January 10, 2019

FOUNDATION INVESTIGATION AND DESIGN REPORT

STRUCTURAL BUNDLE - 11 STRUCTURES ON HIGHWAYS 129, 532 AND 556
HIGHWAY 556 - BEAVER FALLS CULVERT REHABILITATION, 19.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0037/C0)
DEROCHE TOWNSHIP, ALGOMA DISTRICT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5378-11-00; WP 5378-11-01

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REPORT

Golder Associates

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FOUNDATION INVESTIGATION REPORT
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HIGHWAY 556 – BEAVER FALLS CULVERT REHABILITATION, 19.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0037/C0)
DEROCHE TOWNSHIP, ALGOMA DISTRICT, ONTARIO
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GWP 5378-11-00; WP 5378-11-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services to aid in the design of temporary cofferdam systems for the rehabilitation of the Beaver Falls Culvert on Northland Creek where is crosses Highway 556 (Site No. 38S-0037/C0) in Deroche Township, Algoma District, Ontario.

The purpose of the field investigation is to establish the subsurface conditions near the inlet of the existing culvert by methods of borehole drilling, rock coring, in-situ testing and laboratory testing on selected soil samples, where possible.

This report summarizes the factual results of the field and laboratory work (including field investigation procedures, borehole stratigraphy, bedrock lithology, and geotechnical laboratory test results) as well as a description of the interpreted soil, bedrock and groundwater conditions at the Northland Creek site.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal dated May 2016 (Agreement No. 5016E0029) as well as in the change request letter dated April 24, 2018 which was approved by MTO on June 11, 2018 (Change Order No. CO5016E0029001). Golder's proposal for foundation engineering services is contained in Section 17.8 of AECOM's Technical Proposal for this assignment.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

The existing culvert at the site conveys the Northland Creek under Highway 556 in a generally south to north direction close to Beaver Falls which is located approximately 100 m south of the highway in the vicinity of the existing culvert. The culvert was constructed in 1974 and there is no history of the culvert having undergone rehabilitation works since that time.

It is understood that a structural assessment of the existing culvert was carried out in 2015 at which time the culvert was identified as being in fair structural condition with minor deterioration of several elements, and more significant deterioration of the culvert inlet components and structural steel coatings. Deterioration of the concrete apron at the inlet and undermining of the outlet of the culvert over a 3.0 m span length was also noted. It is our understanding that the existing culvert is expected to be rehabilitated by lining the lower portion of the barrel of the existing culvert. An approximately 1.2 m deep cast-in-place concrete cut off wall is also expected to be constructed below the culvert at the outlet and any voids near the cut off wall are expected to be filled with mass concrete.

2.2 Site Description

The site of the proposed culvert rehabilitation is located about 19.9 km east of Highway 17 on Highway 556 in Deroche Township, Algoma District, Ontario, at approximately Station 19+016.

The existing Beaver Falls Culvert consists of a single cell Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with a span of about 5 m and measuring 30.5 m in length. There is about 4.5 m of fill above the obvert of the culvert in the vicinity of the travelled portion of the highway. The invert of the inlet and outlet of the existing culvert is at approximately Elevation 208.15 m and Elevation 207.57 m, respectively. The inlet of the culvert is shown on Photographs 1 to 3 which are presented on Figure 1; the outlet of culvert is shown on Photographs 4 to 6 which are presented on Figure 2.

Existing concrete retaining walls extend southerly from the inlet end of the existing culvert. The existing retaining walls are about 4.5 m and 6 m long at the west and east sides of the culvert, respectively. The walls vary in height from about 1.1 m immediately at the edge of the inlet to about 0.9 m at the ends furthest away from the culvert. The walls appeared to be in relatively poor to fair structural condition with signs of deterioration, cracking, and undermining at the base of the walls. The concrete retaining walls are shown on Photographs 7 and 8 which are presented on Figure 3. A close-up of the base of the retaining wall and concrete apron on the east side of the culvert inlet is shown on Photograph 9 presented on Figure 4.

The Northland Creek at the location of the existing culvert flows in a generally south to north direction. The creek in the immediate vicinity of the inlet and outlet is about 6.5 m and 5 m wide, respectively, but is much narrower further upstream and downstream. For example, about 5 m north of the outlet of the culvert, the creek is only 0.6 m wide. The downstream end of Northland Creek flows into the Goulais River about 415 m north of Highway 556.

Highway 556 at the location of the culvert consists of an approximately 8 m high embankment that carries one lane of traffic in each direction. The travelled portion of the highway consists of an asphalt surface which is super-elevated at this location and varies between approximately Elevation 215.5 m and Elevation 216.0 m in the vicinity of the existing culvert.

Roadway entrances to residential properties are located on the north side of Highway 556, about 85 m west and east of the culvert. There is an entrance on the south side of Highway 556 as well, about 35 m east of the existing culvert; however, at the time of this investigation, the property appeared to be abandoned. Overhead electrical transmission lines run along the highway on the south side of Highway 556.

In general, the topography in the area of the culvert is relatively rugged and is interspersed with bedrock outcrops. Vegetation cover is dense and is comprised predominantly of deciduous and coniferous trees.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

The fieldwork at the Beaver Falls Culvert site was carried out on August 18 and 19, 2018, during which time one borehole (designated as Borehole BFC-01) was advanced near the inlet of the culvert through the existing concrete apron. Given the presence of bedrock outcrops near the outlet of the existing culvert, a borehole was not advanced near the outlet (as approved by MTO).

The subsurface soil and bedrock conditions encountered in the borehole are shown in detail on the Record of Borehole and Drillhole in Appendix A. Lists of abbreviations and symbols and a description of lithological and geotechnical rock terminology are also provided in Appendix A to assist in the interpretation of the borehole and drillhole records. The location of the as-drilled borehole is shown in plan on Drawing 1.

The borehole was advanced using portable tripod drilling equipment supplied and operated by Ohlmann Geotechnical Services (OGS) Drilling Inc. of Almonte, Ontario. The portable equipment was set up on the existing concrete apron next to the retaining wall. The borehole was advanced using ‘BW’ casing with wash boring and coring techniques, as required to penetrate through the apron and cobbles and boulders. Soil sample(s) were obtained using a 50 mm outer diameter split-spoon sampler driven by a manual 22.7 kg (50 lb) hammer, where possible, in general accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*).

The borehole was advanced through the existing concrete apron to a depth of 5.5 m. The borehole depth included 3.2 m of rock coring. Upon completion of drilling the borehole was backfilled with bentonite in accordance with Ontario Regulation 903 (*Wells*) (as amended), and capped with concrete.

Prior to commencement of the fieldwork, Golder arranged for the clearance of underground utilities/services. The field work was observed on a full-time basis by a member of Golder's engineering staff who monitored the drilling and sampling operations and logged the borehole in the field. The soil and rock core samples were transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual/tactile examination and geotechnical laboratory testing.

Geotechnical index testing comprised of a water content test was carried out on the recovered soil sample. Grain size distribution analysis (i.e., sieves and hydrometers) and Atterberg limits tests were not carried out due to the cobbley/bouldery nature of the subsurface conditions and low sample recovery. The result of the water content test is summarized on the borehole record in Appendix A. The water content test was carried out in accordance with MTO's Laboratory Standard.

A temporary benchmark was established and surveyed near the inlet of the existing culvert by Callon Dietz Inc. prior to the drilling crew mobilizing to site. Upon completion of drilling, the borehole offsets and corresponding ground surface elevation changes were recorded and tied-in to the surveyed benchmark location to determine the as-drilled borehole location and ground surface elevation. The borehole survey information, including northing and easting coordinates (presented in the MTM NAD83 Zone 13 and latitude / longitude coordinate systems) and the ground surface elevation referenced to Geodetic datum, are provided on the borehole record in Appendix A, presented on Drawing 1, and summarized below.

Borehole No.	Approximate Location	Coordinates (MTM NAD83 Zone 13)		Ground Surface Elevation	Borehole Depth
		Northing (Latitude)	Easting (Longitude)		
BFC-01	Inlet – South side of Highway 556 embankment	5177726.5 m (46.739040°)	294569.4 m (-84.133882°)	208.4 m	5.5 m [1]

Note:
1. The borehole depth includes 3.2 m of rock coring.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)[1] mapping, the Beaver Falls Culvert site is located near the boundary between an outwash plain, valley train consisting primarily of sandy and gravelly soils, and bedrock knobs/outcrops. The overall area is generally described as undulating to rolling with areas of low relief where watercourses and lakes have formed.

[1] Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

Based on geological mapping developed by the Ontario Ministry of Northern Development and Mines (MNDM)[2], the site is underlain by strong bedrock consisting of foliated to gneissic tonalite to granodiorite.

4.2 Overview of Local Soil and Bedrock Conditions

The subsurface soil and bedrock conditions encountered in the borehole advanced at this site, together with the results of the in-situ and geotechnical laboratory testing, are presented on the Record of Borehole and Drillhole (provided in Appendix A). The results of the in-situ field tests (i.e., SPT 'N'-values) as presented on the borehole record are uncorrected and are based on sampling procedures carried out with a manual hammer.

The stratigraphic boundaries shown on the borehole record and on the interpreted soil/rock strata profile (i.e., Drawing 1) are inferred from observations of drilling progress, non-continuous sampling, and in-situ testing and therefore, represent transitions between soil and rock types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole location.

In general, the subsurface conditions encountered near the inlet of the Beaver Falls Culvert site consist of an existing concrete apron, underlain by a deposit of cobbles and boulders which in turn is underlain by a thin layer of sandy gravelly silt. The granular layer is underlain by bedrock. Bedrock outcrops are present throughout the site in the vicinity of the culvert; in particular, bedrock outcrops are present very close to the culvert outlet as shown on Photographs 10 and 11 as presented on Figure 5.

Detailed descriptions of the subsurface conditions encountered in the borehole advanced at this site are provided in the following subsections.

4.2.1 Concrete

An approximately 300 mm thick layer of concrete was encountered at the surface of Borehole BFC-01 which was advanced through a concrete apron at the inlet of the culvert. The top of the concrete slab is at about Elevation 208.4 m. The top of the concrete apron was in poor to fair structural condition and is shown on Photograph 9 which is presented on Figure 4.

4.2.2 Cobbles and Boulders

A deposit of cobbles and boulders was encountered immediately below the concrete slab at approximately Elevation 208.1 m. The cobbley/bouldery deposit was penetrated using rock coring methods and is approximately 1.9 m thick. It is expected that any coarse-grained and fine-grained particles making up the soil matrix between the cobbles and boulders may have been washed away during advancement of the drill casing using flush water. The recovered cobbles are up to about 120 mm in size and are shown on Figure B1 in Appendix B. Although the recovered rock core samples do not indicate the presence of boulders (i.e., all measured rock core samples are less than 200 mm in size), boulders are inferred to make up this deposit given the presence of large boulders found at the creek bed (refer to Photographs 2 and 3 which are presented on Figure 1 and Photographs 7 and 8 which are presented on Figure 3).

[2] Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.

4.2.3 Sandy Gravelly Silt

An approximately 0.1 m thick layer of sandy gravelly silt, trace clay was encountered below the cobbles and boulders layer at a depth of about 2.2 m below the top of the existing concrete apron, corresponding to approximately Elevation 206.2 m.

A SPT 'N'-value measured within this granular layer is 11 blows per 0.15 m of penetration, suggesting a compact state of compactness. The split-spoon sampler was terminated on top of bedrock.

The water content measured on a sample of the sandy gravelly silt is about 15%. Other geotechnical laboratory index testing was not carried out on this granular layer due to low sample recovery.

4.2.4 Granite Bedrock

Bedrock was encountered immediately below the layer of sandy gravelly silt. The bedrock was encountered at a depth of about 2.3 m below the top of the existing concrete apron, corresponding to Elevation 206.1 m, and was cored for a total length of 3.2 m.

Based on a review of the cored bedrock samples, the bedrock consists of granite rock. The bedrock is described as slightly weathered to fresh, massive, pink, medium to coarse grained, faintly porous, strong to very strong granite. The bedrock details are presented on the drillhole record in Appendix A. Bedrock core photographs are shown on Figure B1 in Appendix B.

The Total Core Recovery (TCR) measured on the rock core samples ranges between about 80% and 100%, and the Solid Core Recovery (SCR) ranges between about 22% and 81%. The Rock Quality Designation (RQD) measured on the rock core samples generally ranges from about 52% to 100%, indicating a rock mass of fair to excellent quality as per Table 3.10 of CFEM (2006). A RQD of 0% was measured on Run No. 2 between depths of about 2.90 m and 3.49 m below the top of the existing concrete apron, indicating a rock mass of very poor quality. The very low RQD is attributed to frequent broken core zones.

It is noted that bedrock outcrops were observed near the outlet of the existing culvert and are shown on Photographs 10 and 11 presented on Figure 5, but are also present upstream of the culvert inlet as shown on Photograph 1 on Figure 1.

4.3 Groundwater Conditions

The groundwater level was measured at the top of the existing concrete apron, corresponding to Elevation 208.4 m, in Borehole BFC-01.

Given the presence of Northland Creek and the granular (i.e., non-cohesive) deposits encountered at the site, the groundwater level is anticipated to be coincident with the water level in the creek. The water level in the creek was measured at approximately Elevation 208.3 m in June 2017.

The water level in the creek and the degree of saturation of the embankment fill is subject to seasonal fluctuations and precipitation events and are expected to be higher during wet seasons and sustained periods of precipitation.

5.0 CLOSURE

This report was prepared by Ms. Manisha Ahuja, P.Eng., P.E. (OH) and reviewed by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer at Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.

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https://golderassociates.sharepoint.com/sites/14262g/deliverables/04-final fidr/beaver falls culvert/1670846-13-rpt-rev0-beaver falls culverts fidr-20190110.docx

PART B

FOUNDATION DESIGN REPORT
STRUCTURAL BUNDLE – 11 STRUCTURES ON HIGHWAYS 129, 532 AND 556
HIGHWAY 556 – BEAVER FALLS CULVERT REHABILITATION, 19.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0037/C0)
DEROCHE TOWNSHIP, ALGOMA DISTRICT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5378-11-00; WP 5378-11-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the support of the rehabilitation of the Beaver Falls Culvert under Highway 556 (Site No. 38S-0037/C0). These recommendations are based on interpretation of the factual data obtained from the borehole advanced during the field investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess feasible temporary protection systems and dewatering alternatives that may be required as part of the culvert rehabilitation. The foundation investigation report, discussion and recommendations are intended for the use of MTO and its designers and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor.

Contractors must make their own interpretation based on the factual data presented in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, and scheduling.

6.1 General

The existing Beaver Falls culvert consists of a single cell Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with a span of about 5 m and measuring 30.5 m in length. There is about 4.5 m of fill above the obvert of the culvert in the vicinity of the travelled portion of the highway. The invert of the inlet and outlet of the existing culvert is at approximately Elevation 208.15 m and Elevation 207.57 m, respectively. The inlet of the culvert is shown on Photographs 1 to 3 which are presented on Figure 1; the outlet of culvert is shown on Photographs 4 to 6 which are presented on Figure 2.

Existing concrete retaining walls extend southerly from the inlet end of the existing culvert. The existing retaining walls are about 4.5 m and 6 m long at the west and east side of the culvert, respectively. The walls vary in height from about 1.1 m immediately at the edge of the inlet to about 0.9 m at the end furthest away from the culvert. The walls appeared to be in relatively poor to fair structural condition with signs of deterioration, cracking, and undermining of the base of the walls. The walls are shown on Photographs 7 and 8 which are presented on Figure 3 and the east wall and concrete apron is shown on Photograph 9 on Figure 4.

It is understood that the existing SPCSPA culvert will be rehabilitated. The rehabilitation work is to include lining the base and the sides of the barrel of the culvert with a cast-in-place concrete liner. An approximately 1.2 m deep cast-in-place concrete cut off wall is also expected to be constructed below the culvert at the outlet and any voids near the cut off wall are expected to be filled with mass concrete. It is our understanding that the rehabilitation will not involve the repair or replacement of the existing concrete apron or retaining walls.

It is further understood that the rehabilitation works will not involve platform widening of the existing Highway 556 embankment in the vicinity of the Northland Creek and there will be no raising of the existing highway grade.

6.2 Temporary Cofferdam Systems

Temporary cofferdams near the inlet and outlet of the culvert are required to support the rehabilitation works. Since the depth of water in the creek near the inlet and at the outlet of the culvert is relatively shallow and considering the presence of cobbles and boulders, shallow bedrock and/or bedrock outcrops, it will likely be most feasible to construct the temporary cofferdams and divert the creek water using one of the following methods:

- Small inflatable bladder cofferdams;
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers; or,
- Multiple rows of large sand bags ("super-bags" or "bulk-bags") lined with an impermeable layer (poly-material).

Given that the culvert is located at the base of an approximately 8 m high embankment and considering the relatively constrained access to the site, the use of smaller, and more modular or inflatable cofferdams is likely preferred as these systems can be maneuvered by small equipment and/or by hand. However, the viability and effectiveness of such systems will depend on the creek water level at the time of construction as well as the available space between where the diversion structure(s)/temporary cofferdams will be located relative to the existing culvert. In addition, any obstructions such as cobbles and boulders may need to be moved from the location of the cofferdam created from modular inflatable bladders, water dams, or large sand bags. However, the contractor will need to work around exposed bedrock.

The temporary cofferdams at the site should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems)* to Performance Level 3. The design of the temporary cofferdam system should include an evaluation of tolerable lateral movement, base stability and hydraulic uplift as defined in the *Canadian Foundation Engineering Manual* (CFEM, 2006). The contractor is responsible for the design and construction of the cofferdam system.

Although more robust groundwater cut-off systems are not anticipated to be required at the site, the use of such robust systems such as, interlocking steel sheet piles, would not be possible due to the presence of the cobbles and boulders and shallow bedrock/bedrock outcrops.

6.3 Obstructions

As described in Section 4.2.2, cobbles and boulders were encountered at the creek bed and underlying the existing concrete apron near the inlet of the existing culvert. Conventional construction equipment should be capable of moving and excavating through such obstructions, if required. It is recommended that a Notice to Contractor be included in the contract documents to address these obstructions as well as the presence of the bedrock outcrops (refer to Appendix C).

6.4 Control of Groundwater and Surface Water

Given that the rehabilitation work will need to be carried out in the dry, control of groundwater / creek flow will be required.

The method and extent of groundwater control required will ultimately depend on the method employed to divert the creek flow during construction and/or on the type of temporary cofferdam system selected by the contractor (described in Section 6.2) as well as on the height and flow rate of water in the creek at the time of construction. If temporary shoring is comprised of inflatable bladders, flexible tubes or sand bags (for cofferdams around the culvert inlet and outlet), the requirements for groundwater may be more extensive depending on the creek flow conditions at the time of construction. The contractor is responsible for the design and installation of all groundwater control measures giving due consideration to the type of temporary cofferdam system selected as well as the requirements for maintaining the stability/integrity of the culvert foundation. It is recommended that MTO's Special Provision 517F01 (*Temporary Flow Passage System*), which is included in Appendix C, be included in the Contract Documents.

If construction water pumping volumes are anticipated to exceed 50 m^3/day, an Environmental Activity Section Registry (EASR) will be required as per the recently introduced changes to the Environmental Protection Act by the Ontario Ministry of Environment, Conservation and Parks (MECP).

Surface water should be directed away from the work area to prevent ponding of water that could interfere with the rehabilitation work.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Manisha Ahuja, P.Eng., P.E. (OH) and reviewed by Mr. Tomasz Zalucki, P.Eng. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.

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Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA). 2014. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14. CSA Special Publication, S6.1-14.

Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central 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 Provincial Standard Specifications (OPSS), Construction:

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

Ontario Regulations:

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Special Provisions (SP):

SP 517F01 Temporary Flow Passage System

DRAWINGS

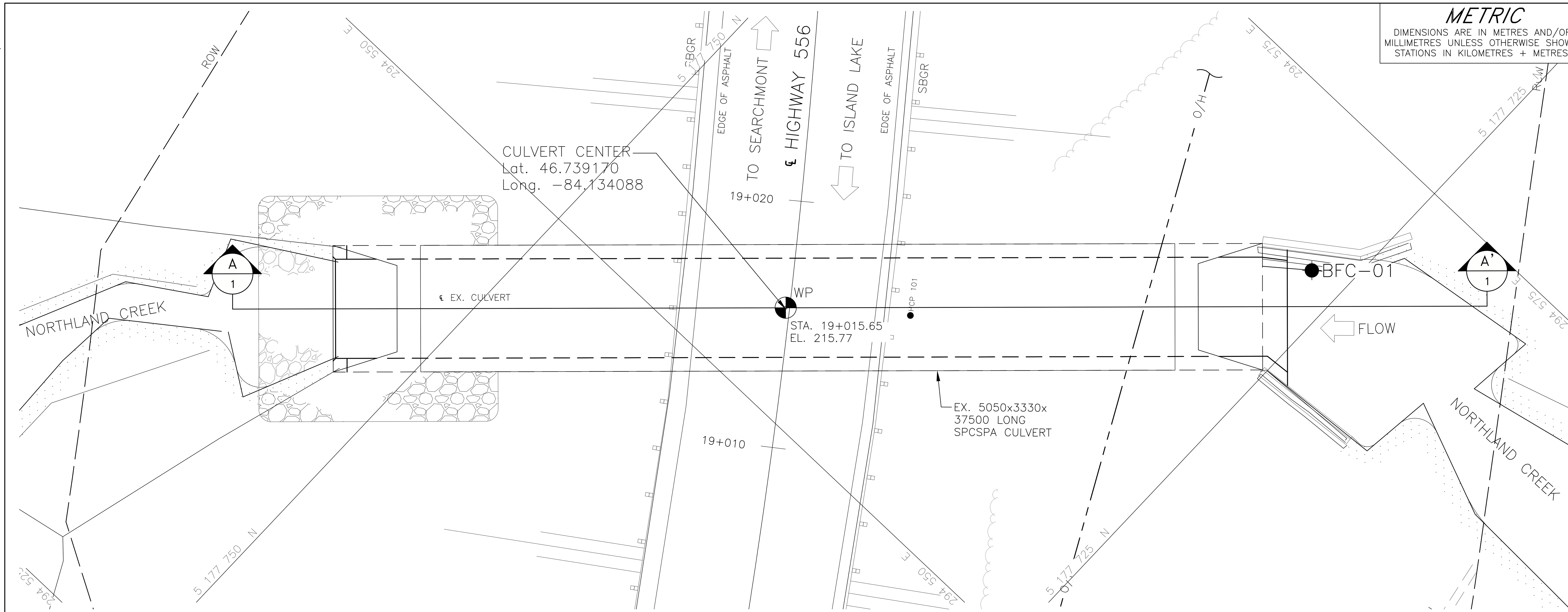
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5378–11–01

SHEET

HIGHWAY 556
BEAVER FALLS CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



PLAN
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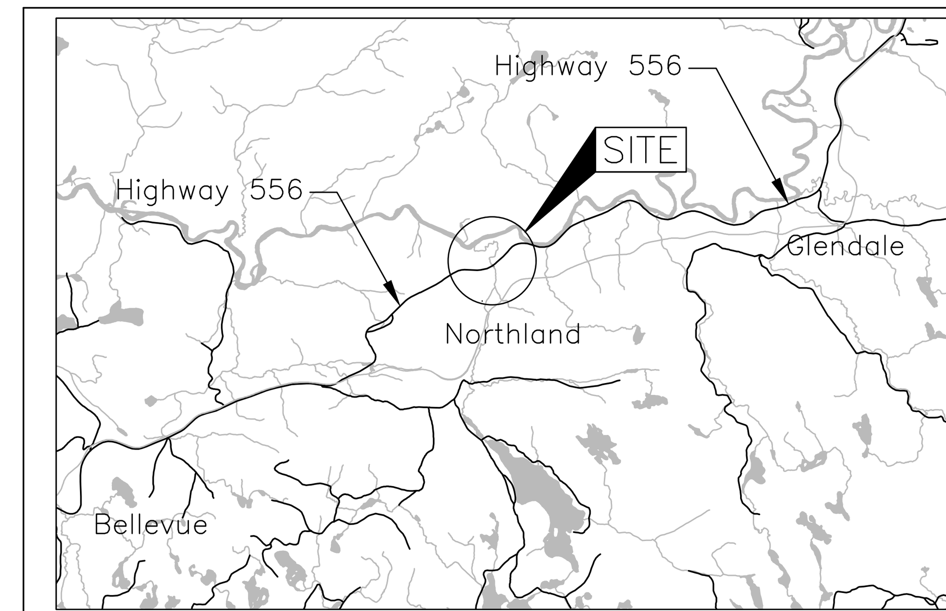
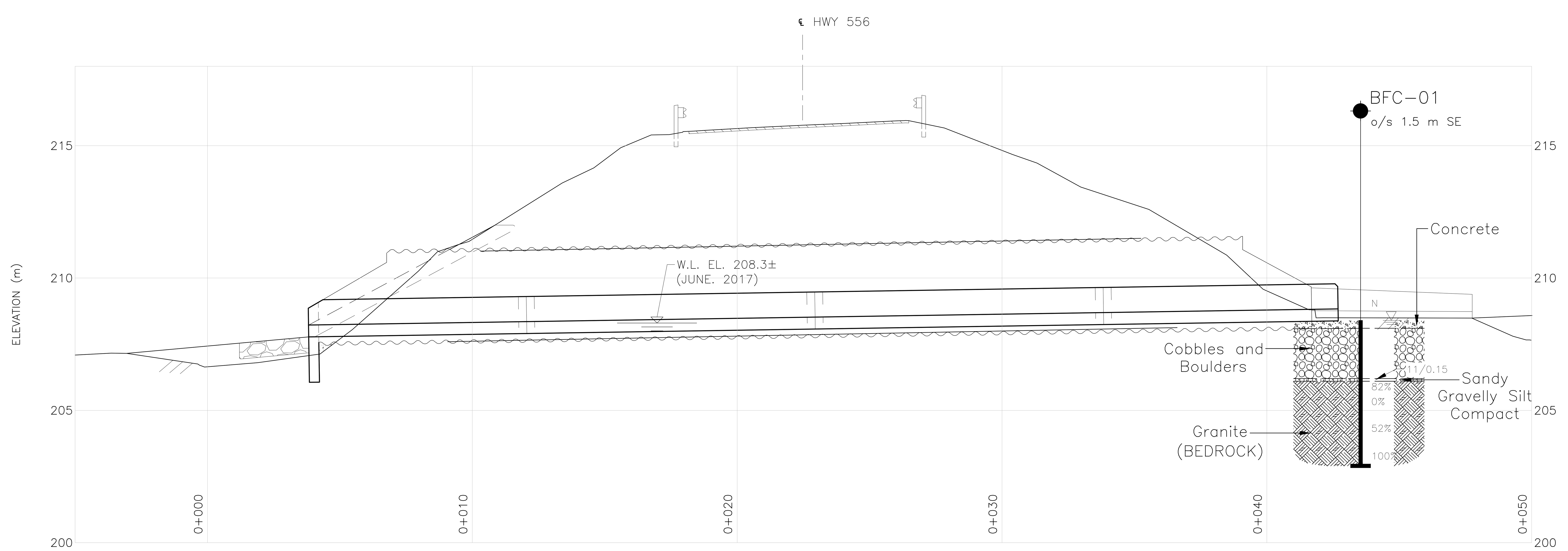


KEY PLAN
SCALE
2 0 2 4 km

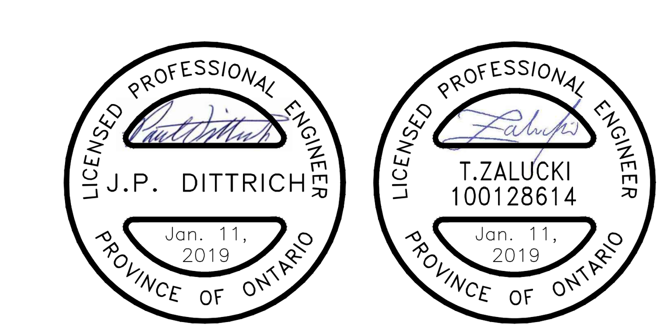
LEGEND

●	Borehole – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
⊻	WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)			
No.	ELEVATION	NORTHING	EASTING
BFC–01	208.4	5177726.5	294569.4



A–A
1
CULVERT PROFILE
SCALE
2 0 2 4 m



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 AECOM, drawing file no. 60546679–S80.dwg, received September 13, 2018.

NO.	DATE	BY	REVISION

Geocres No. 41K–112

HWY. 556	PROJECT NO. 1670846		DIST.
SUBM'D. MA	CHKD. TZ	DATE: 1/11/2019	SITE: 38S-0037/C0
DRAWN: TR	CHKD. JPD	APPD. JPD	DWG. 1

FIGURES

Highway 556 – Beaver Falls Culvert (Site No. 38S-0037/C0)
Inlet of Culvert

Figure 1

Photograph 1: Inlet of culvert (looking northwest).

Photograph 2: Inlet of culvert and (looking south through the culvert).

Photograph 3: Inlet of culvert (looking north).

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Photograph 4: Outlet of culvert (looking south).

Photograph 5: Outlet of culvert (looking south).

Photograph 6: Outlet of culvert (looking southeast).

Photograph 7: Concrete retaining wall on the east side of the culvert (looking northeast towards the inlet).

Photograph 8: Concrete retaining wall on the west side of the culvert (looking northwest towards the inlet).

Photograph 9: Existing concrete apron near the inlet of the culvert (looking down at the concrete slab near the existing retaining wall located on the east side of the culvert)

Highway 556 – Beaver Falls Culvert (Site No. 38S-0037/C0)
Bedrock Outcrops Near Outlet of Culvert

Figure 5

Photograph 10: Bedrock outcrops immediately downstream of the outlet of culvert and (looking north).

Photograph 11: Bedrock outcrops immediately downstream of the outlet of the culvert (looking east).

Date: January 10, 2019
Project No: 1670846

Golder Associates

APPENDIX A

Records of Borehole and Drillhole Sheets

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
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (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 $= (w_l - w_p)$
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 $= \sigma'_p / \sigma'_{vo}$

(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

Notes: 1 $\tau = c' + \sigma' \tan\phi'$
2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. 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.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; 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, 60º 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

Piezo-Cone Penetration Test (CPT)
A 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 (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness Condition	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils
Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
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
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	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

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, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

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 90º 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

JN	Joint	PL	Planar
FLT	Fault	CU	Curved
SH	Shear	UN	Undulating
VN	Vein	IR	Irregular
FR	Fracture	K	Slickensided
SY	Stylolite	PO	Polished
BD	Bedding	SM	Smooth
FO	Foliation	SR	Slightly Rough
CO	Contact	RO	Rough
AXJ	Axial Joint	VR	Very Rough
KV	Karstic Void		
MB	Mechanical Break		

GOLDER

RECORD OF BOREHOLE No BFC-01

SHEET 1 OF 1 **METRIC**

PROJECT 1670846			
W.P. 5378-11-01	LOCATION N 5177726.5; E 294569.4 MTM NAD 83 ZONE 13 (LAT. 46.739040; LONG. -84.133882)	ORIGINATED BY MB
DIST ALGOMA HWY 556	BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing; Rock Coring	COMPILED BY MA
DATUM Geodetic	DATE August 19, 2018	CHECKED BY TZ

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.4	GROUND SURFACE					
0.0 / 208.1	CONCRETE (300 mm)					
0.3	COBBLES and BOULDERS	-	RC	-		
			RC	-		
206.2 / 2.3	Sandy Gravelly SILT, trace clay Compact Grey Wet	1	SS	11/0.15	○ (approx. 15)	
	SPLIT-SPOON REFUSAL GRANITE (BEDROCK) Bedrock cored between depths of about 2.3 m to 5.5 m. For bedrock coring details refer to Record of Drillhole BFC-01.	1	RC	REC 100%		RQD = 82%
		2	RC	REC 100%		RQD = 0%
		3	RC	REC 80%		RQD = 52%
		4	RC	REC 100%		RQD = 100%
202.9 / 5.5	END OF BOREHOLE					

Elevation scale: 208, 207, 206, 205, 204, 203

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

NOTES:

1. Borehole BFC-01 advanced in Northland Creek through a concrete apron near the inlet (south-east side of Highway 556) of the existing culvert.

2. Sample No. 1 was collected with a split-spoon sampler driven by a 50 lb manual hammer, The SPT 'N'-value shown here has been adjusted to reflect a value that would have been obtained with a standard (i.e., 140 lb) hammer.

3. Water level measured at the top of the concrete apron upon completion of drilling.

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

PROJECT: 1670846

RECORD OF DRILLHOLE: BFC-01

SHEET 1 OF 1

LOCATION: N 5177726.5 ;E 294569.4

DRILLING DATE: August 19, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Equipment - Hilti Drill

DRILLING CONTRACTOR: OGS Inc.

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate; BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage; PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular; PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break; BR - Broken Rock. NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE	206.06					
	BW; Hilti Drill Rock Coring; 57 mm Outer Diameter Thinwall Rock Bit	Slightly weathered to fresh, massive, pink, medium to coarse grained, faintly porous, strong to very strong GRANITE	2.34	1	FR,IR,RO	3	1	
3				2	FR,PL,RO	1.3	1	
4				3	FR,PL,SM	1	1	
					FR,CU,SM	2	1	
					FR,IR,RO	3	1	
					FR,PL,SM	2	1	
					FR,PL,SM	1	1	
					FR,CU,SM	2	1	
					FR,IR,RO	3	1	
					FR,CU,RO	3	1	
5				4	FR,CU,RO	3	1	
			202.90					
		END OF DRILLHOLE	5.50					
6								
7								
8								
9								
10								
11								

Other columns: SYMBOLIC LOG; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25 m; B Angle; DIP w.r.t. CORE AXIS; ROCK STRENGTH INDEX (R4 R3 R2 R1); WEATHERING INDEX (W1 W2 W3 W4 W5 W6); FEATURES; R0/R1 ZONES.

FEATURES LEGEND

BROKEN CORE — CLAY SEAM — LIMESTONE — LOST CORE

DEPTH SCALE

1 : 50

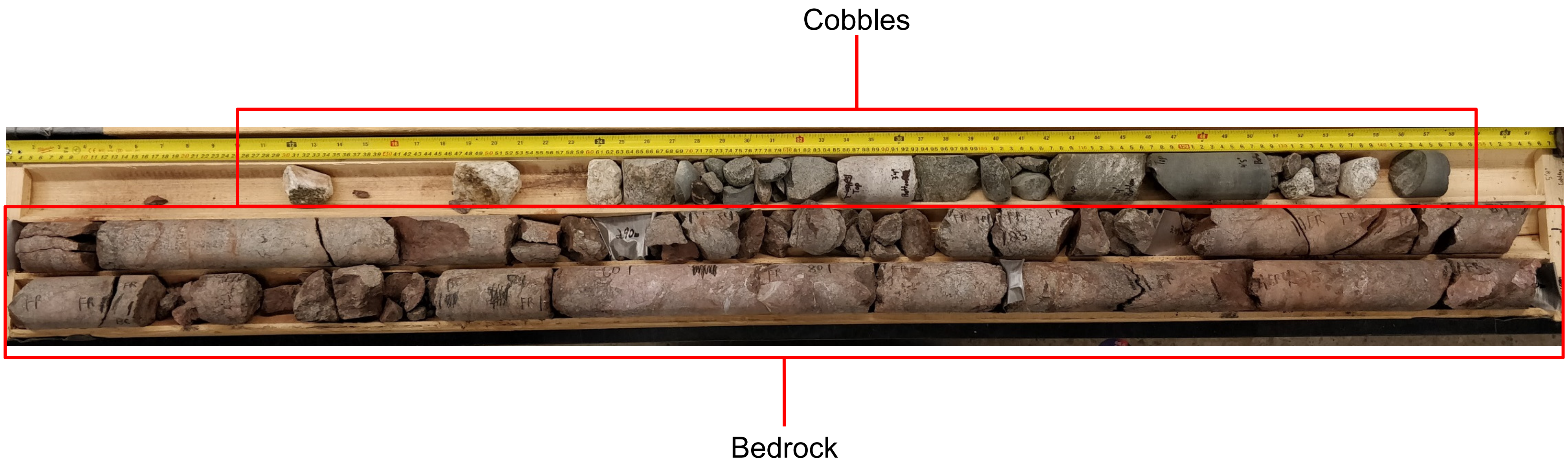
GOLDER

LOGGED: MB

CHECKED: TZ

APPENDIX B

Cobbles and Bedrock Core Photograph



Borehole BFC-01: Cobbles cored between depths of about 0.30 m and 2.20 m; bedrock cored between depths of about 2.34 m to 5.50 m

Scale: 0 m — 0.40 m; 0 ft — 1.0 ft — 2.0 ft

PROJECT	**Highway 556 – Beaver Falls Culvert Rehabilitation, 19.9 km East of Highway 17 (Site No. 38S-0037/C0) Deroche Township, Algoma District, Ontario**
TITLE	**COBBLES AND BEDROCK CORE PHOTOGRAPH BOREHOLE BFC-01**

Golder Associates

PROJECT No. 1670846			FILE No. ----		
DESIGN	MA	20181127	SCALE	NTS	VER. 1.
CADD	--		**FIGURE B1**		
CHECK	TZ	20181127			
REVIEW	JPD	20181130			

REVISION DATE: December 21, 2017 BY: AK Project: 1670846

APPENDIX C

Special Provisions

NOTICE TO CONTRACTOR – Obstructions

Special Provision

The Contactor is advised of the presence of cobbles and boulders and bedrock outcrops at the creek bed near the inlet and outlet of the existing culvert and below the existing concrete apron at the inlet of the existing culvert, located at approximately Station 19+016 (Deroche Township).

Consideration of the presence of the cobbles and boulders and bedrock outcrops must be made in the selection of appropriate equipment/tools for excavation and/or installation of temporary cofferdam systems.

TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01 July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

<table>
<tr><td colspan="2">IDF Curve Location</td><td colspan="4">Latitude: 46.745833</td><td colspan="2">Longitude: -84.062500</td></tr>
<tr><td colspan="8">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name /
Station Reference</td><td rowspan="2">Minimum
Return Period
(Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td colspan="2" rowspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>2
Year</td><td>5
Year</td><td>10
Year</td><td>25
Year</td></tr>
<tr><td>Beaver Falls Culvert
(Site No. 38S-0037/C0)
Rehabilitation (19+015.65)</td><td>N/A</td><td>7.3</td><td>10.0</td><td>12.7</td><td>15.6</td><td colspan="2">Yes</td></tr>
<tr><td colspan="8">Dewatering Systems</td></tr>
<tr><td>Site Name /
Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2)
(m)</td><td colspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>N/A</td><td colspan="5">N/A</td><td colspan="2">N/A</td></tr>
<tr><td colspan="8">Note:
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. “N/A” indicates a preconstruction survey is not required.</td></tr>
</table>

WARRANT: Always with these tender items.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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