



FOUNDATION INVESTIGATION AND DESIGN REPORT

**Highway 17, Station 12+754, Township of Aweres
Culvert Replacement**

Ministry of Transportation, Ontario GWP 5181-13-00

Submitted to:

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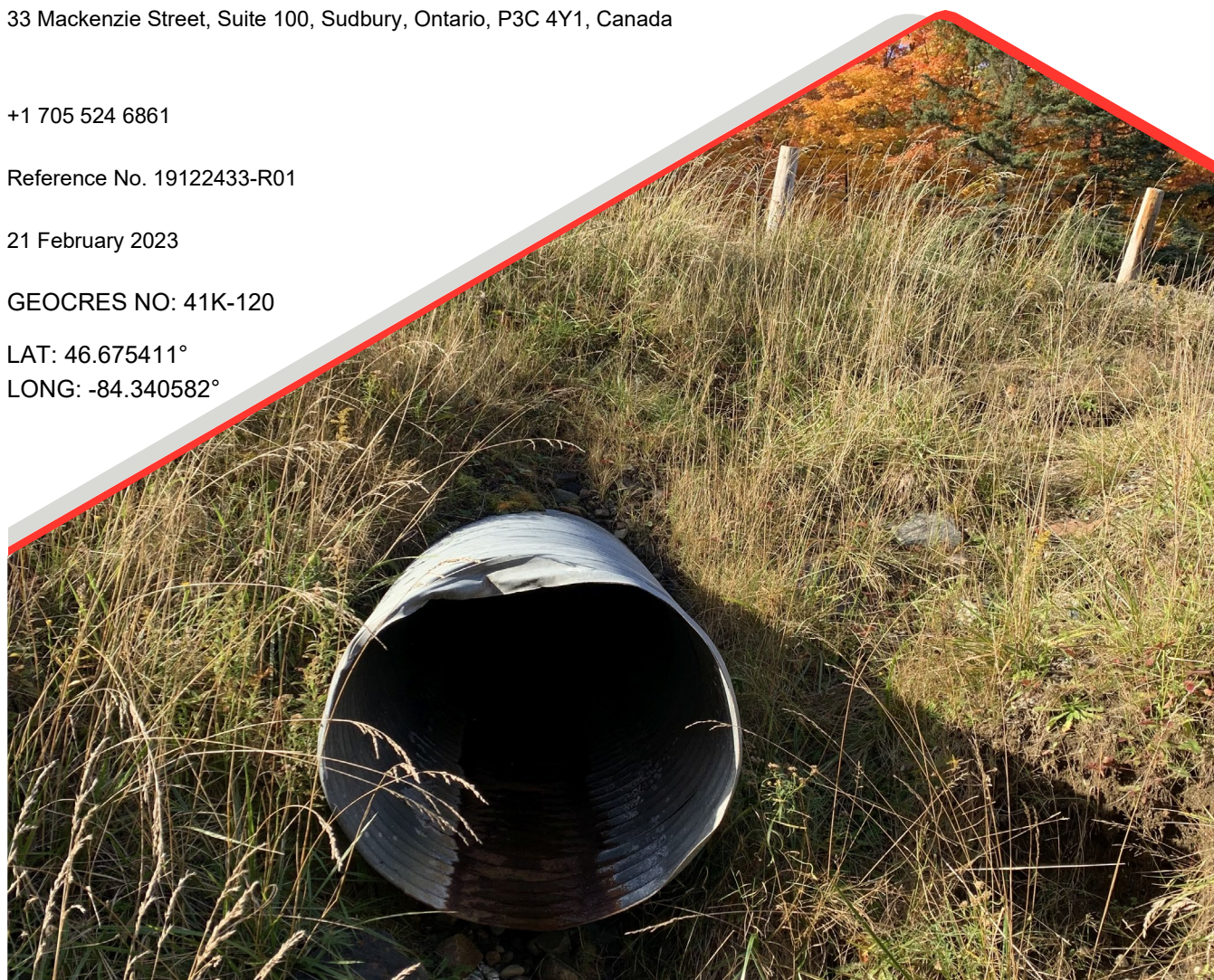
Reference No. 19122433-R01

21 February 2023

GEOCRES NO: 41K-120

LAT: 46.675411°

LONG: -84.340582°



Distribution List

- 1 PDF Copy: Ministry of Transportation, Ontario (NE Region)
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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 17, STA 12+754, TOWNSHIP OF AWERES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5181-13-00**

1.0 INTRODUCTION

Golder Associates Ltd., a member of WSP (WSP Golder) has been retained by AECOM Canada Limited (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services related to the replacement of the culvert on Highway 17 at Station 12+754 in the Township of Aweres, approximately 6.2 km south of Goulais River. The Key Plan showing the general location of this section of Highway 17 and the location of the investigated area are shown in Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the culvert replacement through a foundation investigation consisting of boreholes and in-situ testing, with laboratory testing carried out on selected soil samples.

2.0 SITE DESCRIPTION

Based on the survey provided by AECOM, the existing culvert consists of an approximate 900 mm diameter by 32 m long corrugated steel pipe (CSP) culvert. The culvert inlet (west end) and outlet (east end) inverts are at Elevations 298.4 m and 296.6 m, respectively. The highway grade at the centerline is at approximately Elevation 300.9 m. The topography beyond the vicinity of the culvert is generally sloping downwards to the north – northeast and vegetated with trees and shrubs beyond the MTO right of way.

The average inclination of the east slope of the highway embankment at the culvert location is at about 2 Horizontal and 1 Vertical (2H:1V) and the west embankment slope is inclined at about 2.7H:1V. At the time of the field work, the embankment side slopes were generally grass covered. No signs of deep-seated embankment slope instability were observed in the vicinity of the culvert. The ground surface conditions at select locations of the culvert area are shown in Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for the subsurface exploration was carried out on 23 and 24 August 2022, during which time two boreholes (Boreholes 22-1 and 22-2) were advanced at the approximate locations shown in Drawing 1. The boreholes were advanced using a track-mounted CME-55 drilling rig supplied and operated by Landcore Drilling of Sudbury, Ontario. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

The boreholes were advanced using 108 mm I.D. hollow-stem augers and HQ-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 an automatic hammer in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

To measure a more stabilized groundwater level, a temporary standpipe piezometer was installed in Borehole 22-2 as described in the borehole records provided in Appendix A. The boreholes were backfilled in accordance with Ontario Regulation 903 (as amended) and were capped at the roadway surface using cold patch asphalt.

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

The as-drilled borehole locations were measured relative to the highway centreline and chainage/station marked on the pavement at the culvert centreline by a member of our technical staff and converted into northing/easting coordinates on the base plan drawing provided by AECOM. The ground surface elevation at each borehole location was obtained from the topographic survey provided by AECOM. The northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below. The latitude/ longitude coordinates of the borehole locations are also shown on the borehole records.

Borehole Number	MTM NAD 83 Northing (m)	MTM NAD 83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
22-1	5170695.7	278755.5	301.4	14.3
22-2	5170705.9	278736.5	300.6	14.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the culvert site is located in an area of bedrock knobs.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in-situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The plotted results of the 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 borehole records and discussed in Section 4.2, are uncorrected. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile shown in 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 sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown in Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt

A 180 mm to 200 mm thick layer of asphalt was encountered along Highway 17 at ground surface in Boreholes 22-1 and 22-2.

4.2.2 Gravelly Sand (SP-SM) to Silty Sand (SM) Fill

A 3.6 m and 2.8 m thick layer of fill, consisting of gravelly sand to silty sand was encountered below the asphalt in the boreholes. The top of the fill deposit was encountered at Elevation 301.2 m and 300.4 m in Boreholes 22-1 and 22-2, respectively.

The SPT 'N'-values measured within the fill generally range from 16 blows to 74 blows per 0.3 m of penetration, indicating a compact to very dense compactness condition. Split-spoon refusal was encountered at 3.1 m depth in Borehole 22-1 and at 0.3 m depth in Borehole 22-2, suggesting the potential for obstructions (e.g., cobbles) within the fill.

Grain size distribution testing was carried out on two samples of the fill and the results are presented in Figure B-1 in Appendix B. The natural water content measured on two samples of the fill are 7 percent and 10 percent.

4.2.3 Silty Sand (SM) to Sand and Gravel (SP)

A native granular stratum consisting of silty sand, to gravelly silty sand, to sand, to sand and gravel was encountered below the fill in Boreholes 22-1 and 22-2 at Elevation 297.6 m. Boreholes 22-1 and 22-2 were terminated within this deposit after advancing to a total depth of 14.3 m. Cobbles of approximately 75 mm in diameter were encountered below 3.1 m depth in Borehole 22-2.

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

The SPT 'N'-values measured within the granular deposit range from 17 blows to 112 blows per 0.3 m of penetration indicating a compact to very dense compactness condition. In Borehole 22-2, two SPT tests encountered refusal after 0.1 m of penetration, further suggesting obstructions (e.g., cobbles) within the granular deposit.

The natural moisture content measured on select samples of the granular deposit range between approximately 11 percent and 16 percent.

Grain size distribution testing was carried out on five samples of the deposit and the results are presented on Figure B-2 in Appendix B.

4.3 Groundwater Conditions

The groundwater levels measured in the piezometer installed in Borehole 22-2 are summarized below. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole Number	Depth to Groundwater Level (m)	Approximate Groundwater Elevation (m)	Notes
22-2	9.1	291.5	Piezometer (23 August 2022)
	8.4	292.2	Piezometer (25 August 2022)

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Hayden Buchanan, under the overall direction of Mr. Matthew Thibeault, P.Eng. This Foundation Investigation Report was prepared by Mr. Tibor Berecz, P.Eng. and reviewed by Mr. Paul Dittrich, P.Eng., an MTO Foundations Designated Contact with WSP Golder, who conducted an independent quality control review of this report.

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PART B

**FOUNDATION DESIGN REPORT
HIGHWAY 17, STA 12+754, TOWNSHIP OF AWERES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5181-13-00**

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation recommendations for temporary protection systems and the replacement of the culvert crossing Highway 17 at about Station 12+754, in the Township of Aweres, Algoma District, approximately 15 km north of Sault Ste. Marie. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to facilitate staging construction for the replacement of the culvert. This foundation investigation, 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 an approximately 900 mm diameter by approximately 32 m long corrugated steel pipe (CSP) culvert. The culvert inlet (west end) and outlet (east end) inverts are at Elevations 298.4 m and 296.6 m, respectively. The highway grade at the centerline is at approximately Elevation 300.9 m. The east embankment slope at the culvert location is inclined at about 2 Horizontal and 1 Vertical (2H:1V) and the west embankment slope is inclined at about 2.7H:1V and the embankment is between about 2.5 m and 4.3 m high relative to the culvert invert at the inlet and outlet, respectively. The average thickness of soil cover over the culvert is about 2.5 m.

Based on the drawings provided by AECOM, via email on September 19, 2022, and our site observations during the foundation exploration work, the existing culvert crosses the embankment approximately perpendicular to the existing Highway 17 alignment. It is our understanding that the proposed culvert replacement will consist of a 1200 mm diameter precast concrete, circular pipe culvert along the same alignment as the existing culvert, with invert elevations similar to the existing culvert.

It is further understood that a staged construction approach using temporary shoring will be required to facilitate the culvert replacement. The pavement surface elevation will remain the same after culvert replacement such that a grade raise is not required. However, the east embankment is to be permanently widened by about 3.5 m at the crest with 0.5 m of widening mid-slope to accommodate the new pavement structure and to incline the east side slope to an approximately uniform 2H:1V profile. The west side of the embankment will be temporarily widened by about 1.5 m and re-graded to 2H:1V. At the proposed east embankment crest, the widening results in up to 1.1 m of new fill thickness vertically.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2019) and its *Commentary*, we understand that the culvert along Highway 17 at Station 12+754 in the Township of Aweres is expected to carry medium traffic volumes and the performance will have potential impacts on other transportation corridors. Therefore, the culvert foundation system is classified as having a “typical consequence level” associated with exceeding limits states design. Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, Ψ , from Tables 6.1 and 6.2 of the *CHBDC* have been used for design, as applicable. Given the 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* (2019), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding”. Therefore, the corresponding ultimate limit state (ULS) and serviceability limit state (SLS) geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the *CHBDC* would generally be used for design, as applicable.

6.3 Embankment Stability and Settlement

Based on our site observations at the time of the field investigation, the existing highway embankment in the culvert area appears to be performing satisfactorily with no visual evidence of instability (i.e., tension cracks near the embankment crest or bulging at the embankment toes). The groundwater level measured in the piezometer installed in Borehole 22-2 has been used in the analyses. The following sections address embankment settlement and stability analyses completed for the proposed culvert replacement. Our analyses assume that all organics and existing fill materials have been removed prior to embankment and culvert construction.

As discussed in Section 6.1, the proposed east side slope of the embankment after culvert replacement will be permanently widened by approximately 3.5 m at the crest with a final side slope inclined at 2H:1V and the proposed west side slope will be consistent with the existing slope. The following sections address the widening of the east embankment side slope; the west side of the embankment is not further discussed in these sections because the geometry at this location will not be modified.

6.3.1 Settlement

Although no grade raise is being considered at this location, we understand that an approximately 3.5 m widening is being considered. The proposed widening results in an approximately 1.1 m thick layer of additional fill at the new embankment crest. Given the non-cohesive and compact to very dense nature of the granular soils encountered at this site, and the relatively minor additional loading proposed, settlement along the culvert alignment is estimated to be negligible (i.e., <25 mm).

6.3.2 Stability

The stability analyses were carried out using the embankment geometry of the cross section at approximately Sta. 12+755 based on drawings provided by AECOM. Limit equilibrium slope stability analysis was carried out for the proposed east embankment side slope using the commercially available program GeoStudio 2021 (Version 11.3.1.23726), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety (FoS) of numerous potential surfaces was computed in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure.

For the purpose of the stability analysis, and in the context of the CHBDC (2019), the target FoS is defined as being equal to the inverse of the product of the consequence factor, Ψ , and the geotechnical resistance factor, Φ_{gu} (i.e., $FoS = 1 / (\Psi * \Phi_{gu})$). In particular, for the assessment of the embankment slopes at this culvert location, a “Typical consequence level” from the CHBDC was utilized.

The simplified stratigraphy, the associated soil parameters employed for the stability analyses, and the results of the global stability analysis for the permanent embankment after culvert replacement and slope widening are shown in Figure 1, and indicates a FoS of 1.5 against global instability. The soil parameters utilized in the analyses were selected based on experience and available direct shear testing carried out in similar soils at other locations on the project. Based on the results of the stability analysis, the permanent embankment widening will satisfy the global stability requirements discussed above.

6.4 Pipe Culvert Installation

Pipe culverts (less than 3 m diameter) should be designed in general accordance with the MTO Gravity Pipe Design Guidelines (2014). It is not necessary to found the pipe culvert below the depth of frost penetration, as pipe culverts are generally tolerant of small magnitudes of movement related to freeze-thaw cycles.

The circular concrete pipe culvert replacement should be installed in accordance with Ontario Provincial Standard Drawing (OPSD) 802.031 (*Rigid Pipe Bedding, Cover and Backfill*).

All unsuitable, deleterious and organic materials are to be removed from the base/below the pipe culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and the proposed culvert invert levels and a 300 mm thick bedding layer (discussed below), the subgrade under the replacement culvert will consist of sandy silt to silty sand to sand and gravel. The subgrade should be reviewed by a Foundations Engineering Specialist following excavation and prior to bedding placement to confirm the subgrade is suitable. Sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular ‘A’ or Granular ‘B’ Type II. In wet conditions, it is recommended that Granular B Type II be used as sub-excavation backfill and bedding.

The bedding layer should be 300 mm for a concrete rigid pipe and should consist of OPSS.PROV 1010 (*Aggregates*) Granular ‘A’ if the subgrade is dry or Granular ‘B’ Type II material for either dry or wet subgrade conditions.

From the top of the bedding to 300 mm above the top of the culvert, OPSS.PROV 1010 (*Aggregates*) Granular ‘A’ or well graded Granular ‘B’ Type II should be used as cover around the culvert. All bedding, embedment 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.PROV 401 (*Trenching, Backfilling and Compacting*), and the bedding/embedment/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by Special Provision (SP) 105S22.

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 from 300 mm above the top of culvert to underside of pavement structure. The excavated embankment fill materials from the culvert site will vary in quality and composition; however, given the relatively large amount of silt material observed, it is not recommended that the existing embankment fill be used as trench backfill above the culvert cover layer.

6.5 Construction Considerations

6.5.1 Open Cut Excavation

We understand that the culvert will be replaced using open cut excavations with temporary roadway protection systems to facilitate traffic staging. Open cut excavations should be inclined at no steeper than 1H:1V, should be in place for as little time as possible and if a continuous 24 hour replacement is not specified for the replacement, the excavated slope should be protected from erosion (i.e., tarp, granular cover, or other alternative).

The proposed open cut excavation through the embankment fill and into the subgrade to the base of the culvert bedding level is anticipated to be above the groundwater level. Therefore, the removal of the existing culvert, construction of the new culvert by open-cut, and re-construction of the embankment, is anticipated to be above the groundwater level; however, it should be noted that this is based on the groundwater levels at the time of the foundations investigation, which will fluctuate seasonally and with precipitation events. All excavations must be carried out in accordance with the guidelines outlined in the *Occupation Health and Safety Act* (OHSA) for Construction Activities. Above the water table (at the time of construction), the existing fill materials would be classified as Type 3 soils, 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 1 horizontal to 1 vertical (1H:1V). Below the water table (at the time of construction), the existing fill materials and underlying native 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 3 horizontal to 1 vertical (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/Surface Water Control

Based on measurements in the piezometer during the foundation investigation, the groundwater level is anticipated to be below the excavation for the culvert replacement. As such, depending on the water level at the time of construction, dewatering may not be required, and if required, groundwater could likely be controlled by pumping from properly filtered sumps located within the excavation. The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of excavation/construction for culvert replacement. The design of dewatering, unwatering, and temporary flow passage system(s), if required, is the responsibility of the contractor.

Dewatering of all excavations (if required) should be carried out in accordance with OPSS.PROV 517 (Dewatering), as modified by SSP 517F01. Given the general lack of infrastructure in the vicinity of the culvert and the anticipated/conceptual dewatering strategy (i.e., sumps and pumps), a preconstruction survey is not anticipated to be required and, as such, the designer fill-in in Table A of SSP 517F01 should indicate that a preconstruction survey is not applicable (N/A). The requirements for a preconstruction survey distance should, however, be reviewed/confirmed by the Hydrology and Drainage Engineer(s) and/or by a professional hydrogeologist. Further, referencing the fill-ins for SSP 517F01, the Designer Option requiring that the dewatering system design engineer and design-checking engineer have a minimum five-years experience designing similar systems is not considered to be required at this site. The remaining fill-in information related to the minimum design storm return period and return period flow estimates should be input by AECOM's Hydrology and Drainage Engineer(s).

If dewatering is required, we anticipate that the groundwater lowering would be relatively minor to facilitate the culvert replacement. Therefore, the risk of settlement impacts is considered to be low from a foundation perspective, so long as pumping is carried out from properly filtered sumps.

Surface water should be directed away from open excavation areas to prevent ponding of water, that could result in disturbance and weakening of the subgrade and/or affect construction, as applicable.

6.5.3 Temporary Protection System

The temporary excavation protection and support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105S09. The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539.

Obstructions (i.e., cobbles) were encountered in the boreholes, which indicates that there is a risk that obstructions could be encountered during installation of temporary protection systems. In particular, difficulties could be encountered if a driven interlocking steel sheet pile system is utilized. The contractor could consider using a soldier pile and lagging system with soldier piles potentially requiring coring to install through the cobbles/obstructions.

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 struts, 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 or structures, if present. 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 feasible alternatives.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m ³)	Angle of Internal Friction, ϕ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients ^{1/2}		
				Passive, K_p	Active, K_a	At-rest, K_o
Existing Embankment Fill – Compact to very dense Silty Sand (SM) to Gravelly Sand (SW)	20	35	-	3.69	0.27	0.43
Compact to very dense sandy silt to sand and gravel	18	33	-	3.39	0.29	0.46

Notes:

1. The groundwater level was measured to be at Elevation 292.2 m in the piezometer installed in Borehole 22-2 on 25 August 2022.
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 modified 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 C6.27 of the CHBDC (2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1 horizontal to 1 vertical 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). At this site, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.5.4 Obstructions

Cobbles about 75 mm in diameter were encountered below the fill in Borehole 22-2 below 3.1 m (Elevation 298.8 m) which could impact the installation of the temporary protection systems. In addition, high SPT N-values indicative of refusal conditions (i.e., 75 blows/<0.3 m of penetration) were also measured in both boreholes. A Notice to Contractor to identify the potential obstructions 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 be placed immediately after preparation and approval of the subgrade.

6.5.6 Surficial Embankment Stability and Erosion Protection

Depending on the embankment reconstruction procedures, fill material type used, slope geometry, surface treatment, and weather conditions (i.e., precipitation, cycles of wetting-drying, and/or freezing-thawing), surficial instability of the embankment side slopes may occur, which could include localized sloughing and erosion. As such, in order to maintain the integrity of the new embankment sections, erosion protection measures may be required on the finished embankment slopes.

Based on the specified material types and hence the gradation envelope(s) for the embankment reconstruction material(s), granular fill such as OPSS.PROV 1010 (Aggregates) Granular 'A' or well graded Granular 'B' Type II have a low potential for erosion. On-going maintenance for embankments constructed of this material is not expected to be required once the vegetation has been established.

The specification for OPSS.PROV 1010 (*Aggregates*) SSM allows for much more variation in the gradation of the material compared to Granular 'A' or Granular 'B', and therefore has the potential to be low-erodible to moderate-erodible. Erosion protection for slopes constructed of SSM should consist of erosion control blankets and seeding. Slopes constructed of SSM and properly protected from erosion should require limited on-going maintenance.

7.0 CLOSURE

This Foundation Design report was prepared by Mr. Tibor Berecz, P.Eng., a geotechnical engineer of WSP Golder. Mr. Matthew Thibeault, P.Eng., a senior geotechnical engineer, reviewed the report. Mr. Paul Dittrich, P.Eng., an MTO Foundations Designated Contact with WSP Golder, conducted an independent and quality control review of the report.

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TB/MT/JPD/ca

REFERENCES

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

Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CSA S6:19.

Commercial Software: GeoStudio (Version 11.0.1.21429) by GEOSLOPE International Ltd.

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

Occupational Health and Safety Act and Regulation, Ontario Regulation 213 for Construction Projects (as amended).

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

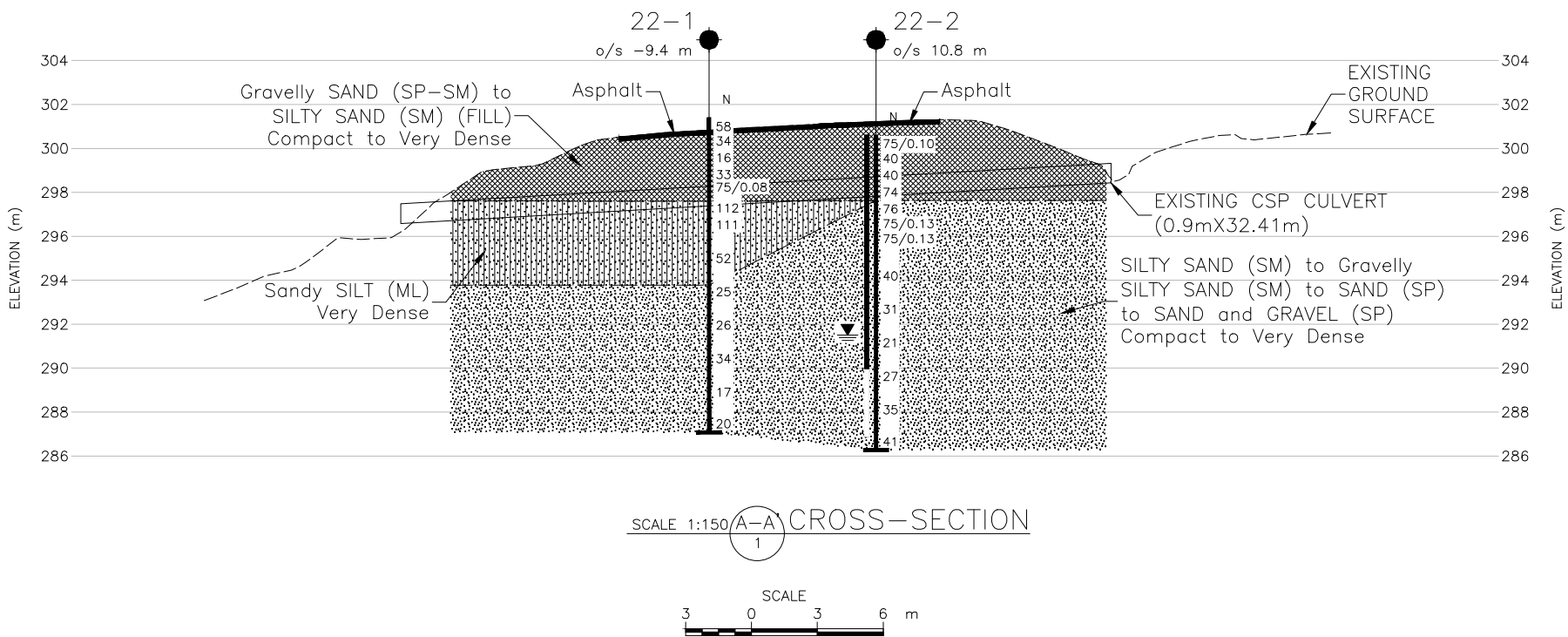
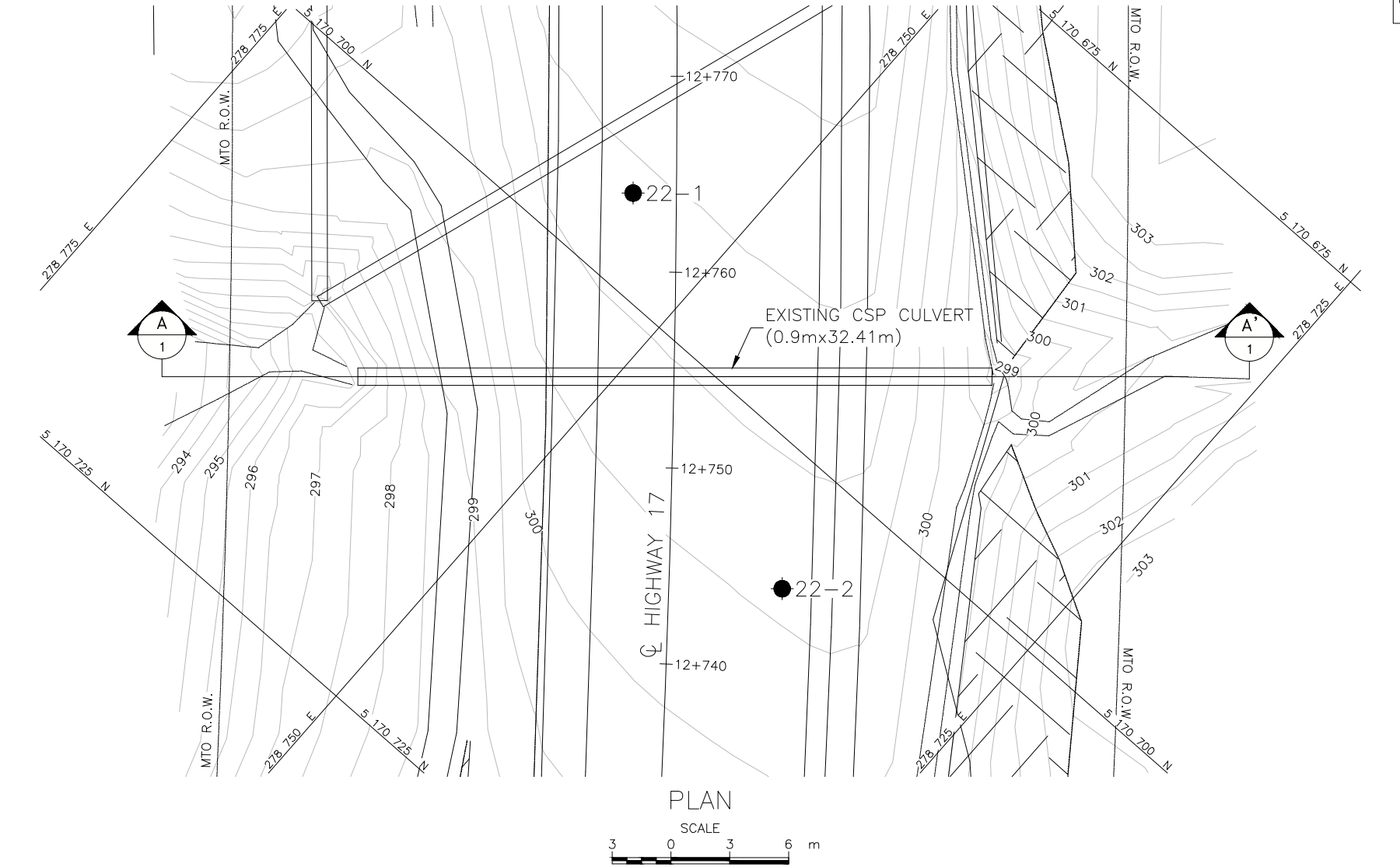
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 421	Pipe Culvert Installation in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, type 3 Soil, Earth excavation
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Ontario Water Resource Act

Regulation 903	Wells (as amended)
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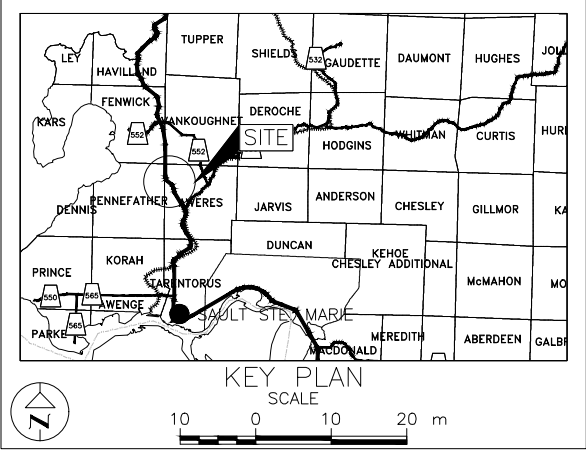


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5181-13-00

HIGHWAY 17
CULVERT AT STATION 12+754
BOREHOLE LOCATION AND SOIL STRATA

GOLDER



LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on August 25, 2022



BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 13)			
No.	ELEVATION	NORTHING	EASTING
22-1	301.4	5170695.7	278755.5
22-2	300.6	5170705.9	278736.5

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 and topography provided in digital format by AECOM LTD., drawing file no. GWP 5181-13-00 Base Plan.dwg, Survey dated NOVEMBER 2019; Received SEPTEMBER 19, 2022.

NO.	DATE	BY	REVISION
Geocres No. 41K-120			
HWY. 17	PROJECT NO. 19122433		DIST. .
SUBM'D.	CHKD. TB	DATE: 02/21/2023	SITE: .
DRAWN: TR	CHKD. MT	APPD. JPD	DWG. 1



Photograph 1: Existing CSP culvert outlet (October 2022)



Photograph 2: Existing CSP culvert inlet (October 2022)

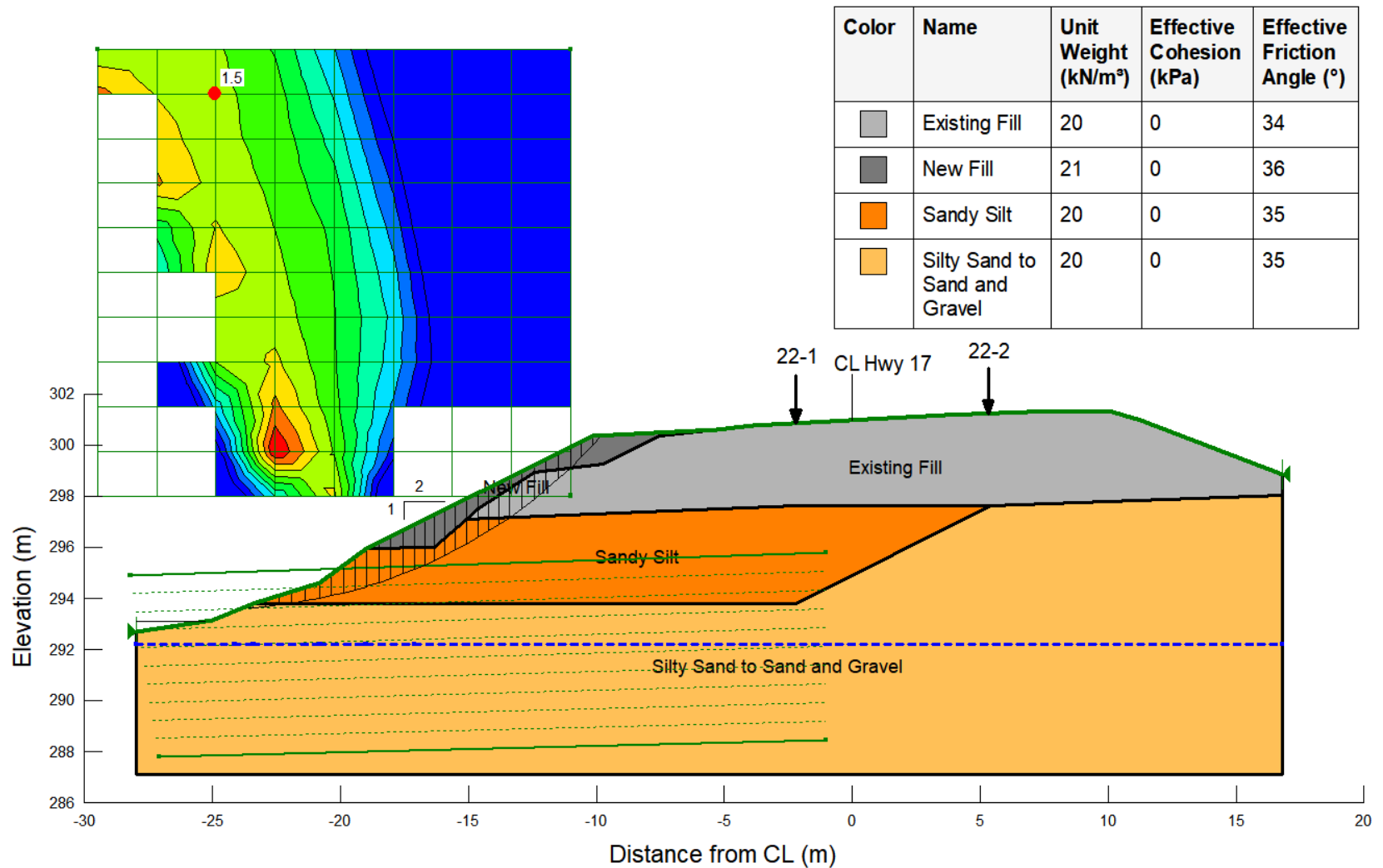


Photograph 3: Highway 17, looking northwest (October 2022)



Photograph 4: Highway 17, looking southeast (October 2022)

East Side Slope Proposed Embankment Widening



APPENDIX A

Record of Boreholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

- Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
- SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

w	water content
w_L or LL	liquid limit
w_P or PL	plastic limit
I_P or PI	plasticity index $= (w_L - w_P)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_P) / I_P$
I_C	consistency index $= (w_L - w) / I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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

PROJECT 19122433			RECORD OF BOREHOLE No. 22-1			1 OF 2 METRIC														
G.W.P. 5181-13-00			LOCATION N 5170695.7; E 278755.5 NAD83 MTM ZONE 13 (LAT. 46.675359; LONG. -84.340421)			ORIGINATED BY HB														
DIST _____ HWY 17			BOREHOLE TYPE CME 55 Trackmount, HQ Casing			COMPILED BY TR														
DATUM GEODETIC			DATE August 24, 2022			CHECKED BY MT														
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m³	GR SA SI CL			
								20 40 60 80 100	20 40 60 80 100	20 40 60	20 40 60									
301.4	GROUND SURFACE																			
0.0	ASPHALT (200 mm)																			
0.2	Gravelly SAND (SP-SM) to SILTY SAND (SM), some silt (FILL) Compact to very dense Brown Moist		1	SS	58		301													
			2	SS	34															
							300													
			3	SS	16															
			4	SS	33		299													
	- Split-spoon refusal encountered in Sample 5, suggesting potential obstructions (e.g. cobbles).		5	SS	75/0.08		298													
297.6																				
3.8	Sandy SILT (ML), trace gravel, trace clay Very dense Grey to brown Wet		6	SS	112		297													
			7	SS	111															
							296													
			8	SS	52		295													
							294													
293.8																				
7.6	SAND (SP) to SAND and Gravel (SP), trace silt Compact to dense Brown to brown grey Wet		9	SS	25		293													
			10	SS	26		292													
							291													
			11	SS	34															
							290													

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

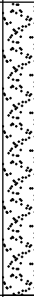
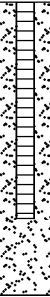
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PROJECT 19122433		RECORD OF BOREHOLE No. 22-1				2 OF 2 METRIC														
G.W.P. 5181-13-00		LOCATION N 5170695.7; E 278755.5 NAD83 MTM ZONE 13 (LAT. 46.675359; LONG. -84.340421)				ORIGINATED BY HB														
DIST _____ HWY 17		BOREHOLE TYPE CME 55 Trackmount, HQ Casing				COMPILED BY TR														
DATUM GEODETIC		DATE August 24, 2022				CHECKED BY MT														
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												
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>													
287.1	SAND (SP) to SAND and Gravel (SP), trace silt Compact to dense Brown to brown grey Wet		12	SS	17		289													
							288													
14.3	END OF BOREHOLE		13	SS	20															

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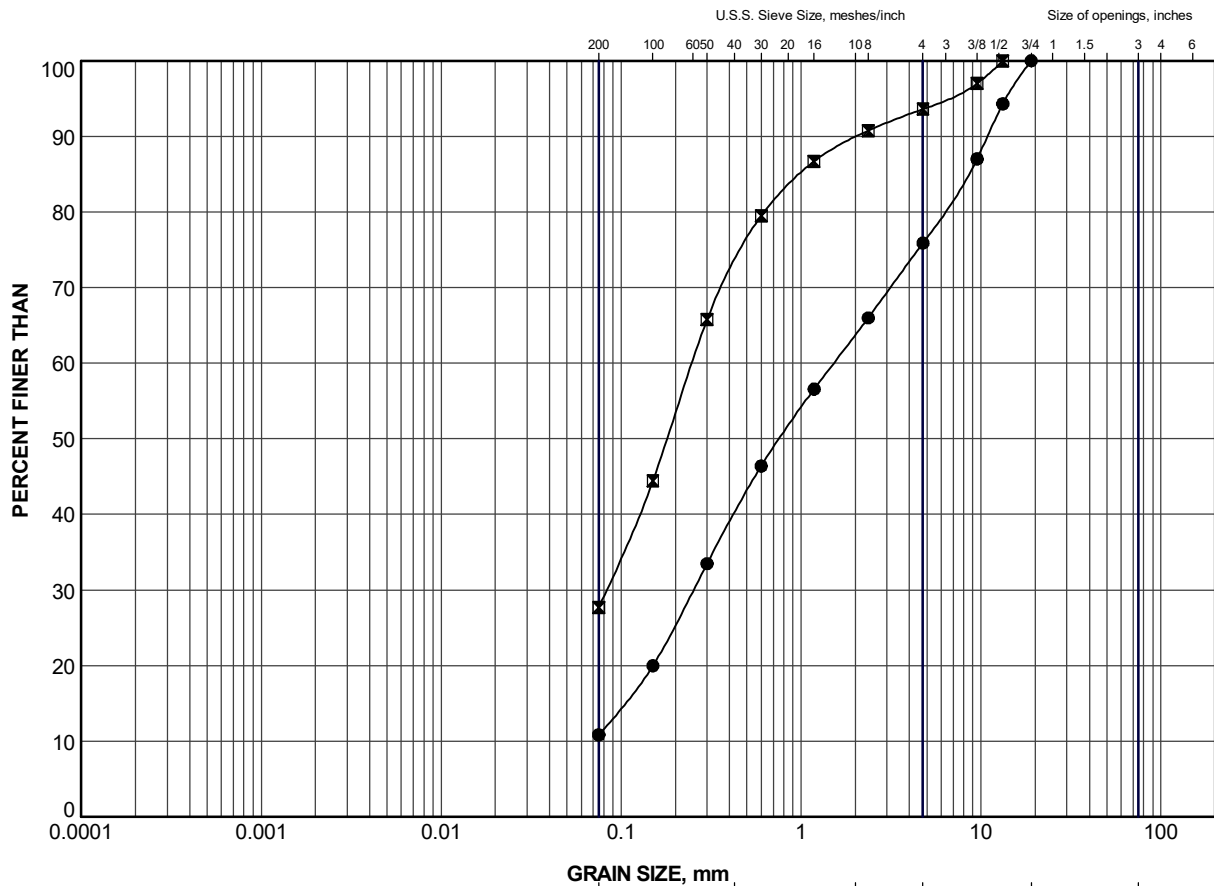
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+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

PROJECT 19122433		RECORD OF BOREHOLE No. 22-2				2 OF 2 METRIC											
G.W.P. 5181-13-00		LOCATION N 5170705.9; E 278736.5 NAD83 MTM ZONE 13 (LAT. 46.675451; LONG. -84.340671)				ORIGINATED BY HB											
DIST _____ HWY 17		BOREHOLE TYPE CME 55 Trackmount, HQ Casing				COMPILED BY TR											
DATUM GEODETIC		DATE August 23, 2022				CHECKED BY MT											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---																
286.3	SILTY SAND (SM) to Gravelly SILTY SAND (SM), trace silt Compact to very dense Brown Wet		12	SS	35		288										22 64 (14)
							287										
14.3	END OF BOREHOLE NOTE: 1. Water level measured in piezometer at a depth of 8.4 m below ground surface (Elev. 292.2 m) on August 25, 2022.																

APPENDIX B

Laboratory Test Results

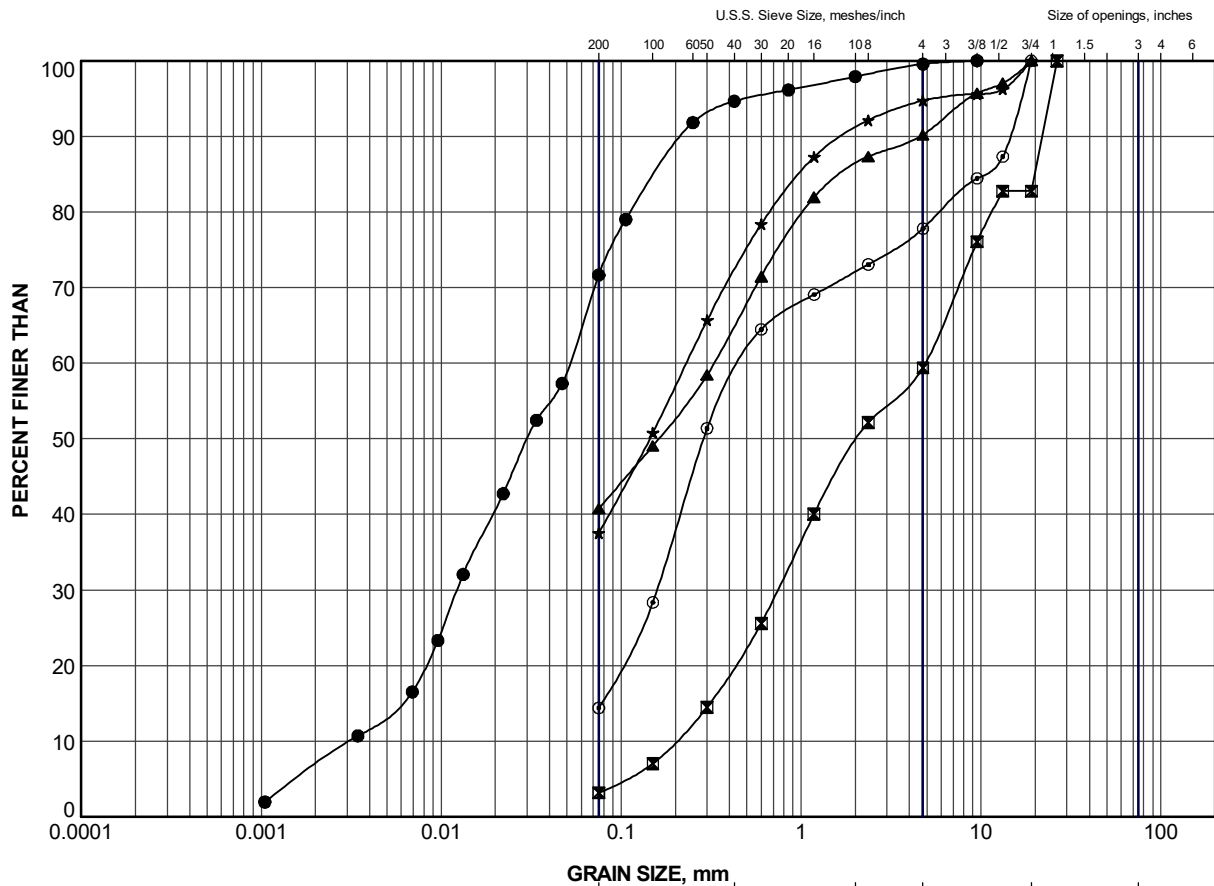


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	22-1	3	299.6
×	22-2	3	298.8

PROJECT						HIGHWAY 17 CULVERT AT STATION 12+754 TOWNSHIP OF AWERES											
TITLE						GRAIN SIZE DISTRIBUTION Gravelly SAND (SP-SM) to SILTY SAND (SM) (FILL)											
						PROJECT No.			19122433			FILE No.			19122433.GPJ		
						DRAWN		TR		Nov 2022		SCALE		N/A		REV.	
						CHECK		TB		Nov 2022							
						APPR		MT		Nov 2022							
SUDBURY, ONTARIO						FIGURE B-1											



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	22-1	6	297.3
⊠	22-1	10	292.0
▲	22-2	5	297.3
★	22-2	8	294.2
⊙	22-2	12	288.1

PROJECT					HIGHWAY 17 CULVERT AT STATION 12+754 TOWNSHIP OF AWERES				
TITLE					GRAIN SIZE DISTRIBUTION Sandy SILT (ML) to Gravelly SILTY SAND (SM) to SAND and Gravel (SP)				
PROJECT No.			19122433		FILE No.			19122433.GPJ	
DRAWN	TR	Nov 2022		SCALE	N/A		REV.		
CHECK	TB	Nov 2022		FIGURE B-2					
APPR	MT	Nov 2022							
					SUDBURY, ONTARIO				

APPENDIX C

Notices to Contractor (NTC)

OBSTRUCTIONS – Item No.

Non-Standard Special Provision

The Contactor shall be alerted to the presence of cobble obstructions at this site, which were encountered in Borehole 22-2 and potentially encountered in Borehole 22-1 (based on split-spoon refusal). Obstructions should be expected between and beyond the borehole locations. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for excavations, and installation of temporary protection systems/cofferdams.



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