PRELIMINARY

FOUNDATION INVESTIGATION AND DESIGN REPORT

CULVERT REPLACEMENT AT SITE #32-213C

HIGHWAY 7, KAWARTHA LAKES, ONTARIO

W.P. 4012-13-01

Geocres Number: 31D-613

Report to

AECOM

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September 22, 2015
File: 19-4406-20

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation completed at the location of a proposed culvert replacement at Site #32-213C on Highway 7 in the Municipality of Kawartha Lakes, Ontario.

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, record of borehole sheets, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to AECOM under the Ministry of Transportation (MTO) Agreement Number 4013-E-0015.

2 SITE DESCRIPTION

The culvert site is located on Highway 7, in the Town of Kawartha Lakes, Ontario, and 350 m east of the intersection of Highway 7 and River Road. The existing culvert is a single span, sectional plate, corrugated steel pipe arch 3.3 m x 2 m x 22.9 m in size. The existing highway embankment at the culvert location is approximately 2.5 m in height.

The surrounding land is flat farmland with occasional rows of trees. The unnamed creek is approximately 2 m to 3 m in width and is part of a network of small creeks bordering areas of farmland. The creek flows north-south through the culvert.

Photographs of the culvert and surrounding area are enclosed in Appendix C.

The site is situated in a physiographic region known as Clay Plain and with the Kame Moraine features in the area. The surficial glaciolacustrine deposits contain mainly silts and clays with minor sands.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigations and field testing at this site were carried out on December 1, 2014 and on May 14, 2015, and involved drilling and sampling of four boreholes, denoted as Borehole 14-01 and

15-01 to 15-03. Boreholes 14-01 and 15-02 were drilled through the shoulders of the highway and extended to a depth of 11.0 m and 9.8 m, respectively, and Borehole 15-01 and 15-03 were drilled to 8.2 m and 7.7 m depth in the vicinity of the culvert invert. The approximate borehole locations are shown on the attached Borehole Locations drawing included in Appendix D.

Prior to commencement of drilling, utility clearances were obtained for the borehole locations. Drilling was carried out using a truck mounted D90 drill rig with solid stem augers to advance Borehole 14-01, and a D52 drill rig with hollow stem augers was used to drill Boreholes 15-01 to 15-03. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by members of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory in Oakville, Ontario, for further examination and testing.

Borehole locations (northings and eastings) were established based on the drawing provided by AECOM.

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations. A standpipe piezometer, consisting of 19 mm Schedule 40 PVC pipe with a 3.0 m long slotted screen, was installed in Borehole 14-01. The piezometer screen was enclosed in filter sand to permit groundwater level monitoring. The boreholes and piezometer were decommissioned after completion of final water reading in general accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

Table 3-1. Borehole Details

Borehole	Borehole Termination Depth/ Elevation (m)	Borehole Backfilling Details
14-01	11.0 / 246.9	Piezometer with 3.0 m slotted screen installed, cave in from 11.0 to 6.1 m, sand filter from 6.1 to 3.0 m (tip Elev. 251.8), bentonite holeplug and cuttings from 3.0 m to ground surface.
15-01	8.2 / 247.4	Borehole encountered groundwater at 8 m depth with an artesian head of 0.4 m above the ground surface. Borehole sealed with concrete to 6.7 m, bentonite holeplug to 4.6 m, cuttings to 1.0 m, holeplug to 0.1 m then concrete to surface.
15-02	9.8 / 247.8	Borehole backfilled with cuttings and bentonite holeplug to 0.3 m, sand and gravel to surface.
15-03	7.7 / 246.7	Borehole backfilled with cuttings and bentonite holeplug to surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the borehole, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets take precedence over this general description and interpretation of the site conditions. It should be recognised that soil conditions may vary beyond the borehole locations.

In general, boreholes drilled through the shoulder of the highway embankment encountered fill materials underlain by a relatively thin layer of clayey silt and sand, which in turn was underlain by a silty clay. Beneath the silty clay was a layer of cohesionless deposit varying in composition from sandy gravel to silty sand.

Boreholes drilled in the vicinity of the culvert invert encountered thin layer of topsoil overlying silty clay, which in turn was overlying silty sand.

More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

Borehole 15-01 and 15-03 were drilled through a topsoil, which was 100 mm and 75 mm in thickness.

5.2 Embankment Fill

Embankment fill consisting of a brown sand and gravel with some silt was encountered extending from the ground surface to depth of 2.2 m (Elev. 255.7 m) and 2.8 m (Elev. 254.8) at the locations of Borehole 14-01 and 15-02, respectively. Occasional cobbles were noted within the fill material.

SPT N values recorded in the fill ranged from 5 to 38 blows per 0.3 m of penetration, indicating a loose to dense relative density, however typically being loose to compact.

The grain size analysis was completed on two samples of the fill. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are presented on Figure B1 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	37 to 42
Sand	45 to 46
Silt and Clay	13 to 17

Moisture contents within the granular fill varied from 3% to 5%, with the exception of one sample located at the base of the fill where moisture content of 21% was measured.

5.3 Clayey Silt and Sand

A layer of clayey silt and sand was encountered below the embankment fill in Boreholes 14-01 and 15-02. The thickness of this layer varied from 0.8 m to 1.3 m with the lower boundary at a depth of 3.0 m (Elev. 254.9 m) and 4.1 m (Elev.253.5) in Boreholes 14-01 and 15-02, respectively. This layer of clayey silt with sand is probably the native silty clay or stream alluvium reworked during construction of the culvert and/or highway embankment.

SPT testing performed in this layer gave N-values of 3 and 4 blows per 0.3 m of penetration, indicating a soft consistency. A moisture contents of 19% and 34% were measured in the deposit.

The grain size analysis was completed on a sample of the clayey silt with sand. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curve is illustrated on Figure B2 of Appendix B. The results of the laboratory testing are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	44
Silt	36
Clay	20

5.4 Silty Clay

A layer of silty clay was encountered in all boreholes drilled at this site either beneath the clayey silt and sand or topsoil. The thickness of the silty clay ranged from 5.2 m to 7.2 m with the lower boundary between depths of 6.1 m (Elev. 248.3) and 10.2 m (Elev. 247.7 m).

SPT tests performed in this layer resulted in N-values between 5 and 28 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. Moisture contents within this layer varied from 13 to 36%.

Grain size analyses were completed on samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are presented on Figure B3 of Appendix B. The results of the laboratory testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0
Sand	0 to 6
Silt	23 to 33
Clay	67 to 77

The Atterberg Limits testing was completed on four samples of the silty clay deposit. The results are included in the Record of Borehole sheets and on the plasticity chart in Figure B5 of Appendix B. The results of the laboratory test indicate intermediate to high plasticity of the deposit.

Parameter	Value
Plastic Limit	20 to 24
Liquid Limit	47 to 53
Plasticity Index	24 to 31

5.5 Silty Sand to Sandy Gravel

A layer of cohesionless deposit ranging from silty sand with some clay and some gravel, through gravelly sand to sandy gravel with trace silt and trace clay was encountered below the silty clay. Occasional cobbles were noted in this deposit.

The SPT N-values varied from 11 blows per 0.3 m of penetration to more than 100 blows per 0.3 m of penetration, indicating a compact to very dense relative density.

Moisture contents of 5% to 11% were measured on the samples tested.

Grain size analyses were completed on samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are presented on Figure B4 of Appendix B. The results of the laboratory test are summarized below:

Soil Particles	Percentage (%)
Gravel	11 to 20
Sand	40 to 48
Silt	29 to 35
Clay	11
Silt and Clay	32

All boreholes were terminated within the silty sand to sandy gravel at depths ranging from 7.7 m to 11.0 m (Elev. 246.7 to Elev. 247.8).

5.6 Groundwater Level

Water level was observed in the open boreholes upon completion of drilling operation. As outlined in Table 3-1, a standpipe piezometer was installed in borehole 14-01 to monitor groundwater levels after drilling.

The measured groundwater levels are summarized below in Table 5-1. The levels shown are short-term readings 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 or prolonged precipitation events.

Table 5-1. Measured Groundwater Levels

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
14-01	Dec. 1, 2014 Dec. 4, 2014 Dec. 18, 2014	2.7 2.6 0.6*	255.2 255.3 257.3	Upon completion of drilling In piezometer In piezometer
15-01	May 4, 2015	-0.4	256.0	Artesian groundwater conditions observed after reaching silty sand at 8.0 m depth
15-02	May 4, 2015	5.2	252.4	Upon completion of drilling
15-03	May 4/2015	Dry	-	Upon completion of drilling to 7.7 m depth

Notes: (*) Frozen

The water level in the open Borehole 14-01 upon completion of drilling is believed to correspond to the water level in the creek at the time of the investigation.

6 MISCELLANEOUS

Walker Drilling Ltd. from Utopia, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field program. Borehole locations were selected and marked in the field by a Thurber staff member.

The field investigation was supervised on a full time basis by Mr. Sean Petrus, EIT of Thurber during the 2014 investigation and by Ms. Eckie Siu during the 2015 investigation. Overall supervision of the investigation program was conducted by Mr. Weiss Mehdawi, P.Eng.

Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario. Interpretation of the data and preparation of this report were carried out by Mr Michael Eastman, EIT and Ms. Anna Piascik, P.Eng.

The report was reviewed by Mr. Alastair Gorman, P.Eng and Dr. P.K. Chatterji, P.Eng. who is a Designated Principal Contact for MTO Foundations Projects.

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PART 2 ENGINEERING DISCUSSION

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and presents a geotechnical engineering discussion for planning of the proposed culvert replacement at Site # 32-213C on Highway 7 in the Municipality of Kawartha Lakes, Ontario.

The existing culvert is a single span, sectional plate, corrugated steel pipe arch 3.3 m x 2 m x 22.9 m in size, and the highway embankment at the culvert location is approximately 2.5 m in height.

No details of the proposed culvert replacement were available at the time of writing of this report.

The discussions presented in this report are for planning purposes only. The Design Builder shall satisfy themselves as to the sufficiency of the information required to meet the demands for detailed design. The Design Builder are solely responsible for selecting the appropriate foundation alternatives for replacement of the structure and detailed design of the structure.

8 CULVERT FOUNDATION

8.1 General

In summary, the embankment fill at the culvert location varied from 2.2 m to 2.8 m in thickness. The embankment fill is underlain by a layer of clayey silt and sand, which was 0.8 m to 1.3 m thick. Underlying the clayey silt and sand beneath the embankment and the topsoil outside of the footprint of the embankment is a layer of firm to very stiff silty clay ranging in thickness from 5.2 m to 7.2 m. The lower boundary of the silty clay was encountered between 6.1 m and 10.2 m depth (Elev. 248.3 and Elev. 249). The silty clay was underlain by a cohesionless deposit varying in composition from silty sand/gravelly sand to sandy gravel extending to depths investigated in the borehole.

Groundwater level in a standpipe piezometer installed at the site was measured at 2.6 m depth below the top of the embankment (Elev. 255.3). Borehole 15-01 encountered groundwater at a depth of 8 m that had an artesian head of 0.4 m with respect to the original ground surface.

8.2 Foundation Alternatives

This section presents discussions on foundation alternatives for culvert replacement and on feasible/preferred foundation options. Some common culvert alternatives are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E.

- Pipe Culvert (Concrete, CSP, HDPE)
- Box Concrete Culvert
- Open Footing Concrete Culvert

All three culvert types are considered to be possible candidates for this site. However, pipe or pre-cast box culvert options would offer relatively easy construction.

Considering the presence of cohesive native deposits underlying the site, the pre-cast box culvert seems to be the preferred option for the replacement structure based on the following considerations:

- pre-cast box elements would form a flexible structure allowing for some mitigation of the differential settlements along the culvert,
- depth of excavation and groundwater control requirements will be less than required for an open-footing concrete culvert,
- pre-cast box culvert can be installed relatively quickly, allowing for shorter duration of the culvert construction.

Details of the proposed culvert replacement were unavailable during writing of this report. The comments on the culvert replacement design are provided for planning purposes.

8.3 Pipe Culvert

Installation of a pipe culvert, including concrete pipe, CSP (circular or arch), or HDPE pipes could be considered for this site.

The native firm to stiff silty clay at or below Elev. 253.5 m is considered to be an adequate founding stratum for support of pipe culverts. If the founding surface is not disturbed and groundwater/surface water is controlled during construction, sufficient bearing capacities can be obtained to install the culverts.

Base on the characteristics of the founding soils, the following bearing capacities can be used in design of a pipe culvert:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 130 kPa.

The geotechnical reaction at SLS assumes the diameter of the culvert of 3 m, similar to the diameter/width of the existing culvert.

A minimum thickness of 300 mm of granular bedding material conforming to OPSS 1010 Granular A or B Type II should be placed under the base of the pipe culvert. Following inspection and subgrade approval, the bedding material should be placed as soon as practical on the approved subgrade for protecting the subgrade from disturbance during construction.

Preparation of the subgrade has been addressed in Sec. 8.7 of this report.

8.4 Box Culvert

Installation of a precast concrete box culvert is considered feasible at this site. The culvert can be founded on the firm to stiff native silty clay below the level of all existing fills, organic matter and soft clayey silt and sand. The top of the silty clay was encountered at 3.0 m depth (Elev. 254.9) and 4.1 m depth (Elev. 253.5) below the top of the embankment and the upper approximately 0.9 m of the silty clay in Borehole 14-01 was soft to firm. The box culvert may be founded at or below Elev. 253.5 m on the undisturbed, stiff silty clay deposit.

Diversion of the creek and dewatering will be required to install the culvert. A sheet pile enclosure will likely be required to maintain a dry excavation for the culvert construction.

A minimum thickness of 300 mm of granular bedding material conforming to OPSS 1010 Granular A or B Type II material should be provided under the base of the box culvert. The bedding material should be placed as soon as practical on the approved subgrade for protecting the subgrade from disturbance during construction. A min of 75 mm of levelling course should be placed on the bedding material.

Construction equipment should not be allowed to travel on the prepared subgrade.

A box culvert 3 m in width placed on undisturbed native silty clay at or below Elev. 253.5 can be designed for the following factored geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS):

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 130 kPa.

The geotechnical resistance and reaction provided above are based on loading applied perpendicular to the footings. Appropriate inclination should be taken into account conforming to the Canadian Highway Bridge Design Code (CHBDC) where the load is not applied perpendicular to the surface of the footing.

Resistance to lateral forces/sliding between precast concrete and the underlying bedding material should be evaluated in accordance with the CHBDC, Section 6.7 assuming an ultimate/unfactored coefficient of friction of 0.5.

The box culvert should be designed to resist external loadings, including lateral earth pressure, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment and activities.

Frost protection measures are not required for the pre-cast concrete box culvert.

8.5 Open Footing Culvert

Strip footings for an open footing culvert replacement should be founded at a minimum depth of 1.6 m below the lowest surrounding ground surface to ensure adequate protection against frost penetration, as per OPSD 3090.101. Furthermore, the footings should extend below any existing embankment fill, surficial organic materials and soft native deposits, where encountered.

Based on the factual data, the current preliminary investigation shows the presence of soft clayey silt and sand deposit below the embankment fill. The strip footing could be founded below that soft deposit on the undisturbed, native, stiff silty clay at or below Elevation 253.5 m (approximately 4.1 m to 4.4 m below the embankment grade).

Groundwater and surface/creek water control will be required during excavation and construction of the open footings for the replacement culvert.

The geotechnical resistance at Ultimate Limit State (ULS) and reaction at Serviceability Limit State (SLS) for footings placed at or below Elevation 253.5 could be assumed as follows:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa

The geotechnical resistance and reaction provided above are based on the assumed footing width of 1 m and the loading applied perpendicular to the footings. Appropriate inclination should be taken into account conforming to the CHBDC where the load is not applied perpendicular to the surface of the footing.

Resistance to lateral forces/sliding between concrete and the underlying bedding material should be evaluated in accordance with the CHBDC assuming an ultimate/unfactored coefficient of friction of 0.4.

8.6 Settlement

It is understood that there is no grade raise at this site and that the culvert will be replaced along the same alignment as the existing culvert. As no substantial additional loads are anticipated at the proposed culvert replacement, the settlement of the foundation soils is estimated to be less than 25 mm, based on this preliminary investigation.

8.7 Subgrade Preparation

After completion of excavation for the new culvert, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, soft creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint should be further sub-excavated to undisturbed, competent native soils. The sub-excavated area should be replaced with well compacted granular fill consisting of OPSS 1010 Granular A or B Type II material, as soon as practical.

The contract should contain an Operational Constraint advising the Contractor to protect the subgrade from disturbance and degradation at all times. This includes, though is not limited to disturbance from traffic, equipment operation and exposure to the weather. The Contractor is not permitted to operate equipment on the exposed subgrade. If protection of the subgrade is required prior to placing the bedding, consideration could be given to methods such as a concrete mud slab. All works should be carried out in accordance with OPSS 902.

9 BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of granular material conforming to OPSS.PROV 1010 Granular A, Granular B Type II or Type III specifications. Backfill to a concrete rigid frame culvert should be completed in accordance with OPSD 803.010, and for the pipe culvert in accordance with OPSD 803.06.

Backfill should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill should not be different more than 400 mm on both sides of the culvert at all times. Compaction equipment to be used adjacent to culverts should be restricted in accordance with OPSS 501 and SP 105S21.

Lateral earth pressures acting on the culvert walls and wing walls may be assumed to be triangularly distributed and to be governed by the characteristics of the abutment backfill and the underlying soils. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$p_h = K(\gamma h + q)$$

Where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 9.1)

γ = unit weight of retained soil (see Table 9.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert and wingwalls (if incorporated in the design) are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Values that could be used in design are shown in Table 9.1.

Table 9-1. Earth Pressure Coefficients

Wall Condition	**Earth Pressure Coefficients (K)**					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°; \gamma = 22.8$ kN/m^3		OPSS Granular B Type I or OPSS Granular B Type III $\phi = 32°; \gamma = 21.2$ kN/m^3		Embankment Fill $\phi = 30°; \gamma = 20.0$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.70	-	3.30	-	3.00	-

Note: Submerged unit weight should be used below the groundwater level.

The use of a material with a high friction angle and low active pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

The parameters in the tables correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC. Active pressures should be used for any wingwalls or unrestrained walls.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or Type III or at a depth of 1.7 m for Granular A or Granular B Type II.

10 EMBANKMENT RESTORATION

Embankment restoration after culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of imported Granular A or B Type II material. Excavated granular fill may also be reused as backfill provided the following conditions are satisfied:

- There is sufficient space to stockpile on site and control moisture content within acceptable limits for compaction;
- No peat or organic materials are included in the fill;

- Gradation and compaction characteristics meet the requirements prior to reuse as backfill.

Where applicable, the keying in of the newly placed fill into the existing embankment fill should be carried out to allow for better interaction between the existing embankment fill and new fill/backfill. Provided that the subgrade is prepared as outlined in Section 8.6 and granular fill is placed as indicated in Section 9, it is anticipated that embankment slopes at inclination of 2H : 1V or flatter, remain stable.

11 EROSION CONTROL

Erosion protection should be provided in the areas of culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces, with which creek water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

A clay seal or a concrete cut-off wall should be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

12 EXCAVATION AND GROUNDWATER CONTROL

12.1 Excavations

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native clayey silt and sand at this site can be classified as Type 3 soils above the water level and Type 4 soils below the water level. The excavation for the culvert replacement will typically be carried out through the existing embankment fill and extend into the underlying native cohesive deposits. At locations where there is space restriction or where a slope has to be retained, the excavation will need to be carried out in conjunction with a protection system. Any protection system should be designed by a licensed Professional Engineer experienced in such designs. OPSS 539 “Construction Specifications for Protection Systems” will have to be included in the contract documents.

12.2 Groundwater Control

It is expected that groundwater and surface water will accumulate in the excavation during culvert construction. The groundwater level is expected to be largely governed by the water level in the creek and seasonal weather patterns. The Contractor should make provisions for creek water diversion and to control any groundwater seepage, surface runoff and ponding by measures including the use of sump pumps, cofferdams, and protection systems such as sheet pile enclosures, etc., to maintain dry excavations during the duration of construction. All dewatering operations should be conducted in accordance with OPSS 518.

13 ROADWAY PROTECTION DESIGN

Roadway protection may be required during various stages of construction. The design of roadway protection should be the responsibility of the Contractor and all shoring systems should be designed by a Professional Engineer experienced in such designs. The roadway protection should be designed for Performance Level 2 (maximum 25 mm horizontal deflection).

14 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT(1) 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction
1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
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 structure are preserved.

DISCONTINUITY SPACING

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

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	(psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

<u>UNIFIED SOILS CLASSIFICATION</u>

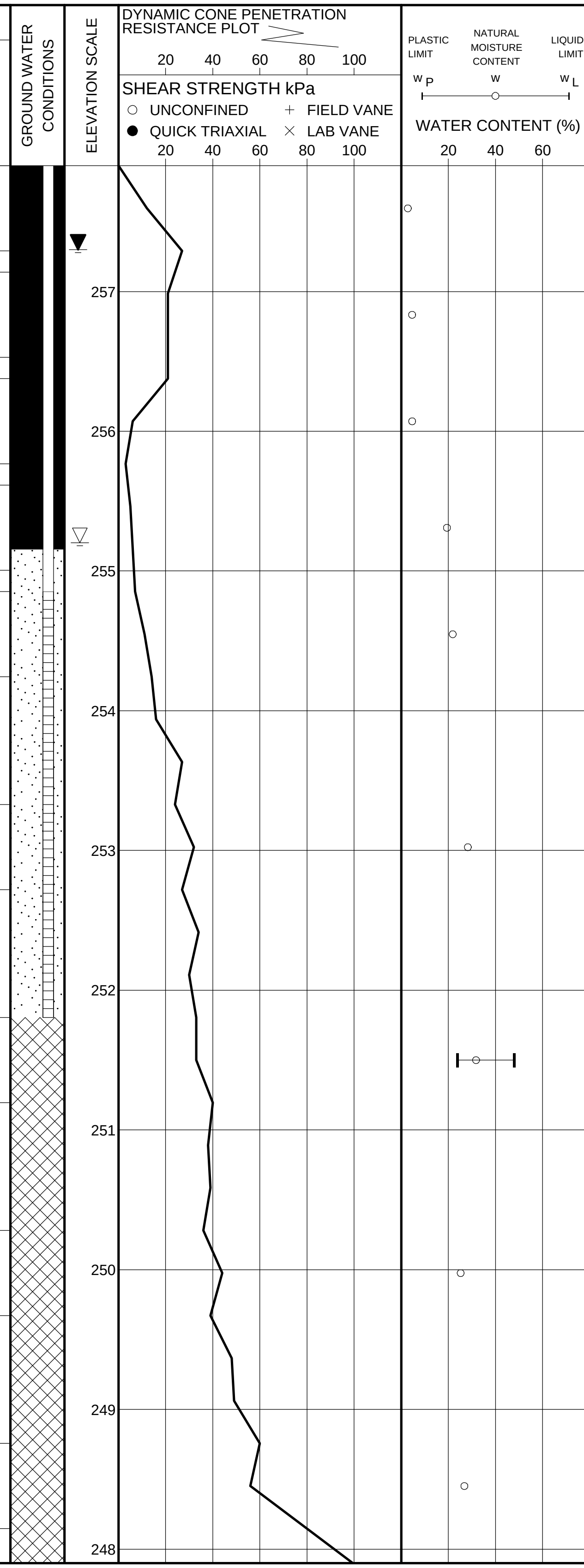
<table>
<tr><th colspan="2">MAJOR DIVISIONS</th><th>GROUP SYMBOL</th><th>TYPICAL DESCRIPTION</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS</td><td rowspan="4">GRAVEL AND GRAVELLY SOILS</td><td>GW</td><td>Well-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GP</td><td>Poorly-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GM</td><td>Silty gravels, gravel-sand-silt mixtures.</td></tr>
<tr><td>GC</td><td>Clayey gravels, gravel-sand-clay mixtures.</td></tr>
<tr><td rowspan="4">SAND AND SANDY SOILS</td><td>SW</td><td>Well-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SP</td><td>Poorly-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SM</td><td>Silty sands, sand-silt mixtures.</td></tr>
<tr><td>SC</td><td>Clayey sands, sand-clay mixtures.</td></tr>
<tr><td rowspan="7">FINE GRAINED SOILS</td><td rowspan="4">SILTS AND CLAYS $W_L < 50\%$</td><td>ML</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.</td></tr>
<tr><td>CL</td><td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).</td></tr>
<tr><td>CI</td><td>Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).</td></tr>
<tr><td>OL</td><td>Organic silts and organic silty-clays of low plasticity.</td></tr>
<tr><td rowspan="3">SILTS AND CLAYS $W_L > 50\%$</td><td>MH</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.</td></tr>
<tr><td>CH</td><td>Inorganic clays of high plasticity, fat clays.</td></tr>
<tr><td>OH</td><td>Organic clays of medium to high plasticity, organic silts.</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td>Pt</td><td>Peat and other highly organic soils.</td></tr>
<tr><td colspan="3">CLAY SHALE</td><td rowspan="5"></td></tr>
<tr><td colspan="3">SANDSTONE</td></tr>
<tr><td colspan="3">SILTSTONE</td></tr>
<tr><td colspan="3">CLAYSTONE</td></tr>
<tr><td colspan="3">COAL</td></tr>
</table>

RECORD OF BOREHOLE No 14-01

METRIC

W.P. 4013-13-01	LOCATION Site 32-213/C, Hwy 7 N 4 908 342.2 E 371 019.7	ORIGINATED BY SDP
HWY 7	BOREHOLE TYPE Solid Stem Augers	COMPILED BY AN
DATUM	DATE 2014.12.01 - 2014.12.01	CHECKED BY MW

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT w (%)	GR	SA	SI	CL
257.9	GROUND SURFACE								
0.0	**SAND** and **GRAVEL**, some silt Loose to Compact Brown Moist (FILL)	1	SS	25					
		2	SS	18		37	46	17 (SI+CL)	
		3	SS	9					
255.7 / 2.2	Clayey **SILT** and **SAND** Soft Brown Wet	4	SS	3		0	44	36	20
254.9 / 3.0	Silty **CLAY**, trace organics in upper zone Firm to Very Stiff Brown to Grey Moist	5	SS	5					
		6	SS	12					
		7	SS	11		0	0	24	76
	NOTE: Shelby tube lost	8	TW						
		9	SS	28					



Continued Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-01

METRIC

W.P. 4013-13-01
LOCATION Site 32-213/C, Hwy 7 N 4 908 342.2 E 371 019.7
ORIGINATED BY SDP

HWY 7
BOREHOLE TYPE Solid Stem Augers
COMPILED BY AN

DATUM
DATE 2014.12.01 - 2014.12.01
CHECKED BY MW

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
247.7											
10.2	Sandy **GRAVEL**, trace silt, trace clay Very Dense Grey Wet		10	SS	100/ 0.300		247		○		
246.9 11.0	END OF BOREHHOLE AT 11.0m ON REFUSAL TO AUGER PENETRATION. WATER LEVEL AT 2.7m ON COMPLETION OF DRILLING. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Dec 04/14	2.6	255.3
Dec 18/14	0.6*	257.3

* Frozen

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Shear strength scale 20 40 60 80 100. Water content: PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; scale 20 40 60.

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-1

METRIC

W.P.	4012-13-01	LOCATION	Site 32-213/C N 4 908 340.1 E 371 031.6	ORIGINATED BY	ES
HWY	7	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2015.05.14 - 2015.05.14	CHECKED BY	AMP

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.6	GROUND SURFACE						
0.0 / 0.1	**TOPSOIL:** (100mm)						
	Silty **CLAY**, trace sand, trace gravel Stiff Grey Moist				255		
		1	SS	10			
		2	SS	12	254		
		3	SS	11	253		0 6 23 71
		4	SS	9	252		
		5	SS	9	251		
		6	SS	10	250		
249.0 / 6.6	Silty **SAND**, some gravel to gravelly, trace clay Dense Grey Wet				249		
		7	SS	34	248		20 48 32 (SI+CL)
247.4 / 8.2	END OF BOREHOLE AT 8.2m. ARTESIAN PRESSURE NOTED 0.4m ABOVE GROUND AT THE END OF BOREHOLE. BOREHOLE BACKFILLED WITH CONCRETE TO 6.7m, BENTONITE HOLEPLUG TO 4.6m, CUTTINGS (CLAY) TO 1.0m, HOLEPLUG TO 0.1m THEN CONCRETE TO SURFACE.						

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3.

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-2

METRIC

W.P. 4012-13-01 LOCATION Site 32-213/C N 4 908 358.2 E 371 022.9 ORIGINATED BY ES

HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM DATE 2015.05.14 - 2015.05.14 CHECKED BY AMP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
257.6	GROUND SURFACE										
0.0	**SAND** and **GRAVEL**, some silt Loose to Dense Brown Dry (FILL)	1	GS			257	○				
	Occasional cobbles	1	SS	38			○				
		2	SS	12		256	○	42	45	13 (SI+CL)	
		3	SS	5		255	○				
254.8 / 2.8	Clayey **SILT** and **SAND**, trace gravel Firm Greyish Brown Wet	4	SS	4		254	○				
253.5 / 4.1	Silty **CLAY**, trace sand, trace gravel Firm to Stiff Grey Moist	5	SS	9	∇	253	⊢○—⊣	0	0	23	77
		6	SS	7		252, 251	○				
		7	SS	7		250, 249	○				
248.3 / 9.3	Silty **SAND**, some gravel, some clay, occasional cobble Dense	8	SS	32		248	○	20	40	29	11
247.8 / 9.8	Grey										

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 15-2

METRIC

W.P. 4012-13-01 LOCATION Site 32-213/C N 4 908 358.2 E 371 022.9 ORIGINATED BY ES

HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM DATE 2015.05.14 - 2015.05.14 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	Wet										
	END OF BOREHOLE AT 9.8m. WATER LEVEL AT 5.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO 0.3m, SAND AND GRAVEL TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-3

METRIC

W.P. 4012-13-01 | LOCATION Site 32-213/C N 4 908 367.5 E 371 011.1 | ORIGINATED BY ES

HWY 7 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM | DATE 2015.05.14 - 2015.05.14 | CHECKED BY AMP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
254.4	GROUND SURFACE								
0.0 / 0.1	**TOPSOIL:** (75mm)				254				
	Silty **CLAY**, trace sand, trace gravel Stiff Brown Moist	1	SS	15	253				
		2	SS	13	252				
	Becoming grey	3	SS	14		0	0	33	67
		4	SS	12	251, 250				
		5	SS	9	249				
248.3 / 6.1	Silty **SAND**, some clay, some gravel, occasional cobbles Compact to Dense Grey Wet	6	SS	11	248, 247				
246.7 / 7.7		7	SS	50/ 0.100		11	43	35	11
	END OF BOREHOLE AT 7.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.								

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; GROUND WATER CONDITIONS; STRAT PLOT.

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

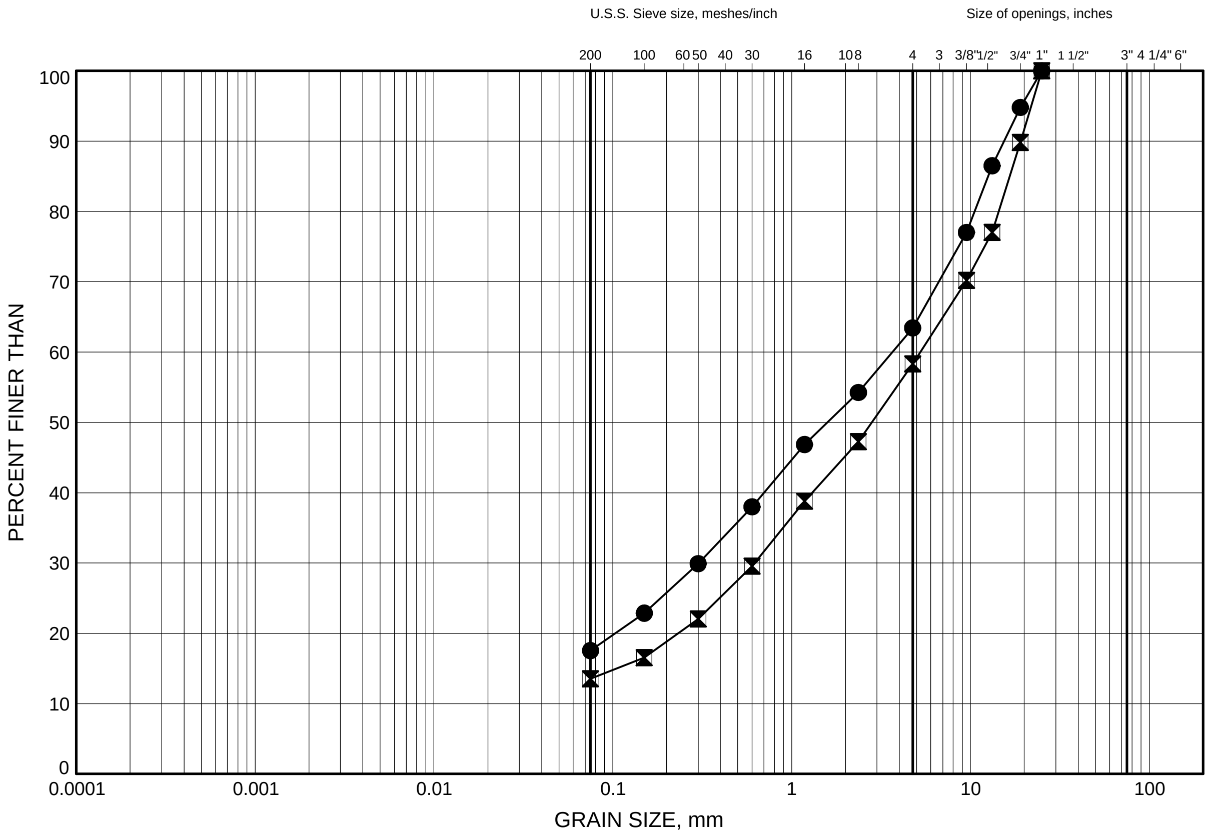
Appendix B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	1.07	256.83
⧗	15-2	1.83	255.77

Date July 2015

W.P. 4012-13-01

THURBER

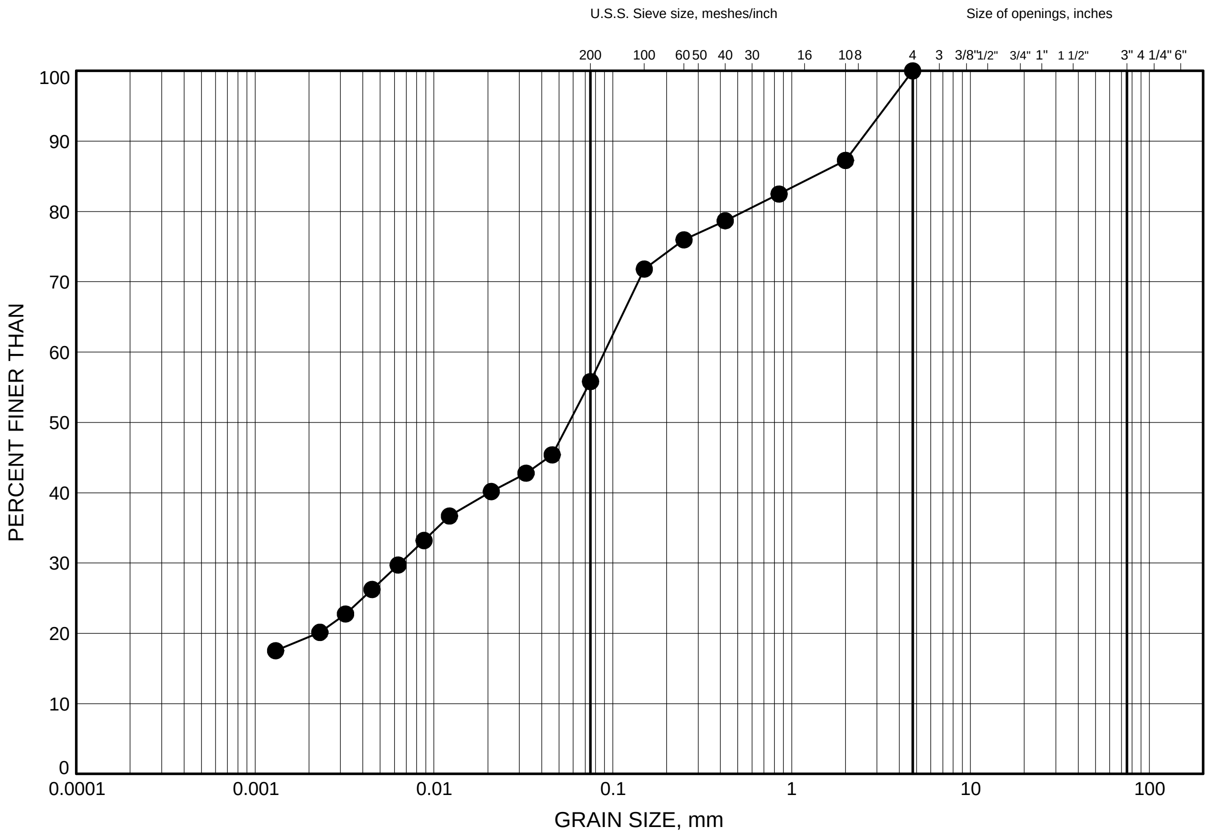
Prep'd AN

Chkd. AMP

GRAIN SIZE DISTRIBUTION

FIGURE B2

CLAYEY SILT & SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	2.59	255.31

Date July 2015

W.P. 4013-13-01

THURBER

Prep'd AN

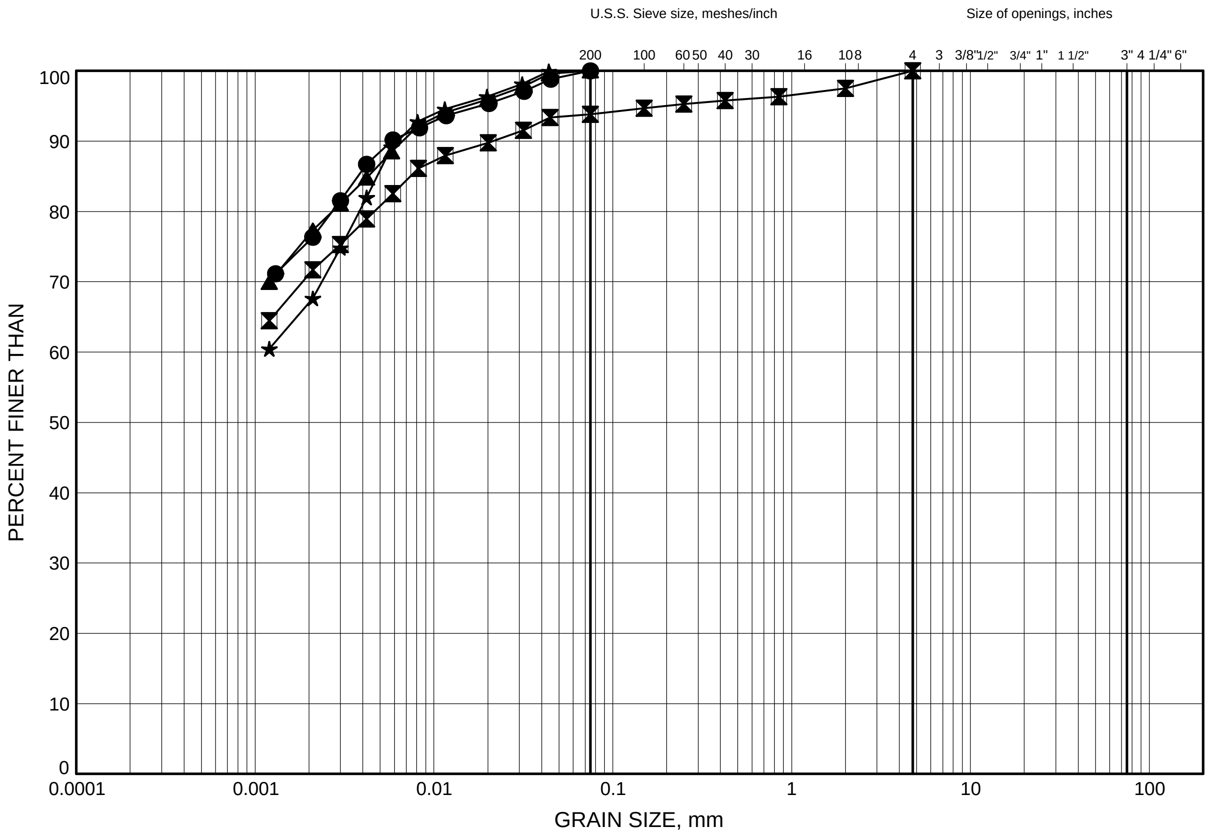
Chkd. AMP

GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 7/23/15

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	6.40	251.50
⧗	15-1	2.59	253.01
▲	15-2	4.88	252.72
★	15-3	2.59	251.81

Date July 2015

W.P. 4012-13-01

THURBER

Prep'd AN

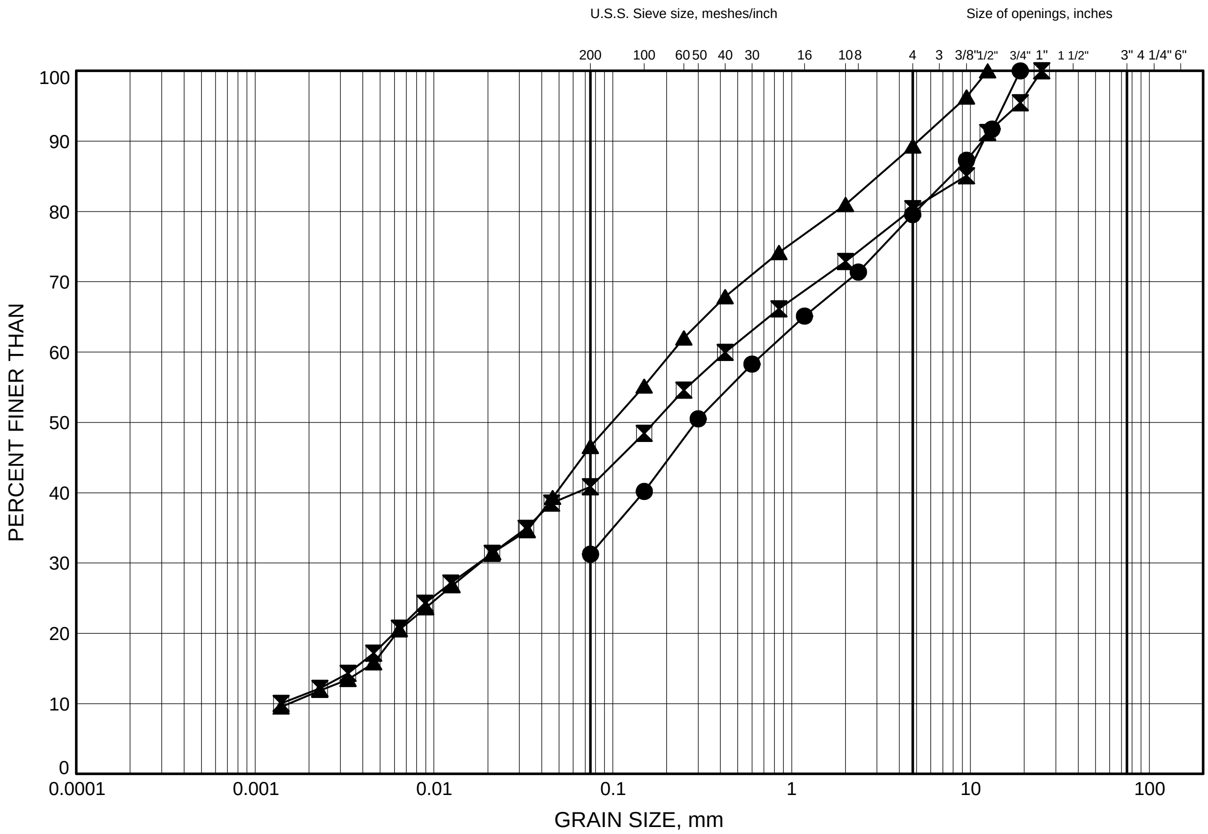
Chkd. AMP

GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 7/23/15

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-1	7.92	247.68
⧗	15-2	9.45	248.15
▲	15-3	7.65	246.75

Date July 2015

W.P. 4012-13-01

THURBER

Prep'd AN

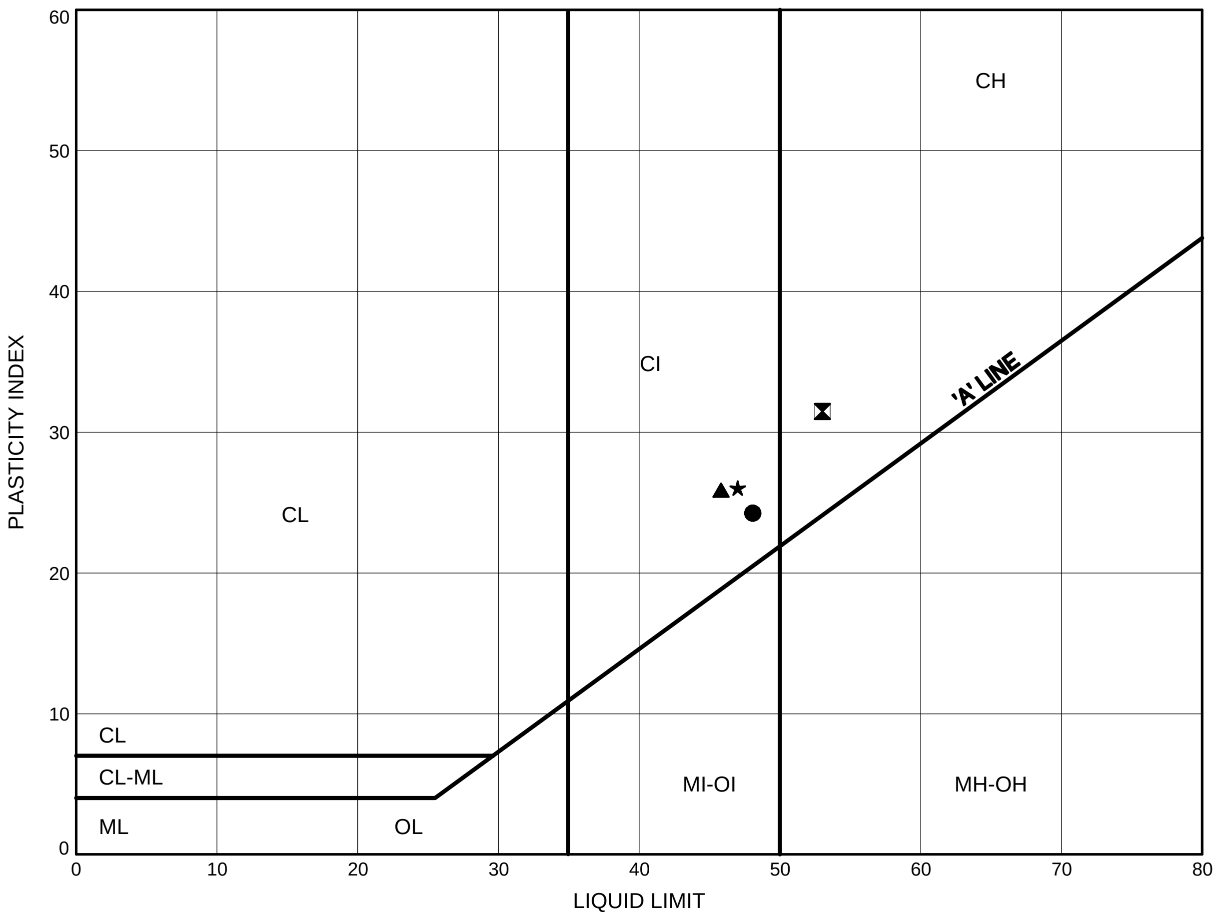
Chkd. AMP

GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 7/23/15

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	6.40	251.50
⧗	15-1	2.59	253.01
▲	15-2	4.88	252.72
★	15-3	2.59	251.81

THURBALT 0620.GPJ 7/23/15

Date July 2015

W.P. 4012-13-01

THURBER

Prep'd AN

Chkd. AMP

Appendix C

Site Photographs

Photograph 1 – South end of the culvert

Photograph 2 – Looking east at the south end of the culvert; the stake marks the location of the borehole

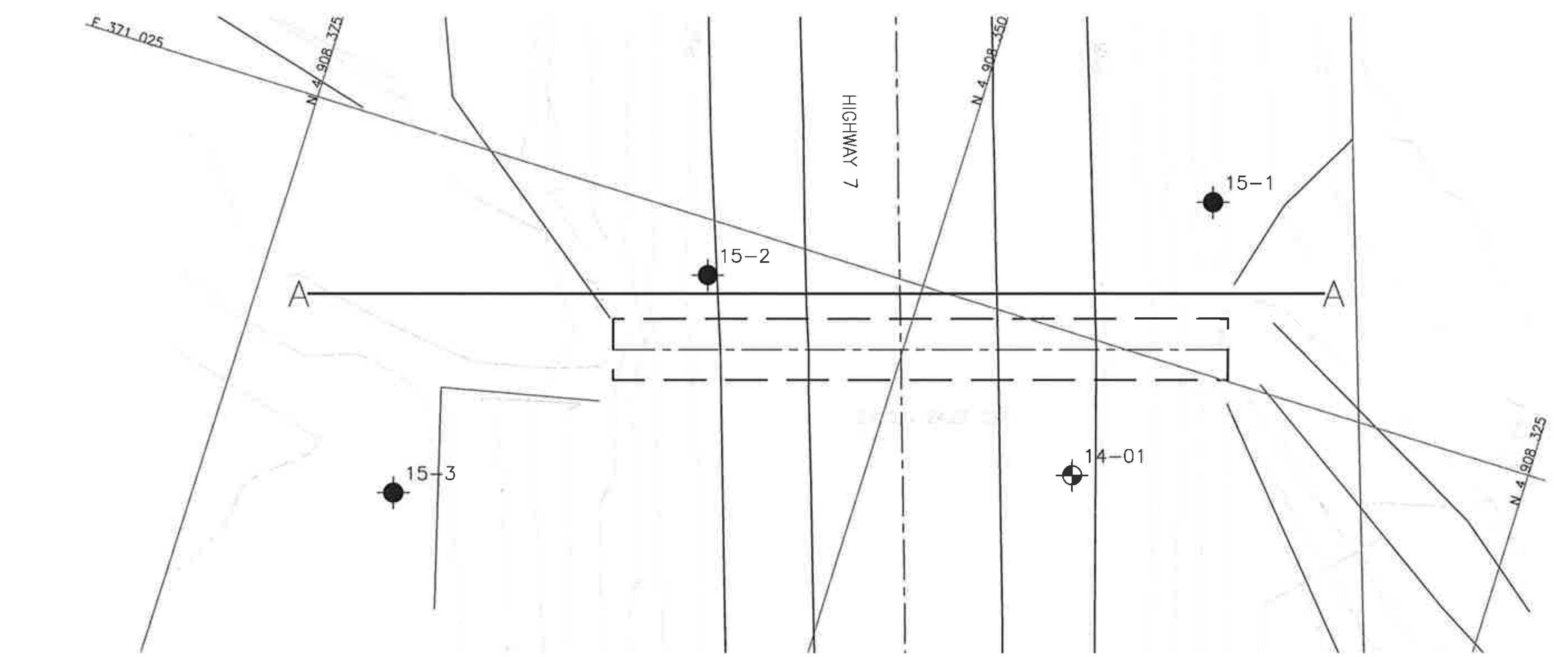
Photograph 3 – Looking south from the south end of the culvert

Photograph 4 – Looking southeast from the south end of the culvert

Photograph 5 – North end of culvert

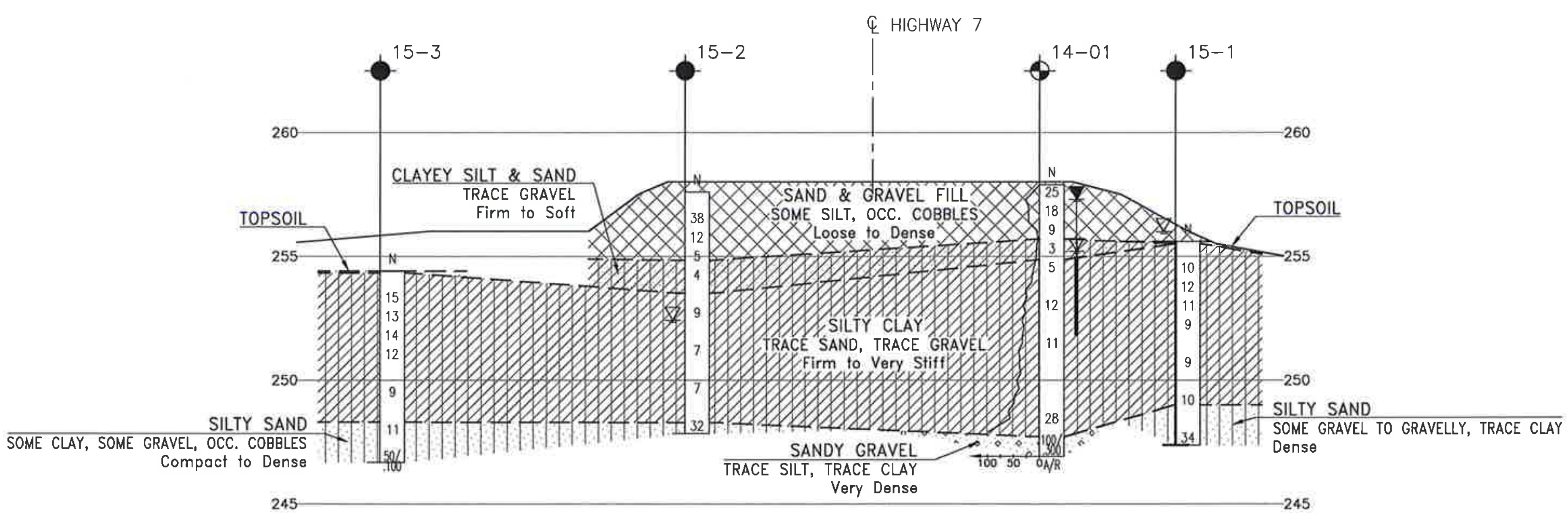
Appendix D

Borehole Location Drawing



PLAN

SCALE 1:250



PROFILE ALONG SECTION A–A

SCALE 1:250

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

LICENSED PROFESSIONAL ENGINEER
A. PIASCIK
Sep. 23/15
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 23/15
PROVINCE OF ONTARIO

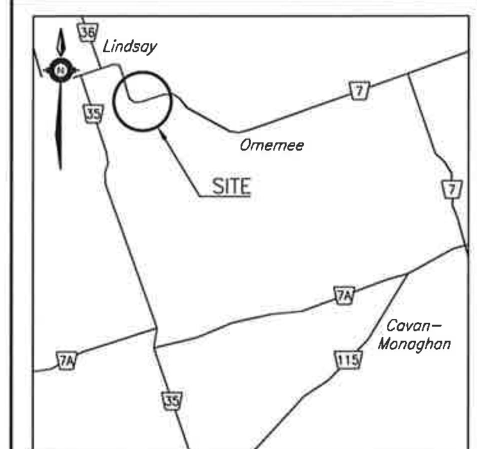
CONT No
WP No 4012–13–01

SHEET

HIGHWAY 7
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

AECOM

THURBER ENGINEERING LTD.



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
14–01	257.9	4 908 342.2	371 019.7
15–1	255.6	4 908 340.1	371 031.6
15–2	257.6	4 908 358.2	371 022.9
15–3	254.4	4 908 367.5	371 011.1

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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

GEOCRES No. 31D-613

REVISIONS | DATE | BY | DESCRIPTION

DESIGN AEG	CHK PKC	CODE	LOAD	DATE SEP 2015	
DRAWN MFA	CHK AEG	SITE 32–213/C	STRUCT	DWG 1	

FILENAME: H:\Drafting\19\4406\20\ted0620–Plan&Profile(Highway7).dwg
PLOTDATE: 9/22/2015 4:52 PM

Appendix E

Comparison of Culvert Foundation Alternatives

COMPARISON OF CULVERT FOUNDATION ALTERNATIVES

Pipe Culvert - Concrete	Pipe Culvert - CSP or HDPE	Concrete Rigid Box Culvert	Concrete Open Footing Culvert
Advantages: i. Relatively simple installation/construction ii. Lower cost than a concrete rigid frame culvert	***Advantages:*** i. Relatively simple installation/construction ii. Can tolerate larger magnitude of settlement than a concrete pipe or rigid frame culvert iii. Lower cost than a concrete pipe or rigid frame culvert	***Advantages:*** i. Relatively rapid installation when precast units are used ii. Minimizes depth of excavation and duration of construction/dewatering iii. Can tolerate larger magnitude of differential settlements than open footing culvert, when precast units are used iv. Smaller magnitude of settlement than an open footing culvert due to lower stress on subgrade	***Advantages:*** i. Relatively rapid installation if precast units used ii. Might better satisfy fisheries requirements, if applicable
Disadvantages: i. Feasibility depends on flow capacity and other hydraulic properties ii. May require deeper excavation than for box culvert **FEASIBLE**	***Disadvantages:*** i. Feasibility depends on flow capacity and other hydraulic properties ii. CSP and HDPE pipes not as durable as a concrete culvert iii. May require deeper excavation than for box culvert **FEASIBLE**	***Disadvantages:*** i. Some risk of disturbance of the founding stratum during construction. **PREFERRED**	***Disadvantages:*** i. Greater risk of disturbance of the founding stratum during construction than for box culvert. ii. May require longer construction duration. iii. Potential for more elaborate dewatering system than for the box culvert. **FEASIBLE**