				VANE			249				
			11	SS	11		248	+1			
246.1							247				0 1 62 37

Continued Next Page

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

RECORD OF BOREHOLE No ED1

2 OF 2 **METRIC**

G.W.P. 5284-19-00 LOCATION Coords: 5 446 643.6 N; 284 954.3 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.16 - 2020.01.17 LATITUDE 49.157580 LONGITUDE -81.272110 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
246.1											
15.0	CLAYEY SILT, trace sand, trace gravel Stiff, Grey, Moist		12	SS	8		246		○		
				VANE			245	+1			
			13	SS	5		244		○		
				VANE				+3			
	gravelly		14	SS	38		243		○⊢		56 29 (15)
242.2											
18.9	Borehole terminated on probable bedrock										

NOTES:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

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

RECORD OF BOREHOLE No ED2

1 OF 2

METRIC

G.W.P. 5284-19-00 LOCATION Coords: 5 446 628.1 N; 284 955.9 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.22 - 2020.01.23 LATITUDE 49.157440 LONGITUDE -81.272080 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
260.9	Ground Surface										
0.0	organics										
	CLAYEY SILT, some sand, trace gravel		1	SS	30						
	Very stiff to stiff, Brown to grey, Moist										
	sandy		2	SS	30		260				
	(FILL)		3	SS	13		259				
258.6											
2.3	organics		4	SS	3		258				
	CLAYEY SILT/SILTY CLAY, trace/some sand, trace gravel			VANE				>>			
	Stiff to firm, Grey, Wet to moist		5	SS	14		257				0 11 57 32
			6	SS	13		256				
			7	SS	10		255				
			8	SS	9						0 16 56 28
							254				
			9	SS	10		253				
							252				
			10	SS	0						0 0 20 80
				VANE			251	+2			
			11	SS	0		250	+2			
				VANE			249				
			12	SS	0		248				
				VANE				>>			
			13	SS	11		247				0 0 76 24
245.9							246				

Continued Next Page

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

RECORD OF BOREHOLE No ED2

2 OF 2 **METRIC**

G.W.P. 5284-19-00 LOCATION Coords: 5 446 628.1 N; 284 955.9 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.22 - 2020.01.23 LATITUDE 49.157440 LONGITUDE -81.272080 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.9											
15.0	CLAYEY SILT, trace sand, trace gravel Stiff, Grey, Moist		14	SS	9	▼	245				
			15	SS	9		244				
242.6							243				
18.3	SAND, trace silt		16	SS	100						0 99 (1)
242.3	Very dense, Grey, Moist										
18.6	Unweathered, fine grained to medium grained Dark grey to black, Hard, Crystalline Diabase Bedrock		RUN 1	RC	REC 100%		242				RQD = 29%
			RUN 2	RC	REC 100%		241				RQD = 93%
			RUN 3	RC	REC 100%		240				RQD = 87%
239.0							239				
21.9	End of borehole										

▼ Groundwater level measured upon completion of drilling

NOTE: No cave-in was noted upon extraction of hollow stem augers.

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

RECORD OF BOREHOLE No ED3

1 OF 2 **METRIC**

G.W.P. 5284-19-00 LOCATION Coords: 5 446 605.1 N; 284 955.0 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.20 - 2020.01.21 LATITUDE 49.157240 LONGITUDE -81.272100 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
260.8	Ground Surface										
0.0	organics										
	CLAYEY SILT, trace sand, trace gravel		1	SS	20						
	Very stiff, Brown to grey, Moist										
	SAND, some gravel, trace silt		2	SS	14		260				
	Compact to loose, Grey, Moist										
	(FILL)		3	SS	9		259				
258.5											
2.3	organics		4	SS	3		258				
	CLAYEY SILT/SILTY CLAY, trace sand, trace gravel			VANE				>>			
	Stiff to firm, Grey, Moist to wet		5	SS	11		257				
			6	SS	9		256				1 10 58 31
			7	SS	6		255				
				VANE				2			
							254				
			8	SS	8		253				0 9 54 37
				VANE				1			
			9	SS	2		252				
				VANE			251	2			
			10	SS	5		250				0 0 27 73
				VANE			249	2			
			11	SS	10		248				
			12	SS	9		247				
											0 0 74 26
245.8							246				

Continued Next Page

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

RECORD OF BOREHOLE No ED3

2 OF 2 **METRIC**

G.W.P. 5284-19-00 LOCATION Coords: 5 446 605.1 N; 284 955.0 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.20 - 2020.01.21 LATITUDE 49.15724 LONGITUDE -81.2721 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.8											
15.0	CLAYEY SILT, trace sand, trace gravel Stiff, Grey, Moist		13	SS	5	▼	245		○		-
				VANE				>>			
244.0						▽	244		○		0 94 (6)
16.8	SAND, trace silt Compact to very dense, Grey, Moist		14	SS	24						
242.4			15	SS	50		243				
18.4	Unweathered, fine grained to medium grained Dark grey to black, Hard, Crystalline Diabase Bedrock		RUN 1	RC	REC 81%		242				RQD = 33%
			RUN 2	RC	REC 100%		241				RQD = 95%
238.7			RUN 3	RC	REC 67%		240				RQD = 33%
22.1	End of borehole						239				

▽ Groundwater level observed during drilling

▼ Groundwater level measured upon completion of drilling

NOTE: No cave-in was noted upon extraction of hollow stem augers.

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

RECORD OF BOREHOLE No ED4

1 OF 1

METRIC

G.W.P. 5284-19-00 LOCATION Coords: 5 446 583.0 N; 284 954.6 E ORIGINATED BY M.M.

DIST Northern HWY 668 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 2020.01.21 LATITUDE 49.157040 LONGITUDE -81.27210 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
261.4	Ground Surface										
0.0	CLAYEY SILT, some sand, some gravel Very stiff, Grey, Moist		1	SS	16		261		○		
			2	SS	16				○		
	Sand, some silt Loose, Brown, Moist (FILL)		3	SS	9		260		○		
259.1											
2.3	organics		4	SS	6		259		○		
	CLAYEY SILT/SILTY CLAY, trace/some sand, trace gravel Stiff to firm, Grey, Moist			VANE				>>			-
			5	SS	12	▽	258		⊢○⊣		1 12 53 34
			6	SS	11		257		○		
			7	SS	9		256		⊢○⊣		1 12 55 32
			8	SS	0		255		○		
				VANE				+1			
			9	SS	0		254		⊢○		0 6 36 58
				VANE			253	+1			
			10	SS	0		252		○		
251.1				VANE				+2			
10.4	End of borehole										

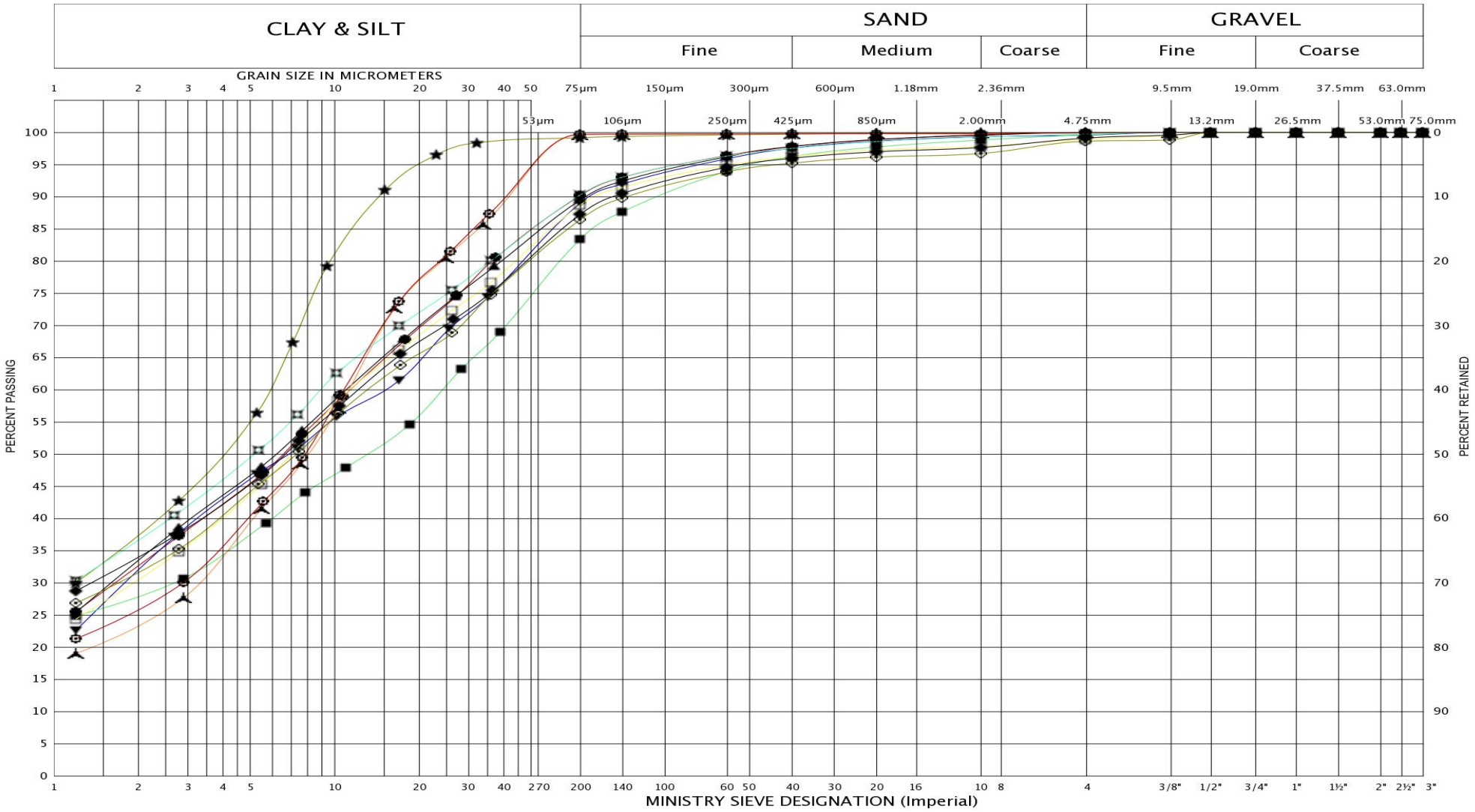
▽ Groundwater level observed during drilling

NOTES:
1. Groundwater level was not encountered upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

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

ONTARIO MTO 18TF002A-SMITH CREEK TMB REV.GPJ ONTARIO MTO.GDT 20-6-4

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	ED1	ED1	ED1	ED2	ED2	ED2	ED3	ED3	ED3	ED4	ED4
	SAMPLE	5	6	11	5	8	13	6	8	12	5	7
	SYMBOL	●	▲	★	▼	■	⅄	□	⊠	⊕	◆	◈

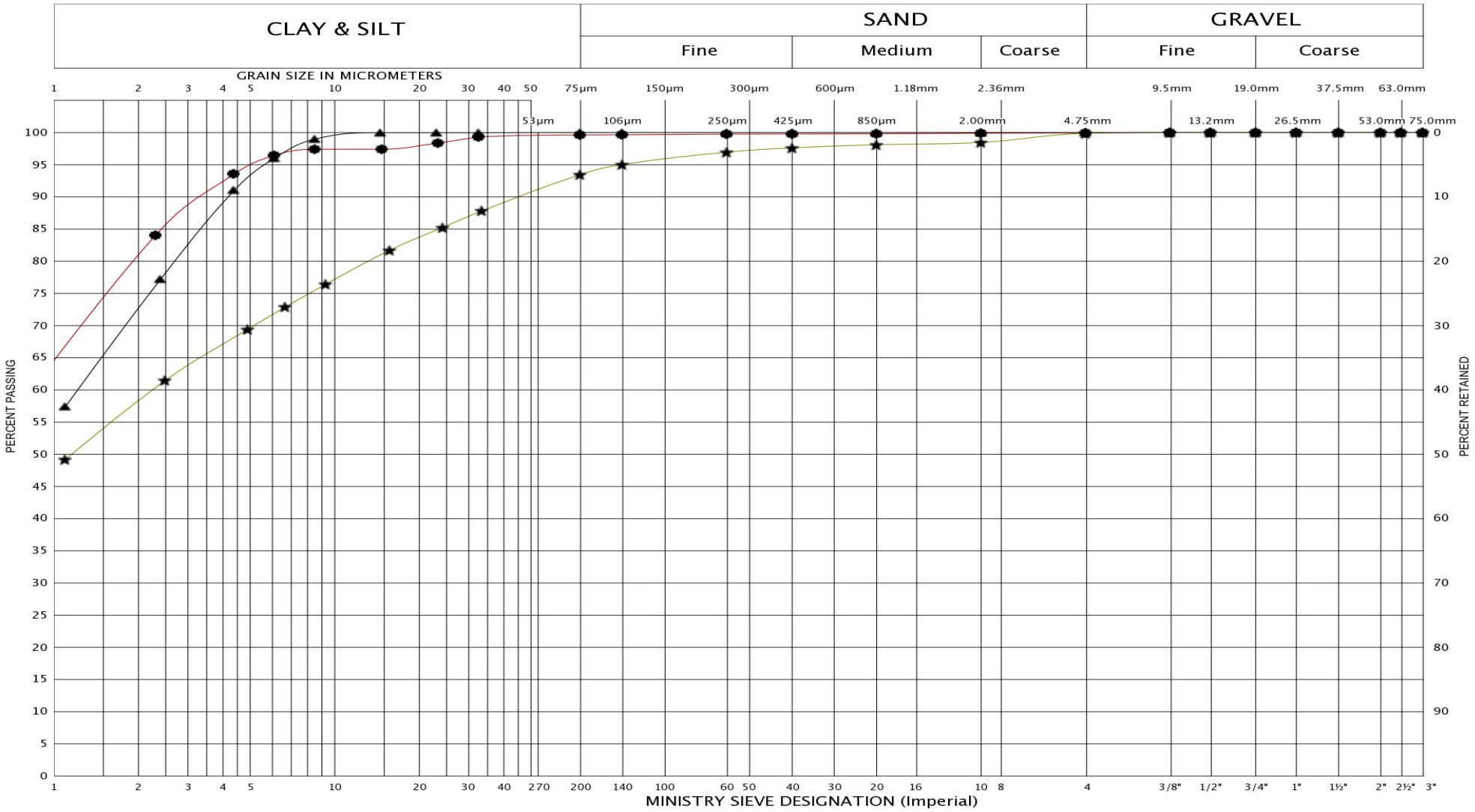
Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, Trace/Some Sand, Trace Gravel

FIG No.:	ED-GS-1
HWY :	668
GWP	5284-19-00

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	ED2	ED3	ED4
	SAMPLE	10	10	9
	SYMBOL	●	▲	★

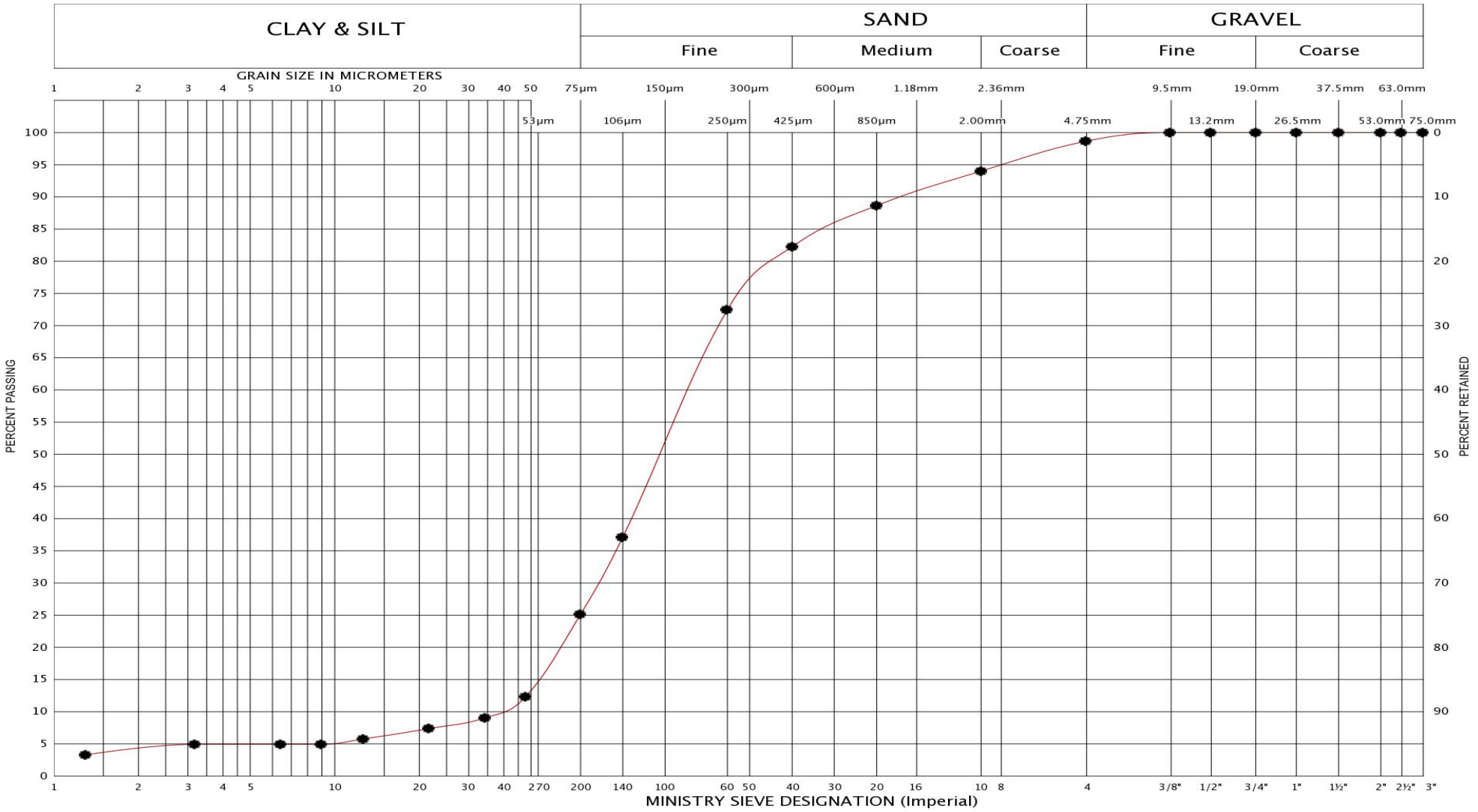
Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, Trace Sand

FIG No.:	ED-GS-2
HWY :	668
GWP	5284-19-00

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	ED1
	SAMPLE	8
	SYMBOL	●

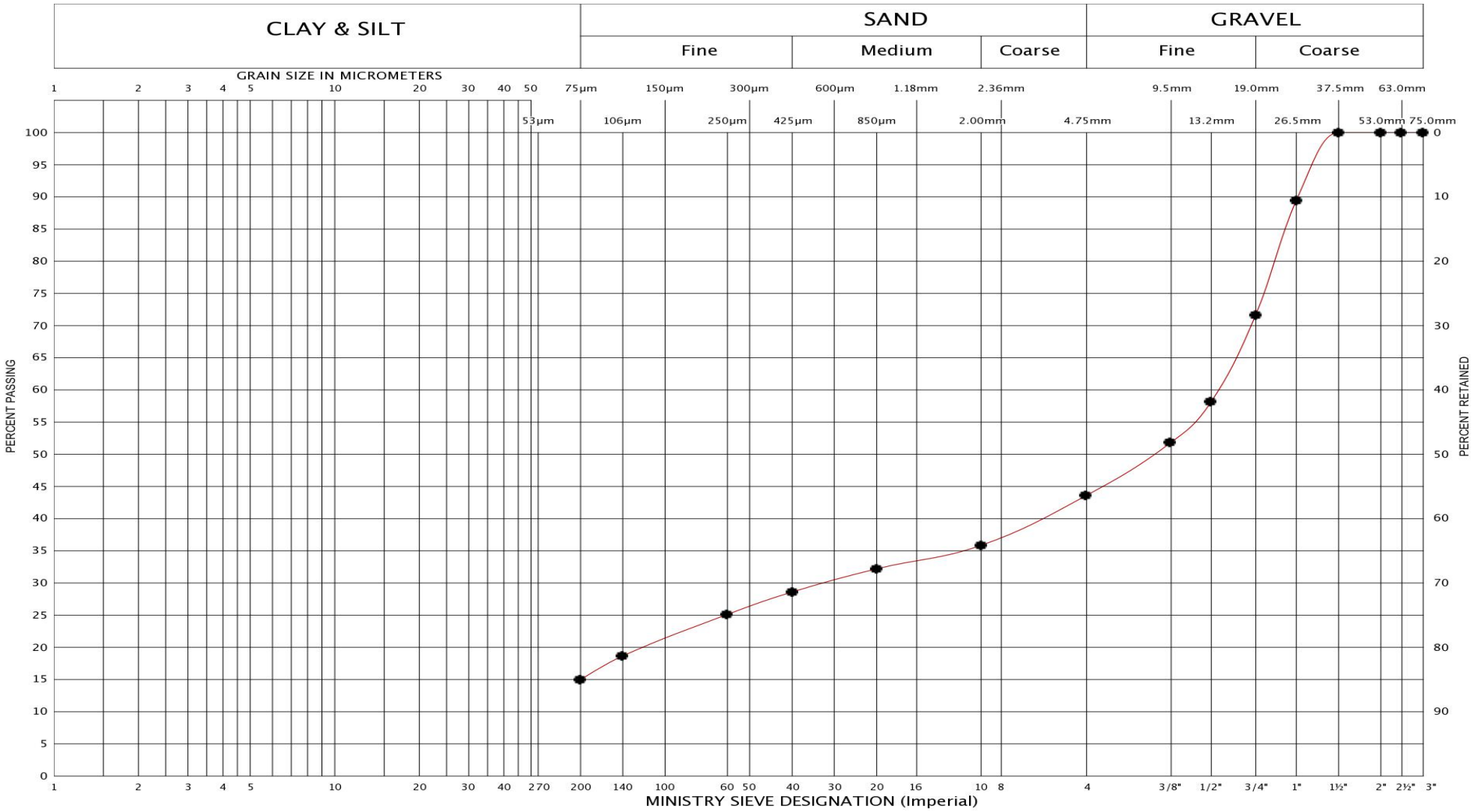
Ontario

GRAIN SIZE DISTRIBUTION

SILTY SAND, Trace Gravel

FIG No.:	ED-GS-3
HWY :	668
GWP	5284-19-00

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	ED1
	SAMPLE	14
	SYMBOL	●

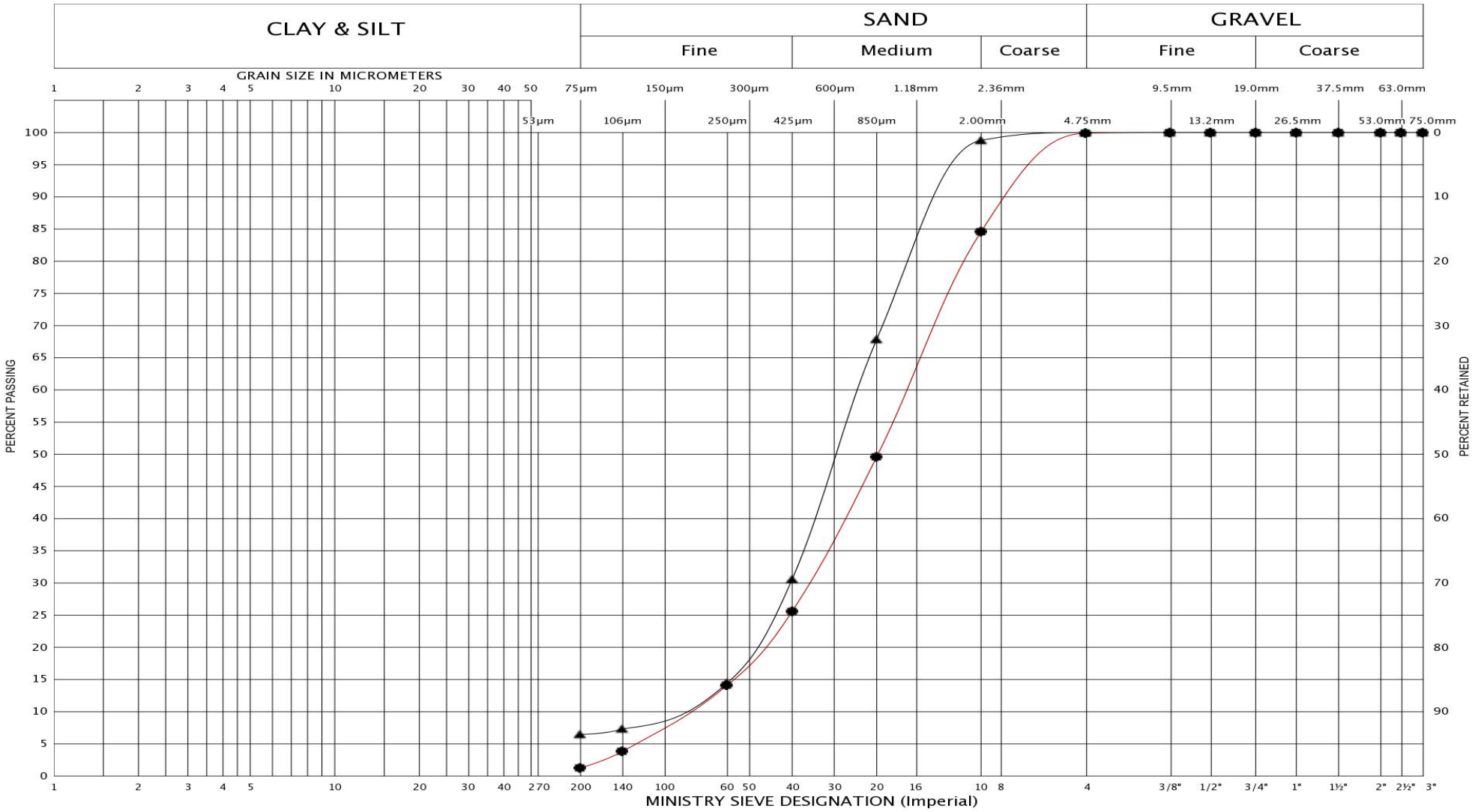
Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY GRAVEL

FIG No.:	ED-GS-4
HWY :	668
GWP	5284-19-00

UNIFIED SOIL CLASSIFICATION SYSTEM



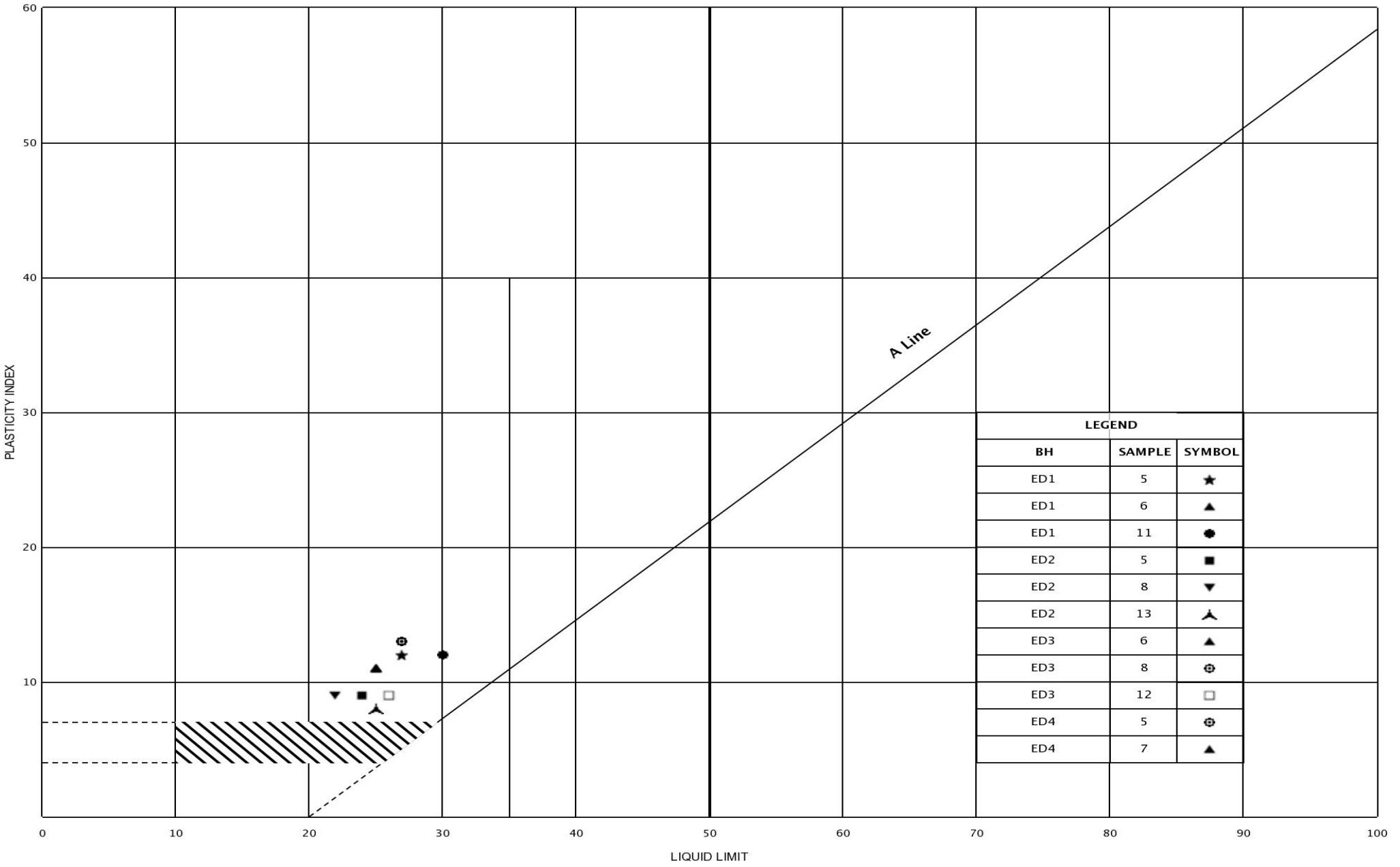
LEGEND	BH	ED2	ED3
	SAMPLE	16	14
	SYMBOL	●	▲

Ontario

GRAIN SIZE DISTRIBUTION

SAND

FIG No.:	ED-GS-5
HWY :	668
GWP	5284-19-00

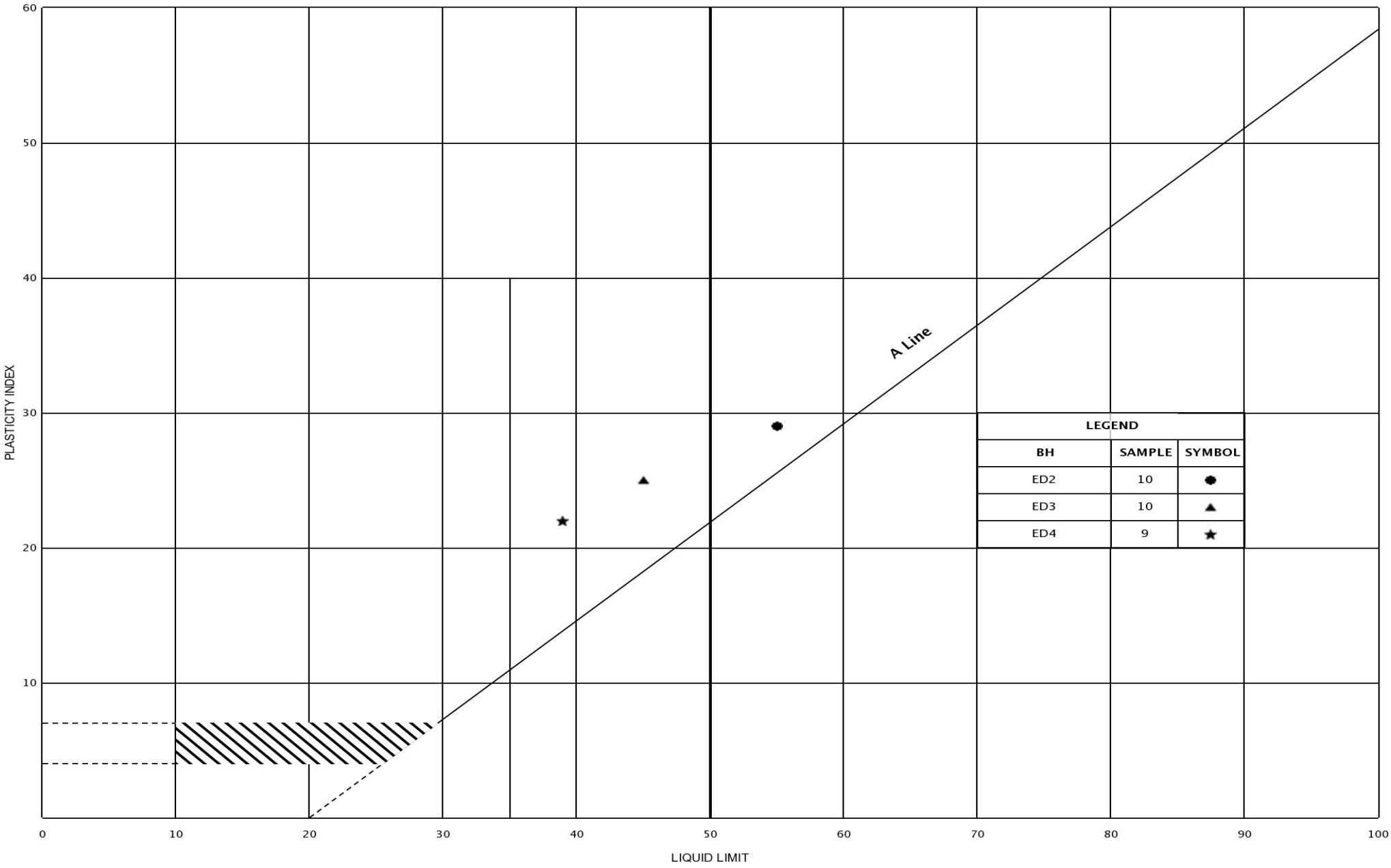


Ontario

PLASTICITY CHART

CLAYEY SILT, Trace Sand

FIG No.:	ED-PC-1
HWY.:	668
GWP	5284-19-00

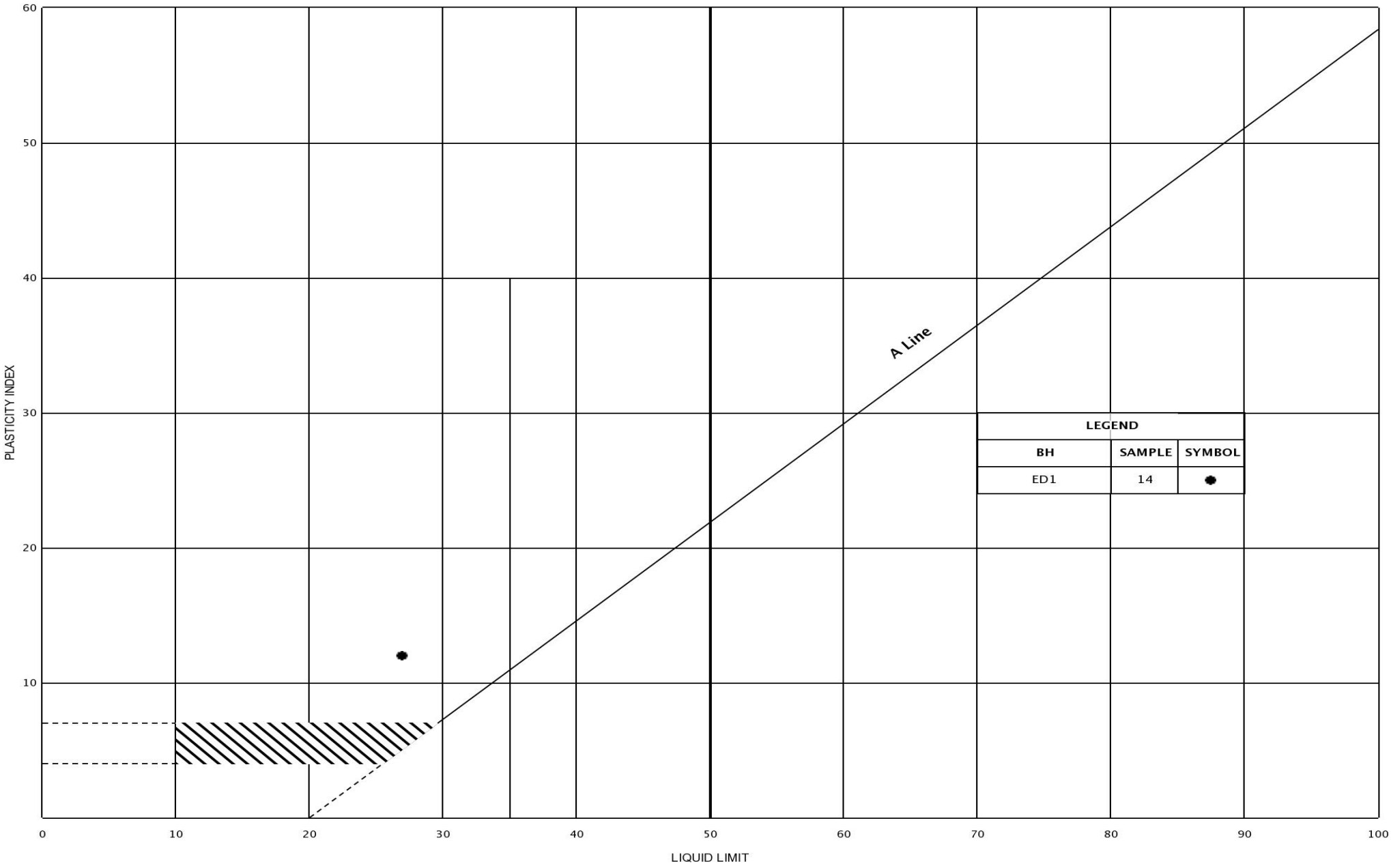


Ontario

PLASTICITY CHART

SILTY CLAY, Trace Sand

FIG No.:	ED-PC-2
HWY.:	668
GWP	5284-19-00



Ontario

PLASTICITY CHART

CLAYEY GRAVEL

FIG No.:	ED-PC-3
HWY.:	668
GWP	5284-19-00

ROCK CORE DESCRIPTION

Location: Smith Creek, Cochrane, ON
Site Name: TMB for Smith Creek Bridge Replacement, Hwy 668

BH No.	CORE RECOVERY				CORE DESCRIPTION	
	RC No.	DEPTH (m)	% CR*	% RQD**	DEPTH (m)	DESCRIPTION
ED 2	1	18.59	+100.0% (1.04 m)	28.7% (0.25 m)	19.46	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, fine to medium grained, massive, dark grey to black, hard, crystalline; **DIABASE** with white; translucent quartz veins (8.0 mm thick) and unweathered, coarse grained, black/white, hard, crystalline **DIORITE**. Occasional features: Presence of sulphides (stringers/nodules).
ED 2	2	19.46	+100.0% (1.63 m)	93.4% (1.42)	20.98	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, fine to medium grained, massive, dark grey to black, hard, crystalline; **DIABASE** with white; translucent quartz veins (3.0 mm thick) and unweathered, coarse grained, black/white, hard, crystalline **DIORITE**. Occasional features: Presence of sulphides (stringers/nodules). Sample taken at 19.69-19.94 m.
ED 2	3	20.98	+100.0% (0.94 m)	86.8% (0.76 m)	21.89	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, fine to medium grained, massive, dark grey to black, hard, crystalline; **DIABASE** with white; translucent quartz veins (8.0 mm thick) and unweathered, coarse grained, black/white, hard, crystalline **DIORITE**. Occasional features: Presence of sulphides (stringers/nodules). Sample taken at 21.72-21.89 m.

CR* - Core Recovery

Logged by: Heather Racher, M.Sc.

RQD** - Rock Quality Designation

Note: Depths are approximated where core recovery is less than 100%. RQDs are calculated according to core recovery (less than designated 1.52 m runs).

ROCK CORE DESCRIPTION

Location: Smith Creek, Cochrane, ON
Site Name: TMB for Smith Creek Bridge Replacement, Hwy 668

BH No.	CORE RECOVERY				CORE DESCRIPTION	
	RC No.	DEPTH (m)	% CR*	% RQD**	DEPTH (m)	DESCRIPTION
ED 3	1	18.44	81.0% (1.32 m)	32.5% (0.53 m)	20.07	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, fine to medium grained, massive, dark grey to black, hard, crystalline; **DIABASE** with white; translucent quartz veins (6.0 mm thick) and unweathered, coarse grained, black/white, hard, crystalline **DIORITE**. Sample taken at: 19.41-19.65
ED 3	2	20.07	100.0% (1.52 m)	95.4% (1.45)	21.59	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, fine to medium grained, massive, dark grey to black, hard, crystalline; **DIABASE** with white; translucent quartz veins (5.0 mm thick) and unweathered, coarse grained, black/white, hard, crystalline **DIORITE**. Sample taken at 20.07-20.29 m.
ED 3	3	21.59	67.2% (0.41 m)	32.8% (0.20 m)	22.20	**NEO-MESOARCHEAN (2.5-3.4 GA)** **MAFIC TO INTERMEDIATE METAVOLCANIC** Unweathered, coarse grained, black/white, hard, crystalline **DIORITE.** Sample taken at 21.59-21.79 m.

CR* - Core Recovery

Logged by: Heather Racher, M.Sc.

RQD** - Rock Quality Designation

Note: Depths are approximated where core recovery is less than 100%. RQDs are calculated according to core recovery (less than designated 1.52 m runs).

Note: Depths are approximated where core recovery is less than 100%. RQDs are calculated according to core recovery (less than designated 1.52 m runs).

Photograph 1: Borehole ED-2; Runs 1, 2, and 3.

Photograph 2: Borehole ED-3; Runs 1, 2, and 3.

ADDENDUM NO. 1
<u>PART B</u> – FOUNDATION DESIGN REPORT
for

TEMPORARY MODULAR BRIDGE FOR SMITH CREEK BRIDGE REPLACEMENT SITE NO. 39E-0014/B0 HIGHWAY 668 – STATION 10+284 TOWN OF COCHRANE, ONTARIO G.W.P. 5284-19-00 W.P. 5368-11-01 LATITUDE AND LONGITUDE: 49.157440, -81.272080

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PML Ref.: 18TF002A
Index No.: 059FDR
GEOCRES No.: 42H-85
July 27, 2020

TABLE OF CONTENTS

PART B - FOUNDATION DESIGN REPORT

ADDENDUM NO. 1
PART B - FOUNDATION DESIGN REPORT
Temporary Modular Bridge for Smith Creek Bridge Replacement
Site No. 39E-0014/B0
Highway 668 – Station 10+284
Town of Cochrane, Ontario
G.W.P. 5284-19-00, W.P. 5368-11-01

7. INTRODUCTION

This foundation investigation and design report with the interpretation and recommendations are intended for the use of Parsons on behalf of MTO, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Where comments are made on construction, they are provided only to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the factual information provided in Part A of the report, as it may affect equipment selection, proposed construction methods and scheduling.

8. PROJECT DESCRIPTION

8.1 General

This report provides recommendations for foundation design based on interpretation of the geotechnical data presented in the factual report (Part A) and the details provided on the General Arrangement (GA) drawing for the proposed replacement of bridge on Highway 668 at the crossing of Smith Creek in the Town of Cochrane, Ontario.

Based on the GA drawing, it is proposed to construct the replacement bridge with a single-span structure supported on integral abutments.

PML understands that the traffic flow during the construction of the replacement bridge across Smith Creek will be diverted through a local detour, which includes a Temporary Modular Bridge (TMB). The geotechnical discussions foundation recommendations for the TMB foundation design is provided in this addendum report.

The discussions and recommendations presented in this report are based on the information provided by Parsons and the factual data obtained during the geotechnical investigation carried out by PML.

8.2 Proposed Detour Structure

Based on the GA drawing for the Smith Creek bridge replacement, the construction of the replacement bridge will be carried out by transferring the traffic onto a TMB located east of the existing bridge. The TMB GA drawing provided by Parsons, via email dated July 24, 2020, indicated that the TMB will be supported on Granular 'A' pads.

8.3 Foundation For Detour Structure

In summary, the subsoil conditions immediately below the ground surface along the alignment of proposed TMB consists of 2.3 m thick fill, composed of layers of clayey silt and sand, overlying very stiff to firm clayey silt. The clayey silt layer is underlain by compact to very dense sand. In Boreholes ED2 and ED3, the sand deposit is underlain by bedrock, which extends to the maximum borehole termination depth of 22.1 m below the existing ground surface.

Groundwater was encountered at 16.8 m (EL. 244.0) and 3.8 m (EL. 257.6) below the existing ground surface during drilling in Boreholes ED3 and ED4, respectively. Groundwater was not encountered in Boreholes ED1 and ED2 during drilling. Groundwater was measured at 16.8 m (EL. 244.1) and 15.2 m (EL. 245.6) below the existing ground surface in Boreholes ED2 and ED3, respectively, upon completion of drilling. Boreholes ED1 and ED4 were dry upon completion of drilling. The water level in the creek was observed at approximate elevation of EL. 257.6 during the fieldwork.

It is our understanding that construction of the detour is planned in 2021 and removal is planned for 2022. Based on the contour map provided by Parsons, the approximate existing ground surface elevation within the proposed south abutment footprint ranges from EL. 260.0 to EL. 258.0 and within the proposed north abutment footprint, the approximate existing ground surface elevation ranges from EL. 260.0 to EL. 258.5.

Option 1: Shallow Foundation – Foundation on Native Soil

The foundation may be placed on stiff clayey silt approximately at EL. 257.5 at the south abutment and approximately at EL. 258.0 at the north abutment based on Boreholes ED3 and ED2, respectively. The geotechnical resistances provided on Table 8.3 are recommended for the design of the TMB, assuming

2.5 m wide by 9.0 m long footing, supported on conventional timber crib or equivalent abutments founded at a level not higher than the elevations provided in Table 8.3.

Table 8.3: Founding Elevation and Geotechnical Resistance for Shallow Foundation

LOCATION	FOUNDING ELEVATION (m)	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	FACTORED GEOTECHNICAL RESISTANCE AT SLS (kPa)	SUBGRADE SOIL
South Abutment	257.5	205	110	Stiff Clayey Silt
North Abutment	258.0			

The proposed founding elevations are based on boreholes ED2 and ED3 only. The final design and design founding elevations should be reviewed by PML because of the sloping ground surface conditions at the site.

In case the TMB is required to be maintained throughout the winter months, the depth of frost should be taken into consideration and an adequate earth cover shall be maintained.

The bearing resistance for inclined loads should be reduced in accordance with the requirements of clause 6.10.4 of the CHBDC (2014). The total settlement under a Serviceability Limit State (SLS) loads recommended is expected to be in the order of 25 mm and the associated differential settlement may be expected to be in the order of 20 mm.

The sliding resistance of footings against lateral loads between the concrete footing and subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014). For cast in place concrete footings constructed on concrete working slabs and on top of stiff clayey silt:

- Cast-In-Place footing on concrete working slab: = 0.6
- Cast-In-Place concrete working slab on stiff clayey silt: = 0.4

<u>Option 2: Shallow Foundation – Foundation on Granular ‘A’ Pad</u>

Alternatively, based on the subsoil and groundwater conditions encountered at the site, it is considered geotechnically feasible to place the TMB on a shallow foundation design comprising a Granular ‘A’ pad.

The GA drawing provided by Parsons via email dated July 24, 2020, indicated that the TMB will be supported on Granular 'A' pads. The Granular 'A' material should meet the requirements of OPSS.PROV 1010. A minimum thickness of 1.5 to 2.0 m should be provided for the granular pad.

Factored geotechnical resistances of 400 kPa at ULS and 200 kPa at SLS for a 2.0 m width strip footing constructed on Granular 'A' pad may be assumed. A minimum 1.0 m offset from the edge of footing to the top edge of the granular pad should be provided.

With regards to serviceability performance of using a granular pad as the TBM foundation, as considered for TMB at Gilles Creek, it is understood that the MTO Contract may relax the usual maximum 25 mm settlement serviceability limits because of the temporary nature of the structure and would allow the contractor to jack and shim the temporary bridge as required during its service life.

The contour map provided by Parsons indicated that the elevation of the existing ground surface at the south abutment ranges from EL. 260.0 to EL. 258.0 and at the north abutment ranges from EL. 260.0 to EL. 258.5. It is anticipated that the Granular 'A' Pad is to be placed on or below the existing ground surface. Prior to the placement of the granular pad, the subgrade must be prepared and levelled prior to Construction.

It is recommended that surficial topsoil, organic, deleterious and/or otherwise unsuitable materials be removed from the subgrade on which the Granular 'A' pad is constructed. The subgrade should be inspected and approved prior to placing Granular 'A'. The Granular 'A' should be placed in lifts not exceeding 200 mm in thickness and compacted to 100% of the Standard Proctor Maximum Dry Density (SPMDD) according to OPSS.PROV 501.

Where the slope of existing ground is steeper than 3H:1V, benching should be carried out in accordance with OPSD 208.010. The forward and side slopes of the Granular 'A' pad for the TMB could be constructed no steeper than 1.75H:1V. The slopes of the pad adjacent to the Smith Creek shall be protected against erosion with rock protection in accordance with OPSS.PROV 511.

For improved stabilization of the pad, biaxial geogrid may be placed at vertical spacing of 0.5 m within the pad to the full extent of the Granular 'A' pad. It should be noted that geogrid products are proprietary products and if adopted as part of the design should be designed by the proprietor design engineer.

The final granular pad design should be determined by the designer considering the varying sloping ground contours, design life and site conditions. The final design should be reviewed by PML and further geotechnical input may be necessary.

OPTION 3: Deep Foundation

For the deep foundation option, steel H-piles driven to bedrock may be designed assuming a factored axial geotechnical resistance of 2000 kN at Ultimate Limit State (ULS), in accordance with the Structural Office Policy Memo 98-01 dated April 15, 1998. Axial capacity at SLS will not govern because the loads required to produce detrimental deformation is anticipated to be larger than the factored resistance at ULS.

Table 8.4.1 below summarizes the approximate pile tip elevations and length of piles that may be considered for design purposes.

Table 8.4.1: Pile Tip Elevations

STRUCTURE SITE	Location	Pile Tip Elevation
Smith Creek Temporary Modular Bridge	North Abutment	242.3 to 241.4* ± 1.0
	South Abutment	242.4 to 241.5* ± 1.0

Note: (*) –The elevations of 241.4 and 241.5 are based on geotechnical information in FIR GEOCRES 42H-65, dated September 16, 2016.

The construction of pile foundation should be in accordance with OPSS.PROV 903 and SP 109F57. Pile splices within 6.0 m below the cut-off elevation should not be permitted. This requirement should be addressed with a note on the structural drawing for foundations. The pile cut-off elevations were not available during the preparation of this report.

The pile tips need to be reinforced to drive the piles through till deposit to avoid damage. Oversized driving shoes similar to Ontario Provincial Standard Design (OPSD) 3000.100 (Foundation Piles Steel H-Pile Driving Shoe) or Titus H bearing are not recommended. The pile tip reinforcement shown on Sketch No. PML-1 in FIDR for Smith Creek Bridge Replacement Report (GEOCRES 42H-83) is recommended.

The borehole data from previous foundation investigation (GEOCRES 42H-65), indicated a layer of boulder and cobbles at depths ranging from EL. 244.9 to EL. 241.5. However, boulders and

cobbles were not encountered in the boreholes drilled during the investigation carried out by PML. Considering the nature of glacial till deposits and data from the preliminary foundation investigation, there may be potential for intercepting boulders or cobbles within this deposit during the installation of piles. For this reason, a NSSP is included in the appendix to alert the contractor for potential obstruction from cobbles or boulders during the pile installation.

Foundation Recommendations

All three options are considered technically feasible from a foundation perspective for the proposed TMB at the Smith Creek. However, economically, deep foundation is not considered feasible for the TMB. Shallow foundation on native soil or on Granular 'A' pad may be utilized for the TMB. The GA drawing provided by Parsons via email dated July 24, 2020, indicated that the TMB will be supported on Granular 'A' pads, which is considered technically and economically feasible.

9. FOUNDATION FROST DEPTH

In accordance with OPSD 3090.100, a minimum of 2.5 m earth cover is required to protect against the frost penetration in the area where the site is located.

Frost tapers within the granular backfill should be constructed in accordance with OPSD 3101.150. The frost penetration depth, f, is measured from the top of the grade to the bottom of the footing.

It is understood from discussions with the designer that construction of the detour is planned in 2021 and removal of the TMB is planned for 2022. The contract should indicate the intended short service period of the detour since the TMB foundation performance may be affected by frost issues without adequate protection. If the temporary structure is to be used for a period beyond its intended short life span, there is likely the perfomacne risk due to frost heave. In this case, foundation elements should be provided with a minimum of 2.5 m of earth cover for frost protection. The equivalent protection could be provided by using polystyrene as suggested by the Canadian Foundation Engineering Manual 2006, Section 13.5.2. It is generally considered that 25 mm of polystyrene provides a protection which is equivalent to 600 mm of soil.

10. SEISMIC CONSIDERATIONS

The Spectral (Sa(T), where T is in seconds) and Peak Ground Acceleration (PGA) for the project site is 0.217 (Sa (0.2)) and 0.142 (2%/50 years) based on the longitude and latitude coordinates of the proposed structure (National Building Code of Canada, 2015). The soil below the founding level at this site for seismic design purposes is classified as Type D in accordance with Clause 4.4.3.2, CHBDC 2014.

The Seismic Performance Category should be determined by the Regulatory Authority (MTO) and no information was provided in the RFP with regards to the category. In the absence of any information, it was assumed that the proposed replacement bridge is located on a Major Route and classified as Seismic Performance Category 2.

11. EXCAVATION AND GROUNDWATER CONTROL

To construct Granular 'A' pad on existing ground surface, as shown on the GA drawing, excavations up to minimum 0.5 m may be required for benching purposes. However, to construct shallow foundation on native soil, approximately up to 2.5 m depth of excavation is anticipated at the south and north abutment locations to EL. 257.5 and EL. 258.0, respectively.

All the excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. In accordance with Ont. Reg.213/91, S. 226. The fill soils may be classified as Type 3 soils. The slope of excavation walls should conform to as described in Ont. Reg. 213/92, S. 234. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation. Therefore, temporary cut slopes over the full depth of excavation inclined at 1H:1V should be provided assuming adequate drainage measures are in place. Temporary shoring systems may be required if such slopes inclination cannot be provided.

Excavating and backfilling of structures should be in accordance with OPSS 902 and SP 109S12. All excavated surfaces should be kept free of frost and water during the period of construction. Runoff shall be directed away from open excavations and should not be allowed to flow into the excavation. Excavated material shall not be stockpiled adjacent to the top of the excavation.

Prior to excavation, the locations and depths of existing underground utilities should be verified. All underground utilities that might be exposed and become unsupported as a result of the excavation should be properly supported to avoid potential damage.

Considering the depth of groundwater level (EL. 245.6 to EL. 244.1) at this site, no major dewatering problems are anticipated to construct the Granular 'A' pads on the ground surface or to found the footings on native soil at the recommended elevations of EL. 257.5 at south abutment and EL. 258.0 at north abutment for the TMB. However, the groundwater levels may fluctuate due to the influence of precipitation and seasonal changes.

It is considered that seepage from soil fissures or surface run-off that enters the excavations can be handled by conventional sump pumping techniques. The groundwater level should be lowered to a minimum of 0.5 m below the base of excavation, where anticipated. It is suggested that construction of the TMB should be carried out during the drier season.

Nevertheless, contractor shall be responsible for the selection, performance and detailed design of the design of dewatering, unwatering, and temporary flow passage system. The dewatering system should be designed to conform to the requirements of OPSS.PROV 517 and SP 517F01.

12. CLOSURE

This Foundation Investigation and Design Report was prepared by Ms. N. Leong-Sem, E.I.T., Geotechnical Services, and reviewed by Mr. N. Rahman P.Eng., and Mr. G. Uwimana, MEng, P.Eng., Senior Engineer. Mr. R. Ng, MBA, PhD, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

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APPENDIX B

List of Standard Specifications Relevant to Report

Non-Standard Special Provisions (NSSP)

LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS 902	Excavation and Backfilling of Structures
OPSS.PROV 903	Construction Specification For Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
SP 109F57	Amendment to OPSS 903
SP 109S12	Amendment to OPSS 902
SP 517F01	Amendment to OPSS 517
OPSD 208.010	Benching of Earth Slopes
OPSD 3090.100	Foundation, Frost Penetration depths for Northern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement

NON-STANDARD SPECIAL PROVISIONS (NSSP)

NSSP – Potential for Cobbles and Boulders during Pile Driving

The Contractor shall be advised that cobbles and boulders were identified immediately below the silty clay to clay deposit in the boreholes advanced during the preliminary foundation investigation. Glacial till deposit overlying the bedrock was also encountered at this site. Considering the nature of the glacial till deposits and the data from the previous boreholes, there is potential for presence of cobbles or boulders within this deposit.

Hence, the Contractor shall allow for these obstructions during the installation of piles. If during pile driving there is evidence that a pile meets refusal on a boulder, the contractor shall inform the Contract Administrator. Piles meeting refusal on a boulder may need to be relocated, have their capacity reduced and / or require additional piles to be installed.

The contractor shall also consider the difficulties associated with the excavation for drilled shafts because of the presence of cobbles and boulders within the sand to silty sand glacial till deposit.