THURBER ENGINEERING LTD.

celebrating 60 YEARS

# FOUNDATION INVESTIGATION AND DESIGN REPORT
# REPLACEMENT OF THE HIGHWAY 401 UNDERPASS AT FLAGG ROAD
# UNITED COUNTIES OF STORMONT, DUNDAS AND GLENGARRY
# SITE 31-203, W.P. 4445-02-01
# AGREEMENT NUMBER: 4014-E-0014

**GEOCRES NUMBER: 31B-91**

**SUBMITTED TO**
**WSP CANADA**

**December 2017**
**19-5161-263**

104, 2460 Lancaster Road, Ottawa ON K1B 4S5 T. 613 247 2121 F. 613 247 2185
thurber.ca

# Table of Contents

**APPENDICES**

**FOUNDATION INVESTIGATION AND DESIGN REPORT**
**REPLACEMENT OF THE HIGHWAY 401 UNDERPASS AT FLAGG ROAD**
**UNITED COUNTIES OF STORMONT, DUNDAS AND GLENGARRY**
**SITE 31-203, W.P. 4445-02-01**
**AGREEMENT NUMBER: 4014-E-0014**

**GEOCRES NUMBER: 31B-91**

**PART 1: FACTUAL INFORMATION**

## 1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the Highway 401 underpass structure at Flagg Road located within the United Counties of Stormont, Dundas and Glengarry. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP), under Agreement No. 4014-E-0014.

General Arrangement (GA) drawings and base plan mapping were provided by WSP for the preparation of this report.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

## 2 SITE DESCRIPTION

Site 21-203 is located on Highway 401, approximately 23 km east of the Highway 416 / Highway 401 Interchange near Morrisburg, Ontario. The location of the structure is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

The existing four-span structure is a slab-on-prestressed girder structure carrying two lanes of Flagg Road traffic over Highway 401. Based on the historical contract documents, the bridge is approximately 63.6 m long, and 10.4 m wide. It is noted that for project orientation purposes, Highway 401 will be assumed to be oriented east-west and Flagg Road to be oriented north-south.

Highway 401 at this location has two through lanes in each direction with paved shoulders. The eastbound and westbound lanes are generally separated by a wide, vegetated median ditch, however, a flat, gravel surfaced area is present in the immediate vicinity of the bridge. There are steel beam guide rails located along both the median and outside lanes of the highway in both directions.

Within the project limits Flagg Road has one lane in each direction with a rural cross-section and gravel shoulders. Concrete safety curbs with metal railing system are present at the edge of pavement on the bridge deck. Both steel beam and cable wire guide rail systems are present at the approach embankments in both directions along with concrete gutters.

The site is located within a physiographic region known as the Glengarry till plain which is characterized as lowlands in which the surface is undulating to rolling, consisting of long morainic ridges and a few well-formed drumlins. The till deposit of sand and gravel till is very stony, and contains large near surface boulders (Chapman and Putnam, 1984).

The lands surrounding the project limits are typically agricultural with some residential properties. Storm water drainage in the area is to existing ditches and culverts. The existing approach embankments are up to approximately 6.4 m high with slopes that extend down at approximately 2H:1V (Horizontal:Vertical). The embankment slopes are vegetated with long grasses, trees, and occasional shrubs.

Site photographs showing the structure and approach embankments are presented in Appendix E.

# 3 SITE INVESTIGATION

## 3.1 Previous Investigations

A GEOCRES report is available for this site (Report 31B00-029, 1962). This investigation was carried out for the design and construction of the current structure and included three boreholes. Copies of the borehole location plan and the Record of Boreholes from the historical investigation are provided in Appendix C.

The stratigraphy in the area of the bridge was generally described as compact to very dense clayey silt, sand and gravel till with frequent cobbles and boulders. The boreholes were terminated within till material and bedrock was not encountered during the 1962 geotechnical investigation.

## 3.2 Field Investigation

The field investigation plan was finalized after discussion with the MTO Foundations Section. The field investigation for this site included advancing eight boreholes between August 15, 2016 and August 30, 2016. The approximate locations and elevations of the boreholes are shown on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

**Table 3-1: Borehole Summary**

| Borehole | Location | Latitude (degrees) | Longitude (degrees) | Ground Surface Elevation (m) | Depth (m) |
|---|---|---|---|---|---|
| 801 | South approach | 44.89171 | -75.25862 | 89.6 | 15.8 |
| 802 | South abutment | 44.89182 | -75.25870 | 89.7 | 31.2 |
| 803 | South abutment | 44.89180 | -75.25876 | 89.7 | 27.7 |
| 804 | Centre Pier | 44.89212 | -75.25887 | 83.3 | 22.4 |
| 805 | Centre Pier | 44.89208 | -75.25906 | 83.3 | 25.5 |
| 806 | North abutment | 44.89240 | -75.25917 | 89.7 | 29.3 |
| 807 | North abutment | 44.89237 | -75.25923 | 89.7 | 32.9 |
| 808 | North approach | 44.89248 | -75.25931 | 89.6 | 15.8 |

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to obtain utility locates/clearances for the intended borehole locations.

The boreholes were advanced with a truck-mounted CME75 drill rig equipped with hollow stem augers and NW casing. Casing and rock coring techniques were required to advance past cobbles and boulders within the glacial till deposit.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing. Bedrock was cored following ASTM Standard D6032-08 in Boreholes 802, 805 and 807 with NQ size coring equipment. Bedrock core samples were stored in core boxes for transport.

A 25 mm inside diameter PVC piezometer was installed in Borehole 807 to allow for measurement of the groundwater level at the site. The piezometer construction details are illustrated on the Record of Borehole sheet for Borehole 807, provided in Appendix B. The piezometer was decommissioned on August 30, 2016, after the water level was read.

The boreholes without piezometer installations were backfilled with a low-permeability combination of auger cuttings, and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Boreholes advanced within paved areas were capped with 300 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on August 26, 2016. The vertical datum used was the horizontal control monument (HCM) identified on the plans provided by WSP, located on west wall of the south abutment. The HCM has a geodetic elevation of 89.934 m. The location of the HCM is indicated on Drawing No. 1 in Appendix A.

### 3.3 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. Grain size distribution analyses and Atterberg Limits testing were carried out on selected samples to MTO and ASTM standards.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix D.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on four soil samples. A copy of the chemical analysis results is provided in Appendix D.

## 4 DESCRIPTION OF SUBSURFACE CONDITIONS

### 4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the site is presented on Drawing No. 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy encountered in the boreholes advanced at the site is characterized by an asphaltic surface, overlying embankment fill over glacial till, containing frequent cobbles and boulders, underlain by a limestone bedrock. This stratigraphy is generally consistent with the stratigraphy encountered in the previous MTO investigation.

More detailed descriptions of the individual strata are presented below.

### 4.2 Asphalt

Six boreholes were advanced through the Flagg Road pavement structure. The thickness of the asphalt ranged from 125 mm to 180 mm.

### 4.3 Fill

<u>Silty Sand Fill</u>

A fill layer consisting predominantly of sand and silt with varying amounts of gravel was encountered below the asphalt surface in the embankment boreholes and at the ground surface of Boreholes 804 and 805. The top of this layer ranges from Elevation 89.5 m to 83.3 m. The thickness of this layer ranged from 0.8 m to 2.8 m. The SPT ‘N’ values ranged from 7 to 53 indicating a loose to very dense condition, but typically compact.

The moisture content of the samples tested ranged from 3% to 16%. The results of grain size analysis conducted on two samples of this material are summarized in Table 4-1 and are illustrated on Figure 1 in Appendix D.

**Table 4-1: Gradation Results for Granular Fill**

| Soil Particles | % |
|---|---|
| Gravel | 0 and 1 |
| Sand | 88 and 90 |
| Silt and Clay | 10 and 11 |

<u>Embankment Fill</u>

An embankment fill layer consisting predominantly of sandy silt to silty sand with gravel was encountered beneath the pavement structure layer. The top of this layer ranges from Elevation 88.4 m to 86.7 m. The thickness of this layer ranged from 4.6 m to 7.0 m. The SPT ‘N’ values ranged from 5 to 97 indicating a loose to very dense condition, but typically compact to dense.

The moisture content of the samples tested ranged from 3% to 18%. The results of grain size analysis conducted on samples this material are summarized in Table 4-2 and are illustrated on Figures 2 and 3 in Appendix D.

**Table 4-2: Gradation Results for Embankment Fill**

| Soil Particles | % |
|---|---|
| Gravel | 8 to 17 |
| Sand | 25 to 47 |
| Silt and Clay | 41 to 67 |

## 4.4 Glacial Till

A glacial till deposit consisting of a heterogeneous mixture of clay, silt, sand, gravel, cobbles and boulders was encountered beneath the fill materials in all boreholes advanced at the site. The till is classified as a silty sand to silty clayey sand with gravel.

The top of this layer ranges from Elevation 82.9 m to 81.0 m. The thickness of this layer where completely penetrated ranged from 19.1 m to 22.5 m. The SPT 'N' values ranged from 6 to greater than 100 indicating a loose to very dense condition, but typically dense. Frequent cobbles and boulders were noted in all boreholes. Coring techniques were required to penetrate through the cobbles and boulders at many locations; these locations are indicated on the borehole logs.

The moisture content of the samples tested ranged from 7% to 17%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-3 and are illustrated on Figures 4 through 9 in Appendix D.

**Table 4-3: Gradation Results for Glacial Till**

| Soil Particles | % |
|---|---|
| Gravel | 1 to 35 |
| Sand | 9 to 42 |
| Silt | 20 to 81 |
| Clay | 7 to 22 |

The results of Atterberg Limits testing completed on samples of this material are summarized in Table 4-4 and are illustrated on Figures 10 to 14 in Appendix D. Based on the results of Atterberg Limits testing the fines content is classified as silty clay (CL-ML).

**Table 4-4: Atterberg Limits Test Results**

| | |
|---|---|
| Plastic Limit | 13 to 19 |
| Liquid Limit | 9 to 15 |
| Plasticity Index | 2 to 8 |

## 4.5 Bedrock

Limestone bedrock was encountered beneath the glacial in Boreholes 802, 805 and 807 which were advanced into the bedrock by coring (NQ size). The bedrock surface ranges from Elevation 60.3 m to 61.9 m.

**Table 4-5: Top of Bedrock Elevation**

| Location | Borehole | Ground Surface Elevation (m) | Depth Below Existing Grade (m) | Top of Bedrock Elevation (m) |
|---|---|---|---|---|
| South Abutment | 802 | 89.7 | 27.8 | 61.9* |
| | 803 | 89.7 | 27.7 | 62.0** |
| Centre Pier | 804 | 83.3 | 22.4 | 60.9** |
| | 805 | 83.3 | 22.4 | 60.9* |
| North Abutment | 806 | 89.7 | 29.3 | 60.4** |
| | 807 | 89.7 | 29.4 | 60.3* |

* Bedrock surface proven by coring
** Inferred Bedrock

The total core recovery ranged from 88% to 100%, the solid core recovery ranged from 71% to 100% and the Rock Quality Designation ranged from 37% to 95%. Based on the RQD value the bedrock is classified as poor to excellent quality; but typically fair quality.

### 4.6 Groundwater Conditions

The groundwater level in the piezometer installed in Borehole 807 was recorded on August 30, 2016, at a depth of 11.3 m; corresponding to Elevation 78.4 m.

Water was observed at a depth of 15.3 m (elev. 74.3 m) in Borehole 801 while the borehole was open, immediately following drilling; this observation is not indicative of the groundwater level as insufficient time had passed for the water level to stabilize in the open borehole.

The reported groundwater observations are considered 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 the spring snowmelt or after periods of heavy rainfall.

## 5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by WSP Canada. Downing George Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Mr. Christopher Murray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.


Kenton C. Power, M.A.Sc., P.Eng.
Geotechnical Engineer


Paul Carnaffan, M.Eng. P.Eng.
Principal, Senior Geotechnical Engineer


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

**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF THE HIGHWAY 401 UNDERPASS AT FLAGG ROAD
UNITED COUNTIES OF STORMONT, DUNDAS AND GLENGARRY
SITE 31-203, W.P. 4445-02-01
AGREEMENT NUMBER: 4014-E-0014**

**GEOCRES NUMBER: 31B-91**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

# 6 GENERAL

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber for the replacement of the Highway 401 underpass structure at Flagg Road in the United Counties of Stormont, Dundas and Glengarry, Ontario. Geotechnical recommendations are provided to assist the design team in designing a suitable foundation for the proposed bridge replacement.

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

The following sections address geotechnical recommendations for the replacement of the existing underpass structure. The discussions and recommendations presented in this report are based on the information provided by WSP and on the factual data obtained during the course of this investigation.

## 6.1 Proposed Structure

It is understood that replacement of the bridge structure will be on the existing alignment with a full closure of Flagg Road with a detour route.

Based on the GA drawing provided by WSP, details regarding the proposed structure include:

- The bridge is to be replaced with a two-span structure;
- The overall structure length is 75 m; and
- The bridge deck will have an approximate width of 10.5 m to accommodate two lanes, shoulders and concrete barrier walls with railings.

Based on the preliminary span configuration, and Highway 401 clearance requirements, the vertical profile for Flagg Road will be raised by approximately 0.7 m and 0.8 m at the north and south abutments, respectively. The proposed grade raise increases to approximately 1.3 m above the existing elevation approximately 100 m south of the south abutment then decreases to tie into the existing grades. The maximum grade raise at the north side is at the abutment and gradually decreases to tie into the existing grades.

## 6.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code, version CSA S6-14 (CHBDC).

In accordance with CHBDC, the analysis and design of structures takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

It is understood that MTO has designated this structure as follows:

**Table 6-1: Bridge Structure Classification**

| Criteria | Classification | CHBDC Section |
|---|---|---|
| Importance Category | Major Route Bridge | 4.4.2 |
| Consequence Classification | Typical Consequence | 6.5.1 |

Accordingly, a consequence factor ($\Psi$) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

The frost penetration depth at this site is 1.6 m as per OPSD 3090.101.

## 6.3 Geotechnical Assessment

Based on the results of the field and laboratory investigation and the information provided by WSP with regards to the proposed project requirements, the geotechnical foundation design considerations include:

- The native glacial till deposit is capable of supporting shallow foundations with moderate to high bearing resistance. Existing fill would have to be removed to place the shallow foundations on native undisturbed dense to very dense glacial till.
- From a geotechnical perspective, the subsurface conditions at the site are generally suitable for integral or semi-integral abutments perched within the approach fills;
- The glacial till deposit is approximately 20 m thick and includes frequent cobbles and boulders. Pre-auguring would be required in order to advance steel H-piles through the till layer to reach the design pile tip elevation and to avoid reaching refusal on obstructions at too shallow a depth.
- The use of down-the-hole hammer drilled in pipe piles could also be considered at this site as they are well suited for penetrating through boulders.
- The existing bridge abutments are supported on steel pipe piles. The potential for interference between existing and new piles should be checked. Existing piles should be cut below the grade of new structures and abandoned in place by filling the pipe piles with concrete. Full removal of the existing piles should be avoided as it may disturb the surrounding soil.
- The soil beneath the base of the approach embankments consists of glacial till; embankment settlement and global stability are not expected to be concerns for the proposed embankment grade raise.

# 7 SEISMIC CONSIDERATIONS

## 7.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values (Sa(T)) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix G.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA).

## 7.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy.

Based on the soil and bedrock conditions encountered below the anticipated bridge foundation elevation, the site is classified as a Seismic Site Class D in accordance with Table 4.1 of the CHBDC.

## 7.3 Seismic Liquefaction

The soils beneath the anticipated founding elevation consist of compact to very dense glacial till deposits, which are not considered susceptible to liquefaction under earthquake loading using the site-specific PGA value of 0.346g.

# 8 STRUCTURE FOUNDATIONS

The results of the field and laboratory investigation and historical data indicate that the embankment fill is underlain by glacial till deposits overlying a limestone bedrock.

Key elevations (approximate) are as follows:

- Existing ground surface at the piers — 83.3 m
- Existing ground surface at the abutments — 89.7 m
- Top of glacial till deposit at the pier (Boreholes 804 and 805) — 81.0 m
- Top of glacial till deposit at the abutments — 81.0 m to 82.9 m
- Top of bedrock where cored (Boreholes 802, 805 and 807) — 60.3 m to 61.9 m

The glacial till deposit predominantly consists of sand and silt with varying amounts of gravel and clay and includes frequent cobbles and boulders.

Based on the soil stratigraphy and anticipated loading, deep foundations will be required to support the perched abutments in the existing embankments fills at this site.

It is understood that the two-span structure would result in loads at the proposed centre pier of approximately 500 kPa at ULS and 325 kPa at SLS, based on a 5.0 m by 11.5 m footing, and that both shallow and deep foundations are being considered.

Given the soil stratigraphy encountered and the requirements of the proposed structure provided by WSP, the following foundation alternatives were considered for the new bridge foundations:

- Driven Steel Pipe Piles
- Micro-Piles
- Driven Steel H-Piles with an Integral Abutment Configuration
- Driven Steel H-Piles with a semi-integral Abutment Configuration
- Augered Concrete Caissons (drilled shaft piles)
- Spread Footings
- Drilled-in Pipe Piles (down-the-hole hammer)

These foundation alternatives have been evaluated from a geotechnical perspective in terms of their respective advantages, disadvantages, risks and consequences. The evaluation is summarized in the tables provided in Appendix F.

### 8.1 Recommended Foundation

Based on the proposed structure geometry and evaluation of foundation alternative presented above and in Appendix F, the recommended foundation approach from a geotechnical perspective is to support the pier on a spread footing founded on native compact to dense glacial till and to support the abutments on drilled in steel pipe piles socketed into the bedrock.

## 9 FOUNDATION DESIGN RECOMMENDATIONS

### 9.1 Drilled-in Pipe/Tube Piles

The abutments may be founded on steel HSS pipe piles end-bearing in bedrock and installed using a down-the-hole hammer to penetrate through the overburden and socketed a minimum of 0.5 m into sound bedrock. The estimated pile tip elevations are summarized in Table 9-1.

**Table 9-1: Estimated Pile Tip Elevations**

| Foundation Element | Underside of Pile Cap Elevation (m) | Estimated Pile Tip Elevation (m) | Estimated Pile Length (m) |
|---|---|---|---|
| North Abutment | 85.5 | 59.8 | 25.7 |
| South Abutment | 85.5 | 61.4 | 24.1 |

Drilled pipe/tube piles must be installed in accordance with OPSS.PROV 903. As per Section 903.07.03.01 the contract documents should indicate that the piles should be advanced into bedrock with a socket length of 0.5 m.

The potential for conflict with the existing steel piles must be checked. Suggested wording for an NSSP to alert the contractor to the potential conflict with existing piles is provided in Appendix I.

### 9.1.1 Axial Compression

Steel piles (Grade 350W steel) at this site may be designed on the basis of the following factored geotechnical resistances for axial compression:

| Pile Size | End Bearing Material | Bedrock Socket Length (m) | Factored Geotechnical Resistance (Axial Compression (kN)) | |
|---|---|---|---|---|
| | | | ULS | SLS |
| | | | Static ($\phi_{gu}$=0.4) | Static ($\phi_{gs}$=0.8) |
| **HSS 356 x 16** | Bedrock | 0.5 | 2,250 | N/A (1) |

NOTES:

1. The SLS condition will not govern for piles end-bearing in or on the bedrock.

The factored geotechnical resistances include the following factors:

- Consequence factor ($\Psi$) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - $\phi_{gu}$ = 0.4 (static analysis; typical degree of understanding)
  - $\phi_{gu}$ = 1.0 (seismic analysis targeting life safety and capacity design (plastic mechanism) checks)
  - $\phi_{gs}$ = 0.8 (static analysis; typical degree of understanding)

Since the piles will be augered through compact to dense glacial till, downdrag on new piles is not considered a design issue.

### 9.1.2 Foundation Lateral Response

The lateral soil response of the contemplated pipe piles was evaluated using the software program LPILE Plus 9.0 published by Ensoft Ltd. The lateral soil response for single piles is presented as p-y data in tables provided in Appendix G. The depths shown in the tables are the depths below top of pile/underside of pile cap set as approximate Elevation 85.5 m. Depending on the pile spacing and the direction of the load, the lateral pile response could be influenced by group interaction effects. Accordingly, we recommend applying p-multipliers (i.e. soil spring reduction factors) following the procedure described in Section C6.11.3 of the CAN-CSA-S6-14 Bridge Code Commentary.

The lateral soil response will be used by the structural designers to ensure an overall response compatible with integral abutments. The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. If required to provide the required flexibility, the upper 3 m of the piles could be surrounded by a 600 mm diameter column of loose sand as specified by the integral abutment design requirements. A 600 mm diameter CSP may be used to contain the sand. An NSSP outlining the gradation requirements for the sand backfill to be used in the CSP has been provided in Appendix I.

The lateral soil response of the abutment endwalls to longitudinal loading was evaluated using the finite element software program Plaxis 2D. PLAXIS 2D is an advanced finite element modelling program that can incorporate soil with varying stiffness and elastic-plastic response along with structural elements such as plates and beams to represent walls and piles.

The result from the Plaxis analysis are provided as equivalent soil springs in the table below:

| Abutment Displacement (m) | Longitudinal Stiffness (kN/mm per metre wall width) Flagg Road Bridge |
|---|---|
| | North & South Abutments |
| 0.005 | 134 |
| 0.01 | 96 |
| 0.02 | 71 |
| 0.05 | 38 |
| 0.10 | 22 |

For structural modelling, the springs should be located two-thirds of the wall height from the top of the endwalls.

## 9.2 Shallow Foundations

Pier foundations with a width of between 4 m and 5.5 m, with a minimum embedment of 1.6 m, and founded on undisturbed native dense to very dense glacial till at or below Elevation 80.9 m, may be designed based on the following factored geotechnical resistances:

- Factored geotechnical resistance at ULS 600 kPa
- Factored geotechnical resistance at SLS 400 kPa

The base of the footing must be below the depth of frost. The glacial till will be easily disturbed when saturated and should be protected with a concrete mud slab promptly after excavation and inspection.

The factored geotechnical resistance at SLS corresponds to total footing settlement of 25 mm.

The factored geotechnical resistances include the following factors:

- Consequence factor ($\Psi$) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
    - $\phi_{gu}$ = 0.5 (static analysis; typical degree of understanding)
    - $\phi_{gs}$ = 0.8 (static analysis; typical degree of understanding)

The geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4. In addition, the geotechnical resistances assume that the footings are constructed on horizontal ground.

Resistance to lateral forces through sliding resistance between concrete and native till deposits should be evaluated using an unfactored coefficient of 0.50 for cast-in-place concrete and 0.45 for pre-cast concrete.

## 9.3 Frost Protection

The frost penetration depth at this site is 1.6 m as per OPSD 3090.101. Accordingly, a minimum of 1.6 m of earth cover, or equivalent insulation, must be provided above the base of the pile caps and shallow foundations to serve as frost protection.

## 9.4 Earth Retaining Structures

The lateral earth pressure parameters provided in Table 9-2 and 9-3 in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

### 9.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures 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 (kPa)
K = earth pressure coefficient
$\gamma$ = unit weight of retained soil (kN/m$^3$)
h = depth below top of fill where pressure is computed (m)
q = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design for a horizontal back-slope are provided in Table 9-2.

**Table 9-2: Static Lateral Earth Pressure Coefficient**

| Parameter | OPSS Granular A & B Type II | Glacial Till | Existing Granular Fill |
|---|---|---|---|
| Soil Unit Weight, kN/m$^3$, $\gamma$ | 21.0 | 21.0 | 20.0 |
| Angle of Internal Friction, $\phi$ | 35° | 35° | 30° |
| Coefficient of at Rest Earth Pressure, $K_o$ (Restrained Wall) | 0.43 | 0.43 | 0.50 |
| Coefficient of Active Earth Pressure, $K_a$ (Unrestrained Wall) | 0.27 | 0.27 | 0.33 |

For rigid structures it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls.

For static analysis, passive earth resistance should be ignored, and therefore passive earth pressure parameters have not been provided. A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

### 9.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- $k_h$ = ½ F(PGA)•PGA for structures that allow for 25 mm to 50 mm of movement, and
- $k_h$ = F(PGA)•PGA for non-yielding walls

The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002 for a yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The recommended seismic lateral earth pressure parameters for use in the design that are provided in Table 9-3 assume the following:

- Horizontal back-slope behind the wall
- Seismic Site Class of D, and a PGA with a 2% probability of exceedance in 50 years of 0.346g; as outlined in Section 7.0

**Table 9-3: Lateral Earth Pressure (Under Seismic Loads)**

| Parameter | OPSS Granular A & B Type II | Glacial Till | Existing Granular Fill |
|---|---|---|---|
| Soil Unit Weight, kN/m³, $\gamma$ | 21.0 | 21.0 | 20.0 |
| Angle of Internal Friction, $\phi$ | 35° | 35° | 30° |
| **Non-Yielding Wall** | | | |
| Dynamic Active Earth Pressure Coefficient, $K_{AE}$ | 0.51 | 0.51 | 0.61 |
| **Yielding Wall** | | | |
| Dynamic Active Earth Pressure Coefficient, $K_{AE}$ | 0.37 | 0.37 | 0.45 |

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soil profile:

$$\sigma_h = K\gamma d + (K_{AE} - K)\,\gamma\,(H - d)$$

where:

$\sigma_h$ = lateral earth pressure at depth, d (kPa)
d = depth below the top of the wall (m)
K = static earth pressure coefficient
($K_a$ for yielding walls, $K_o$ for non-yielding walls)
$\gamma$ = unit weight of the backfill soil (kN/m³)
$K_{AE}$ = combined static and seismic earth pressure coefficient
H = total height of the wall (m)

## 9.5 Approach Embankments

The existing approach embankments are up to approximately 6.4 m high with slopes that extend down at approximately 2H:1V.

The proposed profile and bridge spans require a maximum grade raise of 0.7 m and 0.8 m at the north and south approach embankments respectively. The proposed grade raise across the south approach increases to approximately 1.3 m above the existing grade approximately 100 m south of the south abutment then decreases to tie into the existing grades further to the south. On the north approach, the maximum grade raise occurs at the abutment and then decreases to tie into the existing grades. The proposed grade raise would also result in a widening of the approach embankments in order to maintain the platform width at the top and the existing embankment side slope geometry.

Embankment widening and grade raise construction up to the pavement subgrade level should be carried out in accordance with OPSS.PROV 206. The geometry should match the adjacent slope geometry. The new embankment material should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B (Type I, II or III).

Granular fill should be placed and compacted in accordance with OPSS.PROV 501.

### 9.5.1 Assessment of Settlement

An assessment of the settlement that would result from construction of the proposed grade raise using conventional granular fill with 2H:1V side slopes was carried out using Rocscience's Settle$^{3D}$ modelling software.

Based on settlement analysis, if the proposed grade raise is constructed as outlined above using conventional granular fill, the predicted settlement is less than 20 mm and is considered to be immediate. The predicted settlement values reflect both the maximum embankment height after the grade raise as well as the aerial distribution of fill and fill height.

The estimated settlement of the approach embankments behind the abutments is within the MTO Guidelines for post construction settlement over a period of 20 years after paving as outlined below:

- 25 mm within 20 m behind bridge abutment;
- 50 mm from 20 to 50 m from the bridge abutment; and
- 100 mm for greater than 50 m from the bridge abutment.

### 9.5.2 Assessment of Global Stability

The global stability for the proposed grade raise constructed using conventional granular fill with 2H:1V side slopes was evaluated using GeoStudio 2012 Slope/W software for limit equilibrium analysis. Input parameters for undrained analysis are based on the in-situ SPT 'N' values. The following additional parameters were used in the analysis:

- A traffic surcharge load as per Section 6.12.5 of the CHBDC
- A seismic horizontal loading of 0.167, equal to ½ of the site adjusted PGA value (0.333g) was used for seismic analysis
- Existing embankment side slope geometry (2H:1V)

**Table 9-4: Global Stability Analysis Results**

| Location | Factory of Safety | |
|---|---|---|
| | Static Conditions | Seismic Conditions |
| North Abutment | 1.5 | 1.1 |
| South Abutment | 1.5 | 1.1 |

The factor of safety does meet the target value of 1.5 and 1.0 under static and seismic conditions respectively.

### 9.6 Cement Type and Corrosion Potential

Four soil samples were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations to buried infrastructure. The analysis results are summarized in the Table 9-5. A copy of the test results is provided in Appendix D.

**Table 9-5: Results of Chemical Analysis**

| Borehole | Sample | Depth (m) | pH | Resistivity (Ohm-m) | Chloride (µg/g) | Sulphate (µg/g) |
|---|---|---|---|---|---|---|
| 801 | SS3 | 1.8 | 8.1 | 7.4 | 71 | 1500 |
| 803 | SS5 | 3.4 | 8.0 | 18.0 | 28 | 470 |
| 805 | SS3 | 1.8 | 8.0 | 23.2 | 136 | 21 |
| 808 | SS6 | 4.1 | 8.0 | 12.3 | 147 | 541 |

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The sulphate results in Table 9-5 were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low to moderate degree of sulphate attack potential on concrete structures at this site. Accordingly, a S-3 exposure class should be specified for concrete in below grade applications.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results indicate a moderately corrosive environment.

## 10 CONSTRUCTION CONSIDERATIONS

### 10.1 Excavations

It is anticipated that temporary excavations in the order of 2.5 m will be required for the construction of the piers and abutments.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The soil at the site should be classified as Type 3 in accordance with OHSA.

Subgrade preparation and construction of foundations must be carried out in the dry.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. As cobbles and boulders were observed in the boreholes a NSSP alerting bidders to their presence has been provided in Appendix I.

### 10.2 Temporary Protection Systems

If required, temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2.

The design of temporary protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. Lateral earth pressure coefficients for the use in the design are provided in Table 9.2. The designer of the roadway protection system must ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations and shall consider the slope of temporary embankments above the top of the protection system.

Increased difficulty with the installation of protection systems should be anticipated due to the presence of cobbles and boulders within the native glacial till. Sheet piles systems are not considered suitable within the glacial till deposit. One option is to use driven or drilled in soldier piles and timber lagging with the piles installed in holes predrilled through and set in the till.

### 10.3 Dewatering

All excavations for foundations must be dewatered prior to the placement of concrete, as per OPSS 902.

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit construction in a dry and stable excavation. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill and, surface runoff will tend to seep into, and accumulate in proposed excavations.

Dewatering design and decisions regarding dewatering, must be carried out by the Contractor. The groundwater level at the pier foundation should be lowered to 0.5 m below the final excavation level. Due to the shallow excavation depths being considered and the depth to groundwater at the site it is anticipated that conventional sump and pump techniques should be sufficient.

The design of any dewatering system that may be required must be the responsibility of the Contractor. The Contract Documents must alert them to this responsibility and the need to engage a dewatering specialist to design the system in accordance with OPSS.PROV 517 and MTO Special Provision No. 517F01 Amendment to OPSS.PROV 517, November 2016.

The Temporary Flow Passage System Designer Fill-ins for SP No. 517F01 do not apply for this site.

The Dewatering Systems Designer Fill-in information for SP No. 517F01 are as follows:

| | |
|---|---|
| * | 44.89212, -75.25887 |
| ** | Site 31-203 - Highway 401 Underpass at Flagg Road |
| ***** | No |
| ****** | N/A |

### 10.4 Erosion Protection

Erosion and sediment control should be provided throughout the project duration in accordance with OPSS 805. Vegetation should be re-established on disturbed slopes as soon as possible following construction.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

### 10.5 CONSTRUCTION CONCERNS

The planned construction methodology includes excavations for shallow foundations, abutments and the installation of deep foundations.

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

- Confirmation that the backfill is adequately placed and compacted to specifications.
- Boulders may be encountered in the glacial till subgrade surface at the founding elevation and may require localized sub-excavation and replacement.

The successful performance of the construction of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

## 11 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.


Kenton C. Power, P.Eng.
Geotechnical Engineer

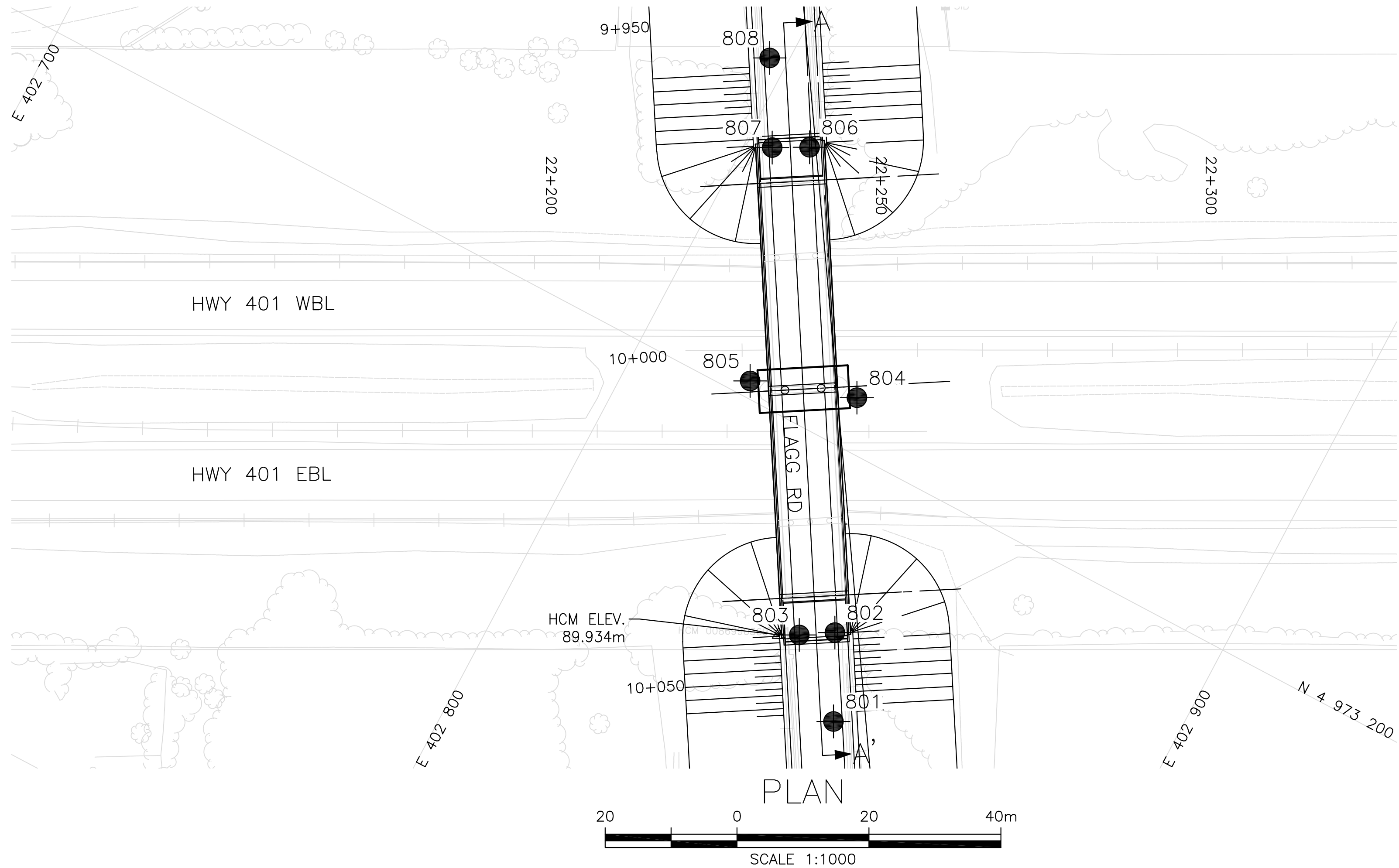

Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer


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

# APPENDIX A

## BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS – 2016 INVESTIGATION

MINISTRY OF TRANSPORTATION, ONTARIO



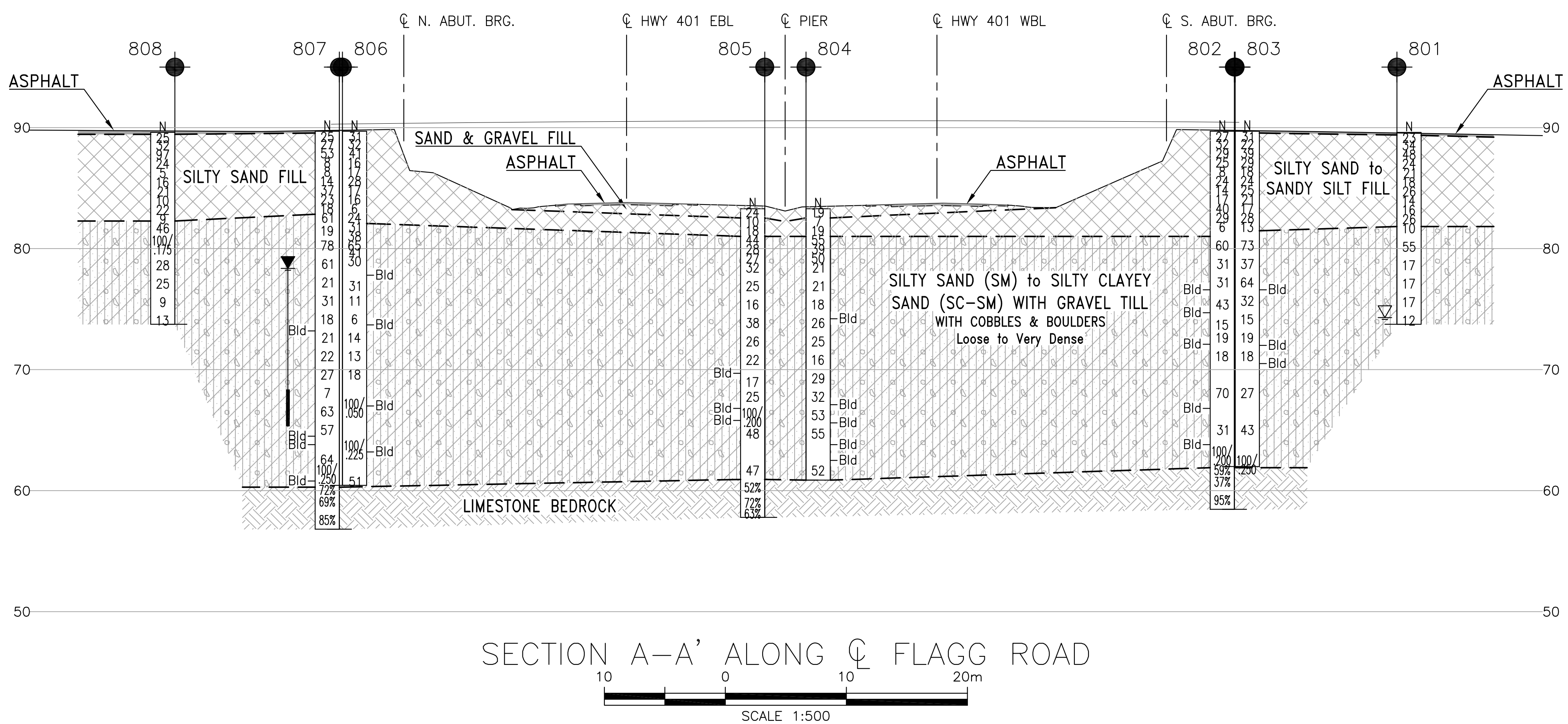

PLAN

# METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
P. N. CHATTERJI
Nov 8/17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
K.T.C. POWER
100130652
2017/11/08
PROVINCE OF ONTARIO




SECTION A–A' ALONG ℄ FLAGG ROAD

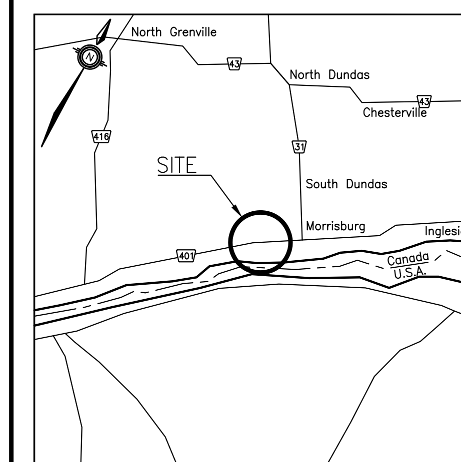
CONT No
GWP No 4445-02-01

HIGHWAY 401 UNDERPASS OF FLAGG ROAD
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

wsp

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 |
| Bld | Boulder |

| NO | ELEVATION | NORTHING | EASTING |
|---|---|---|---|
| 801 | 89.6 | 4 973 162.8 | 402 852.9 |
| 802 | 89.7 | 4 973 174.8 | 402 846.8 |
| 803 | 89.7 | 4 973 172.0 | 402 842.2 |
| 804 | 83.3 | 4 973 207.8 | 402 833.1 |
| 805 | 83.3 | 4 973 202.5 | 402 817.6 |
| 806 | 89.7 | 4 973 238.0 | 402 809.0 |
| 807 | 89.7 | 4 973 235.3 | 402 804.0 |
| 808 | 89.6 | 4 973 247.1 | 402 797.3 |

## -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.
3) Borehole locations are shown in MTM Zone 9 coordinates.

**GEOCRES No. 31B-91**

| REVISIONS | DATE | BY | DESCRIPTION |
|---|---|---|---|
| | | | |

| | | | | |
|---|---|---|---|---|
| DESIGN KP | CHK – | CODE | LOAD | DATE NOV 2017 |
| DRAWN MFA | CHK KP | SITE 31–203 | STRUCT | DWG 1 |

FILENAME: H:\Drafting\19\5161\263\ted1263-FlaggRoadUnderpass.dwg
PLOTDATE: 11/8/2017 11:25 AM

# APPENDIX B

## RECORD OF BOREHOLE SHEETS – 2016 INVESTIGATION
## BEDROCK CORE PHOTOGRAPHS

THURBER

60 YEARS

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

### RECOVERY:

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

### N-VALUE:

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

### DYNAMIC CONE PENETRATION TEST (DCPT):

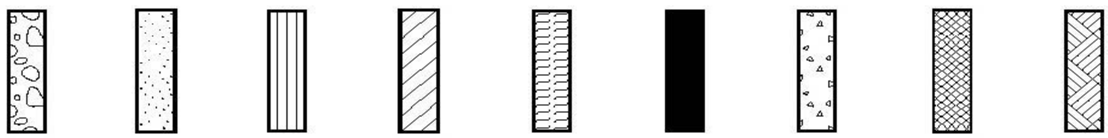
Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an “A” size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The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

THURBER

60 YEARS

## STRATA PLOT:

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



| Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Bedrock |
|---|---|---|---|---|---|---|---|---|

## TEXTURING CLASSIFICATION OF SOILS

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

## SAMPLE TYPES

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

## TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

## TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

| **Descriptive Term** | **SPT "N" Value** |
|---|---|
| Very Loose | Less than 4 |
| Loose | 4 – 10 |
| Compact | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | Greater than 50 |

THURBER

60 YEARS

## MODIFIED UNIFIED SOIL CLASSIFICATION

<table>
<tr><th colspan="2">Major Divisions</th><th>Group Symbol</th><th>Typical Description</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOIL</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="9">FINE GRAINED SOILS</td><td rowspan="3">SILT AND CLAY SOILS $W_L < 35\%$</td><td>ML</td><td>Inorganic silts, 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.</td></tr>
<tr><td>OL</td><td>Organic silts and organic silty-clays of low plasticity.</td></tr>
<tr><td rowspan="3">SILT AND CLAY SOILS $35\% < W_L < 50\%$</td><td>MI</td><td>Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.</td></tr>
<tr><td>CI</td><td>Inorganic clays of medium plasticity, silty clays.</td></tr>
<tr><td>OI</td><td>Organic silty clays of medium plasticity.</td></tr>
<tr><td rowspan="3">SILT AND CLAY SOILS $W_L > 50\%$</td><td>MH</td><td>Inorganic silts, micaceous or diatomaceous fine sandy of 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 high plasticity, organic silts.</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td>Pt</td><td>Peat and other organic soils.</td></tr>
</table>

Note - $W_L$= Liquid Limit

THURBER

60 YEARS

# EXPLANATION OF ROCK LOGGING TERMS

## ROCK WEATHERING CLASSIFICATION

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

## TERMS

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

## DISCONTINUITY SPACING

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

## STRENGTH CLASSIFICATION

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

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 801



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 4445-02-01 | LOCATION | Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 162.8 E 402 852.9 | ORIGINATED BY | CAM/JM |
| HWY | 401 | BOREHOLE TYPE | Hollow Stem Auger | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.08.15 - 2016.08.15 | CHECKED BY | KCP |

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 89.6 | | | | | | |
| 0.0 | **155 mm ASPHALT** | | | | | |
| 0.2 | Silty sand some gravel, Compact to dense, Brown, **FILL** | 1 | SS | 23 | 89 | |
| | | 2 | SS | 34 | | |
| 88.1 / 1.5 | Sandy silt with gravel, Dense to compact, Grey, **FILL** | 3 | SS | 48 | 88 | |
| | | 4 | SS | 24 | 87 | 14 33 53 (SI+CL) |
| | | 5 | SS | 21 | 86 | |
| | - Some clay | 6 | SS | 18 | | |
| 85.0 / 4.6 | Silty sand, Compact, Brown, **FILL** | 7 | SS | 26 | 85 | 9 47 44 (SI+CL) |
| 84.4 / 5.2 | Sandy silt, Compact, Grey, **FILL** | 8 | SS | 14 | 84 | |
| | | 9 | SS | 16 | 83 | |
| | | 10 | SS | 26 | 82 | |
| 81.8 / 7.8 | - Trace organics / **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**, Compact to very dense, Grey | 11 | SS | 10 | 81 | |
| | | 12 | SS | 55 | 80 | 13 31 46 10 |

Column headings: SOIL PROFILE; SAMPLES; 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/m³

Continued Next Page

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

ONTMT4S FLAGG RD UNDERPASS.GPJ 2012TEMPLATE(MTO).GDT 31/1/17

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 801



METRIC

| | | | |
|---|---|---|---|
| GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 162.8 E 402 852.9 | ORIGINATED BY CAM/JM |
| HWY 401 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY JM |
| DATUM Geodetic | DATE 2016.08.15 - 2016.08.15 | CHECKED BY KCP |

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Compact to very dense | | | | | 79 | | | | | |
| | | 13 | SS | 17 | | | o | | | | |
| | | | | | | 78 | | | | | |
| | | 14 | SS | 17 | | 77 | o H | 12 | 35 | 41 | 12 |
| | | | | | | 76 | | | | | |
| | | 15 | SS | 17 | | 75 | o | | | | |
| | | | | | ▼ | | | | | | |
| 73.8 / 15.8 | | 16 | SS | 12 | | 74 | o | | | | |
| | End of Borehole<br>Groundwater level was measured in the open borehole at 15.3 m BGS (elev. 74.3 m) | | | | | | | | | | |

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 (%)

+[3], ×[3]: Numbers refer to Sensitivity

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

ONTMT4S FLAGG RD UNDERPASS.GPJ 2012TEMPLATE(MTO).GDT 31/1/17

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 802



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 174.8 E 402 846.8 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.24 - 2016.08.25 | CHECKED BY KCP

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 89.7 | | | | | | |
| 0.0 | **170 mm ASPHALT** | | | | | |
| 0.2 | Silty sand, Compact to dense, Brown, **FILL** | 1 | SS | 27 | 89 | |
| | | 2 | SS | 32 | | |
| 88.0 / 1.7 | Sandy silt, Loose to compact, Grey, **FILL** | 3 | SS | 29 | 88 | |
| | | 4 | SS | 25 | 87 | 11 32 57 (SI+CL) |
| | | 5 | SS | 8 | 86 | |
| | | 6 | SS | 24 | | |
| 85.1 / 4.6 | Silty sand some gravel, Compact, Brown, **FILL** | 7 | SS | 14 | 85 | |
| 84.4 / 5.3 | Sandy silt, Compact to dense, Brown, **FILL** | 8 | SS | 17 | 84 | |
| | | 9 | SS | 40 | 83 | |
| | | 10 | SS | 29 | | 8 25 67 (SI+CL) |
| 82.1 / 7.6 | Silty, clayey sand with gravel - trace organics, Loose, Grey, **FILL** - Borehole advanced with NW casing below 8.2 m | 11 | SS | 6 | 82 | |
| 81.0 / 8.7 | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**, Very dense, Brown to grey | | | | 81 | |
| | | 12 | SS | 60 | 80 | 14 30 45 11 |

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

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 802



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 4445-02-01 | LOCATION | Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 174.8 E 402 846.8 | ORIGINATED BY | CAM |
| HWY | 401 | BOREHOLE TYPE | Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.08.24 - 2016.08.25 | CHECKED BY | KCP |

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Compact to dense<br><br>- frequent cobbles and boulders below 10.8 m<br>- Grey | | | | | | | | | |
| | | | | | 79 | | | | | |
| | | 13 | SS | 31 | | ○ with plastic/liquid limits | 21 | 32 | 37 | 10 |
| | | | | | 78 | | | | | |
| | | 14 | SS | 31 | | | | | | |
| | | | | | 77 | | | | | |
| | - Boulder from 13.1 m to 13.7 m<br>Advanced by coring | | | | | | | | | |
| | | | | | 76 | | | | | |
| | | 15 | SS | 43 | | ○ | | | | |
| | | | | | 75 | | | | | |
| | - Boulder from 14.9 m to 15.2 m<br>Advanced by coring | | | | | | | | | |
| | | | | | 74 | | | | | |
| | | 16 | SS | 15 | | ○ with plastic/liquid limits | 21 | 33 | 36 | 10 |
| | | | | | 73 | | | | | |
| | | 17 | SS | 19 | | ○ | | | | |
| | - Boulder from 17.5 m to 18.1 m<br>Advanced by coring | | | | 72 | | | | | |
| | | 18 | SS | 18 | | ○ | | | | |
| | | | | | 71 | | | | | |
| | | | | | 70 | | | | | |

Column headings: 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/m$^3$; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 802



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 4445-02-01 | LOCATION | Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 174.8 E 402 846.8 | ORIGINATED BY | CAM |
| HWY | 401 | BOREHOLE TYPE | Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.08.24 - 2016.08.25 | CHECKED BY | KCP |

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Dense to very dense | | | | 69 | | |
| | | 19 | SS | 70 | 68 | o | |
| | | | | | 67 | | |
| | - Boulder from 22.9 m to 23.1 m<br>Advanced by coring | | | | 66 | | |
| | | 20 | SS | 31 | 65 | o with plastic/liquid limits | 18 40 30 12 |
| | | | | | 64 | | |
| | - Boulder from 25.9 to 26.2<br>Advanced by coring | | | | 63 | | |
| 61.9 | | 21 | SS | 100/ 200mm | 62 | o | |
| 27.8 | **Bedrock**<br>Limestone<br>Slightly weathered<br>Very thinly bedded to thinly bedded<br>Poor to excellent quality<br>Grey | 1 | NQ | | | | RUN #1<br>TCR=100%<br>SCR=100%<br>RQD=59% |
| | | 2 | NQ | | 61 | | RUN #2<br>TCR=88%<br>SCR=71%<br>RQD=37% |
| | | | | | 60 | | |

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

# RECORD OF BOREHOLE No 802

 **METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 4445-02-01 | LOCATION | Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 174.8 E 402 846.8 | ORIGINATED BY | CAM |
| HWY | 401 | BOREHOLE TYPE | Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.08.24 - 2016.08.25 | CHECKED BY | KCP |

| ELEV / DEPTH | DESCRIPTION (Continued From Previous Page) | STRAT PLOT | NUMBER | TYPE | "N" VALUES | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Bedrock**<br>Limestone | | 3 | NQ | | | 59 | | | | RUN #3<br>TCR=100%<br>SCR=100%<br>RQD=95% |
| 58.5<br>31.2 | End of Borehole | | | | | | | | | | |

$+^3, \times^3$: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 803



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 172.0 E 402 842.2 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.29 - 2016.08.30 | CHECKED BY KCP

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 89.7 | | | | | | | |
| 0.0 | **170 mm ASPHALT** | | | | | | |
| 0.2 | Silty sand, Compact to dense, Brown, **FILL** | 1 | SS | 31 | | ○ | |
| | | 2 | SS | 22 | 89 | ○ | |
| 87.9 / 1.8 | Sandy silt with gravel, Compact, Grey, **FILL** | 3 | SS | 39 | 88 | ○ | |
| | | 4 | SS | 29 | 87 | ○ | 16 30 54 (SI+CL) |
| | | 5 | SS | 18 | 86 | ○ | |
| | | 6 | SS | 24 | | ○ | |
| 85.1 / 4.6 | Silty sand to silty sand with gravel, Compact, Brown to grey, **FILL** | 7 | SS | 25 | 85 | ○ | |
| | | 8 | SS | 21 | 84 | ○ | |
| | | 9 | SS | 17 | 83 | ○ | |
| | | 10 | SS | 28 | | ○ | |
| | - trace organics 7.6 m to 7.8 m | 11 | SS | 13 | 82 | ○ | |
| 81.5 / 8.2 | - Borehole advanced with NW casing below 8.2 m. **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**, Very dense, Brown to grey | | | | 81 | | |
| | | 12 | SS | 73 | 80 | ⊢○⊣ | 11 30 49 10 |

Continued Next Page

+³, ×³: Numbers refer to Sensitivity; (%) STRAIN AT FAILURE

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT $w$, LIQUID LIMIT $w_L$; UNIT WEIGHT γ kN/m³

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 803



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 4445-02-01 | LOCATION | Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 172.0 E 402 842.2 | ORIGINATED BY | CAM |
| HWY | 401 | BOREHOLE TYPE | Hollow Stem Auger / NW Casing | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.08.29 - 2016.08.30 | CHECKED BY | KCP |

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Compact to very dense | | | | | | | | | |
| | | | | | 79 | | | | | |
| | - Grey | 13 | SS | 37 | | ⊢○⊣ | 35 | 30 | 28 | 7 |
| | | | | | 78 | | | | | |
| | | 14 | SS | 64 | | | | | | |
| | | | | | 77 | | | | | |
| | - frequent cobbles and boulders below 12.8 m<br>- Boulder from 13.1 m to 13.4 m<br>Advanced by coring | | | | | | | | | |
| | | | | | 76 | | | | | |
| | | 15 | SS | 32 | | ○ | | | | |
| | | | | | 75 | | | | | |
| | | 16 | SS | 15 | | ⊢○⊣ | 17 | 35 | 38 | 10 |
| | | | | | 74 | | | | | |
| | | | | | 73 | | | | | |
| | | 17 | SS | 19 | | | | | | |
| | | | | | 72 | | | | | |
| | - Boulder from 17.7 m to 18.0 m<br>Advanced by coring | | | | | | | | | |
| | | 18 | SS | 18 | | ○ | | | | |
| | | | | | 71 | | | | | |
| | - Boulder from 19.2 m to 19.5 m<br>Advanced by coring | | | | | | | | | |
| | | | | | 70 | | | | | |

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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)

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 803



**METRIC**

| | | | |
|---|---|---|---|
| GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 172.0 E 402 842.2 | ORIGINATED BY CAM |
| HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing | COMPILED BY JM |
| DATUM Geodetic | DATE 2016.08.29 - 2016.08.30 | CHECKED BY KCP |

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | |
| | **Silty SAND (SM)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL** Compact to dense | | | | 69 | |
| | | 19 | SS | 27 | 68 | |
| | | | | | 67 | |
| | | | | | 66 | |
| | | 20 | SS | 43 | 65 | 15 42 32 11 |
| | | | | | 64 | |
| | | | | | 63 | |
| 62.0 | | 21 | SS | 100/ 250mm | 62 | |
| 27.7 | End of Borehole Splitspoon refusal on inferred bedrock | | | | | |

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 804



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 207.8 E 402 833.1 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.23 - 2016.08.23 | CHECKED BY KCP

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 83.3 | | | | | | | |
| 0.0 | Sand and gravel<br>Compact<br>Grey<br>**FILL** | 1 | SS | 19 | 83 | ○ | |
| 82.5<br>0.8 | Silty sand to silty sand with gravel<br>Loose to compact<br>Brown<br>**FILL** | 2 | SS | 7 | 82 | ○ | |
| | | 3 | SS | 19 | | ○ | |
| 81.0<br>2.3 | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Compact to very dense<br>Grey | 4 | SS | 55 | 81 | ○ | |
| | | 5 | SS | 39 | 80 | ○ | 1 9 81 9 |
| | | 6 | SS | 50 | 79 | ○ | |
| | | 7 | SS | 21 | 78 | ○ | |
| | | 8 | SS | 21 | 77 | ○ | |
| | | 9 | SS | 18 | 76 | ○ | |
| | - Borehole advanced with NW casing below 8.2 m | | | | 75 | | |
| | - frequent cobbles and boulders 10 m<br>- Boulder from 10.1 m to 10.3 m<br>Advanced by coring | 10 | SS | 26 | 74 | ○ | |

Column headings also include: 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/m³.

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

# RECORD OF BOREHOLE No 804



**METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 207.8 E 402 833.1 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger / NW Casing COMPILED BY JM

DATUM Geodetic DATE 2016.08.23 - 2016.08.23 CHECKED BY KCP

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL** Compact to very dense | | | | 73 | | | | | |
| | | 11 | SS | 25 | | ○ | | | | |
| | | | | | 72 | | | | | |
| | | 12 | SS | 16 | 71 | ○ | | | | |
| | | | | | 70 | | | | | |
| | | 13 | SS | 29 | | ⊢○⊣ | 24 | 31 | 35 | 10 |
| | | | | | 69 | | | | | |
| | | 14 | SS | 32 | 68 | | | | | |
| | - Boulder from 16.3 m to 16.6 m Advanced by coring | | | | 67 | | | | | |
| | | 15 | SS | 53 | 66 | ○ | | | | |
| | - Boulder from 17.7 m to 17.9 m Advanced by coring | | | | 65 | | | | | |
| | | 16 | SS | 55 | | ⊢○⊣ | 26 | 42 | 22 | 10 |
| | | | | | 64 | | | | | |
| | - Boulder from 19.5 m to 19.7 m Advanced by coring | | | | | | | | | |

Column headings: SOIL PROFILE; STRAT PLOT; 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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

# RECORD OF BOREHOLE No 804



**METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 207.8 E 402 833.1 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger / NW Casing COMPILED BY JM

DATUM Geodetic DATE 2016.08.23 - 2016.08.23 CHECKED BY KCP

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Very dense<br><br>- Boulder from 20.7 m to 21.0 m<br>Advanced by coring | | | | | 63 | | | | |
| | | | | | | 62 | | | | |
| | | 17 | SS | 52 | | | 21 | 37 | 26 | 16 |
| 60.9 | | | | | | 61 | | | | |
| 22.4 | End of Borehole<br>Splitspoon refusal on inferred bedrock | | | | | | | | | |

Legend: 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 (%)

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 805



**METRIC**

GWP# 4445-02-01
LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 202.5 E 402 817.6
ORIGINATED BY CAM

HWY 401
BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring
COMPILED BY JM

DATUM Geodetic
DATE 2016.08.22 - 2016.08.22
CHECKED BY KCP

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 83.3 | | | | | | |
| 0.0 | Sand and gravel<br>Compact<br>Grey<br>**FILL** | 1 | SS | 24 | 83 | |
| 82.5<br>0.8 | Silty sand with gravel<br>Compact<br>Brown<br>**FILL** | 2 | SS | 10 | 82 | |
| | | 3 | SS | 18 | | |
| 81.0<br>2.3 | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM) with gravel TILL**<br>Compact to dense<br>Grey | 4 | SS | 44 | 81 | |
| | | 5 | SS | 28 | 80 | |
| | | 6 | SS | 27 | 79 | |
| | | 7 | SS | 32 | 78 | 12 28 44 16 |
| | | 8 | SS | 25 | 77 | |
| | | | | | 76 | |
| | | 9 | SS | 16 | | |
| | - Borehole advanced with NW casing below 8.2 m | | | | 75 | |
| | | 10 | SS | 38 | 74 | |

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

Continued Next Page

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

# RECORD OF BOREHOLE No 805



**METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 202.5 E 402 817.6 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring COMPILED BY JM

DATUM Geodetic DATE 2016.08.22 - 2016.08.22 CHECKED BY KCP

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL** Compact to dense | | | | 73 | | | | | |
| | | 11 | SS | 26 | 72 | | | | | |
| | | 12 | SS | 22 | 71 | ~5 | | | | |
| | - frequent cobbles and boulders below 13 m<br>- Boulder from 13.6 m to 13.9 m Advanced by coring | | | | 70 | | | | | |
| | | 13 | SS | 17 | 69 | ~6 | 23 | 32 | 34 | 11 |
| | | 14 | SS | 25 | 68 | ~7 | | | | |
| | - Boulder from 16.5 m to 16.8 m Advanced by coring | 15 | SS | 100/ 200mm | 67, 66 | ~4 | | | | |
| | - Boulder from 17.5 m to 17.7 m Advanced by coring | 16 | SS | 48 | 65 | ~4 | 21 | 40 | 28 | 11 |
| | | | | | 64 | | | | | |

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

$+^3, \times^3$: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 805



METRIC

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 202.5 E 402 817.6 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.22 - 2016.08.22 | CHECKED BY KCP

| 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 γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | | | | | | |
| | **Sandy SILT (ML)** to **Silty, Clayey SAND (SC-SM)** with gravel **TILL**<br>Compact to very dense | | | | | | 63 | | | | |
| | | | | | | | 62 | | | | |
| | | | 17 | SS | 47 | | | | ○ | | |
| 60.9 | | | | | | | 61 | | | | |
| 22.4 | **BEDROCK**<br>Limestone<br>Slightly weathered<br>Very thinly bedded to thinly bedded<br>Fair quality<br>Grey | | 1 | NQ | | | 60 | | | | RUN #1<br>TCR=100%<br>SCR=96%<br>RQD=52% |
| | | | 2 | NQ | | | 59 | | | | RUN #2<br>TCR=100%<br>SCR=96%<br>RQD=72% |
| 57.8 | | | 3 | NQ | | | 58 | | | | RUN #3<br>TCR=100%<br>SCR=92%<br>RQD=63% |
| 25.5 | End of Borehole | | | | | | | | | | |

Plot legend: 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.

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 806



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 238.0 E 402 809.0 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.16 - 2016.08.17 | CHECKED BY KCP

| ELEV / DEPTH (m) | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 89.7 | | | | | | |
| 0.0 | **150 mm ASPHALT** | | | | | |
| 0.2 | Silty sand with gravel to silty sand<br>Compact to dense<br>Brown to grey<br>**FILL** | 1 | SS | 31 | 89 | |
| | | 2 | SS | 32 | | 1 88 11 (SI+CL) |
| | | 3 | SS | 41 | 88 | |
| | - clayey | 4 | SS | 16 | 87 | |
| 86.7<br>3.0 | Silty sand with gravel<br>Loose to compact<br>Grey<br>**FILL** | 5 | SS | 17 | 86 | |
| | | 6 | SS | 28 | | 17 36 47 (SI+CL) |
| | | 7 | SS | 17 | 85 | |
| | | 8 | SS | 16 | 84 | |
| | | 9 | SS | 6 | 83 | |
| | - Borehole advanced with NW casing below 6.7 m | 10 | SS | 24 | | |
| 82.1<br>7.6 | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Compact to very dense<br>Brown to grey | 11 | SS | 31 | 82 | 24 28 39 9 |
| | | 12 | SS | 38 | 81 | |
| | | 13 | SS | 65 | 80 | |

Column headings also include: 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/m³.

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S FLAGG RD UNDERPASS.GPJ 2012TEMPLATE(MTO).GDT 31/1/17

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 806

 **METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 238.0 E 402 809.0 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger / NW Casing COMPILED BY JM

DATUM Geodetic DATE 2016.08.16 - 2016.08.17 CHECKED BY KCP

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Loose to dense | 14 | SS | 41 | | |
| | | 15 | SS | 30 | 79 | |
| | - frequent cobbles and boulders below 11.5 m<br>- Boulder from 11.9 m to 12.2 m<br>Advanced by coring | | | | 78 | |
| | | 16 | SS | 31 | 77 | 21 33 31 15 |
| | | 17 | SS | 11 | 76 | |
| | | 18 | SS | 6 | 75, 74 | |
| | - Boulder from 16 m to 16.3 m<br>Advanced by coring | | | | 73 | |
| | | 19 | SS | 14 | 72 | 21 33 33 13 |
| | - Grey | 20 | SS | 13 | 71, 70 | |

Continued Next Page

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

+3, ×3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 806



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 238.0 E 402 809.0 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.16 - 2016.08.17 | CHECKED BY KCP

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Compact to very dense | 21 | SS | 18 | | o (~10) | | | | |
| | | | | | 69 | | | | | |
| | | | | | 68 | | | | | |
| | | | | | 67 | | | | | |
| | - Boulder from 22.7 m to 22.9 m<br>Advanced by coring | 22 | SS | 100/ 50mm | | | | | | |
| | | | | | 66 | | | | | |
| | | | | | 65 | | | | | |
| | | | | | 64 | | | | | |
| | | 23 | SS | 100/ 225mm | | o (~5) | | | | |
| | - Boulder from 26.5 m to 27.1 m<br>Advanced by coring | | | | 63 | | | | | |
| | | | | | 62 | | | | | |
| | | | | | 61 | | | | | |
| | | 24 | SS | 51 | | wP–w–wL (~10–15) | 22 | 26 | 30 | 22 |
| 60.4<br>29.3 | End of Borehole<br>Splitspoon refusal on inferred bedrock | | | | | | | | | |

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 807



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 235.3 E 402 804.0 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.18 - 2016.08.19 | CHECKED BY KCP

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 89.7 | | | | | | |
| 0.0 | **180 mm ASPHALT** | | | | | |
| 0.2 | Silty sand with gravel<br>Compact to very dense<br>Brown<br>**FILL** | 1 | SS | 25 | | |
| | | 2 | SS | 27 | 89 | |
| | | 3 | SS | 53 | 88 | |
| 87.4<br>2.3 | Silty sand to sitly sand with gravel<br>Loose to dense<br>Brown to grey<br>**FILL** | 4 | SS | 8 | 87 | |
| | - grey | 5 | SS | 8 | | |
| | | 6 | SS | 14 | 86 | |
| | | 7 | SS | 37 | 85 | |
| | - Borehole advanced with NW casing below 5.2 m | 8 | SS | 23 | 84 | |
| | | 9 | SS | 18 | | 14 45 41 (SI+CL) |
| 82.9<br>6.9 | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Compact to very dense<br>Brown to grey | 10 | SS | 61 | 83 | |
| | | 11 | SS | 19 | 82 | 29 38 20 13 |
| | | 12 | SS | 78 | 81, 80 | |

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

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

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

ONTMT4S FLAGG RD UNDERPASS.GPJ 2012TEMPLATE(MTO).GDT 31/1/17

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No 807



**METRIC**

GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 235.3 E 402 804.0 | ORIGINATED BY CAM

HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.18 - 2016.08.19 | CHECKED BY KCP

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Compact to very dense | | | | | | | | | | |
| | | | | | 79 | | | | | | |
| | | 13 | SS | 61 | | ○ | | | | | |
| | | | | | 78 | | | | | | |
| | | 14 | SS | 21 | | ○H | | 31 | 28 | 30 | 11 |
| | | | | | 77 | | | | | | |
| | | | | | 76 | | | | | | |
| | | 15 | SS | 31 | | ○ | | | | | |
| | | | | | 75 | | | | | | |
| | | 16 | SS | 18 | | ○ | | | | | |
| | | | | | 74 | | | | | | |
| | - frequent cobbles and boulders below 16 m<br>- Boulder from 16.5 m to 16.7 m Advanced by coring<br>- Grey | | | | 73 | | | | | | |
| | | 17 | SS | 21 | | ○ | | | | | |
| | | | | | 72 | | | | | | |
| | | 18 | SS | 22 | | ○H | | 28 | 30 | 32 | 10 |
| | | | | | 71 | | | | | | |
| | | | | | 70 | | | | | | |

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; 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; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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 807



**METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 235.3 E 402 804.0 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring COMPILED BY JM

DATUM Geodetic DATE 2016.08.18 - 2016.08.19 CHECKED BY KCP

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT / PLOT | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Loose to very dense | 19 | SS | 27 | | ○ | |
| | | | | | 69 | | |
| | | 20 | SS | 7 | 68 | ○ | |
| | | | | | 67 | | |
| | | 21 | SS | 63 | | ⊢○⊣ | 23 38 28 11 |
| | | | | | 66 | | |
| | | 22 | SS | 57 | 65 | ○ | |
| | - Boulder from 25.1 m to 25.4 m<br>Advanced by coring | | | | | | |
| | | | | | 64 | | |
| | - Boulder from 25.9 m to 26.2 m<br>Advanced by coring | | | | | | |
| | | | | | 63 | | |
| | | 23 | SS | 64 | | ○ | |
| | | | | | 62 | | |
| | | 24 | SS | 100/ 250mm | 61 | ⊢○⊣ | 22 29 31 18 |
| 60.3 | - Boulder from 28.9 m to 29.1 m<br>Advanced by coring | | | | | | |
| 29.4 | **BEDROCK**<br>Limestone<br>Slightly weathered | 1 | NQ | | 60 | | RUN #1<br>TCR=100%<br>SCR=100%<br>RQD=72% |

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT $w$, LIQUID LIMIT $w_L$; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

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

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No 807



**METRIC**

| | | | |
|---|---|---|---|
| GWP# 4445-02-01 | LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 235.3 E 402 804.0 | ORIGINATED BY CAM |
| HWY 401 | BOREHOLE TYPE Hollow Stem Auger / NW Casing / NQ Coring | COMPILED BY JM |
| DATUM Geodetic | DATE 2016.08.18 - 2016.08.19 | CHECKED BY KCP |

| ELEV DEPTH | SOIL PROFILE – DESCRIPTION | STRAT PLOT | SAMPLES – NUMBER | SAMPLES – TYPE | "N" VALUES | 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) | WATER CONTENT (%) (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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | | | | | | |
| | **BEDROCK**<br>Limestone<br>Slightly weathered<br>Very thinly bedded to thinly bedded<br>Fair to good quality<br>Grey | | 2 | NQ | | | 59 | | | | RUN #2<br>TCR=93%<br>SCR=86%<br>RQD=69% |
| | | | 3 | NQ | | | 58 | | | | RUN #3<br>TCR=98%<br>SCR=97%<br>RQD=85% |
| 56.8 | | | | | | | 57 | | | | |
| 32.9 | End of Borehole<br>Groundwater level was measured in piezometer at 11.3 m BGS<br>(elev. 77.9 m) | | | | | | | | | | |

+ 3, × 3: Numbers refer to Sensitivity

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

# RECORD OF BOREHOLE No 808



**METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 247.1 E 402 797.3 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JM

DATUM Geodetic DATE 2016.08.26 - 2016.08.26 CHECKED BY KCP

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|
| 89.6 | | | | | |
| 0.0 | **125 mm ASPHALT** | | | | |
| 0.2 | Silty sand<br>Compact<br>Brown<br>**FILL** | 1 | SS | 25 | 0 90 10 (SI+CL) |
| | | 2 | SS | 32 | |
| 88.4<br>1.2 | Silty sand to silty sand with gravel<br>Loose to very dense<br>Grey to brown<br>**FILL** | 3 | SS | 97 | |
| | | 4 | SS | 24 | |
| | - clayey from 3 m to 3.8 m | 5 | SS | 5 | |
| | | 6 | SS | 16 | |
| | | 7 | SS | 21 | |
| | | 8 | SS | 10 | |
| | | 9 | SS | 22 | |
| | | 10 | SS | 9 | |
| 82.3<br>7.3 | - trace organics<br>**Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Dense<br>Brown to grey | 11 | SS | 46 | 17 26 42 15 |
| | | 12 | SS | 100/ 175mm | |

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (89, 88, 87, 86, 85, 84, 83, 82, 81, 80); 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.

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 808

 **METRIC**

GWP# 4445-02-01 LOCATION Highway 401 Underpass at Flagg Rd., MTM Zone 9: N 4 973 247.1 E 402 797.3 ORIGINATED BY CAM

HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JM

DATUM Geodetic DATE 2016.08.26 - 2016.08.26 CHECKED BY KCP

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Silty, Clayey SAND (SC-SM)** with gravel to **Silty SAND (SM)** with gravel **TILL**<br>Loose to compact | | | | 79 | | | | | |
| | | 13 | SS | 28 | | ○ | | | | |
| | | | | | 78 | | | | | |
| | - Grey | 14 | SS | 25 | 77 | ○ (with plastic/liquid limits) | 20 | 34 | 32 | 14 |
| | | | | | 76 | | | | | |
| | | 15 | SS | 9 | | ○ | | | | |
| | | | | | 75 | | | | | |
| | | 16 | SS | 13 | 74 | ○ (with plastic/liquid limits) | 20 | 32 | 33 | 15 |
| 73.7 / 15.8 | End of Borehole | | | | | | | | | |

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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

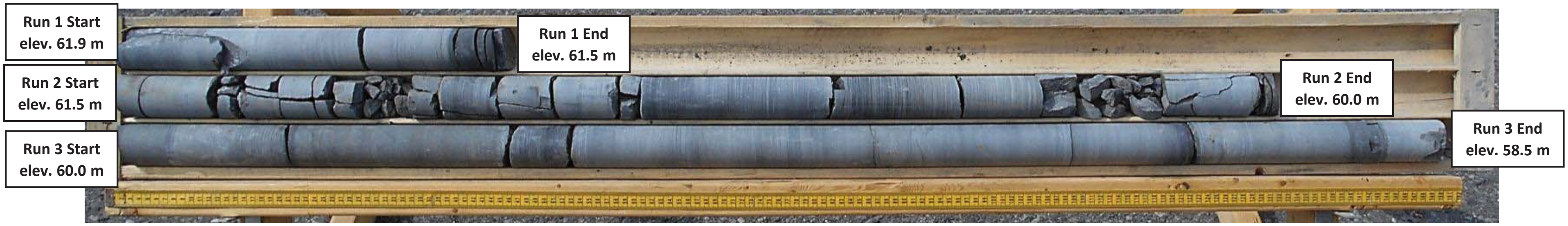
+³, ×³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

# Borehole 802

## Run 1 to 3 (of 3)

## Elevation 61.9 m to 58.5 m




THURBER ENGINEERING LTD.

**Foundation Investigation**
**Highway 401 Underpass of Flagg Road**
**Site 31-203**
**Township of South Dundas, Ontario**

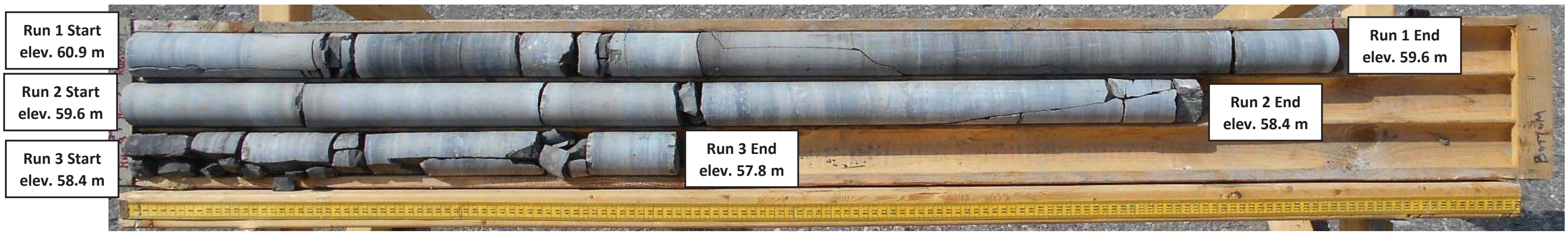
**GWP: 4445-02-01**

**Project No.: 19-5161-263**

# Borehole 805

## Run 1 to 3 (of 3)

## Elevation 60.9 m to 57.8 m




THURBER ENGINEERING LTD.

**Foundation Investigation**
**Highway 401 Underpass of Flagg Road**
**Site 31-203**
**Township of South Dundas, Ontario**

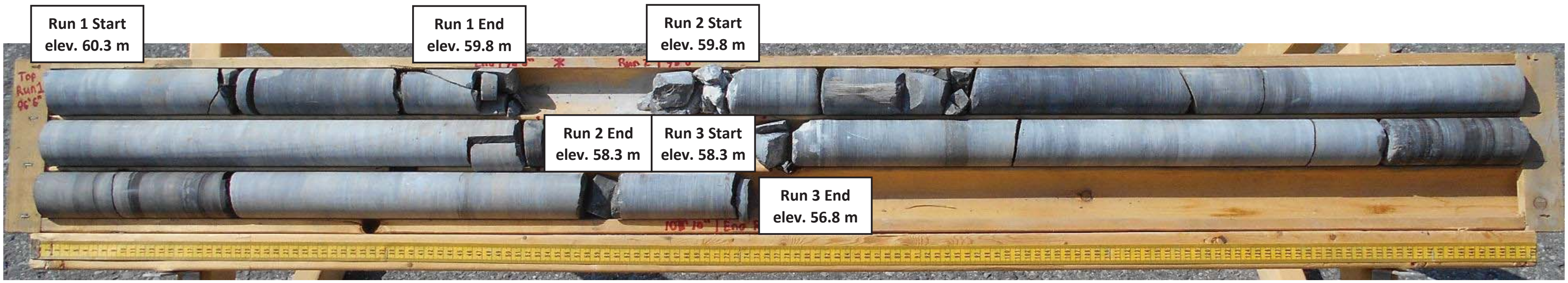
**GWP: 4445-02-01**

**Project No.: 19-5161-263**

# Borehole 807

## Run 1 to 3 (of 3)

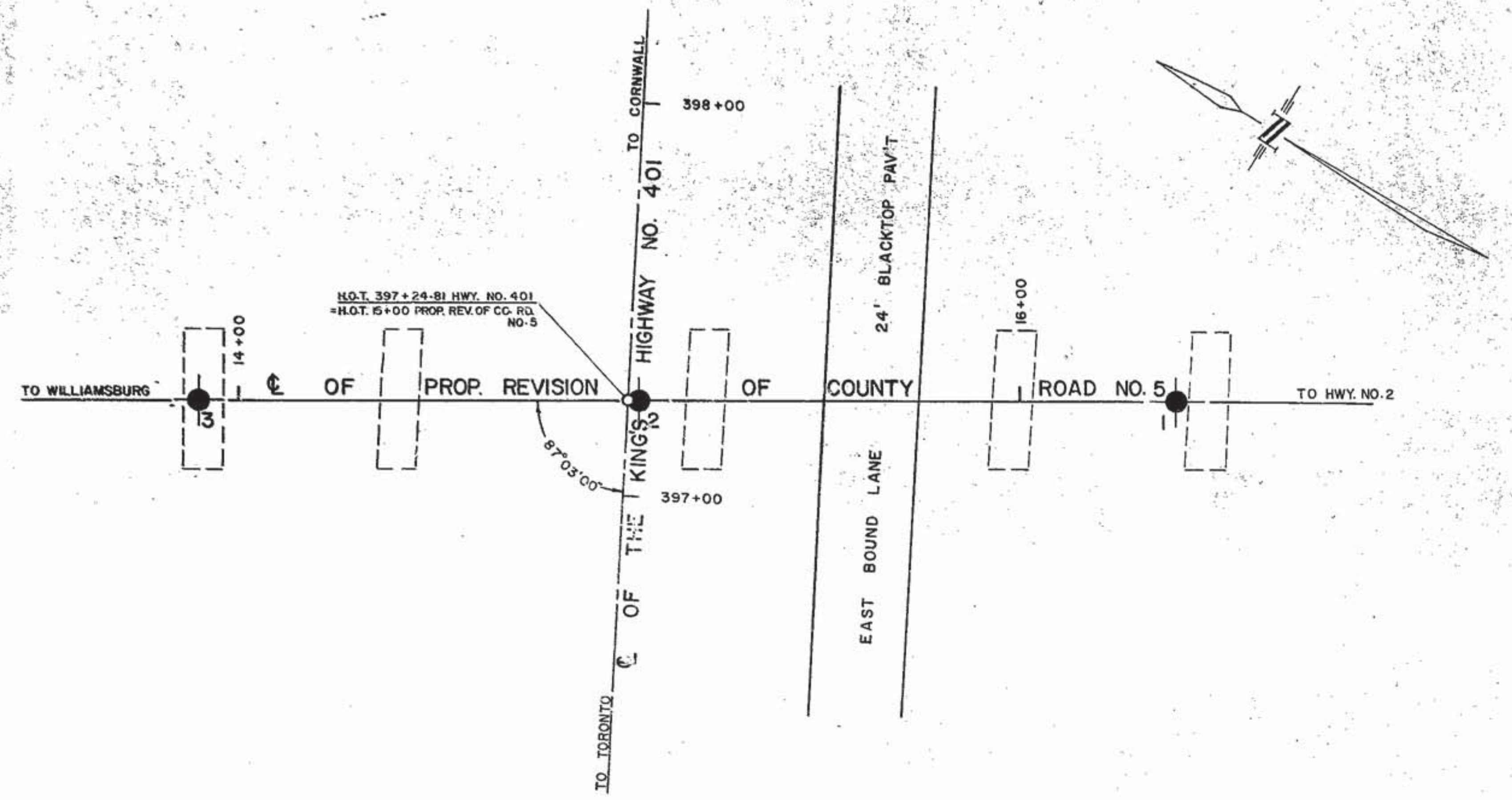
## Elevation 60.3 m to 56.8 m




| | | |
|---|---|---|
| THURBER ENGINEERING LTD. | **Foundation Investigation**<br>**Highway 401 Underpass of Flagg Road**<br>**Site 31-203**<br>**Township of South Dundas, Ontario** | **GWP: 4445-02-01**<br>**Project No.: 19-5161-263** |

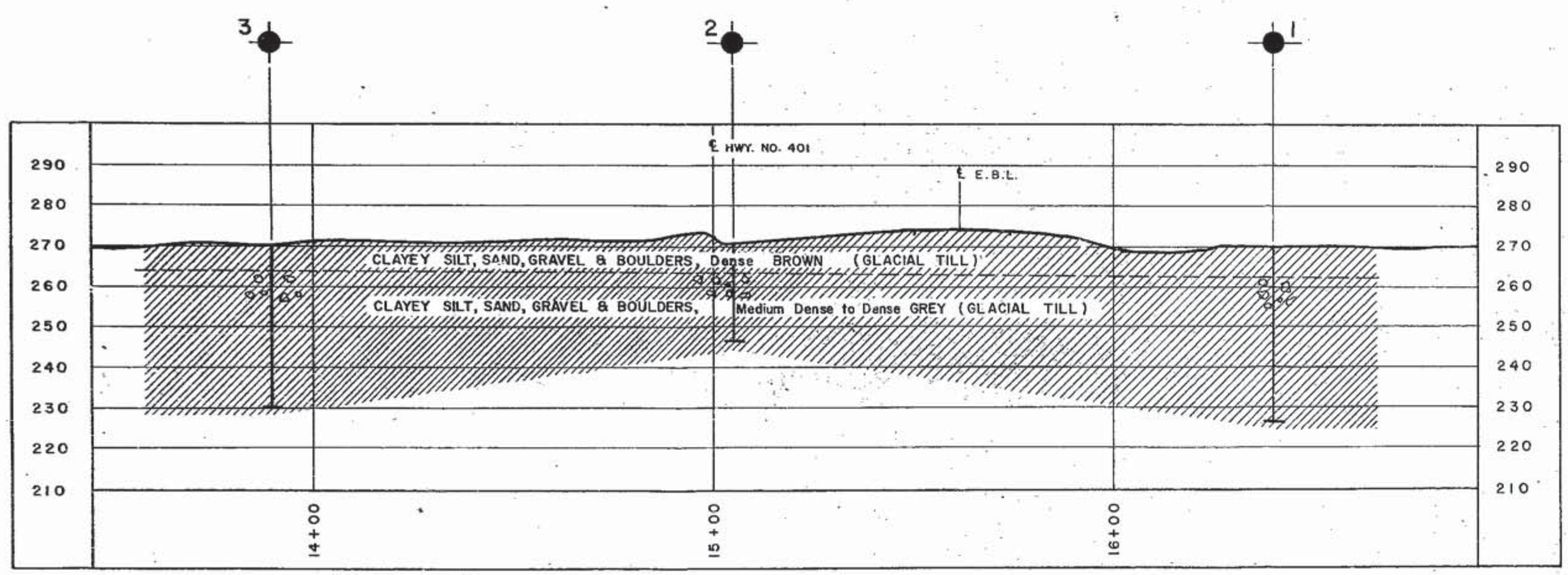
# APPENDIX C

## HISTORICAL BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS
## HISTORICAL RECORD OF BOREHOLE SHEETS



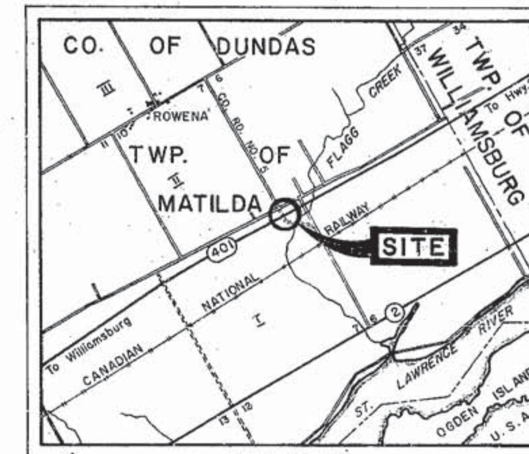

PLAN

SCALE IN FEET




PROFILE

SCALE IN FEET




KEY PLAN

SCALE IN MILES

## LEGEND

- Bore Hole
- Cone Penetration Hole
- Bore & Cone Penetration Hole
- Water Levels established at time of field investigation

| NO. | ELEVATION | STATION | OFFSET |
|---|---|---|---|
| 1 | 270·0 | 16+40 | ℄ |
| 2 | 271·0 | 15+05 | ℄ |
| 3 | 271·0 | 13+90 | ℄ |

**- NOTE -**

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.

REF. NO. E-3845-1

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH DIVISION - FOUNDATION SECTION

# DUNDAS COUNTY ROAD NO. 5

(PROPOSED REVISION)

AND

# HIGHWAY NO. 401

| | | |
|---|---|---|
| ORIGINATED V. KORLU | DISTRICT NO. 9 | DATE FEB. 28, 1962 |
| DRAWN F. CLARK | W.P. NO. 136-59 | JOB NO. - 62-F-8 |
| CHECKED [signature] | CONTRACT NO. | DRAWING NO. |
| APPROVED [signature] | | 62-F-8A |

# ABBREVIATIONS USED IN THIS REPORT

## PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

## DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

| CONSISTENCY | 'N' BLOWS / FT. | c LB. / SQ. FT. | DENSENESS | 'N' BLOWS / FT. |
|---|---|---|---|---|
| VERY SOFT | 0 - 2 | 0 - 250 | VERY LOOSE | 0 - 4 |
| SOFT | 2 - 4 | 250 - 500 | LOOSE | 4 - 10 |
| FIRM | 4 - 8 | 500 - 1000 | COMPACT | 10 - 30 |
| STIFF | 8 - 15 | 1000 - 2000 | DENSE | 30 - 50 |
| VERY STIFF | 15 - 30 | 2000 - 4000 | VERY DENSE | > 50 |
| HARD | > 30 | > 4000 | | |

## TYPE OF SAMPLE

| | | | |
|---|---|---|---|
| S.S. | SPLIT SPOON | T.W. | THINWALL OPEN |
| W.S. | WASHED SAMPLE | T.P. | THINWALL PISTON |
| S.B. | SCRAPER BUCKET SAMPLE | O.S. | OESTERBERG SAMPLE |
| A.S. | AUGER SAMPLE | F.S. | FOIL SAMPLE |
| C.S. | CHUNK SAMPLE | R.C. | ROCK CORE |
| S.T. | SLOTTED TUBE SAMPLE | | |

P.H. SAMPLE ADVANCED HYDRAULICALLY

P.M. SAMPLE ADVANCED MANUALLY

## SOIL TESTS

| | | | |
|---|---|---|---|
| Qu | UNCONFINED COMPRESSION | L.V. | LABORATORY VANE |
| Q | UNDRAINED TRIAXIAL | F.V. | FIELD VANE |
| Qcu | CONSOLIDATED UNDRAINED TRIAXIAL | C | CONSOLIDATION |
| Qd | DRAINED TRIAXIAL | S | SENSITIVITY |

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

# RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 62-F-8 | LOCATION Sta. 16+40 @ ℄ | ORIGINATED BY V.K.

W.P. 136-59 | BORING DATE Feb. 12/62. | COMPILED BY H.S.

DATUM 270.0 | BOREHOLE TYPE Wash Boring, BX Casing | CHECKED BY V.K.

| ELEV. DEPTH | SOIL PROFILE DESCRIPTION | SAMPLE NUMBER | TYPE | BLOWS / FOOT | ELEV. SCALE | WATER CONTENT % (20 40 60) | BULK DENSITY γ P.C.F. | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 270.0 | Groundlevel | | | | 270 | | | Waterlevel in bore-hole. |
| 0.0 | Clayey silt, sand and gravel with frequent boulders Oxidized Very dense (Glacial Till) | 1 | S.S. | 51 | | | 145.0 | |
| 262.0<br>8.0 | | | | | | | | ▽ wl 262' |
| | | | | | 260 | | | |
| | | 2 | S.S. | 54 | | | | |
| | | 3 | S.S. | 45 | | | 148.0 | |
| | Clayey silt, sand and gravel, with frequent boulders Grey Coloured<br>Very dense becoming compact with depth (Glacial Till) | | | | 250 | | | |
| | | 4 | S.S. | 35 | | | | |
| | | 5 | S.S. | 15 | | | | |
| | | 6 | S.S. | 21 | 240 | | | |
| | | 7 | S.S. | 46 | | | | |
| | | | | | 230 | | | |
| 226.5 | | 8 | S.S. | 28 | | | 146.0 | |
| 43.5 | End of borehole. | | | | | | | |

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.

LIQUID LIMIT —— $w_L$; PLASTIC LIMIT —— $w_P$; WATER CONTENT —— $w$

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

# RECORD OF BOREHOLE NO 2

FOUNDATION SECTION

JOB 62-F-8 | LOCATION Sta. 15+05 @ ℄ | ORIGINATED BY V.K.

W.P 136-59 | BORING DATE Feb. 14/62. | COMPILED BY H.S.

DATUM 271.0' | BOREHOLE TYPE Wash Boring, BX Casing | CHECKED BY V.K.

| ELEV / DEPTH | SOIL PROFILE DESCRIPTION | STRAT. PLOT | SAMPLES NUMBER | TYPE | BLOWS / FOOT | ELEV SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT; SHEAR STRENGTH P.S.F. | LIQUID LIMIT wL, PLASTIC LIMIT wP, WATER CONTENT w; WATER CONTENT % 20 40 60 | BULK DENSITY γ P.C.F. | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 271.0 | Groundlevel | | | | | 271 | | | | Assumed W. L. |
| | Clayey silt, sand, gravel and boulders (Glacial Till) Very dense, brown. | | 1 | S.S. | >100 | | | | 142.0 | |
| 263.0 / 8.0 | | | | | | | | | | ▽wl 263' |
| | | | | | | 261 | | | | |
| | | | 2 | S.S. | 96 | | | | | |
| | Clayey silt, sand, gravel and boulders (Glacial Till) Very dense to dense, grey. | | 3 | S.S. | 32 | | | | | |
| | | | | | | 251 | | | | |
| 247.5 / 23.5 | End of borehole. | | 4 | S.S. | 42 | | | | | |
| | | | | | | 241 | | | | |

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

# RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 62-F-8 LOCATION Sta. 13+90 @ ℄ ORIGINATED BY V.K.

W.P. 136-59 BORING DATE Feb. 15/62. COMPILED BY H.S.

DATUM 271.0' BOREHOLE TYPE WashBoring, BX Casing CHECKED BY V.K.

| ELEV. / DEPTH | SOIL PROFILE DESCRIPTION | SAMPLES NUMBER | TYPE | BLOWS / FOOT | ELEV SCALE | WATER CONTENT % (20 40 60) | BULK DENSITY γ P.C.F. | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 271.0 / 0.0 | Groundlevel | | | | 271 | | | Water in borehole. |
| | Clayey silt, sand and gravel with frequent boulders Oxidized Very dense (Glacial Till) | 1 | S.S. | 102 | | o⊢ | 145.6 | |
| 263.5 / 7.5 | | | | | | | | ∇ wl 263.5' |
| | | 2 | S.S. | 94 | 261 | | | |
| | Clayey silt, sand and gravel, with frequent boulders Grey coloured. Very dense becoming compact with depth (Glacial Till) | 3 | S.S. | 26 | | o | | |
| | | | | | 251 | | | |
| | | 4 | S.S. | 27 | | | | |
| | | 5 | S.S. | 17 | 241 | o⊢ | | |
| 231.5 / 39.5 | End of borehole. | 6 | | 83 | 231 | | | |

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.

LIQUID LIMIT — $w_L$ PLASTIC LIMIT — $w_P$ WATER CONTENT — $w$

# APPENDIX D

# LABORATORY TEST RESULTS 2016 INVESTIGATION

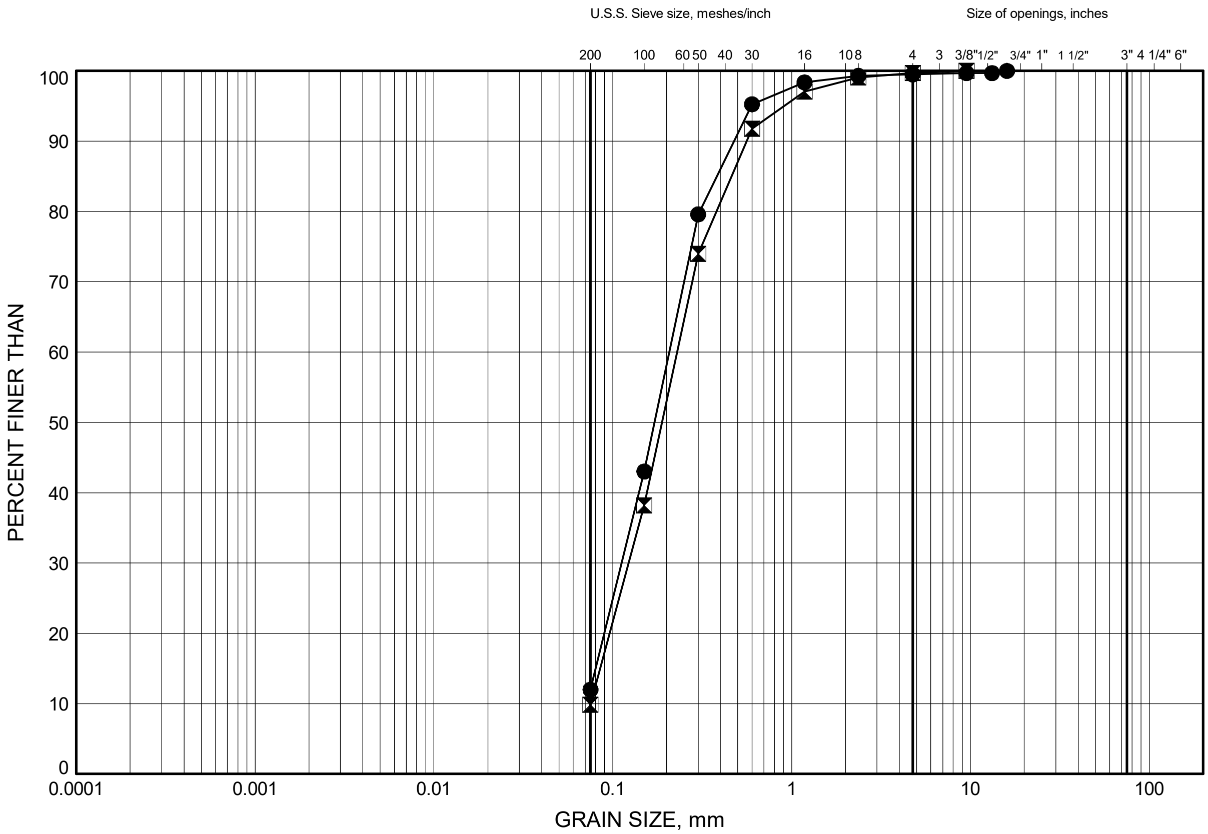
THURBER

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 1

## Fill




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 806 | 1.07 | 88.63 |
| ⧗ | 808 | 0.46 | 89.12 |

GRAIN SIZE DISTRIBUTION - THURBER FLAGG RD UNDERPASS.GPJ 10/6/16

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

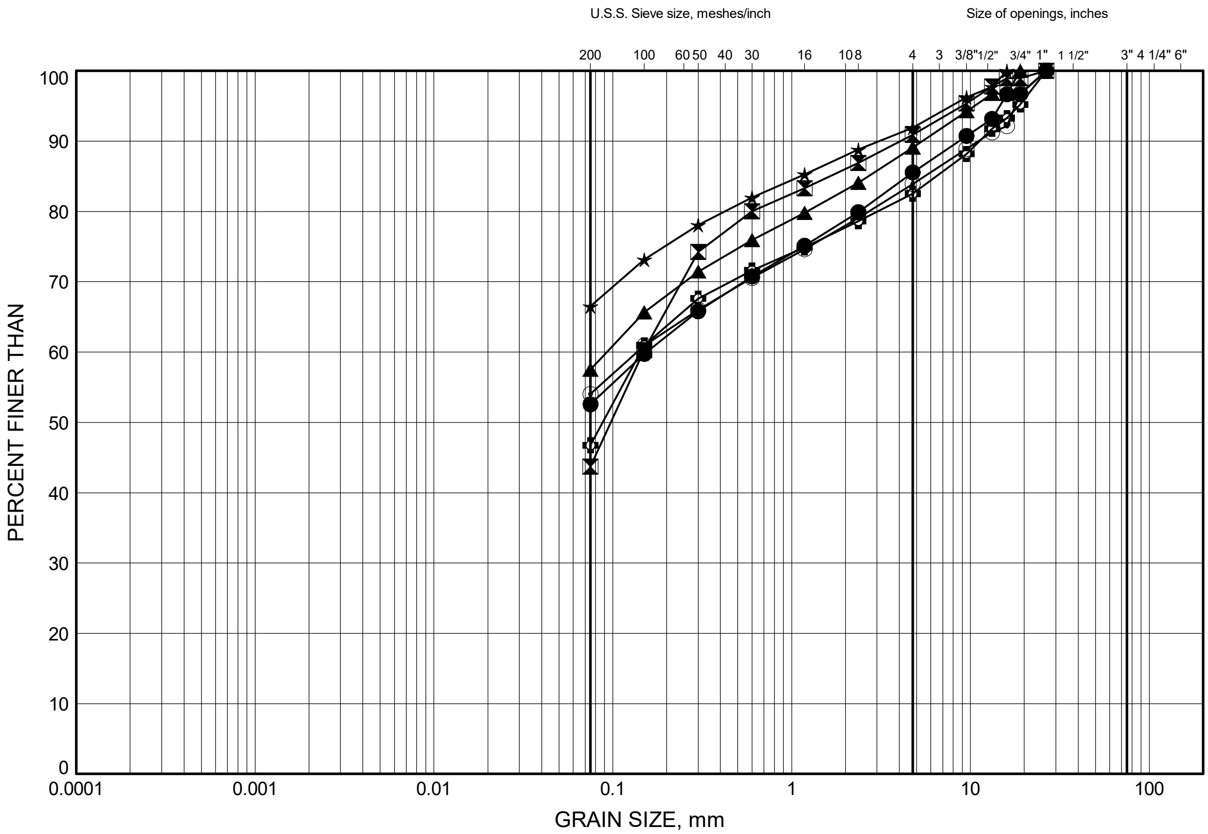
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 2

## Embankment Fill




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 801 | 2.59 | 87.03 |
| ⧗ | 801 | 4.88 | 84.74 |
| ▲ | 802 | 2.59 | 87.11 |
| ★ | 802 | 7.16 | 82.54 |
| ⊙ | 803 | 2.59 | 87.10 |
| ✿ | 806 | 4.11 | 85.58 |

GRAIN SIZE DISTRIBUTION - THURBER FLAGG RD UNDERPASS.GPJ 10/6/16

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

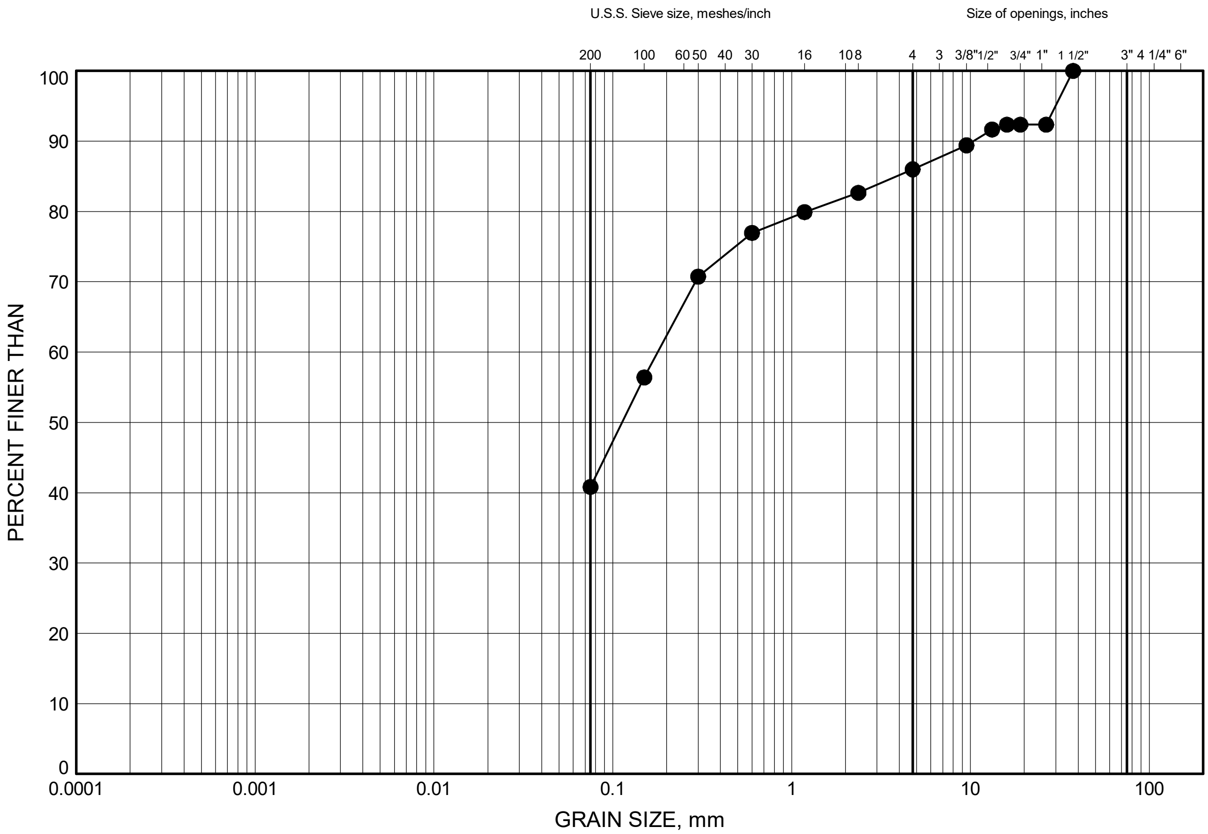
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 3

## Embankment Fill




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

### LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 807 | 6.40 | 83.32 |

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

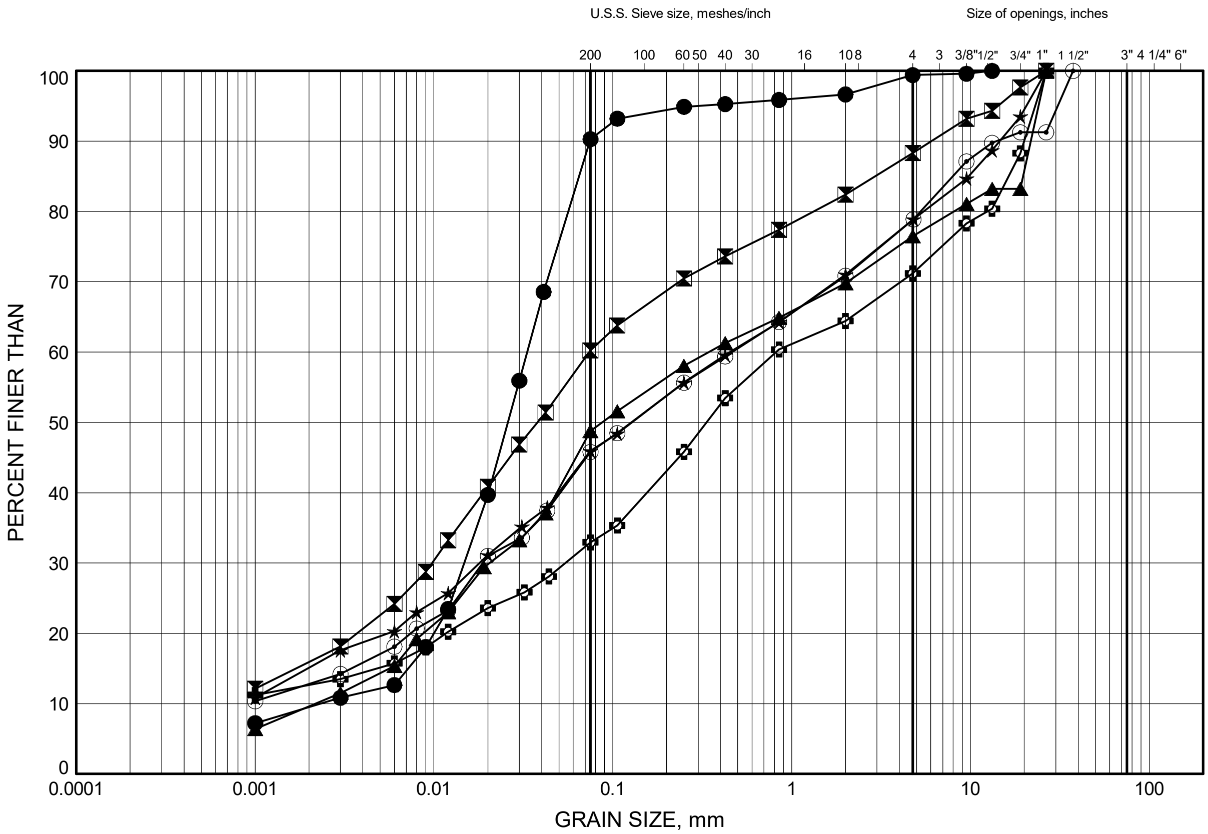
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 4

## Sandy 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) |
|---|---|---|---|
| ● | 804 | 3.35 | 79.95 |
| ⧗ | 805 | 4.88 | 78.42 |
| ▲ | 806 | 7.92 | 81.77 |
| ★ | 806 | 12.80 | 76.90 |
| ⊙ | 806 | 17.07 | 72.63 |
| ✪ | 807 | 8.23 | 81.49 |

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

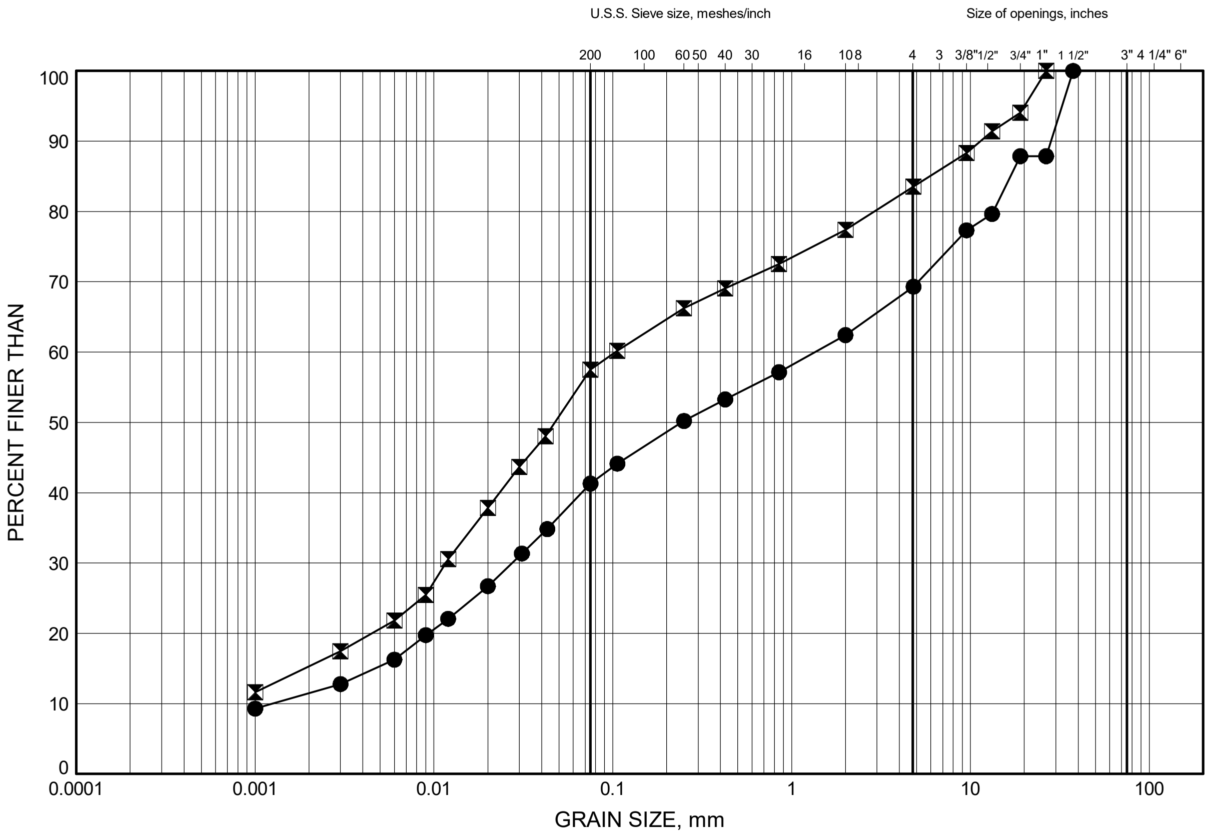
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 5

## Sandy 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) |
|---|---|---|---|
| ● | 807 | 12.50 | 77.22 |
| ⧗ | 808 | 7.92 | 81.65 |



Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

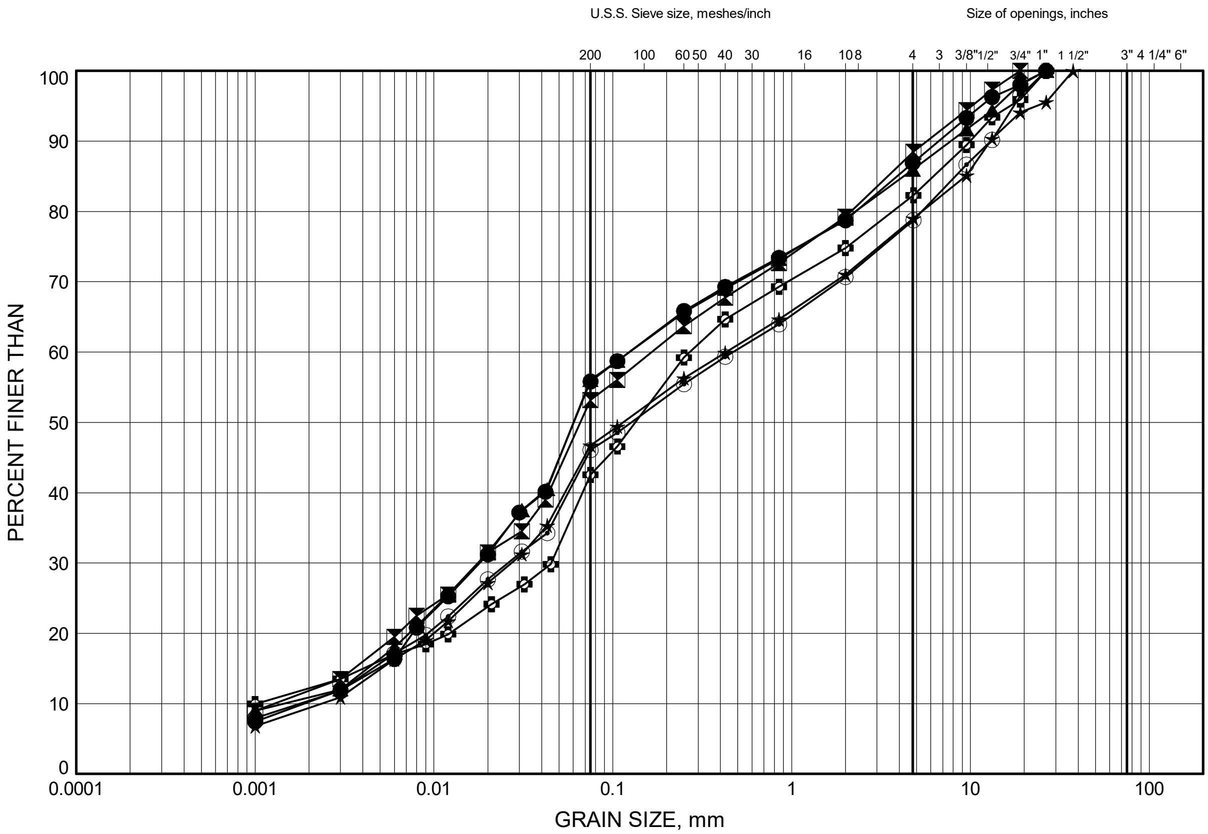
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 6

## Silty Clayey Sand Till




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

### LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 801 | 9.26 | 80.36 |
| ⧗ | 801 | 12.50 | 77.12 |
| ▲ | 802 | 9.45 | 80.26 |
| ★ | 802 | 10.97 | 78.73 |
| ⊙ | 802 | 16.00 | 73.70 |
| ✪ | 802 | 24.69 | 65.02 |

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

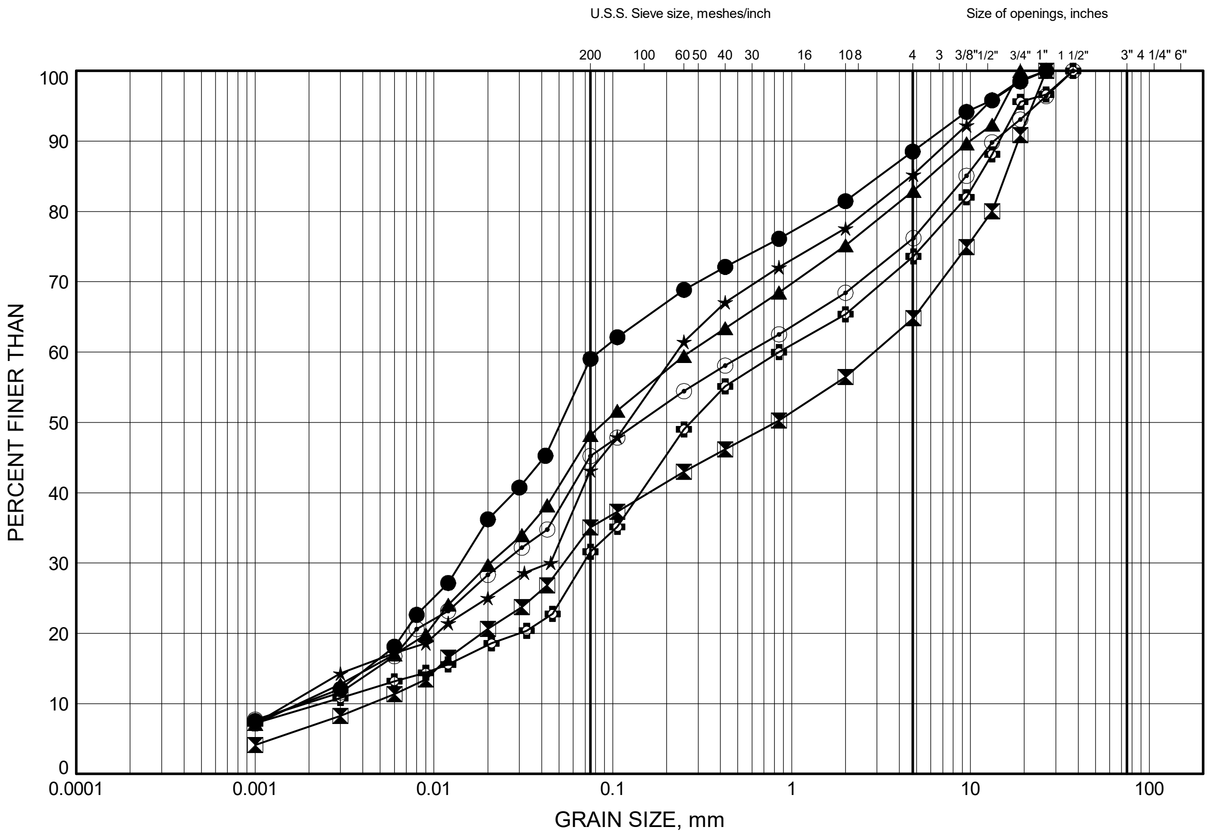
Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 7

## Silty Clayey Sand Till




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 803 | 9.45 | 80.25 |
| ⧗ | 803 | 10.97 | 78.72 |
| ▲ | 803 | 15.54 | 74.15 |
| ★ | 803 | 24.69 | 65.01 |
| ⊙ | 804 | 14.02 | 69.28 |
| ✿ | 804 | 18.59 | 64.71 |

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

Chkd. PC

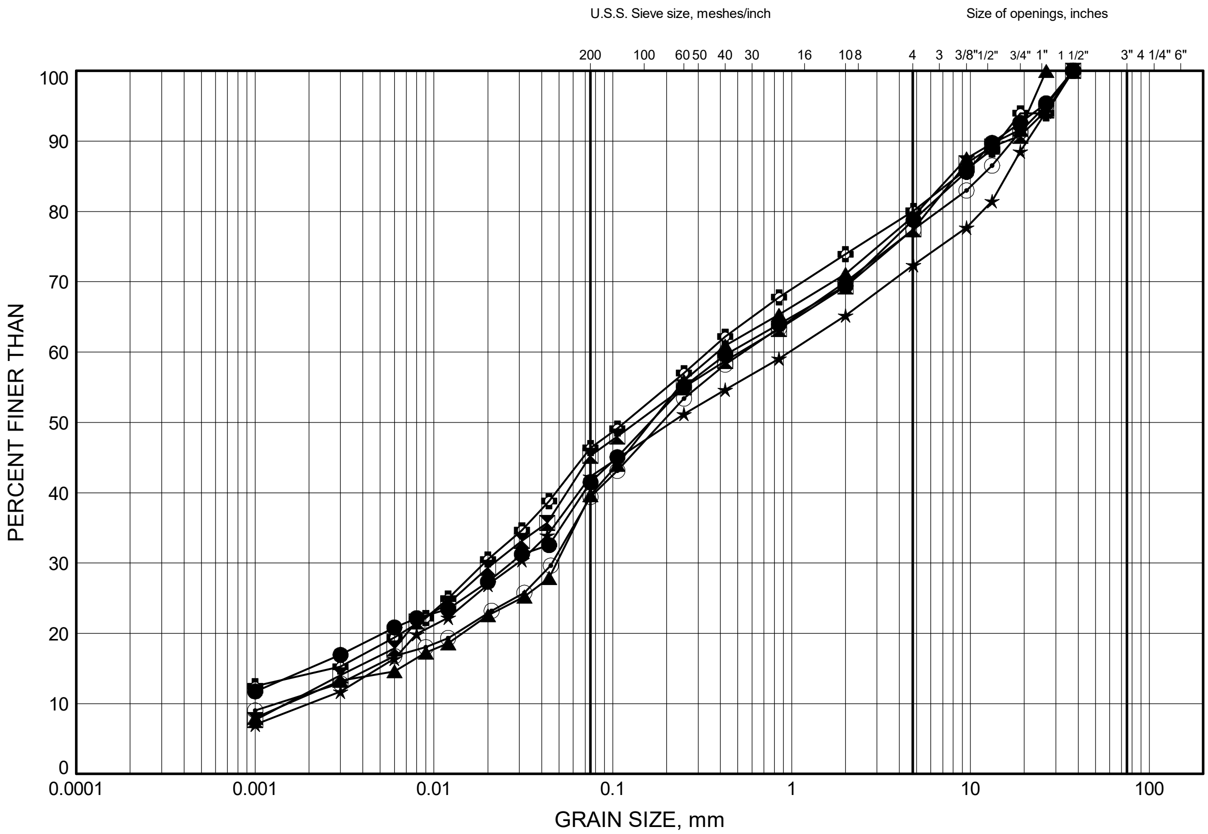
GRAIN SIZE DISTRIBUTION - THURBER FLAGG RD UNDERPASS.GPJ 10/6/16

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 8

## Silty Clayey Sand Till




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 804 | 21.64 | 61.66 |
| ⧗ | 805 | 14.33 | 68.97 |
| ▲ | 805 | 18.59 | 64.71 |
| ★ | 807 | 18.59 | 71.13 |
| ⊙ | 807 | 23.16 | 66.55 |
| ✿ | 808 | 12.50 | 77.08 |

Date October 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

Chkd. PC

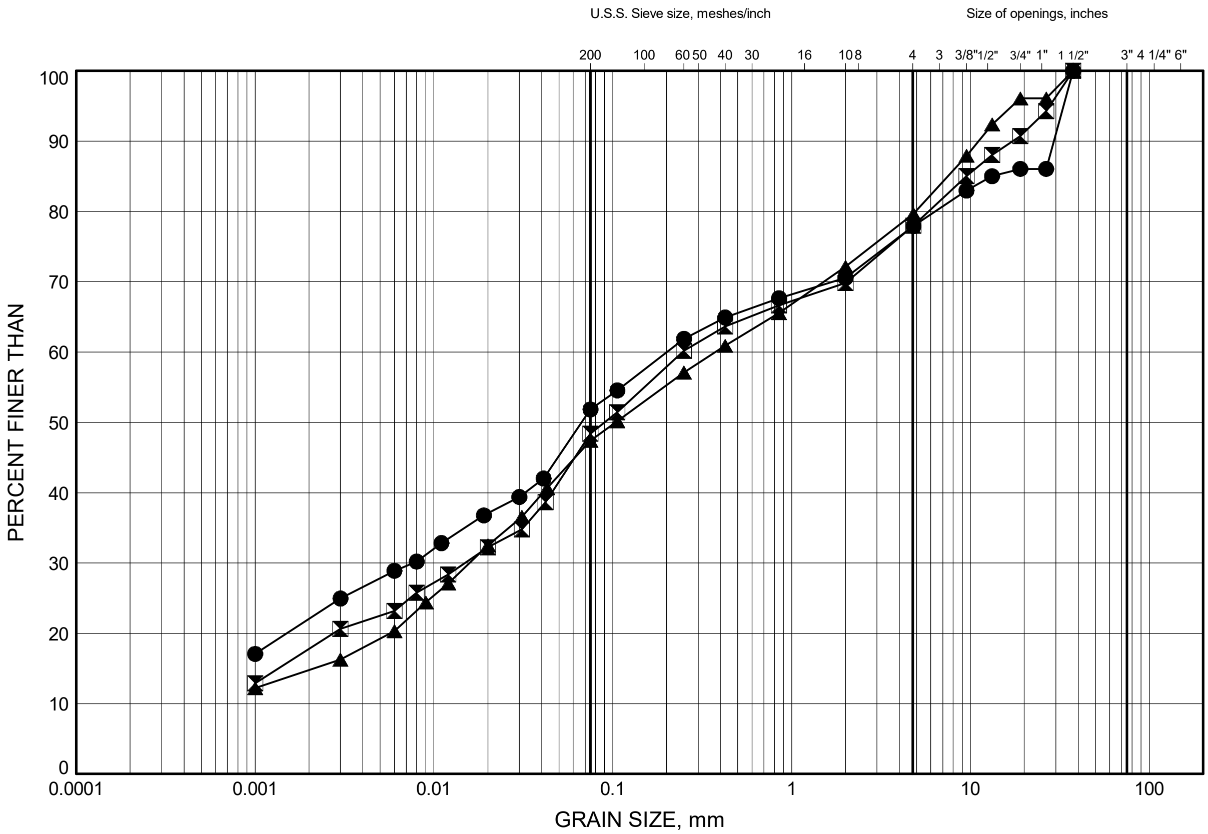
GRAIN SIZE DISTRIBUTION - THURBER FLAGG RD UNDERPASS.GPJ 10/6/16

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# GRAIN SIZE DISTRIBUTION

FIGURE 9

## Silty Clayey Sand Till




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 806 | 28.96 | 60.74 |
| ⧗ | 807 | 28.62 | 61.10 |
| ▲ | 808 | 15.54 | 74.03 |

Date November 2016

GWP# 4445-02-01

THURBER

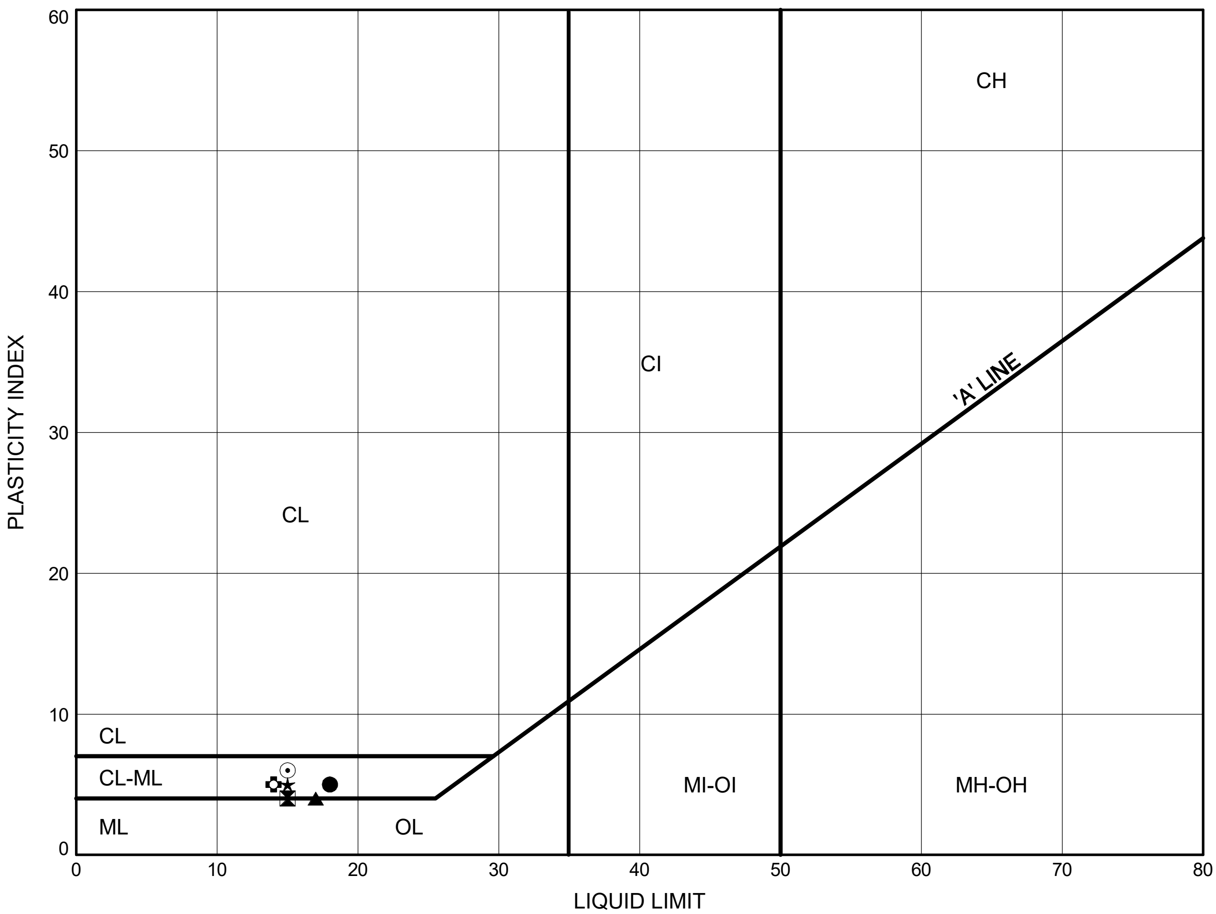
Prep'd KCP

Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# ATTERBERG LIMITS TEST RESULTS

FIGURE 10




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 801 | 9.26 | 80.36 |
| ⧗ | 801 | 12.50 | 77.12 |
| ▲ | 802 | 9.45 | 80.26 |
| ★ | 802 | 10.97 | 78.73 |
| ⊙ | 802 | 16.00 | 73.70 |
| ✿ | 802 | 24.69 | 65.02 |

THURBALT FLAGG RD UNDERPASS.GPJ 21/11/16

Date November 2016

GWP# 4445-02-01

THURBER

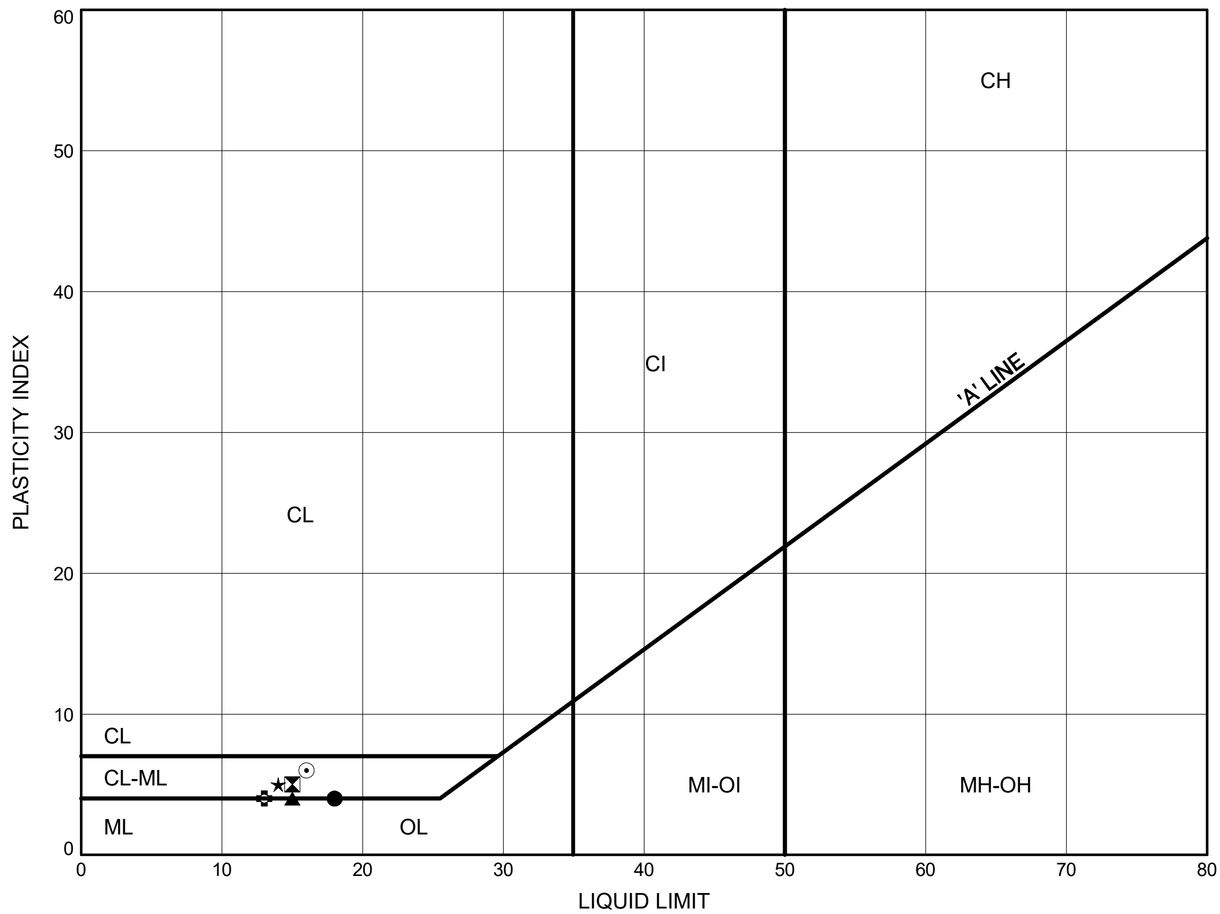
Prep'd KCP

Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# ATTERBERG LIMITS TEST RESULTS

FIGURE 11




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 803 | 9.45 | 80.25 |
| ⧗ | 803 | 10.97 | 78.72 |
| ▲ | 803 | 15.54 | 74.15 |
| ★ | 803 | 24.69 | 65.01 |
| ⊙ | 804 | 14.02 | 69.28 |
| ✿ | 804 | 18.59 | 64.71 |

THURBALT FLAGG RD UNDERPASS.GPJ 21/11/16

Date November 2016

GWP# 4445-02-01

THURBER

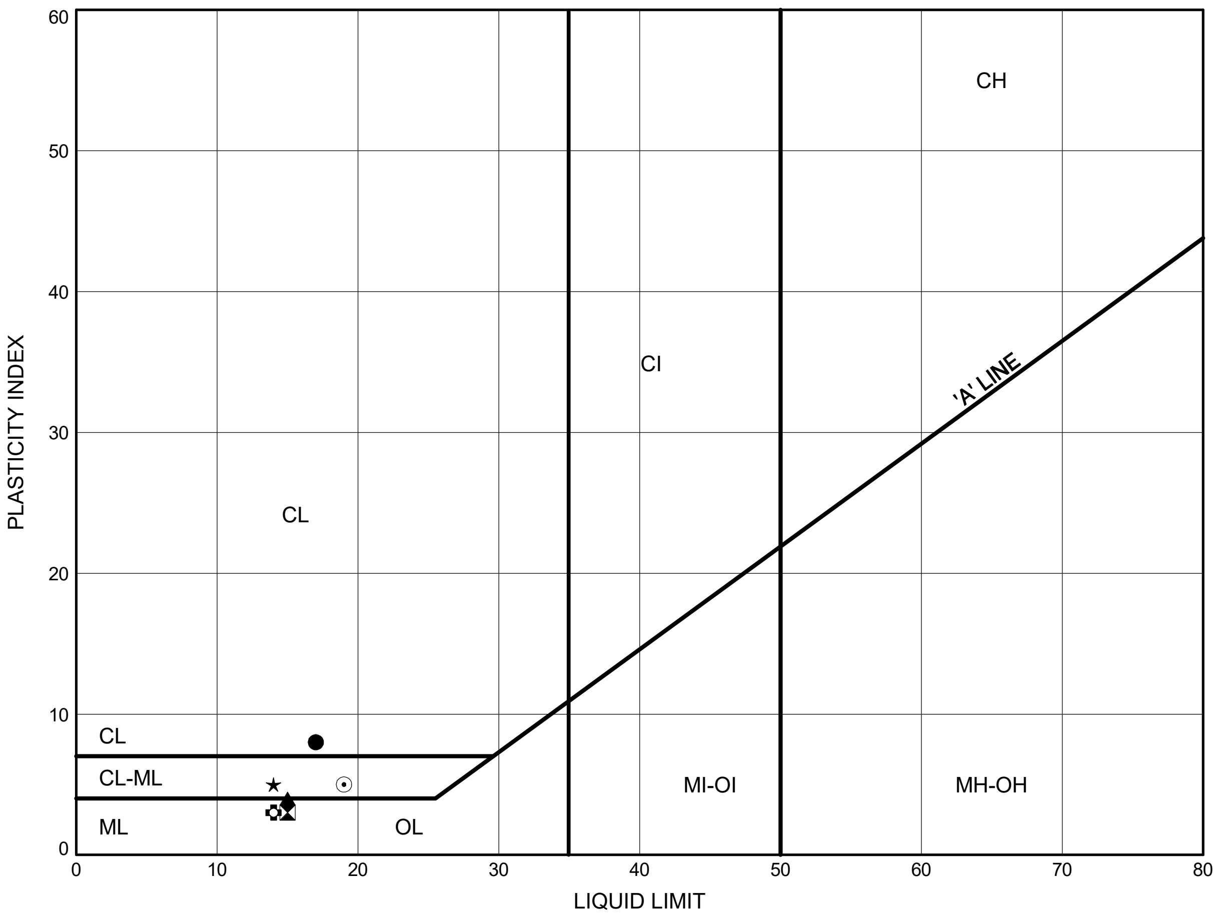
Prep'd KCP

Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# ATTERBERG LIMITS TEST RESULTS

FIGURE 12




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 804 | 21.64 | 61.66 |
| ⧗ | 805 | 4.88 | 78.42 |
| ▲ | 805 | 14.33 | 68.97 |
| ★ | 805 | 18.59 | 64.71 |
| ⊙ | 806 | 7.92 | 81.77 |
| ✪ | 806 | 12.80 | 76.90 |

THURBALT FLAGG RD UNDERPASS.GPJ 21/11/16

Date November 2016

GWP# 4445-02-01

THURBER

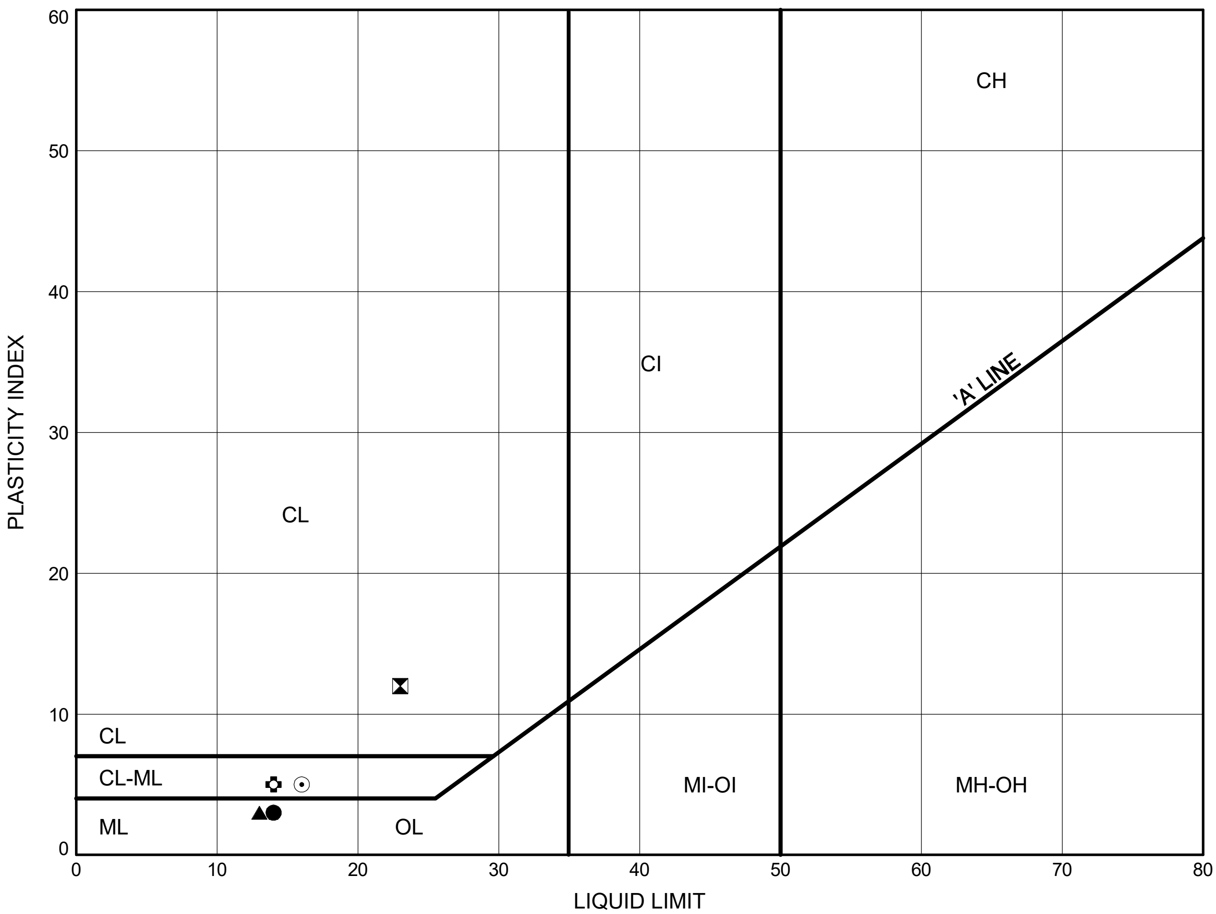
Prep'd KCP

Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# ATTERBERG LIMITS TEST RESULTS

FIGURE 13




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | 806 | 17.07 | 72.63 |
| ⧗ | 806 | 28.96 | 60.74 |
| ▲ | 807 | 8.23 | 81.49 |
| ★ | 807 | 12.50 | 77.22 |
| ⊙ | 807 | 18.59 | 71.13 |
| ✿ | 807 | 23.16 | 66.55 |

THURBALT FLAGG RD UNDERPASS.GPJ 21/11/16

Date November 2016

GWP# 4445-02-01

THURBER

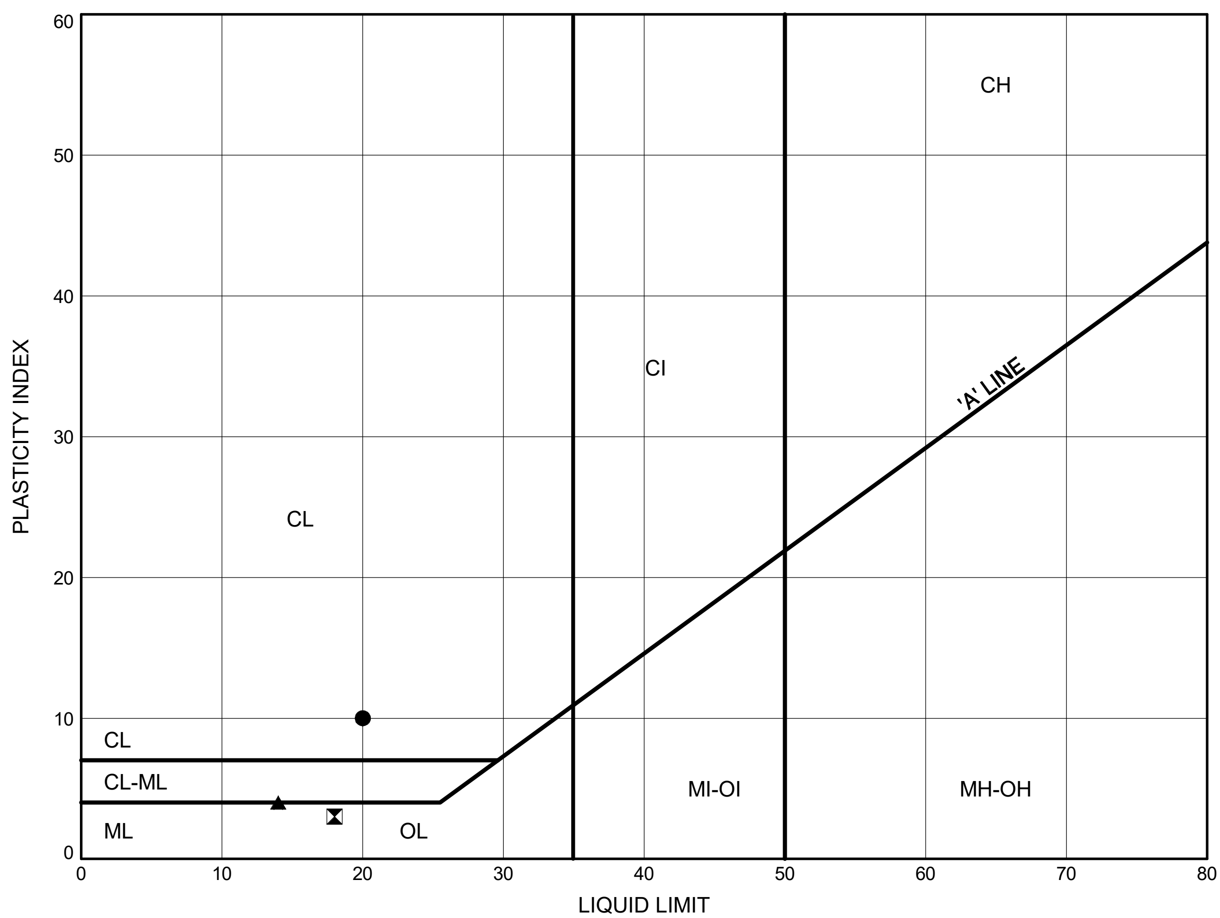
Prep'd KCP

Chkd. PC

Site 31-203 - Highway 401 Underpass at Flagg Rd.

# ATTERBERG LIMITS TEST RESULTS

FIGURE 14




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
| --- | --- | --- | --- |
| ● | 807 | 28.62 | 61.10 |
| ⧗ | 808 | 7.92 | 81.65 |
| ▲ | 808 | 12.50 | 77.08 |
| ★ | 808 | 15.54 | 74.03 |

THURBALT FLAGG RD UNDERPASS.GPJ 21/11/16

Date November 2016

GWP# 4445-02-01

THURBER

Prep'd KCP

Chkd. PC

PARACEL LABORATORIES LTD.
TRUSTED. RESPONSIVE. RELIABLE.

300 - 2319 St. Laurent Blvd
Ottawa, ON, K1G 4J8
1-800-749-1947
www.paracellabs.com

# Certificate of Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO: 19-5161-263
Project: Flagg Rd
Custody: 27355

Report Date: 8-Sep-2016
Order Date: 6-Sep-2016

**Order #: 1637068**

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

| Paracel ID | Client ID |
|---|---|
| 1637068-01 | 801 SS3 5'-7' |
| 1637068-02 | 803 SS5 10'-12' |
| 1637068-03 | 805 SS3 5'-7' |
| 1637068-04 | 808 SS6 12'6"-14'6" |

Approved By: *Mark Foto*

Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis
**Client: Thurber Engineering Ltd.**
**Client PO: 19-5161-263**

Report Date: 08-Sep-2016
Order Date: 6-Sep-2016
**Project Description: Flagg Rd**

## Analysis Summary Table

| Analysis | Method Reference/Description | Extraction Date | Analysis Date |
|---|---|---|---|
| Anions | EPA 300.1 - IC, water extraction | 7-Sep-16 | 7-Sep-16 |
| pH, soil | EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext. | 8-Sep-16 | 8-Sep-16 |
| Resistivity | EPA 120.1 - probe, water extraction | 8-Sep-16 | 8-Sep-16 |
| Solids, % | Gravimetric, calculation | 7-Sep-16 | 7-Sep-16 |

Certificate of Analysis

**Client: Thurber Engineering Ltd.**

**Client PO: 19-5161-263**

Report Date: 08-Sep-2016

Order Date: 6-Sep-2016

**Project Description: Flagg Rd**

| | | | | | |
|---|---|---|---|---|---|
| | **Client ID:** | 801 SS3 5'-7' | 803 SS5 10'-12' | 805 SS3 5'-7' | 808 SS6 12'6"-14'6" |
| | **Sample Date:** | 15-Aug-16 | 29-Aug-16 | 22-Aug-16 | 26-Aug-16 |
| | **Sample ID:** | 1637068-01 | 1637068-02 | 1637068-03 | 1637068-04 |
| | **MDL/Units** | Soil | Soil | Soil | Soil |
| **Physical Characteristics** | | | | | |
| % Solids | 0.1 % by Wt. | 95.6 | 92.5 | 90.0 | 89.6 |
| **General Inorganics** | | | | | |
| pH | 0.05 pH Units | 8.05 | 7.96 | 8.03 | 7.97 |
| Resistivity | 0.10 Ohm.m | 7.42 | 18.0 | 23.2 | 12.3 |
| **Anions** | | | | | |
| Chloride | 5 ug/g dry | 71 | 28 | 136 | 147 |
| Sulphate | 5 ug/g dry | 1500 | 470 | 21 | 541 |

Certificate of Analysis

**Client: Thurber Engineering Ltd.**

**Client PO: 19-5161-263**

Report Date: 08-Sep-2016

Order Date: 6-Sep-2016

**Project Description: Flagg Rd**

## *Method Quality Control: Blank*

| Analyte | Result | Reporting Limit | Units | Source Result | %REC | %REC Limit | RPD | RPD Limit | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Anions** | | | | | | | | | |
| Chloride | ND | 5 | ug/g | | | | | | |
| Sulphate | ND | 5 | ug/g | | | | | | |
| **General Inorganics** | | | | | | | | | |
| Resistivity | ND | 0.10 | Ohm.m | | | | | | |

## *Method Quality Control: Duplicate*

| Analyte | Result | Reporting Limit | Units | Source Result | %REC | %REC Limit | RPD | RPD Limit | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Anions** | | | | | | | | | |
| Chloride | 13.4 | 5 | ug/g dry | 12.7 | | | 4.8 | 20 | |
| Sulphate | 26.8 | 5 | ug/g dry | 26.3 | | | 1.9 | 20 | |
| **General Inorganics** | | | | | | | | | |
| pH | 8.06 | 0.05 | pH Units | 8.05 | | | 0.1 | 10 | |
| Resistivity | 23.3 | 0.10 | Ohm.m | 23.2 | | | 0.5 | 20 | |
| **Physical Characteristics** | | | | | | | | | |
| % Solids | 78.0 | 0.1 | % by Wt. | 80.6 | | | 3.3 | 25 | |

Certificate of Analysis
**Client: Thurber Engineering Ltd.**
**Client PO: 19-5161-263**

Report Date: 08-Sep-2016
Order Date: 6-Sep-2016
**Project Description: Flagg Rd**

## *Method Quality Control: Spike*

| Analyte | Result | Reporting Limit | Units | Source Result | %REC | %REC Limit | RPD | RPD Limit | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Anions** | | | | | | | | | |
| Chloride | 102 | 5 | ug/g | 12.7 | 89.1 | 78-113 | | | |
| Sulphate | 126 | 5 | ug/g | 26.3 | 99.8 | 78-111 | | | |

**Qualifier Notes:**

None

**Sample Data Revisions**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

# APPENDIX E

# SITE PHOTOGRAPHS

**Figure 1: Highway 401 median looking west from Flagg Road**

**Figure 2: Highway 401 median looking east from Flagg Road**

**Figure 3: Underpass looking south towards south embankment and abutment**

**Figure 4: Underpass looking north towards north embankment and abutment**

**Figure 5: Flagg Road looking north**

**Figure 6: Flagg Road looking south**

# APPENDIX F

# COMPARISON OF FOUNDATION ALTERNATIVES

## Comparison of Foundation Alternatives

| Driven Steel Pipe Piles | |
|---|---|
| **Description** | Steel pipe piles driven to bedrock or practical refusal within the glacial till. If driven as closed end pipe piles, the inside would be filled with concrete after driving. |
| **Advantages** | Steel sections readily available in a range of sizes.<br>Conventional equipment used for driving piles. |
| **Disadvantages** | Generally considered more susceptible than H-piles to getting “hung-up” on boulders or damaged during driving in hard conditions.<br>Not commonly used for integral abutments; use with integral abutments would need to be confirmed by structural designer.<br>When driven as closed end pipes, they result in large soil displacement which can cause heave of adjacent piles |
| **Risks / Consequences** | Piles reach refusal on obstructions at shallow depth / need to confirm if required resistance has been achieved (possibly PDA testing). If not, need to add additional piles to pile group, or extract pile, drill down to penetrate obstruction and then re-drive the pile.<br>Piles are damaged during driving / extract or abandon pile in place and add additional piles to pile group.<br>Piles cause heave of adjacent piles / multiple rounds of retapping required to get all piles to refusal.<br>NOTE: These risks can be mitigated by driving the piles to a specified elevation that does not require significant penetration into the glacial, however, the axial resistance would be significantly reduced. The existing abutments are supported on 12 ¾” steel tube piles driven no deeper than 3 m below original ground surface and designed for 40 tons (355 kN) per pile. |
| **Relative Cost** | Moderate |
| **Conclusion** | Not recommended for this site due to high risk of damage and getting hung-up in the till if driving to sufficient depth to achieve high axial resistance. No advantage over driven H-piles for this site. |

THURBER

| Micro-Piles | |
|---|---|
| **Description** | A small diameter drilled pile with a high strength reinforcement bar in the middle surrounded by grout (essentially a rock anchor designed to resist both axial compression and tension loads). |
| **Advantages** | Installed with drills that can penetrate obstructions such as boulders. |
| **Disadvantages** | Low to moderate axial compression loads. A larger number is required to achieve the same overall resistance as driven steel H-piles.<br>Low lateral resistance for an individual micro-pile. Lateral resistance often achieved by installing groups of micro-piles at different inclinations.<br>Not suitable for use with integral abutments. |
| **Risks / Consequences** | May be difficult to control alignment of micropiles due to length and hard drilling conditions / adjustment of design during construction and installation of additional micropiles may be required. |
| **Relative Cost** | High |
| **Conclusion** | Not recommended for this site |

| Driven Steel H-Piles - Integral Abutment | |
|---|---|
| **Description** | The abutment would be supported by a single row of steel H-piles driven to bedrock or practical refusal within the glacial till. Preliminary input from structural engineers indicates that a factored axial resistance at ULS of at least 1600 kN per pile would be required (assuming 8 piles). |
| **Advantages** | Steel H-piles are well suited for use in integral abutment design.<br>Installation of piles can be accommodated around the existing pile group. |
| **Disadvantages** | Steel H-piles can be damaged or “hung-up” on boulders within the glacial till.<br>Integral abutment layout is less forgiving if additional piles are required due to damage to piles during installation or getting hung-up before achieving the required axial resistance. |
| **Risks / Consequences** | Piles reach refusal on obstructions at shallow depth / need to confirm if required resistance has been achieved (possibly PDA testing). If not, need to add additional piles to pile group, or extract pile, drill down to penetrate obstruction and then re-drive the pile.<br>Piles are damaged during driving / extract or abandon pile in place and add additional piles to pile group<br>The risk can be reduced by pre-drilling to a specified elevation in advance of driving. Consideration could also be given to including pre-drilling as a contingency item to be used only if required to advance the piles. |
| **Relative Cost** | Moderate |
| **Conclusion** | Feasible – moderate risk if pre-drilling not carried out |

| Driven Steel H-Piles – Semi-Integral Abutment | |
|---|---|
| **Description** | The abutment would be supported by two rows of steel H-piles driven into the glacial (driving to a set). Preliminary input from structural engineers indicates that a factored axial resistance at ULS of at least 1250 kN per pile would be required (assuming 12 pile arrangement). Pile lengths anticipated to be in the range of 12 to 18 m. |
| **Advantages** | Lower axial design load means piles do not have to be driven as hard, therefore the risk of damage during driving is reduced.<br>Easier to modify pile group layout to add a pile if one is damaged during installation than it is for an integral abutment layout.<br>Installation of piles can be accommodated around the existing pile group. |
| **Disadvantages** | Does not allow for use of an integral abutment design.<br>Pile length may be highly variable (estimated to range from 12 to 18 m).<br>Shorter pile length will result in reduced tensile resistance. |
| **Risks / Consequences** | Piles are damaged during driving / add additional piles to pile group<br>Axial resistance is not achieved at expected tip elevation / continue driving resulting in increased pile length.<br>Overall risk and consequences are considered low since design load is lower than for integral abutment configuration. |
| **Relative Cost** | Moderate |
| **Conclusion** | Feasible |

<table>
<tr><th colspan="2">Augered Concrete Caissons</th></tr>
<tr><td>Description</td><td>A reinforced concrete column installed within an augered hole in the ground that derives axial resistance from shaft friction and/or end-bearing.</td></tr>
<tr><td>Advantages</td><td>High axial geotechnical resistance.</td></tr>
<tr><td>Disadvantages</td><td>Not compatible with integral abutment design approach.<br>Temporary steel casing required to keep hole open during drilling.<br>Can be difficult to clean and inspect the base.<br>Likely requires concrete to be placed using tremie techniques.<br>Significantly slower than drilled in pipe piles approach.<br>Adjustment in proposed span lengths likely required due to potential conflicts with existing piles. Modifications may be significant due to utilities (Bell fibre optic line near south abutment)</td></tr>
<tr><td>Risks / Consequences</td><td>Difficulty penetrating through obstructions such as boulders / construction delays, increased concrete volume if additional soil is pulled in from sidewall while advancing through obstructions. Position and alignment can also be affected by obstructions.</td></tr>
<tr><td>Relative Cost</td><td>High</td></tr>
<tr><td>Conclusion</td><td>Not recommended due to high risk for construction challenges penetrating through boulders.</td></tr>
</table>

| Drilled in Pipe Piles | |
|---|---|
| **Description** | Steel casing is advanced using a down-the-hole hammer with the cuttings/tailings flushed back to surface inside the drill string. Steel casing keeps hole open during drilling and prevents adjacent soil from collapsing into the hole. The casing is left in place as the bearing structure and would be filled with concrete (no rebar). NOTE: this drilling system can also be used with a retrievable casing to construct cast-in-place reinforced concrete caissons. |
| **Advantages** | High geotechnical resistance (5,500 kN at ULS for 610 mm dia.).<br>Drilling system is suitable in almost all ground conditions and well suited for penetrating through boulders.<br>High drilling production rates.<br>Installation of piles can be accommodated around the existing pile group.<br>Well suited for semi-integral abutment arrangement. |
| **Disadvantages** | Smaller number of contractors with suitable equipment.<br>Not commonly used for integral abutments; would require non-traditional detailing and use with integral abutments would need to be confirmed by structural designer. |
| **Risks / Consequences** | Low risk |
| **Relative Cost** | Higher than for driven steel piles. Typical cost per metre for a 610 mm dia. drilled in casing is about 2 to 3 times the cost per metre for driven HP310x110, however axial resistance is also more than double that of the H-pile. Higher unit cost may be offset by fewer piles. |
| **Conclusion** | Feasible, low risk |

# APPENDIX G

# LATERAL SOIL RESPONSE – P-Y DATA

## LPILE Results for P-Y Curves - Flagg Road
***The values P(kN/m) represent soil reaction per metre of pile length**
***The values y(m) represent soil/pile deflection**

### North and South Abutment: Vertical Piles All Directions (HSS 356 x 13)

| Compact Sand Fill (Above WT) | | Compact Sand Fill (Above WT) | | Compact Sand Fill (Above WT) | | Compact Sand Fill (Above WT) | | Till (Above WT) | | Till (Above WT) | | Till (Above WT) | | Till (Below WT) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (m) | | | | | | | | | | | | | | | |
| 0.5 | | 1.5 | | 2.5 | | 3.5 | | 4.5 | | 5.5 | | 6.5 | | 7.5 | |
| y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) |
| 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 |
| 0.0010 | 70.0 | 0.0013 | 120.0 | 0.0015 | 178.5 | 0.0015 | 214.3 | 0.0028 | 469.5 | 0.0028 | 539.6 | 0.0028 | 609.8 | 0.0042 | 680.0 |
| 0.0019 | 134.9 | 0.0025 | 231.3 | 0.0030 | 344.2 | 0.0030 | 413.0 | 0.0056 | 904.9 | 0.0056 | 1040.2 | 0.0056 | 1175.4 | 0.0085 | 1310.7 |
| 0.0029 | 191.0 | 0.0037 | 327.5 | 0.0045 | 487.4 | 0.0045 | 584.9 | 0.0084 | 1281.5 | 0.0084 | 1473.1 | 0.0084 | 1664.6 | 0.0127 | 1856.2 |
| 0.0039 | 236.7 | 0.0050 | 405.9 | 0.0059 | 604.0 | 0.0059 | 724.8 | 0.0111 | 1588.1 | 0.0112 | 1825.4 | 0.0113 | 2062.8 | 0.0169 | 2300.1 |
| 0.0048 | 272.1 | 0.0062 | 466.6 | 0.0074 | 694.3 | 0.0074 | 833.1 | 0.0139 | 1825.4 | 0.0140 | 2098.3 | 0.0141 | 2371.1 | 0.0211 | 2644.0 |
| 0.0058 | 298.5 | 0.0075 | 511.8 | 0.0089 | 761.5 | 0.0089 | 913.8 | 0.0167 | 2002.3 | 0.0168 | 2301.6 | 0.0169 | 2600.8 | 0.0254 | 2900.1 |
| 0.0068 | 317.5 | 0.0087 | 544.5 | 0.0104 | 810.2 | 0.0104 | 972.2 | 0.0195 | 2130.3 | 0.0196 | 2448.7 | 0.0197 | 2767.1 | 0.0296 | 3085.5 |
| 0.0078 | 331.1 | 0.0100 | 567.6 | 0.0119 | 844.7 | 0.0119 | 1013.6 | 0.0223 | 2221.0 | 0.0224 | 2552.9 | 0.0225 | 2884.9 | 0.0338 | 3216.8 |
| 0.0087 | 340.5 | 0.0112 | 583.8 | 0.0133 | 868.8 | 0.0133 | 1042.5 | 0.0251 | 2284.3 | 0.0252 | 2625.7 | 0.0253 | 2967.1 | 0.0380 | 3308.5 |
| 0.0097 | 347.0 | 0.0125 | 595.0 | 0.0148 | 885.4 | 0.0148 | 1062.5 | 0.0278 | 2328.0 | 0.0280 | 2676.0 | 0.0281 | 3023.9 | 0.0423 | 3371.9 |
| 0.0107 | 351.5 | 0.0137 | 602.7 | 0.0163 | 896.8 | 0.0163 | 1076.2 | 0.0306 | 2358.0 | 0.0308 | 2710.4 | 0.0309 | 3062.9 | 0.0465 | 3415.3 |
| 0.0116 | 354.5 | 0.0149 | 607.9 | 0.0178 | 904.6 | 0.0178 | 1085.5 | 0.0334 | 2378.5 | 0.0336 | 2734.0 | 0.0338 | 3089.5 | 0.0507 | 3445.0 |
| 0.0126 | 356.6 | 0.0162 | 611.5 | 0.0193 | 909.9 | 0.0193 | 1091.9 | 0.0362 | 2392.4 | 0.0364 | 2750.0 | 0.0366 | 3107.5 | 0.0549 | 3465.1 |
| 0.0136 | 358.0 | 0.0174 | 613.9 | 0.0208 | 913.5 | 0.0208 | 1096.2 | 0.0390 | 2401.8 | 0.0392 | 2760.8 | 0.0394 | 3119.8 | 0.0592 | 3478.8 |
| 0.0145 | 359.0 | 0.0187 | 615.5 | 0.0222 | 915.9 | 0.0222 | 1099.1 | 0.0418 | 2408.2 | 0.0420 | 2768.2 | 0.0422 | 3128.1 | 0.0634 | 3488.1 |
| 0.0155 | 359.6 | 0.0199 | 616.6 | 0.0237 | 917.6 | 0.0237 | 1101.1 | 0.0445 | 2412.5 | 0.0448 | 2773.1 | 0.0450 | 3133.7 | 0.0676 | 3494.3 |

| Till (Below WT) | | Till (Below WT) | | Till (Below WT) | | Till (Below WT) | | Till (Below WT) | | Till (Below WT) | | Till (Below WT) | | Till (Below WT) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.5 | | 9.5 | | 10.5 | | 11.5 | | 12.5 | | 13.5 | | 14.5 | | 15.5 (or deeper) | |
| y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) |
| 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 |
| 0.0041 | 716.7 | 0.0039 | 753.5 | 0.0038 | 790.2 | 0.0037 | 827.0 | 0.0036 | 863.7 | 0.0035 | 900.5 | 0.0034 | 937.2 | 0.0034 | 974.0 |
| 0.0081 | 1381.5 | 0.0078 | 1452.4 | 0.0076 | 1523.2 | 0.0073 | 1594.1 | 0.0072 | 1664.9 | 0.0070 | 1735.7 | 0.0069 | 1806.6 | 0.0067 | 1877.4 |
| 0.0122 | 1956.5 | 0.0117 | 2056.8 | 0.0113 | 2157.2 | 0.0110 | 2257.5 | 0.0107 | 2357.8 | 0.0105 | 2458.2 | 0.0103 | 2558.5 | 0.0101 | 2658.8 |
| 0.0162 | 2424.5 | 0.0156 | 2548.8 | 0.0151 | 2673.1 | 0.0147 | 2797.5 | 0.0143 | 2921.8 | 0.0140 | 3046.1 | 0.0137 | 3170.5 | 0.0135 | 3294.8 |
| 0.0202 | 2786.9 | 0.0195 | 2929.8 | 0.0189 | 3072.7 | 0.0184 | 3215.6 | 0.0179 | 3358.5 | 0.0175 | 3501.5 | 0.0171 | 3644.4 | 0.0168 | 3787.3 |
| 0.0243 | 3056.9 | 0.0234 | 3213.6 | 0.0227 | 3370.4 | 0.0220 | 3527.2 | 0.0215 | 3683.9 | 0.0210 | 3840.7 | 0.0206 | 3997.4 | 0.0202 | 4154.2 |
| 0.0283 | 3252.3 | 0.0273 | 3419.0 | 0.0264 | 3585.8 | 0.0257 | 3752.6 | 0.0251 | 3919.4 | 0.0245 | 4086.2 | 0.0240 | 4252.9 | 0.0235 | 4419.7 |
| 0.0324 | 3390.7 | 0.0312 | 3564.6 | 0.0302 | 3738.5 | 0.0294 | 3912.4 | 0.0286 | 4086.2 | 0.0280 | 4260.1 | 0.0274 | 4434.0 | 0.0269 | 4607.9 |
| 0.0364 | 3487.4 | 0.0351 | 3666.2 | 0.0340 | 3845.0 | 0.0330 | 4023.9 | 0.0322 | 4202.7 | 0.0315 | 4381.6 | 0.0308 | 4560.4 | 0.0303 | 4739.2 |
| 0.0405 | 3554.1 | 0.0390 | 3736.4 | 0.0378 | 3918.7 | 0.0367 | 4100.9 | 0.0358 | 4283.2 | 0.0350 | 4465.4 | 0.0343 | 4647.7 | 0.0336 | 4830.0 |
| 0.0445 | 3599.9 | 0.0429 | 3784.5 | 0.0416 | 3969.1 | 0.0404 | 4153.8 | 0.0394 | 4338.4 | 0.0385 | 4523.0 | 0.0377 | 4707.6 | 0.0370 | 4892.2 |
| 0.0486 | 3631.2 | 0.0468 | 3817.4 | 0.0453 | 4003.6 | 0.0440 | 4189.8 | 0.0429 | 4376.0 | 0.0420 | 4562.2 | 0.0411 | 4748.4 | 0.0404 | 4934.7 |
| 0.0526 | 3652.4 | 0.0507 | 3839.7 | 0.0491 | 4027.0 | 0.0477 | 4214.3 | 0.0465 | 4401.6 | 0.0455 | 4588.9 | 0.0445 | 4776.2 | 0.0437 | 4963.5 |
| 0.0567 | 3666.8 | 0.0546 | 3854.9 | 0.0529 | 4042.9 | 0.0514 | 4231.0 | 0.0501 | 4419.0 | 0.0490 | 4607.1 | 0.0480 | 4795.1 | 0.0471 | 4983.1 |
| 0.0607 | 3676.6 | 0.0585 | 3865.1 | 0.0567 | 4053.7 | 0.0551 | 4242.2 | 0.0537 | 4430.8 | 0.0525 | 4619.3 | 0.0514 | 4807.9 | 0.0504 | 4996.4 |
| 0.0648 | 3683.2 | 0.0624 | 3872.1 | 0.0604 | 4061.0 | 0.0587 | 4249.9 | 0.0573 | 4438.7 | 0.0560 | 4627.6 | 0.0548 | 4816.5 | 0.0538 | 5005.4 |

### North and South Abutment: Loose Sand (Top 3m)

| Loose Sand (Above WT) | | Loose Sand (Above WT) | | Loose Sand (Above WT) | |
|---|---|---|---|---|---|
| Depth (m) | | | | | |
| 0.5 | | 1.5 | | 2.5 | |
| y (m) | P (kN/m) | y (m) | P (kN/m) | y (m) | P (kN/m) |
| 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 |
| 0.0023 | 7.6 | 0.0022 | 22.2 | 0.0033 | 56.0 |
| 0.0045 | 14.6 | 0.0044 | 42.9 | 0.0067 | 107.9 |
| 0.0068 | 20.7 | 0.0066 | 60.7 | 0.0100 | 152.8 |
| 0.0090 | 25.6 | 0.0088 | 75.2 | 0.0134 | 189.3 |
| 0.0113 | 29.4 | 0.0111 | 86.5 | 0.0167 | 217.6 |
| 0.0136 | 32.3 | 0.0133 | 94.8 | 0.0200 | 238.7 |
| 0.0158 | 34.3 | 0.0155 | 100.9 | 0.0234 | 253.9 |
| 0.0181 | 35.8 | 0.0177 | 105.2 | 0.0267 | 264.8 |
| 0.0203 | 36.8 | 0.0199 | 108.2 | 0.0301 | 272.3 |
| 0.0226 | 37.5 | 0.0221 | 110.3 | 0.0334 | 277.5 |
| 0.0248 | 38.0 | 0.0243 | 111.7 | 0.0367 | 281.1 |
| 0.0271 | 38.3 | 0.0265 | 112.6 | 0.0401 | 283.5 |
| 0.0294 | 38.6 | 0.0287 | 113.3 | 0.0434 | 285.2 |
| 0.0316 | 38.7 | 0.0310 | 113.8 | 0.0468 | 286.3 |
| 0.0339 | 38.8 | 0.0332 | 114.1 | 0.0501 | 287.1 |
| 0.0361 | 38.9 | 0.0354 | 114.3 | 0.0534 | 287.6 |

# APPENDIX H

## GSC SEISMIC HAZARD CALCULATION
## SLOPE STABILITY ANALYSIS RESULTS
## LIST OF REFERENCED SPECIFICATIONS

# 2015 National Building Code Seismic Hazard Calculation

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

October 06, 2016

Site: 44.8921 N, 75.259 W User File Reference: Flagg Rd

Requested by: , Thurber Engineering Ltd.

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

| Sa(0.05) | Sa(0.1) | **Sa(0.2)** | Sa(0.3) | **Sa(0.5)** | **Sa(1.0)** | **Sa(2.0)** | **Sa(5.0)** | **Sa(10.0)** | **PGA (g)** | **PGV (m/s)** |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.578 | 0.661 | **0.540** | 0.402 | **0.278** | **0.132** | **0.060** | **0.016** | **0.0055** | **0.346** | **0.228** |

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

Ground motions for other probabilities:

| | | | |
|---|---|---|---|
| Probability of exceedance per annum | 0.010 | 0.0021 | 0.001 |
| Probability of exceedance in 50 years | 40% | 10% | 5% |
| Sa(0.05) | 0.045 | 0.179 | 0.313 |
| Sa(0.1) | 0.062 | 0.220 | 0.370 |
| Sa(0.2) | 0.056 | 0.186 | 0.307 |
| Sa(0.3) | 0.045 | 0.141 | 0.229 |
| Sa(0.5) | 0.032 | 0.098 | 0.158 |
| Sa(1.0) | 0.016 | 0.047 | 0.076 |
| Sa(2.0) | 0.0062 | 0.021 | 0.035 |
| Sa(5.0) | 0.0012 | 0.0048 | 0.0084 |
| Sa(10.0) | 0.0006 | 0.0019 | 0.0032 |
| PGA | 0.033 | 0.118 | 0.197 |
| PGV | 0.022 | 0.075 | 0.126 |

**References**

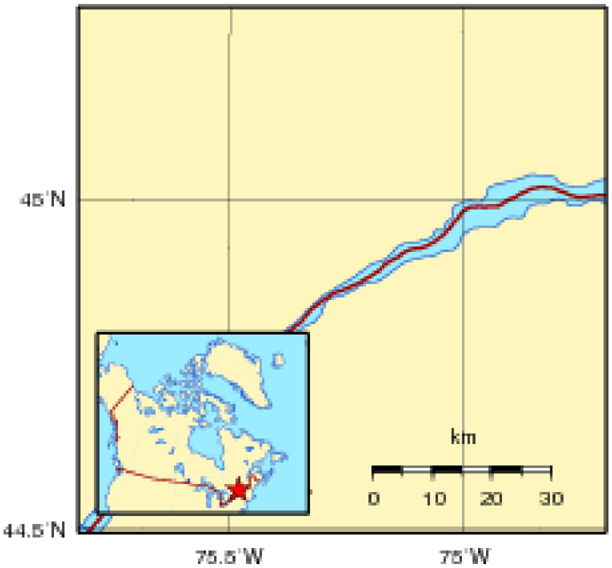

**National Building Code of Canada 2015 NRCC no. 56190;**
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

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

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


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

*Aussi disponible en français*



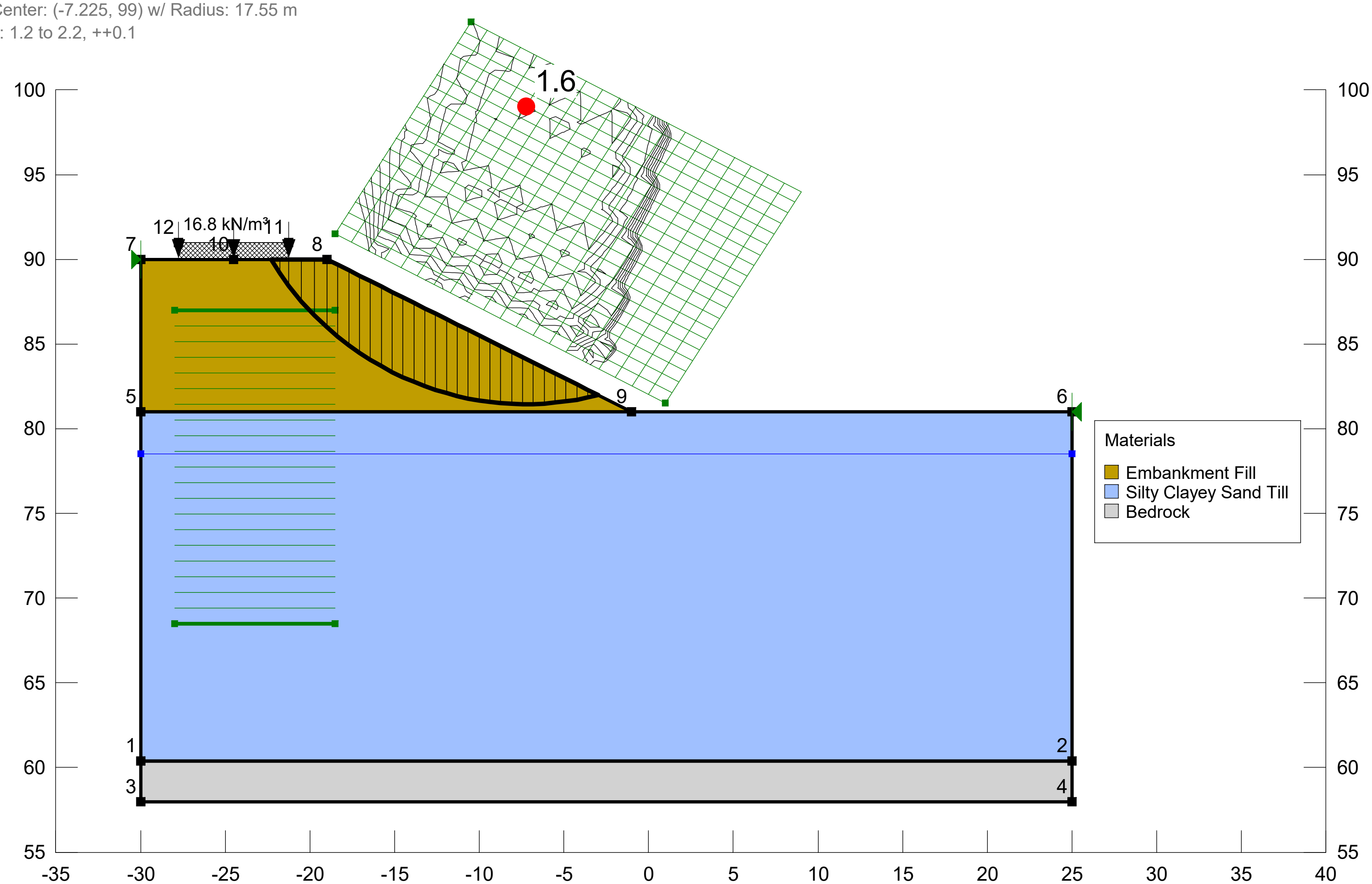

Natural Resources Canada   Ressources naturelles Canada

Canada

# Title: Overpass Replacement at Flagg Rd
# Comments: Existing Conditions
# Name: Static

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic: H\ 0  V\ 0
Slip Surface Center: (-7.225, 99) w/ Radius: 17.55 m
FoS Contours: 1.2 to 2.2, ++0.1

| | | | |
|---|---|---|---|
| Embankment Fill | 20 kN/m³ | 0 kPa | 30 ° |
| Silty Clayey Sand Till | 21 kN/m³ | 0 kPa | 35 ° |
| Bedrock | | | |



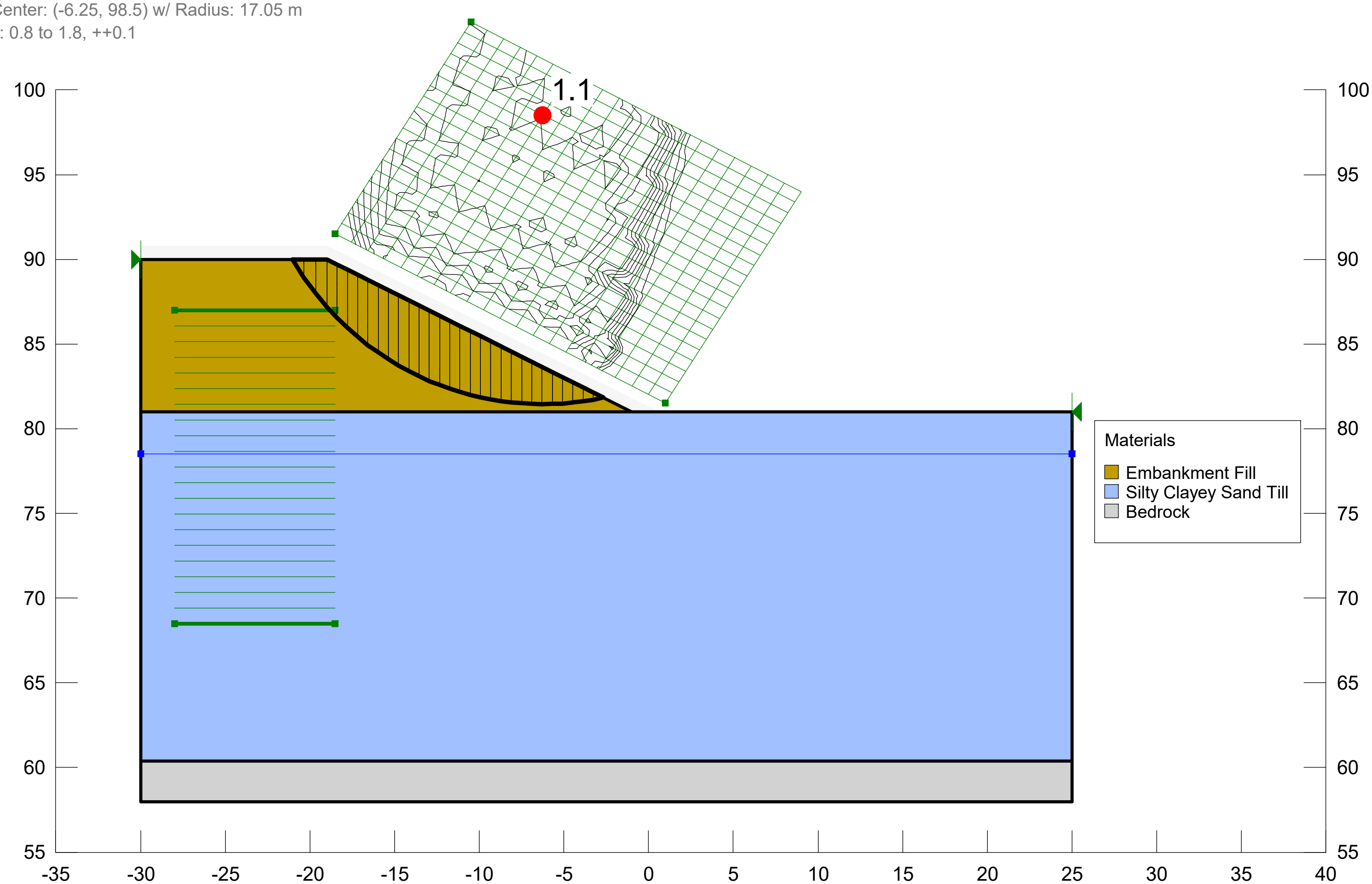

Reviewed By: _______________
Tool Version: 8.15.5.11777
Last Solved Date: 11/22/2016, 12:28:37 PM
Directory: H:\Projects\19\5161\263 - ER Mega 5\Bridges\Site 31-203-Flagg Rd Underpass\Foundations\Analysis\SlopeW\Flagg Rd 2016-11-22.gsz

Figure 1

# Title: Overpass Replacement at Flagg Rd
# Comments: Existing Conditions
# Name: Seismic

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic: H\ 0.167 V\ 0
Slip Surface Center: (-6.25, 98.5) w/ Radius: 17.05 m
FoS Contours: 0.8 to 1.8, ++0.1

| | | | |
|---|---|---|---|
| Embankment Fill | 20 kN/m³ | 0 kPa | 30 ° |
| Silty Clayey Sand Till | 21 kN/m³ | 0 kPa | 35 ° |
| Bedrock | | | |



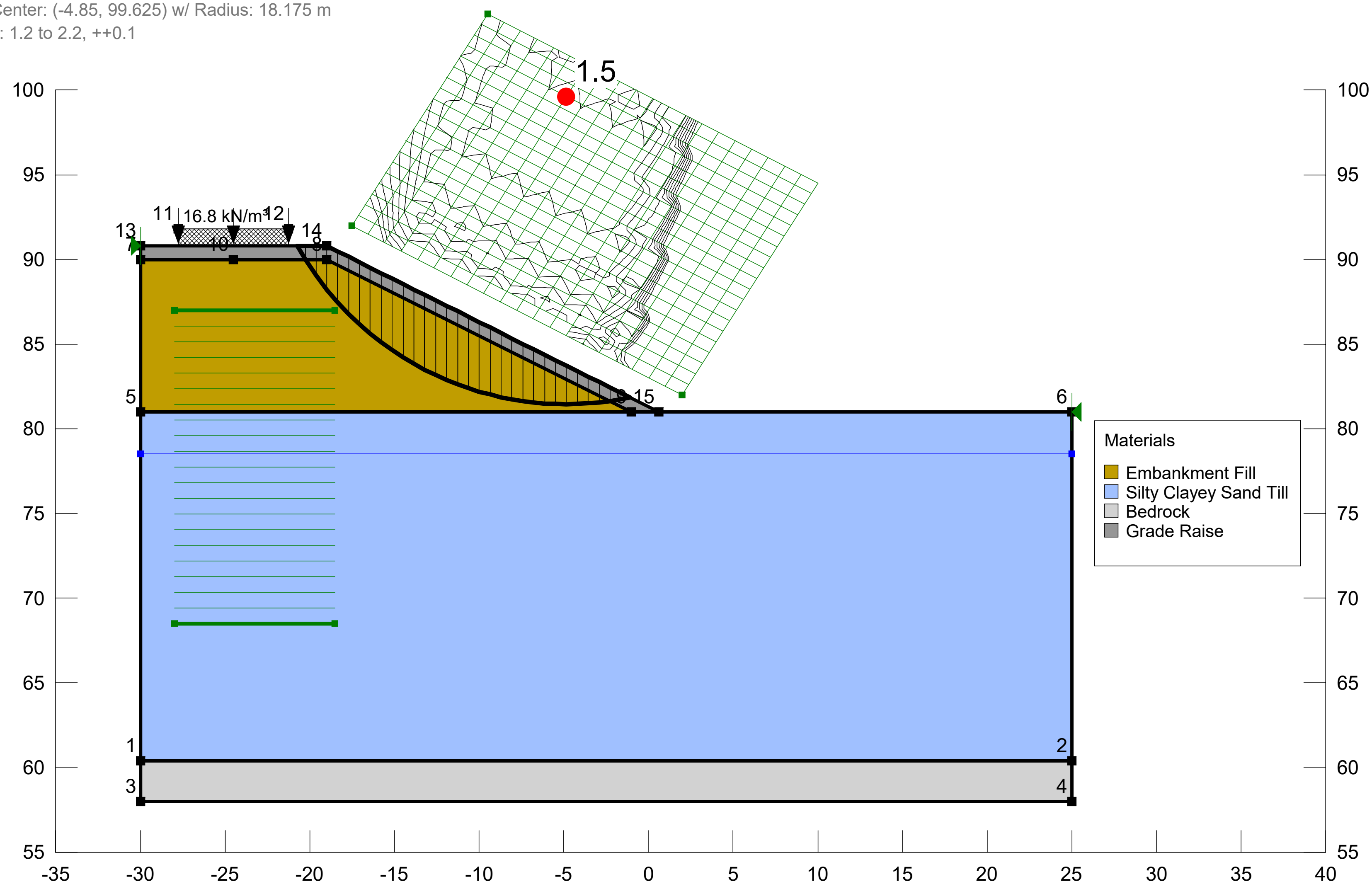

Reviewed By: _______________
Tool Version: 8.15.5.11777
Last Solved Date: 11/23/2016, 4:38:36 PM
Directory: H:\Projects\19\5161\263 - ER Mega 5\Bridges\Site 31-203-Flagg Rd Underpass\Foundations\Analysis\SlopeW\Flagg Rd 2016-11-22.gsz

Figure 2

Title: Overpass Replacement at Flagg Rd
Comments: Proposed Construction
Name: Grade Raise Static

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic: H\ 0 V\ 0
Slip Surface Center: (-4.85, 99.625) w/ Radius: 18.175 m
FoS Contours: 1.2 to 2.2, ++0.1

| | | | |
|---|---|---|---|
| Embankment Fill | 20 kN/m³ | 0 kPa | 30 ° |
| Silty Clayey Sand Till | 21 kN/m³ | 0 kPa | 35 ° |
| Bedrock | | | |
| Grade Raise | 21 kN/m³ | 0 kPa | 35 ° |



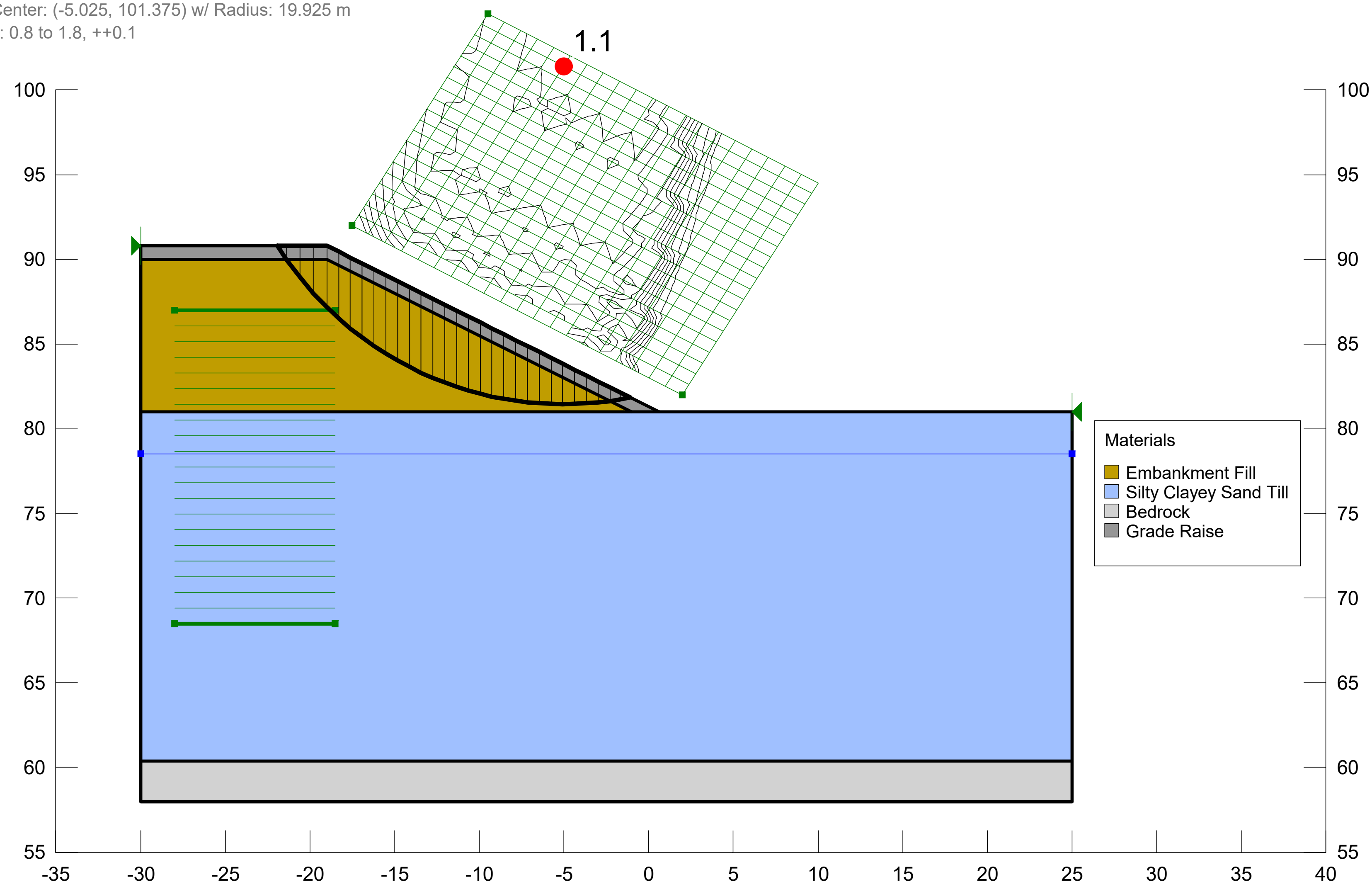

Reviewed By: ________________
Tool Version: 8.15.5.11777
Last Solved Date: 11/22/2016, 1:05:53 PM
Directory: H:\Projects\19\5161\263 - ER Mega 5\Bridges\Site 31-203-Flagg Rd Underpass\Foundations\Analysis\SlopeW\Flagg Rd 2016-11-22.gsz

Figure 3

Title: Overpass Replacement at Flagg Rd
Comments: Proposed Construction
Name: Grade Raise Seismic

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic: H\ 0.167  V\ 0
Slip Surface Center: (-5.025, 101.375) w/ Radius: 19.925 m
FoS Contours: 0.8 to 1.8, ++0.1

Embankment Fill  20 kN/m³  0 kPa  30 °
Silty Clayey Sand Till  21 kN/m³  0 kPa  35 °
Bedrock
Grade Raise  21 kN/m³  0 kPa  35 °




Reviewed By: ______________
Tool Version: 8.15.5.11777
Last Solved Date: 11/23/2016, 4:37:13 PM
Directory: H:\Projects\19\5161\263 - ER Mega 5\Bridges\Site 31-203-Flagg Rd Underpass\Foundations\Analysis\SlopeW\Flagg Rd 2016-11-22.gsz

Figure 4

## LIST OF REFERENCED SPECIFICATIONS

| | |
|---|---|
| OPSD 3090.101 | Foundation, Frost Penetration Depths for Southern Ontario |
| OPSS.PROV 206 | Construction Specification for Grading |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS.PROV 517 | Construction Specification for Dewatering |
| OPSS.PROV 539 | Construction Specification for Temporary Protection Systems |
| OPSS.PROV 804 | Construction Specification for Seed and Cover |
| OPSS 805 | Construction Specification for Temporary Erosion and Sediment Control Measures |
| OPSS 902 | Construction Specification for Excavating and Backfilling-Structures |
| OPSS.PROV 903 | Construction Specification for Deep Foundations |
| OPSS.PROV 1010 | Material Specification for Aggregates - Base, Subbase, Select Subgrade, and Backfill Material |

# APPENDIX I

# NON-STANDARD SPECIAL PROVISIONS

**SUGGESTED TEXT FOR "NSSP – 902.07.05 EXCAVATION"**

Subsection 902.07.05 of OPSS 902 is amended by the addition of the following:

Excavations at the site may be impeded by obstructions within the existing fill and glacial till. The contractor shall be prepared to dislodge and remove these obstructions and extend the excavations to the design depths.

Reference can be made to the Foundation Investigation Report for the Replacement of the Replacement of Highway 401 at Flagg Road, prepared by Thurber Engineering Ltd., 2017, for further details on likely subsurface conditions at the foundation locations.

**SUGGESTED TEXT FOR "NSSP – CONSTRUCTION OF DRILLED-IN PIPE PILES"**

Installation of drilled-in pipe piles shall be in accordance with OPSS.PROV 903 and the following. The Contractor is further advised of the following:

- The drilled-in pipe piles will be installed into bedrock through ground conditions that include fill and glacial till. The Contractor's drilling method must be capable of dislodging, removing or penetrating obstructions such as cobbles, boulders or other obstructions within the fill and glacial till and of penetrating into the bedrock. The drilling method must be capable of advancing the pile without disturbing or fracturing the bedrock at the base of the pile.

- The bedrock consists of limestone which is typically strong to very strong. The strength and hardness of this rock must be taken into account when selecting equipment to advance the pile into rock. Equipment supplied to advance the pile into rock must be capable of penetrating the bedrock without disturbing or fracturing the bedrock adjacent to the pile. Blasting to facilitate the removal of bedrock is not permitted.

- The rock embedment length must be formed entirely within the bedrock below the level of any rubble or highly fractured material. Any length of pile above the bedrock surface will not be considered part of the specified length of rock embedment.

- The length of socket shall be taken from the lowest point of the bedrock surface around the perimeter of the socket.

- During and subsequent to installation, the pipe pile may be partially filled with water and it may not be practical to dewater the pipe prior to concreting. Tremie concreting will be required for concreting these pipe piles.

Reference can be made to the Foundation Investigation Report for the Replacement of the Replacement of Highway 401 at Flagg Road, prepared by Thurber Engineering Ltd., 2017, for further details on likely subsurface conditions at the foundation locations.

## SUGGESTED TEXT FOR "NSSP – PRESENCE OF EXISTING PILES"

The proposed piles are to be advanced within the footprint of the existing pier and abutment pile caps and that existing piles are to remain in place. Although the pile layout on the structural drawings has been selected to avoid conflict with piles supporting the existing bridge piers and abutments the potential for conflict still exists. The Contractor shall review the pile installation program with respect to the theoretical locations of the existing and proposed piles as shown on the General Arrangement and Foundation Layout drawings provided in the contract drawings. Prior to the commencement of pile driving the Contractor must expose the tops of the existing piles and check for possible conflicts prior to the start of piling.

Installation of piles and roadway protection systems could encounter existing piles which may impede installation and prohibit the new piles from reaching the design depth of installation. The Contractor should be prepared to pull an existing pile should it been deemed necessary by MTO.

Should the new piles encounter the existing piles the Contractor shall report the conflict to Contract Administrator to determine if adjustment to the pile driving program is required.

### NSSP – Integral Abutment CSP Sand Backfill

The sand backfill used within the CSP to provide the required flexibility for the piles in the integral abutment design shall meet the following gradation envelope.

Note piles should be driven first before placing the sand backfill in the CSP.

**Integral Abutment Sand Backfill Grading**

| MTO Sieve Designation | Percent Passing (%) |
|---|---|
| #10 | 100 |
| #30 | 80 – 100 |
| #40 | 40 – 80 |
| #60 | 5 – 25 |
| #100 | 0 – 6 |