



FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 65, Station 14+480, Township of Barber Culvert Replacement Ministry of Transportation, Ontario GWP 5204-14-00

Submitted to:

AECOM Canada Ltd.

189 Wyld Street, Suite 103
North Bay, ON, P1B 1Z2

Submitted by:

Golder Associates Ltd.

33 Mackenzie Street, Suite 100
Sudbury, Ontario, P3C 4Y1, Canada
+1 705 524 6861

1896349-R06

August 6, 2019

GEOCRES NO: 41P-81

LAT: 47.660009

LONG: -80.182193



Distribution List

1 Copy + 1 PDF Copy: Ministry of Transportation, Ontario (NE Region)

1 Copy + 1 PDF Copy: Ministry of Transportation, Ontario (Foundations)

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 65, STA 14+480, TOWNSHIP OF BARBER
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert under Highway 65 at Station 14+480, approximately 1.1 km west of the Highway 65 intersection with Barber Cane Township Road, in the Township of Barber, Ontario. The Key Plan of the general location of this section of Highway 65 and the location of the investigated area are shown on Drawing 1.

The purpose of this exploration is to establish the subsurface conditions at the culvert replacement site by borehole drilling, with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of services for the foundation investigation are outlined in MTO's Request for Proposal, dated February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for his project dated November 2018.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on Drawing 1. For the purpose of this report, Highway 65 is oriented in a west-east direction with the culvert positioned north-south, perpendicular to the highway. At the culvert location the creek flows in a north-south direction.

The existing culvert consists of a 1.2 m diameter, 24 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 288.4 m and 288.1 m, respectively. In general, the topography in the vicinity of the culvert consists of relatively flat terrain, with the Montreal River flowing easterly about 1.9 km south of Highway 65. At the culvert location, the highway grade is approximately Elevation 291.3 m and the embankments are approximately 3.2 m high relative to the culvert invert. The ground surface conditions at select locations in the culvert area are shown on Photographs 1 to 3.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out between November 17 and 24, 2018 and on January 22, 2019, during which time three boreholes (Boreholes C27-1 to C27-3) were advanced at approximate locations shown on Drawing 1. One borehole was advanced through the roadway embankment using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling of Grenville-Sur-La-Rouge, Quebec. Two boreholes were advanced near the toes of the highway embankment slopes adjacent to the culvert inlet/outlet using a portable tripod drilling rig supplied and operated by George Downing Estate Drilling and Landcore Drilling from Sudbury, Ontario. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Borehole C27-1 was advanced using 108 mm I.D. Hollow Stem Augers and NW casing with wash boring techniques and Boreholes C27-1 and C27-2 were advanced with NW casing with wash boring techniques. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic hammer (Borehole C27-1) or half weight hammer (Boreholes C27-2 and C27-3) in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

The SPT “N”-values obtained using the half weight hammer were adjusted to the inferred values that would have been obtained using a standard weight (63.6 kg) hammer. The groundwater level inside the augers/casing was observed during the drilling operations. The boreholes were backfilled in accordance with Ontario Regulation 903. The roadway surface at the borehole drilled through Highway 65 was sealed using cold patch asphalt.

Field work was supervised on a full-time basis by a member of Golder’s technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder’s geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable.

The as-drilled borehole locations were measured relative to highway chainages/stations marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevations at the borehole locations were surveyed relative to the highway and culvert centreline, with the elevation of the roadway centreline provided by AECOM. The MTM NAD83-CSRS CBN v6-2010.0 (Zone 12) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

| Borehole Number | MTM NAD 83 Northing (m) [Latitude] | MTM NAD 83 Easting (m) [Longitude] | Ground Surface Elevation (m) | Borehole Depth (m) |
|-----------------|--|--|------------------------------------|-----------------------|
| C27-1 | 5280426.0 (47.660063) | 366224.1 (-80.182178) | 291.3 | 20.4 |
| C27-2 | 5280436.1 (47.660154) | 366220.2 (-80.182228) | 289.4 | 9.8 |
| C27-3 | 5280407.8 (47.659901) | 366222.6 (-80.182201) | 289.4 | 9.8 |

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the culvert site is located within a glaciolacustrine plain and the subsoils reportedly consist of clay and sand.

Based on geological mapping (MNDM)², the site is underlain by siltstone, argillite, sandstone and conglomerate.

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE

² Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the record of borehole governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt/Fill

A layer of asphalt (pavement) approximately 100 mm thick was encountered in roadway Borehole C27-1 at Elevation 291.3 m. Underlying the surface asphalt, the borehole penetrated a 180 mm thick layer of sand and gravel fill, a further 100 mm thick layer of asphalt, and a 2.7 m thick layer of embankment fill comprised of a layer of sand and gravel (0.2 m thick), sand (1.7 m thick) and silt (0.8 m thick).

The SPT “N”-values measured within the sand and the silt layers of fill range between 8 blows and 32 blows per 0.3 m of penetration, indicating a loose to dense compactness condition.

4.2.2 Peat

An approximately 0.8 m thick layer of black fibrous peat was encountered in Borehole C27-2 at ground surface, at Elevation 289.4 m.

One SPT “N”-value measured within the fibrous peat is 1 blow per 0.3 m of penetration, indicating a very soft consistency.

4.2.3 Clayey Silt

An approximately 0.8 m thick deposit of clayey silt, containing trace organics, was encountered in Borehole C27-3 at ground surface, at Elevation 289.4 m.

One SPT “N”-value measured with the clayey silt deposit is 2 blows per 0.3 m of penetration, indicating a very soft consistency.

4.2.4 Silty Sand

An approximately 0.7 m thick deposit of silty sand, containing trace organics, was encountered in Borehole C27-2 below the fibrous peat, at Elevation 288.6 m.

One SPT “N”-value measured with the silty sand deposit is 6 blows per 0.3 m of penetration, indicating a loose compactness condition.

4.2.5 Silt

A non-cohesive deposit of silt with clay layers/seams/laminations was encountered in Boreholes C27-1, C27-2 and C27-3 between Elevations 288.6 m and 287.9 m. The upper approximately 0.7 m thick zone of the deposit contains trace organics/wood in Borehole C27-3. The overall thickness of the deposit is 13.4 m in Borehole C27-1 where it was fully penetrated. The deposit was not fully penetrated in Boreholes C27-2 and C27-3 after exploring the deposit for 8.3 m and 9.0 m, respectively.

The SPT “N”-values measured within the silt deposit range from 5 blows to 22 blows per 0.3 m of penetration, indicating a loose to compact compactness condition.

Grain size distribution analysis was carried out on ten samples of the silt deposit and the results are presented on Figure B-1 in Appendix B. Atterberg limits tests was carried out on seven silt samples of the deposit: five samples were determined to be non-plastic; and two samples yielded liquid limits of about 21 per cent, plastic limits of about 16 per cent and 17 per cent and plasticity indices of about 4 per cent and 5 per cent. The results of the two Atterberg limit tests are presented on Figure B-2 in Appendix B and together with the six non-plastic results indicate the overall deposit is comprised of silt to silt of slight plasticity. The natural moisture content measured on samples of the deposit ranges from 22 per cent to 30 per cent.

4.2.6 Silty Sand and Gravel (Till)

A silty sand and gravel till deposit was encountered in Borehole C27-1, at Elevation 274.8 m. Cobbles are inferred within the deposit from grinding of the augers. Borehole C27-1 was terminated within the silty sand and gravel till deposit after penetrating 3.9 m into the deposit.

The SPT “N”-values measured within the silty sand and gravel till deposit range from 33 blows to 42 blows per 0.3 m of penetration indicating a dense compactness condition.

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface, measured in the augers/casing upon completion of drilling, are summarized below. The top of the frozen creek surface at the culvert outlet, as surveyed by Golder on November 24, 2018, was about Elevation 289.4 m. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

| Borehole No. | Depth to Unstabilized Groundwater Level (m) | Approximate Groundwater Elevation (m) |
|--------------|---|---------------------------------------|
| C27-1 | 2.3 | 289.0 |
| C27-2 | 0.0 | 289.4 |
| C27-3 | 0.1 | 289.3 |

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a soil sample recovered from immediately below the embankment fill in Borehole C27-1. The soil sample was submitted to Maxxam Analytics of Sudbury, Ontario for testing a suite of parameters associated with potential corrosion to steel and deterioration of concrete. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

| Borehole No. | Sample No. | Depth (m) (Elev. m) | Parameters | | | | | |
|--------------|------------|----------------------------|-------------------------|---|---|-------------------------------|-------------------------------|------|
| | | | Resistivity (ohm-cm) | Electrical Conductivity (µmho-cm) | Soluble Sulphate (SO ₄) Content (µg-g) | Sulphide Content (µg-g) | Chloride Content (µg-g) | pH |
| C27-1 | 5 | 3.1 – 3.7 288.2 – 287.6 | 2000 | 508 | <20 ¹ | <0.55 | 250 | 7.54 |

Note:

1. The sulphate concentration is below the reportable detection limit of 20 µg/g.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mat Riopelle, under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Michael Bentley, and Mr. André Bom, P.Eng. provided a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

Golder Associates Ltd.



Michael Bentley, M.A.Sc.
Geotechnical Group



André Bom, P.Eng.
Senior Geotechnical Engineer



Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

MJB/AB/JMAC/sb

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 65, STA 14+480, TOWNSHIP OF BARBER
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert crossing Highway 65 at about Station 14+480, approximately 1.1 km west of the Highway 65 intersection with Barber Cane Township Road, in the Township of Barber, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to design the proposed replacement culvert. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 Proposed Culvert Alignment and Installation Options

The existing culvert consists of a 1.2 m diameter, 24 m long Corrugated Steel Pipe (CSP). Based on the drawings provided by AECOM via email on March 14, 2019 and our site observations during the Foundations Investigation field program, the existing culvert crosses the existing Highway 65 embankment perpendicular to the highway. We understand from AECOM that the proposed replacement culvert will cross the highway on or near the existing culvert alignment and will be of similar circular size as the existing culvert. The existing embankment is about 3.2 m high relative to the culvert invert, and the invert at the inlet (north end) and outlet (south end) of the proposed culvert is about Elevations 288.4 m and 288.1 m, respectively. Based on documentation supplied by AECOM and our site observations, the existing culvert appears to be in poor condition with severe rusting. There are no indications of embankment or pavement distress (i.e. no observed slope instability, sloughing or settlement) in the immediate vicinity of the culvert. We understand from AECOM that a permanent grade raise or widening of the embankment in the culvert area is not required for culvert replacement. We further understand that a temporary detour will not be required/utilized for traffic staging during culvert replacement operations.

Due to the relatively shallow thickness of the embankment fill above the culvert, replacing the culvert using trenchless methods is not considered practical at this site.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, the section of Highway 65 crossing over the proposed culvert and its foundation system is expected to carry medium traffic volumes and its performance will have potential impacts on other transportation corridors; hence, the structure is classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the typical project specific foundation investigation carried out at this site (as presented in Part A of the report), in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS)

consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the *CHBDC* have been used for design.

6.3 Circular Culvert Installation by Open Cut Excavation

6.3.1 Settlement and Stability

Provided the proposed reconstructed embankment is not widened or raised following culvert replacement, immediate or long-term settlement of the foundation soils beneath the culvert is not anticipated. If a temporary or permanent grade raise or widening is ultimately required, then a settlement analysis should be carried out, although it is expected that settlement of the subgrade would be less than 25 mm and occur during construction given the presence of primarily non-cohesive native soils below ground surface.

The proposed reconstructed embankment (after culvert replacement) will be stable from a slope stability perspective if the embankment is reconstructed of granular material, such as OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II, and with side slopes at an inclination of 2 horizontal to 1 vertical (2H:1V).

6.3.2 Bedding and Cover

It is not necessary to found pipe culverts below the depth for frost penetration, as pipe culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. A circular pipe concrete culvert installed by open cut method should be completed in accordance with Ontario Provincial Standard Drawing (OPSD) 802.031 (*Rigid Pipe Bedding, Cover and Backfill for Type 3 Soil*) and should be designed in accordance with the MTO Gravity Pipe Design Guidelines (2014). If the replacement culvert is to consist of a CSP or plastic pipe installed by open cut method, it should be constructed in accordance with OPSD 802.014 (*Flexible Pipe Embedment in Embankment*). All unsuitable, deleterious and organic materials and fill materials are to be removed from the subgrade below the culvert footprint along the entire alignment. The bedding should be compatible with the class of pipe, surrounding subsoil, anticipated loading conditions and should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' material. Depending on the success of the contractor's groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer may be required at some locations where wet and softened soil conditions, unsuitable fill, or organic material are present at base of the excavation. Therefore, the Contract Documents should include a provision for additional thickness of compacted Granular 'A', if required.

From the top of the bedding to 300 mm above the obvert of the culvert, OPSS.PROV 1010 (*Aggregates*) Granular 'A' should be used around the culvert. All bedding and cover materials should be placed, and culvert construction carried out in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) and OPSS 401 (*Trenching, Backfilling and Compacting*), and the bedding/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22. If the bottom of the excavation is wet and dewatering is not satisfactorily maintaining the water level sufficiently below the base of the excavation to allow compaction, it is recommended that OPSS.PROV 1010 (*Aggregates*) Granular 'B' Type II material be used for bedding and as sub-excavation backfill below the bedding, as may be required.

6.3.2.1 Trench Backfill

The excavated materials from the culvert site will vary in quality and composition from sand to silt to clayey silt to fibrous peat. The existing embankment fill (granular materials) to be excavated to allow for culvert construction, where present above the water table, should be generally near their estimated optimum water contents for compaction provided they are protected from precipitation once they are exposed. Soils encountered below the water table would likely require significant drying in order to reach optimum water content for compaction. The excavated granular fill and native sand where encountered above the groundwater level and maintained at suitable water content, may be reused as trench backfill over the culvert cover material, provided these materials are free of organics, or other deleterious material (wood, construction rubble) and are placed and compacted accordance with OPSS.PROV 501 (*Compacting*). The silt fill and native silt, clayey silt and fibrous peat should not be reused as backfill.

Alternatively, granular material which meets the requirements of OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM) or Granular 'B' Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

6.4 Analytical Testing for Construction Materials

The results of analytical tests on one sample of silt recovered in Borehole C27-1, immediately below the embankment fill, is summarized in Section 4.4. The potential for sulphate attack and corrosion are discussed in the following paragraphs, however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class, and ensuring that all aspects of CSA A23.1-14 (2014) Section 4.1.1 "Durability Requirements" are followed when designing concrete elements.

6.4.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("Additional requirements for concrete subjected to sulphate attack") for the potential for sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil sample is less than the reportable detection limit of 0.002 per cent, which is below the exposure class of S-3 (Moderate) and is considered Negligible according to Table 7.2 in the MTO Gravity Pipe Design Guidelines (2014). Therefore, based on the test result for the sample of native silt, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the native silt may not need to be considered.

6.4.2 Potential for Corrosion

The soil has a pH of 7.5 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 2,000 ohm-cm, which indicates that the soil corrosiveness is at the upper limit of Moderate ($2000 < R < 4,500$ ohm-cm) and may be Severe, as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). As the culvert will also be located under the roadway shoulders and be exposed to de-icing salt, therefore, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.5 Construction Considerations

6.5.1 Open Cut Excavation

The proposed open cut trench associated with excavating through the embankments and into the subgrade to the base of the culvert bedding level will generally advance through sand and gravel/sand/silt fill and into the clayey silt/silt/sand/fibrous peat native soils. The excavation is anticipated to extend below the groundwater. Where space permits, an open cut excavation into these materials should be carried out in accordance with the guidelines outlined in the Occupation Health and Safety Act (OHSA) for Construction Activities. Above the water table, the existing fill materials and underlying native soils are classified as Type 3 soil (assuming that the native soils are dewatered), according to OHSA and temporary excavations (i.e. those which are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V. Below the water table the existing fill materials and underlying native fine grained non-cohesive soils are classified as Type 4 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3H:1V.

Depending upon the construction procedures adopted by the contractor, groundwater seepage conditions and weather conditions at the time of construction, some local flattening of the slopes of open cut excavations may be required, especially in looser/softer zones or where localized seepage is encountered. Further, layering of soils and the effectiveness of the contractor's dewatering systems could affect the OHSA classification and, therefore, the classification of soils for OHSA purposes must be made at the time the excavation is open and can be directly observed during construction.

6.5.2 Groundwater Control

The groundwater level is expected to be at or slightly above the proposed culvert invert, therefore for open cut culvert installation should be expected to extend below the groundwater level. Groundwater control will be required to allow for a stable open cut excavation. The groundwater should be lowered to at least 1 m below the base of excavation to maintain basal stability. Groundwater may be controlled by providing an active dewatering system installed and operated in advance of the excavation, or in combination with a sheet piling wall.

The contractor is responsible for the assessment of dewatering requirements, which depends on his chosen method of open cut excavation, as well as constructions / operation / maintenance and decommissioning. The contractor is also responsible for confirming that the radius of the drawdown does not impact the existing embankment and any nearby utilities or infrastructure that may be present. Groundwater and/or surface water control will be required for excavation and construction of the culvert. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) and in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*).

Surface water into excavations should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade.

6.5.3 Temporary Protection Systems

Temporary excavation protection and support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems should meet

Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking sheet pile system would be suitable as the Standard Penetration Test (SPT) "N"-values are generally less than about 20 blows per 0.3 m of penetration. The contractor may elect to use a soldier pile and lagging system; however, the site would need to be adequately dewatered prior to installation of the lagging boards as the sand and silt deposit will not have adequate stand-up time to permit installation of the lagging boards.

The sheet piles, or soldier piles, will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

Vibratory equipment for the installation of temporary protection systems may be used at this site provided that it does not impact the embankment or nearby buried infrastructure. The installation of temporary protection systems by vibratory equipment should be monitored to ensure the vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure / utility and property owners within the zone of influence of the site.

While the selection and design of the temporary protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in the assessment of the approximate construction costs during detail design:

| Stratigraphic Unit | Bulk Unit Weight, γ (kN/m ³) | Internal Angle of Friction, ϕ (Degrees) | Undrained Shear Strength, s_u (kPa) | Lateral Earth Pressure Coefficients ^{1/2} | | |
|--|---|--|---------------------------------------|--|---------------|----------------|
| | | | | Passive, K_p^3 | Active, K_a | At-rest, K_o |
| Embankment Fill - Compact to dense sand and gravel to sand | 20 | 32 | - | 3.25 | 0.31 | 0.47 |
| Fill – Loose to compact silt to sand | 19 | 30 | - | 3.00 | 0.33 | 0.50 |
| Loose to compact silt | 19 | 30 | - | 3.00 | 0.33 | 0.50 |
| Dense silty sand and gravel | 21 | 35 | - | 3.65 | 0.27 | 0.43 |

Notes:

1. The design groundwater level may be assumed to be Elevation 289.4 m, based on the water level measured in the open boreholes at the culvert location.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It is recommended that the ground surface extending back / upwards from the top of the protection system to the existing Highway 65 be graded to an inclination no steeper than 2H:1V. This should be shown on the Contract staging drawings.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1H:1V line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). It is recommended that full removal of the protection system at this site be considered to mitigate potential impediments to future rehabilitation/reconstruction work. If partial removal is required rather than full removal, the NSSP amending OPSS.PROV 539 (*Temporary Protection Systems*) included in Appendix C should be included in the Contract Documents. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.5.4 Obstructions

Cobbles were encountered within the native silty sand and gravel deposit at the site during the drilling of Borehole C27-1. Further, based on experience on similar projects, cobbles and boulders can be present within highway embankment fill which could affect the installation of temporary protection systems. There is also the potential for the presence of organic material (as encountered in Borehole C27-2), roots and tree stumps, at the interface of fill and native soils under the existing embankment, due to possible poor stripping practices during the embankment construction. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders and deleterious material such as asphalt fragments within the fill soils and organics at the fill and native soil interface, should be included in the Contract Documents, a copy of which is included in Appendix C.

6.5.5 Subgrade Protection

For open cut culvert installation, the subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the granular bedding layer be placed immediately after preparation and approval of the subgrade.

6.5.6 Embankment Reconstruction/Erosion Protection/Topsoil-Seeding

Fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I or Type II material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) and OPSS.PROV 206 (Grading). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

Erosion protection should be addressed by the designers at the culvert ends if the potential for hydraulic scour is possible depending on the level of water flow.

To reduce surface water erosion on the granular embankment side slopes, topsoil and seeding as per OPSS 802 (Topsoil) and OPSS.PROV 804 (Seed and Cover) should be carried out as soon as possible after construction of the embankments. If this slope protection is not in place before winter, then alternate protection measures, such as covering the slope with straw, or gravel sheeting as per OPSS.PROV 511 (Rip Rap, Rock Protection and Granular Sheeting), and OPSS.PROV 1004 (Aggregates – Miscellaneous) will be required to reduce the potential for erosion and to reduce the potential for the requirement of remedial works on the side slopes in the spring prior to topsoil dressing and seeding.

7.0 CLOSURE

This foundation design report was prepared by Mr. Michael Bentley a member of the geotechnical group with Golder, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder conducted an independent and quality control review of the report.

Signature Page

Golder Associates Ltd.



Michael Bentley, M.A.Sc.
Geotechnical Group



André Bom, P.Eng.
Senior Geotechnical Engineer



Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

MJB/AB/JMAC/sb

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REFERENCES

Canadian Standards Associations (CSA) Group 2014. Canadian Highway Bridge Design Code and Commentary S6-14

Canadian Standards Association (CSA), 2014. CSA A23.1-09 Concrete Materials and Methods of Construction (R2014)

Ministry of Transportation, Ontario, MTO Gravity Pipe Design Guidelines, April 2014

Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE

Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543

Ontario Regulation 903 (Wells)

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

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

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.014 Flexible Pipe Embedment in Embankment Original Ground: Earth or Rock

OPSD 802.031 Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS.PROV 421 Construction Specification for Pipe Culvert Installation in Open Cut

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 511 Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting

OPSS.PROV 517 Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation

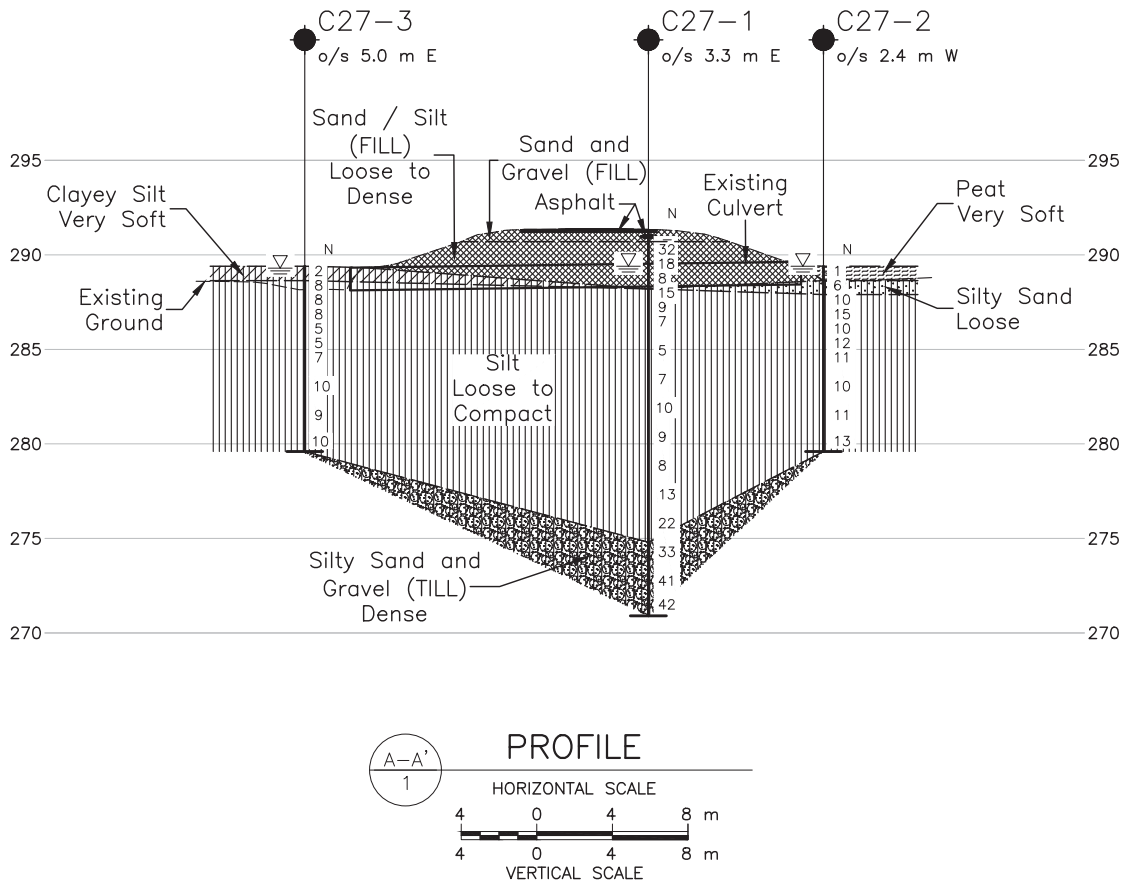
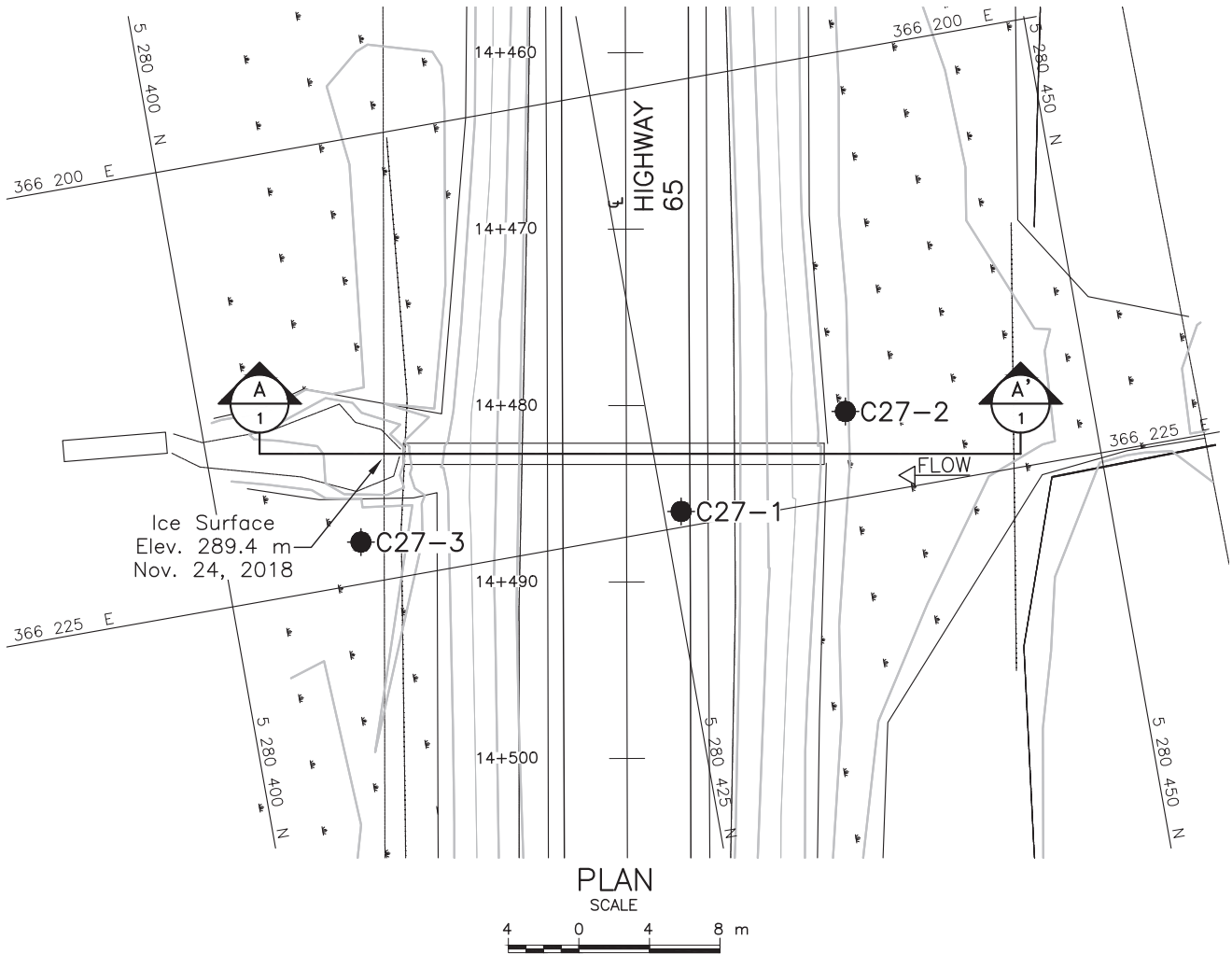
OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 802 Construction Speciation for Topsoil

OPSS.PROV 804 Construction Specification for Seed and Cover

OPSS.PROV 1004 Material Specification for Aggregates - Miscellaneous

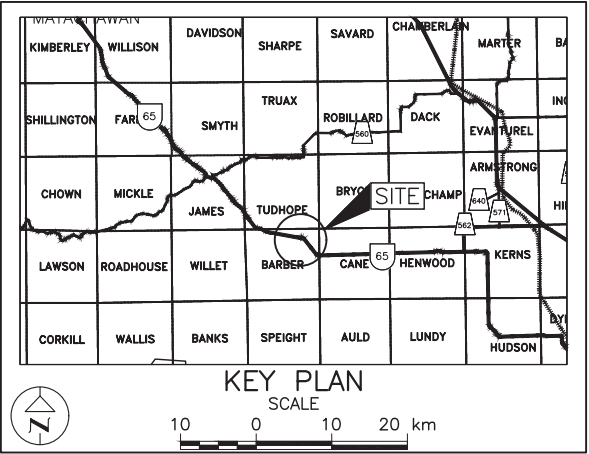
OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material



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

CONT No.
GWP No. 5204-14-00

HIGHWAY 65
STATION 14+480
TOWNSHIP OF BARBER CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA



- LEGEND**
- Borehole – Current Investigation
 - N Standard Penetration Test Value
 - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
 - ▽ WL upon completion of drilling



| BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12) | | | |
|--|-----------|-----------|----------|
| No. | ELEVATION | NORTHING | EASTING |
| C27-1 | 291.3 | 5280426.0 | 366224.1 |
| C27-2 | 289.4 | 5280436.1 | 366220.2 |
| C27-3 | 289.4 | 5280407.8 | 366222.6 |

NOTES

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

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

REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. B065BAR.dwg, received MAR 15, 2019.

| | | | |
|--------------------|---------------------|----------------|----------|
| NO. | DATE | BY | REVISION |
| Geocres No. 41P-81 | | | |
| HWY. 65 | PROJECT NO. 1896349 | | DIST. |
| SUBM'D. MJB | CHKD. TB | DATE: 8/2/2019 | SITE: |
| DRAWN: TR | CHKD. AB | APPD. JMAC | DWG. 1 |



Photograph 1: Highway 65 Facing West from Culvert (November 2018)



Photograph 2: Culvert Inlet, North End (November 2018)



Photograph 3: Culvert Outlet, South End (November 2018)

APPENDIX A

Record of Boreholes and Drillholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

| | |
|-------------|--|
| w | water content |
| w_l or LL | liquid limit |
| w_p or PL | plastic limit |
| I_p or PI | plasticity index = $(w_l - w_p)$ |
| w_s | shrinkage limit |
| I_L | liquidity index = $(w - w_p) / I_p$ |
| I_c | consistency index = $(w_l - w) / I_p$ |
| e_{max} | void ratio in loosest state |
| e_{min} | void ratio in densest state |
| I_D | density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density) |

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

| | |
|------------------|--|
| τ_p, τ_r | peak and residual shear strength |
| ϕ' | effective angle of internal friction |
| δ | angle of interface friction |
| μ | coefficient of friction = $\tan \delta$ |
| c' | effective cohesion |
| c_u, s_u | undrained shear strength ($\phi = 0$ analysis) |
| p | mean total stress $(\sigma_1 + \sigma_3)/2$ |
| p' | mean effective stress $(\sigma'_1 + \sigma'_3)/2$ |
| q | $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$ |
| q_u | compressive strength $(\sigma_1 - \sigma_3)$ |
| S_t | sensitivity |

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

Notes: 1
2

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

| | |
|----------|---|
| w | water content |
| w_p | plastic limit |
| w_l | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test ¹ |
| CIU | consolidated isotropically undrained triaxial test with porewater pressure measurement ¹ |
| D_R | relative density (specific gravity, G_s) |
| DS | direct shear test |
| M | sieve analysis for particle size |
| MH | combined sieve and hydrometer (H) analysis |
| MPC | Modified Proctor compaction test |
| SPC | Standard Proctor compaction test |
| OC | organic content test |
| SO_4 | concentration of water-soluble sulphates |
| UC | unconfined compression test |
| UU | unconsolidated undrained triaxial test |
| V | field vane (LV-laboratory vane test) |
| γ | unit weight |

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

V. MINOR SOIL CONSTITUENTS

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

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

| PROJECT 1896349 | | RECORD OF BOREHOLE No C27-1 | | | | 2 OF 2 METRIC | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------------|--|---|---------|------|------------|-------------------------|--|--|-----------------|--|--|--|--|--|---------------------------------|--|--|-------------------------------|--|--|--------------------------------|--|--|------------------|--|--|---------------------------------------|--|--|
| G.W.P. 5204-14-00 | | LOCATION N 5280426.0; E 366224.1 NAD83 MTM ZONE 12 (LAT. 47.660063; LONG. -80.182178) | | | | ORIGINATED BY MR | | | | | | | | | | | | | | | | | | | | | | | |
| DIST _____ HWY 65 | | BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and wash Boring | | | | COMPILED BY GM | | | | | | | | | | | | | | | | | | | | | | | |
| DATUM GEODETIC | | DATE November 17, 2018 | | | | CHECKED BY AB | | | | | | | | | | | | | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | | | ELEVATION SCALE | | | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | PLASTIC LIMIT W _p | | | NATURAL MOISTURE CONTENT W | | | LIQUID LIMIT W _L | | | UNIT WEIGHT γ | | | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | | | | | | | | | | | | | | | | | |
| --- CONTINUED FROM PREVIOUS PAGE --- | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 278.0 | SILT, trace to some clay Loose to compact Brown Wet | | 12 | SS | 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 13.3 | SILT, some clay, trace sand Compact Brown Wet | | 13 | SS | 13 | | | | | | | | | | | | | | | | | | | | | | | | |
| 276.5 | SILT, trace to some clay Compact Brown Wet | | 14 | SS | 22 | | | | | | | | | | | | | | | | | | | | | | | | |
| 14.8 | SILT, trace to some clay Compact Brown Wet | | 15 | SS | 33 | | | | | | | | | | | | | | | | | | | | | | | | |
| 274.8 | Silty SAND and GRAVEL, some cobbles (TILL) Dense Grey Wet | | 16 | SS | 41 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16.5 | Silty SAND and GRAVEL, some cobbles (TILL) Dense Grey Wet | | 17 | SS | 42 | | | | | | | | | | | | | | | | | | | | | | | | |
| 270.9 | END OF BOREHOLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20.4 | Note: 1. Water level at a depth of 2.3 m below ground surface (Elev. 289.0 m) upon completion of drilling. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

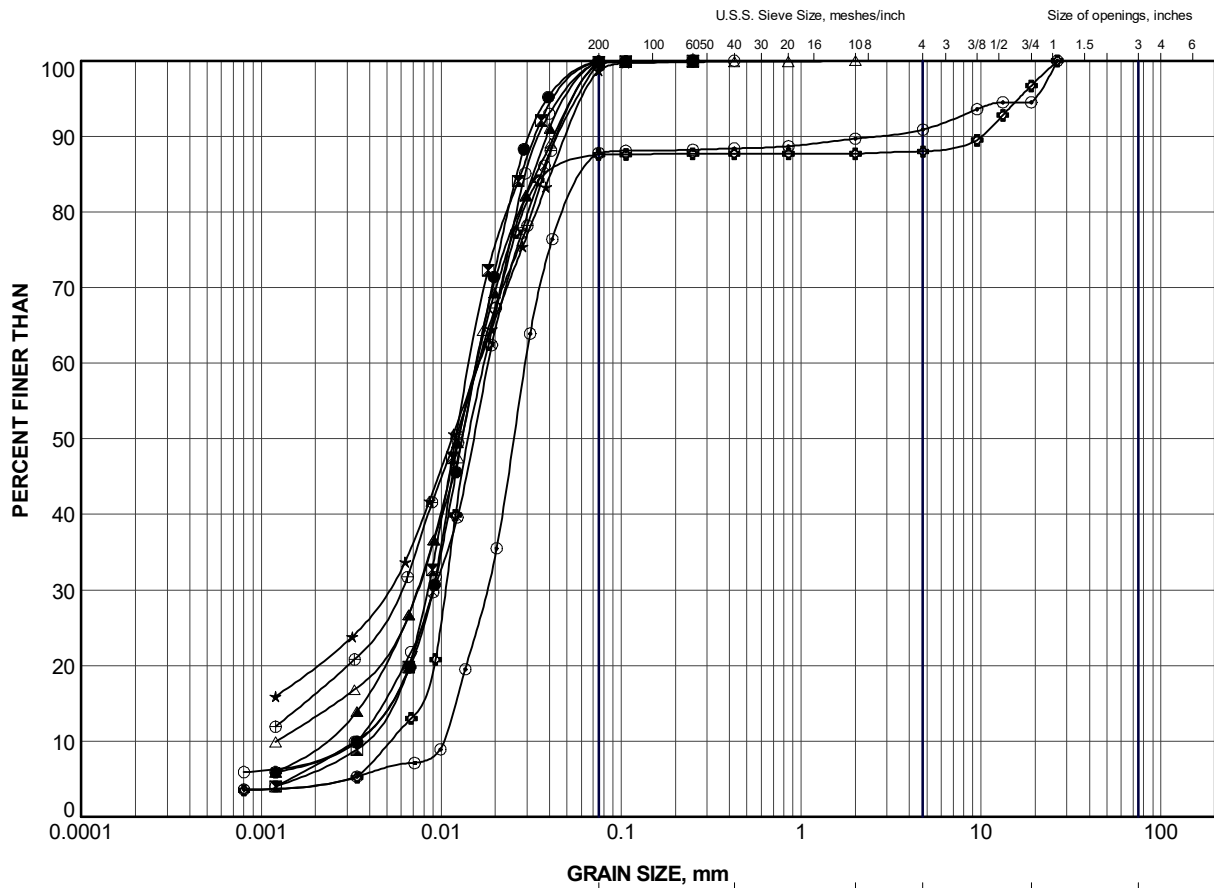
| PROJECT 1896349 | | RECORD OF BOREHOLE No C27-2 | | | | 1 OF 1 METRIC | | | | | | | | | | | |
|-------------------|--|---|---------|------|------------|-------------------------|-----------------|--|--|--|--|--|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| G.W.P. 5204-14-00 | | LOCATION N 5280436.1; E 366220.2 NAD83 MTM ZONE 12 (LAT. 47.660154; LONG. -80.182228) | | | | ORIGINATED BY MR | | | | | | | | | | | |
| DIST _____ HWY 65 | | BOREHOLE TYPE Portable Equipment, NW Casing and Wash Boring | | | | COMPILED BY GM | | | | | | | | | | | |
| DATUM GEODETIC | | DATE January 22, 2019 | | | | CHECKED BY AB | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| 289.4 | GROUND SURFACE | | | | | | | | | | | | | | | | |
| 0.0 | Fibrous PEAT, trace gravel Very soft Black Frozen | | 1 | SS | 1 | | | | | | | | | | | | |
| 288.6 | | | | | | | | | | | | | | | | | |
| 0.8 | SILTY SAND, some gravel, trace organics Loose Grey Wet | | 2 | SS | 6 | | | | | | | | | | | | |
| 287.9 | | | | | | | | | | | | | | | | | |
| 1.5 | SILT, trace to some clay, trace gravel Compact Grey Wet | | 3 | SS | 10 | | | | | | | | | | | | 9 3 83 5 |
| | | | | | | | | | | | | | | | | | |
| | | | 4 | SS | 15 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 5 | SS | 10 | | | | | | | | | | | | 12 0 84 4 |
| | | | | | | | | | | | | | | | | | |
| | | | 6 | SS | 12 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 7 | SS | 11 | | | | | | | | | | | | 0 0 92 8 |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 8 | SS | 10 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 9 | SS | 11 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 10 | SS | 13 | | | | | | | | | | | | |
| 279.6 | | | | | | | | | | | | | | | | | |
| 9.8 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| | NOTES: 1. Water level at ground surface (Elev. 289.4 m) inside casing upon completion of drilling. 2. Split spoon samples obtained by driving with a half weight hammer. SPT 'N' value has been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | | | |

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| PROJECT 1896349 | | RECORD OF BOREHOLE No C27-3 | | | | 1 OF 1 METRIC | | | | | | | | | | | |
|-------------------|--|---|---------|------|------------|-------------------------|--|--------------------|----|----|----|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|-------------------|
| G.W.P. 5204-14-00 | | LOCATION N 5280407.8; E 366222.6 NAD83 MTM ZONE 12 (LAT. 47.659901; LONG. -80.182201) | | | | ORIGINATED BY MR | | | | | | | | | | | |
| DIST _____ HWY 65 | | BOREHOLE TYPE Portable Equipment, NW Casing and Wash Boring | | | | COMPILED BY GM | | | | | | | | | | | |
| DATUM GEODETIC | | DATE November 24, 2018 | | | | CHECKED BY AB | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | ELEVATION SCALE | SHEAR STRENGTH kPa | | | | | | | | | WATER CONTENT (%) |
| 289.4 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 0.0 | CLAYEY SILT, trace to some sand, trace organics Very soft Grey Wet | | 1 | SS | 2 | | 289 | | | | | | | | | | |
| 288.6 | SILT, trace organics/wood Loose Grey Wet | | 2 | SS | 8 | | 288 | | | | | | | | | | |
| 287.9 | SILT, trace to some clay Loose Grey Wet | | 3 | SS | 8 | | 287 | | | | | | | | | | |
| 1.5 | - silty clay laminations at 2.4 m depth | | 4 | SS | 8 | | 286 | | | | | | | | | | |
| | - 50 mm thick SILTY CLAY seam at 3.4 m depth | | 5 | SS | 5 | | 285 | | | | | | | | | | |
| | - silty clay laminations at 4.5 m depth | | 6 | SS | 5 | | 284 | | | | | | | | | | |
| | | | 7 | SS | 7 | | 283 | | | | | | | | | | |
| | | | 8 | SS | 10 | | 282 | | | | | | | | | | |
| | | | 9 | SS | 9 | | 281 | | | | | | | | | | |
| | - silty clay laminations at 7.6 m depth | | 10 | SS | 10 | | 280 | | | | | | | | | | |
| 279.6 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 9.8 | Note: 1. Water level at a depth of 0.1 m below ground surface (Elev. 289.3 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a half weight hammer. SPT 'N' value has been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | | | |

APPENDIX B

Laboratory Test Results



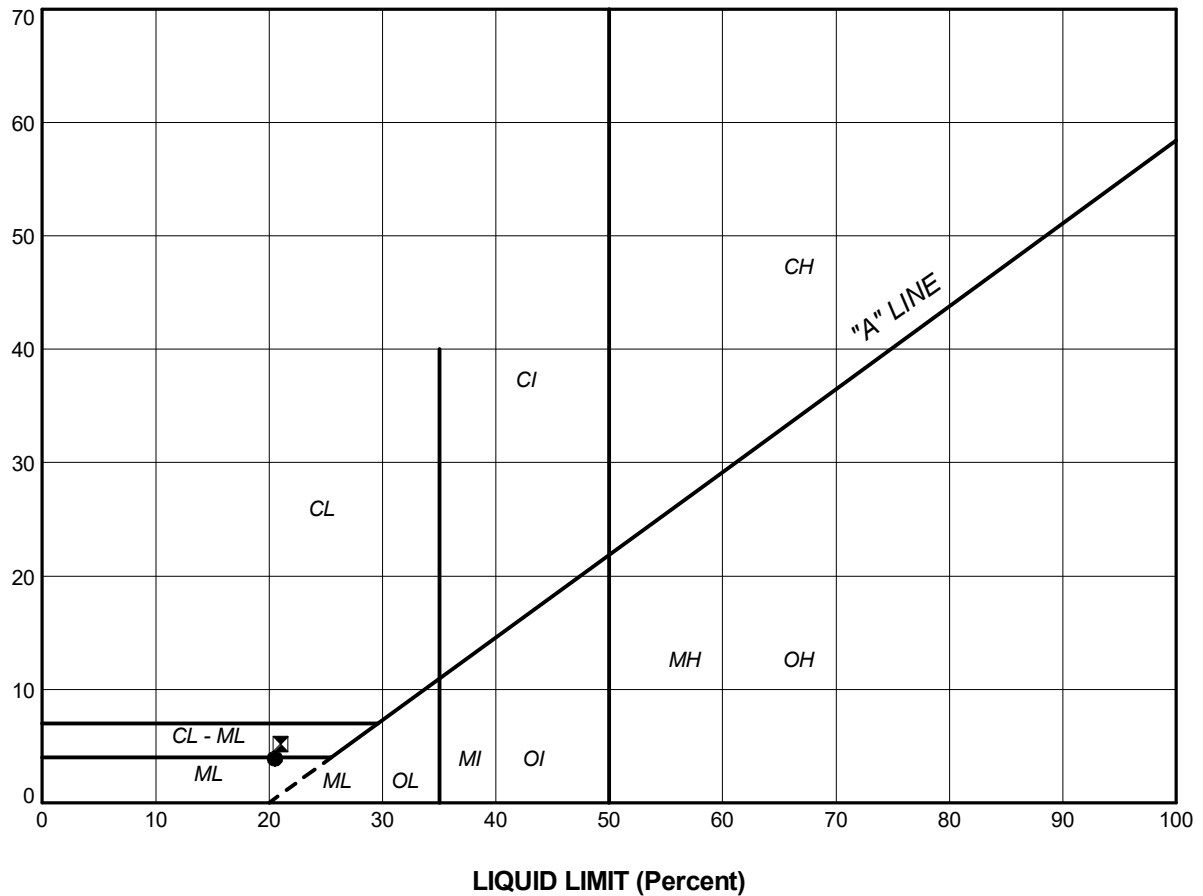
| | | | | | | |
|---------------|---------------|--------|--------|-----------------|--------|-------------|
| CLAY AND SILT | SAND SIZE, mm | | | GRAVEL SIZE, mm | | Cobble Size |
| | fine | medium | coarse | fine | coarse | |
| | SAND SIZE | | | GRAVEL SIZE | | |

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ● | C27-1 | 5 | 287.9 |
| ⊠ | C27-1 | 7 | 286.5 |
| ▲ | C27-1 | 10 | 281.8 |
| ★ | C27-1 | 13 | 277.3 |
| ⊙ | C27-2 | 3 | 287.7 |
| ⊕ | C27-2 | 5 | 286.1 |
| ○ | C27-2 | 7 | 284.6 |
| △ | C27-3 | 3 | 287.6 |
| ⊗ | C27-3 | 6 | 285.3 |
| ⊕ | C27-3 | 9 | 281.6 |

| | | | | | |
|-------------|------|--|------------|----------------------|------|
| PROJECT | | HIGHWAY 65 STATION 14+480 TOWNSHIP OF BARBER CULVERT | | | |
| TITLE | | GRAIN SIZE DISTRIBUTION Silt | | | |
| PROJECT No. | | 1896349 | | FILE No. 1896349.GPJ | |
| DRAWN | TR | May 2019 | SCALE | N/A | REV. |
| CHECK | MB | May 2019 | FIGURE B-1 | | |
| APPR | JMAC | May 2019 | | | |
| GOLDER | | SUDBURY, ONTARIO | | | |

PLASTICITY INDEX (Percent)



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI |
|--------|----------|--------|-------|-------|-----|
| ● | C27-1 | 13 | 20.5 | 16.6 | 3.9 |
| ⊠ | C27-3 | 3 | 21.0 | 15.8 | 5.2 |

| | | | | | |
|-------------|--|--|--|-------------------|--|
| PROJECT | | HIGHWAY 65 STATION 14+480 TOWNSHIP OF BARBER CULVERT | | | |
| TITLE | | PLASTICITY CHART Silt | | | |
| PROJECT No. | | 1896349 | | FILE No. | |
| DRAWN | | TR | | May 2019 | |
| CHECK | | MB | | May 2019 | |
| APPR | | JMAC | | May 2019 | |
| GOLDER | | SUDBURY, ONTARIO | | SCALE N/A REV. | |
| | | | | FIGURE B-2 | |

RESULTS OF ANALYSES OF SOIL

| Maxxam ID | | IKA226 | | | IKA226 | | | IKA227 | IKA228 | | |
|--|---------|---------------------|------|----------|--------------------------|-----|----------|---------------------|---------------------|------|----------|
| Sampling Date | | 2018/11/13 10:41 | | | 2018/11/13 10:41 | | | 2018/11/17 11:30 | 2018/11/18 12:13 | | |
| COC Number | | 62170 | | | 62170 | | | 62170 | 62170 | | |
| | UNITS | C14-3 SA 1 | RDL | QC Batch | C14-3 SA 1 Lab-Dup | RDL | QC Batch | C27-1 SA 1 | C77-1 SA 1 | RDL | QC Batch |
| CONVENTIONALS | | | | | | | | | | | |
| Sulphide | ug/g | 7.35 | 0.50 | 5872398 | | | | <0.55 | 0.64 | 0.55 | 5872398 |
| Calculated Parameters | | | | | | | | | | | |
| Resistivity | ohm-cm | 1200 | | 5859836 | | | | 2000 | 3800 | | 5859836 |
| CONVENTIONALS | | | | | | | | | | | |
| Redox Potential | mV | 140 | N/A | 5865933 | | | | 140 | 130 | N/A | 5865933 |
| Inorganics | | | | | | | | | | | |
| Soluble (20:1) Chloride (Cl-) | ug/g | 430 | 20 | 5862969 | | | | 250 | 90 | 20 | 5862969 |
| Conductivity | umho/cm | 868 | 2 | 5863312 | 909 | 2 | 5863312 | 508 | 266 | 2 | 5863312 |
| Available (CaCl2) pH | pH | 7.23 | | 5864763 | | | | 7.54 | 7.60 | | 5864763 |
| Soluble (20:1) Sulphate (SO4) | ug/g | <20 | 20 | 5862489 | | | | <20 | <20 | 20 | 5862489 |
| Physical Testing | | | | | | | | | | | |
| Moisture-Subcontracted | % | 24 | 0.30 | 5872397 | | | | 17 | 25 | 0.30 | 5872397 |
| RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable | | | | | | | | | | | |

APPENDIX C

**Non-Standard Special Provisions
and Notice to Contractor**

OBSTRUCTIONS – Item No.

Notice to Contractor

The contractor shall be alerted to the presence of cobbles within the native silty sand and gravel deposit, as encountered in Borehole C27-1, and potential presence of boulders, asphalt fragments and organic materials (i.e., roots and tree stumps) within the fill deposits at the Highway 65, Station 14+480, Township of Barber culvert site. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations and installation of temporary protection systems.

TEMPORARY PROTECTION SYSTEM – Item No.

Non-Standard Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finishing grade or ground surface.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work or facility being protected.

All disturbed areas shall be restored to an equivalent to better condition than existing prior to the commencement of construction.



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