

Foundation Investigation and Design Report

DB 2018-4013-Two Structural Culvert Replacements on Highway 17

Structural Culvert No.: 29-146/C

Barbut Creek Crossing of Highway 17

Renfrew County, ON

Project No.: TPB196039

WP 4005-13-01

Ministry of Transportation (MTO), Eastern Region

Geocres No.: 31L-221

Prepared for:

Looby Construction Limited

3035 Ontario Street, Unit 201, Stratford, Ontario N5A 6S5

Attn: Mr. Todd Jeffrey

30-Jul-19

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Part A

Foundation Investigation Report Barbut Creek Culvert Highway 17, Renfrew County, ON

1.0 Introduction

Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited ("Wood") has been retained by Looby Construction Limited to provide foundation design services for two structural culvert replacements on Highway 17 as part of a Design-Build project for the Ministry of Transportation Ontario (MTO), Eastern Region. As part of this assignment, Wood has completed a final Foundation Investigation and Design Report (FIDR) for the culvert replacement over Barbut Creek on Highway 17 in Renfrew County, Ontario.

The scope of this report is strictly limited to the geotechnical and foundation aspects of the proposed works. As part of the Design-Build project, there will be ongoing liaison with other members of the Design-Build team during the design and construction phases of this project to confirm that the recommendations in this report have been interpreted and implemented as intended.

The following Foundation Investigation and Design Report made available by MTO to the Design Builder has been referenced in the preparation of the final FIDR:

- Thurber Engineering Ltd., Geocres Number: 31L-203, Report titled "Foundation Investigation and Design Report, Replacement of Structural Culvert No. 29-146/C, Barbut Creek Crossing of Highway 17, Renfrew County, ON", dated April 2018.

This final report is prepared based on the results of the previous investigation as outlined above and the new boreholes advanced at the site. In total, seven (7) boreholes were completed by Thurber Engineering Ltd. (Thurber) in 2017, to assess the extent and nature of the subsurface conditions. Additional investigation has been completed by Wood through the advancement of two (2) boreholes to supplement the previous subsurface information and to provide additional information related to the foundation soils at the new culvert location.

The results of the additional subsurface investigation completed by Wood are presented in Appendix A. Copies of Record of Borehole sheets from the previous foundation investigation are provided in Appendix A.

2.0 Site Description and Geological Background

2.1 Site Description

The Barbut Creek culvert (No.: 29-146/C) is located on Highway 17 in Renfrew County, approximately 28 km east of Mattawa, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1. It is noted that for project orientation purposes, Highway 17 within the project limits has one through lane in each direction and will be assumed to run west-east. Based on the General Arrangement (GA) drawing the roadway cross-section consists of two, 3.75 m wide lanes with gravel shoulders. Steel beam guide rails are present along both sides of the highway in the vicinity of the culvert. The existing culvert is a cast-in-place, concrete, open bottom, rigid frame, with an internal height of 2.1 m and a span of 6 m that carries creek flow from south to north below the highway. One extension has been added to the north end of the original culvert and two separate extensions have been added to the south end. The extensions are conventional open footing rigid frame culverts. Including the extensions, the total length of the structure is reported to be 40.2 m. The GA drawing, provided in Appendix C, indicates that elevation of the top of stream bed ranges from Elevation 151.18 m and 151.03 m at the inlet and outlet, respectively.

No settlement or stability issues were noted at the culvert at the time of Thurber's field investigation. Due to the high creek water elevation during the field investigation, inspection for scour and erosion at the founding level at the inlet/outlet was not possible. The culvert is located within a high fill section. The height of the embankment in the area of the culvert is approximately 7 m. The slopes of the embankment were observed to be covered with a mix of brush and granular material. Some erosion of the granular slopes on both sides of the highway was noted. The embankment slopes were graded with slopes ranging from approximately 2.2H:1V to 2.8H:1V (Horizontal:Vertical). The elevation of the center line of roadway as reported on the GA drawing is 157.59 m and the elevation of the top of the culvert at the inlet and outlet ends are indicated as approximately 153.5 m and 152.9 m providing for 4.1 m to 4.7 m of cover.

The lands surrounding the project limits include forest and swampy areas. The Ottawa River is approximately 150 m north of the culvert site and is approximately parallel to Highway 17. Storm water drainage in the area is to ditches along the highway, and to Barbut Creek which outlets into the Ottawa River.

2.2 Geological Background

The site is located within a physiographic region known as the Algonquin Highlands which is characterized as having soils that are generally shallow overburden deposits with rough relief of rounded knobs and ridges, areas of outwash sand and gravel deposits, and frequently exposed bedrock. (Chapman and Putnam 1984).

3.0 Investigation Program

3.1 Field Work

A subsurface investigation was carried out by Thurber, with a total of seven (7) boreholes and reported to WSP Canada on behalf of the Ministry of Transportation, Ontario (MTO) for the Barbut Creek Culvert Replacement project.

The initial field investigation was carried out between October 13 and December 15, June 2015, and included advancing four boreholes (501 to 504). Due to the presence of large boulders within the embankment, an additional borehole (502C) was located in the eastbound lane to advance through the existing rock fill. A supplementary field investigation was carried to support the design of a Temporary Modular Bridge (TMB) along the south side of the highway. The supplemental investigation was carried out between June 29 and June 30, 2017 and included advancing two additional boreholes (505 and 506).

According to the Thurber report, the boreholes advanced through the roadway embankment were advanced with either a CME75 truck mounted drill rig equipped with NW size casing or a CME850 truck mounted drill equipped with HW size casing utilizing a telescoping drilling technique. The inlet and outlet boreholes were advanced with portable drilling equipment. Borehole 504 (outlet borehole) was advanced to refusal with Dynamic Cone Penetration Testing (DCPT). Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11.

A 25 mm inside diameter PVC piezometer was installed in Borehole 501 to allow for measurement of the groundwater level at the site. The piezometer construction details were illustrated on the Record of Borehole sheet for Borehole 501. The piezometer was decommissioned on December 15, 2015.

An additional investigation was carried out by Wood between May 14 and May 15, 2019. To confirm the subsurface conditions, two boreholes were advanced in the overburden (BH19-1 and BH19-2). Soil samples were taken at frequent intervals of depth following the Standard Penetration Test (ASTM D1586) procedure. Ground surface elevations at borehole locations are referenced to geodetic elevation. The drilling was conducted under the full-time supervision of Wood's engineering staff who directed the drilling and sampling operation and logged the boreholes. After completion of the boreholes, the augers were extracted, the boreholes were inspected for groundwater and caving, then backfilled using bentonite pellets and grout slurry in accordance with O. Reg. 903. All samples were field logged, placed in airtight containers, and transported to Wood's Ottawa and Richmond Hill laboratories for further examination and testing.

The borehole locations are shown on Drawing 1 and the Record of Borehole sheets are attached in Appendix A.

Tables 3-1 and 3-2 present the locations, ground surface elevations, base elevations and borehole depths for boreholes advanced in the additional and previous investigations, respectively.

Table 3-1: New Boreholes Advanced by Wood

Borehole ID	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Bottom Elevation of Borehole (m)	Depth (m)
BH19-1	5125802.5	393124.0	157.5	141.7	15.8
BH19-2	5125815.9	393118.2	157.6	142.5	15.1

Table 3-2: Previous Boreholes Advanced by Thurber

Borehole ID	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Bottom Elevation of Borehole (m)	Depth (m)
501	5125790.3	393113.8	154.0	149.4	4.6
502	5125810.6	393113.7	157.7	152.3	5.4
502C	5125811.1	393113.0	157.8	141.8	16.0
503	5125807.2	393125.4	157.5	142.2	15.3
504	5125822.7	393124.4	154.4	148.4	6.0
505	5125820.0	393101.0	157.9	144.1	13.8
506	5125794.5	393136.3	157.3	146.4	10.9

3.2 Laboratory Testing

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses testing was also carried out on selected samples to MTO and ASTM standards. Testing was completed in Wood's Richmond Hill laboratory.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix A and are illustrated on the figures in Appendix B.

Chemical analysis for determination of pH, resistivity, soluble sulphate, sulfide, redox potential and chloride concentrations was carried out on two soil samples at AGAT Laboratories in Mississauga, Ontario. A copy of the chemical analysis results is provided in Appendix B.

4.0 Subsurface Conditions

4.1 Subsurface Soil Conditions

The details of the soil stratigraphy encountered in the boreholes are provided on the Record of Borehole sheets attached in Appendix A. Stratigraphic profiles along the culvert alignment and along the highway alignment are presented on Drawing No. 1 for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions at the test locations.

In general, the stratigraphy beneath Highway 17 in the area of the culvert is characterized by an asphalt pavement structure overlying embankment fill containing rock fill, overlying a glacial till deposit. A buried layer of peat was encountered between the fill and till in Boreholes 504, 505 and BH19-1, and thin layers of silt and peat were encountered between the fill and till in Borehole 506.

Asphalt and Topsoil

Six boreholes were advanced through the Highway 17 pavement structure. The thickness of the asphalt ranged from approximately 100 mm to 150 mm.

A topsoil layer with a thickness of 25 mm was encountered at surface in Borehole 504 near the culvert outlet.

Fill

Sand and Gravel with Silt Fill:

A fill layer consisting of sand and gravel with varying amounts of silt was encountered below the asphalt in the embankment boreholes, at the ground surface in Borehole 501 and below the topsoil in Borehole 504. The top of this layer ranged from Elevation 154.0 m to 157.8 m. The thickness of the layer ranged from 0.7 m to 7.6 m. The SPT 'N' values ranged from 2 blows to greater than 100 blows per 0.3 m of penetration; indicating a very loose to very dense state. Cobbles were noted in this layer. The moisture content of the samples tested ranged from 2% to 22%.

Embankment Fill (Rock Fill):

Rock fill was encountered within the core of the embankment beneath the pavement structure in Boreholes 502/502C, 503, 505 and 506. Where encountered, the top of this layer ranged from Elevation 156.1 m to 156.9 m. The thickness of the layer ranged from 4.1 m to 6.7 m. Trace wood pieces were encountered at the base of this layer in Borehole 503. The rock fill contained frequent cobble and boulder sized particles. Where samples were recovered with a split spoon sampler, the fill consisted predominantly of gravel and sand with trace amounts of silt. The SPT 'N' values ranged from 5 blows to greater than 100 blows; indicating a loose to very dense state; but typically compact to dense. The moisture content for the recovered samples tested ranged from 2% to 21%.

Peat

Peat with trace to some wood pieces was encountered below the fill material in Boreholes 504, 505 and BH19-1, and between silt layers in Borehole 506. The peat in Borehole 505 was mixed with sand and gravel. The top of the peat ranged from Elevation 150.5 m to 151.2 m. The thickness of the peat layer ranged from 0.3 m to 1.0 m. The moisture content for the samples tested ranged from 55% to 275%. Test results carried on samples of this material indicated an organic content ranging from 20% to 54%.

A thin silty clay mixed with organics was encountered below the peat in Borehole BH19-1. The thickness of silty clay was about 0.5 m in the borehole. The moisture content for the sample tested was about 284%.

Sand and Silt

A silt deposit was encountered between the fill and the till deposits in Borehole 506. The top of this layer was encountered at Elevation 151.9 m. The overall thickness of the layer was 1.7 m, however, a 300 mm thick layer of peat was encountered in the middle of the silt layer. Trace organic material was observed throughout the silt both above and below the peat. A silt with sand deposit was encountered between the fill and the till deposits in Borehole BH19-2. The SPT 'N' values ranged from 3 to 15; indicating a very loose to compact state. The moisture content of the samples tested were 9% and 138%.

Silty Sand with Gravel - Till

A glacial till layer consisting predominantly of silty sand with varying amounts of gravel was encountered in all advanced boreholes. The top of this layer ranges from Elevation 149.6 m to 150.9 m. The boreholes were terminated in this stratum. The SPT 'N' values ranged from 16 to greater than 100 blows; indicating a compact to very dense state; but typically dense to very dense. The moisture content for the samples tested ranged from was 8% to 20%.

4.2 Groundwater

The groundwater level has been measured during the additional drilling by Wood in a new borehole on May 14, 2019. The result is shown in Table 4-1.

The groundwater level in the piezometer installed in borehole 501 was measured on December 15, 201, and the water level in borehole 505 was measured on June 27, 2017, during the Thurber investigation. The summarized results are shown in Table 4-2.

Table 4-1: Groundwater Elevation in New Borehole

Borehole ID	Existing Ground Surface Elevation (m)	May 14, 2019	
		Water Level Depth (m)	Water Level Elevation (m)
BH19-1	157.5	6.8	150.7

Table 4-2: Groundwater Elevations in Previous Piezometer/Borehole

Borehole ID	Existing Ground Surface Elevation (m)	May 14, 2019		June 27, 2017	
		Water Level Depth (m)	Water Level Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)
501	154.0	2.1	151.9	-	-
505	157.9	-	-	5.65	152.3

The water level in Barbut Creek was measured at the time of Thurber's field investigation at a depth of 1.3 m below the top of the culvert at the inlet; corresponding Elevation 152.2 m. The groundwater level in the area of the culvert is expected to reflect the creek water level.

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

5.0 Closure

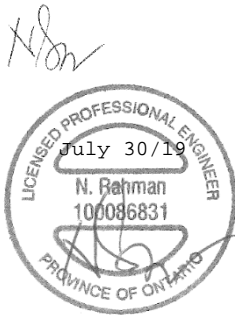
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Mr. Ty Garde, M.Eng., P.Eng., Principal Geotechnical Engineer and a Designated Foundation Contact for Wood, conducted an independent quality control review of the report.

Sincerely,

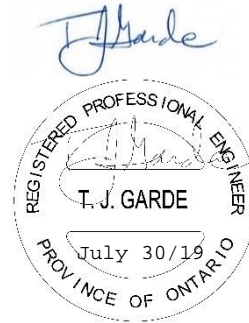
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Part B

**Foundation Design Report
Barbut Creek Culvert
Highway 17, Renfrew County, ON**



6.0 Discussion and Recommendations

6.1 General

This section of the report provides foundation design recommendations for the Barbut Creek Culvert replacement. The recommendations are based on interpretation of the factual data obtained from the previous and new investigations on site. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert.

A General Arrangement (GA) drawing dated June 2019 was provided by the design team for the preparation of this report. A copy of the GA drawing is provided in Appendix C.

The new Barbut Creek Culvert has been designed in accordance with 2014 Canadian Highway Bridge Design Code (2014 CHBDC). Therefore, the discussion provided herein is based on the 2014 CHBDC.

6.2 Proposed Structure

Based on the June 2019 GA drawing, the existing culvert is to be replaced with a 22 m long, open bottom, metal arch culvert with an approximate span of 10.6 m; installed on the existing alignment. A concrete headwall would be constructed at both ends of the culvert with concrete retaining walls set at an approximate angle of 45° to the headwall. The exposed height of the walls is anticipated to be a maximum of 5.8 m at the headwall tapering down to 3.5 m. The design top of stream bed elevation is to range from Elevation 151.03 m to 151.18 m and no permanent changes to the highway profile above the culvert are proposed. The GA also indicates that the span and rise of the new culvert are both about 3 m greater than those of the existing culvert. The new footings will be constructed to the outside of the existing footings, which have been identified as having an outside to outside dimension of 8.28 m. It is expected that the founding elevation of the new footings will be at approximately 150.0 m.

A temporary modular bridge (TMB) is proposed to maintain traffic flow during the culvert replacement. The TMB is to be approximately 43 m in length with a design top of bridge deck elevation ranging from 158.0 m to 157.3 m (sloping west to east). The TMB will reduce traffic flow to a single lane, controlled by temporary signals. The TMB is to be supported on temporary concrete pads perched within the existing rock fill founded at approximate Elevations 156.4 m and 155.7 m at the west and east abutments, respectively.

It is understood that the existing culvert will be removed after the footings and concrete pedestal walls, and lower portion of retaining walls are constructed. Once it is removed, the steel plate arch will be constructed as well as the top portion of the retaining walls.

6.3 Foundation Design Option

Based on the soil stratigraphy and the existing stream bed elevations which range from 151.0 m at the inlet to 150.3 m at the outlet, and the most recent design considerations, it is expected that the replacement culvert will be founded on engineered fill supported on glacial till. If peat is

encountered in the area of the outlet it should be excavated and removed in accordance with OPSS.PROV 902.

The narrow highway platform, high embankment fill and presence of rock fill within the embankment will have an impact on construction and staging approaches. Culvert/foundation alternatives and construction approach are presented and evaluated in the following paragraphs and a preferred replacement alternative from a foundation engineering perspective is recommended.

Common culvert and foundation types are listed below along with a comparison of these alternatives from a foundation perspective. Their respective advantages and disadvantages are outlined below.

- **Circular Pipes:** From a foundation engineering perspective, circular pipes installed with appropriate granular bedding over the native, undisturbed glacial till subgrade are feasible. However, it is understood that numerous circular pipes on new alignments would be required to provide the required hydraulic opening.
- **Closed Box (Concrete):** From a geotechnical perspective, the replacement could also be achieved with a closed bottom culvert. Since the base of the closed box does not need to be founded below frost depth the base of the excavation for a closed box would set at a higher elevation than required for the footings of an open bottom culvert. The shallower excavation would have the advantages of a shorter duration for dewatering, construction staging and reduced material handling.
- **Open Bottom (Steel/Concrete Arch or Concrete Rigid Frame):** With the design stream bed elevation of ranging from approximately 151.0m to 151.2 m, an open bottom culvert founded at elevations ranging from 149.1 m to 149.3 m (1.9 m below top of stream bed elevation) is considered feasible at this site from a foundation standpoint. At this elevation, it is expected that the replacement culvert will be founded on the compact to very dense till. The open bottom culvert could consist of either a concrete rigid frame culvert or an arch structure (steel or precast concrete). The founding elevation for the open bottom structure will be lower than for the closed box option, thereby requiring a deeper excavation.
- **Pre-cast vs Cast-in-Place Concrete Culverts:** From a foundation engineering perspective, the use of pre-cast or cast-in-place culverts are both considered feasible for this project however a pre-cast culvert is the preferred option from a foundations point of view. Pre-cast units are manufactured in a controlled casting environment eliminating the drawbacks imposed by varying weather and site conditions. Pre-cast units can be installed on site and the excavation backfilled and placed into service without delay, which can shorten installation time for projects where there are strict/short in-water working schedules.

Installing pre-cast units is also less labour intensive versus cast-in-place structures also reducing installation time and costs however, larger cranes are likely required for installation of large span pre-cast units which may impact the required construction staging zone. Fabrication and installation of concrete structural culverts under a design build project should be in accordance with Special Provision DBSP3271.

For construction methodology, it is understood that Open Cut with Temporary Modular Bridge construction method is the preferred method for the replacement of Culvert 29-146/C. This approach would consist of installing a temporary modular bridge structure to span the work area, followed by replacement of the culvert beneath the span of the temporary bridge structure. The temporary modular bridge would be founded either on the existing rock fill embankment or on deep foundations (caissons or H-piles installed within pre-drilled holes), depending on the span required. It is understood that a concrete spread foundation placed on competent rock fill is being considered for TMB.

It is understood that an open footing culvert structure is preferred from an environmental perspective or to help with water flow management during construction. An open footing culvert installed using open cut techniques and a temporary modular bridge to maintain traffic flow is considered feasible from a geotechnical perspective.

6.4 Seismic Considerations

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values ($S_a(T)$) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the site-specific peak ground acceleration (PGA).

The 2014 CHBDC contains updated seismic analysis and design methodology. The 2014 CHBDC method uses a site classification system defined by the average soil/bedrock properties (e.g. shear wave velocity, Standard Penetration Test (SPT) resistance, undrained soil shear strength etc.) in the top 30 metres below the foundation level. There are 6 site classes from A to F, decreasing in ground stiffness from A, hard rock, to E, soft soil; with site class F used to denote other soils (e.g., sites underlain by thick peat deposits, high plastic clays, liquefiable soils, etc.). The site class is then used to obtain acceleration and velocity-based site coefficients $F(PGA)$ and $F(PGV)$, respectively, for the effects of site-specific soil conditions in design.

Based on the results of the previous investigations, for seismic design purposes at this site as determined by Section 4.4.3.2 of 2014 CHBDC, it is recommended that a Site Class of C ("Very Dense Soil") be used for the design of the new culvert structure.

In accordance with Section 4.4.3.1 of the CHBDC and based on the location of the culvert, the following are the Site Class C peak seismic hazard values based on the 5th generation seismic hazard maps published by the GSC.

Table 6-1: Seismic Hazard Values for Ground Condition Site Class C

Seismic Hazard Values	10% Exceedance in 50 years (475 return period)	5% Exceedance in 50 years (975 return period)	2% Exceedance in 50 years (2475 return period)
PGA (g)	0.088	0.149	0.262
PGV (m/sec)	0.057	0.097	0.179
Sa (0.2) (g)	0.141	0.234	0.409
Sa (0.5) (g)	0.076	0.124	0.219
Sa (1.0) (g)	0.038	0.061	0.107
Sa (2.0) (g)	0.017	0.028	0.050

The liquefaction cyclic mobility analysis based on SPT-based “simplified method” referenced in the CHBDC was carried out. The results of the liquefaction analysis using the “simplified method” indicated that the soils are not potentially liquefiable in the areas of the structure foundation and approach embankment.

6.5 Frost Depth

The upper stratigraphy of the soils is considered highly frost susceptible in the presence of water, and as such, frost effects should be considered for foundations or surface structure sensitive to movement.

In accordance with the Ontario Provisional Standard Drawing (OPSD 3090.101) the design frost depth below the ground surface for the general area is estimated to be 1.9 m. Therefore, a minimum permanent soil cover of 1.9 m or equivalent thermal insulation is required for frost protection of shallow foundations. It is anticipated that thermal insulation will be required to supplement the earth cover for frost protection purposes.

6.6 Foundation Design Recommendations

6.6.1 Culvert Foundation Bearing Resistances

Based on the GA drawing, the design top of substrate is noted as between Elevations 151.18 m and 151.03 m with a minimum thickness of 350 mm. It is understood that the culvert will be founded at approximately Elevation 150.0 m.

An open footing culvert structure founded on native, undisturbed glacial till at a minimum depth of 1.9 m (frost depth) below top of stream bed elevation (Elevation 149 m) may be designed based

on the factored geotechnical resistance values provided in Table 6-2. It is understood that the concrete headwall for a metal arch would be supported on the same foundations as the arch.

Table 6-2: Soil Bearing Resistances for Open Footing Culvert Foundation On Glacial Till

Footing Elevation (m)	Footing Width (m)	Factored Geotechnical Resistance at ULS (kPa)*	Geotechnical Reaction at SLS (kPa)
149	1.5	420	400
	2.0	450	375
	2.5	480	325
	4.0	525	300
	5.0	575	275

* For intermediate footing sizes, the factored geotechnical resistances values may be interpolated.

To minimize the total length of the Temporary Modular Bridge, and to improve the constructability of the culvert foundations, the design team in consultation with the Design Builder has considered supporting the new culvert foundations on engineered fill supported on the native glacial till. This construction would require the subexcavation of unsuitable material to expose the competent glacial till at approximate elevation 149.0 m and raise the foundation subgrade to the design elevation of 150.0 using engineered fill wrapped in a geotextile filter fabric.

The engineered fill may consist of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II or Granular 'B' Type III material placed in maximum 200 mm thick loose lifts and compacted to 100% of the material's standard proctor maximum dry density.

Table 6-3: Soil Bearing Resistances for Open Footing Culvert Foundation on Engineered Fill

Footing Elevation (m)	Type of Engineered Fill	Footing Width (m)	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa)
150	Granular 'A' or Granular 'B' Type II	4.0	475	300
		5.0	525	275
	Granular 'B' Type III	4.0	400	275
		5.0	450	250

The factored geotechnical resistances in the above tables include the following factors:

- The factored geotechnical resistance values at SLS provided above correspond to the stress increase relative to current site conditions that will result in 25 mm of total settlement.
- Consequence factor (ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
 - Bearing (ULS), $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - Settlement (SLS), $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

The structural design of the culvert should consider differential settlement across the culvert. Based on the SLS bearing resistance provided above, a maximum of 25 mm of differential settlement should be anticipated along the culvert alignment.

The geotechnical resistances provided above are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

Unfactored resistance to lateral forces through sliding resistance between concrete and native till or Granular 'A' bedding materials should be evaluated using an unfactored coefficient of friction of 0.55 for cast-in-place concrete and 0.45 for pre-cast concrete.

6.6.2 Subgrade Preparation and Backfilling

Excavation and backfilling for installation of the new culvert should be carried out in accordance OPSS 902 and MTO Special Provision (SP) No. 109S12, Amendment to OPSS 902, March 2018. Subgrade preparation for the culvert structure and retaining walls should include excavation and removal of the existing culvert, culvert foundations and backfill materials from beneath the founding elevation within the foot print of the new culvert foundation. The existing fill and any soft or organic materials must be removed from within the influence zone of the foundations and replaced with compacted Granular 'B' Type II or Type III (crushed granular). The native subgrade for the culvert foundations and retaining walls will consist of undisturbed native glacial silty sand till. Any boulders encountered at the subgrade elevation should be removed and the excavation backfilled with Granular 'B' Type II or Type III (crushed granular).

It is understood that portions of the existing culvert may be temporarily left in place to help facilitate the temporary flow passage system during construction. A pipe or series of pipes is proposed to be installed through the existing culvert to act as a temporary flow passage during construction while the existing culvert is to be removed in an open excavation beneath the temporary modular bridge. Consideration for the unbalanced earth and hydrostatic pressures that may develop during excavations as outlined above in Section 6.2 will need to be considered.

If peat is encountered at the design subgrade elevation it should be excavated and removed in accordance with OPSS.PROV 902. As noted above, engineered fill will be placed above the glacial till to raise the foundation elevation to 150.0 m. The engineered fill could be disturbed by construction activities. Should it be necessary to protect the prepared fill surface from disturbance, the new fill surface could be covered with a 50 mm thick concrete working slab. After the concrete for the working slab has set, the culvert footing could then be constructed directly on the working slab.

Backfill for the culvert should consist of compacted free-draining granular material. Backfill requirements from the arch culvert supplier must also be confirmed. It is recommended that the backfill detailing of OPSD 3101.150 be utilized with a frost penetration line below the top of the culvert. The frost treatment depth, k , should be set at 1.9 m. The depth of road bed granular, d , should be set at 0.790 m.

6.6.3 Retaining Walls

The June 2019 Preliminary GA drawing includes concrete retaining walls extending out from both side of the concrete headwalls at each end of the culvert. The elevation of the base of the retaining walls is to be at the same elevation as the footings for the arch culvert, and the retaining walls will be founded on engineered fill supported on glacial till, as described in Section 6.6.1, above. The retaining walls are set an approximate angle of 45° to the headwalls. The design of the retaining walls is to include a 2H:1V backslope behind the walls. It is understood that the maximum exposed height of the walls is anticipated to be a maximum of 5.8 m at the headwall tapering down to a height of 3.5 m with an overall length of approximately 5 m and 8 m at the inlet and outlet respectively.

The existing ground conditions beneath the retaining walls may include glacial till, silt, peat, rock fill and granular fill. As noted in Section 6.6.2, the existing fill, loose silt, and organic materials should be removed from beneath the retaining walls.

The bearing resistance values provided in Section 6.6.1 above and the lateral earth pressure recommendations provided in Section 6.6.5 below may be used for design of the proposed retaining walls.

The global stability for the proposed embankment behind the concrete gravity retaining wall constructed using OPSS.PROV 1010 Granular B Type II or Type III, with 2H:1V side slopes was evaluated using GeoStudio Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the in-situ SPT 'N' values.

The following additional parameters were used in the analysis:

- A seismic horizontal loading of 0.131, equal to $\frac{1}{2}$ of the site adjusted PGA value (0.262g) was used for seismic analysis; and
- Maximum exposed wall height of 5.8 m.

The results of the global stability analysis indicate that a factor of safety of 1.5 and 1.2 were obtained under static and seismic conditions respectively.

6.6.4 Embankment Reinstatement

The existing embankments have slopes ranging from approximately 2.2H:1V to 2.8H:1V. Some erosion of the granular cover was reported at the north embankment slope. Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II or Type III material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding or backfill.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501. Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSD 208.010.

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

6.6.5 Lateral Earth Pressures

The lateral earth pressures acting on the culvert walls and retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

Select free-draining granular fill meeting the specifications of Ontario Provincial Standard Specifications (OPSS) Granular "A" or Granular "B" (Type II or III) but with less than 5 percent passing the 200 sieve should be used as backfill behind the walls. This fill should be compacted in accordance with OPSS 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3101.150 and 3121.150;

A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501. Other surcharge loadings should be accounted for in the design, as required.

Approach embankments shall be protected adequately to prevent them from being washed off, eroded, undermined, or damaged due to the effects of heavy rainfall, snow melt, or other potential water flows.

Backfill shall be free draining and designed to prevent development of pressures due to the accumulation of free water in either a fluid or frozen state in the vicinity of culvert and the walls shall be well drained so as to prevent the accumulation of water and avoid the associated risk of settlement and erosion of approaches and slopes.

When rock backfill to structures is specified, the rock backfill shall only be comprised of rock fragments no larger than 250 mm in their greatest dimension in accordance with OPSS 206 and it should be according to OPSD 3101.200.

Consideration should be given to placing the granular fill behind the culvert walls first before placing any embankment rock fill above the granular fill. If the granular fill is placed over the rock fill, a separation layer will be required.

The lateral pressures are based on the proposed embankment fill materials and the following parameters (unfactored) may be used:

Table 6-4: Static Lateral Earth Pressure Coefficients

Parameter	Existing Granular Fill	Rock Fill	Granular 'A' or Granular 'B' Type II	Granular 'B' Type III
Soil Unit Weight (kN/m ³)	20	19	21	21
Horizontal Backfill				
Coefficient of Active Earth Pressure, K_a	0.31	0.17	0.27	0.29
Coefficient of at Rest Earth Pressure, K_o	0.47	0.29	0.43	0.46
Coefficient of Passive Active Earth Pressure, K_p	3.25	5.83	3.69	3.39
2H:1V Sloped Backfill				
Coefficient of Active Earth Pressure, K_a	0.47	0.22	0.39	0.44
Coefficient of at Rest Earth Pressure, K_o	0.68	0.42	0.62	0.66
Coefficient of Passive Active Earth Pressure, K_p	8.61	27.86	10.81	9.27

Table 6-5: Seismic Active Pressure Coefficients, K_{AE}

Parameter	Rock Fill	Granular 'A' or Granular 'B' Type II
Soil Unit Weight (kN/m ³)	19	21
Horizontal Backfill		
Yielding Wall	0.23	0.35
Non-yielding Wall	0.31	0.44
2H:1V Sloped Backfill		
Yielding Wall	0.33	0.66
Non-yielding Wall	0.53	0.86

If the wall support and superstructure allow lateral yielding, active earth pressures may be used in the geotechnical design of the structure. If the abutment support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

- rotation (i.e., ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
- horizontal translation of 0.001 times the height of the wall; or
- a combination of both.

Seismic loading will result in increased lateral earth pressures acting on the walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure.

In accordance with Section 4.6.5 and C4.6.5 of the 2014 CHBDC and its Commentary (2014), for walls which do not allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic lateral earth pressure coefficient, is taken as equal to the seismic horizontal acceleration coefficient at zero wall movement. For structures which allow lateral yielding, k_h is taken as half of the seismic horizontal acceleration coefficient that corresponds to zero wall movement. The seismic vertical acceleration coefficient k_v in both cases should be ignored.

The seismic active pressure coefficients (K_{AE}) for the backfills listed in Table 6-5 may be used in design. The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall

and minimum pressure at its toe (i.e., an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_a \gamma d + (K_{AE} - K_a) \gamma (H-d)$$

Where: $\sigma_h(d)$ is the lateral earth pressure at depth, d , (kPa);

K_a is the static active earth pressure coefficient;

K_{AE} is the seismic active earth pressure coefficient;

γ is the unit weight of the backfill soil (kN/m³), as given previously;

d is the depth below the top of the wall (m); and

H is the total height of the wall (m).

6.6.6 Temporary Modular Bridge Foundations

6.6.6.1 Bearing Resistances

A temporary modular bridge (TMB) may be supported on concrete pad foundations bearing on the existing rock fill. A granular leveling pad consisting of OPSS Granular 'A' placed beneath the proposed concrete pad foundations may also be required. Re-chinking of the rock fill surface should be anticipated. Based on the design drawings provided the bottom of footing is at approximately Elevation 156.4 m and 155.7 m on west and east sides, respectively.

It is recommended that the excavation side slopes in front of the TMB footings for removal and replacement of the existing culvert will be no steeper than 1.25H:1V, as discussed in Section 6.6.6.2. The edge of foundation bases for the TMB should be set back a minimum of 3 m from the proposed face of the cut slope.

Footings for the TBM with a length of 8 m, a width of 2.0 m, constructed at the required minimum setback from the proposed top of slope and placed with a minimum embedment of 0.75 m may be designed based on the following factored geotechnical resistances:

- Factored Geotechnical Resistance at ULS (kPa) 400 kPa
- Geotechnical Reaction at SLS (kPa) 225 kPa.

The factored geotechnical resistances include the factors indicated in Section 6.6.1. The geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4. In addition, the geotechnical resistances assume that the footings are constructed on horizontal ground and will need to be adjusted to account for the proximity to the excavation slope.

Resistance to lateral forces through sliding resistance between cast-in-place concrete and the granular pad should be evaluated using an unfactored friction coefficient of 0.50.

It is noted that some settlement of the approach embankment and TMB foundations may occur due to grading modifications associated with the construction grading. This settlement would be within the loose silt and organic deposits identified beneath the embankment fill.

6.6.6.2 Global Stability

The global stability for the proposed excavation side slope geometry to remove and replace the existing culvert was evaluated using GeoStudio Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the in-situ SPT 'N' values. The following additional parameters were used in the analysis.

- A traffic surcharge load as per Section 6.12.5 of the CHBDC was used for static analysis where required
- Footing service loadings
- A seismic horizontal loading of 0.131g, equal to ½ of the site adjusted PGA value (0.262g) was used for seismic analysis
- A maximum excavation side slope geometry of 1.25H:1V.

The results of the global stability analysis indicate a factor of safety (FOS) of 1.3 and 1.1 under static and seismic conditions respectively. The calculated FOS meets the target values of 1.3 and 1.1 under static and seismic conditions respectively for a temporary condition. The output models from the global stability analysis for both static and seismic conditions are provided in Appendix D.

6.6.7 Corrosion Potential

Select soil samples obtained from boreholes advanced by Wood were sent to AGAT Laboratories in Mississauga, Ontario for determination of pH, electrical resistivity, chloride content and sulphate content. The method of analytical testing used for the soil specimens is indicated in the analytical laboratory report that presented in Appendix B. The results of the test from samples obtained by Wood and Thurber are summarized in Table 6-6.

Table 6-6: Results of Chemical Analysis

Borehole/Sample ID	Sample Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Electrical Resistivity (Laboratory) (Ω-cm)	Sulphide (%)	Redox Potential (mV)
BH19-1/SS13	9.1-9.6	8.83	-	11	11000	<0.05	257-267
BH19-2/SS1	4.6-5.1	8.81	-	7	5950	<0.05	254-260
501/SS6	3.1-3.6	8.0	6	7	15700	-	-

The test results indicate that concrete in contact with the tested soil would have a negligible degree of exposure to sulphate attack based on CSA-A23.1. Based on the results obtained, it is anticipated that the general use hydraulic cement (GU) can be used.

Based on the measured resistivity, pH etc., the tested soil samples would be considered noncorrosive to buried metallic elements in accordance with ANSI/AWWA C105/A21.5-05, Appendix A, Table A.1.

6.7 Construction Considerations

6.7.1 Excavations

It is anticipated that temporary excavations in the order of 8 m will be required for the removal of the existing culvert and foundations. All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects O. Reg. 213/91 as amended. The fills at the site should be classified as Type 3 above and Type 4 below the groundwater table in accordance with OHSA. The glacial till should be classified as Type 2, however, as indicated in the OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation. In accordance with OHSA unsupported excavations made in Type 3 soils must have side slopes having a minimum gradient 1H:1V.

Subgrade preparation and placement of culvert foundations must be carried out in a dry condition. Where the existing substrate and backfill inside the existing culvert is to remain the unbalanced earth pressures and hydrostatic pressured must be considered when excavating the for the foundations of the new culvert. The temporary protection system or dewatering system should be in accordance with OPSS.PROV 539 and/or OPSS.PROV 517 and SP 517F01. Excavation and removal of the peat material encountered in the area of the outlet should be carried out in accordance with OPSS.PROV 902.

6.7.2 Temporary Protection System

In the event a temporary protection system is necessary, temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. Typical lateral earth pressure coefficients are provided in Table 6-3.

The protection systems should be designed with the penetration depth that is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations, and the slope of temporary embankments above the top of the protection system should also be considered. Increased difficulty with the installation of temporary protection systems should be anticipated due to the presence of rock fill within the embankment and boulders present within the glacial till. For preliminary assessment purposes, the use of sheet piles through the rock fill is not considered feasible. One option is to use H-piles and timber lagging with the H-piles installed in pre-drilled holes into the glacial till. Tie back anchors would likely consist of soil anchors installed within the glacial till.

6.7.3 Dewatering

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. The groundwater level for the site at the time of the proposed replacement should be taken as the water level in the creek. It is recommended that the replacement be conducted during a drier period.

Temporary water course diversion will be required to replace the culvert in the dry condition. It is understood that a pipe or a series of pipes is proposed to be installed through the existing culvert to act as a temporary flow passage during construction and that the existing culvert is to be removed in an open excavation under the temporary modular bridge prior to constructing the new culvert. Excavations below the groundwater level are anticipated for constructing the footings for the arch culvert. A cofferdam with pumping from sumps may be required to control inflow of water into the excavation prepare the subgrade and to construct the footings in the dry condition. Dewatering and surface water diversion must remain operational and effective until the culvert is replaced. The design of any dewatering system should be carried out in accordance with OPSS 517 and SP 517F01.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert replacement should be taken as the water level in the creek at the time of construction. Excavation below the groundwater level to construct the culvert foundation will be required and excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work.

Cofferdams may be required to prevent the creek from spilling into the adjacent excavation for the new culvert and during creek realignment. Further assessment of dewatering requirements and the need for a PTTW will be addressed in a separate report.

6.7.4 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805. Erosion protection should be provided at the culvert inlet and outlet areas.

Typically, rock protection should be provided over all surfaces with which culvert water is likely to be in contact. Rip rap treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804. It is recommended that a clay seal be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high-water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

6.7.5 Geotechnical Instrumentation and Monitoring Plan

A geotechnical instrumentation and monitoring plan (GIMP) will be developed as a separate document. The GIMP will address the monitoring requirements prior to (baseline), during and following the construction activities. It will include a description of the instrumentation type and location, monitoring procedures and frequencies and reporting. It is anticipated the GIMP will include vibration wire pressure cells, vibrating wire strain gauges and multipoint borehole extensometers.

7.0 Closure

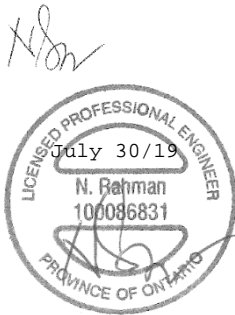
This Foundation Investigation Report was prepared by Mr. Nazmur Rahman, M.A.Sc., PE, P.Eng., Associate Geotechnical Engineer.

Mr. Ty Garde, M.Eng., P.Eng., Principal Geotechnical Engineer and a Designated Foundation Contact for Wood, conducted an independent quality control review of the report.

Sincerely,

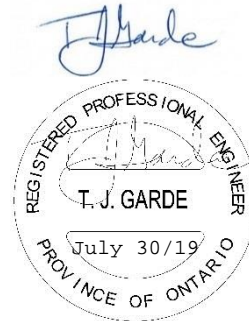
**Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited**

Prepared By:



Nazmur Rahman, M.A.Sc., P.Eng., P.E
Associate Engineer – Geotechnical

Reviewed By:



Ty Garde, M.Eng., P.Eng.
MTO Designated Foundations Contact

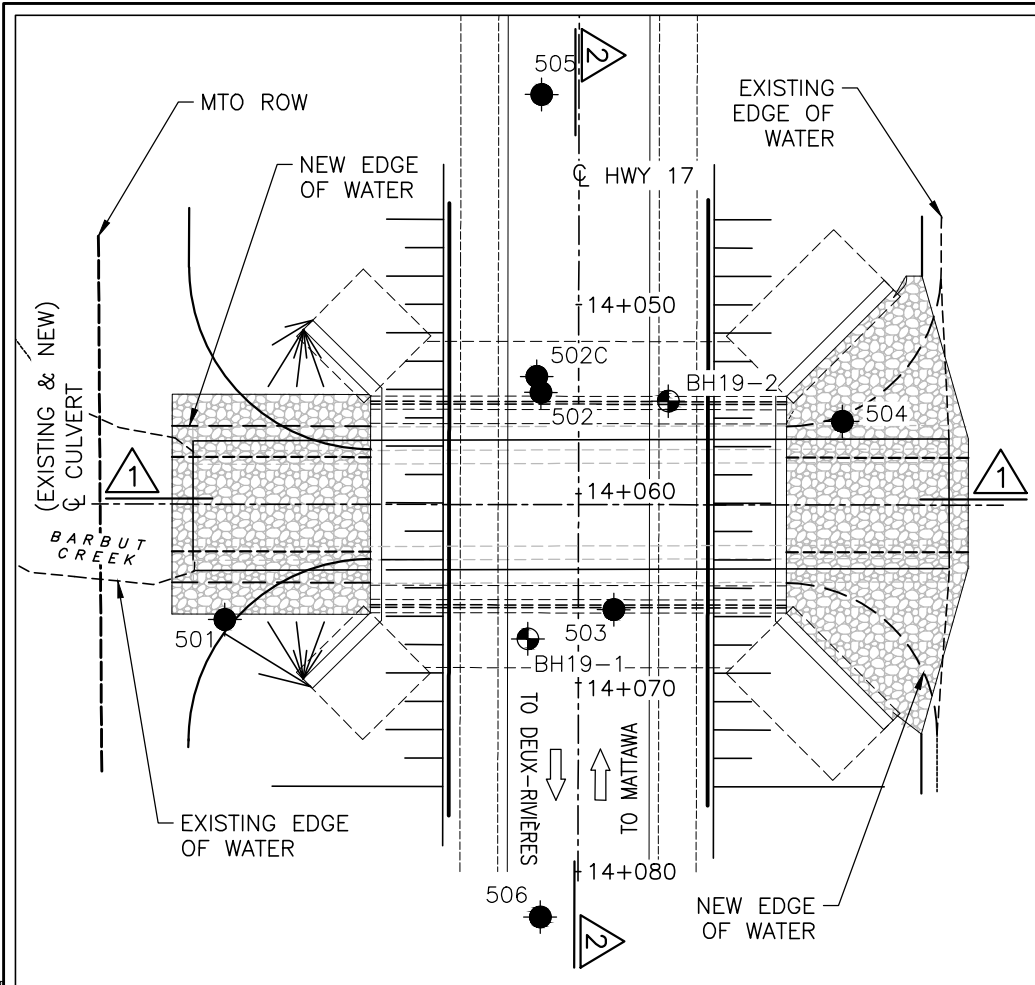


wood.

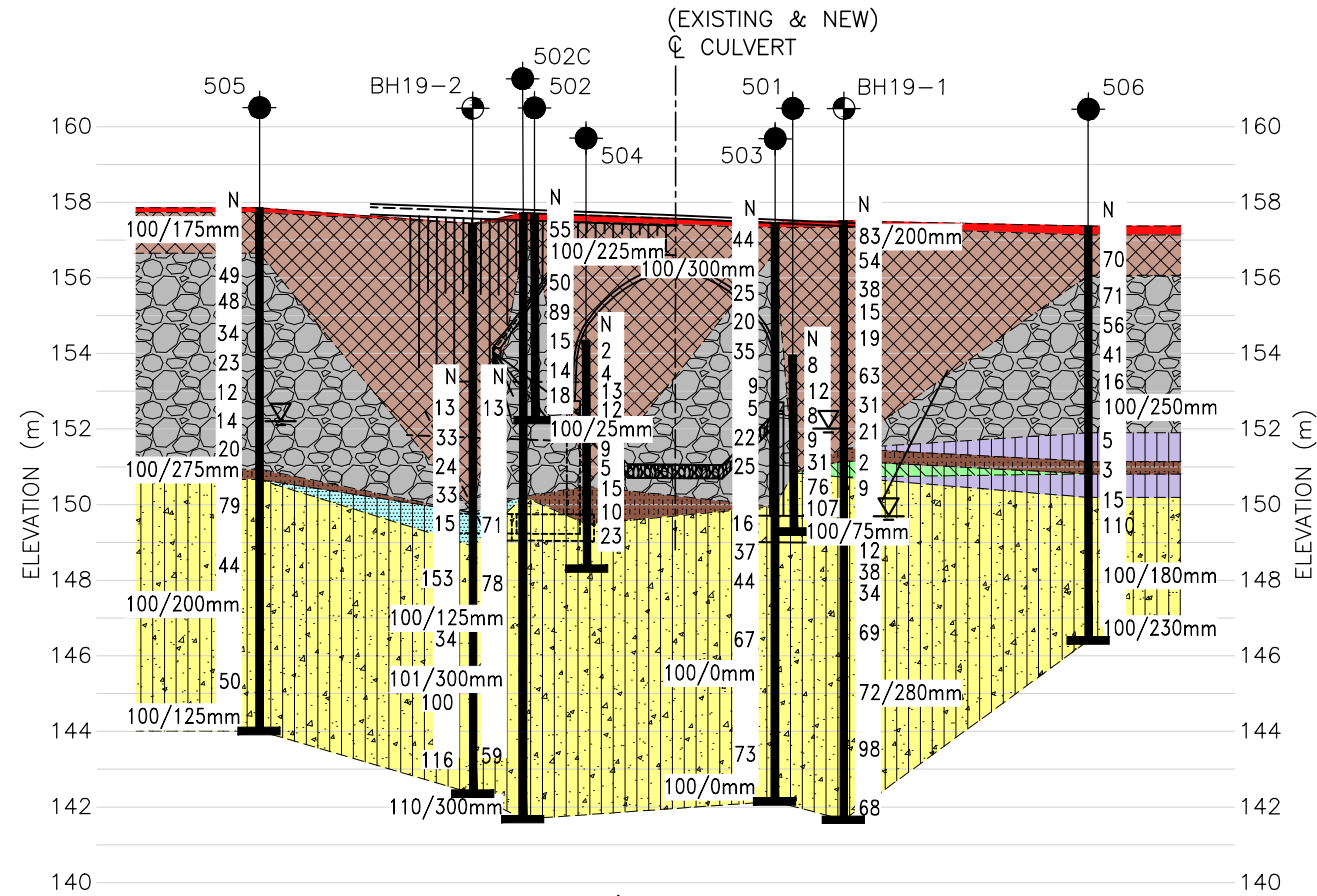
Drawings



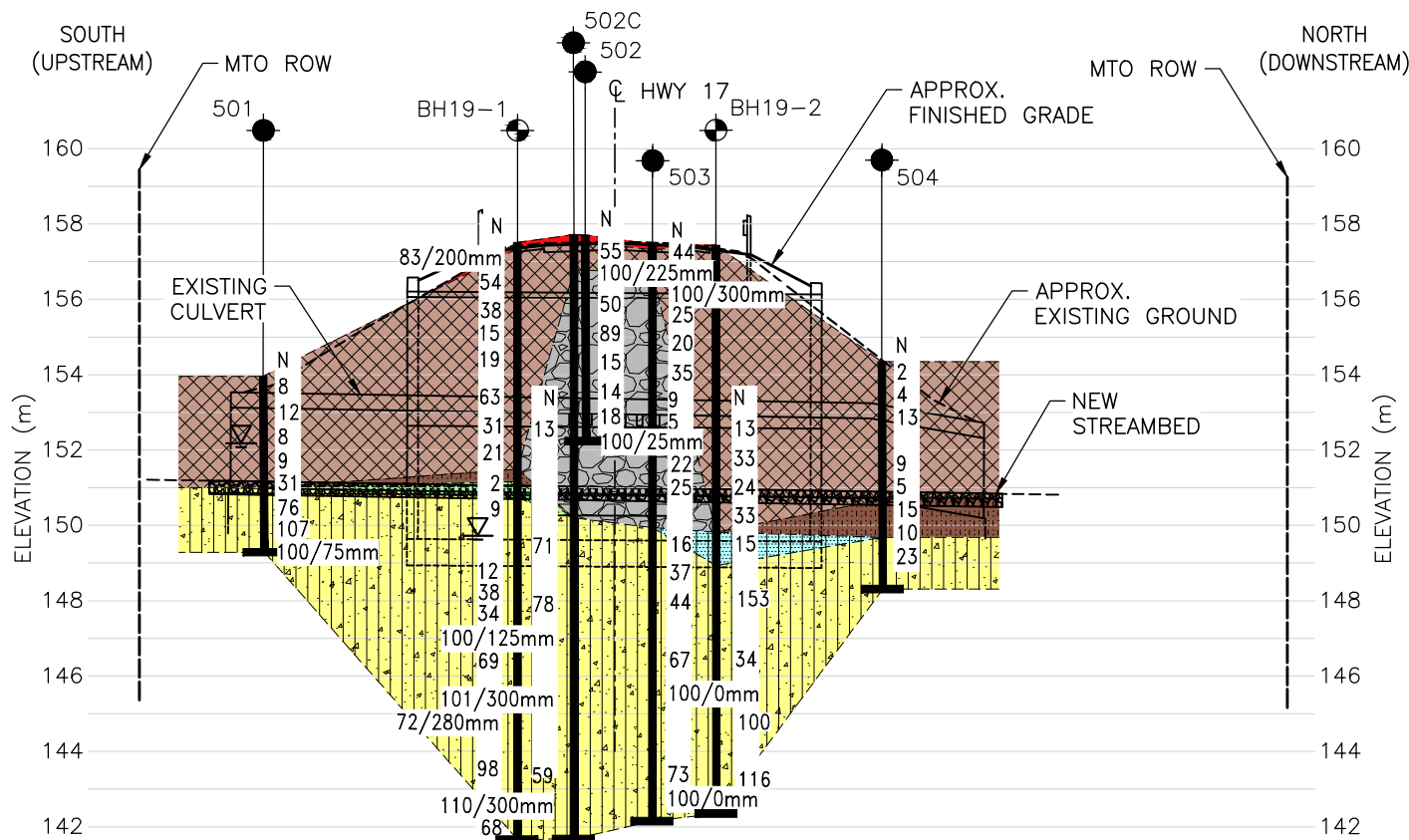
DATE PLOTTED: 7/30/2019 11:04:45 AM
FILE LOCATION: P:\2019\Geotechnical Projects\Other Offices\Barbut Creek Culvert Replacement\Drawing\AutoCAD files\TPB196039-R01001.dwg



PLAN



SECTION



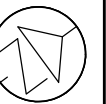
PROFILE

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

Wood
Environment & Infrastructure Solutions
A Division of Wood Canada Limited

Ministry of Transportation (MTO)
Foundation Investigation and Design
Culvert Replacement
Renfrew County, Ontario



BARBUT CREEK CROSSING OF HIGHWAY 17
BOREHOLE LOCATIONS & SOIL STRATA

SHEET
—



KEY PLAN

SCALE
0.25 0 0.5 1Km

LEGEND

- BOREHOLE LOCATION — CURRENT WOOD INVESTIGATION REPORT No. TPB196039, 2019
- BOREHOLE LOCATION — PREVIOUS INVESTIGATION BY OTHERS REPORT No. 19-5161-263, 2018
- N STANDARD PENETRATION TEST VALUE
- 49 BLOWS/0.3m UNLESS OTHERWISE STATED (STD. PEN. TEST, 475 J/BLOW)
- ▽ WATER LEVEL UPON COMPLETION OF DRILLING

NOTES

- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING FOUNDATION INVESTIGATION AND DESIGN REPORT.
- THE INTERPRETED STRATIGRAPHY REPRESENTS SIMPLIFIED SUBSURFACE CONDITIONS. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN DEFINED AT BOREHOLE LOCATIONS ONLY. CONDITIONS BETWEEN BOREHOLE LOCATIONS COULD DIFFER FROM ILLUSTRATED CONDITIONS.
- ELEVATIONS ARE REFERENCED TO GEODETIC DATUM.

REFERENCES

- THURBER ENGINEERING LTD., "HIGHWAY 17, BARBUT CREEK CULVERT REPLACEMENT, BOREHOLE LOCATIONS AND SOIL STRATA", WP No. 4005-13-01, SITE No. 29-146/C, APR 2018.
- WOOD E&I SOLUTIONS, "BARBUT CREEK CULVERT, SITE NO. 29-146/C, GENERAL ARRANGEMENT", WP No. 4005-13-01, SITE No. 29-146/C, SHEET No. S1, JUNE 2019.

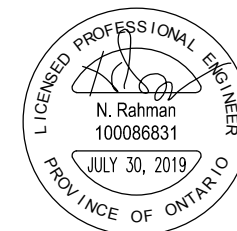
No.	ELEVATION	CO—ORDINATES (MTM, NAD 83 ZONE 10)	
		NORTHING	EASTING
WOOD BOREHOLES			
BH19—1	157.5	5125802.5	393124.0
BH19—2	157.6	5125815.9	393118.2
BOREHOLES BY OTHERS			
501	154.0	5125790.3	393113.8
502	157.7	5125810.6	393113.7
502C	157.8	5125811.1	393113.0
503	157.5	5125807.2	393125.4
504	154.4	5125822.7	393124.4
505	157.9	5125820.0	393101.0
506	157.3	5125794.5	393136.3

Geocres No. 31L-221

REVISIONS	DATE	REV. BY	DESCRIPTION
30-JUL-19	1	SJL	FINAL DESIGN SUBMISSION
21-JUN-19	0	SJL	INITIAL DESIGN SUBMISSION
DESIGN NR	CHK	TG	DRAWING No. 1
DRAWN	SJL	CHK	NR SITE 29-146/C DATE 12-JUN-19

DOC:

TPB196039-R01001



Appendix A

Record of Borehole Sheets



EXPLANATION OF BOREHOLE LOG



This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil strata, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *Modified Unified Soil Classification System* (modified slightly so that an inorganic clay of "medium plasticity" is recognized).

The compactness condition of cohesionless soils based on standard penetration testing (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows (Ref. Canadian Foundation Engineering Manual, 4th Edition, 2006):

Compactness Cohesionless Soils	SPT N-Value
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength	
	kPa	psf
Very Soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very Stiff	100 to 200	2000 to 4000
Hard	Over 200	Over 4000

SOIL SAMPLING

Sample types are abbreviated as follows:

SS Split Spoon TW Thin Walled Open (Pushed) RC Rock Core GS Grab Sample
AS Auger Sample TP Thin Walled Piston (Pushed) WS Washed Sample AR Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Definitions of Penetration Resistance

Standard penetration resistance 'N' – The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 76 cm.

Dynamic penetration resistance – The number of blows required to advance a 50 mm, 60 degree cone, fitted to the end of drill rods, 30 cm into the subsoil, the driving energy being 474.5 Joules per blow.

INSTRUMENTATION INSTALLATION

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section.

WATER LEVEL

Water levels, if measured during fieldwork, are plotted in the depth/elevation column. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors. Other information includes the depth of borehole cave-in, if any. This information is also included in the borehole log footer.

COMMENTS

This column is used to describe non-standard situations or notes of interest.

GENERAL REPORT NOTE

The soil conditions, profiles, comments, conclusions and recommendations found in this report are based upon the samples recovered during the fieldwork. Soils are heterogeneous materials and, consequently, variations (possibly extreme) may be encountered at site locations away from boreholes. During construction, competent, qualified inspection personnel should verify that no significant variations exist from the conditions described in this report.

Rev. date: January 7, 2019

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MTO SOIL CLASSIFICATION Based on MTO Soil Classification Manual



MAJOR DIVISION						GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SPOILS	LABORATORY CLASSIFICATION CRITERIA				
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVEL (TRACE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES		GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GIVE TYPE, NAME, IF NECESSARY INDICATE APPROX % OF SAND & GRAVEL, MAX SIZE, ANGULARITY, SURFACE CONDITION & HARDNESS OF THE COARSE GRAINS, LOCAL OR GEOLOGICAL NAME, OTHER PERTINENT DESCRIPTIVE INFORMATION & SYMBOL IN PARENTHESIS	FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITION & DRAINAGE CHARACTERISTICS	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 4				
			PREDOMINANTLY ONE SIZE OR RANGE OR SIZES WITH SOME INTERMEDIATE SIZES MISSING		GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES			$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3				
		GRAVEL WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION SEE ML BELOW)		GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES			NOT MEETING ALL GRADATION REQUIREMENTS FOR GW				
			PLASTIC FINES (FOR IDENTIFICATION SEE CL BELOW)		GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES							
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SAND (TRACE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNT OF ALL INTERMEDIATE PARTICLE SIZES		SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES			NOT MEETING ALL GRADATION REQUIREMENTS FOR GW				
			PREDOMINANTLY ONE SIZE OR RANGE OF SIZES WITH SOME INTERMEDIATE SIZES MISSING		SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES							
		SAND WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION SEE ML BELOW)		SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES			ATTERBERG LIMITS BELOW A-LINE OR I_p LESS THAN 4	ABOVE A-LINE WITH I_p BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS			
			PLASTIC FINES (FOR IDENTIFICATION SEE CL BELOW)		SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES							
IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425 µm													
FINE GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILT AND CLAYS	LIQUID LIMIT LESS THAN 35	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)								
			NONE	QUICK	NONE	ML							
			MEDIUM TO HIGH	NONE TO VERY SLOW	MEDIUM	CL							
			SLIGHT TO MEDIUM	SLOW	SLIGHT	OL							
		LIQUID LIMIT BETWEEN 35 AND 50	NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	MI							
			HIGH	NONE TO VERY SLOW	MEDIUM TO HIGH	CI							
			SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI							
			SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH							
		LIQUID LIMIT GREATER THAN 50	HIGH TO VERY HIGH	NONE	HIGH	CH							
			MEDIUM TO HIGH	NONE TO VERY SLOW	SLIGHT TO MEDIUM	OH							
HIGH ORGANIC SOILS			READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE		Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	ATTERBERG LIMITS ABOVE A-LINE WITH I_p GREATER THAN 7						

DETERMINE PERCENTAGE OF GRAVEL & SAND FROM GRAIN SIZE CURVE

DEPENDENT ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS:

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL

LESS THAN 5%:

GW, SP, SW, SP

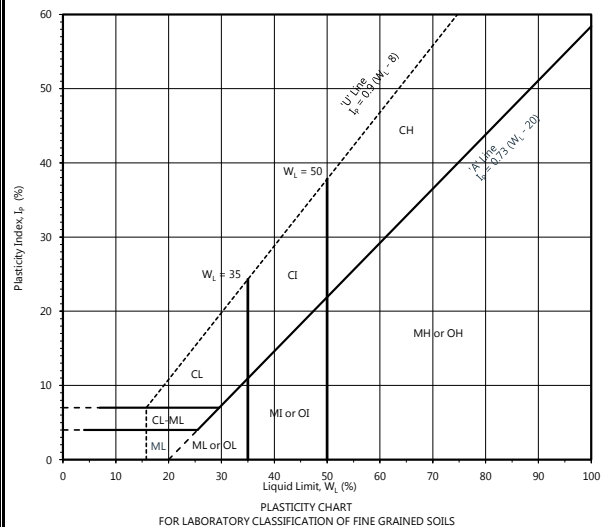
MORE THAN 12%:

GM, GC, SM, SC

5% TO 12%:

BORDERLINE CASES

REQUIRE USE OF DUAL SYMBOL



FRACTION	U.S. STANDARD SIEVE SIZE			DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
		PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL	COARSE	75 mm	26.5 mm	40 - 50	AND
	FINE	26.5 mm	4.75 mm		
SAND	COARSE	4.75 mm	2.00 mm	30 - 40	Y/EY
	MEDIUM	2.00 mm	425 µm	20 - 30	WITH
	FINE	425 µm	75 µm	10 - 20	SOME
				1 - 10	TRACE
FINES (SILT OF CLAY, BASED ON PLASTICITY)			75 µm		
OVERSIZED MATERIAL					
ROUNDED OR SUBROUNDED: COBBLES 75 mm TO 200 mm BOULDERS > 200 mm			NOT ROUNDED: ROCK FRAGMENTS > 75 mm ROCKS > 0.76 CUBIC METRE IN VOLUME		

BOUNDARY CLASSIFICATION:

SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS FOR EXAMPLE GW-GC
WELL GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER

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BEDROCK DESCRIPTION



ROCK QUALITY DESIGNATION

The Rock Quality Designation (RQD) is an indirect measure of the number of natural fractures in a rock mass. It is obtained from the rock cores by summing up the length of core pieces of sound rock that are 100 mm or more in length, measured from the midpoint to midpoint of adjacent natural fractures. Note, a natural fracture that is parallel to the core axis should be ignored so that the RQD is not affected. The RQD value is expressed as a percentage of the summed core lengths (100 mm or greater) to the total core length.

RQD originally specified the use of NW core (54 mm diameter). The technique can be used on different core sizes, if the bulk of the fractures caused by drilling stress and handling can be distinguished from in situ fractures which tend to have some form of joint infill (typically calcite and chlorite being the most common). However, smaller core is more susceptible to breaking; hence, smaller core in a rock mass with little joint infill in which natural fractures are hard to distinguish can produce a less accurate measure of RQD. It is generally accepted that the RQD is applicable to NQ core size (45 mm).

SOLID CORE RECOVERY

Solid Core Recovery (SCR) is defined as the percentage of intact cylindrical core pieces to the total length of core.

TOTAL CORE RECOVERY

Total Core Recovery (TCR) is defined as the percentage of intact core pieces to the total length of core.

STRENGTH CLASSIFICATION

Term (Grade)	Field Identification	Approximate Range of Uniaxial Compressive Strength (MPa)
Extremely Weak (R0)	Indented by thumbnail.	0.25 – 1.0
Very Weak (R1)	Crumbles under firm blows with point of geological hammer; can be peeled by a pocket knife.	1.0 – 5.0
Weak (R2)	Can be peeled with a pocket knife with difficulty; shallow indentations made by firm blow with point of geological hammer.	5.0 – 25
Medium Strong (R3)	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with a single firm blow of geological hammer.	25 – 50
Strong (R4)	Specimen requires more than one blow of geological hammer to fracture it.	50 – 100
Very Strong (R5)	Specimen requires many blows of geological hammer to fracture it.	100 – 250
Extremely Strong (R6)	Specimen can only be chipped with geological hammer.	> 250

JOINT SPACING CLASSIFICATION

Term	Average Joint Spacing (m)
Extremely Close	< 0.02
Very Close	0.02 – 0.06
Close	0.06 – 0.20
Moderately Close	0.2 – 0.6
Wide	0.6 – 2.0
Very Wide	2.0 – 6.0
Extremely Wide	> 6.0

ROCK QUALITY CLASSIFICATION

Rock Quality Designation, RQD (%)	Description of Rock Quality
0 – 25	Very Poor
25 – 50	Poor
50 – 75	Fair
75 – 90	Good
90 – 100	Excellent

Reference: Deere et al, 1967

WEATHERING CLASSIFICATION

Term (Grade)	Description
Fresh (W1)	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces.
Slightly Weathered (W2)	Discoloration indicates weathering of rock material on discontinuity surfaces. Less than 5% of rock mass altered.
Moderately Weathered (W3)	Less than half of the rock material is decomposed and/or disintegrated into a soil. Fresh or discoloured rock is present either as a continuous framework or as core stones.
Highly Weathered (W4)	More than half of the rock material is decomposed and/or disintegrated into a soil. Fresh or discoloured rock is present either as a discontinuous framework or as core stones.
Completely Weathered (W5)	All rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil (W6)	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume but the soil has not been significantly transported.

Reference: Brown, 1981, "Suggested Methods for Rock Characterization Testing and Monitoring". International Society for Rock Mechanics.

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RECORD OF BOREHOLE No. BH19-1

1 OF 2

G.W.P. 4075-13-00 LOCATION E: 393 124.0 N: 5 125 802.5 (MTM Zone 10) ORIGINATED BY KC
 DIST Ontario HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY KC
 DATUM Geodetic DATE May 14, 2019 CHECKED BY NR
 PROJECT Barbut Creek Culvert, Renfrew County, ON JOB NO. TPB196039

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa									
									20 40 60 80 100									
157.5	About 150 mm ASPHALT																	
157.3	Dark brown to light brown FILL - GRAVELLY SAND some silt, trace cobble / boulders, moist		1	SS	83 for 200 mm		157										REC = 85% Cobble / boulders was inferred from augering REC = 75%	
156.0	Light brown to dark brown FILL - SAND / SILTY SAND trace to some gravel, trace clay and cobble / boulders, moist		2	SS	54		1										REC = 75% 1 59 33 7 REC = 20% REC = 100%	
156.0			3	SS	38		2											
155.0			4	SS	50		3											
153.8	Dark brown to light brown FILL - GRAVELLY SAND some silt, trace cobble / boulders, moist		5	SS	50		4										REC = 42%	
153.8			6	SS	63		5										REC = 54%	
151.4	Dark brown ORGANICS / PEAT trace silt and clay, moist		7	SS	31		6										REC = 25%	
151.1	Light brown and light grey SILTY CLAY trace organics, very soft		8	SS	21		7										REC = 92%	
150.7	Dark grey TILL - SAND / SILTY SAND trace to some gravel, trace clay and cobble / boulders, loose to very dense, wet		9	SS	2		8										Groundwater inferred from soil conditions during drilling REC = 17%	
150.7			10	SS	9		9										REC = 63%	
149.0			11	SS	12		10										16 68 14 2 REC = 67%	
148.0			12	SS	38		11										REC = 83%	
148.0			13	SS	34		12										Started adding water inside of	

Continued Next Page

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

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

RECORD OF BOREHOLE No. BH19-2

G.W.P. 4075-13-00	LOCATION E: 393 118.2 N: 5 125 815.9 (MTM Zone 10)	1 OF 2	ORIGINATED BY KC
DIST Ontario HWY 17	BOREHOLE TYPE HQ Core	COMPILED BY KC	
DATUM Geodetic	DATE May 15, 2019	CHECKED BY NR	
PROJECT Barbut Creek Culvert, Renfrew County, ON		JOB NO. TPB196039	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa										WATER CONTENT (%)		
									<div><div>○ UNCONFINED</div><div>● QUICK TRIAXIAL</div><div>+ FIELD VANE</div><div>× LAB VANE</div></div>										<div><div>W_P</div><div>W</div><div>W_L</div></div>		
157.6						20	40	60	80	100	20	40	60								
0.0	CORE WITH WATER AND WITHOUT SOIL SAMPLING																				
153.0	Light brown to dark grey FILL - SAND and GRAVEL trace fines, wet		1	SS	13											REC = 46%					
4.6																	REC = 0%				
			2	SS	33													52 44 (4) REC = 25%			
																		REC = 0%			
149.9	Grey SAND and SILT trace gravel, wet		5	SS	15											REC = 23%					
7.6																		A SPT was not performed at 8.4 m as it was in cobble/boulders			
149.0	Dark grey to grey TILL - SAND / SILTY SAND trace to some gravel, trace clay and cobble/boulders, very dense, moist to wet																REC = 0%				
8.5			6	SS	153																

Continued Next Page

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

G.W.P. 4075-13-00	LOCATION E: 393 118.2 N: 5 125 815.9 (MTM Zone 10)	2 OF 2	ORIGINATED BY KC
DIST Ontario HWY 17	BOREHOLE TYPE HQ Core		COMPILED BY KC
DATUM Geodetic	DATE May 15, 2019		CHECKED BY NR
PROJECT Barbut Creek Culvert, Renfrew County, ON			JOB NO. TPB196039

[illegible]

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

RECORD OF BOREHOLE No 501

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 790.3 E 393 113.8 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.27 - 2015.10.27 CHECKED BY KP

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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
154.0																				
0.0	Sand with silt and gravel Loose to dense Brown FILL		1	SS	8											37 53 10 (SI+CL)				
			2	SS	12															
			3	SS	8															
			4	SS	9															
			5	SS	31															
150.9																				
3.0	Silty SAND (SM) some gravel, TILL Very dense Grey - frequent cobbles and boulders		6	SS	76											11 53 36 (SI+CL)				
			7	SS	107															
			8	SS	100/															
149.3																				
4.6	End of Borehole Splitspoon refusal on inferred boulder Groundwater level was measured in piezometer at 2.1 m BGS (elev. 152.3 m) on 2015/12/15				75mm															

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 502

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 810.6 E 393 113.7 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.15 - 2015.10.15 CHECKED BY KP

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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
157.7																			
0.0	115 mm ASPHALT																		
0.1	Sand with gravel - frequent cobbles Very dense Brown		1	SS	55		157									37 63 0 (SI+CL)			
156.8	FILL		2	SS	100/ 225mm														
0.9	Gravel with sand trace silt - frequent cobbles and boulders Compact to very dense Brown ROCK FILL		3	SS	50		156												
			4	SS	89		155									60 36 4 (SI+CL)			
			5	SS	15														
			6	SS	14		154												
			7	SS	18		153												
152.3			8	SS	100/ 25mm														
5.4	End of Borehole Splitspoon refusal on inferred boulder																		

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

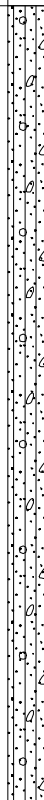
METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

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			20 40 60 80 100	W P W L		
	Continued From Previous Page						SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	WATER CONTENT (%) 20 40 60		GR SA SI C	

Estimated from Test Log Page					
	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		13 SS 67		
			14 SS 100/ 0mm		
			15 SS 73		
			16 SS 100/ 0mm		
142.2	End of Borehole				
15.3	Splitspoon refusal on inferred boulder				

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 504

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 822.7 E 393 124.4 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015/10/26. - 2015/10/26. CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			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							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)							
154.4							20 40 60 80 100												
0.0	25 mm TOPSOIL																		
	Sand with silt and gravel Very loose to compact Brown FILL		1	SS	2														
			2	SS	4														
			3	SS	13														
			4	SS	12														
			5	SS	9														
	- Grey below 3 m		6	SS	5														
150.5																			
3.9	PEAT , trace wood pieces Brown to black - saturated		7	SS	15														
			8	SS	10														
149.6																			
4.9	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact Grey - Casing refusal on inferred boulder Advanced DCPT from 5.5 m to 6.0 m		9	SS	23														
148.4																			
6.0	End of Borehole DCPT Resulsal on inferred boulder																		

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 505

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.26 - 2017.06.27 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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					
								20 40 60 80 100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
				WATER CONTENT (%)				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _P W W _L					
157.9													
0.0	120 mm ASPHALT												
0.1	Sand with silt and gravel - occasional cobbles Very dense Brown FILL		1	AS									28 63 9 (SI+CL)
156.7			2	SS	100/ 175mm								
1.2	Sand with silt and gravel - frequent cobbles and boulders Compact to very dense Brown ROCK FILL		3	SS	49								23 69 8 (SI+CL)
	- switch to HW casing		4	SS	48								
	- cobbles - 240 mm boulder at 2.9 m		5	SS	34								
	- 120 mm cobble at 3.7 m		6	SS	23								
			7	SS	12								
	- cobbles		8	SS	14								
	- 120 mm cobble at 5.8 m		9	SS	20								
151.0													
6.9 150.7	PEAT with sand and gravel, trace wood		10	SS	100/ 275mm							107	27 30 34 9 20% organic content
7.2	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey - 210 mm boulder at 7.3 m		11	SS	79								

Continued Next Page

+ ³ , × ³ : Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

ELEV. DEPTH	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 (%)	
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								W P ——— W ——— W L WATER CONTENT (%)
								20	40				
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
								20 40 60 80 100 20 40 60 80 100					

[illegible]

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 506

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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					
								20 40 60 80 100					
								20 40 60 80 100					
157.3													
0.0	120 mm ASPHALT												
0.1	Sand with gravel - occasional cobbles Very dense Brown FILL		1	AS									39 56 5 (SI+CL)
			2	SS	70								
156.1													
1.2	Sand with silt and gravel - frequent cobbles Compact to very dense Brown ROCK FILL		3	SS	71								
	-switch to HW casing												
			4	SS	56								42 50 8 (SI+CL)
	- cobbles												
			5	SS	41								
			6	SS	16								
	- cobbles		7	SS	100/ 250mm								
151.9													
5.3	SILT (ML), trace organics Loose Grey		8	SS	5								0 11 69 20
151.2													
6.1	PEAT, trace wood		9	SS	3								54% organic content
150.9													
6.4	SILT (ML), trace organics Very loose Grey												
150.3													
7.0	Silty SAND (SM) with gravel, TILL - occasional to frequent cobbles Compact to very dense Grey		10	SS	15								
			11	SS	110								12 58 30 (SI+CL)
			12	SS	100/ 180mm								

Continued Next Page


+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 506

2 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

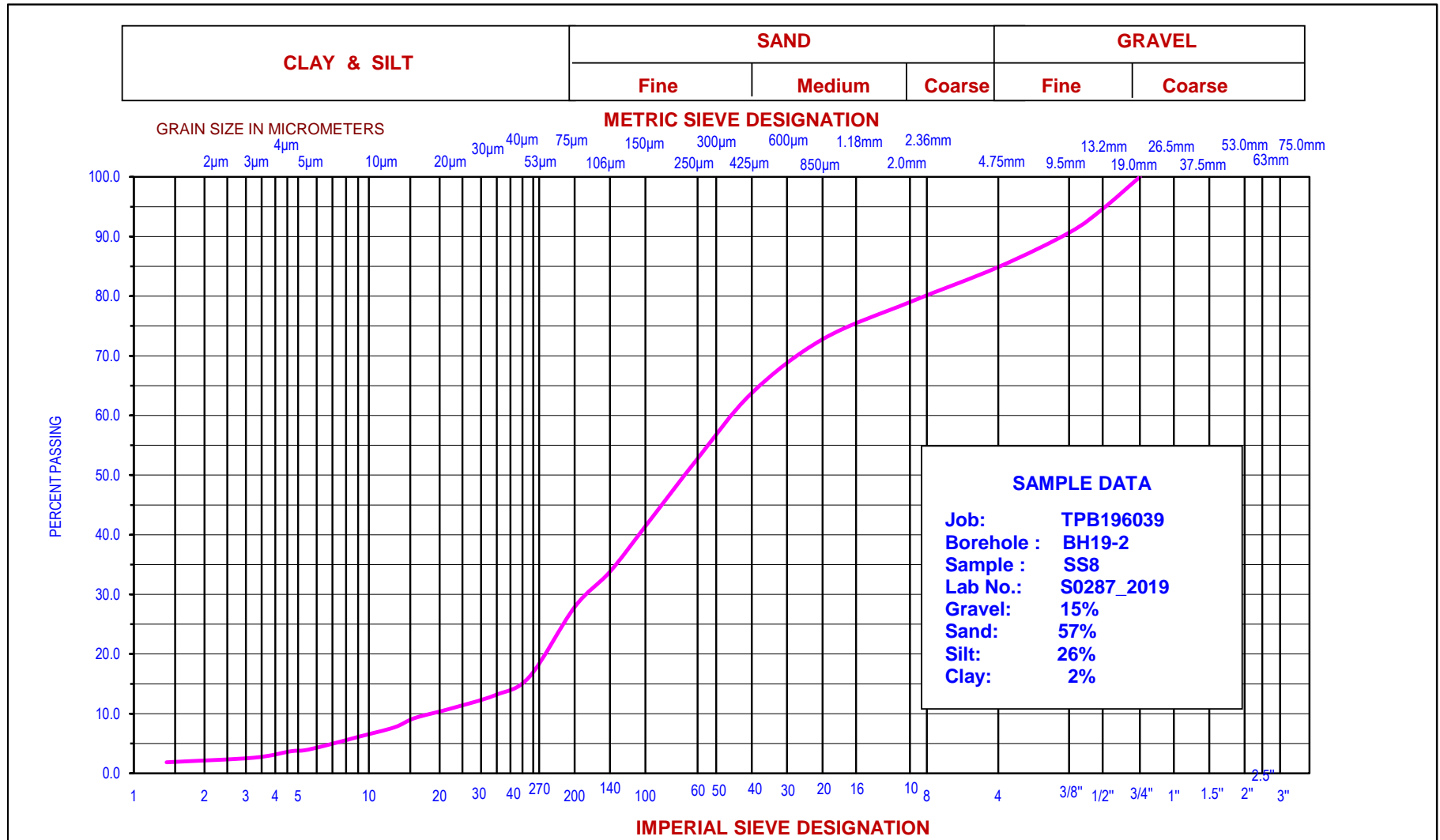
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
146.4	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		13	SS	100/		147										
10.9	End of Borehole				230mm												

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

Appendix B

Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM



Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited 50 Vogell Road, Units 3 & 4, Richmond Hill, Ontario Canada L4B 3K6 Tel. (905) 415-2632, Fax (647) 689-4876 www.woodplc.com	GRAIN SIZE DISTRIBUTION		Client :- Looby Construction Limited	
			Project:- MTO DB Hwy 17 Culvert Replacement	
	SILTY SAND some gravel		Location:- Hwy 17, Ontario	
			Lab No. :- S0287_2019	Date :- 28 May 2019

Grain Size Analysis

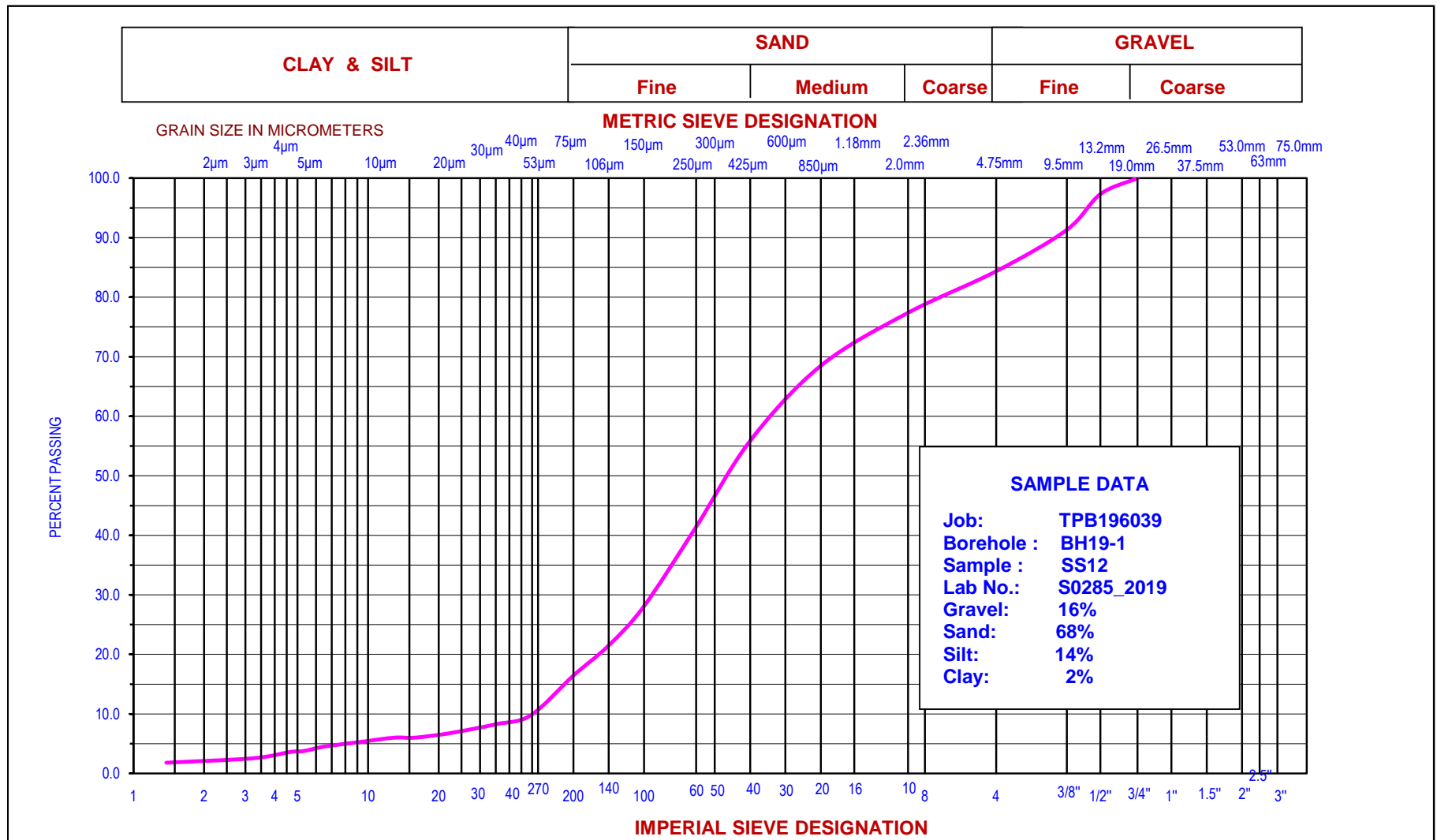
Project:- MTO DB Hwy 17 Culvert Replacement
Client :- Looby Construction Limited
Job# :- TPB196039
Borehole # :- BH19-2
Lab No. :- S0287_2019

Location:- Hwy 17, Ontario
Date :- 28-May-19
Tested By :- DB/WA
Sample # :- SS8
Checked By :- SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
19	0.00	100.0
13.2	17.28	94.6
9.5	30.13	90.6
4.75	48.67	84.9
2.00	67.57	79.0
0.85		72.8
0.425		63.8
0.25		52.8
0.150		41.4
0.106		33.8
0.0750		27.9
0.0482		16.2
0.0345		13.1
0.0220		10.8
0.0156		9.3
0.0128		7.7
0.0091		6.2
0.0065		4.6
0.0053		3.9
0.0047		3.7
0.0033		2.6
0.0014		1.9

Total Wt. (g)		322.33
Wt used for Hydrometer (g)		
50.66		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.850	4.00	92.1%
0.425	9.78	80.7%
0.250	16.83	66.8%
0.150	24.10	52.4%
0.106	28.99	42.8%
0.075	32.79	35.3%
Pan	34.35	

UNIFIED SOIL CLASSIFICATION SYSTEM



Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited 50 Vogell Road, Units 3 & 4, Richmond Hill, Ontario Canada L4B 3K6 Tel. (905) 415-2632, Fax (647) 689-4876 www.woodplc.com	GRAIN SIZE DISTRIBUTION		Client :- Looby Construction Limited	
			Project:- MTO DB Hwy 17 Culvert Replacement	
	SAND some silt and gravel		Location:- Hwy 17, Ontario	
			Lab No. :- S0285_2019	Date :- 28 May 2019

Grain Size Analysis

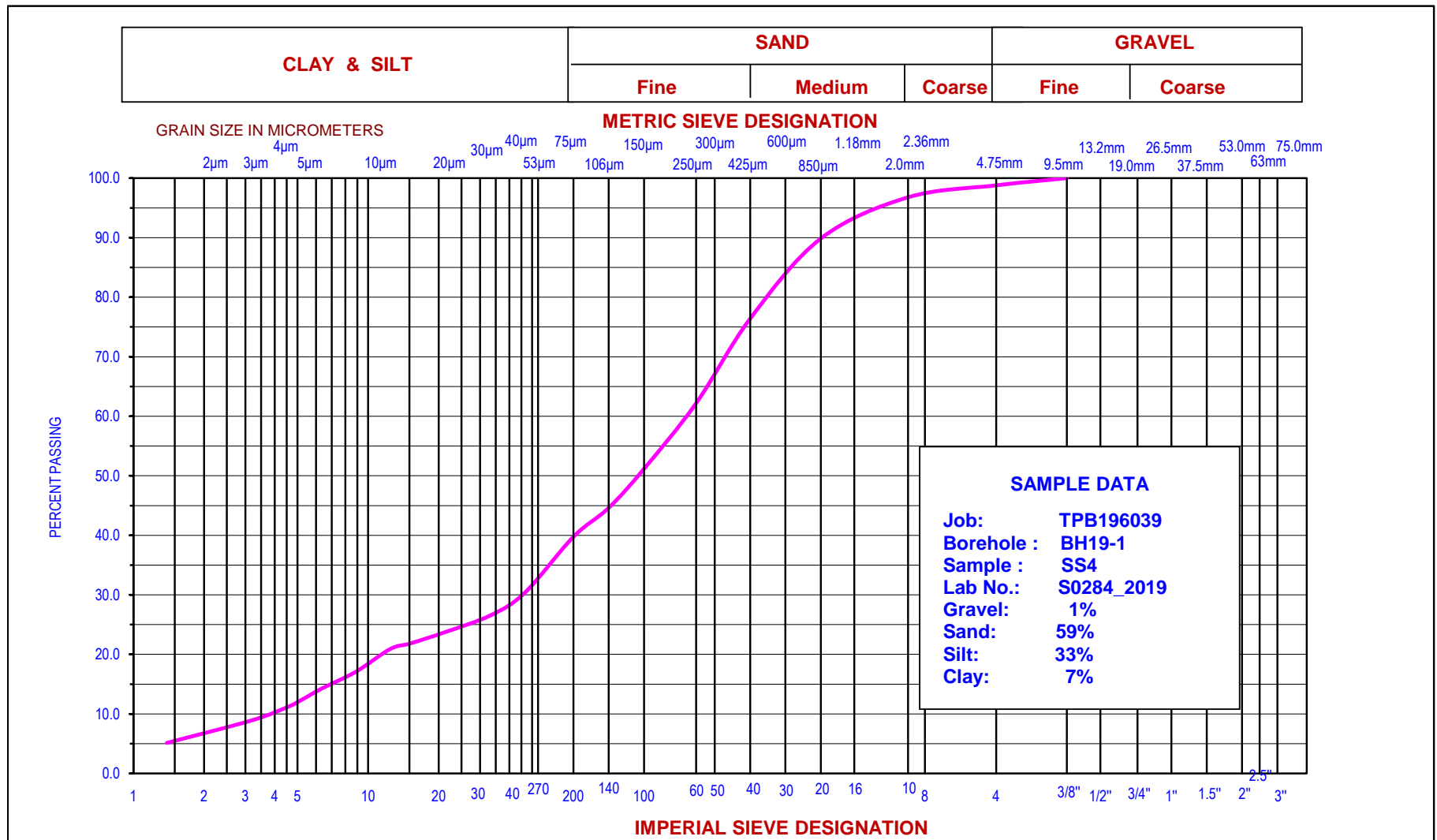
Project:- MTO DB Hwy 17 Culvert Replacement
Client :- Looby Construction Limited
Job# :- TPB196039
Borehole # :- BH19-1
Lab No. :- S0285_2019

Location:- Hwy 17, Ontario
Date :- 28-May-19
Tested By :- DB/WA
Sample # :- SS12
Checked By :- SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
19	0.00	100.0
13.2	8.23	97.3
9.5	26.53	91.3
4.75	47.79	84.4
2.00	69.10	77.4
0.85		68.5
0.425		55.9
0.25		41.4
0.150		28.1
0.106		21.5
0.0750		16.4
0.0494		9.8
0.0351		8.3
0.0223		6.8
0.0158		6.0
0.0129		6.0
0.0092		5.3
0.0065		4.5
0.0053		3.8
0.0047		3.6
0.0033		2.6
0.0014		1.8

Total Wt. (g)		305.88
Wt used for Hydrometer (g)		
50.89		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.850	5.85	88.5%
0.425	14.14	72.2%
0.250	23.65	53.5%
0.150	32.41	36.3%
0.106	36.76	27.8%
0.075	40.08	21.2%
Pan	41.45	

UNIFIED SOIL CLASSIFICATION SYSTEM



Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited 50 Vogell Road, Units 3 & 4, Richmond Hill, Ontario Canada L4B 3K6 Tel. (905) 415-2632, Fax (647) 689-4876 www.woodplc.com	GRAIN SIZE DISTRIBUTION		Client :- Looby Construction Limited	
	SILTY SAND trace gravel and clay		Project:- MTO DB Hwy 17 Culvert Replacement	
			Location:- Hwy 17, Ontario	
			Lab No. :- S0284_2019	Date :- 28 May 2019

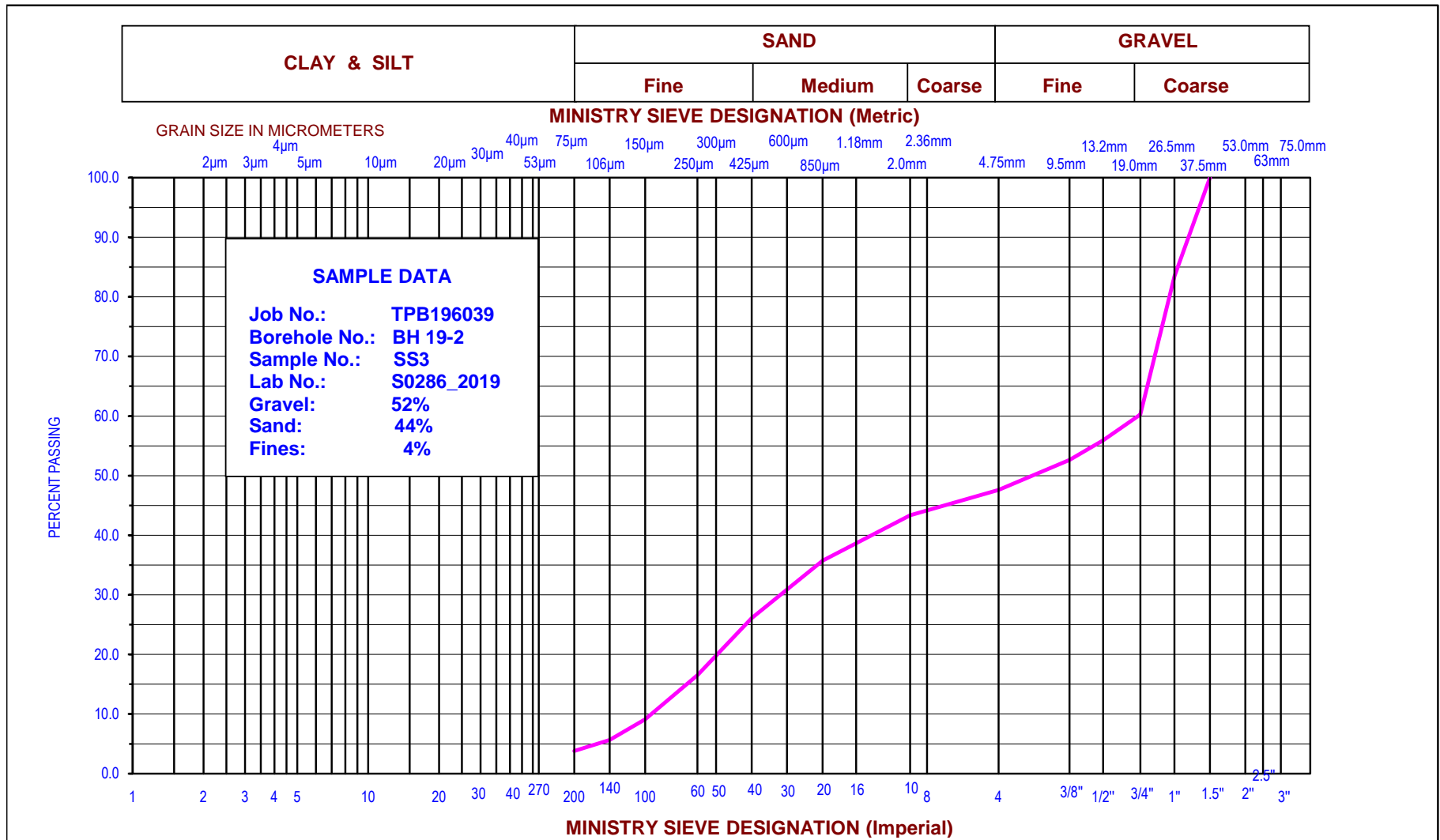
Grain Size Analysis

Project:- MTO DB Hwy 17 Culvert Replacement
Client :- Looby Construction Limited
Job# :- TPB196039
Borehole # :- BH19-1
Lab No. :- S0284_2019

Location:- Hwy 17, Ontario
Date :- 28-May-19
Tested By :- DB/WA
Sample # :- SS4
Checked By :- SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
9.5	0.00	100.0
4.75	0.82	98.8
2.00	2.18	96.8
0.85		89.9
0.425		76.4
0.25		62.2
0.150		51.2
0.106		44.6
0.0750		39.8
0.0466		30.4
0.0334		26.6
0.0213		23.7
0.0152		21.8
0.0124		20.9
0.0089		17.1
0.0063		14.2
0.0052		12.3
0.0046		11.2
0.0032		8.9
0.0014		5.1

Total Wt. (g)		67.97
Wt used for Hydrometer (g)		
50.39		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.850	3.60	92.9%
0.425	10.61	78.9%
0.250	18.01	64.3%
0.150	23.74	52.9%
0.106	27.16	46.1%
0.075	29.69	41.1%
Pan	30.05	



Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited 50 Vogell Road, Units 3 & 4, Richmond Hill, Ontario Canada L4B 3K6 Tel. (905) 415-2632, Fax (647) 689-4876 www.woodplc.com	GRAIN SIZE DISTRIBUTION		Client :- Looby Construction Limited	
			Project:- MTO DB Hwy 17 Culvert Replacement	
	SAND AND GRAVEL trace silt		Location:- Hwy 17, Ontario	
			Lab No. :- S0286_2019	Date :- 28 May 2019

Grain Size Analysis

Job# :- TPB196039
Project:- MTO DB Hwy 17 Culvert Replacement
Client :- Looby Construction Limited
Borehole # :- BH19-2
Sample ID # :- SS3

Date :- 28-May-19
Location:- Hwy 17, Ontario
Tested By :- DB
Lab No. :- S0286_2019
Checked By :- SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
37.50	0.00	100.0
26.5	38.30	83.5
19	92.05	60.3
13.20	102.11	55.9
9.5	109.65	52.7
4.75	121.32	47.6
2.00	131.22	43.3
0.85		35.7
0.425		26.1
0.250		16.5
0.150		9.1
0.106		5.6
0.075		3.8

Total Wt. (g)		231.58
FINES		
100.36 g		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.85	17.63	82.4%
0.425	39.95	60.2%
0.250	62.09	38.1%
0.150	79.28	21.0%
0.106	87.30	13.0%
0.075	91.55	8.8%
Pan	91.64	

**CLIENT NAME: WOOD ENVIRONMENT & INFRASTRUCTURE
50 VOGELL ROAD, UNIT 3&4
RICHMOND HILL, ON L4B 3K6**

ATTENTION TO: S.Baskaran

PROJECT: TPB196039

AGAT WORK ORDER: 19T472490

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Supervisor

DATE REPORTED: Jun 05, 2019

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 19T472490

PROJECT: TPB196039

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: WOOD ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: S.Baskaran

SAMPLING SITE:

SAMPLED BY:

Inorganic Chemistry

DATE RECEIVED: 2019-05-29

DATE REPORTED: 2019-06-05

		SAMPLE DESCRIPTION: BH19-1, SS13		BH19-2, SS1	
		SAMPLE TYPE: Soil		Soil	
		DATE SAMPLED: 2019-05-15		2019-05-15	
Parameter	Unit	G / S	RDL	227952	227971
Sulfide (S2-)	%		0.05	<0.05	<0.05
Sulphate (2:1)	µg/g		2	11	7
pH (2:1)	pH Units		NA	8.83	8.81
Resistivity (2:1)	ohm.cm		1	11000	5950
Redox Potential 1	mV		NA	257	254
Redox Potential 2	mV		NA	262	258
Redox Potential 3	mV		NA	267	260

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

227952-227971 pH, EC and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.

*Sulphide analyzed at AGAT 5623 McAdam

PI note: Redox Potential is not an accredited parameter.

Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:



Quality Assurance

CLIENT NAME: WOOD ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 19T472490

PROJECT: TPB196039

ATTENTION TO: S.Baskaran

SAMPLING SITE:

SAMPLED BY:

Soil Analysis

RPT Date: Jun 05, 2019			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Inorganic Chemistry															
Sulfide (S2-)	227952	227952	< 0.05	< 0.05	NA	< 0.05	97%	80%	120%						
Sulphate (2:1)	225395		43	43	0.0%	< 2	106%	80%	120%	101%	80%	120%	109%	70%	130%
pH (2:1)	227293		7.80	7.79	0.1%	NA	99%	90%	110%	NA			NA		
Redox Potential 1	1						99%	90%	110%						

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL

Certified By:




Method Summary

CLIENT NAME: WOOD ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 19T472490

PROJECT: TPB196039

ATTENTION TO: S.Baskaran

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulfide (S ²⁻)	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H ⁺ B	PH METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE

Appendix C

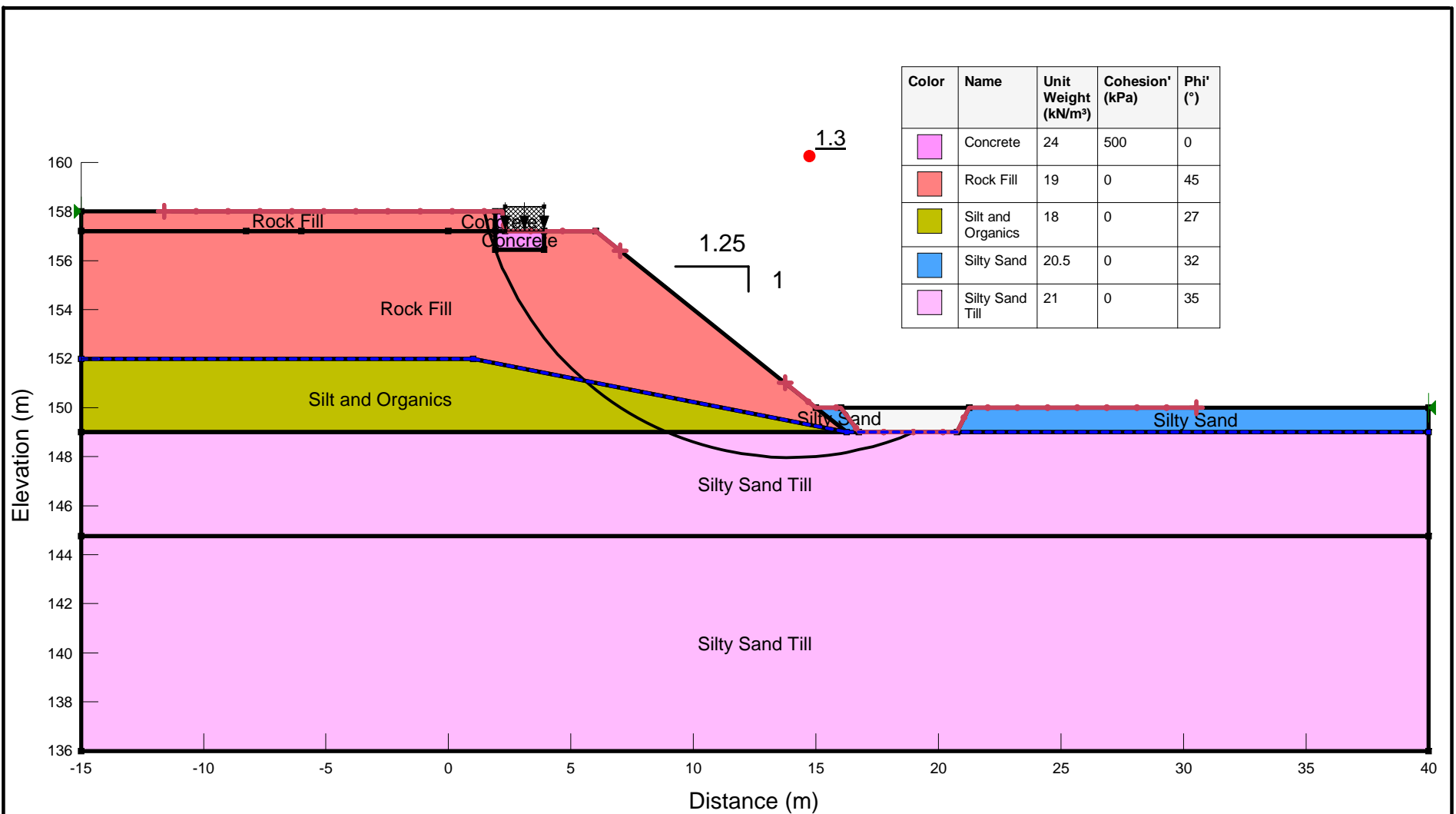
General Arrangement Drawing of Barbut Creek Culvert



Appendix D

Slope Stability Analysis Results

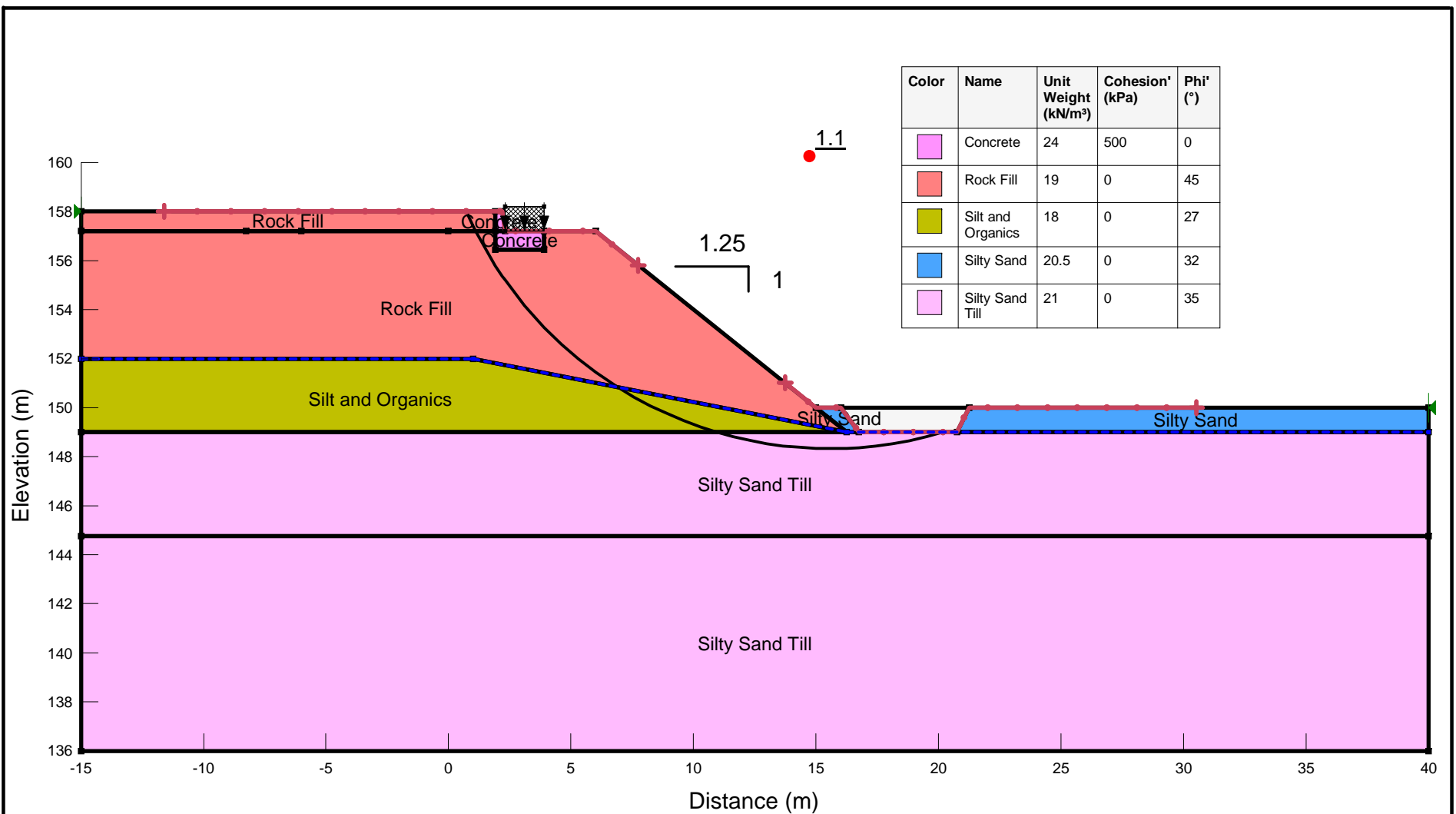




Title: Barbut Culvert_Stage I_Excavation_Static

Figure 1: Stage I - Excavation

Wood Environmental & Infrastructure Solutions,
a Division of Wood Canada Limited



Title: Barbut Culvert_Stage I_Excavation_Seismic

Figure 2: Stage I - Excavation

Wood Environmental & Infrastructure Solutions,
a Division of Wood Canada Limited