FINAL REPORT

Foundation Investigation Report

Culvert Replacement (Site No. 21X-0471/C0)
Highway 401, Station 18+349 Cramahe Township, Northumberland County
MTO GWP 4054-17-00, Agreement No. 4016-E-0034-11

Submitted to:

WSP Canada Inc.
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Submitted by:

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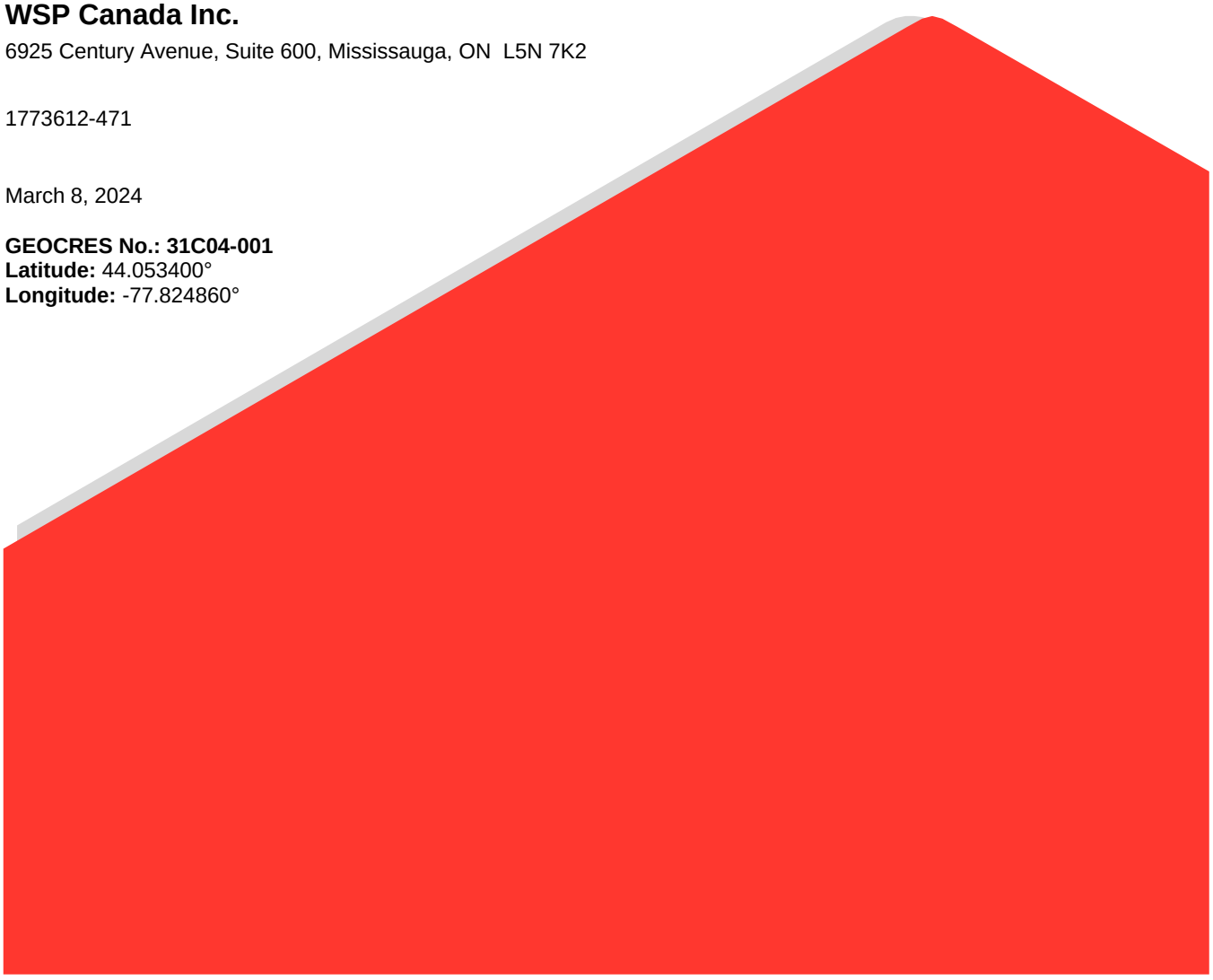
1773612-471

March 8, 2024

GEOCRES No.: 31C04-001
Latitude: 44.053400°
Longitude: -77.824860°



Distribution List

1 e-Copy - MTO Eastern Region

1 e-Copy - MTO Foundations Section

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1.0 INTRODUCTION

WSP Canada Inc. (WSP, formerly Golder Associates Ltd., amalgamated with WSP in 2023) is working as part of the WSP Total Project Management team on behalf of the Ministry of Transportation, Ontario (MTO) to support the rehabilitation and widening of Highway 401 from 0.8 km east of Percy Street to 0.4 km west of Christiani Road in Northumberland County, Ontario. The foundations scope of work includes preliminary design services for the replacement of three underpass structures and detail design services for the replacement of four structural culverts.

This report presents the results of the foundation investigation carried out to support the detail design of replacement of Culvert 21X-0471/C0. The foundation investigation services for this project have been delivered under MTO Agreement No. 4016-E-0034 Assignment #11 as part of GWP 4054-17-00.

2.0 SITE DESCRIPTION

The orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and, therefore, may differ from magnetic north. For the purpose of this report, Highway 401 is described as oriented in a west-east direction. The existing culvert is oriented in a northwest-southeast direction at an approximately 110° skew to the highway, and the proposed culvert, which is positioned on a new alignment west of the existing structure at a 125° skew to the highway, is described as being oriented in a north-south direction.

The existing Culvert 21X-0471/C0 is located on Highway 401 approximately 0.9 km east of Lake Road and 5 km west of County Road 30, at about Station 18+349 Cramahe Township in Northumberland County. The site location is shown on Drawing 1. The existing culvert consists of a 4.3 m wide by 2.4 m high (interior dimensions) reinforced concrete box structure, which was constructed in 1958. The culvert extends below the Highway 401 westbound lanes (WBL), center median, and eastbound lanes (EBL) over a total length of 60 m. According to the original drawings, the culvert inlet and outlet were designed at Elevation 170.85 m and 170.69 m respectively. Based on MTO's 2019 OSIM report, the culvert is good to fair condition but is close to its 75-year design service life.

At the culvert location, Highway 401 has a four-lane cross-section with paved shoulders separated by a paved median and a concrete tall wall barrier. The highway grade is at approximately Elevation 175 m, and there is approximately 3 m of fill above the top of the existing culvert. The EBL embankment is about 3 m high with the south side slope inclined at about 5 horizontal to 1 vertical (5H:1V). The WBL embankment is about 3 m high with the north side slope inclined at 4H:1V. The existing conditions at the culvert location are shown in Photographs 1 to 3 following the text of this report.

The watercourse flow from south to north at this site. Meadow marsh wetlands are present both upstream and downstream of the culvert, south and north of Highway 401, and Little Lake is present approximately 150 m upstream of the culvert on the south side of Highway 401 (as measured from the existing culvert inlet). The existing natural ground surface at the toe of the Highway 401 embankment is at approximately Elevation 172 m at the culvert site, rising to approximately Elevation 174 m to 176 m; the Little Lake water level is at approximately Elevation 174 m.

Based on our site observations at the time of the field investigation and a review of the available site photographs/satellite images, the existing Highway 401 embankments in the culvert area appear to be performing satisfactorily. There was no visual evidence of instability (i.e., soil movement) on the embankment side slopes, nor tension cracks near the embankment crest that would be indicative of instability.

The new replacement culvert will be on an alternate alignment approximately 17 m west of the existing culvert as measured from centreline to centreline. Based on the General Arrangement drawing, the proposed culvert flows from south to north with inlet and outlet inverts of 170.60 m and 170.36 m, respectively.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between June 30 and July 26, 2022, and included advancing four boreholes (471-22-01 to 471-22-04) in the general location of the proposed culvert alignment. The borehole locations are shown on Drawing 1.

Boreholes 471-22-01 to 471-22-03 were advanced with a CME55 truck-mounted drill rig, and Borehole 471-22-04 was advanced with a LAD Multipower track-mounted drill rig. The drilling equipment was supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. (CCC) of Ottawa, Ontario.

Soil samples were obtained using a 50 mm outer diameter split-spoon sampler in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586[1]). Soil samples were obtained at vertical sampling intervals of about 0.76 m.

A monitoring well was installed in Borehole 471-22-01 to observe the stabilised groundwater level at the site. The monitoring well consists of 52 mm outside diameter PVC tubing with a 1.5 m long slotted screen. The boreholes without a monitoring well were backfilled with bentonite mixed with soil cuttings, in general accordance with the intent of Ontario Regulation (O.Reg.) 903, as amended. The site conditions were restored following completion of the field work.

The field work was supervised on a full-time basis by members of WSP's technical staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers, and transported to WSP's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg limits testing were carried out on selected soil samples in accordance with MTO and/or ASTM Standards, as applicable.

One soil sample was sent to Eurofins Environmental Testing Canada Inc. (Eurofins) for basic chemical analysis related to potential corrosion of buried steel elements and sulfate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by WSP using a Trimble R10 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The Trimble R10 GPS data have a vertical accuracy of approximately 0.1 m and a horizontal accuracy of approximately 0.5 m in accordance with the requirements of MTO's Guideline for Foundation Engineering Services (Version 3.0). The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths are summarized below.

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

Borehole No.	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
471-22-01	4880121.3 (44.05340)	198643.5 (-77.824860)	172.5	5.9[1]
471-22-02	4880103.3 (44.053240)	198646.9 (-77.824820)	175.4	10.0
471-22-03	4880070.9 (44.052950)	198648.3 (-77.824790)	174.8	11.7
471-22-04	4880052.9 (44.052790)	198651.2 (-77.824750)	172.3	6.7

Note:
1. Borehole 471-22-01 was terminated due to auger refusal at 5.9 m

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The culvert lies at the boundary of the physiographic regions known as the Iroquois Plain and South Slope, as delineated in The Physiography of Southern Ontario (Chapman and Putnam, 1984)[2]. The Iroquois Plain physiographic region extends around the western part of Lake Ontario, from Niagara River to Trent River. The width of the plain varies from a few hundred meters to approximately 13 km north of the current Lake Ontario shoreline, and it extends inland to include a large area in the Trent River valley. The eastern portion of the South Slope in Northumberland County is covered by large drumlins that are generally oriented northeast-to-southwest.

In the area east of Colborne, the surficial glaciolacustrine deposits of the plain consist of sand, gravelly sand, and gravel, as well as nearshore and beach deposits. Non-cohesive (silt, sand and gravel) till deposits are present below the beach/plain deposits, and at ground surface in proximity to drumlins.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)[3], the site is underlain by bedrock from the Middle Ordovician era consisting of limestone, dolostone, shale, arkose, and sandstone from the Ottawa Group, Simcoe Group and Show Lake Formation.

4.2 General

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in-situ and laboratory tests are provided on the borehole records presented in Appendix A. The detailed results of the geotechnical laboratory testing on soil samples are presented on the laboratory test figures in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the borehole records and in Section 4 are uncorrected and are based on use of an automatic hammer. The results of the analytical testing are provided in Appendix C.

The borehole locations and the interpreted stratigraphic profile projected along the proposed culvert alignment are provided in Drawing 1.

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

[3] Ministry of Northern Development of Mines. Bedrock Geology of Ontario – Southern Sheet, Ontario Geological Survey - Map 2544.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic section in Drawing 1 are inferred from observations of the drilling progress and noncontinuous soil sampling and therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

4.3 Site Stratigraphy Overview

At the borehole locations, the subsurface conditions encountered at this site consist of surficial fill (topsoil and fill in off-road boreholes or pavement structure and embankment fill in highway boreholes) underlain by non-cohesive glacial till deposits comprising silty sand to sand to gravelly sand to sand and gravel containing cobbles and boulders, up to the termination depth of the boreholes. More detailed descriptions of the major soil layers encountered in the boreholes are provided in the following sections.

4.3.1 Surface Cover/ Surficial Materials

Topsoil with thickness of approximately 50 mm was encountered at the surface of Boreholes 471-22-01 and 471-22-04 which were drilled near the north and south toes of the Highway 401 embankment, respectively. Approximately 0.8 m sand to clayey silt fill containing some silt, gravel, organics, cobbles, and boulders was encountered beneath the topsoil in Borehole 471-22-01.

4.3.2 Existing Pavement Structure

An approximately 200 mm to 300 mm thick layer of asphalt pavement was encountered at the ground surface in Boreholes 471-22-02 and 471-22-03. Approximately 0.3 m of granular material consisting of gravelly sand was encountered beneath the asphalt in both boreholes.

4.3.3 Silty Sand (SM) to Sand (SW) Fill

Underlying the existing pavement structure, non-cohesive fill consisting silty sand to sand containing some gravel to gravelly was encountered in Boreholes 471-22-02 and 471-22-03. This fill was encountered at depths of 0.6 m and 0.5 m below ground surface and was about 2.5 m and 1.5 m thick extending to Elevation 172.4 m and 172.5 m at the borehole locations on the north and south shoulders of Highway 401, respectively.

The SPT ‘N’-values measured within this fill range from 16 blows per 0.3 m of penetration to greater than 100 blows for less than 0.3 m of penetration indicating a compact to very dense state of compactness. Within the fill layers, auger grinding was observed between depths of 0.6 m and 3.1 m in Borehole BH471-22-02, and this is interpreted to represent the presence of gravel, cobbles and/or boulders within the fill; in addition, the high SPT ‘N’-values (70 and 121 blows per 0.1 m penetration and 50 blows per 0.3 m of penetration) are considered to represent the presence of gravel, cobbles and/or boulders and may not represent the state of compactness of the fill matrix.

The water content measured on select samples of the fill ranges between approximately 4% and 5%. The results of grain size distribution carried out on three samples of the silty sand fill are shown on Figure B1 in Appendix B.

4.3.4 Silty Sand (SM) to Sand (SW) Till

Glacial till consisting of silty sand to sand was encountered below fill materials or topsoil in all drilled boreholes. The silty sand to sand till generally contained some gravel and trace to some clay, and the presence of cobbles and boulders was inferred based on auger grinding and difficult drilling, as well as auger refusal in Borehole 471-22-01. This till also contains zones or layers of gravelly sand to sand and gravel, which are discussed in the sub-section below. All four boreholes terminated within the till deposit (inclusive of the gravelly zones) after

penetrating it for a thickness of approximately 5.1 m to 9.4 m, extending to a depth of 5.9 m to 11.7 m (to Elevation 166.6 m to 163.1 m).

The SPT ‘N’ values measured in the till range from 5 to greater than 100 blows per 0.3 m penetration; however, the lower SPT ‘N’ values of 5 to 8 blows per 0.3 m of penetration are interpreted to have been affected by groundwater disturbance during sampling, and the more typical SPT ‘N’ values are on the order of 12 blows to greater than 100 blows per 0.3 m of penetration, suggesting a compact to very dense state of compactness. As noted above, frequent auger grinding was observed in both boreholes, indicating the presence of gravel, cobbles and boulder with the glacial till deposit.

The water content measured on samples of the silty sand to sand till range from 5% to 12%. The results of grain size distribution testing carried out on eight samples of this portion of the till are presented on Figure B2.

4.3.5 Gravelly Sand (SP) to Sand and Gravel (SP/SW) Till Zones

Gravelly sand to sand and gravel till layers, at least 0.7 m to 2.1 m in thickness, were encountered within the silty sand to sand till in Borehole 471-22-04 and at the base of the penetrated thickness of the till in Boreholes 471-22-01 and 471-22-03. The gravelly sand to sand and gravel till contained some silt and trace clay. Boreholes 471-22-01 and 471-22-03 were terminated within these zones of the till at 5.9 m depth (Elevation 166.6 m) and 11.7 m depth (Elevation 163.1 m) respectively. Similar gravelly zones of till should be expected between and beyond the borehole locations, and should be expected at varying depths/elevations within the till deposit.

Frequent auger grinding was observed in both boreholes, indicative of the presence of cobbles and boulder with these zones of the glacial till deposit. The SPT ‘N’ values measured in these layers of the till range from 12 blows per 0.3 m of penetration to greater than 50 blows for less than 0.3 m penetration suggesting a compact to very dense state of compactness.

The water content measured on samples of the gravelly sand to sand and gravel till ranges from 5% to 7%. The results of grain size distribution testing carried out on three samples of this portion of the till are presented on Figure B3.

4.4 Groundwater Conditions

A monitoring well was installed in Borehole 471-22-01 to measure the stabilized groundwater level at the site. The groundwater levels measured in the monitoring well are presented in table below.

Borehole	Screened Interval	Ground Surface Elevation (m)	Depth to Groundwater Level (m)	Groundwater Elevation (m)	Date
471-22-01	Silty Sand Till	172.5	0.3	172.2	December 14, 2022

In addition, wet soils were encountered between approximately 1.5 m and 4.0 m depth in the boreholes as noted on the borehole records, corresponding to approximately Elevation 170.8 m to 171.4 m. It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

4.5 Analytical Testing

One soil sample was submitted to Eurofins for chemical testing/analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized below.

Borehole	Sample Depth (m)	Chloride (%)	Sulphate (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)
471-22-03	1.5-2.1	0.016	0.01	0.44	9.24	2,273

5.0 CLOSURE

This Foundation Investigation Report was prepared by Pouya Pishgah, P.Eng., a Principal Geotechnical Engineer with WSP. Ms. Lisa Coyne, P.Eng., Geotechnical Engineering Fellow and MTO Principal Foundations Contact conducted an independent technical and quality review of this report.

WSP Canada Inc.

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Principal Geotechnical Engineer

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

PP/LCC/al

https://golderassociates.sharepoint.com/sites/11407g/wo11 colborne to brighten/3. reporting/4-culvert 471/3-final/1773612 gwp 4045-17-00 fir rev0 culvert 471 2024-03-07.docx

REFERENCES

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

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – Southern Sheet, Ontario Geological Survey – Map 2544.

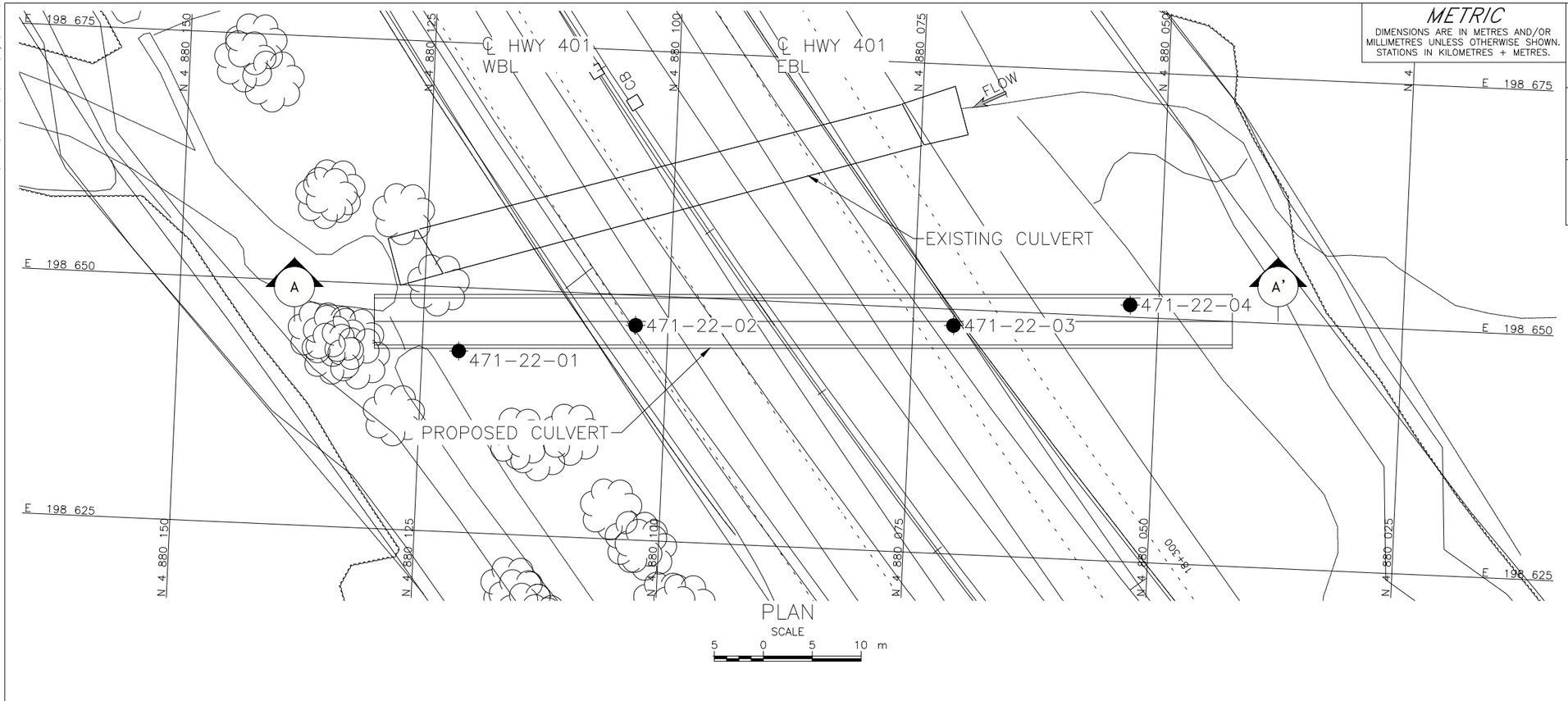
ASTM International

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

Ontario Water Resource Act

Regulation 903 Wells (as amended)

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN
SCALE
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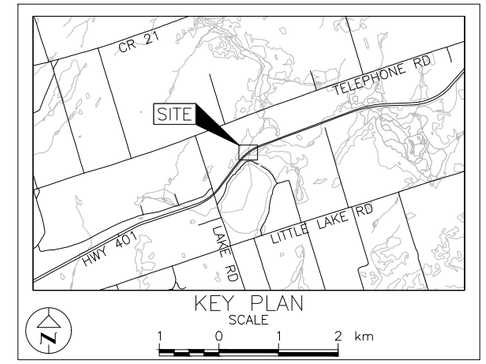


KEY PLAN
SCALE

METRIC

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

CONT No.
WP No. 4054-17-00

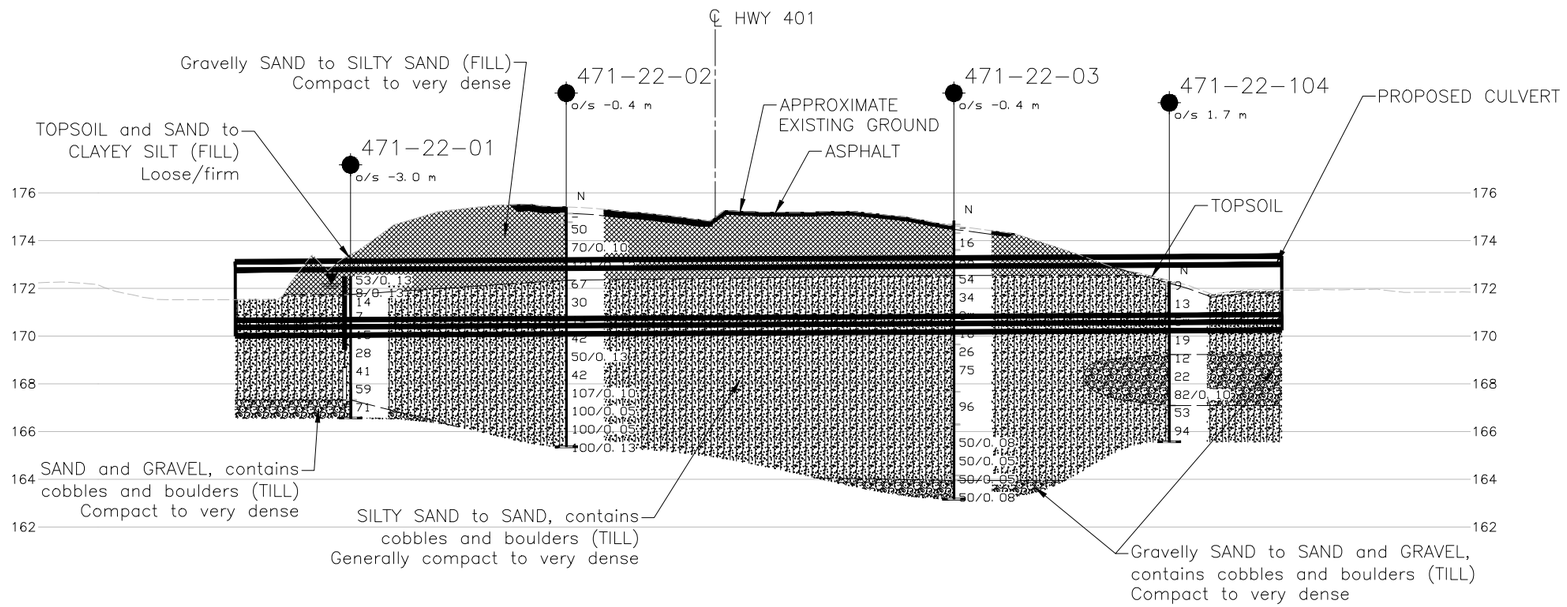
HIGHWAY 401
REPLACEMENT OF CULVERT
21X-0471/CO
BOREHOLE LOCATION PLAN AND SOIL STRATA

SHEET

wsp

LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on December 14, 2022



PROFILE
SCALE
5 0 5 10 m

L.C. COYNE — Mar. 08, 2024
P. PISHGAH-GILANI 100189545 — Mar. 08, 2024
LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
471-22-01	172.5	4880121.3	198643.5
471-22-02	175.4	4880103.3	198646.9
471-22-03	174.8	4880070.9	198648.3
471-22-04	172.3	4880052.9	198651.2

Structural Site Location Latitude: 44.053400 Longitude: -77.824860

NOTES

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

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

REFERENCE

Base plans provided in digital format by WSP, drawing file no. Mainline-8Lane proposed alignment for Culvert Sections_ACAD (updated – April 12 2022).dwg, received APR. 14, 2022 and drawing file no. 17M-01712-11-303-001GA.dwg, received August 4, 2022.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 31C04-001

HWY. 401	PROJECT NO. 1773612		DIST. EASTERN
SUBM'D. BW	CHKD. KCP	DATE: 3/8/2024	SITE: 21X-0471/C0
DRAWN: ZS	CHKD. PP	APPD. LCC	DWG. 1

PLOT DATE: March 5, 2024
FILENAME: S:\Clients\MTO\Hwy_401_Colborne_to_Brighton\99_PRO\1773612_Parsons_CulvertReplacement\45_PROD\0001_Geotech_Culvert_1\1773612-0001-BG-0002.dwg

Photograph 1: Looking north towards Borehole 471-22-01

Photograph 2: Looking east along Highway 401 from north shoulder of westbound lanes; Borehole 471-22-02 in foreground

Photograph 3: Looking east along Highway 401 from south shoulder; Borehole 471-22-03 in foreground, and existing culvert outlet visible

APPENDIX A

Borehole Records

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

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>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.

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

* Density symbol is ρ. Unit weight symbol is γ. where $\gamma = \rho \cdot g$ (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 = σ'_p / σ'_{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 δ
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

PROJECT 1773612

RECORD OF BOREHOLE No 471-22-01 SHEET 1 OF 1 METRIC

G.W.P. 4054-17-00 LOCATION N 4880121.3; E 198643.5 MTM NAD ZONE 9 (LAT. 44.053400; LONG. -77.824860) ORIGINATED BY JS

DIST Eastern HWY 401 BOREHOLE TYPE LAD Multipower Track Mounted, 83 mm ID Hollow Stem Augers COMPILED BY ZS

DATUM GEODETIC DATE June 30, 2022 CHECKED BY PP

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 × 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
172.5	GROUND SURFACE										
0.0	TOPSOIL - SAND to CLAYEY SILT (SM-ML), some silt, some gravel, contains organics, cobbles and boulders (FILL) Brown to black/grey Moist to w<PL		1	SS	53/0.13	▼	172				
171.7			2	SS	8/0.13						
0.8	SILTY SAND (SM), some gravel to gravelly, contains cobbles and boulders (TILL) Loose to very dense Grey-brown Moist to wet		3	SS	14		171		○		17 57 (26)
			4	SS	7						
			5	SS	15		170		○		28 42 23 7
			6	SS	28		169				
			7	SS	41		168				
167.3			8	SS	59				○		30 43 (27)
5.2	SAND and GRAVEL (SP/SW), some silt, trace clay, contains cobbles and boulders (TILL) Very dense Brown-grey to grey Wet		9	SS	71		167				
166.6											
5.9	END OF BOREHOLE AUGER REFUSAL										

NOTES:

1. Borehole was terminated due to auger refusal at 5.9 m.

2. Water level measured in standpipe piezometer:

Date	Depth(m)	Elev.(m)
Dec.14/22	0.3	172.2
May.16/23	0.4	172.1

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

PROJECT 1773612

RECORD OF BOREHOLE No 471-22-02 SHEET 1 OF 1 METRIC

G.W.P. 4054-17-00 LOCATION N 4880103.3; E 198646.9 MTM NAD ZONE 9 (LAT. 44.053240; LONG. -77.824820) ORIGINATED BY JS

DIST Eastern HWY 401 BOREHOLE TYPE CME 55 Truck Mounted, 108 mm ID Hollow Stem Augers COMPILED BY ZS

DATUM GEODETIC DATE July 25, 2022 CHECKED BY PP

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 × 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.4	GROUND SURFACE										
0.0 / 175.2	ASPHALTIC CONCRETE										
0.3 / 174.8	Gravelly SAND (SW) (FILL) Brown Moist		1	AS	-		175				
0.6	SILTY SAND (SM), some gravel to gravelly, contains cobbles and boulders (FILL) Very dense Brown Moist		2	SS	50				○		17 48 (35)
			3	SS	70/0.10		174				
			4	SS	121/0.13		173		○		25 50 (25)
172.4											
3.1	SILTY SAND (SM), some gravel to gravelly, trace to some clay, contains cobbles and boulders (TILL) Very dense to compact Grey to brown, slightly mottled Moist, becoming wet at 4.0 m		5	SS	67		172				
			6	SS	30				○		22 44 (34)
			7	SS	14		171				
	- Dense to very dense below to 5.2 m		8	SS	42		170				
			9	SS	50/0.13		169				
			10	SS	42				○		24 40 (36)
			11	SS	107/0.10		168				
			12	SS	100/0.05		167				
			13	SS	100/0.05		166				
165.4			14	SS	100/0.13						
10.0	End of Borehole										

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

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PROJECT 1773612

RECORD OF BOREHOLE No 471-22-03 SHEET 1 OF 2 METRIC

G.W.P. 4054-17-00 LOCATION N 4880070.9; E 198648.3 MTM NAD ZONE 9 (LAT. 44.052950; LONG. -77.824790) ORIGINATED BY JS

DIST Eastern HWY 401 BOREHOLE TYPE CME 55 Truck Mounted, 108 mm ID Hollow Stem Augers COMPILED BY ZS

DATUM GEODETIC DATE July 26, 2022 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES 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 × 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.8	GROUND SURFACE										
0.0	ASPHALTIC CONCRETE										
0.2 / 174.3	Gravelly SAND (SW), asphalt present (FILL) Brown to black Moist		1	SS	-						
0.5 / 173.6	SAND (SW), some gravel (FILL) Compact Brown Moist		2	SS	16		174				
1.2 / 172.5	SAND to SILTY SAND (SW/SM), some gravel (FILL) Compact to very dense Brown to grey-brown Moist		3	SS	88		173		○		19 53 (28)
2.3	SILTY SAND (SM), some clay, some gravel, contains cobbles and boulders (TILL) Very dense to loose Brown to grey-brown Moist, becoming wet at approximately 3.8 m depth.		4	SS	54		172				
			5	SS	34				○		13 43 (44)
			6	SS	8*		171				
169.6			7	SS	18		170				
5.2	SAND to SILTY SAND (SW/SM), some clay, some gravel, contains cobbles and boulders (TILL) Compact to very dense Grey-brown Moist		8	SS	26						
			9	SS	75		169				
167.6							168				
7.2	SAND (SW), some silt, some gravel, trace clay, contains cobbles and boulders (TILL) Very dense Grey Wet		10	SS	96		167				
166.3											
8.5	SILTY SAND (SW), some clay, some gravel, contains cobbles and boulders (TILL) Very dense Grey Moist		11	SS	50/0.08		166				
			12	SS	50/0.05		165		○		7 49 (44)
164.1											
10.9	SAND to SILTY SAND, some clay, some gravel, contains cobbles and boulders (TILL) Very dense Grey Moist		13	SS	50/0.05		164				
163.1			14	SS	50/0.08				○		40 41 (19)
11.7											

Continued Next Page

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

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PROJECT 1773612

RECORD OF BOREHOLE No 471-22-03 SHEET 2 OF 2 METRIC

G.W.P. 4054-17-00 LOCATION N 4880070.9; E 198648.3 MTM NAD ZONE 9 (LAT. 44.052950; LONG. -77.824790) ORIGINATED BY JS

DIST Eastern HWY 401 BOREHOLE TYPE CME 55 Truck Mounted, 108 mm ID Hollow Stem Augers COMPILED BY ZS

DATUM GEODETIC DATE July 26, 2022 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	w_P w w_L 20 40 60	γ kN/m³	GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and GRAVEL (SW/GW), some silt, contains cobbles and boulders (TILL) Very dense Grey Moist										
	END OF BOREHOLE										

NOTES:

1. * SPT "N" value may be affected by disturbance due to groundwater inflow to borehole

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

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PROJECT 1773612

RECORD OF BOREHOLE No 471-22-04 SHEET 1 OF 1 METRIC

G.W.P. 4054-17-00 LOCATION N 4880052.9; E 198651.2 MTM NAD ZONE 9 (LAT. 44.055130; LONG. -77.817650) ORIGINATED BY JS

DIST Eastern HWY 401 BOREHOLE TYPE LAD Multipower Track Mounted, 83 mm ID Hollow Stem Augers COMPILED BY BW

DATUM GEODETIC DATE July 4, 2022 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	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
172.3	GROUND SURFACE										
0.0 / 0.1	TOPSOIL - SILTY SAND (SM), contains organics Loose Brown Moist		1	SS	9		172				
	SILTY SAND to SAND (SM/SW), some gravel to gravelly, trace clay, contains cobbles and boulders (TILL) Loose to compact Grey-brown Moist, becoming wet at approximately 1.5 m depth		2	SS	13				○		27 45 (28)
			3	SS	5*		171				
			4	SS	19		170				
169.3											
3.1	Gravelly SAND (SW), some silt, trace clay, contains cobbles and boulders (TILL) Compact to very dense Grey Wet to moist		5	SS	12		169		○		31 44 (25)
			6	SS	22		168				
167.1			7	SS	82/0.10				○		32 45 (23)
5.2	SAND (SW), some silt, some grave, trace clay, contains cobbles and boulders (TILL) Very dense Grey Moist to wet		8	SS	53		167				
			9	SS	94		166				
165.6											
6.7	END OF BOREHOLE										

NOTES:

1. * SPT "N" value may be affected by disturbance due to groundwater inflow to borehole

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

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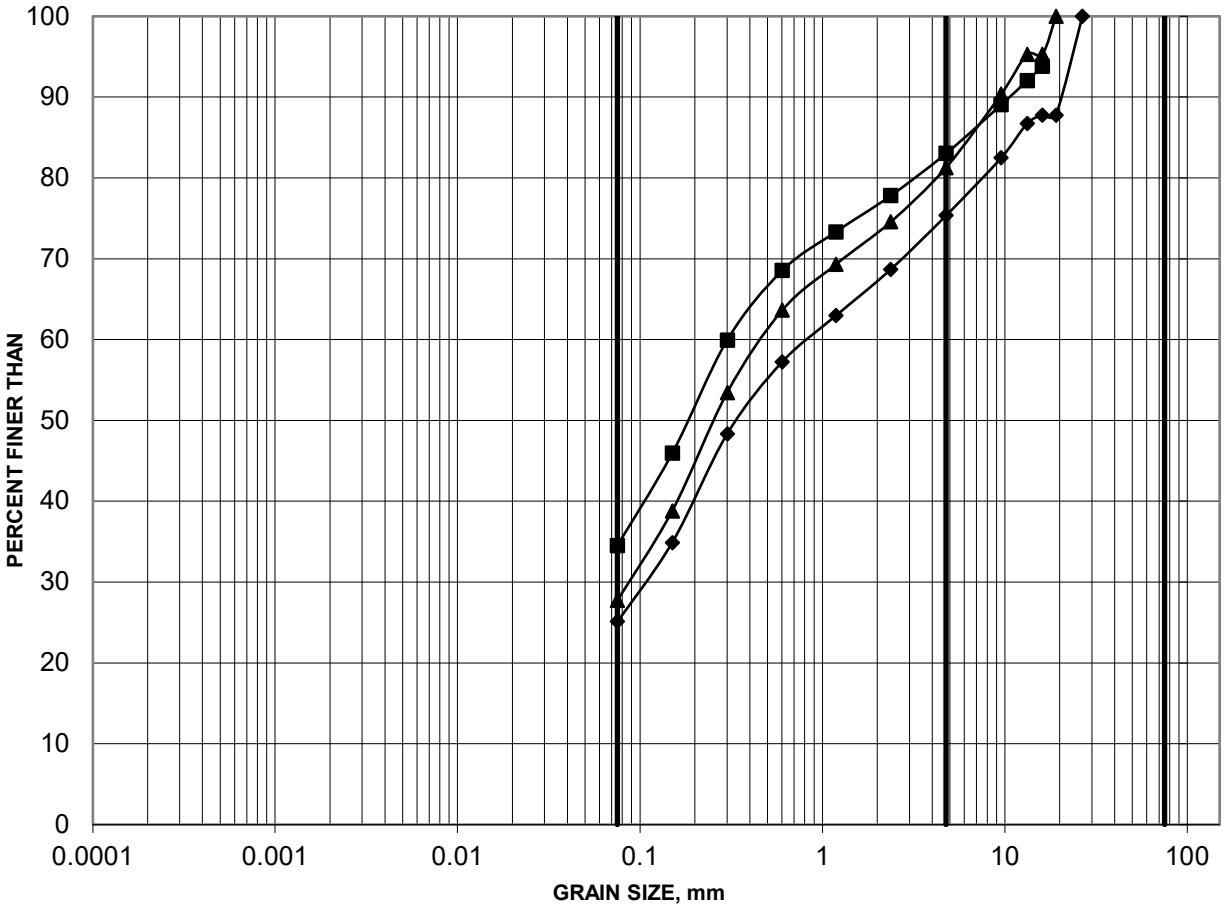
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY SAND FILL



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

	Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
■	471-22-02	2	0.76-1.37	17	48	35	
◆	471-22-02	4	2.29-2.90	25	50	25	
▲	471-22-03	3	1.52-2.13	19	53	28	

Project: 1773612_WO 11

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Checked by: PP

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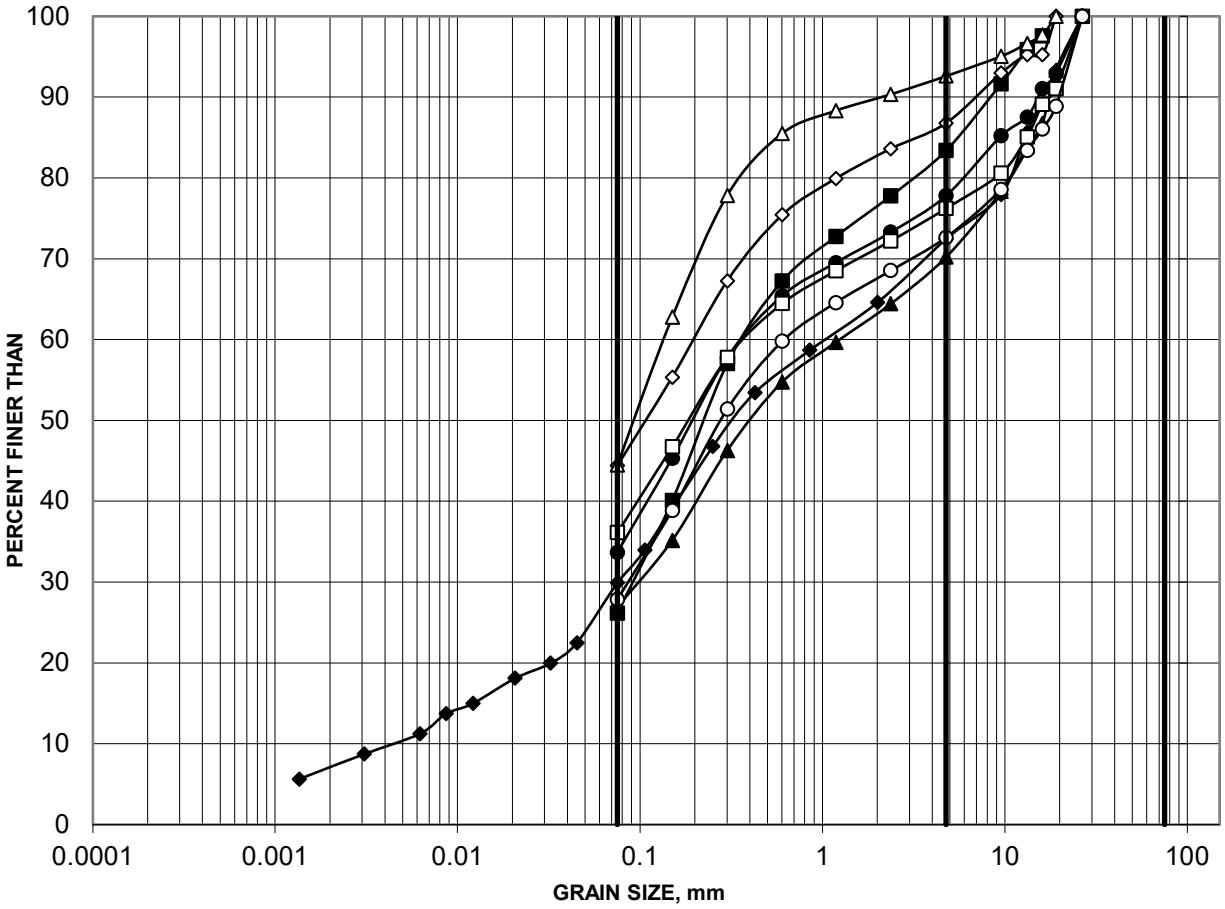
GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY SAND TO SAND TILL



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

	Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
■	471-22-01	3	0.91-1.52	17	57	26	
◆	471-22-01	5	2.29-2.90	28	42	23	7
▲	471-22-01	8	4.57-5.18	30	43	27	
●	471-22-02	6	3.81-4.42	22	44	34	
□	471-22-02	10	6.86-7.47	24	40	36	
◇	471-22-03	5	3.05-3.66	13	43	44	
△	471-22-03	12	9.91-10.11	7	49	44	
○	471-22-04	2	0.76-1.37	27	45	28	

Project: 1773612_WO 11

GOLDER
MEMBER OF WSP

Created by: BW
Checked by: PP

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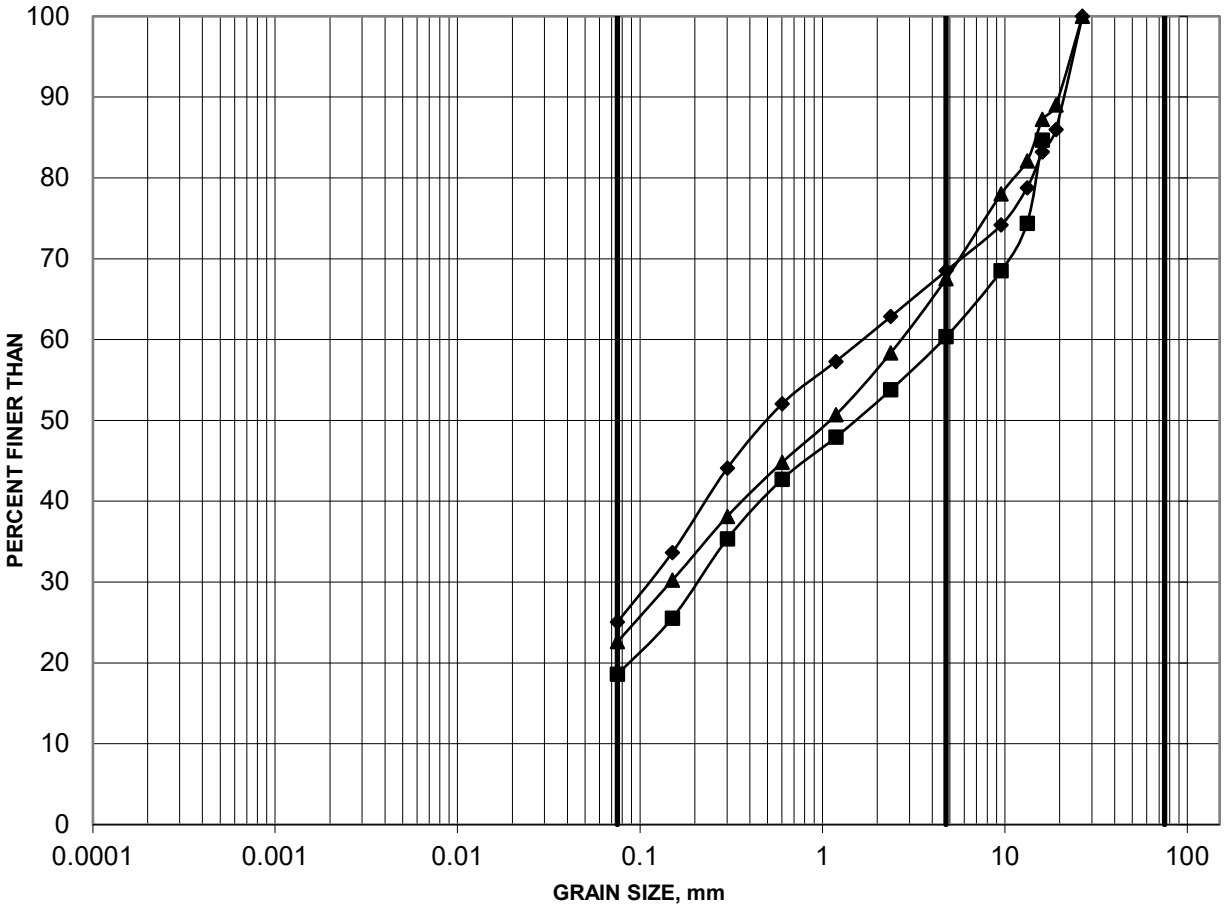
GRAIN SIZE DISTRIBUTION

FIGURE B3

GRAVELLY SAND TO SAND AND GRAVEL TILL



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

	Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
■	471-22-03	14	11.43-11.66	40	41	19	
◆	471-22-04	5	3.05-3.66	31	44	25	
▲	471-22-04	7	4.57-5.18	32	45	23	

Project: 1773612_WO 11

GOLDER
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Created by: BW
Checked by: PP

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APPENDIX C

Analytical Laboratory Test Results

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
.
Attention: Mr. Kenton Power
PO#:
Invoice to: Golder Associates Ltd

Report Number: 1985544
Date Submitted: 2022-09-07
Date Reported: 2022-09-15
Project: 1773612-W011
COC #: 899907

Dear Kenton Power:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

APPROVAL: _____
Emma-Dawn Ferguson, Chemist

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: https://directory.cala.ca/.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is licensed by the Ontario Ministry of the Environment, Conservation, and Parks (MECP) for specific tests in drinking water (license #2318). A copy of the license is available upon request.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

Certificate of Analysis

eurofins | Environment Testing

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
.
Attention: Mr. Kenton Power
PO#:
Invoice to: Golder Associates Ltd

Report Number: 1985544
Date Submitted: 2022-09-07
Date Reported: 2022-09-15
Project: 1773612-W011
COC #: 899907

Group	Analyte	MRL	Units	Guideline	Lab I.D. / Sample Matrix / Sample Type / Sampling Date / Sample I.D.			
					1649736 Soil 2022-07-14 CR26-22-01 Sa3/5-7'	1649737 Soil 2022-07-20 H 22-02 Sa2/2.5-4.5'	1649738 Soil 2022-07-19 L-22-01 Sa2/2.5-4.5'	1649739 Soil 2022-07-26 471-22-03 Sa3/5-7'
Anions	Cl	0.002	%		0.058	0.005	0.007	0.016
	SO4	0.01	%		0.01	0.01	<0.01	0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm		1.27	0.25	0.23	0.44
	pH	2.00			8.88	9.89	9.32	9.24
	Resistivity	1	ohm-cm		787	4000	4348	2273

Group	Analyte	MRL	Units	Guideline	Lab I.D. / Sample Matrix / Sample Type / Sampling Date / Sample I.D.		
					1649740 Soil 2022-07-06 472-22-04 Sa2/2.5-4.5'	1649741 Soil 2022-07-27 473-22-03 Sa2/2.5-4.5'	1649742 Soil 2022-07-04 474-22-04 Sa3/5-7'
Anions	Cl	0.002	%		0.014	0.011	0.013
	SO4	0.01	%		0.06	<0.01	0.13
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.55	0.36	0.89
	pH	2.00			8.15	9.01	8.15
	Resistivity	1	ohm-cm		1818	2778	1124

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

Certificate of Analysis

eurofins | Environment Testing

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
.
Attention: Mr. Kenton Power
PO#:
Invoice to: Golder Associates Ltd

Report Number: 1985544
Date Submitted: 2022-09-07
Date Reported: 2022-09-15
Project: 1773612-W011
COC #: 899907

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 429467 **Analysis/Extraction Date** 2022-09-13 **Analyst** IP **Method** Cond-Soil			
Electrical Conductivity		90	90-110
pH	7.24	101	90-110
Resistivity			
Run No 429500 **Analysis/Extraction Date** 2022-09-14 **Analyst** IP **Method** AG SOIL			
SO4	<0.01 %	104	70-130
Run No 429575 **Analysis/Extraction Date** 2022-09-14 **Analyst** CK **Method** C CSA A23.2-4B			
Chloride	<0.002 %		90-110

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

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