



FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 11 Russel Creek Culvert Rehabilitation Site 39E-210/C near Matheson Ministry of Transportation, Ontario GWP 5070-20-00

Submitted to:

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 11 RUSSEL CREEK CULVERT REHABILITATION
SITE 39E-210/C NEAR MATHESON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5070-20-00

1.0 INTRODUCTION

WSP Golder (formerly Golder Associates Ltd.) 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 Russel Creek Culvert on Highway 11, approximately 0.9 km west of Highway 101 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 culvert site, for the installation of cofferdams for the culvert rehabilitation, by borehole drilling with laboratory testing carried out on selected soil samples.

2.0 SITE DESCRIPTION

Based on DM Will's survey, the existing culvert consists of an approximately 4 m diameter by 47.1 m long structural plate corrugated steel pipe culvert. The culvert inlet (north end) and outlet (south end) inverts are at Elevations 246.6 m and 246.8 m, respectively. The highway grade at the culvert location is at approximately Elevation 254.0 m, with the embankment about 7.4 m high relative to the culvert inlet invert. In general, the topography within the vicinity of the culvert consists of generally flat forest with some hilly terrain.

The embankment slopes at the culvert location are generally inclined at 2.5 Horizontal and 1 Vertical (2.5H:1V). At the time of the subsurface exploration field work, the embankment side slopes were generally granular fill material or grass/shrub covered. No signs of deep-seated embankment slope instability were observed in the vicinity of the culvert. The ground surface conditions at select locations of the culvert area are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface exploration was carried out on 8 June and 9 June 2020, during which time four boreholes (Boreholes RC-1 to RC-4) were advanced at the approximate locations shown on Drawing 1. All four 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. 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 hammer in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). In situ vane shear tests were carried out in cohesive soils for determination of undrained shear strengths in accordance with Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils (ASTM 2573), using an MTO standard 'N'-size vane.

The water level inside the augers was observed during and upon completion of drilling operations. The water level readings are indicated on the borehole records contained in Appendix A. The boreholes were backfilled in accordance with Ontario Regulation 903 (as amended).

Field work was supervised on a full-time basis by a member of WSP 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 WSP 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 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 end of culvert by a member of our technical staff and converted into northing/easting coordinates on the base plan drawing provided by D.M. Wills. The ground surface elevation at each borehole location was surveyed by WSP Golder relative to the culvert end with the elevations 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. The latitude/ longitude coordinates of the borehole locations are also shown on the borehole records.

Borehole Number	MTM NAD 83 Northing (m)	MTM NAD 83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
RC-1	5377262.5	343500.0	248.8	9.8
RC-2	5377266.9	343480.0	250.3	11.3
RC-3	5377318.1	343498.5	248.5	11.3
RC-4	5377316.0	343480.3	248.9	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS) ¹ mapping, the culvert site is located within a glaciolacustrine plain, with the soils consisting primarily of clay.

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.

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

The results of the analytical laboratory testing by Bureau Veritas Laboratories (BVL) 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.

4.2.1 Fill

Each of the four boreholes encountered fill as follows:

- A 0.1 m thick layer of cobbles was encountered at the ground surface in Borehole RC-1 at Elevation 248.8 m.
- Below the cobbles in Borehole RC-1, a 0.6 m thick layer of silty topsoil fill was encountered at Elevation 248.7 m. An 80 mm thick layer of topsoil fill was encountered at the surface in Borehole RC-4 at Elevation 248.9 m.
- A 0.6 m to 2.4 m thick layer of silty sand fill to sand and gravel fill was encountered at the ground surface in Boreholes RC-2 and RC-3 and below the topsoil in Borehole RC-4 between Elevations 250.3 m and 248.5 m. Auger grinding was encountered in Borehole RC-4 between Elevations 248.6 m and 248.4 m.
- A 2.4 m to 3.4 m thick layer of clayey silt to clay fill was encountered below the silty topsoil in Borehole RC-1 and below the silty sand fill to sand and gravel fill in Boreholes RC-2 to RC-4. Peat and organics pockets were encountered in some samples of the clayey silt to clay fill.

The SPT 'N'-values measured within the silty topsoil fill in Borehole RC-1 was 10 blows per 0.3 m of penetration indicating a loose compactness condition. The SPT 'N'-values measured within the silty sand to sand and gravel fill range from 4 to 26 blows per 0.3 m of penetration indicating a loose to compact compactness condition. The SPT 'N'-values measured within the clayey silt to clay fill range from 1 to 15 blows per 0.3 m of penetration suggesting a very soft to stiff consistency.

Atterberg limit testing was carried out on four samples of the clayey silt to clay fill and the results are presented on Figure B-1. The test results measured liquid limits ranging from 38 to 52, plastic limits ranging from 18 to 21 and plasticity indices ranging from 20 to 31, and indicate the samples consist of a silty clay of intermediate plasticity to clay of high plasticity. The natural moisture contents measured on select samples of the clayey silt to clay fill range between approximately 31 per cent and 38 percent.

4.2.2 Peat

An approximately 1.4 m thick layer of fibrous peat was encountered below the fill in Borehole RC-4 at Elevation 245.7 m. Wood fragments were encountered throughout the deposit.

Two SPT 'N'-values measured within the peat were 6 and 10 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

4.2.3 Sand

Sand was encountered in Borehole RC-2 below the fill at Elevation 245.3 m which generally extends to the bottom of the borehole with a thin clay layer encountered at Elevation 240.8 m and a lower clay layer encountered at Elevation 239.2. The borehole did not penetrate the lower clay layer at the bottom of the borehole at Elevation 239.0 m. Auger grinding was encountered during drilling at Elevation 244.2 m. Heaving sand was encountered at Elevations 244.2, 243.5, and 239.9 m as noted on the Record of Borehole.

The SPT 'N'-values measured within sand deposit range from 3 to 9 blows per 0.3 m of penetration indicating a very loose to loose compactness condition.

Grain size distribution testing was carried out on one sample of the sand and the results are presented on Figure B-2 in Appendix B.

The natural moisture content measured on one sample of the deposit is about 11 per cent.

4.2.4 Silty Clay to Clay

A deposit of silty clay to clay was encountered in Boreholes RC-1, RC-3, and RC-4, which were terminated in the deposit at depths ranging from 9.8 to 11.3 metres below ground surface. Silt pockets, seams, layers and/or laminations were encountered throughout the deposit in Boreholes RC-1, RC-3, and RC-4.

In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 24 kPa to 48 kPa and sensitivities ranging from 3 to 6. The SPT 'N'-values measured within the deposit range from weight of hammer to 9 blows per 0.3 m of penetration. The field vane test results, together with the SPT "N"-values, suggest that the deposit generally has a soft to stiff consistency.

Atterberg limit testing was carried out on five silty clay to clay samples which are plotted on Figure B-3. The test results measured liquid limits ranging from 48 to 68, plastic limits ranging from 18 to 25 and plasticity indices ranging from 28 to 44, and indicate a silty clay of intermediate plasticity to a clay of high plasticity. The natural moisture content measured on the select samples of the deposit range between about 26 per cent and 58 per cent.

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 creek water level was surveyed by Callon Dietz Inc. in August 2020 at Elevation of 247.7 m. Groundwater and creek 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)	Notes
RC-1	Dry	-	Open borehole (unstabilized)
RC-2	8.2	242.1	Open borehole (unstabilized)
RC-3	Dry	-	Open borehole (unstabilized)
RC-4	Dry	-	Open borehole (unstabilized)

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of the sand fill deposit from Borehole RC-2 by BVL for corrosivity testing. The results are provided on Figure B-4 in Appendix B and are summarized below.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO ₄) Content (µg/g)	Chloride (Cl) Content (µg/g)	Sulphide (mg/kg)	pH
RC-2	3	1.5-2.1	14,000	74	<20 ¹	<20 ¹	0.5	8.21

⁽¹⁾ The sulphate and chloride concentrations are below the reportable detection limit of 20 µg/g.

5.0 CLOSURE

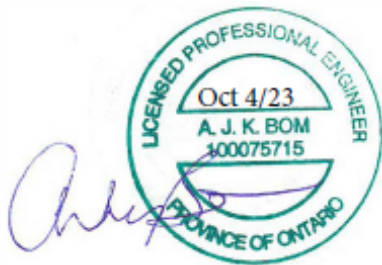
The field drilling program was carried out under the supervision of Mr. Tibor Berecz, P.Eng. under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Trevor Romanyszyn C.E.T. and reviewed by Mr. Bom. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated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

Signature Page

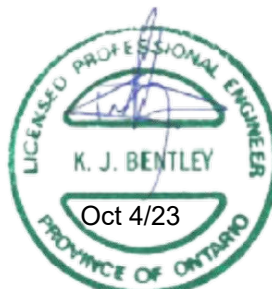
WSP GOLDER



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TB/AB/WC/kjb/ar

[https://golderassociates.sharepoint.com/sites/111953/project files/6 deliverables/foundations/1. reporting/6-russel/final/19126505-r06-rev0-russel creek culvert hwy 11 fidr final 04oct_23.docx](https://golderassociates.sharepoint.com/sites/111953/project%20files/6%20deliverables/foundations/1.%20reporting/6-russel/final/19126505-r06-rev0-russel%20creek%20culvert%20hwy%2011%20fidr%20final%2004oct_23.docx)

PART B

FOUNDATION DESIGN REPORT
HIGHWAY 11 RUSSEL CREEK CULVERT REHABILITATION
SITE 39E-210/C NEAR MATHESON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5070-20-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation engineering recommendations for cofferdams, associated with the rehabilitation of the Russel Creek culvert on Highway 11 at about 15+184, about 0.9 km west of Highway 101 in Matheson, Ontario, in the Township of Bowman. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at this site.

The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible alternatives for cofferdams. The foundation investigation report, discussion, and recommendations are intended for the use of the Ministry of Transportation, Ontario (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 Part A (Foundation Investigation) of the 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

The existing culvert consists of an approximate 4 m diameter by 47.1 m long structural plate corrugated steel pipe culvert. The culvert inlet (south end) and outlet (north end) inverts are at Elevations 246.8 m and 246.6 m, respectively. The highway grade at the culvert location is at approximately Elevation 254 m. The embankment slopes in the culvert area are generally inclined at 2.5 Horizontal and 1 Vertical (2.5H:1V). At the time of the subsurface exploration field work, the embankment side slopes were generally granular fill material and grass/shrub covered. No signs of deep-seated embankment slope instability were observed in the vicinity of the culvert. The height of the embankment based on the survey is about 7.4 m relative to the invert at the outlet (north end) and 7.2 m relative to the invert at the inlet (south end). The average thickness of soil cover over the culvert is about 3.3 m.

A steel sheet pile cut-off wall with deadman tiebacks is present at each end of the existing culvert.

We understand from DM Wills that the existing culvert is to be rehabilitated with a tunnel plate liner, and that dewatering/unwatering at both ends of the culvert will be required to allow the lining to be carried out in dry conditions. Repairs to the existing culvert will be performed from the interior of the culvert and excavation into the existing embankment side slopes is not anticipated. Removal of the sediment to expose the culvert invert at the ends and along the culvert will be required.

6.2 Control of Groundwater and Surface Water

The measured creek water level was at Elevation 247.7 m in August 2020 which is about 1 m above the culvert invert. The highest open hole water level measured in the boreholes was at Elevation 242.1 m (i.e., greater than about 4 m below the culvert invert) within the sand deposit in Borehole RC-2. The remainder of the boreholes were dry upon completion of drilling. The groundwater levels may be higher than encountered since the measured water levels would not have had time to stabilize during the short time the boreholes remained open.

Temporary control of creek water will be necessary to allow the tunnel plate liner (and any grouting operations as required) to be constructed in dry conditions inside the culvert. It is anticipated that a surface cofferdam (e.g., water or sand filled bladder / bags placed on creek bed) or sheet piles installed at the ends of the culvert adjacent to the existing sheet pile cut-off wall will provide sufficient control of creek water for the lining. Although peat and wood fragments were encountered within and below the fill deposits, installation of sheet piles is considered feasible at the site. If large branches or tree stumps/roots are present within the fill or buried within the creek channel, installation of sheet piles may be challenging and may require a temporary guide or bracing system during installation to maintain tolerances to achieve an effective sheetpile box / cut-off system.

The type of cofferdam will depend on the excavation configuration, water levels at the time of construction, and anticipated surface water / groundwater volumes to be discharged from within the work area. The contractor is responsible for the detail design of the temporary cofferdam systems.

The following geotechnical parameters for the foundation soils are provided to the designers, if needed, to assess the feasibility of the cofferdam system.

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
Very Soft to Stiff Clayey Silt to Silty Clay (FILL)	18	28	12 to 50	0.36	0.53	2.77
Very Loose to Loose Sand	19	28	-	0.36	0.53	2.77
Soft to Firm Silty Clay to Clay	18	28	25 to 40	0.36	0.53	2.77

Notes:

- 1) The design groundwater level may be assumed to be equal to the creek water level measured to be at El. 247.7 m when measured in August 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 or cofferdam) may be calculated based on the values of K_o 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.

Depending on the creek water level and flow conditions and groundwater levels at the time of construction, it may be feasible to divert the creek flow and/or pump creek water from behind the temporary cofferdams; DMW has included the need for a temporary bypass pipe through the existing culvert during rehabilitation.

Dewatering operations must be in accordance with OPSS.PROV 517 and consideration should be given to including MTO's Special Provision 517F01. Depending on the design of the cofferdam and dewatering / unwatering system, if construction water pumping rates are anticipated to exceed 50 m³/day, an Environmental Activity Section Registry (EASR) or Permit to Take Water (PTTW) will be required.

7.0 CLOSURE

This Foundation Design report was prepared by Mr. Tibor Berecz, P.Eng., a geotechnical engineer at WSP Golder. Mr. Andre Bom, P.Eng., a senior geotechnical engineer and Associate, reviewed the report. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact with WSP Golder, conducted an independent and quality control review of the report.

Signature Page

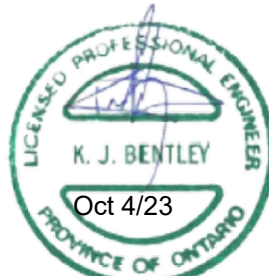
WSP GOLDER



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[https://golderassociates.sharepoint.com/sites/111953/project files/6 deliverables/foundations/1. reporting/6-russel/final/19126505-r06-rev0-russel creek culvert hwy 11 fidr final 04oct_23.docx](https://golderassociates.sharepoint.com/sites/111953/project%20files/6%20deliverables/foundations/1.%20reporting/6-russel/final/19126505-r06-rev0-russel%20creek%20culvert%20hwy%2011%20fidr%20final%2004oct_23.docx)

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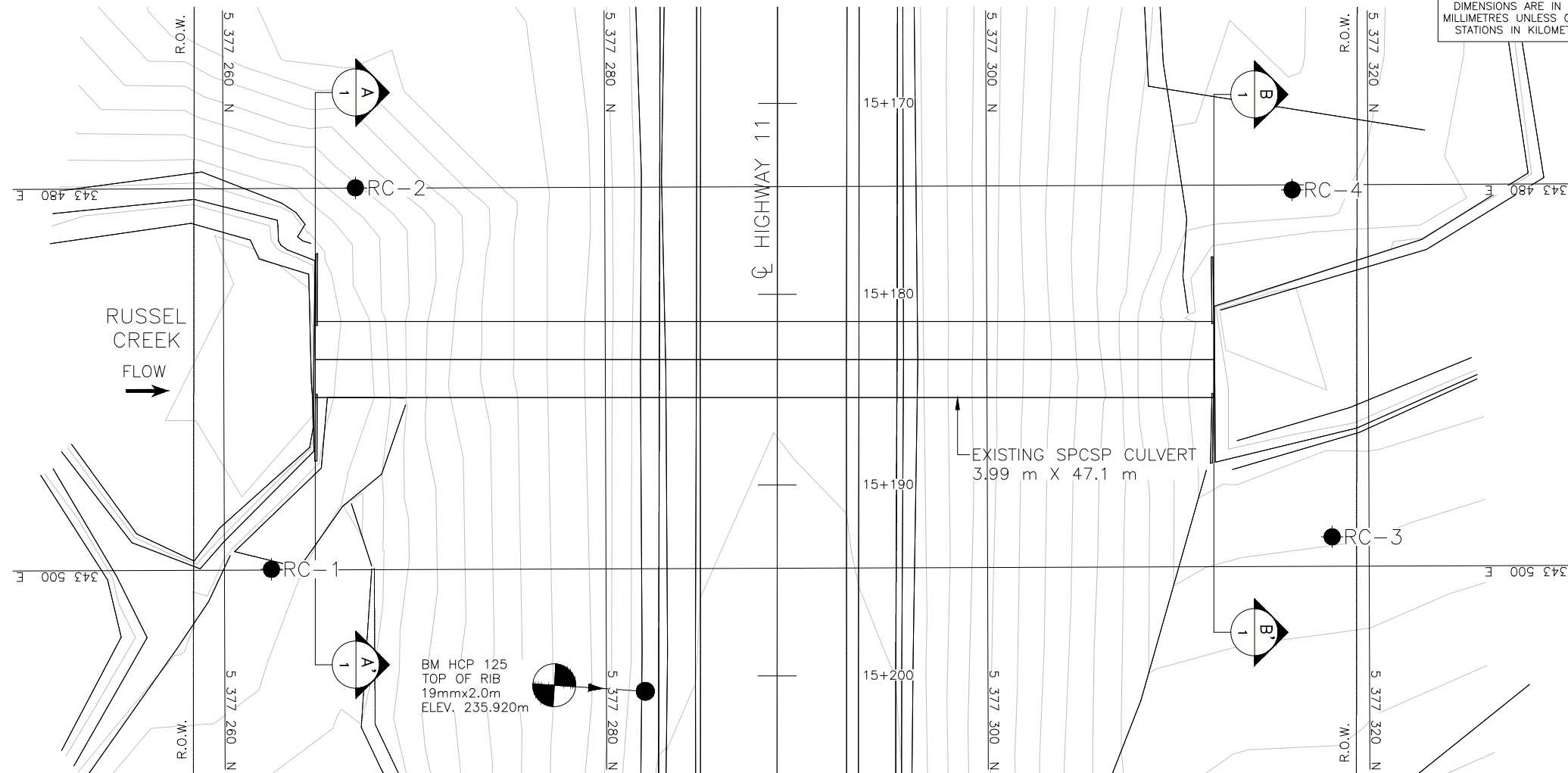
Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ANE

ASTM International:

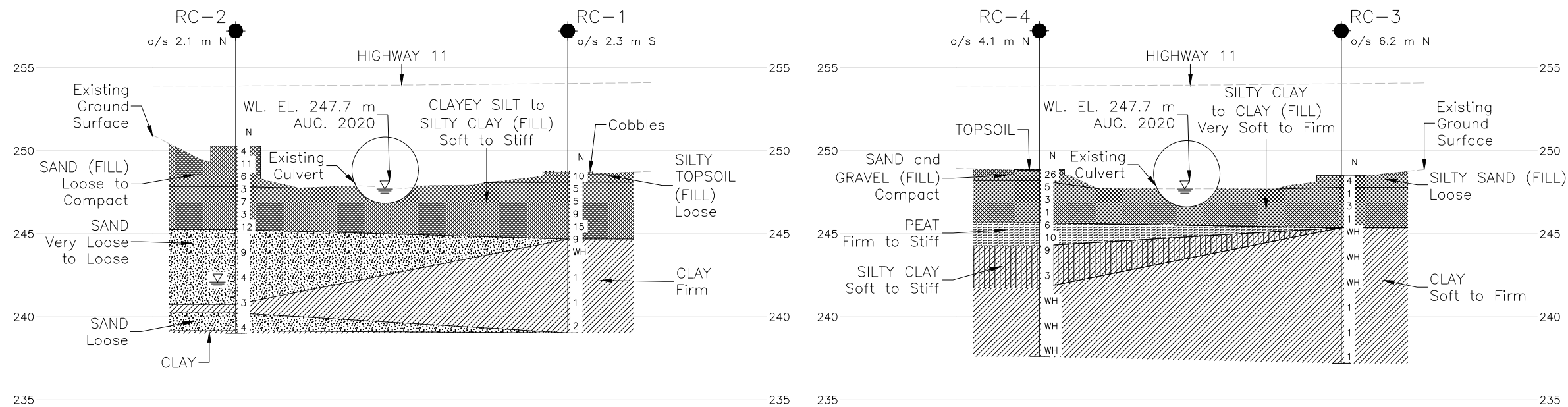
ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587	Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
ASTM D2573	Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

Ontario Water Resource Act

Ontario Regulation 903/90	Wells: O.Reg. 468/10 Amendment to Ontario Regulation 903
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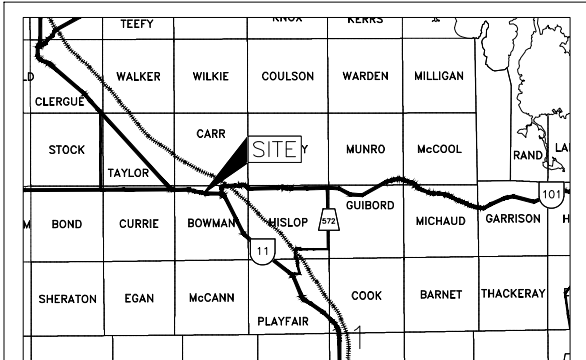


PLAN



A-A CROSS SECTION

B-B CROSS SECTION

CONT No.
GWP No. 5070-20-00HIGHWAY 11
RUSSEL CREEK CULVERT REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATAKEY 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



BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
RC-1	248.8	5377262.5	343500.0
RC-2	250.3	5377266.9	343480.0
RC-3	248.5	5377318.1	343498.5
RC-4	248.9	5377316.0	343480.3

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 LTD., drawing file no. GWP 5217-13-00 HWY 11.dwg, received OCTOBER 15, 2020.

NO.	DATE	BY	REVISION

Geocres No. 42A-147		PROJECT NO. 19126505		DIST.	
HWY. 11		CHKD. TB		DATE: 10/05/2023	
SUBM'D.		CHKD. AB		SITE: 39E-210/C	
DRAWN: TR		APPD. KJB		DWG. 1	



Photograph 1: Looking east (June 2020).



Photograph 2: Existing SPCSP Culvert (June 2020).



Photograph 3: Existing SPCSP culvert and south embankment, looking west (June 2020).



Photograph 4: Existing SPCSP culvert and north embankment, looking north west (June 2020).

APPENDIX A

Record of Boreholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

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

GRADATIONAL COMPONENT TERMS

% (by mass)	Term
≤ 5	Use "trace"
> 5 to ≤ 12	Use "few"
> 12 to <30	Use "little"
≥ 30 to <50	Use "some"
≥ 50	Use "mostly"

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 frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); Nd:

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, pushed tube sampler, or geoprobe macro-core – note size
DS	Denison type sample
FS	Foil Sample
GS	Grab Sample
MC	Modified California Samples – note sample diameter and hammer weight
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split-spoon sampler (50 mm OD); larger sizes use MC
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

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)
γ	unit weight

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

NON-COHESIVE (COHESIONLESS) SOILS

Compactness²

Term	SPT 'N' (blows/0.3m) ¹
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in general accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

2. 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.

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.

COHESIVE 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 general 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.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

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

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	nonplastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
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	$(\sigma_1 - \sigma_3)/2$ 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 $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)



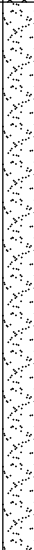

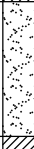

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

PROJECT		19126505				RECORD OF BOREHOLE No. RC-1				1 OF 1 METRIC							
G.W.P.		5070-20-00		LOCATION		N 5377262.5; E 343500.0 NAD83 MTM ZONE 12 (LAT. 48.532765; LONG. -80.475942)				ORIGINATED BY		TB					
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Hollow Stem Augers				COMPILED BY		TR					
DATUM		GEODETIC		DATE		June 8, 2020				CHECKED BY		AB					
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									
248.8	GROUND SURFACE																
0.0	Cobbles on surface																
0.1	SILTY TOPSOIL, trace gravel, trace clay, trace rootlets (FILL)		1	SS	10												
248.1	Loose Brown Moist to wet																
0.7	CLAYEY SILT (CL), trace gravel, trace sand, trace organics (FILL)		2	SS	5												
	Firm Brown Wet																
			3	SS	5												
246.6																	
2.2	SILTY CLAY (CI) (FILL)																
	Stiff Brown to grey Wet		4	SS	9												
	- Trace peat encountered in Sample No. 5.		5	SS	15												
			6A	SS	9												
244.7																	
4.1	CLAY (CH)		6B	SS	9												
	Firm Grey Wet																
	- Silt pockets, seams, layers and laminations encountered throughout deposit.		7	SS	WH												
			8	SS	1												
			9	SS	1												
			10	SS	2												
239.0																	
9.8	NOTES:																
	1. Borehole dry upon completion of drilling.																

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PROJECT		19126505		RECORD OF BOREHOLE No. RC-2				1 OF 2 METRIC						
G.W.P.		5070-20-00		LOCATION				N 5377266.9; E 343480.0 NAD83 MTM ZONE 12 (LAT. 48.532805; LONG. -80.476213)						
DIST		HWY 11		BOREHOLE TYPE				108 mm I.D. Hollow Stem Augers						
DATUM		GEODETIC		DATE				June 8, 2020						
								ORIGINATED BY TB						
								COMPILED BY TR						
								CHECKED BY AB						
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						
250.3	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	SAND (SP), some gravel (FILL) Loose to compact Brown Moist - Trace organics in Sample No. 1.		1	SS	4		250							
			2	SS	11		249							
			3	SS	6		248							
247.9	SILTY CLAY (CI), peat and organic pockets (FILL) Soft to stiff Grey Moist to wet		4A	SS	3		248							
2.4			4B											
			5	SS	7		247							
			6	SS	3		246							
			7A	SS	12									
245.3	SAND (SP), some gravel Very loose to loose Grey Wet - Auger grinding at 6.1 m depth. - 0.3 m of heaving sand inside augers at 6.1 m depth. - 0.8 m of heaving sand inside augers at 6.8 m depth.		7B				245							
5.0														
			8	SS	9		244							18 81 (1)
							243							
			9	SS	4		242							
							241							
240.8	CLAY (CH) Grey Wet		10A	SS	3									
9.5			10B											
240.2	SAND (SP), trace gravel, trace silt Loose Grey Wet - 0.3 m of heaving sand inside augers at 10.4 m depth.						240							
10.1			11A	SS	4									
239.2	CLAY (CH) Grey Wet		11B											
11.3	END OF BOREHOLE													

Continued Next Page

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

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PROJECT 19126505		RECORD OF BOREHOLE No. RC-2				2 OF 2 METRIC													
G.W.P. 5070-20-00		LOCATION N 5377266.9; E 343480.0 NAD83 MTM ZONE 12 (LAT. 48.532805; LONG. -80.476213)				ORIGINATED BY TB													
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY TR													
DATUM GEODETIC		DATE June 8, 2020				CHECKED BY AB													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W			W _L		
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between; font-size: small;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between; font-size: x-small;"> ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED </div>												
	NOTE: 1. Water level measured at a depth of 8.2 m below ground surface (Elev. 242.1 m) upon completion of drilling.																		

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PROJECT 19126505		RECORD OF BOREHOLE No. RC-3		1 OF 1 METRIC	
G.W.P. 5070-20-00		LOCATION N 5377318.1; E 343498.5 NAD83 MTM ZONE 12 (LAT. 48.533265; LONG. -80.475957)		ORIGINATED BY TB	
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers		COMPILED BY TR	
DATUM GEODETIC		DATE June 9, 2020		CHECKED BY AB	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	20	40	60	80	100	w _p	w		w _L			
248.5	GROUND SURFACE																			
0.0	SILTY SAND (SM), trace organics (FILL) Loose Brown Moist to wet		1	SS	4															
247.8																				
0.7	SILTY CLAY (CI), trace gravel, trace sand (FILL) Very soft to soft Brown to grey Moist		2	SS	1															
			3	SS	3															
	- Peat pockets in Sample No. 4.		4	SS	1															
245.4																				
3.1	CLAY (CH) Soft to firm Grey Wet		5	SS	WH															
	- Silt laminations encountered throughout deposit.																			
			6	SS	WH															
			7	SS	WH															
			8	SS	1															
			9	SS	1															
			</																	

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

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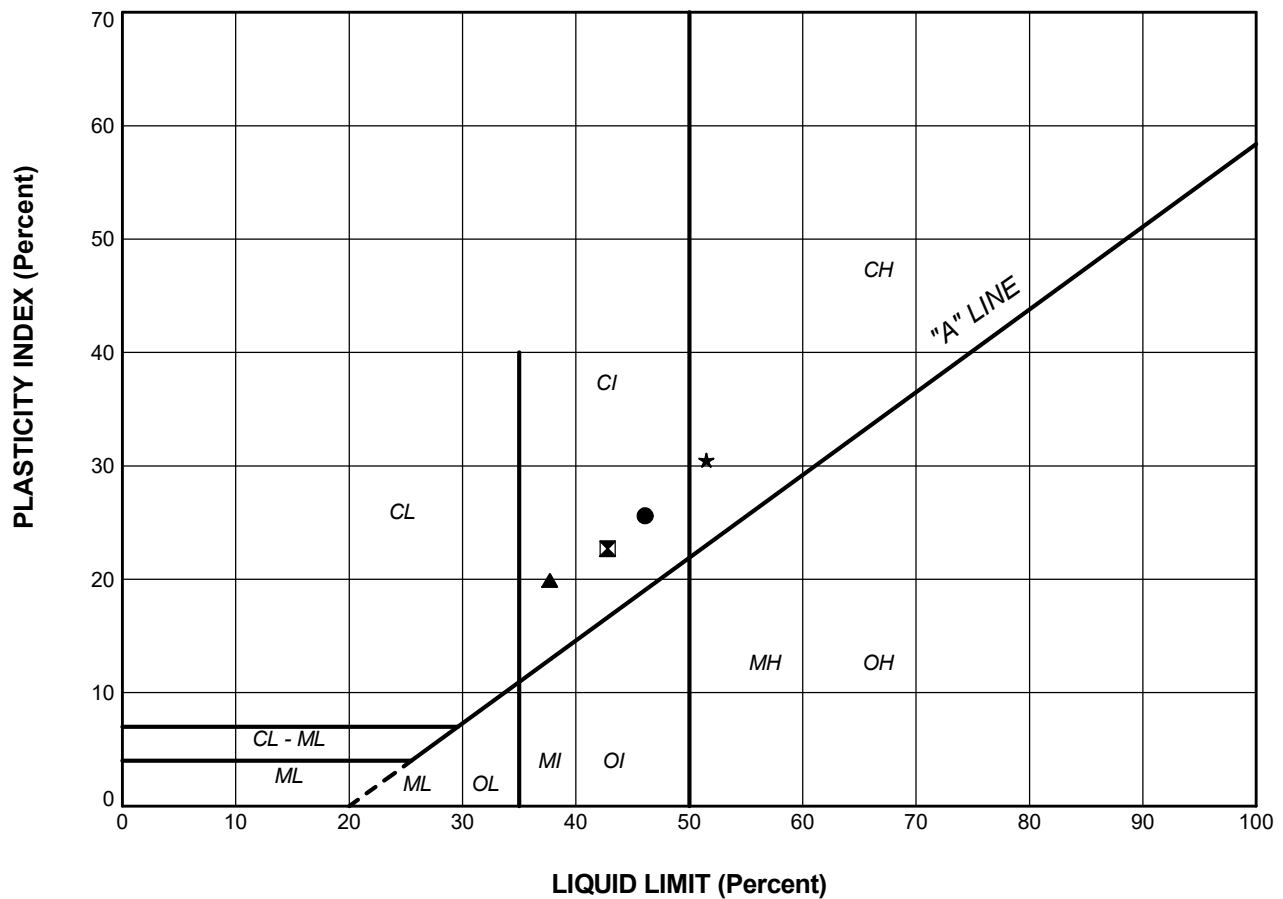
PROJECT 19126505		RECORD OF BOREHOLE No. RC-4				1 OF 1 METRIC							
G.W.P. 5070-20-00		LOCATION N 5377316.0; E 343480.3 NAD83 MTM ZONE 12 (LAT. 48.533247; LONG. -80.476204)				ORIGINATED BY TB							
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY TR							
DATUM GEODETIC		DATE June 9, 2020				CHECKED BY AB							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
248.9	GROUND SURFACE												
0.0	TOPSOIL (80 mm)		1	SS	26								
248.2	SAND (SP) and gravel (FILL) Compact Brown Moist												
0.7	- Auger grinding from 0.3 m to 0.5 m depth.		2	SS	5								
	CLAY (CH), trace silt, trace organics (FILL) Very soft to firm Brown to grey Moist to wet		3	SS	3								
	- Silt pockets encountered in Sample No. 4.		4	SS	1								
245.7			5A										
3.2	PEAT (PT), with wood fragments Firm to stiff Black Moist		5B	SS	6								
			6	SS	10								
244.3													
4.6	SILTY CLAY (CI) Soft to stiff Brown to grey Moist to wet		7	SS	9								
	- Silt pockets encountered in Sample No. 8.		8	SS	3								
241.7													
7.2	CLAY (CH) Soft to firm Grey Wet		9	SS	WH								
	- Silt pockets, seams, layers and laminations encountered throughout deposit.												
			10	SS	WH								
			11	SS	WH								
237.6													
11.3	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.												

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


APPENDIX B

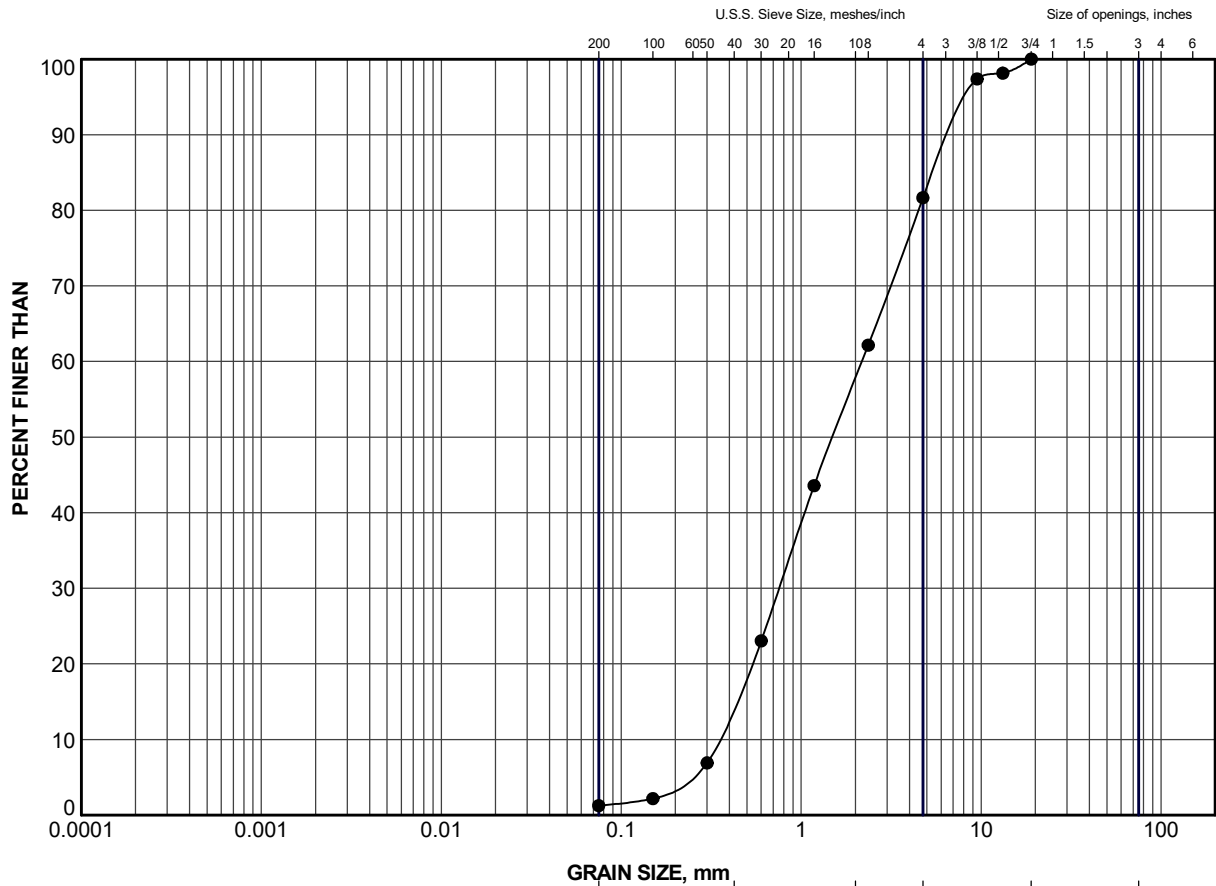
Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	RC-1	4	46.1	20.5	25.6
⊠	RC-2	5	42.8	20.1	22.7
▲	RC-3	4	37.7	17.8	19.9
★	RC-4	3	51.5	21.0	30.5


PROJECT					HIGHWAY 11 RUSSEL CREEK CULVERT REHABILITATION				
TITLE					PLASTICITY CHART SILTY CLAY (CI) to CLAY (CH) (FILL)				
PROJECT No.			19126505		FILE No.			19126505.GPJ	
DRAWN	TR	Feb 2021		SCALE	N/A		REV.		
CHECK	AB	Feb 2021		FIGURE B-1					
APPR		Feb 2021							
 GOLDER SUDBURY, ONTARIO									

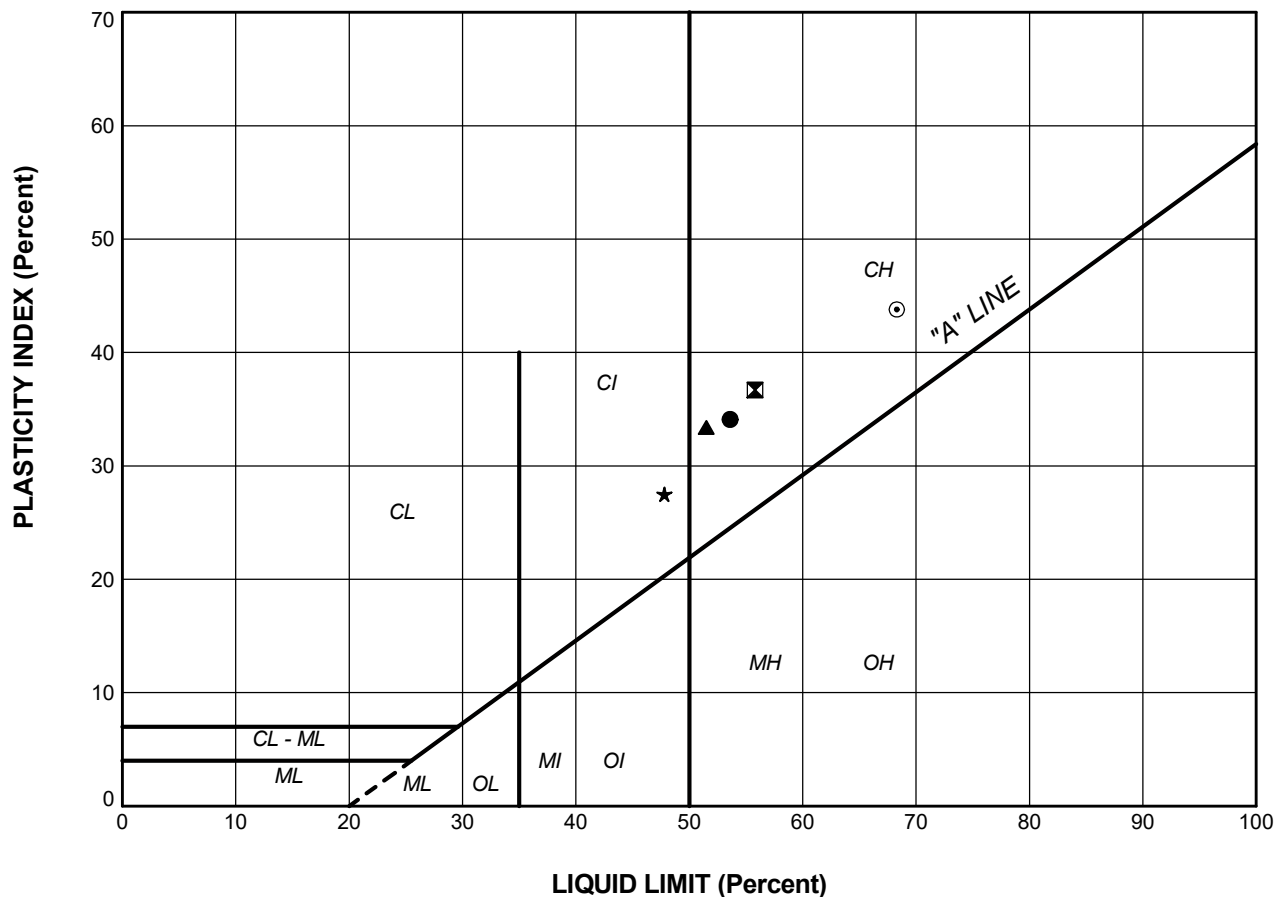


CLAY AND SILT	GRAIN SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
SAND SIZE				GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	RC-2	8	243.9

PROJECT						HIGHWAY 11 RUSSEL CREEK CULVERT REHABILITATION					
TITLE						GRAIN SIZE DISTRIBUTION SAND (SP)					
PROJECT No.			19126505			FILE No.			19126505.GPJ		
DRAWN	TR	Feb 2021	SCALE	N/A	REV.	FIGURE B-2					
CHECK	AB	Feb 2021									
APPR		Feb 2021									
 GOLDER SUDBURY, ONTARIO											



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	RC-1	7	53.6	19.5	34.1
⊠	RC-1	9	55.8	19.1	36.7
▲	RC-3	8	51.5	18.1	33.4
★	RC-4	7	47.8	20.3	27.5
⊙	RC-4	10	68.3	24.5	43.8

PROJECT				
HIGHWAY 11 RUSSEL CREEK CULVERT REHABILITATION				
TITLE				
PLASTICITY CHART SILTY CLAY (CI) to CLAY (CH)				
PROJECT No.		19126505		FILE No.
DRAWN		TR	Feb 2021	SCALE N/A
CHECK		AB	Feb 2021	REV.
APPR		Feb 2021		FIGURE B-3



GOLDER

SUDBURY, ONTARIO



BV Labs Job #: COE8089
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.							



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