



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
NORWICH AVENUE REALIGNMENT AT HIGHWAY 401
NORTH END RETAINING WALL
CITY OF WOODSTOCK, ONTARIO
G.W.P. 3054-13-00**

GEOCRES No. 40P2-85

Report

to

MMM Group Limited

Date: November 24, 2016
File: 19-5161-224



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the detailed design of a retaining wall as part of the north end realignment of Norwich Avenue (Highway 59) at Highway 401 in Woodstock, Ontario.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM) under the Ministry of Transportation Ontario (MTO) Agreement Number 3013-E-0027.

The purpose of this investigation was to explore the subsurface conditions along the retaining wall alignment and, based on the data obtained, to provide a borehole location plan, records of boreholes, laboratory test results and a written description of the subsurface conditions.

2. SITE DESCRIPTION

The project site is located to the north of Highway 401 and to the west of Norwich Avenue (County Road 59), in the south end of the City of Woodstock. The alignment of the proposed retaining wall is within the existing Quality Inn and Suites (Quality Inn) parking lot. The surface of the parking lot is below the levels of the adjacent roadways. A sloped grassy area with occasional trees is present between the roadway and the parking lot. Select photographs showing the general nature of the project site are presented in Appendix C.

At the project site, Highway 401 runs approximately in the southwest-northeast direction, and for the purpose of this report, Highway 401 is assumed to run west-east. The surrounding land use generally consists of a mixture of commercial properties and agricultural land. The developed area of the City of Woodstock lies to the north.

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Based on the Quaternary Geology Map, the site is situated in the Physiographic Region known as the Oxford Till Plain characterized by drumlinized till deposits. The surficial deposits contain mainly silt with variable amounts of clay, sand and gravel particles.

3. INVESTIGATION PROCEDURES

The field investigation for this project was carried out on June 23, 2016 when two boreholes (denoted 16-01 and 16-02) were advanced at selected locations along the proposed retaining wall alignment within the parking lot of the Quality Inn property. The location of the boreholes were determined based on AutoCAD drawings provided by MMM, and the approximate locations are shown on the Borehole Location and Soil Strata Drawing in Appendix D. The borehole locations were located in the field using a handheld Garmin GPS unit. The boreholes were advanced using solid stem augers to 8.2 m depth. Soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

Groundwater conditions were observed in the boreholes during and upon completion of the drilling operations. The boreholes were backfilled in general accordance with Ontario Regulation 903. Details of the borehole depths, base elevation and completion are summarized in Table 3.1 below.

Table 3.1- Borehole Installation and Backfilling Details

| Borehole | Borehole Depth (m) | Borehole Elevation (m) | Borehole Backfilling Details |
|----------|--------------------|------------------------|--|
| 16-01 | 8.2 | 298.3 | Bentonite holeplug and cuttings from 8.2 m to 0.6 m, concrete to 0.1 m and asphalt coldpatch to surface. |
| 16-02 | 8.2 | 298.2 | Bentonite holeplug and cuttings from 8.2 m to 0.6 m, concrete to 0.1 m and asphalt coldpatch to surface. |

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who located the boreholes in the field, cleared borehole location of underground utilities, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The supervisor processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Results of field sampling and testing are presented in the Record of Borehole sheets included in Appendix A.



Ground surface elevation and coordinates at Boreholes 16-01 and 16-02 were obtained from the base drawing provided by MMM.

4. LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. Laboratory testing results 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

5.1 General

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 boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In addition to the boreholes drilled as part of current investigation, Borehole Q1-01 was advanced in a previous investigation carried out for the replacement of the commercial sign proposed within the Quality Inn parking lot and near the alignment of the wall. The borehole information from the previous investigation has been incorporated into this investigation and the borehole log is provided in Appendix A.

In summary, the subsurface conditions at the site comprised a pavement structure underlain by a glacial sand and silt till deposit. The sand and silt till was locally underlain by clayey silt till at the center of the alignment. Water level was measured at a depth of 7.6 m (Elev. 290.7) in the borehole at the north of the alignment upon completion of drilling, and the water level in the piezometer installed in Borehole Q1-01 was at a depth of 6.1 m (Elev. 291.1).

5.2 Pavement Structure

Boreholes 16-01, 16-02 and Q1-01 were drilled through the parking lot pavement structure and encountered 50 mm of asphalt and 0.7 m of pavement base material. The fill consisted of gravelly sand with trace silt and extended to a depth of 0.8 m (Elev. 297.5 to 297.2).

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Moisture contents ranging from 3% to 7% were measured in the fill material.

5.3 Sand and Silt to Sandy Silt Till

A brown sand and silt to sandy silt till containing trace to some clay and trace gravel was encountered below the pavement structure in the boreholes from the current and previous investigation. The thickness of this till ranged from 6.4 m to more than 8.6 m. Boreholes 16-01 and Q1-01 were terminated in the till at a depth of 8.2 m (Elev. 290.1) and 9.4 m (Elev. 288.6) respectively.

In Borehole Q1-01 at approximately 2.4 m depth, a 1.0 m thick interlayer of coarser till comprising gravelly sand with trace silt was separating the fine-grained till deposit.

It should be noted that cobbles and boulders inherently occur in glacial deposits, and even though not encountered during drilling the boreholes, they should be expected within the soil matrix.

SPT 'N' Values obtained in the till varied from 11 to 176 blows per 0.3 m of penetration, indicating a compact to very dense relative density. SPT 'N' Values obtained in the gravelly sand varied from 57 to 96 blows per 0.3 m of penetration, indicating a very dense relative density. Natural moisture contents of the till ranged from 8 to 29%. Moisture contents in the gravelly sand layer ranged from 5 to 7%.

Grain size analyses were completed on selected samples of the till and gravelly sand interlayer. The results are presented on the Record of Borehole sheets in Appendix A and are shown on Figures B1, B2 and B3 in Appendix B. The results of the grain size distribution tests are summarized below:

| Soil Particles | Sand and Silt to Sandy Silt Till | Gravelly Sand |
|----------------|----------------------------------|---------------|
| | Percentage (%) | |
| Gravel | 0 to 7 | 33 |
| Sand | 34 to 61 | 58 |
| Silt | 35 to 69 | 9 |
| Clay | 4 to 18 | |

Atterberg Limits testing was completed on selected samples of the till. The results are presented on the Record of Borehole sheets in Appendix A and are shown on Figure B5 in Appendix B. The results of the Atterberg limits testing is summarized below:



| Index Property | Percentage (%) |
|----------------|----------------|
| Liquid Limit | 17 to 18 |
| Plastic Index | 6 |

The results of the Atterberg Limits testing indicate presence of layers of low plasticity silt with group symbol CL-ML. Although some samples exhibited plasticity, the clay content was not sufficient to describe the deposit as clayey.

Glacial till inherently contains cobbles and boulders.

5.4 Clayey Silt Till

A grey clayey silt till comprising some sand and trace gravel was encountered below the sand and silt till in Borehole 16-02. The clayey silt till extended to the borehole termination depth of 8.2 m (Elev. 290.0).

An SPT 'N' Value obtained in the clayey silt till was 75 blows per 0.3 m of penetration, indicating a hard consistency. A moisture content recorded in the clayey silt till was 13%.

A grain size analyses was completed on a select sample of the clayey silt till. The results are presented on the Record of Borehole sheet in Appendix A and are shown on Figure B4 in Appendix B. The results of the grain size distribution test are summarized below:

| Soil Particles | Percentage (%) |
|----------------|----------------|
| Gravel | 0 |
| Sand | 16 |
| Silt | 62 |
| Clay | 22 |

Atterberg Limits testing was completed on a select sample of the clayey silt till. The results are presented on the Record of Borehole sheet in Appendix A and is shown on Figure B6 in Appendix B. The results of the Atterberg limits testing is summarized below:

| Index Property | Percentage (%) |
|----------------|----------------|
| Liquid Limit | 20 |
| Plastic Index | 6 |

The results of the Atterberg Limits testing indicate the layer to be of low plasticity silt with group symbol CL-ML.



Glacial till inherently contains cobbles and boulders.

5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. A piezometer was installed for water level measurements in Borehole Q1-01 in the previous investigation. The groundwater levels observed in the boreholes are summarized in Table 5.1 below.

Table 5.1 – Groundwater Level Measurements

| Borehole | Date | Water Level (m) | | Remark |
|----------|---------------|-----------------|-----------|---------------|
| | | Depth | Elevation | |
| Q1-01 | July 15, 2015 | 6.1 | 291.9 | Piezometer |
| 16-01 | June 23, 2016 | 7.6 | 290.7 | Open Borehole |
| 16-02 | June 23, 2016 | Dry | - | Open Borehole |

The groundwater levels above are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained subsurface utility clearances prior to drilling.

Altech Drilling & Investigative Services of Elmira, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Troy Mackinnon of Thurber. Overall supervision of the field program was provided by Ms. Deanna Pizycki, EIT of Thurber.

The coordinates and ground surface elevations at the borehole locations were established based on drawings provided by MMM.



Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Interpretation of the field data and preparation of this report was carried out by Ms. Deanna Pizycki, EIT and Mr. Alastair Gorman, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This section of the report presents an interpretation of the geotechnical data in the factual report and provides foundation recommendations for the proposed retaining wall at the Norwich Avenue north end realignment at Highway 401 in the City of Woodstock, County of Oxford, Ontario.

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

The proposed retaining wall is part of the Highway 401 and Norwich Avenue intersection improvement and will facilitate shifting Norwich Avenue alignment to the west. The retaining wall will cross the exiting Quality Inn and Suites (Quality Inn) parking lot in the north-west quadrant of the intersection of the Norwich Avenue and Highway 401 N/S-W Ramp.

Based on the preliminary drawings provided by MMM Group Ltd. (MMM) dated May 12, 2016, the proposed retaining wall is approximately 90 m in length, and up to 4.5 m in height and runs in the general north-south direction. The base of the retaining wall will lie between Elevations 297.7 and 300.9 (approximate) and the top of the wall will be at approximate Elevation 302.2. The first approximately 20 m northern section of the wall will cross the original ground surface, and the remaining section of the alignment will intersect the eastern sliver of the existing parking lot of the Quality Inn. As shown on the provided sections, the retaining wall is envisioned as the Retained Soil System (RSS) wall.

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This report presents recommendations for design and construction of both RSS wall and concrete cantilever wall to aid in selection of the type of retaining wall.

The recommendations are based on the subsurface soil and groundwater conditions encountered during the current investigation. In addition, subsurface information obtained from a borehole drilled for the commercial sign at the Quality Inn parking lot and in proximity to the south end of the wall alignment was incorporated in the data base. The soil conditions may vary between and beyond the borehole locations, and accordingly geotechnical inspection during construction is important to assess any variation of subsurface conditions and to provide additional recommendations if necessitated by such variations.

8. RETAINING WALL

8.1 Subsurface Conditions

In summary, the subsurface conditions at the site comprised a pavement structure underlain by a glacial sand and silt to sandy silt till deposit. The pavement structure consisted of 50 mm of asphalt underlain by approximately 0.7 m of compact to dense gravelly sand fill forming base of the pavement. The gravelly sand fill extended to a depth of 0.8 m or varied from Elev. 297.2 to Elev. 297.5. The underlying glacial till ranged in composition from sand and silt to sandy silt. The till contained local zones with some clay, which resulted in slight plasticity of the deposit. The lower zone of the deposit in Borehole 16-02 was classified as a clayey silt till. Interlayer of gravelly sand till was also encountered in the borehole located in the southern end of the alignment. The till was compact to very dense. All boreholes were terminated in the till deposit at depths ranging from 8.2 m (Elev. 290.0) to 9.4 m (Elev. 288.6).

Water level measured in the piezometer installed in Borehole Q1-01 near the south end of the alignment was at a depth of 6.1 m (Elev. 291.9) and the water level in Borehole 16-01 was observed at a depth of 7.6 m (Elev. 290.7) upon completion of drilling.

8.2 Retained Soil System (RSS) Wall

According to the MTO RSS manual, RSS wall at this site should be specified as “High Performance” and “High Appearance”, although the Ministry may wish to specify different performance and appearance levels. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and reference to SP 599S22 and/or SP599S23.



Based on the preliminary drawings, the ground surface along the alignment varies from approximately Elev. 298.0 to 298.3 within the parking area, to as high as Elevation 301.0 at the ends of the wall. The subgrade at the proposed wall founding level will vary and it will be located within the native soils in the northern section of the alignment extending to approximately Sta. 9+800, and then, along the remaining section of the alignment, it will encounter gravelly sand fill within the existing parking area as well as a new embankment fill.

The concrete levelling strips supporting the front panels of the wall may need to be stepped to accommodate specific geometric configurations.

The performance of a RSS wall is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to excessive settlements and distortion of the RSS and, in severe cases, to possible failure of the system.

The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement. To provide an acceptable foundation performance, the RSS mass should be founded on a 150 mm thick granular bedding resting on the existing compact to dense granular fill (pavement base material) or native compact to very dense sand and silt till subgrade. Where there is a requirement to raise the founding level or place the RSS wall on the new embankment fill, the levelling strips and bedding material should be placed on engineered fill.

The bedding material placed under the RSS mass should consist of OPSS PROV Granular A or Granular B Type II (crushed stone) and should be placed and compacted in accordance with OPSS PROV 501. The bedding should extend at least 300 mm beyond the limits of the RSS levelling base/strip.

Any engineered fill placed under the RSS mass to achieve the design founding level should consist of OPSS Granular "A" compacted to 100% of SPMDD at a moisture content within 2% of optimum (OMC). The engineered fill pad should extend at least 500 mm beyond the limits of the RSS mass and leveling strip.

Proper attention to subgrade preparation and inspection during construction will be essential for adequate performance of the wall. Subgrade preparation should follow the requirements of Section 8.4, below.

The following geotechnical capacities could be used for a RSS wall placed on the engineered pad founded on properly prepared subgrade (Section 8.4)



Factored Geotechnical Resistance at ULS of 200 kPa

Geotechnical Reaction at SLS of 150 kPa.

The above values of the geotechnical resistance and geotechnical reaction account for variation in the subgrade materials, namely varying from native sand and silt till to pavement base material and new embankment fill.

The resistance value assume that the RSS wall reinforcement will extend a distance behind the wall face of approximately 70% of the wall height. The geotechnical reaction at SLS is based on a settlement of 25 mm of the foundation soils.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth should be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.5 for a granular fill subgrade.

The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for the site. The global stability is dependent on the characteristics of the fill and foundation soils and the geometry of the system. Global stability is not expected to be a concern for a RSS wall founded on the engineered fill and/or native soils at this site.

The proprietary RSS system should meet the Ministry's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design.

8.3 Concrete Cantilever Wall

Based on the borehole information, construction of a concrete cantilever wall supported on spread footing is considered feasible.

The spread footings supporting the wall may need to be stepped to accommodate specific geometric configurations. Spread footings should be founded on native sand and silt till at or below Elev. 297.2. Consideration could also be given to raising the founding level and placing the strip footings on the engineered fill pad placed on the native till, and at least 500 mm in thickness.



The following bearing capacities for footings founded on the native, undisturbed compact to very dense sand and silt till and/or engineered fill pad placed on native till can be used in design:

Factored Geotechnical Resistance at ULS 300 kPa

Geotechnical Reaction at SLS of 250 kPa

The spread footing could also be placed at higher elevations on the engineered fill pad constructed on the existing fill (pavement base material) or new embankment fill, as noted in Section 8.2. In such case, the preparation of subgrade will be critical to the performance of the foundation and the rigid/concrete retaining wall. The following geotechnical capacities could be used for a spread footing on the engineered pad founded on properly prepared subgrade (Section 8.4):

Factored Geotechnical Resistance at ULS of 300 kPa

Geotechnical Reaction at SLS of 250 kPa.

The above geotechnical resistance and geotechnical reaction values account for variation in the subgrade materials.

The bearing resistance values are for vertical concentric loads only. Effects of load inclination and eccentricity need to be taken into account as per the CHBDC (2014), Clauses 6.10.3 and 6.10.4.

For footings designed on the basis of the geotechnical resistance and reaction values given above, total settlement under a footing is not expected to exceed 25 mm for the assumed footing width of 3 m.

Differential settlements are not expected to exceed 15 mm. For frost protection purposes, a minimum earth cover of 1.3 m or its thermal equivalent should be provided for all footing bases.

The horizontal resistance against sliding between cast-in-place concrete and the granular fill can be computed using an ultimate friction factor of 0.5.

The subgrade for the footings should be prepared as outlined in Section 8.4, below.

8.4 Subgrade Preparation

Based on the preliminary design drawings, the subgrade below the proposed retaining wall founding grade may consist of the various types of soils along the proposed alignment. At the



north end and extending to Approximate Sta. 9+800, the alignment crosses the original ground/native soils, and then extending to the south, the alignment will intersect paved parking at the adjacent Quality Inn with the south end located in the new Norwich Avenue embankment fill.

Topsoil, asphalt layer, loose fill and any soft/wet materials should be stripped from the footprint of the retaining wall. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. The subgrade under the footprint of the wall and the foundation should be proof rolled to detect and replace any soft/loose areas with compacted granular materials in accordance with OPSS PROV 902. The work should be carried out in the dry.

Once the subgrade is prepared the construction equipment should not travel on the subgrade.

8.5 Recommended Retaining Wall Option

From the foundation perspective, the use of the RSS wall is preferable in light of variable materials at the subgrade level and inherent flexibility of the system. Moreover, the RSS wall typically offers cost effectiveness and relatively rapid construction time in comparing with the cast-in-place concrete retaining wall.

9. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site included shallow embankment fill underlain by a compact to very dense cohesionless till underlain by a cohesive till to the depths investigated in the boreholes. In accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC, the site can be classified as a Seismic Site Class C. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.071g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 9.1 may be used:



Table 9.1 – Earth Pressure Coefficients for Earthquake Loading

| Condition | Earth Pressure Coefficient (K) | |
|------------------------|--|--|
| | OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | OPSS Granular B Type I (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$ |
| Active (K_{AE})* | 0.29 | 0.33 |
| Passive (K_{PE}) | 3.6 | 3.2 |
| At Rest (K_{OE})** | 0.51 | 0.55 |

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

In view of the existing subsurface conditions (compact to very dense cohesionless tills) and low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

10. BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the concrete retaining walls should consist of free-draining, non-frost susceptible granular materials conforming to OPS Granular A or Granular B Type II requirements.

The lateral earth pressures acting on the wall, assuming full drainage from behind the walls, may be computed using the following equation:

$$p = K (\gamma H + q)$$

where:

- p = lateral earth pressure acting at depth H , kPa
- K = earth pressure coefficient
- γ = unit weight of retained soil or backfill, kN/m^3
- H = depth below top of wall where pressure is computed, m
- q = surcharge pressure including traffic loads, kPa

Table 10-1, below, lists the unfactored parameters recommended for design, assuming an essentially level ground surface behind and in front of the walls:



Table 10-1. Earth Pressure Parameters

| Parameter | Retained Material | |
|-------------------------------------|---------------------------------------|------------------------|
| | OPSS Granular A or Granular B Type II | OPSS Granular B Type I |
| Unit Weight, kN/m^3 | 22.8 | 21.2 |
| Friction Angle, degrees | 35 | 32 |
| Active Pressure Coefficient, K_a | 0.27 | 0.31 |
| At-Rest Pressure Coefficient, K_0 | 0.43 | 0.47 |
| Passive Pressure Coefficient, K_p | 3.7 | 3.3 |

If the design includes a sloping ground surface behind or in front of the wall, the earth pressure parameters will require modification. Thurber should be contacted to provide appropriate earth pressure coefficients for a sloping ground conditions.

The earth pressure coefficients in the table above do not include potential compaction effects. In accordance with Clause 6.12.3 of the CHBDC, 2014, 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 at a depth of 1.7 m for Granular A or Granular B Type II.

Wall backfill should be placed in maximum 200 mm loose lifts and compacted to 95% of the material's SPMDD. To avoid imposing excessive lateral stresses, care should be taken not to over-compact adjacent to the walls. As such, hand-operated compaction equipment should be used above a line inclined upwards at 1H:1.5V from the base of the wall (OPSS. PROV 501). In order to achieve the desired density, the backfill material should have a moisture content within 2% of the OMC.

Design of the wall should incorporate measures such as weepholes to permit drainage of the backfill and avoid potential build-up of hydrostatic pressures behind the walls.

11. EXCAVATION AND GROUNDWATER CONTROL

Excavations for the retaining wall construction will be relatively shallow and will extend through the native deposit and the fill material. The excavation and backfilling for the wall construction should be carried out in accordance with OPSS PROV 902.



All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the granular fill and native sand and silt till at this site are classified as Type 3 soils above the water level.

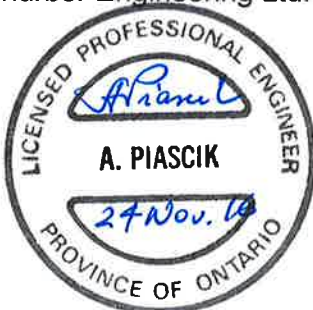
The base of excavation will be located above the groundwater level. Surface runoff and perched groundwater within the fill may seep into the excavations during subgrade preparation. Any water should be diverted from the excavation or pumped from filtered sumps, if required.

The subgrade preparation and retaining wall construction could be carried out in the dry.

12. CLOSURE

Engineering assessment and preparation of this report was 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.

Thurber Engineering Ltd.



Anna Piascik, P.Eng.
Senior Foundations Engineer



Alastair Gorman, P.Eng.
Senior Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



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
 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.

UNIFIED SOILS CLASSIFICATION

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

METRIC

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | |
|---------------|--|------------|---------|------|------------|-------------------------|-----------------|--|----|----|---|--|--|---------------------------------------|---------------------------------------|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | WATER CONTENT (%) | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | |
| 298.3 0.0 | GROUND SURFACE | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 0.0 | ASPHALT: (50mm) | [Pattern] | 1 | SS | 29 | | | | | | | | | | | |
| 297.5 0.8 | Gravelly SAND, trace silt Compact Brown Moist (FILL) | [Pattern] | 2 | SS | 11 | | | | | | | | | | | |
| | SAND and SILT, some clay, trace gravel Compact to Very Dense Brown Moist (TILL) | [Pattern] | 3 | SS | 28 | | | | | | | | | | | |
| | | [Pattern] | 4 | SS | 18 | | | | | | | | | | | |
| | | [Pattern] | 5 | SS | 28 | | | | | | | | | | | |
| | Content of clay decreases below 4.1m | [Pattern] | 6 | SS | 74 | | | | | | | | | | | |
| | | [Pattern] | 7 | SS | 74 | | | | | | | | | | | |
| | | [Pattern] | 8 | SS | 87 | | | | | | | | | | | |
| 290.1 8.2 | END OF BOREHOLE AT 8.2m. WATER LEVEL AT 7.6m IN OPEN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m AND ASPHALT COLD PATCH TO SURFACE. | | | | | | | | | | | | | | | |

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-02

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Overhead Signs/Norwich Ave. N 4 775 367.5 E 204 148.2 ORIGINATED BY TM
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.06.23 - 2016.06.23 CHECKED BY DJP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|-----------------------------------|-------------------|--|---|--|--|---|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 40 60 80 100 | W _P W W _L | WATER CONTENT (%) | | | | | | |
| 298.2 | GROUND SURFACE | | | | | | | | | | | | | | | |
| 0.0 | ASPHALT: (50mm) | | | | | | 298 | | | | | | | | | |
| | Gravelly SAND , trace silt Dense Brown Moist | | 1 | SS | 31 | | | | | | | | | | | |
| 297.4 | (FILL) | | | | | | | | | | | | | | | |
| 0.8 | SAND and SILT , some clay, trace gravel Compact to Very Dense Brown Moist (TILL) | | 2 | SS | 19 | | 297 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | 3 | SS | 20 | | 296 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | 4 | SS | 36 | | 295 | | | | | | | | 5 40 38 17 | |
| | | | | | | | | | | | | | | | | |
| | | | 5 | SS | 33 | | 294 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | 6 | SS | 83 | | 293 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | 7 | SS | 70 | | 292 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 291.0 | Clayey SILT , some sand, trace gravel Hard Grey Moist (TILL) | | | | | | 291 | | | | | | | | | |
| 7.2 | | | 8 | SS | 75 | | | | | | | | | | 0 16 62 22 | |
| 290.0 | | | | | | | | | | | | | | | | |
| 8.2 | END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m AND ASPHALT COLD PATCH TO SURFACE. | | | | | | 290 | | | | | | | | | |

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 11/17/16

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

RECORD OF BOREHOLE No Q1-01

1 OF 2

METRIC

GWP# 3079-09-00 LOCATION Overhead Signs/Norwich Ave. N 4 775 331.5 E 204 130.0 ORIGINATED BY AN
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.06.26 - 2015.06.26 CHECKED BY AMP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|--|--|--|---|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| 298.0 | GROUND SURFACE | | | | | | | | | | | | | |
| 0.0 | ASPHALT:(50mm) | | | | | | | | | | | | | |
| | Gravelly SAND , trace silt Compact Brown Dry to Moist (FILL) | | 1 | GS | | | | | | | | | | |
| 297.2 | | | | | | | | | | | | | | |
| 0.8 | SAND and SILT , some clay, trace gravel Compact to Dense Brown Moist (TILL) | | 1 | SS | 26 | | 297 | | | | | | | 7 39 39 15 |
| | | | | | | | | | | | | | | |
| | | | 2 | SS | 34 | | 296 | | | | | | | |
| | | | | | | | | | | | | | | |
| 295.6 | | | | | | | | | | | | | | |
| | Gravelly SAND , trace silt Very Dense Brown Dry to Moist (TILL) | | 3 | SS | 57 | | 295 | | | | | | | |
| | | | | | | | | | | | | | | |
| 294.6 | | | 4 | SS | 96 | | 294 | | | | | | | 33 58 9 (SI+CL) |
| | | | | | | | | | | | | | | |
| 3.4 | SILT to Sandy SILT , some clay, trace gravel Very Dense Grey Moist (TILL) | | 5 | SS | 84 | | 293 | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 6 | SS | 100 | | 292 | | | | | | | 0 13 69 18 |
| | | | | | | | | | | | | | | |
| | | | | | | | 291 | | | | | | | |
| | | | | | | | | | | | | | | |
| | Auger grinding from 7.6m to 9.4m | | 7 | SS | 100 | | 290 | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | 289 | | | | | | | |
| | | | | | | | | | | | | | | |
| 288.6 | | | 8 | SS | 176/ | | | | | | | | | 3 34 51 12 |
| | | | | | | | | | | | | | | |
| 9.4 | END OF BOREHOLE AT 9.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.04m slotted screen. | | | | 0.250 | | | | | | | | | |

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No Q1-01

2 OF 2

METRIC

GWP# 3079-09-00 LOCATION Overhead Signs/Norwich Ave. N 4 775 331.5 E 204 130.0 ORIGINATED BY AN
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.06.26 - 2015.06.26 CHECKED BY AMP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|--|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | Continued From Previous Page | | | | | | | | | | | | | | | | |
| | WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.07.15 6.1 291.9 | | | | | | | | | | | | | | | | |



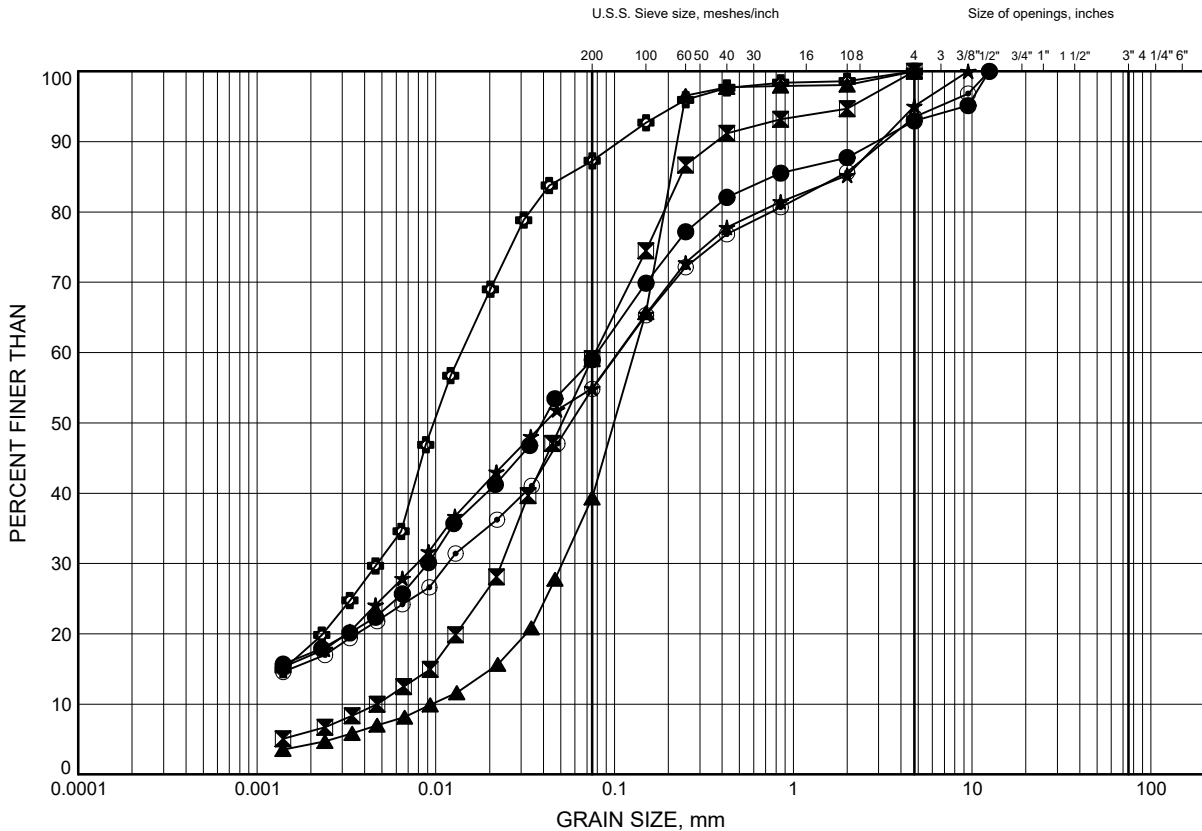
Appendix B

Laboratory Test Results

Overhead Signs/Norwich Ave.
GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND and SILT to Silty SAND TILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 16-01 | 1.07 | 297.23 |
| ⊠ | 16-01 | 4.88 | 293.42 |
| ▲ | 16-01 | 7.92 | 290.38 |
| ★ | 16-02 | 2.59 | 295.61 |
| ⊙ | Q1-01 | 1.07 | 296.93 |
| ⊕ | Q1-01 | 6.40 | 291.60 |

Date November 2016

GWP# 3079-09-00



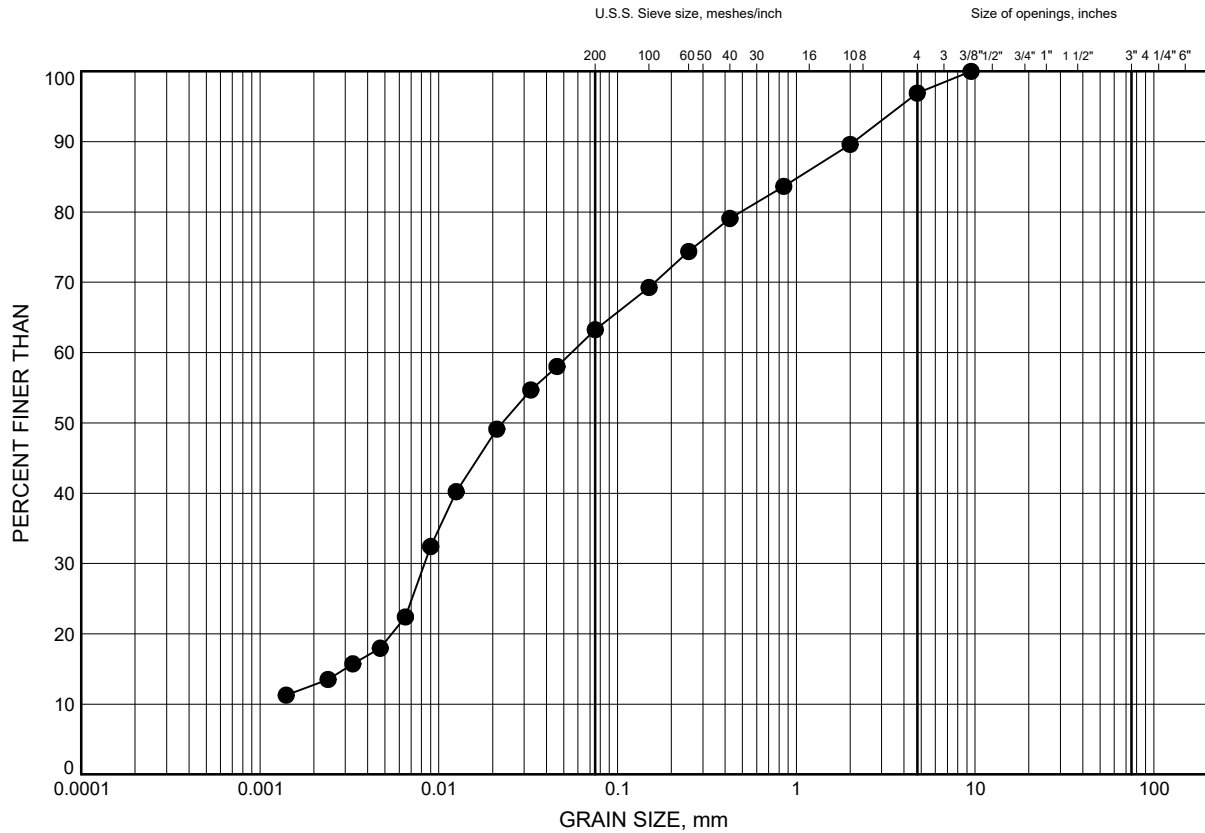
Prep'd AN

Chkd. AMP

Overhead Signs/Norwich Ave.
GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND and SILT to Silty SAND TILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | Q1-01 | 9.28 | 288.72 |

Date November 2016

GWP# 3079-09-00



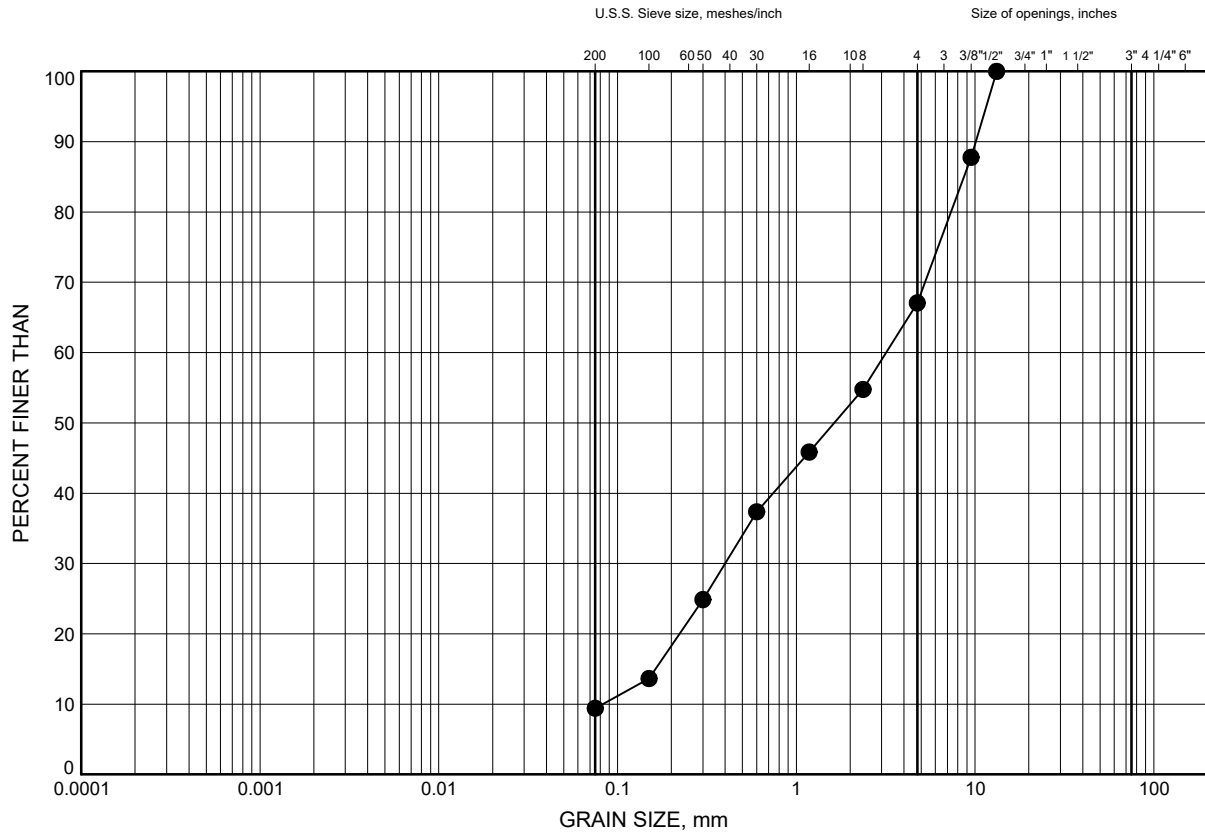
Prep'd AN

Chkd. AMP

Overhead Signs/Norwich Ave.
GRAIN SIZE DISTRIBUTION

FIGURE B3

Gravelly SAND



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | Q1-01 | 3.30 | 294.70 |

Date November 2016
 GWP# 3079-09-00

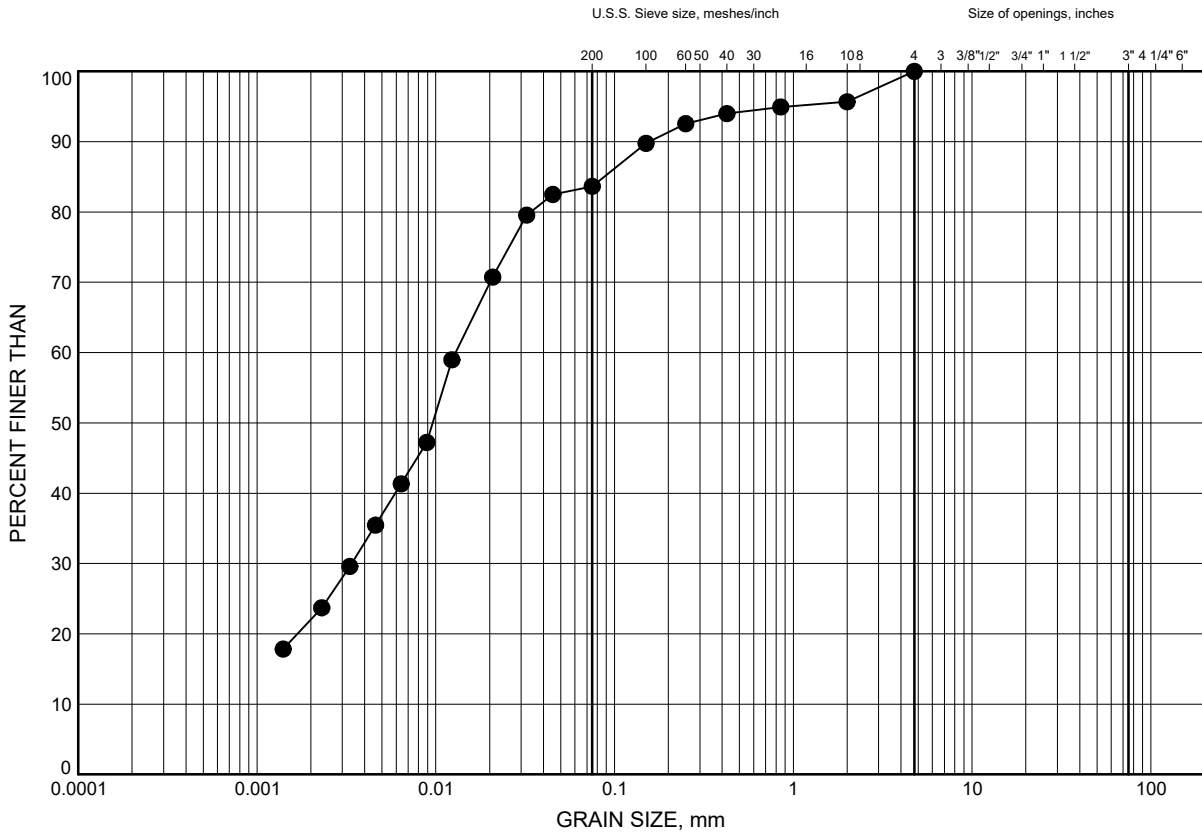


Prep'd AN
 Chkd. AMP

Overhead Signs/Norwich Ave.
GRAIN SIZE DISTRIBUTION

FIGURE B4

Clayey SILT TILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 16-02 | 7.92 | 290.28 |

Date November 2016
 GWP# 3054-13-00

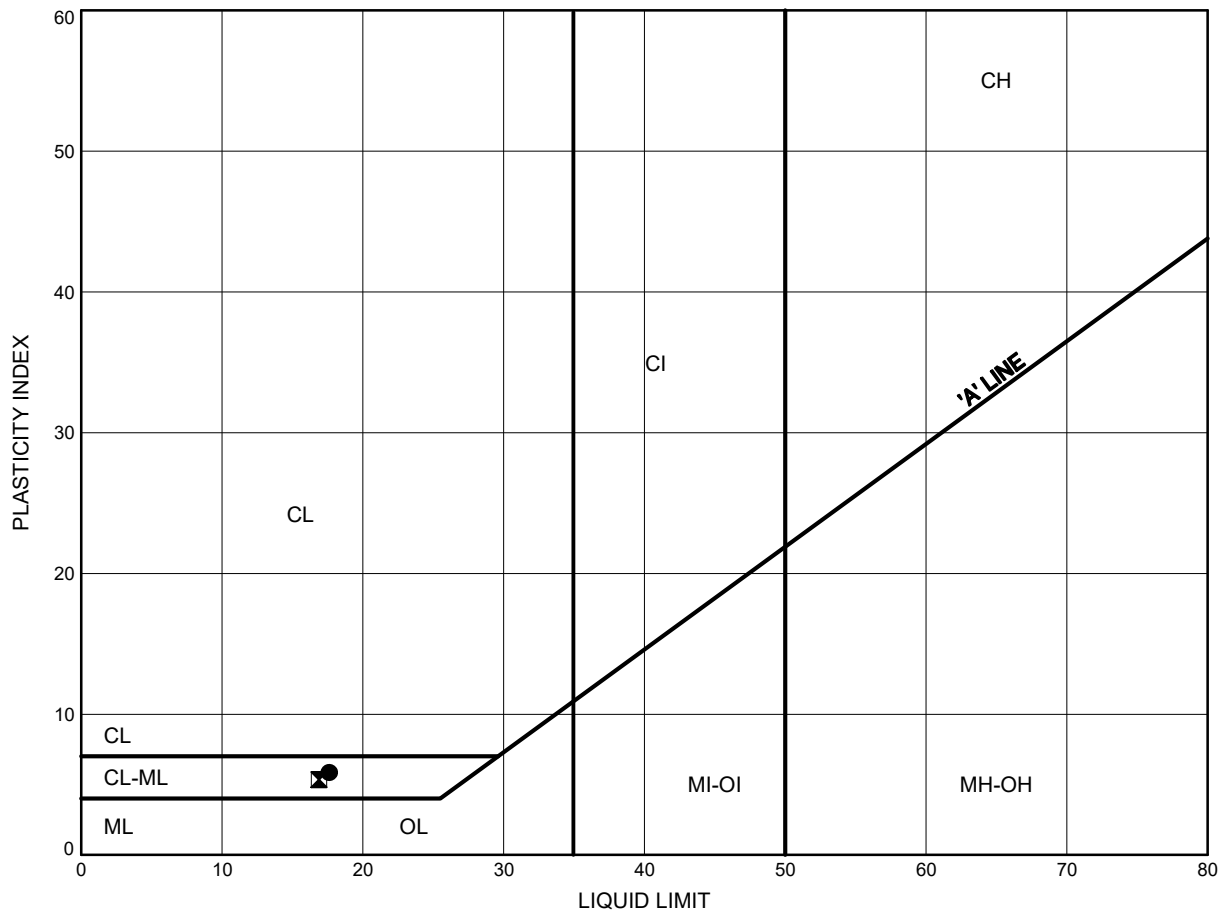


Prep'd AN
 Chkd. AMP

Overhead Signs/Norwich Ave.
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

SAND and SILT TILL



LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 16-01 | 1.07 | 297.23 |
| ⊗ | 16-02 | 2.59 | 295.61 |

Date November 2016
 GWP# 3054-13-00

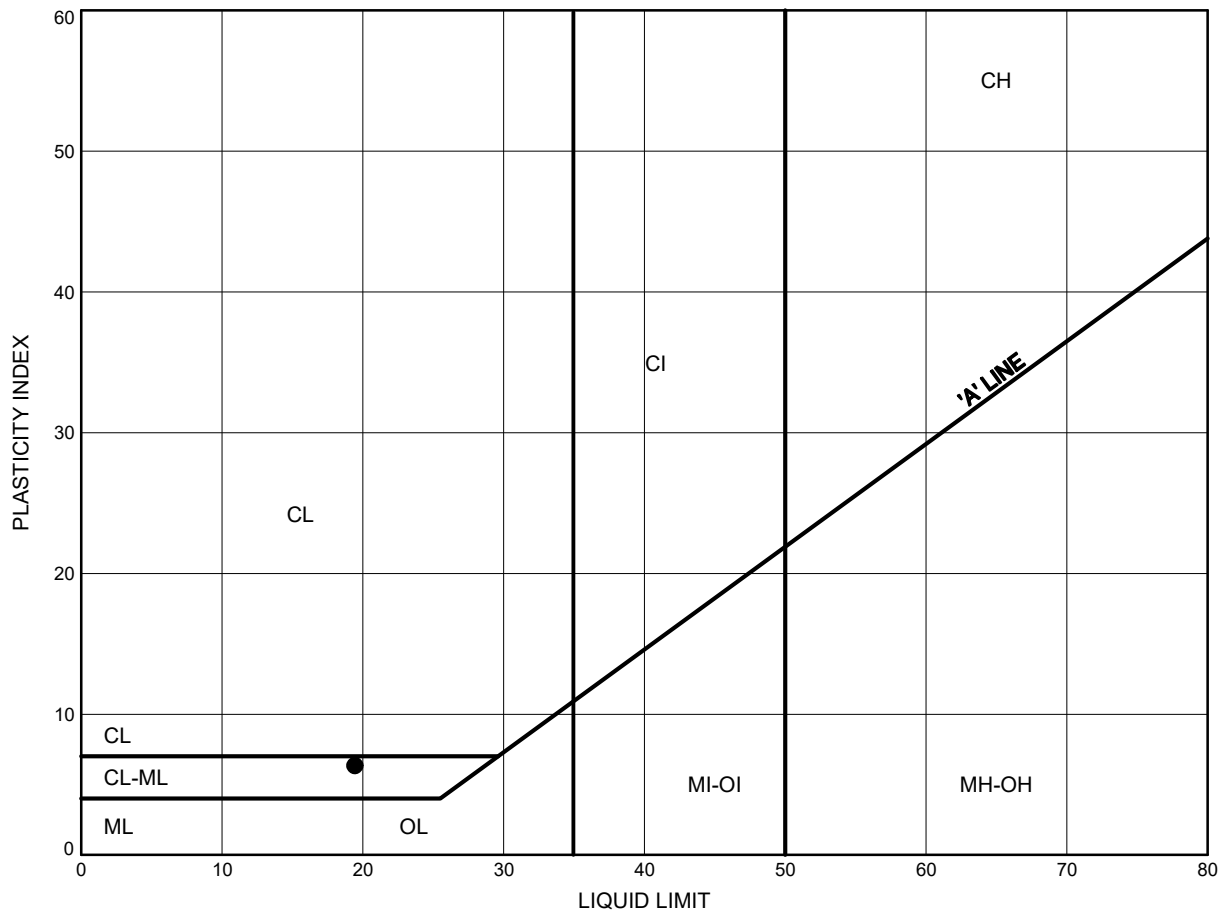


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 Chkd. AMP

Overhead Signs/Norwich Ave.
ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Clayey SILT TILL



LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 16-02 | 7.92 | 290.28 |

Date November 2016
 GWP# 3054-13-00



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Appendix C

Site Photographs



Photograph 1 – Quality Inn Parking Lot, Looking North-West

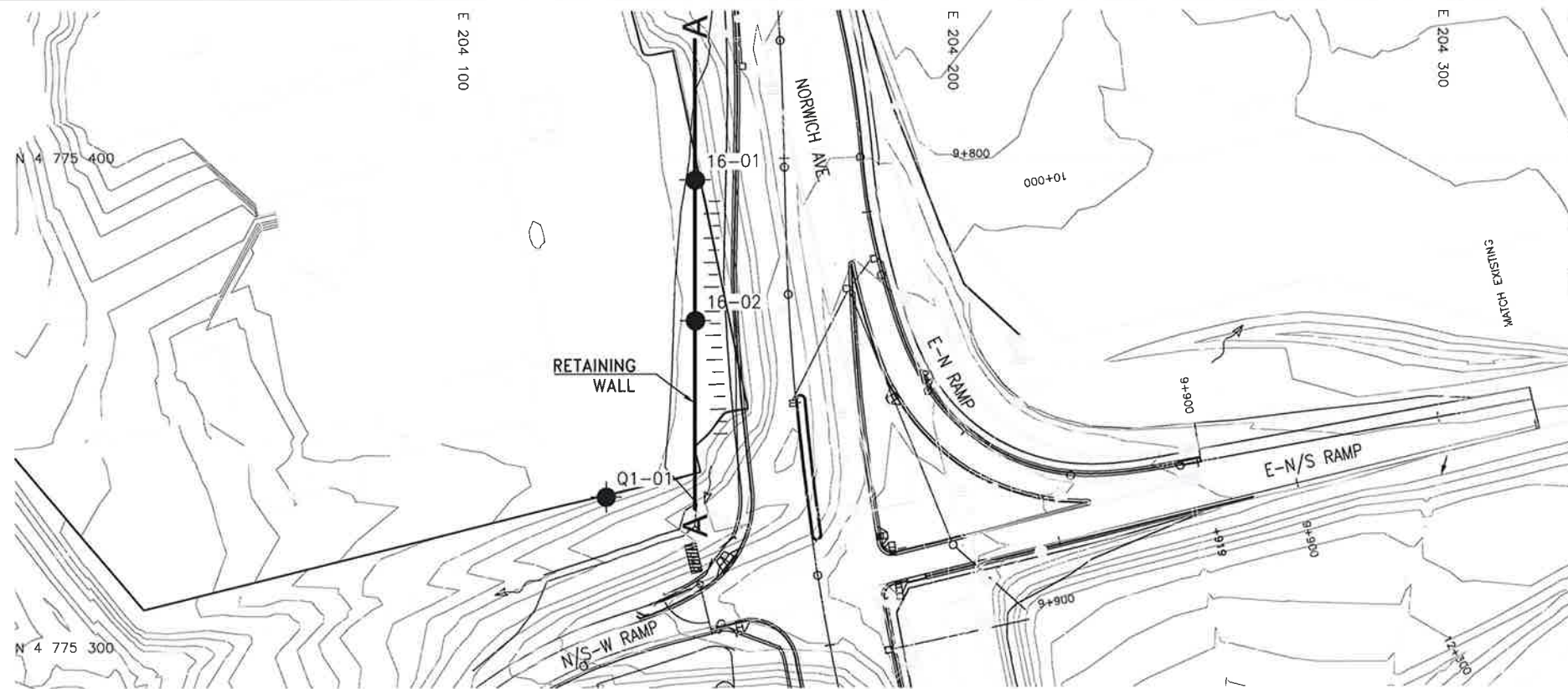


Photograph 2 – Quality Inn Parking Lot Looking South-West

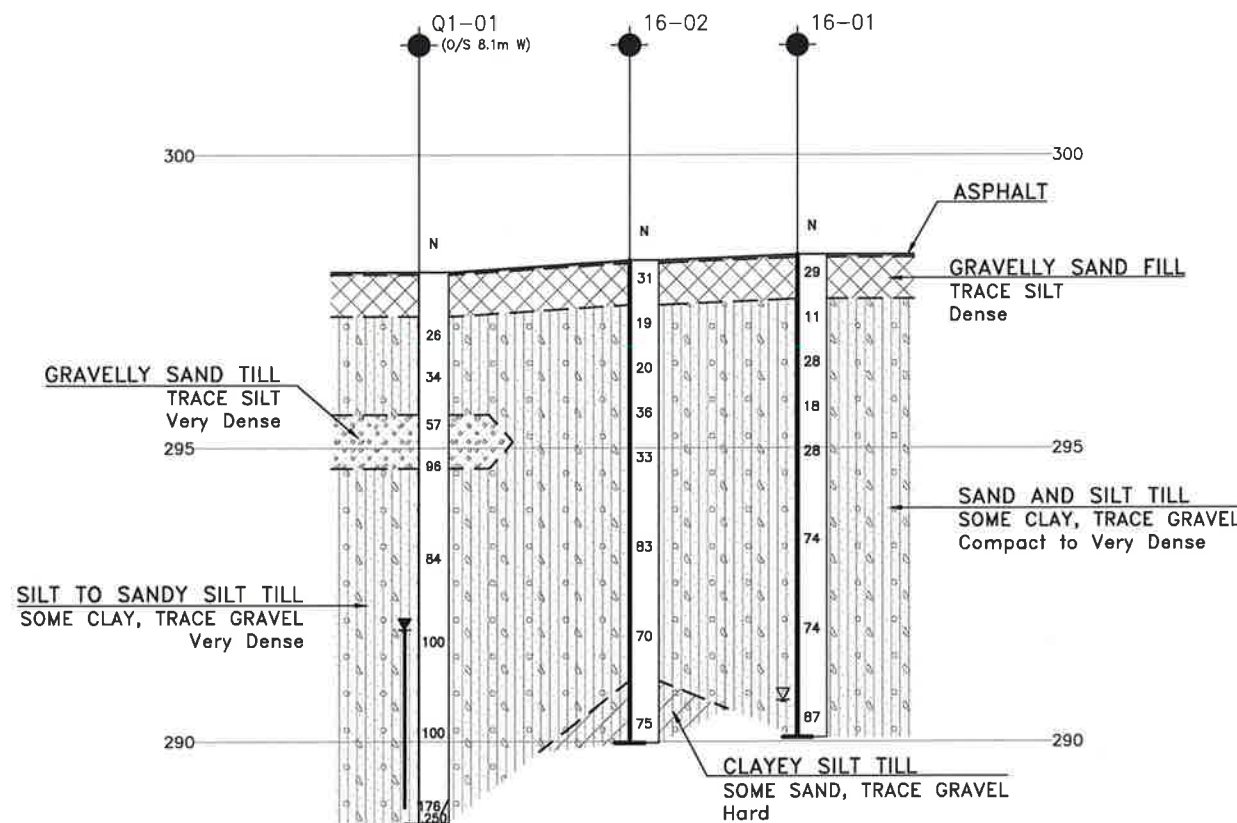


Appendix D

Borehole Locations and Soil Strata Drawing



PLAN
SCALE 1:1250



SECTION ALONG A-A

HOR 1:1250
VER 1:125

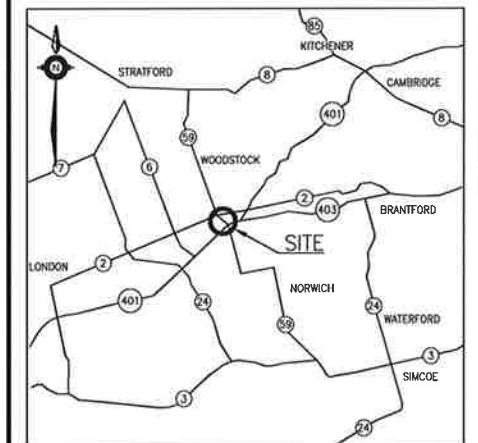
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 3054-13-00

HIGHWAY 401 &
NORWICH AVENUE
RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

MMM GROUP

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 |
|-------|-----------|-------------|-----------|
| 16-01 | 298.4 | 4 775 396.2 | 204 148.1 |
| 16-02 | 298.2 | 4 775 367.5 | 204 148.2 |
| Q1-01 | 298.0 | 4 775 331.5 | 204 130.0 |

-NOTES-

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

GEOCRES No. 40P2-85



| REVISIONS | DATE | BY | DESCRIPTION |
|-----------|------|---------|-------------|
| DESIGN | DJP | CHK AMP | CODE |
| DRAWN | AN | CHK DJP | SITE |
| | | | STRUCT |
| | | | DWG 1 |