FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 11, Watabeag River Bridge Rehabilitation (Site 39E-141)
Matheson, Ontario
Ministry of Transportation, Ontario
GWP 5217-13-00, WP 5175-17-01

Submitted to:

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

Submitted by:

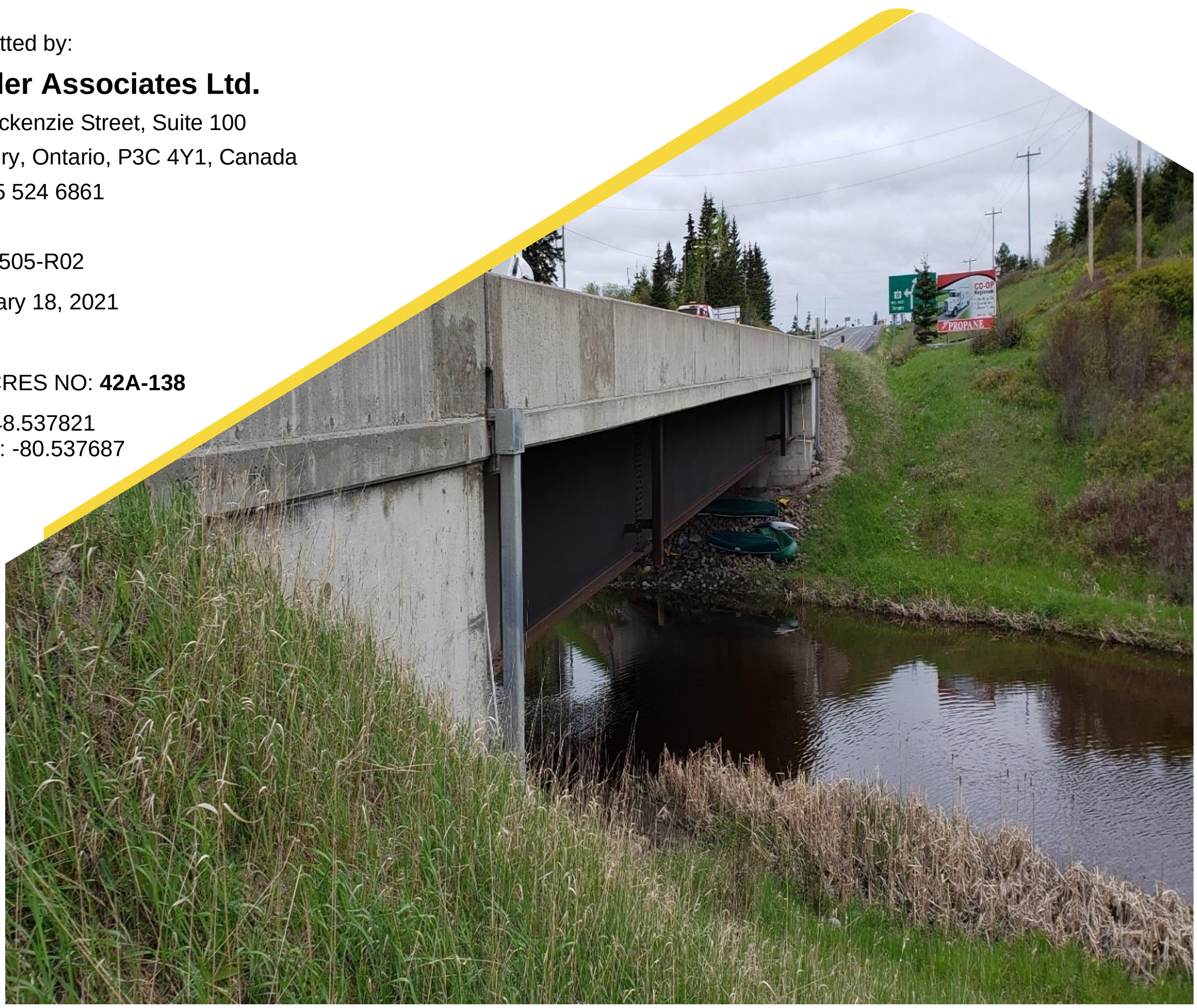
Golder Associates Ltd.
33 Mackenzie Street, Suite 100
Sudbury, Ontario, P3C 4Y1, Canada
+1 705 524 6861

19126505-R02

February 18, 2021

GEOCRES NO: **42A-138**

LAT: 48.537821
LONG: -80.537687



Distribution List

1 PDF Copy: Ministry of Transportation, Ontario (NE Region)

1 PDF Copy: Ministry of Transportation, Ontario (Foundations)

1 PDF Copy: D.M. Wills Associates Limited

1 PDF Copy: Golder Associates Ltd.

Table of Contents

APPENDICES

APPENDIX A Record of Boreholes

Lists of Symbols and Abbreviations

Record of Boreholes WR-1 and WR-2

APPENDIX B Laboratory Test Results

Figure B-1 Grain Size Distribution – Sand to Gravelly Sand (Fill)

Figure B-2 Plasticity Chart – Clay

Bureau Veritas Laboratories Test Results

APPENDIX C NOTICE TO CONTRACTOR

Obstructions

PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 11, WATABEAG RIVER BRIDGE REHABILITATION

MATHESON, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5217-13-00, WP 5175-17-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Limited (DM Wills) on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services related to the rehabilitation of the Watabeag River bridge on Highway 11 in Matheson, Ontario. The Key Plan of the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the bridge site by borehole drilling, with laboratory testing carried out on selected soil samples.

2.0 SITE DESCRIPTION

The existing bridge consists of a 46 m long single span bridge supported on two concrete abutments. In general, the topography within the vicinity of the bridge consists of relatively flat farmland with some hilly terrain.

At the time of the subsurface exploration field work, the embankment side slopes were generally grass covered. The embankment appeared to be stable with no signs of slope instability or roadway settlement. The observed ground surface conditions at the bridge site are shown on Photographs 1 and 2 following the text of this report.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on June 7, 2020, during which time, two boreholes (Boreholes WR-1 and WR-2) were advanced at the approximate locations shown on Drawing 1. The boreholes were advanced using a track mounted CME-55 drilling rig supplied and operated by Landcore Drilling of Sudbury, Ontario. Traffic control, where required, was performed in accordance with MTO’s Ontario Traffic Control Manual Book 7 – Temporary Conditions.

The boreholes were advanced using 108 mm I.D. Hollow Stem Augers or NW casing and wash boring. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic or cathead hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). In-situ vane shear tests were carried out in cohesive soils for estimation of undrained shear strengths, in accordance with the Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils (ASTM D2573), using an MTO standard ‘N’-size vane.

The water level inside the augers was observed and measured during and upon completion of drilling operations. The boreholes were abandoned in general accordance with Ontario Regulation 903 (as amended). The boreholes drilled through the roadway were capped at the roadway surface using cold patch asphalt.

Field work was supervised on a full-time basis by a member of Golder’s technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling 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 geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and/or MTO LS standards, as applicable. In addition, one soil sample was submitted to Bureau Veritas Laboratories in Sudbury, Ontario, an accredited analytical laboratory, for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to the highway chainage/station marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at each borehole location was surveyed by Golder relative to the highway centreline elevation provided by DM Wills. The northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m)	MTM NAD 83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
WR-1	5377795.2	338937.0	254.1	9.8
WR-2	5377786.8	338871.2	254.4	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)[1] mapping, the bridge is located within a glaciolacustrine plain, with the subsoils consisting primarily of clay.

The results of the site-specific investigation confirm the presence of native clayey soils below the fill embankment.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in-situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The plotted results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values and in-situ (field) vane undrained shear strengths), as presented on the Record of Borehole sheets and discussed in Section 4.2, are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing by Bureau Veritas Laboratories are summarized in Section 4.4.

The subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented on the Record of Borehole sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

[1] Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ANE.

4.2.1 Fill

A 150 mm to 180 mm thick layer of asphalt was encountered from ground surface in both boreholes. A 5.4 m to 7.1 m thick layer of sand to sand and gravel (fill) was encountered below the asphalt in both boreholes. Split spoon refusal was encountered in the sand and gravel fill at 0.3 m depth in Borehole WR-1.

Underlying the sand fill in Borehole WR-1, the split spoon sample at a depth of 7.3 m encountered predominantly wood/timber. Difficulties were encountered advancing the augers and casing was required to advance the borehole through the inferred wood layer to about 9.1 m below ground surface.

The SPT ‘N’-values measured within the sand to sand and gravel (fill) range from 14 blows to 96 blows per 0.3 m of penetration, indicating a compact to very dense compactness condition. One SPT ‘N’-value measured within the wood was 60 blows for 0.3 m of penetration.

Grain size distribution testing was carried out on four samples of the sand to gravelly sand (fill) and the results are presented on Figure B-1 in Appendix B. In summary, the fill samples contained 0 - 25% gravel, 65 - 98% sand, and 2 - 10% fines. The natural moisture content measured on samples of the sand to sand and gravel (fill) range from about 2% to 15%.

4.2.2 Silt

In Borehole WR-1, silt was encountered below the wood deposit at Elevation 245.0 m. The borehole was terminated after exploring the silt for 0.7 m.

The SPT ‘N’-value measured within the silt was 14 blows for 0.3 m of penetration, indicating a compact compactness condition.

An Atterberg limit test was attempted on the sample and the results indicate the sample is non-plastic. The natural moisture content measured on the sample was 27%.

4.2.3 Clay

A cohesive deposit of clay was encountered in Borehole WR-2 at Elevation 248.8 m and the borehole was terminated in the deposit after exploring for 4.2 m. The clay deposit contained silt seams, layers, and laminations throughout.

The SPT ‘N’-values measured within the clay were 0 blows (weight of hammer) per 0.3 m of penetration. Two in-situ field vane tests carried out within the deposit measured undrained shear strengths of 40 kPa and a sensitivity of 4. The field vane test results suggest that the deposit generally has a firm consistency.

Atterberg limit testing carried out on one sample of the clay measured a liquid limit of 61, plastic limit of 18, and a plasticity index of 43. The results are plotted on Figure B-2 and indicate that the deposit consists of clay with a high plasticity. The natural moisture content measured on the sample of the clay was 55%.

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface, measured inside the open boreholes upon completion of drilling are summarized below. The river water level was surveyed at Elevation 247.7 m in July 2020, based on information provided by DM Wills. Groundwater and river water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Approximate Groundwater Elevation (m)
WR-1	5.9 (unstabilized)	248.2
WR-2	Dry (unstabilized)	-

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample from Borehole WR-1. The soil sample was submitted to Bureau Veritas Laboratories of Sudbury, Ontario, for corrosivity testing and the test results are summarized below.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (μmho/cm)	Soluble Sulphate (SO4) Content (μg/g)	Chloride (Cl) Content (μg/g)	Sulphide (mg/kg)	pH
WR-1	7	4.6-5.2	770	1310	490	410	593	11.9

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Tibor Berecz, EIT, under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Andre Bom, P.Eng., and Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact and Associate with Golder, conducted an independent quality control review of this report.

Signature Page

Golder Associates Ltd.

André Bom, P.Eng.
Senior Geotechnical Engineer, Associate

Kevin Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

AB/KJB/sm

https://golderassociates.sharepoint.com/sites/111953/project files/6 deliverables/foundations/1. reporting/2-watabeag/final/19126505-r02-rev0-watabeag hwy 11 fidr final 18feb_2021.docx

PART B

FOUNDATION DESIGN REPORT

HIGHWAY 11, WATABEAG RIVER BRIDGE REHABILITATION

MATHESON, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5217-13-00, WP 5175-17-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides recommendations regarding temporary protection systems for the rehabilitation of the existing Watabeag River Bridge. The recommendations presented are based on an interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the existing structure and design the bridge rehabilitation, and to assess the feasible conceptual temporary roadway protection systems to support the construction staging. The Foundation Investigation Report, discussion, and recommendations are intended for the use of the MTO and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor 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 the 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.

6.1 General

We understand from D.M. Wills that the proposed rehabilitation will include concrete repairs to the existing abutments and wingwalls, as well as either conversion to semi-integral abutments or expansion joint replacements. We further understand that a staged construction approach (half-and-half) is being proposed and that temporary roadway protection systems may be required within each approach embankment to support the traffic staging.

6.2 Frost Protection

The frost penetration depth in the area of the bridge is estimated to be 2.4 m, as interpreted from Ontario Provincial Standard Drawing (OPSD) 3090.100 (Foundation Frost Penetration Depths for Northern Ontario). Therefore, to minimize the potential for damage due to frost action, foundations, or components sensitive to frost, action should be provided with at least 2.4 m of conventional soil cover or an equivalent combination of insulation and soil cover.

6.3 Corrosion Resistance

The results of analytical tests on one sample of the sand fill recovered in Borehole WR-1 are summarized in Section 4.4. The potential for sulphate attack and corrosion should be assessed by the designer to determine the appropriate construction materials.

6.4 Construction Considerations

6.4.1 Excavation and Temporary Roadway Protection

We understand from DM Wills that temporary excavations (anticipated to be up to 2 - 2.5 m below road surface) will be required into the existing granular embankment fill for the semi-integral conversion. Temporary protection systems, if necessary, shall be constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems shall meet Performance Level 2, as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking steel sheet pile system is suitable at this site and is preferred from a foundations perspective, provided it does not need to penetrate into the wood layer encountered at a depth of 7.3 m in Borehole WR-1. Alternatively, soldier piles and lagging may need to be considered at this site if deeper excavations are required. The sheet piles/soldier piles will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. If penetration lengths are deeper than 7.3 m, pre-drilling may be required to penetrate into/through the wood layer encountered in WR-1. Additional lateral support to the sheet pile or soldier pile wall could be provided in the form of struts, rakers, or temporary anchors, if and as required.

The design of the temporary protection system will be the responsibility of the contractor and the following information is provided to MTO and its designers to aid in the assessment of feasible alternatives, if applicable.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m^3)	Angle of Internal Friction, φ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients[1,2]		
				Active, K_a	At-rest, K_o	Passive, K_p[3]
Embankment Fill – Compact to very dense sand to gravelly sand	19	30	-	0.33	0.50	3.00
Compact silt	19	28	-	0.36	0.53	2.77
Firm clay	18	28	35[4]	0.36	0.53	2.77

Notes:

1. The design groundwater level may be assumed to be El. 248.2 m measured in Borehole WR-1, which is above the river water level measured to be at El. 247.7 m by DM Wills' surveyors in July 2020 but will depend on the water level at the time of construction.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement, in accordance with Figure C6.27 of the CHBDC (2019), to account for the fact that a large strain would be required for mobilization of the full passive resistance.
4. Derived from the in-situ vane shear test results and corrected for plasticity index.

If required, it is recommended that the ground surface extending back/upwards from the top of the protection system to the existing Highway 11 surface be graded to an inclination no steeper than 2 horizontal to 1 vertical (2H:1V). This should be shown on the Contract staging drawings.

As previously indicated, temporary excavations are anticipated to be up to 2.5 m below road surface, resulting in excavations down to about Elevation 251.6 m. Given the groundwater was measured to be at El. 248.2 m (above the river water level measured in July 2020), temporary excavations are not anticipated to be below the groundwater or river level.

Open cut excavations must be carried out in accordance with the guidelines outlined in the *Occupation Health and Safety Act* (OHSA) for Construction Activities. Above the water table, the existing fill materials are classified as Type 3 soil according to OHSA, and temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Although not anticipated, below the water table, the existing fill materials and underlying native soils are classified as Type 4 soil according to OHSA, and temporary excavations (i.e., those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3H:1V.

The loading from traffic, construction equipment, as well as any material stockpiles within a distance defined by a 1H/1V line, drawn from the bottom of the excavation to the existing ground surface, should be included as a surcharge in the design of the temporary protection system.

Design of the temporary protection system shall include an evaluation of base stability, soil squeezing stability, and hydraulic uplift stability, as defined in the Canadian Foundation Engineer Manual (CFEM 2006).

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required) as per OPSS.PROV 539.

6.4.2 Obstructions

Borehole WR-1 encountered split spoon refusal at 0.3 m depth, which could be indicative of a cobble and/or boulder. Also, wood was encountered at a depth of 7.3 m and is inferred to be present to a depth of 9.1 m below ground surface. These obstructions could influence the choice, design, and installation procedures of the temporary protection systems. A Notice to Contractor to identify the presence of these obstructions should be included in the Contract Documents; a copy of which is included in Appendix C.

7.0 CLOSURE

This Foundation Design report was prepared by Mr. Andre Bom, P.Eng., and Associate with Golder. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact and Associate with Golder, conducted an independent and quality control review of the report.

Signature Page

Golder Associates Ltd.

André Bom, P.Eng.
Senior Geotechnical Engineer, Associate

Kevin Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

AB/KJB/sm

https://golderassociates.sharepoint.com/sites/111953/project files/6 deliverables/foundations/1. reporting/2-watabeag/final/19126505-r02-rev0-watabeag hwy 11 fidr final 18feb_2021.docx

REFERENCES

Canadian Standards Associations (CSA) Group 2019. Canadian Highway Bridge Design Code and Commentary.

Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition.

Ontario Regulation 903 (Wells).

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils.

ASTM D2573 Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils.

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

MINISTRY OF TRANSPORTATION, ONTARIO

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

CONT No.
WP No. 5175–17–01

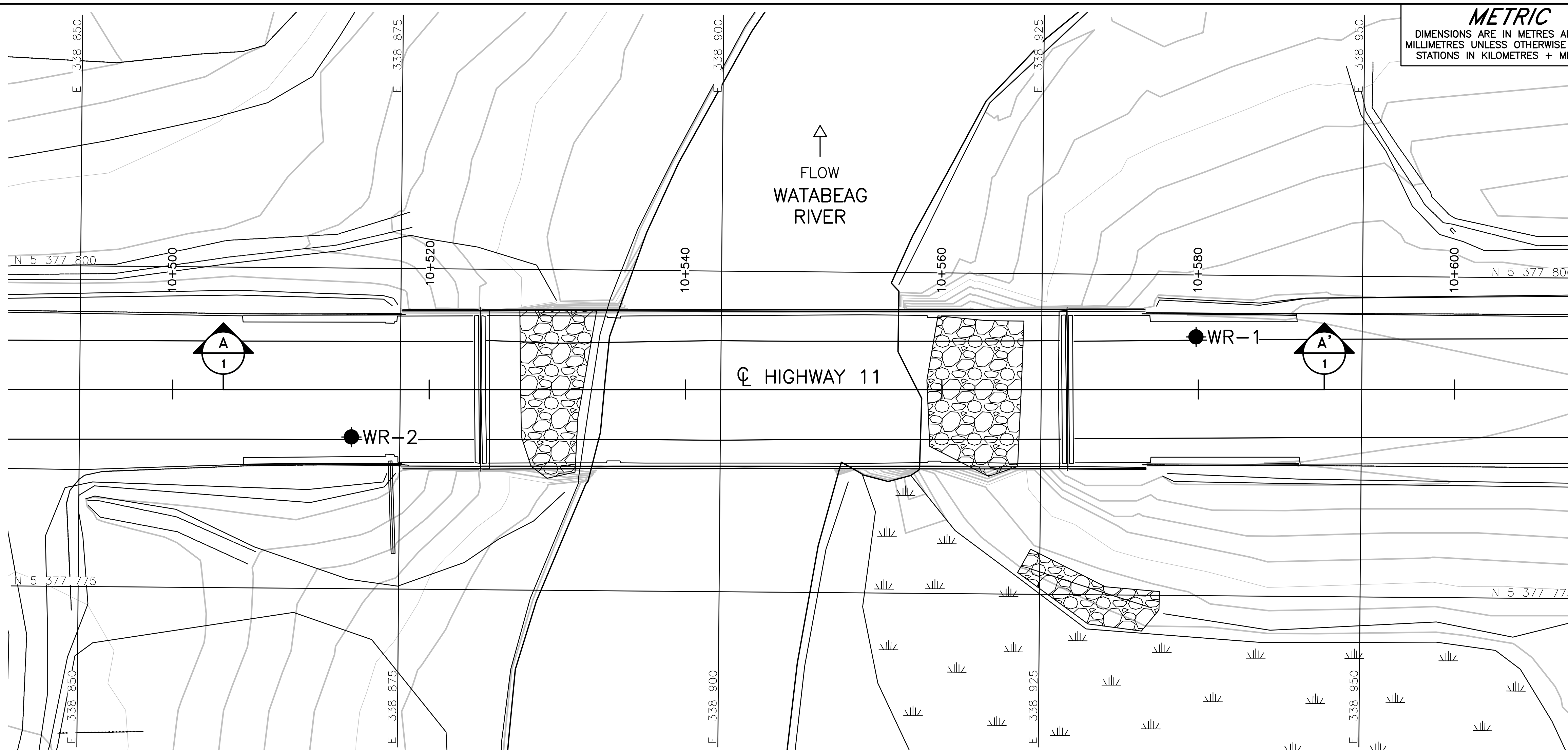
SHEET

HIGHWAY 11

WATABEAG RIVER BRIDGE
TOWNSHIP OF BOWMAN

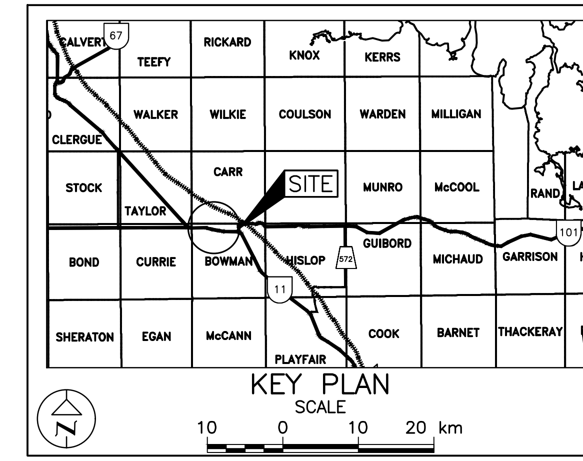
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



PLAN

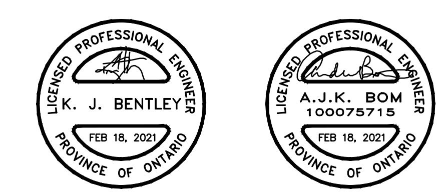
SCALE 4 0 4 8 m

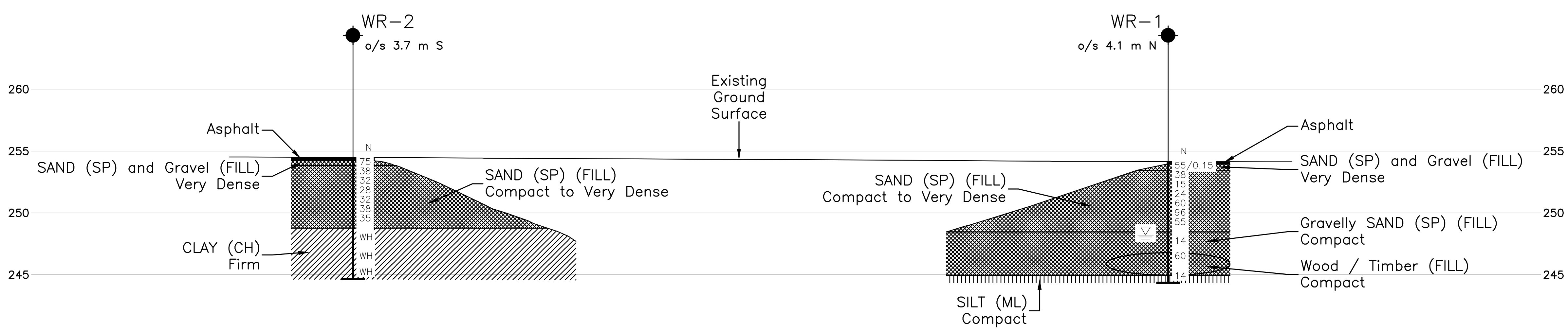


KEY PLAN
SCALE
10 0 10 20 km

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





A–A BRIDGE CENTRELINE PROFILE

HORIZONTAL SCALE 4 0 4 8 m
4 0 4 8 m VERTICAL SCALE

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
WR–1	254.1	5377795.2	338937.0
WR–2	254.4	5377786.8	338871.2

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 D.M. WILLS, drawing file no. watabeag river bridge, received JULY 30, 2020.

NO.	DATE	BY	REVISION

Geocres No. 42A–138

HWY. 11	PROJECT NO. 19126505		DIST.
SUBM'D.	CHKD.	DATE: 2/18/2021	SITE: 39E–141
DRAWN: TR	CHKD. AB	APPD. KB	DWG. 1

PLOT DATE: February 18, 2021
FILENAME: R:\Sudbury\SM\Clients\MTO\Hwy11&101\99_PROJ\19126505\40_PROD\0002_WR\19126505-0002-BH-0001.dwg

Photograph 1: South side of bridge looking east (June 2020)

Photograph 2: Looking west along bridge from east side (June 2020)

APPENDIX A

Record of Boreholes

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	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
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

1. 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.
2. 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.

LIST OF SYMBOLS
MINISTRY OF TRANSPORTATION, ONTARIO

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
σ_1, σ_2, σ_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 $\gamma = \rho \cdot g$ (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
$C_{\alpha(e)}$	secondary compression index
C_α	rate of secondary compression
$C_{\alpha(\varepsilon)}$	modified 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 $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

RECORD OF BOREHOLE No. WR-1

 METRIC

PROJECT	19126505		
W.P.	5175-17-01	LOCATION	N 5377795.2; E 338937.0 NAD83 MTM ZONE 12 (LAT. 48.537821; LONG. -80.537687)
DIST		HWY	11
BOREHOLE TYPE	108 mm I.D. Hollow Stem Augers, NW Casing with Wash Boring		
DATUM	GEODETIC	DATE	June 7, 2020
ORIGINATED BY	TB	COMPILED BY	TR
CHECKED BY	AB		

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
254.1	GROUND SURFACE						
0.0	ASPHALT (150 mm)	1	SS	55/0.15			
	SAND (SP) and gravel (FILL) Very dense Brown Moist - Split spoon refusal at 0.3 m depth						
253.6 / 0.5	SAND (SP) (FILL) Compact to very dense Brown Moist	2	SS	38			0 97 (3)
		3	SS	15			
		4	SS	24			
		5	SS	60			
		6	SS	96			
		7	SS	55			
248.5 / 5.6	Gravelly SAND (SP) (FILL) Compact Brown Moist to wet				∇ (Elev. 248.2)		
		8	SS	14			25 65 (10)
246.8 / 7.3	Wood / Timber (FILL) Brown Wet - Difficult / hard augering from 7.3 m to 7.6 m depth, switched to NW Casing at 7.6 m depth and difficult casing advancement from 7.9 m to 8.5 m.	9	SS	60			
245.0 / 9.1	SILT (ML), trace clay, trace wood Compact Grey Wet	10	SS	14		NP	
244.3 / 9.8	END OF BOREHOLE						

NOTE:

1. Water level measured at a depth of 5.9 m below ground surface (Elev. 248.2 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 (%): 20 40 60

ELEVATION SCALE: 254, 253, 252, 251, 250, 249, 248, 247, 246, 245

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

GOLDER

RECORD OF BOREHOLE No. WR-2

 METRIC

PROJECT 19126505
W.P. 5175-17-01
LOCATION N 5377786.8; E 338871.2 NAD83 MTM ZONE 12 (LAT. 48.537748; LONG. -80.538579)
ORIGINATED BY TB
DIST ____ HWY 11
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
COMPILED BY TR
DATUM GEODETIC
DATE June 7, 2020
CHECKED BY AB

SOIL PROFILE

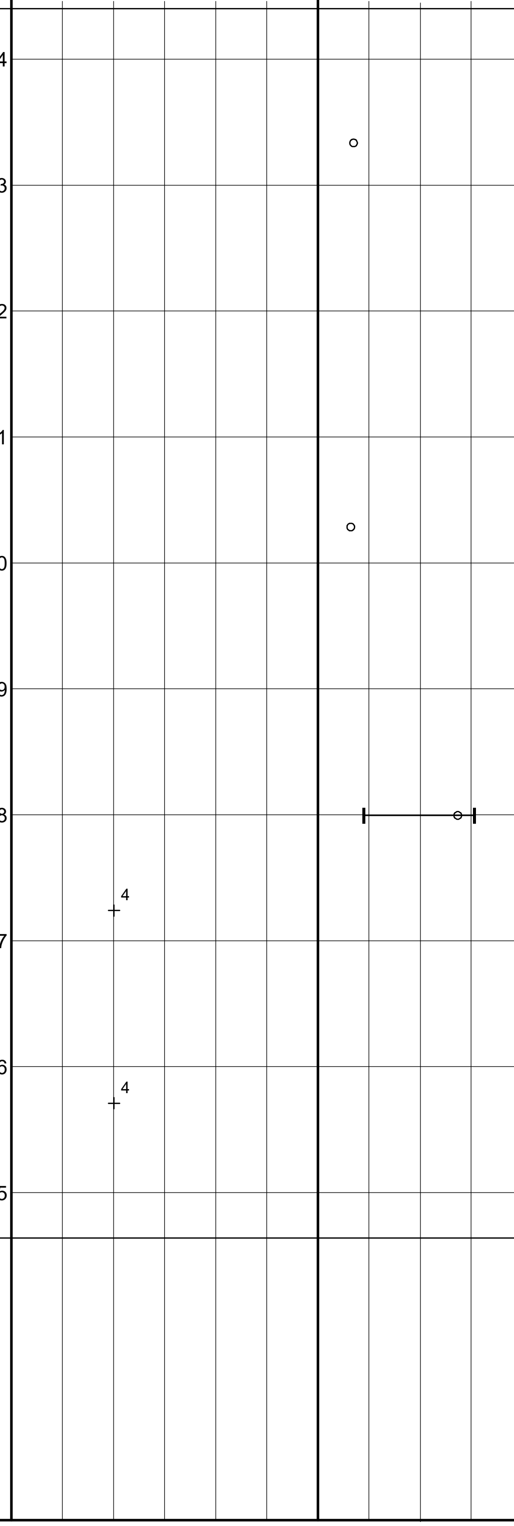
ELEV / DEPTH	DESCRIPTION
254.4	GROUND SURFACE
0.0	ASPHALT (180 mm)
0.3	SAND (SP) and gravel (FILL) Very dense Grey Moist
	SAND (SP) (FILL) Compact to dense Brown Moist
248.8 / 5.6	CLAY (CH) Firm Grey Wet - Silt seams, layers and laminations encountered throughout deposit
244.6 / 9.8	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	75	
2	SS	38	0 97 (3)
3	SS	32	
4	SS	28	
5	SS	32	
6	SS	38	0 98 (2)
7	SS	35	
8	SS	WH	
9	SS	WH	
10	SS	WH	

GROUND WATER CONDITIONS | ELEVATION SCALE (254, 253, 252, 251, 250, 249, 248, 247, 246, 245)

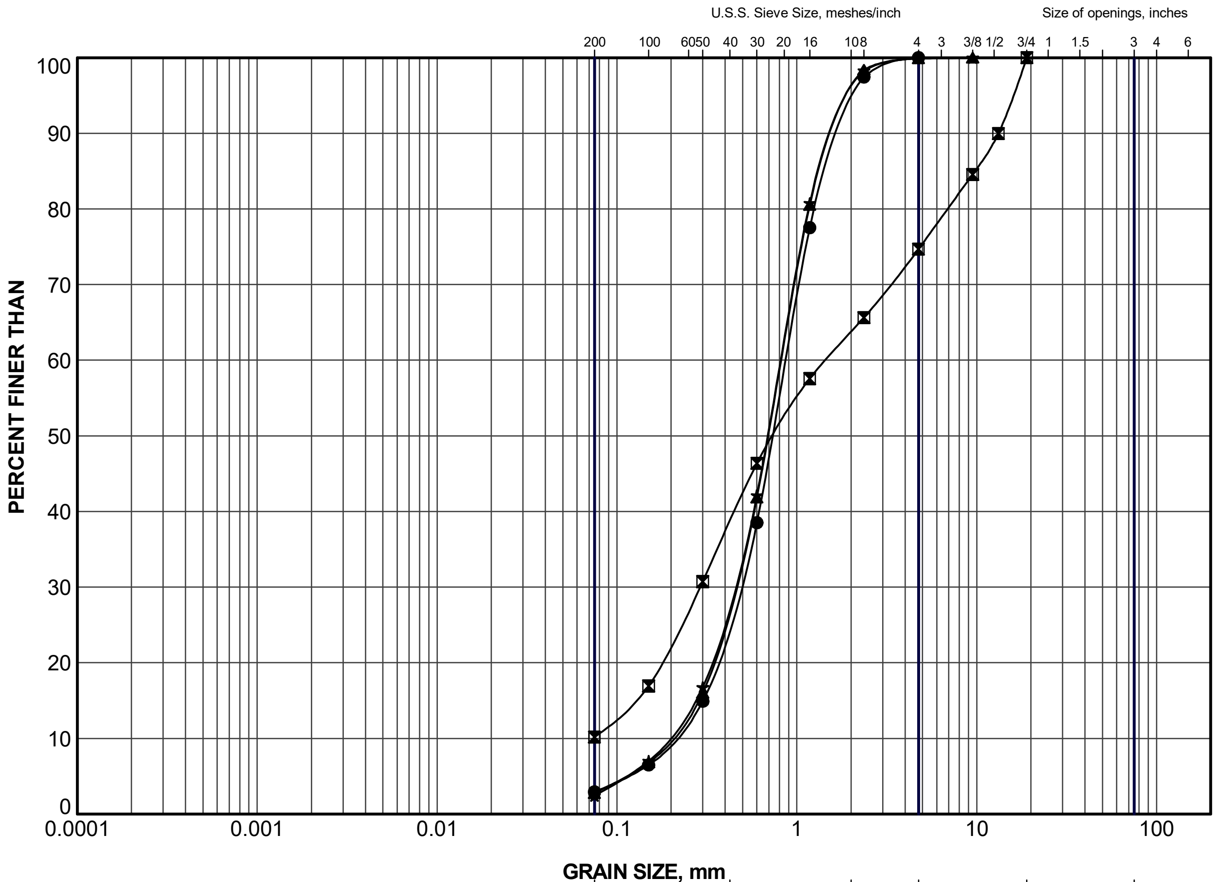
DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100)
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) (20, 40, 60)
UNIT WEIGHT γ kN/m³



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

APPENDIX B

Laboratory Test Results



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WR-1	2	253.0
⊠	WR-1	8	247.7
▲	WR-2	2	253.3
★	WR-2	6	250.3

PROJECT

HIGHWAY 11
WATABEAG RIVER BRIDGE
TOWNSHIP OF BOWMAN

TITLE

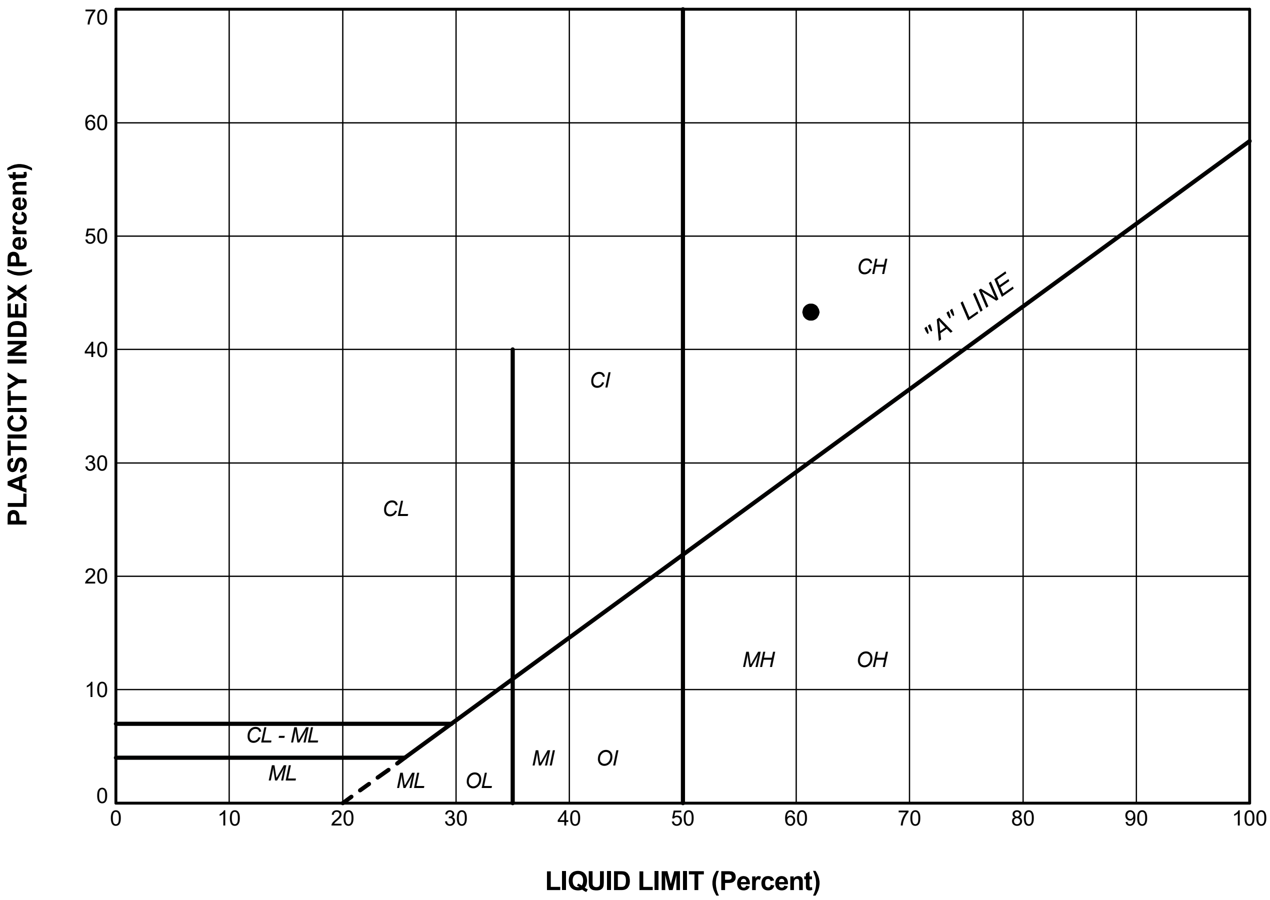
GRAIN SIZE DISTRIBUTION

SAND (SP) to Gravelly SAND (SP) (FILL)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		19126505	FILE No.	19126505.GPJ
DRAWN	TR	Feb 2021	SCALE N/A	REV.
CHECK	AB	Feb 2021		
APPR	KB	Feb 2021	**FIGURE B-1**	

SUD-MTO GSD GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WR-2	8	61.3	18.0	43.3

PROJECT
HIGHWAY 11
WATABEAG RIVER BRIDGE
TOWNSHIP OF BOWMAN

TITLE
PLASTICITY CHART
CLAY (CH)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		19126505	FILE No.	19126505.GPJ
DRAWN	TR	Feb 2021	SCALE N/A	REV.
CHECK	AB	Feb 2021	**FIGURE B-2**	
APPR	KB	Feb 2021		

SUD-MTO PL GLDR_LDN.GDT

BV Labs Job #: C0E8089
Report Date: 2020/07/02

Golder Associates Ltd
Client Project #: 19126505/2000
Sampler Initials: TB

RESULTS OF ANALYSES OF SOIL

BV Labs ID		MWN864			MWN864			MWN865		
Sampling Date		2020/06/04			2020/06/04			2020/06/08		
COC Number		137483			137483			137483		
	UNITS	C12-5 SA3	RDL	QC Batch	C12-5 SA3 Lab-Dup	RDL	QC Batch	RC-2 SA3	RDL	QC Batch
Calculated Parameters										
Resistivity	ohm-cm	3300		6789098				14000		6789098
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	83	20	6792715				<20	20	6792715
Conductivity	umho/cm	306	2	6793003				74	2	6793003
Available (CaCl2) pH	pH	7.80		6792746				8.21		6792740
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6792716				<20	20	6792716
Sulphide	mg/kg	<0.5 (1)	0.5	6816007	<0.5	0.5	6816007	0.5 (1)	0.5	6816007
Physical Testing										
Moisture-Subcontracted	%	38	0.30	6816006				2.8	0.30	6816006

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
(1) Sample contained greater than 10% headspace at time of extraction.

BV Labs ID		MWN865			MWN866		
Sampling Date		2020/06/08			2020/06/07		
COC Number		137483			137483		
	UNITS	RC-2 SA3 Lab-Dup	RDL	QC Batch	WR-1 SA7	RDL	QC Batch
Calculated Parameters							
Resistivity	ohm-cm				770		6789098
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	6792715	410	20	6792715
Conductivity	umho/cm	73	2	6793003	1310	2	6793003
Available (CaCl2) pH	pH				11.9		6792740
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6792716	490	20	6792716
Sulphide	mg/kg				593 (1)	10	6816007
Physical Testing							
Moisture-Subcontracted	%				9.7	0.30	6816006

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
(1) Detection limits raised due to dilution to bring analyte within the calibrated range. Sample contained greater than 10% headspace at time of extraction.

APPENDIX C

Non-Standard Special Provisions and Notice to Contractor

TEMPORARY PROTECTION SYSTEMS – OBSTRUCTIONS – Item No.

Notice to Contractor

The contactor shall be alerted to the presence of obstructions within and directly below the sand to sand and gravel (fill) at the approach embankments. Specifically, in Borehole WR-1, possible cobbles and/or boulders were encountered at a depth of 0.3 m below road surface. In addition, wood was encountered at a depth of 7.3 m below road surface and is inferred to be a stump, log, or wood layer extending to a depth of 9.1 m below ground surface. Consideration of the presence of these obstructions must be made in the design and selection of appropriate equipment and procedures for open cut excavations and installation of temporary protection systems. If required, removal of and/or methods to penetrate into/through the obstructions (e.g., pre-drilling) must be included as part of this tender item.

golder.com