



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
NON-STRUCTURAL CULVERT, STN 10+187, N/S-E RAMP
HIGHWAY 401/COUNTY ROAD 30, BRIGHTON, ON
AGREEMENT 4017-E-0047
ASSIGNMENT 4**

Geocres No.: 31C-282

Report to:

Ontario Ministry of Transportation

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed at a culvert beneath the N/S-E ramp of the Highway 401 and County Road 30 Interchange, within the County of Northumberland. Thurber carried out the investigation as a consultant to the Ministry of Transportation (MTO) as part of Assignment No. 4 under Retainer Agreement No. 4017-E-0047.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation.

No previous foundation investigation information was available for the subject culvert site within the online Geocres Library.

2 SITE DESCRIPTION

The existing culvert conveys drainage flow from within the interchange loop westerly under the N/S-E ramp towards the nearby Proctor Creek. Highway 401 in this area consists of a four lane freeway with a rural cross-section and vegetated median of variable width. The terrain ranges from flat to gently rolling and the land adjacent to the highway typically consists of farm fields or occasional forest.

The existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.61 m and a length of 39.4 m. The invert of the culvert was surveyed at approximate elevations of 191.1 and 190.4 m at the inlet (east) and outlet (west), respectively.

At the location of the culvert, the N/S-E ramp is a single lane on-ramp with curbs and gravel shoulders. The ramp fill height above the culvert is approximately 5.2 m with the road surface at approximate elevation 196.6 m. The existing embankment slopes are inclined at approximately 2.4H:1V and 2.1H:1V for the east and the west slopes, respectively. Steel

guiderails are present on both sides of the ramp in the vicinity of the culvert. The highway ramp embankment is generally performing well with no noticeable signs of surface settlement. However, a gully has formed on the eastern side-slope due to erosion where surface water is directed onto the slope.

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the culvert site lies within the physiographic region known as Iroquois Plain. The Iroquois Plain generally consists of glacio-lacustrine sand and silty sand. The soil deposit is underlain by limestone bedrock.

Photographs showing the existing conditions in the area of the culvert at the time of the field investigation are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between November 29th and December 4th, 2018. The field investigation consisted of advancing three boreholes identified as 18-1 through 18-3. The drilling was carried out using portable equipment for off-road Boreholes 18-1 and 18-3 and a truck-mounted CME 55 drill rig for on-road Borehole 18-2. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B and in Table 3-1. The termination depth of each borehole is also provided, below. The site is within MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
18-1	Inlet	4 882 288.4	203 101.4	193.1	8.2
18-2	Ramp Embankment	4 882 288.4	203 083.4	196.6	16.4
18-3	Outlet	4 882 273.9	203 069.2	192.3	10.3

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A half-weight (32 kg) hammer was used for the SPT testing in off-road Boreholes 18-1 and 18-3. The N-values reported herein for the off-road boreholes have been corrected to an equivalent standard weight hammer (64 kg). A standard weight hammer (64 kg) was used for SPT testing for on-road Borehole 18-2.



Off-road Borehole 18-1 was drilled from a platform due to accessibility issues. The depths presented on the Record of Borehole Sheet for Borehole 18-1 are from the surface of the platform which was 0.2 m higher than the ground surface.

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's Ottawa geotechnical laboratory for further examination and testing.

A 19 mm diameter standpipe piezometer was installed in Borehole 18-3 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole Sheet provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg 903, as amended). Borehole 18-2 was backfilled with granular material within the depth of pavement structure to reinstate the shoulder surface.

The horizontal positions of the as-drilled boreholes were determined using a measuring tape in the field relative to the existing site features (culvert inlet and outlet, and edge of asphalt) and then converted to northing and easting grid coordinates (MTM Zone 9) based on the georeferenced CAD drawing provided by the MTO. The ground surface elevations at the borehole locations were surveyed by Thurber using a rod and level relative to geodetic benchmark GBM 819698089 which is set horizontally in one of the south pillars of the Highway 401/County Road 30 underpass. The accuracy of the horizontal and vertical surveys are 0.5 m and 0.1 m, respectively, in accordance with the Terms of Reference.

4 LABORATORY TESTING

The recovered soil samples were subjected to inspection and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole Sheets included in Appendix B. One sample of soil recovered from Borehole 18-3 was selected and submitted for analytical testing of corrosivity parameters. All laboratory test results are provided in Appendix C. The borehole and sample numbers for the tested samples are indicated on the Borehole Records in Appendix B and the Laboratory results in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general

description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by embankment fill overlying native deposits of sandy silt to silt over glacial till.

5.1 Pavement Structure Fill: Silty Sand with Gravel

From surface in Borehole 18-2, a pavement structure fill consisting of silty sand with gravel was observed. The underside of the pavement structure was at 1.5 m below the existing roadway surface (elev. 195.1 m).

The SPT tests conducted in the silty sand with gravel fill gave N-values of 22 and 10 blows, indicating a compact relative density.

Recorded moisture contents were 4 and 9%. The results of a grain size analysis conducted on one sample of the pavement structure fill indicated this material to consist of 20% gravel, 48% sand, and 32% fines. These results are illustrated on Figure C1 in Appendix C.

5.2 Topsoil/Fill: Silty Sand to Silt

At surface in Boreholes 18-1 and 18-3 was a layer of topsoil fill consisting of silty sand to silt with trace gravel. Some roots and organics were also encountered throughout this layer. The thickness of the topsoil fill ranged from 0.3 to 1.0 m (underside elev. 191.3 to 192.6 m), respectively.

The SPT tests conducted in the topsoil fill gave N-values ranging from 3 to 5 blows, indicating a very loose to loose relative density.

Recorded moisture contents ranged from 14 to 25%.

5.3 Embankment Fill: Sandy Silt to Sand

A layer of embankment fill consisting of sandy silt trace to some gravel was encountered below the pavement structure fill in Borehole 18-2 and the topsoil fill in Boreholes 18-1 and 18-3. A layer of sand with a thickness of 0.3 m was encountered within this fill in Borehole 18-3 (underside elev. 190.5 m). Some organics were also encountered within the embankment fill in Boreholes 18-1 and 18-3. The thickness of the embankment fill ranged from 0.8 to 4.6 m (underside elev. 190.5 to 191.6 m), respectively.

The SPT tests conducted in the embankment fill gave N-values ranging from 3 to 14 blows, indicating a very loose to compact relative density.

Recorded moisture contents ranged from 9 to 37%. The results of grain size analyses conducted on three samples of the embankment fill are summarized in the table below and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	3 – 12
Sand	37 – 43
Silt	38 – 50
Clay	4 – 13

Atterberg Limit tests were completed on three samples of the embankment fill and indicated that the two samples from Boreholes 18-1 and 18-2 are non-plastic. The results of Atterberg Limit testing completed on the sample from Borehole 18-3 is summarized in the table below and illustrated on Figure C7 in Appendix C.

Parameter	Value
Liquid Limit	16
Plastic Limit	14
Plasticity Index	2

The laboratory results indicated that the sandy silt has low plasticity (ML).

5.4 Fill: Gravel with Silt and Sand

A layer of fill consisting of gravel with silt and sand was encountered below the embankment fill in all boreholes. Occasional cobbles were noted within this fill in Boreholes 18-1 and 18-3. The gravel fill ranged from 0.7 to 1.5 m in thickness with base elevations between 189.0 and 190.3 m.

SPT tests conducted in the gravel fill gave N-values ranging from 31 to 43 blows, indicating a dense relative density.

Recorded moisture contents ranged from 7 to 11%. The results of a grain size analysis conducted on one sample of the gravel fill indicated this material to consist of 48% gravel, 43% sand, and 9% fines. These results are illustrated on Figure C3 in Appendix C.

5.5 Sandy Silt to Silt (ML)

A native deposit of sandy silt to silt with trace to some gravel was encountered below the gravel fill in all boreholes. In Borehole 18-2 the silt deposit was noted to be 6.1 m thick with a base elevation of 182.9 m. Boreholes 18-1 and 18-3 were terminated within the deposit at elevations of 184.9 and 182.0 m, respectively (total depths of 8.0 and 10.3 m below ground surface, respectively). The presence of cobbles was inferred at a depth of 3.7 m (elev. 188.6m) in Borehole 18-3.

SPT tests conducted in the deposit gave N-values ranging from 4 to 40 blows, indicating a relative density of loose to dense.

Recorded moisture contents ranged from 15 to 26%. The results of grain size analyses conducted on four samples are summarized in the table below and are illustrated on Figure C4 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0 – 14
Sand	8 – 38
Silt	51 – 80
Clay	4 – 9

Atterberg Limit tests completed on four samples of the deposit indicated that the material is non-plastic.

5.6 Silty Sand (SM)

A thin layer of silty sand with a thickness of 0.3 m was encountered within the silt layer at a depth of 7.4 m (elev. 185.5 m) in Borehole 18-1.

An SPT test conducted in the silty sand layer gave an N-value of 81 blows, indicating a very dense relative density.

The recorded moisture content of the silty sand was 11%. The results of a grain size analysis conducted on one sample of the silty sand layer indicated the material to consist of 0% gravel, 74% sand and 26% fines. The results of the grain size analysis are illustrated on Figure C5 in Appendix C.

5.7 Silty Sand (SM) with Gravel – Glacial Till

A deposit of glacial till consisting of silty sand with gravel was encountered below the silt layer in Borehole 18-2. Borehole 18-2 was terminated 2.7 m into the glacial till at a base elevation of 180.2 m (total depth of 16.4 m below ground surface).

SPT tests conducted in this layer gave N-values ranging from 4 to 88 blows, indicating a very loose to very dense relative density.

Recorded moisture contents ranged from 11 to 16%. The results of a grain size analysis conducted on one sample of the till indicates this material consists of 15% gravel, 41% sand, 39% silt and 5% clay. These results are illustrated on Figure C6 in Appendix C.

An Atterberg Limit test completed on one sample of the till indicated that the material is non-plastic.

5.8 Groundwater

The groundwater water level measured in the standpipe piezometer installed in Borehole 18-3 was at 0.2 m above the ground surface (elev. 192.5 m) on December 7, 2018. The culvert was dry at the time of the field investigation.

Following the completion of drilling on-road Borehole 18-2, the open borehole water level was measured at 4.9 m below the road surface (elev. 191.7 m). Upon completion of drilling off-road Borehole 18-1 and 18-3, slight artesian conditions were noted, with water elevations of 193.4 and 192.7 m, respectively (0.5 and 0.4 m above ground surface, respectively).

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.9 Analytical Testing

One sample of the native soils encountered at the site was submitted for analysis of pH, water soluble sulphate, sulphide, chloride, conductivity and resistivity. The analysis results are summarized in Table 5-1. A copy of the test results is provided in Appendix C.

Table 5-1: Results of Chemical Analysis

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
18-3 (SS4)	1.8 – 2.4	9	7.70	4260	235	52	<0.02



6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the existing culvert location. The as-drilled locations and ground surface elevation of the boreholes were measured by Thurber following completion of the field program. Survey elevation benchmarks were provided by MTO.

CCC Geotechnical and Environmental Drilling Ltd. of Ottawa, Ontario and Forage M3 of Hawkesbury, Ontario supplied and operated the drilling equipment for the on-road and off-road boreholes, respectively, and carried out the drilling, soil sampling, in-situ testing, standpipe installation and borehole decommissioning. Beacon Lite of Kingston, Ontario supplied the traffic control equipment and personnel for shoulder closures required for the field investigation. The field investigation was supervised on a full time basis by Allison Chow, EIT and Sean O'Bryan CET of Thurber. Overall supervision of the investigation program was provided by Stephen Dunlop, P.Eng.

Low complexity laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Allison Chow, EIT, and Stephen Dunlop P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the Ministry in designing a suitable replacement of the existing deep fill culvert crossing the N/S-E ramp of the Highway 401/County Road 30 Interchange at Station 10+187. The discussion and recommendations presented in this report are based on the information provided by the Ministry of Transportation (MTO) and on the factual data obtained during the course of the investigation.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The existing culvert conveys drainage flow from the east to the west under a high fill embankment supporting the N/S-E ramp at the Highway 401/County Road 30 Interchange. Based on information provided by the MTO, the existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.61 m and a length of 39.5 m. The invert of the culvert was surveyed at approximate elevations of 191.1 and 190.4 m at the inlet (east) and outlet (west), respectively. The ramp fill height above the culvert is approximately 5.2 m with the road surface at approximate elevation 196.6 m. The existing embankment slopes are inclined at approximately 2.4H:1V and 2.1H:1V for the east and the west slopes, respectively. Groundwater was measured at an elevation of 192.5 m on December 7, 2018.

This foundation investigation was initiated because this is classified as a high embankment fill site.

No previous foundation investigation information at the subject culvert was available within the online Geocres Library. Several foundation investigation reports for other assets at the subject interchange were available, these reports were reviewed prior to the field investigation, but are not discussed further within.

7.1 Proposed Work

It is understood that the existing culvert will be replaced with a non-structural culvert of similar size, length and alignment. It is assumed that the invert elevation of the new culvert will be similar to that of the existing culvert.

It is noted that this report provides geotechnical guidelines for the replacement of a non-structural culvert. If additional foundation design guidelines are required (e.g., for a structural culvert or retaining walls), further geotechnical guidance will be required.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). The seismic hazard for this site has been obtained from the GSC online calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values ($S_a(T)$) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.105g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class.

8.2 Seismic Liquefaction Potential

Based on the depth of ground water, the low reference PGA, the subsurface conditions encountered at the drilled locations at this site and using the Seed & Idriss Simplified Method for liquefaction assessment, the soils below the culvert inverts are not considered susceptible to liquefaction during a design seismic event. Some local slope instability may be noted at the culvert inlet and outlet for a design seismic event during a period of higher water levels.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

At the time of preparation of the Foundation Investigation and Design Report it is understood that the replacement culvert is to be replaced with a circular type culvert (Concrete, HDPE, Steel) having a similar cross-sectional area and invert elevations as the existing culvert.

9.2 Construction Methodology Alternative

For the proposed culvert replacement, the following construction methods were considered. A table comparing the options is provided in Appendix E.

- Open Cut with Full Ramp Closure
Installation of a new culvert using open cut techniques and a full ramp closure would allow for an expedited construction schedule and would reduce costs associated with roadway protection and water flow diversion. It is understood that the ramp will need to be closed for an extended period for the ramp re-alignment, thus culvert replacement can be carried out at that time.
- Open Cut and Temporary Protection System (TPS) and Temporary Widening
If maintaining traffic flow is needed, the use of open cut techniques in conjunction with a staged culvert replacement is considered a feasible construction option from a geotechnical perspective. This option includes the use of temporary protection system (TPS) installed along the embankment centerline in conjunction with temporary ramp widening to maintain a single lane of traffic along the current ramp alignment. The TPS would need to support a temporary cut height in the order of 6 m. The height of the TPS could be reduced if a temporary grade lowering was also included.
- Trenchless Techniques
It is noted that a gravel fill with occasional cobbles is present at the culvert level. Although a trenchless technique (pipe ramming or jack and bore) is considered feasible, the cobbles are potential obstructions and represent an increased risk.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacing the existing culvert with a circular pipe culvert using open cut techniques with a full ramp closure is the recommended culvert replacement option. It is anticipated that replacement would occur during the ramp closures required to realign the N/S-E ramp. Replacement using a trenchless method is also considered feasible but would introduce unnecessary risks to the project. A trenchless replacement should only be considered if a full ramp closure is not possible.

10 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert include subgrade conditions, settlement of the founding soils, imposed loading pressures, erosion control and groundwater control. The culvert must be designed to resist loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

10.1 Subgrade Preparation, Bedding and Backfilling

Pipe culverts should be constructed in accordance with OPSS.PROV 401 and OPSS.PROV 421.

For a replacement culvert constructed along the same alignment as the current culvert, the existing culvert and embedment materials should be removed. After excavation and removal of the existing culvert and existing fill, unsuitable materials at the subgrade level should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction.

The silt subgrade will be easily disturbed; therefore construction equipment should not travel on the exposed subgrade. The compaction of granular material directly above the silt subgrade may result in disturbance of the material with pumping of fines into the granulars and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of Class II non-woven geotextile with a maximum FOS of 75 to 150 μm (OPSS 1860) installed beneath the Granular layer. The geotextile should have overlapping joints and be placed as soon as possible after reaching the subgrade level.

For flexible pipe culverts it is recommended that culvert embedment material be in accordance with OPSD 802.010 and OPSS.PROV 401 and consist of OPSS Granular A material extending to at least 150 mm below the culvert.

For rigid pipe culverts it is recommended that culvert bedding and cover be in accordance with OPSD 802.031 and OPSS.PROV 401 and consist of OPSS Granular A material. The bedding should be at least 150 mm thick.

Culvert backfill material should meet the requirements of OPSS Granular B Type I or SSM and should be constructed in accordance with OPSS.PROV 401. Granular B Type III can also be specified in lieu of Granular B Type I.

Construction of the culvert will need to take place in the dry. At the time of investigation some surface water was encountered in ditches near the inlet and outlet; however, construction will extend below the ditch elevation and seasonal fluctuations may occur. Water diversion and dewatering may be required to prepare the subgrade in the dry. Additional comments on groundwater and surface water control are provided in Section 11.2.

10.2 Frost Depth

The depth of frost penetration at this site is 1.4 m (as per OPSD 3090.101). The frost penetration line falls above the pipe. A frost taper will not be required.

10.3 Embankment Design and Reinstatement

10.3.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Granular B Type I or SSM. The fill should be placed and compacted in accordance with OPSS.PROV 401.

10.3.2 Embankment Settlement and Stability

The condition of the existing embankment slopes was examined in the field during the field investigation and no evidence of instability (tension cracks etc.) was noted at that time. The embankment slopes were vegetated with grass.

It is understood that no permanent grade raise or embankment widening is required anticipated at this site and therefore negligible settlement of the soils beneath the embankment is expected to occur.

The magnitude of compression for embankment fill materials is in the order of 0.5% of the embankment height and is expected to occur following fill placement.

Provided no grade raise or embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments re-built at this site. Material stockpiling above the existing grades is a temporary construction measure and the associated stability/settlement implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as heavy cranes) are also the Contractor's responsibility.

10.4 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.9 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the existing fills above the groundwater level may be classified as Type 3 soil. The native soils and fills below the groundwater level and are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS.PROV 401 and will be carried out through the existing embankment fill and will extend into the underlying native silt deposit. The sides of temporary excavations must be sloped in accordance with the requirement of OHSA. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Protection of adjacent utilities will need to be taken into consideration when evaluating the excavation limits.

11.2 Surface and Groundwater Control

At the time of the borehole investigation, the ditches held some surface water but there was no flow through the culvert. However, creek diversion may be required depending on the surface water depth at the time of construction. The groundwater water level measured in the standpipe piezometer installed in Borehole 18-3 was recorded at an elevation of 192.5 m which is above the culvert invert. However, this was a short term reading and the water level is expected to fluctuate. Water from surface flow and/or groundwater must be diverted away from excavation(s) at all times. Groundwater perched within the embankment and surface water will tend to seep into and accumulate in excavations. The Contractor must be prepared to control the groundwater and surface water at the site to permit construction in a dry and stable environment.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility.

For non-structural pipe culverts, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01. The Design Engineer Fill-In ***** in SP 517F01 for Dewatering System should be "Yes". The preconstruction survey distance should be "100 m".

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of construction should be taken as the water level from the design storm period defined in SP 517F01.

Construction of cofferdams may be required to divert flow away from the area of the culvert. A sand bag cofferdam and sump pumps would likely be sufficient.

Excavation below the groundwater level to replace the existing culvert without prior dewatering is not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work. Disturbance of the silt subgrade soils is considered to be a risk without proper consideration of groundwater lowering. The groundwater level should be lowered to 0.5 m below the planned base of excavation.

The need for a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

11.3 Scour Protection and Erosion Control

Scour and erosion protection should be provided for the culvert inlet and outlet areas. Design of the scour and erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Based on the subsurface conditions encountered at the drilled locations through the embankment at this site the embankment fill materials are considered to have moderate susceptibility to erosion as per the Wischmeier Nomograph. The native soils are considered to have high susceptibility to erosion.

Typically, rock protection should be provided over all earth surfaces in contact with flowing water. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

12 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Cobbles were encountered within the fill and native soil. Buried obstructions may be encountered during excavation. Suggested wording for a Notice to Contractor on “Obstructions” is included in Appendix G.
- Groundwater levels will fluctuate. Excavation will require lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes. Suggested wording for an NSSP on “Dewatering” is included in Appendix G.
- The Contractor’s selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment.


The successful performance of the culvert installation will depend largely upon good workmanship and quality control during construction.



13 CLOSURE

Engineering analysis and preparation of this report were carried out by Justin Gray, P.Eng. and Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:


For Justin Gray, P.Eng.
Geotechnical Engineer



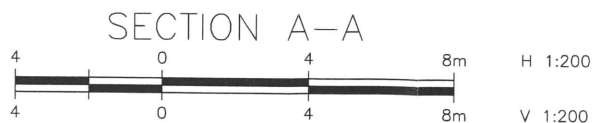
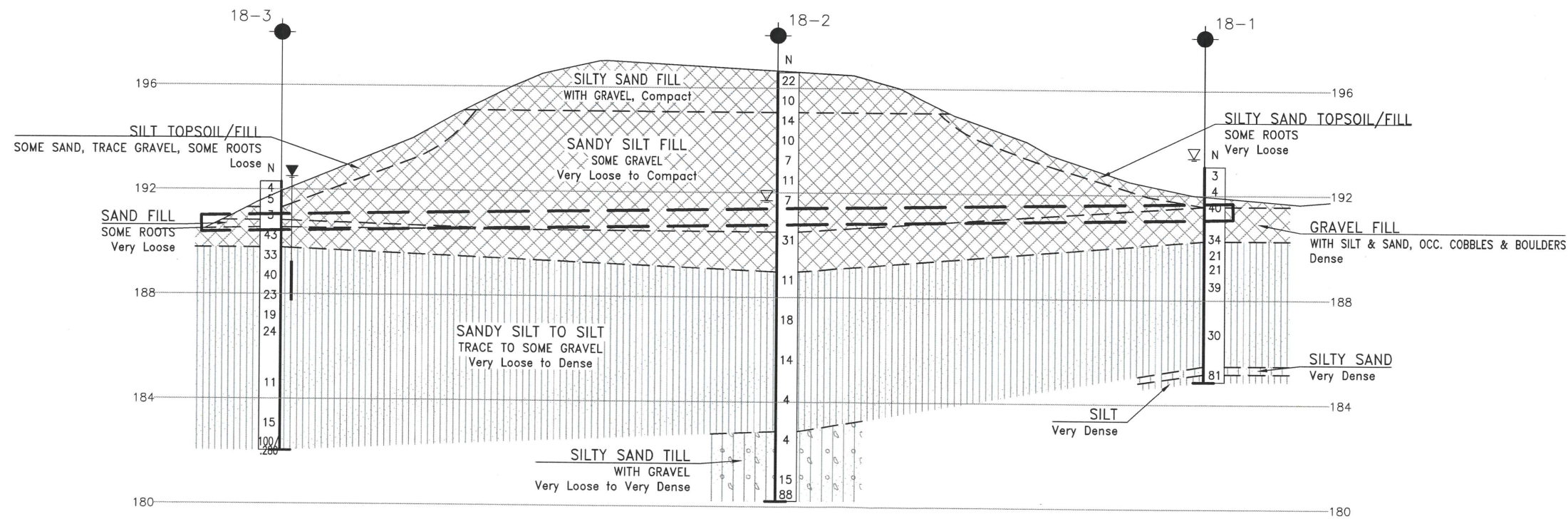
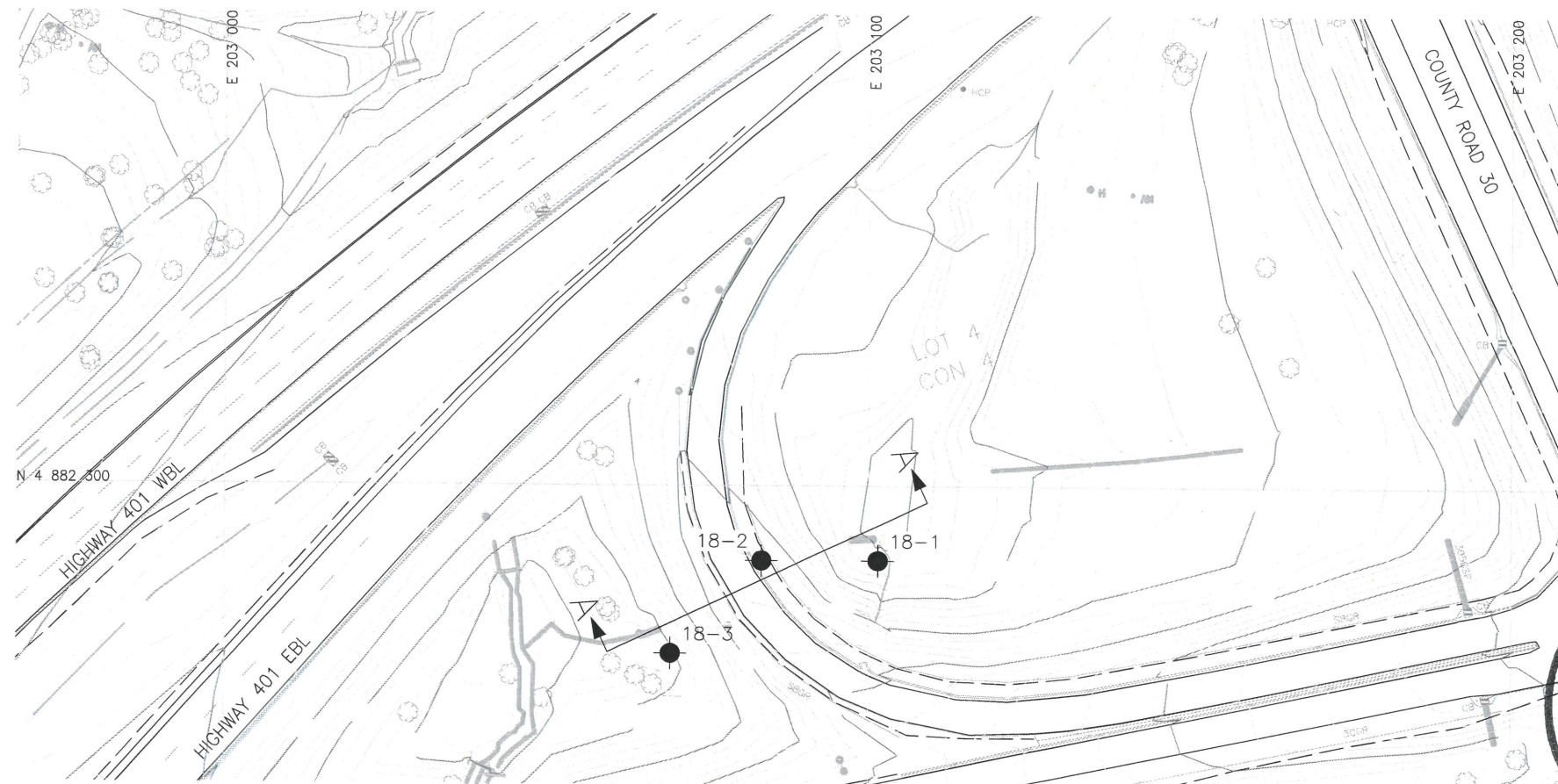
Stephen Dunlop, M.A.Sc., P.Eng.
Senior Geotechnical Engineer



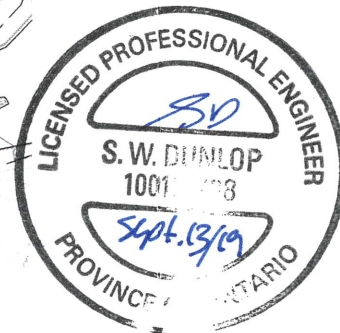
Dr. Fred Griffiths, Ph.D., P.Eng.
Review Principal
Senior Geotechnical Engineer

Appendix A.

Borehole Location Plan and Stratigraphic Drawings

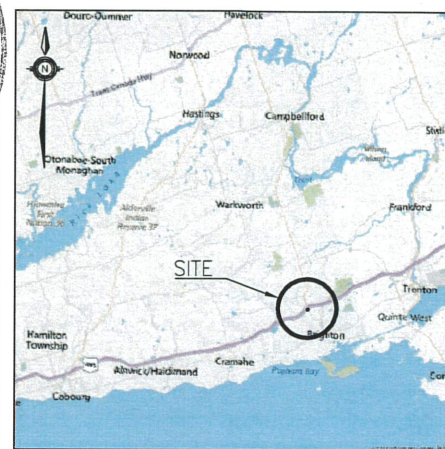


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
WP No

HIGHWAY 401
COUNTY ROAD 30
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN
LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18-1	193.1	4 882 288.4	203 101.4
18-2	196.6	4 882 288.4	203 083.4
18-3	192.3	4 882 273.9	203 069.2

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 9.

GEOCREs No. 31C-282

REVISIONS	DATE	BY	DESCRIPTION
DESIGN AC	CHK -	CODE	LOAD
DRAWN MFA	CHK AC	SITE	STRUCT
			DWG 1

Appendix B.

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No 18-1

1 OF 2

METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073532°, Long: -77.769657°
MTM z9: N 4 882 288.4 E 203 101.4 ORIGINATED BY AC
HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC
DATUM Geodetic DATE 2018.11.29 - 2018.11.30 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
193.1								20	40	60	80	100							
0.0	Platform						193												
0.2	SILTY SAND		1	SS	3														
192.6	some roots																		
0.5	very loose																		
	dark grey																		
	TOPSOIL/FILL		2	SS	4														
	SANDY SILT						192												
	some organics																		
	trace gravel																		
191.6	loose		3	SS	40														
1.5	grey																		
	FILL																		
	GRAVEL with silt and sand						191												
	occasional cobbles																		
	dense																		
	brown																		
	FILL		4	SS	34														
190.3																			
2.8	SANDY SILT to SILT (ML)						190												
	trace to some gravel		5	SS	21														
	compact to dense																		
	grey brown		6	SS	21														
							189												
			7	SS	39														
							188												
			8	SS	30		187												
							186												
185.5																			
7.6	SILTY SAND (SM)																		
185.2	very dense		9	SS	81														
7.9	dark grey																		
184.9							185												
8.2	SILT																		
	very dense																		
	grey-brown																		
	Practical Refusal																		
	Notes:																		
	1) Practical refusal to advancement																		
	was encountered after the casing																		
	was jammed and 2.1 m of "blow-up"																		
	occurred at 8.2 m depth.																		

DOUBLE LINE 24731 - HWY 401 CR 30 CULVERT GPU 2012TEMPLATE(MTO).GDT 13/9/19

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

ELEV DEPTH	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	20 40 60				
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100		WATER CONTENT (%) 20 40 60				

2) A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer.

3) Slight artesian condition noted at elev. 185.5 m during drilling, water rose to elev. 193.4 m within casing.

RECORD OF BOREHOLE No 18-2

1 OF 2

METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073531°, Long: -77.769881°
MTM z9: N 4 882 288.4 E 203 083.4 ORIGINATED BY SOB
HWY 401/CR 30 BOREHOLE TYPE HSA COMPILED BY AC
DATUM Geodetic DATE 2018.12.04 - 2018.12.04 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)			GR	SA	SI	CL	
								20 40 60 80 100					w _P w w _L							
196.6																				
0.0	SILTY SAND with gravel compact brown FILL		1	SS	22															
				2	SS	10														
195.1																				
1.5	SANDY SILT some gravel loose to compact brown FILL		3	SS	14															
				4	SS	10														
				5	SS	7														
				6	SS	11														
			7	SS	7															
190.5																				
6.1	GRAVEL with silt and sand dense brown FILL		8	SS	31															
189.0																				
7.6	SANDY SILT to SILT (ML) trace to some gravel compact grey brown		9	SS	11															
				10	SS	18														

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

METRIC

[illegible][illegible]

DOUBLE LINE 24731 - HWY 401 CR 30 CULVERT.GPJ 2012TEMPLATE(MTO).GDT 13/9/19

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-3

1 OF 2

METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073397°, Long: -77.770056° MTM z9: N 4 882 273.9 E 203 069.2 ORIGINATED BY AC
 HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC
 DATUM Geodetic DATE 2018.12.03 - 2018.12.04 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
192.3								20	40	60	80	100							
0.0	SILT some sand trace gravel some roots loose brown to grey-brown TOPSOIL/FILL		1	SS	4		192												
191.3			2	SS	5														
1.0	SANDY SILT some gravel very loose grey-brown FILL		3	SS	3		191												11 38 41 10
190.8																			
1.5																			
190.5	SAND some roots very loose black FILL		4	SS	43		190												
1.8																			
189.8	GRAVEL with silt and sand occasional cobbles dense orange-brown FILL		5	SS	33														14 19 63 4 non-plastic
2.5	SANDY SILT to SILT (ML) trace to some gravel compact to dense grey-brown inferred cobbles at 3.7 m (elev. 188.6 m)		6	SS	40		189												
			7	SS	23		188												
			8	SS	19		187												
			9	SS	24		186												
							185												7 8 80 5 non-plastic
			10	SS	11		184												
			11	SS	15		183												

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Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-3

2 OF 2

METRIC

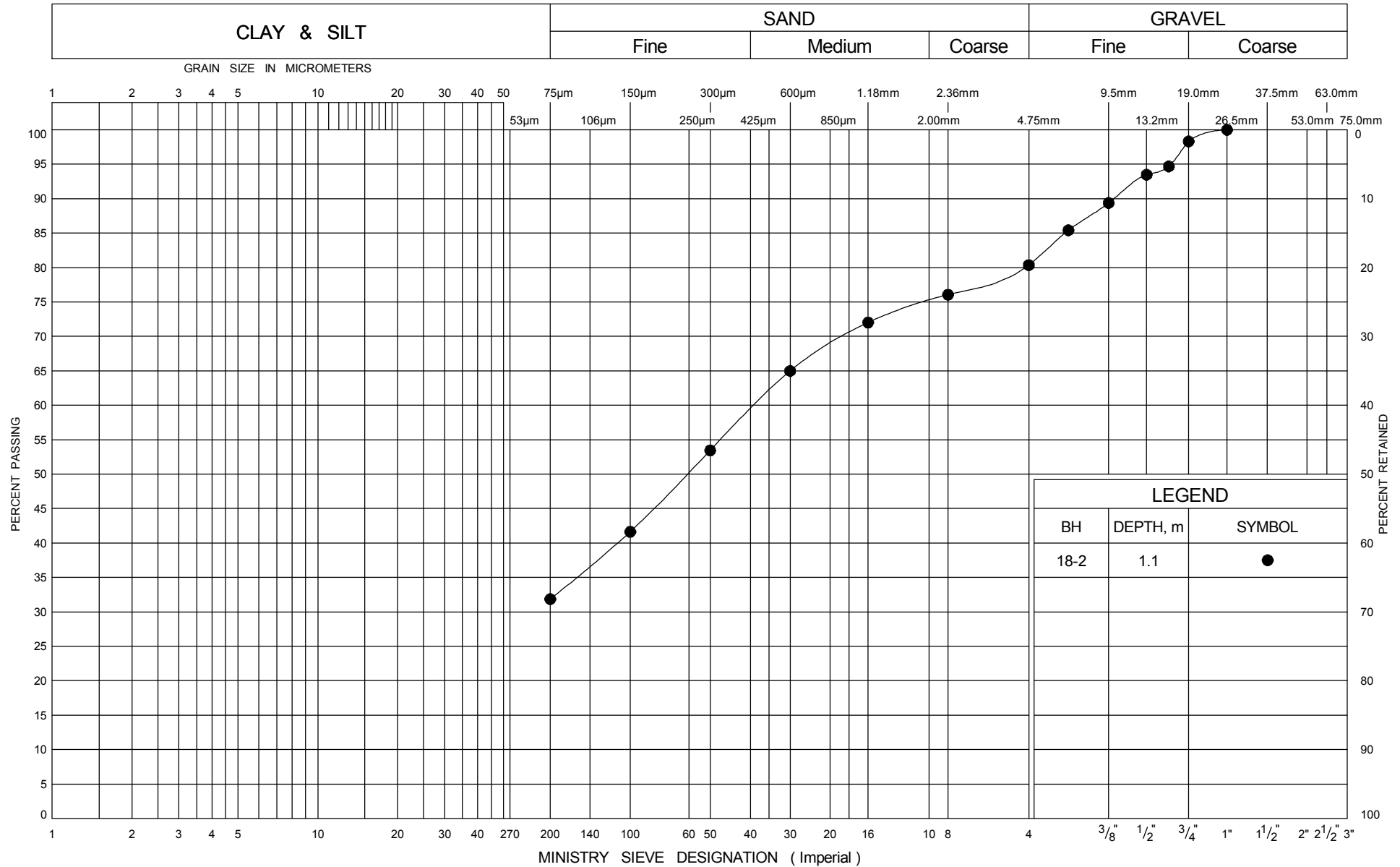
GWP# 4012-18-00 LOCATION Lat: 44.073397°, Long: -77.770056°
MTM z9: N 4 882 273.9 E 203 069.2 ORIGINATED BY AC
HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC
DATUM Geodetic DATE 2018.12.03 - 2018.12.04 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							<div><div>20406080100</div><div></div><div>20406080100</div></div>						
182.0 10.3	<div><div><div>SANDY SILT to SILT (ML)</div><div>trace to some gravel compact to dense grey-brown</div><div>Refusal</div><div>Notes: 1) Water level in 19 mm standpipe measured at 0.2 m above ground surface (elev. 192.5 m) on 2018.12.07 2) A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer. 3) Slight artesian conditions noted at elev. 184.4 m during drilling, water rose to elev. 192.7 m within casing.</div></div></div>		12	SS	100/ 280 mm									

Appendix C.
Laboratory Testing

Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

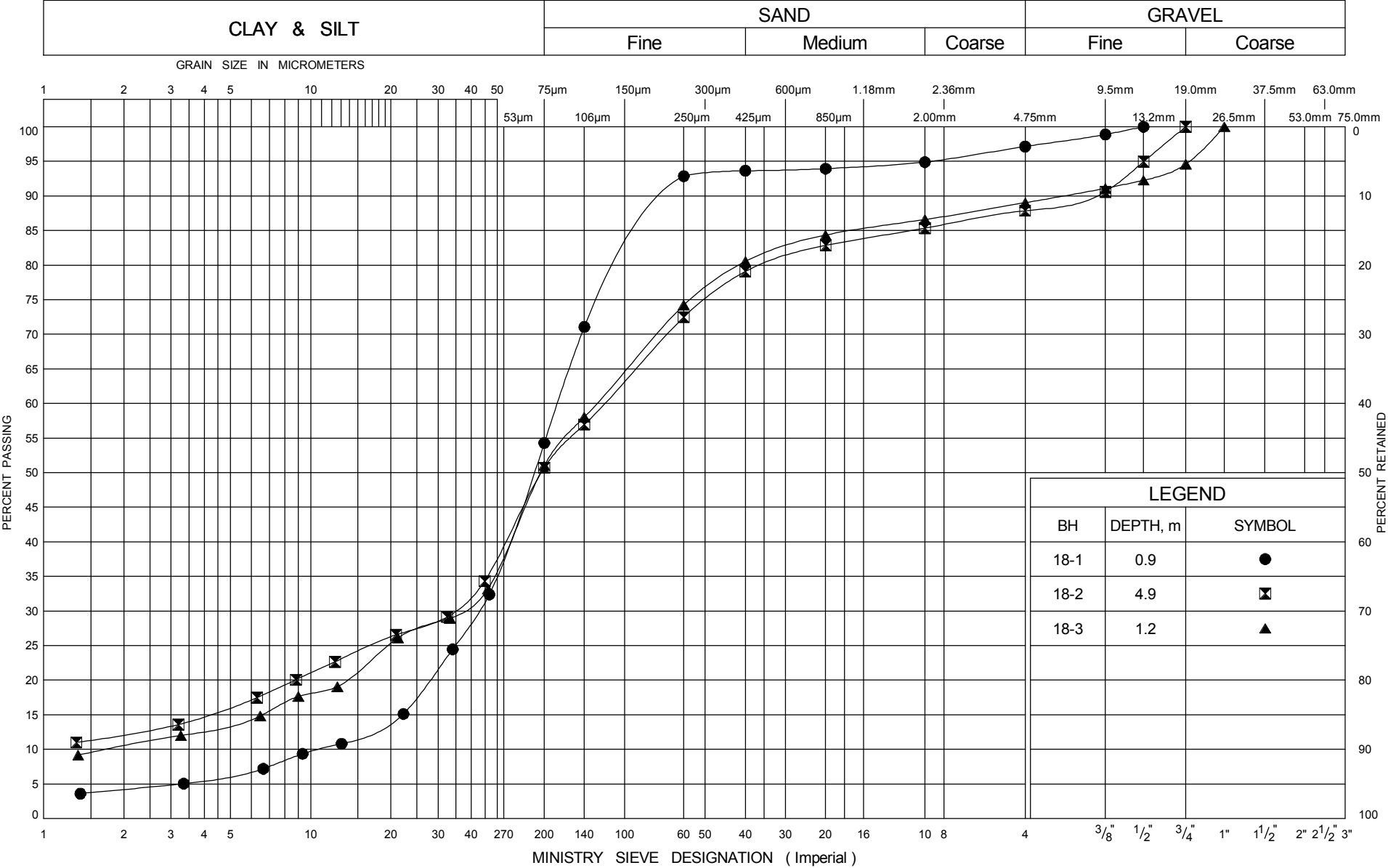
Fill: Silty Sand with Gravel

FIG No C1

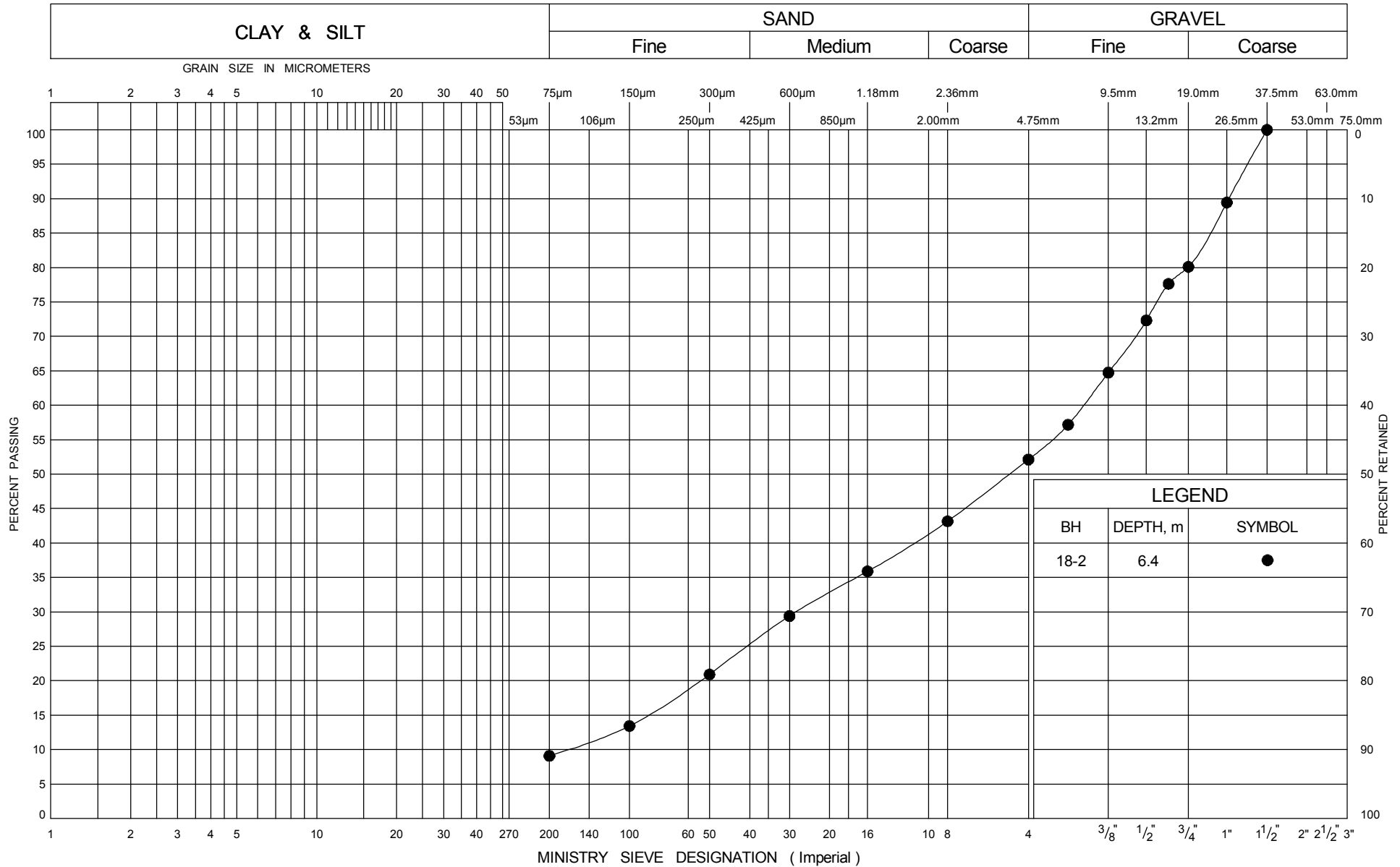
W P -

HWY 401/CR 30

UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

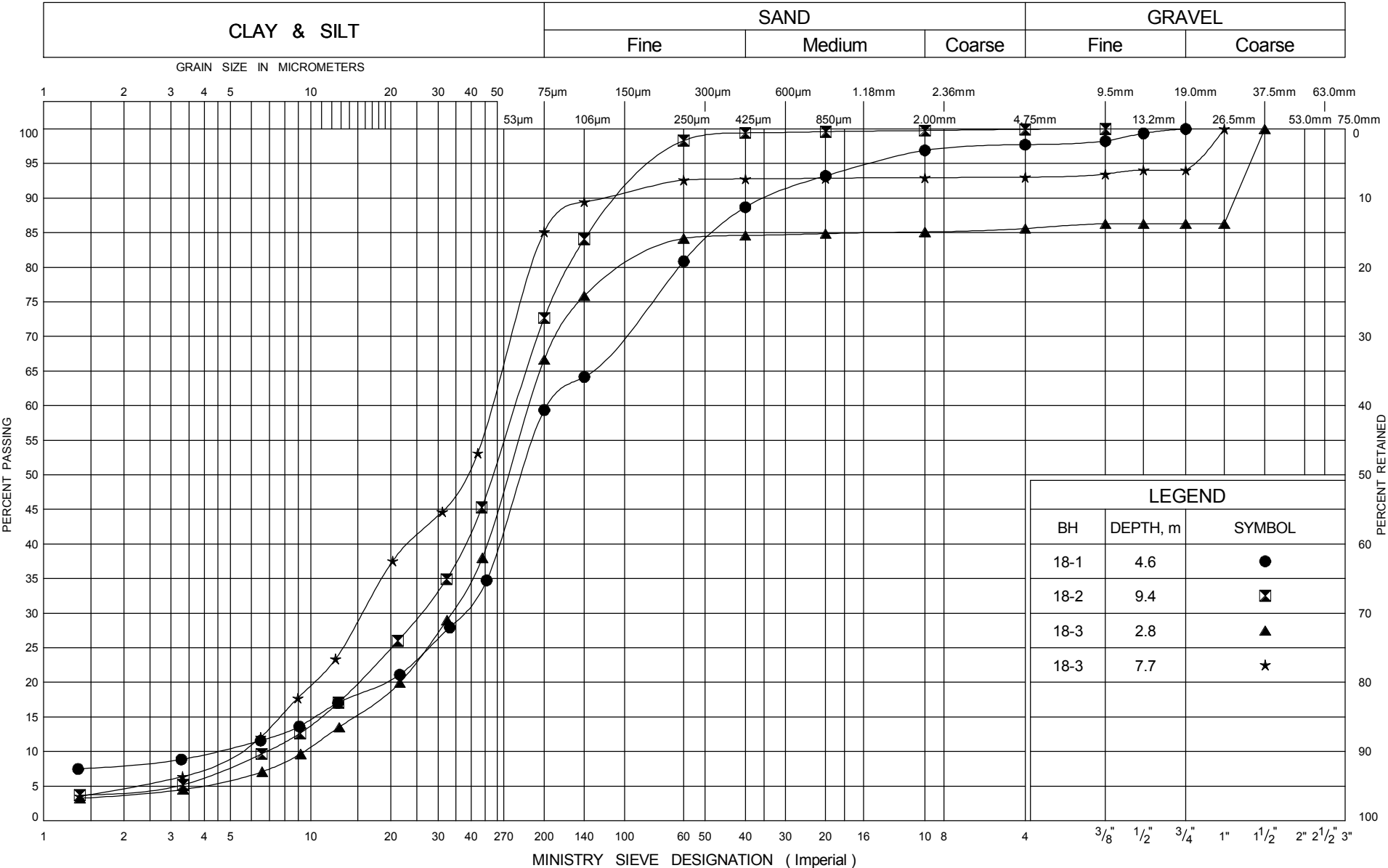
Fill: Gravel with Silt and Sand

FIG No C3

W P -

HWY 401/CR 30

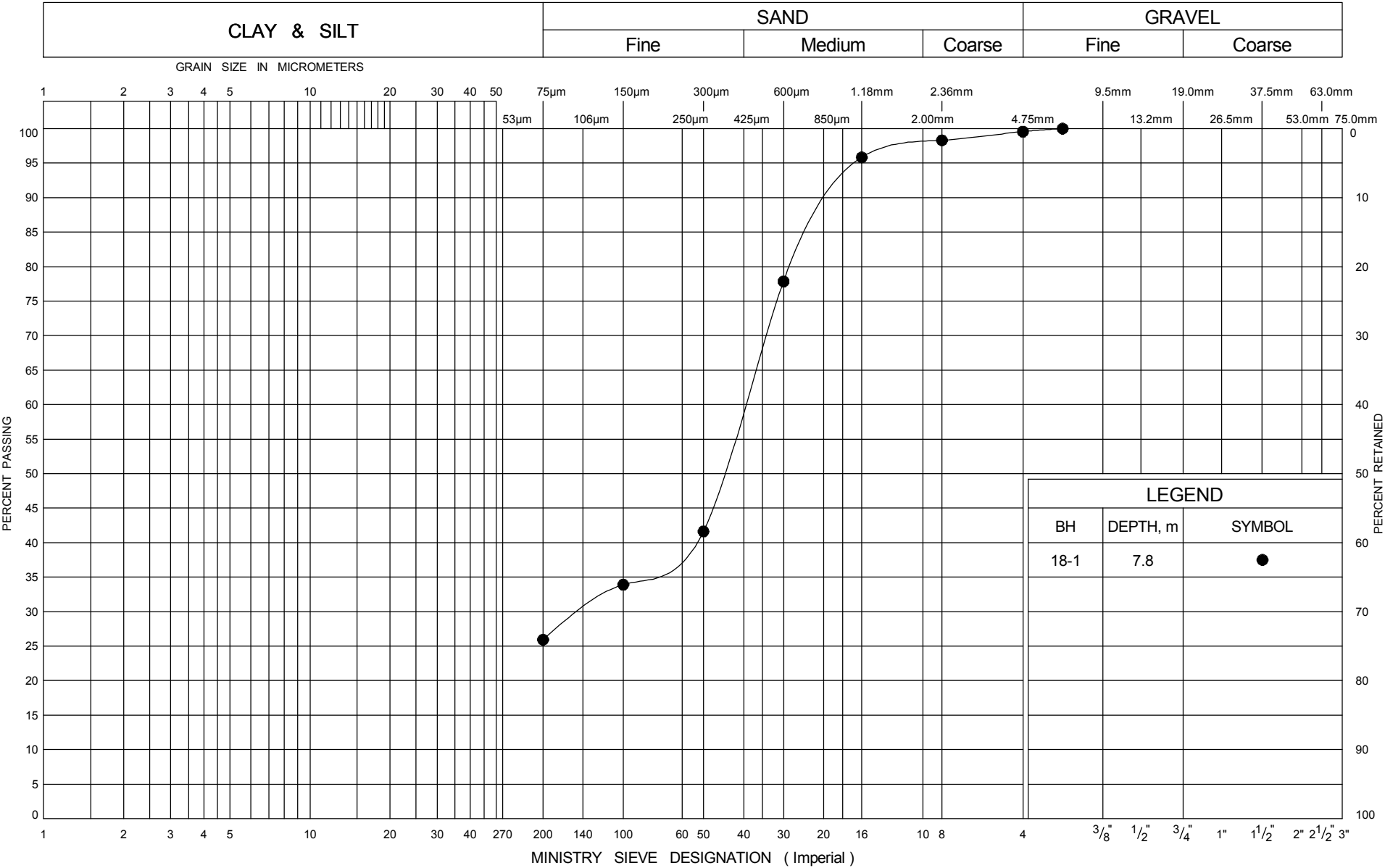
UNIFIED SOIL CLASSIFICATION SYSTEM



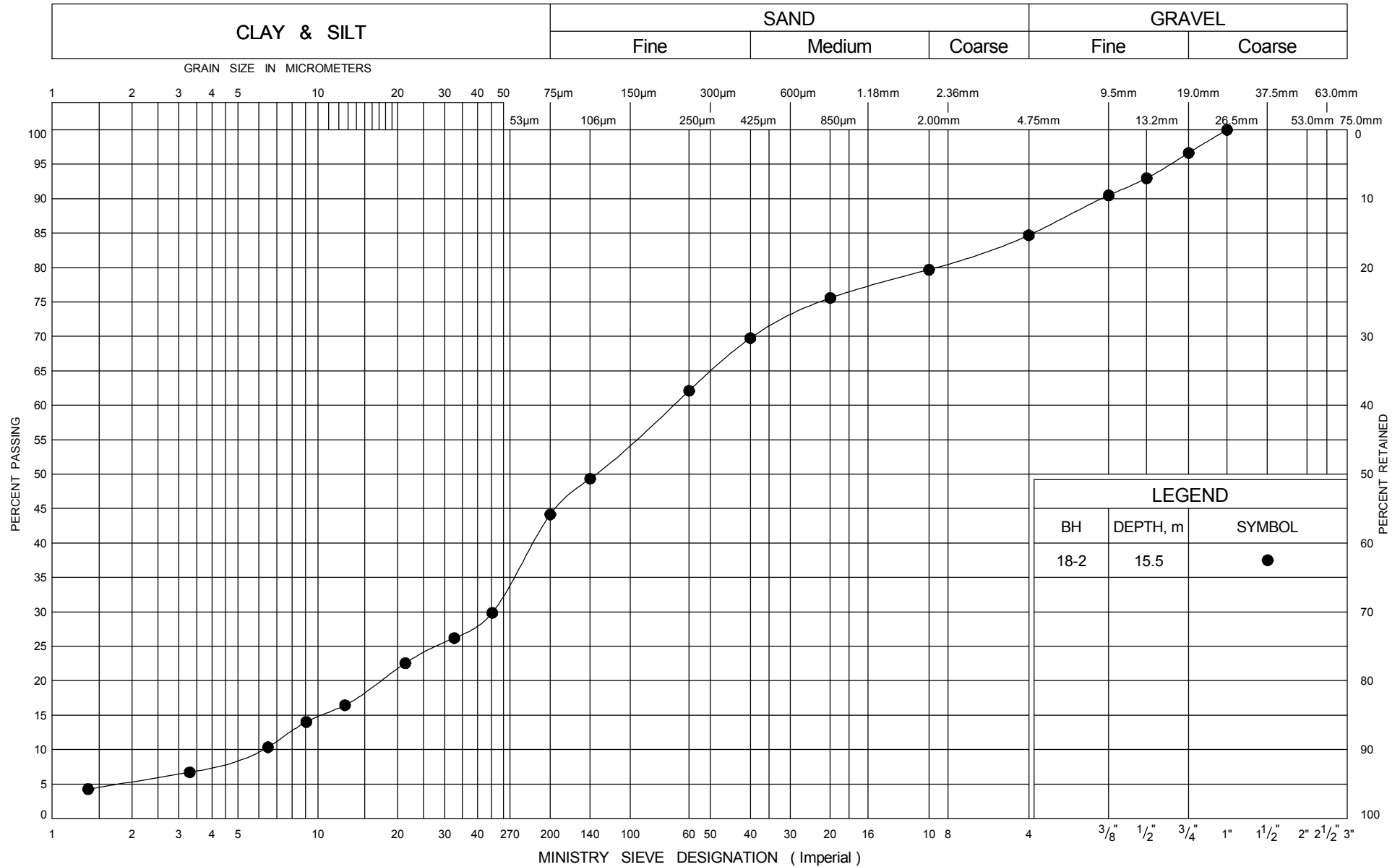
GRAIN SIZE DISTRIBUTION
Sandy Silt to Silt (ML)

FIG No C4
W P -
HWY 401/CR 30

UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

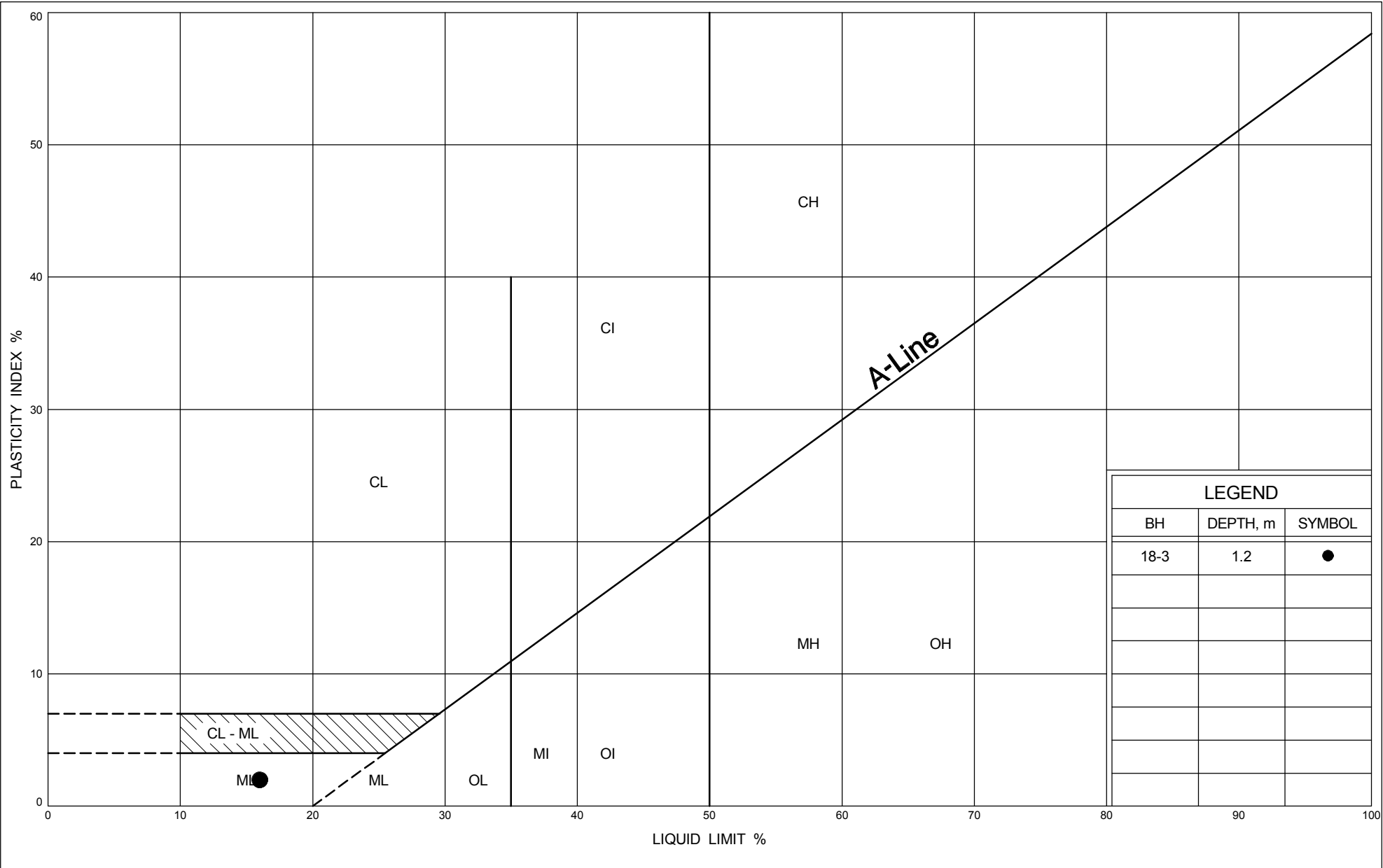
GRAIN SIZE DISTRIBUTION

Silty Sand (SM) with Gravel - (Glacial Till)

FIG No C6

W P -

HWY 401/CR 30



Appendix C.2
Analytical Testing Results

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24731

Report Date: 12-Dec-2018

Order Date: 6-Dec-2018

Project Description: HWY 401/CR30

Client ID:		18-3, SS4, 5'9"-7'9"	18-4, SS5, 10'-12'	18-5, SS4, 7'6"-9'6"	-
Sample Date:		12/03/2018 09:00	12/03/2018 09:00	12/03/2018 09:00	-
Sample ID:		1849437-01	1849437-02	1849437-03	-
MDL/Units		Soil	Soil	Soil	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.9	93.4	88.3	-
General Inorganics					
Conductivity	5 uS/cm	235	298	417	-
pH	0.05 pH Units	7.70	7.97	7.78	-
Resistivity	0.10 Ohm.m	42.6	33.5	24.0	-
Anions					
Chloride	5 ug/g dry	52	128	184	-
Sulphate	5 ug/g dry	9	11	8	-
Subcontract					
Sulphide	0.02 %	<0.02 [1]	<0.02 [1]	<0.02 [1]	-

Appendix D.

Site Photographs



Photo 1. Looking north towards culvert crossing (2018/12/07)



Photo 2. Looking west towards culvert outlet (2018/12/04)



Photo 3. Looking southwest at culvert inlet (2018/11/28)

Appendix E.

Foundation Comparison

COMPARISON OF REPLACEMENT OPTIONS

	<i>Circular Pipe with Open Cut using Full Ramp Closure</i>	<i>Circular Pipe with Open Cut using Staged Approach</i>	<i>Circular Pipe Culvert using Trenchless Installation</i>
<i>Advantages</i>	<ul style="list-style-type: none"> ▪ Simple construction ▪ Relatively expedient installation ▪ Can easily handle oversized obstructions 	<ul style="list-style-type: none"> ▪ Site soils conducive to installing roadway protection ▪ Maintains traffic flow 	<ul style="list-style-type: none"> ▪ Avoids large open cuts ▪ Allows traffic to be maintained throughout construction ▪ If replaced on new alignment, existing culvert can provide surface water flow during construction
<i>Disadvantages</i>	<ul style="list-style-type: none"> ▪ Requires large excavation ▪ Requires water flow management ▪ Requires ramp closure 	<ul style="list-style-type: none"> ▪ Requires large excavation ▪ Requires water flow management ▪ Requires roadway protection and temporary embankment widening ▪ Some disruption to traffic ▪ Ramp geometrics must be reviewed 	<ul style="list-style-type: none"> ▪ Requires construction of entry and exit pits and access to toes of slope ▪ Must maintain surface and groundwater control ▪ Requires specialised construction equipment ▪ Cobbles are present in the existing granular bedding/ surround of existing culvert
<i>Risks/ Consequences</i>	Minimal risks.	Minimal risks.	Obstructions can slow or halt progress.
<i>Relative Cost</i>	Low	Medium to High	Medium to High
<i>Recommendation</i>	Recommended	Feasible	Feasible

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

November 27, 2018

Site: 44.0735 N, 77.7698 W User File Reference: Hwy401/CR30

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.148	0.188	0.167	0.135	0.104	0.060	0.030	0.0077	0.0032	0.105	0.087

Notes. Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.015	0.047	0.078
Sa(0.1)	0.023	0.066	0.107
Sa(0.2)	0.024	0.066	0.101
Sa(0.3)	0.021	0.057	0.084
Sa(0.5)	0.017	0.045	0.067
Sa(1.0)	0.0084	0.026	0.039
Sa(2.0)	0.0035	0.012	0.019
Sa(5.0)	0.0007	0.0029	0.0045
Sa(10.0)	0.0005	0.0012	0.0019
PGA	0.013	0.037	0.060
PGV	0.010	0.034	0.053

References

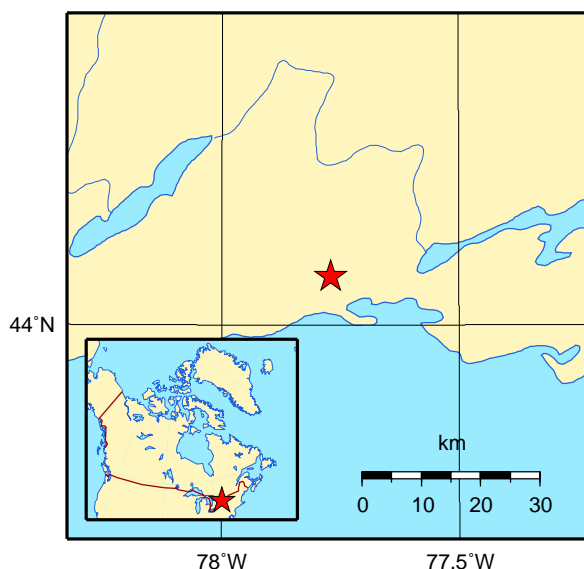
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report Suggested Wording for Notice to Contractor and NSSP

1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1860	Material Specification for Geotextile
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill Type 3 Soil – Earth Excavation
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSS.PROV 517	Construction Specification for Dewatering
SP 517F01	Design Storm Return Period and Preconstruction Survey

2. Suggested Wording for Notice to Contractor on “Obstructions”

Excavation and Installation of roadway protection system and coffer dams will encounter obstructions such as cobbles within the fill and native soils. Such obstructions may impede the work from reaching design elevations. The contractor shall use appropriate equipment and methodologies to remove the obstructions.

3. Suggested Wording for NSSP on “Dewatering”

Effective dewatering shall be designed and provided by the Contractor during excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening and may cause boiling of the subgrade. The contractor shall engage a dewatering specialist for the design of an effective dewatering scheme to enable construction in the dry and prevent any disturbance of the subgrade soil. The dewatering system must maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.