THURBER ENGINEERING LTD.

MEMORANDUM

To: Aaron E. Stuart
McIntosh Perry

Date: July 13, 2020

From: Rocío Palomeque Reyna, P.Eng.
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File: 25504

**HIGHWAY 404 S-E/W OFF RAMP
TO BLOOMINGTON ROAD
HIGHWAY 404 REHABILITATION
STOUFFVILLE ROAD TO MULOCK DRIVE
REGIONAL MUNICIPALITY OF YORK, ONTARIO
G.W.P. 2459-16-00 & 2461-16-00**

GEOCRES No. 30M14-519

Dear Mr. Stuart:

This technical memorandum presents the factual findings, discussions and engineering recommendations of a foundation investigation conducted to assess the settlement reported at the existing S-E/W Ramp of the Highway 404 and Bloomington Road interchange in the Regional Municipality of York, Ontario.

The project terms of reference indicate that the existing ramp has experienced settlement through the years and that maintenance works have been carried out to remediate the situations. Information provided by McIntosh Perry indicated that a section of the ramp was constructed on a swamp and that sub-excavation was carried out to remove organic materials prior to backfilling. It is also confirmed that the MTO has no construction and other records available on the settlement issues and the associated repair works.

This technical memorandum with the interpretation and recommendations are intended for the use of the Ministry of Transportation and McIntosh Perry, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the first part 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.

Thurber carried out this study as a sub-consultant to McIntosh Perry under an MTO Agreement No. 2018-E-0051.

1. SITE DESCRIPTION

The S-E/W ramp is located at the southeast quadrant of the Highway 404 and Bloomington Road interchange. A distressed zone is identified within the southerly portion of the ramp and is approximately 210 m south of Bloomington Road, from approximate Stations 21+160 to 21+190 along the ramp. The actual extent of the distressed zone is undocumented. Based on site observations and images from Google, this zone is generally characterized by darker coloured vegetation and is in the order of 30 m in length along the ramp.

The lands immediately east and along the ramp are gently undulating. Vegetation cover largely consists of grass with shrubs and small trees.

2. INVESTIGATION PROCEDURES

The foundation investigation for this distressed zone includes the following components:

- Review of available background information from the MTO Geocres library.
- Site visit to delineate the nature and extent of the reported issues.
- Field borehole investigation to determine the subsurface conditions.
- Engineering assessment based on the available information.

The following reports from the Geocres information has been reviewed.

- Foundation Investigation and Design Report, Bloomington Road and Highway 404 Interchange, Ramp Realignments, Regional Municipality of York, MTO Central Region, Geocres 30M14-449, prepared by Terraprobe Inc. dated September 2016 (Reference 1).

- Foundation Investigation and Design Report, Bloomington Road Twin Overpass Bridges, Highway 404 Widening, Regional Municipality of York, Geocres 30M14-275, prepared by Golder Associates Ltd. dated December 1999 (Reference 2).

Visual observations of the site conditions within the 25 m to 30 m long distress zone were made during the field borehole investigation and a recent site visit carried out on April 8, 2020. The following observations have been noted:

- Longitudinal (parallel to ramp) cracks at the outside (easterly) edge of the shoulder.
- The row of guide rail posts near the slope crest appears upright.
- Localized instability at mid-slope which is evident by some fresh scarping and soil washing down towards the swampy area at the toe of the slope; it is possible that this is a result of surface water running perpendicularly down the slope.
- Localized wet area at the toe of this slope characterized by vegetation such as bullrush that is typical of swampy areas.

- About 8 m to the north of the mid-slope instability, a cut has been made at the curb presumably to allow water to flow down the slope; as a result, a gully has been formed on the slope immediately below this cut.
- There was no visible sign of asphalt patching and resurfacing in the vicinity of this location at the time of the site visits.

Selected photographs of the site and some of the observations outlined above are presented in Appendix C.

As part of this study, Thurber completed a foundation investigation consisting of boreholes advanced at selected locations along the S-E/W Ramp to assess the subsurface and groundwater conditions at the site.

The field investigation was carried out from September 30 to October 3, 2019 and consisted of drilling and sampling three (3) boreholes, designated as Boreholes BL19-01 to BL19-03. The boreholes were drilled along the ramp alignment from ramp grade at selected locations base on visual observations and embankment height. These three boreholes were extended to 15.8 m depth (Elevations 291.6 to 290.5). Two shallower boreholes (numbered BL19-01A and BL19-01B) were drilled at short distances on the south and north sides of Borehole BL19-01, to further delineate the extent of an organic silt layer, which was encountered only in Borehole 19-01 which was located within the distress area outlined above. Boreholes PL19-01A and 19-01B were augered without sampling to 4.6 m and terminated at 10.5 m and 9.0 m depth (Elevations 297.0 and 298.5), respectively.

Standard Penetration Tests (SPTs) were carried out in accordance with ASTM D1586 in the boreholes at regular intervals of depth and samples of the soils encountered were recovered using split-spoon sampling equipment. In the cohesive deposits, the undrained shear strength of the material was measured in-situ by means of field vane tests (MTO N-Vane) and thin-walled Shelby tube samples were collected.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. One standpipe piezometer (25 mm diameter) was installed in Borehole BL19-01 to permit groundwater level monitoring. The piezometer will be decommissioned in general conformance with O.Reg. 903.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D. The coordinates of the boreholes were surveyed by Thurber and the elevations were provided by McIntosh Perry. These values are shown on this drawing and on the individual Record of Borehole Sheets in Appendix A.

3. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. Two samples of the organic silt and clayey silt were collected and submitted for analytical testing for organic content.

The results of the geotechnical laboratory testing are summarized on the Record of Borehole sheets in Appendix A, and also presented in Appendix B. Results of the analytical testing are also presented in Appendix B.

4. DESCRIPTION OF SUBSURFACE CONDITIONS

An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

4.1 Pavement Structure

Pavement structure consisting of approximately 100 mm of asphalt overlying granular (sand with some gravel fill) road base was encountered surficially in Borehole BL19-01. The thickness of the granular road fill was 900 mm. Grain size analysis was conducted on a sample of the granular which contains 10 percent gravel, 82 percent sand, and 8 percent silt and clay size particles.

4.2 Embankment Fill

Embankment fill was contacted below the pavement structure in Borehole BL19-01, and surficially in Boreholes BL19-02 and BL19-03. Boreholes BL19-01A and BL19-01B also encountered fill below the non-sampled depth. The embankment fill generally consists of brown silty sand/gravelly sand containing trace clay, and layers of clayey silt with sand containing trace gravel and trace to some clay and occasional wood fibres. The base of the embankment fill varied in depth from 5.3 m to 7.2 m and locally in Borehole BL19-03 at 2.1 m depth (Elevations 300.3 to 304.3).

SPT 'N' values measured in the silty sand/gravelly sand ranged from 12 to 66 blows per 0.3 m of penetration, indicating a compact to very dense state. The cohesive fill has a firm to hard consistency, based on SPT 'N' values ranging from 7 to 50 blows per 0.3 m of penetration. Moisture contents measured in the fill ranged from 2 percent to 17 percent.

Grain size analysis was conducted on samples of the cohesionless and cohesive fill. The tested cohesionless soil samples contain 2 to 31 percent gravel, 49 to 59 percent sand, 24 to 33 percent silt, 7 to 11 percent clay, or 10 percent silt and clay size particles. The tested cohesive soil sample contains 3 percent gravel, 32 percent sand, 44 percent silt and 21 percent clay size particles. Atterberg Limits test done on one sample of the clayey silt fill indicates a liquid limit of 21 percent, a plastic limit of 12 percent and a plasticity index of 9 percent. The clayey silt fill has a low plasticity with a group symbol of CL. The grain size distribution curves and Atterberg Limits results are presented on Figures B1 to B3 and B8 in Appendix B.

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4.3 Organic Silt

Dark brown to black organic silt containing some sand, some clay, trace gravel and occasional rootlets and wood fibres was contacted below the embankment fill at 6.1 m to 7.2 m depth in Boreholes BL19-01, BL19-01A and BL19-01B, drilled within the zone where ramp settlement has been observed. The approximate thickness of the organic silt varied from 0.7 m to 3.0 m in the three boreholes and the base elevations of this stratum ranged between 297.5 and 300.7.

SPT 'N' values measured in the organic silt ranged from 6 to 16 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. A vane shear test conducted within the organic silt in Borehole BL19-01A measured an in-situ undrained shear strength of 116 kPa, which corresponds to a very stiff consistency. Measured moisture contents in the organic silt ranged from 96 percent to 233 percent.

Two sampling attempts were made in Boreholes BL19-01A using thin-walled Shelby tubes but the sample recovery was small.

The high moisture contents reflect the organic content which was measured at 22 percent in one sample.

There was insufficient sample of the organic silt to carry out grain size analysis. An attempt was made to carry out Atterberg Limits test on Sample SS3 just below 6 m depth in Borehole BL19-01B. Results of this test indicates liquid and plastic limits greater than 100 percent and a plasticity index of 7 percent. These results would have plotted outside of the plasticity chart where the liquid limit scale has a maximum value of 100 percent. These results indicate that this is a sample of high plasticity organics.

4.4 Clayey Silt

A layer of grey clayey silt containing trace to some sand, trace to some gravel, and occasional organics and wood fibres was contacted below the organic silt in Boreholes BL19-01 and BL19-01B at 9.1 m and 6.8 m depth, respectively (Elevations 298.3 to 300.7). The thickness of the clayey silt layer was 0.9 m and 1.5 m in the two boreholes and the base elevations of this stratum ranged from 297.5 to 299.2.

An SPT 'N' value of 9 blows per 0.3 m of penetration was measured in the clayey silt, indicating a stiff consistency. A field vane shear test measured an undrained shear strength of 97 kPa in Borehole BL19-01B. Measured moisture contents in the clayey silt varied from 9 percent to 38 percent.

One Shelby tube sample of this clayey silt was recovered in Borehole BL19-01B. However, a suitable specimen could not be retrieved to carry out an oedometer test due to the presence of large gravel throughout the tube sample. A specific gravity of 2.58 was measured for this clayey silt.

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Grain size analysis was conducted on one sample of the clayey silt. The tested sample contains 7 percent gravel, 10 percent sand, 63 percent silt and 20 percent clay size particles. Atterberg Limits tests of the clayey silt indicates liquid limits of 19 to 34 percent, plastic limits of 12 to 22 percent and plasticity indices of 7 to 11 percent. The clayey silt has a low to slight plasticity with a group symbol of CL to CL-ML. The grain size distribution curve and Atterberg Limits results are presented on Figures B5 and B9 in Appendix B.

An organic content in the clayey silt was measured at 7.2 percent.

4.5 Sands and Silts

Brown sand and silt containing trace gravel and trace clay was contacted below the fill at 5.3 m and 2.1 m depth in Boreholes BL19-02 and BL19-03, respectively. The thickness of the sand and silt layer was between 1.9 m and 3.5 m and the base elevations of this stratum ranged from 299.4 to 300.7.

A 1.0-m thick layer of sandy silt was contacted at 12.4 m depth in Borehole BL19-01. Sandy silt was also contacted at 10.0 m depth in Borehole BL19-01A which was terminated in this layer.

SPT ‘N’ values in the sands and silts ranged from 7 to 57 blows per 0.3 m of penetration, indicating a loose to very dense state. Moisture contents in the sands and silts varied from 8 to 22 percent.

Grain size analysis was conducted on three samples of the sands and silts. The tested samples contain 0 to 1 percent gravel, 31 to 53 percent sand, 38 to 60 percent silt and 5 to 9 percent clay size particles. The grain size distribution curves are presented on Figure B4 in Appendix B.

4.5 Clayey Silt Till

Brown to grey clayey silt till with sand containing trace gravel was encountered below the sand and silt and clayey silt in all the boreholes except in Borehole BL19-1A, at depths ranging from 5.6 m to 10.0 m. Borehole BL19-01A was not sufficiently deep to reach the clayey silt till. Where fully penetrated, the thickness of the clayey silt till was 2.3 m and 5.5m in Boreholes BL19-02 and BL19-03, respectively, and the base elevations of this till ranged between 295.2 and 295.8.

Boreholes BL19-01 and BL19-01B were terminated within the clayey silt till at 15.8 m and 9.0 m depth (Elevations 291.6 and 298.5), respectively.

Measured SPT ‘N’ values in the clayey silt till ranged from 15 to 35 blows per 0.3 m of penetration indicate a very stiff to hard consistency.

Grain size analysis was conducted on three samples of the clayey silt till. The tested samples contain 2 to 7 percent gravel, 21 to 39 percent sand, 42 to 55 percent silt and 12 to 19 percent clay size particles. Atterberg Limits tests on the clayey silt till indicate liquid limits of 16 to 20 percent, plastic limits of 10 to 12 percent and plasticity indices of 6 and 7 percent. The soil has a low to slight plasticity with a group symbol of CL to CL-ML. The grain size distribution curves and Atterberg Limits results are presented on Figures B6 and B10 in Appendix B. Glacial tills inherently contain cobbles and boulders.

4.5 Sand

Brown to grey sand containing trace to some silt, trace gravel, trace clay and occasional cobbles was contacted at 10.8 m and 11.1 m depth in Boreholes BL19-02 and BL19-03, respectively. A 1.3 m thick layer of sand was also contacted at 7.2 m depth in Borehole BL19-02.

Boreholes BL19-02 and BL19-03 were terminated within the sand at 15.8 m depth (Elevations 290.7 and 290.5).

Based on the SPT ‘N’ values ranging from 18 to 48 blows per 0.3 m of penetration, the sand is in a compact to dense state. Grinding of augers was noted at 7.9 m and 11 m depths in Borehole 19-02. Moisture content in the sand ranged from 6 percent to 13 percent.

Grain size analysis was conducted on a sand sample. The tested sample contains 8 percent gravel, 81 percent sand, and 11 percent silt and clay size particles. The grain size distribution curve is presented on Figure B7 in Appendix B.

4.6 Groundwater Conditions

Groundwater levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. A standpipe piezometer was installed in Borehole BL19-01 to permit monitoring of groundwater levels. Water levels measured in the installed piezometer and open boreholes are presented in Table 4.1 below.

Table 4.1- Groundwater Level Measurements

Borehole	Date	Groundwater Level		Comments
		Depth (m)	Elev. (m)	
BL19-01	September 30, 2019 October 23, 2019 December 4, 2019	4.3 5.6 5.2	303.2 301.9 302.3	Open borehole Piezometer Piezometer
BL19-01A	October 2, 2019	5.0	302.5	Open borehole
BL19-01B	October 2, 2019	2.4	305.1	Open borehole
BL19-02	October 1, 2019	5.7	300.8	Open borehole
BL19-03	October 3, 2019	4.1	302.3	Open borehole

5. BACKGROUND INFORMATION

As outlined earlier, McIntosh Perry advised that the MTO has not been able to provide any record of past observations and maintenance works regarding the settlement issues at the S-E/W ramp.

Based on information provided by McIntosh Perry, the S-E/W Ramp from Highway 404 northbound to Bloomington Road was initially built in the early 1980's. The contract drawings showed that a section of the ramp alignment was built across a swamp. It was indicated that the treatment of the swamp included sub-excavation of the organic deposits within the swamp, which extended to firm bottom, and subsequently backfilled with suitable swamp backfill material. In the late 1990's, the existing speed change lane of the S-E/W Ramp at Bloomington Road was extended. It is apparent that new fill of up to about 3 m in height was placed during this time. There were no construction records available for confirmation.

There is no relevant subsurface information available from the Geocres information for the subject ramp at the southeast quadrant of this interchange. Review of Reference 1 for the bridge structure and Reference 2 for the ramps at other quadrants indicate that the subsurface conditions at the previous boreholes are consistent with those encountered in Boreholes BL19-01, 1A, 1B, 02 and 03 with the exception that the layer of organic silt was not present.

6. POSSIBLE CAUSES OF SETTLEMENT

Based on the review of the available background information, the site inspection results, and the results of the current field investigation, the following mechanisms were considered as possible causes of the distress observed at the S-E/W Ramp:

- Global slope instability of the ramp embankment;
- Surficial slope instability of the ramp embankment;
- Embankment and subgrade settlement due to incomplete removal of swamp material as indicated by presence of organic silt layer within the distress area;
- Inadequate pavement structure and construction.

McIntosh Perry is responsible for pavement engineering for this project and is anticipated to provide comments on the adequacy of the pavement structure and construction.

7. SLOPE STABILITY

7.1 Global Stability

Global stability of the existing ramp embankment was carried out for the area where the organic silt layer was encountered and settlement has been observed. The analyses were carried out utilizing the commercially available slope stability analysis program Slope/W (Version 2019) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for limit equilibrium analyses. Analyses were completed for both static and seismic loading conditions. The stability of the embankment was checked under seismic loading assuming an acceleration of 0.116 g.

The soil parameters used in the analyses were estimated from empirical correlations using the results of the in situ Standard Penetration Tests (SPTs), vane shear strengths and geotechnical laboratory index properties including moisture contents, gradation and Atterberg limits. The groundwater level in our analysis was based on readings obtained from a standpipe piezometer.

Based on survey data of the slope and visual estimation using a clinometer, the slope inclination in the vicinity of the organic silt is in the order of 2.5H : 1V and the slope height is about 3 m. For the analyses, a more conservative slope inclination of 2H : 1V (MTO standard) has been used.

Results of the stability analyses are presented on Figures E1 to E3 in Appendix E. The results are also summarized in Table 5.1 below.

Table 5.1- Computed Factors of Safety

Condition	Factor of Safety	Figure (Appendix E)
Embankment height 3.0 m		
Static Drained	1.5	E1
Static Undrained	1.5	E2
Seismic Coefficient 0.116 g (H)	1.1	E3

As per typical MTO requirements, a Factor of Safety (F.S.) of 1.3 is acceptable for short term conditions and for total stress (undrained) conditions. A F.S. of 1.5 is acceptable for long term (drained) conditions. Under the assumed seismic loading, the minimum acceptable factor of safety is 1.0. Accordingly, the computed factors of safety are considered to be acceptable for the existing ramp embankment. In other words, global stability of the ramp embankment is satisfactory in the distress area.

Figures E1 to E3 indicate that the organic silt layer has no influence on the global stability of the ramp embankment at this location.

7.2 Surficial Stability

Results of our visual inspections summarized in Section 2 above indicate that there is evidence of surficial erosion such as gullies and cracking at the edge of the shoulder. The gullies may be attributed to surface water running perpendicularly down the slope (see Section 9 below). Given that there is no evidence of surficial downslope movement, the cracking at the edge of shoulder may be attributed to a combination of lack of compaction efforts during construction, surficial freeze/thaw actions, and erosion effects of surface runoff and precipitation.

Moreover, it is possible that lateral spreading at the embankment toe has occurred during and post construction due to the presence of the localized “swampy area” and/or incomplete removal of swamp material under the ramp embankment. Given that the ramp construction and realignment has completed for more than 20 years, it can be assumed that the lateral spreading has stabilized.

8. SETTLEMENT

Site observations indicate that a localized zone near the south end of the ramp (approximately 180 m south of Bloomington Road) has shown distress including settlement. This zone generally coincides with a swampy area observed at the toe area. The current foundation investigation reveals the presence of compressible organic and clayey soils below the fill at this zone, which indicates that the organic soils of the swamp were not fully removed. It is envisaged that the consolidation settlement of these compressible soils has been contributing to the observed settlements over the past years.

Boreholes BL19-01, BL19-01A and BL19-01B, drilled within the settlement zone, revealed the presence of 1 m to 3 m thickness of compressible soils (organic silt and clayey silt) just beneath the existing embankment fill. The measured thickness of the fill at this location varied from 6.1m to 7.2 m. Based on these findings, it appears that the sub-excavation during original construction outlined above did not completely remove the compressible materials. It is envisaged that placement of fill on the organic silt and clayey silt layers has induced consolidation settlement over the years. It is also likely that lateral spreading (mentioned previously) could have resulted in additional settlement of the ramp. However, lateral spreading typically occurred during and shortly after fill placement and, therefore, can be assumed to have been completed some 20 years after the last fill placement.

In addition, it is estimated that settlement has also occurred due to self-compression of the embankment fill typically up to 0.5 percent of the embankment height. For a 6.0 m to 7.0 m thickness of granular fill, the self-compression is estimated to be approximately 30 to 35 mm and this settlement is generally expected to be completed within one to two years after completion of fill placement.

As part of our assessment of the settlement issue at this ramp, a settlement analysis was carried out to provide approximate time-dependent settlement estimates that can be expected over certain time periods in the future. This information would be useful to assist us in providing our recommendations for feasible measures moving forward. It is noted, however, that there is no further information on the construction sequence, fill placement, swamp treatment and subsequent settlement observations other than what is outlined in this report.

Also given that there was no suitable undisturbed sample of the compressible materials to facilitate laboratory consolidation (oedometer) testing, the input parameters for the analyses were based on correlation with soil index properties derived from laboratory testing, field data and published data of similar materials.

The settlement analysis was performed using the commercially available software "Settle 3D" V4 by Rocscience to estimate the one-dimensional consolidation settlements due to embankment construction. Stresses on the foundation soils imposed by the embankment fill were calculated using the Boussinesq method. Settlements due to lateral spreading and fill self-compression are deemed complete and are not considered. The estimates of primary and secondary consolidation settlements due to the embankment load are presented in Table 6.1.

Table 6.1. Estimates of Consolidation Settlement for Fill Height of 7.0 m

Time Period	Consolidation Settlements
1985 to 2000	~ 640 to 670 mm
2000 to 2020	~ 30 to 40 mm
2020 to 2040	~ 20 to 25 mm
2040 to 2060	~ 10 to 15 mm

The remaining settlement estimates indicated above satisfy the MTO Embankment Settlement Criteria for Design (2010) regarding maximum tolerable limits during pavement design life for embankment on compressible soils not close to structures.

9. ENGINEERING RECOMMENDATIONS

Based on the above, it is considered that the reported settlements, presumably in the vicinity of the swampy area, has been a result of time-dependent settlement of organic and other compressible materials that are present below the embankment fill. Given the depth of these materials and the presence of the swampy area adjacent to the toe, deep sub-excavation and backfilling is not a feasible option. It is considered that a feasible option moving forward is to monitor potential future settlement and distress, and manage the situations within future roadway maintenance contracts.

It is recommended that the following measures be considered:

- Establish a visual and settlement monitoring program for the pavement surface and embankment slope where surficial distress has been observed. The visual monitoring program should include regularly scheduled site inspections to delineate potential zones of distress. The settlement monitoring may include establishing survey markers at selected locations on the pavement (including shoulder) and on the slope surface where existing distress is present. A baseline condition should be established by carrying out a topographical survey of the section of the ramp and slope where monitoring is required.

- Improve drainage parallel to the ramp alignment such that surface runoff and precipitation would not run perpendicularly down the slope surface. Concrete curb and gutter as per OPSD 600.010 should be used where applicable. Alternatively, consideration should be given to using asphalt barrier curbs as schematically shown on OPSD 601.010.

- If drainage or surface runoff are to be discharged along the slope, consideration should be given to diverting the discharge in a controlled manner, such as installing a series of riprap lined channels, perpendicular to the ramp, at periodic intervals along the face of the slope. These channels should be aligned with openings in the curb.

- The notch at the curb, which has apparently resulted in the gully immediately below it, should be filled. The gully and other surficial distress should be repaired and the original slope grade of 2.5H : 1V or flatter should be re-established to match adjacent slopes. Sloughed materials should be removed and the embankment slope be reinstated. New granular fill (Granular B Type II, as per OPSS.PROV 1010) should be placed on the slope from the toe upwards and keyed into the slope via a series of earth benches on the slope face. Permanent slope surfaces should be vegetated and seeded in accordance with current MTO practice with reference to OPSS.PROV 804. Remedial measures such as re-vegetation and/or placement of gravel sheeting may be required at some locations to minimize the potential of further erosion.

- Consideration may be given to patching the pavement where required and incorporating provisions to address potential future settlements and slope distress within the pavement maintenance program.

We trust the above assessment and recommendations address McIntosh Perry's requirements. Should you have any questions, please do not hesitate to contact our office.

Yours truly,
THURBER ENGINEERING LTD.

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Review Principal, Designated MTO Contact

Attachments:

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical Laboratory Test Results
Appendix C	Selected Site Photographs
Appendix D	Borehole Locations and Soil Strata Drawing
Appendix E	Selected Slope Stability Outputs

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

- CLAYSTONE
- SILTSTONE
- SANDSTONE
- COAL
- Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BL19-01

METRIC

W.P. 2459-16-00 & 2461-16-00 | LOCATION MTM NAD 83 Zone 10: N 4 870 724.9 E 313 498.6 | ORIGINATED BY ES

DIST ____ HWY 404 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY BH

DATUM Geodetic | DATE 2019.09.30 - 2019.09.30 | LATITUDE 43.976456 | LONGITUDE -79.391579 | CHECKED BY CZ

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
307.5	GROUND SURFACE				
0.0 / 0.1	**ASPHALT** (100mm)				
	SAND, some gravel, trace silt and clay, Brown, Moist (FILL)	1	GS		10 82 8 (SI+CL)
306.4 / 1.0	Clayey **SILT**, some sand, trace gravel, Very Stiff, Brown, Moist (FILL)	2	SS	23	
305.9 / 1.5	Silty **SAND**, trace gravel, some clay, Very Dense to Compact, Brown, Moist (FILL)	3	SS	66	2 54 33 11
		4	SS	46	
		5	SS	15	
	occasional wood fibres	6	SS	38	
		7	SS	21	
302.1 / 5.3	Clayey **SILT**, with sand, trace gravel, Stiff, Brown, Moist (FILL)	8	SS	13	3 32 44 21
301.4 / 6.1	**ORGANIC SILT**, trace gravel, some sand, some clay, occasional rootlets and wood fibres, Firm to Stiff, Dark Brown to Black, Moist	9	SS	6	Very little sample recovery (w = 96)
		10	SS	9	Very little sample recovery (w = 185)
298.3 / 9.1	Clayey **SILT**, trace sand, trace gravel, occasional organics, occasional wood fibres, Stiff, Grey, Wet	11	SS	9	
297.5					

Elevation scale: 307, 306, 305, 304, 303, 302, 301, 300, 299, 298

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 BL19-01

METRIC

W.P. 2459-16-00 & 2461-16-00	LOCATION MTM NAD 83 Zone 10: N 4 870 724.9 E 313 498.6		ORIGINATED BY ES
DIST HWY 404	BOREHOLE TYPE Solid Stem Augers		COMPILED BY BH
DATUM Geodetic	DATE 2019.09.30 - 2019.09.30	LATITUDE 43.976456 LONGITUDE -79.391579	CHECKED BY CZ

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
10.0	Clayey **SILT**, with sand, trace gravel Very Stiff Grey Wet (TILL)				297					
		12	SS	19		Wp–w–wL ≈ 13–17	5	21	55	19
					296					
295.1 / 12.4	Sandy **SILT**, trace gravel Very Dense Grey Moist	13	SS	57	295	○				
294.1 / 13.4	Clayey **SILT**, with sand, trace gravel Very Stiff to Hard Grey Moist (TILL)				294					
		14	SS	24	293	○				
	occasional sand seams	15	SS	35	292	○				
291.6 / 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 14.8m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.									

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2019.10.23	5.6	301.9
2019.12.04	5.2	302.3

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/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 BL19-01A

METRIC

W.P. 2459-16-00 & 2461-16-00 LOCATION MTM NAD 83 Zone 10: N 4 870 719.1 E 313 494.6 ORIGINATED BY ES

DIST HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY BH

DATUM Geodetic DATE 2019.10.02 - 2019.10.02 LATITUDE 43.976403 LONGITUDE -79.391629 CHECKED BY CZ

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
307.5	GROUND SURFACE									
0.0	Augered from ground surface to 4.6m (no sampling).						307, 306, 305, 304			
303.0 / 4.6	Clayey **SILT**, with sand, trace gravel Very Stiff to Firm Brown Moist (FILL)		1	SS	29	∇	303			
			2	SS	7		302			
			3	SS	11		301			
			4	SS	6					
300.3 / 7.2	**ORGANIC SILT**, trace gravel, some sand, some clay, occasional rootlets and wood fibres Firm Dark Brown to Black Moist						300	233		
			5	TW	PH					
			6	TW	PH		299			
			7	GS				135	Organic content 22.9%	
297.5							298			

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

Continued Next Page

+ 3 , × 3 : Numbers refer to Sensitivity

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

ONTMT4S2 MTO-25504.GPJ 2017TEMPLATE(MTO).GDT 4/24/20

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THURBER

RECORD OF BOREHOLE No BL19-01A

METRIC

W.P. 2459-16-00 & 2461-16-00 LOCATION MTM NAD 83 Zone 10: N 4 870 719.1 E 313 494.6 ORIGINATED BY ES

DIST HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY BH

DATUM Geodetic DATE 2019.10.02 - 2019.10.02 LATITUDE 43.976403 LONGITUDE -79.391629 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	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)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page													
10.0 297.0 10.5	Sandy **SILT**, trace gravel, trace clay Compact Grey Moist		8	SS	16				○		1	31	60	8
	END OF BOREHOLE AT 10.5m. BOREHOLE OPEN AND WATER LEVEL AT 5.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.15m, THEN CONCRETE TO SURFACE.													

REMARKS & GRAIN SIZE DISTRIBUTION (%)

ONTMT4S2 MTO-25504.GPJ 2017TEMPLATE(MTO).GDT 4/24/20

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BL19-01B

METRIC

W.P. 2459-16-00 & 2461-16-00 LOCATION MTM NAD 83 Zone 10: N 4 870 729.8 E 313 502.5 ORIGINATED BY ES

DIST HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY BH

DATUM Geodetic DATE 2019.10.02 - 2019.10.02 LATITUDE 43.976500 LONGITUDE -79.391531 CHECKED BY CZ

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
307.5	GROUND SURFACE								
0.0	Augered from ground surface to 4.6m (no sampling).					▽ (approx. 305.1)	307, 306, 305, 304, 303		
302.9 / 4.6	Clayey **SILT**, with sand, trace gravel, occasional wood fibres; Very Stiff to Hard; Grey; Moist; (FILL)		1	SS	15		302		
			2	SS	50				
301.4 / 6.1	**ORGANIC SILT**, trace gravel, some sand, some clay, occasional rootlets and wood fibres; Very Stiff; Dark Brown to Black; Moist		3	SS	16		301		Very little sample recovery; 0 8 80 12
300.7 / 6.8	Clayey **SILT**, trace gravel, some sand; Very Stiff; Grey; Moist		4	TW	PH		300	Gs=2.583; Organic content 7.2%	7 10 63 20
299.2 / 8.3	Clayey **SILT**, with sand, trace gravel; Very Stiff; Grey; Moist; (TILL)		5	SS	15		299		
298.5 / 9.0	END OF BOREHOLE AT 9.0m. BOREHOLE OPEN AND WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND								

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

Field vane reading at approx. elev. 299.6: + 1.7 (approx. 97 kPa)

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

Water contents: Sample 1 ≈ 17%; Sample 2 ≈ 10%; Sample 3 >> 208%; Sample 4: w_P ≈ 22, w ≈ 38 (upper); w ≈ 11, w_L ≈ 15 (lower); Sample 5 ≈ 14%

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below): (%) STRAIN AT FAILURE

ONTMT4S2 MTO-25504.GPJ 2017TEMPLATE(MTO).GDT 4/24/20

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THURBER

RECORD OF BOREHOLE No BL19-01B

METRIC

W.P. 2459-16-00 & 2461-16-00 LOCATION MTM NAD 83 Zone 10: N 4 870 729.8 E 313 502.5 ORIGINATED BY ES

DIST HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY BH

DATUM Geodetic DATE 2019.10.02 - 2019.10.02 LATITUDE 43.976500 LONGITUDE -79.391531 CHECKED BY CZ

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
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	AUGER CUTTINGS TO 0.08m, THEN CONCRETE TO SURFACE.										

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

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

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Ontario

THURBER

RECORD OF BOREHOLE No BL19-02

METRIC

W.P. 2459-16-00 & 2461-16-00 | LOCATION MTM NAD 83 Zone 10: N 4 870 830.7 E 313 589.0 | ORIGINATED BY ES

DIST | HWY 404 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY MFA

DATUM Geodetic | DATE 2019.10.01 - 2019.10.01 | LATITUDE 43.977407 | LONGITUDE -79.390450 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
306.5	GROUND SURFACE						
0.0	Silty **SAND**, some gravel to gravelly, trace clay, Compact, Brown, Moist (FILL)	1	GS			o	
		2	SS	15		o	
		3	SS	25		o	
		4	SS	16		o	20 49 24 7
		5	SS	25		o	
		6	SS	28		o	
		7	SS	24		o	
301.2 / 5.3	**SAND** and **SILT**, trace clay, trace gravel, Dense to Compact, Brown, Moist to Wet	8	SS	32	∇	o	1 44 50 5
		9	SS	18		o	
299.4 / 7.2	**SAND**, some gravel, trace silt, trace clay, occasional cobbles, Compact, Brown, Wet	10	SS	23		o	Auger grinding at 7.9m
298.0 / 8.5	Clayey **SILT**, with sand, trace gravel, Very Stiff, Grey, Moist (TILL)	11	SS	17		o (wp–w)	2 27 52 19

Elevation scale: 306, 305, 304, 303, 302, 301, 300, 299, 298, 297

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 BL19-02

METRIC

W.P. 2459-16-00 & 2461-16-00 | LOCATION MTM NAD 83 Zone 10: N 4 870 830.7 E 313 589.0 | ORIGINATED BY ES

DIST ____ HWY 404 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY MFA

DATUM Geodetic | DATE 2019.10.01 - 2019.10.01 | LATITUDE 43.977407 | LONGITUDE -79.390450 | CHECKED BY RPR

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Clayey **SILT**, with sand, trace gravel Very Stiff Grey Moist (TILL)				296		
295.8 10.8	**SAND**, trace gravel, trace to some silt and clay Compact to Dense Brown to Grey Wet	12	SS	27		○	Auger grinding at 11.0m
					295		
	occasional cobbles	13	SS	31	294	○	
					293		
		14	SS	37		○	8 81 11 (SI+CL)
					292		
290.7		15	SS	48	291	○	
15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 14.9m AND WATER LEVEL AT 5.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.						

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/m³

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No BL19-03

METRIC

W.P. 2459-16-00 & 2461-16-00 | LOCATION MTM NAD 83 Zone 10: N 4 870 894.1 E 313 585.2 | ORIGINATED BY ES

DIST ______ HWY 404 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY MFA

DATUM Geodetic | DATE 2019.10.03 - 2019.10.03 | LATITUDE 43.977978 | LONGITUDE -79.390496 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
306.4	GROUND SURFACE					
0.0	Gravelly **SAND**, trace silt, trace clay Compact Brown Moist (FILL)	1	GS			31 59 10 (SI+CL)
		2	SS	12		
304.8 / 1.5	Clayey **SILT**, some sand, trace gravel Very Stiff Dark Brown Moist (FILL)	3	SS	29		
304.3 / 2.1	**SAND** and **SILT**, trace gravel, trace clay Dense to Loose Brown Moist	4	SS	43		
		5	SS	12		
		6	SS	13	∇	0 53 38 9
		7	SS	7		
300.7 / 5.6	Clayey **SILT**, with sand, trace gravel Very Stiff Brown to Grey Moist (TILL)	8	SS	15		
	occasional sand seams, occasional oxidized	9	SS	17		
		10	SS	19		7 39 42 12

Elevation scale: 306, 305, 304, 303, 302, 301, 300, 299, 298, 297

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

Continued Next Page

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

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No BL19-03

METRIC

W.P.	2459-16-00 & 2461-16-00	LOCATION	MTM NAD 83 Zone 10: N 4 870 894.1 E 313 585.2	ORIGINATED BY	ES
DIST	HWY 404	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	MFA
DATUM	Geodetic	DATE	2019.10.03 - 2019.10.03 LATITUDE 43.977978 LONGITUDE -79.390496	CHECKED BY	RPR

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Clayey **SILT** with sand, trace gravel Very Stiff Grey Moist (TILL)				296	
		11	SS	27		
295.2 11.1	**SAND**, trace to some silt, trace gravel, trace clay Compact to Dense Grey Wet				295	
		12	SS	18	294	
					293	
		13	SS	26	292	
		14	SS	33	291	
290.5 15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 4.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.					

Column headings: SOIL PROFILE; 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; UNIT WEIGHT γ kN/m³.

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

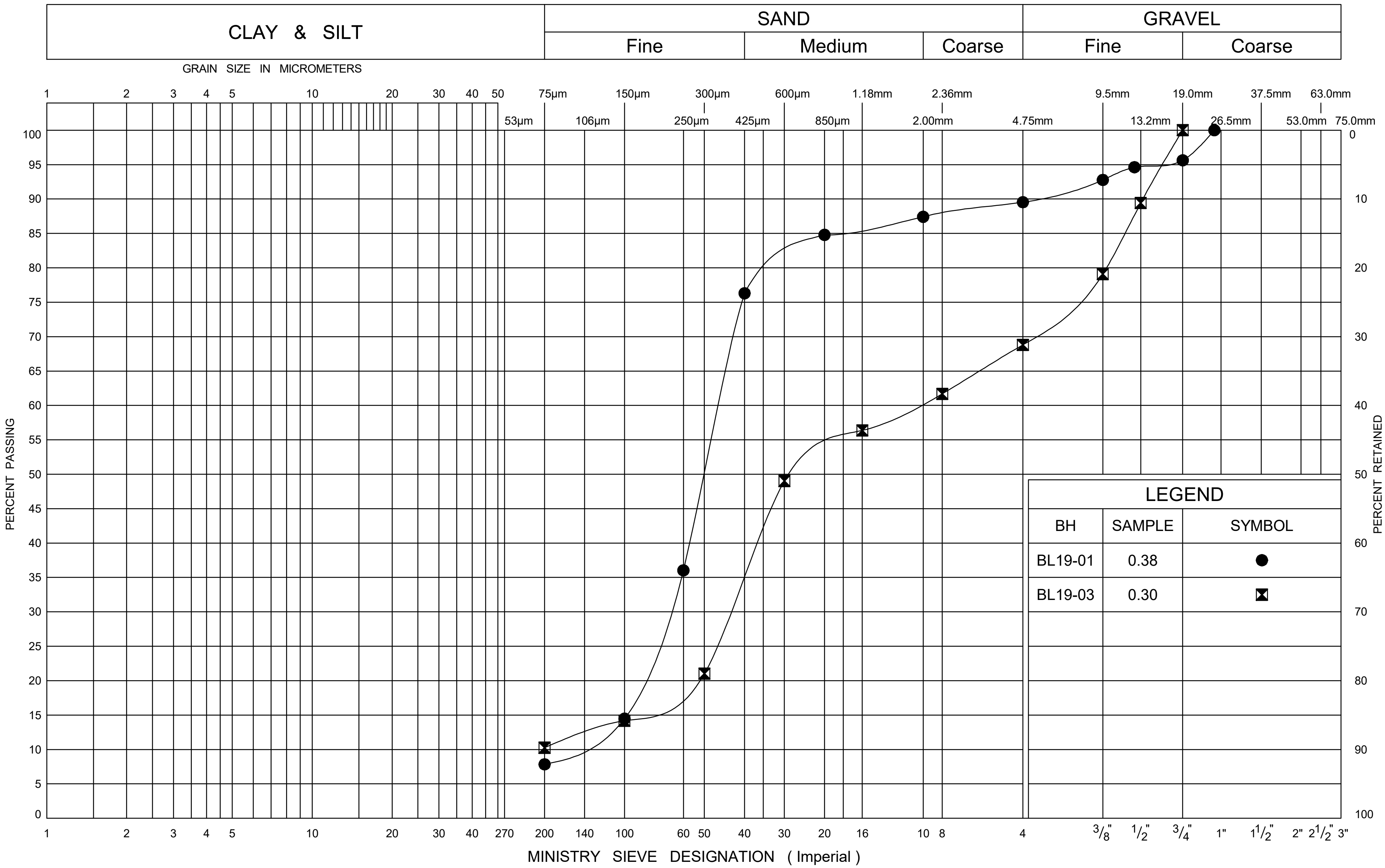
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-25504.GPJ 2017TEMPLATE(MTO).GDT 4/24/20

THURBER

Appendix B

Geotechnical and Analytical Laboratory Test Results



LEGEND

BH	SAMPLE	SYMBOL
BL19-01	0.38	●
BL19-03	0.30	⊠

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GRAIN SIZE DISTRIBUTION

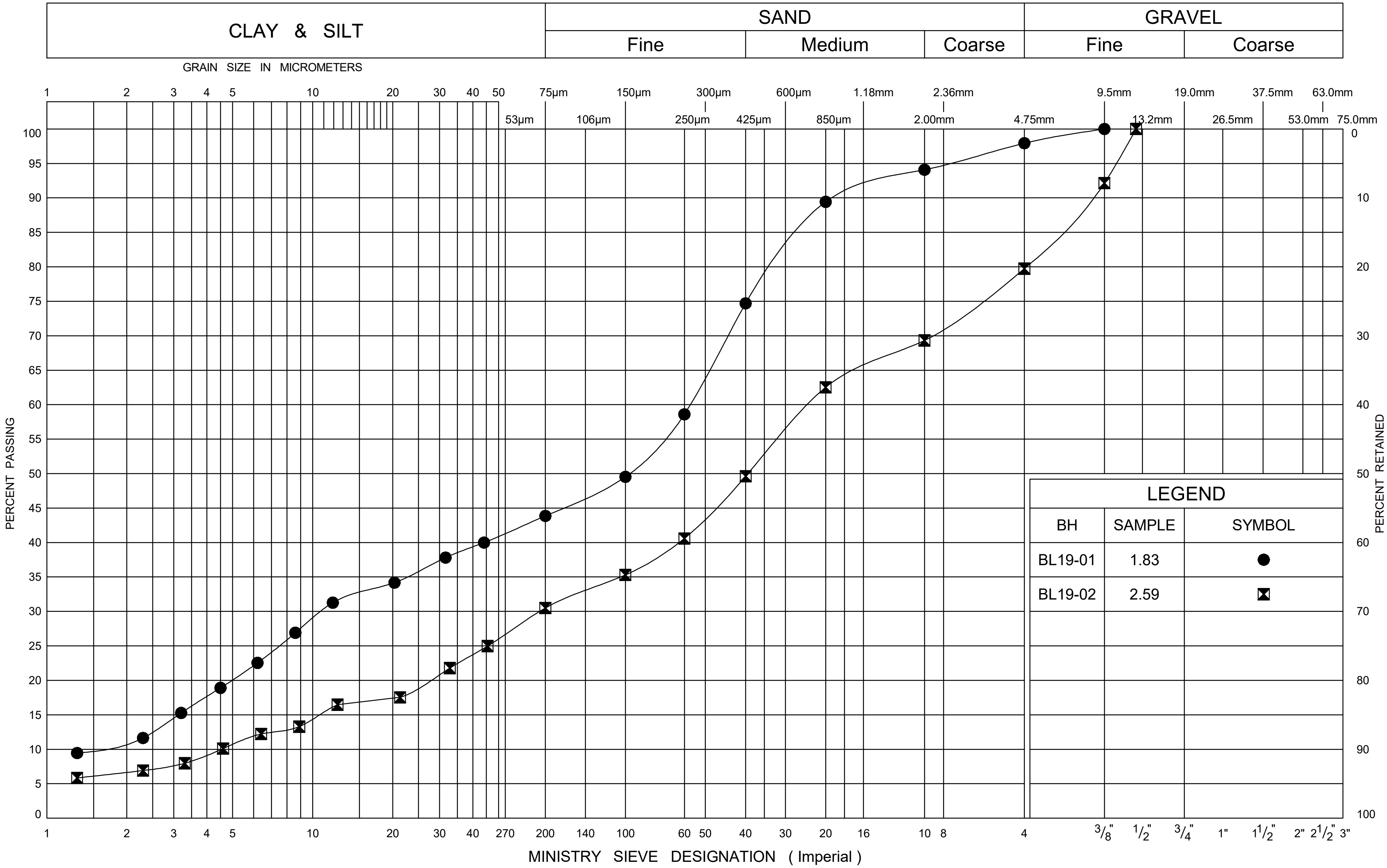
SAND FILL, Gravelly SAND FILL

FIG No B1

W P 2459-16-00 & 2461-16-00

ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19

78 12 M



BH	SAMPLE	SYMBOL
BL19-01	1.83	●
BL19-02	2.59	⊠

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GRAIN SIZE DISTRIBUTION

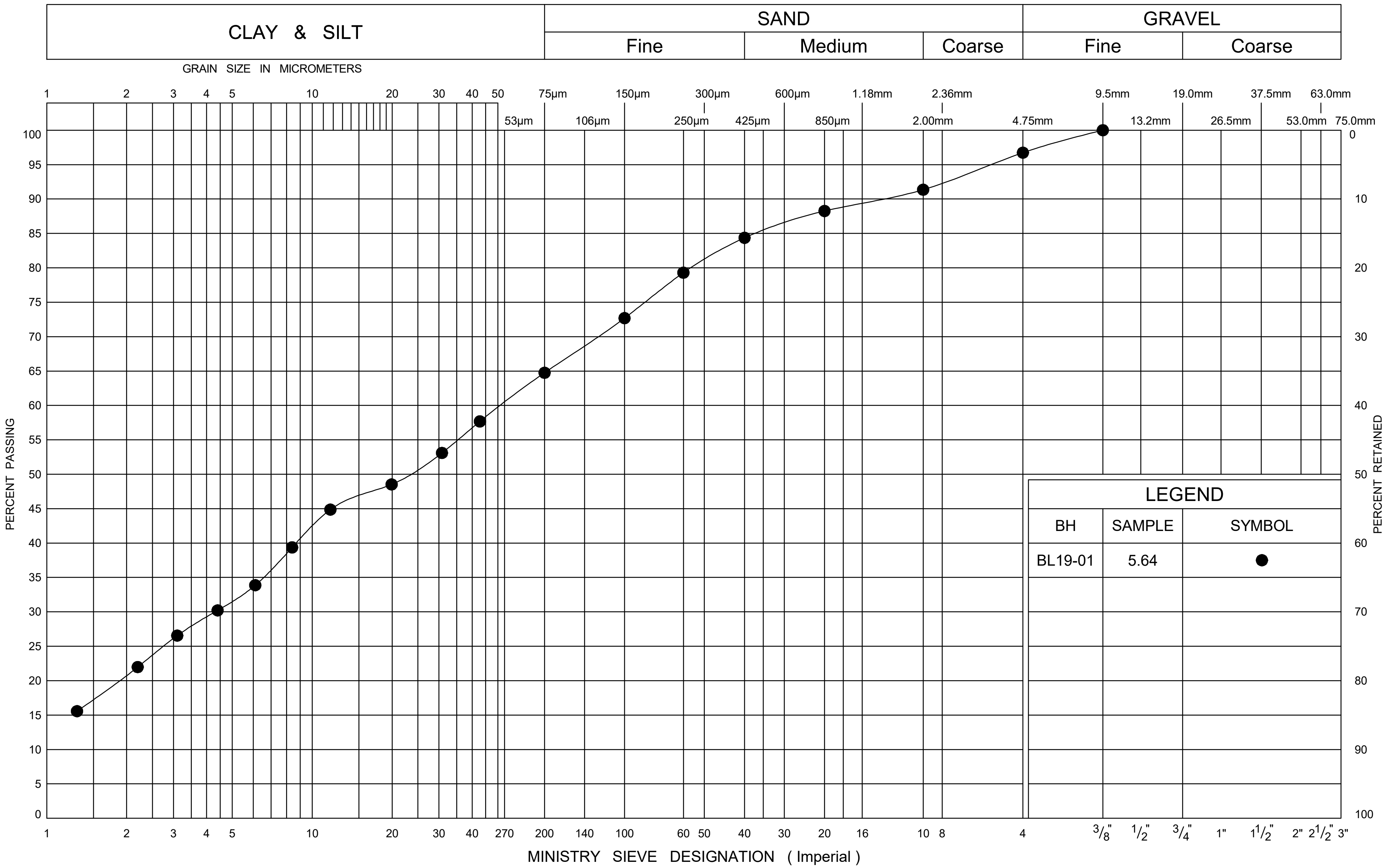
Silty SAND FILL

FIG No B2

W P 2459-16-00 & 2461-16-00

ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19

78 12 M



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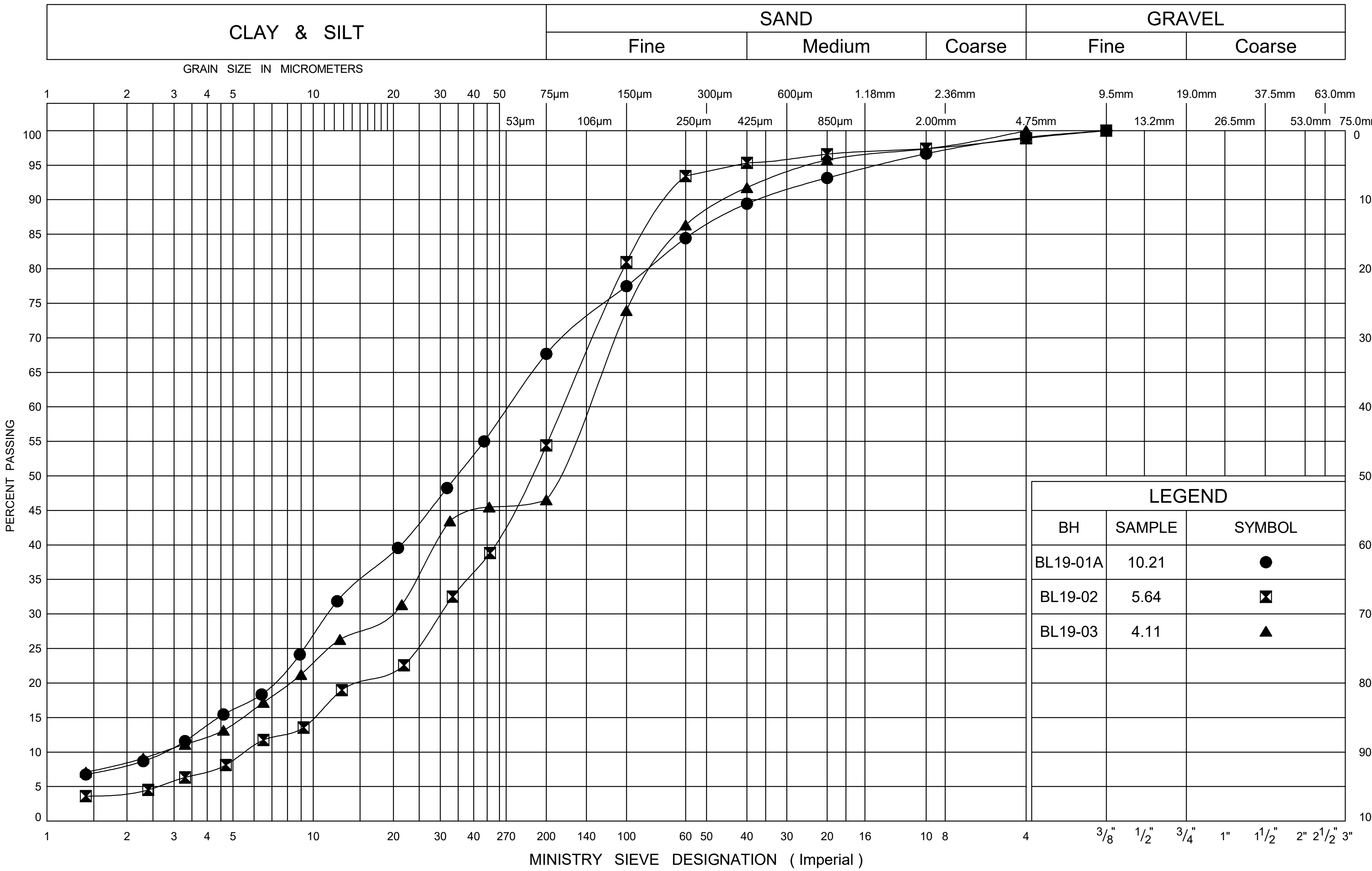
GRAIN SIZE DISTRIBUTION

Clayey SILT FILL

FIG No B3

W P 2459-16-00 & 2461-16-00

ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19



LEGEND

BH	SAMPLE	SYMBOL
BL19-01A	10.21	●
BL19-02	5.64	⊠
BL19-03	4.11	▲

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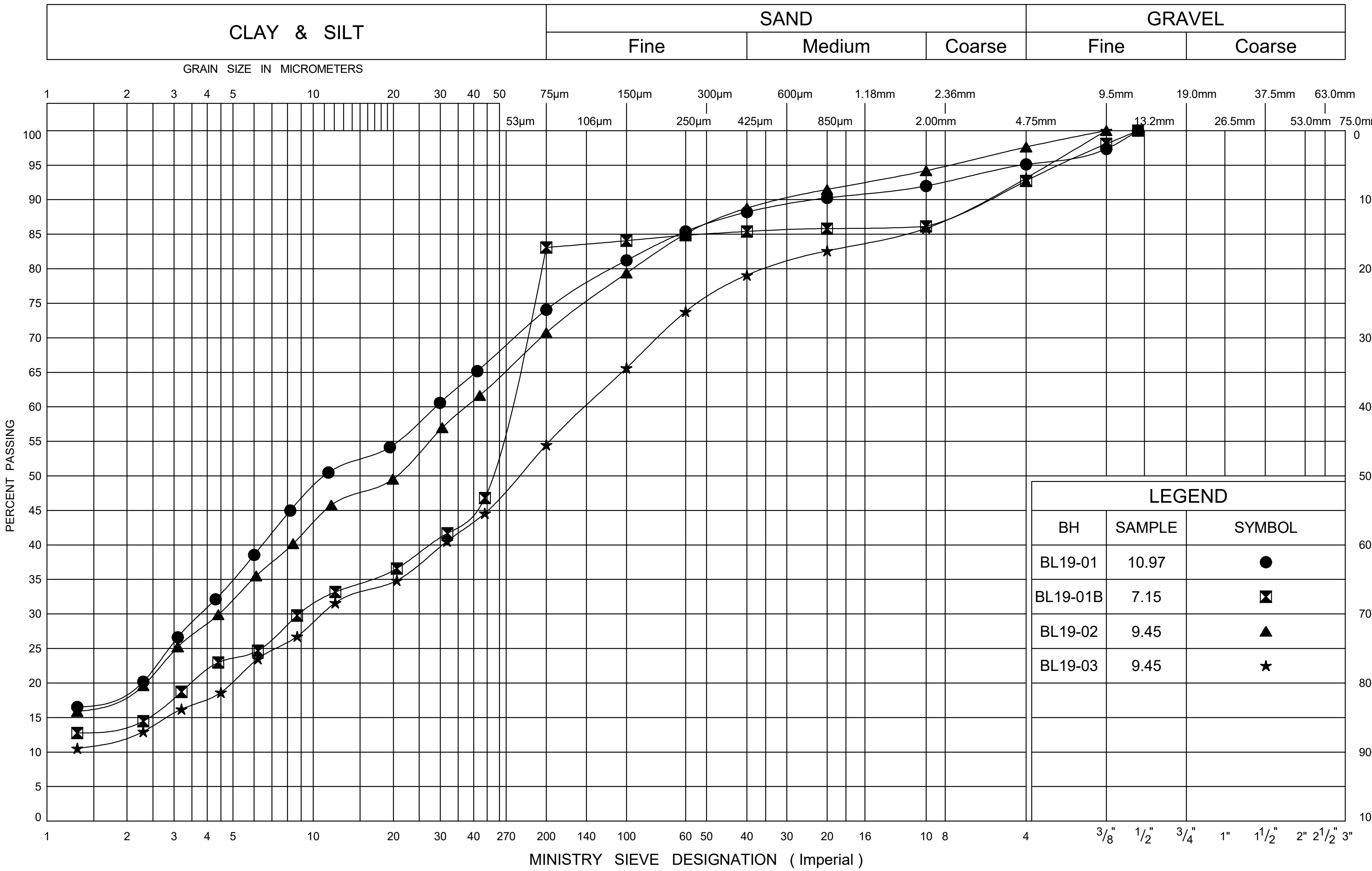
GRAIN SIZE DISTRIBUTION

SAND and SILT, Sandy SILT

FIG No B4

W P 2459-16-00 & 2461-16-00

ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19



BH	SAMPLE	SYMBOL
BL19-01	10.97	●
BL19-01B	7.15	⊠
BL19-02	9.45	▲
BL19-03	9.45	★

Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

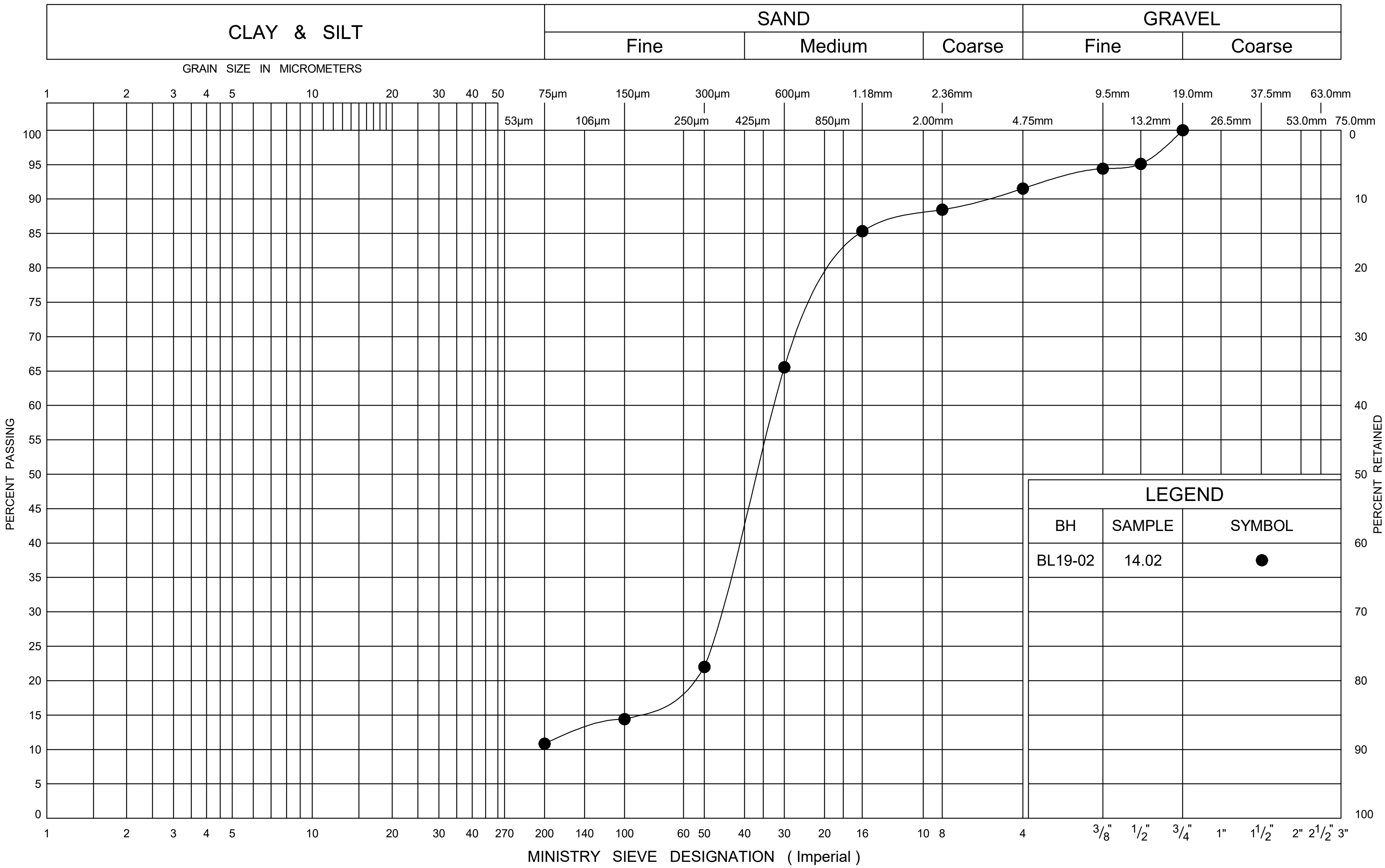
Clayey SILT, Clayey SILT TILL

FIG No B5

W P 2459-16-00 & 2461-16-00

ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19

78 12 M



ONTARIO MOT GRAIN SIZE 2 MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19

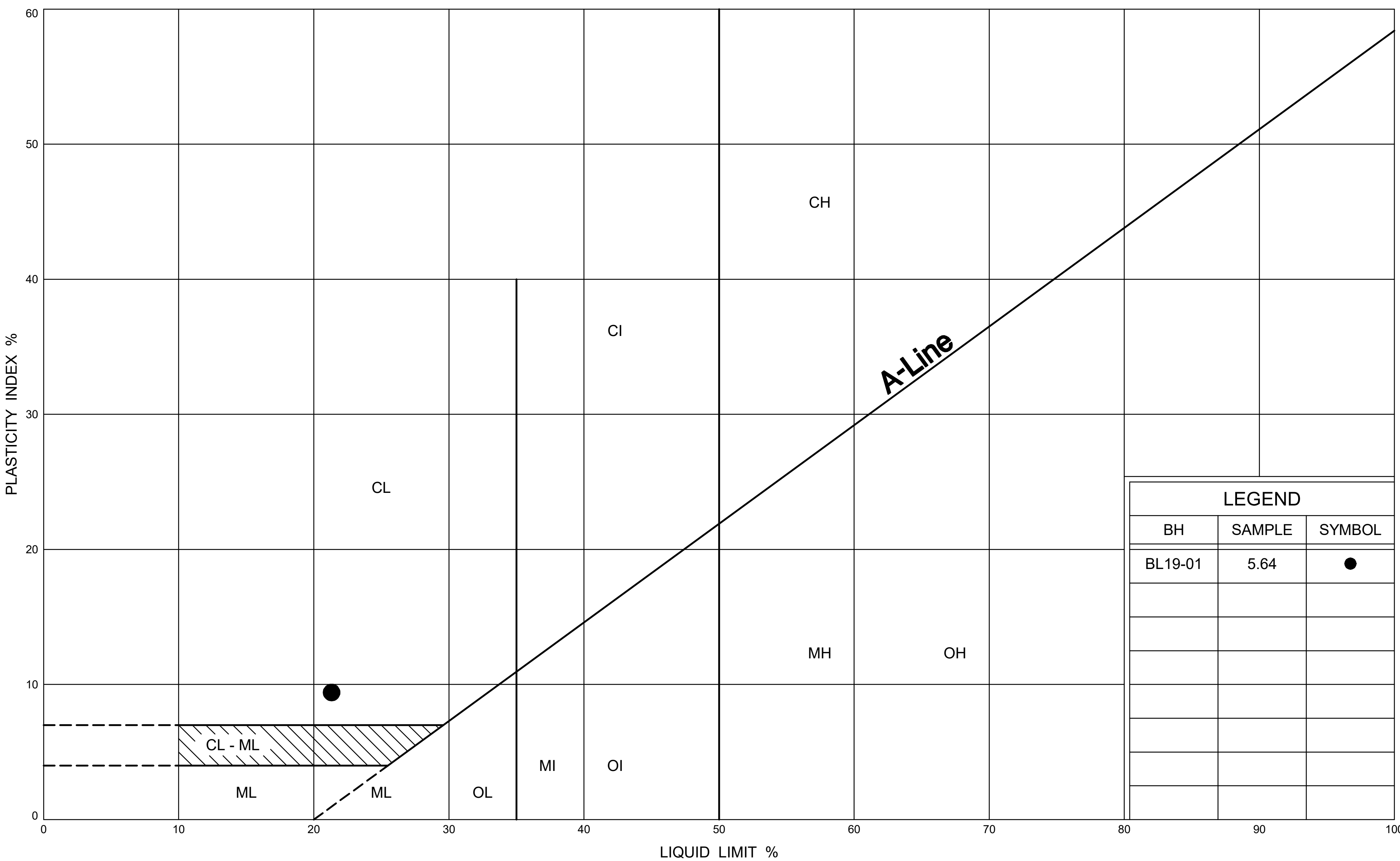
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND

FIG No B6

W P 2459-16-00 & 2461-16-00



PLASTICITY CHART

Clayey SILT FILL

FIG No B7

W P 2459-16-00 & 2461-16-00

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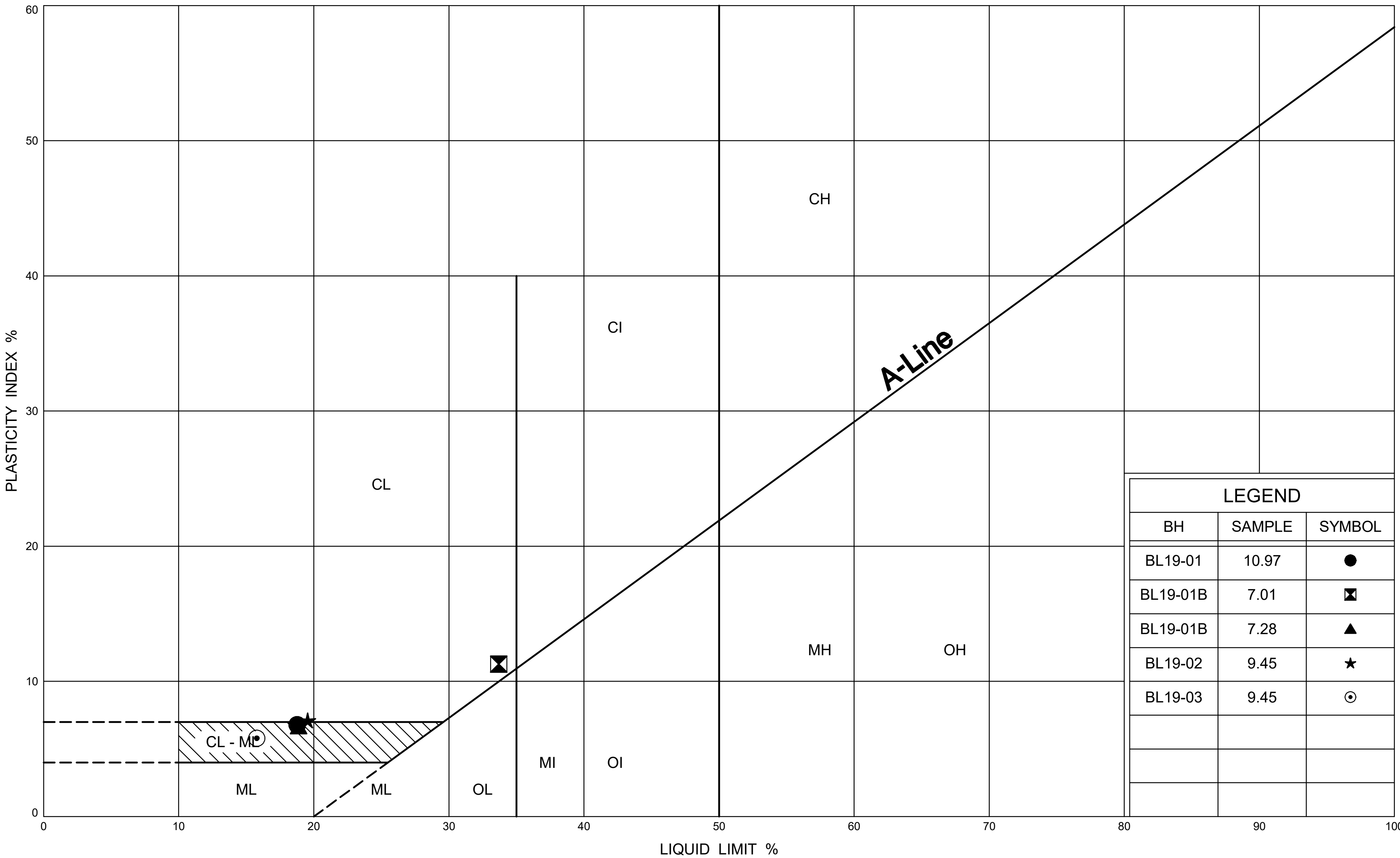

LEGEND

BH	SAMPLE	SYMBOL
BL19-01	10.97	●
BL19-01B	7.01	⧗
BL19-01B	7.28	▲
BL19-02	9.45	★
BL19-03	9.45	⊙

ONTARIO MOT PLASTICITY CHART MTO-25504.GPJ ONTARIO MOT.GDT 11/28/19

Ministry of Transportation
Ontario

PLASTICITY CHART

Clayey SILT, Clayey SILT TILL

FIG No B8

W P 2459-16-00 & 2461-16-00

SGS AGRIFOOD LABORATORIES

AgTest Farm Soil Report

1-503 Imperial Road North   Guelph, ON, N1H 6T9   t: 519-837-1600   1-800-265-7175   f: 519-837-1242   ca.agri.guelph.lab@sgs.com

Report # 558043   SGS LAKEFIELD - Katrina Wells - CA14826 OCT19 OM

Sample ID:	Lab #	pH	BpH	Total Salts (mmhos/cm)	Organic Matter (%)	Nitrogen NO3-N (ppm)	Phosphorus - P (ppm)		Potassium K (ppm)	Magnesium Mg (ppm)	Calcium Ca (ppm)
GS-7 - BL 19-01A	31910814				22.9						
TW4 - BL 19-01B	31910815				7.2						

Sample ID:	Zinc Zn (ppm)	Zn Index	Manganese Mn (ppm)	Mn Index	Copper Cu (ppm)	Iron Fe (ppm)	Boron B (ppm)	Texture	Cation Exchange MEQ/100g	Base Saturation K%	Mg%	Ca%	H%
GS-7													
TW4													

Sample ID:	Sodium Na (ppm)	Sulphate Sulphur SO4-S (ppm)	Chloride Cl (ppm)	Aluminum Al (ppm)	K/Mg Ratio	Exchangeable Acidity						
GS-7												
TW4												

Authorized By: *Jack Legg - CCA-ON, 4R NMS*

SGS LAKEFIELD - Katrina Wells - CA14826 OCT19 OM
185 Concession St.
Lakefield, ON K0L 2H0

Email

Date Received: Oct-30-2019

Date Reported: Nov-08-2019

Fax: 705-652-6365
Email: katrina.wells@sgs.com; brad.moore@sgs.com

THURBER

Appendix C

Selected Site Photographs

Photo 1- East side of the S-E/W Ramp
Modified swale at the of the curb. Fill observed at the top of the slope.

Photo 2- East side of the S-E/W Ramp
Looking southwest at the modified swale location

Photo 3- Existing slope at the S-E/W Ramp, looking south

Localized instability at mid-slope, with some fresh scarping and soil washing down towards the swampy area at the toe of the slope;

Photos 4 and 5- Existing slope at the S-E/W Ramp, looking towards the slope from top and mid-slope. Localized wet area at the toe of the slope.

Photo 6- Existing slope at the S-E/W Ramp, looking north
Mid-slope instability

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Appendix D

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

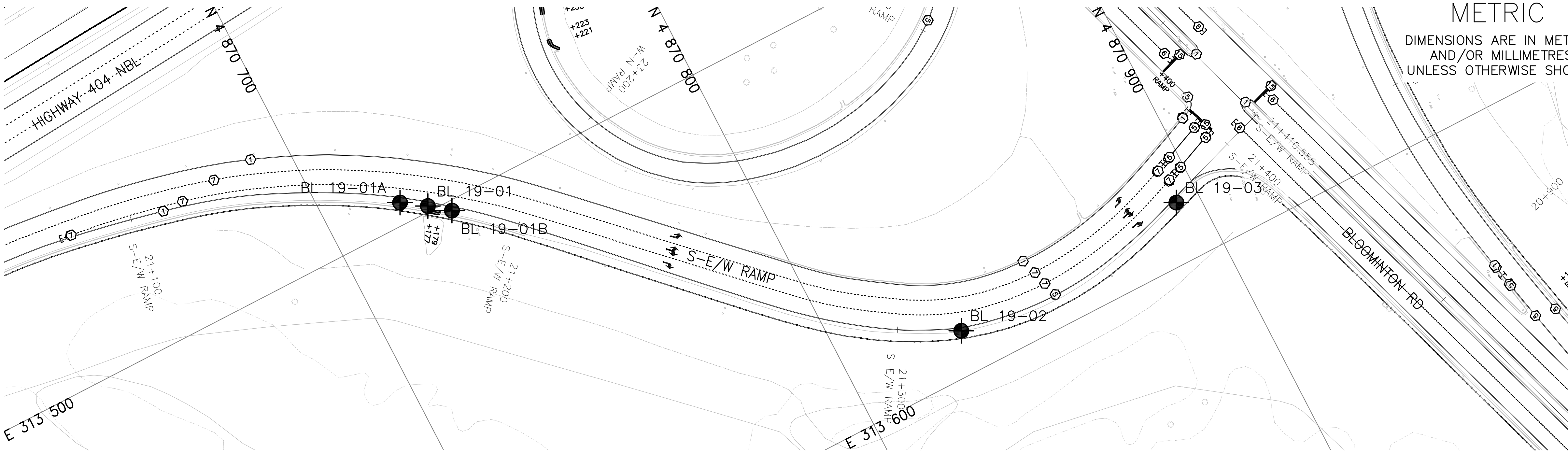
WP No 2459-16-00/2461-16-00

SHEET

HIGHWAY 404
S-E/W RAMP TO
BLOOMINGTON ROAD
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY

THURBER ENGINEERING LTD.



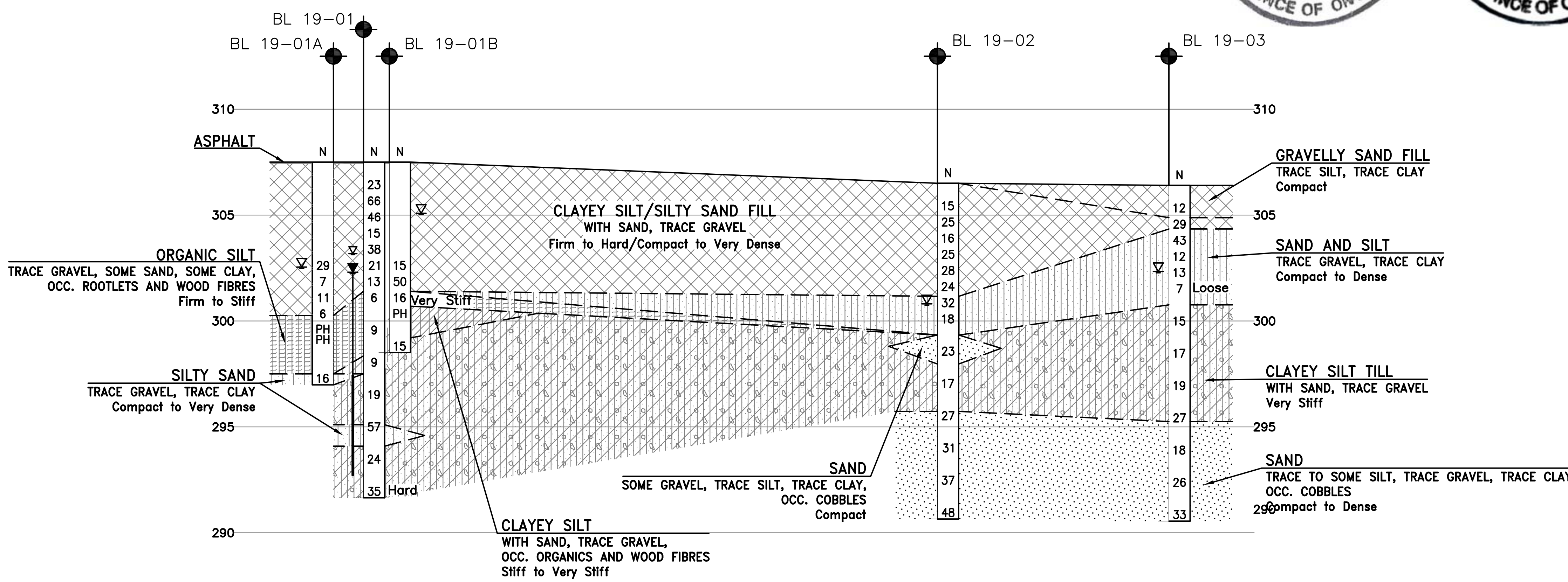
PLAN

25 0 25 50m

SCALE 1:1250

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
07/13/2020
PROVINCE OF ONTARIO

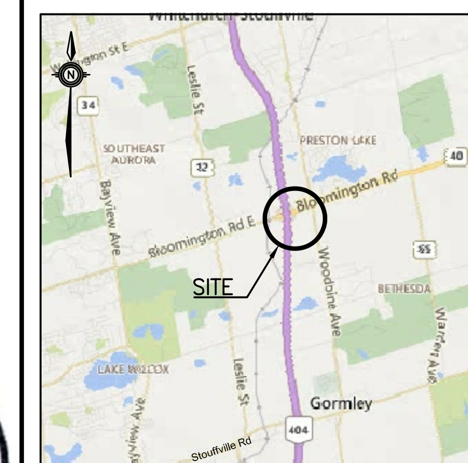
LICENSED PROFESSIONAL ENGINEER
S. PANG
35314509
07/13/2020
PROVINCE OF ONTARIO



PROFILE ALONG S-E/W RAMP

25 0 25 50m H 1:1250

5 0 5 10m V 1:250



43.976456 KEYPLAN -79.391579

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
BL 19-01	307.5	4 870 724.9	313 498.6
BL 19-01A	307.5	4 870 719.1	313 494.6
BL 19-01B	307.5	4 870 729.8	313 502.5
BL 19-02	306.5	4 870 830.7	313 589.0
BL 19-03	306.4	4 870 894.1	313 585.2

-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) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M14-519

REVISIONS	DATE	BY	DESCRIPTION
DESIGN RCR	CHK RCR	CODE	LOAD	DATE JUL 2020
DRAWN BH	CHK SKP	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\25000\25504\TED-25504-BHPP.dwg
PLOTDATE: 7/14/2020 2:57 PM

MINISTRY OF TRANSPORTATION, ONTARIO

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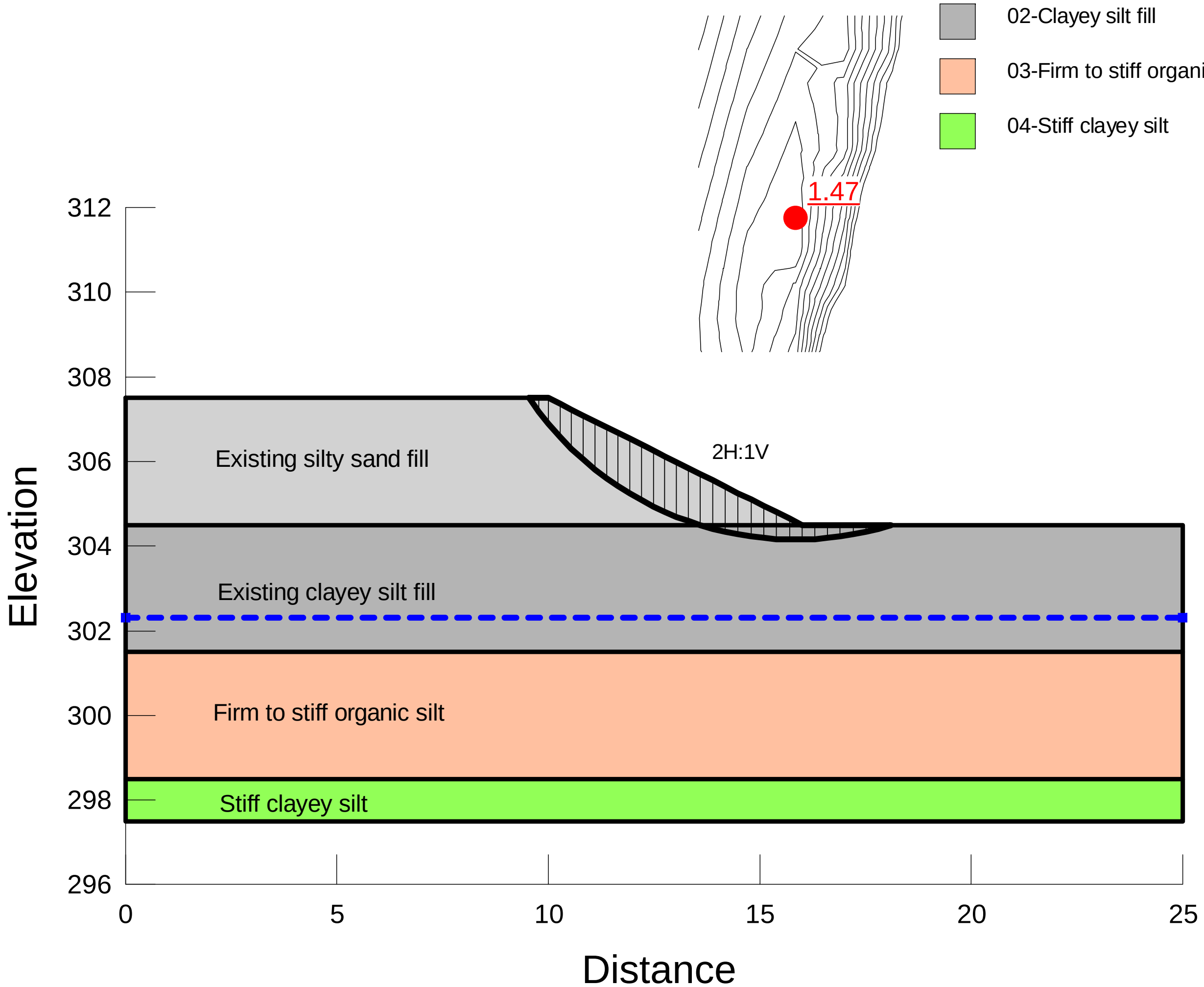
Appendix E

Selected Slope Stability Outputs



Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	01-Existing silty sand fill	Mohr-Coulomb	20	0	30	1
	02-Clayey silt fill	Mohr-Coulomb	19	0	29	1
	03-Firm to stiff organic silt	Mohr-Coulomb	13	0	22	1
	04-Stiff clayey silt	Mohr-Coulomb	19	0	29	1

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Project
25504 - Highway 404 and Bloomington Road interchange

Analysis
S-E/W Ramp - Drained Analysis

Seismic Coefficient
H: 0g, V: 0g

Last Run
04/21/2020,07:53:11 AM

Scale
1:175

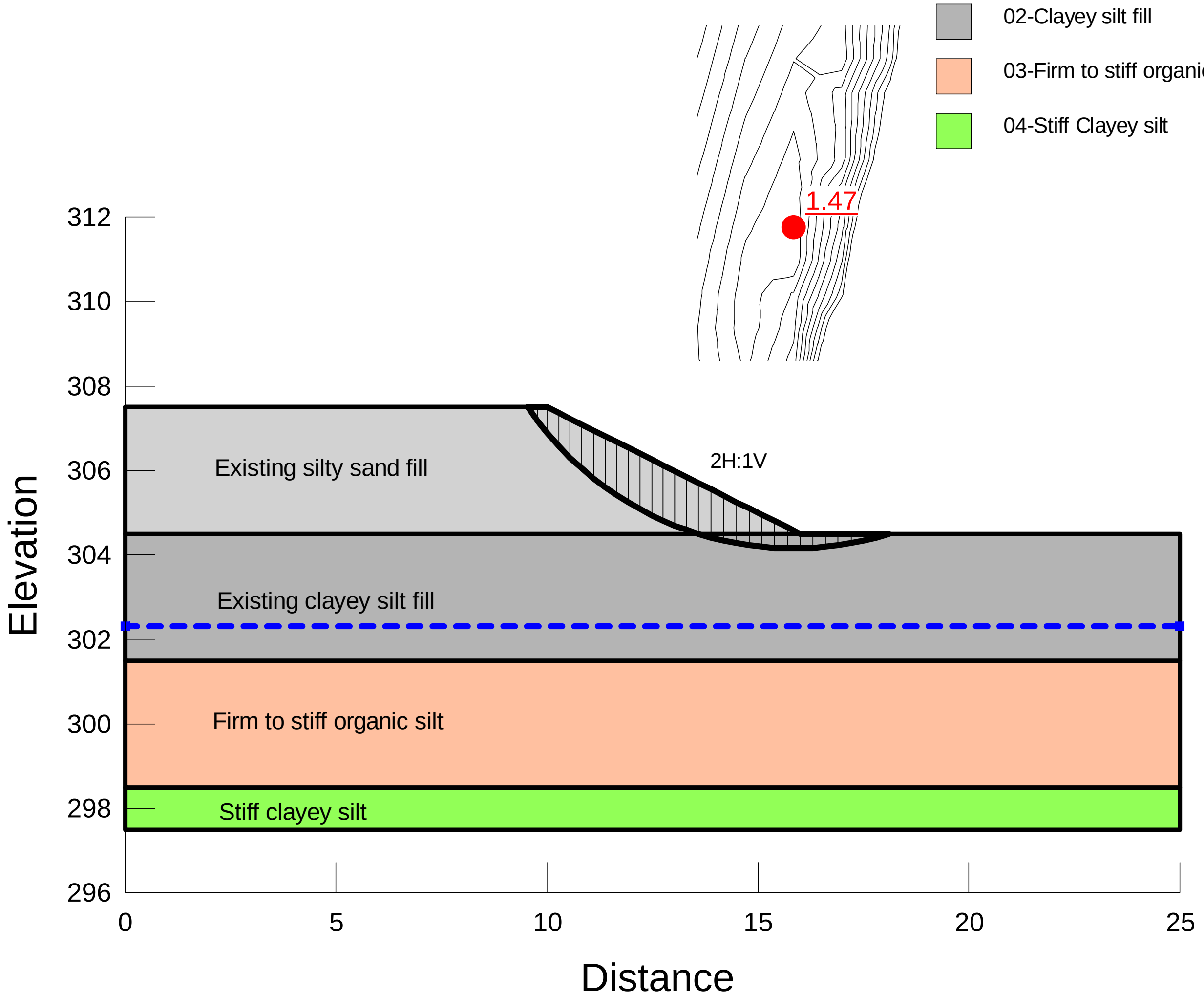
Additional Details
Name: Slope Stability Analysis
Comments: Embankment height 3.0m
Method: Morgenstern-Price, Half-Sine

Figure E1

H:\20000-29999\25000-25999\25504 Hwy 404 Rehabilitation 2018-E-0051\Analysis\Ramp\Slope Stability\25504- Ramp Hwy 404-Bloomington Rd- Drained.gsz

Tool Version: 10.2.1.19666

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	01-Existing silty sand fill	Mohr-Coulomb	20	0	30	1
	02-Clayey silt fill	Mohr-Coulomb	19	0	29	1
	03-Firm to stiff organic silt	Mohr-Coulomb	13	50	0	1
	04-Stiff Clayey silt	Mohr-Coulomb	19	80	0	1



Project: 25504 - Highway 404 and Bloomington Road interchange		
Analysis: S-E/W Ramp - Undrained Analysis		
Seismic Coefficient: H: 0g, V: 0g	Last Run: 04/21/2020,07:56:22 AM	Scale: 1:175

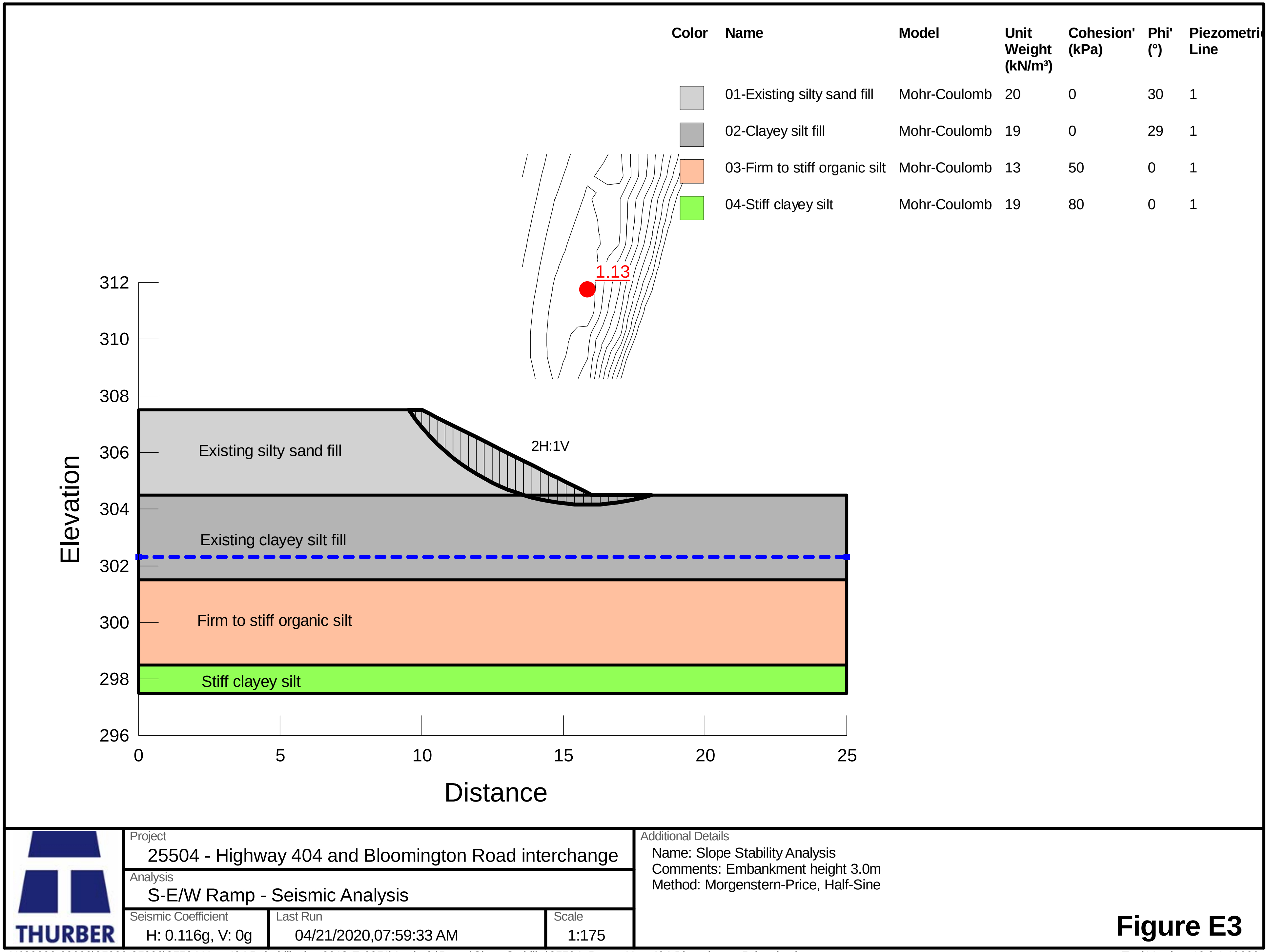
Additional Details
Name: Slope Stability Analysis
Comments: Embankment height 3.0m
Method: Morgenstern-Price, Half-Sine

THURBER

Figure E2

H:\20000-29999\25000-25999\25504 Hwy 404 Rehabilitation 2018-E-0051\Analysis\Ramp\Slope Stability\25504- Ramp Hwy 404-Bloomington Rd- Undrained.gsz

Tool Version: 10.2.1.19666


Color
Name
Model
Unit Weight (kN/m³)
Cohesion' (kPa)
Phi' (°)
Piezometric Line
01-Existing silty sand fill Mohr-Coulomb 20 0 30 1
02-Clayey silt fill Mohr-Coulomb 19 0 29 1
03-Firm to stiff organic silt Mohr-Coulomb 13 50 0 1
04-Stiff clayey silt Mohr-Coulomb 19 80 0 1
1.13
2H:1V
Existing silty sand fill
Existing clayey silt fill
Firm to stiff organic silt
Stiff clayey silt
Elevation
312
310
308
306
304
302
300
298
296
0
5
10
15
20
25
Distance
THURBER
Project
25504 - Highway 404 and Bloomington Road interchange
Analysis
S-E/W Ramp - Seismic Analysis
Seismic Coefficient
H: 0.116g, V: 0g
Last Run
04/21/2020,07:59:33 AM
Scale
1:175
Additional Details
Name: Slope Stability Analysis
Comments: Embankment height 3.0m
Method: Morgenstern-Price, Half-Sine
Figure E3