



December 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Culvert Rehabilitation, Foldens Creek
Site No. 23-383/C, Station 20+107, Highway 401
Contract 3 Structure Replacements and Rehabilitation
GWP 3045-11-00
Ministry of Transportation, West Region**

Submitted to:

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REPORT



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FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REHABILITATION, FOLDENS CREEK, SITE 23-383/C, HIGHWAY 401

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

DRAWING 1 - Borehole Locations and Soil Strata

APPENDICES

APPENDIX A

Laboratory Test Data

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Site Photographs



PART A

FOUNDATION INVESTIGATION REPORT

**CULVERT REHABILITATION, FOLDENS CREEK
SITE NO. 23-383/C, STATION 20+107, HIGHWAY 401
CONTRACT 3 STRUCTURE REPLACEMENTS AND REHABILITATION
GWP 3045-11-00
MINISTRY OF TRANSPORTATION - WEST REGION**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3045-11-00. The project involves the detailed design of the replacement and rehabilitation of several structures along multiple highways in Southern Ontario. This report addresses the proposed rehabilitation of the culvert at Foldens Creek (Site 23-383/C) at Station 20+107 on Highway 401 in the Geographic Township of West Oxford in Oxford County.

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed retaining wall replacement to be carried out for the culvert rehabilitation by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P2-1132-0163 dated February 25, 2013. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.



2.0 SITE DESCRIPTION

The subject culvert is situated at Station 20+108 on Highway 401, approximately 530 metres west of Foldens Line in the Township of West Oxford in Oxford County, Ontario. The Town of Ingersoll is approximately 7.0 kilometres west of the site. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 401 is currently a six lane divided highway with paved shoulders. It is generally oriented east-west in the vicinity of the subject site. Foldens Creek flows in the culvert from south to north beneath Highway 401. The existing culvert is a concrete rigid frame open footing (RFO) structure constructed in 1954 and extended in 1992 with the following characteristics:

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt ¹	Rt ¹	
6.10 x 2.44 x 57.85	300.2	300.4	Concrete RFO

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of Foldens Creek channel immediately upstream and downstream of the culvert are grass covered with gabion wall slope protection on all four corners. Foldens Creek flows through fields adjacent to Highway 401. Site photographs are provided in Appendix B.

2.1 Site Geology

The project area is located within the Oxford Till Plain physiographic region. This region is characterized by drumlins composed of Guelph loam consisting of grey brown luvisol.¹ The overburden in the area of the site generally consists of Zorra till consisting of yellowish brown silt to sandy silt till.²

The geological mapping indicates that the underlying bedrock consists of brown and tan microcrystalline and sublithographic limestone of the Anderdon Member of the Lucas Formation of the Detroit River Group of Middle Devonian age.³ The bedrock surface at the site is at about elevation 251 metres, with the overburden thickness being about 52 metres.⁴

¹ Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map. P.2715 (coloured), scale 1:600,000.

² Cowan, W.R. et al. 1970: Quaternary Geology. Woodstock. Southern Ontario; Ontario Division of Mines Map 2281, scale 1:63,360.

³ Sanford B.V., 1969: Geology Toronto-Windsor Area, Ontario; Ontario Geological Survey of Canada Map 1263A, Scale 1:250,000.

⁴ Davies, L.L. and McClymont, W.R. 1962: Bedrock Topography Series, Woodstock Sheet. Ontario Department of Mines Prelim. Map.P.169, Scale 1:50,000.



3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out on September 3, 2015, during which time 2 boreholes were drilled at the locations shown on the Borehole Location Plan, Drawing 1.

The boreholes were drilled using track-mounted CME 55 drilling equipment supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

The recorded SPT N values are noted on the Record of Borehole sheets. The SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres after an initial 150 millimetres of penetration. The results of the SPT testing as presented on the Record of Borehole sheets, Drawing 1 and in Section 4.0 of this report are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders, are known to be present in the tills as discussed in the text of this report.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a piezometer was installed in borehole 301 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced members of our staff who located the boreholes in the field, monitored the drilling, sampling and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations and grain size distribution analyses, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawing 1. The table below summarizes the coordinates, ground surface elevations and depths of the boreholes.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
301	4 768 367	196 722	303.60	9.60
302	4 768 394	196 728	298.98	5.03



4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered the existing pavement structure or surficial topsoil overlying variable embankment fill materials then, in sequence, buried topsoil, sandy silt till, silty sand and sand.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile, are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Soil Conditions

4.2.1 Pavement Structure

Asphalt was encountered at the ground surface in borehole 301, which was drilled in the paved shoulder of Highway 401. The asphalt was 250 millimetres thick. Pavement granular roadbase material was encountered beneath the asphalt in borehole 301. The granular roadbase material was about 1.9 metres thick. The granular roadbase had N values of 50 and 57 blows per 0.3 metres and water contents of 4 and 5 per cent.

4.2.2 Topsoil

Topsoil was encountered at the ground surface in borehole 302 and beneath the granular fill at elevation 299.9 metres in borehole 301. The surficial topsoil in borehole 302 was 150 millimetres thick. The buried topsoil in borehole 301 was 2.3 metres thick and contained layers of peat. Water contents of the buried topsoil ranged from 52 to 130 per cent.

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.2.3 Fill

Clayey silt fill materials were encountered beneath the pavement structure in borehole 301 at elevation 301.5 metres. The cohesive fill was 0.8 metres thick. The clayey silt fill material had a measured N value of 9 blows per 0.3 metres and a water content of 18 per cent.

Granular fill materials were encountered beneath the topsoil in borehole 302 at elevation 298.8 metres and beneath the clayey silt fill in borehole 301 at elevation 300.7 metres. The fill consisted of sand, silty sand and sandy silt. The granular fill materials were 0.8 and 2.0 metres thick with standard penetration test N values of 4



to 14 blows per 0.3 metres. Samples of the granular fill had water contents of 12 to 19 per cent. The gradation of a sample of sandy silt fill is presented on Figure A-1 in Appendix A.

4.2.4 Sandy Silt Glacial Till

Layers of loose to compact sandy silt glacial till were encountered beneath the fill materials in borehole 302 at elevation 296.9 metres and beneath the buried topsoil in borehole 301 at elevation 297.7 metres. The sandy silt till was 2.3 and 1.5 metres thick where fully penetrated. Measured N values for the sandy silt till layers ranged from 8 to 13 blows per 0.3 metres. Water contents of the samples ranged from 10 to 16 per cent. Cobbles and boulders should be expected in the sandy silt till. Grain size distribution curves for samples of the sandy silt till are provided on Figure A-2.

4.2.5 Silty Sand

Silty sand layers were encountered beneath the sandy silt till in boreholes 301 and 302 at elevations 295.4 and 295.3 metres, respectively. Borehole 302 was terminated in the silty sand after exploring the layer for about 1.4 metres. The silty sand was 0.8 metres thick in borehole 301. The compact silty sand had measured N values of 11 to 21 blows per 0.3 metres and water contents of 17 to 21 per cent. A grain size distribution curve for a sample of the silty sand is provided on Figure A-3.

4.2.6 Sand

A sand layer was encountered beneath the silty sand in borehole 301 at elevation 294.6 metres. The sand layer was explored for 0.6 metres before being terminated. The compact sand had a measured N value of 28 blows per 0.3 metres and a water content of 12 per cent. A grain size distribution curve for a sample of the sand is provided on Figure A-4.

4.3 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and a groundwater observation piezometer was installed in borehole 301. Installation details are provided on the corresponding Record of Borehole sheet following the text of this report. Groundwater was encountered in boreholes 301 and 302 at depths of 6.0 and 5.2 metres, or at elevations 297.6 and 296.9 metres, respectively. A summary of the encountered and measured groundwater levels is provided in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level Elevation (m)	
			Sept. 4, 2015	Nov. 11, 2015
301	303.60	297.6	298.02	298.45
302	298.98	296.9	-	-



The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. On September 4, 2015, the water level in the piezometer installed in borehole 301 was about 5.6 metres below ground surface or at about elevation 298.0 metres. On November 11, 2015, the water level in the piezometer installed in borehole 301 was about 5.2 metres below ground surface or at about elevation 298.5 metres. The November reading was taken 48 hours after a significant precipitation event.


Based on the observed groundwater levels and the surrounding topography, the groundwater level is inferred to typically be at about elevation 298.0 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions.




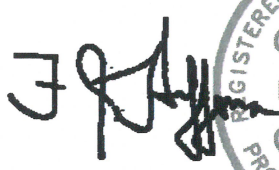
5.0 MISCELLANEOUS

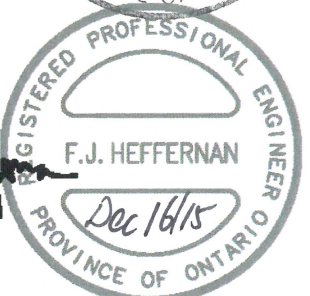
The investigation was carried out using equipment supplied and operated by London Soil Test Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Brett Thorner, E.I.T. under the direction of the Field Investigation Manager, Mr. David J. Mitchell. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Brett Thorner, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. W. Michael Kellestine, P.Eng., a Senior Consultant with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment conducted an independent quality review of the report.

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PART B

FOUNDATION DESIGN REPORT

**CULVERT REHABILITATION, FOLDENS CREEK
SITE NO. 23-383/C, STATION 20+107, HIGHWAY 401
CONTRACT 3 STRUCTURE REPLACEMENTS AND REHABILITATION
GWP 3045-11-00
MINISTRY OF TRANSPORTATION - WEST REGION**



6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations on the foundation aspects of the design of the proposed retaining wall to be carried out as part of the minor rehabilitation of Culvert Site 23-383/C at Foldens Creek at Station 20+107 on Highway 401 in the Geographic Township of West Oxford in Oxford County, Ontario.

The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

The existing culvert is a 57.9 metre long concrete RFO structure with a 6.1 metre span and a 2.4 metre high opening with invert elevations of 297.9 and 297.7 metres at the inlet and outlet, respectively. The existing northeast gabion wall segment is about 20.0 metres long and about 2.7 metres in height. Based on information provided by Stantec, it is understood that a new 0.8 metre long section of retaining wall may be added on the northeast (outlet) quadrant as part of the minor rehabilitation of the culvert. This section will replace the section of retaining wall adjacent to the culvert which is rotating.

Biennial inspection reports for the Ontario Bridge Management System (OBMS) for 2007, 2009 and 2011 indicate that this wall has been rotating. In 2009, the rotation was measured at 750 millimetres from the top or some 15.5 degrees to the vertical. By 2011, the wall had rotated some 30 degrees to the vertical.

Since only a section of the retaining wall is to be replaced, a gabion wall is the preferred technical alternative. A reinforced soil system (RSS) wall is a potentially feasible option if the entire wall is to be replaced. The retaining wall options are discussed below.

6.2 Retaining Walls

6.2.1 Retaining Wall Options

Gabion Walls

Gabion walls do not require an embedment depth equivalent to the frost depth provided they are founded on a granular pad of 300 millimetres compacted thickness, and the foundations have adequate embedment to provide a stable structure. Advantages of gabion walls compared to more rigid structures include the ability to accommodate differential settlements, dissipation of the energy of flowing water, and they are free-draining provided an adequate filter is placed behind the wall. Gabion walls can be constructed relatively quickly with minimal equipment and materials.



RSS Walls

The height of the retaining wall will be relatively low. Therefore, a reinforced soil system wall utilizing an interlocking block system and geogrid reinforcement is a geotechnically feasible alternative. RSS walls are proprietary systems which are to be designed by the supplier and constructed in accordance with their specifications. The internal stability of the mechanically-reinforced soil walls should be verified by the RSS supplier/designer. If a RSS block wall system is selected, the global stability of the wall system including bearing eccentricity and sliding resistance should be reviewed by the MTO designer prior to construction. Depending on the design approach selected, an embedment depth equivalent to the frost depth may not be required for foundations of an RSS block system wall. RSS walls are to be designed in accordance with the MTO's RSS Design Guidelines (2008) and Special Provision (SP) 599S22. This wall type can be constructed relatively quickly and inexpensively using small equipment.

6.2.2 Foundations – Retaining Walls

Gabion walls may be founded directly on a 300 millimetre thick compacted Granular A pad. Non-woven geotextile is to be placed between the gabions and the backfill. The gabion wall is to be constructed in accordance with Ontario Provincial Standard Specifications (OPSS) 1860, and the manufacturer's specifications.

RSS walls may be designed such that the facing blocks are built on a levelling pad constructed with Granular A to a minimum thickness of 300 millimetres. Depending on the design selected by the RSS supplier, it may not be necessary to provide 1.2 metres of earth cover or thermal equivalent for frost protection. However the foundations must have adequate embedment to provide a stable structure. Typically the embedment depth, defined as the distance between the top of the levelling pad and the top of the adjoining finished grade, is a minimum of 500 millimetres.

All retaining wall foundations must be protected against scour as noted in the Canadian Highway Bridge Design Code (CHBDC) Section 1.9.5. It is recommended that the replacement retaining wall be founded on the native sandy silt till encountered between elevations 296.9 and 297.7 metres which may be below the water level in the creek at the time of construction.

If required, engineered fill used to backfill subexcavated areas should consist of OPSS Granular B Type II and should be compacted to at least 95 per cent standard Proctor maximum dry density.

Retaining walls founded on the native sandy silt till may be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 200 kilopascals and a geotechnical resistance at Serviceability Limit States (SLS) of 125 kilopascals. The SLS values correspond to 25 millimetres of settlement.

6.2.3 Resistance to Lateral Forces

The resistance to lateral forces/sliding resistance between the retaining walls and the subgrade soils should be calculated in accordance with Section 6.7.5 of the CHBDC. Each retaining wall shall be checked for overturning. Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, the following angles of friction and corresponding unfactored coefficient of friction, $\tan \delta$, may be used for the interaction between the base of the wall and the founding soil:



Wall Type	Interaction	Angle of Interface Friction, δ (degrees)	Coefficient of Interface Friction, $\tan \delta$
Gabion Wall	Gabion basket on Granular A leveling pad	30	0.58
RSS Block System Wall	Pre-cast concrete block facing units on Granular A levelling pad	30	0.58

6.2.4 Lateral Earth Pressures for Design

The lateral pressures acting on the proposed retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free-draining granular fill meeting the specifications of OPSS Granular A or Granular B Type II but with less than 5 per cent passing the 0.075 millimetre sieve should be used as backfill behind the walls. The fill should be compacted in loose lifts not greater than 200 millimetres in thickness. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with CHBDC Figure 6.6.
- If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the walls (case (a) from commentary on CHBDC Figure C6.20).
- If the wall support allows lateral yielding (unrestrained structure, such as typically the case for retaining walls), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedged shaped zone with a width equal to at least 1.2 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical (case (b) from commentary on CHBDC Figure C6.20).



- For walls backfilled using granular materials in accordance with case (b), the unrestrained case, the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B</u> <u>TYPE II</u>
Fill unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of lateral earth pressure:		
'active' or unrestrained, K_a	0.27	0.27
'passive', K_p	3.7	3.7

6.3 Construction Considerations

6.3.1 General

Rotation of the existing section of gabion wall may be attributable to construction on an overly loose or organic foundation material and/or the presence of topsoil with peat layers behind the gabion wall. Care should be taken during construction to avoid disturbance of the subgrades prior to constructing foundations for the replacement retaining wall. All existing fill and any topsoil, organics, and soft or loose soils should be stripped from the proposed foundation footprint and backfill areas prior to placement of base materials. It is not considered necessary or practical to remove the topsoil and peat layers from beneath the Highway 401 platform but it must be removed if found within the backfill or foundation area for optimal performance of the wall. Subgrade preparation should be performed and monitored in accordance with OPSS 902. The appropriate Non-Standard Special Provision (NSSP) or modified SP should be included in the contract documents to alert the contractor about the need for care to be taken during construction to protect the founding soils, all existing fill and deleterious material should be stripped from the proposed foundation footprint and backfill areas and any topsoil and peat layers must be removed from within the backfill and foundation areas.

It is recommended that the footing excavations be carried out such that the final 0.5 metres of excavation is completed with a Quality Verification Engineer (QVE) experienced in geotechnical engineering on site. The prepared excavation bases should be inspected by the QVE and granular base materials should be placed immediately after inspection (within 4 hours) to protect the founding materials.

Sediment control such as silt fences and erosion control blankets may be required during construction. All retaining wall foundations must be protected against scour as noted in the CHBDC Section 1.9.5.

6.4 Excavations and Groundwater Control

Excavations will extend through the existing fill and topsoil to the underlying native sandy silt till. Depending on the wall type and selected foundation system, the excavation for the retaining wall may extend up to 1.1 metres below the inferred groundwater level of elevation 298.0 metres. Seepage volumes from the sandy silt till are anticipated to be such that groundwater control may be achieved by using properly constructed and filtered



sumps. Sumps should be maintained outside of the actual wall footing limits. Some seepage from the granular fill layers should be expected particularly after the spring thaw or other periods of heavy precipitation.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water runoff should be directed away from the excavations at all times. The existing culvert flows may need to be diverted/piped during construction.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill materials would be classified as a Type 3 soil and the native sandy silt till would be classified a Type 2 soil.

6.5 Temporary Roadway Protection

It is understood that temporary roadway protection is required to maintain the shoulder and on ramp of Highway 401 at the culvert location during rehabilitation of the retaining wall. Temporary support systems could consist of cantilevered soldier piles and lagging or steel sheet piles.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line, or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p' in kN/m^2 ; increasing with depth) can be calculated as follows:

$$p' = K_a (H - h_w) \gamma + K_a (\gamma - \gamma_w) h_w + \gamma_w h_w + K_a q$$

where H = the height of the excavation at any point in metres

K_a = active coefficient of earth pressure

γ = soil unit weight

γ_w = unit weight of water or 9.8 kN/m^3

q = surcharge for traffic and other loading

h_w = height of groundwater level above excavation base; water level to be taken as elevation 298.0 metres



The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Bulk Unit Weight γ (kN/m ³)	Effective Unit Weight γ' (kN/m ³)
	Active, K_a	At Rest, K_o	Passive, K_p			
Fill	0.38	0.55	2.7	27	19	9.0
Sandy Silt Till	0.31	0.47	3.3	32	21	11.0
Silty Sand	0.35	0.52	2.9	29	18.5	8.5
Sand	0.33	0.50	3.0	30	19	9.0

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased.



7.0 MISCELLANEOUS

This section of the report was prepared by Mr. Brett Thorner, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. W. Michael Kellestine, P.Eng., a Senior Consultant with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

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part a&b fdns rehab clvrt 23-383.docx

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Consistency

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

(b) Cohesive Soils

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

IV. SOIL TESTS

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

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

LIST OF SYMBOLS

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

I. General

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

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

- Notes:**
- 1 $\tau = c' + \sigma' \tan \phi'$
 - 2 shear strength = (compressive strength)/2
 - * density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

PROJECT		12-1132-0163		RECORD OF BOREHOLE No 301		1 OF 1		METRIC				
W.P.		3045-11-00		LOCATION		N 4768367.2, E 196722.4		ORIGINATED BY				
DIST		HWY 401		BOREHOLE TYPE		POWER AUGER, HOLLOW STEM		COMPILED BY				
DATUM		GEODETIC		DATE		September 3, 2015		CHECKED BY				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	GR SA SI CL
303.60	PAVEMENT SURFACE											
0.00	ASPHALT											
0.25	FILL, sand and gravel, trace silt Very dense Brown		1	SS	50							
301.47	FILL, clayey silt, some sand, some topsoil, trace gravel Stiff Brown		2	SS	57							
2.13	FILL, sandy silt, some clay, trace gravel Compact Brown		3	SS	9							
2.90	TOPSOIL, silty, with peat layers Firm to stiff Black		4	SS	14							
299.94	TOPSOIL, silty, with peat layers Firm to stiff Black		5	SS	10							
3.66	SANDY SILT TILL, trace to some gravel, trace to some clay Loose to compact Brown		6	SS	9							
297.65	SANDY SILT TILL, trace to some gravel, trace to some clay Loose to compact Brown		7	SS	7							
5.95	SAND, fine to medium, some silt, trace gravel, trace clay, with silty sand seams Compact Brown		8	SS	8							
8.23	SAND, fine to medium, some silt, trace gravel, trace clay, with silty sand seams Compact Brown		9	SS	8							
8.99	SAND, fine to medium, some silt, trace gravel, trace clay, with silty sand seams Compact Brown		10	SS	11							
294.61	SAND, fine to medium, some silt, trace gravel, trace clay, with silty sand seams Compact Brown		11	SS	21							
294.00	SAND, fine to medium, some silt, trace gravel, trace clay, with silty sand seams Compact Brown		12	SS	28							
9.60	END OF BOREHOLE											
<p>Groundwater encountered at about elev. 297.6m during drilling on September 3, 2015.</p> <p>Water level measured in piezometer at elev. 298.02m on September 4, 2015.</p> <p>Water level measured in piezometer at elev. 298.45m on November 11, 2015.</p>												

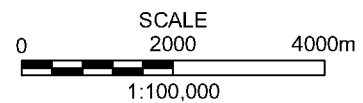
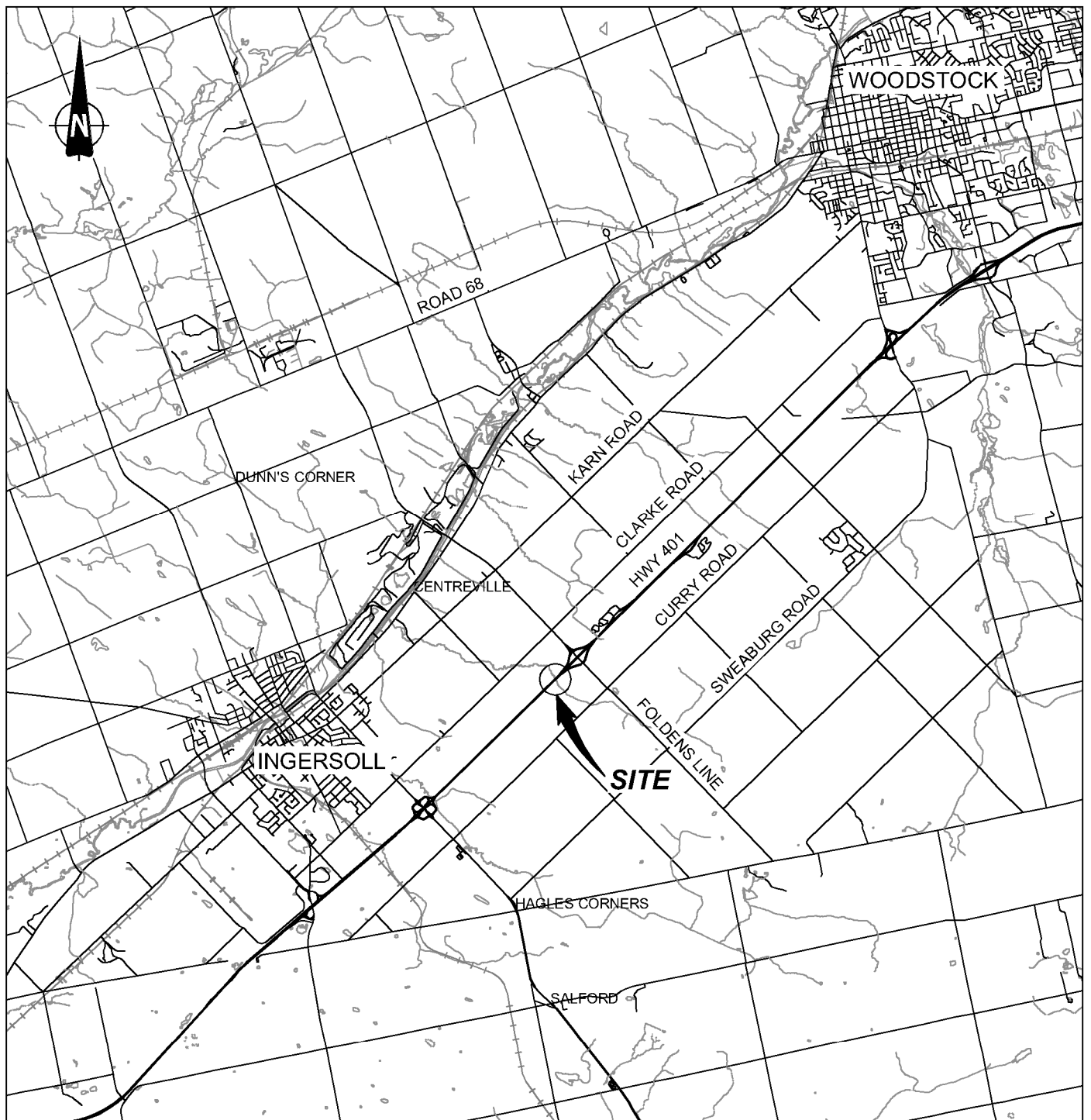
RECORD OF BOREHOLE No 302

1 OF 1

METRIC

PROJECT 12-1132-0163
W.P. 3045-11-00 LOCATION N 4768394.3 , E 196728.0 ORIGINATED BY BT
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE September 3, 2015 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE		w _p	w	w _L				
298.98	GROUND SURFACE															GR	SA	SI	CL
0.00	TOPSOIL, silty Black																		
0.15																			
0.43	FILL, sand, some silt, trace gravel Brown																		
	FILL, silty sand, some gravel, with topsoil Loose to compact Brown to black		1	SS	4							○							
			2	SS	14								○						
296.85																			
2.13	SANDY SILT TILL, trace to some gravel, trace to some clay Loose to compact Brown		3	SS	9							○							
			4	SS	13								○						
295.32																			
3.66	SILTY SAND, trace gravel, trace clay Compact Brown		5	SS	17								○						
293.95			6	SS	11								○						
5.03	END OF BOREHOLE																		
	Groundwater encountered at about elev. 296.9m during drilling on September 3, 2015.																		



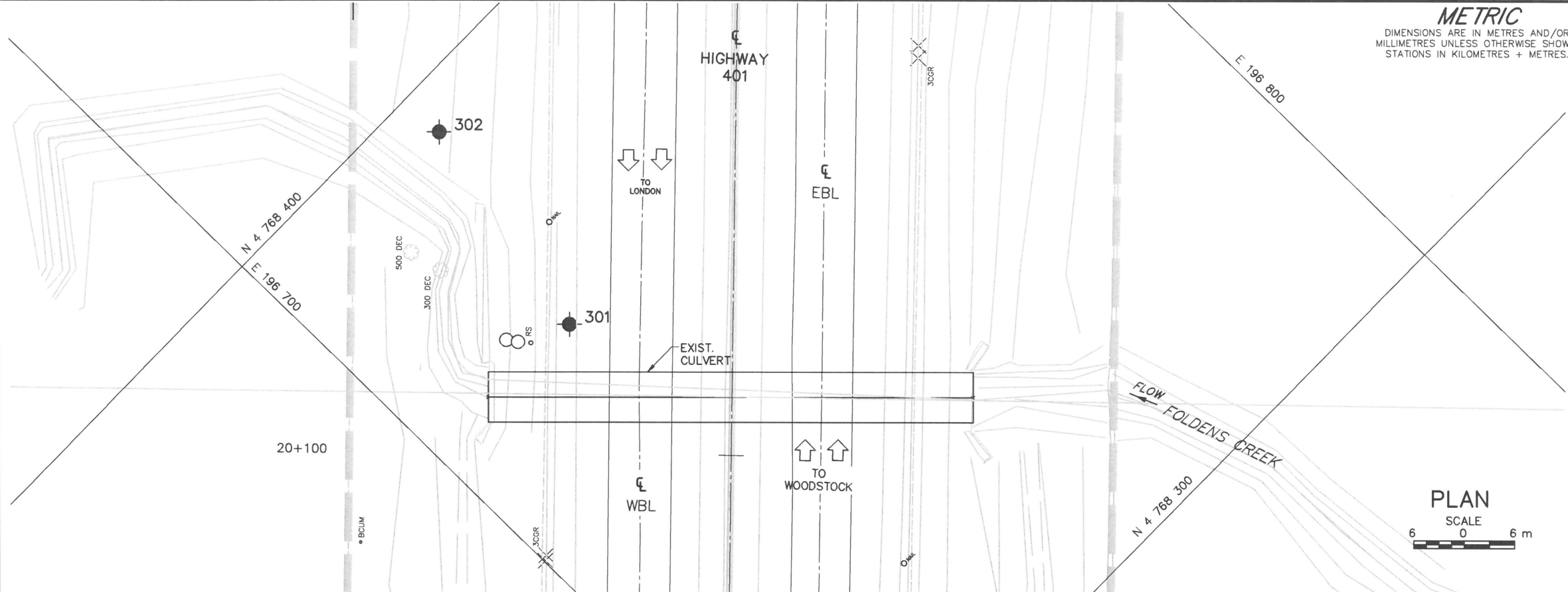
REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING TEXT.

PROJECT		FOLDENS CREEK CULVERT, SITE 23-383/C STATION 20+107, HIGHWAY 401 GWP 3045-11-00	
TITLE		KEY PLAN	
PROJECT No.		12-1132-0163	FILE No. 1211320163-3000-F03001
CADD	WDF/LMK	Sept. 23/15	SCALE AS SHOWN REV. 0
CHECK			FIGURE 1



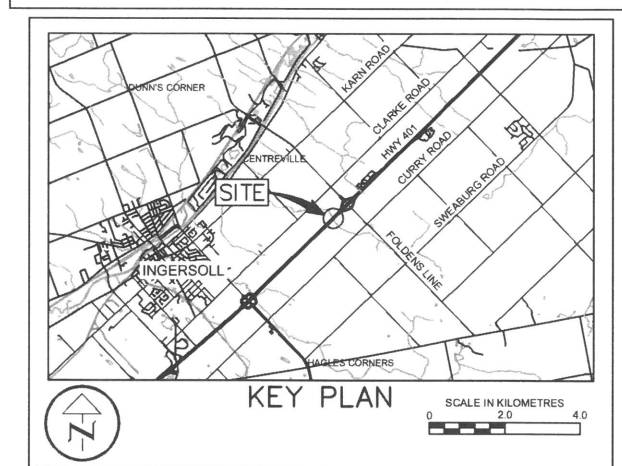
METRIC
 DIMENSIONS ARE IN METRES AND/OR
 MILLIMETRES UNLESS OTHERWISE SHOWN.
 STATIONS IN KILOMETRES + METRES.

CONT No.
 WP No. 3045-11-00

FOLDENS CREEK CULVERT
 HIGHWAY 401
 STRUCTURE REHABILITATION
 BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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LEGEND

- Borehole - Current Investigation
- Seal
- Standpipe
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL measured on September 4 and November 11, 2015.
- WL encountered during drilling
- DRY Water level not established

No.	ELEVATION	CO-ORDINATES (MTM NAD83 ZONE 10)	
		NORTHING	EASTING
301	303.60	4 768 367.2	196 722.4
302	298.98	4 768 394.3	196 728.0

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

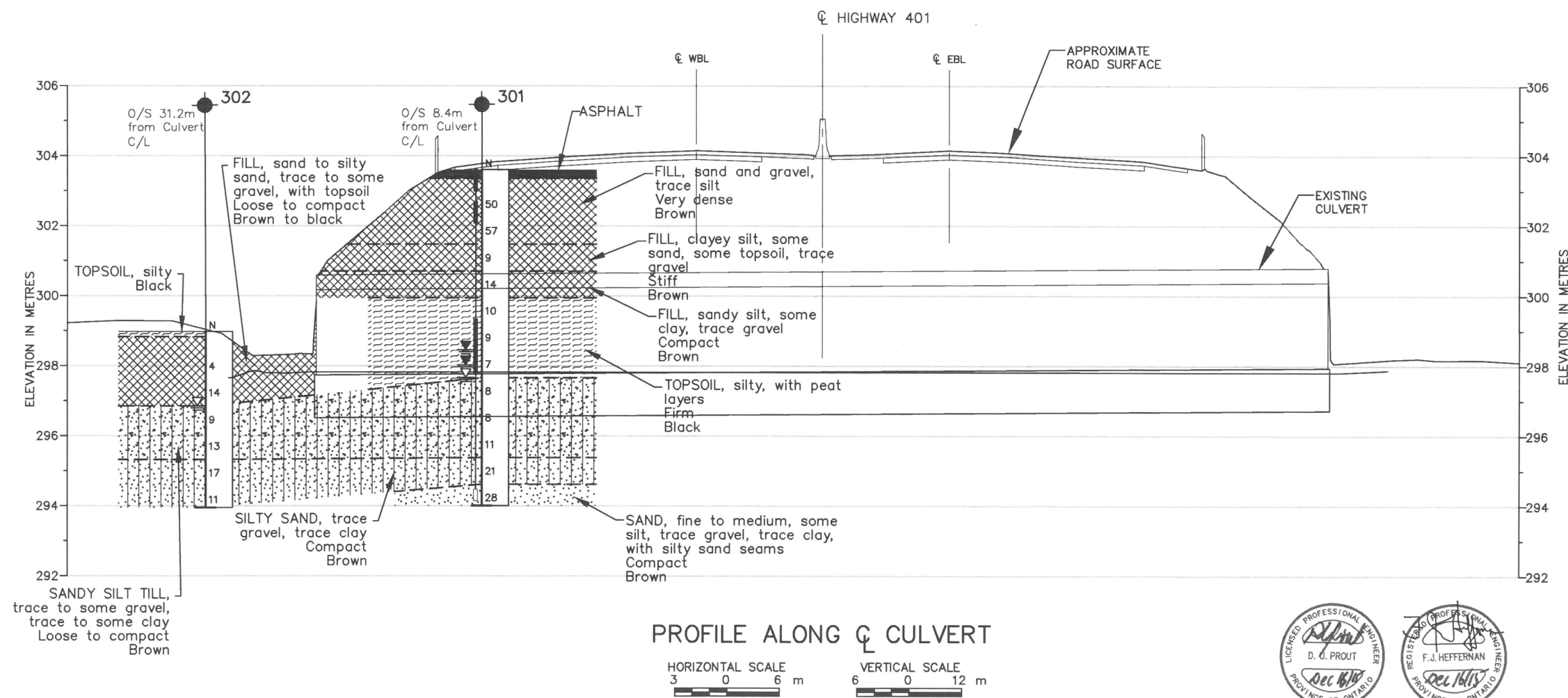
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided by Stantec.

NO.	DATE	BY	REVISION

Geocres No. 40P2-81
 HWY. 401 PROJECT NO. 12-1132-0163 DIST.
 SUBM'D. BT CHKD. DUP DATE: Nov 12/15 SITE: 23-383/0
 DRAWN: LMK CHKD. WMK APPD. FJH DWG. 1



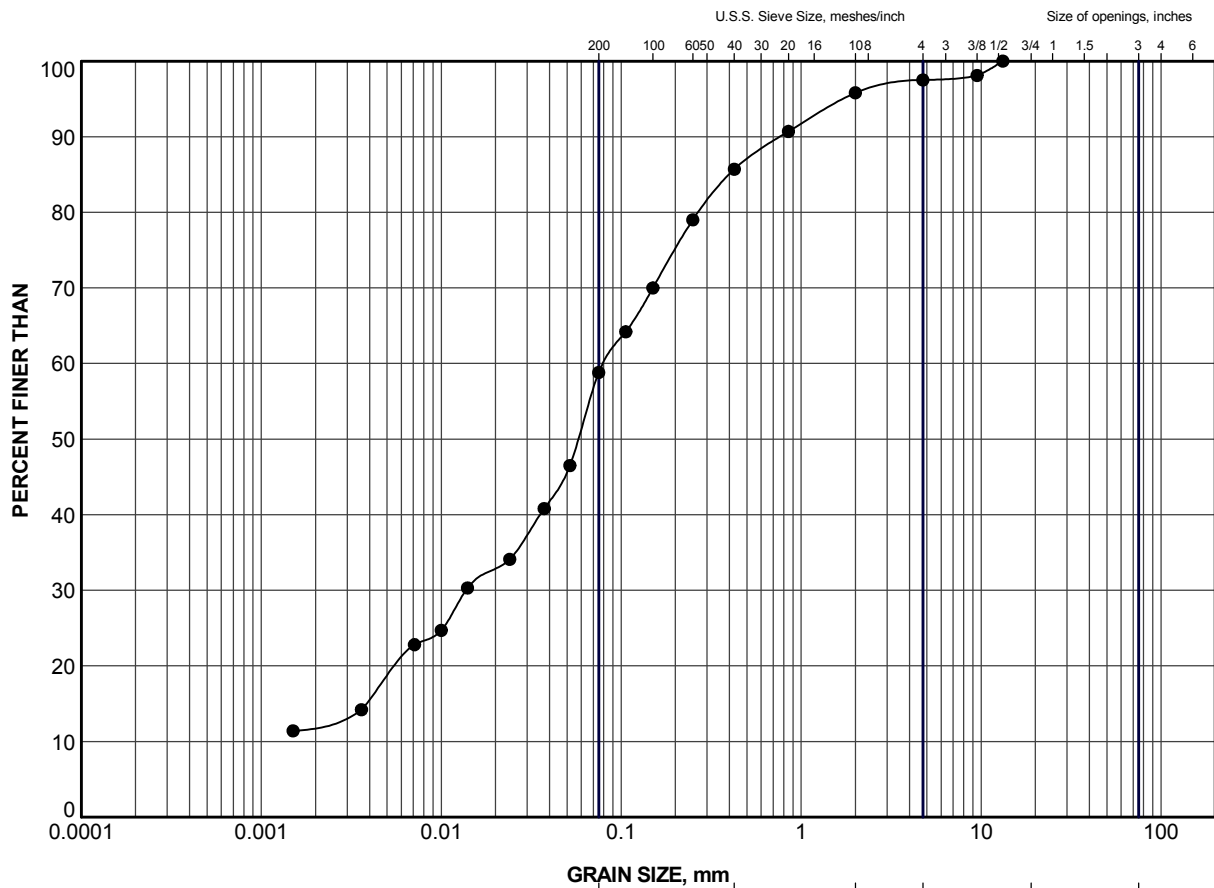
PROFILE ALONG CULVERT





APPENDIX A

Laboratory Test Data



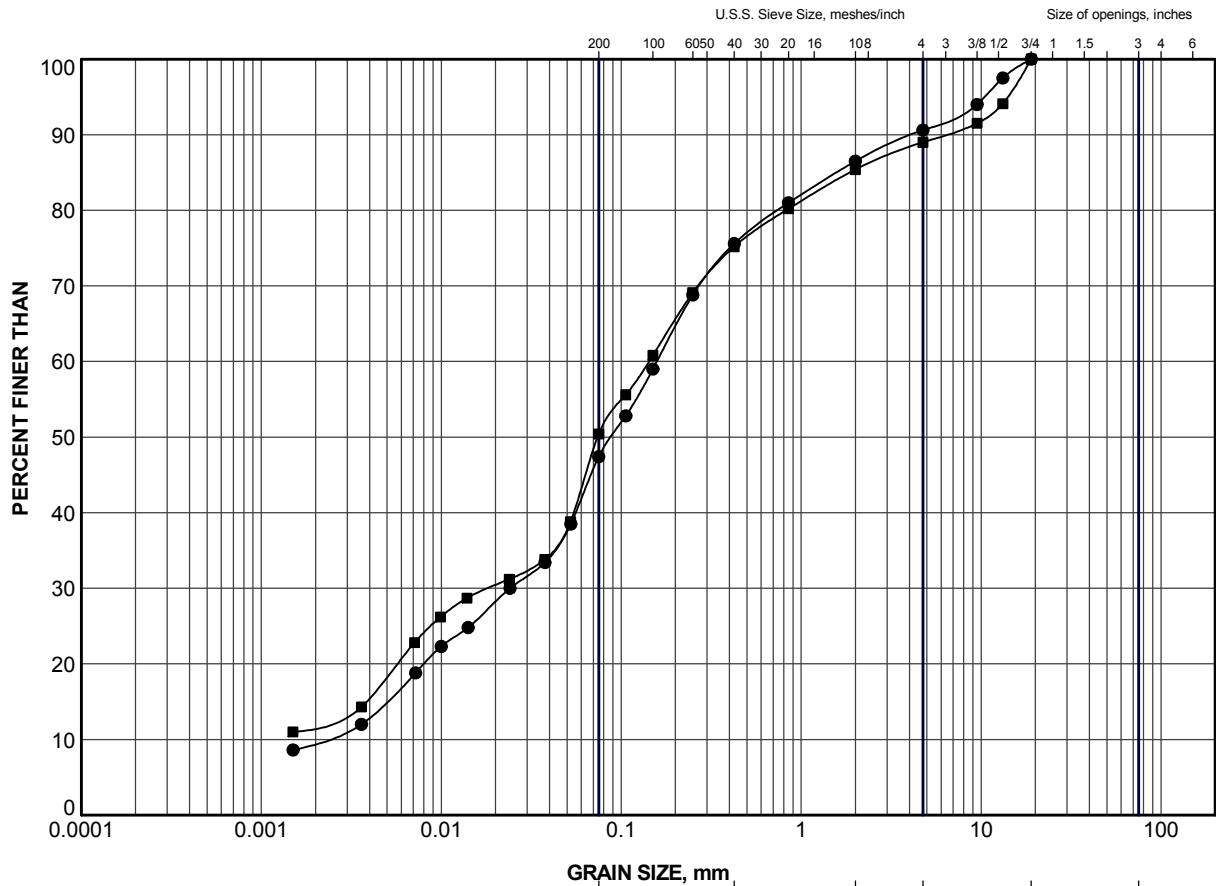
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	4	300.3

PROJECT				FOLDENS CREEK CULVERT, SITE 23-383/C STATION 20+107, HIGHWAY 401 GWP 3045-11-00			
TITLE				GRAIN SIZE DISTRIBUTION FILL			
PROJECT No.		12-1132-0163		FILE No. 1211320163-3000-F030A1			
DRAWN		LMK		Sep 23/15		SCALE N/A REV.	
CHECK						FIGURE A-1	





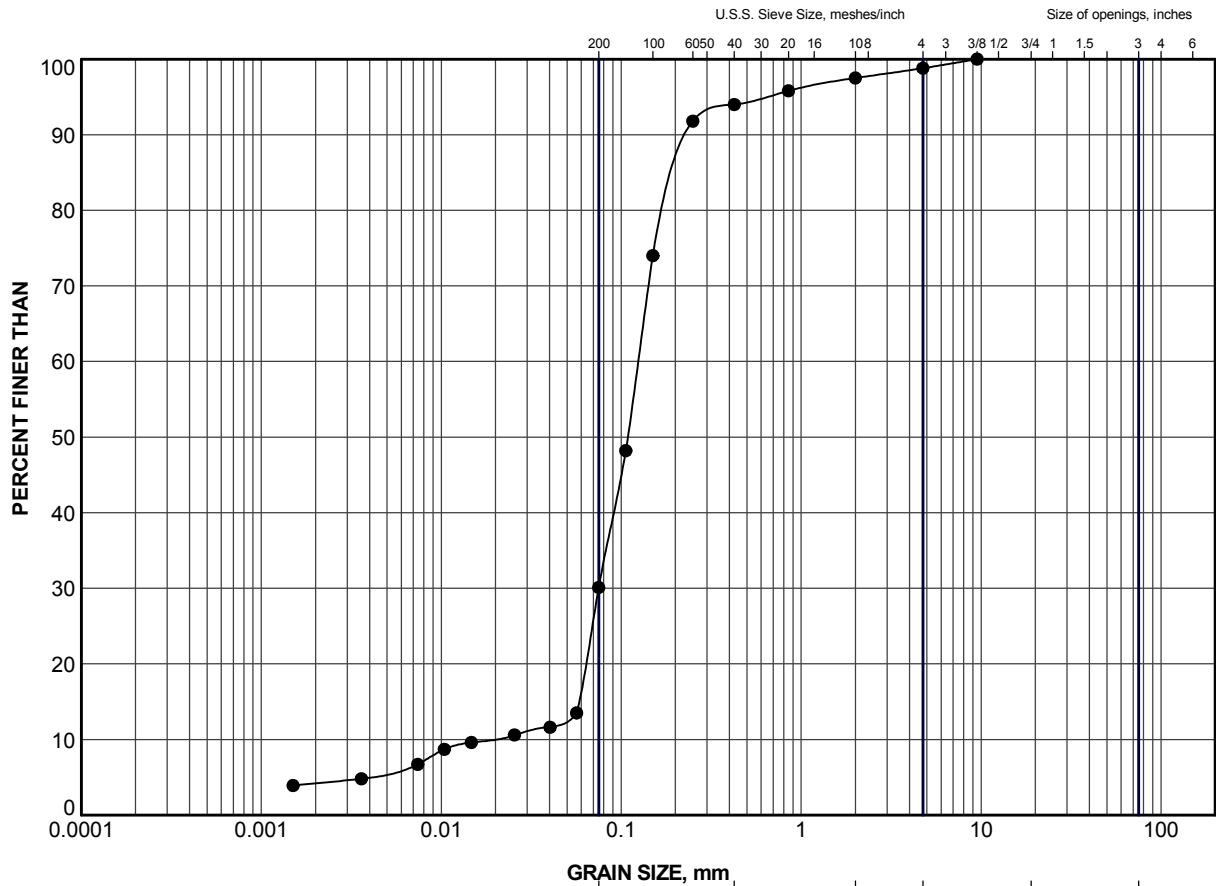
CLAY AND SILT		SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
		fine	medium	coarse	fine	coarse	
		SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	9	296.5
■	302	4	295.7

PROJECT				FOLDENS CREEK CULVERT, SITE 23-383/C STATION 20+107, HIGHWAY 401 GWP 3045-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT TILL			
PROJECT No.		12-1132-0163		FILE No. 1211320163-3000-F030A2			
DRAWN		LMK		Sep 23/15		SCALE N/A REV.	
CHECK						FIGURE A-2	





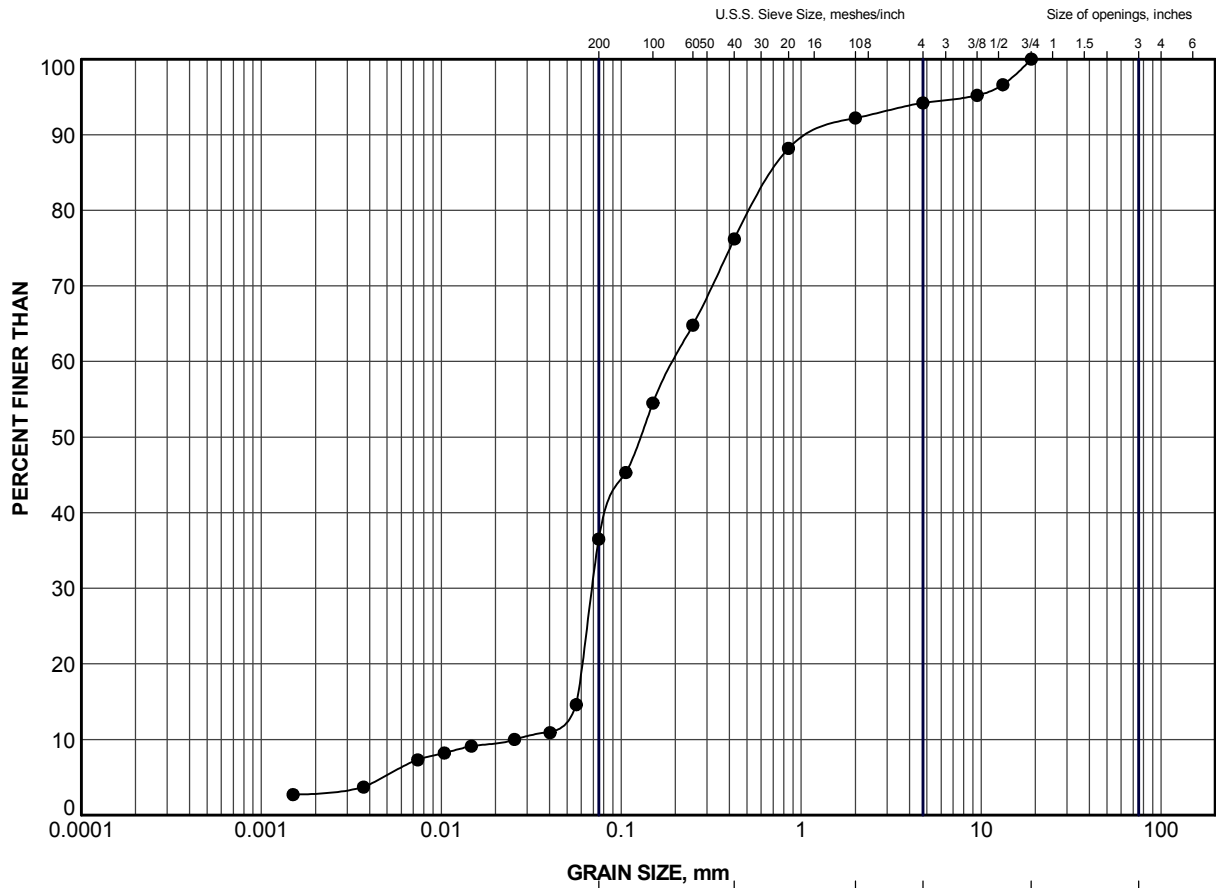
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	302	5	294.9

PROJECT				FOLDENS CREEK CULVERT, SITE 23-383/C STATION 20+107, HIGHWAY 401 GWP 3045-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY SAND			
PROJECT No.		12-1132-0163		FILE No. 1211320163-3000-F030A3			
DRAWN		LMK		Sep 23/15		SCALE N/A REV.	
CHECK						FIGURE A-3	



LDN_MTO_GSD_GLDR_LDN.GDT 23/09/15



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

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	301	12	294.2

PROJECT				FOLDENS CREEK CULVERT, SITE 23-383/C STATION 20+107, HIGHWAY 401 GWP 3045-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND (with silty seams)			
		PROJECT No.		12-1132-0163		FILE No. 1211320163-3000-F030A4	
		DRAWN		LMK		Sep 23/15	
		CHECK					
		SCALE		N/A		REV.	
		FIGURE A-4					



APPENDIX B

Site Photographs



APPENDIX B PHOTOGRAPHS



Photograph 1: North elevation (outlet) of Culvert Site 23-383/C.



Photograph 2: Northeast gabion retaining wall.



APPENDIX B PHOTOGRAPHS



Photograph 3: S/N-W On Ramp of Highway 401 looking west from Culvert Site 23-383/C.

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app b - photos.docx

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