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FOUNDATION INVESTIGATION AND DESIGN REPORT RETAINING WALLS AND REINFORCED EARTH SLOPES QEW WIDENING FROM HIGHWAY 406 TO GARDEN CITY SKYWAY, ST. CATHARINES

G.W.P. 607-00-00

Submitted to:

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FOUNDATION INVESTIGATION REPORT
RETAINING WALLS AND REINFORCED EARTH SLOPES
QEW WIDENING FROM HIGHWAY 406
TO GARDEN CITY SKYWAY
ST. CATHARINES, ONTARIO
G.W.P. 607-00-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the widening of the Queen Elizabeth Way (QEW) between Highway 406 and the Garden City Skyway in the City of St. Catharines, in the Region of Niagara. Foundation engineering services are required for the widening or replacement of five structures (Third Street overpass, Martindale Road underpass, Lake Street underpass, Geneva Street overpass, and Welland Avenue overpass), new retaining walls and noise barrier walls, culvert extensions, and high mast light poles.

This report addresses the foundation investigation carried out for the design of retaining walls west and east of the Geneva Street overpass structure, retaining walls east of Martindale Road along the south side of the QEW, and retained soil system (RSS) slopes to the west and east of the Welland Avenue overpass structure.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal for Agreement No. 2005-A-000564, issued in July 2002, and in Section 6.8 of MH's *Technical Proposal* for G.W.P. 607-00-00.

2.0 SITE DESCRIPTION

The proposed retaining walls and reinforced earth slopes extend along the north and south side of the QEW in the vicinity of the Geneva Street and Welland Avenue overpasses, and along the south side of the QEW east of Martindale Road, in the City of St. Catharines, in the Region of Niagara.

Throughout the study area, the QEW runs roughly parallel to and north of (below) the Niagara escarpment, and sub-parallel to and south of Lake Ontario; the highway is located closer to the lake near the western portion of the study area, and trends away from the lake toward the eastern portion of the study area. The overall surface topography in the City of St. Catharines is relatively flat-lying, with a gentle slope downward to the north towards Lake Ontario. The surrounding area is occupied by commercial and residential property developments.

East of Martindale Road, the QEW has been constructed in a cut with the QEW pavement grade at about Elevation 90 m to 90.5 m, approximately 2 m to 3 m below the natural ground surface which is at about Elevation 92 m to 93 m. The existing cut slope separating the QEW from the natural ground surface to the south is oriented at approximately 2 horizontal to 1 vertical.

The natural ground surface in the vicinity of the Geneva Street overpass is at about Elevation 99 m to 100 m, Geneva Street and other local roads are at about Elevation 100 m, and the existing QEW grade has a maximum elevation of approximately 106 m at the existing overpass. The natural ground surface around the Welland Avenue structure site is at about Elevation 100 m to 101 m, and the existing QEW grade has a maximum elevation of approximately 108 m as it crosses Welland Avenue, which is at an elevation of about 101.5 m. In the vicinity of both the Geneva Street and Welland Avenue overpass sites, the QEW embankment is up to about 6 m to 7 m in height and is sloped at approximately 2 horizontal to 1 vertical along the north and south sides of the QEW. Existing concrete retaining walls, approximately 2 m to 4 m in height, are present along both sides of the QEW, separating the QEW embankment from the adjacent local roads.

3.0 INVESTIGATION PROCEDURES

Subsurface investigations were carried out in June and July 2005 and November 2006, during which time thirty-two boreholes (Boreholes 06-1, 06-2, W-33 to W-46, W-51 to W-55, W-63 to W-66, W-69 to W-73, W-76 and W-77) were advanced as part of the foundation investigation for the proposed retaining walls. Use has also been made of selected boreholes advanced as part of Golder's investigations for the Martindale Road underpass structure site (Borehole 207) in November 2004, the Geneva Street overpass structure site (Boreholes 401 to 406) in June and July 2005, and for the Welland Avenue overpass structure site (Boreholes 501 to 507) in December 2004. In addition, use has been made of boreholes advanced along the QEW near Geneva Street as part of a 1955 investigation by the Department of Highways, Ontario (MTO GEOCRES No. 30M3-29, titled "Foundation Investigation Report for the Geneva Street Overpass, MTO Project F-55-16", dated 1955). The borehole locations are shown on Drawings 1 to 8.

The field investigation was carried out using truck-mounted and track-mounted drill rigs supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using solid stem or hollow stem augers, to depths ranging from 5.2 m to 15.9 m for boreholes advanced along the retaining wall alignments, and to depths ranging from 6.7 m to 36.7 m below the ground surface for boreholes advanced at the overpass/underpass structure sites.

Soil samples were obtained at 0.75 m to 3 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure. In-situ vane testing (using an MTO "N"-sized vane) was carried out at selected depths where firm to stiff cohesive soils were encountered, and relatively undisturbed, thin-walled Shelby tube samples of these materials were obtained.

The groundwater conditions in the open boreholes were observed throughout the drilling operations, and piezometers were installed in seven selected boreholes to permit monitoring of the groundwater level at these locations. The piezometers consist of 50 mm outside diameter rigid PVC tubing with a 1.5 m long screen that is sealed at a selected depth within the boreholes (typically within the clayey silt to silty clay till deposit); the piezometer tip and filter sand pack were backfilled to ground surface using bentonite pellets. All other boreholes were backfilled to ground surface using bentonite pellets on completion of drilling.

The field work was supervised on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, arranged for the clearance of underground service locations, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg limits testing, and grain size distribution analyses were carried out on selected soil samples, and oedometer (consolidation) testing was conducted on one sample from the Welland Avenue site.

The borehole locations and ground surface elevations were measured by Golder personnel relative to site features and survey stakes placed by MH. The borehole locations (MTM NAD83 northing and easting coordinates) and the ground surface elevations (referenced to geodetic datum) at the borehole locations are presented on the Record of Borehole sheets that follow the text of this report, and on Drawings 1 to 8.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This area of the QEW lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*[1] and *Urban Geology of Canadian Cities*[2].

The Iroquois Plain extends around the western shores of Lake Ontario; on the south side of the lake, in the St. Catharines area, the Plain is located between the present Lake Ontario shorebluffs and the foot of the Niagara Escarpment. The Plain is comprised of the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession.

The surficial soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts. However, in the St. Catharines area, surficial deposits of beach sand and gravel are present. The surficial sands, silts and clays are underlain by an extensive till deposit; portions of the till are considered to be "water-lain" (that is, formed by sediment rain-out either from a floating ice margin or from iceberg dumping), resulting in a predominantly massive, matrix-supported structure, as well as relatively thin sand to silt stringers or interlayers. This extensive till deposit may be underlain by or interlayered with a lower glaciolacustrine clay deposit, although this glaciolacustrine layer is absent in some portions of the Iroquois Plain in the St. Catharines area. Finally, the till and/or glaciolacustrine layer may be underlain by a lower till unit, that typically has increasing gravel content with proximity to the underlying bedrock (Menzies and Taylor, 1998).

The overburden soils are underlain by red shale bedrock of the Queenston Formation. This shale formation contains siltstone interlayers as well as "occasional patches of gypsum" (Menzies and Taylor, 1998).

4.2 Subsoil Conditions

Thirty-two boreholes were advanced along the proposed retaining wall alignments, and these have been supplemented by fourteen boreholes advanced at as part of the foundation investigations at the Martindale Road underpass, Geneva Street overpass and Welland Avenue overpass sites. The locations of these boreholes, in addition to boreholes advanced as part of a 1955 investigation near Geneva Street, are shown on Drawings 1 to 8.

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

[2] J. Menzies and E.M. Taylor. "Urban Geology of St. Catharines-Niagara Falls, Region Niagara". In *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report and on Figures 1A to 11. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Subsurface conditions will vary between and beyond the borehole locations.

In general, the subsoil conditions consist of fill materials associated with embankments for the QEW and local roads, overlying a thick deposit of clayey silt to silty clay till of firm to hard consistency. Relatively thin surficial deposits of silty sand to sandy silt and clayey silt to silty clay were encountered in some of the boreholes overlying the till deposit. In the deeper boreholes, the clayey silt to silty clay till was underlain by dense to very dense gravelly sand to silt and residual soil deposits.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

About 100 mm of topsoil was encountered at the ground surface in Boreholes 501, 502 and 503, which were advanced in landscaped areas at the Welland Avenue grade.

4.2.2 Asphalt and Fill Materials

Asphalt, approximately 100 mm to 200 mm in thickness, was encountered at the ground surface in all of the boreholes advanced through the QEW or local road pavements.

Fill materials were encountered below the topsoil or asphalt, and were encountered immediately below the ground surface in all of the remaining boreholes, which were advanced through unpaved road shoulders.

The fill material encountered in boreholes near Martindale Road varies from about 0.8 m in thickness along the QEW shoulder, up to about 2.6 m in thickness at the Martindale Road embankment. The fill material encountered in boreholes near Geneva Street varies from about 4.1 m to 9.1 m in thickness for boreholes advanced through the QEW embankment, and from about 0.8 m to 1.8 m in thickness in boreholes advanced at the toe of the QEW embankment/retaining walls, adjacent to the local roads. The fill material encountered in boreholes near Welland Avenue varies from about 4.6 m to 7.6 m in thickness for boreholes advanced through the QEW embankment, and from about 0.6 m to 1.5 m in thickness for boreholes advanced at the toe of the QEW embankment, adjacent to the local roads.

The existing fill materials vary in composition from sand to sand and gravel or crushed limestone, clayey silt to silty clay, and foundry sand. A 150 mm to 200 mm thick layer of concrete was encountered in Boreholes W-37, W-42 and W-54, within or at the base of the fill material. The results of grain size distribution testing carried out on thirteen selected samples of the fill are shown on Figures 1A and 1B.

Atterberg limits testing was carried out on five selected samples of the cohesive fill, and measured plastic limits of 14 to 18 per cent, liquid limits of 25 to 35 per cent, and plasticity indices of 11 to 18 per cent. These results, which are plotted on a plasticity chart on figure 2, indicate that the tested fill materials are comprised of clayey silt of low plasticity.

The SPT “N” values measured within the cohesionless fill ranged from 4 to 70 blows per 0.3 m of penetration, indicating that the fill has a variable, loose to very dense relative density. The layers of foundry sand that were encountered within the QEW embankment fill in some boreholes yielded SPT “N” values ranging from 10 to 107 blows per 0.3 m of penetration, indicating that this portion of the fill has a compact to very dense, and generally very dense, relative density. The measured SPT “N” values within the cohesive fill ranged from 6 to 32 blows per 0.3 m of penetration, indicating that the clayey silt fill has a variable, firm to hard consistency.

4.2.3 Surficial Silty Sand to Sandy Silt

Surficial deposits of cohesionless soil were encountered in some of the boreholes (Borehole 207 near Martindale Road, and Boreholes 403, 406, W-36, W-39, W-41, W-44, W-45, W-53 and W-54 near Geneva Street), generally below the topsoil or fill and on top of the clayey silt to silty clay till deposit. Where encountered, the surficial cohesionless deposits varied from approximately 0.2 m to 2 m in thickness.

The surficial cohesionless soils vary in composition from silty sand to sandy silt containing trace to some gravel; silty clay seams were observed within the deposit at some locations. The results of grain size distribution tests conducted on four selected samples of the surficial silty sand to sandy silt are shown on Figure 3; on this figure, the result for Borehole 207, Sample 4 demonstrates the presence of silty clay seams within the deposit. In addition, organic matter, rootlets and wood fragments were observed in recovered samples of the surficial silty sand to sandy silt.

The measured SPT “N” values ranged from 7 to 21 blows per 0.3 m of penetration, indicating that the surficial silty sand to sandy silt has a loose to compact relative density.

4.2.4 Surficial Clayey Silt to Silty Clay

Surficial layers of cohesive soil were encountered in some of the boreholes (Boreholes W-35, W-38, W-41 near Geneva Street, and Borehole W-72 near Welland Avenue) below the topsoil or fill, and on top of the clayey silt to silty clay till deposit. Where encountered as part of this investigation, the surficial cohesive soils varied from about 0.7 m to 1.5 m in thickness.

The surficial cohesive soils vary in composition from clayey silt to silty clay containing trace to some sand, trace gravel, and trace quantities of organic material. The result of a grain size distribution test conducted on one sample of the surficial clayey silt to silty clay is shown on Figure 4. Atterberg limits testing was carried out on one sample of the surficial soil, and measured a plastic limit of 18 per cent, a liquid limit of 29 per cent, and a plasticity index of 11 per cent; this result, which is plotted on a plasticity chart on Figure 5, indicates that the tested material is a clayey silt of low plasticity.

The SPT “N” values measured within the surficial clayey silt to silty clay deposit range from 4 to 25 blows (but typically 4 to 6 blows) per 0.3 m of penetration, indicating that the deposit has a firm to very stiff, but typically firm, consistency.

4.2.5 Clayey Silt to Silty Clay Till

An extensive till deposit was encountered beneath the topsoil, fill and surficial soil deposits, where present, in all of the boreholes. The surface of this deposit was encountered at a depth of 0.6 m to 2.3 m below the ground surface in boreholes advanced near the local road grade, and at a depth of 6.1 m to 9.4 m below the ground surface in boreholes advanced through the QEW embankments near Geneva Street and Welland Avenue. All of the W-series boreholes were terminated within the till deposit; where fully penetrated in the 200-, 400- and 500-series boreholes, the till deposit is greater than 20 m in thickness.

The till consists of brown to grey clayey silt to silty clay, containing trace to some sand and gravel/shale fragments. Seams of silt and sandy silt have been noted within some of the recovered till samples. Interlayers of moist to wet silty sand to sand and silt were encountered within the clayey silt to silty clay till in Boreholes 207, W-42 and W-45; these interlayers vary from 0.2 m to 3 m in thickness. The results of grain size distribution testing completed on twenty-six selected samples of the clayey silt to silty clay till are shown on Figure 6A to 6C. Although boulders and cobbles were not encountered within the deposit in the boreholes advanced as part of this investigation, the deposit is glacially-derived and may contain cobbles and boulders.

Atterberg limit testing was carried out on ninety samples of the till deposit; the results, which are plotted on plasticity charts on Figures 7A to 7F, confirm that the till material grades from a low plasticity clayey silt to an intermediate plasticity silty clay. In general, the till in the vicinity of Martindale Road consists of lower plasticity clayey silt, grading toward the east to an intermediate plasticity silty clay in the vicinity of Welland Avenue.

The till deposit has a generally stiff to hard consistency, with measured SPT "N" values in the upper portion of the till ranging from 10 to 40 blows per 0.3 m of penetration, and measured SPT "N" values in the lower portion of the till ranging from 15 to greater than 100 blows per 0.3 m of penetration; these SPT "N" values are indicative of a stiff to hard consistency. A thin layer, about 1 m in thickness, of firm till is present immediately below the fill or surficial deposits in some of the boreholes, and a zone of firm to stiff soil is present within the till deposit near Geneva Street and Welland Avenue, as follows:

- In the vicinity of the Geneva Street overpass, the zone of firm to stiff till ranges in thickness between 1.5 m and 8.5 m where fully penetrated. The surface of the firm to stiff till was encountered below approximately Elevation 88.2 m and 82.2 m in the majority of the boreholes in this area, but is as high as Elevation 99.5 m in Borehole W-45 east of Geneva Street.
- In the vicinity of the Welland Avenue overpass, the surface of the firm to stiff till zone was encountered between about Elevation 96.0 m and 88.0 m, and the base (where fully penetrated) was encountered between about Elevation 84.0 m and 82.0 m. The zone of firm to stiff till varies in thickness between about 4.0 m and 14.0 m where this zone was fully penetrated.

The measured SPT "N" values within the firm to stiff zones of the till deposit range from 6 to 12 blows per 0.3 m of penetration, and field vane tests in this zone measured undrained shear strengths of approximately 45 kPa to 100 kPa, with the higher vane shear strengths typically associated with the top or bottom of the "softened" zone, close to the interfaces with the overlying or underlying stiffer soils. These results confirm that the "softened" zone within the till has a firm to stiff consistency.

An oedometer test was conducted on a sample of the firm to stiff till from Borehole 503 near Welland Avenue, and measured a preconsolidation pressure of approximately 250 kPa. The oedometer test results are present on Figures 8A to 8D, and are summarized in the following table:

Borehole/ Sample No.	Sample Depth/Elev.	Unit Wt. (kN/m^3)	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	C_c	C_r	e_o	OCR
503 / 10	9.4 m / 92.0 m	19.8	185	255	70	0.32	0.04	0.75	1.4

NOTES:

σ_p'	Apparent preconsolidation pressure	σ_{vo}'	Computed existing vertical effective stress
C_c	Compression index	C_r	Recompression index
e_o	Initial void ratio	OCR	Overconsolidation ratio

4.2.6 Lower Gravelly Sand to Silt

In the vicinity of Welland Avenue, a cohesionless soil deposit is present below the clayey silt till deposit. The surface of the cohesionless soil was encountered in Boreholes 502 to 505 between Elevations 75.3 m and 77.0 m (at depths of between 24.4 m and 25.9 m below the Welland Avenue grade). All of these boreholes were terminated within this deposit; the deposit has a minimum thickness of 4.7 m to 4.8 m at these locations.

The deposit varies in composition from silty sand containing trace gravel/shale fragments, gravelly sand containing some silt, to silt containing trace to some sand, trace gravel and clay; clayey silt seams were noted within a sandy silt portion of this deposit, as encountered in Borehole 503. The results of grain size distribution tests completed on two selected samples of this lower gravelly sand to silt deposit are shown on Figure 9.

The SPT "N" values measured within the lower gravelly sand to silt deposit range from 33 to greater than 100 blows per 0.3 m of penetration, indicative of a dense to very dense relative density. Typically, the lower SPT "N" values (33 to 82 blows per 0.3 m of penetration) were encountered in the upper 1 m to 1.5 m of the deposit; the surface of the "100-blow" material was encountered in the boreholes between approximately Elevations 75.5 m and 74 m.

4.2.7 Lower Till/Residual Soil

In the vicinity of Geneva Street and Martindale Road, a till/residual soil deposit was encountered below the clayey silt to silty clay till. The surface of the till/residual soil was encountered between Elevations 72.3 m and 77.7 m (about 28.3 m to 33.5 m below the QEW grade) in Boreholes 401 to 404 near Geneva Street, and at about Elevation 70.6 m (a depth of approximately 24.5 m) in Borehole 207 near Martindale Road.

The till/residual soil deposit varies in composition from clayey silt with sand, to silty sand or sand and silt, containing trace gravel, shale and limestone fragments. The results of grain size distribution testing conducted on two samples of this deposit are shown on Figure 10. Atterberg limits testing was carried out on five samples of the cohesive lower till/residual soil, and measured plastic limits between 12 and 16 per cent, liquid limits between 18 and 22 per cent, and plasticity indices between 6 and 8 per cent. These results, which are plotted on a plasticity chart on Figure 11, confirm that the cohesive portion of the lower till/residual soil is a clayey silt of low plasticity.

The measured SPT “N” values within the residual soil range from 81 to greater than 100 blows, but are generally greater than 100 blows per 0.3 m of penetration, indicating that this deposit has a hard consistency.

4.2.8 Bedrock

Bedrock was encountered near Geneva Street in Borehole 403, where it was observed in a split-spoon sample. The surface of the bedrock was encountered in this borehole at about Elevation 70.8 m (at a depth of approximately 35.1 m below the QEW grade).

The bedrock observed in the sample consists of red shale of the Queenston Formation. Although not noted in the split-spoon sample collected, interlayers of strong limestone and siltstone are anticipated to be present within the Queenston Formation shale bedrock.

4.3 Groundwater Conditions

The water levels were noted during and after the drilling operations in the open boreholes. Typically, the open boreholes were dry upon completion of drilling. However, the surficial silty sand to sandy silt soils (where present) may be water-bearing, with water “perched” on top of the underlying, less permeable clayey silt to silty clay till deposit. Water may also be present at the base of cohesionless fill materials, again “perched” on top of the underlying clayey silt to silty clay till deposit.

Piezometers were installed in seven boreholes, sealed within the clayey silt till. Details of the piezometer installations are shown in the Record of Borehole Sheets and in Appendix A following the text of this report. The water levels measured in the piezometers are summarized in the following table; it is noted that the groundwater levels will be subject to seasonal variations, and will rise during wet periods of the year.

Borehole No.	***Ground Surface Elevation***	***Water Level Depth***	***Water Level Elevation***	***Date***
207	95.1 m	13.9 m	81.3 m	November 26, 2004
		13.2 m	81.9 m	May 13, 2005
		13.4 m	81.7 m	December 6, 2005
405	100.0 m	2.8 m	97.2 m	August 8, 2005
		0.6 m	99.4 m	December 6, 2005
503	101.4 m	13.7 m	87.7 m	December 20, 2004
		11.6 m	90.2 m	May 13, 2005
		11.6 m	90.2 m	December 6, 2005
507	101.5 m	6.0 m	95.5 m	December 20, 2004
		1.6 m	99.9 m	May 13, 2005
		1.9 m	99.6 m	December 6, 2005
W-39	99.5 m	1.5 m	98.0 m	August 8, 2005
		0.9 m	98.6 m	December 6, 2005
W-65	101.2 m	4.2 m	97.0 m	August 8, 2005
		1.2 m	100.0 m	December 6, 2005
W-77	1014 m	3.2 m	98.2 m	August 8, 2005
		1.1 m	100.3 m	December 6, 2005

In the vicinity of Geneva Street and Welland Avenue, the measured water level in piezometers sealed within the till deposit is typically between 0.6 m and 1.6 m below the ground surface; the water level typically varies from about Elevation 98.6 m and 100.3 m across this area. The water level measurement in the piezometer sealed within the lower gravelly sand to silt deposit in Borehole 503 near Welland Avenue is lower, at about 11.6 m depth or Elevation 90.2 m, indicative of a downward hydraulic gradient through the till in this area.

The water level in the vicinity of Martindale Road (immediately to the west of Martindale Pond), is also lower, at about Elevation 81.5 m to 82 m (about 13 m to 13.5 m deep relative to the natural ground surface), as measured in piezometers sealed within the lower till/residual soil deposit.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Houda Jadi, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., an Associate and Geotechnical Engineer with Golder. Mr. Fin Heffernan, P.Eng., a Designated MTO Contact for Golder, carried out an independent review of the report.

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PART B

FOUNDATION DESIGN REPORT
RETAINING WALLS AND REINFORCED EARTH SLOPES
QEW WIDENING FROM HIGHWAY 406
TO GARDEN CITY SKYWAY
ST. CATHARINES, ONTARIO
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed retaining walls and reinforced earth slopes as part of the QEW widening between Highway 406 and the Garden City Skyway. The foundation design recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigations at the retaining wall sites. The interpretation and recommendations are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure foundations. Where comments are made on construction they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the contract documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Retaining walls are required to separate the QEW from the adjacent local roads near Geneva Street and Welland Avenue; alternatively, where sufficient room is available (as is the case near Welland Avenue), consideration could be given to the use of reinforced earth slopes rather than retaining walls. Near Geneva Street and Welland Avenue, the QEW has been constructed on an embankment that is between 6 m and 7 m in height relative to the adjacent local roads, which have been constructed at or near the natural ground surface in the area. New retaining walls, where adopted, would be constructed along the existing retaining wall alignment (where present).

The height of the retaining walls will vary from about 1.2 m to 6.3 m; the highest retaining walls will be constructed immediately adjacent to the Geneva Street and Welland Avenue overpass structures. The locations and heights of the proposed retaining walls, together with the maximum thickness of additional embankment fill/retaining wall backfill required to bring the widened sections of the QEW to the design grade, are presented in the table below. As shown in this table, the maximum thickness of the "wedge" of new fill that will be placed on top of the existing embankment side slopes will vary from about 0.5 m to 3.5 m.

Area	*Retaining Wall*	*Approximate Station*	*Approximate Length of Wall*	*Approximate Height of Wall*	*Maximum Thickness of Additional Fill*
Geneva Street	Northwest	12+700 to 12+987 Toronto-Bound	287 m	2.0 to 6.0 m	0.5 to 2.8 m
	Southwest	12+590 to 12+987 Niagara-Bound	397 m	2.0 to 5.7 m	0.5 to 2.4 m
	Northeast	13+005 to 13+390 Toronto- Bound	385 m	2.0 to 6.3 m	0.5 to 3.5 m
	Southeast	13+005 to 13+375 Niagara-Bound	370 m	2.0 to 6.0 m	0.5 to 3.5 m

Area	*Retaining Wall*	*Approximate Station*	*Approximate Length of Wall*	*Approximate Height of Wall*	*Maximum Thickness of Additional Fill*
Welland Avenue	Northwest	14+100 to 14+420 Toronto Bound	320 m	1.3 to 2.5 m	0.5 to 2.0 m
	Southwest	14+275 to 14+375 Niagara Bound	100 m	1.5 to 2.8 m	1.5 to 2.0 m
	Northeast	14+455 to 14+675 Toronto Bound	220 m	1.5 to 2.8 m	1.5 to 2.0 m
	Southeast	14+412 to 14+550 Niagara Bound	138 m	1.5 to 1.8 m	1.4 to 1.8 m

Retaining walls are also required along the south side of the QEW east of Martindale Road, west of the Henley Bridge (Martindale Pond); in this area, the widened QEW will be constructed in a cut that is generally between 2 m and 4 m deep relative to the ground surface on the adjacent property to the south. The existing ground surface along and south of the proposed retaining walls is typically at or greater than approximately Elevation 92 m, up to about Elevation 94.5 m immediately adjacent to Martindale Road (which has been constructed on embankment fill). Following the QEW cut widening, the design grade for the QEW widening will be at approximately Elevation 90.0 m to 90.2 m in front of the walls.

6.2 Summary of Settlement Considerations

The main concern for the design and construction of the retaining walls in the vicinity of Geneva Street and Welland Avenue is the post-construction consolidation settlement of the firm to stiff zones of silty clay to clayey silt till that will occur as a consequence of the additional embankment fill placed behind the new retaining walls. The firm to stiff till zone varies in thickness from about 2.0 m to 8.5 m near Geneva Street, and from about 4 m to 14 m near Welland Avenue.

Settlement is not a significant concern for the retaining walls east of Martindale Road, where the existing grade will be cut down for the QEW widening, and no grade raise is proposed on the property to the south.

The magnitude of settlement under the embankment widening/retaining wall loadings in the vicinity of Geneva Street and Welland Avenue has been estimated using the commercially-available computer program *Unisettle* (Version 3.0), and checked with hand calculations.

The preconsolidation pressure / overconsolidation ratio (OCR) profile was established using the results of the oedometer testing as well as correlations with the results of the in situ vane tests, based on the following relationship between field vane shear strength and preconsolidation pressure (Mesri, 1975):

$$s_u = 0.22\ \sigma_p'$$

where : s_u = average mobilized undrained shear strength (kPa)
σ_p' = preconsolidation pressure

The compression and recompression indices (C_c and C_r) have been determined from the oedometer tests and from correlations with Atterberg limits, and water contents/void ratios as given below:

$C_c = 0.009\ (w_L - 10)$ (Terzaghi and Peck, 1967 – for low to medium-sensitivity clays)
$C_c = 0.75 \times (e_o - 0.50)$ (Azzouz et al., 1976 – for low-plasticity soils)
$C_c = PI/74$ (Kulhawy and Mayne, 1990 – for natural clays)
$C_r = C_c / 10$ (Becker)

The immediate compression of the surficial silty sand to sandy silt deposit and of stiff to hard clayey silt to silty clay till soils was modelled by estimating an elastic modulus of deformation based on the SPT "N" values and correlations proposed by Bowles (1984).

6.2.1 Geneva Street Retaining Walls

Settlement analyses for the retaining walls near Geneva Street were carried out using the consolidation parameters and elastic deformation moduli given in the table below, based on the correlations as outlined above:

Soil Unit	*Bulk Unit Weight (kN/m^3)*	*P_c' (kPa)*	*Cc*	*Cr*	*e_o*	*Elastic Modulus (MPa)*
Embankment fill (range of parameters assumed for earth fill and granular fill), typically above Elevation 96 m to 98 m	19-21	–	–	–	–	–
Surficial sandy silt / clayey silt, typically between Elevation 96 m and 98 m	20	–	–	–	–	25-35
Stiff to hard clayey silt to silty clay till, typically below Elevation 96 m to 98 m	20	–	–	–	–	40-50
Firm to stiff zone of clayey silt to silty clay till, approximately 1.5 m to 8.5 m in thickness (surface of firm to stiff zone variable, encountered between Elevation 82 m and 95.5 m)	19	275-400	0.16-0.35	0.030-0.044	0.65-0.8	–
Hard/very dense (100-blow) till/residual soil, typically below about Elevation 75 m	21	–	–	–	–	100

For the Geneva Street retaining walls, the "wedge" of fill to be placed on the existing embankment side slopes will have a maximum thickness of 1.2 m to 3.5 m. Based on placement of a wedge of conventional earth or granular fill on the existing embankment side slopes, the following magnitudes of settlement have been estimated below the embankment widening/retaining wall footprint:

Retaining Wall	***Approximate Station***	***Representative Borehole(s)***	***Maximum Additional Fill Thickness***	***Estimated Total Settlement (mm)***
Northwest	12+750	W-38, W-39	1.8 m	10 – 15
	12+825	W-40	2.7 m	10 – 15
	12+900	W-41	2.8 m	10 – 15
	12+975	401	3.0 m	10 – 15
Southwest	12+675	W-34	2.0 m	10 – 15
	12+750	W-35	2.1 m	10 – 15
	12+900	W-37	2.4 m	10 – 15
	12+975	403	2.4 m	10 – 15
Northeast	13+020	402	2.8 m	30 – 40
	13+075	405, W-51	2.9 m	15 – 25
	13+150	W-52	3.0 m	15 – 25
	13+225	W-53	3.5 m	25 – 35
	13+375	W-55	0.5 m	5 – 10
Southeast	13+020	404	2.6 m	10
	13+050	No. 15A	3.0 m	15 – 20
	13+100	W-42	3.2 m	20 – 25
	13+170	W-43	3.5 m	25 – 30
	13+225	W-44	3.5 m	25 – 30
	13+330	W-45	1.2 m	10 – 15

Approximately one-third to one-half of the predicted settlement for the Geneva Street retaining walls is associated with elastic compression of the stiff to hard portions of the clayey silt to silty clay till deposit, and this settlement will occur during and immediately following the embankment widening/retaining wall construction.

For portions of the retaining wall to the northeast and southeast of the Geneva Street overpass structure, approximately 25 mm of consolidation settlement will remain following completion of construction and the immediate elastic settlement. This magnitude of settlement would affect the widening area, including the Toronto-bound QEW pavement/shoulder and the new retaining wall at the QEW embankment toe. Figure B-1, contained in Appendix B, shows the estimated percentage of consolidation settlement with time for the retaining walls in the vicinity of Geneva Street. As shown on this figure, it is estimated that 90 per cent of the consolidation settlement will be completed within approximately fifteen months following completion of the embankment widening/retaining wall construction east of Geneva Street.

6.2.2 Welland Avenue Retaining Walls

Settlement analyses for the retaining walls near Welland Avenue were carried out using the consolidation parameters and elastic deformation moduli given in the table below, based on the correlations as outlined above:

Soil Unit	*Bulk Unit Weight (kN/m^3)*	*P_c' (kPa)*	*Cc*	*Cr*	*e_o*	*Elastic Modulus (MPa)*
Embankment fill (range of parameters assumed for earth fill and granular fill), generally above Elevation 100 m to 101.5 m	19-21	–	–	–	–	–
Stiff to very stiff silty clay till ("crust"), with surface generally at about Elevation 100 m and base between Elevation 88 m and 97 m	20	–	–	–	–	30
Middle firm to very stiff silty clay till, typically between Elevation 95 m (though upper surface varies) and 90 m	19	260 – 400	0.2 to 0.3	0.025 to 0.03	0.75-0.9	–
Lower firm to stiff silty clay till, typically between Elevation 90 m and 82 m to 84 m	19	210 – 300	0.35 to 0.4	0.04 to 0.05	0.75-0.9	–
Stiff to hard clayey silt till, typically below Elevation 82 m to 84 m, extending down to about Elevation 75 m	21	–	–	–	–	30-50
Very dense (100-blow) lower gravelly sand to silt, typically below Elevation 75 m	21	–	–	–	–	100

Based on placement of a wedge of conventional earth or granular fill on the existing embankment side slopes, the following magnitudes of settlement have been estimated below the embankment widening/retaining wall footprint:

Retaining Wall	*Approximate Station*	*Representative Borehole(s)*	*Max. Additional Fill Thickness (m)*	*Estimated Total Settlement (mm)*
Northwest	14+125	W-63	1.0	20 – 30
	14+200	W-64	1.3	30 – 40
	14+280	W-65	1.6	40 – 50
	14+400	503	2.0	60 – 75
Southwest	14+275	W-69	1.6	40 – 50
	14+350	506	1.9	50 – 60
	14+375	504	2.0	60 – 75
Northeast	14+475	502	2.0	45 – 60
	14+600	W-72	1.8	40 – 50
Southeast	14+420	505	1.8	40 – 50
	14+500	W-77	1.4	30 – 40

The additional loading due to the placement of conventional earth or granular fill on the embankment side slopes will exceed the preconsolidation pressure in the firm to stiff portion of the silty clay till deposit in this area. As a result, up to about 60 mm to 75 mm of settlement will occur within this deposit. Approximately one-third of the predicted settlement is associated with elastic compression of the stiff to hard soils, and this settlement will occur during and immediately following the embankment widening/retaining wall construction, leaving up to about 40 mm to 50 mm of post-construction consolidation settlement for the walls immediately west of Welland Avenue and up to about 25 mm to 40 mm of post-construction consolidation settlement for the walls immediately east of Welland Avenue.

Figure B-2, contained in Appendix B, shows the estimated percentage of consolidation settlement with time for the retaining walls in the vicinity of Welland Avenue. As shown on this figure, it is estimated that 90 per cent of the consolidation settlement will be completed within approximately 2.5 years following completion of the embankment widening/retaining wall construction in this area.

6.3 Summary of Stability Considerations

The global stability of RSS walls and concrete retaining walls supported on shallow foundations was assessed using the commercially available program SLOPE/W (Version 5.13), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum factor of safety. A target factor of safety of 1.5 is normally used for design of retaining walls under static conditions. This target factor of safety is considered appropriate for the retaining walls at these sites, considering the design and performance requirements and the available subsurface data.

Effective stress parameters were employed in the analyses assuming drained conditions for the soils. The effective stress parameters (effective friction angle and cohesion) for these soils were estimated from empirical correlations using the results of in situ Standard Penetration Tests (for cohesionless soils) and plasticity index (for cohesive soils), in conjunction with engineering judgement considering experience in similar soil conditions.

For cohesive deposits, total stress parameters were also employed in analyses assuming undrained conditions for these soils. The total stress parameters for the clayey silt to clay deposit were assessed based on the results of field vane shear tests, inferred from the oedometer (consolidation) tests results, and estimated from correlations with the natural water content and Atterberg limits. For the oedometer tests, the following correlation proposed by Mesri (1975) was employed to estimated undrained shear strength:

$$s_u = 0.22\sigma_p'$$

where: s_u = average mobilized undrained shear strength (kPa); and
σ_p' = preconsolidation pressure (kPa).

6.3.1 Geneva Street Retaining Walls

Stability analyses were performed for selected sections of the proposed Geneva Street retaining walls corresponding to the greatest wall heights and/or weakest soil conditions, using the parameters summarized in the following table:

Soil Deposit	*Effective Unit Weight (kN/m^3)*	*Undrained (Short-Term) Conditions*	*Effective Stress (Long-Term) Conditions*
Existing embankment fill	19 – 21	$\phi' = 32°$	$\phi' = 32°$
Surficial silty sand/sandy silt	20	$\phi' = 30°$	$\phi' = 30°$
Surficial clayey silt	20	$c_u = 50$ kPa	$\phi' = 28°$
Upper stiff to hard clayey silt till	20	$c_u = 100$ kPa	$\phi' = 35°$
Firm to stiff silty clay to clayey silt till	19	$c_u = 70$ kPa	$\phi' = 28°$
Lower very stiff to hard clayey silt till	21	$\phi' = 35°$	$\phi' = 35°$

The stability analyses indicate that a minimum factor of safety of 1.5 is achieved for RSS walls with a reinforcement length equivalent to at least two-thirds of the height of the wall, or concrete retaining walls with footings founded at a depth of 1.2 m below the ground surface in front of the wall, for wall heights of up to 6 m. A sample stability analysis for the Geneva Street retaining walls is contained in Appendix B.

6.3.2 Welland Avenue Retaining Walls

Stability analyses were performed for selected sections of the proposed Welland Avenue retaining walls corresponding to the greatest wall heights and/or weakest soil conditions, using the parameters summarized in the following table:

Soil	*Effective Unit Weight (kN/m^3)*	*Undrained (Short-Term) Conditions*	*Effective Stress (Long-Term) Conditions*
Existing embankment fill	19 – 21	$\phi' = 32^\circ$	$\phi' = 32^\circ$
Upper stiff to very stiff silty clay till	20	$c_u = 95$ kPa	$\phi' = 28^\circ$
Middle stiff silty clay till	19	$c_u = 75$ kPa	$\phi' = 28^\circ$
Lower firm to stiff silty clay till	19	$c_u = 40$ kPa	$\phi' = 28^\circ$
Lower very stiff to hard clayey silt to silty clay till	21	$\phi' = 35^\circ$	$\phi' = 35^\circ$

The results of the stability analyses indicate that a minimum factor of safety of 1.5 is achieved for RSS walls with a reinforcement length equivalent to at least two-thirds of the height of the wall, or concrete retaining walls with footings founded at a depth of 1.2 m below the ground surface in front of the wall, for wall heights of up to 2.8 m. A sample stability analysis for the Welland Avenue retaining walls is contained in Appendix B.

6.3.3 Martindale Road Retaining Walls

Stability analyses were performed for a selected section of the proposed retaining walls east of Martindale Road, corresponding to the highest wall height, using the parameters summarized in the following table:

Soil	*Effective Unit Weight (kN/m^3)*	*Undrained (Short-Term) Conditions*	*Effective Stress (Long-Term) Conditions*
Stiff to very stiff clayey silt till	20	$c_u = 100$ kPa	$\phi' = 32^\circ$
Very stiff to hard clayey silt till	21	$\phi' = 35^\circ$	$\phi' = 35^\circ$
Lower sands and silts	21	$\phi' = 30^\circ$	$\phi' = 30^\circ$
Lower till/residual soil	21	$\phi' = 35^\circ$	$\phi' = 35^\circ$

The results of the stability analyses indicate that a minimum factor of safety of 1.5 is achieved for RSS walls with a reinforcement length equivalent to at least two-thirds of the height of the wall, or concrete retaining walls with footings founded at a depth of 1.2 m below the ground surface in front of the wall, for wall heights of up to 4 m.

6.4 Summary of Retaining Wall Options

Based on the results of the settlement analyses as presented in Section 6.2, the estimated post-construction consolidation settlements for the retaining walls in the vicinity of Geneva Street are generally less than about 25 mm. Near Welland Avenue, the post-construction consolidation settlements will be up to about 25 mm to 50 mm. Differential settlement will occur between wall sections where there is a significant change in the thickness of the additional embankment fill, and at transitions between retaining walls supported on the near-surface soils and pile-supported structures. To reduce the magnitudes of post-construction total and differential settlements to acceptable levels, settlement mitigation measures (i.e., the use of lightweight fill) could be adopted for portions of the embankment widening and retaining wall backfill or, alternatively, consideration could be given to the use of pile-supported concrete retaining walls. Three retaining wall foundation options are presented based on consideration of the subsoil conditions encountered in the boreholes, the proposed embankment widening/wall geometry and cross-sectional profiles, and the results of the settlement analyses as discussed in Section 6.2.

1- **Mechanically-reinforced soil retaining systems:** Mechanically reinforced or retained soil system (RSS) walls are geotechnically feasible and can be considered for all of the retaining walls required as part of the QEW widening project. Due to the variability in the thickness of additional fill to be placed and natural variability in the thickness and depth of the zone of firm to stiff till near Geneva Street and Welland Avenue, it is recommended that vertical slip joints be incorporated into the RSS walls at regular intervals to accommodate differential settlements along the RSS walls. Where post-construction settlements of greater than 25 mm to 35 mm are predicted near Welland Avenue, the use of ultra-lightweight slag (having a bulk unit weight of 11.5 kN/m^3) could be considered for the RSS wall fill, to improve the performance and aesthetic appearance of the RSS wall facing panels.

2- **Reinforced earth slopes:** Reinforced, steepened embankment side slopes are geotechnically feasible and could be considered around Welland Avenue, where there is sufficient space to construct reinforced earth slopes at inclinations varying from 1H:1V to 1.5H:1V (except in the immediate vicinity of the Welland Avenue overpass structure, where short concrete retaining walls will be required), and surrounding the Spruce Street stormwater management pond. Reinforced earth slopes are not an option near Geneva Street or Martindale Road as there is not sufficient space at these locations.

3- **Concrete retaining walls on shallow foundations:** This type of wall and foundation can be considered where the total post-construction settlements are less than approximately 25 mm – i.e. for the retaining walls around Geneva Street and east of Martindale Road. Concrete walls on shallow footings can also be considered near Welland Avenue with the use of a combination of appropriately-spaced construction joints along the walls and/or partial use of EPS fill or ultra-lightweight slag fill at critical wall sections where the estimated post-construction settlements are greater than 25 mm. However, there is concern regarding the durability of EPS blocks in the QEW embankment, based on the high traffic volume and heavy truck loading in this area; as a result, the use of EPS fill is not recommended in conjunction with this foundation option.

4- **Concrete retaining walls on deep pile foundations:** This type of wall and foundation can be considered where the total post-construction settlements are greater than approximately 25 mm. This wall type is not considered necessary near Geneva Street or Martindale Road, where suitable settlement-performance and lower cost can be achieved using wall systems supported on the shallow subsoils. However, it would be appropriate for the short retaining walls adjacent to the pile-supported Welland Avenue overpass, where the predicted post-construction settlements will be up to 25 mm to 50 mm (assuming the use of earth or granular fill for the embankment widening and retaining wall backfill).

5- **Soldier pile and concrete lagging walls:** This type of wall is considered feasible and appropriate for the retaining walls east of Martindale Road, where the existing ground surface will be cut relative to the property on the south side of the QEW. The soldier pile and concrete lagging system can be installed as part of the cut widening, without significant excavation onto the property south of the QEW (as would be required for the installation of shallow foundations, pile caps or reinforced soil masses).

The advantages and disadvantages for the various retaining wall and reinforced slope options are summarized in Table 1 following the text of this report. In this regard, it is understood that short (less than 15 m length) retaining walls are planned immediately adjacent to the Geneva Street and Welland Avenue overpass abutments: at Geneva Street, shallow foundations are recommended as the preferred option for support of the concrete walls; and at Welland Avenue, deep foundations are recommended as the preferred option for support of concrete walls based on settlement considerations. For all other retaining walls near Geneva Street, RSS walls are recommended as the preferred option from a foundations perspective based on cost considerations, and for all other retaining walls near Welland Avenue, reinforced earth slopes are recommended as the preferred option from a foundations perspective since they are the most economical and the most tolerant of settlement. For the retaining walls east of Martindale Road, RSS walls are considered the most economical, followed by concrete retaining walls supported on shallow foundations; however, if temporary open-cut excavation works on the property to the south of the QEW are not feasible, then the use of a soldier pile and concrete lagging wall system is considered the most feasible and appropriate from a geotechnical perspective.

The following sections provide further discussion and geotechnical recommendations regarding the retaining wall foundation options outlined above.

6.5 Retained Soil System (RSS) Walls

Mechanically-reinforced soil retaining systems (retained soils system or RSS walls) can be considered and will be the most cost-effective vertical wall option for both the Geneva Street and Welland Avenue retaining walls. The use of RSS walls is also geotechnically feasible and could also be considered for the retaining walls along the south side of the QEW cut widening east of Martindale Road; however, significant additional excavation would be required to construct the reinforced soil mass as part of the cut widening, and so this option may not be the most advantageous in terms of effect on the property to the south.

Based on discussions with MTO is understood that, from an aesthetic perspective, the tolerable total settlement for the RSS walls is approximately 35 mm. The estimated settlements under the embankment widening/retaining wall construction around Geneva Street and east of Martindale Road meet this criterion, although it is still recommended that vertical slip joints be provided at regular intervals along the RSS walls as well as at locations where the RSS walls abut pile-supported structures, to provide increased wall flexibility to tolerate the estimated total and differential settlements while maintaining the aesthetic appearance of the wall facing panels.

To reduce the predicted post-construction settlements to the acceptable criterion (approximately 35 mm) for RSS walls in the vicinity of Welland Avenue, ultra-lightweight slag fill could be used instead of granular fill for RSS wall construction in critical sections, where post-construction settlements of greater than 35 mm are predicted for the use of granular fill. With the use of ultra-lightweight slag fill at these locations, the total post-construction settlement would be reduced from 40 mm to 50 mm, to approximately 25 mm to 35 mm.

The "critical sections" for RSS walls near Welland Avenue are identified in the table below, which also provides an estimate of the volumes of ultra-lightweight slag fill that would be required in these areas; this includes tapering of the ultra-lightweight fill thickness away from the critical sections along the QEW using a 5H:1V slope. As for RSS walls near Geneva Street, if RSS walls are adopted around Welland Avenue it is recommended that vertical slip joints be incorporated at regular intervals along the RSS walls as well as at locations where the RSS walls abut pile-supported structures, to provide increased wall flexibility to tolerate the estimated total and differential settlements while maintaining the aesthetic appearance of the wall facing panels.

Retaining Wall	*Critical Section (Stations)*	*Length (m)*	*Maximum Fill Thickness[1] (m)*	*Estimated Volume of Slag Fill (m^3)*
Northwest	14+200 – 14+425 Toronto-bound	225	2	1,300
Southwest	14+290 – 14+375 Niagara-bound	85	2	600
Northeast	14+455 – 14+665 Toronto-bound	210	2	1,200
Southeast	14+412 – 14+540 Niagara-bound	128	2	800
Total Estimated Volume of Ultra-Lightweight Slag Fill:				**3,900**

[1] Excluding pavement structure thickness

To reduce the amounts of ultra-lightweight slag fill required for vertical RSS walls around Welland Avenue, the use of reinforced earth slopes (rather than vertical reinforced soil system walls) could be considered, and discussion on this option is provided in Section 6.6.

It is noted that the use of ultra-lightweight slag fill can affect the geometry of the RSS wall. If this slag fill is used in RSS wall construction, it may be necessary to either lengthen the reinforcing strips beyond the "standard" reinforced width or, if a "standard" reinforced width is used, to place a wedge of ultra-lightweight slag fill behind the reinforced soil mass. Based on discussions with RSS wall suppliers, both of these approaches are considered feasible and acceptable. If ultra-lightweight slag fill is adopted for RSS wall construction in the Welland Avenue area, the potentially longer reinforced zone should be assessed by MH to determine potential impacts on traffic staging.

It is also noted that ultra-lightweight slag fill contains components that could be corrosive to the wall reinforcing strips, although literature reviews and discussions with RSS wall suppliers has suggested that this has not been a significant problem. However, the RSS wall supplier should ensure that, if this option is adopted, appropriate steps are taken to protect the RSS wall against potential corrosion of the reinforcing strips, such as installing additional reinforcing strips.

6.5.1 Stability

The global stability of RSS walls near Geneva Street, Welland Avenue and Martindale Road has been analyzed and discussed in Sections 6.3.1 to 6.3.3 above. Based on the analysis results, the factor of safety against global instability of RSS walls (assuming that the reinforcing strips have a length of at least two-thirds of the height of the wall) is greater than 1.5 for all sites.

6.5.2 Geotechnical Resistance

A typical RSS wall has a front facing supported on a strip footing placed at shallow depth below the ground surface in front of the wall. The footing must be founded below any topsoil, loose fill or unsuitable native soils. In areas where the RSS walls are constructed along the alignment of the existing retaining walls, the existing concrete footings will be left in place and would form an acceptable “levelling pad” for the new wall facing panels. Elsewhere, for an assumed width of 0.6 m for the facing footing and assuming the footing is placed on a granular levelling pad or properly prepared undisturbed subgrade, a factored geotechnical resistance at ULS of 125 kPa may be used for design of the facing footing.

Assuming that the RSS wall acts as a unit and utilizes the full width of the reinforced soil mass, which is taken as two-thirds of the height of the wall, the factored geotechnical resistances at ULS given in the following table may be used for assessment of the reinforced mass founded on the properly prepared embankment fill materials or on the stiff to hard silty clay to clayey silt till deposits.

Wall Height	*Assumed Reinforced Width*	*Factored Geotechnical Resistance at ULS*
2.0 m	1.3 m	150 kPa
6.3 m	4.2 m	250 kPa

The settlement of the wall is governed by the loading due to the embankment widening, rather than the wall itself. The total predicted settlements along the wall are presented in Section 6.2. As discussed in that section, the post-construction settlement for RSS walls around Geneva Street will be up to 25 mm for the placement of up to 3.5 m of additional fill (i.e. walls up to approximately 6.3 m in height). The post-construction settlement for RSS walls around Welland Avenue would be up to 40 mm to 50 mm with the use of conventional granular fill, or up to 25 mm to 35 mm with the use of ultra-lightweight slag fill, for the new walls up to approximately 2.8 m in height.

The resistance to lateral forces / sliding resistance between the compacted backfill and the subgrade should be calculated in accordance with Section 6.7.5 of the CHBDC. The coefficient of friction, tan φ', between the compacted granular fills of the RSS wall and the properly prepared subgrade may be taken as 0.6. This represents an unfactored value; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.6 Reinforced Earth Slopes

Reinforced, steepened embankment side slopes are geotechnically feasible and could be considered around Welland Avenue, where there is sufficient space to construct reinforced earth slopes (except in the immediate vicinity of the Welland Avenue overpass where short concrete retaining walls are planned). At most locations around Welland Avenue, there is sufficient room to construct reinforced earth slopes at 1.5H:1V, although local areas with steeper inclinations may be necessary.

Reinforced cut slopes are also geotechnically feasible at the Spruce Street stormwater management pond, where property limitations will require construction of cut slopes oriented at 1H:1V.

6.6.1 Stability

The global stability of the reinforced earth slopes was assessed using the commercially available program SLOPE/W (Version 5.13), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum factor of safety. A target factor of safety of 1.3 is normally used for design of embankment slopes under static conditions. These target factors of safety are considered appropriate for the reinforced soil embankments at these sites, considering the design and performance requirements and the available subsurface data.

Reinforced Earth Slopes at Welland Avenue

Stability analyses were performed for selected sections of the proposed Welland Avenue reinforced earth slopes corresponding to the greatest embankment height and/or weakest soil conditions, using the parameters summarized in the following table:

Soil	*Effective Unit Weight (kN/m^3)*	*Undrained (Short-Term) Conditions*	*Effective Stress (Long-Term) Conditions*
Existing embankment fill	19 – 21	$\phi' = 32^\circ$	$\phi' = 32^\circ$
Upper stiff to very stiff silty clay till	20	$c_u = 95$ kPa	$\phi' = 28^\circ$
Middle stiff silty clay till	19	$c_u = 75$ kPa	$\phi' = 28^\circ$
Lower firm to stiff silty clay till	19	$c_u = 40$ kPa	$\phi' = 28^\circ$
Lower very stiff to hard clayey silt to silty clay till	21	$\phi' = 35^\circ$	$\phi' = 35^\circ$

The results of the stability analyses for the Welland Avenue area indicate that a minimum factor of safety of 1.3 is achieved for reinforced earth slopes up to approximately 6 m in height, with side slopes constructed at orientations of 1.5H:1V to 1H:1V, assuming that the reinforcing strips have a length corresponding to at least two-thirds of the height of the embankment. An example global stability analysis for reinforced earth slopes near Welland Avenue is contained in Appendix B.

Reinforced Earth Slopes at Spruce Street Stormwater Management Pond

Stability analyses were performed for the proposed reinforced earth slopes at the Spruce Street stormwater management pond, using the parameters summarized in the table below. The analyses also assumed a maximum reinforced slope height of 6 m, with the pond base constructed at Elevation 96.0 m and the natural and finished ground surface surrounding the pond varying between Elevation 100.5 m and 102.0 m.

Soil	*Effective Unit Weight (kN/m^3)*	*Undrained (Short-Term) Conditions*	*Effective Stress (Long-Term) Conditions*
Fill above Elevation 101 m	20	$\phi' = 32^\circ$	$\phi' = 32^\circ$
Stiff clayey silt to silty clay till between Elevation 101 m and 94 m	20	$c_u = 80$ kPa	$\phi' = 32^\circ$
Stiff to very stiff clayey silt till below Elevation 94 m	21	$c_u = 120$ kPa	$\phi' = 28^\circ$

The results of the stability analyses for the Spruce Street stormwater management pond indicate that a minimum factor of safety of 1.3 is achieved for reinforced earth slopes up to 6 m in height, with side slopes constructed at 1H:1V, provided that the reinforcing strips have a length corresponding to at least 0.8H (where H is the vertical height of the reinforced slope).

6.6.2 Settlement

The settlement of reinforced earth slopes in the vicinity of Welland Avenue will be consistent with the magnitudes of settlement as presented in Section 6.2.2. That is, up to about 60 mm to 75 mm of total settlement will occur in the foundation soils under the widened embankment loading. Approximately one-third of this predicted settlement is associated with elastic compression of the stiff to hard soils, which will occur during and immediately following the embankment widening/retaining wall construction. Therefore, up to 40 mm to 50 mm of post-construction consolidation settlement will occur under the reinforced earth slopes west of Welland Avenue, and up to 25 mm to 40 mm of post-construction consolidation settlement will occur under the reinforced earth slopes east of Welland Avenue. The maximum settlement will occur under the vegetated embankment side slopes, with lesser settlement occurring under the new outside lane/shoulder of the QEW Toronto-bound and Niagara-bound lanes. As discussed in Section 6.2.2, it is estimated that 90 per cent of the post-construction consolidation settlement will be completed within approximately 2.5 years following completion of the embankment widening in this area.

6.7 Concrete Retaining Walls Supported on Shallow Foundations

Concrete retaining walls supported on shallow foundations can be considered where the total predicted settlements as given in Section 6.2 are less than approximately 25 mm to 35 mm. Concrete retaining walls on spread footings could also be considered if EPS fill or ultra-lightweight slag fill is used behind “critical” wall sections (i.e. those sections where the anticipated total settlements exceed 25 mm to 35 mm and/or differential settlements exceed 25 mm, as identified in Sections 6.2 and 6.4). However, it is understood based on discussions with MH and MTO that the use of EPS for the QEW embankment widening is not acceptable, due to the high traffic loadings and volume on this approach to the international border. In any case, appropriately-spaced construction joints are recommended along the retaining walls to accommodate differential settlement due to varying thicknesses of fill for the widening and varying subsurface conditions.

The following summarizes the feasibility of concrete retaining walls supported on shallow foundations:

- **Retaining Walls Near Geneva Street**: These retaining walls may be supported on shallow foundations, using conventional earth/granular fill for the embankment widening fill and retaining wall backfill. Maximum settlements of approximately 10 mm to 40 mm are predicted along these walls for the proposed embankment widening; of this, approximately one-third to one-half will occur during construction, and so the maximum post-construction settlement will be restricted to less than 25 mm.

- **Retaining Walls Near Welland Avenue**: Since post-construction settlements of up to 40 mm to 50 mm are predicted under the widened QEW embankment loading, spread footings are not preferred for support of concrete retaining walls near Welland Avenue. The use of lightweight fill could be considered as backfill to the retaining walls; assuming the use of ultra-lightweight slag fill (bulk unit weight of 11.5 kN/m^3), the post-construction settlements could be reduced to less than approximately 30 mm.

- **Retaining Walls East of Martindale Road:** It is feasible to support these retaining walls on shallow foundations, although temporary excavation support may be necessary if open-cut excavations are not feasible behind the proposed retaining wall alignment.

6.7.1 Geneva Street Retaining Walls

As discussed in Section 6.3.1, concrete retaining walls up to 6 m in height in this area, supported on shallow foundations founded at a minimum depth of 1.2 m below lowest surrounding grade, will have a factor of safety of 1.5 or greater against global instability.

Shallow footings for support of concrete retaining walls adjacent to the Geneva Street overpass should be founded on the stiff to hard till deposit below the existing embankment fill, at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration; design elevations are provided in the table below. Excavation through the existing embankment fill and some subexcavation of the surficial sandy silt and upper portion of the till deposit will be required.

The subsoils in the vicinity of the east abutment of the Geneva Street overpass include a thicker zone of compressible, firm to stiff clayey silt to silty clay till. As a result, spread footings for the support of concrete retaining walls adjacent to the east abutment will have a lower geotechnical resistance at SLS. The following founding elevations and geotechnical resistances at ULS and SLS may be used for the design of 3 m wide spread footings placed on the properly prepared clayey silt to silty clay till:

Retaining Wall	*Founding Elevation*	*Factored Geotechnical Resistance at ULS*	*Geotechnical Resistance At SLS**
Retaining Walls West Of Geneva Street	97.5 m	400 kPa	275 kPa
Retaining Walls East Of Geneva Street	96.5 m	350 kPa	225 kPa

* Limiting to 25 mm of settlement, assuming a 3 m wide footing.

The ULS resistance and the magnitude of settlement are dependent on the footing size, configuration and applied loads. Therefore, if this option is adopted, geotechnical resistances for spread footings should be reviewed as the detail design progresses.

The geotechnical resistances provided above are given under the assumption that the loads are applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary*, using the curves for cohesive soils.

Resistance to lateral forces / sliding resistance between the concrete footings and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, tan φ', between cast-in-place concrete footings and the undisturbed, properly prepared, stiff to hard clayey silt to silty clay till may be taken as 0.45. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.7.2 Geotechnical Resistance – Welland Avenue Retaining Walls

As discussed in Section 6.3.2, concrete retaining walls up to 2.8 m in height in this area, supported on shallow foundations founded at a minimum depth of 1.2 m below lowest surrounding grade, would have a factor of safety of 1.5 or greater against global instability.

Shallow foundations may be feasible for support of the retaining walls adjacent to the Welland Avenue overpass, with the use of appropriately-spaced construction joints along the walls and/or partial use of ultra-lightweight slag fill behind the walls to satisfy the SLS loading requirements.

Shallow footings for support of concrete retaining walls adjacent to the Welland Avenue overpass should be founded on the stiff to hard till deposit below the existing embankment fill, at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration; design elevations are provided in the table below. Excavation through the existing embankment fill will be required.

The following founding elevations, factored geotechnical resistances at ULS and geotechnical resistances at SLS may be used for the design of 2 m wide spread footings placed on the properly prepared clayey silt to silty clay till:

Retaining Wall	*Founding Elevation*	*Factored Geotechnical Resistance at ULS*	*Geotechnical Resistance At SLS**
Retaining Walls West Of Welland Avenue	100.0 m	300 kPa	80 kPa
Retaining Walls East Of Welland Avenue	100.0 m	300 kPa	80 kPa

* Limiting to 25 mm of settlement, for a footing width of 2 m.

The ULS resistance and the magnitude of settlement are dependent on the footing size, configuration and applied loads. Therefore, if this option is adopted, the geotechnical resistances for spread footings should be reviewed as the detail design progresses.

The geotechnical resistances provided above are given under the assumption that the loads are applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary*, using the curves for cohesive soils.

Resistance to lateral forces / sliding resistance between the concrete footings and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, tan φ', between cast-in-place concrete footings and the undisturbed, properly prepared, stiff to hard clayey silt to silty clay till may be taken as 0.45. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.7.3 Geotechnical Resistance – Martindale Road Retaining Walls

As discussed in Section 6.3.3, concrete retaining walls up to 4 m in height in this area, supported on shallow foundations founded at a minimum depth of 1.2 m below lowest surrounding grade, will have a factor of safety of 1.5 or greater against global instability.

Shallow footings for support of concrete retaining walls along the south side of the QEW east of Martindale Road should be founded on the stiff to hard clayey silt till deposit at a minimum depth of 1.2 m below the lowest surrounding grade. Based on the final grade at Elevation 90.0 m to 90.2 m in front of these retaining walls, the strip footings would be founded at a maximum elevation of 88.8 m to 89 m. This would require excavation of slightly more than 3 m relative to the existing ground surface along the proposed retaining wall alignment.

For spread footings founded at or below the design elevation given above, the following factored geotechnical resistances at ULS and geotechnical resistances at SLS can be used for design:

Footing Width	*Factored Geotechnical Resistance at ULS*	*Geotechnical Resistance At SLS**
1 m	250 kPa	200 kPa
2 m	350 kPa	200 kPa

* Limiting to 25 mm of settlement.

The geotechnical resistances provided above are given under the assumption that the loads are applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary*, using the curves for cohesive soils.

Resistance to lateral forces / sliding resistance between the concrete footings and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, tan φ', between cast-in-place concrete footings and the undisturbed, properly prepared, stiff to hard clayey silt to silty clay till may be taken as 0.45. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.8 Pile-Supported Concrete Walls

Immediately adjacent to the Welland Avenue overpass, consideration could be given to the use of a concrete retaining wall supported on pile foundations that extend through the firm to stiff till soils, to reduce post-construction settlements of the retaining wall. Based on the information from Boreholes 502 to 505, the piles would be driven to found within the very dense, "100-blow" lower gravelly sand to silt deposit. The surface of the "100-blow" soil was encountered between about Elevation 75.5 m and 74 m in the boreholes, as summarized in the table below. For design, the following pile tip levels may be assumed based on approximately 2 m of penetration into the "100-blow" lower gravelly sand to silt deposit.

Foundation Element	*Relevant Boreholes*	*Estimated Elevation Of "100-Blow" Soil*	*Estimated Pile Tip Elevation*
Concrete Walls Adjacent to West Abutment	503, 504	74 m to 75.5 m	72 m to 73.5 m
Concrete Walls Adjacent to East Abutment	502, 505	74 m to 75 m	72 m to 73 m

In the installation of steel H-piles, consideration must be given to the potential presence of cobbles and boulders within the silty clay to clayey silt till and lower gravelly sand to silt deposits at this site. Steel H-piles should be stiffened with MTO flange plates for protection during driving, in accordance with OPSS 903.07.05.04.

6.8.1 Axial Resistance for Driven Piles

For HP 310 x 110 piles driven to practical refusal within the very dense lower gravelly sand to silt deposit at the Welland Avenue site, a factored axial resistance at ULS of 1,650 kN can be used for design. The axial geotechnical resistance at SLS may be taken as 1,450 kN.

Pile installation should be in accordance with MTO's Special Provision SP903S01. The pile termination or set criteria will be dependent on the pile driving hammer type, helmet, selected pile and length of pile; the criteria must therefore be established at the time of construction after the piling equipment is known. For piles driven into the very dense lower gravelly sand to silt deposit, the following note is considered appropriate for the design and site conditions assuming a resistance factor of 0.5 is applied to the use of the Hiley formula:

> *"Piles to be driven in accordance with Standard SS 103-11 using an ultimate capacity of 3,300 kN per pile."*

6.8.2 Downdrag Load (Negative Skin Friction)

The loading due to the QEW embankment widening will cause consolidation settlement of the firm to stiff zones of silty clay till around Welland Avenue, as discussed in Section 6.2. Assuming the use of conventional earth or granular fill, the widened embankment loading will cause up to approximately 65 mm of total settlement (up to about 40 mm to 50 mm of post-construction settlement) immediately adjacent to the Welland Avenue overpass structure. For pile-supported retaining walls immediately adjacent to the Welland Avenue overpass structure, negative skin friction or downdrag loads will need to be taken into account in the design of the piles supporting the walls. In calculating the magnitude of the downdrag force, the methods described in both the *Canadian Foundation Engineering Manual* and the US Transportation Research Board's report, "Design and Construction Manual for Downdrag on Uncoated and Bitumen-Coated Piles" (Briaud and Tucker, 1994) were considered. Considering the larger predicted settlement of the silty clay till deposit versus the elastic shortening of the piles, the neutral plane used in these analyses was assumed to be at the underside of the silty clay till deposit.

The pile structural design should be based on the full downdrag load acting on the piles within and above the firm till zone. The estimated unfactored downdrag load acting on the HP 310x110 piles may be taken as 400 kN per pile. The load calculated in this manner is an unfactored load. The structural capacity of the piles must be checked for the factored dead and downdrag loads in accordance with Section 6.8.4 of the *CHBDC* for ULS conditions.

Downdrag loads could be eliminated with the use of EPS fill as backfill behind the retaining walls within the widening area; however, it is understood that the use of EPS is not acceptable on this heavily-travelled section of highway. Alternatively, consideration could be given to the use of bitumen coating on the piles to eliminate the downdrag loads. The use of bitumen coating increases the pile costs by approximately 20 to 45 per cent depending on the size of the job; for the QEW widening project, it is estimated that the cost increase would be close to the upper limit.

6.8.3 Resistance to Lateral Loads

Lateral loading could be resisted fully or partially by the use of battered steel H-piles. If vertical piles are used, the resistance to lateral loading will have to be derived from the soil in front of the piles. The resistance to lateral loading in front of the pile may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction is determined based on the equations given below:

For cohesionless soils:

$$k_h = \frac{n_h z}{B}$$

where

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

For cohesive soils:

$$k_h = \frac{67 s_u}{B}$$

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 (m).

The following ranges for the value of n_h and s_u may be assumed in the structural analyses. Approximate elevation intervals are given in this table for each deposit for concrete retaining walls adjacent to the west and east abutments of the Welland Avenue overpass.

Soil Unit	*Elevation*	n_h	s_u
Retaining Walls Adjacent to West Abutment:			
Existing compact to dense embankment fill	Above 100 m	15 MPa/m	–
Stiff to very stiff silty clay till	100 m to 96 m	–	150 kPa
Upper firm to very stiff silty clay till	96 m to 90 m	–	90 kPa
Lower firm to stiff silty clay till	90 m to 82 m	–	60 kPa
Very stiff to hard clayey silt till	82 m to 76 m	–	200 kPa
Very dense (“100-blow”) lower gravelly sand to silt	Below 76 m	35 MPa/m	–
Retaining Walls Adjacent to East Abutment:			
Existing compact to dense embankment fill	Above 100 m	15 MPa/m	–
Stiff to very stiff silty clay till	100 m to 94 m	–	150 kPa
Stiff silty clay till	94 m to 89 m	–	100 kPa
Firm to stiff silty clay till	89 m to 83 m	–	60 kPa
Very stiff to hard clayey silt till	83 m to 76 m	–	200 kPa
Very dense (“100-blow”) lower gravelly sand to silt	Below 76 m	35 MPa/m	–

Group action for lateral loading should also be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R, 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

Reference: Foundations and Earth Structures – Design Manual 7.2, NAVFAC DM-7.2. Department of the Navy, Naval Facilities Engineering Command (1982).

A maximum factored lateral resistance of 180 kN at ULS and a maximum lateral resistance of 85 kN at SLS (for 10 mm of horizontal deflection at pile cap level) are recommended for HP 310 x 110 piles. These values are based on the "Assessed Horizontal Passive Resistance Values for Various Pile Types" provided in Table C6.8.7.1(a) of the *Commentary* to the *CHBDC*.

6.9 Soldier Pile and Concrete Panel Walls

A soldier pile and concrete panel wall could be adopted for the approximately 2 m to 4 m high retaining walls east of Martindale Road. The soldier pile and concrete panel wall system is advantageous in this area, since it will minimize temporary excavation into the property south of the QEW as would be necessary for all other wall types (i.e., for construction of spread footings, pile caps or reinforced soil masses).

This wall system would consist of soldier piles socketted to sufficient depth to provide the necessary passive resistance for the 2 m to 4 m retained soil height. Lateral support to the soldier pile and concrete panel wall system could be provided in the form of permanent soil anchors.

The concrete lagging panels should be installed as soon as space permits. The unsupported height should not exceed 1.2 m at any time and the space behind the lagging should be immediately packed with granular material; this will aid in achieving proper drainage. A 50 mm thick insulation layer should also be provided immediately behind the wall to provide for frost protection to the soils behind the wall.

6.9.1 Passive Resistance for Soldier Pile Sockets

The factored passive resistance at ULS in front of the soldier piles below the base of the wall may be assessed using the equation and the design parameters provided below:

$$P_p = 1.5\, K_p \gamma' z\, B$$

where P_p is the factored lateral resistance at ULS (kN);
K_p is the coefficient of passive earth pressure, which may be taken as 3.0;
γ' is the effective unit weight of the soil in front of the solider pile socket, which may be taken as 21 kN/m^3 above Elevation 82 m;
d is the depth from the ground surface in front of the pile to the base of the pile socket (m); and
B is the diameter of the soldier pile socket (m).

The equation above assumes that the lateral resistance acts over a width equal to three times the socket diameter. The upper 1.2 m of overburden should be ignored in the calculation of the passive resistance, to account for frost effects.

6.9.2 Permanent Soil Anchors

Soil anchor support must be designed to accommodate the loads applied from lateral earth pressures and surcharge pressures from area, line or point loads and take into account any sloping ground behind the retaining wall system. The anchors may be sized based on the following factored bond stresses acting between the grout and soil.

Soil Deposit	*Single-Stage Grouted Anchors*	*Secondary Grouted Anchors*
Stiff to very stiff clayey silt till above Elevation 86 m	45 kPa	75 kPa
Very stiff to hard clayey silt till below Elevation 86 m	75 kPa	130 kPa

The sustained working load should not be greater than 60 per cent of the ultimate tensile strength of the anchor tendons or bars. The fixed length (bond zone) of the anchors should be maintained behind a line drawn upward at 45 degrees from the base of the piles. The permanent soil anchors should be provided with suitable corrosion protection.

Anchor installation, grouting and testing should be carried out in accordance with MTO's Special Provision SP999S26.

6.10 Lateral Earth Pressures for Design of Concrete Retaining Walls

The lateral earth pressures acting on the retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. The following recommendations are made concerning the design of the walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select free-draining granular fill meeting the specifications of Ontario Provincial Standard Specifications (OPSS) Granular “A” or Granular “B” Type II (but with less than 5 per cent passing the No. 200 sieve) should be used as backfill behind the walls. This fill should be placed and compacted in accordance with MTO’s Special Provision SP105S10. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, in accordance with CHBDC Section 6.9.3 and Figure 6.9.3. Compaction equipment should be used in accordance with MTO’s Special Provision SP105S10. Other surcharge loadings should be accounted for in the design, as required.

- The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I in Figure C6.9.1(l) of the Commentary to the CHBDC) or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II in Figure C6.9.1(l) of the Commentary to the CHBDC).

- For Case I, the pressures are based on the existing and proposed embankment fill materials and the following parameters (unfactored) may be used based on the use of Select Subgrade material for the existing embankment:

Soil Unit Weight:	21 kN/m^3
Coefficients of Static Lateral Earth Pressure:	
active, K_a	0.35
at rest, K_o	0.50

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	Granular “A”	**Granular “B” Type II**	**Ultra-Lightweight Slag Fill**
Soil Unit Weight:	22 kN/m^3	21 kN/m^3	11.5 kN/m^3
Coefficients of Static Lateral Earth Pressure:			
Active, K_a	0.27	0.27	0.27
At rest, K_o	0.43	0.43	0.43

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the abutment support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

6.11 Construction Considerations

6.11.1 Temporary Excavations and Cut Slopes

Excavations for the foundation elements will extend through the existing fill, and may extend into the underlying surficial sandy silt or clayey silt to silty clay till deposit if spread footings are adopted. Open-cut excavations into these materials should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. The existing fill and the surficial soils are classified as Type 3 soil, according to the OHSA. Where space and construction staging layouts permit, 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).

6.11.2 Temporary Roadway Protection

It is expected that temporary excavation support will be required in some areas, particularly immediately adjacent to the existing Geneva Street and Welland Avenue overpass structures, to facilitate excavation for the new foundation elements for the replacement structure. Where required, the temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision SP 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 105S19.

6.11.3 Groundwater Control

The surficial silty sand to sandy silt deposit, which is present in localized areas atop the till deposit, and the base of the existing embankment fill should be expected to be water-bearing, particularly during wet periods of the year, with groundwater "perched" on top of the underlying, less permeable clayey silt to silty clay till deposit. It is anticipated that the groundwater in the excavations can be adequately controlled by pumping from properly filtered sumps.

6.11.4 Placement and Compaction of Ultra-Lightweight Slag Fill

Ultra-lightweight slag fill, if adopted, will require special placement and compaction procedures to prevent overcrushing and overcompaction. MTO's Non-Standard Special Provision (NSSP) for the supply and placement of ultra-lightweight slag fill should be included in the Contract Documents; this NSSP is included in Appendix C.

6.11.5 Vibration Monitoring During Pile Driving

If pile-supported concrete retaining walls are adopted in residential areas, consideration could be given to conducting vibration monitoring during the pile driving works. A sample NSSP is provided in Appendix C.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Houda Jadi, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., an Associate and geotechnical engineer with Golder. Technical input was provided by Mr. Murty Devata, P.Eng., a Specialist Foundations Consultant with Golder. Mr. Fin Heffernan, P.Eng., a Designated MTO Contact for Golder, carried out an independent review of the report.

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TABLE 1
COMPARISON OF RETAINING WALL FOUNDATION AND REINFORCED EARTH SLOPE ALTERNATIVES QEW WIDENING BETWEEN HIGHWAY 406 AND GARDEN CITY SKYWAY, G.W.P. 607-00-00

	Geotechnical Feasibility, Applicability and Relative Cost				
Retaining Wall System / Foundation Option	***Geneva Street Walls***	***Welland Avenue Walls***	***Martindale Road Walls***	***Advantages***	***Disadvantages***
RSS Walls	Feasible and considered most appropriate option from a foundations perspective; least expensive wall/foundation option	Feasible, though will require regularly-spaced construction joints and/or the use of ultra-lightweight slag for RSS wall fill at "critical sections"; least expensive wall/ foundation option	Feasible but may not be best option if trying to minimize excavation on property south of QEW; least expensive wall/ foundation option	• Wall system can tolerate predicted magnitudes of settlement; differential settlement can be accommodated with use of regularly-spaced construction joints to maintain aesthetic appearance • Relatively easy construction and less expensive option compared to concrete retaining walls • Can be integrated with noise walls	• Special requirements for placement and compaction of ultra-lightweight slag fill, if adopted for Welland Avenue retaining walls
Reinforced Earth Slopes	Not feasible (insufficient space)	Feasible and considered most appropriate option from a foundations perspective; least expensive solution	Not feasible (insufficient space)	• Relatively easy construction and least expensive option compared to all other wall options • Vegetated surface, so can accommodate predicted settlements for walls near Welland Avenue	• Special treatment of reinforced earth slope surfaces required to allow vegetation to grow and minimize erosion
Concrete Retaining Walls On Shallow Foundations	Feasible and considered most appropriate option from a foundations perspective for short (less than 15 m in length) retaining walls adjacent to overpass; medium-cost foundation option	Feasible and considered acceptable option from a foundations perspective for short (less than 15 m in length) retaining walls adjacent to overpass if predicted post-construction settlements can be tolerated through use of construction joints and/or ultra-lightweight slag fill; medium-cost wall/foundation option	Feasible but may not be best option if trying to minimize excavation on property south of QEW; medium-cost foundation option	• Relatively easy construction in conjunction with construction of new Geneva Street and Welland Avenue overpasses	• Will require excavation through existing embankment fill and existing retaining wall footings, where present • Special requirements for placement and compaction of ultra-lightweight slag fill, if adopted behind Welland Avenue retaining walls

TABLE 1
COMPARISON OF RETAINING WALL FOUNDATION ALTERNATIVES (Continued)
QEW WIDENING BETWEEN HIGHWAY 406 AND GARDEN CITY SKYWAY, G.W.P. 607-00-00

	Geotechnical Feasibility, Applicability and Relative Cost				
Retaining Wall System / Foundation Option	***Geneva Street Walls***	***Welland Avenue Walls***	***Martindale Road Walls***	***Advantages***	***Disadvantages***
Concrete Retaining Walls On Deep Foundations	Feasible but not considered necessary based on settlement and stability analyses; most expensive foundation option	Feasible and considered most appropriate option from a foundations perspective for short (less than 15 m in length) retaining walls adjacent to overpass; although this is the most expensive foundation option, it will produce the lowest risk of settlement	Feasible but not considered necessary based on settlement and stability analyses; most expensive foundation option	• Minimizes settlement of walls, and differential settlement relative to new Welland Avenue overpass which will be supported on piles	• Most expensive option • Vibrations during pile driving could be a concern to residential neighbours
Soldier Pile and Concrete Panel Walls	Feasible but not considered most appropriate option for embankment widening; medium-cost wall/foundation option	Feasible but not considered most appropriate option for embankment widening; medium-cost wall/ foundation option	Feasible and considered most appropriate option from a foundations perspective, since it minimizes excavation on property to south ; medium-cost wall/ foundation option	• Retaining walls east of Martindale Road can be constructed as part of cut for QEW widening; minimal excavation required on property south of QEW	• Easement for soil anchors still required on property south of QEW

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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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 cm^2 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) Cohesionless Soils

Density Index (Relative Density)	N 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.

LIST OF SYMBOLS

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

I. General

π	3.1416
in x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

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
v	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

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

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
l_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p/\sigma'_{vo}$

(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

Notes: 1 $\tau = c' + \sigma' \tan\phi'$
2 Shear strength = (Compressive strength)/2

RECORD OF BOREHOLE No 06-01

1 OF 1 **METRIC**

PROJECT	04-1111-002		
W.P.	607-00-00	LOCATION	N 4782000.0 ;E 323054.2
DIST	Central	HWY	QEW
BOREHOLE TYPE	108 mm Diameter Solid Stem Augers		
DATUM	Geodetic	DATE	November 26, 2006
ORIGINATED BY	PKS		
COMPILED BY	MSM		
CHECKED BY	LCC		

SOIL PROFILE

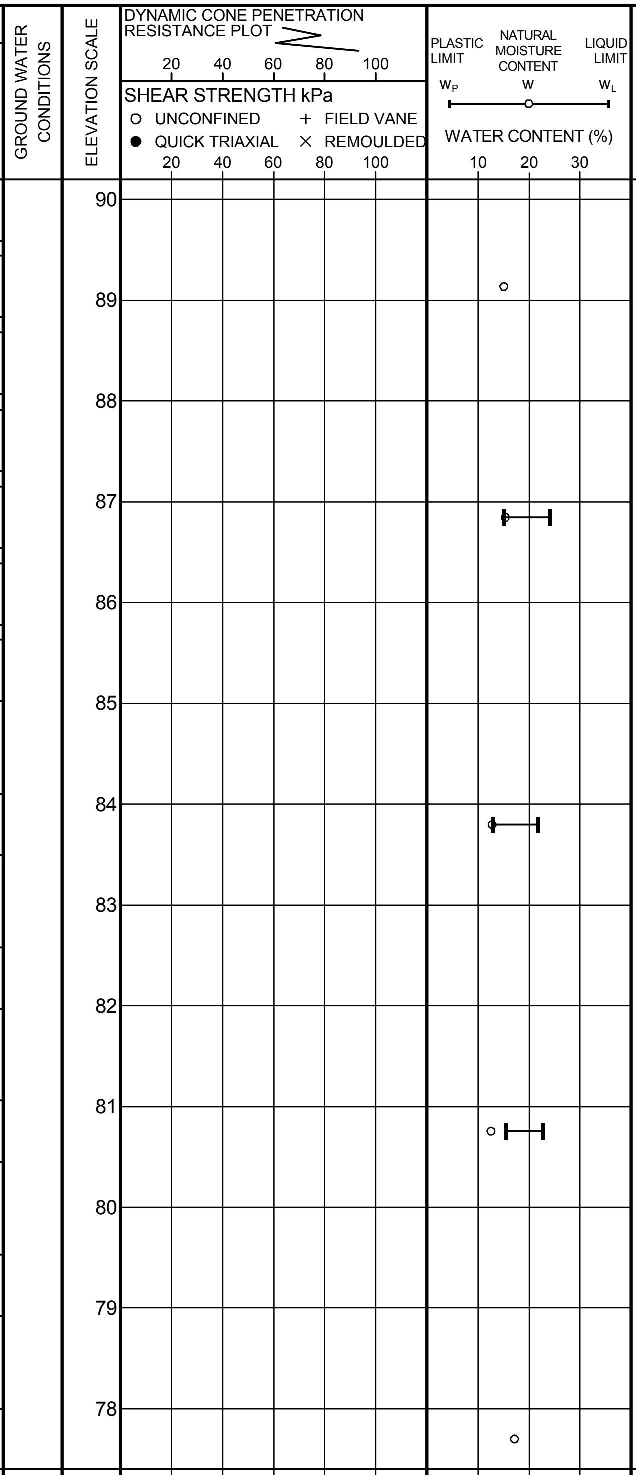
ELEV DEPTH	DESCRIPTION
90.2	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Compact Brown Moist
89.4 0.8	CLAYEY SILT, trace to some sand, trace gravel (TILL) Stiff to hard Grey Moist
77.4 12.8	END OF BOREHOLE

Note:

1. Borehole dry upon completion of drilling operations.

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	AS					
2	SS	7				
3	SS	14				
4	SS	14				
5	SS	13	4	13	56	27
6	SS	15				
7	SS	18				
8	SS	24	0	8	70	22
9	SS	54				
10	SS	38	5	10	62	23
11	SS	20				
12	SS	25				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

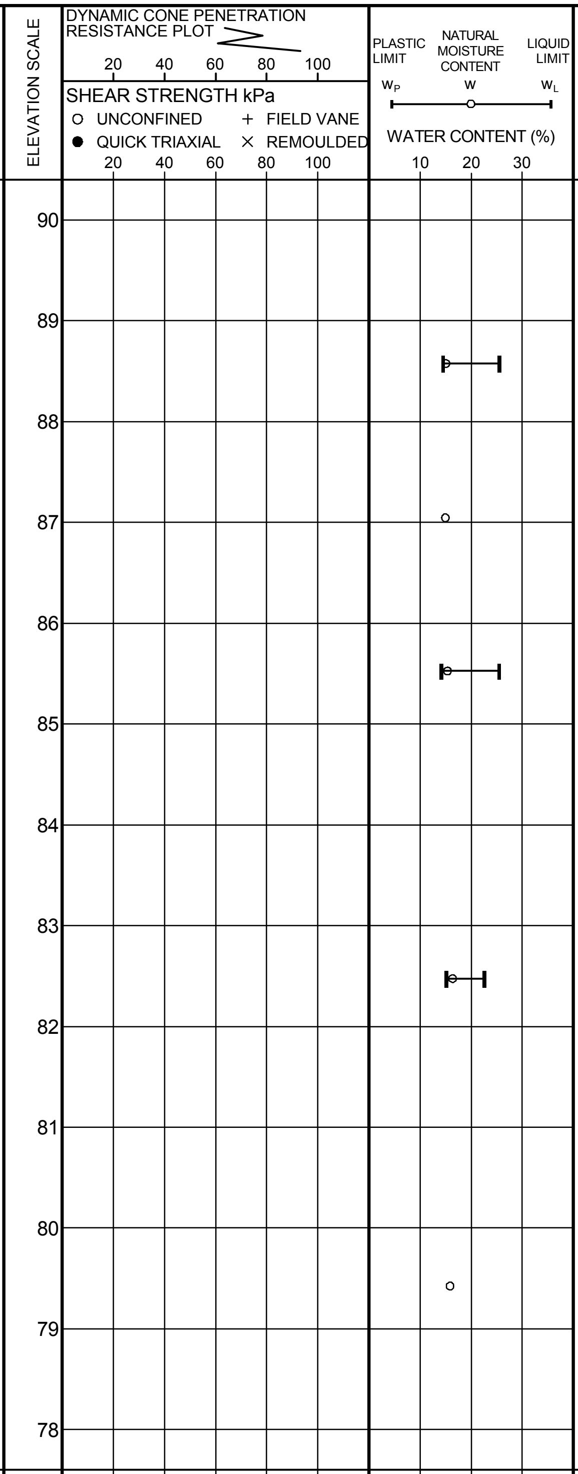
MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 23/1/07

RECORD OF BOREHOLE No 06-02

1 OF 1 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4782017.2 ;E 323101.7	ORIGINATED BY PKS	
DIST Central	HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY MSM
DATUM Geodetic	DATE November 26, 2006	CHECKED BY LCC	

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
90.4	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Compact Brown Moist	1	SS	9				
89.6 0.8	CLAYEY SILT, trace to some sand, trace gravel (TILL) Stiff to hard Grey Moist	2	SS	19				
		3	SS	12	0	13	57	30
		4	SS	12				
		5	SS	13				
		6	SS	13				
		7	SS	11	1	13	56	30
		8	SS	25				
		9	SS	30	1	7	67	25
		10	SS	24				
		11	SS	27				
		12	SS	24				
77.6 12.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.							



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+3, ×3: Numbers refer to Sensitivity

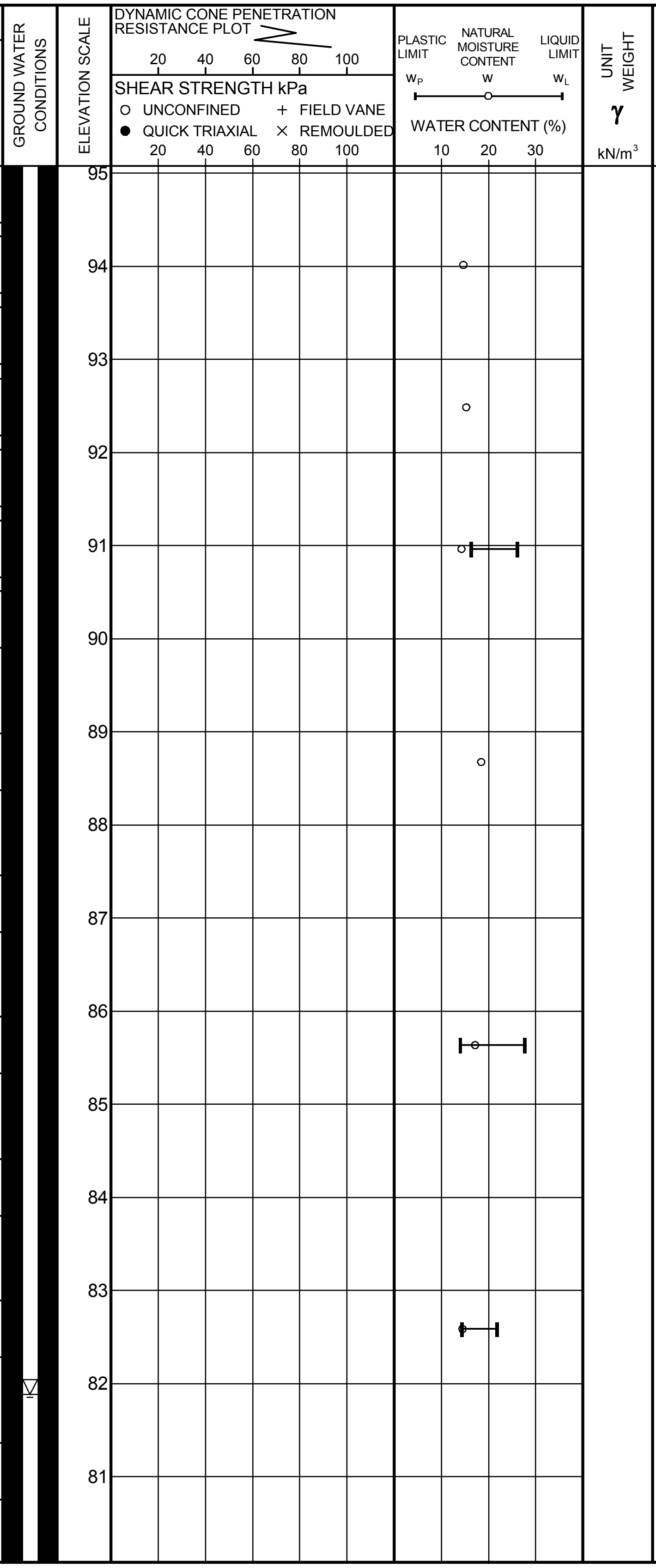
○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 207

1 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781962.5 ;E 323012.9
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE November 11, 12, 2004
ORIGINATED BY PKS
COMPILED BY BLT
CHECKED BY ASP

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
95.1	GROUND SURFACE							
0.0	Sand and gravel (FILL) Compact Brown Moist	1	SS	18				
94.3 0.8	Clayey silt, some sand, trace gravel, trace organics (FILL) Stiff to very stiff Brown Moist	2	SS	13				
		3	SS	16				
92.5 2.6	Silty SAND, trace clay, containing organics Compact Blackish brown Moist	4	SS	17	2	18	58	22
92.0 3.1	CLAYEY SILT, some sand, trace to some gravel, containing sand/silt seams (TILL) Stiff to hard Greyish brown to grey Moist to wet	5	SS	27				
		6	SS	35	11	33	41	15
		7	SS	31				
		8	SS	20				
		9	SS	22				
		10	SS	18				
		11	SS	27				
		12	SS	23				
		13	SS	31				



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+3, ×3: Numbers refer to Sensitivity   O3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 207

2 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781962.5 ;E 323012.9
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE November 11, 12, 2004
ORIGINATED BY PKS
COMPILED BY BLT
CHECKED BY ASP

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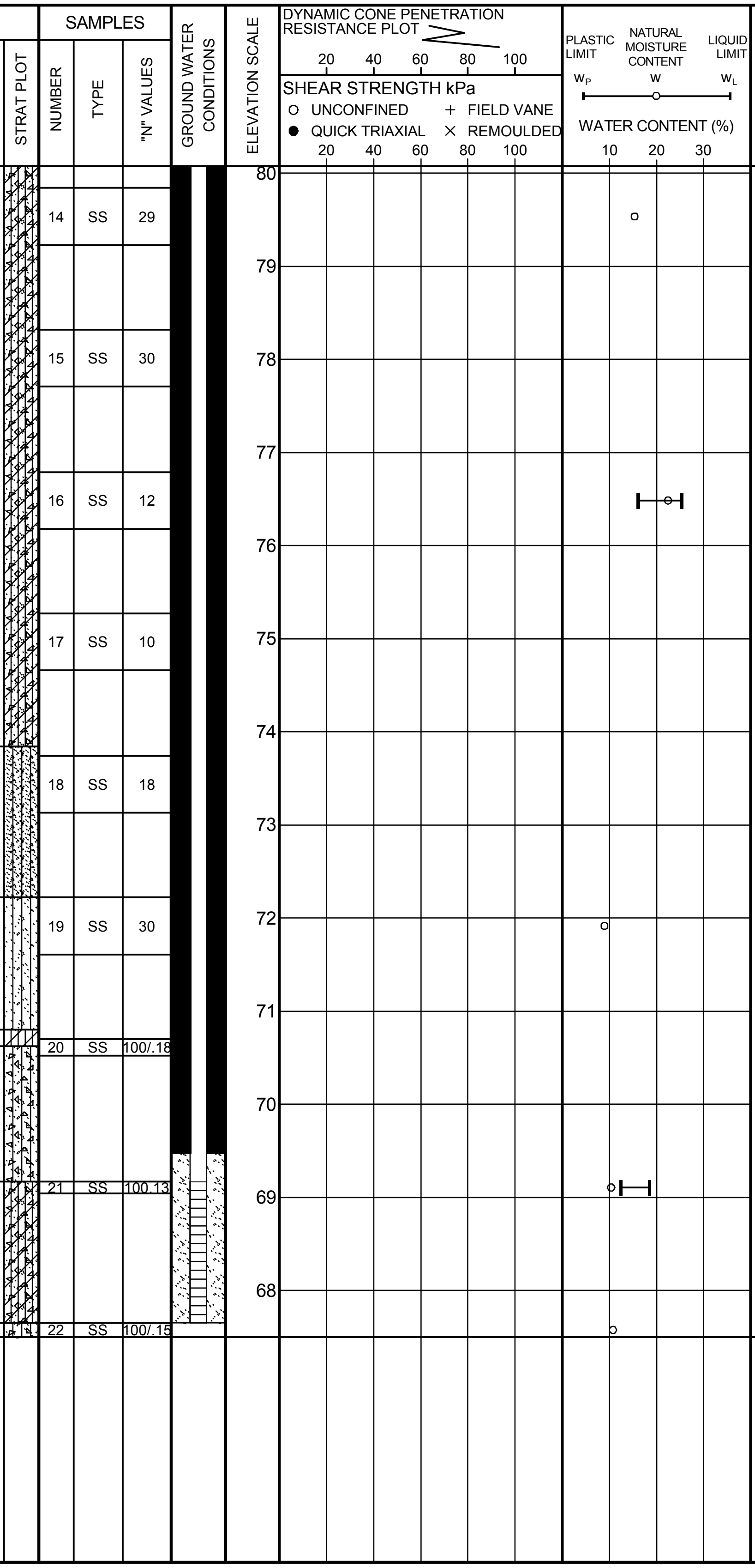
ELEV DEPTH	SOIL PROFILE DESCRIPTION
	CLAYEY SILT, some sand, trace to some gravel, containing sand/silt seams (TILL) Stiff to hard Greyish brown to grey Moist to wet
73.8 21.2	Sandy SILT Compact Grey Wet
72.2 22.9	Silty SAND, some gravel Compact to dense Grey/red Wet
70.8 24.5	CLAYEY SILT, some sand, trace gravel Hard Grey
	Silty SAND, trace gravel (TILL/RESIDUAL SOIL) Very dense Red Wet
69.2 25.9	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL/RESIDUAL SOIL) Hard Red Moist
67.7 27.6	Silty SAND, trace gravel, containing shale pieces (TILL/RESIDUAL SOIL) Very dense Red Wet
	END OF BOREHOLE

SAMPLES NUMBER	TYPE	"N" VALUES
14	SS	29
15	SS	30
16	SS	12
17	SS	10
18	SS	18
19	SS	30
20	SS	100/.18
21	SS	100.13
22	SS	100/.15



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 207

3 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781962.5 ;E 323012.9

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY BLT

DATUM Geodetic

DATE November 11, 12, 2004

CHECKED BY ASP

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 × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Notes: 1. Water level at 25.9 m depth (Elev. 69.2 m) on completion of drilling. 2. Water level measured at 13.85 m depth (Elevation 81.3 m) on Nov. 26, 2004, at 13.2 m depth (Elev. 81.9 m) on May 13, 2005, and at 13.4 m depth (Elev. 87.1 m) on December 6, 2005.										

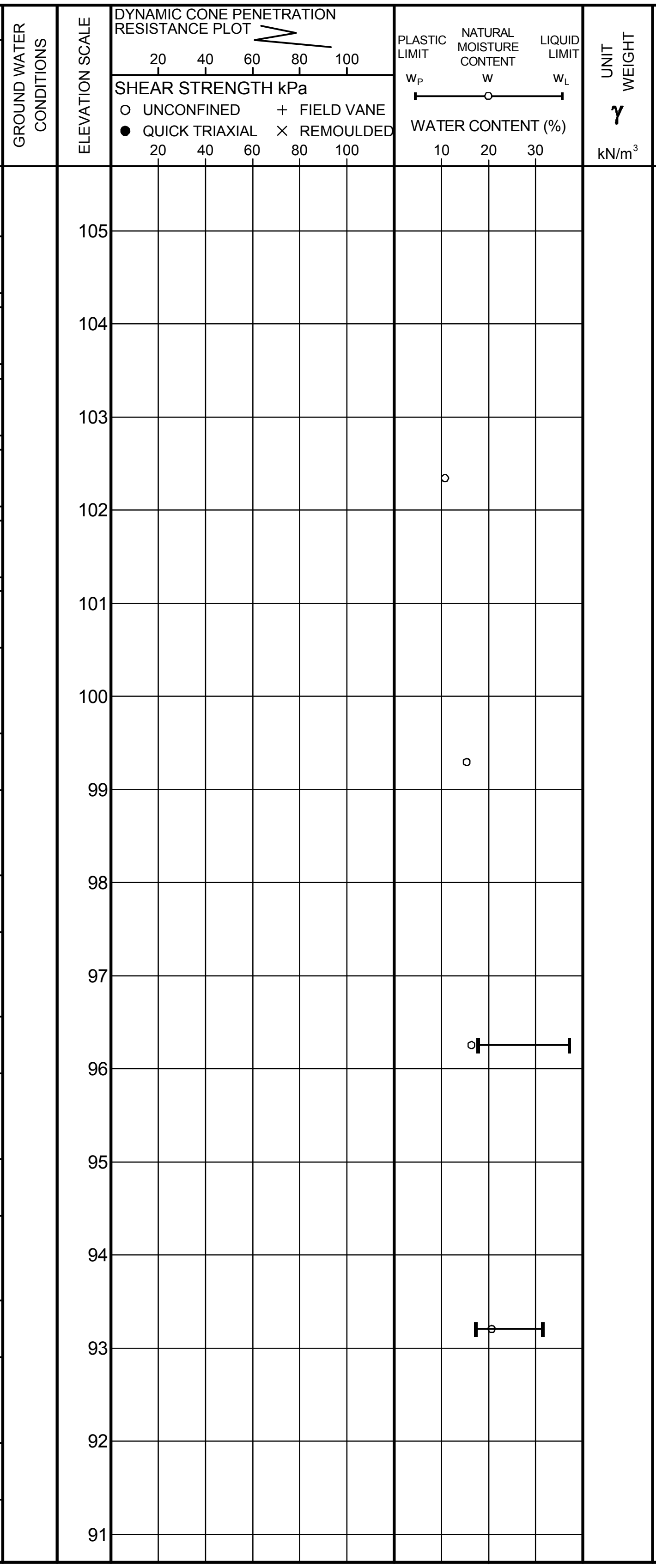
$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 401

1 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781742.3 ;E 325860.8	ORIGINATED BY PKS	
DIST Central	HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY HJ
DATUM Geodetic	DATE June 29, 2005	CHECKED BY LCC	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
105.7	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Compact to dense Red Moist	1	SS	40				
		2	SS	26				
103.4 2.3	Foundry sand (FILL) Dense to very dense Black Moist	3	SS	61				
		4	SS	40				
		5	SS	47				
		6	SS	71				
		7	SS	87	33	55	10	2
98.1 7.6	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown Moist Grey below 10.7 m depth	8	SS	40				
		9	SS	30				
95.0 10.7	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL) Stiff to very stiff Grey Moist	10	SS	21				
		11	SS	12	2	11	49	38
		12	SS	15				



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

RECORD OF BOREHOLE No 401

2 OF 3 **METRIC**

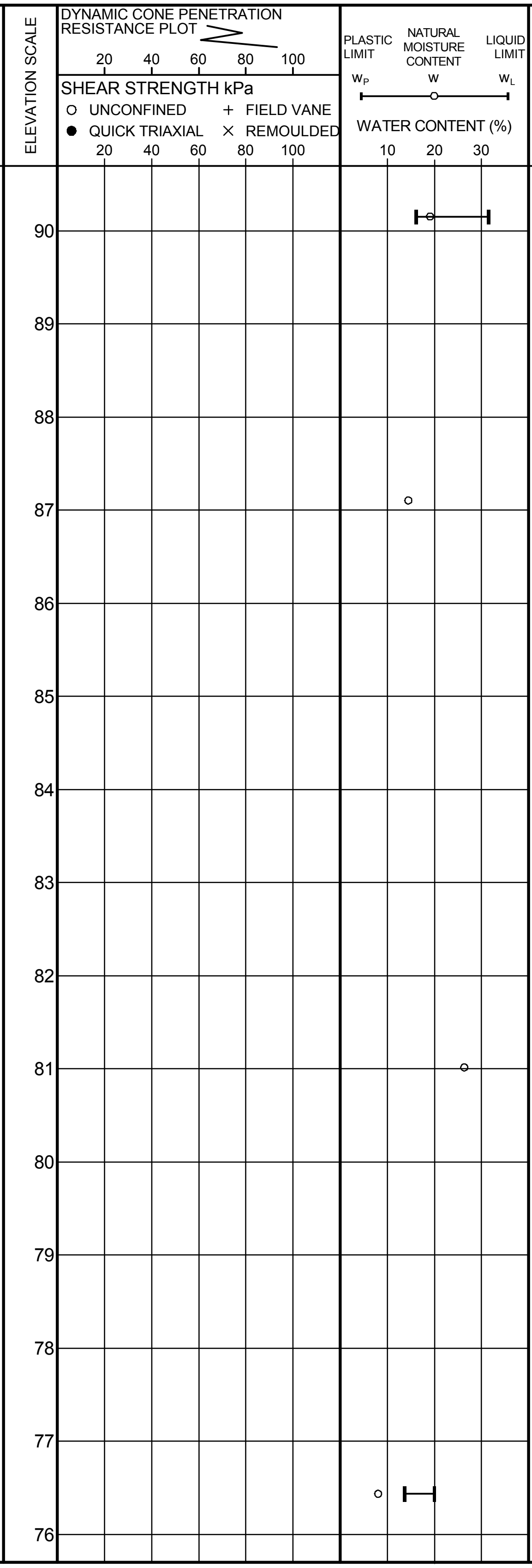
PROJECT	04-1111-002		
W.P.	607-00-00	LOCATION	N 4781742.3 ;E 325860.8
DIST	Central HWY QEW	BOREHOLE TYPE	108 mm Diameter Solid Stem Augers
DATUM	Geodetic	DATE	June 29, 2005

ORIGINATED BY PKS

COMPILED BY HJ

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
	--- CONTINUED FROM PREVIOUS PAGE ---					
	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL) Stiff to very stiff Grey Moist		13	SS	14	
			14	SS	14	
			15	SS	17	
			16	SS	20	
			17	SS	17	
	Becoming red below 25.0 m depth					
	Containing shale pieces below 27.4 m depth		18	SS	25	
77.4 28.3	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL/RESIDUAL SOIL) Hard Red Moist		19	SS	81	



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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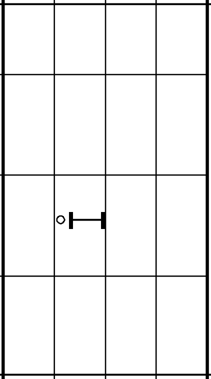
$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 401

3 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781742.3 ;E 325860.8
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY HJ
DATUM Geodetic
DATE June 29, 2005
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---													
	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL/RESIDUAL SOIL) Hard Red Moist		20	SS	153		75							
							74							
			21	SS	100/0.13						11	21	55	13
							73							
72.0 33.7	END OF BOREHOLE Note: 1.) Borehole dry upon completion of drilling operations.		22	SS	100/.15									

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

RECORD OF BOREHOLE No 402

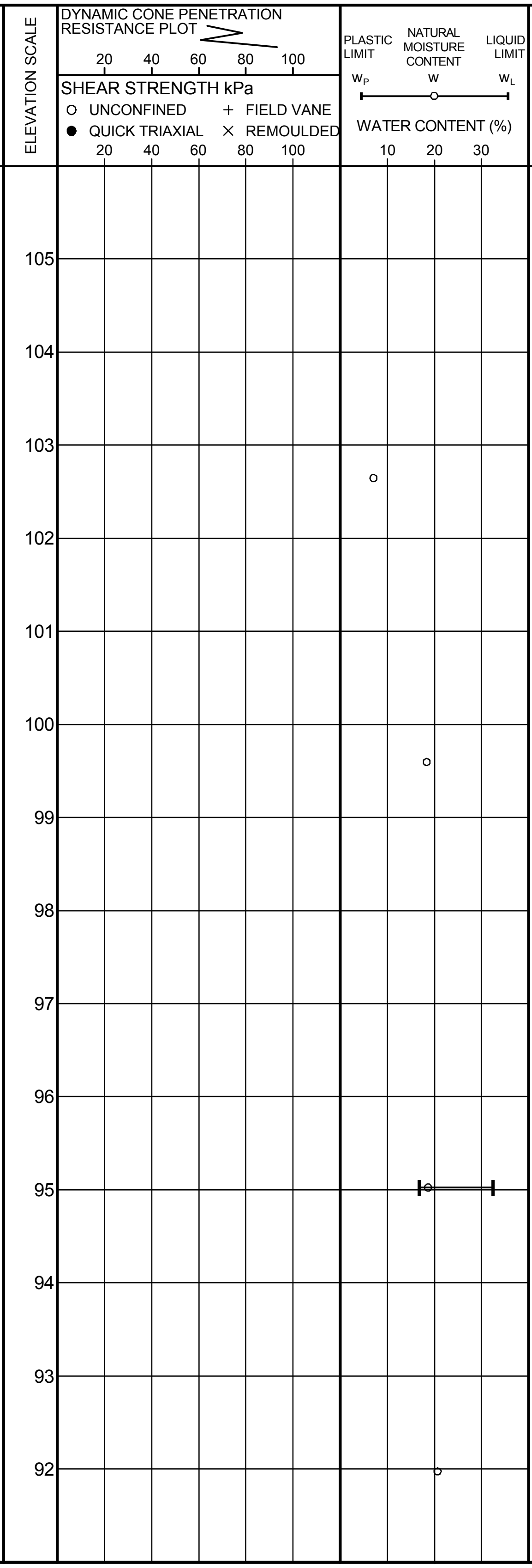
1 OF 3 **METRIC**

PROJECT	04-1111-002		
W.P.	607-00-00	LOCATION	N 4781732.1 ;E 325899.5
DIST	Central HWY QEW	BOREHOLE TYPE	108 mm Diameter Solid Stem Augers
DATUM	Geodetic	DATE	June 27, 2005

ORIGINATED BY PKS
COMPILED BY HJ
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
106.0	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Compact to very dense Red Moist	1	SS	53				
		2	SS	24				
		3	SS	13				
103.0 3.1	Silty sand to sand, some silt, trace to some gravel (FILL) Loose to compact Red Moist	4	SS	7	24	59	12	5
		5	SS	12				
		6	SS	4				
99.6 6.4	Sand and gravel (FILL) Compact to very dense Grey/brown Moist	7	SS	30				
	Wet below 7.6 m depth	8	SS	50				
96.9 9.1	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL) Stiff to very stiff Grey Moist/wet	9	SS	16				
		10	SS	15				
		11	SS	15				
		12	SS	13				

STRAT PLOT | GROUND WATER CONDITIONS | ELEVATION SCALE | UNIT WEIGHT γ kN/m³



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

RECORD OF BOREHOLE No 402

2 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781732.1 ;E 325899.5

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

DATE June 27, 2005

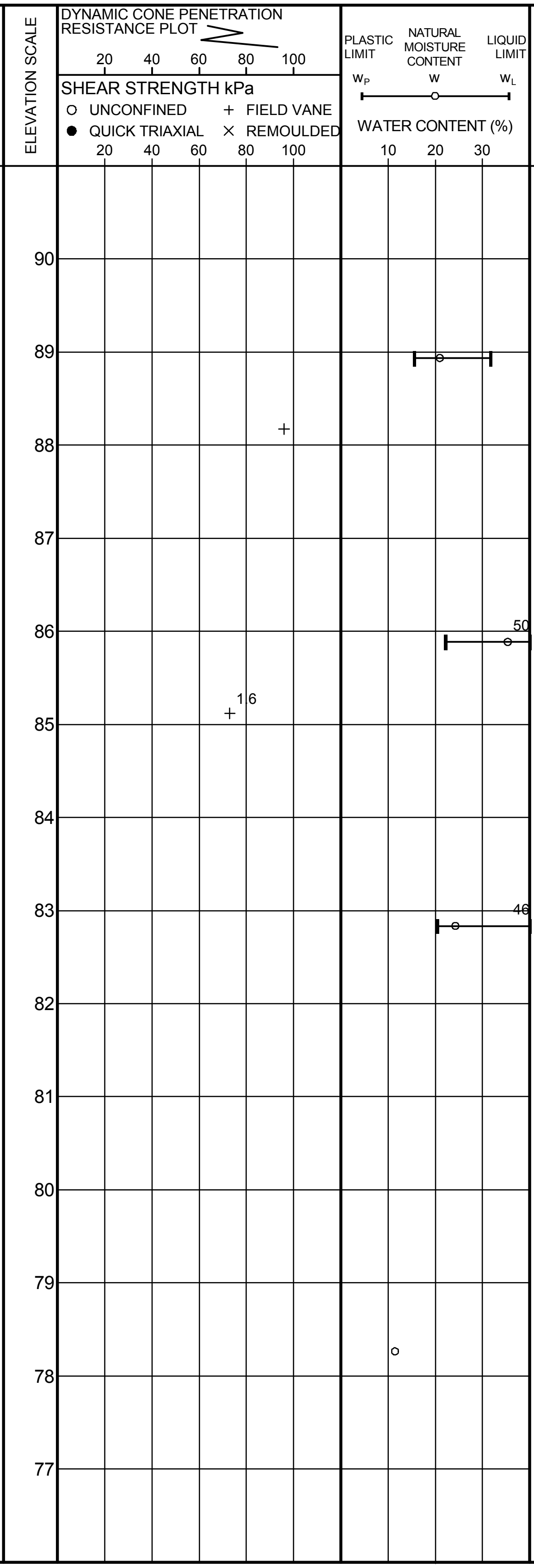
ORIGINATED BY PKS

COMPILED BY HJ

CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	CLAYEY SILT, some sand, trace gravel and shale pieces (TILL) Stiff to very stiff Grey Moist/wet	13	SS	11				
		14	SS	10				
88.2 17.8	SILTY CLAY, some sand, trace gravel and shale fragments (TILL) Firm to Stiff Grey Wet	15	SS	8				
		16	SS	8	0	4	37	59
		17	SS	9				
		18	SS	10				
	Containing sand seams below 24.4 m depth	19	SS	11				
79.8 26.2	CLAYEY SILT, some sand, trace gravel, shale and limestone pieces (TILL) Hard Grey to red Wet	20	SS	43				
77.7 28.3	CLAYEY SILT, some sand, trace gravel, shale and limestone pieces (TILL/RESIDUAL SOIL) Hard Red Wet	21	SS	93				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

O ³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 402

3 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781732.1 ;E 325899.5

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY HJ

DATUM Geodetic

DATE June 27, 2005

CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
	CLAYEY SILT, some sand, trace gravel, shale and limestone pieces (TILL/RESIDUAL SOIL) Hard Red Wet	22	SS	103		75
		23	SS	110/.30	∇	74
						73
72.2 / 33.8		24	SS	116		
	END OF BOREHOLE					

Note:

1. Water level measured in open borehole at 32.6 m depth (Elev. 73.4 m) upon completion of drilling operations.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

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

RECORD OF BOREHOLE No 403

1 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781714.1 ;E 325863.9	ORIGINATED BY PKS
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY HJ
DATUM Geodetic	DATE June 19, 2005	CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
105.8	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Loose to dense Reddish brown to red Moist
102.0 3.8	Foundry sand (FILL) Compact to very dense Black Moist
99.3 6.6	Sandy SILT Very dense Brown Moist
98.2 7.6	CLAYEY SILT to SILTY CLAY, trace sand, trace gravel (TILL) Stiff to very stiff Grey-brown Moist Becoming grey below 10.7 m depth
90.8	

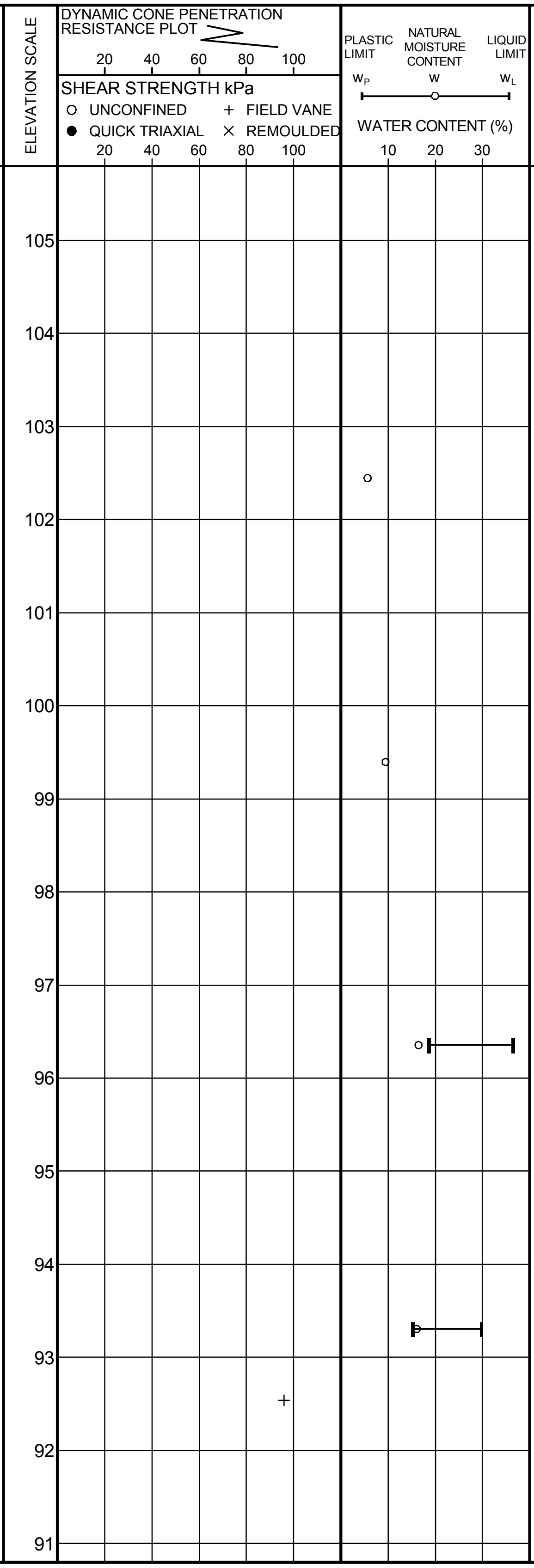
Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	38				
2	SS	25				
3	SS	8				
4	SS	8	42	45	9	4
5	SS	10				
6	SS	25				
7	SS	82				
8	SS	24				
9	SS	28	0	10	48	42
10	SS	14				
11	SS	12				
12	SS	14				

GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m³



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

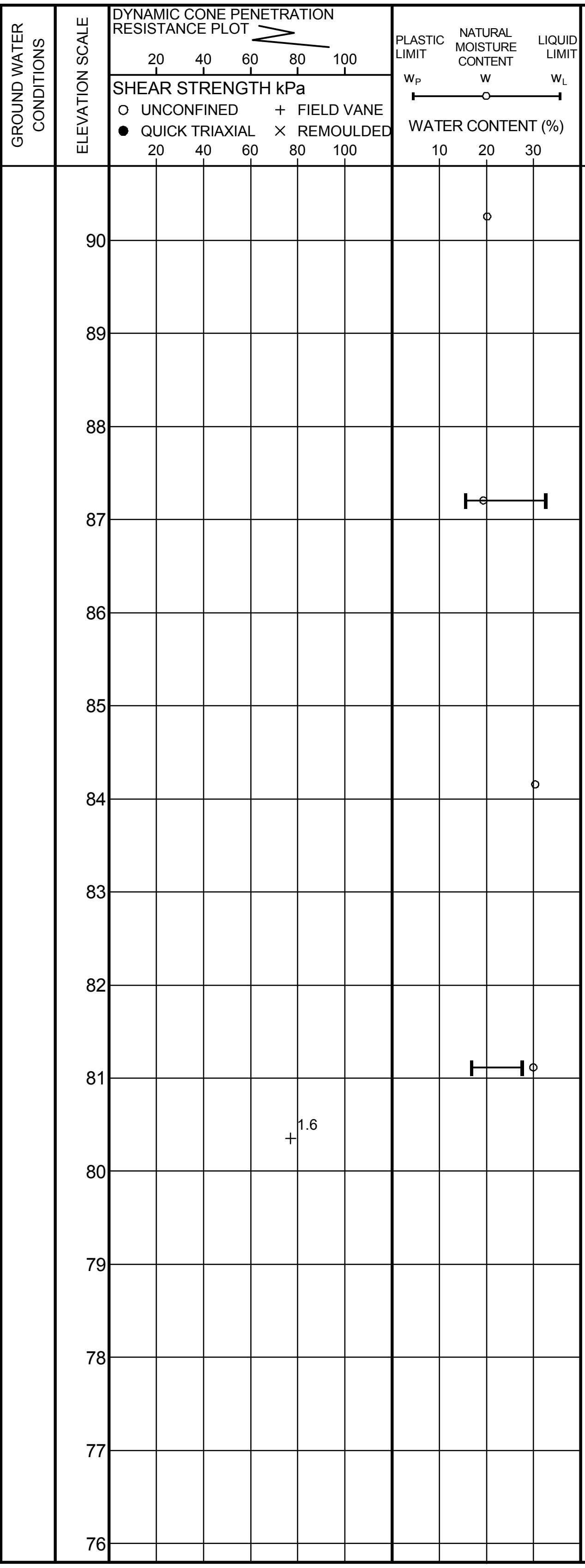
RECORD OF BOREHOLE No 403

2 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781714.1 ;E 325863.9
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY HJ
DATUM Geodetic
DATE June 19, 2005
CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
15.0	CLAYEY SILT to SILTY CLAY, trace sand, trace gravel (TILL) Stiff to very stiff Grey Moist	13	SS	15	
		14	SS	14	
		15	SS	16	
		16	SS	15	
		17	SS	14	
		18	SS	13	
82.2 23.6	CLAYEY SILT, trace sand, trace gravel (TILL) Firm to stiff Grey Moist	19	SS	8	0 7 61 32
79.6 26.2	CLAYEY SILT, trace sand, trace gravel (TILL) Hard Grey Moist	20	SS	45	



UNIT WEIGHT γ kN/m³

Continued Next Page

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

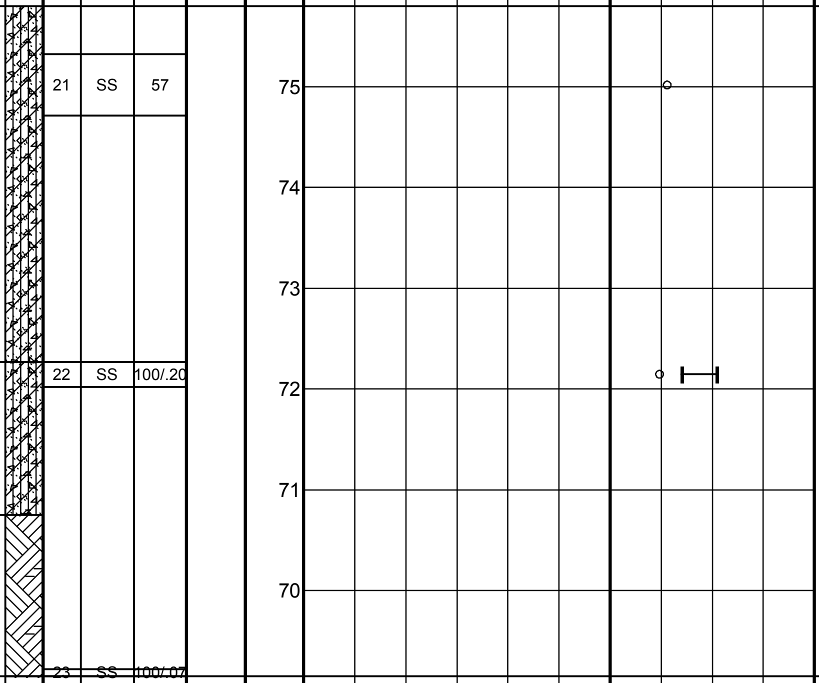
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 403

3 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781714.1 ;E 325863.9	ORIGINATED BY PKS	
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY HJ	
DATUM Geodetic	DATE June 19, 2005	CHECKED BY LCC	

SOIL PROFILE			SAMPLES							
ELEV DEPTH	DESCRIPTION — *CONTINUED FROM PREVIOUS PAGE* —	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT, trace sand, trace gravel (TILL) Hard Grey Moist Containing shale pieces and red in color below 30.5 m depth		21	SS	57		75 74 73			
72.3 33.5	CLAYEY SILT, some sand, containing shale pieces (TILL/RESIDUAL SOIL) Hard Red Moist		22	SS	100/.20		72 71			
70.8 35.1	Red SHALE (BEDROCK)		23	SS	100/.07		70			
69.2 36.7	END OF BOREHOLE Note: 1.) Borehole dry upon completion of drilling operations.									



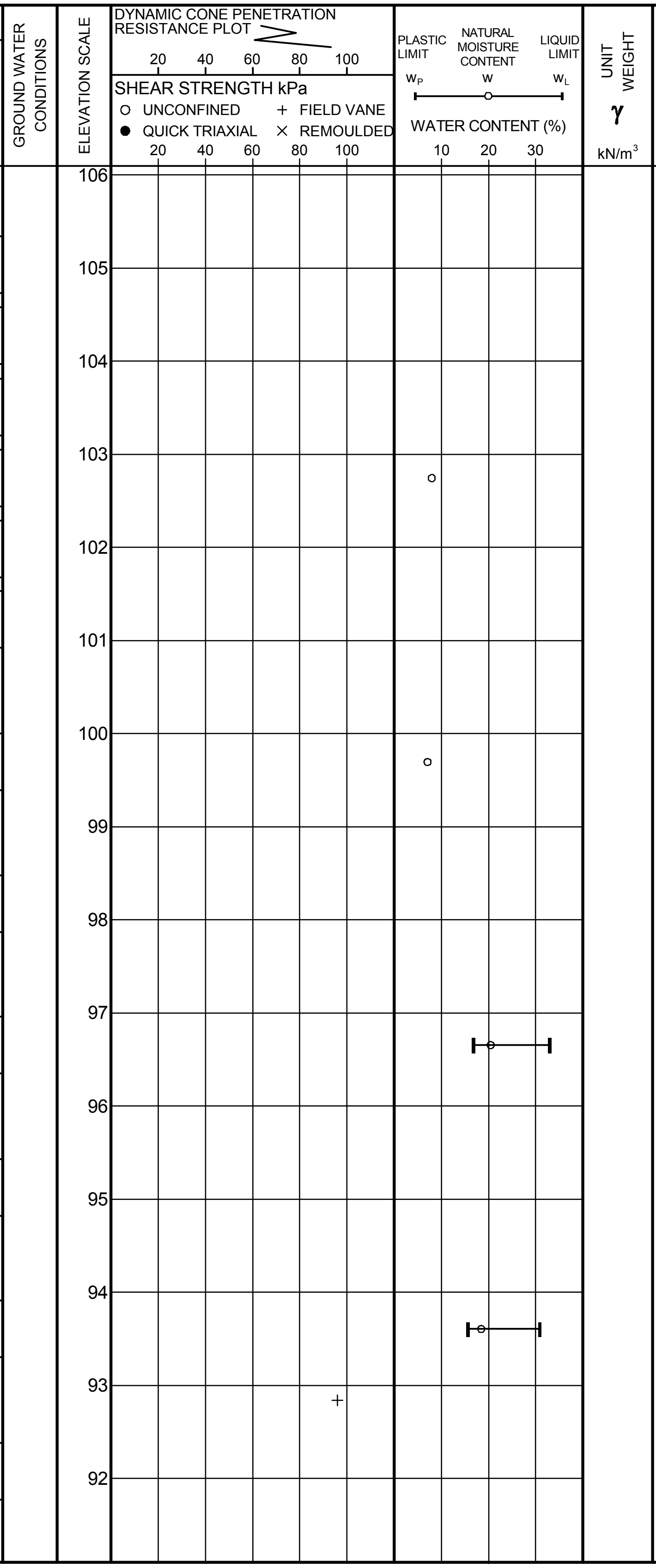
+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 404

1 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781705.4 ;E 325898.0
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE June 22, 2005
ORIGINATED BY PKS
COMPILED BY HJ
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
106.1	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Compact Red Moist							
		1	SS	24				
104.6 1.5	Silty sand to sand, some silt, trace gravel (FILL) Compact to dense Reddish brown Moist	2	SS	25				
		3	SS	27				
		4	SS	24	1	77	16	6
		5	SS	21				
		6	SS	22				
99.7 6.4	Foundry sand (FILL) Dense Black Moist	7	SS	40				
98.5 7.6	CLAYEY SILT, trace sand, trace gravel (TILL) Very stiff to hard Brown Moist	8	SS	41				
	Grey below 9.0 m depth	9	SS	28				
	Wet below 10.7 m depth	10	SS	18				
94.5 11.6	CLAYEY SILT, trace sand and gravel (TILL) Stiff to very stiff Grey Wet	11	SS	13				
		12	SS	13				



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 404

2 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781705.4 ;E 325898.0

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY HJ

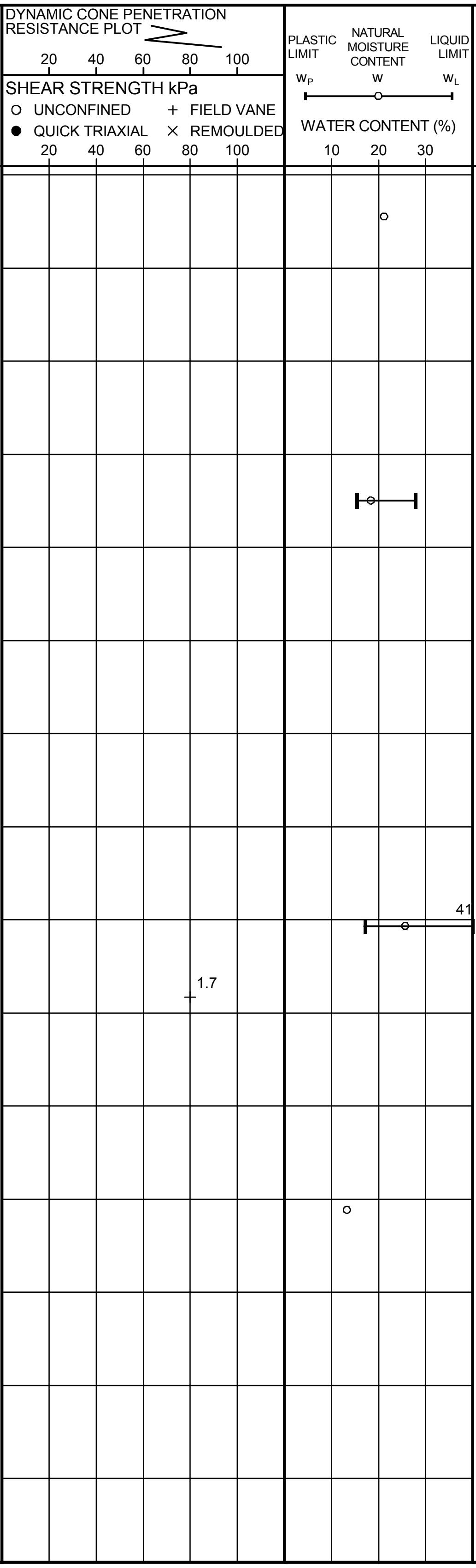
DATUM Geodetic

DATE June 22, 2005

CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT, trace sand and gravel (TILL) Stiff to very stiff Grey Wet	13	SS	14	91	
					90	
		14	SS	15	89	
					88	
		15	SS	14	87	
		16	SS	14	86	
					85	
84.2		17	SS	12		
22.0	SILTY CLAY, trace sand, trace gravel (TILL) Stiff Grey Wet				84	
		18	SS	9	83	
81.7					82	
24.4	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Grey Moist	19	SS	17	81	
		20	SS	19	80	3 21 58 18
					79	
					78	
		21	SS	17	77	



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+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 404

3 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781705.4 ;E 325898.0

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY HJ

DATUM Geodetic

DATE June 22, 2005

CHECKED BY LCC

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 × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---					76							
75.6 30.5	SAND and SILT, trace to some gravel and shale fragments, trace clay (TILL/RESIDUAL SOIL) Very dense Grey to red Moist to wet					75							
		22	SS	100/.10		74				5	36	53	6
						73							
72.5 33.6	CLAYEY SILT, some sand trace gravel and shale pieces (TILL/RESIDUAL SOIL) Hard Red Wet					72							
		23	SS	100/.13		71							
70.9 35.2	END OF BOREHOLE Note: 1.) Open borehole wet below 10.7m depth upon completion of drilling operations.												

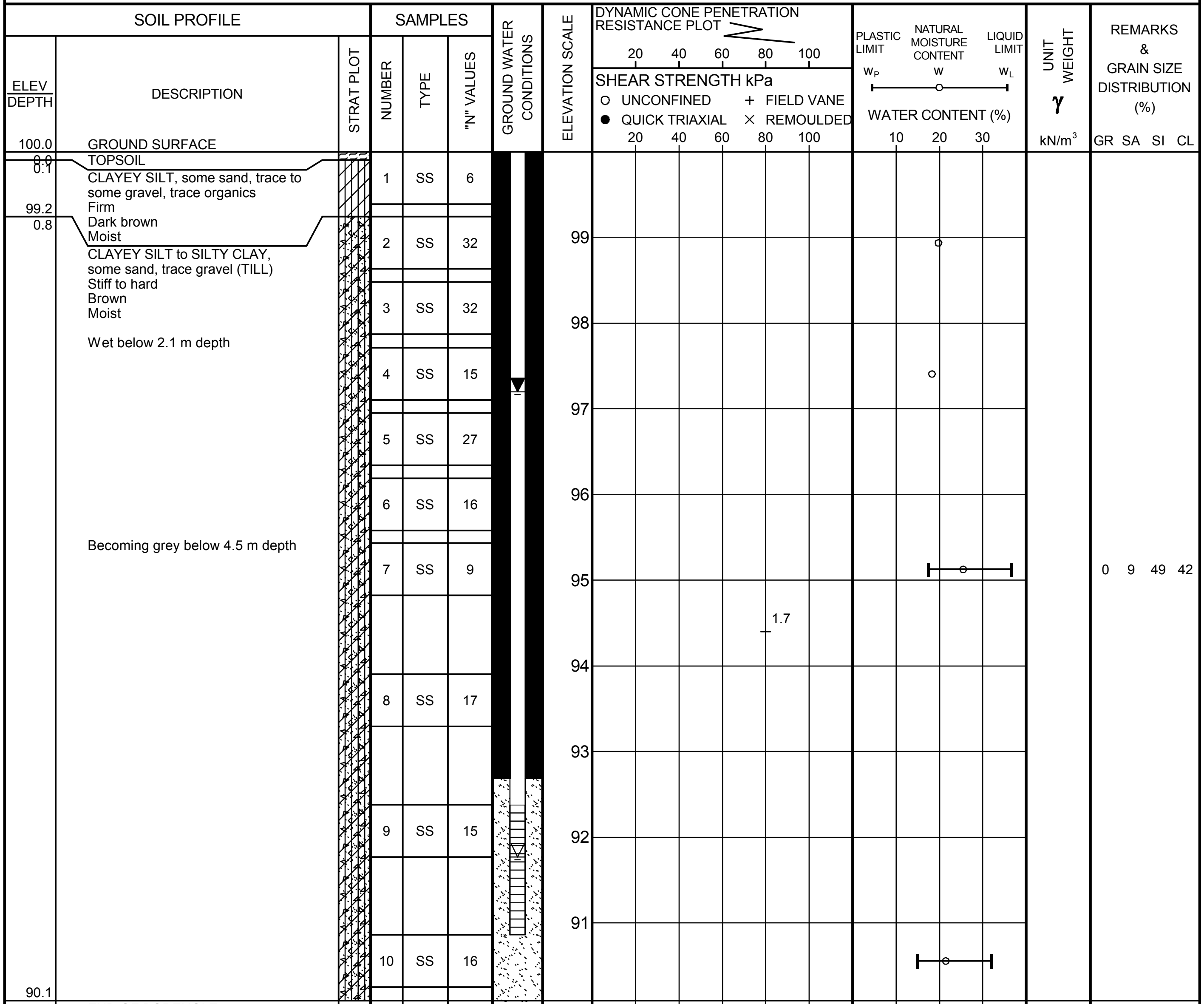
$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 405

1 OF 1 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781733.9 ;E 325941.6	ORIGINATED BY PKS
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY HJ
DATUM Geodetic	DATE July 28, 2005	CHECKED BY LCC



SOIL PROFILE

ELEV DEPTH	DESCRIPTION
100.0	GROUND SURFACE
0.0	TOPSOIL
0.1	CLAYEY SILT, some sand, trace to some gravel, trace organics Firm Dark brown Moist
99.2 0.8	CLAYEY SILT to SILTY CLAY, some sand, trace gravel (TILL) Stiff to hard Brown Moist Wet below 2.1 m depth Becoming grey below 4.5 m depth
90.1 9.9	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	6	
2	SS	32	
3	SS	32	
4	SS	15	
5	SS	27	
6	SS	16	
7	SS	9	0 9 49 42
8	SS	17	
9	SS	15	
10	SS	16	

Note:

1. Water level measured in open borehole at 8.2 m depth upon completion of drilling operations.

2. Water level measured in piezometer at 2.8 m depth (Elevation 97.2 m) on August 8, 2005.

3. Water level measured in piezometer at 0.6 m depth (Elelevation 99.4 m) on December 6, 2005.

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

RECORD OF BOREHOLE No 406

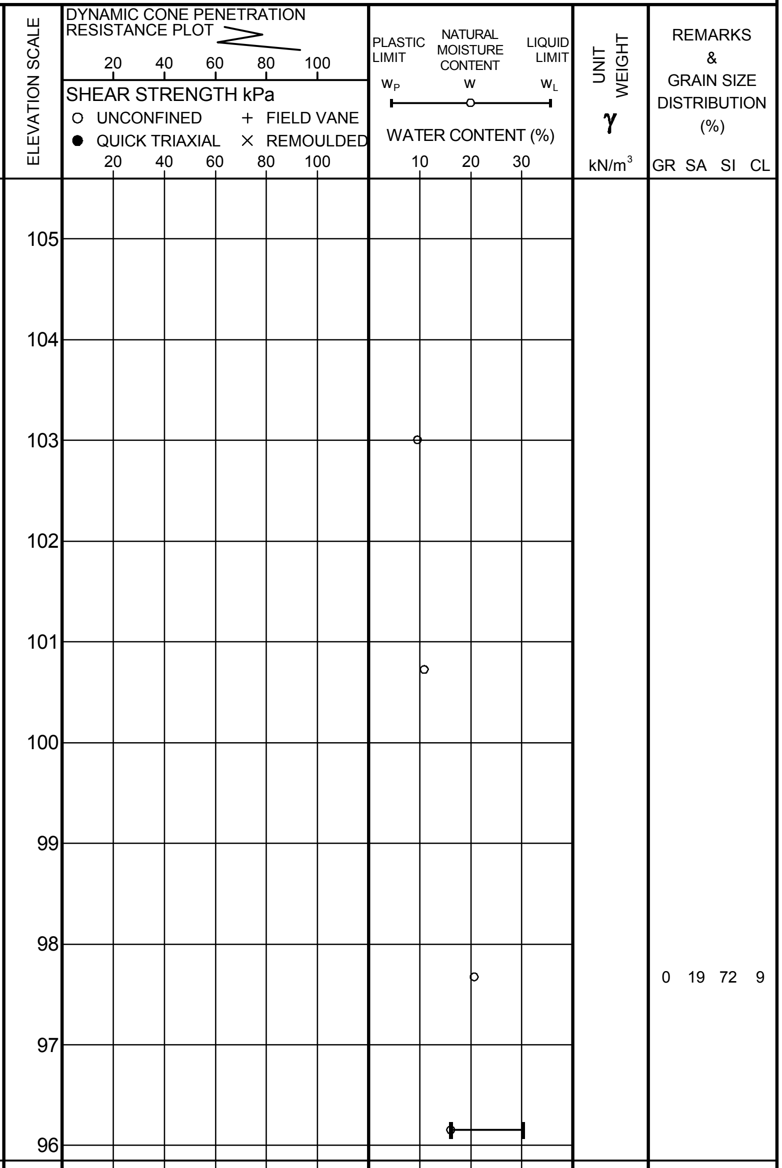
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781719.6 ;E 325844.8
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY HJ
DATUM Geodetic
DATE June 17, 2005
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
105.6	GROUND SURFACE							
0.0	ASPHALT							
0.2	Sand and gravel (FILL) Very dense Red Moist							
104.5 1.1	Foundry sand (FILL) Very dense Black Moist	1	SS	107				
		2	SS	77				
		3	SS	60				
		4	SS	53				
		5	SS	78				
		6	SS	74				
99.2 6.4	Sand and gravel (FILL) Very dense Grey Moist	7	SS	55				
98.0 7.6	Sandy SILT Compact Brown Wet	8	SS	16	0	19	72	9
96.2	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Wet	9	SS	26				
95.9 9.8	END OF BOREHOLE							

Note:

1. Bottom of borehole wet upon completion of drilling operations.



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

RECORD OF BOREHOLE No 406

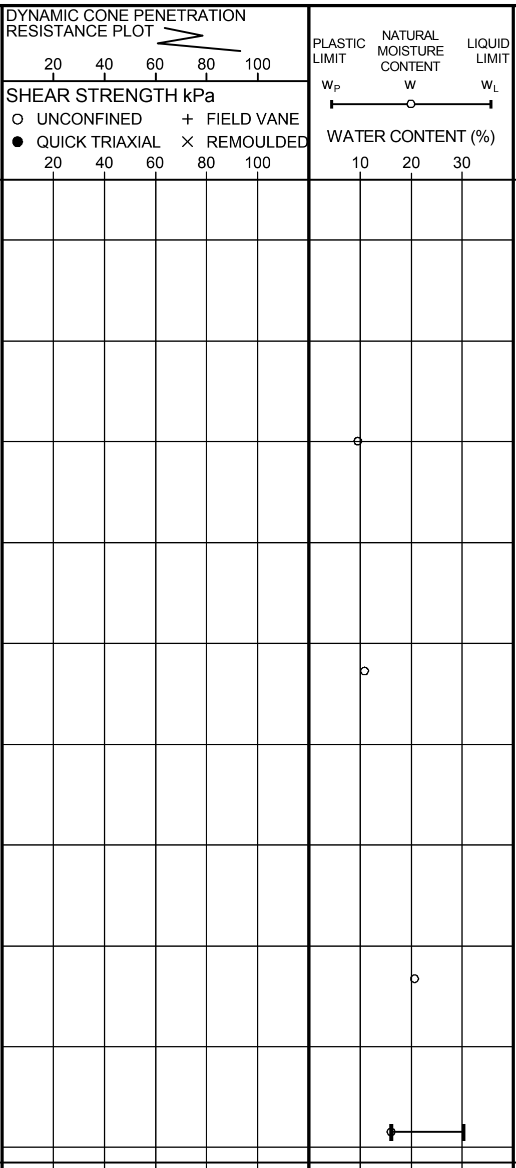
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781719.6 ;E 325844.8
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY HJ
DATUM Geodetic
DATE June 17, 2005
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
105.6	GROUND SURFACE											
0.0	ASPHALT											
0.2	Sand and gravel (FILL) Very dense Red Moist						105					
104.5 1.1	Foundry sand (FILL) Very dense Black Moist		1	SS	107							
			2	SS	77		104					
			3	SS	60		103					
			4	SS	53		102					
			5	SS	78							
			6	SS	74		101					
							100					
99.2 6.4	Sand and gravel (FILL) Very dense Grey Moist		7	SS	55		99					
98.0 7.6	Sandy SILT Compact Brown Wet		8	SS	16		98		0	19	72	9
							97					
96.2	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Wet		9	SS	26		96					
95.9 9.8	END OF BOREHOLE											

Note:

1. Bottom of borehole wet upon completion of drilling operations.



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

RECORD OF BOREHOLE No 501

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781339.1 ;E 327298.4
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SLP
DATUM Geodetic
DATE December 13, 2004
CHECKED BY LCC

SOIL PROFILE

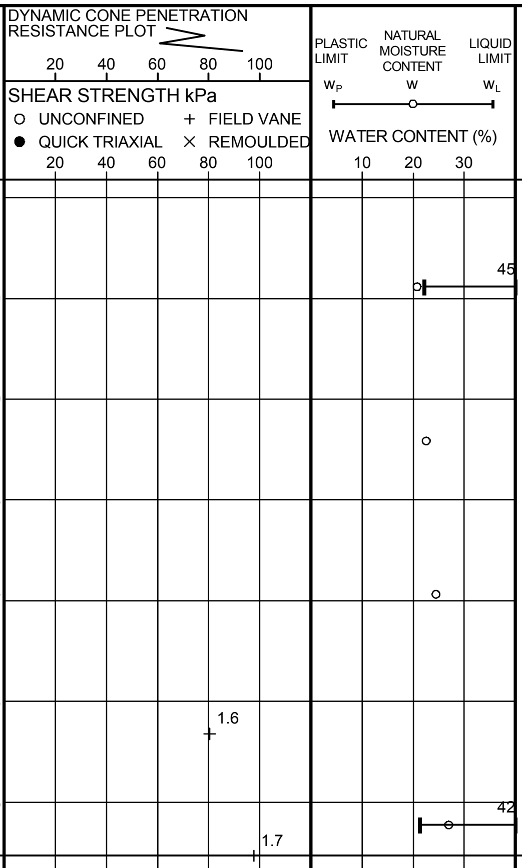
ELEV DEPTH	DESCRIPTION
101.2	GROUND SURFACE
0.0	TOPSOIL
0.1	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist
96.8 4.4	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Moist to wet
94.5 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	9
2	SS	17
3	SS	22
4	SS	21
5	SS	23
6	SS	13
7	SS	7
8	SS	8

GROUND WATER CONDITIONS

ELEVATION SCALE: 101, 100, 99, 98, 97, 96, 95



UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

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

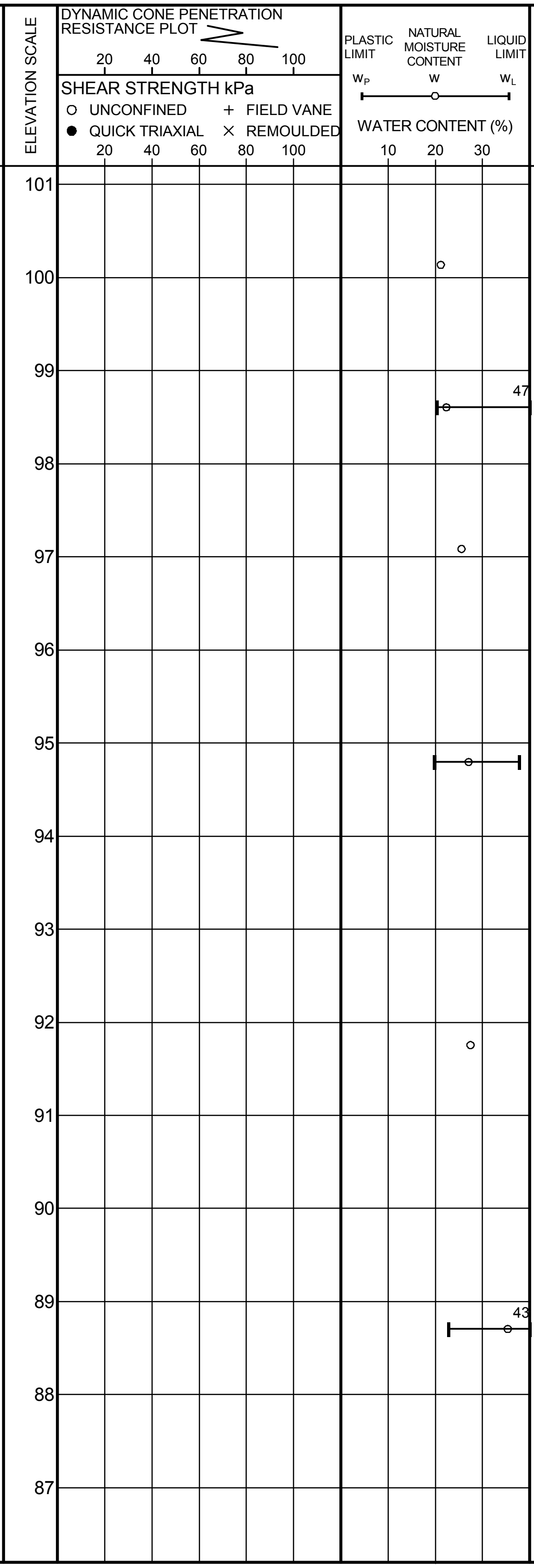
Golder Associates

RECORD OF BOREHOLE No 502

1 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781342.0 ;E 327287.0
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE December 13, 2004
ORIGINATED BY PKS
COMPILED BY SLP
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.2	GROUND SURFACE						
0.0	TOPSOIL						
0.1	Sand and gravel, trace rootlets (FILL) Loose Red Moist	1	SS	7			
100.4 0.8	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist to wet	2	SS	9			
		3	SS	22			
		4	SS	23			
		5	SS	17			
		6	SS	14			
		7	SS	13			
95.5 5.7	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff Grey to reddish grey Wet	8	SS	11			
		9	SS	9			
		10	SS	8			
		11	SS	8			
89.5 11.7	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey to reddish grey Wet	12	SS	5			
		13	SS	7			



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

$\circ^{3\%}$ STRAIN AT FAILURE

MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 23/1/07

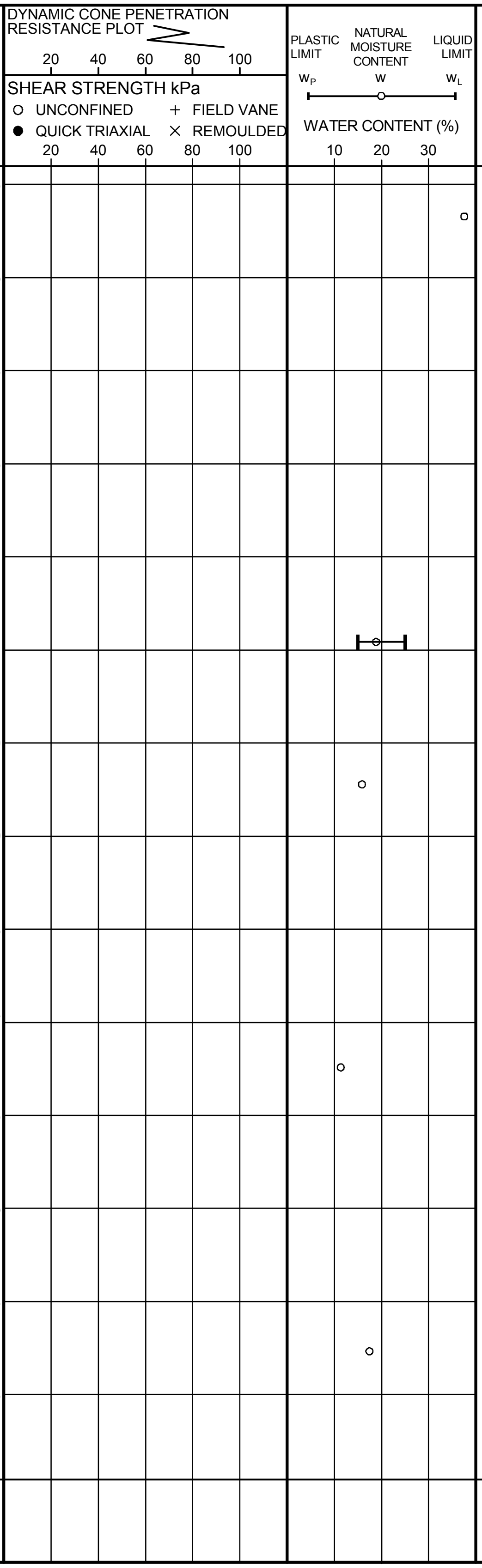
RECORD OF BOREHOLE No 502

2 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781342.0 ;E 327287.0	ORIGINATED BY PKS	
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY SLP	
DATUM Geodetic	DATE December 13, 2004	CHECKED BY LCC	

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey to reddish grey Wet					86	
		14	SS	10			
						85	
		15	SS	8		84	8 8 48 36
						83	
		16	SS	7			
82.0 19.2	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey/red Moist to wet					82	
		17	SS	12		81	
						80	
		18	SS	15			
						79	
		19	SS	24		78	
					∇	77	
76.8 24.4	SILTY SAND, trace gravel, trace shale fragments Dense to very dense Grey/red Wet	20	SS	38			
						76	
		21	SS	109		75	
						74	
		22	SS	107			
						73	
72.1		23	SS	100/.13			
29.1							



UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No 502

3 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781342.0 ;E 327287.0

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SLP

DATUM Geodetic

DATE December 13, 2004

CHECKED BY LCC

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 × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	END OF BOREHOLE Note: 1. Water level at 24.4 m depth upon (Elev. 76.8 m) completion of drilling operations.										

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

○$^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 503

1 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781350.0 ;E 327255.0

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SLP

DATUM Geodetic

DATE December 16, 2004

CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
101.4	GROUND SURFACE							
0.0 0.1	TOPSOIL							
	Clayey silt, some sand and gravel (FILL) Very stiff Brown/red Moist	1	SS	15				
100.6 0.8	Sand, some gravel (FILL) Loose Red Wet	2	SS	8				
100.0 1.4	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown to brown/grey Wet	3	SS	16				
		4	SS	24				
		5	SS	16				
		6	SS	15				
		7	SS	12				
96.0 5.4	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff Grey Wet	8	SS	7				
		9	SS	7				
		10	TO	PH				
		11	SS	7				
89.5 11.9	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet	12	SS	7				
		13	SS	9	5	1	38	56

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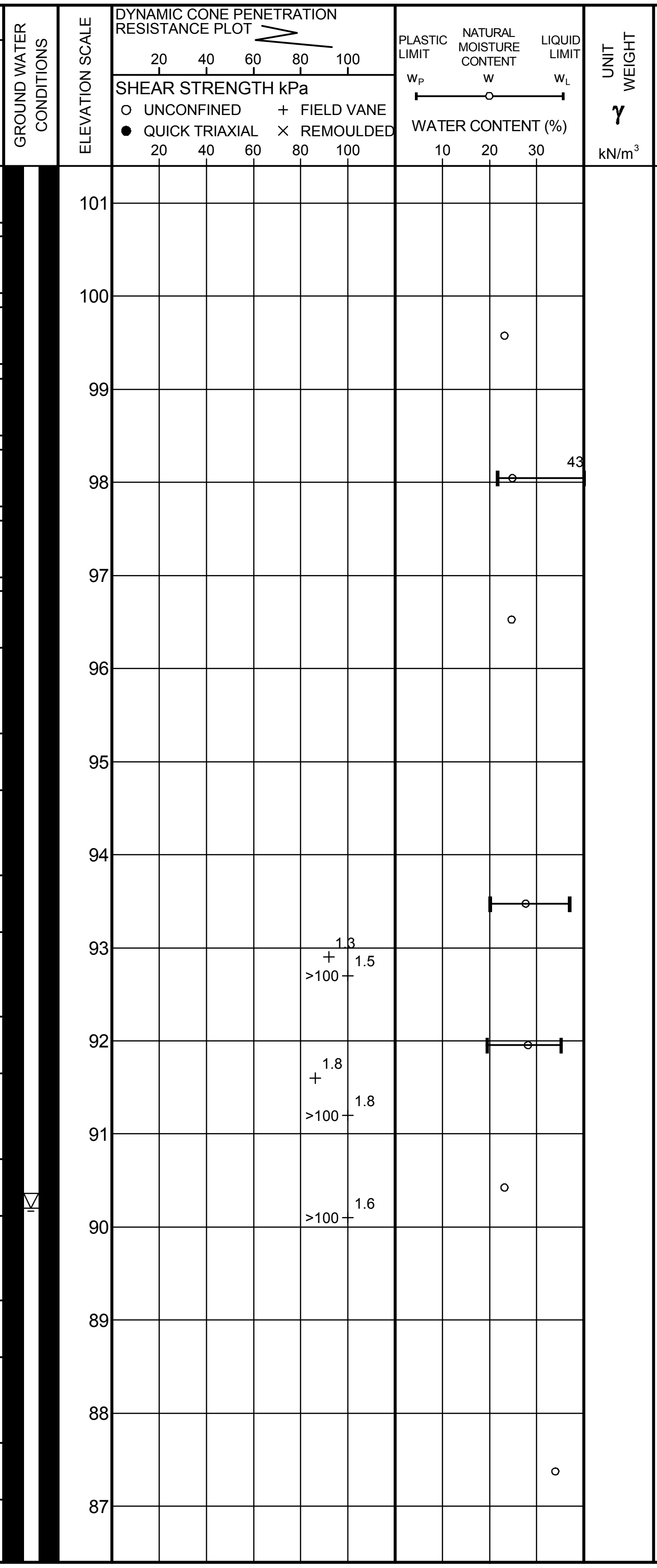


$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

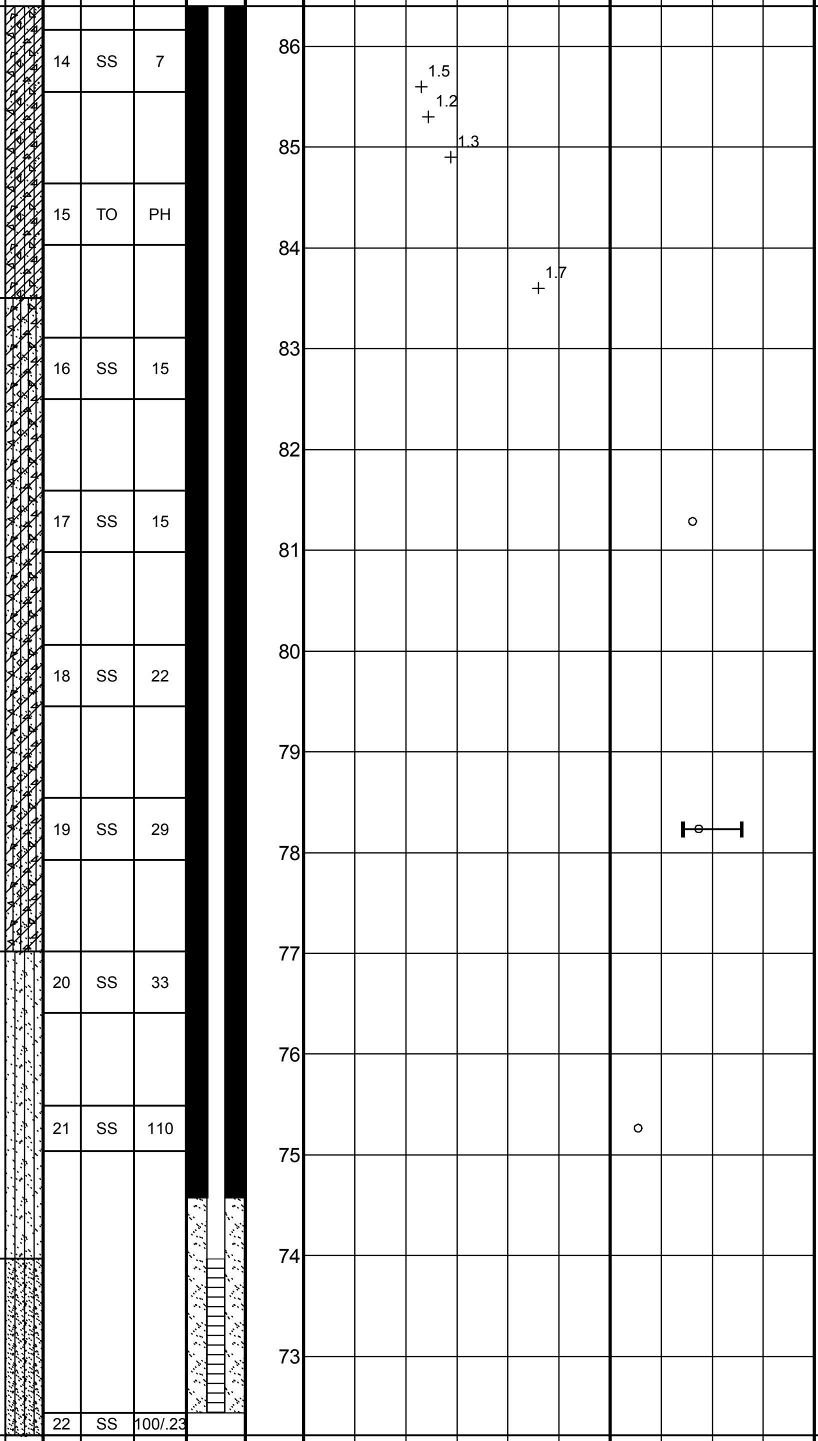
Golder Associates

RECORD OF BOREHOLE No 503

2 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781350.0 ;E 327255.0	ORIGINATED BY PKS	
DIST Central	HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY SLP
DATUM Geodetic	DATE December 16, 2004	CHECKED BY LCC	

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---							
	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet	14	SS	7				
		15	TO	PH				
83.5 17.9	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Wet	16	SS	15				
		17	SS	15				
		18	SS	22				
	Contains shale fragments below 22.0 m depth	19	SS	29				
77.0 24.4	GRAVELLY SAND to SAND, some gravel, some silt, trace clay, containing shale fragments Dense to very dense Grey Wet	20	SS	33				
		21	SS	110	24	54	17	5
74.0 27.4	SANDY SILT, containing clayey silt seams Very dense Grey Wet							
		22	SS	100/.23				
72.2 29.2								



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

RECORD OF BOREHOLE No 503

3 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781350.0 ;E 327255.0

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SLP

DATUM Geodetic

DATE December 16, 2004

CHECKED BY LCC

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	END OF BOREHOLE Note: 1. Water level at 24.4 m depth upon completion of drilling operations. 2. Water level in piezometer at 13.7 m depth (Elevation 87.7 m) on December 20, 2004. 3. Water level in piezometer at 11.6 m depth (Elevation 89.8 m) on May 13, 2005 and on December 6, 2005.										

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

RECORD OF BOREHOLE No 504

1 OF 3 **METRIC**

PROJECT	04-1111-002		
W.P.	607-00-00	LOCATION	N 4781321.0 ;E 327215.0
DIST	Central HWY QEW	BOREHOLE TYPE	108 mm Diameter Solid Stem Augers
DATUM	Geodetic	DATE	December 20, 2004
ORIGINATED BY	PKS		
COMPILED BY	SLP		
CHECKED BY	LCC		

SOIL PROFILE

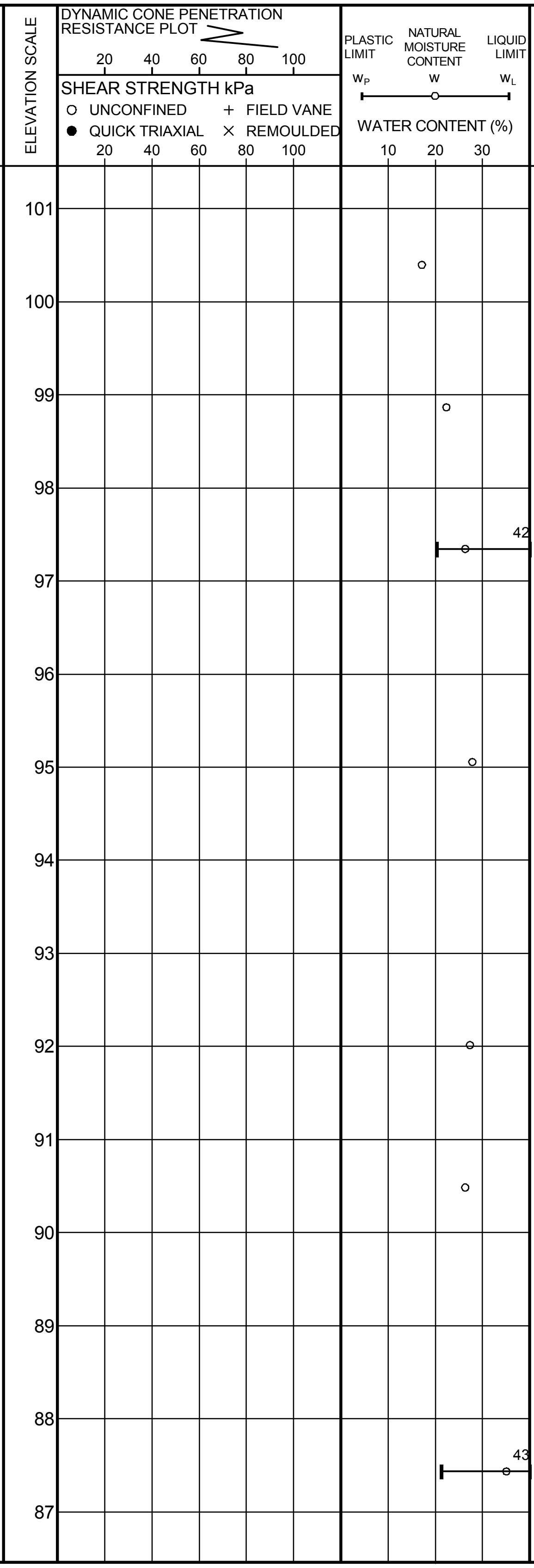
ELEV DEPTH	DESCRIPTION
101.5	GROUND SURFACE
0.0	Asphalt
0.2	Sand and gravel (FILL) Compact Brown/red Moist
100.3 1.2	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist
96.0 5.5	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff Grey Wet
89.5 12.0	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	28				
2	SS	13				
3	SS	17				
4	SS	19				
5	SS	16				
6	SS	14				
7	SS	13				
8	SS	8				
9	SS	7				
10	SS	9	0	7	46	47
11	SS	8				
12	SS	7				
13	SS	6				

STRAT PLOT | GROUND WATER CONDITIONS | UNIT WEIGHT γ kN/m³



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

RECORD OF BOREHOLE No 504

2 OF 3 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781321.0 ;E 327215.0

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

DATE December 20, 2004

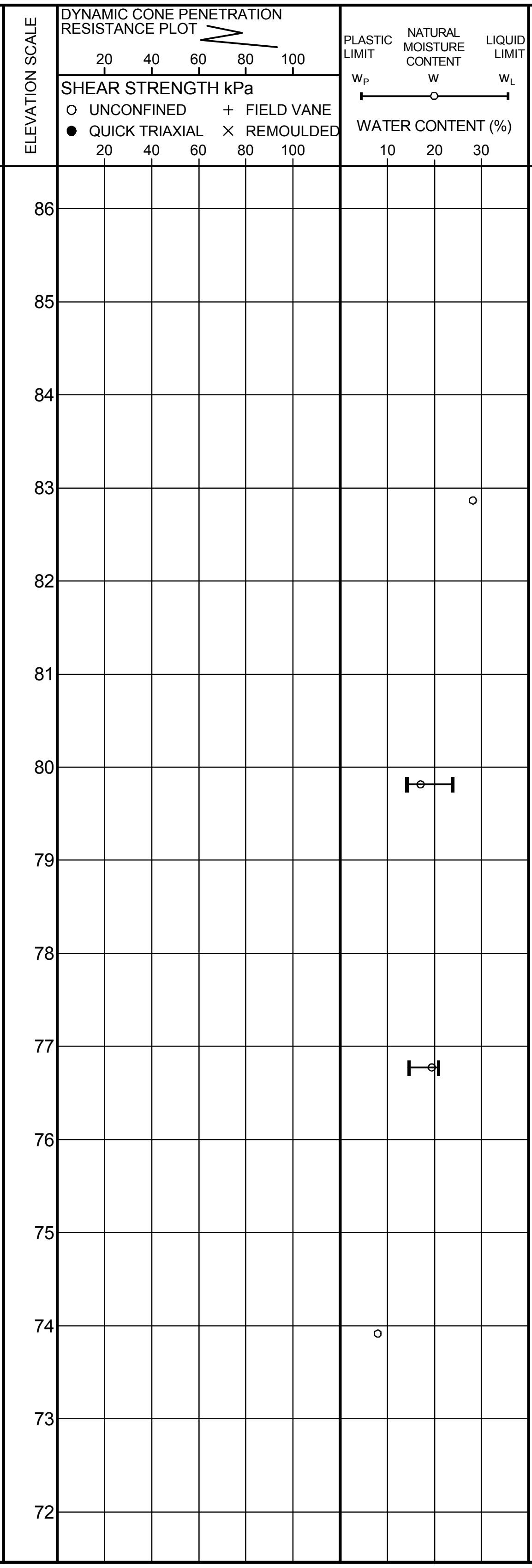
ORIGINATED BY PKS

COMPILED BY SLP

CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet	14	SS	7	
		15	SS	7	
		16	SS	8	
82.0 19.5	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey Wet	17	SS	12	
		18	SS	17	
		19	SS	16	
		20	SS	20	
75.3 26.2	SILTY SAND, trace gravel Very dense Grey/red Wet	21	SS	82	∇
		22	SS	100/.23	



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No 504

3 OF 3 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781321.0 ;E 327215.0
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE December 20, 2004
ORIGINATED BY PKS
COMPILED BY SLP
CHECKED BY LCC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---													
71.0 30.5	SILT, trace to some sand, trace clay, trace gravel Very dense Grey Wet		23	SS	106		71				3	7	82	8
70.6 30.9	END OF BOREHOLE Note: 1. Water level in open borehole at 25.9 m depth (Elev. 75.6 m) upon completion of drilling operations.													

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

RECORD OF BOREHOLE No 505

1 OF 3 **METRIC**

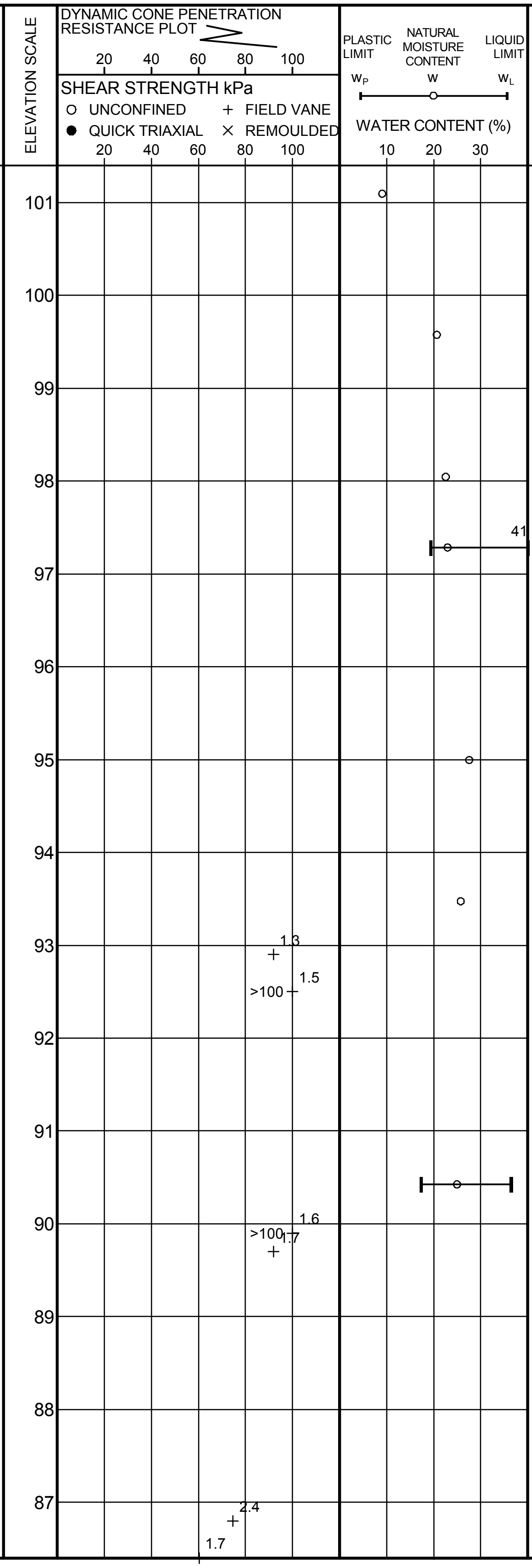
PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic

LOCATION N 4781313.0 ;E 327227.0
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE December 15, 2004

ORIGINATED BY PKS
COMPILED BY SLP
CHECKED BY LCC

SOIL PROFILE		SAMPLES		
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
101.4	GROUND SURFACE			
0.0	Asphalt			
0.2	Sand and gravel (FILL) Compact Red Wet	1	SS	14
		2	SS	20
99.9 1.5	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown/grey Wet	3	SS	25
		4	SS	24
		5	SS	15
		6	SS	34
		7	SS	21
		8	SS	13
94.5 6.9	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff Grey Wet	9	TO	PH
		10	SS	9
		11	SS	9
	Containing trace shale fragments below 12.5 m depth	12	SS	18
88.0 13.4	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet	13	SS	8

GROUND WATER CONDITIONS



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

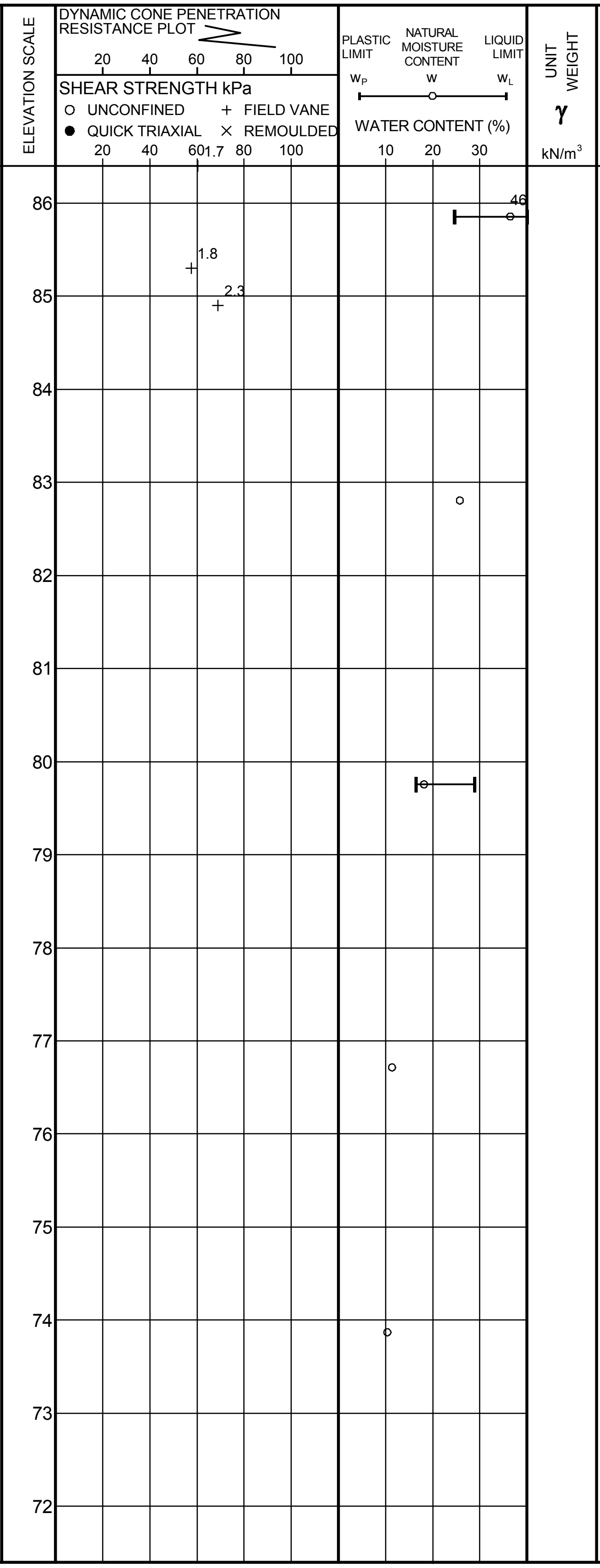
RECORD OF BOREHOLE No 505

2 OF 3 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781313.0 ;E 327227.0	ORIGINATED BY PKS
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY SLP
DATUM Geodetic	DATE December 15, 2004	CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY, trace to some sand, trace gravel (TILL) Firm to stiff Grey Wet		14	SS	12		
			15	TO	PH		
84.0 17.4	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Grey Wet		16	SS	16		
			17	SS	18		
			18	SS	31		
			19	SS	27		3 24 58 15
			20	SS	27	∇	
75.5 25.9	SILTY SAND, trace gravel Dense to very dense Grey/red to grey Wet		21	SS	49		
			22	SS	100/.20		



Continued Next Page

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

PROJECT 04-1111-002	**RECORD OF BOREHOLE No 505**	3 OF 3	**METRIC**
W.P. 607-00-00	LOCATION N 4781313.0 ;E 327227.0		ORIGINATED BY PKS
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers		COMPILED BY SLP
DATUM Geodetic	DATE December 15, 2004		CHECKED BY LCC

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION *--- CONTINUED FROM PREVIOUS PAGE ---*	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
70.7			23	SS	100/.23		71				
30.7	END OF BOREHOLE Note: 1. Water level in open borehole at 24.4 m depth (Elev. 77.0 m) upon completion of drilling operations.										

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

RECORD OF BOREHOLE No 506

1 OF 1 **METRIC**

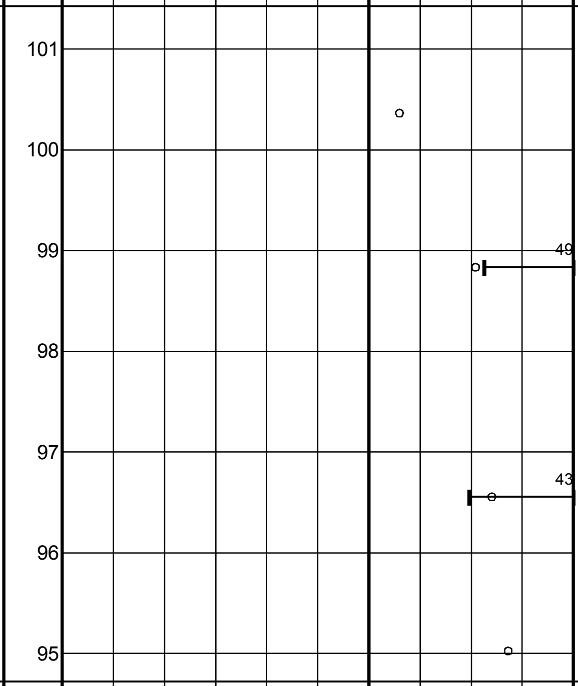
PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781316.5 ;E 327181.5	ORIGINATED BY PKS	
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY SLP	
DATUM Geodetic	DATE December 21, 2004	CHECKED BY LCC	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			
101.4	GROUND SURFACE						
0.0	Asphalt						
0.2	Sand and gravel (FILL) Compact Brown/red Moist	1	SS	24			
		2	SS	13			
99.9 1.5	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown to brown/grey Moist	3	SS	18			
		4	SS	21			
		5	SS	14			
		6	SS	14			
		7	SS	14			
		8	SS	16			
94.7 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%) 10 20 30



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

Golder Associates

RECORD OF BOREHOLE No 507

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781306.1 ;E 327232.2

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

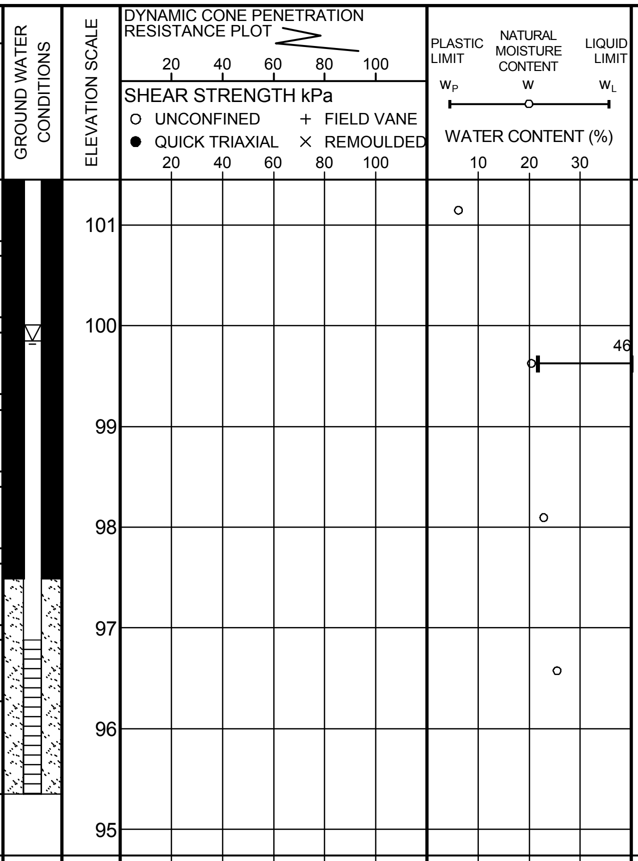
DATE December 14, 2004

ORIGINATED BY PKS

COMPILED BY SLP

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
101.5	GROUND SURFACE							
0.0	Sandy silt, trace gravel (FILL) Compact Red Moist	1	SS	15				
		2	SS	11				
100.4 1.1	SILTY CLAY, trace to some sand, trace gravel and shale fragments (TILL) Stiff to hard Brown/grey Moist	3	SS	28				
		4	SS	31				
		5	SS	36				
		6	SS	18	0	5	40	55
		7	SS	16				
96.0 5.5	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff Grey Wet	8	SS	10				
94.7 6.7	END OF BOREHOLE							



UNIT WEIGHT γ kN/m³

Notes:

1. Borehole dry upon completion of drilling operations.

2. Water level in piezometer at 6.0 m depth (Elevation 95.5 m) on December 20, 2004.

3. Water level in piezometer at 1.6 m depth (Elevation 99.9 m) on May 13, 2005.

4. Water level in piezometer at 1.9 m depth (Elevation 99.6 m) on December 6, 2005.

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

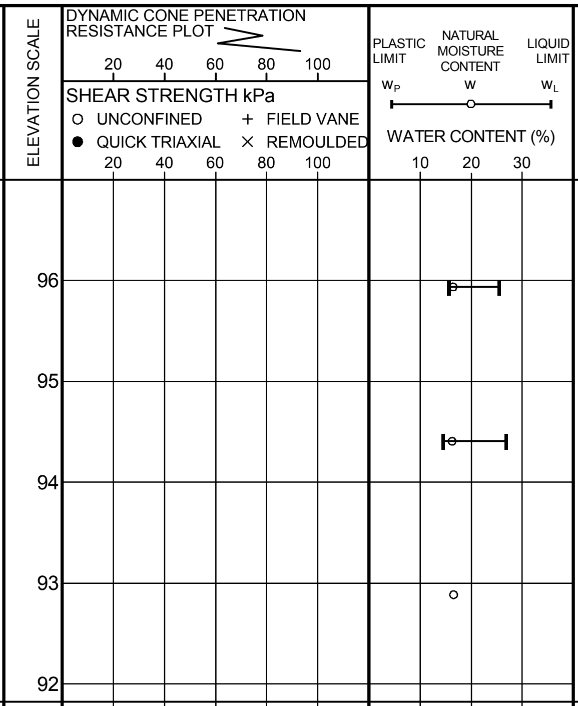
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-33

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781805.7 ;E 325469.4
BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers
DATE June 13, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE			SAMPLES						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
97.0	GROUND SURFACE							
0.0	Sand and gravel (FILL) Compact Grey Moist		1	SS	35			
96.2 0.8	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist		2	SS	18			
			3	SS	20			
			4	SS	12			
			5	SS	10			
			6	SS	12			
			7	SS	15			
91.8 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.							



+³, ×³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

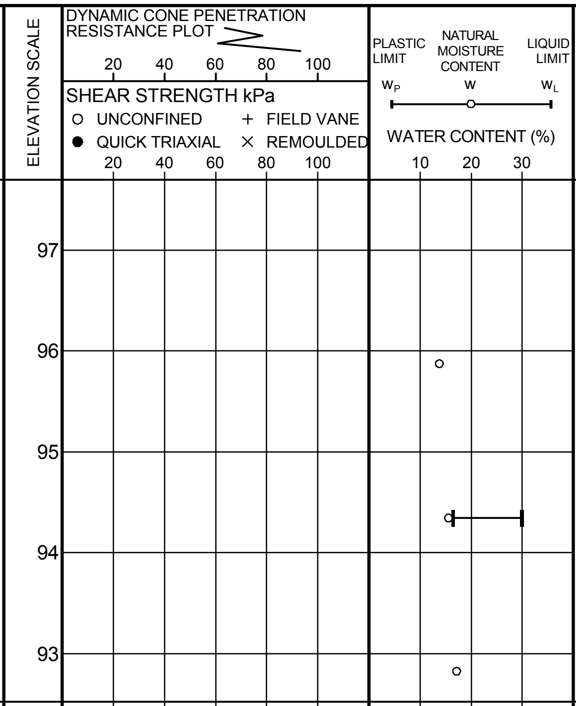
Golder Associates

RECORD OF BOREHOLE No W-34

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781781.9 ;E 325561.5
BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers
DATE June 13, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		GR	SA	SI	CL
97.7	GROUND SURFACE									
0.0 96.9	Sand and gravel (FILL) Compact Grey Moist	▩	1	SS	30					
0.8	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Brown/grey Moist	▨	2	SS	11					
			3	SS	13					
			4	SS	28					
			5	SS	27		1	16	52	31
			6	SS	24					
92.5			7	SS	24					
5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.									



UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No W-35

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781762.7 ;E 325633.9

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers

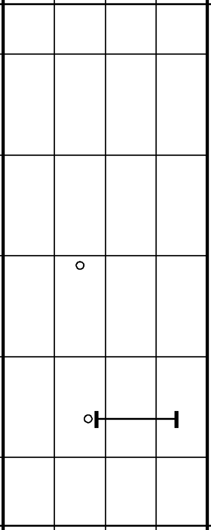
COMPILED BY SG

DATUM Geodetic

DATE June 13, 2005

CHECKED BY LCC

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 × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES						
98.5	GROUND SURFACE									
0.0	Sand and gravel (FILL) Compact Brown Moist	1	SS	23		98				
98.2 0.3										
97.7 0.8	Clayey silt, some sand, trace gravel (FILL) Very stiff Brown Moist	2	SS	25		97				
97.0 1.5	CLAYEY SILT, some sand, containing organics Very stiff Brown/black Moist	3	SS	12						
	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	4	SS	21		96				
		5	SS	23		95				
		6	SS	24		94				
		7	SS	22						
93.3 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.									



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-36

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781744.4 ;E 325706.6

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers

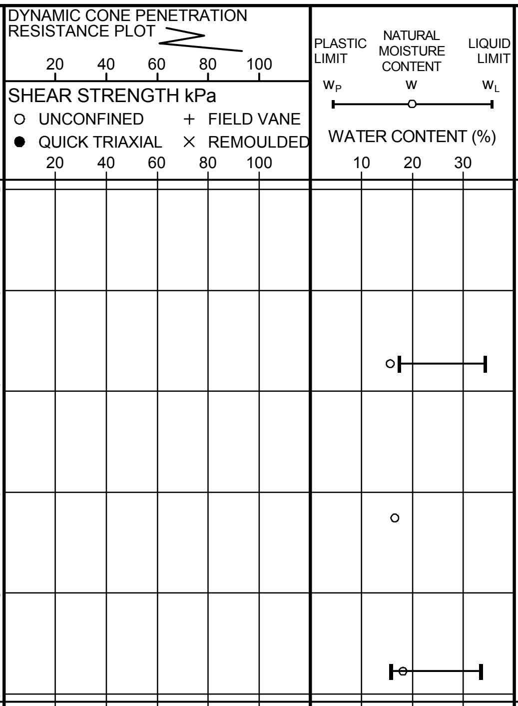
COMPILED BY SG

DATUM Geodetic

DATE June 13, 2005

CHECKED BY LCC

SOIL PROFILE			SAMPLES							REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³		GR	SA	SI	CL
99.1	GROUND SURFACE												
0.0 98.8 0.3	Sand and gravel (FILL) Compact Brown Moist		1	SS	10		99						
98.3 0.8	Clayey silt, some sand, trace gravel (FILL) Stiff Brown Moist		2	SS	17		98						
97.6 1.5	SILTY SAND, containing organics Compact Brown/black Moist		3	SS	17		97						
	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown Moist		4	SS	31		96						
			5	SS	26								
			6	SS	28		95						
			7	SS	23		94			1	11	51	37
93.9 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.												



$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-37

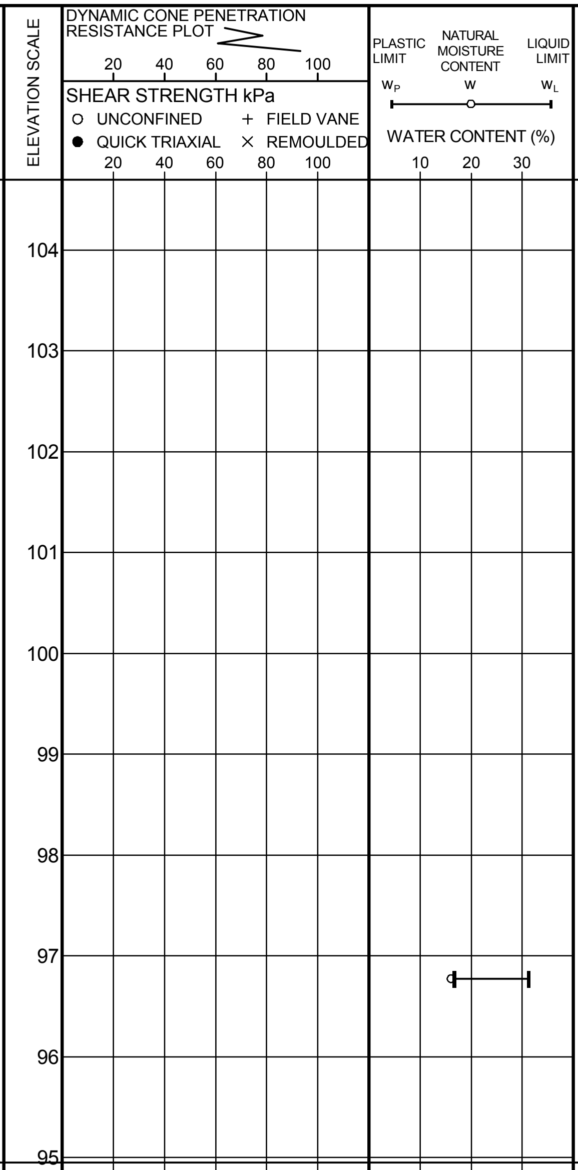
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781736.7 ;E 325782.0
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE June 16, 2005
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
104.7	GROUND SURFACE			
0.0	ASPHALT			
0.2	Sand and gravel (FILL) Compact Brown Moist			
104.1 0.6	Foundry sand (FILL) Very dense Black Moist	1	SS	90
		2	SS	46
		3	SS	78
		4	SS	70
		5	SS	53
		6	SS	66
98.8	Concrete			
6.1	Silty sand (FILL) Loose Black Moist	7	SS	9
97.1 7.6	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to hard Brown Moist	8	SS	32
	Grey below 9.1 m depth	9	SS	11
95.0 9.8	END OF BOREHOLE			

Note:

1. Borehole dry upon completion of drilling operations.



UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

+3, ×3: Numbers refer to Sensitivity

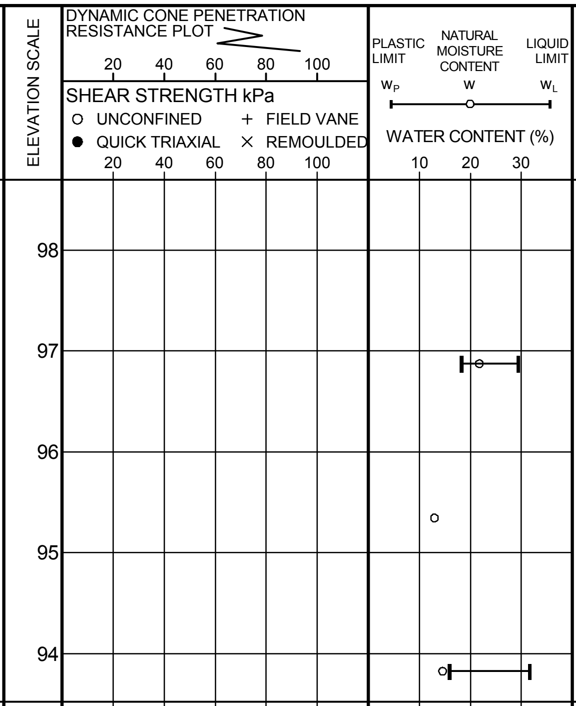
O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-38

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781821.5 ;E 325597.1
BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers
DATE June 15, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			GR	SA	SI	CL
98.7	GROUND SURFACE									
0.0	Sand and gravel (FILL) Compact Grey Moist	1	SS	22						
97.9 0.8	Sandy silt, some gravel, some clay (FILL) Stiff Brown/grey Moist	2	SS	12			24	30	31	15
97.2 1.5	CLAYEY SILT, some sand, trace gravel, organics Firm Grey/black Moist	3	SS	7						
96.4 2.3	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown/grey Moist	4	SS	13						
		5	SS	25						
		6	SS	30						
		7	SS	21						
93.5 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.									



+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-39

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781801.9 ;E 325669.4

BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers

DATE June 15, 2005

ORIGINATED BY PKS

COMPILED BY SG

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
99.5	GROUND SURFACE								
0.0	Sand and gravel (FILL) Dense Grey Moist	1	SS	30	99				
98.7 0.8	Foundry sand (FILL) Loose to very dense Black Moist	2	SS	64					
		3	SS	7	98				
97.7 1.8	Organic Silty SAND Loose Grey/black Moist								
97.2 2.3	CLAYEY SILT, trace to some sand, trace gravel (TILL) Very stiff to hard Brown Moist	4	SS	17	97	0	9	58	33
		5	SS	29	96				
		6	SS	32	95				
		7	SS	19					
94.3 5.2	END OF BOREHOLE								

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

Notes:

1. Borehole dry upon completion of drilling operations.

2. Water level measured at 1.5 m depth (Elev. 98.0 m) on August 8, 2005, and at 0.9 m depth (Elev. 98.6 m) on December 6, 2005.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-40

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781782.7 ;E 325741.8

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers

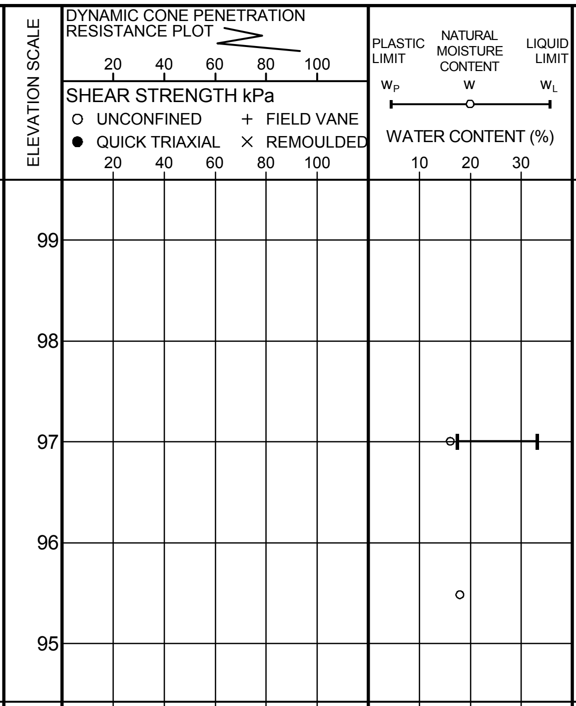
COMPILED BY SG

DATUM Geodetic

DATE June 7, 2005

CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			
99.6	GROUND SURFACE							
0.0	Sand and gravel (FILL) Compact Brown Moist		1	SS	23			
			2	SS	18			
98.2 1.5	Foundry sand (FILL) Compact Black Moist		3	SS	11			
	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist		4	SS	19			
			5	SS	25			
			6	SS	21			
	Grey below 4.6 m depth		7	SS	14			
94.4 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.							



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-41

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781754.1 ;E 325812.2

BOREHOLE TYPE Power Auger, 108 mm Solid Stem Augers

DATE July 8, 2005

ORIGINATED BY PKS

COMPILED BY SG

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
105.0	GROUND SURFACE									
0.0	ASPHALT									
0.2	Sand and gravel (FILL) Compact Brown Moist									
104.2 0.8	Foundry sand (FILL) Very dense Black Moist	1	SS	80		104				
		2	SS	69		103				
		3	SS	78		102				
		4	SS	76			7	80	10	3
		5	SS	75		101				
		6	SS	90		100				
98.9 6.1	Silty SAND, some gravel, trace clay Compact Brown Moist	7	SS	21		99	14	58	21	7
						98				
97.4 7.6	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown Moist	8	SS	32		97				
		9	SS	23		96				
95.3 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.									

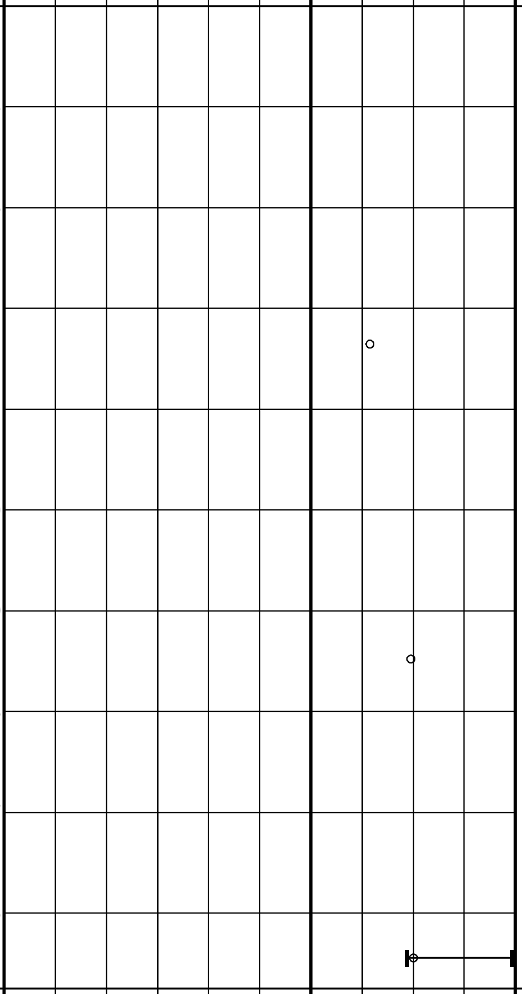
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³



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

RECORD OF BOREHOLE No W-42

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781686.7 ;E 325975.7

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SG

DATUM Geodetic

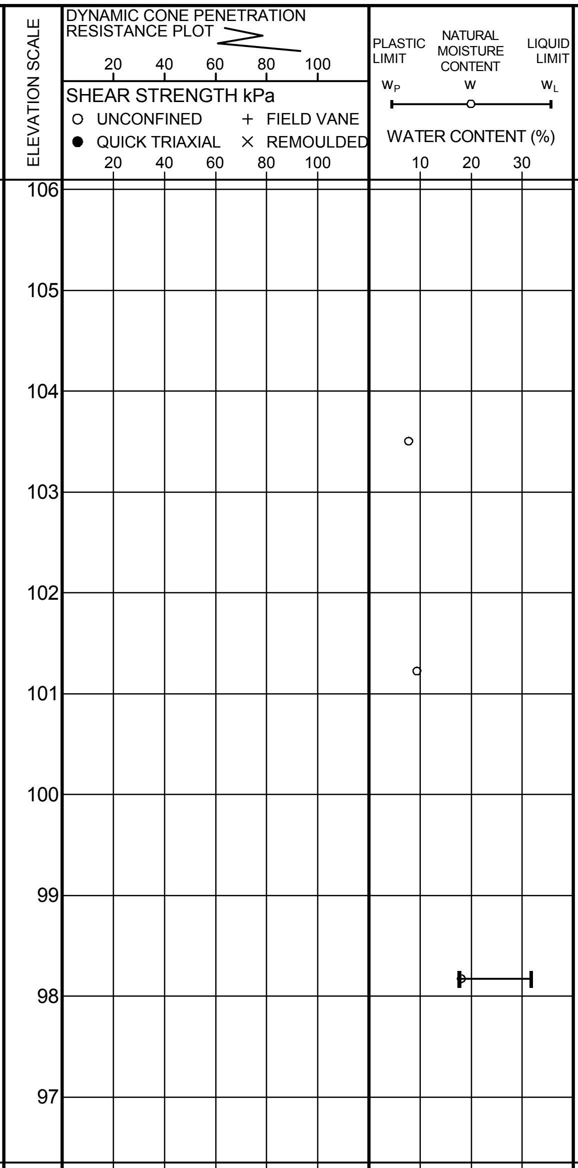
DATE June 17, 2005

CHECKED BY LCC

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
106.1	GROUND SURFACE									
0.0	ASPHALT									
0.2	Silty sand, trace gravel, trace slag pieces (FILL) Compact to dense Red Moist	1	SS	46						
		2	SS	17						
		3	SS	18			1	75	20	4
		4	SS	14						
		5	SS	27						
		6	SS	18						
100.2	Concrete									
6.1	CLAYEY SILT, some sand, containing organics Firm Grey/black Moist/wet	7	SS	6						
98.5 7.6	CLAYEY SILT, some sand, trace gravel (TILL) Hard Brown Moist	8	SS	35						
97.0 9.1	Silty SAND Dense Grey Wet	9	SS	46						
96.4 9.8	END OF BOREHOLE									

Note:

1. Borehole dry upon completion of drilling operations.



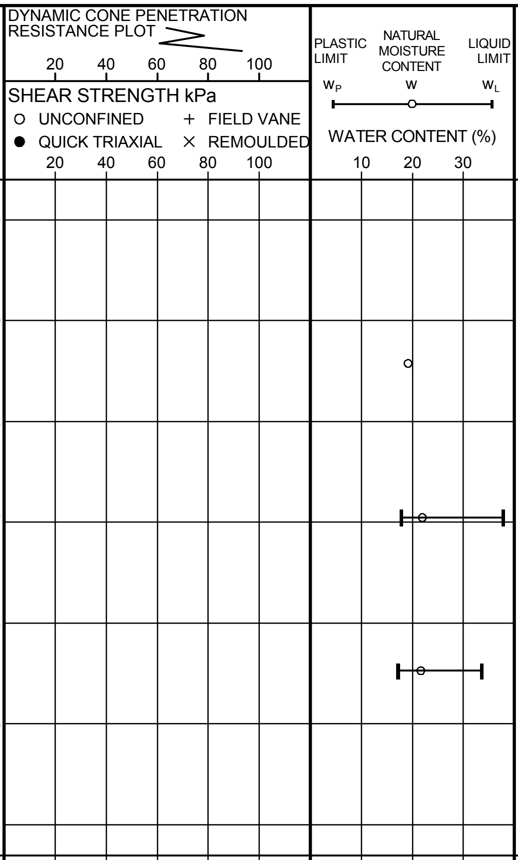
+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-43

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781657.9 ;E 326045.0
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 12, 2005
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.4	GROUND SURFACE							
0.0	ASPHALT							
0.1	Sand and gravel (FILL) Compact Brown Moist					100		
99.3 1.1	CLAYEY SILT to SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	1	SS	17				
		2	SS	19		99		
		3	SS	14		98		
		4	SS	12		97		
		5	SS	13		96		
		6	SS	9		95		
		7	SS	12		94		
93.7 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.							



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

RECORD OF BOREHOLE No W-44

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781638.0 ;E 326117.2
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 13, 2005
CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
100.8	GROUND SURFACE
0.0	ASPHALT
0.1	Sand and gravel (FILL) Compact Brown Moist
100.0 0.8	Silty SAND, trace gravel Loose Brown/black Moist
99.3 1.5	SILTY CLAY, trace sand and gravel (TILL) Stiff to very stiff Brown becoming grey below 2.3 m depth Moist
94.1 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	7				
2	SS	23	1	6	45	48
3	SS	14				
4	SS	8				
5	SS	8				
6	SS	12				

GROUND WATER CONDITIONS

ELEVATION SCALE

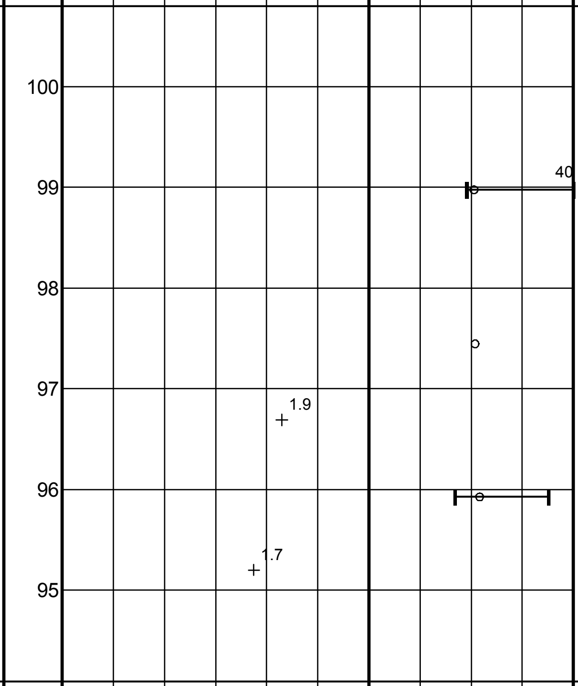
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³



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

RECORD OF BOREHOLE No W-45

1 OF 2 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781618.7 ;E 326189.8
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 13, 2005
CHECKED BY LCC

SOIL PROFILE

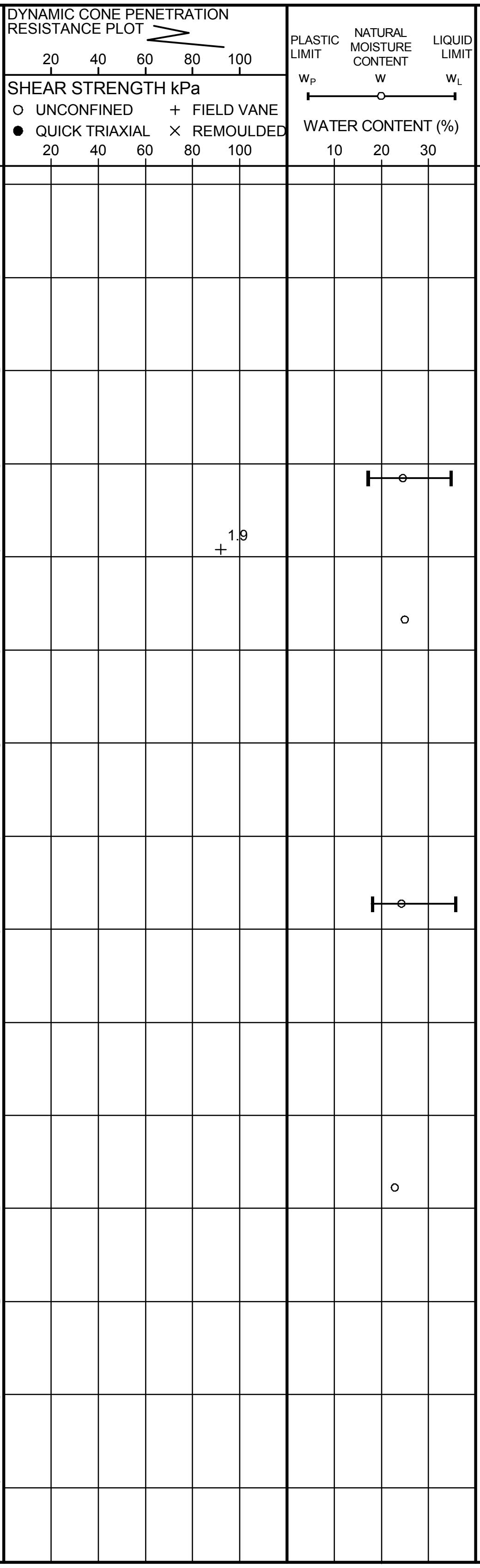
ELEV / DEPTH	DESCRIPTION
101.2	GROUND SURFACE
0.0	ASPHALT
0.1	Sand and gravel (FILL) Compact Brown Moist
99.7 / 1.7	Silty SAND, trace gravel Compact Brown Moist
	CLAYEY SILT, some sand, trace gravel (TILL) Stiff Grey Moist
94.3 / 6.9	SILTY CLAY to CLAYEY SILT, trace to some sand, trace gravel (TILL) Stiff to very stiff Grey Moist
87.0 / 14.3	Silty SAND, some gravel, trace clay Compact Red

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	17				
2	SS	11				
3	SS	7				
4	SS	6				
5	SS	7				
6	SS	7				
7	SS	11	1	7	46	46
8	SS	15				
9	SS	11				
10	SS	12				
11	SS	16				

STRAT PLOT | GROUND WATER CONDITIONS | ELEVATION SCALE | UNIT WEIGHT γ kN/m³

ELEVATION SCALE: 101, 100, 99, 98, 97, 96, 95, 94, 93, 92, 91, 90, 89, 88, 87



Continued Next Page

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-45

2 OF 2 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781618.7 ;E 326189.8
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 13, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Moist		12	SS	18		86				
85.4 15.9	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.										

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

RECORD OF BOREHOLE No W-51

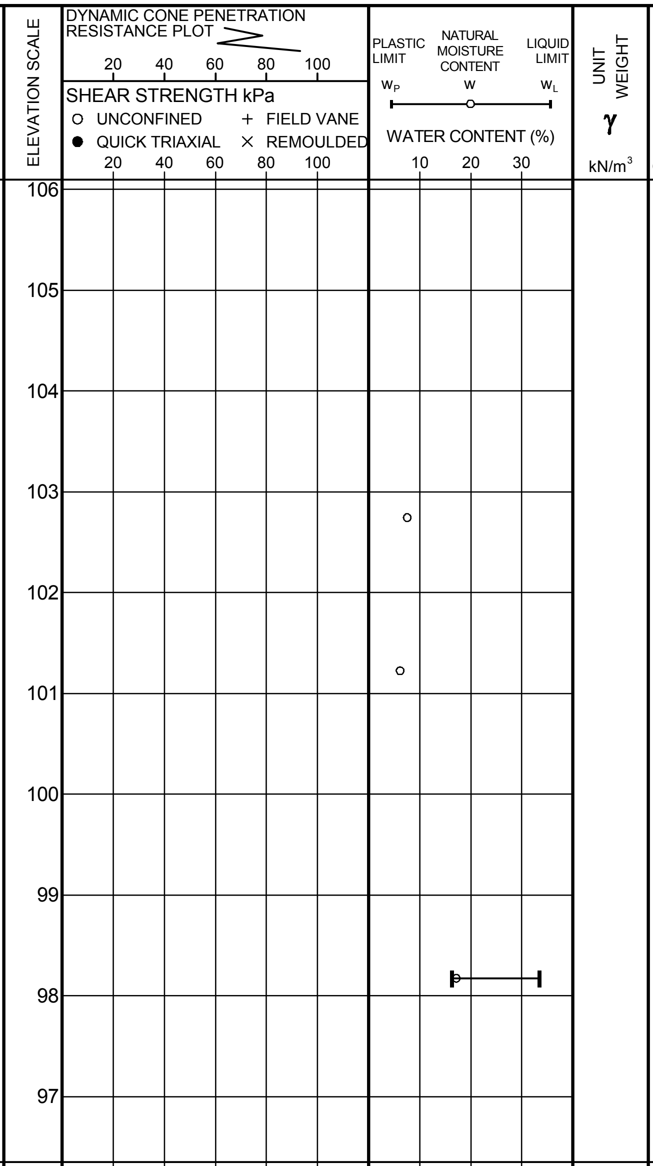
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781716.5 ;E 325957.4
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 8, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
106.1	GROUND SURFACE								
0.0	Sand and gravel (FILL) Compact Grey Moist								
105.2 0.9	Silty sand, trace gravel, trace clay (FILL) Compact to dense Reddish brown Moist	1	SS	47					
		2	SS	47					
		3	SS	26					
		4	SS	17		1	74	20	5
		5	SS	21					
		6	SS	18					
99.7	Sand and gravel, containing foundry sand, brick and asphalt fragments (FILL) Very dense Grey/black Moist	7	SS	66					
99.4 6.7	CLAYEY SILT, some sand, trace gravel (TILL) Hard Brown Moist to wet	8	SS	47					
96.4		9	SS	30	∇				
9.8	END OF BOREHOLE								

Note:

1. Water level in open borehole measured at 9.5 m (Elev. 96.6 m) upon completion of drilling operations.



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

RECORD OF BOREHOLE No W-52

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781709.9 ;E 326033.1
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 12, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	
100.0	GROUND SURFACE				
0.0	ASPHALT				
0.1	Sand and gravel (FILL) Compact Brown Moist				
99.1 0.9	SILTY CLAY, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	1	SS	15	
		2	SS	18	
		3	SS	20	
		4	SS	15	
96.2 3.8	CLAYEY SILT, some sand, trace gravel (TILL) Stiff Grey Moist	5	SS	10	
		6	SS	9	
		7	SS	11	
93.3 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.				

ELEVATION SCALE

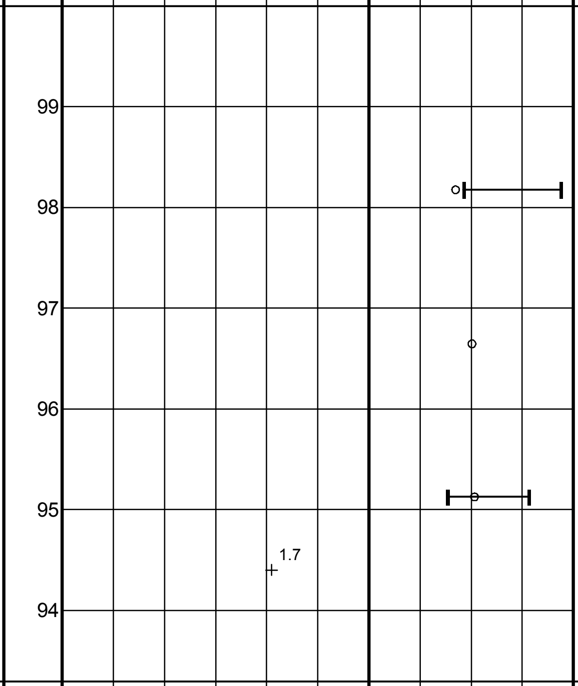
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
O UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%)
10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL



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

RECORD OF BOREHOLE No W-53

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781691.2 ;E 326105.8

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SG

DATUM Geodetic

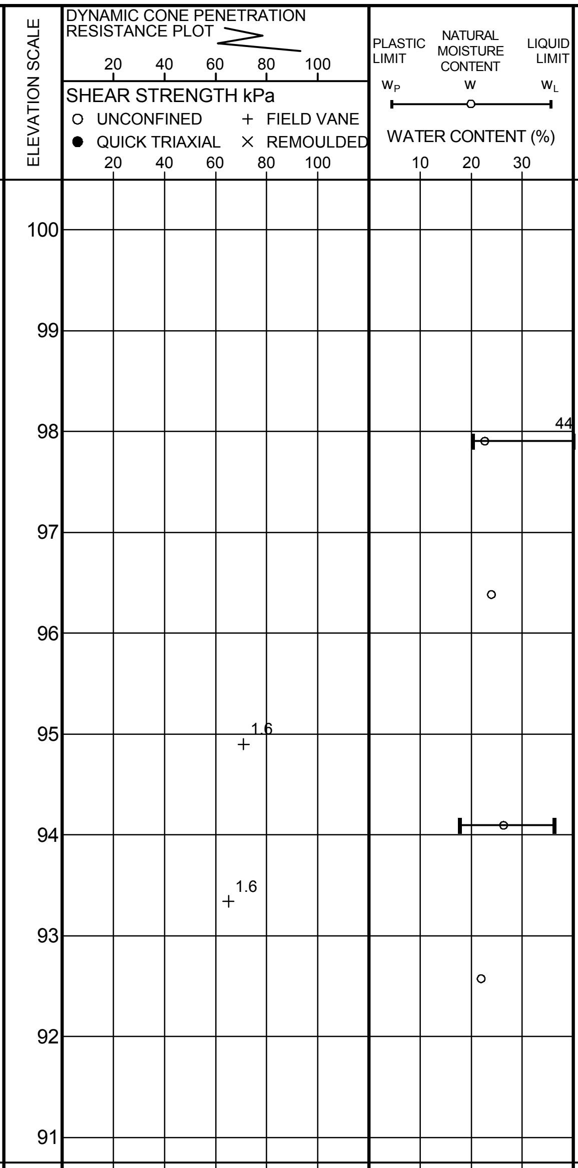
DATE July 11, 2005

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE — DESCRIPTION
100.5	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Compact Brown Moist
99.7 0.8	Silty SAND, trace gravel, containing roots Compact Brown Moist
99.0 1.5	SILTY CLAY, some sand, trace to some gravel (TILL) Stiff to very stiff Brown Moist
97.5 3.0	SILTY CLAY to CLAYEY SILT, trace sand, trace gravel (TILL) Stiff Grey Moist
90.8 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.

SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	11				
2	SS	19				
3	SS	13				
4	SS	10				
5	SS	11				
6	SS	8				
7	SS	7				
8	SS	7	1	8	48	43
9	SS	14				

STRAT PLOT | GROUND WATER CONDITIONS | UNIT WEIGHT γ kN/m³



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

$O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-54

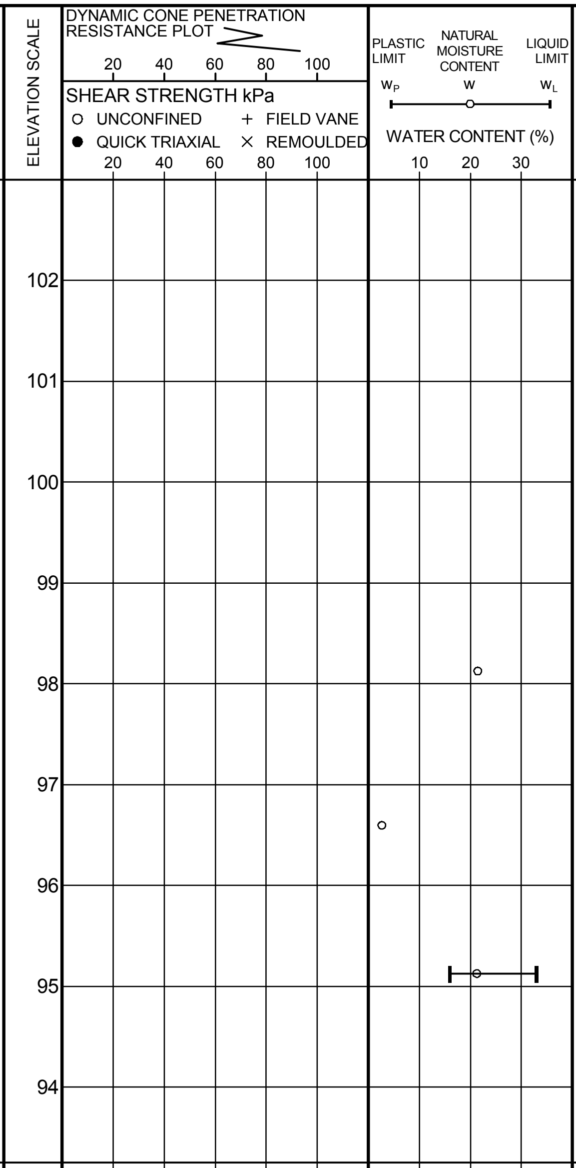
1 OF 1 **METRIC**

PROJECT	04-1111-002		
W.P.	607-00-00	LOCATION	N 4781660.5 ;E 326175.3
DIST	Central HWY QEW	BOREHOLE TYPE	108 mm Diameter Solid Stem Augers
DATUM	Geodetic	DATE	July 7, 2005

ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION
103.0	GROUND SURFACE
0.0	ASPHALT
0.2	Silty sand, trace to some gravel, trace clay (FILL) Compact to very dense Reddish brown Moist
99.0	CONCRETE
4.1	SAND and SILT, trace gravel, trace clay Compact Brown Wet
96.9 6.1	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey Moist
93.3 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.

SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	66				
2	SS	28				
3	SS	19	1	75	18	6
4	SS	45				
5	SS	100/.15				
6	SS	14	1	36	56	8
7	SS	18				
8	SS	14				
9	SS	14				



GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m^3

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

O $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-55

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781653.3 ;E 326250.8

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SG

DATUM Geodetic

DATE July 11, 2005

CHECKED BY LCC

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100

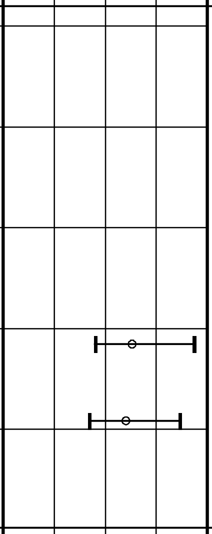
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

SOIL PROFILE			SAMPLES					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³
101.2	GROUND SURFACE							
0.0	ASPHALT							
0.2	Silty sand, trace gravel (FILL) Compact Brown Moist		1	SS	10		101 100	
99.7 1.5	SILTY CLAY, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist		2 3 4	SS SS SS	14 19 10		99 98	
97.4 3.8	CLAYEY SILT, trace sand, trace gravel (TILL) Stiff Grey Moist		5 6	SS SS	8 9		97	
96.0 5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.							



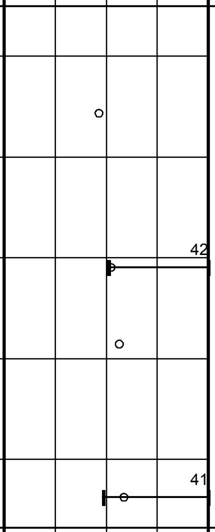
+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-63

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781447.8 ;E 326973.2
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 19, 2005
CHECKED BY LCC

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 × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.5	GROUND SURFACE										
0.0	Silty sand, trace gravel (FILL) Loose Red Moist	▩	1	SS	9		101				
100.7 0.8	SILTY CLAY, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	▨	2	SS	15		100				
			3	SS	15		99				
			4	SS	17				42		
			5	SS	14		98				
			6	SS	12		97				
96.3			7	SS	14				41		
5.2	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.										



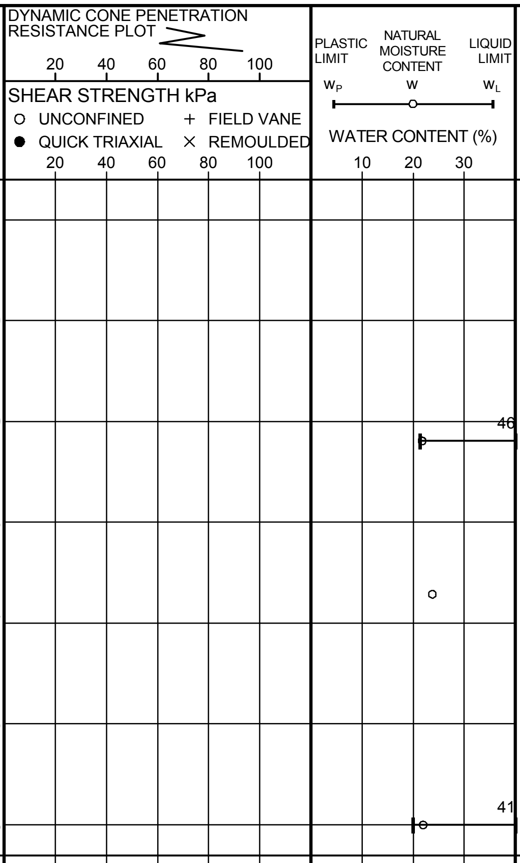
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-64

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781425.2 ;E 327045.0
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 19, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE			SAMPLES						REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m^3	GR	SA	SI	CL
101.4	GROUND SURFACE											
0.0	Clayey silt, some sand and gravel (FILL) Very stiff Brown Moist		1	SS	17		101					
100.6 0.8	Silty sand and gravel, trace clay (FILL) Compact Brown Moist		2	SS	13		100					
99.9 1.5	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist		3	SS	18							
			4	SS	16		99					
			5	SS	14		98					
			6	SS	14		97					
	Becoming grey below 4.6 m depth		7	SS	12		96					
			8	SS	11		95		0	4	42	54
94.7 6.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.											



$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

MIS-MTO 001 04111002AAMTO.GPJ GAL-MISS.GDT 23/1/07

RECORD OF BOREHOLE No W-65

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781402.1 ;E 327116.4

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY SG

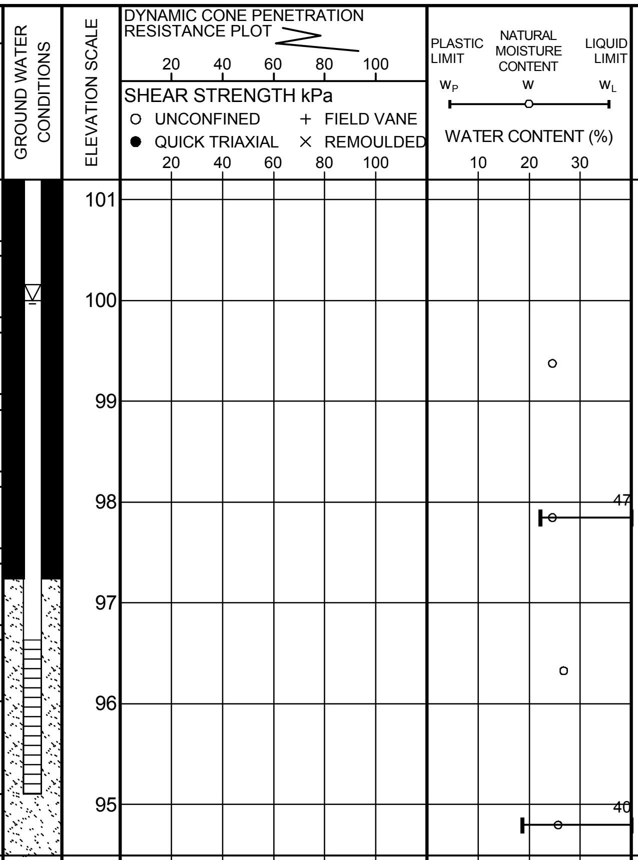
DATUM Geodetic

DATE July 19, 2005

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION
101.2	GROUND SURFACE
0.0	Clayey silt, some sand and gravel (FILL) Stiff Brown Moist
100.5 0.7	Silty sand and gravel, containing asphalt fragments (FILL) Compact Brown Moist/wet
99.7 1.5	SILTY CLAY, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist Grey below 4.6 m depth
94.5 6.7	END OF BOREHOLE

NUMBER	TYPE	"N" VALUES
1	SS	12
2	SS	11
3	SS	19
4	SS	27
5	SS	19
6	SS	13
7	SS	15
8	SS	11



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

Notes:

1. Borehole dry upon completion of drilling operations.

2. Water level measured at 4.2 m depth (Elev. 97.0 m) on August 8, 2005.

3. Water level measured at 1.2 m depth (Elev. 100.0 m) on December 6, 2005.

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-66

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

DIST Central HWY QEW

DATUM Geodetic

LOCATION N 4781363.3 ;E 327182.7

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

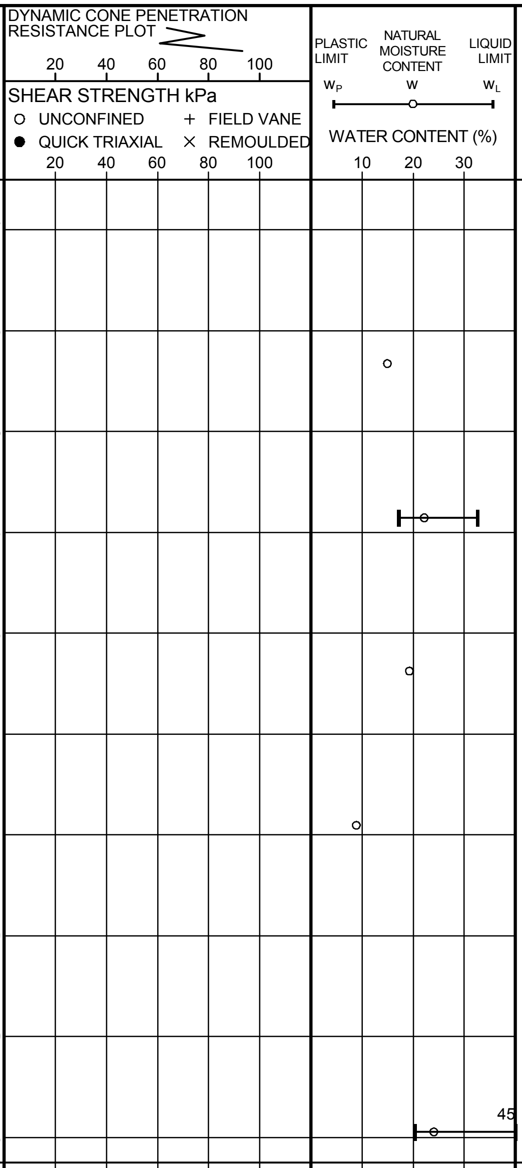
DATE July 25, 2005

ORIGINATED BY PKS

COMPILED BY SG

CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
107.5	GROUND SURFACE					
0.0	ASPHALT					
0.2	Sand and gravel (FILL) Brown Moist				107	
106.7 0.8	Clayey silt, some sand, trace gravel (FILL) Firm to very stiff Brown Moist	1	SS	7		
		2	SS	16	106	
		3	SS	7	105	
		4	SS	11	104	
		5	SS	11	103	
		6	SS	15	102	
101.4 6.1	Gravelly sand, some silt (FILL) Compact Brown Moist to wet	7	SS	28	101	23 55 18 4
99.9 7.6	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown Moist	8	SS	60	100	
					99	
97.8		9	SS	22	98	
9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.					



GROUND WATER CONDITIONS — UNIT WEIGHT γ kN/m³ — STRAT PLOT

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

RECORD OF BOREHOLE No W-69

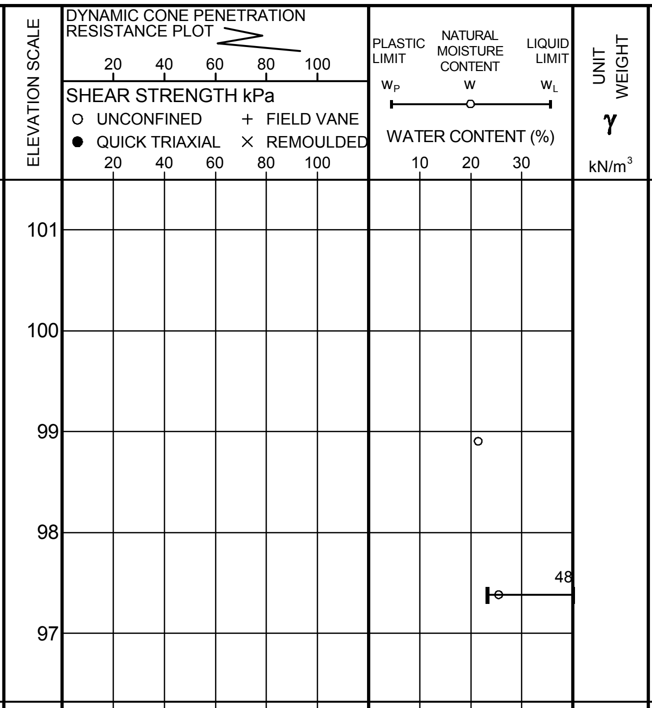
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781343.3 ;E 327097.9
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 21, 2005
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
101.5	GROUND SURFACE							
0.0	ASPHALT							
0.2	CONCRETE							
	Silty sand, trace gravel (FILL) Compact Red Moist	1	SS	18				
100.1 1.4	SILTY CLAY, trace to some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	2	SS	20				
		3	SS	22				
		4	SS	18				
		5	SS	15	1	3	38	58
		6	SS	14				
96.3 5.2	END OF BOREHOLE							

Note:

1. Borehole dry upon completion of drilling operations.



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

RECORD OF BOREHOLE No W-70

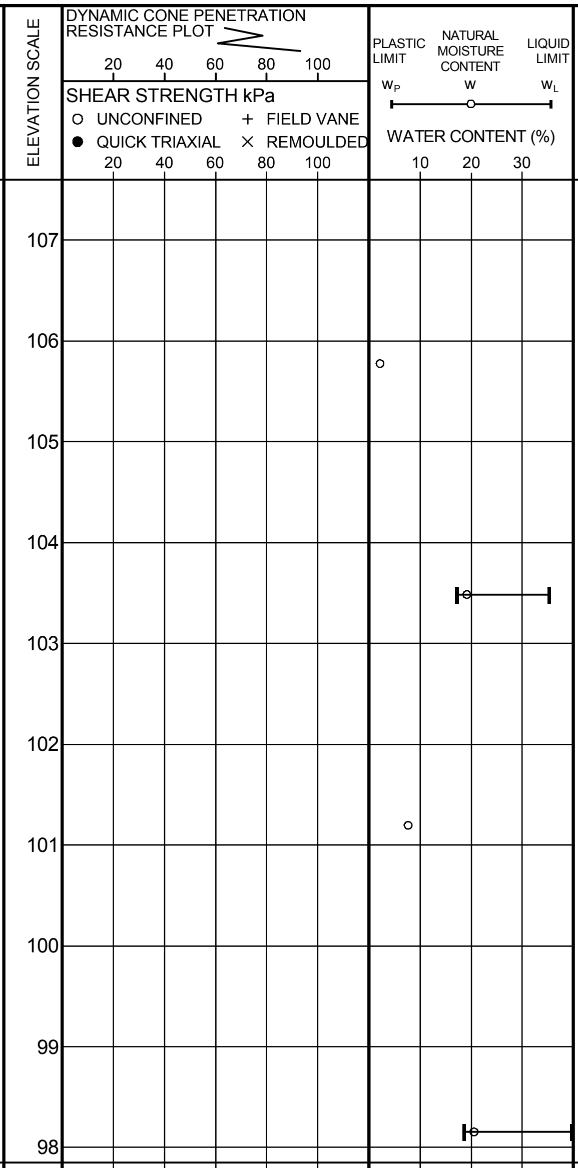
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781323.1 ;E 327306.1
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 24, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
107.6	GROUND SURFACE									
0.0	ASPHALT									
0.2	Sand and gravel to gravel, some sand, trace silt (FILL) Loose Brown/grey Moist									
		1	SS	7						
		2	SS	8			84	13	(3)	
105.0 2.6	Clayey silt to silty clay, some sand, trace to some gravel (FILL) Stiff Brown Moist	3	SS	6						
		4	SS	13						
		5	SS	12						
		6	SS	10						
101.5 6.1	Silty sand and gravel (FILL) Very dense Brown/red Moist	7	SS	70						
100.0 7.6	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown Moist	8	SS	32						
		9	SS	28						
97.9 9.8	END OF BOREHOLE									

Note:

1. Borehole dry upon completion of drilling operations.



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

RECORD OF BOREHOLE No W-71

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781309.5 ;E 327348.7
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 24, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
107.2	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Compact Brown Moist
106.4 0.8	Clayey silt, some sand, trace to some gravel (FILL) Firm to very stiff Brown Moist
101.7 5.6	Sand and gravel (FILL) Grey Moist
	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown Moist
97.5 9.8	END OF BOREHOLE

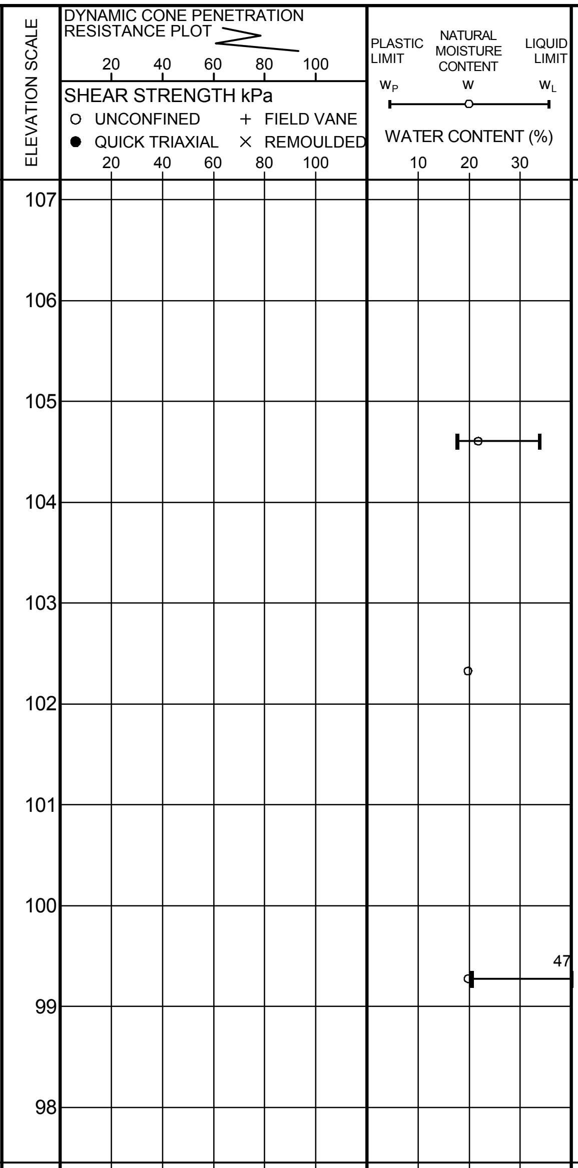
Note:

1. Borehole dry upon completion of drilling operations.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	8
2	SS	5
3	SS	6
4	SS	6
5	SS	14
6	SS	22
7	SS	15
8	SS	27
9	SS	31

GROUND WATER CONDITIONS



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

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

RECORD OF BOREHOLE No W-72

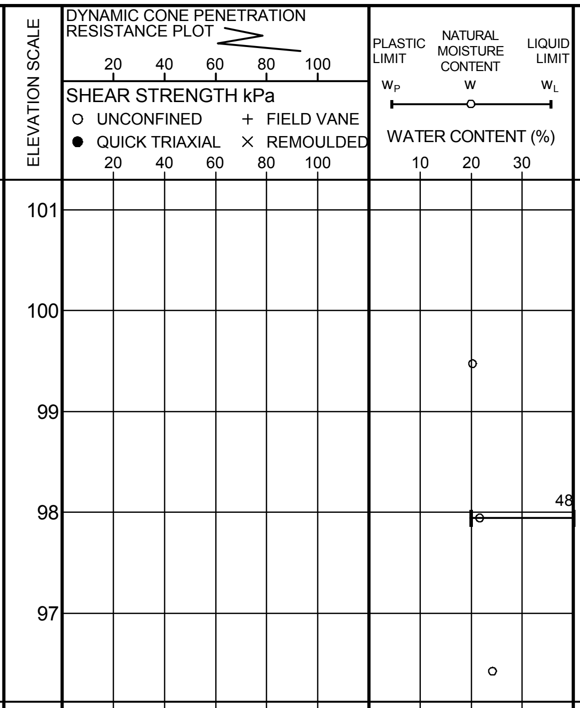
1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
LOCATION N 4781300.4 ;E 327426.3
ORIGINATED BY PKS
DIST Central HWY QEW
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
COMPILED BY SG
DATUM Geodetic
DATE July 21, 2005
CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.3	GROUND SURFACE						
0.0	ASPHALT						
	CONCRETE						
	Sand and gravel (FILL) Compact Brown Moist						
100.5 0.8	SILTY CLAY, some sand, trace gravel, containing organics Firm Grey to grey-black Moist	1	SS	4			
99.8 1.5	SILTY CLAY, some sand, trace gravel (TILL) Stiff to very stiff Brown Moist	2	SS	14			
		3	SS	14			
		4	SS	17			
		5	SS	15			
		6	SS	13			
96.1 5.2	END OF BOREHOLE						

Note:

1. Borehole dry upon completion of drilling operations.



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-73

1 OF 1 **METRIC**

PROJECT 04-1111-002

W.P. 607-00-00

LOCATION N 4781263.8 ;E 327492.2

ORIGINATED BY PKS

DIST Central HWY QEW

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

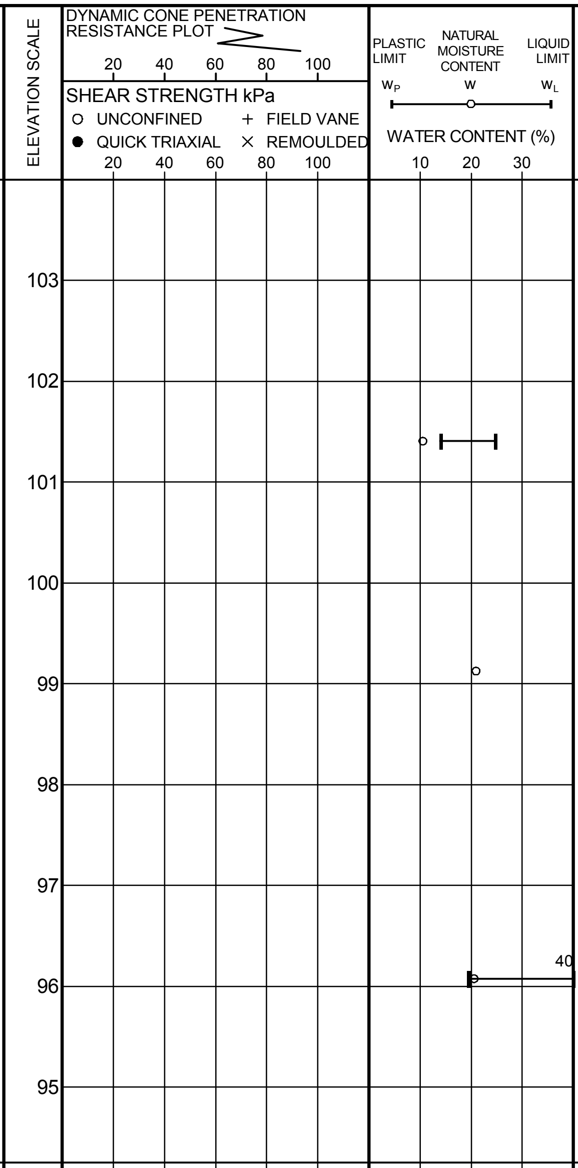
COMPILED BY SG

DATUM Geodetic

DATE July 24, 2005

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
104.0	GROUND SURFACE									
0.0	ASPHALT									
0.2	Sand and gravel (FILL) Compact Brown Moist									
103.2 0.8	Clayey silt, some sand, trace to some gravel (FILL) Stiff to hard Brown/red Moist	1	SS	11						
		2	SS	15						
		3	SS	24			5	27	47	21
		4	SS	32						
		5	SS	11						
99.4 4.6	CLAYEY SILT to SILTY CLAY, some sand, trace gravel (TILL) Very stiff Brown Moist	6	SS	18						
		7	SS	20						
		8	SS	27						
		9	SS	29						
94.3 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.									



+3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No W-76

1 OF 1 **METRIC**

PROJECT 04-1111-002
W.P. 607-00-00
DIST Central HWY QEW
DATUM Geodetic
LOCATION N 4781307.0 ;E 327269.3
BOREHOLE TYPE 108 mm Diameter Solid Stem Augers
DATE July 27, 2005
ORIGINATED BY PKS
COMPILED BY SG
CHECKED BY LCC

SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
107.8	GROUND SURFACE	
0.0	ASPHALT	■
0.2	Sand and gravel (FILL) Brown Moist	▨
107.2 0.6	Clayey silt, trace to some sand, trace gravel (FILL) Stiff to very stiff Reddish brown to brown Moist	▨
101.7 6.1	Sand and gravel (FILL) Compact Brown/grey Moist/wet	▨
101.1 6.7	SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown/grey Moist	
98.0 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling operations.	

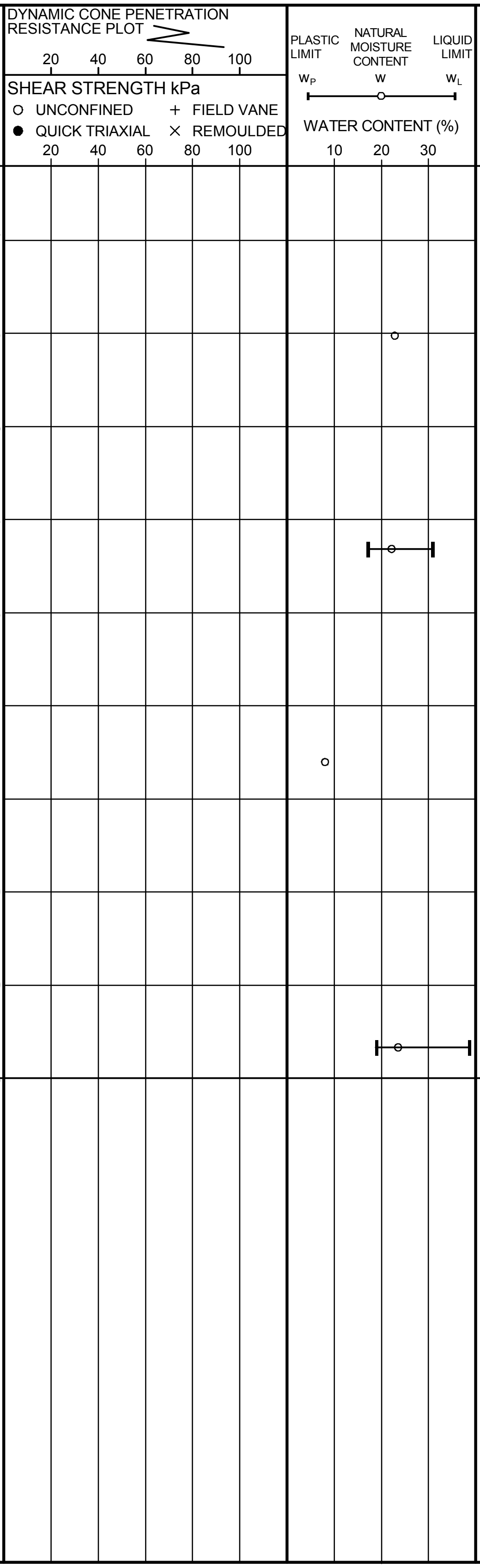
SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	13				
2	SS	11				
3	SS	14				
4	SS	13				
5	SS	20	5	6	56	33
6	SS	18				
7	SS	22				
8	SS	41				
9	SS	21				

GROUND WATER CONDITIONS

ELEVATION SCALE: 107, 106, 105, 104, 103, 102, 101, 100, 99, 98

UNIT WEIGHT γ kN/m³



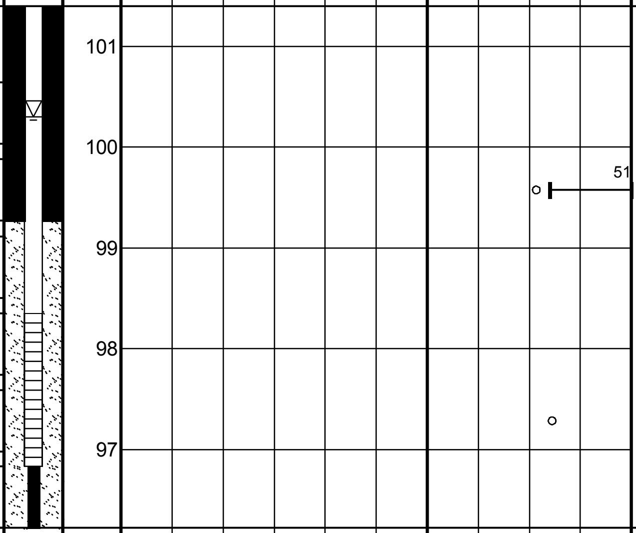
$+^3, \times^3$: Numbers refer to Sensitivity ○$^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No W-77

1 OF 1 **METRIC**

PROJECT 04-1111-002			
W.P. 607-00-00	LOCATION N 4781265.1 ;E 327334.9	ORIGINATED BY PKS
DIST Central HWY QEW	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY SG
DATUM Geodetic	DATE July 21, 2005	CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES
101.4	GROUND SURFACE			
0.0	ASPHALT			
0.2	Sand and gravel (FILL) Compact Brown Moist			
100.8 0.6	SILTY CLAY, some sand, trace gravel (TILL) Firm to very stiff Brown Moist	1	SS	6
		2	SS	15
		3	SS	20
		4	SS	14
		5	SS	13
		6	SS	11
96.2 5.2	END OF BOREHOLE			



Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Notes:

1. Borehole dry upon completion of drilling operations.

2. Water level measured in piezometer at 3.2 m depth (Elev. 98.2 m) on August 8, 2005.

3. Water level measured in piezometer at 1.1 m depth (Elev. 100.3 m) on December 6, 2005.

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

APPENDIX A

BOREHOLE RECORDS FROM
1955 INVESTIGATION BY DEPARTMENT OF HIGHWAYS, ONTARIO

APPENDIX B

RESULTS OF SETTLEMENT AND STABILITY ANALYSES

APPENDIX C

NON-STANDARD SPECIAL PROVISIONS

ULTRA LIGHTWEIGHT SLAG FILL

Non Standard Special Provision

SCOPE

This non standard special provision covers the requirements for the supply and placement of ultra lightweight blast furnace slag.

DEFINITIONS

Quality Verification Engineer: means an Engineer with a minimum of five (5) years experience related to embankment materials and construction, or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and issue of certificate(s)of conformance.

SUBMISSION AND DESIGN REQUIREMENTS

The Contractor shall submit to the Contract Administrator Certificates of Conformance sealed and signed by the Quality Verification Engineer as follows:

1. Prior to the placement of the ultra lightweight fill material on the Contract, the Contractor shall submit to the Contract Administrator a Certificate of Conformance stating that the material satisfies the material properties specified in Table 1. The material properties shall be determined using the test procedure specified in Table 1.

2. Following embankment construction, the Contractor shall submit to the Contract Administrator a Certificate of Conformance stating that the material satisfies the requirements of this specification and that the work has been carried out in general conformance with the contract documents and specifications.

In addition, the Contractor shall submit to the Contract Administrator, for information only, all Quality Control Test Results.

MATERIAL

The Ultra Lightweight Blast Furnace Slag shall satisfy the physical, mechanical and chemical property requirements specified in Table 1:

Table 1: Material Properties and Construction Requirements

Property	Requirement	Test Method
Angle of Internal Friction	> 35 °	ASTM 2850-95
Hydraulic Conductivity	> 8 E-03 cm/s	ASTM 5856-95, Method A
Chemical Composition	The material shall meet the Leachate Criteria Established Under Ontario Regulation 347.	
In-Situ Wet Unit Weight, maximum when placed and compacted in accordance with the requirements of this Special Provision	< 12.5 kN/m^3	ASTM D2922

The Contractor shall retain a laboratory that has been inspected and accepted by the MTO under the "Soil and Rock - High Complexity Testing" to undertake the testing of the material properties. Laboratory testing shall be signed and sealed by an Engineer, licensed to practice in the Province of Ontario.

CONSTRUCTION

The Contractor is advised that the ultra lightweight blast furnace slag is susceptible to crushing if overcompacted and that careful construction supervision is required.

The Contractor shall place the ultra lightweight fill material and shall achieve compaction without crushing the material since crushing increases its unit weight.

The Contractor shall place the ultra lightweight fill material without exceeding the specified in-situ unit weight.

To prevent overcrushing and overcompaction, the ultra lightweight fill shall be placed as follows:

1. For embankments, the ultra lightweight fill shall be placed in lifts of 300 mm and compacted by three (3) passes using single drum vibratory equipment such as a Bomag 142 or equivalent.
2. For backfill to structures, the ultra lightweight fill shall be placed in lifts of 300 mm and compacted with 8 passes of manually guided tamper such as a Bomag BPR 30/38 D or equivalent.
3. The Contractor shall place and spread the loose lifts using a rubber tire front-end loader such as a Caterpillar 980 F or equivalent.

Compaction equipment technical details are provided in Table 2.

Table 2 – Compaction Equipment Technical Details

	Bomag 142 D	Bomag BPR 30/38 D
Weights		
▪ Operating weight (kg)	4690±	175±
▪ Mass per square metre of base plate (kg/m^2)	N/A	1439
Dimensions		
▪ Drum width (mm)	1426±	N/A
▪ Drum diameter (mm)	1058±	N/A
▪ Width of Base Plate (mm)	N/A	380
▪ Length of Base Plate (mm)	N/A	730
Drive		
▪ Performance DIN 6271 IFN (kW)	37±	3.7
▪ Performance SAE (Kw)	39.5	N/A
▪ Speed (rpm)	2300	3600
Vibratory System		
▪ Frequency (Hz)	32±	68±
▪ Amplitude (mm)	1.24±	N/A
▪ Centrifugal force (Kn)	66±	30±

QUALITY CONTROL

General

Quality Control (QC) testing shall be carried out by the Contractor for purposes of ensuring that the ultra lightweight fill material is placed and compacted to the requirements specified in the Contract. Field density and field moisture determination shall be made in accordance with ASTM D2922 and ASTM D3017.

Acceptability of compaction shall be based on achieving the target in situ unit weight.

Control Strip

Under the Supervision of the Quality Verification Engineer, the Contractor shall build a control strip to verify that the placement and compaction procedure will achieve the requirements of this Special Provision without evidence of crushing and without exceeding the specified maximum in-situ unit weight of 12.5 kN/m^3.

Prior to incorporating any of the material into the work the Contractor shall build a minimum trial area of 400 m^2 in area consisting of two equal lifts of 300 mm thickness. The Contractor shall give the Contract Administrator written notice of the construction of the control strip 48 hours prior to commencement of this work.

Material placed in the control strip shall have the moisture content that will yield the specified in-situ unit weight. For the Control strip determination, the nuclear gauge method will not be considered an acceptable method of determining the in-situ moisture content of the ultra lightweight material. Moisture content shall be determined by the oven dry method on selected compacted embankment material samples in accordance with ASTM D2216.

After the trial area is complete, samples for moisture content and in-situ unit weight determination testing shall be as per ASTM D2922.

All test results will be used to determine compliance with the specification. Any proposed changes to the specified compaction method shall be reviewed and approved by the Contract Administrator prior to implementation. The requirements of the control strip must be satisfied as part of the acceptance criteria of any proposed change to the specified compaction method of this Special Provision.

MEASUREMENT OF PAYMENT

The unit measurement will be cubic metres for the ultra lightweight fill material placed in situ as per the requirements of the contract.

BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour equipment and materials required to do the work.

VIBRATION MONITORING - Item No.

Special Provision

Scope

This special provision describes requirements for vibration monitoring during pile installation works.

Definitions

Quality Verification Engineer (QVE): An Engineer with a minimum of five (5) years experience in the field of installation of piling and vibration monitoring or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to ensure general conformance with the contract documents and issue certificate(s) of conformance.

Submission Requirements

The Contractor shall submit details of the vibration monitoring plan to the Quality Verification Engineer for review. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

Qualifications of vibrations monitoring specialist.
Proposed instrumentation.
Proposed location of instruments on existing Third Street overpass structure.
Proposed frequency of readings.
Proposed methods for adjusting piling methods if readings show vibrations exceeding tolerable levels.

The submittals shall satisfy the specifications and at a minimum contain the above information as provided to the Contractor's Quality Verification Engineer.

Monitoring

The Contractor shall take readings during driving of each pile. As a minimum, the readings should be taken and recorded during the first 6 m of driving and during seating of the pile on the bedrock.

The measured vibrations shall not exceed 50 mm/s (peak particle velocity).

The results shall be submitted to the Contract Administrator after each pile has been driven prior to continuing with the subsequent piles. As a minimum, the pile number, location, set criteria and driving log must be submitted with vibration monitoring results.

If the vibration monitoring results are acceptable, the Contractor may continue with the next piles with readings taken during driving of each pile. The results of subsequent piles should be submitted to the Contract Administrator after each pile has been driven.

If the readings are not within the limits stated above, the Contractor must alter the driving procedures until the vibrations are within acceptable levels. The above process must be repeated for each pile.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION