



Foundation Investigation and Design Report

Highway 9 - South Holland Canal Bridge (WBL) Rehabilitation and Protection Systems, Site No. 37-32/2, King, Ontario, Assignment No. 2016-E-0029-06, GWP 2263-16-00

Submitted to:

AECOM Canada

300 Water Street
Whitby, Ontario
L1N 9J2

Submitted by:

Golder Associates Ltd.

6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada

+1 905 567 4444

GEOCRES No.: 31D-711

Lat. 44.026878, Long. -79.604865

1671430 WO7-1

October 3, 2018



Distribution List

3 Hard Copies, 1 Electronic Copy - MTO - Central Region

1 Hard Copy, 1 Electronic Copy - MTO - Foundations Section

1 Electronic Copy - AECOM Canada Ltd.

1 Electronic Copy - Golder Associates Ltd.

Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
3.1 1965 Investigation	1
3.2 1997 Investigation	2
3.3 2018 Investigation	2
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 General Overview of Subsurface Conditions	4
4.2.1 Topsoil	4
4.2.2 Asphalt	4
4.2.3 Fill	5
4.2.4 Peat / Organic Silt	5
4.2.5 Upper Clayey Silt to Silty Clay Deposit	5
4.2.6 Upper Sandy Clayey Silt Till	6
4.2.7 Lower Silty Clay	6
4.2.8 Lower Clayey Silt to Silty Clay Till	7
4.2.9 Silt and Sand	7
4.3 Groundwater Conditions	7
5.0 CLOSURE	9

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	10
6.1 General	10
6.2 Consequence and Site Understanding Classification	10
6.3 Assessment of Existing Foundations	11

6.3.1	Resistance to Lateral Loads	11
6.4	Frost Penetration.....	13
6.5	Excavation and Groundwater Control	13
6.6	Temporary Protection Systems.....	14
6.7	Obstructions	15
7.0	CLOSURE	16

REFERENCES

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

APPENDICES

APPENDIX A - Borehole Records and Laboratory Test Results from Previous Investigations (GEOCREC No. 31D-022 and 31D-364)

APPENDIX B - Borehole Records from Current Investigation

Lists of Symbols and Abbreviations
Record of Boreholes C2-1, C2-2, TP-1, TP-2

APPENDIX C - Geotechnical Laboratory Test Results

Figure C1 Grain Size Distribution – Silt and Sand (Fill)
Figure C2 Plasticity Chart – Silt and Sand (Fill)
Figure C3 Grain Size Distribution – Clayey Silt (Fill)
Figure C4 Plasticity Chart – Clayey Silt (Fill)
Figure C5 Grain Size Distribution – Clayey Silt
Figure C6 Plasticity Chart – Clayey Silt – Silt to Clayey Silt

APPENDIX D - Drawing D5868-1

APPENDIX E - Non-Standard Special Provisions

Protection Systems
Obstructions

PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 9 - SOUTH HOLLAND CANAL BRIDGE (WBL) REHABILITATION
AND TEMPORARY PROTECTION SYSTEMS
SITE NO. 37-32/2
KING, ONTARIO
ASSIGNMENT NO. 2016-E-0029-06, GWP 2263-16-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed superstructure replacement and substructure repair of the existing Highway 9 – South Holland Canal Bridge (MTO Structure Site No. 37-32/2), GWP 2263-16-00, located in Kettleby, Ontario, as shown on the Key Plan on Drawing 1.

This report addresses the foundation investigation carried out to support the rehabilitation of the existing Highway 9 – South Holland Canal Bridge. This report was developed based on information from the current investigation, supplemented with information from 1965 and 1997 foundation investigations completed previously by others at the structure site, as follows:

- **MTO GEOCREs No. 31D-022:** “Foundation Investigation Report for Proposed Holland Marsh Drainage Canal Bridge, Lot 35, Con. VI, Twp of King, Co. of York, Hwy #9, Line ‘K’, District #6 (Toronto). W.J. 65-F-109 - - W.P. 170-65”, prepared by Department of Highway Ontario, Foundation Section – Materials and Testing Division, dated December 9, 1965.
- **MTO GEOCREs No. 31D-364:** “Foundation Investigation Report for Highway 9 – Holland Drainage Canal East Bridge Widening, WP 4-95-01, Site No. 37-32, Highway 9, Central Region, Region of York, Agreement # 9690-4444-9917,” prepared by Thurber Engineering Ltd., dated May 8, 1997.

The Terms of Reference for the foundation engineering services are outlined in MTO's Work Item Order Form dated January 15, 2018 which forms part of the Consultant's Assignment for the Central Region Large Value Retainer under Agreement No. 2016-E-0029-007 for this project.

2.0 SITE DESCRIPTION

The South Holland Canal Bridge is located about 800 m west of Highway 400 along Highway 9, near South Canal Bank Road in Kettleby Ontario. The site is surrounded by marshland to the south and farmland to the north, with the ground generally flat-lying. Highway 9 is at approximately Elevation 222.1 m at the South Holland Canal Bridge, and slopes down to about Elevations 220.9 m to 220.3 m west and east of the bridge, respectively. South Holland Canal is trapezoidal in cross-section with an about 9 m wide base at about Elevation 217 m and the side slopes are inclined at about 2 Horizontal and 1 Vertical (2H:1V). The water level within the canal was measured at Elevation 218.2 m in February 2014.

The South Holland Canal Bridge consists of a three-span concrete box girder structure with span lengths of 11.9 m from the abutment to the piers and 13.4 m from pier to pier. The bridge was constructed on a skew of approximately 45 degrees over South Holland Canal. The abutments and piers are supported on concrete filled 323 mm outer diameter closed end steel tube piles, driven into the very dense sandy till to Elevation 198.7 m.

3.0 INVESTIGATION PROCEDURES

3.1 1965 Investigation

A total of four boreholes (Boreholes 1 to 4) and three cone penetration tests (Boreholes 2, 4 and 5) were advanced as part of the 1965 investigation (GEOCREs No. 31D-022) for the Highway 9 – Holland Drainage Canal Bridge. The boreholes and cone penetration tests are located within or immediately adjacent to the footprint of the existing

abutment foundations of the westbound structure, as shown on Drawing 1. These borehole locations have been developed based on plotting the coordinates and offsets shown on the 1965 drawings, and converting these to MTM NAD83 (Zone 10) coordinates. The borehole records from the 1965 investigation are presented in Appendix A.

The Standard Penetration Test (SPT) “N” values in the 1965 investigation were obtained using a manual hammer.

3.2 1997 Investigation

A total of four boreholes (Boreholes 97-1 to 97-4) were advanced as part of the 1997 investigation (GEOCREC No. 31D-364) for the Highway 9 – Holland Drainage Canal Bridge. Two of these boreholes are located within or immediately adjacent to the footprint of the existing abutments of the eastbound structure, while the other two are located within the approach embankments as shown on Drawing 1. These borehole locations have been developed based on plotting the UTM coordinates shown on the 1997 borehole records and drawings and converting these to MTM NAD 83 (Zone 10) coordinates. The borehole records from the 1997 investigation are presented in Appendix A.

3.3 2018 Investigation

The field work for the current South Holland Canal Bridge investigation was carried out on May 10, 14 and 16, 2018, during which time four boreholes (designated as Boreholes C2-1, C2-2, TP-1 and TP-2) were advanced at the site. Boreholes C2-1 and C2-2 were advanced along the banks of the South Holland Canal, while Boreholes TP1 and TP2 were advanced at Highway 9 grade within the westbound lanes, at approximately the locations shown on Drawing 1.

Boreholes C2-1 and C2-2 was drilled using 152 mm outer diameter hollow-stem augers by a D25 truck-mounted drill rig and Boreholes TP-1 and TP-2 were drilled using 210 mm outer diameter hollow stem augers by a D90 truck-mounted drill rig, both supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven with a manual hammer in Boreholes C2-1 and C2-2, and driven by an automatic hammer in Boreholes TP-1 and TP2 in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)¹.

Boreholes C2-1 and C2-2 were advanced on the northwest and northeast bank of the South Holland Canal adjacent to the Bridge to depths of 11.3 m and 12.8 m below ground surface, respectively. Boreholes TP-1 and TP-2 were advanced from the highway surface to depths of about 12.8 m and 15.8 m, respectively, below existing roadway surface. Traffic protection consisted of a lane closure for boreholes advanced from the roadways platforms, and shoulder and / lane closures to aid in the loading and unloading of the track-mounted drill rig for the borehole advanced off of the roadway, all consistent with Book 7 requirements.

The groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in Borehole TP-1 to permit monitoring of the water level. The installed piezometer in Borehole TP-1 consists of a 50 mm diameter PVC pipe, with a 1.5 m slotted screen within a filter sand pack sealed within the clayey silt deposit about 2 m above the bottom of the borehole. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to near ground surface with bentonite pellets and the upper 200 mm of the borehole was capped with cold patch asphalt to the roadway surface. Boreholes C2-1, C2-2 and TP-2 were backfilled to ground surface with bentonite and the upper 200 mm of Borehole

¹ ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

TP-2 was sealed to the roadway surface with cold patch asphalt upon completion, in accordance with Ontario Regulation 903, Wells (as amended).

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the sampling and in situ testing operations, logged the boreholes and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further visual review and geotechnical laboratory testing on selected samples, consisting of natural moisture content, Atterberg limits and grain size distribution conducted in accordance with MTO and / or ASTM Standards as applicable.

The borehole locations were marked in the field by Golder personnel relative to the existing guardrails and other site features. The locations given in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, including in geographic (Latitude / Longitude) coordinates, the ground surface elevations and borehole drilled depths are summarized below.

Borehole No.	MTM NAD83		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
C2-1	4,876,341.1 (44.027018)	296,387.4 (-79.604949)	220.9	11.3
C2-2	4,876,350.1 (44.027099)	296,422.9 (-79.604506)	220.3	12.8
TP-1	4,876,318.8 (44.026817)	296,355.2 (-79.605350)	222.0	12.8
TP-2	4,876,339.5 (44.027004)	296,426.9 (-79.604456)	222.2	15.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 9 is located in the Sand Plains within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)².

The Simcoe Lowlands physiographic region covers the central portion of the County of Simcoe. Following the retreat of the last glacial ice sheet, the lowland was flooded by the now extinct post-glacial Lake Algonquin. This past post-glacial lacustrine environment is marked by deep sand, silt and clay beds overlying glacial ground moraine material. The Holland River valley, which crosses Highway 400 just north of Highway 9 and South Canal Road, is

²Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

located within the Simcoe Lowlands region. This valley extends to the southwest from Cook Bay at the south end of Lake Simcoe, and was once a shallow extension of the lake. The floor of the valley consists of peat, soft clays and loose sands. It is understood that during initial construction of Highway 400 through this area, a layer of peat about 2 m to 3 m thick was removed to allow construction of the road upon the underlying sand and clay; towards Lake Simcoe the peat deposit is considerably thicker. The Sand Plains is covered by peat / topsoil underlain by sand and clay deposits.

4.2 General Overview of Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes of the current investigation including piezometer installation details and water level readings, and the results of the in situ and laboratory tests are provided on the Record of Borehole Sheets in Appendix B. The results of the in situ field tests (i.e., SPT “N”-values) as presented on the borehole records and in Section 4 are uncorrected. The Standard Penetration Test “N”-values from the 1965 investigation and Boreholes C2-1 and C2-2 from the 2018 investigation are based on use of a manual hammer, while those in the 1997 investigation and Boreholes TP-1 and TP-2 from the 2018 investigation are based on use of an automatic hammer and the values are reported with no adjustment in this report, although it is recognized that SPT “N” values obtained using a manual hammer are frequently higher than those obtained using an automatic hammer (CFEM, 2006)³. The results of the geotechnical laboratory testing on soil samples are presented on the Laboratory test figures in Appendix C.

The stratigraphic boundaries shown on the borehole records and on the stratigraphic profile and cross-section on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected, however, the factual data presented on the borehole records governs any interpretation of the site conditions.

In general, the native subsurface soils encountered consist of surficial layers of topsoil and asphalt, underlain by fill material and peat / organic silt. The fill and / or organic materials are underlain by interlayered deposits of clayey silt to silty clay and clayey silt to silty clay till, with the till underlain by a silt and sand deposit.

4.2.1 Topsoil

An approximately 0.7 m thick layer of topsoil was encountered immediately below ground surface in Boreholes C2-1 and C2-2. Borehole BH97-1 to BH97-4 encountered an approximately 100 mm to 150 mm thick layer of topsoil immediately below ground surface. Black “muck” was encountered in Boreholes 2 to 4, which were advanced in the then-existing canal or on the banks of the canal. The “muck” material is described as being comprised of silt and clay with decayed organic matter and extended to a depth of up to 1 m.

Standard Penetration Tests (SPT) “N” values-measured within the topsoil are 8 blows and 10 blows per 0.3 m of penetration, suggesting a stiff consistency. The “muck” material was described as having a very soft consistency.

4.2.2 Asphalt

An approximately 220 mm thick layer of asphalt pavement was encountered immediately below ground surface in Boreholes TP-1 and TP-2.

³ Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition.

4.2.3 Fill

Fill was encountered underlying the asphalt in Boreholes TP-1 and TP-2 and underlying the topsoil in Boreholes C2-1, C2-2, BH97-1, BH97-3 and BH97-4. The fill layer is between 1.5 m and 5.4 m thick, with its base extends to approximately between Elevations 219.3 m and 215.3 m. The fill is variable in composition and is comprised of an upper layer of gravelly sand to sand and gravel, underlain by a layer of clayey silt to clayey silt with sand in Boreholes TP-1 and TP-2; clayey silt to silty clay fill in Boreholes C2-1, C2-2, BH97-1, and BH97-4; and sandy silt to sand and silt fill in Borehole BH97-3.

SPT “N”-values measured within the non-cohesive portion of the fill range from 19 blows to 76 blows per 0.3 m of penetration with one value of compact of 50 blows per 0.13 m of penetration, indicating a compact to very dense compactness condition. The SPT “N”-values measured within the cohesive portion of the fill range from 4 blows to 30 blows per 0.3 m of penetration and field vane tests measured undrained shear strengths between approximately 39 kPa and over 96 kPa. These results suggest that the cohesive fill has a firm to stiff consistency.

A grain size distribution was carried out on two samples of the non-cohesive silt and sand fill and the results are shown on Figure C1 in Appendix C. Atterberg limits testing was carried out on two samples of the silt and sand fill and measured liquid limits of 14 and 16 per cent, plastic limits of 13 and 14 per cent, and corresponding plasticity indices of 1 and 2 per cent. These results, which are plotted on a plasticity chart on Figure C2 in Appendix C, indicate the presence of low plasticity silt within the silt and sand fill. The natural water content measured on two samples of the gravelly sand to sand and gravel fill is 3 and 7 per cent. The natural water content measured on four samples of the sandy silt to silt and sand fill range between 8 and 17 per cent.

Grain size distribution tests were carried out on four samples of the cohesive clayey silt fill and the results are shown on Figure C3 in Appendix C. Atterberg limits testing was carried out on four samples of the cohesive fill and measured liquid limits ranging between 31 and 33 per cent, plastic limits ranging between 17 and 18 per cent, and plasticity indices ranging between 12 and 16 per cent. These results, which are plotted on a plasticity chart on Figure C4 in Appendix C, indicate the fill consists of clayey silt of low plasticity. The natural water content measured on selected samples of the cohesive fill ranges from about 12 to 34 per cent.

4.2.4 Peat / Organic Silt

A 0.1 m and 0.7 m thick layer of amorphous granular peat was encountered underlying the cohesive fill in Boreholes BH97-1 and BH97-4, respectively. A 0.8 m thick layer of organic silt was encountered underlying the topsoil in Borehole BH97-2, while Borehole BH97-4 terminated within an organic silt layer, penetrating it for 0.3 m.

The SPT “N”-values measured within the peat layer are 8 blows and 10 blows per 0.3 m of penetration and two field vane tests measured undrained shear strengths of about 38 kPa and over 120 kPa, suggesting a firm to very stiff consistency.

The natural water content measured on one sample of the peat is 128 per cent. The natural water content measured on two samples of the organic silt is 23 and 49 per cent.

4.2.5 Upper Clayey Silt to Silty Clay Deposit

A upper deposit of cohesive material comprised of an upper layer of clayey silt to silty clay and lower layer of silty clay was encountered underlying the fill in Boreholes C2-1, C2-2, TP-1, TP-2, and BH97-3 and is described as laminated in BH97-3; underlying the peat / organic silt in Boreholes BH97-1 and BH97-2; underlying the “muck” in Boreholes 2 to 4; and beneath the water in Borehole 1. Boreholes C2-1, C2-2, TP-1, TP-2 and BH97-1 terminated within this deposit, penetrating into it for approximately 1.0 m to 9.1 m, corresponding to bottom of borehole

Elevations 206.4 m to 218.2 m. The deposit is between approximately 11.6 m and 19.4 m thick in Boreholes BH97-2, BH97-3 and 1 to 4. The surface of the deposit was encountered between Elevations 219.2 m and 215.3 m.

The SPT “N”-values measured within the clayey silt to silty portion of the deposit range from 2 blows to 45 blows per 0.3 m of penetration and field vane tests measured undrained shear strengths ranging between approximately 58 kPa and over 120 kPa and within the silty clay portion of the deposit the undrained shear strength range between about 23 kPa and 76 kPa. These results indicate that the upper clayey silt to silty clay deposit has a stiff to very stiff consistency and the silty clay portion of the deposit has a soft to stiff consistency. Unconfined shear strength tests in Shelby tube samples of the upper clayey silt to silty clay deposit from Boreholes 1 to 4 measures shear strengths between of 20 kPa and 125 kPa. The bulk density measured within the upper clayey silt to silty clay deposit was 18 to 21 kN/m³.

Grain size distribution carried out on six samples of the upper clayey silt to silty clay deposit from the current investigation and the results are shown on Figure C5 in Appendix C. Atterberg limits testing was carried out on twenty three selected samples of the upper clayey silt to silty clay deposit (including seven samples from the current investigation) and measured liquid limits ranging between 22 and 60 per cent, plastic limits ranging between 15 and 24 per cent, and plasticity indices ranging between 5 and 36 per cent. These results, which are plotted on the borehole records for the previous (1965 and 1997) investigations, and six of which are plotted on a plasticity chart on Figure C6 in Appendix C, indicate that the deposit consists of clayey silt of low plasticity to silty clay of high plasticity. The natural water content measured on selected samples of the upper clayey silt to silty clay deposit ranges from about 13 to 33 per cent.

4.2.6 Upper Sandy Clayey Silt Till

A 1.5 m and 2.5 m thick upper till deposit comprised of sandy clayey silt (described as silty clay on Boreholes BH97-2 and BH97-3) containing trace to some gravel was encountered underlying a 1.1 m to 1.2 m thick wet sand seam separating the till from the upper clayey silt to silty clay deposit at Elevations 206.5 m and 206.4 m in Boreholes BH97-2 and BH97-3, respectively. The upper till deposit may contain cobbles as per the notes on the boreholes records.

The SPT “N”-values measured within the upper till deposit are 9 and 10 blows per 0.3 m of penetration, suggesting a stiff consistency. Atterberg limits testing was carried out on one sample of the upper till deposit and measured a liquid limit of 22 per cent, a plastic limit of 12 per cent, and a corresponding plasticity index of 10 per cent. These results indicate that the upper till deposit consists of a clayey silt of low plasticity. The natural water content measured on two samples of the upper till deposit are about 14 and 15 per cent.

4.2.7 Lower Silty Clay

A 4.4 m and 3.5 m thick lower silty clay deposit was encountered underlying the upper till deposit at Elevations 205.0 m and 203.9 m in Boreholes BH97-2 and BH97-3, respectively.

The SPT “N”-values measured within the lower silty clay deposit in these two boreholes range between 21 and 26 blows per 0.3 m of penetration, suggesting a very stiff consistency. Atterberg limits testing was carried out on one sample of the lower silty clay deposit and measured a liquid limit of 48 per cent, a plastic limit of 21 per cent, and a corresponding plasticity index of 27 per cent, indicating that the deposit consists of a silty clay of intermediate plasticity. The natural water content measured on selected samples of the lower silty clay deposit range between 25 and 35 per cent.

4.2.8 Lower Clayey Silt to Silty Clay Till

A lower cohesive till deposit comprised of clayey silt to silty clay was encountered underlying the lower silty clay deposit at Elevations 200.6 m and 200.4 m in Boreholes BH97-2 and BH97-3, respectively. A till deposit described as sandy till comprising of a mixture of sand, gravel, silt and clay was encountered underlying the upper clayey silt to silty clay deposit between Elevations 200.0 m and 199.5 m in Boreholes 1 to 4. Boreholes 1 to 4 terminated within the sandy till deposit, penetrating it for a thickness of between 0.2 m and 0.6 m. The lower cohesive till deposit is 2.2 m and 3.9 m thick in Boreholes BH97-2 and BH97-3, respectively, including an interlayer of sandy silt to silt layer, which is 0.2 m and 1.5 m thick, respectively in these boreholes.

The SPT “N”-values measured within the lower cohesive till deposit, including across the interface with the sandy silt / silt interlayers range between 30 blows and 98 blows per 0.3 m of penetration and 81 blows per 0.24 m of penetration, suggesting a hard consistency. The natural water content measured on selected samples of the lower till deposit range between 14 and 19 per cent.

4.2.9 Silt and Sand

A silt and sand deposit was encountered underlying the lower cohesive till at Elevations 198.4 m and 196.5 m in Boreholes BH97-2 and BH97-3, respectively. The boreholes terminated within this deposit, penetrating it for a thickness of 2.6 m and 3.5 m in Boreholes BH97-2 and BH97-3, respectively.

The SPT “N”-values measured within the silt and sand deposit range from 26 blows to 64 blows per 0.3 m of penetration with N-values of zero weight of hammer and 97 blows per 0.28 m of penetration. The “N”-values with the silt and sand deposit indicate a compact to very dense compactness condition, however artesian groundwater conditions and boiling sand conditions were noted within the deposit and boiling sand conditions were encountered in Borehole BH97-2 at approximately Elevation 197.0 m, which caused the augers to drop about 0.8 m. The natural water content measured on selected samples of the silt and sand deposit range between 18 and 26 per cent.

4.3 Groundwater Conditions

The groundwater levels in the open boreholes were measured upon completion of drilling operations. A standpipe piezometer was installed in Boreholes TP-1 and BH97-4 to permit monitoring of the groundwater level at this site. The groundwater level recorded in the open boreholes and piezometers are shown on the borehole records in Appendices A and B and are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C2-1	220.9	5.4	215.5	May 10, 2018	Open borehole (borehole caved to 9.1m)
C2-2	220.3	4.5	215.8	May 10, 2018	Open borehole
TP-1	222.0	1.9	220.1	June 22, 2018	Piezometer
TP-2	222.2	5.9	216.3	May 14, 2018	Open borehole
BH97-1	220.9	Dry	-	January 27, 1997	Open borehole

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
BH97-2	219.9	1.2 above ground surface	221.1	February 1, 1997	Inside Augers in Open borehole
BH97-3	220.9	0.3 above ground surface	221.2	January 24, 1997	Inside Augers in Open borehole
BH97-4	221.1	Dry	-	January 23, 1997	Piezometer
		1.6	219.5	January 31, 1997	
		1.8	219.3	February 10, 1997	
		1.4	219.7	February 26, 1997	

The groundwater level measured in the piezometer sealed within the upper clayey silt deposit during the current (2018) investigation was at Elevation 220.1 m, below the existing ground surface. The groundwater level measured in the shallow piezometer installed within the peat deposit / clayey silt till during the 1997 investigation was at Elevation 219.7 m. These readings suggest that the groundwater level is at about Elevation 220 m. The GEOCRE information further notes that during the 1997 investigation, Boreholes BH97-2 and BH97-3, encountered artesian water conditions, with a flow rate on the order of 0.5 litres per minute once they penetrated the silt and sand deposit below Elevations 198.4 m to 196.5 m, respectively. Reportedly, the upward flow ceased in the backfilled boreholes after about 25 days in Borehole BH97-2 and 1 day in Borehole BH97-3. Further, during the 1965 investigation artesian conditions were encountered at about Elevation 199.6 m, with a head of approximately 0.7 m, and ground surface corresponding to approximately Elevation 219.8 m.

The groundwater level observations at this site will be subject to seasonal fluctuations and precipitation events; the water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation.

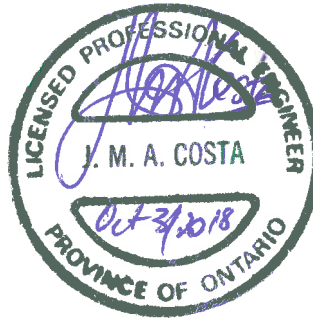
5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Graham Gilles and reviewed by Ms. Nikol Kochmanová, P.Eng. Mr. Jorge M.A. Costa, P.Eng., a Senior Consultant and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Golder Associates Ltd.



Nikol Kochmanová, Ph.D., P.Eng., PMP
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

GPG/NK/JMAC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

<https://golderassociates.sharepoint.com/sites/15994g/6.deliverables/wo007-hollanddrainagecanal/fnds/1.37-32/3.final/1671430wo7rpt2018oct3hwy937-32temporaryprotection.docx>

PART B

FOUNDATION DESIGN REPORT
HIGHWAY 9 – SOUTH HOLLAND CANAL BRIDGE (WBL) REHABILITATION
AND TEMPORARY PROTECTION SYSTEMS
SITE NO. 37-32/2
KING, ONTARIO
ASSIGNMENT NO. 2016-E-0029-06, GWP 2263-16-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report presents an assessment of the axial resistance at the existing foundations and provides foundation engineering parameters / values and general design considerations for the proposed temporary protection systems required for rehabilitation of the Highway 9 - Holland Canal Bridge (WBL), Site 77-32/2 in Kettleby, Ontario.

The discussions are based on interpretation of the factual data obtained from the boreholes advanced during previous and current subsurface investigations. The discussion and geotechnical parameters presented are intended to provide the designers with sufficient information to assess the feasible alternatives of the type of protection system, and to develop approximate costs for the feasible temporary protection systems. The discussion and recommendations in the Foundation Design Report are intended for the use of the MTO and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report to develop their temporary protection system designs. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

The proposed bridge rehabilitation includes replacement of the superstructure, replacement of bearings, reconstruction of the top portion of abutments/pier caps and construction of new bearing pedestals, replacement of expansion joints, replacement of a portion of the approach slabs to facilitate the expansion joint replacement, patch repair of the substructure, and strengthening of existing pipe piles (if required). Protection systems are required to facilitate the removal and replacement of the approach slabs, while maintaining traffic on Highway 9. The depth of excavation is anticipated to extend to approximately Elevation 220.2 m, about 750 mm below the top of abutment stem wall. Although the geometry and design of the protection system is the responsibility of the contractor, based on the design drawings provided by AECOM, it is anticipated that the temporary protection systems will extend along the Highway 9 centerline/median between the westbound and eastbound lanes both to the west and to the east of the bridge abutments.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* CAN/CSA S6-14 (CHBDC (2014)) and its *Commentary*, the bridge structure and its foundation system may be classified as having large traffic volumes and their performance as having potential impacts on other transportation corridors, resulting in a “typical consequence level” associated with exceeding limit states design.

Based on the level of foundation investigations completed to date at this location in comparison to the degree of site understanding in Section 6.5 of CHBDC (2014), the level of confidence for design for the Highway 9 - Holland Canal Bridge has been assessed as “typical degree of site and prediction model understanding” based on having boreholes at / near each foundation element and through the approach embankments. While only two of the boreholes were advanced to the design tip elevations of the existing pile foundations, there is sufficient information to assess the shaft resistance for this site from the three investigations.

The corresponding consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the CHBDC (2014) have been used for the design.

6.3 Assessment of Existing Foundations

Based on the 1966 design drawing (Drawing D5868-1 (General Arrangement)) for WP No. 160-65 (attached in Appendix D), the Highway 9 - Holland Drainage Canal Bridge consists of a three-span concrete box beam structure with the abutments and piers supported on concrete filled 323 mm outer diameter closed end steel tube piles, driven into the very dense sandy till to Elevation 198.7 m.

The pile details for the existing abutment and pier foundations are summarized below. Based on Golder's interpretation of the available information from the 2018, 1997 and 1965 investigations, and applying the applicable resistance factors from Tables 6.1 and 6.2 of the CHBDC (2014) for a "typical" consequence level and "typical" degree of site understanding, the factored ultimate geotechnical resistance and the factored serviceability geotechnical resistance (for 25 mm of settlement) for the abutment and pier foundations are summarized below. These values are based on the founding elevations/depths inferred from Drawing D5868-1, based on current grading in the vicinity of the foundation elements.

Foundation Element	Pile Cut-off Elevation (m)	Pile Tip Elevation (m)	Pile Length (m)	Factored Ultimate Geotechnical Resistance (kN)	Factored Serviceability Geotechnical Resistance, for 25 mm of Settlement (kN)
Abutments	218.8	198.7	20.1	600	-*
Piers	220.4	198.7	21.7	550	-*

* The factored serviceability geotechnical resistance for 25 mm of settlement is greater than the factored ultimate geotechnical resistance and does not govern at this site.

It is understood that the rehabilitation works will reduce the existing loading on the existing structure due to the lighter superstructure type. From a geotechnical perspective, the proposed rehabilitation works will not negatively impact the existing pile foundations at the Highway 9 - Holland Canal Bridge site. Together with guidance from MTO's *Bridge Office Bulletin: Design and Evaluation of Foundations* dated August 20, 2013, it is considered that the proposed rehabilitation works do not require foundation mitigation or enhancement.

6.3.1 Resistance to Lateral Loads

Resistance to lateral loading may be derived using vertical piles, with enhanced support offered by inclined (battered) piles, if required. For vertical piles, the resistance to lateral loading will be derived solely from the soil in front of the piles, whereas inclined piles derive lateral resistance from the soil in front of the piles as well as the horizontal component of the axial load present in the inclined pile.

Where ground conditions are generally competent and the lateral loads on piles are relatively small such that the maximum lateral pile deflections will be relatively small, the resistance to lateral loading in front of a single pile can be estimated using subgrade reaction theory (as outlined below). However, it should be noted that the response of a pile to lateral loads is highly nonlinear and methods that assume linear behavior (such as subgrade reaction theory) are only appropriate where the maximum pile deflections are less than 1 per cent of the pile diameter, where the loading is static (no cycling) and where the pile material is linear (CFEM, 2006). Where these conditions are not met, the non-linear lateral behavior of the soil should be considered by the use of P-y curves.

The factored serviceability geotechnical response of the soil in front of the piles under lateral loading at this site may be calculated using subgrade reaction theory suggested in CHBDC (2014) Commentary (Section C6.11.2.2), where the coefficient of horizontal subgrade reaction, k_h , (kPa/m) is based on the equation given below, as described by Terzaghi (1955) and the Canadian Foundation Engineering Manual (CFEM, 1992).

For non-cohesive soils:

$$k_h = \frac{n_h z}{B} \quad \text{Where}$$

k_h is the coefficient of horizontal subgrade reaction (kPa/m);
 n_h is the constant of subgrade reaction (kPa/m);
 z is the depth (m); and
 B is the pile diameter or width (m).

For cohesive soils:

$$k_h = \frac{67 s_u}{B} \quad \text{Where}$$

k_h is the coefficient of horizontal subgrade reaction (kPa/m);
 s_u is the undrained shear strength of the soil (kPa); and
 B is the pile diameter or width (m).

The following values of n_h and s_u (Terzaghi, 1995) may be incorporated into the calculations of horizontal subgrade reaction (k_h) for structural analyses for a single vertical pile, based on the interpreted stratigraphic profiles shown on the borehole records. The ranges in values reflect the variability in the subsurface conditions, the soil properties and the approximate nature of the analysis and the non-linear nature of the soil behaviour (such that k_h is a function of deflection).

Soil Unit	Approximate Elevation (m)	n_h (kPa/m)	s_u (kPa)
Existing Gravelly Sand to Sand and Gravel to Silt and Sand Fill (Compact to very dense) above the groundwater table	222.0 – 220.0	6,600	-
Existing Gravelly Sand to Sand and Gravel to Silt and Sand Fill (Compact to very dense) below the groundwater table	220.0 – 215.0	4,400	-
Upper Clayey Silt to Silty Clay (Soft to very stiff)	215.0 – 206.5	-	60
Upper Sandy Clayey Silt Till (Stiff)	206.5 – 204.5	-	75
Lower Silty Clay (Very Stiff)	204.5 – 200.5	-	150
Lower Clayey Silt to Silty Clay Till (Hard)	200.5 – 197.0	-	250

Both the structural and geotechnical resistances of the piles should be evaluated to establish the governing case at Ultimate Limit States (ULS). At Serviceability Limit States (SLS), the horizontal reaction of the piles will be controlled by deflections and the horizontal resistance of the pile should be calculated based on the coefficient of horizontal subgrade reaction (k_h) of the soil as discussed above. The SLS reaction should be taken as that corresponding to a horizontal deflection of 10 mm at the underside of the pile cap for units supporting the abutments (CHBDC (2014) Commentary Section 6.11.2.2).

The upper zone of the soil (down to a depth below the pile cap equal to about $1.5 \times B$ (where B is the pile diameter) should be neglected in the calculation of lateral resistance of the pile to account for disturbance effects during installation.

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters between rows of driven steel H-piles. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R (NAVFAC DM-7.2, 1986) as follows:

Pile Spacing in Direction of Loading (D = Pile Diameter)	Subgrade Reaction Reduction Factor, R
8D	1.00
6D	0.70
4D	0.40
3D	0.25

The subgrade reaction reduction factor should be interpolated for pile spacings in between those provided in the above summary. Reduction for group effects is negligible when the centre to centre pile spacing exceeds three pile diameters measured in the direction perpendicular to loading.

6.4 Frost Penetration

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation Frost Penetration Depths for Southern Ontario), the frost penetration depth in the area is interpreted to be 1.5 m.

6.5 Excavation and Groundwater Control

It is understood that the excavations for the bridge rehabilitation works will extend about 750 mm below the top of abutment stem walls, to about Elevation 220.2 m. The proposed excavations will require removal of the asphalt and existing non-cohesive and cohesive fill material. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fills are classified as Type 3 soils above the groundwater level, and Type 4 soils if encountered below the groundwater table. Temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V) in Type 3 soil and 3H:1V in Type 4 soils.

During construction, stockpiles/equipment/materials should be located a minimum distance of 1.5 m from the top of the excavation or a distance equal to the depth of the excavation, whichever is greater; stockpile heights should be controlled to prevent surcharging the sides of the excavation and/or overall slope.

The water level was measured in the piezometer in Borehole TP-1 at a depth of approximately 1.9 m below ground surface, corresponding to Elevation 220.1 m, which is at or just below the proposed base of excavation. The non-cohesive fill layer that is anticipated to be encountered at this level should be expected to be water-bearing. However, as this deposit will not form the bearing surface for proposed permanent works, it is anticipated that the groundwater can be controlled by pumping from properly filtered sump pumps installed within the excavation.

6.6 Temporary Protection Systems

The protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems shall meet Performance Level 2 as specified in OPSS.PROV 539.

It is anticipated that a driven interlocking sheet pile system would be suitable and constructible at this site, provided that the sheet piles can be driven through the compact to very dense gravelly sand to sand and gravel and silt and sand fill layers that are present within the upper 1.5 m to 3.0 m of the fill deposit. The sheet pile system can be driven through or into the underlying clayey silt layers and clayey silt deposit as the Standard Penetration Test (SPT) "N"-values in the cohesive fills and in the native deposits are generally less than about 30 blows per 0.3 m of penetration. A soldier pile and lagging system is also feasible, although it would be necessary to include measures to control seepage from behind the lagging boards, where the excavation extends below the water table.

The sheet piles or soldier piles will need to extend/be socketed to a sufficient depth into the upper clayey silt to silty clay deposit to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

While the selection and design of the protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in assessment of a temporary protection system and its approximate construction cost.

Soil Type	Unit Weight (γ , kN/m ³)	Internal Angle of Friction (Φ , degrees)	Coefficient of Lateral Earth Pressure ¹		
			Active K_a	At Rest K_o	Passive K_p ²
Existing Gravelly Sand to Sand and Gravel to Silt and Sand Fill (Compact to very dense)	20	34	0.28	0.44	3.54
Upper Clayey Silt to Silty Clay (Soft to very stiff)	20	30	0.33	0.5	3.0
Upper Sandy Clayey Silt Till (Stiff)	21	32	0.31	0.47	3.25
Lower Silty Clay (Very Stiff)	20	32	0.31	0.47	3.26
Lower Clayey Silt to Silty Clay Till (Hard)	21	33	0.30	0.46	3.35

1. The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present behind the temporary protection system, the coefficient of earth pressure should be adjusted accordingly.
2. The total passive resistance below the base of the excavation (i.e., adjacent to the protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It should be noted that the pressure distributions resulting from the above parameter values are the minimum for the ultimate stress condition. A stiffer design may be required to maintain displacements within an acceptable range.

Depending on the time of year, there may be perched water in the non-cohesive fill materials, above the cohesive fill. As noted above, if perched groundwater is present and/or where the excavation extends below the groundwater level at the site, it would be necessary to control seepage or include measures to mitigate loss of soil particles through lagging boards if a soldier pile and lagging system is employed.

Consideration could be given to either partial or full removal of the protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the culvert site, or to the road structure above. If the temporary protection system is left in place, it should be cut-off not less than 1.5 m below the underside of the pavement layer. An NSSP is included in Appendix E which addressed the removal or cut-off of the protection system in the Contract Documents.

6.7 Obstructions

The fill material contains wood fragments and may potentially contain cobbles, boulders or rubble-type materials. The type and depth of potential obstructions, as inferred from auger grinding and/or split spoon advancement, are described in the Foundation Investigation Report (Part A of this report). It is recommended that a Notice to Contractor be included in the Contract Documents to warn the Contractor of the possible presence of cobbles and/or boulders within the overburden soils; a Notice to Contractor is provided in Appendix E.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng. Mr. Jorge M.A. Costa, P.Eng., a Senior Consultant and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Golder Associates Ltd.



Nikol Kochmanová, Ph.D, P.Eng., PMP
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

GPG/NK/JMAC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

<https://golderassociates.sharepoint.com/sites/15994g/6. deliverables/wo 007 - holland drainage canal/fnds/1. 37-32/3. final/1671430 wo7 rpt 2018oct3 hwy 9 37-32 temporary protection.docx>

REFERENCES

- Canadian Geotechnical Society. 1992. Canadian Foundation Engineering Manual (CFEM), 3rd Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.
- Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Standards Association, 2014. Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-14. CSA Group.
- Chapman, L.J. and Putnam, D. F. 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.
- Terzaghi, K.V., 1955. Evaluation of Coefficient of Subgrade Reaction. Getechnique, 5(4): 297-326.
- Unified Facilities Criteria, U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.

ASTM International

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS) and Drawings (OPSD)

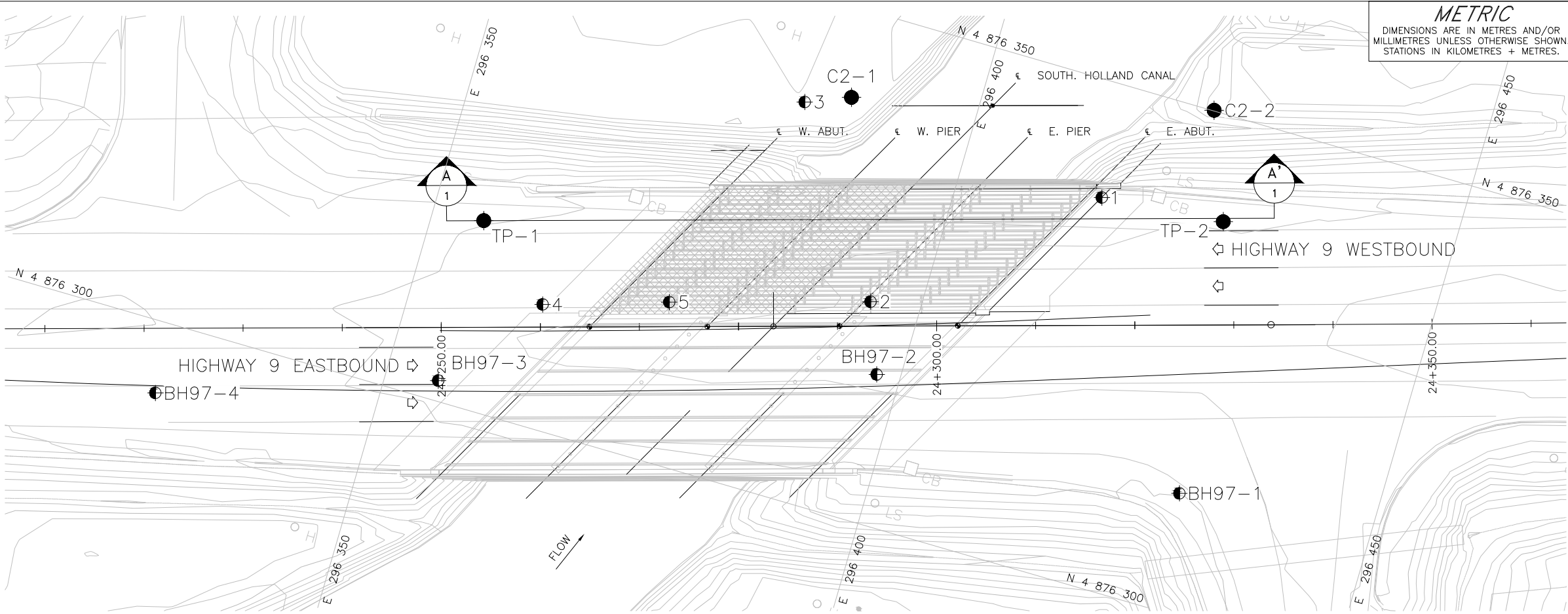
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario

Ontario Water Resources Act

Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903

Ontario Occupational Health and Safety Act

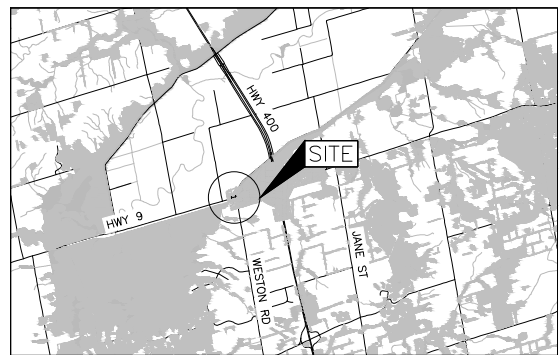
Ontario Regulation 213 (Construction Projects)



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

CONT No. .
GWP No. 2263-16-00

SOUTH HOLLAND CANAL
HIGHWAY 9 WBL
BOREHOLE LOCATIONS
AND SOIL STRATA



KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole - Current Investigation
- ⊕ Borehole - Previous Investigation (GEOCRETS 31D-022 and 31D-364)

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
1	218.9	4876338.5	296414.5
2	219.7	4876321.9	296395.0
3	218.9	4876339.4	296383.0
4	219.7	4876312.4	296363.3
5	219.8	4876316.2	296375.5
BH97-1	220.9	4876312.0	296430.3
BH97-2	219.9	4876315.0	296397.6
BH97-3	220.9	4876302.0	296355.3
BH97-4	221.1	4876292.9	296328.2
C2-1	220.9	4876341.1	296387.4
C2-2	220.3	4876350.1	296422.9
TP-1	222.0	4876318.8	296355.2
TP-2	222.2	4876339.5	296426.9

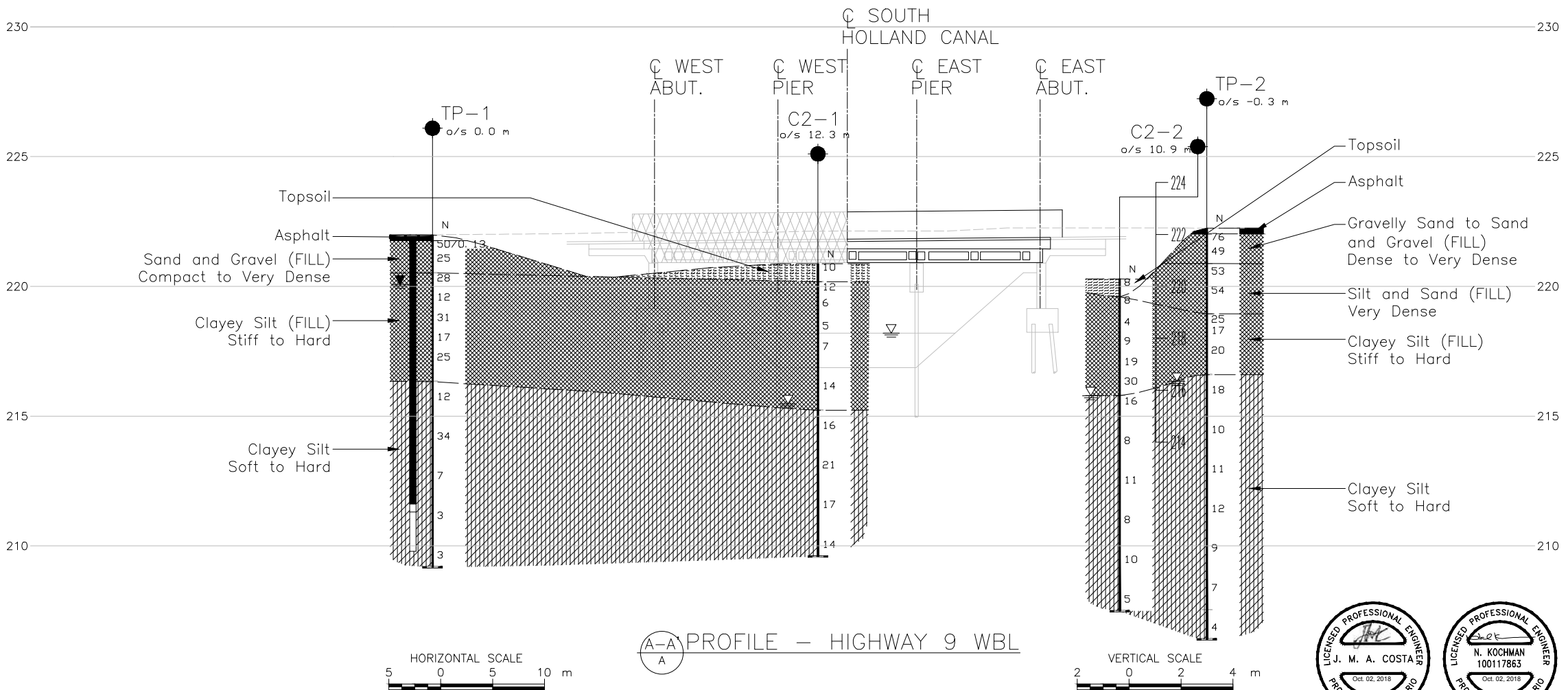
NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

REFERENCE

Base plans and general arrangement provided in digital format by Aecom, drawing file nos. 60570685-Holland Canal Bridge_37-32 REHAB.DWG, X-60570685-ALIGN.dwg and DTM.dwg, received June 06, 2017, X-60570685-BASE-B-74-9-81503.DWG, X-60570685-BASE-B-74-9-81504.DWG and X-60570685-BASE-B-74-400-90529.DWG, received June 07, 2018.



A-A PROFILE - HIGHWAY 9 WBL

HORIZONTAL SCALE
5 0 5 10 m

VERTICAL SCALE
2 0 2 4 m



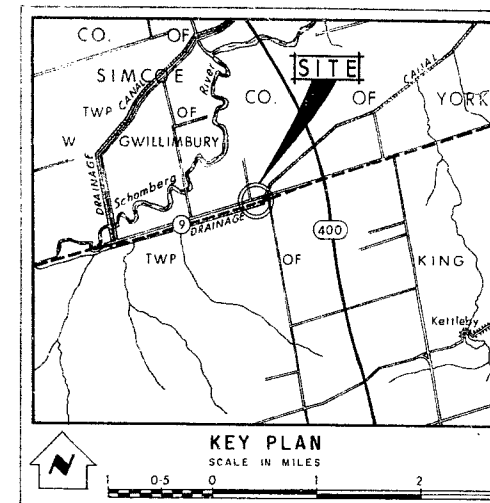
NO.	DATE	BY	REVISION
1	10/02/2018	JMAC	ISSUED FOR CONSTRUCTION
2	10/02/2018	JMAC	REVISED

Geocres No. 31D-711





HWY. 9	PROJECT NO. 1671430	DIST. .
SUBM'D. NK	CHKD. NK	DATE: 10/02/2018
DRAWN: DD	CHKD. NK	APPD. JMAC
		SITE: 37-32/2
		DWG. 1

APPENDIX A

**Borehole Records and Laboratory Test
Results from Previous Investigations
(GEOCRES No. 31D-022 and 31D-364)**



E-601118
N-4875600
Z-17

LEGEND			
	Bore Hole		
	Cone Penetration Hole		
	Bore & Cone Penetration Hole		
	Water Levels established at time of field investigation.		
NO.	ELEVATION	STATION	OFFSET
1	718.1	344 + 33	17' RT.
2	720.9	345 + 14	17' LT.
3	718.1	345 + 47	17' RT.
4	720.7	346 + 24	17' LT.
5	721.2	345 + 83	17' LT.

- 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.

[illegible]

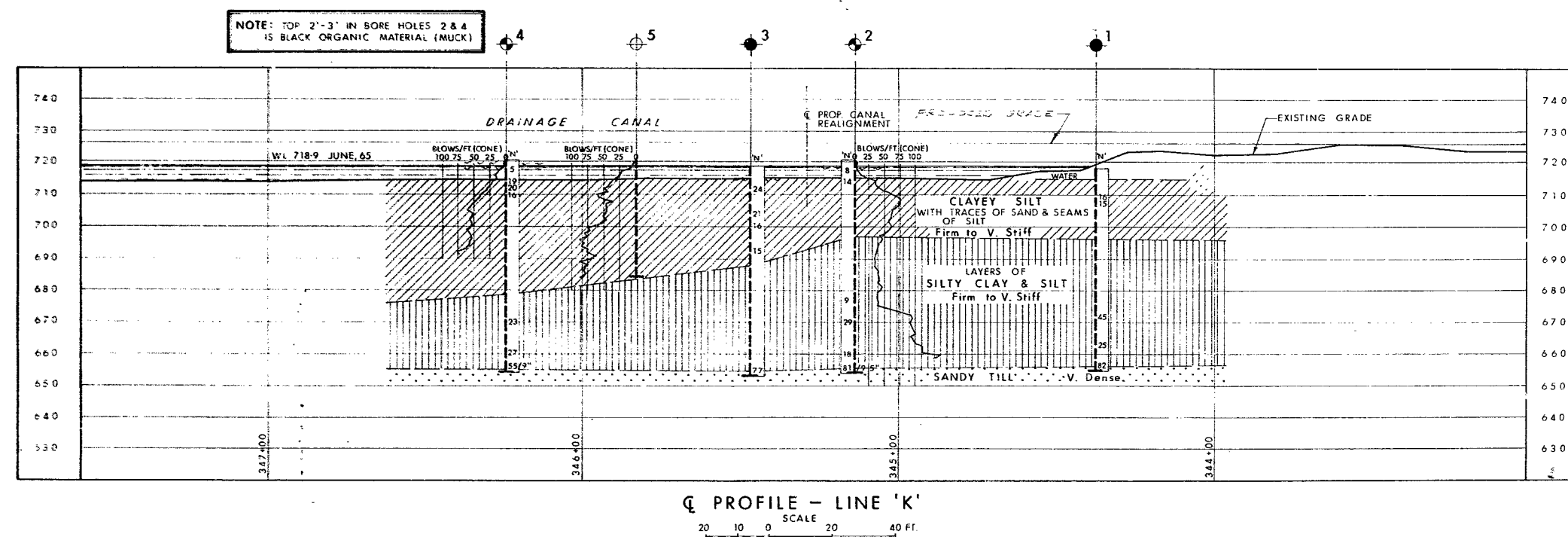
HOLLAND MARSH DRAINAGE CANAL

KING'S HIGHWAY NO. 9 LINE 'K' DIST. NO. 6
CO. YORK
TWP. KING LOT 35 CON. VI

BORE HOLE LOCATIONS & SOIL STRATA

SUBM'D P. P.	CHECKED	W.P. NO	170-65	M.B.T. DRAWING NO.
DRAWN S.O.	CHECKED	JOB NO.	65-F-109	65-F-109 A
DATE 29 NOV 1965		DATE NO		BRIDGE DRAWING NO.
APPROVED <i>[Signature]</i>		CONT NO		

REF. NO. E-4719

[illegible]

FOUNDATION SECTION

ORIGINATED BY _____ P.P.

COMPILED BY _____ P.P.

CHECKED BY AK

Gr	0%
Sa	1%
Si	73%
Cl	26%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 6-E-109

LOCATION East Pier - South Corner

ORIGINATED BY P.P.

W.P. 170-65

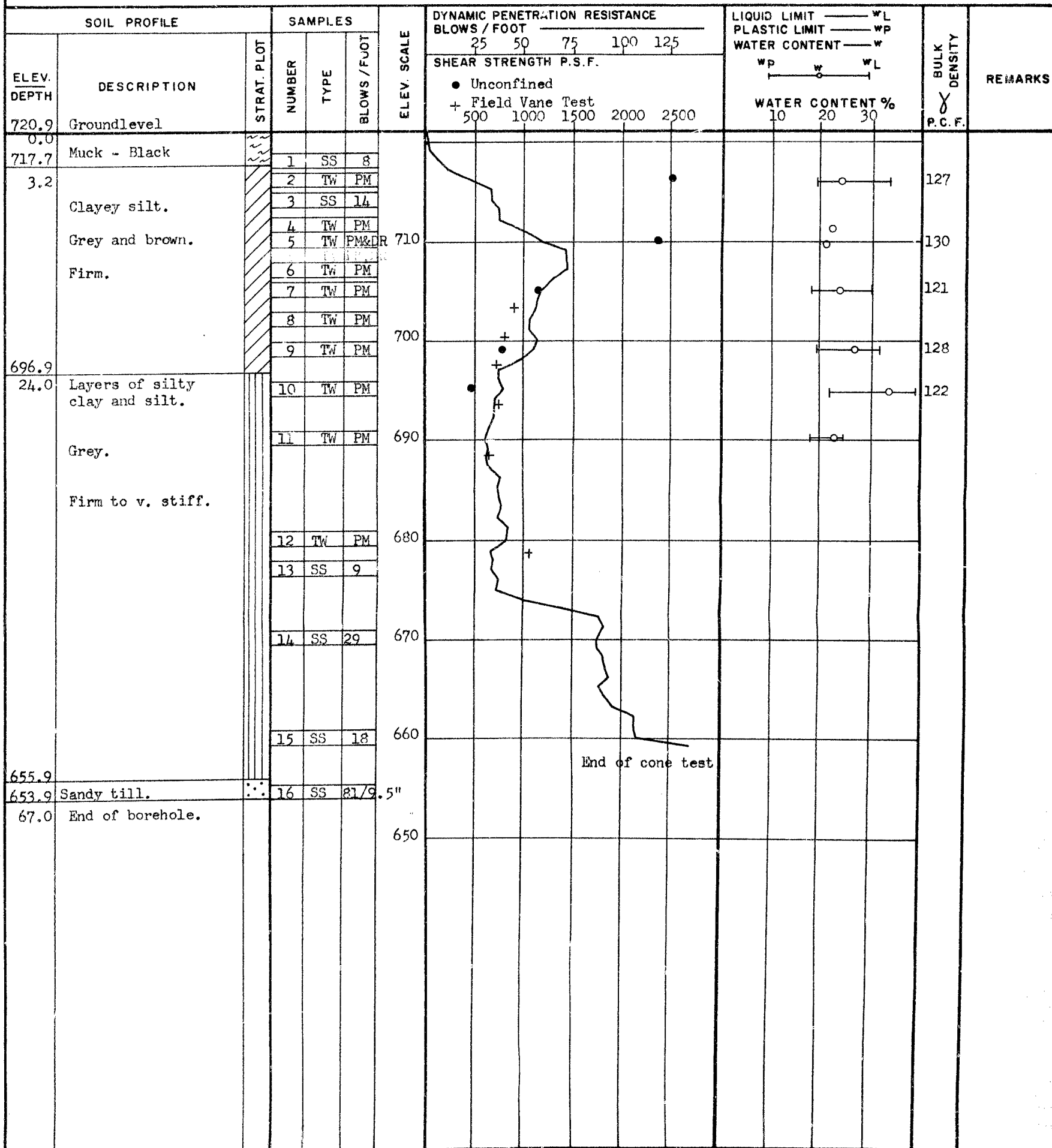
BORING DATE Oct. 12, 13 & 14, 1965.

COMPILED BY P.P.

DATUM Geodetic

BOREHOLE TYPE Washbore - NX Casing.

CHECKED BY ll



FOUNDATION SECTION

CHECKED BY HL

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	Liquid Limit ——— WL	Plastic Limit ——— WP	Water Content ——— W	BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SPEAR STRENGTH P.S.F.					
718.1	Water											
0.0												
715.3	Muck											
4.5												
	Clayey silt with some sand and gravel.		1	SS	24							
			2	TW	PM	710						
			3	TW	PM&DR							
	Brown and grey.		4	SS	21							
	Firm.		5	SS	16	700						
			6	TW	36							
			7	SS	15							
			8	TW	PM	690						
687.1												
31.0	Layers of silty clay and silt.		9	TW	PM							
	Grey.		10	TW	PM	680						
	Firm to stiff.		11	TW	PM							
						670						
			12	TW	16							
						660						
654.5												
653.3	Sandy till.		13	SS	77							
64.8	End of borehole.					650						

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 65-F-109

LOCATION West Abutment - South Corner

ORIGINATED BY P.P.

W.P. 170-65

BORING DATE Oct. 18 & 19, 1965.

COMPILED BY P.P.

DATUM Geodetic

BOREHOLE TYPE Washbore - NX Casing.

CHECKED BY *dk*

SOIL PROFILE		STRAT. PLOT	SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT ——— w_L PLASTIC LIMIT ——— w_p WATER CONTENT ——— w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE	BLOWS / FOOT		25	50	75	100	125	w_p	w	w_L		
720.7	Groundlevel															
0.0	Muck - Black															
2.3	Clayey silt with traces of sand. Firm to stiff. Brown and grey.		1	SS	5										133	
			2	TW	PM											
			3	SS	19											
			4	SS	20											
			5	SS	16	710										
			6	TW	PM											
			7	TW	PM											
			8	TW	PM	700										
			9	TW	PM											
			10	TW	PM	690										
678.1	Layers of silty clay and silt. Grey. V. stiff.		11	TW	PM	680										
42.6			12	SS	23	670										
			13	SS	27	660										
655.0	Sandy fill.		14	SS	55/9"											
654.2																
66.5	End of borehole.					650										

SHEAR STRENGTH P.S.F.
• Unconfined
+ Field Vane Test

500 1000 1500 2000 2500

WATER CONTENT %
10 20 30

End of cone test

Gr 0%
Sa 0%
Si 51%
Cl 49%

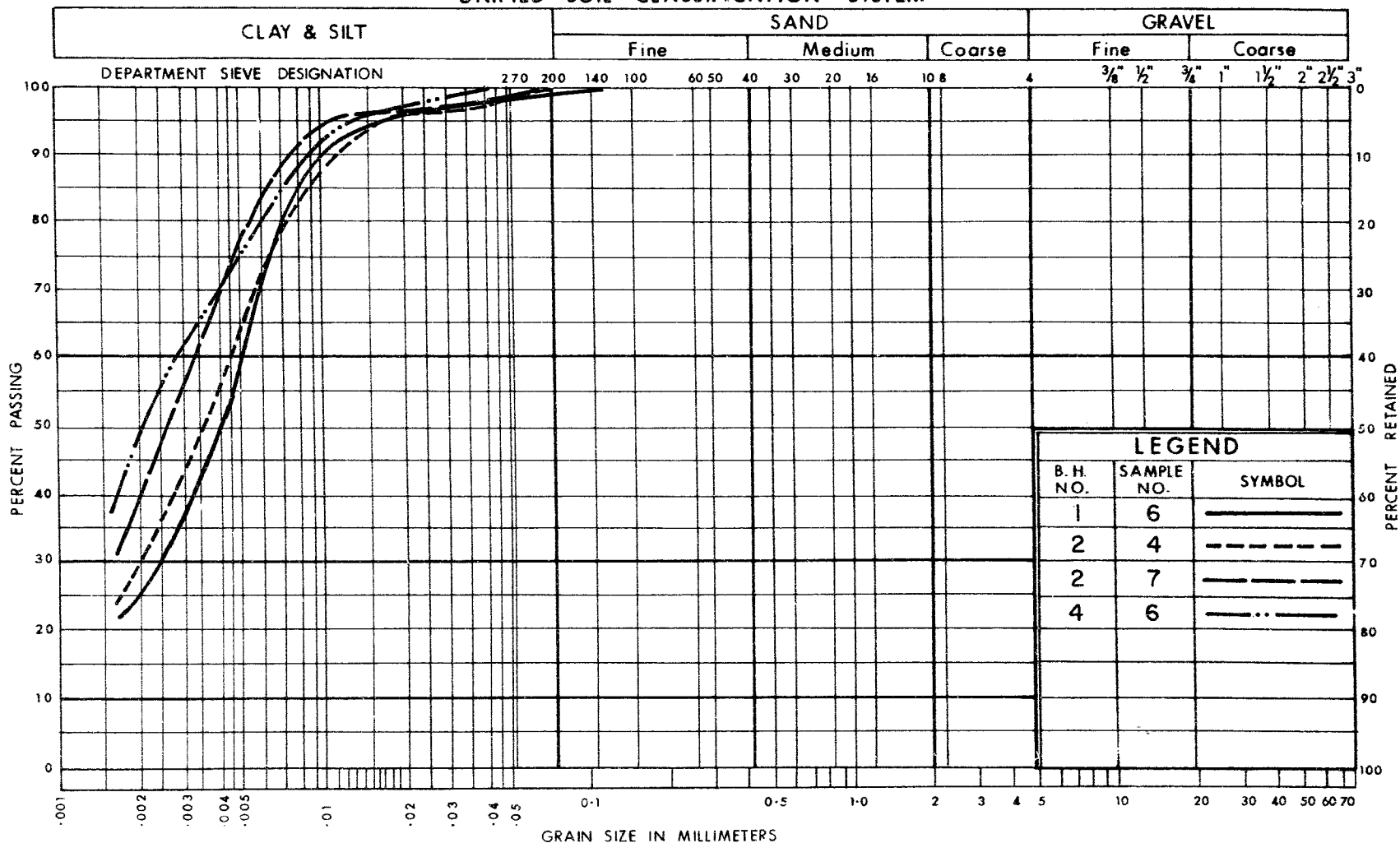
Gr 0%
Sa 2%
Si 78%
Cl 20%

FOUNDATION SECTION

CHECKED BY HK

[illegible]

UNIFIED SOIL CLASSIFICATION SYSTEM

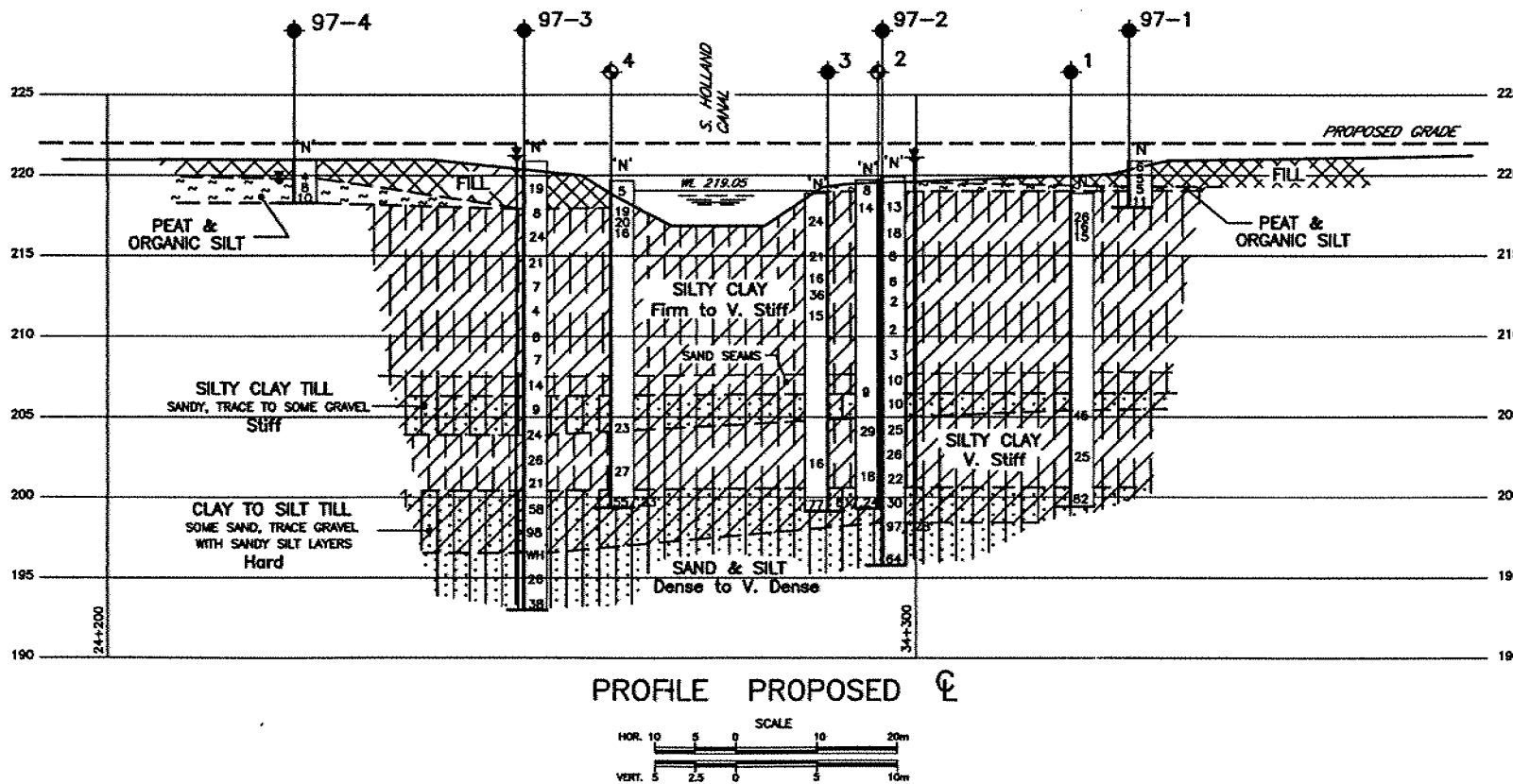
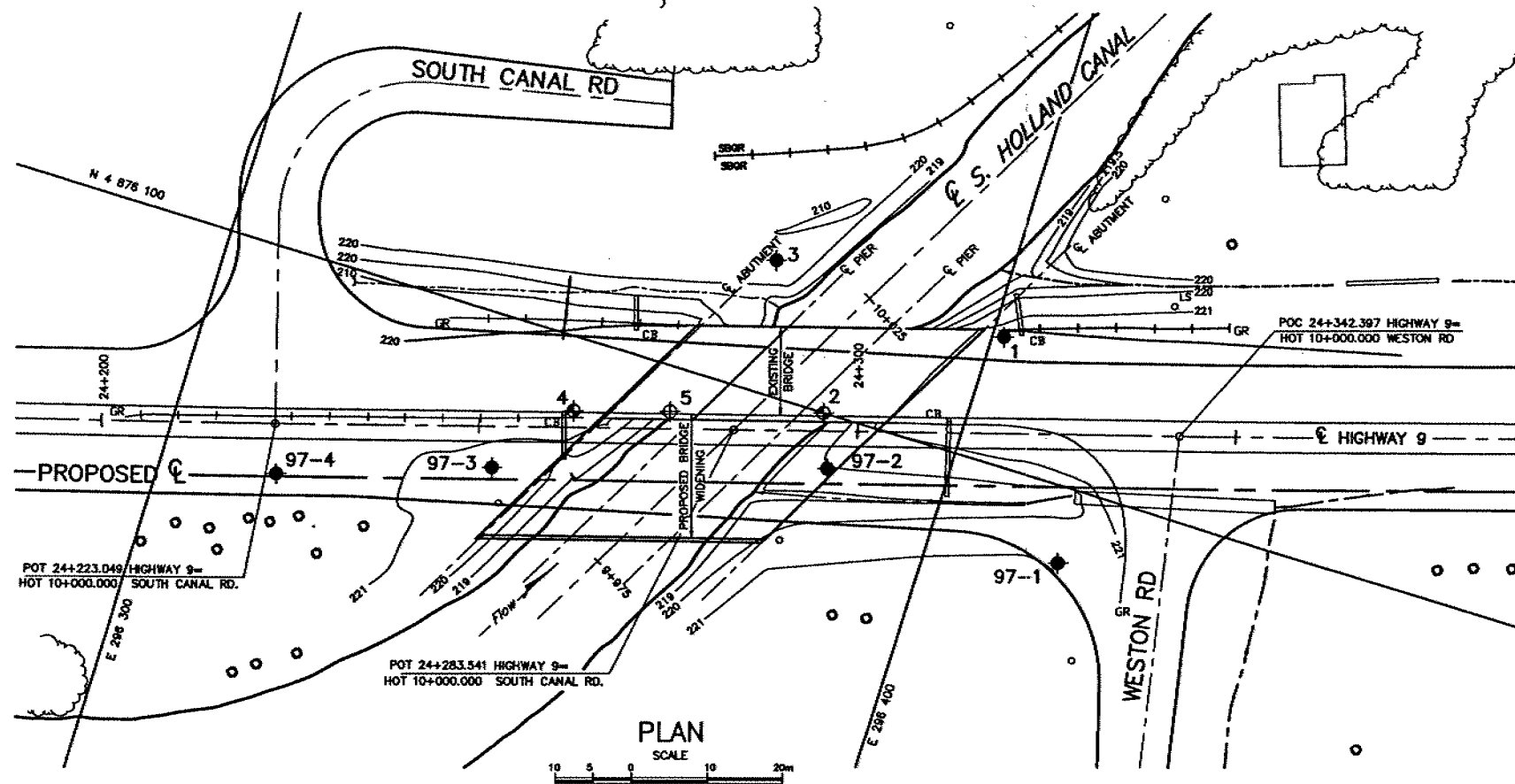


DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION

GRAIN SIZE DISTRIBUTION

W.P. No. 170 - 65

JOB No. 65-F-109



METRIC

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

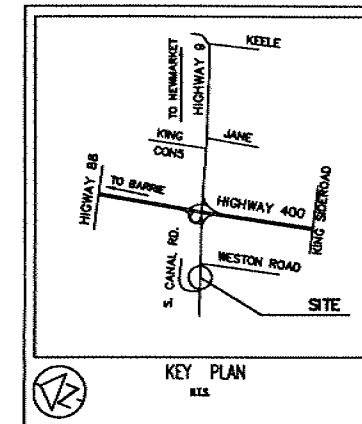
CONT No
WP No 4-95-01



SHEET

BORE HOLE LOCATIONS & SOIL STRATA

THURBER ENGINEERING LTD.



LEGEND	
	Bore Hole
	Dynamic Cone Penetration Test (Cone)
	Bore Hole & Cone
N	Blows/0.3m (Std Pen Test, 475J/blow)
CONE	Blows/0.3m (60° Cone, 475J/blow)
	WL at time of investigation Feb.26,1997
	Head Artesian Water
	Piezometer

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
97-1	220.9	4876090.120	296417.335
97-2	219.9	4876093.127	296384.850
97-3	220.9	4876080.188	296342.314
97-4	221.1	4876071.030	296315.254
1	218.9	4876116.6	296401.5
2	219.7	4876100.0	296382.0
3	218.9	4876117.5	296370.0
4	219.7	4876090.5	296350.3
5	219.8	4876094.5	296362.5

NOTE
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Hole the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV	DATE	BY	DESCRIPTION
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			
61			
62			
63			
64			
65			
66			
67			
68			
69			
70			
71			
72			
73			
74			
75			
76			
77			
78			
79			
80			
81			
82			
83			
84			
85			
86			
87			
88			
89			
90			
91			
92			
93			
94			
95			
96			
97			
98			
99			
100			

RECORD OF BOREHOLE No BH97-1

1 OF 1

METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 090.120 E296 417.335 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 110mm SOLID STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.27 - CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100		W _p W W _L				
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100		10 20 30				
220.9														
220.8														
0.1	TOPSOIL (125mm), frozen		1	SS	6									
	SILTY CLAY FILL, with pockets of dark brown topsoil and organics Brown, Firm to Stiff		2	SS	5		220							
219.3														
1.7	PEAT, amorphous granular		3	SS	5		219							
219.2	CLAYEY SILT													
1.7	with sand laminations													
218.8	Brown, Firm		4	SS	11									
2.1														
218.2	SILTY CLAY													
2.7	with oxide staining Grey, Very Stiff to Stiff													
	END OF BOREHOLE AT 2.9m Borehole dry upon completion.													

RECORD OF BOREHOLE No BH97-2

1 OF 2

METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 093.127 E296 384.650 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.30 - 97.02.01 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
219.9	TOPSOIL (150mm), frozen		1	SS								48.120	
219.8	ORGANIC SILT												
219.0	some sand and clay												
0.9	Dark Brown						219						
	SILTY CLAY		2	SS	13		218						
	with oxide staining												
	Light Grey												
	Stiff to Very Stiff												
			3	SS	18		217						
216.0													
	SILTY CLAY						216						
3.9	Gray												
	Stiff		4	SS	8		215						
	seepage at 4.6m												
			5	SS	6		214						
							213						
			6	SS	2		212						
							211						
			7	SS	2		210						
							209						
207.7							208						
12.2	wet sand seams		9	SS	10		207						
206.5							206						
13.4	SILTY CLAY TILL, sandy, trace to some gravel		10	SS	10								
	Gray, Stiff												
205.0	tried vane @ 14.5m but could not insert into						205						
	Continued Next Page												

+³, ×³: Numbers refer to
Sensitivity

20
15- ϕ 5
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BH97-2

2 OF 2

METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 093.127 E296 384.650 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.30 - 97.02.01 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
14.9	soil (possible cobble)												
	SILTY CLAY laminated Grey Very Stiff		11	SS	25		204						
			12	SS	26		203						
			13	SS	22		202						
200.6							201						
19.3	SILTY CLAY TILL, some sand, trace gravel						200						
200.0	Grey, Hard		14	SS	30		200						
199.8	SANDY SILT						199						
20.2	CLAYEY SILT TILL, some sand, trace gravel						199						
198.4	Grey, Hard		15	SS	97/ 28		198						
21.5	SILT and SAND occasional pockets of silty clay						197						
	Grey Very Dense						197						
197.1							196						
22.9	augers dropped 0.8m due to boiling sand condition		16	SS	64		196						
195.8													
24.1	END OF BOREHOLE AT 24.1m UPON COMPLETION: Water level in augers rose to 1.2m above ground surface (el. 221.1m)												

RECORD OF BOREHOLE No BH97-3

1 OF 2

METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 080.188 E296 342.314 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 110mm SOLID STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.23 - 97.01.24 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
220.9	TOPSOIL (150mm), frozen		1	SS			220							
220.0 0.1	SANDY SILT FILL, some clay, trace gravel some pockets of organics, trace rootlets													
219.4	Grey		2	SS	19		219							
1.5	SAND and SILT FILL, trace gravel Brown, Compact													
218.0	SILTY CLAY with oxide staining Grey to Brown Stiff to Very Stiff		3	SS	8		218							
2.9							217							
			4	SS	24		216							
215.3														
5.6	SILT CLAY Grey Very Stiff to Stiff		5	SS	21		215							
							214							
			6	SS	7		213							
			7	SS	4		212							
							211							
			8	SS	8		210							
			9	SS	7		209							
							208							
207.5														
13.4	wet sand seams		10	SS	14		207							
206.4														
14.5	SILTY CLAY TILL, sandy, trace gravel Grey						206							

Continued Next Page

+ 3, x 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BH97-3

2 OF 2

METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 080.188 E296 342.314 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 110mm SOLID STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.23 - 97.01.24 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
203.9	Stiff tried vane at 15.2m but could not insert into soil (possible cobble)		11	SS	9		205							
17.0			12	SS	24		204							
	SILTY CLAY laminated Grey Very Stiff		13	SS	26		203							
			14	SS	21		202							
200.4			15	SS	58		200							
20.5	SILTY CLAY TILL, trace sand, trace gravel Grey Hard		16	SS	98		199							
199.3			17	SS	WH		198							
21.6	SILT some sand Grey Very Dense		18	SS	26		197							
197.8			19	SS	38		196							
23.1	SILTY CLAY TILL, some sand, trace gravel Grey Hard						195							
196.5							194							
24.4	SAND and SILT Grey Dense N values for samples #17,18,19 are not representative due to disturbance by artesian ground water conditions						193							
193.0														
27.9	END OF BOREHOLE AT 27.9m UPON COMPLETION OF DRILLING: Water in augers rose to 0.3m above ground surface (el. 221.2m) Borehole backfilled and sealed with granular bentonite and cement/bentonite grout.													

RECORD OF BOREHOLE No BH97-4

1 OF 1

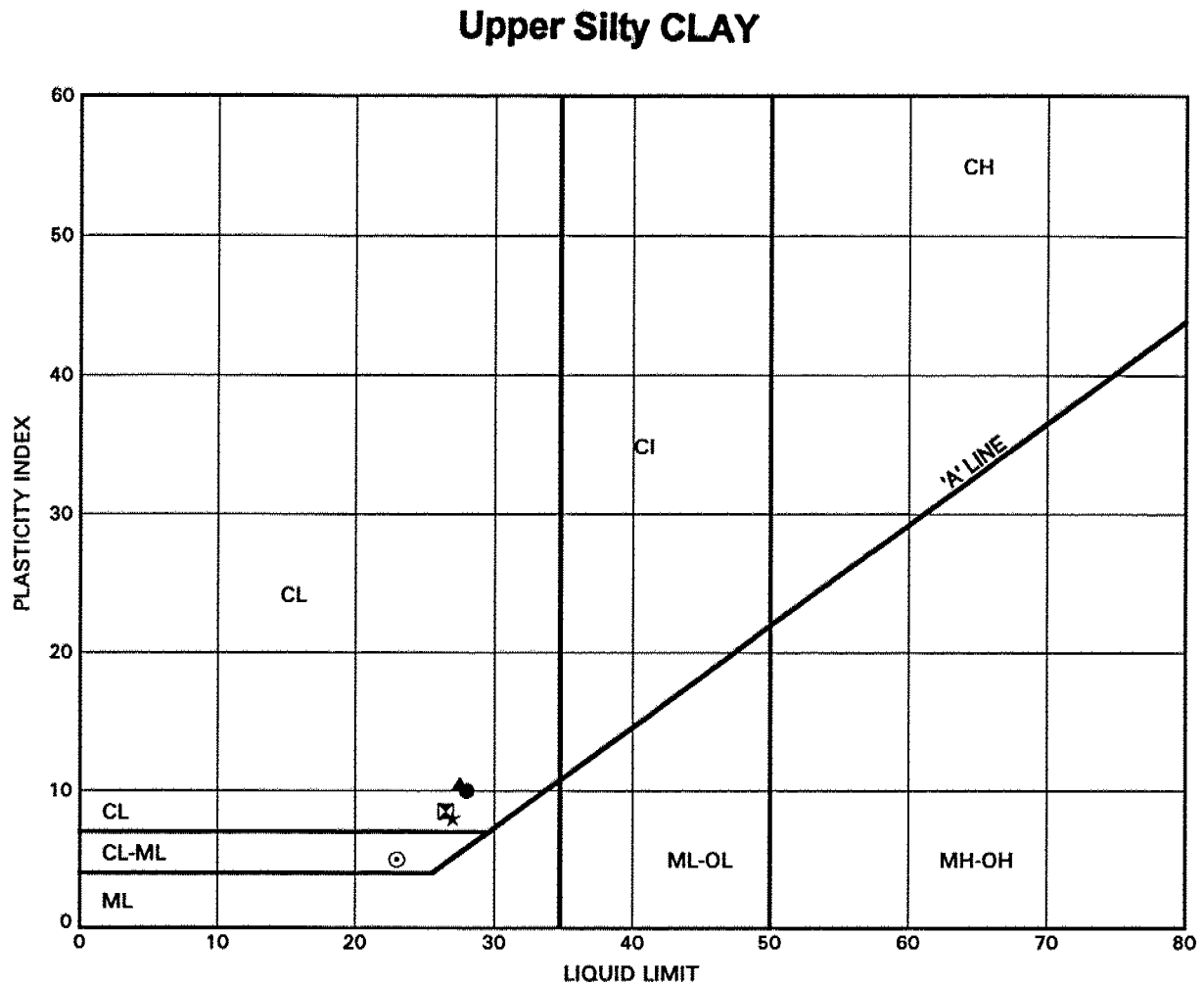
METRIC

W.P. 4-95-01 LOCATION Coords: N4 876 071.030 E296 315.254 ORIGINATED BY EDK
DIST CR HWY 9 BOREHOLE TYPE 110mm SOLID STEM AUGERS COMPILED BY DWP
DATUM Geodetic DATE 97.01.23 - CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
221.1	TOPSOIL (100mm), frozen		1	SS			221							
220.0	CLAYEY SILT FILL, sandy with sand pockets trace gravel and organics Brown to Gray Firm		2	SS	4		220							
219.3			3	SS	8		219							
218.7	PEAT, amorphous granular Dark Brown, Firm to Very Stiff		4	SS	10									
218.4	ORGANIC SILT (MARL) Light Gray, Stiff													
217.7	END OF BOREHOLE AT 2.7m BOREHOLE DRY UPON COMPLETION.													
WATER LEVEL READINGS DATE DEPTH ELEVATION (m) (m) 97/01/23 dry 97/01/31 1.56 219.50 97/02/10 1.77 219.29 97/02/26 1.43 219.67														

W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
ATTERBERG LIMITS TEST RESULTS

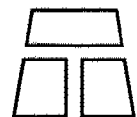
FIGURE B1



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	BH1	1.43	217.47
⊠	BH1	3.69	215.21
▲	BH1	5.28	213.62
★	BH1	7.29	211.61
⊙	BH1	10.40	208.50

Date December 1997

Project 4-95-01



THURBER

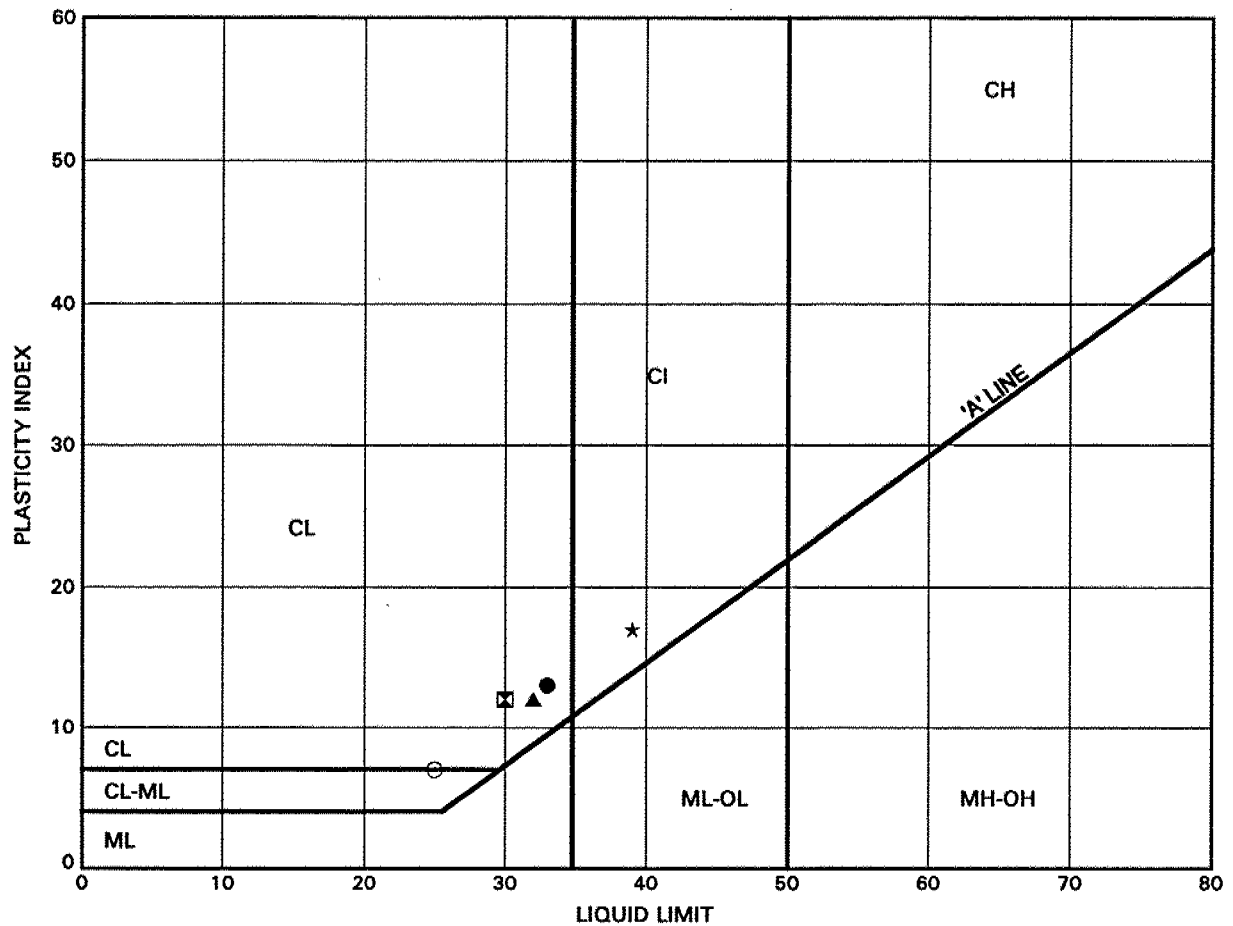
Prep'd

Chkd.

W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
ATTERBERG LIMITS TEST RESULTS

FIGURE B2

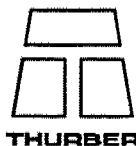
Upper Silty CLAY (Cont'd)



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	BH2	1.49	218.21
⊠	BH2	4.79	214.91
▲	BH2	6.58	213.12
★	BH2	7.95	211.75
⊙	BH2	9.36	210.34

Date December 1997

Project 4-95-01



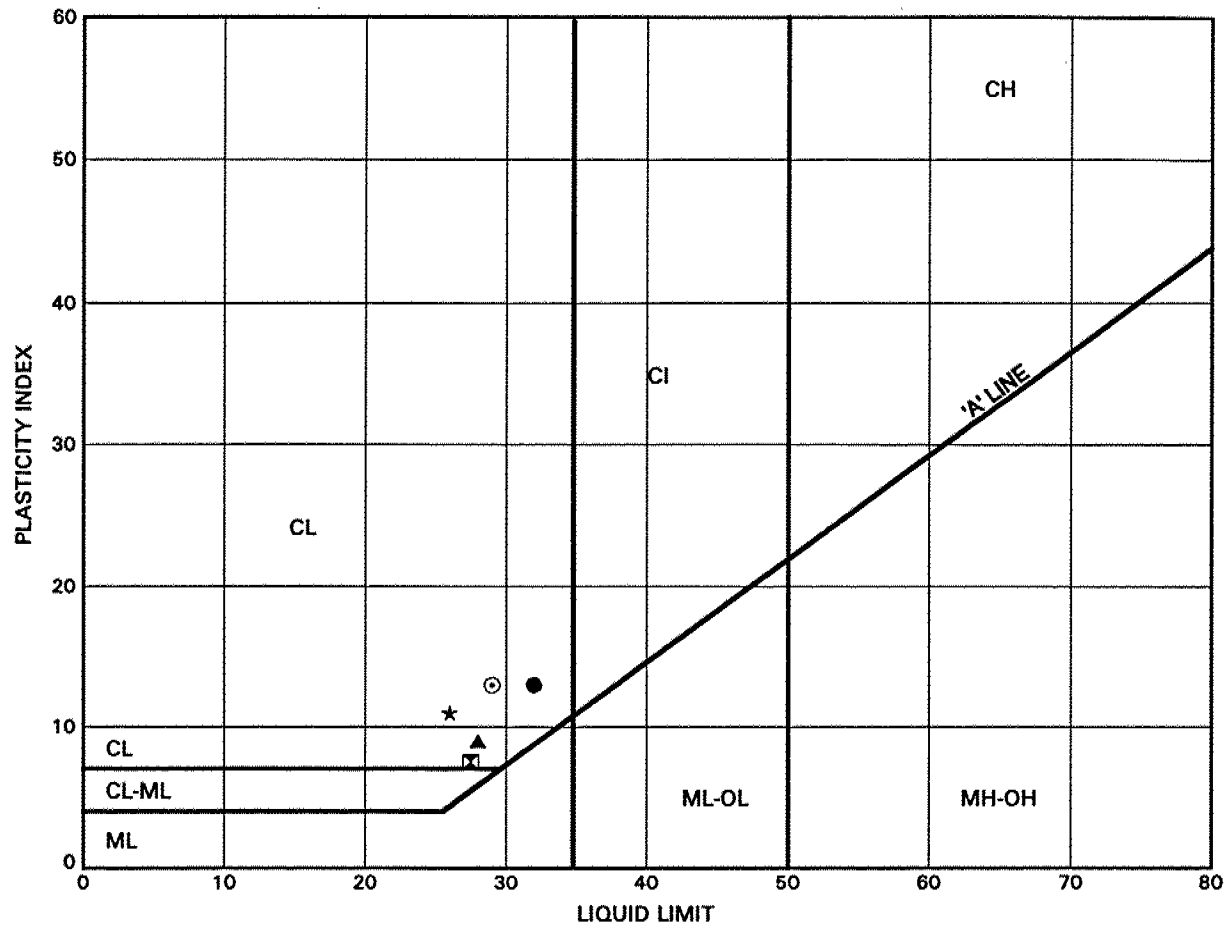
Prep'd

Chkd.

W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
ATTERBERG LIMITS TEST RESULTS

FIGURE B3

Upper Silty CLAY (Cont'd)



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	BH3	2.47	216.43
⊠	BH3	8.93	209.97
▲	BH3	10.52	208.38
★	BH4	1.49	218.21
⊙	BH4	4.42	215.28

Date December 1997
 Project 4-95-01

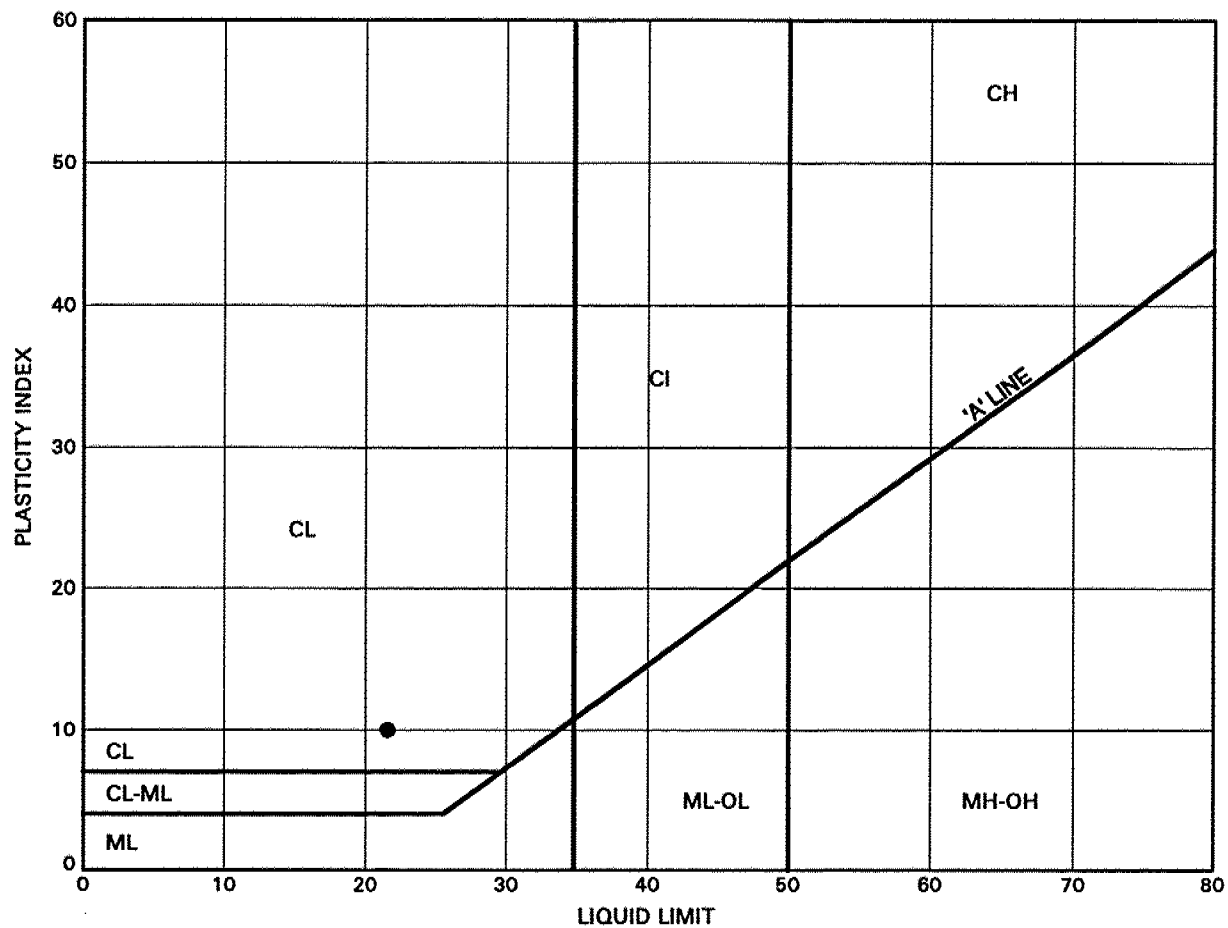


Prep'd
 Chkd.

W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
ATTERBERG LIMITS TEST RESULTS

FIGURE B4

Upper Silty CLAY TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	BH97-3	15.47	205.42

Date December 1997
 Project 4-95-01

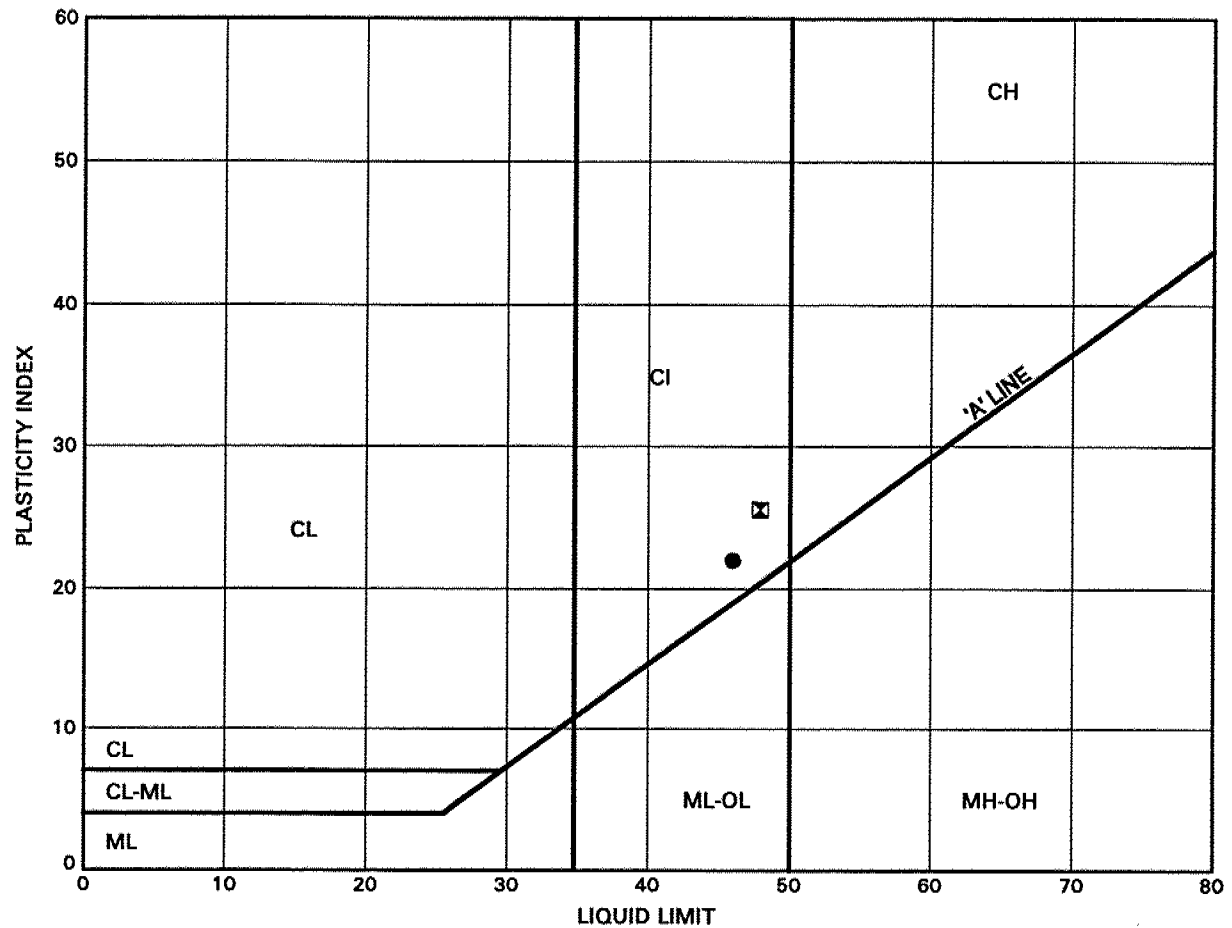


Prep'd WM
 Chkd. DWP

W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

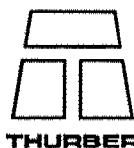
Lower Silty CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	BH3	16.49	202.41
⊠	BH97-2	18.52	201.42

Date December 1997

Project 4-95-01



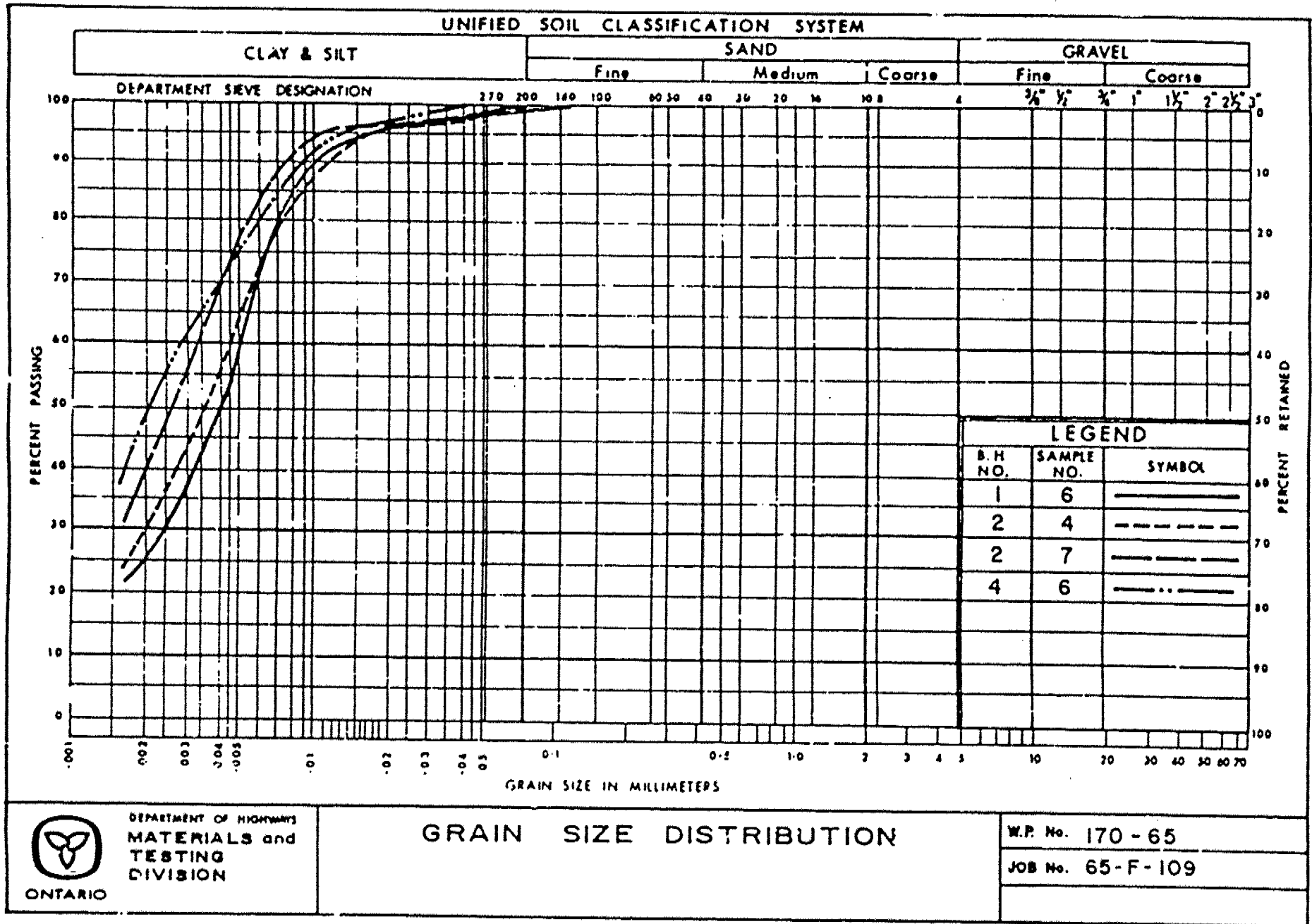
THURBER

Prep'd

Chkd.

Upper Silty CLAY

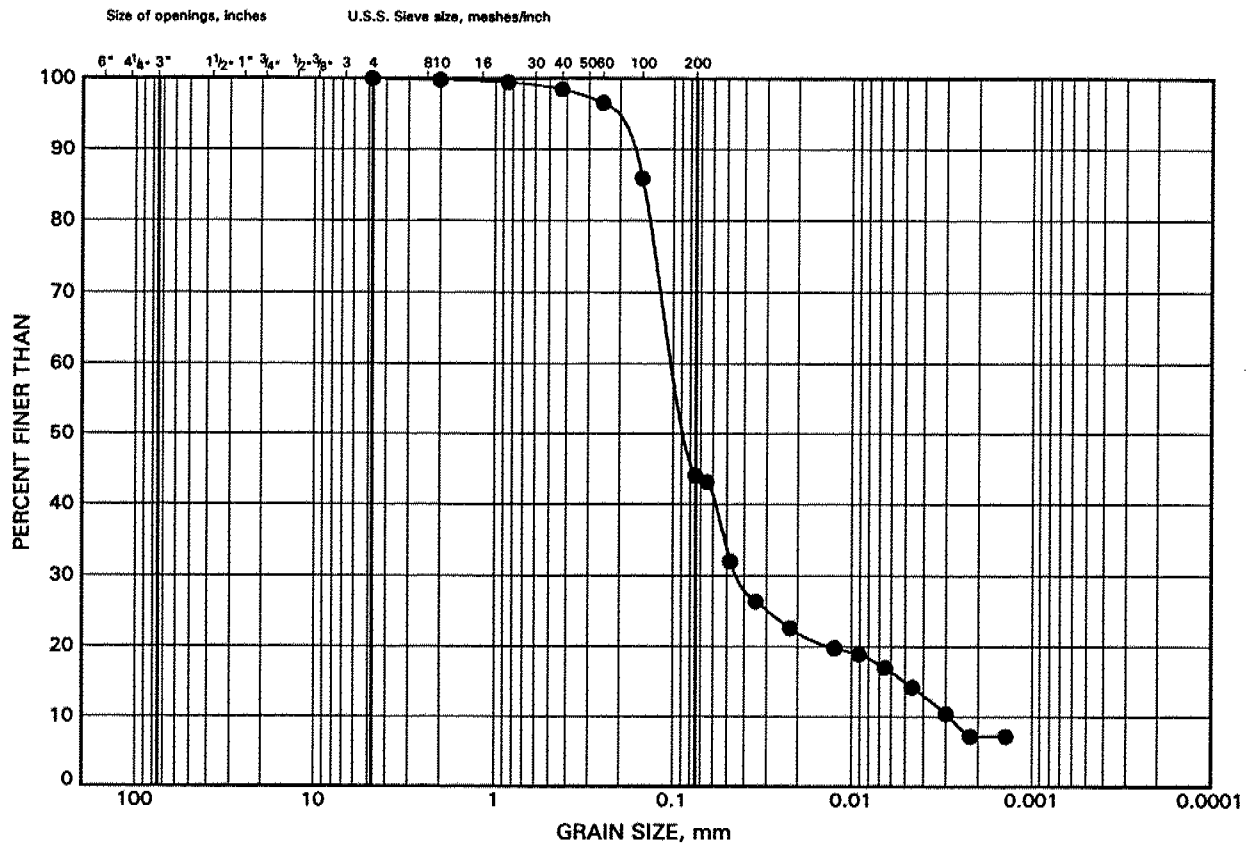
FIGURE B6



W.P. NO. 4-95-01 HIGHWAY 9/HOLLAND DRAINAGE CANAL
GRAIN SIZE DISTRIBUTION

FIGURE B7

SAND and SILT



APPENDIX B

Borehole Records from Current Investigation

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_{α}	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

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

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness	N
Condition	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS


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

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 1671430		RECORD OF BOREHOLE No C2-1		SHEET 1 OF 1		METRIC							
G.W.P. 2016-E-0029		LOCATION N 4876341.1; E 296387.4 MTM NAD 1983 ZONE 10 (LAT. 44.027018; LONG. -79.604949)		ORIGINATED BY CC									
DIST CENTRAL HWY 9		BOREHOLE TYPE 152 mm O.D. Hollow Stem Augers, D-25 - Truck-mounted Drill Rig		COMPILED BY AM									
DATUM Geodetic		DATE May 10, 2018		CHECKED BY NK									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL	
220.9	GROUND SURFACE												
0.0	(TOPSOIL) - Clayey silt, trace to some gravel, some sand, trace organics, rootlets, grass		1	SS	10								
220.2	Brown		2	SS	12								
0.7	Stiff Moist		3	SS	6								
	Clayey silt, trace to some gravel, trace sand, trace organics to 2.2 m (FILL)		4	SS	5								
	Brown		5	SS	7								
	Firm to very stiff												
	Moist to wet below 3.1 m		6	SS	14								
215.3	CLAYEY SILT, trace sand												
5.6	Grey		7	SS	16								
	Stiff to very stiff												
	Wet		8	SS	21								
			9	SS	17								
			10	SS	14								
209.6	END OF BOREHOLE												
11.3	NOTE:												
	1. Water level measured at a depth of 5.4 m below ground surface (Elev. 215.5 m) upon completion of drilling.												
	2. Borehole caved to a depth of 9.1 upon removal of augers.												

PROJECT		1671430		RECORD OF BOREHOLE No C2-2		SHEET 1 OF 1		METRIC						
G.W.P.		2016-E-0029		LOCATION		N 4876350.1; E 296422.9 MTM NAD 1983 ZONE 10 (LAT. 44.027099; LONG. -79.604506)		ORIGINATED BY						
DIST		CENTRAL HWY 9		BOREHOLE TYPE		152 mm O.D. Hollow Stem Augers, D-25 - Truck-mounted Drill Rig		COMPILED BY						
DATUM		Geodetic		DATE		May 10, 2018		CHECKED BY						
								NK						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
220.3	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	(TOPSOIL) - Clayey silt, trace organics, rootlets		1	SS	8	▽	220							0 1 64 35
219.6	Brown Stiff Moist		2	SS	8		219							
0.7	Clayey silt, trace sand, trace organics from 0.7 m to 2.1 m (FILL)		3	SS	4		218							
	Brown-grey Firm to hard Moist		4	SS	9		217							
	- Wood fragments from 1.5 m to 2.1 m depths		5	SS	19		216							
	- Minor seepage at 2.4 m		6	SS	30		215							
215.8	CLAYEY SILT, trace sand Grey	7	SS	16	214								0 1 52 47	
4.5	Firm to very stiff Moist to wet below 6.1 m	8	SS	8	213									
	- Wood fragments from 3.8 m to 5.2 m depth	9	SS	11	212									
		10	SS	8	211									
		11	SS	10	210									
		12	SS	5	209									
207.5	END OF BOREHOLE													
12.8	NOTE: 1. Water level measured at a depth of 4.5 m below ground surface (Elev. 215.8 m) upon completion of drilling following auger removal.													

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GINT\HWY_9.GPJ GAL-GTA-GDT 08/08/18

PROJECT		1671430		RECORD OF BOREHOLE		No TP-1		SHEET 1 OF 2		METRIC			
G.W.P.		2016-E-0029		LOCATION		N 4876318.8; E 296355.2 MTM NAD 1983 ZONE 10 (LAT. 44.026817; LONG. -79.605350)		ORIGINATED BY		CC			
DIST		CENTRAL HWY 9		BOREHOLE TYPE		210 mm O.D. Hollow Stem Augers, D-90 - Truck-mounted Drill Rig		COMPILED BY		AM			
DATUM		Geodetic		DATE		May 16, 2018		CHECKED BY		NK			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
222.0	GROUND SURFACE												
0.0	ASPHALT (220 mm)												
0.2	Sand and gravel, trace to some silt (FILL) Brown Compact to very dense Moist		1	SS	50/0.13								
			2	SS	25								
220.5													
1.5	Clayey silt, trace to with sand, trace gravel, trace organics (FILL) Grey-brown Stiff to hard Moist		3	SS	28								
			4	SS	12								
	- 0.1 m thick silt and sand interlayer at 3.0 m		5	SS	31								3 44 44 9
			6	SS	17								
			7	SS	25								0 1 56 43
216.4													
5.6	CLAYEY SILT Grey Soft to hard Moist to wet below 9.1 m		8	SS	12								
			9	SS	34								
			10	SS	7								
			11	SS	3								0 0 72 28
			12	SS	3								
209.2													
12.8	END OF BOREHOLE												
NOTES:													
1. Water level measured at a depth of 10.6 m below ground surface (Elev. 211.4 m) upon completion of well installation.													

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GINT\HWY_9.GPJ GAL-GTA.GDT 08/08/18



+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE


GTA-MTO 001 S:\CLIENTS\MTO\HWY 9\02 DATA\GINT\HWY 9.GPJ GAL-GTA.GDT 08/08/18

PROJECT		1671430		RECORD OF BOREHOLE No TP-2		SHEET 1 OF 2		METRIC						
G.W.P.		2016-E-0029		LOCATION		N 4876339.5; E 296426.9 MTM NAD 1983 ZONE 10 (LAT. 44.027004; LONG. -79.604456)		ORIGINATED BY						
DIST		CENTRAL HWY 9		BOREHOLE TYPE		210 mm O.D. Hollow Stem Augers, D-90 - Truck-mounted Drill Rig		COMPILED BY						
DATUM		Geodetic		DATE		May 14, 2018		CHECKED BY						
								NK						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.2	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	ASPHALT (220 mm)													
0.2	Gravelly sand to sand and gravel, trace silt (FILL) Brown Dense to very dense Moist		1	SS	76									
			2	SS	49									
220.8														
1.4	Silt and sand, trace to some clay, trace gravel, trace organics, trace rootlets, trace cobbles (FILL) Grey to brown Very dense Moist		3	SS	53									
			4	SS	54									
218.9			5A											
3.3	Clayey silt, trace sand (FILL) Grey-brown Very stiff Moist - Organic matter/wood fragments observed at a depth of 4.0 m		5B	SS	25									
			6	SS	17									
			7	SS	20									
216.6														
5.6	CLAYEY SILT, trace sand to sandy Grey Firm to very stiff Moist to wet below 7.6 m		8	SS	18									
			9	SS	10									
			10	SS	11									
			11	SS	12									
			12	SS	9									
			13	SS	7									
207.5														
14.7														

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GINT\HWY_9.GPJ GAL-GTA.GDT 08/08/18

PROJECT		1671430		RECORD OF BOREHOLE No TP-2				SHEET 2 OF 2				METRIC				
G.W.P.		2016-E-0029		LOCATION				N 4876339.5; E 296426.9 MTM NAD 1983 ZONE 10 (LAT. 44.027004; LONG. -79.604456)				ORIGINATED BY				
DIST		CENTRAL HWY 9		BOREHOLE TYPE				210 mm O.D. Hollow Stem Augers, D-90 - Truck-mounted Drill Rig				COMPILED BY				
DATUM		Geodetic		DATE				May 14, 2018				CHECKED BY				
NK																
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W		
	--- CONTINUED FROM PREVIOUS PAGE ---															
206.4	CLAYEY SILT-SILT Grey Soft Wet		14	SS	4		207									
15.8	END OF BOREHOLE															
	NOTE: 1. Water level measured at a depth of 5.9 m below ground surface (Elev. 216.3 m) upon completion of drilling.															

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GINT\HWY_9.GPJ GAL-GTA.GDT 08/08/18

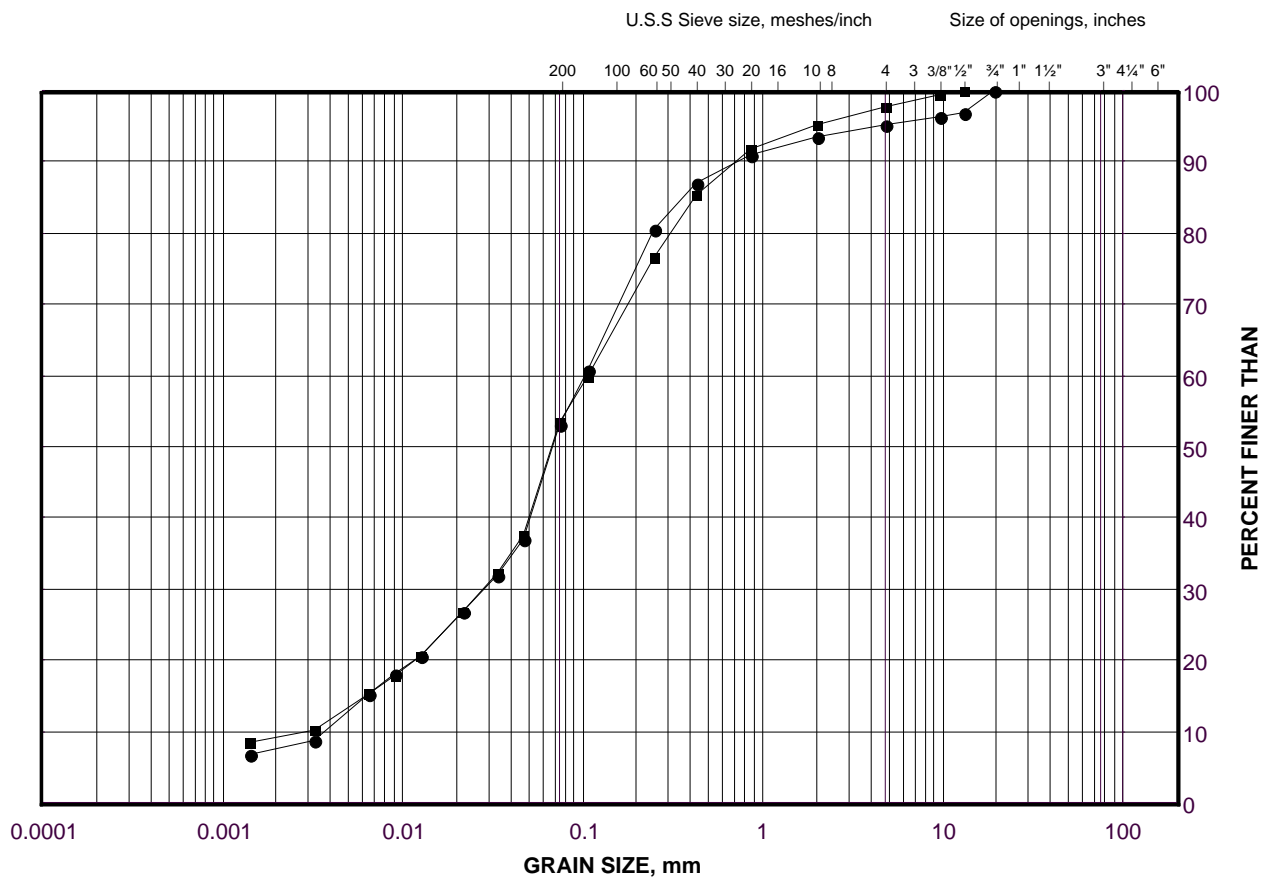
APPENDIX C

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silt and Sand (Fill)

FIGURE C1



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

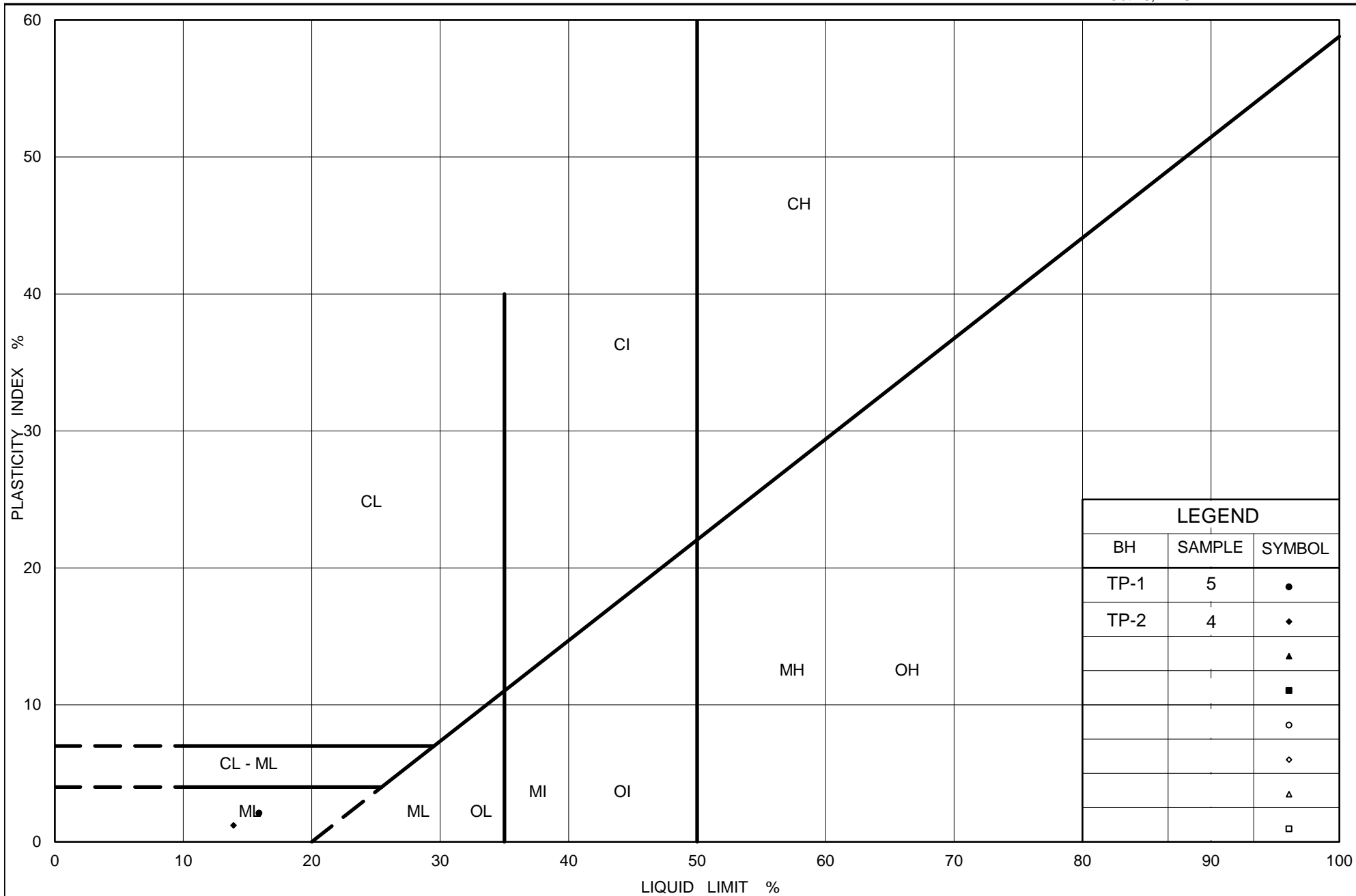
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	TP-2	4	219.7
■	TP-1	5	218.6

Project Number: 1671430

Checked By: NK

Golder Associates

Date: 31-Jul-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Silt and Sand (Fill)

Figure No. C2

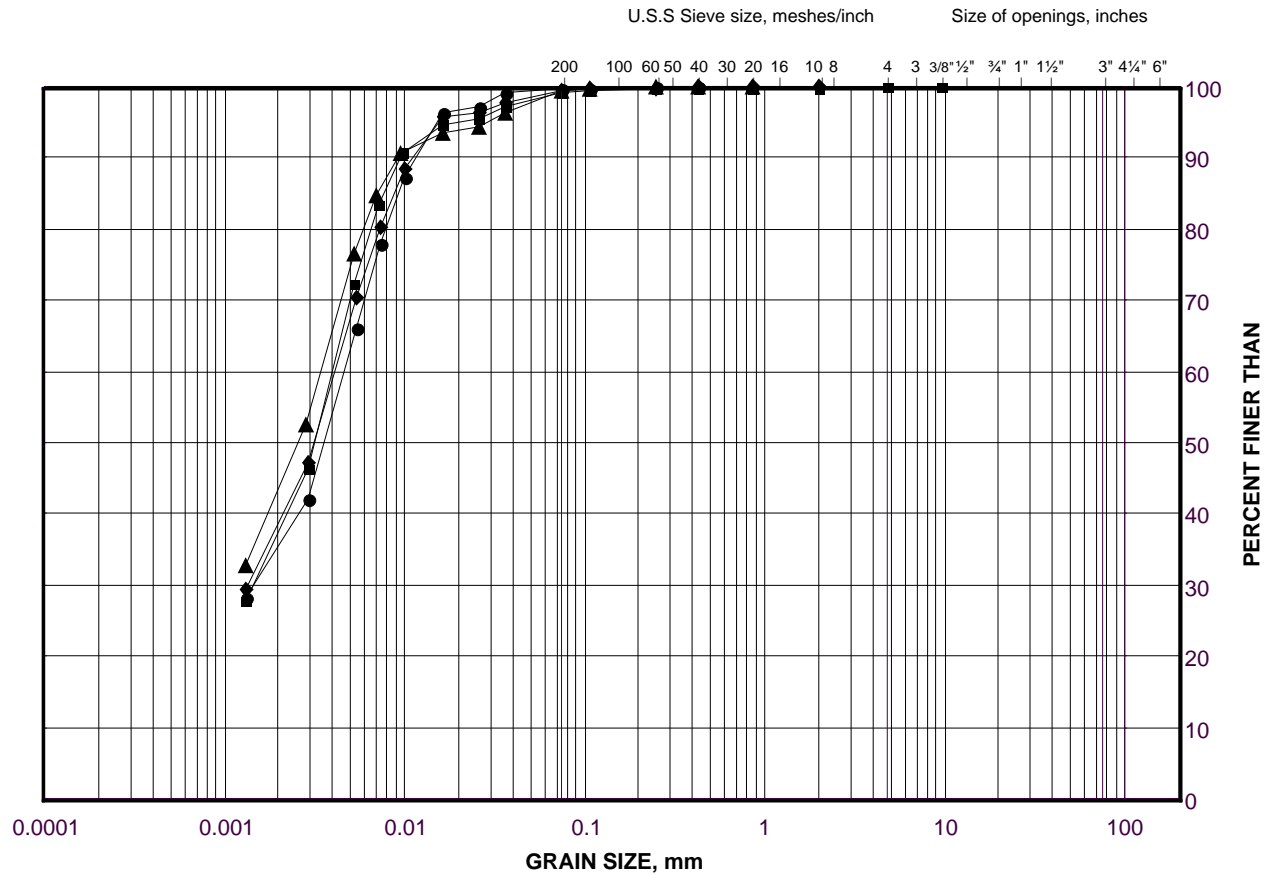
Project No. 1671430

Checked By: NK

GRAIN SIZE DISTRIBUTION

Clayey Silt (Fill)

FIGURE C3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

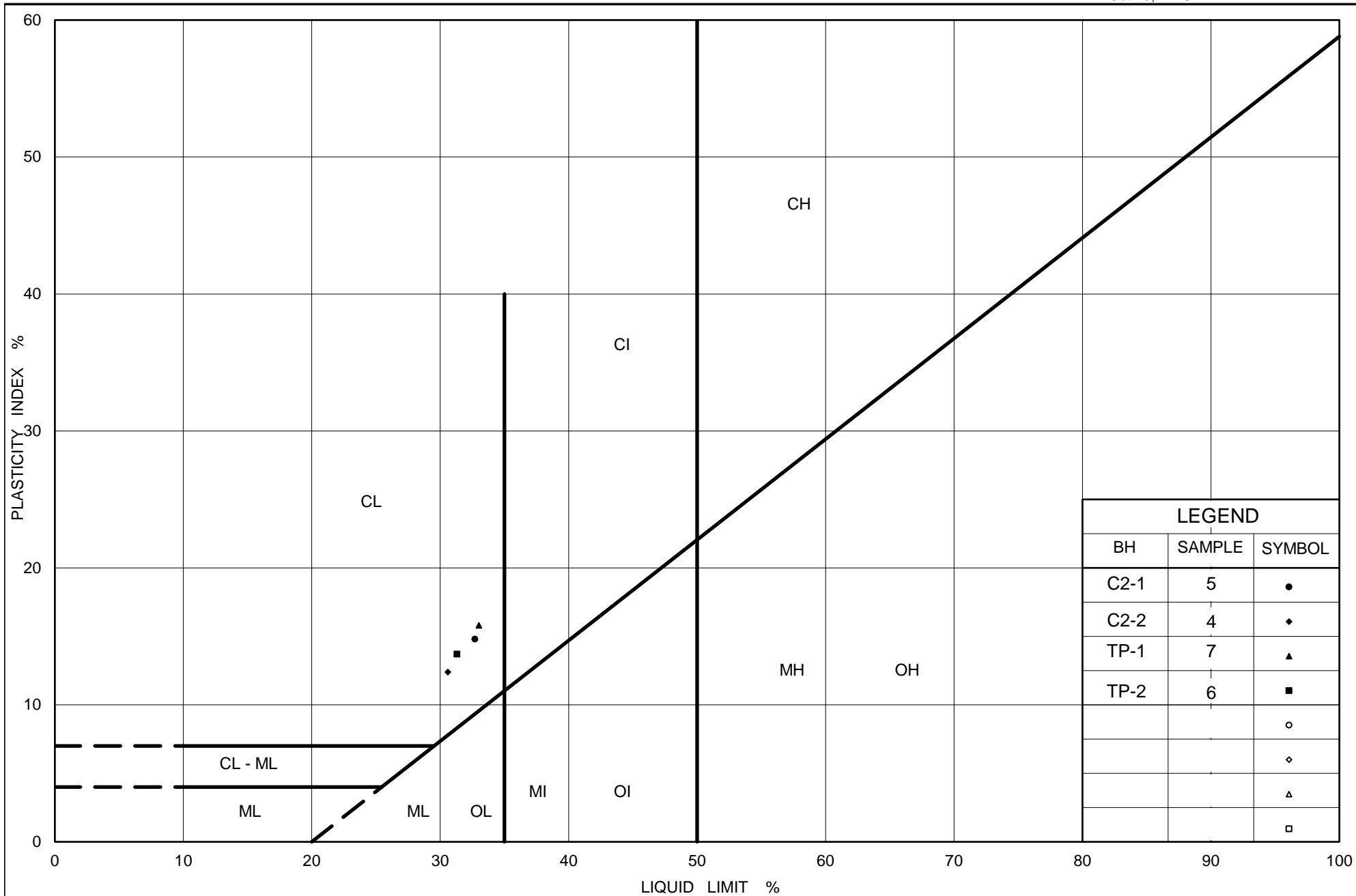
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C2-2	4	217.7
■	C2-1	5	217.5
◆	TP-2	6	218.1
▲	TP-1	7	217.1

Project Number: 1671430

Checked By: NK

Golder Associates

Date: 31-Jul-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt (Fill)

Figure No. C4

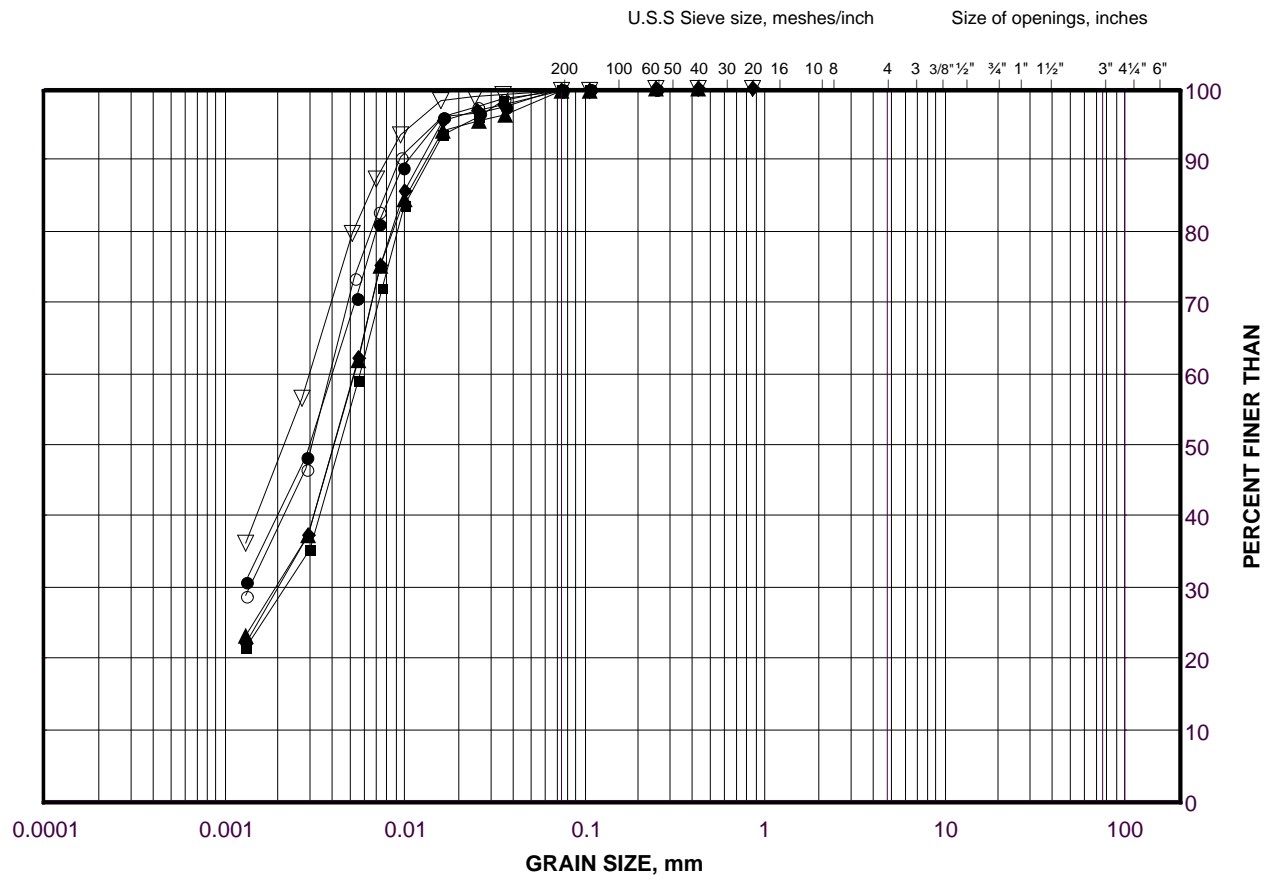
Project No. 1671430

Checked By: NK

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE C5



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

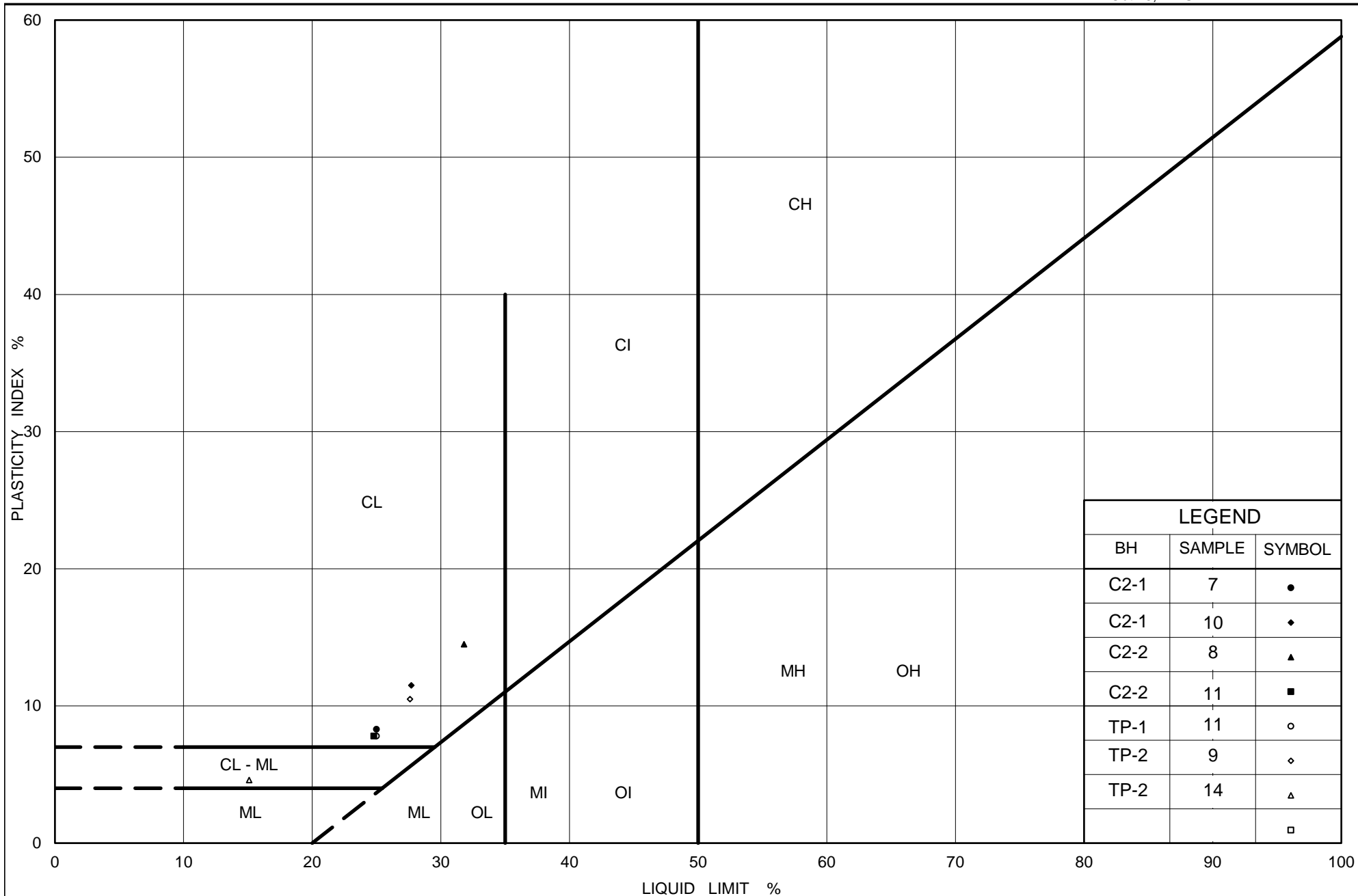
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C2-1	10	209.9
■	TP-1	11	211.0
◆	C2-2	11	209.3
▲	C2-1	7	214.5
▽	C2-2	8	213.9
○	TP-2	9	214.3

Project Number: 1671430

Checked By: NK

Golder Associates

Date: 31-Jul-18



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt-Silt to Clayey Silt

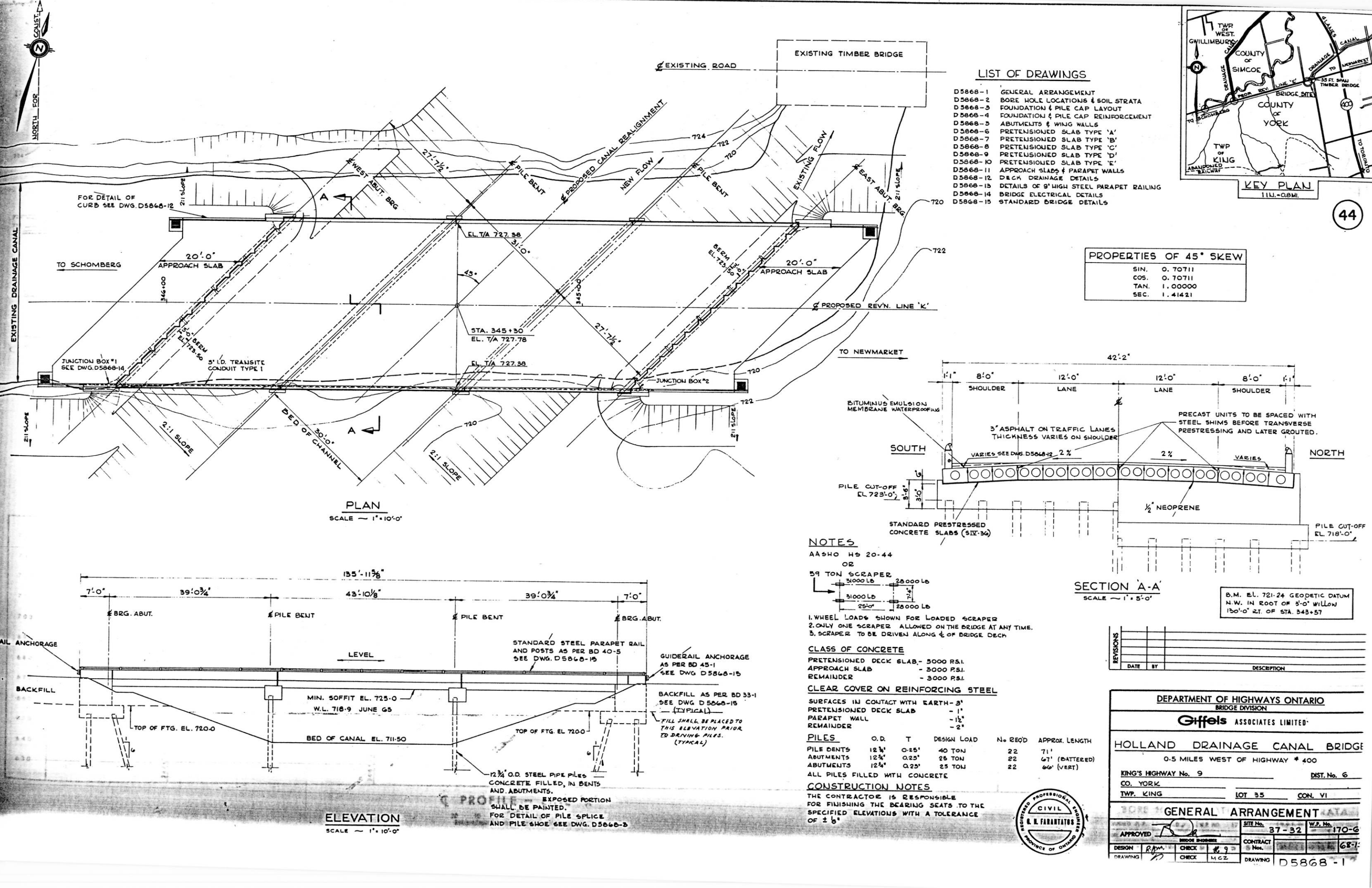
Figure No. C6

Project No. 1671430

Checked By: NK

APPENDIX D

Drawing D5868-1



44

APPENDIX E

Non-Standard Special Provisions

PROTECTION SYSTEM – Item No.

Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.5 m below the finished grade or ground level.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work and facility being protected.

All disturbed areas shall be restored to an equivalent or better condition than existing prior to the commencement of construction.

OBSTRUCTIONS – Item No.

Notice to Contractor

The Contractor shall be alerted to the potential presence of wood fragments in the fill material and the potential presence of cobbles and boulders within the fill and the native deposits. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for excavations and installation of temporary protection systems.



golder.com