

REPORT

Foundation Investigation Report

Maintenance Patrol Yard Garage Replacement

1010 Middle Road, Kingston, Ontario

MTO GWP 4130-21-00; Agreement No. 4021-E-0021

Submitted to:

Ministry of Transportation Ontario

1355 John Counter Boulevard

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Submitted by:

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22513877B

February 23, 2023

GEOCREs No.: 31C-319

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1.0 INTRODUCTION

WSP Golder (formerly Golder Associates Ltd., now a member of WSP Canada Inc. and hereafter referenced as WSP Golder in this report) has been retained by of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the design and construction of a new garage at the existing MTO Kingston Maintenance Patrol Yard. The scope of work for the foundation investigation services associated with this project were carried out as part of MTO Agreement No. 4021-E-0021, Assignment No. 2, delivered in association with MTO GWP 4130-21-00, Contract 2022-4020.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 Site Description

MTO's Middle Road Patrol Yard is located at 1010 Middle Road in Kingston, Ontario. The site location is shown on the key plan on Drawing 1.

At present the site is an active maintenance facility with several buildings and at-grade parking for both heavy and light vehicles. The area of the proposed building is generally flat, grass-covered and surrounded by gravel access roads.

Site photographs showing the general conditions of the site are presented in Appendix D.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, the Middle Road facility lies within the physiographic region known as the Napanee Plain which is characterized as a flat-to-undulating plain of limestone overlain by thin overburden deposits with some deeper glacial till in valleys. In some southern areas, shallow deposits of stratified clay are present.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between November 17 to 22, 2022, and included advancing five boreholes, numbered 22-01 to 22-05, at the locations shown on Drawing 1. Boreholes 22-01 to 22-04 are located within the footprint of the proposed garage while Borehole 22-05 is located near the proposed cold storage building.

The boreholes were advanced with a CME55 rubber track-mounted drill rig. The drilling equipment was supplied and operated by George Downing Estate Drilling Ltd. of Hawkesbury, 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 D1586²). Soil samples were obtained at vertical sampling intervals of about 0.76 m. Bedrock core samples were obtained at all borehole locations using rotary diamond drilling techniques retrieving NQ-sized core with a triple-tube core-barrel.

¹ 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. Ontario Ministry of Natural Resources.

² ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

A piezometer was installed at Borehole 22-02, to observe the stabilised groundwater level at the site. The monitoring well consists of 32 mm outside diameter PVC tube with a 1.5 m long slotted screen. The groundwater level was measured in the well on December 6, 2022.

The boreholes without a piezometer were backfilled with bentonite within the bedrock, and bentonite mixed with soil cuttings within the overburden. The boreholes were backfilled 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 Golder'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 and bedrock samples were identified in the field, placed in labelled containers, and transported to WSP Golder'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 and uniaxial compressive strength (UCS) testing was carried out on a selected sample of the bedrock. The laboratory tests were carried out to MTO and/or ASTM Standards, as applicable at WSP Golder's Ottawa laboratory.

Two soil samples were 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 Golder using a Trimble R10 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates as well as geographic coordinates, ground surface elevations, and drilled depths are summarized in Table 1.

Table 1: Summary of Borehole Locations

Borehole No.	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Depth (m)	Comments
	Northing (m) (Latitude)	Easting (m) (Longitude)			
22-01	4905768.2 (44.291897°)	311309.9 (-76.418429°)	116.3	4.6	Bedrock Cored
22-02	4905776.4 (44.291971°)	311326.2 (-76.418225°)	116.1	5.6	Bedrock Cored
22-03	4905759.1 (44.291815°)	311321.5 (-76.418283°)	116.6	5.0	Bedrock Cored
22-04	4905763.9 (44.291858°)	311333.7 (-76.418130°)	116.9	5.1	Bedrock Cored
22-05	4905826.0 (44.292417°)	311349.6 (-76.417930°)	116.2	5.1	Bedrock Cored

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ testing from the investigation are shown on the borehole and drillhole records presented in Appendix A. Photographs of the core recovered from the underlying bedrock at all boreholes are shown on Figures A1 to A10, provided in Appendix A. The results of the geotechnical laboratory testing are presented on the borehole records as well as on Figures B1 to B7 in Appendix B. The results of the basic chemical testing/analysis completed on a selected soil sample are provided in Appendix C.

The stratigraphic boundaries shown on the borehole and drillhole records are inferred from observations of the drilling progress together with continuous soil sampling and may represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

4.2 Site Stratigraphy Overview

At the boreholes, the subsurface conditions generally consist of a topsoil cover overlying compact non-cohesive fill and stiff to very stiff silty clay fill, overlying a native clay layer, all underlain by bedrock which was encountered at shallow depths of 1.2 m to 2.3 m below ground surface. A more detailed description of the overburden soil and bedrock geology conditions encountered during the field investigation is provided in the following sections.

4.2.1 Surface Cover/ Surficial Materials

Topsoil with thickness of approximately 80 mm to 100 mm was encountered at the surface of all boreholes.

4.2.2 Fill

A non-cohesive fill consisting of gravelly silty sand to silty sand and gravel was encountered below the topsoil at Boreholes 22-01 through 22-04 within the footprint of the proposed garage. The top of this layer was encountered at elevations ranging from 116.8 m to 116.0 m, and the thickness of this layer is about 0.5 m. The SPT N-values recorded in this layer range from 12 to 14 blows per 0.3 m of penetration indicating a compact state of compactness. The measured moisture contents of the two samples tested were 15% and 4%. The results of grain size analysis testing carried out on two samples of the non-cohesive fill material are provided in Figure B1 in Appendix B.

A cohesive fill consisting of silty clay was encountered below the non-cohesive fill at Boreholes 22-01, 22-02, and 22-04. The top of this layer was encountered at elevations ranging from 116.3 m to 115.5 m, and the total thickness of this layer ranges from approximately 0.6 m to 0.8 m. The SPT N-values recorded in the layer were 8 and 10 blows per 0.3 m of penetration, suggesting a stiff consistency, with one higher blow count (54 blows per 0.28 m of penetration) at Borehole 22-01 that may have been influenced by the presence of the underlying bedrock surface rather than the consistency of the soil matrix. The result of grain size distribution testing carried out on one sample of the cohesive fill material is provided in Figure B2 in Appendix B. The results of Atterberg limits testing completed on one sample of this material indicate a liquid limit of 46, a plastic limit of 21 and a plasticity index of 25, as shown on Figure B3 in Appendix B. These Atterberg limits testing results indicate a silty clay of medium plasticity (CI). The measured moisture contents of the two samples tested were 32% and 35%, which is above the plastic limit of the material.

4.2.3 Gravelly Silty Sand to Sandy Gravel

Gravelly silty sand to sandy gravel was encountered below the fill materials at Borehole 22-02 within the footprint of the proposed garage, and at Borehole 22-05 within the footprint of the proposed cold storage building. The top of this layer was encountered at Elevation 114.7 m and 116.1 m in these boreholes, respectively, and it has a thickness of about 0.9 m to 1.5 m. The SPT N-values recorded in this material range from 15 to 21 blows per 0.3 m of penetration indicating a compact state of compactness. The higher blow count (50 blows per 0.05 m) recorded at the base of this layer in Borehole 22-05 has been influenced by the presence of the underlying bedrock surface, rather than the compactness of the soil matrix.

The measured moisture content of tested samples was 4% to 30%. The results of grain size analysis testing carried out on sample of this deposit are provided in Figure B4 in Appendix B.

4.2.4 Clay

Clay was encountered below the fill materials at Boreholes 22-03 and 22-04. This clay layer has been weathered into a stiff to very stiff crust. The top of this layer was encountered at elevations of 116.0 m and 115.5 m and the layer has a thickness of 0.9 m and 0.4 m at Boreholes 22-03 and 22-04, respectively. One measured SPT N-value of 8 blows per 0.3 m of penetration suggests a stiff consistency, while a second SPT N-value of 50 blows per 0.08 m of penetration is reflective of the underlying bedrock surface; based on visual and textural observation, this weathered clay is interpreted to have a very stiff consistency.

The results of grain size analysis testing carried out on one sample of this material are provided in Figure B5 in Appendix B. The results of Atterberg limits testing completed on one sample of clay layer indicate a liquid limit of 53, a plastic limit of 21 and a plasticity index of 32, as plotted on a plasticity chart in Figure B6 in Appendix B. These Atterberg limits testing results indicate a clay of high plasticity (CH). The moisture content of two tested samples of the clay were 29% and 30% which is above the plastic limit of this material.

4.3 Bedrock

The overburden materials are underlain by calcareous dolostone and limestone bedrock. Bedrock core samples were obtained at all boreholes using an NQ-sized, triple-tube core-barrel.

Table 2 summarizes the depths and the elevations of the bedrock surface as encountered at the borehole locations.

Table 2: Summary of Bedrock Surface Depths and Elevations

Borehole	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
22-01	116.3	1.2	115.1
22-02	116.1	2.3	113.8
22-03	116.6	1.5	115.1
22-04	116.9	1.8	115.1
22-05	116.2	1.6	114.6

Rock Quality Designation (RQD) values measured on the recovered dolostone, and limestone bedrock core samples ranged from about 29% to 100% but more typically 53% to 100% indicating a fair to excellent rock quality. UCS testing on four samples measured UCS values ranging from 77 MPa to 123 Mpa, indicating a strong to very strong bedrock. The results of UCS testing are provided in Figure B7 in Appendix B.

4.4 Groundwater Condition

A piezometer was installed at Borehole 22-02 to measure the stabilized groundwater level at the site. The groundwater levels measured in the piezometer are presented in Table 3.

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

Table 3: Summary of Groundwater Conditions

Borehole	Screened Interval	Ground Surface Elevation (m)	Depth to Groundwater Level (m)	Ground Water Elevation (m)	Date
22-02	Silty clay fill to native silty sand	116.1	0.9	115.2	December 6, 2022

4.5 Corrosivity Test Results

Two soil samples were 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 in Table 4.

Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis – Soil Samples

Borehole	Sample Depth (m)	Chloride (%)	Sulphate (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)
22-03	0.1-0.6	<0.002	0.02	0.12	8.1	8,333
22-04	0.8-1.4	<0.002	0.03	0.13	8.0	7,692

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ben Waechter, EIT and reviewed by Kenton Power, P.Eng., a senior geotechnical engineer with WSP Golder. Lisa Coyne, P.Eng., a Fellow and MTO Designated Foundations Contact for WSP Golder, conducted an independent technical and quality review of this report.

WSP Golder



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[https://golderassociates.sharepoint.com/sites/158306/project files/6 deliverables/22513877b middle rd/fidr and fir/22513877b fir rev0 middle rd 2023'02'23.docx](https://golderassociates.sharepoint.com/sites/158306/project%20files/6%20deliverables/22513877b%20middle%20rd/fidr%20and%20fir/22513877b%20fir%20rev0%20middle%20rd%202023%02%23.docx)

APPENDIX A

Borehole Records

Lists of Abbreviations and Symbols
Lithological and Geotechnical Rock Description Terminology
Records of Boreholes and Drill Holes 22-01 to 22-05
Bedrock Core Photographs, Figures A1 to A10

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	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(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>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

- Only applicable to components not described by Primary Group Name.
- 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 cm² 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, G_s)
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)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

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

- 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 grain size. 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.
- 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

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- 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
ν	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

(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
$C_{\alpha(e)}$	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 = $\tan \delta$
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

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

Notes: 1
2

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING CLASSIFICATION

Fresh (W1): no visible sign of rock material weathering.

Slightly Weathered (W2): discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

Moderately Weathered (W3): less than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Highly Weathered (W4): more than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Completely Weathered (W5): 100% of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

Residual Soil (W6): all rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole, a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250



RECORD OF BOREHOLE No 22-01 SHEET 1 OF 2 **METRIC**

PROJECT 22513877B

G.W.P. 4130-21-00 LOCATION N 4905768.2; E 311309.9 MTM NAD_ZONE (LAT. 44.291897; LONG. -76.418429) ORIGINATED BY DG

DIST Eastern HWY 401 BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring COMPILED BY NV

DATUM Geodetic DATE November 22, 2022 CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80						100	SHEAR STRENGTH kPa
											○ UNCONFINED	+	FIELD VANE					
											● QUICK TRIAXIAL	×	REMOULDED		WATER CONTENT (%)			
														25	50	75		GR SA SI CL
116.3	GROUND SURFACE																	
0.0	TOPSOIL - SILTY SAND (SM) Brown Moist		1	SS	14													
0.1	Gravelly SILTY SAND (SM) (FILL) Compact Brown Moist																	
115.7	SILTY CLAY (Cl) (FILL) Dark Grey W>PL		2	SS	54/0.28													
0.6																		
115.1	LIMESTONE (BEDROCK)																	
1.2	Bedrock cored from 1.2 m to 4.6 m For rock coring details see Record of Drillhole 22-01		1	RC	REC 87%													RQD = 41%
			2	RC	REC 100%													RQD = 99%
			3	RC	REC 100%													RQD = 100%
111.7	END OF BOREHOLE																	
4.6																		

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



RECORD OF BOREHOLE No 22-02 SHEET 1 OF 2 **METRIC**

PROJECT 22513877B

G.W.P. 4130-21-00 LOCATION N 4905776.4; E 311326.2 MTM NAD_ZONE (LAT. 44.291971; LONG. -76.418225) ORIGINATED BY DG

DIST Eastern HWY 401 BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring COMPILED BY NV

DATUM Geodetic DATE November 22, 2022 CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)							
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL		
116.1	GROUND SURFACE																							
0.0	TOPSOIL - SILTY SAND (SM) Brown Moist		1	SS	12																		29 48 (23)	
115.5	Gravelly SILTY SAND (SM), contains brick fragments (FILL) Compact Brown Moist		2	SS	10																		0 10 28 62	
114.7	SILTY CLAY (CI) (FILL) Very stiff Dark grey W>PL		3	SS	16																		25 28 (47)	
113.8	LIMESTONE (BEDROCK)		1	RC	REC 100%																		RQD = 82%	
	Bedrock cored from 2.3 m to 5.6 m For rock coring details see Record of Drillhole 22-02		2	RC	REC 100%																			RQD = 59%
			3	RC	REC 100%																			RQD = 100%
110.5	END OF BOREHOLE																							
5.6	NOTE: 1. Water level measured at a depth of 0.9 m below ground surface (Elev. 115.2 m) on December 6, 2022.																							

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



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

PROJECT 22513877B

G.W.P. 4130-21-00 LOCATION N 4905759.1; E 311321.5 MTM NAD_ZONE (LAT. 44.291815; LONG. -76.418283) ORIGINATED BY DG

DIST Eastern HWY 401 BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring COMPILED BY NV

DATUM Geodetic DATE November 17, 2022 CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80						100
116.6	GROUND SURFACE																
0.0	TOPSOIL - SILTY SAND (SM) Brown Moist		1	SS	13												
116.0	SILTY SAND (SM), some clay (FILL) Compact Brown-grey Moist		2	SS	8												
115.1	CLAY (CH) slightly fissured (Weathered Crust) Very Stiff Brown W>PL																
1.5	LIMESTONE (BEDROCK) Bedrock cored from 1.5 m to 5.0 m For rock coring details see Record of Drillhole 22-03		1	RC	REC 100%												RQD = 29%
			2	RC	REC 100%												RQD = 91%
			3	RC	REC 100%												RQD = 100%
111.6	END OF BOREHOLE																

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



RECORD OF BOREHOLE No 22-04 SHEET 1 OF 2 **METRIC**

PROJECT 22513877B

G.W.P. 4130-21-00 LOCATION N 4905763.9; E 311333.7 MTM NAD_ZONE (LAT. 44.291858; LONG. -76.418130) ORIGINATED BY DG

DIST Eastern HWY 401 BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring COMPILED BY NV

DATUM Geodetic DATE November 17, 2022 CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)							
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL		
116.9	GROUND SURFACE																							
0.0	TOPSOIL - SILTY SAND (SM) Brown Moist		1	SS	14																			
0.1	SAND and GRAVEL (SM) (FILL) Compact Brown Moist																							
116.3	SILTY CLAY (Cl), rootlets, slightly fissured (FILL) Very stiff Brown W~PL		2	SS	8																			
0.6	CLAY (CH) slightly fissured (WEATHERED CRUST) Brown W>PL		3	SS	50/0.08																			
115.5	LIMESTONE (BEDROCK)																							
1.4	Bedrock cored from 1.8 m to 5.1 m For rock coring details see Record of Drillhole 22-04		1	RC	REC 89%																		RQD = 53%	
115.1			2	RC	REC 100%																			RQD = 75%
1.8			3	RC	REC 100%																			RQD = 100%
111.8	END OF BOREHOLE																							
5.1																								

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



RECORD OF BOREHOLE No 22-05 SHEET 1 OF 2 **METRIC**

PROJECT 22513877B

G.W.P. 4130-21-00 LOCATION N 4905826.0; E 311349.6 MTM NAD_ZONE (LAT. 44.292417; LONG. -76.417930) ORIGINATED BY DG

DIST Eastern HWY 401 BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring COMPILED BY NV

DATUM Geodetic DATE November 17, 2022 CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)						
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL	
116.2	GROUND SURFACE																						
0.0	TOPSOIL - SILTY SAND (SM) Brown Moist		1	SS	15																		
0.1	Sandy SILTY GRAVEL (GM), contains cobbles Compact Grey-brown Moist		2	SS	21																		71 22 (7)
114.6	LIMESTONE (BEDROCK)		3	SS	50/0.05																		
1.6	Bedrock cored from 1.6 m to 5.1 m For rock coring details see Record of Drillhole 22-05		1	RC	REC 100%																		RQD = 43%
			2	RC	REC 100%																		RQD = 67%
			3	RC	REC 100%																		RQD = 95%
111.1	END OF BOREHOLE																						
5.1																							

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

BH 22-01 (Dry)
Core Box 1 of 1

Cobbles and
Boulders

Elevation 115.1 m Top of Bedrock



Elevation 111.7 m EOH

BH 22-01 (Wet)
Core Box 1 of 1

Cobbles and
Boulders

Elevation 115.1 m Top of Bedrock



Elevation 111.7 m EOH



Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

Review: LCC

Figure A2

**BH 22-02 (Dry)
Core Box 1 of 1**

Elevation 113.8 m Top of Bedrock



Elevation 110.5 m EOH



**Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario**

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

Review: LCC

Figure A3

BH 22-02 (Wet)
Core Box 1 of 1

Elevation 113.8 m Top of Bedrock



Elevation 110.5 m EOH

BH 22-03 (Dry)
Core Box 1 of 1

Elevation 115.1 m Top of Bedrock



Elevation 111.6 m EOH



Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

Review: LCC

Figure A5

BH 22-03 (Wet)
Core Box 1 of 1

Elevation 115.1 m Top of Bedrock



Elevation 111.6 m EOH



Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

Review: LCC

Figure A6

BH 22-04 (Dry)
Core Box 1 of 1

Elevation 115.1 m Top of Bedrock



Elevation 111.8 m EOH



Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

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Figure A7

BH 22-04 (Wet)
Core Box 1 of 1

Elevation 115.1 m Top of Bedrock



Elevation 111.8 m EOH



Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

Checked: KCP

Review: LCC

Figure A8

BH 22-05 (Dry)
Core Box 1 of 1

Elevation 114.6 m Top of Bedrock



Elevation 111.1 m EOH

**BH 22-05 (Wet)
Core Box 1 of 1**

Elevation 114.6 m Top of Bedrock



Elevation 111.1 m EOH



**Foundation Investigation and Design
Middle Road Patrol Yard
GWP 4130-21-00
1010 Middle Road Kingston Ontario**

Project No. 22513877B

Drawn: BW

Date: 2022-11-21

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Figure A10

APPENDIX B

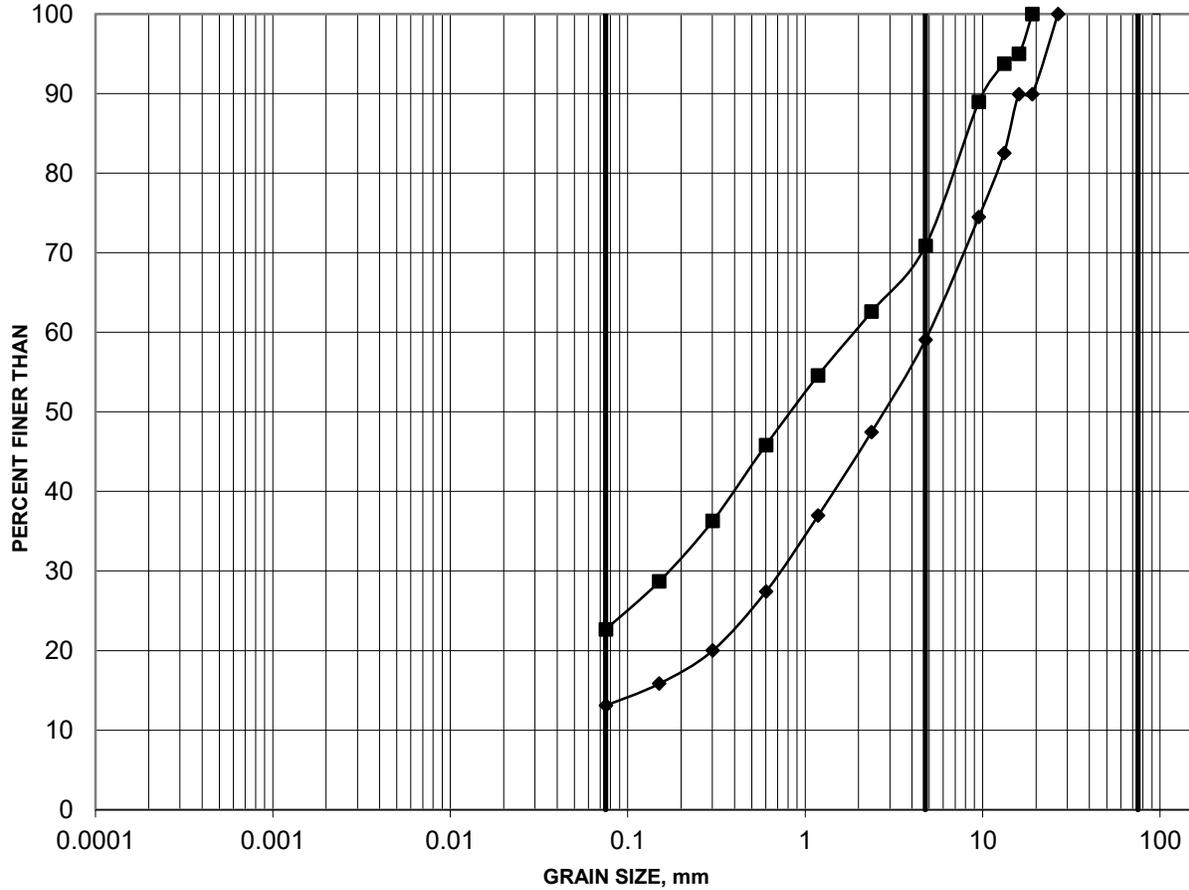
Geotechnical Laboratory Test Results

Figures B1 to B8

GRAIN SIZE DISTRIBUTION

FIGURE B1

GRAVELLY SILTY SAND TO SILTY SAND AND GRAVEL (SM) (FILL)



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

Borehole	Sample	Depth (m)	Constituents (%)			
			Gravel	Sand	Silt	Clay
■ 22-02	1	0.10-0.61	29	48	23	
◆ 22-04	1	0.10-0.61	41	46	13	

Project: 22513877B

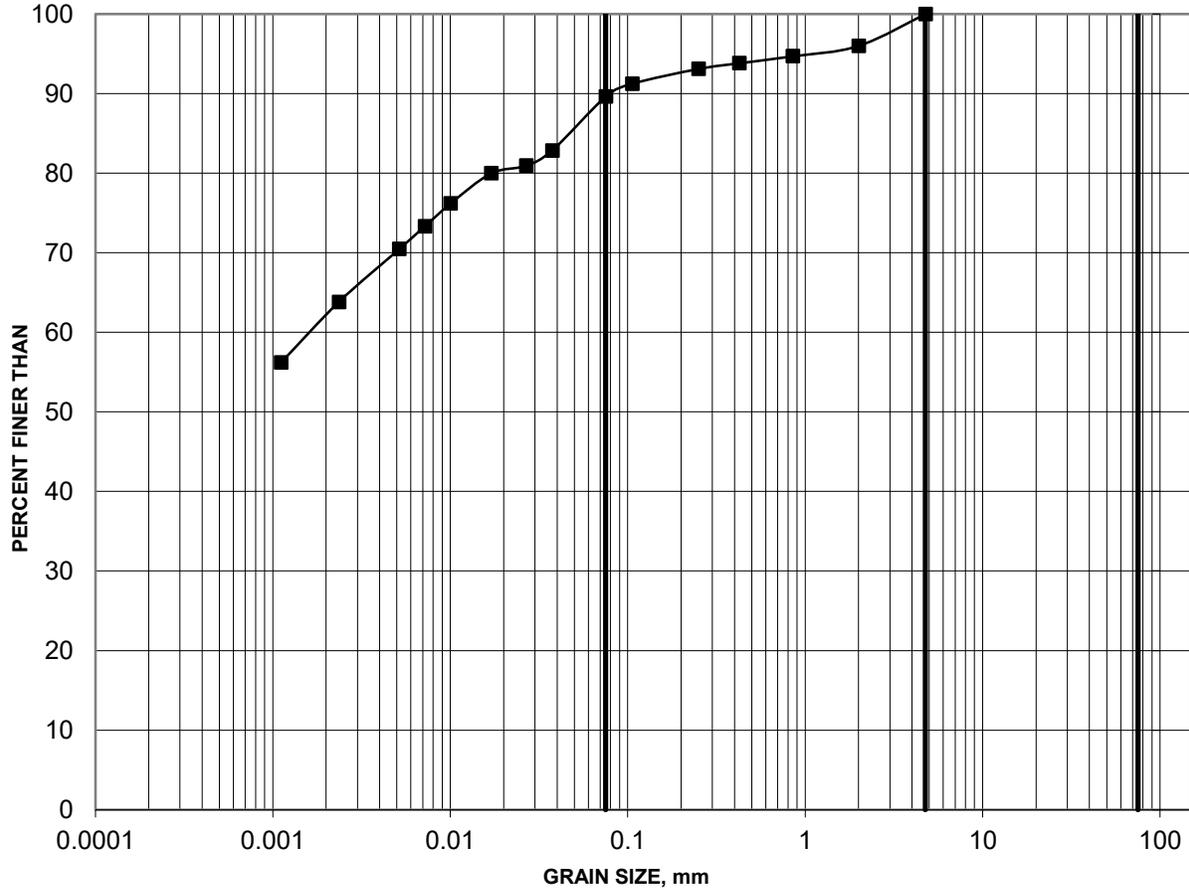


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Checked by: CW

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY (CI) (FILL)



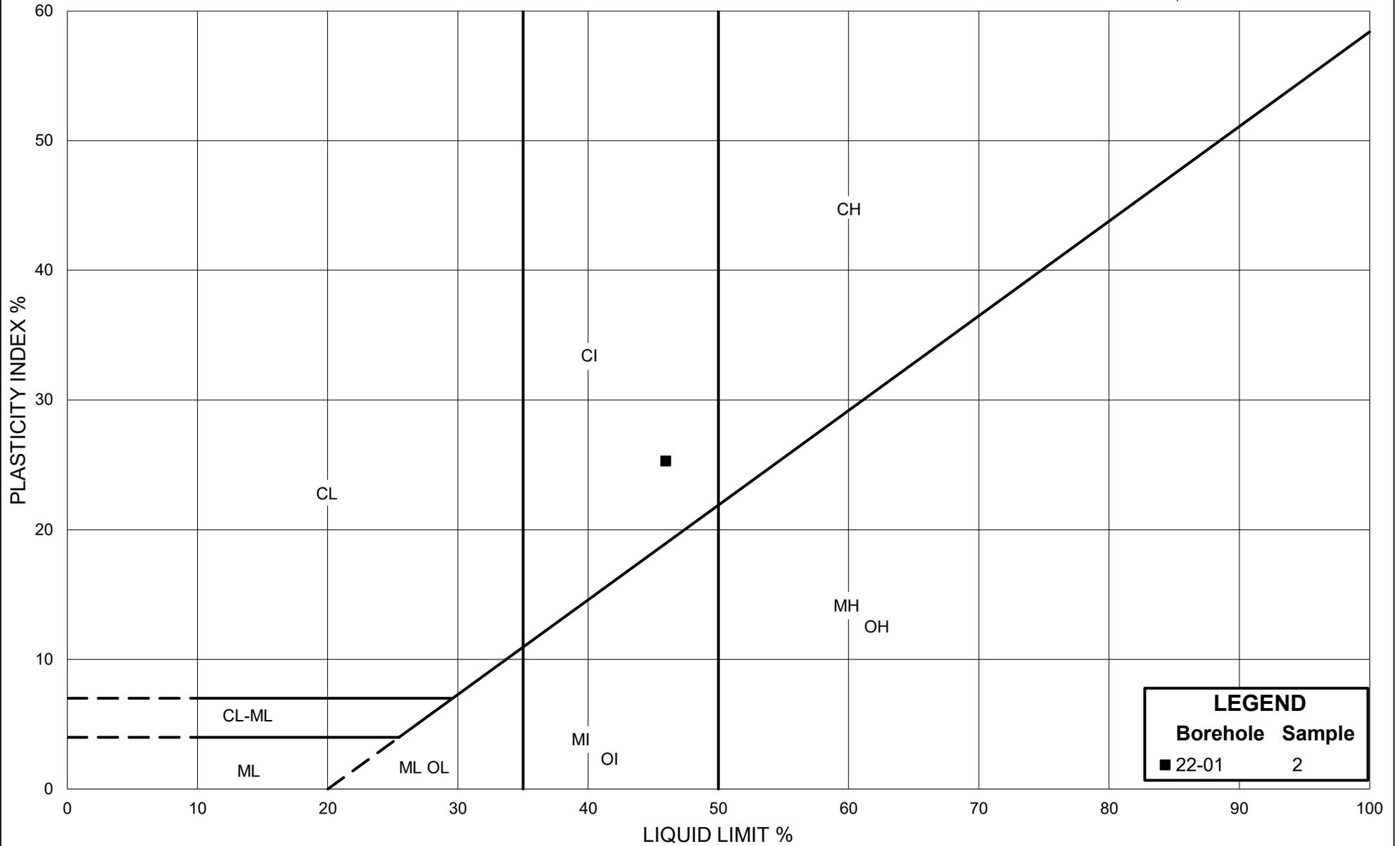
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)	Constituents (%)			
			Gravel	Sand	Silt	Clay
■ 22-02	2	0.76-1.37	0	10	28	62

Project: 22513877B



Created by: BW
Checked by: CW



LEGEND	
Borehole	Sample
■ 22-01	2

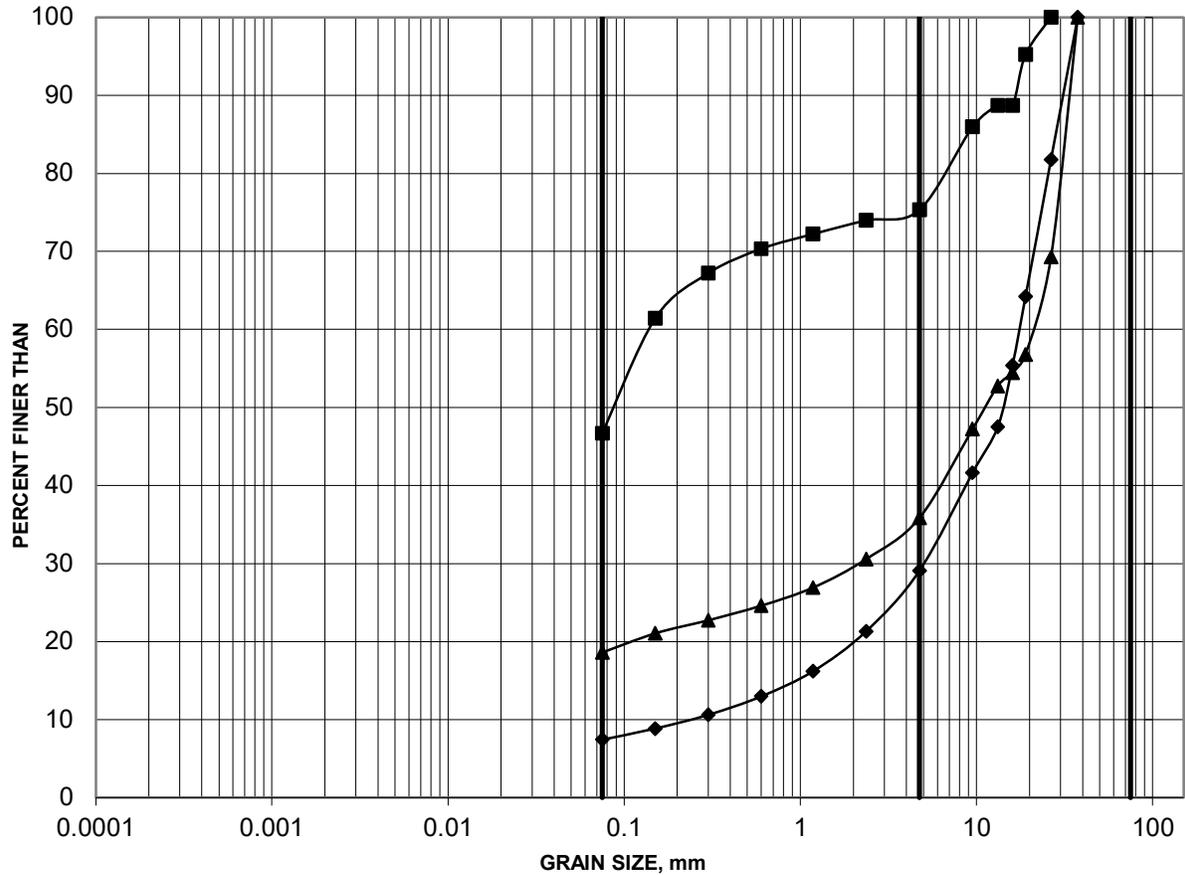
PLASTICITY CHART

SILTY CLAY (CI) (FILL)

GRAIN SIZE DISTRIBUTION

FIGURE B4

GRAVELLY SILTY SAND to SANDY GRAVEL (SM-GM)



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

Borehole	Sample	Depth (m)	Constituents (%)			
			Gravel	Sand	Silt	Clay
■	22-02	3	1.52-2.13	25	28	47
◆	22-05	1B	0.08-0.61	71	22	7
▲	22-05	2	0.76-1.30	64	17	19

Project: 22513877B

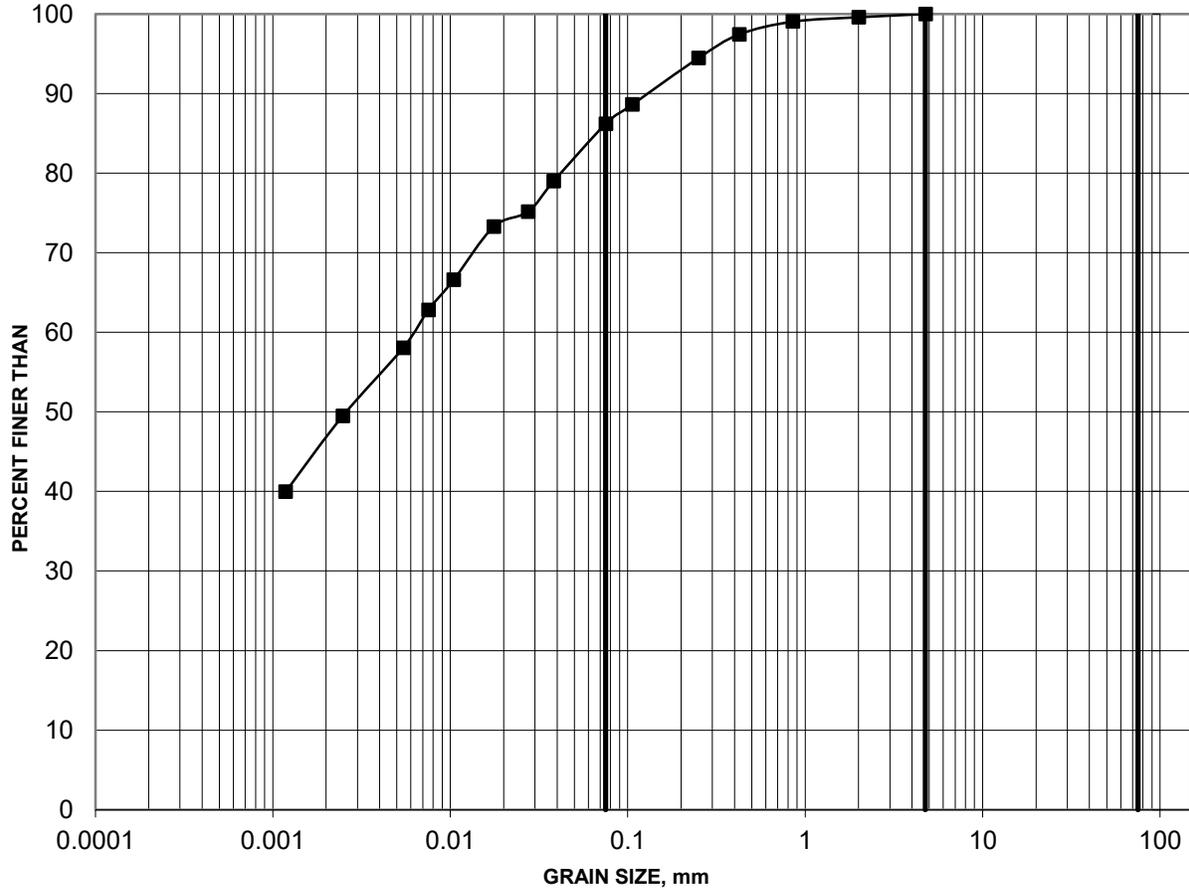


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Checked by: CW

GRAIN SIZE DISTRIBUTION

FIGURE B5

CLAY (CH) (WEATHERED CRUST)



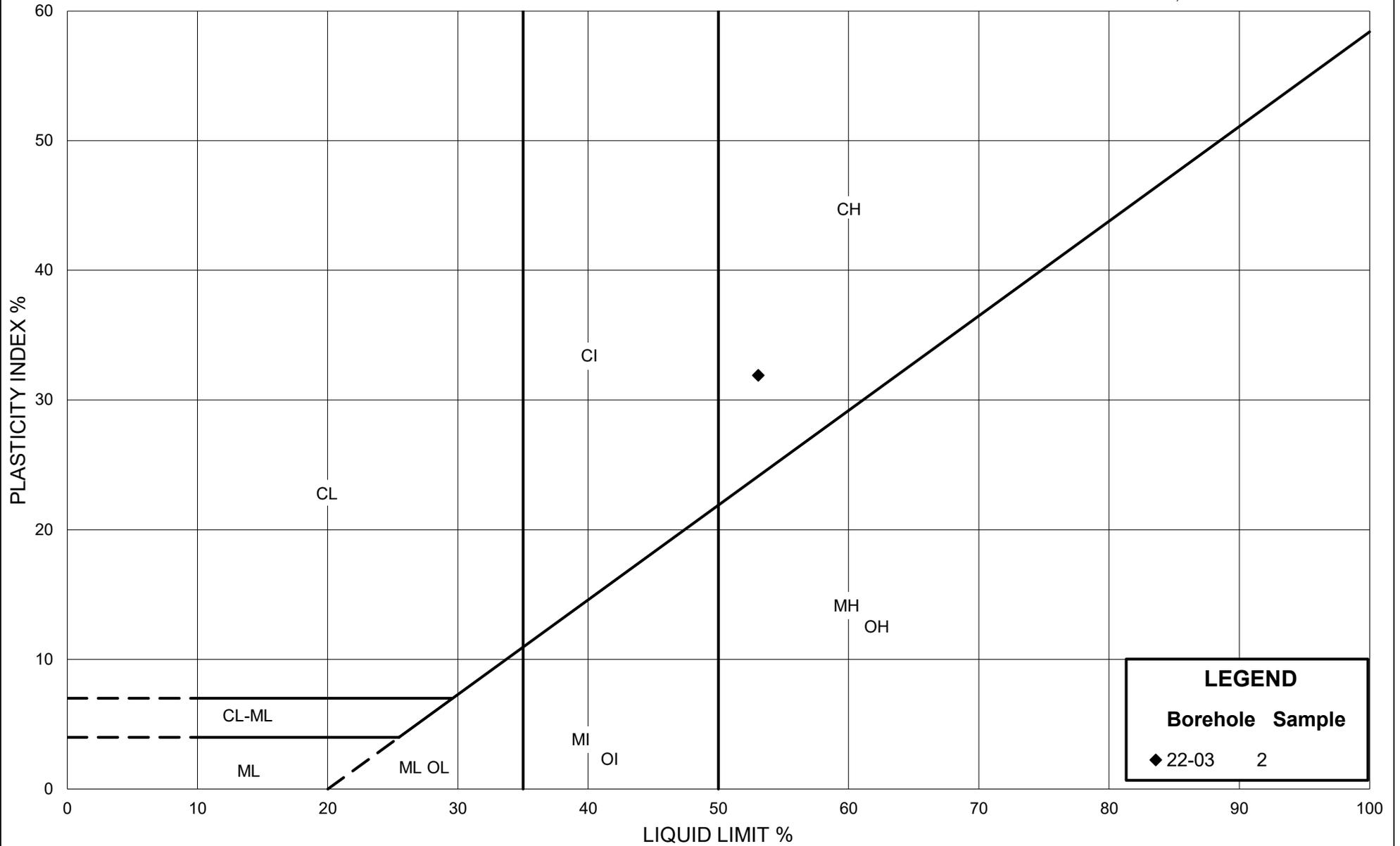
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)	Constituents (%)			
			Gravel	Sand	Silt	Clay
■ 22-04	3	1.52-1.75	0	14	39	47

Project: 22513877B



Created by: BW
Checked by: CW

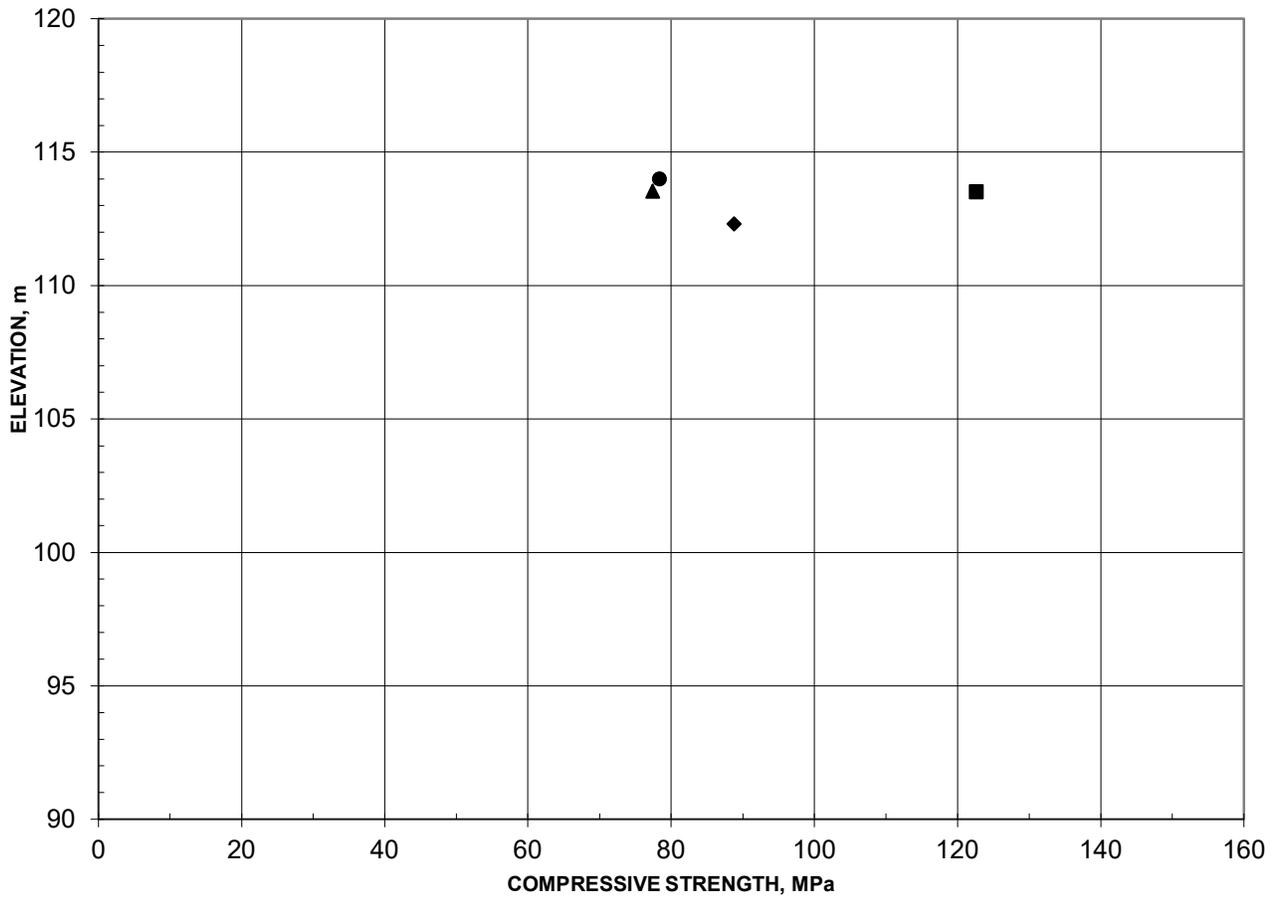


PLASTICITY CHART

CLAY (CH) (WEATHERED CRUST)

ASTM D7012 - Method C
UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE
SUMMARY OF LABORATORY TEST RESULTS

FIGURE B7



Borehole	Depth (m)	L/D	Bulk Density (kg/m ³)	Lithology	UCS (MPa)	Failure Type
■ BH22-01 RC1	2.8	2.3	2560	Limestone	123	1
◆ BH22-02 RC1	3.8	2.4	2436	Dolostone	89	1
▲ BH22-03 RC1	3.0	2.5	2490	Dolostone	77	1
● BH22-04 RC1	2.9	2.5	2538	Limestone	78	1

Notes:

Failure Types

1. Well formed cones on both ends
2. Well formed cones on one end, vertical cracks through cap
3. Columnar vertical cracking through both ends
4. Diagonal fracture with no cracking through ends
5. Side fractures at top or bottom
6. Side fractures at both sides of top or bottom

Remarks

- Cores tested in vertical direction.
- Cores tested in air-dry condition.
- Time to failure > 2 and < 15 minutes.

Project: 22513877B



Created by: BW

Checked by: CW

APPENDIX C

Results of Chemical Analysis

Eurofins Environmental Testing Report Number 1990635

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario

Attention: Mr. Kenton Power

PO#:

Invoice to: Golder Associates Ltd

Report Number: 1990635
Date Submitted: 2022-11-28
Date Reported: 2022-12-05
Project: 22513877B
COC #: 903281

Page 1 of 3

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

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario

Attention: Mr. Kenton Power
PO#:

Invoice to: Golder Associates Ltd

Report Number: 1990635
Date Submitted: 2022-11-28
Date Reported: 2022-12-05
Project: 22513877B
COC #: 903281

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1665274 Soil 2022-11-17 22-03 Sa1/0.33-2.0'	1665275 Soil 2022-11-17 22-04 Sa2/2.5-4.5'
Anions	Cl	0.002	%			<0.002	<0.002
	SO4	0.01	%			0.02	0.03
General Chemistry	Electrical Conductivity	0.05	mS/cm			0.12	0.13
	pH	2.00				8.08	8.02
	Resistivity	1	ohm-cm			8333	7692

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

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario

Attention: Mr. Kenton Power
PO#:

Invoice to: Golder Associates Ltd

Report Number: 1990635
Date Submitted: 2022-11-28
Date Reported: 2022-12-05
Project: 22513877B
COC #: 903281

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 434454 Analysis/Extraction Date 2022-12-03 Analyst AsA Method C CSA A23.2-4B			
Chloride	<0.002 %		90-110
Run No 434473 Analysis/Extraction Date 2022-12-03 Analyst AsA Method Cond-Soil			
Electrical Conductivity	<0.05 mS/cm	100	90-110
pH	8.13	99	90-110
Resistivity			
Run No 434508 Analysis/Extraction Date 2022-12-05 Analyst IP Method AG SOIL			
SO4	<0.01 %	100	70-130

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

APPENDIX D

Site Photographs



Photograph 1: Looking Northeast at Borehole 22-01



Photograph 2: Looking North at Borehole 22-02



Photograph 3: Looking East from Borehole 22-03



Photograph 4: Looking North at Borehole 22-5

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golder.com