



September 2009

INITIAL GEO-ENGINEERING DESIGN DRAFT REPORT

HIGHWAY 407 STATION TORONTO-YORK SPADINA SUBWAY EXTENSION

Submitted to:
Toronto Transit Commission
TYSSE Department
5160 Yonge Street, 11th Floor
Toronto, Ontario, M2N 6L9

CONTRACT NO. A85-77



Toronto-York Spadina
Subway Extension

REPORT

Report Number: 08-1111-0039(2340) Ver. B

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October 22, 2009

Project No. 08-1111-0039 (2340)

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**TORONTO-YORK SPADINA SUBWAY EXTENSION
HIGHWAY 407 STATION
CONTRACT NO. A85-77**

Dear Mr. Bidhendi;

Golder Associates Ltd. is pleased to submit the Initial Geo-Engineering Design Draft Report (Ver. B) for Highway 407 Station for your review and comments. The scope of work for this assignment was carried out under Contract No. A85-77 for the Toronto-York Spadina Subway Extension (TYSSE). Thirty-six hard copies and ten CDs (PDF copy) of the draft report are provided as required for your distribution.

For the purpose of this report, the project and initial design information described in this report has been based on the information contained in the base plan and alignments provided by TTC to Golder on February 12, 2009, titled TYSSE Alignment Plan and Profile, drawing No. A0328-G3200. Subsequent to the preparation of Ver. B of this report, a revised alignment was provided by TTC to Golder on July 10, 2009. The information provided on the revised alignment will be incorporated in the Complementary Geo-Engineering Design Report.

In addition, the 10% Conceptual Design Report, Option E2.2 prepared by AECOM, dated May 2009, was reviewed and considered in the preparation of this initial design draft report.

We look forward to continue working with your staff on this project.

Yours truly,

GOLDER ASSOCIATES LTD.



Dave L. Walters, Ph.D, P.Eng.
Geotechnical Engineering Specialist

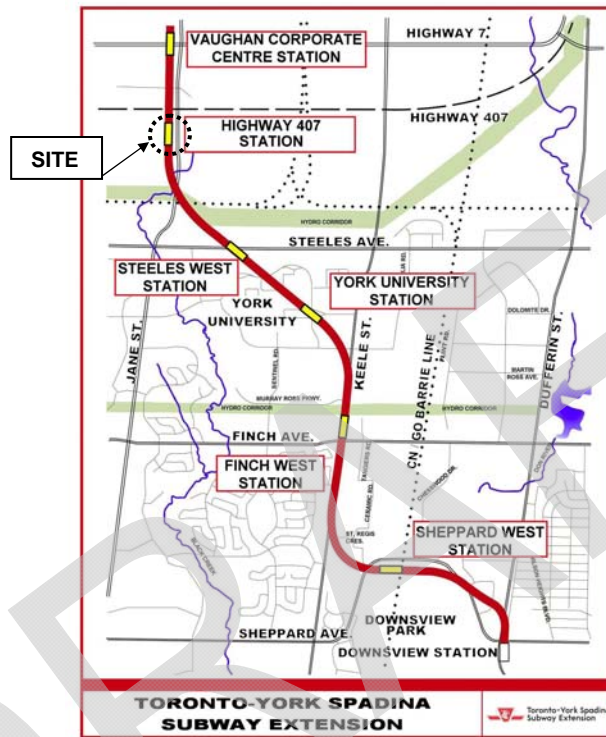
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HIGHWAY 407 STATION TORONTO-YORK SPADINA SUBWAY EXTENSION



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APPENDICES

APPENDIX A

Important Information and Limitations of This Report



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by the Toronto Transit Commission (TTC) to provide geo-engineering services as the Principal Geo-Engineering Consultant (PGEC) for the proposed Toronto-York Spadina Subway Extension (TYSSE) Project that extends from the City of Toronto to the City of Vaughan.

This report focuses on the proposed Highway 407 Station that is west of Jane Street and south of Highway 407. The purpose of this report is to summarise the geotechnical information (soil and groundwater) acquired to date in this area and to provide preliminary recommendations and comments on the geotechnical aspects of the design and construction of the proposed station. Preliminary soil design parameters are provided in this report, together with discussion and comments on relevant aspects such as excavations, methods of ground support and backfilling, as well as management options for soil and groundwater that may be removed during the proposed works.

This report primarily addresses the geotechnical (physical) aspects of the subsurface conditions as encountered at this site. Select soil samples were submitted for analytical testing to assess the environmental quality of the subsurface soil conditions in proximity to proposed excavation areas in order to provide preliminary soil management options for excess materials that will be generated during construction of the proposed Highway 407 Station. In addition, groundwater samples were taken and submitted for analyses to assess the groundwater quality for potential discharge options in the event that dewatering activities will be required during construction. It should be noted that a Phase I Environmental Site Assessment was not conducted as part of this investigation.

This report should be read in conjunction with the "Important Information and Limitations of This Report" provided in Appendix A, following the text of the report. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 PROJECT AND SITE DESCRIPTION

For the purpose of this report, the project and initial design information described in this report has been based on the information contained in the base plan and alignment drawings provided by TTC to Golder on February 12, 2009, titled TYSSE Alignment Plan and Profile, drawing No. A0328-G3200. In addition, it should be noted that the underside elevations of the proposed station box are taken from the 10% Conceptual design Report, Option E2.2 prepared by Aecom, dated June 5, 2009.

2.1 Project Description

The extension to the Spadina Subway line is proposed to extend from the present Downsview Station terminus in Toronto to the proposed Vaughan Corporate Centre Station in Vaughan for a total length of 8.7 km and is proposed to include six (6) new stations.

The proposed subway alignment within the vicinity of Highway 407 Station is located beneath properties owned by Ontario Realty Corporation/Province of Ontario. The location of the project is illustrated on Figure H407-1. It is also understood that the station will be constructed using cut and cover methods and that the subway alignment beneath the existing Highway 407 travelled lanes, the Hydro Corridor and associated towers, and Black Creek will be constructed using machine bored tunnelling methods.

The proposed location and vertical alignment of Highway 407 Station are shown on Figures H407-1 and H407-2. The Highway 407 Station is proposed to be a two level underground concrete box structure, with a platform about 150 m in length. Both the subway platform and the overlying mezzanine levels will be about 20 m wide



and have a total height of about 12 m. The proposed Highway 407 Station platform will be constructed between STA 18+192 and STA 18+342, generally running in a south-north direction on the west side of Jane Street, immediately north of Black Creek. The proposed subway alignment south of the proposed Highway 407 Station will cross beneath several towers within the Hydro Corridor, Black Creek, Canadian National Railway (CNR) and Jane Street, and then beneath Highway 407 and its associated ramps north of the proposed Station. The base of the station box structure will be at about Elevation 174 m, and the top of rail will be at about Elevation 175 m at STA 18+182 at the south end of the box structure and rise to about Elevation 176.5 m at STA 18+341 at the north end of the box structure, providing approximately 5 m to 6 m of soil cover above the station box.

Based on the February 2009 drawings, it is understood that two working shafts for launching of the tunnel boring machines are to be constructed at each end of the station box; however, the construction sequence for this station and connecting tunnels is not known at this time.

It is understood that the proposed Highway 407 Station is to be integrated with the 407 Transitway project and interim GO facilities (including bus terminals, commuter parking lots and passenger pick-up/drop-off area); also portions of the terminal facilities may be constructed over and to the west of the Highway 407 Station box. It is further understood that a bridge structure, extending over Black Creek to provide access to the south portion of the proposed facility access to Jane Street, is to be constructed. Further discussion can be provided under separate cover once design information for the ancillary structures has been confirmed.

2.2 Site Description

The ground surface along the station box varies between about Elevation 190 m and Elevation 196 m, generally sloping downward from north to south.

The proposed station box alignment is located approximately 50 m to 70 m west of Jane Street and will extend from about 15 m south of the Highway 407 W-N/S ramp to about 10 m north of Black Creek. Between these two features, the proposed station box will be constructed primarily beneath an existing agricultural field, with the south portion of the station box extending into the floodplain. This property is currently accessed from Jane Street, south of Black Creek by means of a gravel road. The existing gravel road also travels north along the east side of the field to a residential structure that is located east of the station box, within the proposed limits of the station facility development.

An existing man made pond is located immediately west of Jane Street and adjacent to the proposed location of the Black Creek Bridge, which is located approximately 75 m southeast of the proposed Highway 407 Station. A series of hydro towers are located south of Black Creek, within the proposed tunnelled portion of the alignment.

Most of the underground utilities in the area of the Highway 407 Station are buried along Jane Street, east of the proposed station box; however, a trunk sewer runs northwest/southeast through the agricultural field, in close proximity to the proposed station and associated ancillary structures, and will need to be supported and/or relocated prior to construction.

3.0 SOURCES OF INFORMATION

The documents listed in this report section have been used in developing this report; however, these documents are not to be considered as part of this report, nor should they be considered individually as suitable documents for judging subsurface/excavation conditions at the proposed Highway 407 Station, as some of the reports were developed for other purposes, and none of the reports incorporate all of the data that is available.



3.1 Geotechnical Standards

Subsurface Investigations completed for TTC projects were in general accordance with the TTC Geotechnical Standards, Appendix A, "Direction for Conducting Site investigations". Information gathered from other sources may not have been completed using similar standards.

3.2 Geotechnical Investigation and Interpretive Reports

The documents listed below were prepared for geotechnical investigations carried out in the vicinity of Highway 407 Station; two are unrelated to the TYSSE project. Although these reports were considered in preparation of this report, this report supersedes any interpretive recommendations or conclusions contained within these referenced documents with respect to the TYSSE project.

- Technical Memorandum, Single Well Respond Test, Inspec-Sol Inc., Reference No. T040233-2.0, dated August 6, 2009.
- Draft Geotechnical Factual Data Report, Highway 407 Station – Contract A85-78, Toronto, Ontario, Inspec-Sol Inc., Reference No. T040233-2.0, dated July 2009
- Geotechnical and Hydrogeological Investigation for Proposed Jane Street Sewer, Town of Vaughan, Golder Associates Ltd., Project No. 851-1136, dated September 1985.
- Geotechnical Investigation for Proposed Jane Street Sanitary Trunk Sewer, Town of Vaughan, Ontario, Golder Associates Ltd., Project No. 811-1156, dated September 1981.

3.3 Environmental Assessment Geotechnical Reports

The documents listed below were prepared for environmental assessments related either to projects initiated by the TTC for the Spadina Subway Extension project or to projects related to the York Rapid Transit project, in the vicinity of, or pertaining to, Highway 407 Station. Although these reports were considered in preparation of this report, this report supersedes any interpretive recommendations or conclusions contained within these referenced documents with respect to the TYSSE project.

- Geotechnical Investigation Report, York Rapid Transit Plan, Vaughan North-South Subway Link, Supplementary to Environmental Assessment, Regional Municipality of York, Ontario. Golder Associates Ltd., Report No. 06-1111-040-1, dated January 2007.
- Geotechnical / Hydrogeological Assessment, York Rapid Transit Plan, Vaughan North-South Subway Link, Environmental Assessment, Regional Municipality of York, Ontario. Golder Associates Ltd., Report No. 06-1111-040, dated January 2007.
- Addendum to Report on Geotechnical Investigation, Spadina Subway Extension, Environmental Assessment, City of Toronto, Golder Associates Ltd., Project No. 04-1111-054, dated July 2006.
- Report on Geotechnical Investigation, Spadina Subway Extension, Environmental Assessment, City of Toronto, Golder Associates Ltd., Project No. 04-1111-054, dated January 2006.



3.4 Publications

The following publications provide information on surficial and bedrock geology along the proposed Spadina Subway extension alignment:

- Chapman, L.J. and D.F. Putnam. The Physiography of Southern Ontario, Ontario Geological Survey, Volume 2, 1984.
- Coleman, A.P. The Pleistocene of the Toronto Region (Including the Toronto Interglacial Formation), Ontario Department of Mines, Forty-First Annual Report, Part 7, 1932.
- Karrow, P.F. Pleistocene Geology of the Thornhill Area, Ontario Department of Mines, Industrial Mineral Report 32, 1970.
- Karrow, P.F and White, O. L. Urban Geology of Canadian Cities, Geological Association of Canada Special Paper 42, 1998.
- Rumsey, P.B. & Cooper, I. Trenches in Soil. In: Attewell, P.B. & Taylor, R.K. (eds) Ground Movements and the Effects on Structures, Surrey University Press, pg. 110 – 131, 1984.
- Sharpe, D.R. Quaternary Geology of Toronto and Surrounding Area, Ontario Geological Survey, Geological Series Preliminary Map P. 2204, 1980. Scale 1:100,000.
- Watt, A.K. Pleistocene Geology and Groundwater Resources of the Township of North York, York County. Ontario Department of Mines, Sixty Fourth Annual Report, Volume LXIV, Part 7, 1955.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The Quaternary age deposits of Toronto and York Region consist predominantly of glacial till, glaciolacustrine sand, silt, and clay deposits, and shallow post glacial lacustrine sediments. These deposits were laid down by glacial ice sheets and associated rivers and lakes. Recent deposits of alluvium are found in the river and stream valleys and their flood plains.

The Quaternary soil deposits overlie the Ordovician age bedrock of the Georgian Bay Formation which consists predominantly of shale with interbeds of limestone and siltstone. This bedrock formation is about 250 m thick and has a regional dip to the southeast of about 5 m/km. A deep valley trending northwest-southeast is inferred east and outside the study area. This deep valley would have been eroded in the past by ancient rivers. The overburden thickness is in excess of 50 m in the study area and it is expected that bedrock will be at depths exceeding those necessary for foundations and excavations.

The Quaternary soil deposits are believed to have been deposited over the course of at least two glaciation stages and one interglacial (i.e. warmer) stage. The oldest soil deposits identified in the region are the Illinoian tills which, where present, immediately overlie bedrock. These tills are overlain by interglacial period lacustrine sands, silts, and clays that are, in turn, overlain by the most recent glacial deposits. The significant deposits encountered at the site location and the surrounding York Region include the fine grained soils of the Newmarket Till, Halton Till, Sunnybrook Till and sandy/granular soils from the Thorncliffe, Scarborough and Don Formations.

The majority of the surficial deposits in the study area are believed to have been deposited during the Wisconsinian glacial period. This period saw several glacial advances and retreats. During the glacial advances, till deposits were set down and during retreats, glaciofluvial and glaciolacustrine deposits formed in



meltwater streams and lakes. The Scarborough, Pottery Road and Thorncliffe Formations were formed during the glacial retreats while the Sunnybrook Till and the younger Leaside and Wildfield Tills were formed during ice advances. Numerous small pockets of lake or pond deposits are to be found scattered throughout the till plain in depressions at the till surface. These deposits tend to be concentrated along the edges of the major stream valleys.

The study area is located within the physiographic region known as the Peel Plain. Most of the tableland area consists of till partly modified by the former presence of shallow glacial lakes or post-glacial erosion features (locally existing streams and rivers). The till in the study area is mapped as Halton Till.

The Halton Till is generally considered a fine-grained diamicton with minor fine-grained lacustrine sediments incorporated within the body of the unit, likely from glacial reworking of underlying lacustrine sediments. The Halton Till is typically stiff to hard in consistency, though near the ground surface, weathering can result in it being degraded to consistencies ranging from soft to firm. The Halton Till also contains cobbles and boulders. In some areas, "boulder pavements" can be encountered where boulders are nested or concentrated in a layer within the till unit. Experience on other construction projects in this deposit suggests that boulders may typically form about 0.1 to 0.5 percent of the total deposit volume, though in some areas, boulders can form up to 2 percent of the total deposit volume.

The Oak Ridges Moraine Complex (ORMC) is a well-known and important geologic feature within the region. It is believed that the moraine was formed between the Lake Simcoe and Lake Ontario lobes of regionally extensive glacial ice sheets. In most areas, the ORMC is composed primarily of fine sand, though there are also local deposits of coarse, stratified sand and gravel; these coarse deposits have historically been mined for aggregate/construction uses. In most of the study area, the ORMC has been overridden by the Halton Till and, therefore, may be compact to very dense.

4.2 Highway 407 Station Site Stratigraphy

The initial subsurface investigation for the proposed Highway 407 Station was carried out by Inspec-Sol Inc. (Inspec-Sol) and the factual information from this investigation (i.e. borehole logs, in situ and laboratory testing) is available in Inspec-Sol's factual data report referenced in Section 3.2.

As part of the initial subsurface investigation for the proposed Highway 407 Station, twenty-three (23) boreholes designated as Boreholes 407-001, 407-003 to 407-012, 407-012A, 407-012B, 407-012C, 407-013 to 407-015, and 407-017 to 407-022 were advanced in the vicinity of the proposed alignment at this station site between February 2, 2009 and June 19, 2009. At the locations of Boreholes 407-002 and 407-016, PQ sized coring (PQ) and Pressuremeter Testing (PMT) was carried out. The laboratory testing from the PQ and PMT locations was not complete at the time of preparation of this report, and therefore, will be addressed under separate cover and is not discussed herein.

In addition, Boreholes Y-140 and Y-141 (Golder Report No. 06-1111-040, dated January 2007), and Boreholes 1, 2 and 7, (Golder Report No. 811-1156 dated September 1981) were reviewed during preparation of this report and used to supplement the initial subsurface investigation at this station site. The approximate locations of the boreholes are illustrated on Figure H407-1. The subsurface soil and groundwater conditions encountered in the boreholes, together with the laboratory tests carried out on selected soil samples, are provided in the reports referenced in Section 3.2.

The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling, observations of drilling progress and results of Standard Penetration Tests and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations. It should be noted that the interpreted stratigraphy shown on the cross-sections



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of Figures H407-2 to H407-4 are a simplification of the subsurface conditions. Variation in the stratigraphic boundaries between boreholes will exist and are to be expected. The interpreted stratigraphy also does not necessarily represent a direct borehole to borehole linking of similar soil types. In some areas, borehole off-set distances (away from the center line interpretation), description of soil types on the original boreholes, and overall geologic considerations suggests that a departure from individual sample descriptions on the borehole logs is appropriate for description of the overall geologic deposit. It should be noted that planned future complementary investigation findings may result in changes to the interpreted stratigraphy along the proposed station alignment.

The soil types described on the Record of Borehole sheets found in the factual report (referenced in Section 3.2) and figures in this report are given twelve different classifications and graphical symbols (Types 1 through 12) consistent with the range of soil deposits anticipated to be encountered for subway construction in the Greater Toronto Area. The classification system that has been used on the stratigraphic sections is listed below:

- Fill (Type 1);
- Organics (Type 2);
- Gravel to Sand and Gravel (Types 3 and 4);
- Sand to Silty Sand (Types 5 and 6);
- Sandy Silt to Silt (Types 7 and 8);
- Clayey Silt to Clay (Types 9 and 10);
- Clayey Silt Till (Type 11); and
- Sandy Silt Till (Type 12).

The graphical representations of these material types are supplemented by colour to facilitate visualization of the geologic and material characteristics of the soil deposits. It is to be noted that soil Types 11 and 12 are interpreted as a till deposit (lodgement or basal till) on the basis of their heterogeneous structure, the relatively broad grain size distribution and the documented local geology.

Note that soil Type 3 (gravel) has not been encountered in the vicinity of Highway 407 Station to date, but might be by future investigations. These soil material types have also been grouped together according to the major sedimentary deposits identified along the TYSSE alignment and near the proposed station, as illustrated in Figures H407-2 to H407-4. Within this report, the stratigraphy is defined and described without reference to the regional geologic deposit naming convention and, instead, definition of the major soil deposits is based on the likely geologic origin and grain size distribution and plasticity characteristics. This convention is used to avoid geologic unit classifications based on geologic age or stage of glacial advance. In some instances, geologic nomenclature, although correct in defining the geologic origin and age of a particular deposit, does not necessarily convey indications of material type or potential engineering behaviour. Precedence in this report has therefore been given to naming the different soil units based on relative elevation and grain size composition and plasticity.

The boreholes drilled-to-date in the vicinity of the proposed Highway 407 Station suggest that the site is generally underlain by four major soil deposits, in order of depth – an Upper Till Deposit, an Upper Sand/Silt Deposit, a Lower Till Deposit and a Lower Sand/Silt Deposit. As discussed subsequently, the Upper Till



Deposit and/or Upper Sand/Silt Deposit are overlain by Fill and/or layers of topsoil. The Lower Till Deposit, containing waterbearing lenses and interlayers of sand to silt, is underlain by the Lower Sand/Silt Deposit as evidenced in Boreholes 407-005, 407-011, 407-013, 407-018 and 407-019. Bedrock has not been encountered in the boreholes advanced for the proposed Highway 407 Station.

The following subsections provide further information on the major subsoils encountered in the geotechnical investigation at the proposed station.

4.2.1 Topsoil (Type 2)

Surficial layers of topsoil, approximately 75 mm to 250 mm thick, were encountered at ground surface in all the boreholes except Borehole 407-003, which was advanced near the existing farm access road. The topsoil layers encountered in boreholes advanced in the floodplain were generally less than 150 mm thick, and greater thickness of topsoil were noted within the farmed tableland. The topsoil encountered at these borehole locations were generally underlain by fill materials; therefore the topsoil thicknesses at these locations may not be indicative of the thickness of naturally formed topsoil that would have existed prior to urbanization/agricultural use of the area.

4.2.2 Fill (Type 1)

Heterogeneous fill materials, varying from sand and gravel to silty clay, were encountered at all borehole locations during the initial drilling investigation. The fill materials encountered in boreholes advanced within the existing farm fields contained varying amounts of organic matter including topsoil and rootlets, and is considered to be reworked/disturbed material as a result of past/present farm tilling processes.

The fill materials in twenty-one of the twenty-three boreholes consist of dark brown to brown and grey silty clay to sandy clayey silt containing trace to some gravel, pockets of organic matter including topsoil and rootlets beneath the topsoil. Layers of sandy silt fill were encountered beneath the topsoil at the locations of Boreholes 407-012, 407-012A, 407-012C, 407-013 and 407-019. Wood fragments were also encountered within the fill materials in six boreholes (407-001, 407-003, 407-010, 407-011, 407-013 and 407-015) and pieces of charcoal were noted in Borehole 407-013; with the exception of Borehole 407-003, these boreholes were advanced within the floodplain of Black Creek. Further, approximately 150 mm of sand and gravel fill (granular base) was present at ground surface or beneath a surficial layer of topsoil, at the location of Boreholes 407-003 and 407-007, which were advanced along and adjacent to the existing farm access road, respectively.

The base of the fill was generally encountered between about Elevation 187.9 m and Elevation 194.7 m and the fill thickness ranged from about 0.9 m to 3.1 m.

The Standard Penetration Test (SPT) 'N' values measured within the fill material typically ranged from 2 blows to 27 blows per 0.3 m of penetration, indicating loose to compact relative density for the cohesionless fills and very soft to very stiff consistency for the plastic fills. A single blow count of 58 was recorded in the clayey silt fill in Borehole 407-012C.

An envelope of grain size distribution results on samples of the fill material is presented on Figure H407-5. Measured water contents on samples of the fill generally ranged from about 3 percent to 35 percent. A single water content of about 51 percent was measured in Borehole 407-001, indicative of the presence of organic matter/topsoil. Atterberg limits testing carried out on three samples of the cohesive fill material measured liquid limits between about 23 percent and 40 percent, plastic limits between 16 percent and 23 percent, and plastic indices ranging between about 7 percent and 17 percent, indicating that the cohesive fill materials ranges from a clayey silt to a silty clay of medium plasticity, as shown on Figure H407-6.



4.2.3 Upper Till Deposit

The Upper Till Deposit generally consists of broadly graded soils that range in composition from non plastic silts, containing sand, gravel and trace amounts of clay, to plastic clayey silt to silty clays containing trace to some sand and gravel. Pockets of laminated and more uniformly graded clayey silt and silty clay material were logged in isolated boreholes. These materials appear to have been waterlain, while at a similar depth, nearby boreholes have encountered more heterogeneous soils containing sands and gravels that are more characteristic of till soils. For the purpose of this report, the laminated waterlain cohesive soils have been interpreted as part of the Upper Till Deposit on the basis of their grain size composition and Atterberg Limits test results. The engineering behaviour/ characteristics of these waterlain layers will generally be similar to those other materials that are included as part of the Upper Till Deposit.

The Upper Till Deposit is generally encountered beneath existing fill materials and overlies the Upper Sand/Silt Deposit; however, the Upper Till Deposit is absent at some borehole locations. Where present, the Upper Till Deposit ranged in thickness from about 0.5 m to 4.7 m extends to about Elevation 183.5 m in the floodplain to about Elevation 193 m in the tableland.

The following subsections provide further information on the soils that comprise the Upper Till Deposit.

4.2.3.1 Clayey Silt to Silty Clay Till (Types 9 to 11)

The cohesive portions of the Upper Till Deposit, consists of brown to grey clayey silt to silty clay containing trace gravel, was encountered in Boreholes 407-001, 407-008, 407-010, 407-012, 407-012A, 407-012B, 407-013, 407-017, 407-018 and 407-020 to 407-022 advanced near within Black Creek floodplain and the northern and southern limits of the proposed station site. Oxidation stains were noted on some of the Record of Borehole sheets within the top portion of this deposit.

The SPT 'N' values measured within the stiff to hard cohesive till deposit generally ranged from 11 blows to 70 blows per 0.3 m of penetration; however, a single 'N' value of 90 blows per 0.23 m of penetration was measured in Borehole 407-010. The measured SPT 'N' values generally increase with depth, though lower measurements were noted in the southwest and northeast portions of the site (i.e. Boreholes 407-021 and 407-018).

An envelope of grain size distribution results on samples of the clayey silt to silty clay till deposit is presented on Figure H407-7.

Measured water contents on samples of the plastic portions of the till deposit ranged from about 5 percent to 21 percent. Atterberg limits testing carried out on samples of the cohesive deposit measured liquid limits between about 15 percent and 36 percent, plastic limits between 10 percent and 19 percent, and plastic indices ranging between about 5 percent and 17 percent. The measured water contents were generally near the plastic limit of the tested samples. The envelope of the Atterberg test results, presented on Figure H407-8, classifies the deposit as clayey silt to silty clay of low to medium plasticity.

4.2.3.2 Silty Sand to Silt Till (Type 12)

The Upper Till Deposit also contains slightly to non-plastic zones of grey to brown sandy silt to gravelly sandy silt, containing trace gravel, trace to some clay, sand seams and rock fragments. These non-plastic soils were encountered in Borehole 407-020, at a depth below ground surface and subsequent thickness of about 1.1 m.

Two SPT 'N' values measured within the non-plastic portions of the Upper Till Deposit were 14 and 17 blows per 0.3 m penetration, indicating a compact relative density.



A single water content measured on a sample of the granular portion of the Upper Till Deposit was about 17 percent.

4.2.4 Upper Sand/Silt Deposit

Granular deposits ranging in gradation from silty sand to silt were encountered in the majority of the boreholes advanced at the proposed Highway 407 Station. These granular soils are considered to be interstadial deposits and are referred to collectively as the Upper Sand/Silt Deposit. The Upper Sand/Silt Deposit was generally encountered below the Upper Till Deposit, except west of the station near Jane Street and across the central portion of the proposed station box (as illustrated on Figure A-A', Figure H407-2 and Section C-C', Figure H407-4) where the Upper Sand/Silt Deposit immediately underlies the fill materials. The deposit exhibits significant variation in thickness from less than a metre south of the station to about 10 m in the central portion of the station box.

The Upper Sand/Silt Deposit is comprised of discrete layers/zones of materials exhibiting a broad range of grain size distribution, and in which there is no distinct patterns. Such layers/zones are discussed in the following subsections.

4.2.4.1 Silty Sand (Type 6)

Discontinuous layers of silty sand were noted within the Upper Sand/Silt Deposit in Boreholes 407-011 and 407-020. The silty sand layers were encountered between Elevation 187.1 m and Elevation 190.5 m and the thickness of these layers were about 0.7 m and 1.5 m.

The SPT 'N' values measured within these interstadial layers generally ranged from 16 to 93 blows per 0.3 m penetration, indicating a compact to very dense relative density.

Grain size distribution results carried out on two samples of the silty sand layers within the Upper Sand/Silt Deposit are presented on Figure H407-9.

Measured water contents on two samples of these granular layers generally ranged from about 9 percent and 15 percent.

4.2.4.2 Sand and Silt to Silt (Types 7 and 8)

The majority of the Upper Sand/Silt Deposit, consists of brown to grey sand and silt to sandy silt to silt containing trace to some gravel and clay, which were present in nineteen of the Boreholes (407-001, 407-003, 407-005, 407-006, 407-008 to 407-011, 407-012B, 407-012C, 407-013 to 407-015 and 407-017 to 407-022). These layers ranged in thickness from less than 0.8 m to 10.0 m and extended to an Elevation of 181.0 m in the floodplain to Elevation 193.2 m in the tableland. Boreholes 407-020 and 407-021, located in the south portion of the proposed parking area, were terminated within this deposit.

The SPT 'N' values measured within the interstadial sand and silt to silt layers generally ranged from 10 blows per 0.3 m of penetration to 91 blows per 0.28 m of penetration, indicating a compact to very dense relative density for the sand and silt to sandy silt and/or a stiff to hard consistency for the silt. SPT 'N' values between 6 and 9 were measured within the sand and silt and sandy silt materials at the location of Boreholes 407-003, 407-005 and 407-015. These lower 'N' value results were recorded between Elevation 191.3 m and Elevation 194.4 m, indicating that these zones have a loose relative density. In Borehole 407-001, a single SPT 'N' value of 2 was recorded at an Elevation 181.2 m, which was immediately above a deposit of silty clay.



An envelope of grain size distribution results on samples of the interstadial sand and silt and silt are presented on Figures H407-9.

Measured water contents on samples of the Upper Sand/Silt Deposit generally ranged from about 5 percent to 31 percent. Atterberg limits testing carried out on five samples of sand and silt to silt layers measured liquid limits from 13 percent to 20 percent and plastic limits from 10 percent to 16 percent, corresponding to plastic indices ranging from 2 percent to 4 percent. The envelope of the Atterberg limits test results, presented on Figure H407-10, classify the deposit as a silt of low plasticity.

4.2.5 Lower Till Deposit

The subsurface soils at the site of the proposed Highway 407 Station are predominantly comprised of the Lower Till Deposit that underlies the fill materials and/or Upper Sand/Silt Deposit and extends below the presently anticipated station invert elevation. The Lower Till Deposit generally consists of broadly graded soils that range in composition from non plastic silts, containing sand, gravel and trace amounts of clay, to plastic clayey silt to silty clays containing trace to some sand and gravel. Layers of uniformly graded/laminated clayey silt and silty clay material was logged within the Lower Till Deposit in all boreholes. These materials appear to have been waterlain, while at a similar depth, nearby boreholes have encountered more heterogeneous soils containing sands and gravels that are more characteristic of till soils. For the purpose of this report, the laminated waterlain cohesive soils have been interpreted as part of the Till Deposit on the basis of their grain size composition and Atterberg limits test results. The engineering behaviour/characteristics of these waterlain layers will generally be similar to those other materials that are included as part of the Lower Till Deposit. The Lower Till Deposit also contains, at depth, pockets and layers of interstadial gravelly sand to sandy silt to silt (Type 4 through Type 8). The thicknesses of these discontinuous layers are generally between about 0.6 m and 3.1 m.

The following subsections provide further information on the soils that comprise the Lower Till Deposit, including the characteristics of the cohesionless interstadial layers within the Lower Till Deposit.

4.2.5.1 Clayey Silt to Silty Clay Till (Types 9 to 11)

The Lower Till Deposit consists of brown to grey broadly graded clayey silt to silty clay containing trace to some sand and gravel, was encountered in all the boreholes (except Boreholes 407-012, 407-012A, 407-020 and 407-021) advanced in the vicinity of Highway 407 Station. The Lower Till Deposit was generally encountered at about Elevation 180.5 m in the floodplain and Elevation 193.4 m in the tableland and extended to about Elevation 155.3 m. All boreholes terminated within this deposit, except for Boreholes 407-005, 407-011, 407-013, 407-018 and 407-019. In these boreholes, the Lower Till Deposit was about 27.2 m to 36.7 m thick and extended to depths of 32.8 m to 39.2 m below ground surface, which corresponds to elevations ranging from 156.4 m to 157.2 m.

The SPT 'N' values measured within the very stiff to hard cohesive till deposit generally ranged from 16 blows per 0.3 m of penetration to over 60 blows per 0.08 m of penetration, typically increasing with depth. A single SPT 'N' value of 0 blows was measured in Borehole 407-019 at a depth of 32.2 m below ground surface at the interface between the cohesive till (Type 10) and underlying silt and sand deposit (Type7); this measurement may be indicative of soil disturbance during augering or disturbance from seepage gradients.

An envelope of grain size distribution results on samples of the clayey silt to silty clay till deposit is presented on Figure H407-11.

Measured water contents on samples of the plastic portions of the till deposit ranged from about 7 percent to 33 percent. Atterberg limits testing carried out on samples of the cohesive deposit typically measured liquid



limits between about 22 percent and 47 percent, plastic limits between 13 percent and 27 percent, and plastic indices ranging between about 8 percent and 23 percent. However, two Atterberg limits tests from Boreholes 407-003 and 407-005 measured higher liquid limits of 49 and 50 percent, plastic limits of 21 and 22 percent and corresponding plasticity indices of 28 and 37 percent. The measured water contents were generally near the plastic limit of the tested samples. The envelope of the Atterberg limits test results, presented on Figure H407-12, classifies the deposit as a clayey silt to silty clay of low to medium plasticity.

4.2.5.2 Silty Sand to Silt Till (Type 12)

The Lower Till Deposit also contains slightly to non-plastic zones of brown to grey sandy silt to gravelly sandy silt, containing trace gravel, trace to some clay, sand seams and rock fragments. These non-plastic soils were encountered in Boreholes 407-004, 407-007 and 407-008, between Elevation 191.3 m and Elevation 185.3 m.

The SPT 'N' values measured within the non-plastic portions of the till deposit generally ranged from 25 blows per 0.3 m penetration to 85 blows per 0.28 m penetration, typically increasing with depth, indicating a compact to very dense relative density.

Three grain size distribution analyses results on samples of the silty sand to sandy silt till deposit are presented on Figure H407-13.

Measured water contents on samples of the granular portions of the till deposit generally ranged from about 7 percent to 15 percent.

4.2.5.3 Interstadial Sands to Silts (Types 4 and 6 to 8)

Interstadial layers of sands to silts within the Lower Till Deposit were encountered within the general footprint area of the excavation, between about Elevation 171.3 m and Elevation 188.4 m, and the various soil types making up the interstadial sands to silts are summarized below.

4.2.5.3.1 Interstadial Gravelly Sand (Type 4)

An interstadial granular layer consisting of grey gravelly sand containing some silt was encountered in Borehole 407-017. The granular layer was encountered between Elevation 185.3 m and Elevation 188.4 m and was about 3.1 m in thickness

Two SPT 'N' values measured within this layer were both 50 blows per 0.08 m penetration, indicating very dense relative density.

A single grain size distribution analysis was carried out on this material and is illustrated on Figure H407-14. The measured water contents on the two samples of gravelly sand were 5 and 7 percent.

4.2.5.3.2 Interstadial Silty Sand (Type 6)

Interstadial granular layers consisting of grey silty sand containing trace to some gravel and trace clay was encountered within the Lower Till Deposit in Borehole 407-009. The silty sand layer was about 3 m thick and extended to an Elevation of 182.1 m at this borehole location.

Two SPT 'N' values measured within this interstadial layer were 36 blows per 0.3 m penetration and 98 blows per 0.28 m penetration, indicating a very loose to very dense relative density.



A single grain size distribution result on a sample of the interstadial sand and silty sand are presented on Figure H407-14.

Measured water contents on samples of these granular layers generally ranged from about 7 percent to 15 percent.

4.2.5.3.3 Interstadial Sand and Silt to Silt (Types 7 and 8)

Interstadial layers of brown to grey sand and silt to sandy silt to silt containing trace to some gravel and clay, were encountered within the Lower Till Deposit in Boreholes, 407-006, 407-010 and 407-011. These interstadial layers ranged in thickness from about 0.9 m to 1.6 m and extended to an Elevation of 171.3 m in the floodplain to about Elevation 182.6 m in the tableland.

The SPT 'N' values measured within the interstadial sand and silt to silt layers generally ranged from 41 to 46 blows per 0.3 m of penetration, indicating a dense relative density for the sand and silt to sandy silt and/or a hard consistency for the silt.

Three grain size distribution results carried out on samples of the interstadial sand and silt and silt are presented on Figures H407-14.

Measured water contents on samples of these interlayers generally ranged from about 18 percent to 23 percent. A single Atterberg limits test carried out on a sample of sandy silt from Borehole 407-006 measured a liquid limit 13 percent, a plastic limit of 11 percent, and a corresponding plastic index 2 percent, as shown on Figure H407-15.

4.2.6 Lower Sand/Silt Deposit (Types 4 to 8)

A Lower Sand/Silt Deposit, consisting layers of sand to silt underlies the Till Deposit. The deposit was only encountered in deep Boreholes 407-005, 407-011, 407-013, 407-018 and 407-019; however, it is believed that the Deposit underlies the entire site. The top of this granular deposit was encountered between Elevation 156.4 m and Elevation 157.2 m, and extended to the bottom of all boreholes in which it had been encountered. All other boreholes in the vicinity of Highway 407 Station were terminated at about Elevation 157 m or higher, prior to encountering the Lower Sand/Silt Deposit. The Lower Sand/Silt Deposit is about 17 m below the proposed station base level.

The Lower Sand/Silt Deposit generally consist of grey sand and silt and was encountered at about Elevation 156.4 to 157.2 m in Boreholes 407-5, 407-011, 407-013, 407-018 and 407-019. All five boreholes were terminated in this deposit, extending up to 15.8 m into the Lower Sand/Silt Deposit. Boreholes 407-018 and 407-019 encountered subsequent interlayers of grey gravelly sand, silt, grey silty clay and grey silty sand, in which the borehole was terminated. These interlayers were encountered between Elevation 150.0 m and 143.6 m and ranged in thickness from 1.2 m to 2.8 m.

The SPT 'N' values measured within these layers were typically between 45 blows per 0.3 m penetration to 99 blows for less than 0.3 m of penetration, indicating a very dense relative density.

A total of six grain size distribution analyses were carried out on the variable Lower Sand/Silt Deposit and are presented on Figure H407-16 as individual curves as well as a general envelope to encompass soil types 5, 6 and 7.

Further, a single grain size distribution analysis, as illustrated on Figure H407-17, was carried out on the cohesive layer within the Lower Sand/Silt Deposit. Three Atterberg limits tests were also carried out on samples



of the cohesive clayey silt to silty clay layers within the Lower Sand/Silt Deposit from Boreholes 407-018 and 407-019, and measured liquid limits of 30 to 36 percent, plastic limits ranging from 17 to 25 percent, and plasticity indices of 13 to 18 percent, as shown on Figure H407-18.

4.3 Highway 407 Station Hydrogeology

The proposed Highway 407 Station is located about 10 m north of Black Creek. General drainage of the study area is toward Black Creek via tributary streams. The hydrogeology within the glacial deposits of the area can be relatively complex. The lower permeability glacial till layers tend to impede groundwater flow and downward seepage whereas, the Lower Sand/Silt Deposit provides for underdraining well below the base of the structure.

As indicated from the shallow monitoring wells (installed above Elevation 181 m), the interpreted groundwater levels within the Upper Sand/Silt Deposit vary between 189 m and 195 m. The groundwater elevation in the Lower Sand/Silt Deposit is significantly lower, at about Elevation 173 m. The Lower Sand/Silt Deposit provides underdrainage for the entire site and is responsible for downward seepage gradients that are present through the Lower Till Deposit.

Monitoring wells were not installed between Elevation 156.2 m and Elevation 167.0 m during the initial investigation study because granular deposits were not encountered at the borehole locations in this elevation range. However additional monitoring wells are planned to be installed within this zone during the complementary investigation to fill the “gap” in groundwater pressure distribution.

The water levels measured between June 25, and August 13, 2009 in the piezometers/wells of boreholes installed at the proposed Highway 407 Station site are summarized below:

Borehole Number	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Soil Deposit at Screen Level	Date Measured
407-001	189.07	8.79	180.28	Lower Till	June 25, 2009
		2.56	186.51	Upper Sand/Silt	June 25, 2009
407-003	195.65	4.66	190.99	Upper Sand/Silt	June 30, 2009
407-004	195.23	0.93	194.3	Lower Till	June 30, 2009
407-005	195.68	20.53	175.15	Lower Sand/Silt	June 25, 2009
407-006	195.85	3.54	192.31	Interstadial Sand/Silt	June 30, 2009
407-007	192.16	14.42	177.74	Lower Till	May 21, 2009
407-008	190.89	9.78	181.11	Lower Till	June 25, 2009
407-009	193.78	2.46	191.32	Interstadial Sand/Silt	June 25, 2009
		1.89	191.89	TILL Deposit	June 25, 2009
407-010	189.08	12.39	176.69	Lower Till	June 30, 2009
		1.29	187.79	Upper Till	August 13, 2009
407-011	189.6	15.62	173.98	Lower Sand/Silt	June 25, 2009
		-0.7	181.86	Lower Till	August 13, 2009



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Borehole Number	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Soil Deposit at Screen Level	Date Measured
407-012	190.33	0.57	189.76	Upper Till	June 25, 2009
407-012A	189.91	2.76	187.15	Upper Till	June 25, 2009
407-012B	189.81	0.61	189.2	Upper Sand/Silt	June 25, 2009
407-012C	189.89	0.66	189.23	Upper Sand/Silt	June 25, 2009
407-013	190.08	14.88	175.2	Lower Sand/Silt	August 13, 2009
		5.09	184.99	Lower Till	June 25, 2009
		0.25	189.83	Upper Till	June 25, 2009
407-014	194.32	7.6	186.72	Lower Till	June 25, 2009
407-015	195.96	23.59	172.37	Lower Till	August 13, 2009
407-017	195.64	13.4	182.24	Lower Till	June 30, 2009
		0.99	194.65	Interstadial Sand/Silt	June 30, 2009
407-018	196.39	23.59	172.8	Lower Sand/Silt Deposit	May 21, 2009
407-019	189.46	15.99	173.47	Lower Sand/Silt	June 30, 2009
		15.63	173.83	Lower Sand/Silt	June 30, 2009
407-020	193.56	3.36	190.2	Upper Sand/Silt	May 21, 2009
407-021	192.53	0.47	192.06	Upper Sand/Silt	May 21, 2009
407-022	195.25	0.67	194.58	Lower Till	May 21, 2009

All water levels measured to date in the monitoring wells installed during the initial investigation are available in the Draft Factual Report referenced in Section 3.2. Monitoring well installations and water level measurements are shown on the interpreted stratigraphic profiles on Figures H407-2 to H407-4.

The interpreted groundwater levels in the Upper Sand/Silt Deposit and the Lower Sand/Silt Deposit are illustrated on Figures H407-2 to H407-4. Groundwater pressure conditions for preliminary station design, as illustrated on Figures H407-19 and H407-20, should be considered hydrostatic and can be calculated by multiplying the depth of any point below the interpreted groundwater level (plus 2 m to account for seasonal fluctuations and uncertainty in the short term data) by the unit weight of water (9.8 kN/m^3).

Perched groundwater levels are expected in the fill soils above the Upper Till Deposit and or Upper Sand/Silt Deposit. It should be expected that the groundwater level along the alignment will be subject to seasonal fluctuations, particularly the perched levels in the fills during spring flows and precipitation events.

A total of ten single well response tests were conducted at the Highway 407 Station site at the monitoring wells in Boreholes 407-001, 407-003, 407-005, 407-011A, 407-012, 407-013B, 407-017A, 407-018, 407-019A and 407-020. The results of these tests are presented in the technical memorandum dated August 6, 2009, referenced in Section 3.2. It should be noted that the calculated hydraulic conductivity values are only representative of the general soil mass between the top and bottom elevations of the sand-pack around the well



screen or piezometer and for a limited distance within the soil deposit. The calculated hydraulic conductivity values should only be considered an indicator of the formation hydraulic properties and not a definitive measure of the overall formation behaviour. Layers of coarse material within this zone may unduly influence such tests and for final design and prior to construction, field pumping tests should be conducted in any areas in which dewatering or groundwater flow issues may be critical.

A total of two single well response tests conducted within the Till Deposit suggested hydraulic conductivity of about 1.8×10^{-6} cm/s and 9.6×10^{-4} cm/s with an average of about 1.4×10^{-6} cm/s. The results of three tests carried out within the Interstadial Sands and Silts suggested hydraulic conductivity of about 3.3×10^{-4} cm/s to 2.7×10^{-5} cm/s with an average of about 1.4×10^{-4} cm/s. The results of the three tests carried out within the Lower Sand/Silt Deposit suggested hydraulic conductivity of about 1.5×10^{-4} cm/s to 4.7×10^{-5} cm/s with an average of about 3.7×10^{-4} cm/s. interstadial sand/silt layers suggested hydraulic conductivity of about 5.4×10^{-3} cm/s and 3.0×10^{-2} cm/s with an average of about 3.7×10^{-4} cm/s.

4.4 Subsurface Hazards

Some geological and hydrogeological conditions at the Highway 407 Station site could create potentially difficult or hazardous situations during construction. Special consideration should be given in the design to ensure that these potentially hazardous conditions are successfully overcome.

4.4.1 Cohesionless Sands and Gravels

The Upper Sand/Silt Deposit and cohesionless soil lenses and layers within the Lower Till Deposit will be penetrated by excavations for the station. These lenses are comprised of narrowly-graded granular soils. Flowing soil conditions, with associated ground loss and surface settlement, may occur in these soils unless groundwater control is in place and fully operating prior to excavating through the deposits.

4.4.2 Boulders

Boulders are commonly encountered in the overburden soils of Southern Ontario. Boulders and cobbles were not sampled or cored in the boreholes advanced at the site; however, instances of auger grinding were recorded in at least two boreholes during the drilling and it is inferred that the Till and/or Upper Sand/Silt Deposits contain cobbles and boulders at this site. The specific presence of boulders can significantly affect the selection of equipment and progress of construction works.

During construction of the Sheppard Subway Line, the size and frequency of boulders that could be encountered along the alignment were estimated based on correlation of field data from an early construction contract with borehole information; the estimates were later verified based on actual field observations. This method has shown to be a reasonable means of estimating the quantity of boulders that could be anticipated in similar glacial deposits.

The borehole information in the area of Highway 407 Station documented significantly fewer instances of auger grinding and other indications of cobbles and boulders than did the borehole investigations for the Sheppard Subway. This suggests that there will be fewer boulders encountered during construction of this station than was typical for the Sheppard Subway construction. However, there is yet no experience with deep excavations where boulder occurrences have been quantified in this area and the till soils are similar in origin to those at the Sheppard Subway. Therefore, for planning purposes it is considered appropriate to use the average boulder data for the Sheppard Subway Line. The average Boulder Volume Ratio (BVR is the ratio between volume of



boulders and the volume of soil excavated) for till soils was 0.22 percent and the Boulder Number Ratio (BNR is the number of boulders to make up one (1) cubic meter of boulders) was 11.3 per cubic metre.

Based on the above, for an excavated volume of 1000 cubic metres, approximately 25 boulders could be anticipated. The maximum recorded size of boulders found in the Toronto area soils has been about 3 m in maximum dimension.

4.4.3 Organic Vapour Concentrations

In general, the findings reveal that there were no obvious visual or olfactory indications of significant contamination in the fill materials and native soil samples obtained from Boreholes 407-001, 407-003 to 407-015, and 407-017 to 407-022. We note however that some localized debris / aesthetic contaminants were encountered in some of the boreholes, as described in Section 5.2.

Soil vapour “headspace” testing was carried out on the majority of the soil samples using a photoionization detector (PID) (mini-RAE™, calibrated to isobutylene). The organic vapour concentrations are presented on the borehole logs of the July 2009 Draft Geotechnical Factual Data Report (Report No. T040233-2.0).

The results of the soil vapour testing indicate that measurable soil gas concentrations in the fill and native materials were generally less than 10 parts per million (ppm), which are low and considered not of significance.

In order to assess the potential for the presence of methane gas, the existing monitoring wells and future drilling operations will be specified to be screened using a combustible gas instrument (i.e., Gastector). While instances of methane gas in the natural soil strata have not been encountered during the TYSSE investigation, naturally occurring methane has been found in the Toronto Area, although it is considered to be a very rare occurrence.

Both methane and gasoline vapours can form an explosive mixture with air should there be a sufficient accumulation of vapours, and are a potential hazard for excavation and construction work. Care should be taken to avoid creating areas in temporary or permanent structures where there is no air movement, as this could lead to an accumulation of gas. It should be noted that changes in groundwater pressure, which may be caused by dewatering or seepage into underground spaces, can lead to migration of gaseous or dissolved methane or hydrocarbons. Therefore, the current absence of organic vapours in a particular area should not be construed to indicate that there is no risk of its presence in the future. Air monitoring and adequate ventilation may be required during and after construction.

5.0 MAN-MADE FEATURES SIGNIFICANT TO DESIGN AND CONSTRUCTION

5.1 Existing Structures and Utilities

The subway alignment is proposed to continue northward from the crossover tracks of the future Steeles Subway Station, under the existing CNR (Halton) tracks, towers in the hydro right-of-way, Black Creek and its two tributaries, and Highway 407, and will terminate north of Highway 7.

There are no buildings or structures immediately above the proposed Highway 407 Station; however, there is a residential building located immediately east of the proposed station which, is assumed to be removed prior to construction of the station and the ancillary structures.

Numerous utilities are buried at the site, generally located within the Jane Street allowance; some of these will be relocated as part of the construction works, while others may remain near the excavation limits. It is



understood that a trunk sanitary sewer runs northwest/southeast through the agricultural field and is located in close proximity to the proposed station and will require be supporting and/or relocating during construction. It will be necessary to assess the impact of the excavation and shoring work on nearby structures and utilities, including relocated and new utilities, that are within the zone of influence (as defined in the TTC Design Manual) of the proposed works.

5.2 Subsurface Contaminants

A preliminary assessment of the environmental quality of the subsurface soil and groundwater conditions in relation to applicable environmental regulations was carried out for the Highway 407 Station to help identify the potential of encountering subsurface contaminants and to provide management options for excavated materials that will be generated during construction.

For characterization purposes, select soil samples were obtained within the anticipated excavation depths, and groundwater was sampled from above and below the proposed station invert depth; these samples were analyzed for a list of commonly expected contaminants, as discussed in Section 5.2.2.

Soil management strategies could include re-use of excavated materials on-site, transfer of excess soils to a site requiring fill, or disposal of excess material to a licensed facility. It is anticipated that groundwater from dewatering activities (should it be necessary) will be discharged to the municipal sewer system.

The predominant soil types encountered during this investigation included surficial ground coverings (i.e., topsoil, vegetation, granulars) and fill materials overlying native soils comprising glacial till deposits, with interstadial gravelly sand, and sandy silt to silt layers. As previously mentioned, the above native soil types have been grouped together according to the major sedimentary deposits identified along the TYSSE alignment and near the proposed station and include an Upper Till Deposit, an Upper Sand/Silt Deposit, a Lower Till deposit and a Lower Sand/Silt Deposit. The Lower Sand/Silt Deposit will not be encountered within the excavation depth for the proposed station.

Fill soils were encountered in all boreholes drilled and primarily included different layers of brown and grey clayey silt, sandy silt and/or sand and gravel which extended from near grade to depths of approximately 0.9 m to 3.1 m below the ground surface (bgs). Typically, the fill material contains organic matter (i.e., topsoil, rootlets), particularly in boreholes advanced within the existing farm fields. Debris / deleterious materials (i.e., wood pieces and possibly black organic matter) were encountered within the fill materials in Boreholes 407-001, 407-003, 407-010, 407-011, 407-012, 407-013 and 407-015. Charcoal pieces were noted within the fill in Borehole 407-013.

In Boreholes 407-001, 407-011, 407-013 and 407-019, black "staining" was noted on the boreholes logs within the native soils below depths of approximately 2 m and 19 m bgs, with the Upper and Lower Till Deposits.

In general, the findings reveal that there were no obvious visual or olfactory indications of chemical contamination in the soil or groundwater samples obtained from Boreholes 407-001, 407-003 to 407-015 and 407-017 to 407-022, with the exception of possible black organic matter / staining in the fill and native soil samples, noted above. Organic vapour headspace testing indicates that measurable soil gas concentrations in the fill and native materials were not considered high enough to suggest significant contamination by organic compounds.

The samples analysed in this investigation were tested to screen for a suite of general parameters. Impacted soils and groundwater identified from this investigation, or during construction, may require special handling and disposal at licensed landfill facilities. Preliminary management strategies for impacted materials are present in Section 9.0.



5.2.1 Applicable Regulatory Standards

Soil and groundwater quality standards provided under Ontario Regulation 153/04 in the Ontario Ministry of the Environment's ("MOE") document "*Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*", March 2004, were used to assess the site data.

The "site" for the proposed station is classified as a "sensitive site" under Ont. Reg. 153/04 due to the presence of a surface water body (i.e., Black Creek) that is located near the southern portion of the proposed station. It is understood that the creek will be realigned to accommodate construction of the proposed station. However, the final alignment of the creek has not been finalized at the time of this report, and therefore, the entire "site" was considered as a "sensitive site" for purposes of environmental characterization of the soil and groundwater at this time. As a result, the analytical data was compared to the MOE's Table 1 (Background Quality) Standards, as discussed below.

5.2.1.1 Soil Quality

a) Re-Use of soil on site / Removal of excess soil off site

To assess the potential for re-using the soil on site or transferring excess soils off-site to a property requiring fill, the analytical results were compared with the full-depth background Site Condition Standards provided in Table 1 (for non-agricultural property use) of the March 2004 MOE Document. These soil standards are considered background values derived from the Ontario Typical Range values for the specified land uses and are considered by the MOE to be representative of upper limits of typical province-wide background concentrations in soils that are not contaminated by point sources. Where no values are available under the Table 1 Standards, the results of chemical analyses were compared to the respective Table 2 Full Depth Generic Site Condition Standards in a potable Ground Water Condition for commercial/industrial/community property uses.

b) Landfill Disposal

For disposal of excess material to a licensed landfill facility (i.e., for material that is considered to be waste, and/or has Table 3 exceedances), the results of leachate analyses that was carried out in accordance with Ontario Regulation 347 (as amended by Ontario Regulation 558/00) were compared to the Schedule 4 Criteria provided under the Regulation in order to characterize the waste materials.

In summary, if soil is to be transferred to another site as inert fill, the MOE generally requires that the analytical data for the excess soil meet MOE's Table 1 standards provided in the document entitled "*Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act* (MOE, March 2004). We note that on a case by case basis the MOE does allow the transfer of excess soil which meets Table 2 or Table 3 standards. Consultation with the MOE should be carried out prior to construction to ensure their concurrence with the management strategy for the large volume of materials that will be generated during construction. However, at this point we have assumed that Table 1 is the benchmark standard and will apply to soils being transferred to another site or for soil to be re-used on site for engineering purposes.

In October 2008, MOE released proposed revised soil and groundwater standards for public review. Although the revised standards are not in effect, the analytical data were also compared with these standards to allow potential environmental implications of the soil conditions at the site to be understood, in case the revised standards are adopted.



5.2.1.2 *Groundwater Quality*

- a) To assess the general quality of the groundwater conditions at the site for indication of possible contaminants, the data was compared to the MOE Table 1 standards.
- b) For potential discharge of groundwater related to possible dewatering measures, the groundwater analytical results were compared to the discharge limits of Vaughan's Sanitary and Storm Sewer Discharge Guidelines By-Law 1140-82, dated 1982.

5.2.2 **Chemical Testing Protocol**

A total of fifty-two (52) soil samples obtained from the boreholes (Boreholes 407-001, 403-003 to 407-015, and 407-017 to 407-022) advanced for the Highway 407 Station initial investigation were selected for analysis. Thirty-nine (39) bulk soil samples representative of different soil types including fill materials and native soils were submitted for analyses of select metals and inorganic parameters in accordance with the March 2004 MOE Document. Sixteen (16) bulk soil samples were analysed for petroleum hydrocarbons (PHCs) fractions (F₁ to F₄), Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) and polycyclic aromatic hydrocarbons (PAHs). Eleven (11) soil samples were submitted for analyses of volatile organic compounds (VOCs)

For waste classification purposes for possible landfill disposal, three (3) soil samples were submitted for leachate analyses of metals and inorganic compounds, ignitability, PCBs, and VOCs in accordance with Ontario Regulation 347 (as amended by Ontario Regulation 558/00). The three (3) samples consisted of sandy silt, silty clay and till materials that were obtained within the proposed excavation depths from Boreholes 407-005 (Fill/Upper Sand-Silt/Lower Till), 407-010 (Lower Till) and 407-011 (Lower Till). These samples consisted of composites to analyse samples representative of proposed excavated materials that will inherently be mixed during excavation.

The distribution of soil samples submitted for analytical testing to provide representation of the major soil types are summarized below:



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Major Soil Type	Inorganic Testing (pH, Metals)	Organic Testing (One or more of PHCs, BTEX, PAHs, PCBs, VOCs)	Leachate Testing (TCLP)
Fill	6	0	0
Fill / Upper Till / Upper Sand - Silt	5	0	0
Fill / Upper Sand - Silt / Lower Till	0	0	1
Upper Till Deposit	0	0	0
Upper Sand - Silt	3	1	0
Lower Till Deposit (incl. Interstadial Layers)	23	14	2
Lower Sand - Silt	2	2	0

It is noted that eight (8) of the above samples were submitted from zones where drilling procedures changed from hollow stem augers to rotary drilling techniques (due to difficult drilling conditions) in order to advance the boreholes to the required depths. In particular, samples prior to and immediately following the utilization of rotary drilling (with the possible use of water and/or drilling mud) were analysed for a host of parameters to verify that the introduction of drilling mud or water was not adversely impacting the environmental quality of the retained soil samples. In general, this comparison testing indicates that the drilling mud did not affect the chemical test results, however as is discussed subsequently, it is possible that the mud may be responsible for marginal concentrations of petroleum hydrocarbon (F_1 fractions) being measured in one borehole at depth.

Four (4) groundwater samples from monitoring wells in Boreholes 407-003, 407-006, 407-012 and 407-015 were collected and submitted for analyses of Vaughan's Sanitary and Storm Sewer Discharge By-Law 1140-82. In order to obtain a general understanding of the groundwater chemistry in the area of the proposed station, twelve (12) groundwater samples were submitted for the analysis of pH and metals, PHCs/BTEX, PCBs and VOCs. In addition, two (2) of these groundwater samples were submitted for the analysis of alcohols from monitoring wells in Boreholes 407-006 and 407-009B to assess the potential for groundwater contamination caused by embalming fluids originating from the adjacent cemetery.

The chemical testing protocol for the above analyses is presented in Table 1 and Table 2 of the July 2009 Draft Factual Data Report prepared by Inspec-Sol Inc., which summarises the sample location and depth, media type and selected analyses.

5.2.3 Results of Analytical Data

Certificates of Analysis for the chemical testing carried out for this investigation are included in Appendix C of Inspec-Sol Inc.'s July 2009 Draft Geotechnical Factual Data Report. For comparison purposes, the available MOE Table 1 Standards, Regulation 347/558 Criteria, and Limits of Vaughan's Sanitary and Storm Sewer Discharge By-Law 140-82 have been provided on the summary tables for the respective bulk, leachate and groundwater analyses, with highlighted values denoting resulting concentrations above the respective standard/limit.



5.2.3.1 Soil Analysis

Based on the analytical results and the standard comparison, the concentrations of all of the tested parameters of soil samples submitted for analysis met MOE's Table 1 Background Standards, with the exception of barium concentrations in two samples of the Lower Till Deposit from Borehole 407-008 (15.2 m to 15.9 m depth) and Borehole 407-018 (22.9 m to 23.5 m depth). The measured barium concentrations were 238 µg/g and 274 µg/g, respectively, which are above the MOE Table 1 Standard (210 µg/g for 2004, and 220 µg/g for the proposed 2008 standard). It is noted that these concentrations meet MOE's Table 2 Standards (2,000 µg/g for 2004, and 670 µg/g for the proposed 2008 standard).

In addition, two (2) samples that were submitted from Borehole 407-017 (depths of 7.6 to 7.8 m bgs and 9.2 to 9.4 m bgs) due to a change in drilling procedures (i.e., adding of water and bentonite) had naphthalene levels of 0.12 µg/g to 0.18 µg/g, respectively. These concentrations are slightly above MOE's current (2004) and proposed (2008) Table 1 Background Site Condition Standard of 0.09 µg/g, but are below the 2004 and proposed 2008 MOE Table 2 Standards of 4.6 µg/g and 17 µg/g. Given that naphthalene levels were not detected in the other fourteen (14) samples tested, these concentrations may be considered an anomaly. Additional PAH testing will be conducted at this depth interval during complementary investigations to verify if these naphthalene results are anomalous.

No PHCs or BTEX parameters were detected in the sixteen (16) samples tested with the exception of PHC F₁ fractions of 6.1 µg/g in a sample from Borehole 407-019 (34.4 m to 34.5 m bgs). This sample was collected after changing the drilling method from hollow stem augers to mud rotary drilling techniques. There are no 2004 MOE Table 1 standards for PHCs in soil, however it is noted that the concentration is below the proposed 2008 Table 1 standard of 10 µg/g. The concentrations are well below the Table 2 Standard for PHC F₁ of 230 µg/g.

No VOCs were detected in the eleven (11) samples tested for these parameters.

No PAH parameters were detected in twelve (12) of the sixteen (16) samples tested. Slightly elevated levels of naphthalene were measured in two (2) of the samples tested, as indicated above; and, the following PAH parameters were detected in four (4) other soil samples, although the concentrations are well below the 2004 Table 1 standards. A benzo(a)anthracene concentration of 0.02 µg/g was reported at the laboratory detection limit in a sample from Borehole 407-006 (6.1 m to 6.5 m depth); fluorene and/or phenanthrene and pyrene (0.02 µg/g, 0.02/0.04 µg/g and 0.02 µg/g respectively) were detected at or slightly above the detection limits in two (2) samples from Borehole 407-017 (7.6 m to 7.8 m, and 9.2 m to 9.4 m depth); and, benzo(g,h,i)perylene was detected at the detection limit (0.02 µg/g) in a sample from Borehole 407-015 (15.2 m to 15.9 m depth). The slight detections are considered to be within general laboratory analytical precision limits.

Should the proposed 2008 standards be adopted, there would be no further exceedances for the samples tested.

It is noted that select native soil samples of the Lower and Upper Till Deposits exhibited black discoloration. No testing of these samples for organic parameters was conducted during this investigation. However, the results of previous testing that were conducted in the general area of the Sheppard, York University and Steeles West Stations has indicated that the black discoloration at depth is considered to be naturally occurring and is not a contaminant.

5.2.3.2 Leachate Analysis

The results of the three (3) leachate analyses on composite soil samples from Boreholes 407-005, 407-010 and 407-011 met the respective Schedule 4 criteria provided under Ontario Regulation 347, and the material was not ignitable.



5.2.3.3 Groundwater Analysis

Four (4) groundwater samples were collected from Boreholes 407-003 (screen tip at 10.7 m depth), 407-006 (screen tip at 12.6 m depth), 407-012 (screen tip at 4.4 m depth) and 407-015 (screen at 26.0 m depth) and submitted for analysis of Vaughan's Sanitary and Storm Sewer Discharge Guidelines By-Law 1140-82 dated 1982. A review of the chemical test results indicates that the concentrations met the respective limits for sanitary sewer discharge with the exception of total suspended solids (TSS) levels of 6,350 mg/L in a groundwater sample from Borehole 407-015 that exceeded the Sanitary Sewer By-Law Limit of 600 mg/L (and the storm limit of 15 mg/L). It should be noted that is a function of how the test wells were developed and sampled.

The concentrations in the four (4) groundwater samples met the majority of the storm sewer limits with the exception of the following:

- In addition to the above noted sanitary exceedence, TSS concentrations in three (3) groundwater samples from Boreholes 407-003, 407-006 and 407-012 of 239 mg/L, 156 mg/L and 103 mg/L were above the storm sewer discharge limit of 15 mg/L;
- Phenols in the groundwater sample from Borehole 407-003 was 0.048 mg/L and exceeded the storm sewer discharge limit of 0.02 mg/L;
- Total phosphorus in the groundwater sample from Borehole 407-015 was 4.15 mg/L and exceeded the storm sewer discharge limit of 1.0 mg/L;
- Aluminum concentrations of 2 mg/L and 17 mg/L in two (2) groundwater samples from Boreholes 407-012 and 407-015 exceeded the storm sewer discharge limit of 1 mg/L;
- Barium concentrations of 0.214 mg/L, 0.165 mg/L and 0.217 mg/L in three groundwater samples from Boreholes 407-003, 407-006 and 407-015 exceeded storm sewer discharge limit of 0.1 mg/L; and,
- Iron concentrations of 3.07 mg/L and 22.6 mg/L in two (2) groundwater samples from Boreholes 407-012 and 407-015 exceeded storm sewer discharge limit of 1 mg/L.

In terms of general groundwater chemistry, the results of chemical testing were below the laboratory method detection limit (MDL) and/or met the respective MOE 2004 Table 1 Standards for metals, PHCs, BTEX, VOCs and PCB parameters, with the exception of the following. Toluene concentrations were above the MOE 2004 Table 1 Standard of 0.80 µg/L in Boreholes 407-005 (1.3 µg/L; screen tip at 39.6 m depth), 407-010A (4.1 µg/L; screen tip at 16.0 m depth) and 407-011A (18 µg/L; screen tip at 40.4 m depth), although the concentrations were below the MOE 2004 Table 2 (and proposed 2008) Standard of 24 µg/L. Chloroform was detected above the MOE 2004 Table 1 Standard of 0.5 mg/L at Borehole 407-001A (0.73 µg/L screen tip at 12.2 m depth) although the concentration was below the respective MOE 2004 Table 2 Standard of 5 µg/L (and proposed 2008 Table 2 Standard of 8.6 µg/L). It is noted that the presence of chloroform may be laboratory related.

Select metals were also detected at six (6) borehole locations at concentrations above the MOE 2004 Table 1 Standards but were below the respective MOE 2004 Table 2 Standards. These include Boreholes 407-001A (chromium, cobalt, copper, lead, molybdenum, vanadium and zinc), 407-005 (boron and chromium), 407-007 (chromium), 407-009B (chromium), 407-013B (copper) and 407-021 (cobalt and zinc).

No alcohol compounds were detected in the two groundwater samples that were analyzed to assess the potential of impact related to the adjacent cemetery.

In comparison to the proposed 2008 Standards, concentrations of chromium, copper, lead, molybdenum, and vanadium continue to exceed the respective Table 1 Standards in Boreholes 407-001A, 407-005, 407-007, 407-009B and 407-013B. The concentrations of all of the tested parameters met the respective MOE 2008 Table 2 Standards, with the exception of molybdenum and vanadium levels in Borehole 407-001A which had



concentrations of 90.4 µg/L and 8.68 µg/L and exceeded the proposed standards of 70 µg/L and 6.2 µg/L, respectively.

6.0 SOIL UNITS RELATED TO EXCAVATION

6.1 Subway Station

The interpreted stratigraphy for the proposed Highway 407 Station, shown on Figures H407-2 to H407-4, may be used for preliminary design purposes to assess the soil and groundwater conditions at various positions along the station. The interpretation is based on relatively widely spaced boreholes, some of which are offset from the section line and station alignment; therefore, the design and contract specifications must allow for the actual site conditions, especially the strata boundaries, to vary from those illustrated.

It is understood that cut and cover construction methods will be used for the construction of the Highway 407 Station. The approximately 20 m deep excavation for the station box structure will extend through the stratigraphic sequence as described in Section 4.2, consisting of topsoil and/or Fill, the Upper Till Deposit, the Upper Sand/Silt Deposit and into the Lower Till Deposit. The excavation will terminate in the Lower Till Deposit at approximately Elevation 174 m. Excavation through the Lower Till Deposit will encounter lenses and interlayers of water-bearing sands and silts.

7.0 RECOMMENDATIONS FOR DESIGN

7.1 General

This section of the report provides preliminary geotechnical engineering recommendations for the proposed Highway 407 Station on the Toronto-York Spadina Subway Extension. The recommendations are based on interpretation of the factual geotechnical data obtained from the geotechnical investigation reports referenced in Section 3.2. Further geotechnical and geo-environmental investigations and analyses are required prior to the final design of the station.

The interpretation and recommendations provided in this report are intended to provide the designers with information for preliminary station design and to assess feasible construction approaches and constraints to construction that may be related to the ground conditions. 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 planning and undertaking specific 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.

7.2 Station Box Structure Design

It is understood that the underground concrete box structure required for the station will be constructed by cut and cover methods.

The side walls of the box structure should be designed to resist a triangular earth and groundwater pressure distribution illustrated on Figure H407-21, which includes an allowance for surcharge loads. The interpreted stratigraphic conditions and interpreted groundwater level, as illustrated on Figures H407-2 to H407-4, together with the groundwater pressure distribution illustrated on Figures H407-19 and H407-20, may be used to develop design sections for the box structure for calculation of the earth and groundwater pressure distribution.



Geotechnical literature suggests that at-rest in situ horizontal stresses, often described in terms of the ratio of in situ horizontal to vertical effective stress (K_o), within heavily over-consolidated glacial tills may be high, with K_o values on the order of 1 or more. Because of excavation processes, such high lateral stresses will likely be relieved to some degree. Although active stresses may be developed during excavation, relieving the at-rest in situ stresses, the permanent underground structures will likely be restrained against displacement and there may be some long-term reestablishment of in situ stresses that are closer to the initial conditions. Therefore, for preliminary design of permanent underground structures, lateral (horizontal) earth pressures may be assumed to be approximately half of the vertical effective stress (Figure H407-21 $K=K_o=0.4$ or 0.5 , refer to Table H407-1 for details).

The vertical effective stress at any given depth for preliminary design purposes can be calculated as:

$$p'_z = \gamma d - u_w$$

Where: p'_z is vertical effective stress (kPa)

γ is soil unit weight (assume 21 kN/m^3)

u_w is groundwater pressure (kPa)

d is depth below ground surface (m)

For preliminary design, groundwater pressure may be estimated to be about $9.8d_w$ (kPa), where d_w is the groundwater pressure head, which is determined from Figures H407-19 and H407-20.

The station box structure, assumed to be of slab-on-grade raft design, will be founded at approximately Elevation 173.1 m, as specified in the 10% Conceptual Design Report, Option E2.2. Based on the interpreted stratigraphy shown on Figures H407-2 to H407-4, the founding soils for the proposed base slab will generally consist of very stiff to hard clayey silt to silty clay till. A factored resistance at Ultimate Limit States (ULS) for these founding soils at the base of the proposed station box may be taken as 700 kPa, assuming that the base slab will be founded on undisturbed subsoil at or below Elevation 174 m. A factored ULS value for the ancillary structures will be provided under a separate cover.

Although the founding soils are anticipated to consist of very stiff to hard clayey silt to silty clay, interstadial silty sand to sandy silt to silt layers may be present at the founding elevation. These cohesionless saturated layers are sensitive to disturbance from construction traffic and wetting/drying cycles. If encountered at subgrade level, a layer of lean concrete (mudcoat) placed directly on the subgrade to form a working mat is recommended in order to minimise disturbance of the subgrade soils. To control the seepage from the till soils, the mudcoat should be placed on a drainage layer that will allow drainage into filtered sumps at the base of the excavation. Provision should be made in the specifications such that:

- The Contractor should maintain an adequate pumping system within the excavation in order to keep the subgrade dry;
- The Contractor should minimise disturbance to the exposed subgrade; and,
- The subgrade should be inspected by a Geotechnical Engineer, immediately prior to placement of the drainage layer and mudcoat.

The design of underground box structures is not governed by bearing failure, as the construction of such structures typically provides a net unloading of the founding soils. The factored ULS bearing capacity is only provided to check that the local stress conditions beneath the base slab do not include “punching failure” into the subgrade soils.



For design of the base slab using a spring constant, a vertical modulus of subgrade reaction, K_s , of 60 MPa/m may be assumed for preliminary design. The modulus of subgrade reaction provided has been adjusted from that interpreted for a 0.3 m by 0.3 m square plate, K_{s1} , and assumes that the sum of slab and wall thicknesses will be about 2 m. The design modulus of subgrade reaction is derived based on the assumption that the subgrade is not disturbed during construction.

It is understood that the underground station will be designed as a watertight structure and, as the base of the station structure is located below the groundwater table, it should be designed for hydrostatic uplift forces. Permanent drainage systems are not recommended due to maintenance requirements and the potential for inducing migration of contaminants. At the Highway 407 Station site, it should be assumed that a 14 m water head will develop at the base of the station slab; in addition, a further 2 m of water head to account for seasonal fluctuations should be allowed for. For different base slab thicknesses or ancillary structures that may be founded at different elevations, the groundwater pressure head diagram of Figure H407-20 may be used to assess the uplift pressure. Resistance against uplift forces must be maintained at every stage of the construction.

For calculation of the resistance to uplift pressure, and the loads imposed on the structure roof slab, the total unit weight of backfill may be taken as:

- 20 kN/m³ for compacted native soils;
- 22 kN/m³ for compacted Granular 'A' or 'B'; and
- 23 kN/m³ for unshrinkable fill.

7.3 Foundations for Ancillary Structures

It is understood that the Highway 407 is to be integrated with the 407 Transitway project and interim GO facilities (including bus terminals, commuter parking lots and passenger pick-up/drop-off area), and that part of the proposed structures may be located directly above the station box.

Fill, placed for past urban development and/or agricultural activities, may be encountered throughout the proposed alignment, particularly in the immediate vicinity of the Black Creek tributaries, the CNR line, and Highway 407. In general, the fill should be considered to be uncontrolled in both material and placement and should, therefore, be considered unsuitable for foundation support. In some areas, particularly the right-of-way at the existing Highway 407 and Jane Street, some of the fill materials may have been placed in a more controlled manner for highway construction. However, the support capabilities of these materials, outside of the main roadways, should not be relied upon until detailed reviews of construction records are completed in further design stages. The Upper/Lower Till Deposits are likely to be the primary native deposit encountered along the proposed alignment. This deposit is relatively very stiff to hard and should be suitable for both foundation support and pavement subgrades, if necessary.

Foundation excavations into the Upper Till Deposit may be constrained by the underlying groundwater pressures anticipated in the Upper Sand/Silt Deposit. The base stability of each excavation will have to be assessed and determine if groundwater pressure control measures will be necessary to maintain base stability. Further, excavations to extend into the Upper Sand/Silt Deposit, particularly in the central to north portion of the site where this deposit was up to 10 m thick, will require groundwater control and excavation support.

If a portion of the structure is to be above the station box, then consideration will have to be given to the different settlement performance between those portions founded on native material and those portions founded on station backfill materials. If differential settlement cannot be tolerated, then consideration will have to be given to



deep foundation systems and/or founding some ancillary structures directly on the station box. Once preliminary design information for the ancillary structures is confirmed, further input can be provided under separate cover.

7.4 Temporary Ground Support Systems

This section provides a discussion on the temporary ground support systems which will be required for the Highway 407 Station design and construction. It is expected that the Contractor will be required to undertake the detailed design of temporary works. However, the Designer must consider the temporary works design as part of the assessment of ground movements and their impact on structures and underground utilities at the site. The criteria for the design and performance of the temporary works must consider such analysis. Sufficient design and analysis will have to be carried out in order to conduct cost estimates of the temporary works, to determine the feasibility of the design criteria, to assess construction feasibility of temporary works alternatives, and to indicate to the Contractor the temporary ground support system(s) which are to form the basis of the bid.

Excavation for the proposed station will penetrate varying amounts of cohesionless, granular soils located below the water table. Without adequate dewatering, an open unsupported excavation to install the station will not be stable even for short periods of time, considering the high groundwater level. Moreover, open cut excavation may not be considered feasible for the station box structure due to the close proximity of Black Creek, Jane Street and Highway 407. For ancillary structures and parking areas, consideration could be given to suitably sloped open cut excavation with side slopes in the range of 1H:1V to 1.5H:1V through the very stiff to hard Upper Till Deposit, where space permits, provided base stability is evaluated and, where necessary dewatering works are put in place to maintain stability against basal uplift. Local flattening of side slopes and/or use of temporary support will be required if shallow excavation extends through the Upper Sand/Silt Deposit.

It is expected, however, that in most instances, vertical excavation sides will be required, and temporary shoring needed.

7.4.1 Shoring Methods

The shoring methods selected to support the station box structure excavation must take into account of the soil stratigraphy, the groundwater conditions, the methods adopted to control the groundwater, and the ground movements associated with the shoring system and their impact on adjacent structures and utilities.

Traditionally for underground construction, TTC has opted to construct station box structures separately within temporary shoring systems, so this report has not explicitly addressed “top down” station construction in which slurry wall construction is used to form temporary and permanent station walls.

Based on the existing ground conditions and the presence of Black Creek adjacent to the proposed excavation limits, consideration could be given to the use of a traditional strutted soldier pile and lagging shoring walls for the locations that are not immediately adjacent to existing roadways and otherwise, continuous concrete walls (caisson or diaphragm walls) could be used. An important design exercise for this station will be the assessment of performance criteria for shoring systems adjacent to existing structures and the degree to which protection measures are specified in the contract documents. It is anticipated that sheet pile walls will have limited application, if any, for this project since the ground is too hard for driven sheet pile installation to the depth required. Concrete diaphragm walls are also seldom used in the Greater Toronto Area since continuous concrete walls can be constructed in situ using the secant pile wall technique, for which many local contractors are equipped.

Use of soldier pile and lagging shoring walls will require that groundwater lowering be undertaken in the Upper Sand/Silt Deposit and/or Interstadial sands and silts that are within the Lower Till Deposit prior to the excavation through these lenses and layers. Dewatering of the Lower Till Deposit is not anticipated to be necessary;



however, some ravelling of isolated interlayers and lenses within the till soils during lagging installation is to be expected and lagging boards should be installed as quickly as possible, with the lagging boards backed by a filter fabric and the space behind packed with granular material. Further discussion on groundwater lowering is provided in Section 7.5.

During construction the ground surrounding the excavations, which may be supported by soldier piles and lagging walls, may deform up to about 0.2 percent of the excavation depth in both the horizontal and vertical directions. Ground displacements for secant pile walls can be about half of this value, depending on design and workmanship. The use of walers and pre-stressed soil anchors along the temporary support walls may further reduce the amount of deformation when compared to strut supported shoring systems. In general, the maximum displacements occur near the edge of the excavation and dissipate to nominal values at distances ranging from approximately equal to the excavation depth or up to twice this distance for relatively poor ground conditions. The ground movements induced by excavation construction can be damaging to buildings or utilities that are within the “zone of influence” of the excavation. Further guidance on assessing ground movements from station excavation is provided in Section 8.0.

In areas where ground movements adjacent to the excavation are to be minimised due to the presence of settlement sensitive structures and underground utilities, continuous concrete walls are more suitable than soldier pile and lagging walls. Continuous concrete walls would provide an alternative means of groundwater control at this site, as they would extend through the Fills, the Upper Sand/Silt Deposit and Interstadial sands/silts layers into the Lower Till Deposit, providing a groundwater cut off from these water-bearing lenses and layers. It is our understanding that launching and retrieving shafts will be constructed at each end of the station box. To facilitate shoring at the station-end walls, consideration should be given to construction of preinstalled station headwalls that incorporate a “soft-eye” through which the tunnels could be bored; these would be installed ahead of tunnel construction, presumably as part of the tunnel contract.

Use of secant pile headwalls installed prior to tunnel construction has several advantages with respect to station shoring construction, particularly with respect to minimizing the risk of ground loss during shoring installation around the tunnels that would be necessary if the end walls were built as part of the station contract. However, this alternative requires that the portion of the station shoring be designed by the owner’s engineer, rather than those retained by the station contractor, as would normally be the case. Also, the end limits of the station must be confirmed and fixed early in the station design process, if pre-installed headwalls are to be utilized.

The ground movements and risks associated with the wall installations, together with a cost comparison of the wall alternatives, should be carried out as part of the station design.

7.4.2 Lateral Pressures and Restraints

The temporary retaining system should be designed to account for horizontal earth loads, groundwater pressure and surcharge loads (including foundation loads from adjacent structures). Lateral pressures for design of the temporary structures will depend on the temporary structure design and the nature of the lateral support provided.

For temporary flexible walls, such as soldier pile and lagging walls, the distribution of lateral pressure may take on a trapezoidal shape, whereas for stiffer walls, such as secant pile or concrete diaphragm walls, the lateral pressure distribution would be similar to a more common triangular active earth pressure distribution with a shape similar to that given on Figure H407-21 for the design of the permanent structure, but instead for preliminary design purposes, utilising an “active” coefficient of lateral earth pressure $K=K_a$ equal to 0.27, for the Upper and Lower Till Deposits (refer to Table H407-1 for K_a values for other soil types). The groundwater pressure distribution, calculated in accordance with Figures H407-19 and H407-20, is to be added to the earth pressure distribution shown on Figure H407-21.



It is anticipated that lateral restraint to the soldier pile and lagging or continuous concrete walls will be principally provided by struts, although grouted prestressed tiebacks are a feasible alternative within the Lower Till Deposit, providing that measures are taken to properly support the anchor drill hole when advancing through the Upper Sand/Silt Deposit and Interstadial sand/silt layers within the Lower Till Deposit.

For preliminary assessment of the design of strutted temporary soldier pile and lagging walls, the lateral earth pressure diagram illustrated on Figure H407-22 may be used, assuming the highest strut level is at about 2 m below ground surface, and the lowest strut level is at about 5 m above the base of the excavation. A coefficient of lateral earth pressure, K , of 0.25 may be assumed for preliminary design.

The design earth pressures for temporary works should be reviewed after the governing criteria for wall design (i.e. limitation of ground movement and/or groundwater cut off) have been assessed and the wall type selected.

7.4.3 Toe Restraint

7.4.3.1 Passive Toe Restraint for Soldier Pile Sockets

The maximum factored passive resistance, $P_{p(f)}$, which may be mobilized at any depth in front of the socketed length of a soldier pile may be calculated as follows:

For the Sand/Silt Deposits:

Portion above water table: $P_{p(f)} = \Phi [3K_p \gamma zB]$

Portion below water table: $P_{p(f)} = \Phi [3K_p B (\gamma D_w + (\gamma - \gamma_w) (z - D_w))]$

where $P_{p(f)}$ is the factored resistance at any depth below base of excavation (kN/m)

Φ is the resistance factor
 $\Phi = 0.6$ for Limit States Design
 $\Phi = 0.5$ for Working Stress Design

γ is the total unit weight of soil, from Table H407-1 (kN/m³)

γ_w is the unit weight of water = 9.8 kN/m³

B is the socket diameter, assumed to be < 1/3 pile spacing (m)

D_w is the depth of groundwater below excavation base (m)

z is the depth below the base of excavation (m)

K_p is the coefficient of passive pressure, from Table H407-1

Where dewatering works are required to maintain the groundwater level below the excavation base, the parameter D_w should be assumed to equal zero for design purposes.



For the cohesive deposits (including Upper Till Deposit below excavation base):

$$P_{p(f)} = \Phi 3B(\gamma z + 2S_u)$$

where $P_{p(f)}$ is the factored resistance at any depth below base of excavation (kN/m)

Φ is the resistance factor
 $\Phi = 0.6$ for Limit States Design
 $\Phi = 0.5$ for Working Stress Design

γ is the total unit weight of soil, from Table H407-1 (kN/m³)

B is the socket diameter, assumed to be < 1/3 pile spacing (m)

z is the depth below the base of excavation (m)

S_u is the undrained shear strength, from Table H407-1 (kPa)

For cohesive deposits, the resistance over the upper 1.2 m should be ignored.

The stratigraphy used for assessing soldier pile resistance should be taken from the interpreted stratigraphy given on Figures H407-2 to H407-4. Soil types 9, 10 and 11 of the Upper and Lower Till Deposits may be analyzed as cohesive deposits for the purpose of assessing toe penetration.

7.4.3.2 *Passive Toe Restraint for Continuous Walls*

The maximum factored passive soil pressure, $P_{p(f)}$, that can be mobilized at any depth in front of the embedded length of a continuous wall may be calculated as follows:

For the Sand/Silt Deposits:

Portion above water table $P_{p(f)} = \Phi [K_p' \gamma z]$

Portion below water table $P_{p(f)} = \Phi K_p' [(\gamma D_w + (\gamma - \gamma_w)(z - D_w))]$

Where $P_{p(f)}$ is the factored resistance at any depth below base of excavation (kN/m²)

Φ is the resistance factor
 $\Phi = 0.6$ for Limit States Design
 $\Phi = 0.5$ for Working Stress Design

γ is the total unit weight of soil, from Table H407-1 (kN/m³)

γ_w is the unit weight of water = 9.8 kN/m³

D_w is the depth of groundwater below excavation base (m)

z is the depth below the base of excavation (m)

K_p' is the coefficient of passive pressure, which accounts for friction on the embedded wall, from Table H407-1

Where dewatering works are required to maintain the groundwater level below the excavation base, the parameter D_w should be assumed to be zero for design purposes.



For the cohesive deposits:

$$P_{p(f)} = \Phi [\gamma z + 2S_u]$$

where $P_{p(f)}$ is the factored resistance at any depth below base of excavation (kN/m)

Φ is the resistance factor
 $\Phi = 0.6$ for Limit States Design
 $\Phi = 0.5$ for Working Stress Design

γ is the total unit weight of soil, from Table H407-1 (kN/m³)

z is the depth below the base of excavation (m)

S_u is the undrained shear strength, from Table H407-1 (kPa)

For the cohesive deposits, the resistance over the upper 1.2 m should be ignored. The stratigraphy used for assessing wall toe resistance should be taken from the interpreted stratigraphy given on Figures H407-2 to H407-4. Soil types 9, 10 and 11 of the Upper and Lower Till Deposits may be analyzed as cohesive deposits for the purpose of assessing toe penetration.

7.5 Dewatering/Groundwater Control

Based on the results of the borehole investigations carried out at the Highway 407 Station site, the base of the excavation will generally be within the cohesive very stiff to hard Lower Till Deposit below the groundwater level. The Lower Till Deposit is expected to be stable upon initial exposure and active groundwater lowering is not expected to be necessary to maintain base stability. However, the granular and low plasticity silts within the Lower Till Deposit will loosen/unravel as a result of groundwater seepage. Supplementary drainage measures (trenches and sumps) are likely to be necessary to maintain stability of the Lower Till Deposit. It should also be noted that in the complex glacial environmental, conditions may change significantly between boreholes.

If soldier pile and lagging is selected as the retaining system, dewatering of the Upper Sand/Silt Deposit and the interstadial sand/silt layers will be required prior to excavation in order to allow for controlled installation of lagging. The Upper Sand/Silt are interpreted to form a near continuous layer over the length of the station excavation, between about Elevations 181 m and 193 m. It is considered feasible to control the groundwater pressure in this layer through a system of closely spaced educator wells installed outside of the perimeter of the station excavation. As an alternative, consideration may be given to installing and operating well-point system from within the excavation. Such well-points would be installed at an angle from the top of such layers and extend to the base of the layer, outside of excavation limits.

Excavations into and through these surficial soils might require active groundwater control through the use of trenches and sumps, or shallow well-point systems. Alternatively, groundwater seepage may be controlled with cut-off walls to limit the influence of groundwater on both the construction and the effects of groundwater lowering on the adjacent properties. A continuous excavation support wall (e.g. secant pile or concrete diaphragm walls) may be constructed to pass through and cut off the surficial deposits and the interstadial sands/silts.

Further investigations and analyses are recommended at the station site to better define the hydraulic conductivity of the Till Deposit as well as the interstadial sand/silt layers and dewatering quantities for final design and construction. It is, however, anticipated that a Permit To Take Water (PTTW) will be required if dewatering from the interstadial sand/silt layers is specified to allow for soldier pile and lagging wall construction. As part of the additional site investigations, monitoring wells are planned to be installed between proposed



dewatering locations and potential receptors (e.g. watercourses) in order to determine the relative degree of hydraulic connection. Information gained through these field studies will also be used to develop monitoring, mitigation and contingency plans to be implemented during construction in order to minimize potential impacts.

7.6 Backfilling

Backfill over the box structure has to be free of topsoil or other organic matter, rubble and not contain particles greater than 150 mm. In general, it is considered that the native deposits such as the Upper and Lower Till Deposit will be suitable for use as backfill above the top of the structure, provided that provision is made to remove cobbles and boulders and that materials are at a suitable water content; that is a water content of not more than 2 percent above the materials optimum moisture content. The Upper and Lower Till Deposit soils generally have in situ water contents that meet this criterion; however, some separation of locally wetter soils will be required.

The in situ water contents measured in the saturated Upper Sand/Silt Deposit and interstadial sand/silt soils are generally above the optimum moisture content for compaction. Groundwater control works will act to depressurise these deposits, but may not significantly change the water content of these excavated soils. These excavated soils could, therefore, be too wet for immediate placement and compaction on this project. Drying of these cohesionless soils and selective removal of cobbles and boulders will allow these materials to be used.

Samples of the excavated material proposed for re-use as backfill should be submitted for laboratory testing to determine the compaction characteristics. Any stockpiled materials proposed for re-use must be protected from precipitation.

8.0 GROUND MOVEMENTS

During the excavation of the station box, lateral deformation and vertical settlement of the adjacent ground will occur as a result of installation of shoring and groundwater control systems and the deflection of the retaining system(s), including the bending of walls, compression of struts and the deformation of soil in which the toes of the walls are embedded. The ground movements induced could affect the stability or performance of buildings or underground utilities adjacent to the excavation. Therefore, the magnitude and extent of ground movement and the specific impact on surrounding structures must be assessed.

The requirements for the assessment of structures is described in the TTC Design Manual and is a two step process: a Level I assessment is carried out to screen for structures which are anticipated to have more than slight damage; and a Level II assessment, a more rigorous soil structure interaction analysis of the impact of ground movement and the options for building protection, is carried out on those structures identified in the Level I assessment as having the potential for moderate or greater damage. To assess the impacts of ground movements on utilities, a movement tolerance for each utility must be established which takes account of the utility type, its age, jointing details and the consequence of damage to the specific utility.

8.1 Level I Assessment of Ground Movements

A series of empirical settlement profile curves, based on case records as summarised by Rumsey and Cooper (1984) are presented on Figure H407-23. These curves may be used for Level I assessment of ground settlement adjacent to excavations supported by soldier piles and lagging. The values calculated from this figure represent total settlement due to the combined effects of soldier pile installation, excavation and strut removal during backfilling. Superposition may be used to estimate the total ground settlement adjacent to the excavation.



For Level I assessment, the horizontal ground movement may be assumed to equal the vertical settlement. It should be noted that the use of Figure H407-23 is based on the following assumptions:

- A properly designed system of struts or tie-backs is used to support the wall, with each level being installed as soon as practical;
- The top level of struts or tie-backs is placed within 2 m of ground surface;
- The struts or tie-backs are pre-loaded;
- There is no over excavation or ground loss during pile or lagging installation;
- Each level of struts is not removed until adequate alternative support is provided, either from the permanent structure or from the backfill over the structure.

If a continuous concrete retaining system (caisson wall or diaphragm wall) is specified, the Level I assessment of ground settlement may be assumed to be half of that calculated for a soldier pile and lagging wall.

The use of the generalised relationship between excavation depth and settlement does not take into account the detailed stratigraphy, soil properties or the specific retaining wall system for the site. It is only intended to provide an initial screening for buildings and utilities within the “zone of influence”, as defined in the TTC Design Manual. A more detailed assessment should be carried out for any buildings or utilities not screened out by Level I assessment.

9.0 MANAGEMENT OF SOIL AND GROUNDWATER

This section of the report provides management strategies for excavated soils and removal of groundwater that will be required to accommodate construction of the Highway 407 Station. In general, management options for excavated soils may include re-use of excavated materials on-site, transfer of excess soils to a site requiring fill and/or disposal of excess material to a licensed landfill facility.

The fill materials and native soils at this site which are to be excavated are suitable for reuse as backfill material at this site, subject to physical requirements detailed in Section 9.1. The majority of excavated fill and native soils are generally acceptable for use as infilling material at some private clean fill sites and possibly as cover material at a licensed landfill; such use will be subject to the approval of the site owners or operators. It is anticipated that groundwater from possible dewatering measures may be discharged to the municipal sewer system, subject to additional testing that will be carried out for verification of sanitary discharge due to the presence of Total Suspended Solids. In terms of general groundwater chemistry, toluene, chloroform and selected metals were detected in various wells at concentrations above MOE’s background standards, but were below the next stringent 2004 potable groundwater standards (and the majority of the proposed 2008 standards). Additional groundwater testing will be carried out during the complementary investigations to verify that the elevated concentrations will not have implications on the discharge of the groundwater.

Based on the variable nature of existing fill materials at the site (i.e., generally containing black organic matter and wood fragments, with localized charcoal pieces), there is a possibility of encountering contaminants at locations between the boreholes that were advanced for this investigation. We note that a small percentage of the fill materials were tested during this phase of the investigation (i.e., 6 of 20 borehole locations). As such, the overall environmental quality of these fill materials is unknown at this time and will be targeted for further assessment during subsequent investigations at the site.

Provisions must be made in the Contract Specifications for the identification, handling and disposal of any other excess soils which exceed MOE Standards and foreign material that might be encountered during excavation



activities, as well as for possible treatment measures of the groundwater prior to discharge that may be required should TSS levels (and possibly associated metals) in the groundwater be confirmed.

The management strategies provided in this report should be periodically reviewed to verify that they remain applicable for the proposed construction works in the event that new regulations, standards or criteria are put in place prior to the time of the proposed construction. Further, no statement made herein should be construed as relieving the Contractor of the duty to comply with all applicable regulations related to disposal/discharge of the excess soil and groundwater.

9.1 Management of Excavated Soils

Excavated soils for construction of this portion of the Highway 407 Station are anticipated to consist of fill materials and native soils generally comprising glacial till deposits with interstadial sand, gravelly sand, and sandy silt to silt layers. Beneath a surficial topsoil layer, fill materials were encountered in all boreholes drilled and primarily consisted of different layers of brown and grey clayey silt, sandy silt and/or sand and gravel that extended to relatively shallow depths of approximately 1 m to 3 m below the ground surface.

Based on the results of chemical analyses and the comparisons with MOE criteria, the results of soil gas headspace readings and the field observations, the following management options are provided for the majority of the excavated materials for Highway 407 Station:

1. **Re-use of Soil on Site:** The majority of the fill materials and native soils can be managed by re-using on site for an engineering purpose (i.e., site grading fill or backfill). The surface cover materials (i.e., topsoil) should be suitable for reuse on site as surface cover, or at other sites requiring this material. The environmental quality of the topsoil will be verified during subsequent investigation(s) at the site, however, the investigation and testing carried out will not be suitable to assess the use of topsoil for cultivation purposes.

Within the anticipated depth of excavation for the proposed station (i.e., 15 m to 20 m below grade), slightly elevated levels of barium were detected in one sample of the Lower Till Deposits in Boreholes 407-008 (about 15 m below grade). Given the depth of the sample, this result is likely naturally-occurring or may be a testing anomaly. In addition, slightly elevated levels of naphthalene were detected in two samples of gravelly sand that was encountered within the Lower Till Deposit (Borehole 407-017, about 7.5 m and 9.3 m bgs). Excavated materials from these zones may be reused on site, but should be placed in areas that are more than 30 m from the proposed realignment of Black Creek. However, the Contract Documents should provide appropriate measures for the handling of these materials. Additional testing during the complementary investigation will target the area of the slightly elevated naphthalene to assess if the results are accurate / representative of the existing soil conditions from this one zone.

2. **Management of Excess Soils for Transfer off Site:** Based on the existing chemical test results, and with no significant odour noted within soil samples obtained during the investigations to date, the majority of the excavated fill and native soils should be suitable for transfer to another site requiring fill for an engineering purpose, pending approval of the owner of the receiving site. As noted above, the chemical test results indicate slightly elevated levels of barium (one sample) and naphthalene (in two samples) from Boreholes 407-008 and 407-017. The concentrations are only slightly above the background standard and below the generic site condition (Table 2) standards, and primarily, appear to be localized. Some degree of blending will inherently occur during excavation activities, and therefore, the slightly elevated levels of barium and naphthalene are not expected to be a concern for transfer of material off-site (or re-use on site). However, this will have to be confirmed by the Contractor with the receiving Site operators.



3. Questionable Materials or Areas: The fills will predominately need to be screened and sorted during excavation due to the heterogeneous nature of these materials.

For the brown and grey clayey silt, sandy silt or sand and gravel fills with organic matter (i.e., topsoil, rootlets), the materials would need to be reassessed during excavation for their organic content to determine their suitability for re-use from a geotechnical perspective. However, given that there will be a surplus of material following excavation for the box structure, it should be assumed at this time that the existing fills will not be suitable for re-use on Site as engineered fill.

The materials (predominately fills) that exhibit possible visual or olfactory evidence of contamination (i.e., "black organic matter) or contain foreign materials (i.e., charcoal, wood fragments) will need to be segregated during construction with testing undertaken at that time to determine if they can be transferred for reuse or whether they will need to be handled as waste soil. The contract documents should include an allowance and unit rate for handling and disposal of waste materials.

Further investigation would need to be carried out prior to or during construction in order to fully delineate the extent of the potentially impacted materials (i.e., with debris / aesthetic contaminants), and to determine if segregation is required. Alternatively, the materials may be disposed of off site at a licensed operating landfill facility with a Certificate of Authorization to receive this material (pending approval of receiving site authorities). Based on the Ontario Regulation 347 (as amended by Ontario Regulation 558/00) leachate analyses, the material would be classified as non-hazardous solid waste.

It is recommended that the excavated materials be visually monitored during construction to verify the materials are consistent with the tested soil samples. If materials are encountered that are different than the tested samples or there is visual and/or olfactory evidence of contamination, the materials should be separately stockpiled on site and re-assessed to determine appropriate handling options.

9.2 Management of Construction Water

The analytical test results indicate that the groundwater quality generally meets Vaughan's By-Law Limits for discharge to Sanitary Sewers, with the exception of Total Suspended Solids (TSS) in one groundwater sample. The groundwater quality in four (4) samples met the majority of the By-Law Limits for Storm Sewers except for exceedences of barium, iron, total suspended solids, aluminum, phenols and total phosphorus. The elevated levels of barium, iron and aluminum may be attributed to some degree to the levels of suspended solids which are a function of how the test wells were developed and sampled. Testing from other monitoring wells in other areas of the subway alignment suggests that treating (i.e., filtering) of the groundwater prior to discharge may be effective in reducing the solids/parameter concentrations that may be present.

In this regard, and provided that dewatering wells are located within the same stratigraphic units as the monitoring wells analyzed, it appears that the groundwater from dewatering works at the 407 Station site should be suitable for discharge to the sanitary sewer, subject to additional testing to verify one TSS level. If disposal to the storm sewer system is to be considered, additional sampling and analysis will be required to assess if the groundwater would be suitable for discharge to the storm sewer, as will consultation and liaison with the Town of Vaughan/York Region and/or the MOE.

The Contract Specifications should include requirements that dewatering wells be developed such that the total suspended solids (TSS) concentration meets the Town of Vaughan's Sanitary Sewer By-Law. Provided that TSS levels are satisfied, the groundwater from dewatering works at the 407 Station site appears to be suitable for discharge to the sanitary sewer, and possibly the storm sewer.



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It is recommended that prior to construction, a test of the water to be discharged to the municipal sewer system be completed before initial discharge to confirm the results of these analyses and that filtering activities being undertaken during construction are appropriate.

The presence of toluene and select metals (as well as phenols and phosphorus) that were detected as part of the general groundwater chemistry, may be indicative of potential contaminants that could exist within the groundwater regime at the site. If the monitoring well is located near the edge of a plume, the contaminants could potentially be drawn to the Site during dewatering. As such, there may be a requirement for groundwater treatment measures during dewatering at the Site. As previously mentioned, supplemental sampling and testing of the groundwater will be carried out to verify the presence and levels of these contaminants and further assess the potential risk of encountering contaminants during construction. A contingency should be provided in the Contract Specifications at this time for the treatment of groundwater for the above parameters.

10.0 CLOSURE

This report is intended to summarise available data on subsurface soil and groundwater conditions at the Highway 407 Station and provide geo-engineering comments and recommendations as input to the preliminary design of the proposed works. The data contained in this report were obtained from the current initial investigations as well as number of older sources. More detailed subsurface information will be required in order to provide further input to the design process, and as such, further geo-engineering investigations are planned to be carried out (or are presently underway at the time of this report preparation) at the station location. The findings of the subsequent investigations will result in refinement to the current understanding and interpretation of ground conditions and soil behaviour in the vicinity of the station and its ancillary structures.

We trust this report is sufficient for your immediate requirements. Should you have any comments or questions, please do not hesitate to contact us.

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[https://extranet.golder.com/sites/tyssepws/2300 initial ge design reports/2340 hwy407 stn/geo-engineering initial design report/08-1111-0039_drtrpt_aug09_initial_geo-engineering_design_-_h407.doc](https://extranet.golder.com/sites/tyssepws/2300%20initial%20ge%20design%20reports/2340%20hwy407%20stn/geo-engineering%20initial%20design%20report/08-1111-0039_drtrpt_aug09_initial_geo-engineering_design_-_h407.doc)

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TABLE H407-1

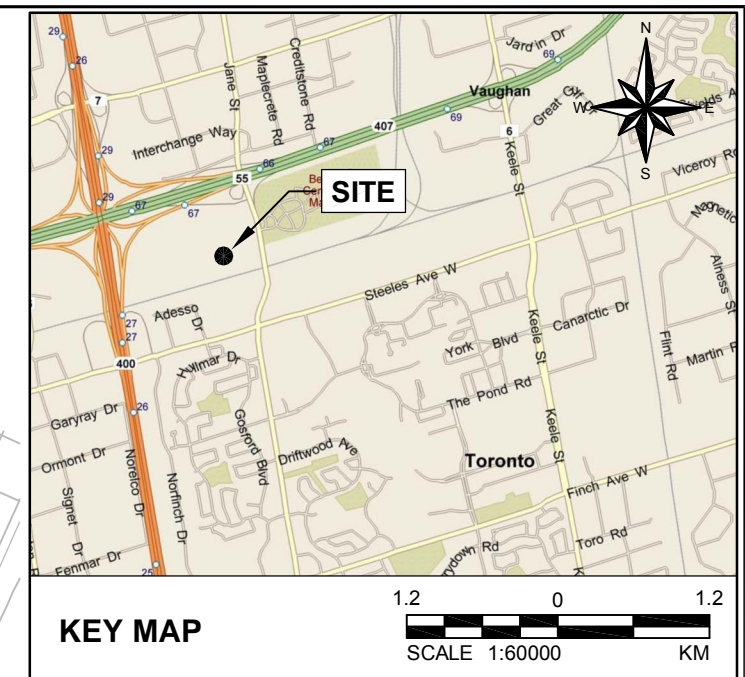
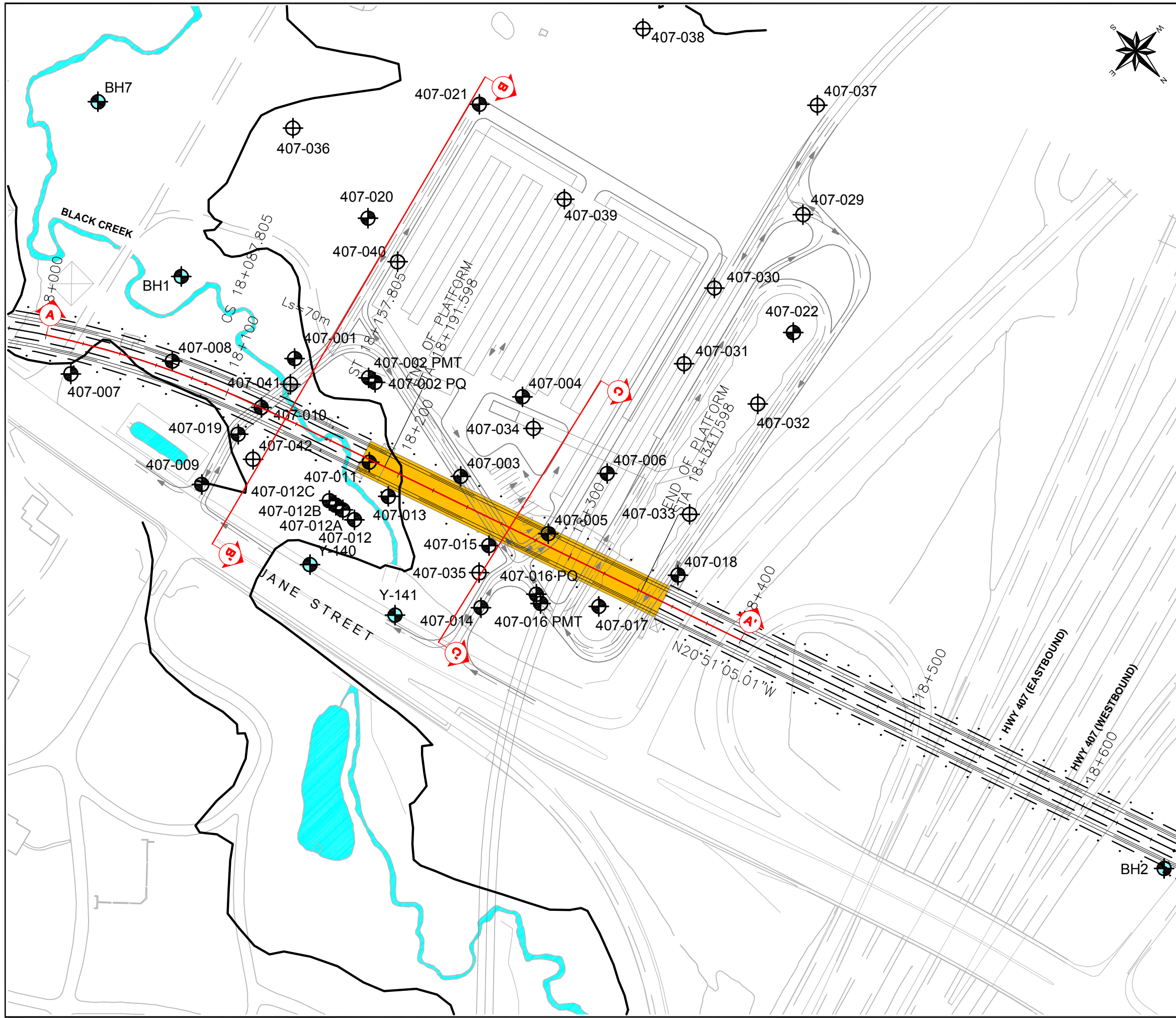
PRELIMINARY GEOTECHNICAL DESIGN PARAMETERS – HIGHWAY 407 STATION
TORONTO-YORK SPADINA SUBWAY EXTENSION

PARAMETER	DESCRIPTION	FILL (EXISTING IN PLACE) ¹	COMPACTED BACKFILL		NATIVE SOIL DEPOSIT	
			NATIVE	IMPORTED GRANULAR	UPPER / LOWER TILL DEPOSIT ²	UPPER SAND / SILT DEPOSIT ³
γ (kN/m ³)	Total Unit Weight	19	20	22	20	21
ϕ'	Effective Angle of Internal Friction	28°	28°	36°	35°	36°
S_u (kPa)	Undrained Shear Strength	-	-	-	250	-
K_a	Active Earth Pressure Coefficient (for temporary secant walls)	0.36	0.36	0.26	0.27	0.26
K_p	Passive Earth Pressure Coefficient (for pile sockets)	2.8	2.8	3.9	3.7	3.9
K_p	Passive Earth Pressure Coefficient (for continuous walls)	4.2	4.2	7.6	7.0	7.6
K_o	Coefficient of "At-Rest" Earth Pressure (for permanent box structures)	0.5	0.5	0.4	0.4	0.4
k_s (MN/m ³)	Subgrade Reaction Modulus (for permanent box structures)	-	-	-	60	-

Notes:

- 1- Soil Type: 1
- 2- Soil Types: 9 to 12
- 3- Soil Types: 4 to 8
- 4- Preliminary earth pressure coefficients recommended above are based on horizontal ground surface condition behind retaining structures. The recommended coefficients should be revised to reflect any sloping effects, if applicable.

PLOT DATE: October 26, 2009
 FILENAME: T:\Projects\2008\08-1111-0039 (TTC, York Spadina Subway Ext., Toronto)\-AMB- Initial Design Report 407\0811110039AMB001.dwg



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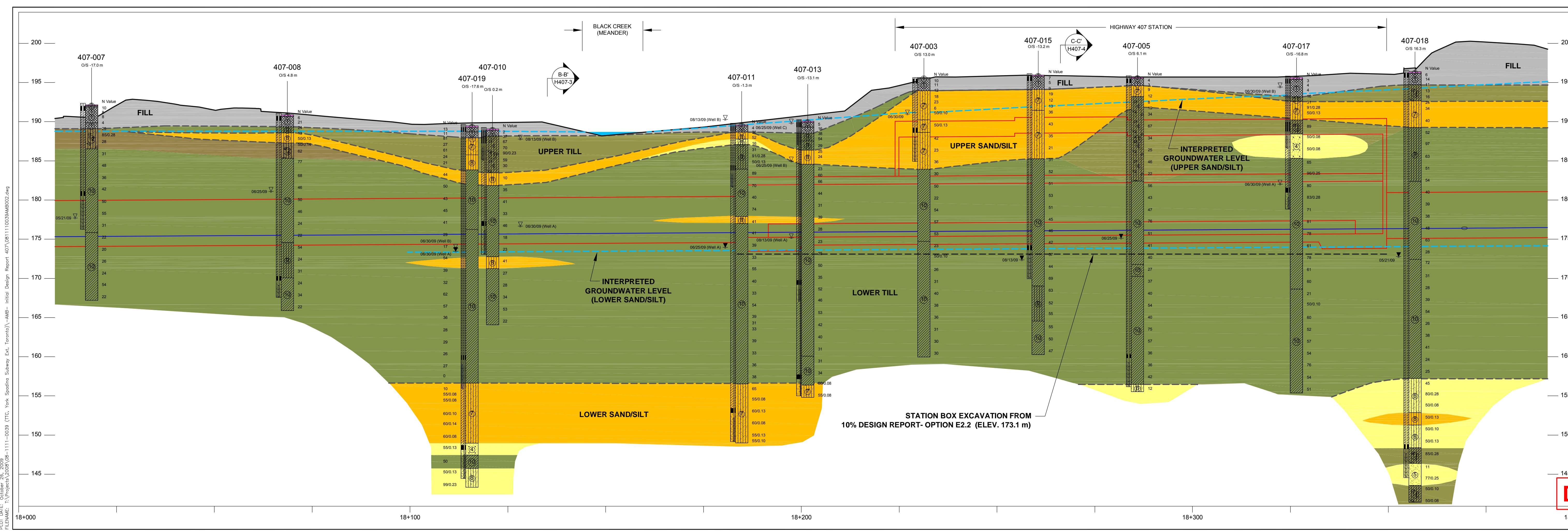
- LEGEND:**
- INITIAL INVESTIGATION BOREHOLE, (TYSSE, 2009)
 - EXISTING BOREHOLE (GOLDER 1981 AND 2006)
 - FLOODLINE

- NOTES:**
1. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009
 2. PQ CORING (PQ) AND PRESSUREMETER TESTING (PMT) WAS CARRIED OUT AT THE LOCATION OF BOREHOLES 407-002 AND 407-016.

- REFERENCES:**
1. BASE PLAN AND ALIGNMENT PROVIDED IN DIGITAL FORMAT BY TORONTO TRANSIT COMMISSION, RECEIVED ON FEBRUARY 12, 2009.



PROJECT		INITIAL GEO-ENGINEERING DESIGN TORONTO-YORK SPADINA SUBWAY EXTENSION CONTRACT NO. A85-77	
TITLE		BOREHOLE LOCATION PLAN HIGHWAY 407 STATION	
	PROJECT No.	08-1111-0039	FILE No. 0811110039AMB001.dwg
	DESIGN	DLW	Dec. 10, 2008
	CAD	DDRJ	Oct. 26, 2009
	CHECK	SLP	Oct. 26, 2009
REVIEW	JW	Oct. 26, 2009	SCALE AS SHOWN
			FIGURE No. H407-1



BOREHOLE MATERIAL SYMBOLS:

NOTES:

- THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.
- THE CHARACTERISTICS AND VARIABILITY ANTICIPATED WITHIN THE MAJOR SOIL DEPOSITS ARE DESCRIBED IN THE TEXT OF THIS REPORT. SIGNIFICANT LAYERS, INTERLAYERS AND LENSES WITHIN THE MAJOR DEPOSITS ILLUSTRATED FROM INTERPRETATION OF THE BOREHOLE RECORDS. THE BOUNDARIES ILLUSTRATED ARE INTENDED TO HIGHLIGHT THE VARIABILITY WITHIN THE DEPOSITS, WHICH EXHIBIT GRADUAL TRANSITIONS FROM ONE SOIL TYPE TO ANOTHER. IN ADDITION, LENSES AND INTERLAYERS NOT DETECTED BY THE SUBSURFACE INVESTIGATION WILL BE PRESENT BETWEEN BOREHOLES.
- THIS INTERPRETED STRATIGRAPHY FIGURE IS A SIMPLIFICATION OF SUBSURFACE CONDITIONS. DETAILED DESCRIPTIONS OF THE CONDITIONS ENCOUNTERED AT THE BOREHOLE LOCATION ARE FOUND ON THE RECORDS OF BOREHOLES CONTAINED IN THE GEOTECHNICAL INVESTIGATION REPORTS LISTED IN SECTION 3 OF THE INITIAL GEO-ENGINEERING DESIGN REPORT NO. 08-1111-0039 (2340), DATED SEPTEMBER 2009.
- THIS FIGURE IS PREPARED FOR PRELIMINARY DESIGN PURPOSES ONLY. IT IS NOT A BASELINE FOR CONSTRUCTION CONTRACT TENDERING PURPOSE.
- BOREHOLE WIDTH IN PROFILE IS NOT TO SCALE.

REFERENCES:

- BASE PLAN AND ALIGNMENT PROVIDED IN DIGITAL FORMAT BY TORONTO TRANSIT COMMISSION, RECEIVED ON FEBRUARY 12, 2009. THE PROFILES ARE APPROXIMATE AND ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY.

GENERAL LEGEND:

- INTERPRETED MAJOR DEPOSIT BOUNDARY
- - - INTERPRETED PIEZOMETRIC LEVEL

WATER LEVEL IN SINGLE OR SHALLOW MONITORING WELL

PIEZOMETER

WATER LEVEL IN DEEP MONITORING WELL

WATER LEVEL DATE

SCALE VERTICAL 1:250 METRES

SCALE HORIZONTAL 1:500 METRES

Toronto-York Spadina Subway Extension

PROJECT INITIAL GEO-ENGINEERING DESIGN
TORONTO-YORK SPADINA SUBWAY EXTENSION
CONTRACT NO. A85-77

TITLE INTERPRETED STRATIGRAPHIC PROFILE A - A'
HIGHWAY 407 STATION
CHAINAGE 18+000 TO 18+400

PROJ. No. 08-1111-0039 **FILE No.** 0811110039AMB002.dwg

DESIGN CAD **SCALE** AS SHOWN **REV.** B

CHECK SLP **FIGURE No.** H407-2

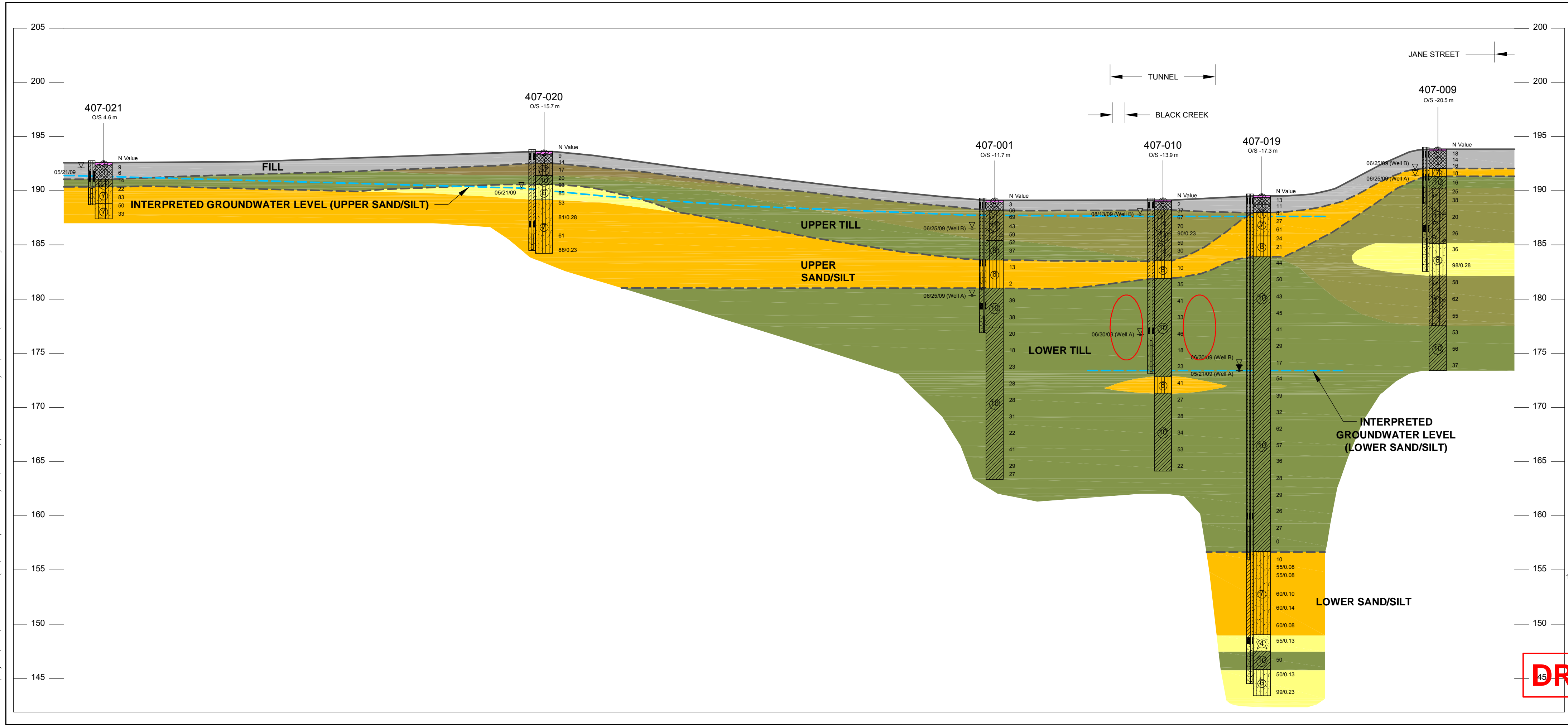
REVIEW JW **DATE** Oct. 26, 2009

Goldier Associates
Mississauga, Ontario, Canada

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PLOT DATE: October 26, 2009
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PLOT DATE: October 26, 2009
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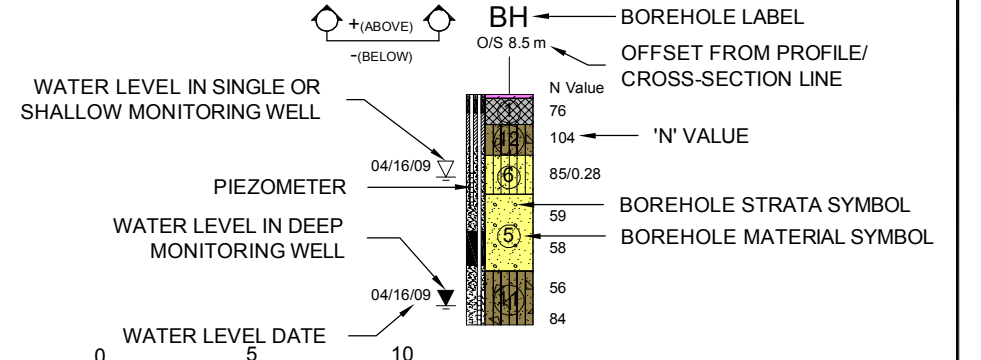


BOREHOLE MATERIAL SYMBOLS:

- NOTES:**
1. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.
 2. THE CHARACTERISTICS AND VARIABILITY ANTICIPATED WITHIN THE MAJOR SOIL DEPOSITS ARE DESCRIBED IN THE TEXT OF THIS REPORT. SIGNIFICANT LAYERS, INTERLAYERS AND LENSES WITHIN THE MAJOR DEPOSITS ILLUSTRATED FROM INTERPRETATION OF THE BOREHOLE RECORDS. THE BOUNDARIES ILLUSTRATED ARE INTENDED TO HIGHLIGHT THE VARIABILITY WITHIN THE DEPOSITS, WHICH EXHIBIT GRADUAL TRANSITIONS FROM ONE SOIL TYPE TO ANOTHER. IN ADDITION, LENSES AND INTERLAYERS NOT DETECTED BY THE SUBSURFACE INVESTIGATION WILL BE PRESENT BETWEEN BOREHOLES.
 3. THIS INTERPRETED STRATIGRAPHY FIGURE IS A SIMPLIFICATION OF SUBSURFACE CONDITIONS. DETAILED DESCRIPTIONS OF THE CONDITIONS ENCOUNTERED AT THE BOREHOLE LOCATION ARE FOUND ON THE RECORDS OF BOREHOLES CONTAINED IN THE GEOTECHNICAL INVESTIGATION REPORTS LISTED IN SECTION 3 OF THE INITIAL GEO-ENGINEERING DESIGN REPORT NO. 08-1111-0039 (2340), DATED SEPTEMBER 2009.
 4. THIS FIGURE IS PREPARED FOR PRELIMINARY DESIGN PURPOSES ONLY. IT IS NOT A BASELINE FOR CONSTRUCTION CONTRACT TENDERING PURPOSE.
 5. BOREHOLE WIDTH IN PROFILE IS NOT TO SCALE.

- REFERENCES:**
1. BASE PLAN AND ALIGNMENT PROVIDED IN DIGITAL FORMAT BY TORONTO TRANSIT COMMISSION, RECEIVED ON FEBRUARY 12, 2009. THE PROFILES ARE APPROXIMATE AND ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY.

- GENERAL LEGEND:**
- INTERPRETED MAJOR DEPOSIT BOUNDARY
 - INTERPRETED PIEZOMETRIC LEVEL



Toronto-York Spadina Subway Extension

PROJECT: INITIAL GEO-ENGINEERING DESIGN
 TORONTO-YORK SPADINA SUBWAY EXTENSION
 CONTRACT NO. A85-77

TITLE: INTERPRETED STRATIGRAPHIC CROSS SECTION B - B'
 HIGHWAY 407 STATION
 CHAINAGE 18+135

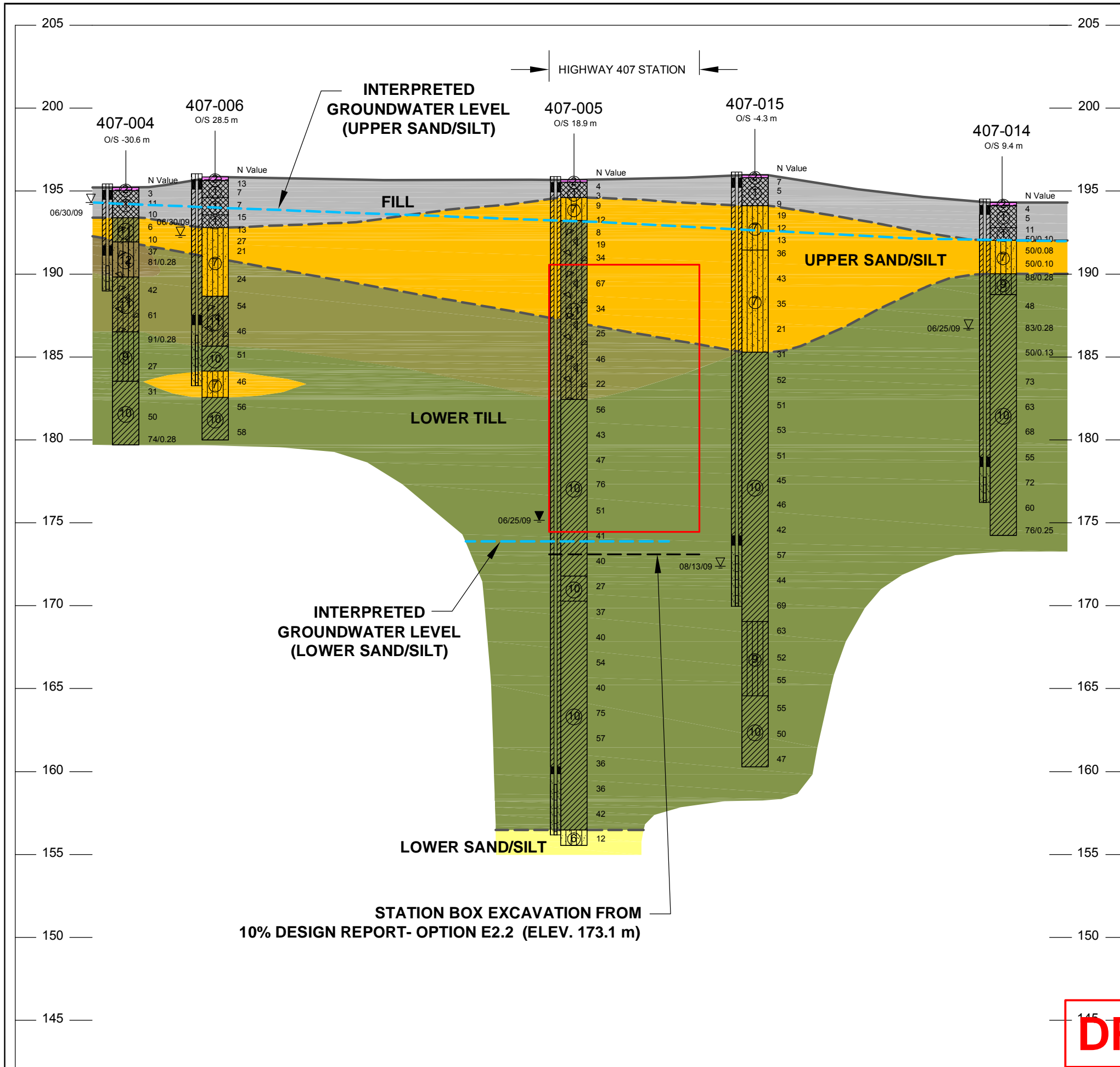
Golden Associates
 Mississauga, Ontario, Canada

DESIGN	DOFLJ	Oct. 26, 2009	SCALE AS SHOWN	REV. B
CHECK	SLP	Oct. 26, 2009	FIGURE No.	
REVIEW	JW	Oct. 26, 2009		

H407-3

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PLOT DATE: October 26, 2009
 FILENAME: T:\Projects\2008\08-1111-0039 (TTC, York Spadina Subway Ext, Toronto)\-AMB- Initial Design Report 407\0811110039AMB004.dwg



BOREHOLE MATERIAL SYMBOLS:

① FILL	⑤ SAND	⑨ CLAYEY SILT
② ORGANICS	⑥ SILTY SAND	⑩ CLAY/SILTY CLAY
③ GRAVEL	⑦ SANDY SILT/ SAND AND SILT	⑪ SILTY CLAY TILL / CLAYEY SILT TILL
④ SAND AND GRAVEL/ GRAVELLY SAND	⑧ SILT	⑫ SANDY SILT/SILTY SAND/ SAND AND SILT TILL

- NOTES:**
1. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.
 2. THE CHARACTERISTICS AND VARIABILITY ANTICIPATED WITHIN THE MAJOR SOIL DEPOSITS ARE DESCRIBED IN THE TEXT OF THIS REPORT. SIGNIFICANT LAYERS, INTERLAYERS AND LENSES WITHIN THE MAJOR DEPOSITS ILLUSTRATED FROM INTERPRETATION OF THE BOREHOLE RECORDS. THE BOUNDARIES ILLUSTRATED ARE INTENDED TO HIGHLIGHT THE VARIABILITY WITHIN THE DEPOSITS, WHICH EXHIBIT GRADUAL TRANSITIONS FROM ONE SOIL TYPE TO ANOTHER. IN ADDITION, LENSES AND INTERLAYERS NOT DETECTED BY THE SUBSURFACE INVESTIGATION WILL BE PRESENT BETWEEN BOREHOLES.
 3. THIS INTERPRETED STRATIGRAPHY FIGURE IS A SIMPLIFICATION OF SUBSURFACE CONDITIONS. DETAILED DESCRIPTIONS OF THE CONDITIONS ENCOUNTERED AT THE BOREHOLE LOCATION ARE FOUND ON THE RECORDS OF BOREHOLES CONTAINED IN THE GEOTECHNICAL INVESTIGATION REPORTS LISTED IN SECTION 3 OF THE INITIAL GEO-ENGINEERING DESIGN REPORT NO. 08-1111-0039 (2340), DATED SEPTEMBER 2009.
 4. THIS FIGURE IS PREPARED FOR PRELIMINARY DESIGN PURPOSES ONLY. IT IS NOT A BASELINE FOR CONSTRUCTION CONTRACT TENDERING PURPOSE.
 5. BOREHOLE WIDTH IN PROFILE IS NOT TO SCALE.

- REFERENCES:**
1. BASE PLAN AND ALIGNMENT PROVIDED IN DIGITAL FORMAT BY TORONTO TRANSIT COMMISSION, RECEIVED ON FEBRUARY 12, 2009. THE PROFILES ARE APPROXIMATE AND ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY.

GENERAL LEGEND:

- INTERPRETED MAJOR DEPOSIT BOUNDARY
- - - - INTERPRETED PIEZOMETRIC LEVEL

WATER LEVEL IN SINGLE OR SHALLOW MONITORING WELL

PIEZOMETER

WATER LEVEL IN DEEP MONITORING WELL

BH BOREHOLE LABEL

O/S 8.5 m OFFSET FROM PROFILE/ CROSS-SECTION LINE

N Value 'N' VALUE

BOREHOLE STRATA SYMBOL

BOREHOLE MATERIAL SYMBOL

WATER LEVEL DATE

SCALE VERTICAL 1:250 METRES

SCALE HORIZONTAL 1:500 METRES

DRAFT

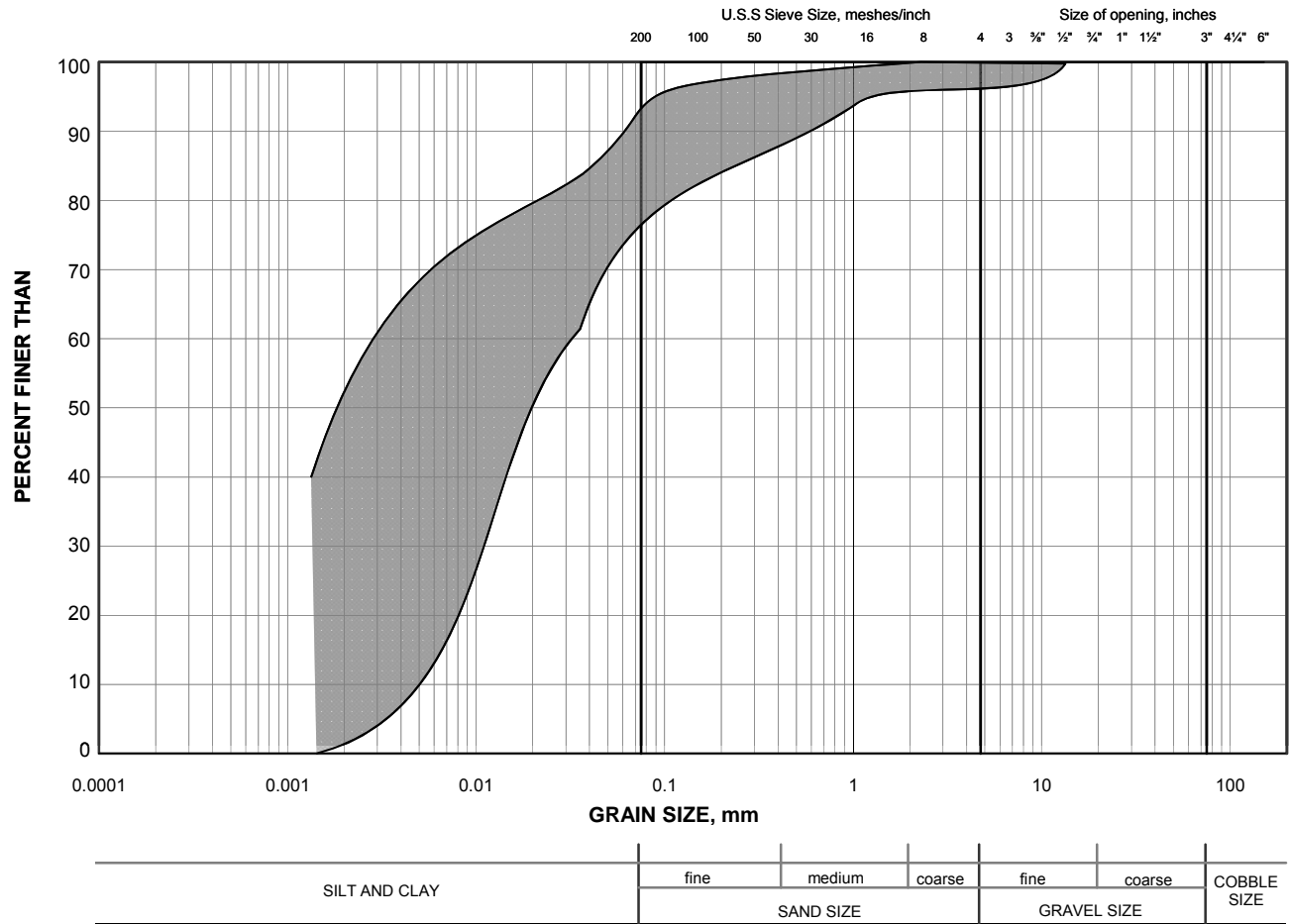
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INITIAL GEO-ENGINEERING DESIGN TORONTO-YORK SPADINA SUBWAY EXTENSION CONTRACT NO. A85-77			
TITLE			
INTERPRETED STRATIGRAPHIC CROSS SECTION C - C' HIGHWAY 407 STATION CHAINAGE 18+265			
PROJECT No.	08-1111-0039	FILE No.	0811110039AMB004.dwg
DESIGN		SCALE	AS SHOWN
CAD	DD/RJ	Oct. 26, 2009	REV. B
CHECK	SLP	Oct. 26, 2009	FIGURE No.
REVIEW	JW	Oct. 26, 2009	



GRAIN SIZE DISTRIBUTION Fill (Type 1)

FIGURE H407-5

DRAFT

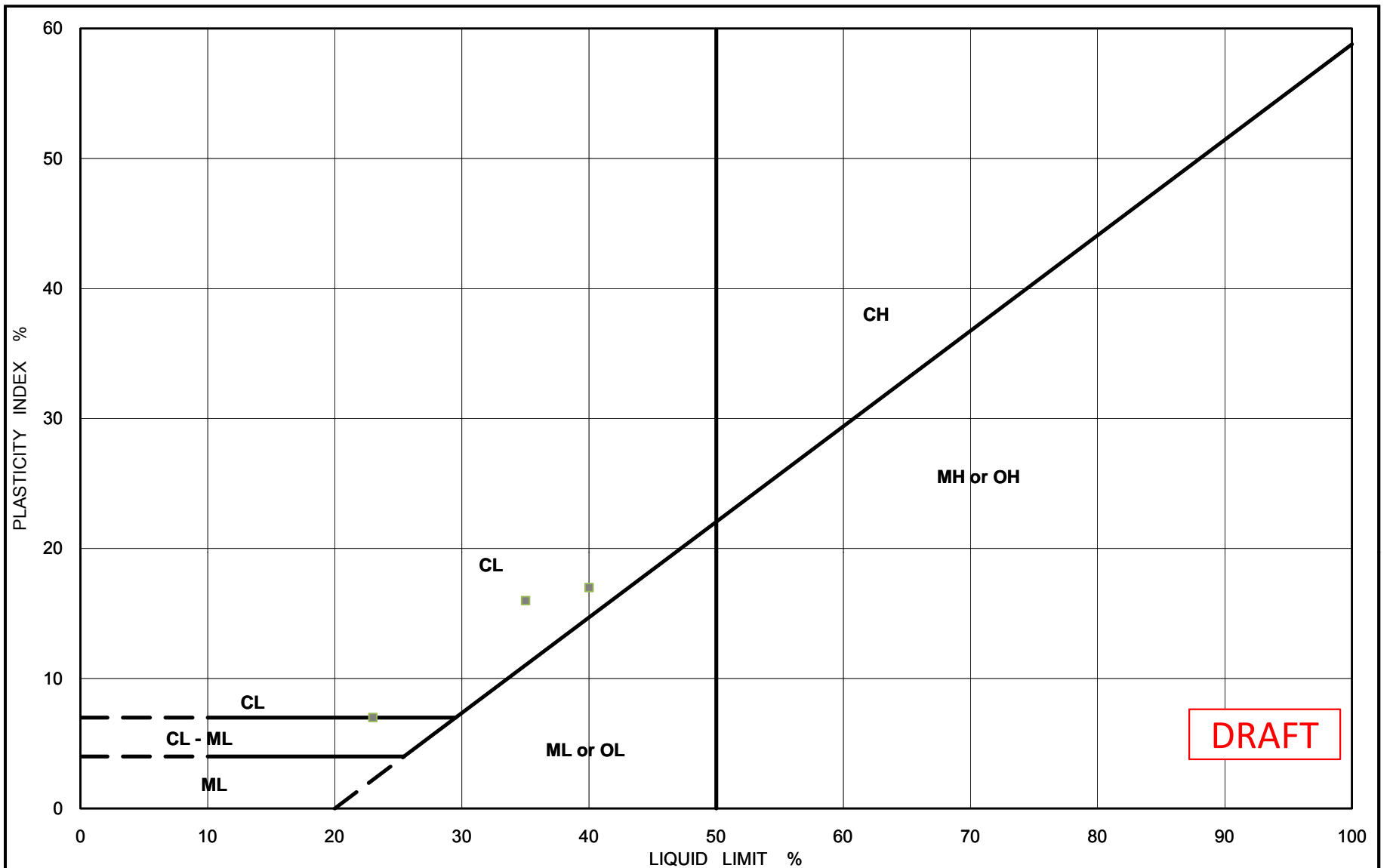


NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 4 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
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 Checked: SP





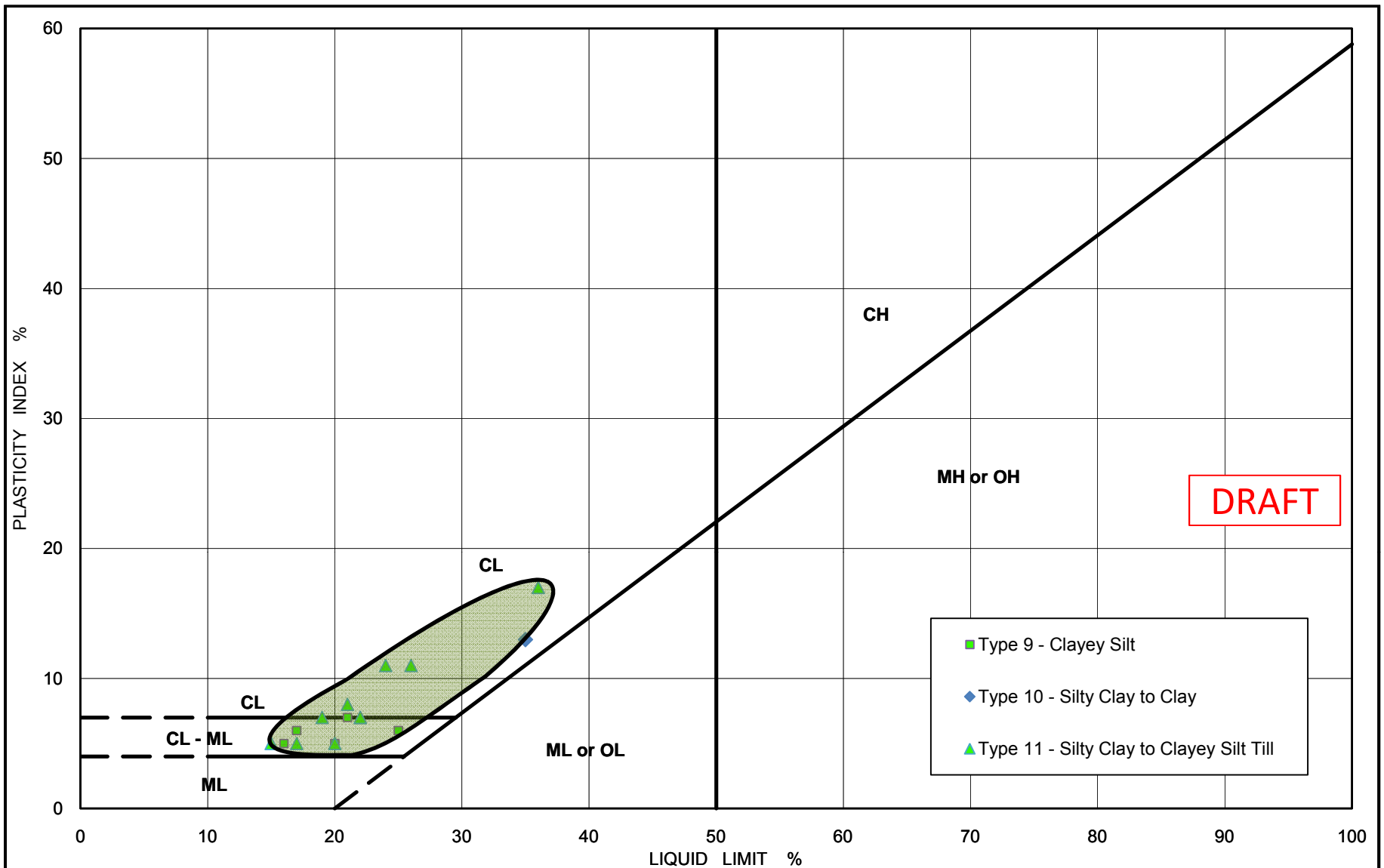
Toronto-York Spadina
Subway Extension

PLASTICITY CHART
Fill
(Type 1)

Figure H407-6

Project No. 08-1111-0039

Checked By: SP



Toronto-York Spadina
Subway Extension

PLASTICITY CHART
Upper Till Deposit - Clayey Silt to Silty Clay Till
(Types 9 to 11)

Figure H407-8

Project No. 08-1111-0039

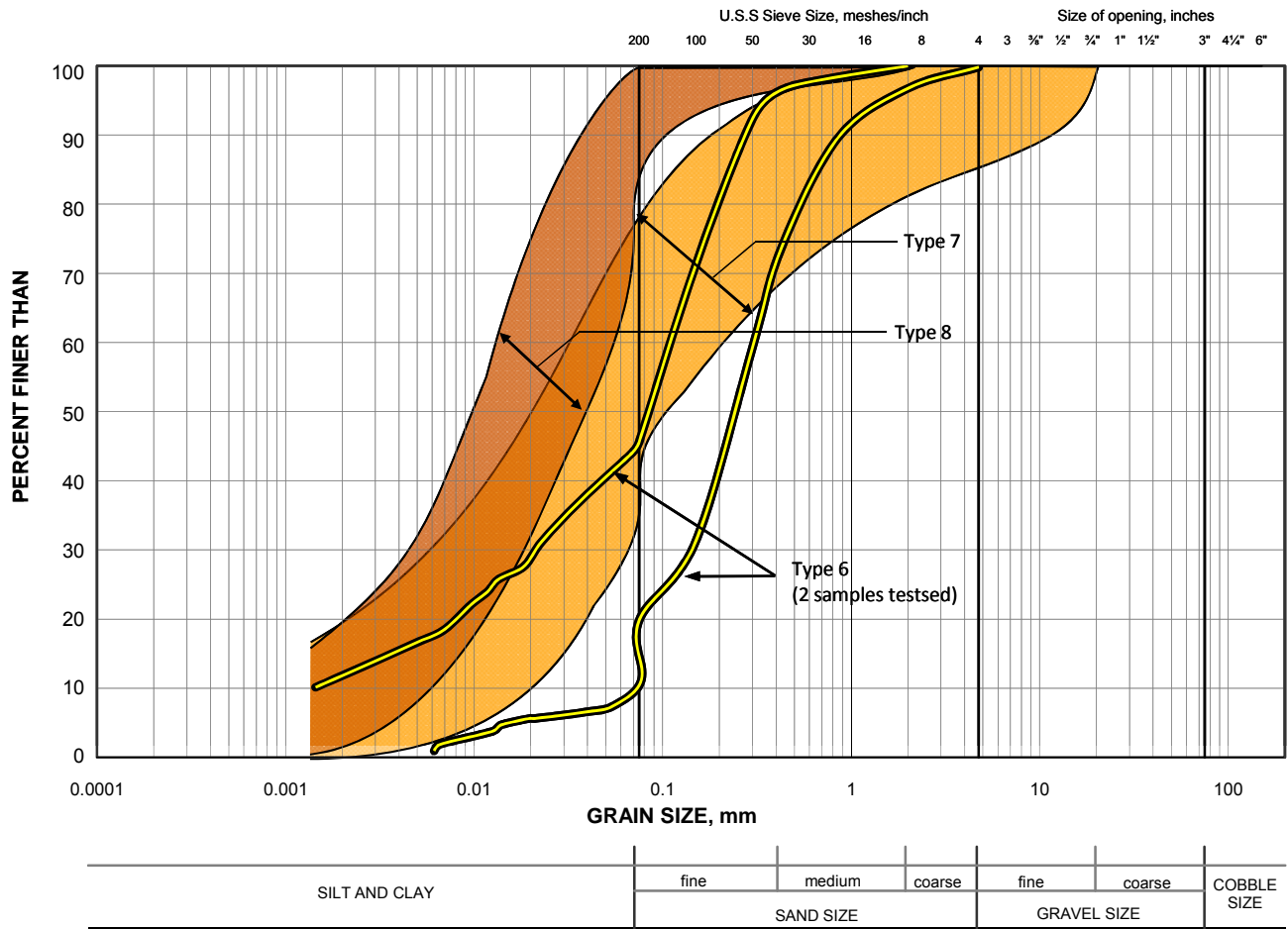
Checked By: SP

GRAIN SIZE DISTRIBUTION

Upper Sand/Silt Deposit - Silty Sand to Silt (Types 6 to 8)

FIGURE H407-9

DRAFT

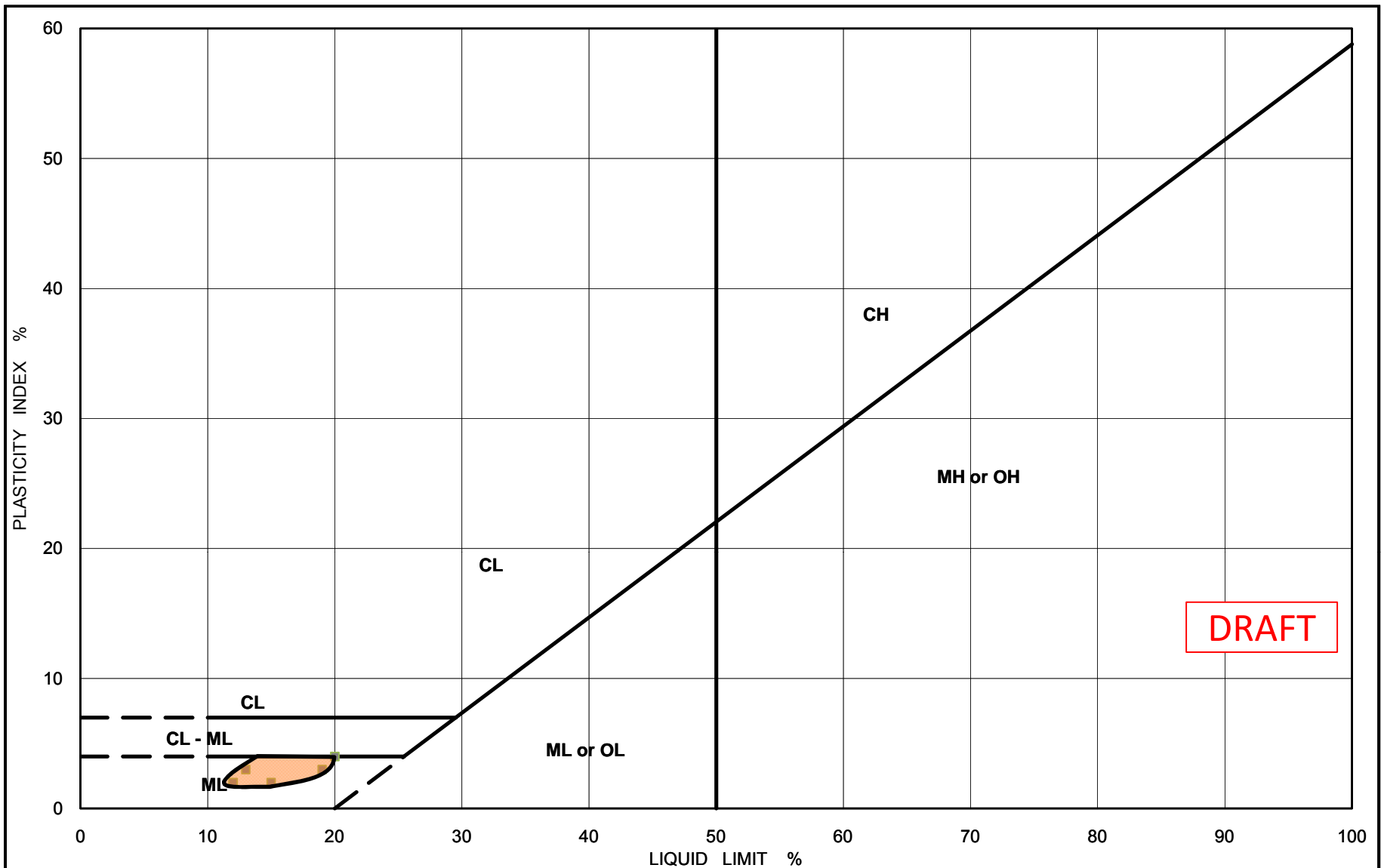


NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 25 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
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Toronto-York Spadina
Subway Extension

PLASTICITY CHART
Upper Sand/Silt Deposit - Sand and Silt to
Silt (Types 7 and 8)

Figure H407-10

Project No. 08-1111-0039

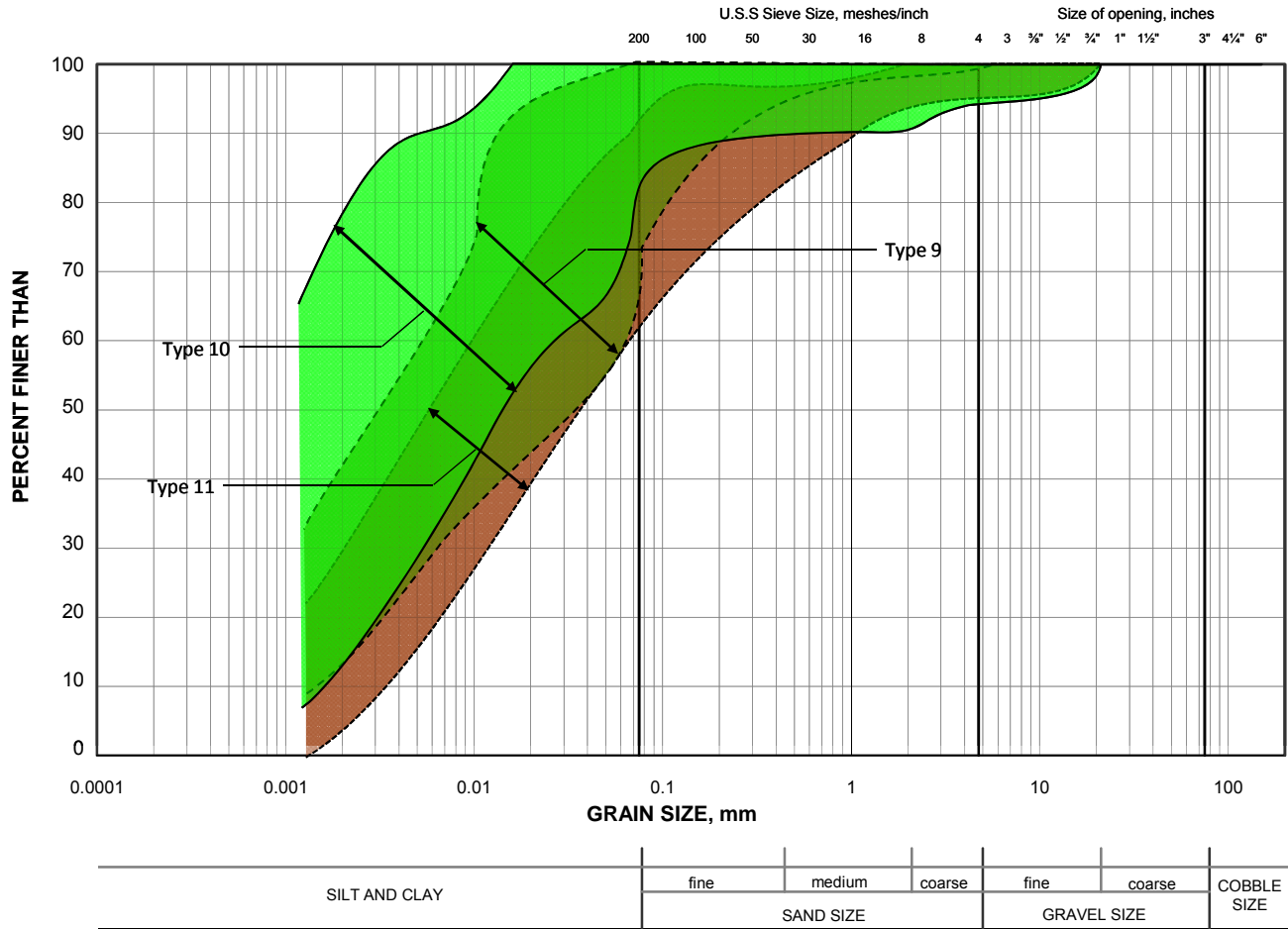
Checked By: SP

GRAIN SIZE DISTRIBUTION

Lower Till Deposit - Clayey Silt to Silty Clay Till (Types 9 to 11)

FIGURE H407-11

DRAFT

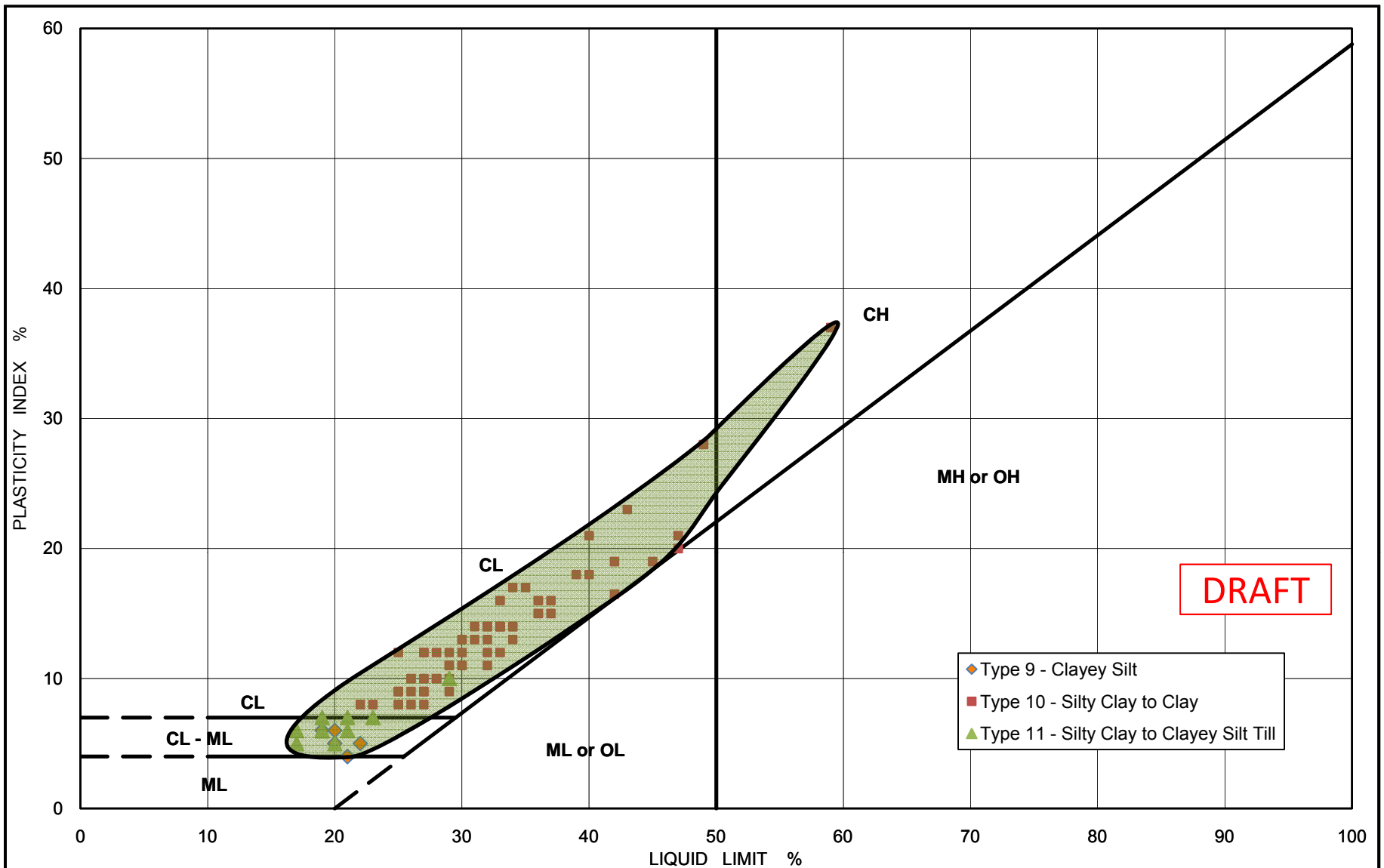


NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 80 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
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Toronto-York Spadina
Subway Extension

PLASTICITY CHART
Lower Till Deposit - Clayey Silt to Silty Clay Till
(Types 9 to 11)

Figure H407-12

Project No. 08-1111-0039

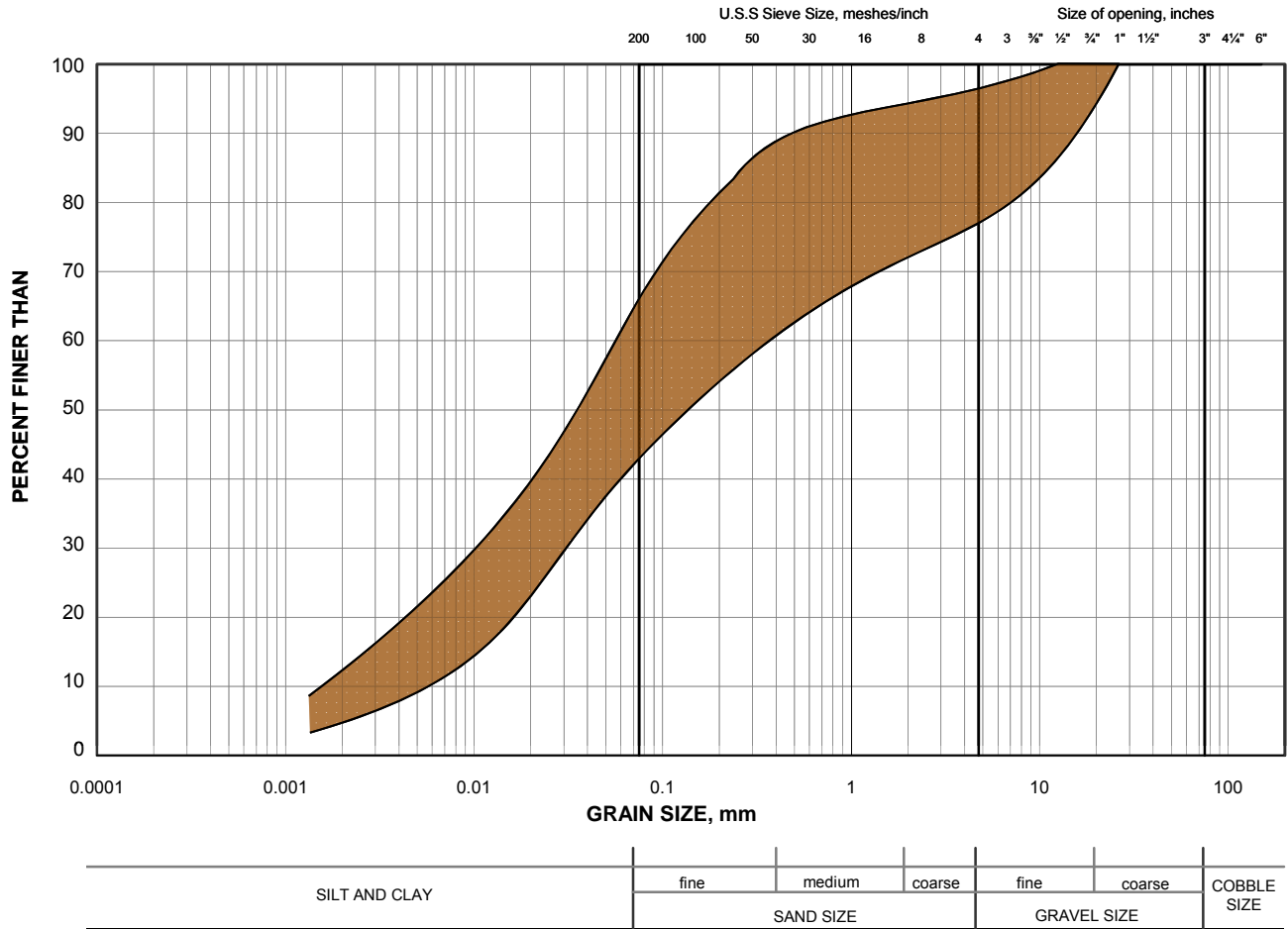
Checked By: SP

GRAIN SIZE DISTRIBUTION

Lower Till Deposit - Silty Sand to Sand Silt Till (Type 12)

FIGURE H407-13

DRAFT



NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 3 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
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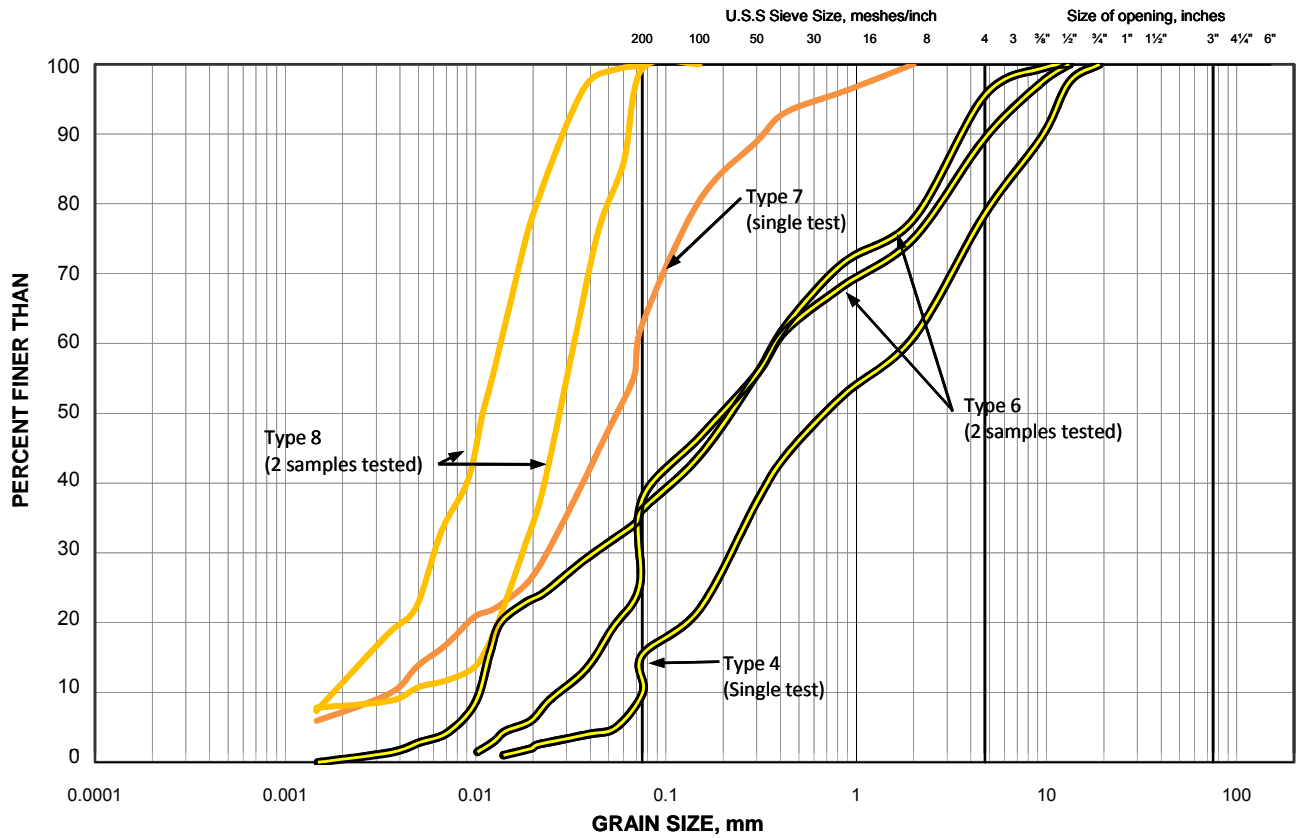


GRAIN SIZE DISTRIBUTION

Interstadial Sand/Silt Deposit - Sand and Gravel to Silt (Types 4, 6, 7 and 8)

FIGURE H407-14

DRAFT



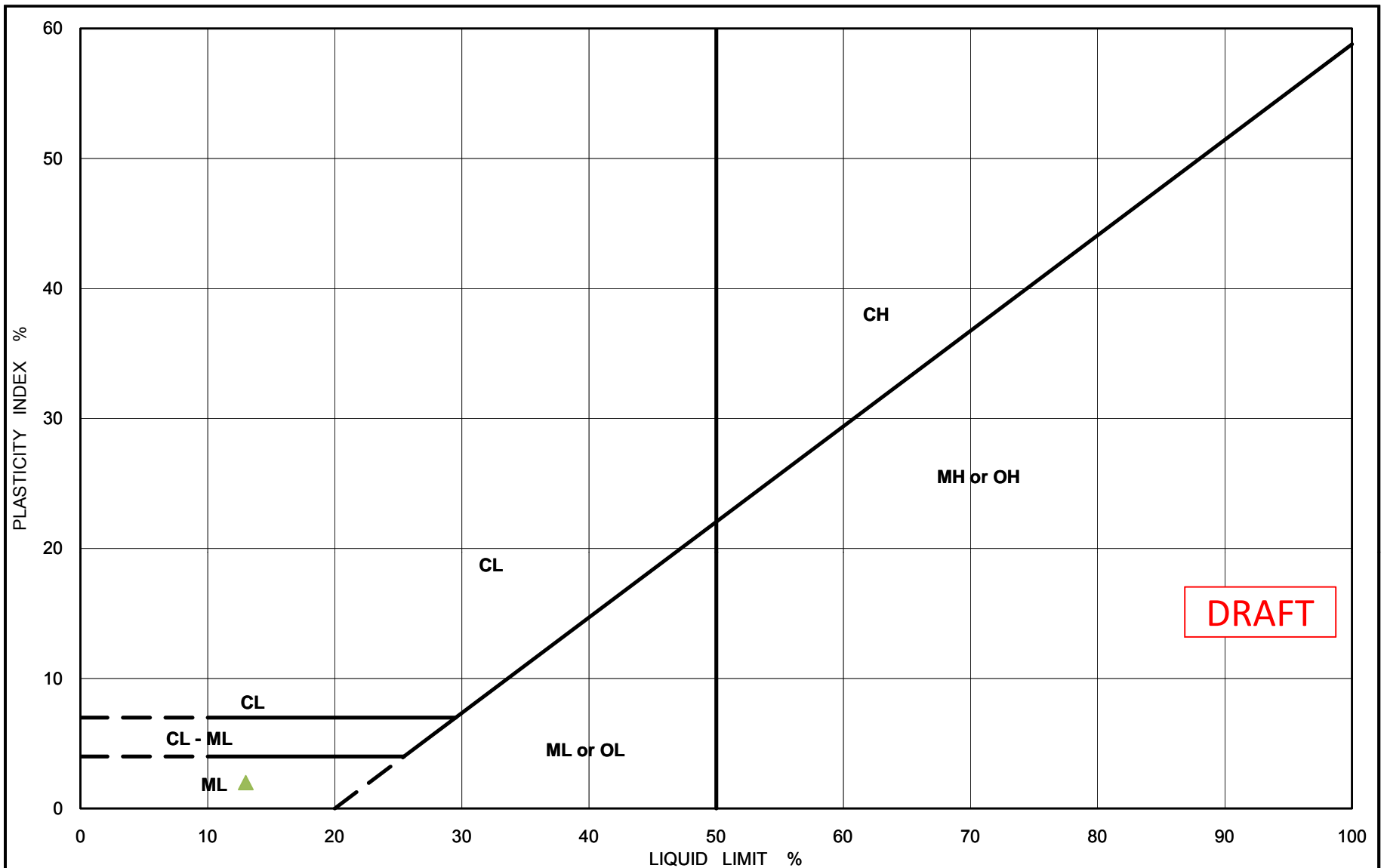
SILT AND CLAY	fine	medium	coarse	fine	coarse	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 6 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
 Input: AT
 Checked: SP



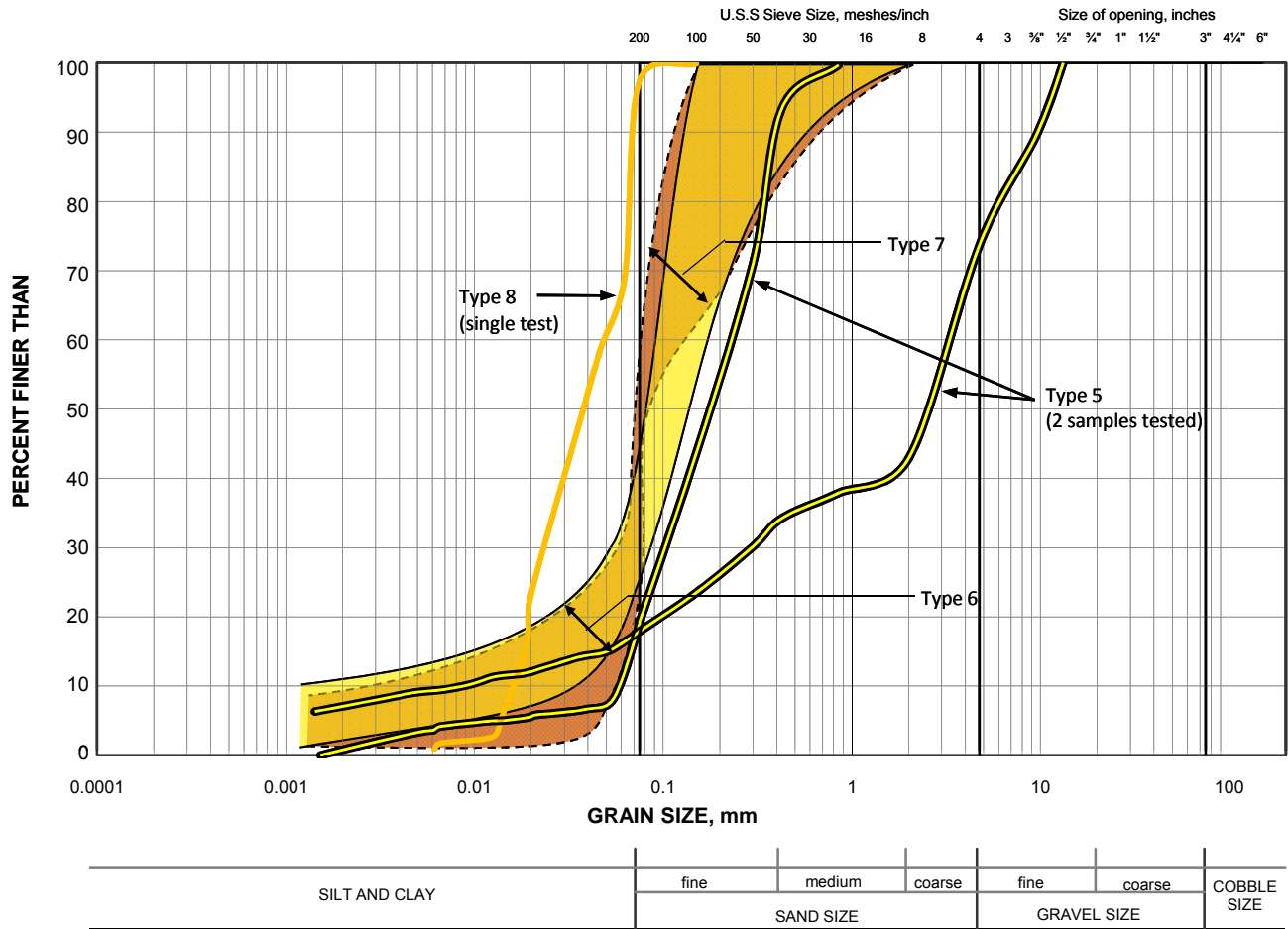


GRAIN SIZE DISTRIBUTION

Lower Sand/Silt Deposit - Silty Sand to Silt (Types 5 to 8)

FIGURE H407-16

DRAFT



NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 11 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
 Input: AT
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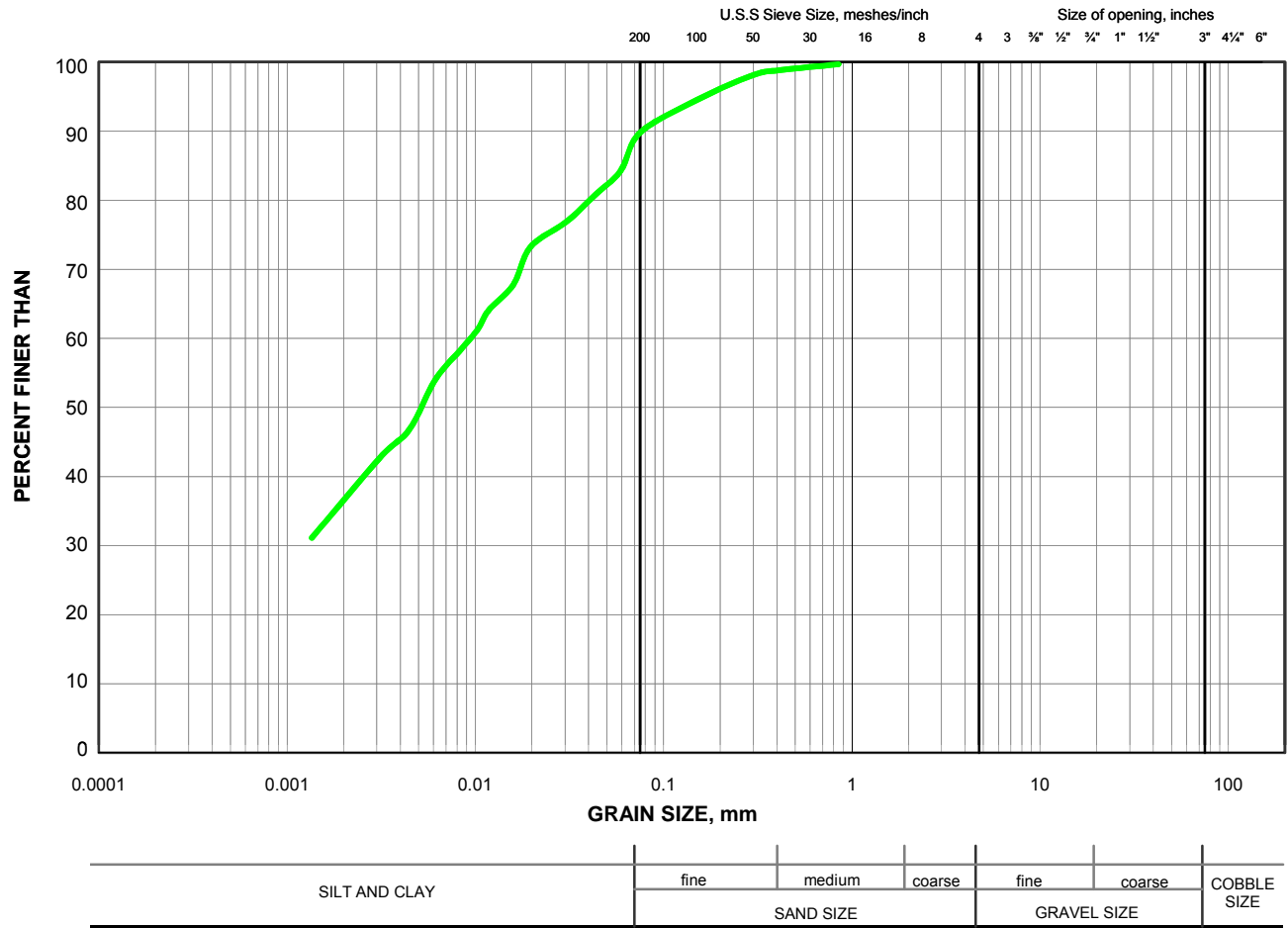


GRAIN SIZE DISTRIBUTION

Cohesive Layers within the Lower Sand/Silt Deposit Silty Clay (Type 10)

FIGURE H407-17

DRAFT

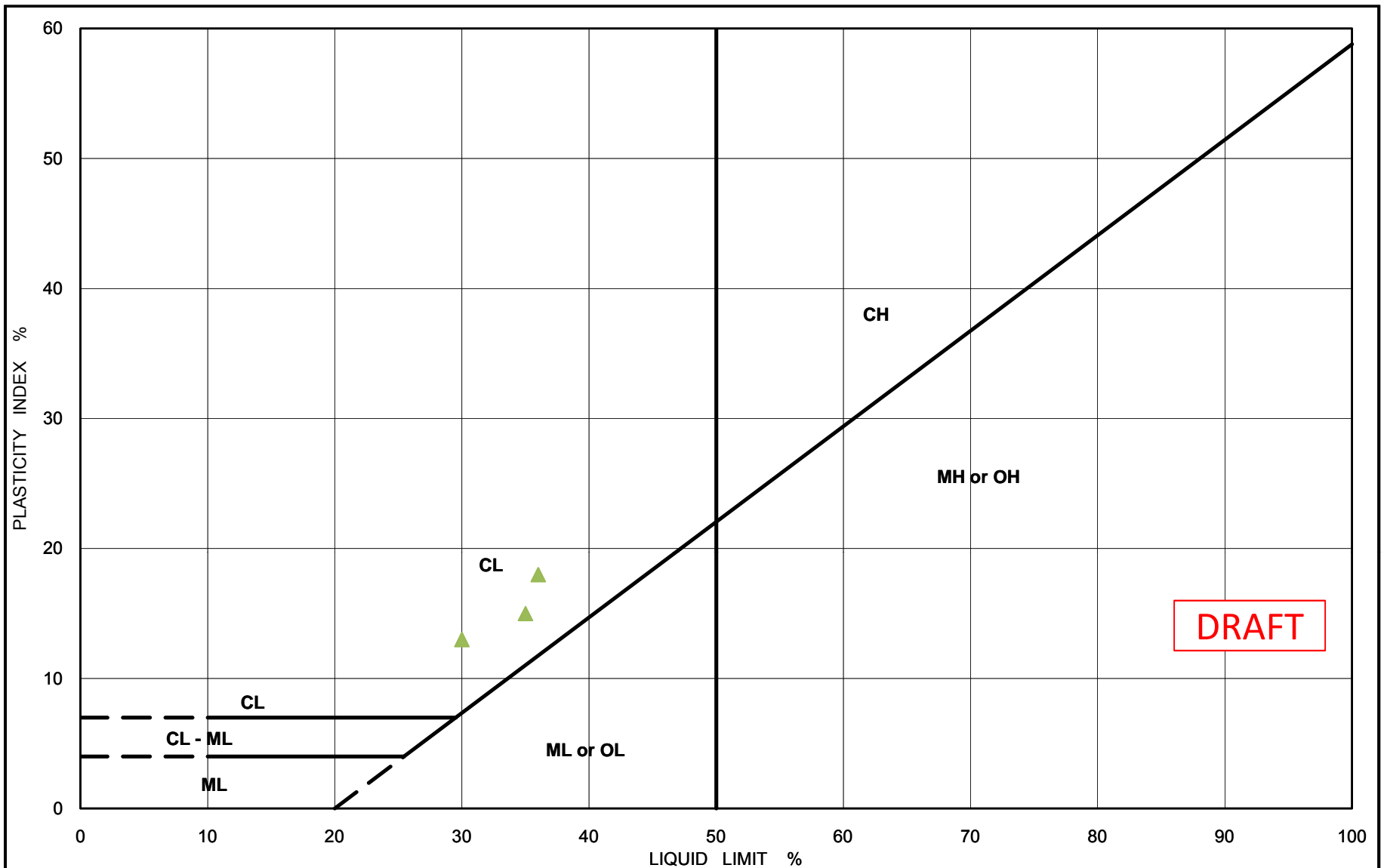


NOTES:

1. THIS GRAIN SIZE DISTRIBUTION ENVELOPE IS BASED ON THE THE TEST RESULTS FOR 11 SAMPLES OBTAINED AT THE HIGHWAY 407 STATION STATION SITE. FOR SAMPLE SPECIFIC RESULTS AND INFORMATION, REFER TO THE DRAFT GEOTECHNICAL FACTUAL DATA REPORTS REFERENCED IN SECTION 3.2.
2. THE SIZE OF THE SAMPLES USED DURING THE FIELD INVESTIGATION WORK LIMITS THE MAXIMUM RETRIEVED PARTICLE SIZE TO ABOUT 35 MM DIAMETER.
3. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE DRAFT REPORT TITLED "INITIAL GEO-ENGINEERING DESIGN, HIGHWAY 407 STATION, TORONTO-YORK SPADINA SUBWAY EXTENSION", DATED SEPTEMBER 2009.

Date: Sep-09
 Project: 08-1111-0039
 Input: AT
 Checked: SP





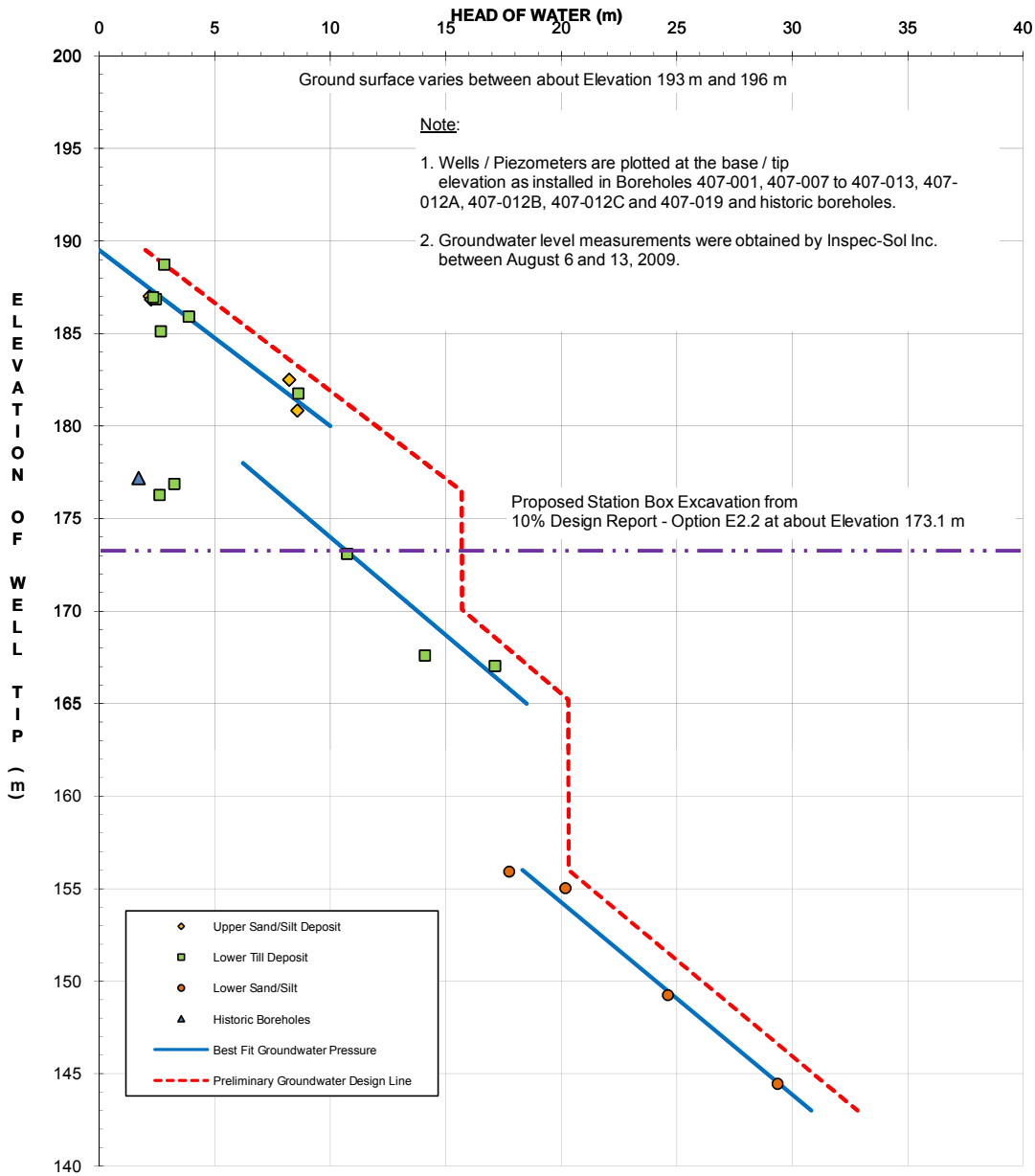
PLASTICITY CHART
 Cohesive Layers within the Lower Sand/Silt
 Deposit - Silty Clay (Types 10 and 11)

Figure H407-18
 Project No. 08-1111-0039
 Checked By: SP

**DESIGN POREWATER PRESSURE DISTRIBUTION
FLOODPLAIN AT HIGHWAY 407 STATION**

FIGURE H407-19

DRAFT



Preliminary Design Porewater Pressure (ρ_w) = Head of Water x 9.81 kN/m³

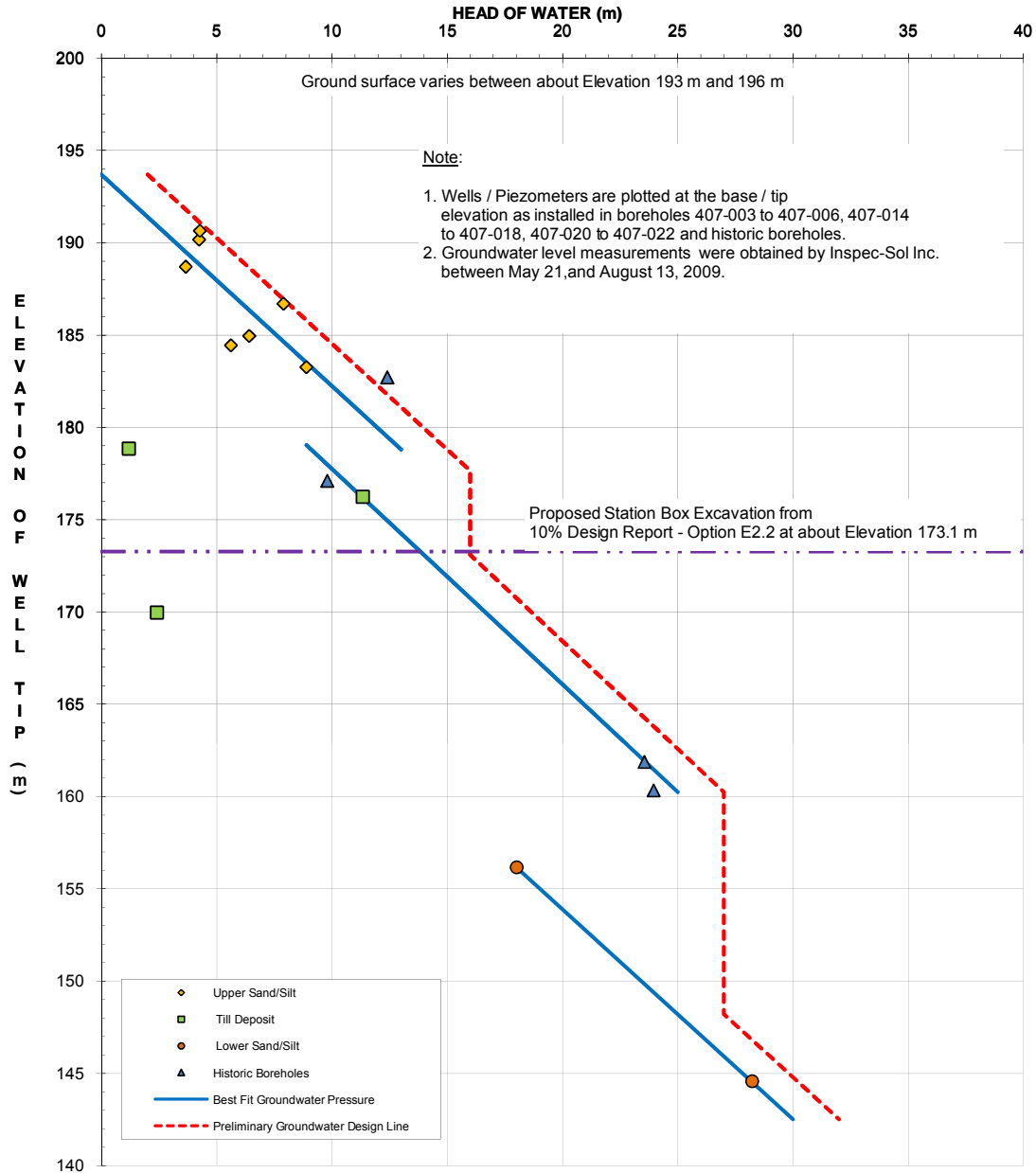
Date: Sep-09
 Project No.: 08-1111-0039 (2340)
 Drawn by: SLP
 Checked by: JW/MF



**DESIGN POREWATER PRESSURE DISTRIBUTION
TABLE LAND AT HIGHWAY 407 STATION**

FIGURE H407-20

DRAFT



Preliminary Design Porewater Pressure (ρ_w) = Head of Water x 9.81 kN/m³

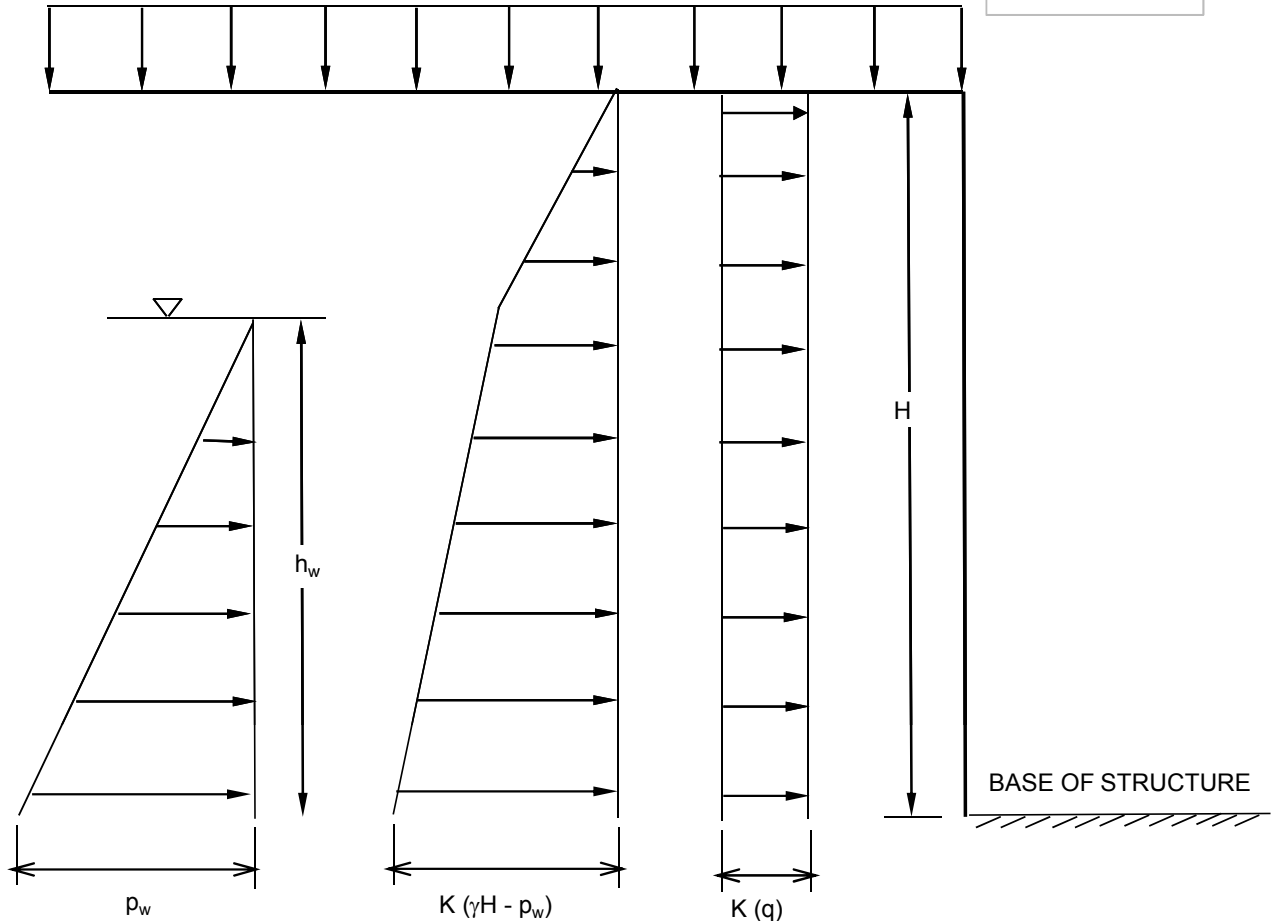
Date: Sep-09
 Project No.: 08-1111-0039 (2340)
 Drawn by: SLP
 Checked by: JW/MF



**DESIGN LATERAL EARTH PRESSURE DISTRIBUTION FOR
PERMANENT SUBWAY BOX STRUCTURES AND TEMPORARY
CONTINUOUS CONCRETE WALLS**

FIGURE H407-21

DRAFT



**TOTAL PRESSURE ON SUBWAY BOX OR
CONTINUOUS CONCRETE WALLS**

$$K(\gamma H - p_w) + K(q) + p_w$$

γ = TOTAL UNIT WEIGHT OF SOIL

K = EARTH PRESSURE COEFFICIENT
(REFER TO TEXT OF REPORT)

p_w = POREWATER PRESSURE
(SEE TEXT OF REPORT AND FIGURES H407-19 and H407-20)

NOTE: THE ABOVE FIGURE DOES NOT PROVIDE FOR THE EFFECTS OF CONCENTRATED SURCHARGE AS MAY ARISE FROM ADJACENT BUILDING FOUNDATIONS.

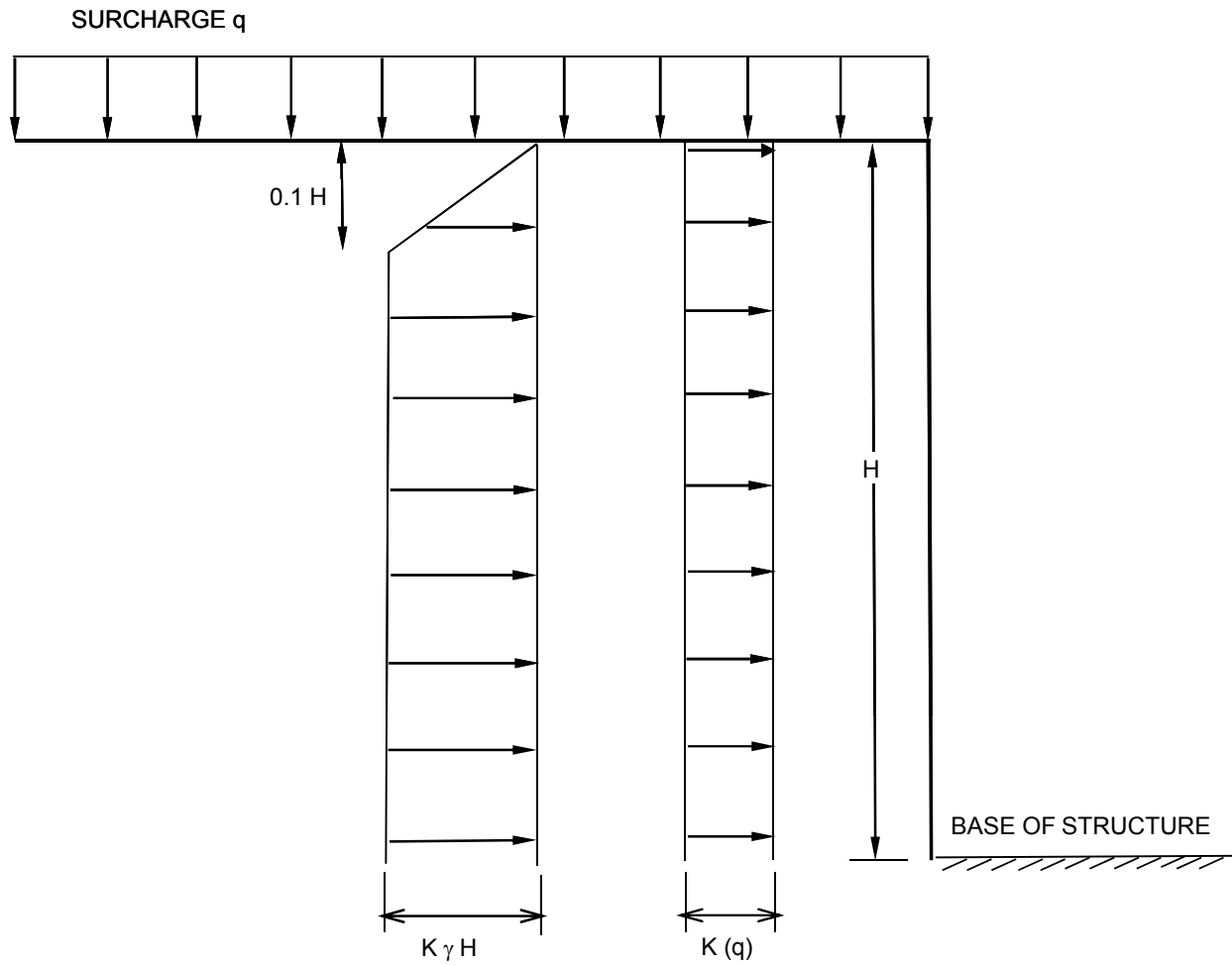
Date: August 2009
Project No.: 08-1111-0039(2340)
Drawn by: SLP
Checked by: MRF



DESIGN LATERAL EARTH PRESSURE DISTRIBUTION FOR
TEMPORARY BRACED EXCAVATIONS

FIGURE H407-022

DRAFT



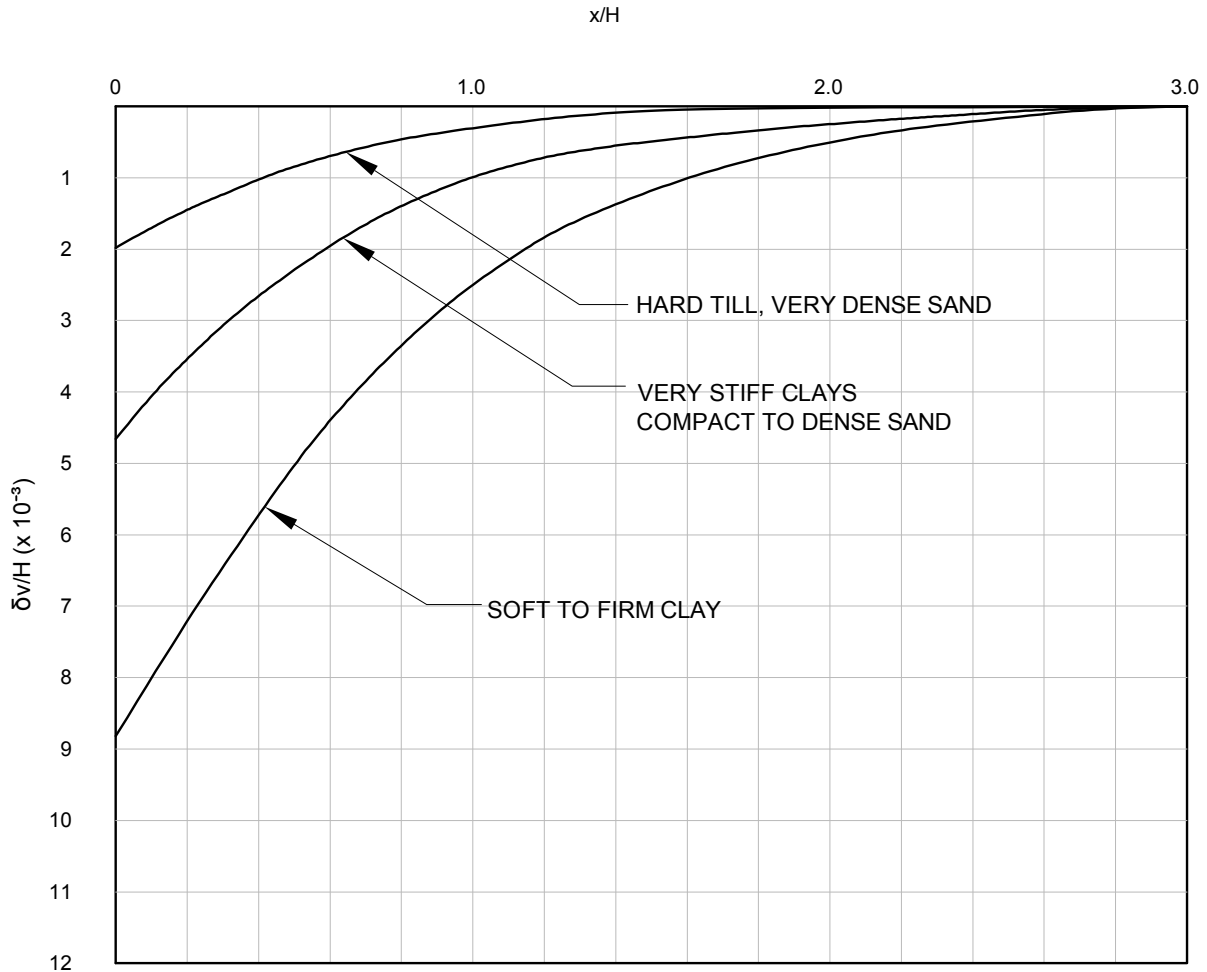
γ = TOTAL UNIT WEIGHT OF SOIL

K = EARTH PRESSURE COEFFICIENT
(REFER TO TEXT OF REPORT)

Date: August 2009
Project No.: 08-1111-0039 (2340)
Drawn by: SP
Checked by: MF



DRAFT



LEGEND:

- δ_v - VERTICAL SETTLEMENT
- x - HORIZONTAL DISTANCE FROM EDGE OF WALL
- H - DEPTH OF EXCAVATION

Date September 2009

Project 08-1111-0039 (2340)

Drawn.....DD/RJ

ChkdSLP...



Toronto-York Spadina
Subway Extension

PLOT DATE: September 16, 2009
FILENAME: T:\Projects\2008\08-1111-0039 (TTC, York Spadina Subway Ext, Toronto)\-AMB- Initial Design Report 407\0811110039AMB023.dwg



APPENDIX A

Important Information and Limitations of This Report

DRAFT

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. Golder's responsibility is limited to documenting the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data contained herein pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information contained in this report are for the sole benefit of the Client and its consultants. *No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the Report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this Report by the regulatory agency as an Approved user for the specific and identified purpose of the applicable permit review process. The factual portion of this report may be provided to specified third parties identified by the Client upon Golder's express written consent. Any other use of this report by others is prohibited and is without responsibility to Golder.* The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. *In order to properly understand the contents of the report, reference must be made to*

**IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT (cont'd)**

the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out to date. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. The soil must be protected from these changes during construction.

**IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT (cont'd)**

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated based on this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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