REPORT

April 2012

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

Bridge Widening and Replacement Highway 401 Rehabilitation from Warden Avenue to Brock Road Toronto, Ontario W.O.07-20012

Submitted to:
URS Canada Inc.
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PART A

PRELIMINARY FOUNDATION INVESTIGATION REPORT
BRIDGE WIDENING AND REPLACEMENT
HIGHWAY 401 REHABILITATION
FROM WARDEN AVENUE TO BROCK ROAD
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services in support of the rehabilitation of Highway 401 between Warden Avenue and Brock Road in Toronto, Ontario.

This report addresses the results of the desktop studies and preliminary foundation investigations carried out for the following bridge structures:

- **Birchmount Road overpass** (Site No. 37-212): Southward widening, with possible superstructure replacement.
- **CP Rail overhead** (Site No. 37-213), approximately 200 m east of Birchmount Road: Full replacement of the existing structure plus southward widening.
- **Kennedy Road overpass** (Site No. 37-214): Northward and southward widening, with possible superstructure replacement.
- **CN Rail overhead** (Site No. 37-215), located approximately 400 m east of Kennedy Road: Full replacement of the existing structure, plus northward and southward widening.
- **Midland Avenue overpass** (Site No. 37-216): Northward widening, with possible superstructure replacement.
- **Markham Road overpass** (Site No. 37-218): Northward widening, with possible superstructure replacement.

This report was developed with information from previous geotechnical/foundations investigations at the structure sites, as follows:

- **MTO GEOCRES No. 30M14-32:** Report titled "Foundation Investigation Report for the Proposed New Structure at Markham Road and Highway 401, District #6 (Toronto), W.J. 67-F-40 – W.P. 262-61", prepared by MTO Foundation Section – Materials and Testing Division, dated June 9, 1967.
- **MTO GEOCRES No. 30M14-68:** Report titled "Foundation Investigation Report for the Proposed Highway 401 and C.N.R. Overhead Extensions, ¼ Mile East of Kennedy Road Interchange, Twp. of Scarborough, District #6, Toronto, W.J. 66-F-88 – W.P. 259-61", prepared by MTO Foundation Section – Materials and Testing Division, dated January 12, 1967.
- **MTO GEOCRES No. 30M14-71:** Report titled "Foundation Investigation Report for the Proposed New Structure at Highway 401 and Kennedy Road Intersections, Scarborough Twp., York County, District No. 6 (Toronto), W.J. 66-F-33 – W.P. 258-61", prepared by MTO Foundation Section – Materials and Testing Division, dated June 14, 1966.
- **MTO GEOCRES No. 30M14-73:** Report titled "Foundation Investigation Report for Proposed Extension of the Existing Bridge at Highway 401 and Birchmount Road, County of York, Township of Scarborough, District #6 (Toronto), W.J. 65-F-49 – W.P. 256-61", prepared by MTO Foundation Section – Materials and Testing Division, dated August 3, 1965.

- **MTO GEOCRES No. 30M14-74:** Report titled "Foundation Investigation Report for the Proposed Extension of Highway 401 and Midland Avenue Crossing, Metropolitan Toronto, District #6, W.J. 66-F-87 – W.P. 260-61", prepared by MTO Foundation Section, Materials and Testing Division, dated January 4, 1967;
- **MTO GEOCRES No. 30M14-75:** Report titled "Foundation Investigation Report for the Proposed Extension of Highway 401 and C.P.R. Overhead, Metropolitan Toronto – District #6, W.J. 66-F-89 – W.P. 257-61", prepared by MTO Foundation Section – Materials and Testing Division, dated January 15, 1967;

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) dated October 2007, and in Section 5.8 of URS's *Technical Proposal* for this assignment.

2.0 SITE DESCRIPTION

The six structure sites addressed in this report are located along the Highway 401 westbound and eastbound core and collector lanes between Birchmount Road and Markham Road in Toronto, Ontario. The approximate locations, approximate Highway 401 and local road grades, structure and foundation types for the existing structures are summarized in the following table:

Structure Site	Site No.	Approximate Station	Approximate Highway 401 Grade	Approximate Local Road Grade	Existing Structure Type	Existing Foundation Type
Birchmount Road Overpass	37-212	12+100	185 m	180 m	Two-span	Spread footings
CP Rail Overhead	37-213	12+300	182 m	175 m	Single-span	Spread footings
Kennedy Road Overpass	37-214	12+900	176 m	170 m	Two-span	Spread footings
CN Rail Overhead	37-215	13+360	174 m	165.5 m	Single-span	Spread footings
Midland Road Overpass	37-216	13+760	172 m to 173 m	166 m	Single-span	Spread footings
Markham Road Overpass	37-218	17+100	164 m to 165 m	158 m to 159 m	Two-span	Spread footings

In general, the terrain in the vicinity of each structure site is relatively flat, with the original ground surface sloping downward from west to east, from approximately Elevation 177 m to 158 m. The existing Highway 401 grade also slopes from west to east, from approximately Elevation 185 m to 164 m. Industrial parks are located south of the highway, and in some areas on the north, while residential zones dominate the north side of the highway.

3.0 INVESTIGATION PROCEDURES

The field work for the current subsurface investigation was carried out in April 2011, during which time two boreholes (2011-01 and 2011-05) were advanced using a track-mounted CME-55 drill rig and a truck-mounted CME-75 drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Milton, Ontario. The borehole locations for the current investigation, together with the locations of boreholes from previous investigations by others, are shown on the Borehole Location and Soil Strata drawings contained in Appendices A to F.

Soil samples were obtained in the 2011 boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure.

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations and a standpipe piezometer was installed in Borehole 2011-05 to permit monitoring of the groundwater level. The piezometer consists of 50 mm diameter PVC pipe, with a slotted screen sealed within a sand filter pack at a selected depth interval within the borehole. Above the sand filter pack and piezometer screen, the annulus surrounding the piezometer pipe was backfilled to the ground surface with bentonite pellets. The piezometer installation details and water level readings are indicated on the record for Borehole 2011-05. The remaining borehole (2011-01) was backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water content determinations, Atterberg limits testing and grain size distribution analyses were carried out on selected soil samples.

The borehole locations were measured on-site relative to the existing structures and site features and the ground surface elevations were obtained from the Digital Terrain Model for the site, provided by URS. The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are summarized below and are shown on the Borehole Location and Soil Strata drawings contained in Appendices A to F. Also shown on these drawings are the locations of 26 boreholes advanced as part of the previous investigations at the structure sites (MTO GEOCRES Nos. 30M14-32, 30M14-68, 30M14-71, 30M14-73, 30M14-74, and 30M14-75).

Structure	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Birchmount Road Overpass	73-1	4,848,065.7	321,384.5	176.5	11.1
	73-2	4,848,054.1	321,349.6	175.9	12.6
	73-3	4,848,072.9	321,353.0	176.8	12.6
	73-4	4,848,129.9	321,320.5	175.0	11.1
	73-5	4,848,142.8	321,358.9	174.3	12.6
	73-6	4,848,121.5	321,356.0	175.0	11.1

Structure	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
CP Rail Overhead	75-7	4,848,192.2	321,528.7	175.6	9.6
	75-8	4,848,200.5	321,553.5	174.8	18.7
	75-9	4,848,215.1	321,584.8	174.2	15.7
	75-10	4,848,108.3	321,539.3	178.8	18.7
	75-11	4,848,102.0	321,503.2	177.7	15.7
Kennedy Road Overpass	71-1	4,848,340.5	322,165.4	167.9	15.2
	71-2	4,848,367.8	322,114.1	168.1	15.2
	71-3	4,848,401.3	322,146.5	169.8	12.6
	71-4	4,848,307.8	322,135.7	170.4	14.2
	71-5	4,848,322.1	322,186.2	168.2	18.7
	71-6	4,848,389.0	322,102.7	171.1	21.8
CN Rail Overhead	68-1	4,848,518.0	322,518.9	164.3	18.7
	68-2	4,848,520.9	322,537.6	163.6	15.7
	68-3	4,848,481.2	322,535.9	165.0	12.6
	68-4	4,848,443.9	322,556.6	165.6	18.7
	68-5	4,848,438.0	322,543.4	165.9	15.7
	2011-01	4,848,414.2	322,538.0	166.3	43.3
Midland Avenue Overpass	74-1	4,848,650.4	322,931.3	166.1	36.6
	74-1A	4,848,615.6	322,957.3	171.3	14.2
	74-2	4,848,645.5	322,914.7	165.6	11.1
	74-2A	4,848,601.5	322,911.9	170.9	15.7
	74-3	4,848,561.5	322,923.5	165.2	11.1
	74-4	4,848,573.7	322,966.5	166.1	11.1
Markham Road Overpass	32-1	4,849,502.2	326,139.3	157.7	9.6
	32-2	4,849,511.6	326,117.1	157.4	9.6
	32-3	4,849,489.1	326,104.6	157.3	9.6
	32-4	4,849,574.8	326,078.3	158.5	7.6
	32-5	4,849,566.6	326,099.6	158.1	9.1
	32-6	4,849,588.9	326,113.2	160.2	7.6
	2011-05	4,849,605.9	326,125.8	163.5	15.9

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geological Conditions

This section of Highway 401 is located within the physiographic region known as the Peel Plain, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).

A surficial till sheet, which generally follows the surface topography, is generally present throughout much of this area. The till is typically comprised of clayey silt to silty clay, with occasional sand to silt zones; it is mapped in

this area as the Halton Till. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial melt water ponds scattered throughout the Peel Plain and concentrated near river valleys, such as the West Don River valley. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay.

4.2 Subsurface Soil and Groundwater Conditions

A summary of the subsoil and groundwater conditions encountered at each structure site, together with site-specific drawings showing the borehole locations and interpreted stratigraphic profiles, are presented in the individual Preliminary Foundation Investigation and Design Report sheets contained in Appendices A to F, following the text of this report.

The subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation and previous investigations, and the results of geotechnical laboratory tests carried out on selected soil samples, are given on the Record of Borehole sheets and on the laboratory test result figures included in Appendices A to F.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic sections on the Borehole Location and Soil Strata drawings contained in the appendices are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

It should be noted that in the previous investigations, the water levels were observed in the open borehole immediately following completion of the drilling operations, and these measurements may not represent the stabilized groundwater level at the sites. The water levels are expected to fluctuate seasonally and should be expected to rise during the spring and other wet periods of the year.

5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Ms. Nikol Kochmanová, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
BRIDGE WIDENING AND REPLACEMENT
HIGHWAY 401 REHABILITATION
FROM WARDEN AVENUE TO BROCK ROAD
TORONTO, ONTARIO
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the preliminary design of the widening and/or replacement of six bridge structures associated with the rehabilitation of Highway 401 from Warden Avenue to Brock Road.

The preliminary recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation and borehole data from previous investigations by MTO at or near the structure sites. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the structure foundations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Foundation Options for Overpass Structures

Preliminary foundation recommendations for each structure site are provided in the individual Preliminary Foundation Design Report (PFDR) sheets found in Appendices A to F, following the text of this report. These preliminary recommendations are based on existing subsurface information in the vicinity of each structure site, and limited additional boreholes advanced as part of the current study at locations where insufficient information was available. Further investigations will be required during detail design to obtain subsurface information specific to the new or widened foundation locations and to confirm that the subsurface conditions and the geotechnical parameters and resistance values provided in this preliminary design phase are appropriate for the detail design of the foundations.

Based on the proposed structure geometry and the subsurface conditions at these sites, both shallow and deep foundation options have been considered for support of the widened and/or new abutments and piers. A summary each option is provided below.

- **Strip or spread footings founded on native soil:** Strip or spread footings are generally feasible for support of the abutments, associated wing walls/retaining walls, and piers at the sites. It may be necessary to found the footings deeper than the standard frost penetration depth either to match the existing footings or to extend below any loose to compact or stiff to very stiff near-surface soils. Temporary protection systems will be required along Highway 401 as well as parallel to the local road or railway to facilitate such excavation and staging throughout construction. Although further investigation and measurement of groundwater level will be required at the detail design stage, it is anticipated that footing excavations at the Birchmount Road and CP Rail sites could be maintained above the groundwater level; however, footing excavations at the Kennedy Road, CN Rail, Markham Road and Midland Road sites would extend to or below the groundwater level, requiring some dewatering. Shallow foundations are consistent with the existing structure foundations; where adopted for a widening, some differential settlement (on the order of

about 10 mm to 20 mm) is expected between the existing and new widened portions of the structure, although further assessment of this magnitude would be required during detail design.

- **Footings "perched" on a compacted granular pad in the approach embankment:** "Perched" footings are feasible for support of the abutments and associated wing walls/retaining walls at the sites, and may be considered for replacement structures. However, the existing structures have a "closed" configuration, and a widening supported on perched footings will not be compatible.
- **Driven steel H-piles or steel pipe (tube) piles:** Driven steel H-piles or steel pipe piles are suitable and feasible for support of the abutments (and would permit integral or semi-integral abutment design, respectively), as well as associated wing walls/retaining walls and piers at the structure sites. The biggest advantage of driven pile foundations is that they would minimize differential settlement between the existing and widened portions of a structure. However, in the case of a widening, the compatibility of driven pile foundations – with the pile cap either perched in the approach embankments or founded below the local road/rail grade at a minimum depth of 1.2 m for frost protection purposes – with the existing spread footings will have to be considered. Where full structure replacement is required, perched pile caps would be advantageous in maintaining the pile caps above the groundwater level at the various sites; however, significant excavation may still be required to remove the existing walls and potentially the existing foundations, and to install geo-grid for reinforced soil system walls where integral abutments are adopted. As discussed in the site-specific Preliminary Foundation Investigation and Design Report sheets contained in Appendices A to F, at some of the structure sites, very dense or hard soils (having Standard Penetration Test 'N' values of greater than 100 blows per 0.3 m of penetration) are present at shallow depth, and pre-augering may be required to facilitate pile installation. The soils at the sites are glacially derived and it is considered that a minor risk exists for piles "hanging up" on cobbles or boulders during installation. Based on the existing borehole information, there is also potential for variable pile lengths (although further investigation is required in this regard at the detail design stage).
- **Caissons:** Caissons are not considered to be a desirable option for these sites, due to the higher construction risks associated with the water-bearing cohesionless soils and the potential for loosening or heaving of the soils at the base of the caissons.

The following subsections provide project-wide preliminary recommendations generally applicable to all structure sites, including design assumptions and limitations associated with the recommendations provided in the PFDR sheets found in Appendices A to F.

6.3 Shallow Foundations

Preliminary foundation recommendations for spread footings on native undisturbed soil or on a compacted Granular A pad perched within the approach embankments are provided where subsoil conditions are considered to be suitable for shallow foundations, as indicated on the individual Preliminary PFDR sheets for each structure site as contained in Appendices A to F.

6.3.1 Founding Level

For support of the widened or new abutments, associated wing walls/retaining walls and piers, strip or spread footings should be founded below any fill or softened/loosened surficial soils, on suitable native soils. The maximum (highest) founding elevations recommended for preliminary design of footings are provided in the individual PFDR sheets. These founding elevations should be checked relative to the adjacent grades to ensure they are founded at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration, per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario)*.

For spread footings perched within the approach embankments on a compacted Granular A pad, the geotechnical resistance values provided in the PFDR sheets assume a minimum 2 m thick Granular A pad placed below the base of the footing. The Granular A pad should extend at least 1 m beyond the plan limits of the footing and be sloped no steeper than 1 horizontal:1 vertical (1H:1V) in general accordance with MTO guidelines (see Figure 1).

6.3.2 Preliminary Geotechnical Resistances

The individual PFDR sheets provide preliminary recommendations for the factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement assuming the new footing will match the existing footing width and founding elevation. Where structure replacement is being considered, geotechnical resistance values have been provided for footing widths of 3 m and 4 m, with founding elevations as given in the individual PFDRs.

The preliminary geotechnical resistances provided in Appendices A to F should be reviewed if the selected footing width or founding elevation differ from those given in the PFDRs. In addition, these preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary.*

The preliminary geotechnical resistance values will have to be re-evaluated and modified as necessary during detail design, based on future additional subsurface investigation at the proposed abutment and pier locations.

6.4 Steel H-Pile or Steel Pipe (Tube) Pile Foundations

At all of the bridge sites, the widened or new abutments and piers may be supported on end-bearing steel H-piles or steel pipe piles driven to found within very dense/hard soil (having SPT 'N' values of greater than 100 blows per 0.3 m of penetration). Preliminary recommendations for driven pile foundations are provided in the site-specific PFDRs contained in Appendices A to F. These recommendations assume the use of either an HP 310x110 pile section or closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thicknkess of 9.5 mm (3/8 in.).

6.4.1 Founding Level

The pile caps should be constructed at a minimum depth of 1.2 m for frost protection purposes, per OPSD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario)*. The site-specific PFDR sheets contained in Appendices A to F provide recommended pile tip elevations for preliminary design purposes.

For the installation of steel H-piles or steel pipe piles, consideration must be given to the potential presence of cobbles and boulders within the soil deposits. In this regard, steel H-piles are preferred over steel pipe piles as pipe piles are considered to pose a slightly higher risk of "hanging up" or being deflected away from their vertical or battered orientation during installation, due to their larger end area. The piles should be reinforced at the tip with driving shoes or flange plates for protection during driving in accordance with OPSS 903 *(Deep Foundations)* and OPSD 3000.100 *(Foundation Piles – Steel H-Pile Driving Shoe)*. In very dense/hard and/or boulder soils, as may be encountered at these structure sites, driving shoes such as Titus Standard "H" Bearing Pile Points are preferred over flange plates. If steel pipe piles are used, driving shoes should be in accordance with OPSD 3001-100 Type II *(Steel Tube Pile Driving Shoe)*.

At some of the structure sites, due to the presence of very dense/hard soil (having SPT 'N' values of greater than 100 blows per 0.3 m of penetration) at a shallow depth, pre-augering may be required before pile installation.

6.5 Approach Embankments

The configuration of the approach embankments varies from site to site. Based on the available information provided at each bridge site, preliminary recommendations associated with the approach embankment stability and settlement are provided on the site-specific PFDR sheets contained in Appendices A to F following the text of this report. The following subsections provide additional project-wide comments or recommendations related to the preliminary design and future construction of the bridge approaches.

6.5.1 Subgrade Preparation and Embankment Construction

For all the bridge sites, it is recommended that all topsoil/organic material or existing surficial fill materials be stripped from the footprint of the proposed approach embankment widening areas. The depth and extent of stripping should be assessed during detail design when additional subsurface information will be available for the approach embankment areas.

The embankment fill should be placed and compacted in accordance with OPSS 501 *(Compacting)*. Benching of existing embankments should be carried out to "key in" the new fill materials for the widening, in accordance with OPSD 208.010 *(Benching of Earth Slopes)*.

Additional fill for construction of the Highway 401 embankment widening could consist of clean earth fill or granular fill. From a geotechnical/foundations perspective, both earth and granular fill will provide good compatibility with the existing embankment fill materials – both those fill materials remaining in-place in the existing embankment side slope, and any existing embankment fill that is re-used for the widening after being cut from the benches.

In accordance with MTO's standard practice, a minimum 2 m wide bench should be provided where the embankment side slopes are equal to or greater than 8 m in height, such that the uninterrupted slope height does not exceed 8 m. To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection should be in accordance with OPSS 572 (*Seed and Cover*).

6.5.2 Approach Embankment Stability

Preliminary slope stability analyses have been performed for the proposed approach embankment widening at each structure site using the commercially available program SLIDE, produced by Rocscience Inc., to check that a minimum factor of safety of 1.3 is achieved for the proposed embankment heights and geometries under static conditions. This minimum factor of safety is considered appropriate for the proposed widening on this project, considering the design requirements and the available field and laboratory testing data.

The following general parameters have been used in the preliminary stability analyses, based on field and laboratory test data as well as accepted correlations:

Soil Deposit	Bulk Unit Weight (kN/m^3)	Effective Friction Angle	Undrained Shear Strength (kPa)
Embankment fill	21	32-35°	-
Very stiff to hard clayey silt/clayey silt till, including compact to dense interlayers	21	34°	-
Loose silty sand to sandy silt	19	28°	-
Compact silty sand to sandy silt	20	32°	-
Dense to very dense silty sand to sandy silt	21	34°	-
Compact to very dense sand to sand and gravel	21	34°	-

The analysis results indicate that widened approach embankments with side slopes no steeper than 2H:1V will have a factor of safety of at least 1.3 against global instability, assuming appropriate subgrade preparation and proper placement and compaction of the embankment fill materials. This preliminary assessment of the stability of the approach embankments should be reviewed and confirmed based on the subsoil conditions encountered within the proposed approach embankment widening footprints during detail design.

6.5.3 Approach Embankment Settlement

The preliminary settlement analyses for the anticipated soil conditions below the proposed approach embankment widening areas were carried out using both hand calculations and the commercially available computer program *Settle-3D* from Rocscience. The preliminary analyses have been completed with the estimated elastic deformation moduli as given in the table below, based on correlations with the SPT 'N' values

and engineering judgement from experience with similar soils in this region of Ontario (Bowles, 1984; Kulhawy and Mayne, 1990; Peck et al., 1974).

Soil Deposit	Bulk Unit Weight (kN/m^3)	Elastic Modulus (MPa)
Embankment fill	21	-
Very stiff to hard clayey silt/clayey silt till, including compact to dense interlayers	21	40-60
Loose to compact silty sand to sandy silt	20	20
Dense to very dense silty sand to sandy silt	21	50
Compact sand to sand and gravel	21	50
Dense to very dense sand to sand and gravel	21	100
Hard lower clayey silt till	21	100

Based on the preliminary assessments, the settlement of the foundation soils under the widened approach embankments is generally estimated to be less than 25 mm, as discussed in each site-specific PFDR sheet contained in Appendices A to F. This settlement is expected to occur relatively quickly during and immediately following construction of the approach embankments based on the nature of the soils at the site. This estimated magnitude of settlement should be reassessed based on the subsurface and groundwater conditions under the widened approach embankments as determined during the detail design.

The above preliminary estimates do not include compression of the fill itself, which would occur during and after the construction of the embankment depending on the type of materials used. The magnitude of fill compression may range from 0.5 to 1 per cent of the height of the embankment, assuming approximately 95 to 98 per cent compaction of the embankment fill is achieved, relative to the material's standard Proctor maximum dry density. In the case where granular fill is used for embankment construction, settlement of the fill itself is expected to occur essentially during embankment construction, whereas non-granular earth fill materials are expected to exhibit some additional settlement over time.

6.6 Construction Considerations

The following subsections identify future construction considerations that should be considered at this stage as they may impact the planning and preliminary design, or the future detail design. Where applicable, Non-Standard Special Provisions (NSSP) should be developed during detail design for incorporation in the Contract Documents.

6.6.1 Excavation

Preliminary recommendations for open-cut excavations are provided on a site-specific basis on the PFDR sheets for each structure site and include the type of soils anticipated to be encountered within the foundation excavations according to the Occupational Health and Safety Act (OHSA), as well as the recommended

maximum side slope inclination for temporary excavations. In general, all soils that are expected to be encountered in the foundation excavations will consist of Type 2 or Type 3 soils, assuming appropriate dewatering is in place where required, and temporary excavations (i.e., those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V.

6.6.2 Groundwater and Surface Water Control

The anticipated groundwater levels at each of the structure sites and the anticipated groundwater and surface water control measures are reported on the site-specific PFDR sheets. It is noted that the past investigations, the water level was measured in the open boreholes immediately following completion of drilling, and thus may not represent the stabilized groundwater level at the site.

At the Birchmount Road and CP Rail structure sites, it is anticipated based on the available information that excavations for shallow foundations (if adopted) would be maintained above the groundwater level. Some groundwater seepage should still be anticipated, either perched above cohesive soils or from cohesionless lenses or interlayers. The seepage volume at these sites is expected to be relatively small, such that the water inflow can be handled by pumping from filtered sumps placed at the base of the excavation.

At the Kennedy Road, CN Rail, Markham Road and Midland Avenue sites, it is anticipated that excavations for shallow foundations (if adopted) would extend near to or below the groundwater level at the site, particularly during wet periods of the year. Dewatering in advance of and throughout excavation and foundation construction will be required at these sites, to allow for construction of new/widened foundation elements in dry conditions. As the existing groundwater level and aquifer permeability information is limited, it is recommended that the need for a Permit to Take Water (PTTW) be assessed at each structure site during detail design.

6.6.3 Temporary Protection Systems

At this preliminary stage, it is anticipated that temporary protection systems will be required along the edges of the widened sections of Highway 401, as well as parallel to the local road or rail line, to facilitate construction of the abutments, piers, and any wing wall/retaining wall foundations. Temporary protection systems may also be required at other locations along the Highway 401 lanes to facilitate construction staging where a superstructure replacement or full replacement is adopted.

These temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (*Temporary Protection Systems)*. At this stage, it is recommended that the lateral movement of the temporary protectionsystem meet Performance Level 2 as specified in OPSS 539 for the Birchmount Road, Kennedy Road, Markham Road and Midland Avenue sites, provided that the existing Highway 401 structures and any adjacent utilities can tolerate this magnitude of deformation. At the CP and CN Rail sites, the temporary protection system should meet Performance Level 1b as specified in OPSS 539.Although the selection and design of the protection systems will be the responsibility of the Contractor, for conceptual purposes, it is considered that either a driven, interlocking sheetpile system or a soldier pile and timber lagging system would be suitable for the temporary excavation support at the structure sites, based on the subsurface soil and groundwater conditions. An interlocking sheetpile system would contribute to both ground and, where applicable, groundwater control – the groundwater control could be an advantage for the Kennedy Road, CN

Rail, Markham Road and Midland Avenue sites. For a soldier pile and lagging system, it would be necessary to control seepage or include measures to mitigate loss of soil particles through the lagging boards.

The sheetpiles or soldier piles would have to be socketted to sufficient depth to provide the necessary passive resistance for the retained soil height. Lateral support to the sheetpiles or soldier piles could be provided in the form of rakers or temporary anchors.

6.6.4 Obstructions

The soils at this site are glacially derived and as such should be expected to contain cobbles and boulders, which could affect the installation of deep foundations and/or protection systems. Flange plate reinforcement for steel H-Piles may be required at some sites to facilitate driving into the very dense deposits. Pre-augering may also be required at some sites due to the presence of very dense soil at shallow depths. Further observation is recommended in the next stage of investigation in support of the detail design. If conditions warrant, an NSSP should be included in the Contract Documents developed during the detail design stage to identify to the contractor the possible presence of cobbles and/or boulders within the overburden soils.

6.6.5 Subgrade Protection

The embankment fill and the native soils that will be exposed at the foundation subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement can be addressed with a note on the General Arrangement drawing and/or with an NSSP, which can be developed during the detail design stage.

6.6.6 Vibration Monitoring During Pile Installation

A maximum peak particle velocity (PPV) of 100 mm/s is generally considered applicable for bridge structures in good condition. Based on vibration monitoring experience, it is considered unlikely that vibrations induced by conventional construction activities (such as pile driving) will reach this threshold level. Therefore, vibration monitoring is not expected to be required during construction at this site.

6.7 Recommendations for Further Work During Detail Design

Additional borehole investigation will be required at all sites during the detail design stage, within the footprint of the new/widened foundation elements and/or within the footprint of the widened approach embankment areas, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report, as follows:

- Abutments and piers:
  - Assessment of the type and depth of fill present.

- Assessment of the variability of the near-surface soils to confirm the bearing resistance and founding elevation for shallow foundations.
- Confirmation of the depth of "100-blow" materials and confirmation of the tip elevation for driven steel H-piles. (At some sites, the depth to "100-blow" soils is quite variable.)
- Confirmation of the groundwater elevation and the grain size distribution characteristics to aid in assessment of the need for a Permit to Take Water (PTTW) associated with foundation excavation and dewatering.
- Observation of the presence of cobbles and/or boulders within the soil deposits, to assess the need for an NSSP to warn the contractor of the presence of such obstructions as they may affect excavations and the installation of driven steel H-pile foundations.

- Approach embankments and adjacent high fill embankments:
  - Assessment of the depth and extent of stripping of topsoil/organics and fill materials within the footprint of the widened approach embankments.
  - Further assessment of the estimated magnitude of settlement under the new approach embankments.

7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder, with technical input from Mr. Murty S. Devata, P.Eng., a senior geotechnical/foundations consultant at Golder. Mr. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

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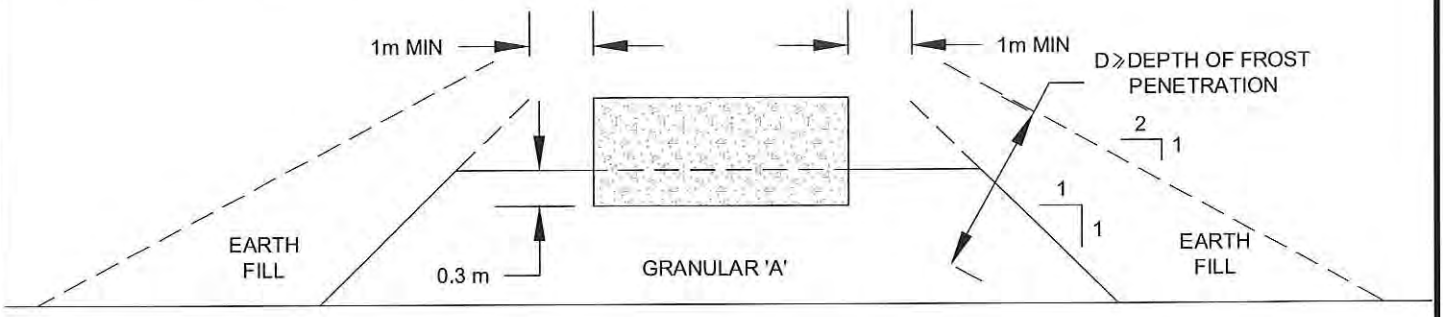
Ontario Provincial Standard Specifications (OPSS)

OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 572	Construction Specification for Seed and Cover
OPSS 1002	Material Specification for Aggregates - Concrete
OPSS 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

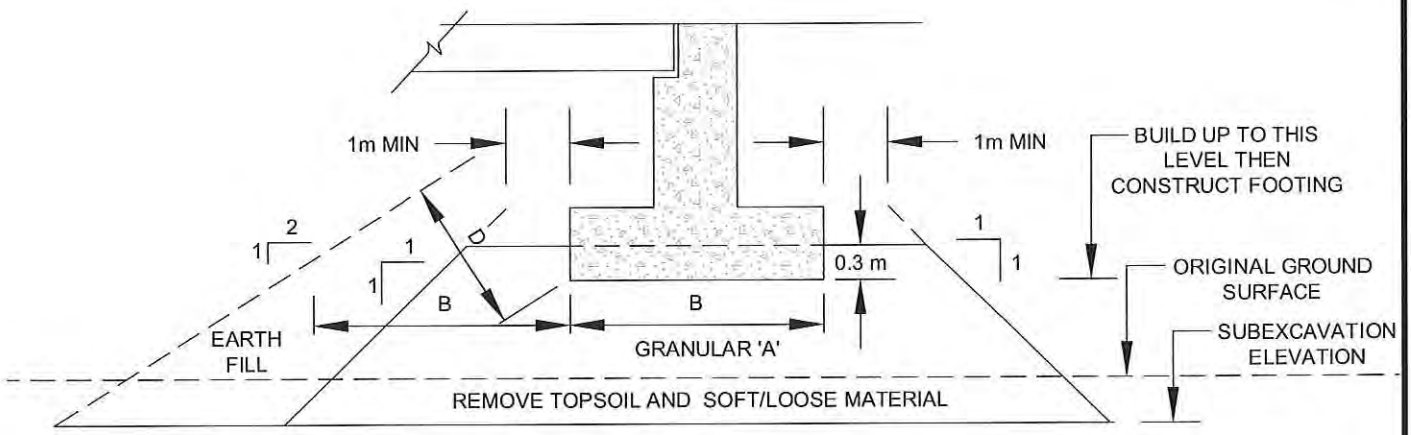
OPSD 208-010	Benching of Earth Slopes
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario

BEFORE SUBEXCAVATION



CROSS-SECTION

AFTER SUBEXCAVATION



LONGITUDINAL SECTION

NOTES:

1. REMOVE TOPSOIL AND SOFT/LOOSE SUBSOIL UNDER FOOTPRINT OF COMPACTED GRANULAR 'A'.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO SP 105 510.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

NOT TO SCALE

Golder Associates
Mississauga, Ontario, Canada

FILE No.	0911116055EB001dwg.dwg
PROJECT No.	09-1111-6055
REV.	A
SCALE	NOT TO SCALE
DATE	Jul. 14, 2011
DESIGN	JFC
CAD	JFC
CHECK	NK
REVIEW	LCC

TITLE

PROPOSED SUBEXCAVATION GEOMETRY

HIGHWAY 401 REHABILITATION

FIGURE 1

PLOT DATE: November 30, 2011
FILENAME: T:\Projects\2009\09-1111-6055 (URS, GTA)\-EB-\0911116055EB001dwg.dwg

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

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

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

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

Consistency

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LIST OF SYMBOLS

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I. GENERAL

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in x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
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t	time
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V	volume
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ε_v	volumetric strain
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G	shear modulus of deformation
K	bulk modulus of compressibility

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e	void ratio
n	porosity
S	degree of saturation

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w_p	plastic limit
I_p	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

Structure Description: Highway 401 EBL - Birchmount Road Overpass, South Widening
Site No.: 37-212

Existing Hwy 401 Grade: ~185 m
Local Road Ground Elevation: ~176 m (north end) to 179.5 m (south end) **Approximate Station: 12+100**
Original Ground Surface Elevation: 176 m to 177 m

FOUNDATION INVESTIGATION

Site Description:

The site is located on the south side of Highway 401 EBL at the Birchmount Road overpass (Structure Site No. 37-212) in the City of Toronto, Ontario. An industrial park is located south of the highway, while a residential zone is located north of the highway. See key plan on Drawing 1.

Borehole Information:

Boreholes 73-1 to 73-6 were drilled as part of a 1973 investigation at this site by others (MTO Geocres No. 30M14-73).

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
73-1	East Abutment	4,848,065.7	321,384.5	176.5	11.1
73-2	West Abutment	4,848,054.1	321,349.6	175.9	12.6
73-3	West Abutment	4,848,072.9	321,353.0	176.8	12.6
73-4	West Abutment	4,848,129.9	321,320.5	175.0	11.1
73-5	East Abutment	4,848,142.8	321,358.9	174.3	12.6
73-6	West Abutment	4,848,121.5	321,356.0	175.0	11.1

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Topsoil:** 300 mm of topsoil was encountered immediately below ground surface in Boreholes 73-1, 73-2, 73-4, and 73-5.
- **Sand and Gravel Fill:** 300 mm to 500 mm of sand and gravel fill was encountered immediately below ground surface in Boreholes 73-3 and 73-6.
- **Silty Sand to Sandy Silt:** Silty sand to sandy silt containing trace clay and gravel was encountered underlying the topsoil and fill in all boreholes. All boreholes terminate within this deposit, penetrating it for a thickness of 10.8 m to 12.3 m. The measured Standard Penetration Test (SPT) 'N' values vary from 7 blows per 0.3 m of penetration to 80 blows per 0.06 m of penetration. However, in general the values are over 30 blows per 0.3 m of penetration, indicating a dense to very dense relative density.

Groundwater Conditions:

The groundwater level was measured in the open boreholes upon completion of drilling, as summarized in the following table:

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)
73-1	8.4	168.1
73-2	8.2	167.6
73-3	8.8	167.9
73-4	7.4	167.6
73-5	7.0	167.3
73-6	7.0	167.9

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site.

The groundwater level at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 EBL - Birchmount Road Overpass, South Widening
Site No.: 37-212

Existing Hwy 401 Grade: ~185 m
Local Road Ground Elevation: ~176 m (north end) to 179.5 m (south end)
Original Ground Surface Elevation: 175 m to 177 m

Approximate Station: 12+100

FOUNDATION RECOMMENDATIONS

Note: These site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

It is understood that up to 4.5 m of southward widening is proposed for Highway 401 EBL - Birchmount Road overpass. In addition, the superstructure may be replaced, using the existing foundations.

ASSESSMENT OF EXISTING FOUNDATIONS

The existing Birchmount Road overpass consists of two spans, with span lengths of 14.9 m between the abutments and the pier. Based on available drawings, the existing abutments are supported on 5.3 m to 6.3 m wide spread footings founded at Elevation 173.6 m (west abutment) and 173.8 m to 174.2 m (east abutment, stepping upward to the south), and the existing centre pier is supported on a 1.8 m wide footing founded at Elevation 174.0 m. The existing abutment footings also contain a shear key. The Birchmount Road grade rises toward the south, such that these founding levels are approximately 2 m to 2.5 m deep at the north end and 5 m to 6 m deep at the south end relative to the adjacent local road grade. Golder has assessed the factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS) for the existing abutment and pier foundations, using the existing founding elevations, foundation geometry, and subsurface conditions to complete preliminary bearing capacity and settlement analyses. The following table summarizes the geotechnical resistances for the existing footings:

Founding Stratum	Geotechnical Resistance	
	Factored ULS	SLS
Dense to Very Dense Silty Sand to Sandy Silt (Pier)	600 kPa	400 kPa
Dense to Very Dense Silty Sand to Sandy Silt (Abutments except Northeast Quadrant)	650 kPa	400 kPa
Loose to Very Dense Silty Sand to Sandy Silt (Abutment – Northeast Quadrant)	550 kPa	350 kPa

FOUNDATION OPTIONS

Based on the existing subsurface information, the feasible foundation options for the proposed overpass widening are listed below, along with the advantages and disadvantages associated with each option.

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense silty sand to sandy silt	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • Allows for semi-integral abutment design • Excavations can be maintained above the groundwater table	• Requires excavations to a depth of up to about 5 m to 6 m below original ground surface near the south end of the existing structure • It may be possible to found footings for the south widening higher; however, at this preliminary stage when the composition and consistency/relative density of the existing fill materials are not known, there is a high risk that the existing fill materials may not be suitable for this foundation option, or that subexcavation of the existing fill materials would be required to support this option • Potential for up to 10 mm to 15 mm differential settlement to occur between existing and new portions of structure; construction joint is required to accommodate differential movements between new and existing footings
"Perched" footings founded in the widened approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the footings above the groundwater level at the site	• Poor compatibility with existing closed abutment configuration and spread footings founded on native soils below Birchmount Road grade • Potential for differential settlement
Steel H-piles or steel pipe (tube) piles driven into "100-blow" silty sand to sandy silt deposit for abutment foundations	• Pile caps may be perched in widened approach embankments, or founded at minimum frost protection depth, minimizing depth of excavation as compared with shallow foundation option • Allows for integral abutment design with H-piles, and semi-integral abutment design with pipe piles • Minimal differential settlement between existing and widened portions of structure	• At a minimum, requires driving shoes to facilitate driving through very dense soils (possibly containing cobbles/boulders) • Native soils are very dense and pre-augering of piles may be necessary to achieve target depths/ resistances, with annular space to be filled with sand or lean concrete • Potential vibration impacts on existing overhead structure; however, vibrations are anticipated to have a peak particle velocity of less than 100 mm/s

Recommended Foundation Option: The Birchmount Road grade was raised significantly as part of the reconstruction of this structure site under a 1969 contract, such that the existing spread footings are founded approximately 5 m to 6 m below the road grade at the south end of the existing structure. As such, significant excavation and temporary protection systems would be required to construct widened footings that match the existing founding levels.

For the southward widening of the abutments, from a foundations perspective, the use of deep foundations with the pile caps "perched" in the widened approach embankments is considered to be advantageous to minimize excavation. This option would allow the use of integral abutments if the existing structure can be converted as part of the superstructure replacement to be compatible. In addition, the differential settlement between the existing abutment footings and the widened, pile-supported abutments would be negligible. However, it is noted that for the relatively small width of the southward widening, this configuration is not aesthetically compatible with the existing structure.

The use of deep foundations for the southward widening of the centre pier is also preferred from a foundations perspective. With this option, the pile caps could be maintained at a minimum depth of 1.2 m (for frost protection purposes), within the existing fill, minimizing the depth of excavation relative to spread footings constructed to match the existing footings. This option would also minimize differential settlement between the existing and new portions of the centre pier foundation elements.

Structure Description: Highway 401 EBL - Birchmount Road Overpass, South Widening
Site No.: 37-212

Existing Hwy 401 Grade: ~185 m
Local Road Ground Elevation: ~176 m (north end) to 179.5 m (south end)
Original Ground Surface Elevation: 175 m to 177 m

Approximate Station: 12+100

To minimize the depth of excavation and requirements for protection systems for the southward widening of the abutments and centre pier, it may be possible to use spread footings or pile caps placed higher than the existing footings at a minimum depth of 1.2 m below the Birchmount Road grade. However, the composition and properties of this existing fill material is not known at this preliminary stage, and this option therefore carries a high risk that the existing fill materials may not be appropriate for the support of spread footings, and that subexcavation and backfilling with Granular A could be required to improve the bearing capacity for spread footings if the existing fill materials are poor. Additional investigation will be required through the existing Birchmount Road fill during the detail design stage.

Based on preliminary assessment and the assumption that the existing Birchmount Road fill has been engineered and has a compact to very dense relative density, it is considered that there is potential for up to approximately 10 mm to 15 mm of differential settlement between the existing and widened portions of the structure. Alternatively, and to minimize the potential risk of changes during detail design associated with the presence of poor quality fill, the southward widening could be supported by driven piles, with the pile caps placed at a depth of 1.2 m below the Birchmount Road grade.

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the southward widening may be founded on dense to very dense silty sand to sandy silt at the same level as the existing footings (Elevation 173.6 m and 174.2 m for the south end of the west and east abutments, respectively, and Elevation 174.0 m for the centre pier), although this would require excavations to extend to a depth of approximately 5 m to 6 m below the present Birchmount Road grade, and significant protection systems would be required. For this case, the factored geotechnical resistance at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) for preliminary design may be taken as the same as the existing capacity provided above, assuming the new footings will match the existing footings in width and founding elevation.

Alternatively, as discussed above, the footings for the southward widening could be constructed higher than the existing footings, at a minimum depth of 1.2 m below the Birchmount Road grade for frost protection purposes. For preliminary design purposes, assuming that the existing fill materials have a compact to dense relatively density, the factored geotechnical resistance at ULS and geotechnical resistance at SLS may be taken as 600 kPa and 300 kPa for the abutments and 350 kPa and 300 kPa for the centre pier; these preliminary recommendations are based on a footing width of 4.0 m at the abutments and 1.8 m at the centre pier. However, as noted above, the composition and properties of the existing fill materials are unknown at this preliminary stage and there is a risk that the materials will be less competent, requiring subexcavation and replacement with compacted granular fill. Further investigation will be required during the detail design stage to assess the properties of the existing Birchmount Road fill, to confirm the viability of this option and the preliminary geotechnical resistances.

Steel H-Piles

Steel HP 310x110 piles founded within the very dense/hard soils (where SPT "N" values exceed 100 blows per 0.3 m of penetration) can be used for support of the southward abutment and centre pier widening. If the pile caps are placed at a depth of 1.2 m below the Birchmount Road grade, pre-augering may be required to reach the design pile tip elevation as presented in the table below, due to the presence of very dense/hard soil at shallow depths. The following factored axial geotechnical resistance at ULS and geotechnical resistance at SLS may be used for preliminary design:

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
South abutment and pier widening	168.0 m	1,600 kN	1,400 kN

Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.), founded at the same design pile tip elevation.

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments. However, the existing structure is supported on spread footings and an integral abutment system for the widening will not be compatible unless the existing structure can be converted to semi-integral abutments.

Approaches and Backfill

- Height: Approximately 10 m at the abutments.
- Stability: Approach embankments up to 10 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) will have an adequate factor of safety against deep-seated slope instability. As the approach embankments are greater than 8 m in height, the widening should incorporate a minimum 2 m wide mid-height bench, in accordance with MTO requirements.
- Settlement: Assuming the use of conventional earth fill or granular fill, it is expected that less than 25 mm of settlement will occur under the footprint of the approach embankment widening area. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).
- The widened approach embankment fill should be keyed into the existing fill as per MTO standards.

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt deposit is classified as a Type 2 soil, while the existing embankment fill would be classified as Type 3 soil according to OHSA. Temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

It is anticipated that foundation excavations will be maintained above the groundwater table at the site (approximately Elevation 168 m based on borehole observations, although the stabilized groundwater level may be higher). Some groundwater seepage may occur from within cohesionless soils or fills "perched" on top of the finer-grained native soil deposit; however, it is expected that such seepage volumes will be adequately controlled by pumping from properly filtered sumps within the foundation excavations.

Protection Systems

It is anticipated that temporary protection systems will be required along the edge of Highway 401 to facilitate removal of the existing wing walls/retaining walls to construct the widening. Temporary protection systems would also be required along Birchmount Road due to the depth of excavation required to match the existing footings; if shallower founding elevations are adopted, the protection systems would be less extensive. These temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.

Structure Description: Highway 401 EBL - Birchmount Road Overpass, South Widening
Site No.: 37-212

Existing Hwy 401 Grade: ~185 m
Local Road Ground Elevation: ~176 m (north end) to 179.5 m (south end)
Original Ground Surface Elevation: 175 m to 177 m

Approximate Station: 12+100

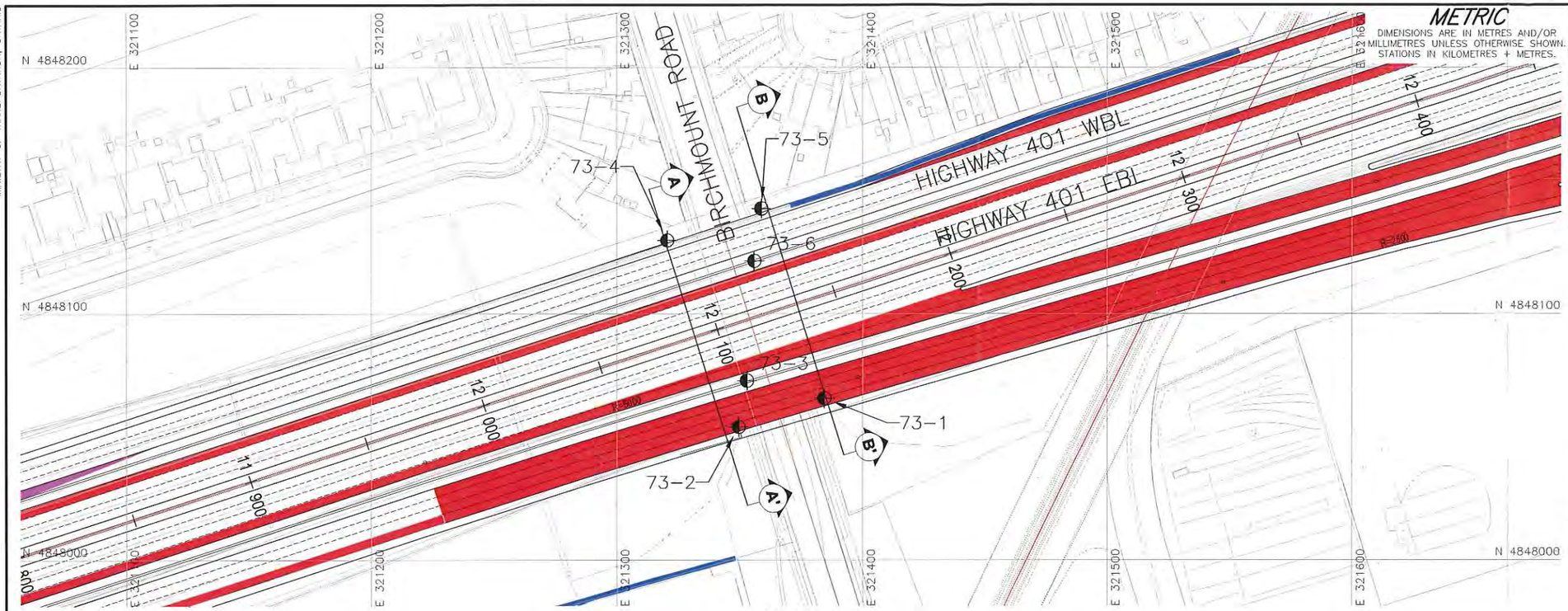
Obstructions During Pile Driving

If deep foundations are adopted, pre-augering may be required at the site due to the presence of very dense soil at shallow depths. In addition, it is recommended that driving shoes be used to facilitate pile driving into the very dense silty sand to sandy silt.

RECOMMENDATIONS FOR ADDITIONAL WORK

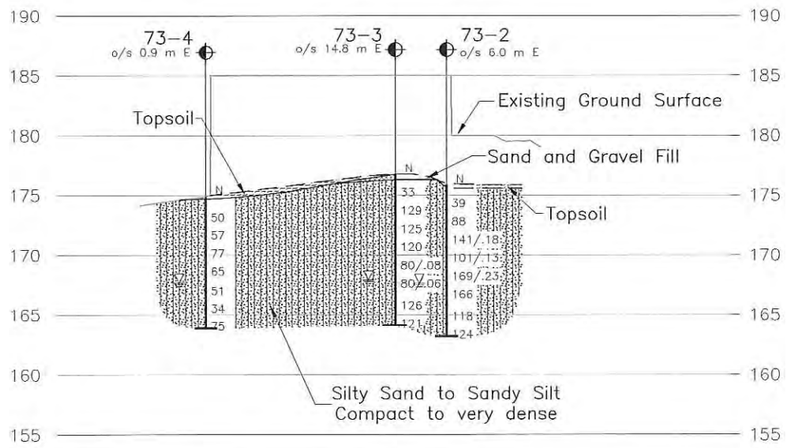
Further subsurface investigation should be carried out during detail design to confirm the subsoil and groundwater conditions at the location of the bridge foundation elements and any associated retaining walls, and in particular to assess the properties of the existing Birchmount Road fill, to refine the founding elevations and geotechnical resistances for shallow foundations.

MINISTRY OF TRANSPORTATION, ONTARIO



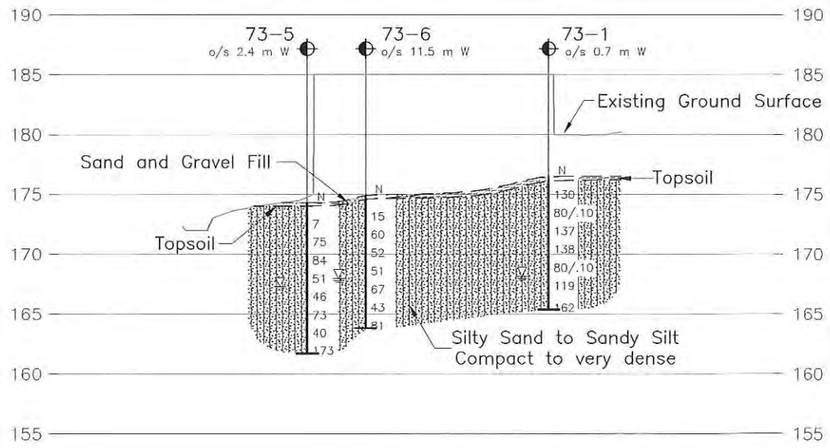
PLAN

SCALE
20 0 20 40 m



A-A' WEST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
VERTICAL SCALE
5 0 5 10 m



B-B' EAST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
VERTICAL SCALE
5 0 5 10 m

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

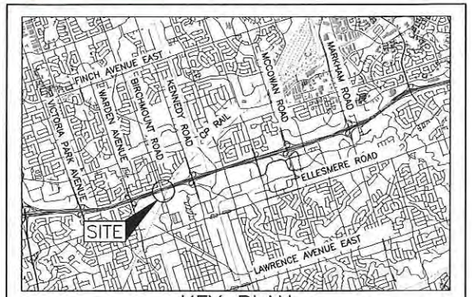
CONT No.
WO No. 07-20012

BIRCHMOUNT ROAD OVERPASS
HIGHWAY 401 WIDENING

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole – Current Investigation
- Borehole – 1965 Investigation (Geocres 30M14-73)
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
73-1	176.5	4848065.7	321384.5
73-2	175.9	4848054.1	321349.6
73-3	176.8	4848072.9	321353.0
73-4	175.0	4848129.9	321320.5
73-5	174.3	4848142.8	321358.9
73-6	175.0	4848121.5	321356.0

NOTES

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

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN Feb. 24, 2012 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE Feb. 24, 2012 PROVINCE OF ONTARIO

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHKD. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD	CHKD. NK	APPD. LCC	DWG. A1

PLOT DATE: February 24, 2012
FILENAME: N:\Projects\2009\09-1111-6055 (URS, GPA)\~CC-Foundation Conditions and Recommendations\09111160550004.dwg

FORM ... 126 (FORMERLY ... -126 ... ICE ... ORT ... SOIL ... PLO ... ON
65-1831

BH 73-1

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 65-F-49 LOCATION Hwy. #401 & Birchmount Rd Hwy #401 Ch 316+92 130'-0" Rt ORIGINATED BY W.W.K.

W.P 256-61 BORING DATE May 12, 1965. COMPILED BY W.W.K.

DATUM 579.0 BORE HOLE TYPE Penndrill 4" Auger. CHECKED BY K.G.S.

(m) ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
176.5 579.0	Groundlevel					
176.2 578.7	Black Org. Topsoil					
0.3 1.0	Silty sand to sandy silt with traces of clay and gravel. Compact to very dense.		1	SS	130	570
			2	SS	80 for 4"	
			3	SS	137	
			4	SS	138	560
			5	SS	80 for 4"	
			6	SS	119	550
165.4 542.5			7	SS	162	
11.1 36.5	End of borehole.					540

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

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

w_P w w_L

WATER CONTENT % 5 10 15

BULK DENSITY — P.C.F.

REMARKS

W.L. El. 551.5 Observed in Borehole.

FORM 126 EARLY 6-122 ...ICE ...PORT ... SOIL ...PLORATION

65-1831

BH 73-2

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 65-F-49 LOCATION Hwy. #401 Birchmount Rd Hwy #401 Ch 315+72 130'-0" Rt. ORIGINATED BY W.W.K.

W.P. 256-01 BORING DATE May 12, 1965. COMPILED BY W.W.K.

DATUM ...0 BOREHOLE TYPE Penndrill 4" Auger CHECKED BY

(W) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
175.9 ...0.0	Groundlevel					
175.6 ...0.3	Black org. topsoil					
	Silty sand to sandy silt with traces of clay and gravel. Compact to very dense.		1	SS	39	570
			2	SS	88	
			3	SS	141 for 7"	560
			4	SS	101 for 5"	
			5	SS	169 for 9"	550
			6	SS	166	
			7	SS	118	540
163.2 ...12.6	End of borehole.		8	SS	124	
						530

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

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

w_P w w_L

WATER CONTENT % — 5 10 15

BULK DENSITY P.C.F.

REMARKS

W.L. El. ▼ 550.0 Observed in Borehole.

DRM -126 ERLY IL-12

...ICE ...PORT ON SOIL EXPLORATION

BH 73-3

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 65-F-69 LOCATION Hwy #401 & Birchmount Rd Hwy #401 Ch 316+02 75'-0" Rt. ORIGINATED BY W.W.K.

W P 256-61 BORING DATE May 12 & 13, 1965. COMPILED BY W.W.K.

DATUM S.D.D. BOREHOLE TYPE Penndrill 4" Auger. CHECKED BY

(W) ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE
176.8 / 0.0	580.0 Groundlevel					
176.3 / 0.5	579.5 Sand, gravel - Fill					
	578.5 / 1.5		1	SS	33	
	Silty sand to sandy silt with traces of clay and gravel. Compact to very dense.		2	SS	129	570
			3	SS	125	
			4	SS	120	560
			5	SS	80 for 3"	
			6	SS	80 for 2"	550
			7	SS	126	
164.1 / 12.6	538.5 / 41.5 End of borehole.		8	SS	121	540

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

LIQUID LIMIT —— W_L
PLASTIC LIMIT —— W_P
WATER CONTENT —— W

W_P W W_L

WATER CONTENT % — 5 10 15

BULK DENSITY P.C.F.

REMARKS

W.L. El. 551.0 Observed in Borehole.

FORM OR-MT-12a (FORMERLY OR-ML-12a) 65-1831

OFFICE REPORT — SOIL EXPLORATION

BH 73-4

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 65-F-49 LOCATION Hwy #401 & Richmond Rd Hwy #401 Ch 315+60 135'-0" Lt. ORIGINATED BY W.W.K.

W.P. 256-61 BORING DATE May 13, 1965. COMPILED BY W.W.K.

DATUM 574.0 BORE HOLE TYPE Penndrill 4" Auger. CHECKED BY

(M) ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV SCALE
175.0 574.0	Groundlevel					
174.7 573.7	Black org. topsoil					
0.3 2.0						570
	Silty sand to sandy silt with traces of clay and gravel.		1	SS	50	
			2	SS	57	
	Compact to very dense.					560
			3	SS	77	
			4	SS	65	
						550
			5	SS	51	
			6	SS	34	
						540
163.8 537.5			7	SS	75	
11.1 30.9	End of borehole.					
						530

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

LIQUID LIMIT —— w_L

PLASTIC LIMIT —— w_p

WATER CONTENT —— w

w_p — w — w_L

WATER CONTENT % — 5 10 15

BULK DENSITY γ P.C.F.

REMARKS

W.L. El. 550.0 Observed in Borehole.

FORM C... 126 (... ERLY ... L-126 ... ICE ... ORT ... SOIL ... PLO... ...ON

65-1831

BH 73-5

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

JOB 65-F-49 LOCATION Hwy #401 & Birchmount Rd Hwy #401 Ch 316+92 135'-0" Lt ORIGINATED BY W.W.K.

W.P. 256-61 BORING DATE May 14, 1965. COMPILED BY W.W.K.

DATUM 572.0 BORE HOLE TYPE Penndrill 4" Auger. CHECKED BY

(M) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W WATER CONTENT % 5 10 15	BULK DENSITY P.C.F.	REMARKS
(174.3) 572.0	Groundlevel									
(174.0) 571.0	Black org. topsoil									
0.3 1.0	Silty sand to sandy silt with traces of clay and gravel. Compact to very dense.		1	SS	7	570				
			2	SS	75	560				
			3	SS	84					
			4	SS	51	550				W.L. El. ▼ 549.0 Observed in Borehole.
			5	SS	46					
			6	SS	73	540				
			7	SS	40					
(161.7) 530.5			8	SS	173	530				
12.6 41.5	End of borehole.									

FORM MT-126 MERL ML-12 FIELD REPORT OF SOIL EXPLORATION
65-1831

BH 73-6

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 65-F-49 LOCATION Hwy #401 & Birchmount Rd hwy #401 Ch 316+61 70'-0" Lt ORIGINATED BY W.W.K.

W. P. 250-01 BORING DATE May 14, 1965. COMPILED BY W.W.K.

DATUM 574.0 BOREHOLE TYPE Pennidrill 4" Auger CHECKED BY

(W)	ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
175.0	574.0	Groundlevel					
174.7	573.7	Sand, Gravel-Fill					
0.3	1.0						570
		Silty sand to sandy silt with traces of clay and gravel.		1	SS	15	
				2	SS	60	
		Compact to very dense.					560
				3	SS	52	
				4	SS	51	
				5	SS	67	550
				6	SS	43	
							540
163.8	537.5			7	SS	81	
11.1	36.5	End of borehole.					
							530

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

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

w_P — w — w_L

WATER CONTENT % — 5 10 15

BULK DENSITY P.C.F.

REMARKS

W.L. El. 551.0 Observed in Casing.

Structure Description: Highway 401 - CP Rail Overhead
Site No.: 37-213

Existing Hwy 401 Grade: ~182 m
Rail Elevation: ~175 m
Original Ground Surface Elevation: ~175 m

Approximate Station: 12+300

FOUNDATION INVESTIGATION

Site Description:

The site is located on the north and south sides of Highway 401 at the CP Rail overhead structure (Site No. 37-213), approximately 200 m east of Birchmount Road, in the City of Toronto. See key plan on Drawing 1.

Borehole Information:

Boreholes 75-7 to 75-11 were drilled as part of a 1966 investigation at this site by others (MTO Geocres No. 30M14-75).

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
75-7	West Abutment	4,848,192.2	321,528.7	175.6	9.6
75-8	West Abutment	4,848,200.5	321,553.5	174.8	18.7
75-9	East Abutment	4,848,215.1	321,584.8	174.2	15.7
75-10	East Abutment	4,848,108.3	321,539.3	178.8	18.7
75-11	West Abutment	4,848,102.0	321,503.2	177.7	15.7

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Fill:** About 1.5 m of fill material was encountered immediately below the ground surface in Borehole 75-9. One Standard Penetration Test (SPT) 'N' value of 6 blows per 0.3 m of penetration was measured, indicating a loose relative density.
- **Clayey Silt to Silt:** A deposit of clayey silt to silt containing trace gravel and pockets of silty sand was encountered underlying the fill material in Borehole 75-9, and immediately below the ground surface in Boreholes 75-7, 75-8 and 75-11. Boreholes 75-7, 75-8 and 75-9 terminated within this deposit, penetrating it for a thickness of 9.6 m to 18.7 m. The clayey silt deposit in Borehole 75-11 (where the deposit was fully penetrated) has a thickness of 11.6 m. Atterberg limits testing measured plastic limits of about 11 to 14 per cent, liquid limits of about 13 to 18 per cent, and plasticity indices of about 2 to 6 per cent. Measured SPT 'N' values vary from 12 blows per 0.3 m of penetration to 100 blows per 0.08 m of penetration; however, in general, SPT 'N' values are over 80 blows per 0.3 m of penetrations, suggesting a generally hard consistency/very dense relative density.
- **Silty Sand to Sandy Silt:** A deposit of silty sand to sandy silt containing trace clay and gravel was encountered immediately below the ground surface in Borehole 75-10, and underlying the clayey silt in Borehole 75-11. Both boreholes terminated within this deposit, penetrating it for a thickness of 18.7 m and 4.1 m in Boreholes 75-10 and 75-11, respectively. Measured SPT 'N' values vary from 32 blows per 0.3 m to over 100 blows per 0.125 m; however in general the values are over 60 blows per 0.3 m of penetration, indicating a generally very dense relative density.

Groundwater Conditions:

The groundwater level was observed in the open boreholes upon completion of drilling, as summarized in the table below.

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)
75-7	4.6	171.0
75-8	4.1	170.7
75-9	3.5	170.7
75-10	10.3	168.5
75-11	9.1	168.6

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site.

The groundwater levels at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 - CP Rail Overhead
Site No.: 37-213

Existing Hwy 401 Grade: ~182 m
Rail Elevation: ~175 m
Original Ground Surface Elevation: ~175 m

Approximate Station: 12+300

FOUNDATION RECOMMENDATIONS

These site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

As part of the future rehabilitation of Highway 401 from Warden Avenue to Brock Road, the existing CP Rail overhead structure will require replacement. Based on the planning study completed to date, it is understood that the replacement structure will also be widened up to 10 m on the south side to accommodate the proposed Highway 401 widening in the area.

The existing structure consists of a single-span structure (19.2 m long on square or 27.0 m long on skew), with the existing abutments supported on spread footings. Based on available drawings, the existing foundation details are summarized as follows:

Foundation Element	Width (m)	Existing Structure Founding Elevation (m)
Northeast Abutment	2.1	172.8
Northwest Abutment	2.1	172.2
Southeast Abutment	3.0	173.0
Southwest Abutment	3.0	173.3

FOUNDATION OPTIONS

Based on the proposed underpass geometry and the subsurface conditions at this site, both shallow and deep foundation options have been considered for support of the abutments for the new CP Rail overhead structure. A summary of the advantages and disadvantages associated with each option is provided below.

- **Strip or spread footings founded on very dense silty sand to sandy silt / hard clayey silt or on top of existing footings:** Strip or spread footings are feasible for support of the new abutments and associated wing walls/retaining walls at this site. Significant excavation would be required through the existing embankment fill to reach the top of the existing footings or the native soils; however, the excavation below the rail grade would be relatively shallow and would be maintained above the groundwater level. Temporary protection systems will be required adjacent to the rail tracks if the abutments are reconstructed close to the existing rail tracks, and along Highway 401 as part of the staging for the structure replacement. Because of the stringent performance requirements for protection systems adjacent to rail tracks and the time required during design and/or construction for approval of track protection systems by the rail authority, it is recommended that consideration be given to lengthening the replacement structure to eliminate the requirement for a protection system beside the rail tracks. In this case, reuse of the existing footings would not be possible, and it would be further recommended to leave the existing footings in the ground to avoid excavation in close proximity to the rail tracks.
- **Footings "perched" on a compacted granular pad in the approach embankments**: "Perched" footings are feasible for support of the new abutments for the replacement and widening of the structure, to minimize the excavation through the existing embankment fill. However, it would be necessary to increase the span length for an open abutment configuration for this option.
- **Driven steel H-piles or pipe (tube) piles**: Driven steel piles are suitable and feasible for support of the abutments, as well as associated wing walls/retaining walls at this site. It is assumed that the pile caps would be perched in the embankment fill; however, significant excavation would still be required through the existing approach embankments to remove the existing structure, and to construct the reinforced soil walls. The use of a conventional abutment with the pile cap constructed at a depth of 1.2 m below the ground surface (rail grade) is not considered to be advantageous over the use of spread footings at this site, owing to the very shallow depth to very dense/hard soils; however, if this option is considered, it would be necessary to pre-auger into the 100-blow soils at the pile locations prior to installing the piles.

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense silty sand to sandy silt / hard clayey silt, or on top of existing footings	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • Excavations can be maintained above the groundwater table	• Requires excavation through approximately 10 m of embankment fill and into native soil • Protection systems will be required adjacent to rail tracks and along Highway 401 during staging; however, consideration should be given to lengthening the replacement structure to eliminate the need for protection systems adjacent to the rail tracks
"Perched" footings founded in the widened approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the footings above the groundwater level at the site	• Span length would need to be increased for an open abutment configuration to adopt this type of foundation
Steel H-piles or steel pipe (tube) piles driven into "100-blow" silty sand to sandy silt deposit or clayey silt	• Supports integral abutments for replacement and widening, with reduced maintenance costs	• If pile caps are perched in approach embankments, significant excavation through embankment fill would still be required to remove the existing structure, and to construct the retained soil system walls • If pile caps are constructed below the rail grade, pre-augering would be required due to shallow depth to 100-blow soil • Requires driving shoes to facilitate driving through very dense soils (possibly containing cobbles/boulders) • Protection systems will be required along Highway 401 as part of staging of replacement to facilitate removal of existing abutments/footings and construction of RSS walls (similar to requirements for spread footings)

Recommended Foundation Option: If the existing abutment footings must be removed, the preferred option from a foundations perspective is spread footings, as excavation through the existing embankment fill would be required to remove the existing structure for either a shallow foundation or a deep foundation option. If the existing abutment footings can be left in place to minimize excavation adjacent to the rail tracks, then deep foundations in an integral abutment configuration are preferred from a foundations perspective. This option would require a longer span length to allow the piles to be installed behind the existing footings, and in addition a greater width of excavation may be

Structure Description: Highway 401 - CP Rail Overhead
Site No.: 37-213

Existing Hwy 401 Grade: ~182 m
Rail Elevation: ~175 m
Original Ground Surface Elevation: ~175 m

Approximate Station: 12+300

required behind the abutments for deep foundations (assuming the use of perched abutments) to accommodate the length of the reinforcing strips for the retained soil system walls.

To minimize excavation requirements adjacent to the rail tracks, new spread footings founded on the existing spread footings are also considered a feasible option from a foundations perspective.

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the CP Rail overhead structure replacement and widening may be founded on the very dense silty sand to sandy silt or the hard/very dense clayey silt to silt at a minimum founding depth of 1.2 m for frost protection purposes. In order to extend below the firm to very stiff portions of the fill/clayey silt, the footings should be founded below Elevation 173 m at the north end, stepping up to Elevation 175 m at the south end of the abutments. New spread footings may also be founded on top of the existing spread footings, which meet the founding elevation requirements as described above. Alternatively, spread footings for the abutments and wing walls for the replacement structure can be founded within the approach embankment on a compacted Granular A pad.

The factored geotechnical resistance at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) may be taken as follows for preliminary design:

Founding Conditions	Width (m)	Geotechnical Resistance	
		Factored ULS	SLS
New structure founded on top of existing footings, or new footings founded on native soils at a minimum depth of 1.2 m below adjacent grade; footings must be founded below Elevations 173 m and 175 m at the north and south ends of the abutments, respectively	3	625 kPa	450 kPa
	4	750 kPa	400 kPa
Footings perched on a compacted Granular 'A' pad within approach embankments	3 – 4	800 kPa	350 kPa

Driven Steel H-Piles or Steel Pipe (Tube) Piles

Steel HP 310x110 piles founded within the very dense/hard soils (where SPT "N" values exceed 100 blows per 0.3 m of penetration) can be used for support of the new widened CP Rail overhead structure. The following factored axial geotechnical resistance at ULS and geotechnical resistance at SLS may be used for preliminary design:

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
All abutment widening locations	165.0 m	1,600 kN	1,400 kN

Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.), founded at or above the same design pile tip elevation.

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments.

Approach Embankments and Backfill

- Height: Approximately 10 m at the abutments.
- Stability: Approach embankments up to 10 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) will have an adequate factor of safety against deep-seated slope instability. As the approach embankments are greater than 8 m in height, a minimum 2 m wide mid-height bench should be incorporated, in accordance with MTO requirements.
- Settlement: Assuming the use of conventional earth fill or granular fill, it is expected that less than 25 mm of settlement will occur under the footprint of the widened approach embankments. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt and clayey silt to silt deposits are classified as a Type 2 soil, while the existing embankment fill would be classified as Type 3 soil according to OHSA. Temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

It is anticipated that foundation excavations will be maintained above the groundwater table at the site (approximately Elevation 171 m based on borehole observations, although the stabilized groundwater level may be higher). Some groundwater seepage may occur from within cohesionless soils or fills "perched" on top of the clayey silt deposit, or from lenses or interlayers of cohesionless soil within the clayey silt deposit. However, it is expected that such seepage volumes will be adequately controlled by pumping from properly filtered sumps within the foundation excavations.

Protection Systems

It is anticipated that temporary protection systems will be required along Highway 401 to facilitate the staged removal of the existing bridge structures and wing walls/retaining walls. Depending on the depth of excavation, temporary protection systems may also be required parallel to the rail tracks. However, it is recommended that consideration be given to lengthening the replacement structure to eliminate the requirements for a protection system adjacent to the rail tracks. Refer to Section 6.7 of the Preliminary Foundation Design Report for further comments.

Obstructions During Pile Driving

It is recommended that driving shoes be used to facilitate pile driving into the very dense silty sand to sandy silt / hard clayey silt soils, which may contain cobbles and boulders.

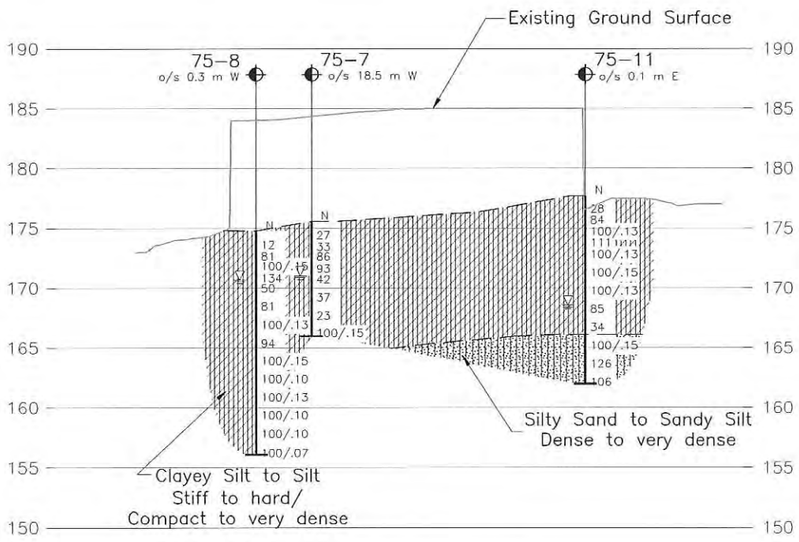
RECOMMENDATIONS FOR ADDITIONAL WORK

Further subsurface investigation should be carried out during detail design to confirm the shallow subsoil conditions and the stabilized groundwater levels, to refine the founding elevations and geotechnical resistances for shallow foundations. This should include boreholes in the core lanes of Highway 401 to confirm the founding elevation for shallow foundations, if adopted, due to the difference in elevation from north to south.

MINISTRY OF TRANSPORTATION, ONTARIO

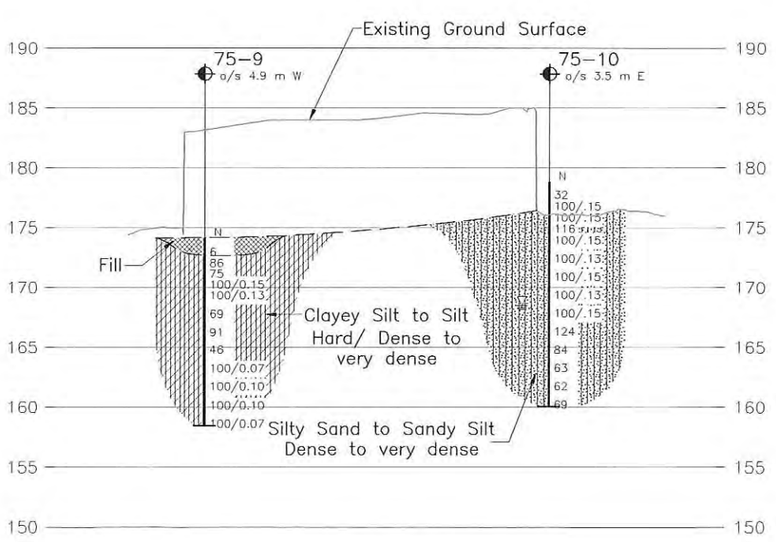
PLAN

SCALE
20 0 20 40 m



A-A' WEST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE



B-B' EAST ABUTMENTS

HORIZONTAL SCALE
0 20 40 m
5 0 5 10 m
VERTICAL SCALE

CONT No.
WO No. 07-20012

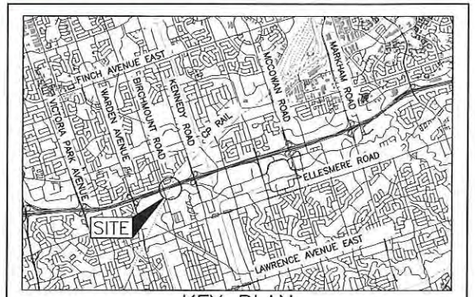
SHEET

CP RAIL OVERHEAD
HIGHWAY 401 WIDENING

BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole – Current Investigation
- Borehole – 1966 Investigation (Geocres 30M14-75)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
75-7	175.6	4848192.2	321528.7
75-8	174.8	4848200.5	321553.5
75-9	174.2	4848215.1	321584.8
75-10	178.8	4848108.3	321539.3
75-11	177.7	4848102.0	321503.2

NOTES

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

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

The complete Preliminary foundation investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE PROVINCE OF ONTARIO

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHKD. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD	CHKD. NK	APPD. LCC	DWG. B1

PLOT DATE: February 24, 2012
FILENAME: C:\Projects\2009\09-1111-6055 (URS, GTA)\-02-Foundation Conditions and Recommendations\091111605500081.dwg

RM 126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 75-7

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

JOB 66-F-89 LOCATION Hwy.401 & C.P.R.(Ret.Wall No.2) Sta. 322 + 70 118' Lt. ORIGINATED BY V.K.

W.P. 257-61 BORING DATE November 29, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Pen Drill Auger CHECKED BY

(M) ELEV.	DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
175.6	576.0	GROUND LEVEL									
	0.0	(Brown) (trace of organics in sample No. 1)		1	SS	27					2.7% Org.
		Clayey silt to silt with sand and trace of gravel. (Grey)		2	SS	33	570				Gr.5, Sa.44 Si.46 Cl.5
				3	SS	86					
				4	SS	93					El. 561.
				5	SS	42	560				
		Very stiff to Hard.		6	SS	37					Gr. 7 Sa.47 Si.40 Cl. 6
				7	SS	23	550				
166.0	544.5			8	SS	100/6"					
9.6	31.5	End of Borehole					540				

FORM OB-MT-126
66-4646

OFFICE REPORT ON SOIL EXPLORATION

BH 75-8

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 8

FOUNDATION SECTION

JOB 66-F-89 LOCATION Hwy. 401 & C.P.R., Sta. 323 + 59 119' Lt. ORIGINATED BY V.K.
W.P. 257-61 BORING DATE November 30, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Pen Drill Auger CHECKED BY

SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F.	LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT w WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE				
(M) 174.8 573.6	GROUND LEVEL									
0.0						570				
			1	SS	12					Gr.1,Sa.43 Si.47 Cl. 9
			2	SS	81					
	Clayey silt to		3	SS	100/6"					El. 560.1
	(Grey)		4	SS	134	560				
	silt with pockets of silty sand and occ. gravel.		5	SS	50					
			6	SS	81					Gr.1,Sa.44 Si.45 Cl.10
	Hard					550				
			7	SS	100/6"					
			8	SS	94					
						540				
			9	SS	100/6"					
			10	SS	100/4"					
						530				
			11	SS	100/5"					
			12	SS	100/4"					
						520				
			13	SS	100/4"					
56.1 512.1										
61.7 61.5	End of Borehole		14	SS	100/3"	510				

FORM 08-MT-124
56-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 75-9

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 9

FOUNDATION SECTION

JOB 66-F-89 LOCATION Hwy.401 & C.P.R., Sta. 324 + 74 133' Lt. ORIGINATED BY V.K.
W.P. 257-61 BORING DATE November 25, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Drive BX Casing & Wash CHECKED BY

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
571.4	GROUND LEVEL									
0.0	(Brown) Fill material					570				
566.4			1	SS	6			o		
5.0			2	SS	86			o I		Gr.2,Sa.45 Si.43 Cl.10 El.559.9
			3	SS	75	560				
	Clayey silt to silt with pockets		4	SS	100/6"			o		Gr.7 Sa.43 Si.41 Cl. 9
	(Grey)		5	SS	100/5"					
	of silty sand and trace of gravel		6	SS	69	550		o		
			7	SS	91					
	Hard		8	SS	46	540		o I		Gr.4,Sa.40 Si.53 Cl. 3
			9	SS	100/3"					
			10	SS	100/4"	530				
			11	SS	100/4"			o		Gr. 1 Sa.13 Si.78 Cl. 8
519.9			12	SS	100/3"	520				
51.5	End of Borehole									
						510				

FORM 66-MT-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 75-10

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 10

FOUNDATION SECTION

JOB 66-F-89 LOCATION Hwy. 401 & C.P.R. (Sta. 322 + 22 155' Rt. ORIGINATED BY V.K.
W.P. 257-61 BORING DATE December 2, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Pen-Drill Auger CHECKED BY

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — w_P w w_L — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
586.7	GROUND LEVEL									
0.0	(Brown)		1	SS	32					Gr.2,Sa.48 Si.38 Cl.12
			2	SS	100/6"	580				
			3	SS	100/6"					
	Silty sand to sandy silt with trace of clay and occasional gravel.		4	SS	116					Gr.1,Sa.46 Si.44 Cl. 9
			5	SS	100/6"	570				
			6	SS	100/6"					
	Dense to very dense.		7	SS	100/6"	560				
			8	SS	100/6"					El. 552.7 ▽
			9	SS	100/6"	550				
			10	SS	124					Gr.0,Sa.81 Si.&Cl. 19
			11	SS	84	540				
			12	SS	63					
			13	SS	62	530				
60.1	525.2		14	SS	69					
61.5	End of Borehole					520				

BH 7-11

DEPARTMENT OF HIGHWAYS ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 11

FOUNDATION SECTION

JOB 66-F-89 LOCATION Hwy. 401 & C.P.R., Sta. 321 + 02, 131' Rt. ORIGINATED BY V.K.

W.P. 257-61 BORING DATE December 2, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Drive BX Casing & Wash CHECKED BY

(m) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (20 40 60 80 100) SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_p / WATER CONTENT w — WATER CONTENT % (10 20 30)	BULK DENSITY γ P.C.F.	REMARKS
177.7 583.0	GROUND LEVEL									
0.0	(Brown)					580				
			1	SS	28					
			2	SS	84			o		Gr.2,Sa.47 Si.38 Cl.13
	Clayey silt with pockets of silty sand and trace of gravel.		3	SS	100/5"			o		
			4	SS	111	570		o		
			5	SS	100/5"					
	Very Stiff to Hard		6	SS	100/6"			o		Gr.6,Sa.45 Si.38 Cl.11
			7	SS	100/5"	560				
			8	SS	85					El.553. ▼
166.1 545.0			9	SS	34	550		o		
11.6 38.0	Silty sand to sandy silt, occasional gravel.		10	SS	100/6"			o		Gr.0,Sa.91 Si.&Cl. 9
	Very Dense.		11	SS	126	540				
162.0 531.5			12	SS	106					
15.7 51.5	End of Borehole					530				

APPENDIX C

Kennedy Road Overpass

April 2012
Report No. 09-1111-6055-1

Golder Associates

Structure Description: Highway 401 - Kennedy Road Overpass
Site No.: 37-214

Existing Highway 401 Grade: ~176 m
Local Road Elevation: ~ 170 m
Original Ground Surface Elevation: 168 m to 171 m

Approximate Station: 12+950

FOUNDATION INVESTIGATION

Site Description:

The site is located on the north and south sides of Highway 401 WBL and EBL at the Kennedy Road overpass (Structure Site No. 37-214) in the City of Toronto, Ontario. This site is surrounded by commercial/industrial parks with the exception of the southwest quadrant, which contains a residential area. See key plan on Drawing 1.

Borehole Information:

Boreholes 71-1 to 71-6 were drilled as part of a 1966 investigation at this site by others (MTO Geocres No. 30M14-71).

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
71-1	East Abutment	4,848,340.5	322,165.4	167.9	15.2
71-2	West Abutment	4,848,367.8	322,114.1	168.1	15.2
71-3	East Abutment	4,848,401.3	322,146.5	169.8	12.6
71-4	West Abutment	4,848,307.8	322,135.7	170.4	14.2
71-5	East Abutment	4,848,322.1	322,186.2	168.2	18.7
71-6	West Abutment	4,848,389.0	322,102.7	171.1	21.8

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Clayey Silt Fill:** Approximately 1.5 m of clayey silt fill was encountered immediately below ground surface in Borehole 71-5 during the 1966 investigation. One Standard Penetration Test (SPT) 'N' value of 14 blows per 0.3 m of penetration was measured in this fill, suggesting a stiff consistency. Atterberg limits testing measured a plastic limit of approximately 13 per cent, a liquid limit of approximately 17 per cent and a plasticity index of 4 per cent.
- **Silty Sand to Sandy Silt:** A deposit of silty sand to sandy silt containing trace clay and gravel was encountered underlying the fill in Borehole 71-5, and immediately below ground surface in all other boreholes. Clayey silt layers were observed within this deposit in Boreholes 71-5 and 71-6. The thickness of this deposit varies from about 8.9 m to at least 15.2 m (Borehole 71-2 terminated within this deposit, penetrating it for a thickness of 15.2 m). The measured SPT 'N' values vary from 12 blows per 0.3 m of penetration to 100 blows per 0.08 m of penetration. The lower SPT 'N' values are generally in the upper 3 m of the deposit, with the lower portion of the deposit having SPT 'N' values greater than 50 blows per 0.3 m, indicating that the upper 3 m of the deposit has a compact to dense relative density, while the lower portion of the deposit has a very dense relative density.
- **Clayey Silt:** A deposit of clayey silt with sand was encountered underlying the silty sand to sandy silt deposit in Borehole 75-5. The deposit has a thickness of 3.0 m. The measured SPT 'N' values were 100 blows per 0.15 m of penetration and 100 blows per 0.13 m of penetration, suggesting a hard consistency. Atterberg limits testing measured a plastic limit of approximately 12 per cent, a liquid limit of approximately 22 per cent and a plasticity index of 10 per cent.
- **Glacial Till**: A deposit of glacial till, consisting of a heterogeneous mixture of clayey silt, sand and gravel, was encountered underlying the silty sand to sandy silt deposit in all boreholes except Borehole 71-5, where it was found underlying the clayey silt. All boreholes, with the exception of Borehole 71-2, terminate within this deposit, penetrating it for a thickness of approximately 3.5 m to 7.1 m. The measured SPT 'N' values vary from 112 blows per 0.3 m of penetration to 100 blows per 0.08 m of penetration, indicating a hard consistency.

Groundwater Conditions:

The groundwater level was measured in the open boreholes upon completion of drilling, as summarized in the following table:

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)
71-1	1.7	166.3
71-2	2.7	165.4
71-3	2.5	167.3
71-4	4.3	166.1
71-5	3.7	164.5
71-6	4.0	167.1

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site.

The groundwater level at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 - Kennedy Road Overpass
Site No.: 37-214

Existing Highway 401 Grade: ~176 m
Local Road Elevation: ~170 m
Original Ground Surface Elevation: 168 m to 171 m

Approximate Station: 12+950

FOUNDATION RECOMMENDATION

Note: The site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Preliminary Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

It is understood that up to 0.6 m of southward widening and up to 5.4 m of northward widening is proposed for the Highway 401-Kennedy Road overpass. In addition, the superstructure may be replaced using the existing foundations.

ASSESSMENT OF EXISTING FOUNDATIONS

The existing Kennedy Road overpass consists of a two-span structure. Based on available drawings, the existing abutments are supported on 3.4 m wide spread footings founded at Elevation 167.6 m, and the piers are supported on 1.8 m wide footings founded at Elevation 167.5 m. Golder has assessed the factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS) for the existing abutment and pier foundations, using the existing founding elevations, foundation geometry, and subsurface conditions from the 1966 boreholes to complete bearing capacity and settlement analyses. The following table summarizes the geotechnical resistances that have been assessed for the existing footings:

Foundation Element	Founding Elevation and Stratum	Footing Width	Geotechnical Resistance	
			Factored ULS	SLS
Abutments	167.6 m – Dense to very dense sandy silt to silty sand	3.4 m	650 kPa	350 kPa
Pier	167.5 m – Dense to very dense sandy silt to silty sand	1.8 m	500 kPa	350 kPa

FOUNDATION OPTIONS

Based on the existing subsurface information, both shallow and deep foundations have been considered for the proposed overpass widening and potential replacement of the superstructure (using the existing foundations); the advantages and disadvantages associated with each option are summarized below:

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense sandy silt to silty sand	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • Allows for semi-integral abutment design	• Requires excavation to a depth of about 2.5 m below Kennedy Road grade to match existing founding level; this will extend to/below the groundwater level, and some dewatering will be required • Protection system required along Highway 401 to facilitate removal of existing wing walls/retaining walls and excavation through highway embankment fill • Potential for up to 10 mm to 15 mm of differential settlement to occur between existing and new portions of structure; construction joint required to accommodate differential movement
"Perched" footings founded in the widened approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the footings above the groundwater level at the site	• Poor compatibility with existing closed abutment configuration and spread footings founded on native soils below Kennedy Road grade • Potential for differential settlement
Steel H-piles or steel pipe (tube) piles driven into "100-blow" sandy silt to silty sand deposit for abutment foundations	• Pile caps may be perched in widened approach embankments, or founded at minimum frost protection depth, minimizing depth of excavation as compared with shallow foundation option • Allows for integral abutment design with H-piles, and semi-integral abutment design with pipe piles; may be compatible if the existing structure can be converted to semi-integral abutments • Minimal differential settlement between existing and widened portions of structure	• For pile caps constructed at a shallow depth below the local road grade (at the centre pier for example, or for conventional pile-supported abutments in a closed configuration), pre-augering would be required prior to installation of the piles due to the very shallow depth to 100-blow soils; pre-augering may also be required if piles for integral abutments are placed before construction of the reinforced soil mass • Requires driving shoes to facilitate driving through very dense soils (possibly containing cobbles/boulders) • Potential vibration impacts on existing overhead structure; however, vibrations are anticipated to have a peak particle velocity of less than 100 mm/s • Protection systems likely still required along the north and south edges of Highway 401 to facilitate the removal of the existing wing walls/retaining walls before constructing the widening

Recommended Foundation Option: For the widening of the centre pier, spread footings are preferred from a foundations perspective, although there is potential for up to approximately 10 mm to 15 mm of differential settlement between the existing and new portions of the structure.

At the abutments, the use of deep foundations with the pile caps "perched" in the widened approach embankments is considered to be advantageous to minimize excavation and groundwater control; this option would allow the use of integral abutments if the existing structure can be converted as part of the superstructure replacement to be compatible. The differential settlement between the existing abutment footings and the widened, pile-supported abutments would be negligible. However, it is noted that for the relatively small width of the northward and southward widening, this configuration may not be aesthetically compatible with the existing structure, and in this case spread footings are considered to be an acceptable alternative for support of the widened abutments.

Structure Description: Highway 401 - Kennedy Road Overpass
Site No.: 37-214

Existing Highway 401 Grade: ~176 m
Local Road Elevation: ~170 m
Original Ground Surface Elevation: 168 m to 171 m

Approximate Station: 12+950

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the northward and southward widening may be founded on the dense to very dense sandy silt to silty sand at the same level as the existing footings (Elevation 167.6 m and 167.5 m for the abutments and pier, respectively). This founding level will satisfy the minimum depth of 1.2 m for frost protection purposes. Alternatively, spread footings for the widened abutments and associated wing walls could be founded within the approach embankments on a compacted Granular 'A' pad; however, as noted above, this may not be compatible with the existing structure. The factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS, for 25 mm of settlement) for preliminary design may be taken as the same as the existing capacity (provided in the table at left) assuming the new footings will match the existing footings in width and founding elevation. If "perched" footings are adopted on a compacted granular pad in the widened approach embankments, the factored geotechnical resistance at ULS and geotechnical resistance at SLS may be taken as 800 kPa and 350 kPa, respectively.

Steel H-Piles

Steel HP 310x110 piles driven to found within the sandy silt to silty sand deposit soils (where SPT "N" values exceed 100 blows per 0.3 m of penetration) can be used for support of the northward and southward widening. For preliminary design, the following pile tip elevation may be assumed:

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
Abutment widening – southeast	160.0 m	1,600 kN	1,400 kN
Abutment widening – all other quadrants	164.0 m	1,600 kN	1,400 kN
Centre pier widening – south end	160.0 m	1,600 kN	1,400 kN
Centre pier widening – north end	164.0 m	1,600 kN	1,400 kN

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments. However; the existing structure is supported on spread footings and an integral abutment system for the widening will not be compatible unless the existing structure can be converted to semi-integral abutments.

Approaches and Backfill

- Height: Approximately 6 m at the abutments.
- Stability: Approaches up to 6 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) will have a factor of safety of at least 1.3 against deep-seated slope instability.
- Settlement: Assuming the use of conventional earth fill or granular fill, it is expected that less than 25 mm of settlement will occur under the footprint of the approach embankment widening area. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).
- The widened approach embankment fill should be keyed into the existing fill as per MTO standards.

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt deposit is classified as a Type 2 soil, while the existing embankment fill would be classified as Type 3 soil according to OHSA. The side slopes for temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

The groundwater level at the site was measured to be as high as approximately 167 m based on the observations following completion of drilling at the time of the 1966 borehole investigation; the stabilized groundwater level may differ. If shallow foundations are adopted to match the existing footings, it is anticipated that excavations will extend near to or possibly below the groundwater level at the site. In this case, some dewatering would be required in the silty sand to sandy silt deposit to lower the groundwater level to at approximately 1 m below the founding elevation; it is expected that pumping from filtered sumps alone would not be sufficient, and that it would be necessary to use some well-points to assist in lowering the groundwater level in the silty sand to sandy silt soils.

Protection Systems

It is anticipated that temporary protection systems will be required along the edges of Highway 401 to facilitate excavation through the existing highway embankment fill as well as the fill located between the highway and ramps, for removal or cutting down of the existing wing walls/retaining walls and to construct the north and south widening. Temporary protection systems are also likely to be required along the edge of Kennedy Road due to the depth of excavation required to match the existing footings, where shallow foundations are adopted for widening of the abutments or centre pier. These temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.

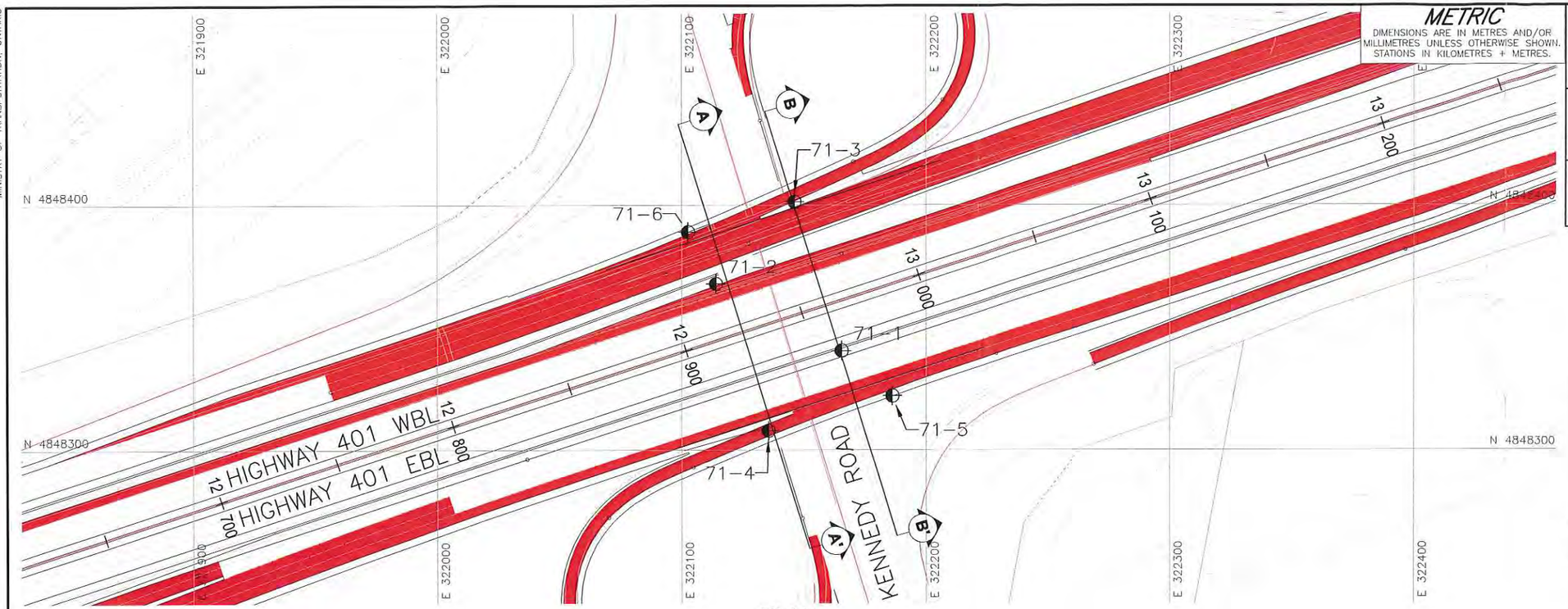
Obstructions During Pile Driving

If deep foundations are adopted with the pile cap founded below the Kennedy Road grade (for example, at the centre pier), pre-augering will be required due to the presence of very dense soil at shallow depths. In addition, it is recommended that driving shoes be used to facilitate pile driving into the very dense silty sand to sandy silt.

RECOMMENDATIONS FOR ADDITIONAL WORK

Further subsurface investigation should be carried out during detail design to confirm the shallow subsoil conditions and the groundwater level in the widening area, to refine the founding elevations and geotechnical resistances, as well as to assess the dewatering requirements associated with the use of shallow foundations constructed to match the existing founding levels.

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE
20 0 20 40 m

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

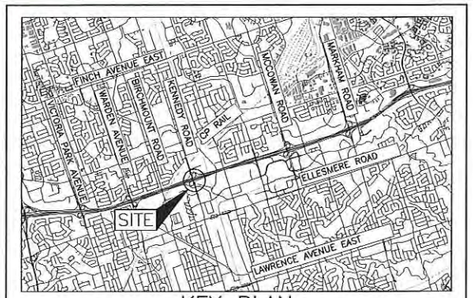
CONT No.
WO No. 07-20012

KENNEDY ROAD OVERPASS
HIGHWAY 401 WIDENING

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



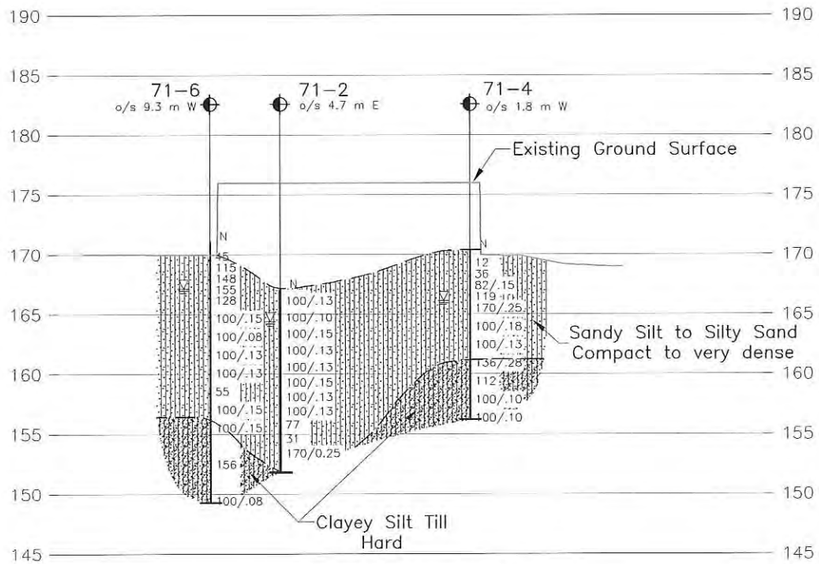
KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole — Current Investigation
- Borehole — 1966 Investigation (Geocres 30M14-71)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

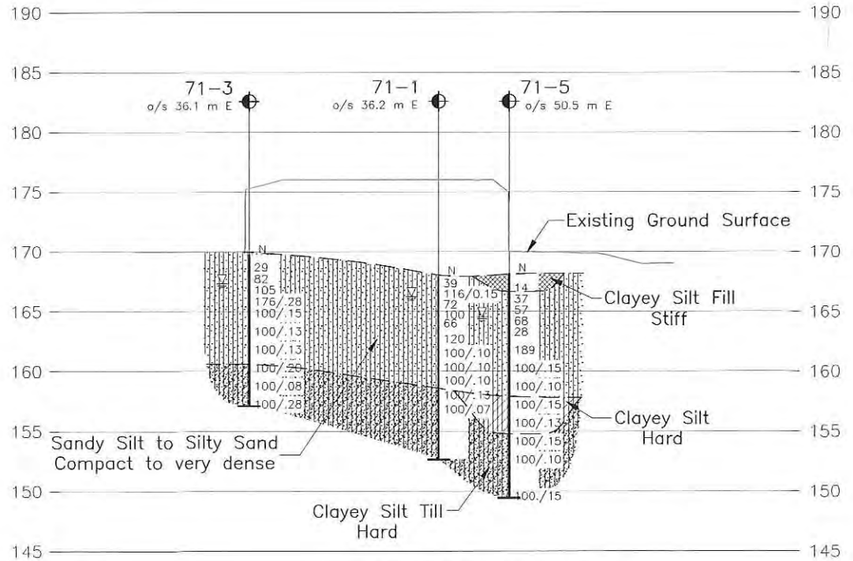
BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
71-1	167.9	4848340.5	322165.4
71-2	168.1	4848367.8	322114.1
71-3	169.8	4848401.3	322146.5
71-4	170.4	4848307.8	322135.7
71-5	168.2	4848322.1	322186.2
71-6	171.1	4848389.0	322102.7



A-A' WEST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE



B-B' EAST ABUTMENTS

HORIZONTAL SCALE
0 20 40 m
5 0 5 10 m
VERTICAL SCALE

NOTES

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

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE PROVINCE OF ONTARIO

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHK'D. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD	CHK'D. NK	APP'D. LCC	DWG. C1

PLOT DATE: February 24, 2012
DRAWING: I:\Projects\09-1111-6055 (URS, GTA)\-CO-Foundation Conditions and Recommendations\09111160555CC001.dwg

BH71-1

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. Sta. 344+11 64' Rt. ORIGINATED BY V.K.

W.P. BORING DATE April 4, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Penn-Drill CHECKED BY

(w)	ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 15 30 45	BULK DENSITY P.C.F.	REMARKS
16.9	550.0	Ground Level									
	0.0	Sandy Silt to Silty Sand with traces of Gravel and Clay		1	SS	39	550				Gr-2 Sa-14 Si-78 Cl-6
				2	SS	72					
		Dense to V. Dense		3	SS	116/6"	540				▽ W.L. 545.5 5.5
				4	SS	100					
				5	SS	66					Gr-2 Sa-8 Si-82 Cl-8
				6	SS	120	530				
				7	SS	100/4"					
18.8	521.0										
9.1	30.0	Heterogeneous mixture of Clayey Silt, Sand and Gravel		8	SS	100/4"	520				Gr-5 Sa-21 Si-52 Cl-22
		GLACIAL TILL		9	SS	100/4"					
		Hard		10	SS	100/5"	510				
				11	SS	100/3"					
15.2	491.0	End of Borehole					500				

BH 71-2

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. Sta. 342+78 72' Lt. ORIGINATED BY V.K.
W.P BORING DATE April 5, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Penn Drill CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (20 40 60 80 100) / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w (WATER CONTENT % 15 30 45)	BULK DENSITY P.C.F.	REMARKS
(M) 168.1 551.5 0.0	Ground Level					550				
	Sandy Silt to Silty Sand with traces of Gravel and Clay		1	SS	100/5"					Gr-1 Sa-25 Si-55 Cl-9
			2	SS	100/4"					
			3	SS	100/3"	540				▽ W.L. 542.5 9.0
			4	SS	100/5"					
			5	SS	100/5"					Gr-0 Sa-64 Si-33 Cl-3
	Very Dense		6	SS	100/6"	530				
			7	SS	100/5"					
			8	SS	100/5"	520				
			9	SS	77					
			10	SS	31	510				Gr-0 Sa-41 Si-55 Cl-4
152.9 501.5 (M) 50.0	End of Borehole		11	SS	170/10"	500				

DEFECTS IN NEGATIVE DUE TO CONDITION OF ORIGINAL DOCUMENT

BH 71-3

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. Sta. 344/13 143' Lt. ORIGINATED BY V.K.

W.P. BORING DATE April 7, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Penn - Drill CHECKED BY

ELEV (m) / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 15 30 45	BULK DENSITY γ P.C.F.	REMARKS
168 557.0	Ground Level									
0.0			1	SS	29					
			2	SS	82	550				W.L. 549.0 8.0
	Sandy Silt to Silty Sand with traces of gravel and clay		3	SS	105					
			4	SS	176/11"					Gr-1 Sa-11 Si-83 Cl-5
			5	SS	100/6"	540				
	Dense to Very Dense		6	SS	100/5"					
			7	SS	100/5"	530				Gr-1 Sa-23 Si-71 Cl-5
166 527.0 9.1 30.0										
	Heterogeneous mixture of Clayey Silt, Sand and Gravel GLACIAL TILL		8	SS	100/3"					
			9	SS	100/3"	520				
163 515.5 12.6 41.5	Hard		10	SS	100/11"					Gr-4 Sa-15 Si-38 Cl-43
	End of Borehole					510				

BH 71-4

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. Sta. 342+84 140' Rt. ORIGINATED BY V.K.

W. P. BORING DATE April 12, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Penn - Drill CHECKED BY

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — w_P w w_L — WATER CONTENT % 15 30 45	BULK DENSITY P.C.F.	REMARKS
(ML) 170.4 559.0 0.0	Ground Level									
	Sandy Silt to Silty Sand with traces of Gravel and Clay		1	SS	12					Gr-2 Sa-52 Si-39 Cl-7
			2	SS	36	550				
			3	SS	32/6"					Gr-1 Sa-30 Si-65 Cl-4
			4	SS	119					∇ W.L. 545.0 14.0
			5	SS	170/10"					
						540				
	Compact to very Dense		6	SS	100/7"					
			7	SS	100/5"					
161.2 529.0 30.0						530				
9.1	Heterogeneous Mixture of Clayey Silt, Sand and Gravel		8	SS	136/11"					Gr-5 Sa-28 Si-58 Cl-9
			9	SS	113					
	GLACIAL TILL					520				
			10	SS	100/4"					
156.2 512.5 46.5	Hard		11	SS	100/4"					
14.2										

FORM GD-MT-126
66-4946

OFFICE REPORT ON SOIL EXPLORATION

BH71-5

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. ORIGINATED BY V.K.
W.P. 258-61 BORING DATE December 6, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Pen Drill Auger & Drive & Wash BX casing CHECKED BY

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — w_P w w_L — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
551.8	GROUND LEVEL									
0.0	Clayey silt, sand & gravel (fill)					550				
546.8			1	SS	14			o——		Gr.3,Sa.35 Si.51,Cl.11
5.0	(Brown) Sandy silt to silty sand with traces of gravel and		2	SS	37					
			3	SS	57	540		o		Gr.0,Sa35 Si.59 w_L 1.12. Cl 6
	(Grey) occasional layers of clayey silt.		4	SS	68					
			5	SS	28			o		Gr.1,Sa.29 Si.66,Cl.4
	Compact to very dense		6	SS	189	530				
			7	SS	100/6"					
			8	SS	100/4"	520				
517.8										
34.0	Clayey silt with sand and trace of gravel		9	SS	100/6"			o——		Gr.1,Sa.25 Si.46,Cl.28
			10	SS	100/5"	510				
507.8	(Hard)									
44.0	Glacial till Het mixture of clayey silt, sand and gravel.		11	SS	100/6"			o		Gr.0,Sa.85 Si.&Cl.15
			12	SS	100/4"	500				
	Hard or Very Dense									
490.3			13	SS	100/6"	490				
61.5	End of Borehole									

FORM OR-MT-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 71-6

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 66-F-33 LOCATION Hwy. 401 & Kennedy Rd. ORIGINATED BY V.K.
W.P. 258-61 BORING DATE December 5, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Pen Drill Auger; Drive & wash BX Casing CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT W_L / PLASTIC LIMIT W_P / WATER CONTENT W — W_P W W_L — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT					
561.25	GROUND ELEVATION									
0.0	(Brown)					560				
			1	SS	45					Gr.4, Sa.22 Si.61, Cl.7
			2	SS	115					
	Sandy silt to silty		3	SS	148	550				
	sand with traces of		4	SS	155				Gr.6 Sa.22 Si.67 Cl.	W.L. 13.0
	gravel,		5	SS	128					
	(Grey)									
	and occasional layers		6	SS	100/6"	540				
	of clayey silt.		7	SS	100/3"					Gr. 2 Sa.13 Si.75 Cl.10
	Very dense.		8	SS	100/5"	530				
			9	SS	100/5"					
			10	SS	55	520				Gr.0 Sa.43 Si.51 Cl. 6
51.4 513.25			11	SS	100/6"					
48.0	Glacial till Het mixture of clayey silt, sand & gravel.		12	SS	100/6"	510				Gr.0 Sa.41 Si.57 Cl.2
	Hard or Very dense.		13	SS	156	500				
71.3 489.75			14	SS	100/3"	490				
71.50	End of Borehole									

APPENDIX D

CN Rail Overhead

Structure Description: Highway 401 - CN Rail Overhead
Site No.: 37-215

Existing Hwy 401 Grade: ~174 m
Rail Elevation: ~165.5 m
Original Ground Surface Elevation: ~164 m (north side) to 165 m (south side)

Approximate Station: 13+360

FOUNDATION INVESTIGATION

Site Description:

The site is located on the north and south sides of Highway 401 WBL and EBL at the CN Rail overhead structure (Structure Site No. 37-215), approximately 400 m east of Kennedy Road, in the City of Toronto, Ontario. Commercial/industrial parks are located north and south of the highway. See key plan on Drawing 1.

Borehole Information:

Boreholes 68-1 to 68-5 were drilled as part of a 1966 investigation at this site by others (MTO Geocres No. 30M14-68). One additional borehole (2011-01) was drilled as part of the current investigation.

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
68-1	West Abutment	4,848,518.0	322,518.9	164.3	18.7
68-2	East Abutment	4,848,520.9	322,537.6	163.6	15.7
68-3	West Abutment	4,848,481.2	322,535.9	165.0	12.6
68-4	East Abutment	4,848,443.9	322,556.6	165.6	18.7
68-5	West Abutment	4,848,438.0	322,543.4	165.9	15.7
2011-01	West Abutment	4,848,414.2	322,538.0	166.3	43.3

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Topsoil:** About 200 mm of topsoil was encountered immediately below ground surface in Borehole 2011-01.
- **Clayey Silt Fill:** Approximately 0.6 m of clayey silt fill was encountered below the topsoil in Borehole 2011-01. One Standard Penetration Test (SPT) 'N' value of 12 blows per 0.3 m of penetration was measured, suggesting this fill has a stiff consistency.
- **Upper Clayey Silt:** A 1.8 m thick upper layer of clayey silt was encountered immediately below the ground surface in Borehole 68-1. One Atterberg limits test was completed and measured a plastic limit of 17 per cent, a liquid limit of 23 per cent, and a plasticity index of 6 per cent. One SPT 'N' value of 33 blows per 0.3 m of penetration was measured in this layer, suggesting a hard consistency.
- **Silty Sand to Silt:** A deposit of silty sand to silt (containing occasional layers of clayey silt) was encountered underlying the upper clayey silt in Borehole 68-1, immediately below ground surface in Boreholes 68-2 to 68-5, and below an upper till deposit in Borehole 2011-01. Boreholes 68-1, 68-3, 68-4 and 68-5 terminated within this deposit, penetrating it for a thickness of 12.6 m to 18.7 m. The deposit is 14.2 m thick in Borehole 68-2, and 7.6 m thick in Borehole 2011-01. The measured SPT 'N' values vary from 17 blows to 185 blows per 0.3 m of penetration, indicating a compact to very dense relative density.
- **Upper Sand and Silt to Clayey Silt Till:** A 12.6 m thick till deposit was encountered below the fill in Borehole 2011-01. The till consists of an upper 2.3 m thick zone of silty sand till, a 1.5 m thick zone of clayey silt till, and a lower 8.8 m thick zone of sand and silt till. This till deposit in Borehole 2011-01 is similar to the silty sand to silt deposit in Boreholes 68-1 to 68-5. The measured SPT 'N' values vary from 7 to 90 blows per 0.3 m of penetration, indicating a loose to very dense relative density in the cohesionless portions of the till, and a very stiff consistency in the clayey silt till. One SPT 'N' value of 1 blow per 0.3 m of penetration was measured within the till deposit; however, this value is considered to have been affected by sample disturbance due to groundwater inflow.
- **Clayey Silt Interlayers:** Clayey silt interlayers were encountered within the silty sand to silt deposit in Boreholes 68-2, 68-4, and 68-5. Borehole 68-2 terminated within the layer, penetrating it for a thickness of 1.5 m, while the thickness in the remaining boreholes was 2.1 m and 2.2 m. Atterberg limits testing measured plastic limits of 11 to 14 per cent, liquid limits of 19 to 23 per cent, and plasticity indices of 7 to 8 per cent. The measured SPT 'N' values vary from 76 to 116 blows per 0.3 m of penetration, suggesting a hard consistency.
- **Lower Clayey Silt:** An 11.3 m thick lower deposit of clayey silt was encountered below the sand and silt deposit in Borehole 2011-01. Atterberg limits testing measured plastic limits of 16 per cent, liquid limits of 23 and 26 per cent, and plasticity indices of 7 and 10 per cent. The measured SPT 'N' values vary from 22 to 56 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.
- **Lower Clayey Silt Till:** A lower deposit of clayey silt till was encountered at a depth of about 32.3 m (Elevation 134.0 m) underlying the lower clayey silt in Borehole 2011-01. The borehole terminated within this deposit, penetrating it for a thickness of 11.0 m. Atterberg limits testing measured a plastic limit of 12 per cent, a liquid limit of 19 per cent, and a plasticity index of 7 per cent. The measured SPT 'N' values vary from 20 to 36 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

Groundwater Conditions:

The groundwater level was measured in the open boreholes upon completion of drilling, as summarized in the following table:

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)
68-1	1.2	163.1
68-2	1.1	162.5
68-3	3.7	161.4
68-4	1.8	163.8
68-5	5.5	160.4
2011-01	4.3	162.0

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site.

The groundwater levels at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 - CN Rail Overhead
Site No.: 37-215

Existing Hwy 401 Grade: ~174 m
Rail Elevation: ~165.5 m
Original Ground Surface Elevation: ~164 m (north side) to 165 m (south side)

Approximate Station: 13+360

FOUNDATION RECOMMENDATIONS

Note: The site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Preliminary Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

As part of the future rehabilitation of Highway 401 from Warden Avenue to Brock Road, the existing CN Rail overhead structure will require replacement. Based on the planning study completed to date, it is understood that the replacement structure will also be widened by up to 1.1 m on the south side, and up to 10.3 m on the north side to accommodate the proposed Highway 401 widening in the area.

The existing overhead consists of a 13.7 m long single-span structure. Based on available drawings, the existing west and east abutments are supported on 1.8 m to 3.4 m wide spread footings (for the core and collector structures, respectively), which are founded at Elevation 163.1 m at the north end, and Elevation 164.2 m at the south end.

FOUNDATION OPTIONS

Based on the proposed underpass geometry and the subsurface conditions at this site, both shallow and deep foundation options have been considered for support of the abutments for the replacement and widening of the CN Rail overhead structure. A summary of the advantages and disadvantages associated with each option is provided below.

- **Strip or spread footings founded on dense to very dense silty sand to sandy silt or on top of existing footings:** Strip or spread footings are feasible for support of the new abutments and associated wing walls/retaining walls at this site. Significant excavation would be required through the existing Highway 401 embankment fill to reach the top of the existing footings or the native soils. In addition, about 1.2 m to 2 m of excavation would be required into the native soils to extend below the compact portion of the deposit, and this excavation may extend below the groundwater level. Temporary protection systems will be required adjacent to the rail tracks if the abutments are reconstructed close to the existing rail tracks, and along Highway 401 as part of the staging for the structure replacement. Because of the stringent performance requirements for protection systems adjacent to rail tracks and the time required during design and/or construction for approval of track protection systems by the rail authority, it is recommended that consideration be given to lengthening the replacement structure to eliminate the requirement for a protection system beside the rail tracks. In this case, reuse of the existing footings would not be possible, and it would be further recommended to leave the existing footings in the ground to avoid excavation in close proximity to the rail tracks.
- **Footings "perched" on a compacted granular pad in the approach embankments**: "Perched" footings are feasible for support of the new abutments for the replacement and widening of the structure, to minimize the excavation through the existing embankment fill. However, it would be necessary to increase the span length for an open abutment configuration for this option.
- **Driven steel H-piles or pipe (tube) piles:** Driven steel piles are suitable and feasible for support of the abutments, as well as associated wing walls/retaining walls at this site. It is assumed that the pile caps would be perched in the embankment fill; however, significant excavation would still be required through the existing approach embankments to remove the existing structure, and to construct the reinforced soil walls. The use of a conventional abutment with the pile cap constructed at a depth of 1.2 m below the ground surface (rail grade) is not considered to be advantageous over the use of spread footings at this site, as dewatering and temporary protection systems along the rail tracks would still be required. The depth to "refusal" for the piles is expected to be variable based on the borehole results, and further investigation is recommended at the detail design stage in this regard.

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense silty sand to sandy silt, or on top of existing footings	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • If new structure is founded on existing footings, depth of excavation will be less with reduced requirements for dewatering	• Requires excavation through approximately 10 m of embankment fill and into native soil • Footing excavations may extend below the groundwater level at the site, and dewatering would be required; appropriate measures would be required to minimize or eliminate impacts of dewatering on the rail tracks • Protection systems will be required adjacent to rail tracks and along Highway 401 during staging; however, consideration should be given to lengthening the replacement structure to eliminate the need for protection systems adjacent to the rail tracks
"Perched" footings founded in the approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the footings above the groundwater level at the site	• Span length would need to be increased for an open abutment configuration to adopt this type of foundation
Steel H-piles driven into "100-blow" silty sand to sandy silt deposit for abutment foundations	• Supports integral abutments for replacement and widening, with reduced maintenance costs • Assuming pile caps are perched in the approach embankments, they can be maintained above the groundwater level at the site	• If pile caps are perched in approach embankments, significant excavation through embankment fill would still be required to remove the existing structure, and to construct the retained soil system walls; this excavation may be slightly longer (behind the existing abutments) to accommodate the length of the reinforcing strips for the retained soil system wall • Although perched pile caps would be maintained above the groundwater level at the site, dewatering and temporary protection systems would still be required to remove the existing structure foundations, unless they can be left in place and the piles installed behind in a longer bridge span • If pile caps are constructed below the rail grade, dewatering would be required • Driving shoes required to facilitate driving

Structure Description: Highway 401 - CN Rail Overhead
Site No.: 37-215

Existing Hwy 401 Grade: ~174 m
Rail Elevation: ~165.5 m
Original Ground Surface Elevation: ~164 m (north side) to 165 m (south side)

Approximate Station: 13+360

Foundation Option	Advantages	Disadvantages
		through very dense soils (possibly containing cobbles/boulders); pre-augering is also expected to be required at the northwest and southeast foundation elements if pile caps are located below the CN Rail grade, due to the relatively shallow depth to "100-blow" soil • Protection systems will be required along Highway 401 as part of staging of replacement to facilitate removal of existing abutments/footings and construction of RSS walls (similar to requirements for spread footings)

Recommended Foundation Option: Excavation through the existing embankment fill will be required to remove the existing structure for either a shallow foundation or a deep foundation option. From a foundations perspective, deep foundations (driven steel H-piles or steel pipe piles) are preferred as these can be maintained above the groundwater level at the site. Dewatering may still be required if the existing foundations are to be fully removed; however, if the existing foundations can be left in place (with the piles installed behind, or driven after coring through the existing foundation), then the requirements for dewatering and protection systems will be reduced or eliminated as compared with a shallow foundation option. In addition, driven steel H-piles would allow for an integral abutment structure, with reduced maintenance costs.

To minimize excavation requirements adjacent to the rail tracks, new spread footings founded on the existing spread footings are also considered a feasible option from a foundations perspective.

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the CN Rail overhead structure replacement may be founded on the dense to very dense silty sand to sandy silt at a minimum founding depth of 1.2 m in order to satisfy frost protection requirements. For the southern widening, it is recommended that the footings be founded below Elevation 163 m in order to extend below the compact portions of the native soil deposit. New spread footings may also be founded on the existing spread footings. Alternatively, spread footings for the new abutments and associated wing walls can be founded within the approach embankment on a compacted Granular A pad. The factored geotechnical resistance at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) may be taken as follows for preliminary design:

Founding Conditions	Width (m)	Geotechnical Resistance	
		Factored ULS	SLS
New footings founded on existing footings, or on native soils at or below Elevation 163 m	3.0	500 kPa	350 kPa
	4.0	550 kPa	350 kPa
Footings perched on a compacted Granular 'A' pad within widened approach embankments	3.0	800 kPa	350 kPa

Driven Steel H-Piles or Steel Pipe (Tube) Piles

Steel HP 310x110 piles founded within the very dense/hard soils (where SPT "N" values exceed 100 blows per 0.3 m of penetration) can be used for support of the new widened CN Rail overhead structure.

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
Abutments – northeast and southwest	151.0 m	1,600 kN	1,400 kN
Abutments – northwest and southeast	157.0 m	1,600 kN	1,400 kN

Due to the presence of very dense soils at a shallow depth, particularly at the northwest and southeast abutment areas, pre-augering of the piles may be required if the pile caps are founded below the CN Rail grade. Additional investigation is required during the detail design stage to confirm the subsurface conditions at the site and further assess the design pile tip elevations and requirements for pre-augering.

Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.), founded at the same design pile tip elevation.

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments.

Approaches and Backfill

- Height: Approximately 9 m at the abutments.
- Stability: Approaches up to 9 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) and a mid-height bench (minimum 2 m wide per MTO requirements for embankments higher than 8 m) will have an adequate factor of safety against deep-seated slope instability.
- Settlement: Assuming the use of conventional earth fill or granular type fill, it is expected that less than 25 mm of settlement will occur under the footprint of the new embankments. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).
- The widened approach fill should be keyed into the existing fill as per MTO standards.

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt and clayey silt deposits are classified as a Type 2 soil, assuming appropriate groundwater control is in place, while the existing embankment fill would be classified as Type 3 soil according to OHSA. The sides of temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

The groundwater level at the site was measured to be as high as approximately Elevation 164 m based on the observations following completion of drilling at the time of the 1966 borehole investigation; the stabilized groundwater level may differ. If shallow foundations are adopted to match the existing footings, it is anticipated that excavations will extend below the groundwater level at the site, particularly for the southern portion of the structure replacement and widening. In this case, some dewatering would be required in the silty sand to sandy silt deposit to lower the groundwater level to approximately 1 m below the founding elevation. It is expected that

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Approximate Station: 13+360

pumping from filtered sumps alone may not be sufficient, and that it would be necessary to use some well-points to assist in lowering the groundwater level in the silty sand to sandy silt soils.

Protection Systems

It is anticipated that temporary protection systems will be required along Highway 401 to facilitate the staged removal of the existing bridge structures and wing walls/retaining walls. Depending on the depth of excavation, temporary protection systems may also be required parallel to the rail tracks; in this regard, if the existing foundations can be left in place and a longer replacement structure adopted (with perched pile caps behind the existing footings), excavation below the CN Rail grade will be minimized to only that required to cut off the existing abutment wall stems. Refer to Section 6.7 of the Preliminary Foundation Design Report for further comments.

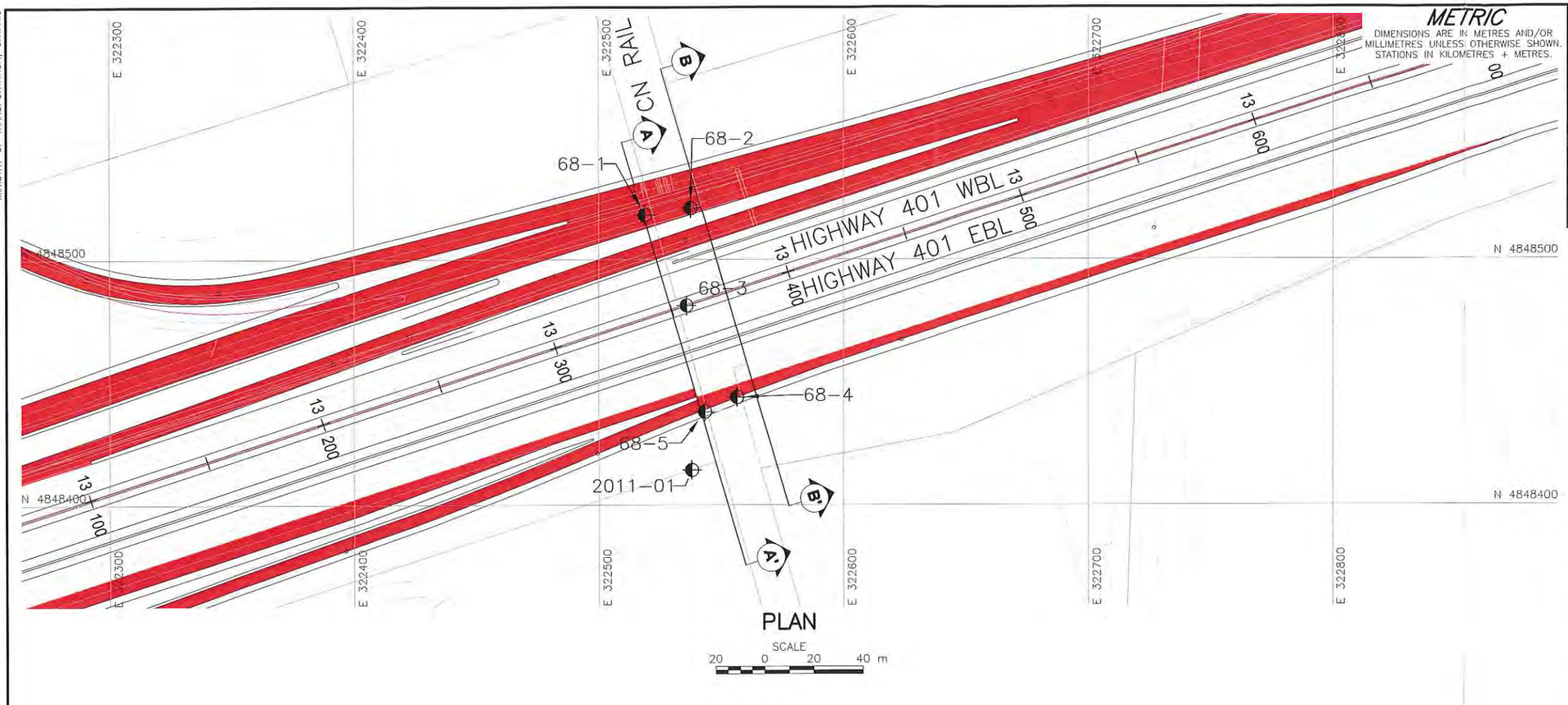
Obstructions During Pile Driving

It is recommended that driving shoes be used to facilitate pile driving into the very dense/hard soils at this site, which may contain cobbles and boulders.

RECOMMENDATIONS FOR ADDITIONAL WORK

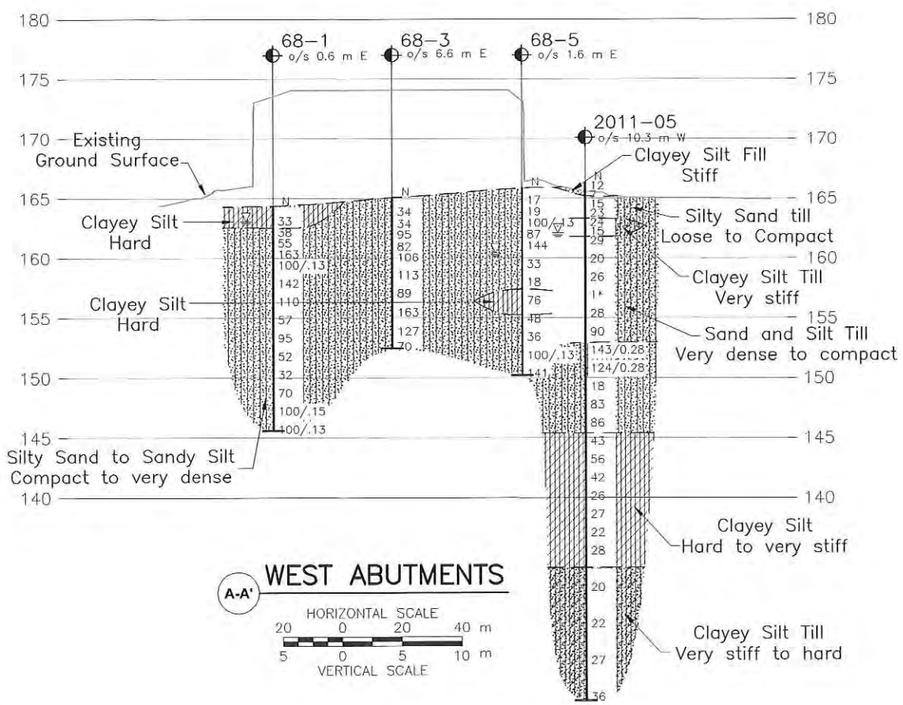
Further subsurface investigation should be carried out during detail design to confirm the subsoil conditions and stabilized groundwater levels, to refine the founding elevations and geotechnical resistances for both shallow and deep foundations (due to the variation in the depth to "100-blow" soil), as well as to assess the dewatering requirements associated with excavation to remove the existing foundations or to construct new shallow foundations.

MINISTRY OF TRANSPORTATION, ONTARIO



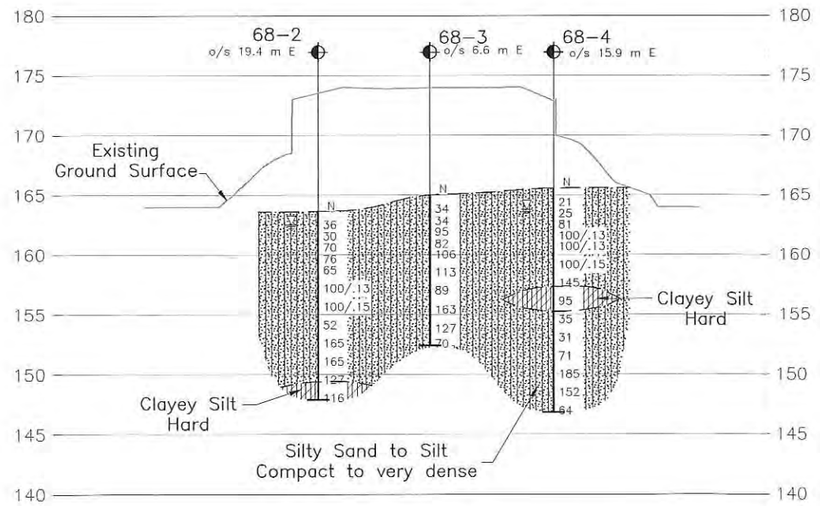
PLAN

SCALE
20 0 20 40 m



A-A' WEST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE



B-B' EAST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE

METRIC

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

CONT No.
WO No. 07-20012

N

SHEET

CN RAIL OVERHEAD
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

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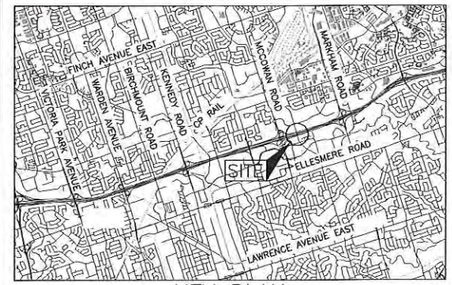
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole – Current Investigation
- Borehole – 1966 Investigation (Geocres 30M14-75)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
68-1	164.3	4848518.0	322518.9
68-2	163.6	4848520.9	322537.6
68-3	165.0	4848481.2	322535.9
68-4	165.6	4848443.9	322556.6
68-5	165.9	4848438.0	322543.4
2011-01	166.3	4848414.2	322538.0

NOTES

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

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE PROVINCE OF ONTARIO

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHKD. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD/JFC	CHKD. NK	APPD. LCC	DWG. D1

PLOT DATE: February 24, 2012
FILENAME: T:\Projects\2009\09-1111-6055 (URS, GTA)\-CO-Foundation Conditions and Recommendations\091111605500D1.dwg

Golder Associates

RECORD OF BOREHOLE No 2011-01

1 OF 4 **METRIC**

PROJECT 09-1111-6055 | G.W.P. 07-20012 | LOCATION N 4848414.2 ;E 322538.0 | ORIGINATED BY SB

DIST Central HWY 401 | BOREHOLE TYPE CME 75 Truck-mount, 108 mm Inner Diameter Hollow Stem Augers | COMPILED BY MAS

DATUM Geodetic | DATE April 5-6, 2011 | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
166.3	GROUND SURFACE										
0.0	TOPSOIL										
0.2	Clayey silt with sand, trace gravel, containing organics and rootlets (FILL)		1	SS	12		166		○		
165.5											
0.8	Stiff Brown Moist		2	SS	7						
	Silty SAND, trace clay, trace gravel (TILL) Loose to compact Brown Moist		3	SS	15		165		○		3 39 53 5
			4	SS	23		164				
163.3											
3.1	CLAYEY SILT with sand, trace gravel (TILL) Very stiff Brown to grey Moist		5	SS	24		163		○		4 33 48 15
			6	SS	15	▽	162				
161.7											
4.6	SAND and SILT, trace clay, trace gravel (TILL) Compact to very dense Grey Moist		7	SS	29				○		
			8	SS	20		160				
			9	SS	26		159		○		3 38 48 11
	Becoming wet below a depth of 9.1 m		10	SS	1*		158				
			11	SS	28		157		○		
			12	SS	90		156				
152.9							155				
13.4	SAND and SILT, trace gravel Very dense to compact Grey Moist		13	SS	143/0.28		154				
							153		○		
							152				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No 2011-01

2 OF 4 **METRIC**

PROJECT 09-1111-6055 | G.W.P. 07-20012 | LOCATION N 4848414.2 ;E 322538.0 | ORIGINATED BY SB

DIST Central HWY 401 | BOREHOLE TYPE CME 75 Truck-mount, 108 mm Inner Diameter Hollow Stem Augers | COMPILED BY MAS

DATUM Geodetic | DATE April 5-6, 2011 | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	— CONTINUED FROM PREVIOUS PAGE —										
	SAND and SILT, trace gravel Very dense to compact Grey Moist		14	SS	124/0.28		151				
							150				
	Becoming wet below a depth of 16.8 m		15	SS	18		149		○		0 55 40 5
			16	SS	83		148				
							147				
			17	SS	86		146		○		
145.3											
21.0	CLAYEY SILT, trace sand Hard to very stiff Grey Moist		18	SS	43		145				
							144				
			19	SS	56		143		⊢○⊣		0 0 72 28
			20	SS	42		142				
							141				
			21	SS	26		140				
							139				
			22	SS	27		138		⊢○⊣		0 0 70 30
			23	SS	22		137				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No 2011-01

3 OF 4 **METRIC**

PROJECT 09-1111-6055 | G.W.P. 07-20012 | DIST Central HWY 401 | DATUM Geodetic

LOCATION N 4848414.2 ;E 322538.0 | BOREHOLE TYPE CME 75 Truck-mount, 108 mm Inner Diameter Hollow Stem Augers | DATE April 5-6, 2011

ORIGINATED BY SB | COMPILED BY MAS | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- *CONTINUED FROM PREVIOUS PAGE* ---										
	CLAYEY SILT, trace sand Hard to very stiff Grey Moist		24	SS	28		136		○		
134.1							135				
	CLAYEY SILT with sand to trace sand, trace gravel (TILL) Very stiff to hard Grey Moist		25	SS	20		134				
							133				
			26	SS	22		132		⊖		1 26 55 18
							131				
			27	SS	27		130				
							129				
			28	SS	36		128		○		
123.0							127				
43.3							126				
							125				
							124				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No 2011-01

4 OF 4 **METRIC**

PROJECT 09-1111-6055 | G.W.P. 07-20012 | LOCATION N 4848414.2 ;E 322538.0 | ORIGINATED BY SB

DIST Central | HWY 401 | BOREHOLE TYPE CME 75 Truck-mount, 108 mm Inner Diameter Hollow Stem Augers | COMPILED BY MAS

DATUM Geodetic | DATE April 5-6, 2011 | CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	— *CONTINUED FROM PREVIOUS PAGE* —										
	END OF BOREHOLE										
	NOTES:										
	*SPT "N" value considered to have been affected by sample disturbance due to groundwater inflow to borehole.										
	1. Borehole open to a depth of 9.8 m (Elev. 156.5 m) on completion of drilling.										
	2. Water level in open borehole at a depth of 4.3 m (Elev. 162.0 m) on completion of drilling.										

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

FORM OB-MT-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 66-1

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 66-F-88 LOCATION Hwy. 401 & C.N.R. Sta. 356 + 93 133' Lt. ORIGINATED BY V.K.
W.P. 259-61 BORING DATE November 14, 1966 COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Drive Casing & Wash CHECKED BY

SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (20 40 60 80 100) SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % (10 20 30)	BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE				
539.0	GROUND LEVEL									
	Clayey silt Hard (Brown)		1	SS	33					El. 535.0 ▽ W.L. gr.2%, Sa.47% Si.46% Cl.5%
533.0										
6.0	Silty sand to silt with traces of clay and gravel and occasional layers of clayey silt		2	SS	38	530				
			3	SS	55					
			4	SS	163					Gr.4%, Sa.47% Si.46% Cl. 6%
	Very dense.		5	SS	100/5"					
	Grey					520				
			6	SS	142					
			7	SS	110					
						510				
			8	SS	57					
			9	SS	95					
524 499.0						500				
22 40.0	Silty sand with traces of gravel.		10	SS	52					
			11	SS	32					Gr.4%, Sa.76% Si.Cl. 20%
	Dense to very dense.					490				
			12	SS	70					
			13	SS	100/6"					
						480				
6 77.5			14	SS	100/5"					
61.5	End of Borehole									
						470				

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2 BH 68-2

FOUNDATION SECTION

JOB 66-F-88 LOCATION Hwy. 401 & C. N.R. 357 ± 54 124' Lt. ORIGINATED BY V.K.

W.P. 259-61 BORING DATE November 22, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Drive casing and wash CHECKED BY

(M) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
163.6 / 536.7	GROUND LEVEL					
	(Brown)		1	SS	36	
	(Grey)		2	SS	30	530
	Silty sand to silt with traces of clay and occasional gravel.		3	SS	70	
			4	SS	76	
	Dense to Very Dense		5	SS	65	520
			6	SS	100/5"	
			7	SS	100/6"	510
			8	SS	52	
			9	SS	165	500
			10	SS	165	
149.4 / 490.2			11	SS	127	490
14.2 / 46.5	Clayey silt, traces of sand and gravel					
147.9 / 485.2	Hard		12	SS	116	
15.7 / 51.5	End of Borehole					480

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT
20 40 60 80 100
SHEAR STRENGTH P.S.F.

LIQUID LIMIT ——— w_L
PLASTIC LIMIT ——— w_P
WATER CONTENT ——— w
w_P w w_L
WATER CONTENT %
10 20 30

BULK DENSITY γ P.C.F.

REMARKS

El. 533.2
W.L.
Gr.4, Sa.38%
Si. 53%
Cl. 5%

Gr.3%
Sa.55%
Si.37%
Cl.5%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3 BH 68-3

FOUNDATION SECTION

JOB 66-F-86 LOCATION Hwy. 401 & C.N.R., Sta. 357 + 09 ℄ ORIGINATED BY V.K.

W.P. 259-61 BORING DATE November 15, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Pen Drill Auger CHECKED BY

(w)	ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
165.0	541.5	GROUND LEVEL									
		(Brown)					540				gr. 0 Sa. 30% Si. 68% Cl. 2%
				1	SS	34					
		(Grey)		2	SS	34					
		Silty sand to silt with occasional pockets of clayey silt.		3	SS	95	520				El. 529.5 W.L. gr. 0 Sa. 39% Si. 58% Cl. 3%
				4	SS	82					
		(647.5' clayey silt Layer)		5	SS	106					
				6	SS	113	520				
		Dense to Very Dense									
				7	SS	89					
				8	SS	163	510				
				9	SS	127					
152.4	500.0			10	SS	70	500				
12.6	41.5	End of Borehole									
							490				

DRM 68-MT-126
6-4546

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 4 BH 68-4

FOUNDATION SECTION

JOB 66-F-88 LOCATION Hwy. 402 & C.N.R. Sta. 357 + 36, 138' Rt. ORIGINATED BY V.K.

W.P. 259-61 BORING DATE November 18, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Drive BX Casing & Wash CHECKED BY

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
543.3	GROUND LEVEL									
	(Brown) Silty sand to silt with traces of clay and occasional gravel. Compact to Very Dense		1	SS	21	540				gr. 0 Sa. 7% Si. 89% Cl. 4 ▽ W.L.
			2	SS	25					
			3	SS	81					
			4	SS	100/5"	530		o		Gr. 1 Sa. 38 Si. 51 Cl. 10
			5	SS	100/5"			o		
	(Grey)		6	SS	100/6"	520				
516.3			7	SS	145					Gr. 0 Sa. 3 Si. 92 Cl. 5
27.0	Clayey silt with traces of sand and occasional gravel Hard		8	SS	95			o——		
509.3						510				
34.0	Silty sand to sandy silt with traces of gravel. Dense to Very Dense.		9	SS	35					
			10	SS	31	500				
			11	SS	71					
			12	SS	185	490		o		
			13	SS	152					
31.8			14	SS	64					
61.5	End of Borehole					480				

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 5 BH 68-5

FOUNDATION SECTION

JOB 66-F-88 LOCATION Hwy. 401 & C.N.R., Sta. 356 + 89 144 Rt. ORIGINATED BY V.K.

W.P. 259-61 BORING DATE November 14, 1966 COMPILED BY V.K.

DATUM Geodetic BOREHOLE TYPE Pen Drill and Diamond Drill CHECKED BY

(m) ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
168.9 544.2	GROUND LEVEL					
	(Brown) Silty sand to silt with occasional layers of clayey silt		1	SS	17	540
			2	SS	19	
			3	SS	100/5"	
			4	SS	87	530
	Compact to Very Dense		5	SS	144	
	(Grey)		6	SS	33	
						520
157.3 516.2			7	SS	18	
8.5 28.0	Clayey silt with traces of sand and occasional gravel		8	SS	76	
155.2 509.2	Hard					510
10.7 35.0	Silty sand to sandy silt with traces of gravel		9	SS	48	
			10	SS	36	
	Dense to Very Dense					500
			11	SS	100/5"	
150.2 492.7			12	SS	141	
15.7 51.5	End of Borehole					490

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.

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

w_P w w_L

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

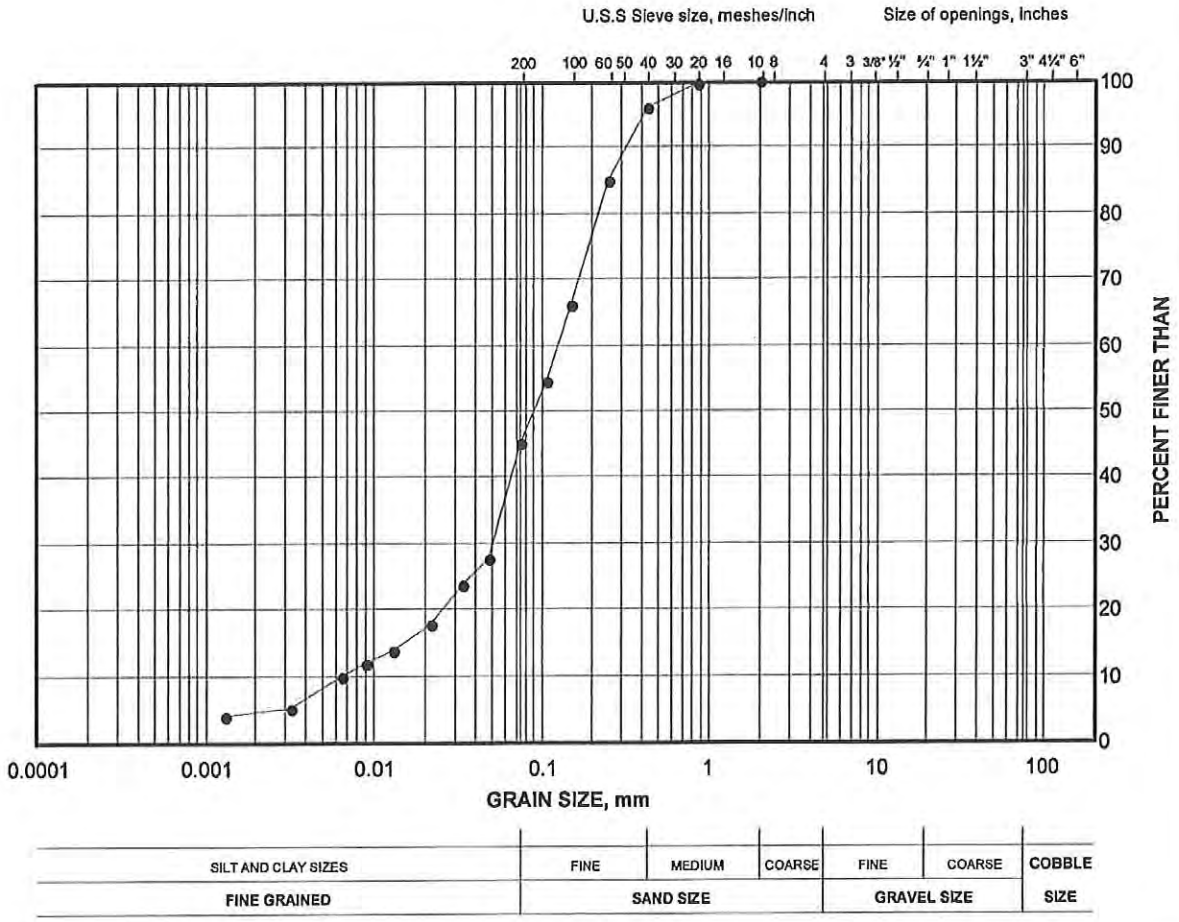
Gr. 6%
Sa. 52%
Si. 37%
Cl. 5

El. 526.2
W.L.

GRAIN SIZE DISTRIBUTION TEST RESULT

Silty Sand to Silt

FIGURE D1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-01	15	149.2

Project Number: 09-1111-6055

Checked By: _____

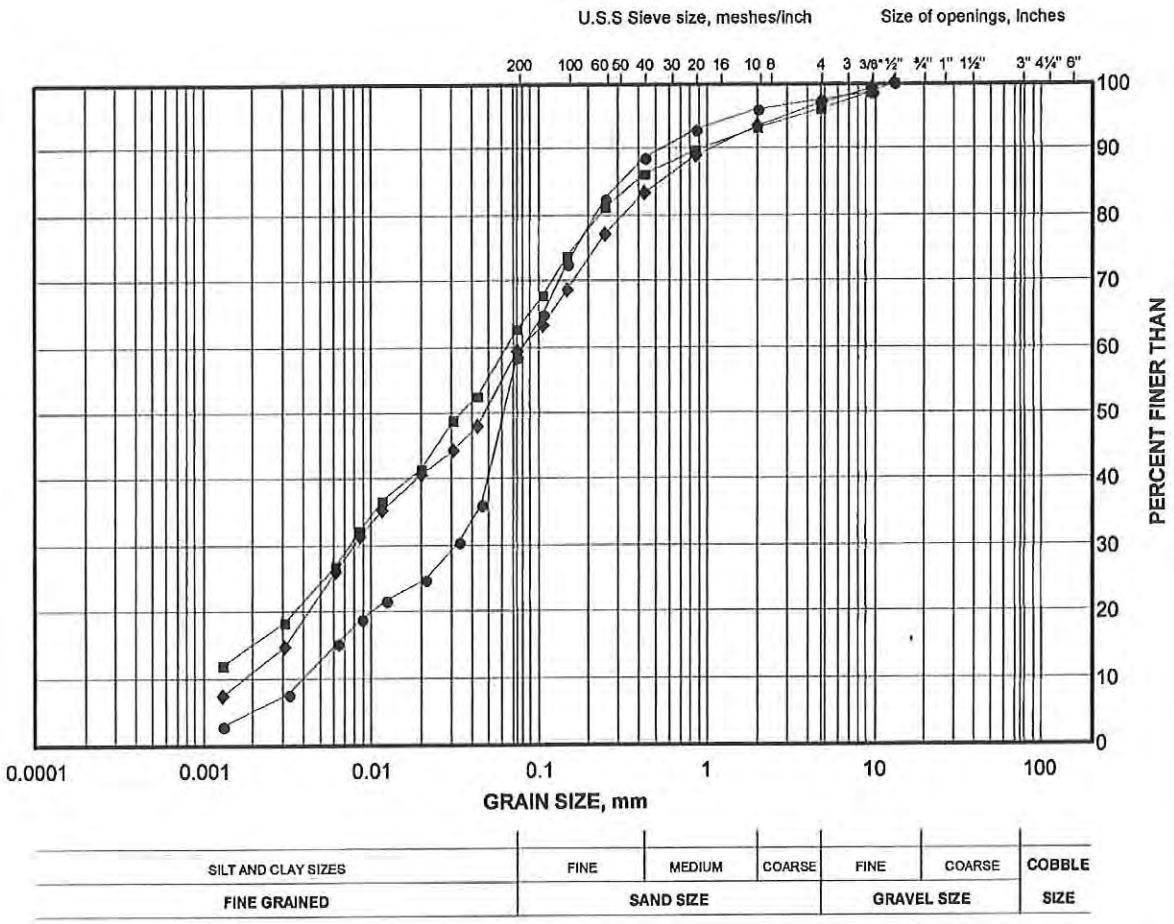
Golder Associates

Date: 21-Dec-11

GRAIN SIZE DISTRIBUTION TEST RESULTS

Upper Sand and Silt to Clayey Silt Till

FIGURE D2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-01	3	164.5
■	2011-01	5	162.9
◆	2011-01	9	158.4

Project Number: 09-1111-6055

Checked By: _____

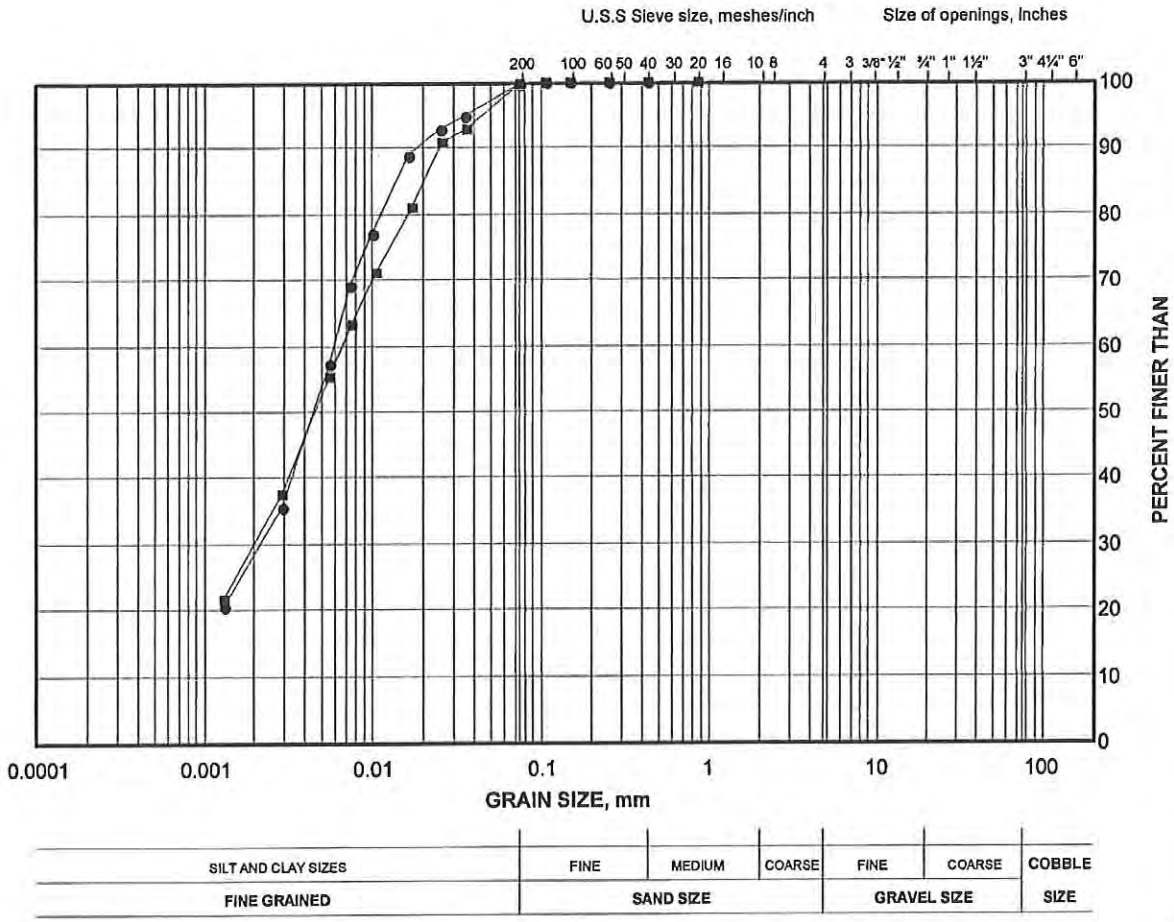
Golder Associates

Date: 21-Dec-11

GRAIN SIZE DISTRIBUTION TEST RESULTS

Lower Clayey Silt

FIGURE D3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-01	19	143.1
■	2011-01	22	138.6

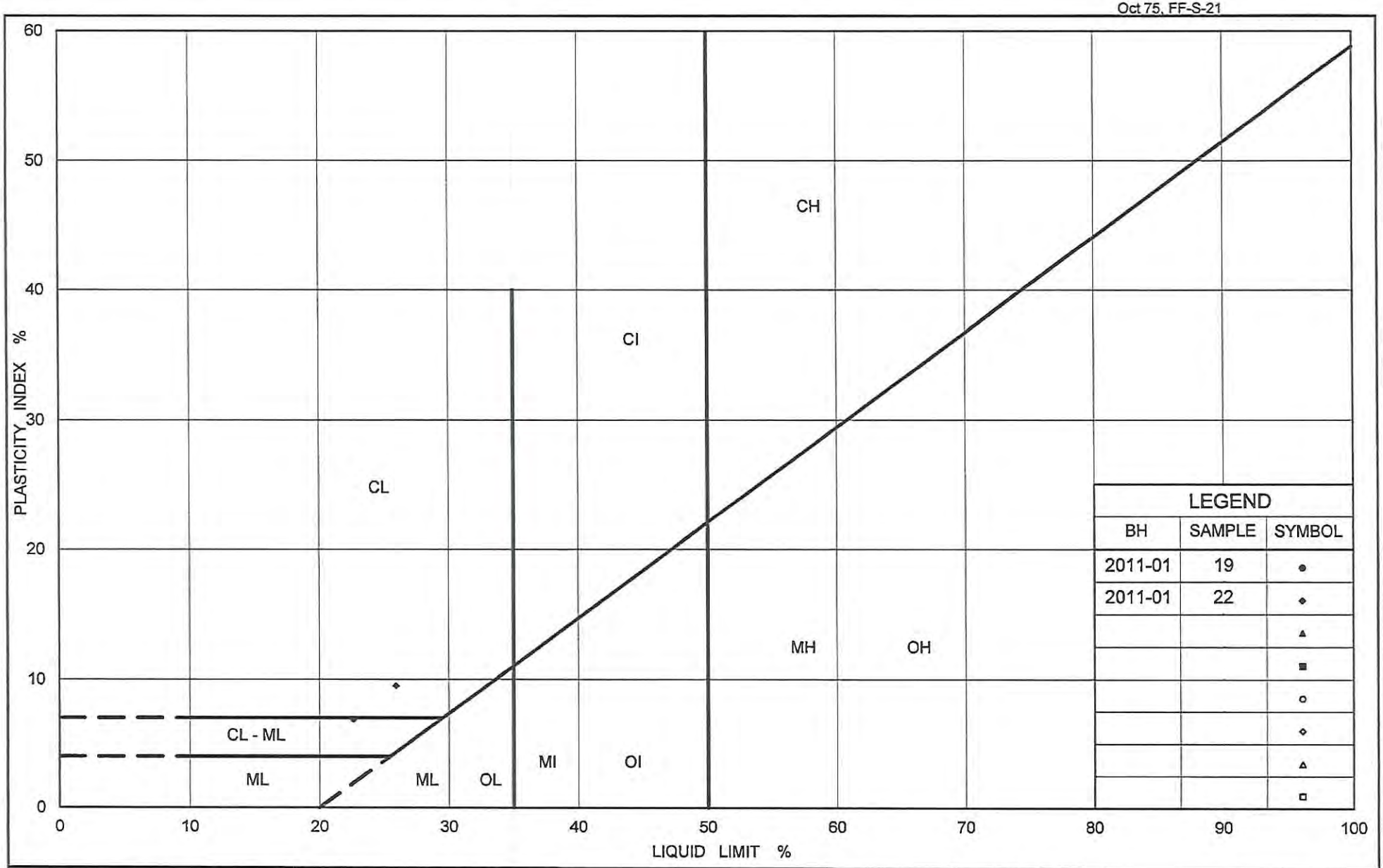
Project Number: 09-1111-6055

Checked By: _____

Golder Associates

Date: 21-Dec-11

Oct 75, FF-S-21



Ministry of Transportation

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PLASTICITY CHART
Lower Clayey Silt

Figure No. D4

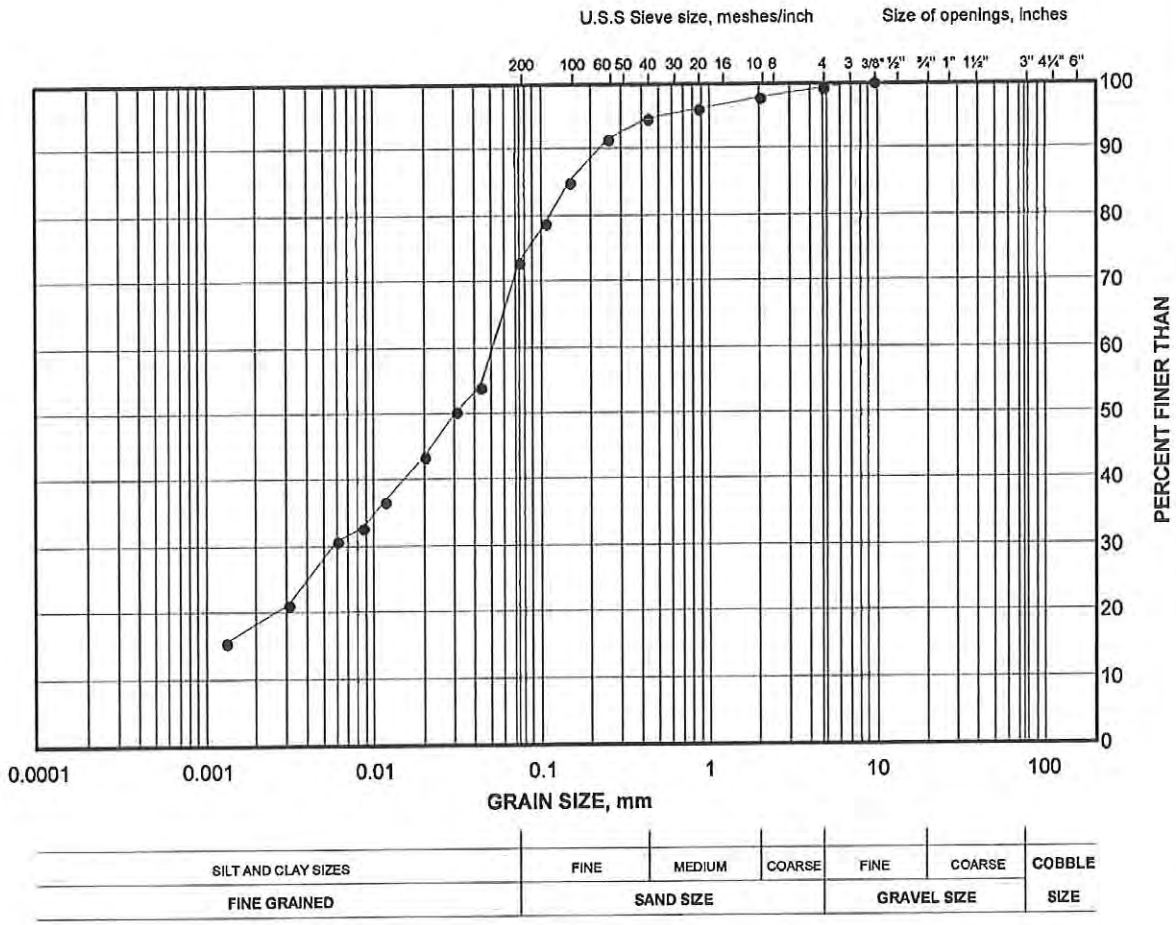
Project No. 09-1111-6055

Checked By:

GRAIN SIZE DISTRIBUTION TEST RESULT

Lower Clayey Silt Till

FIGURE D5



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-01	26	129.4

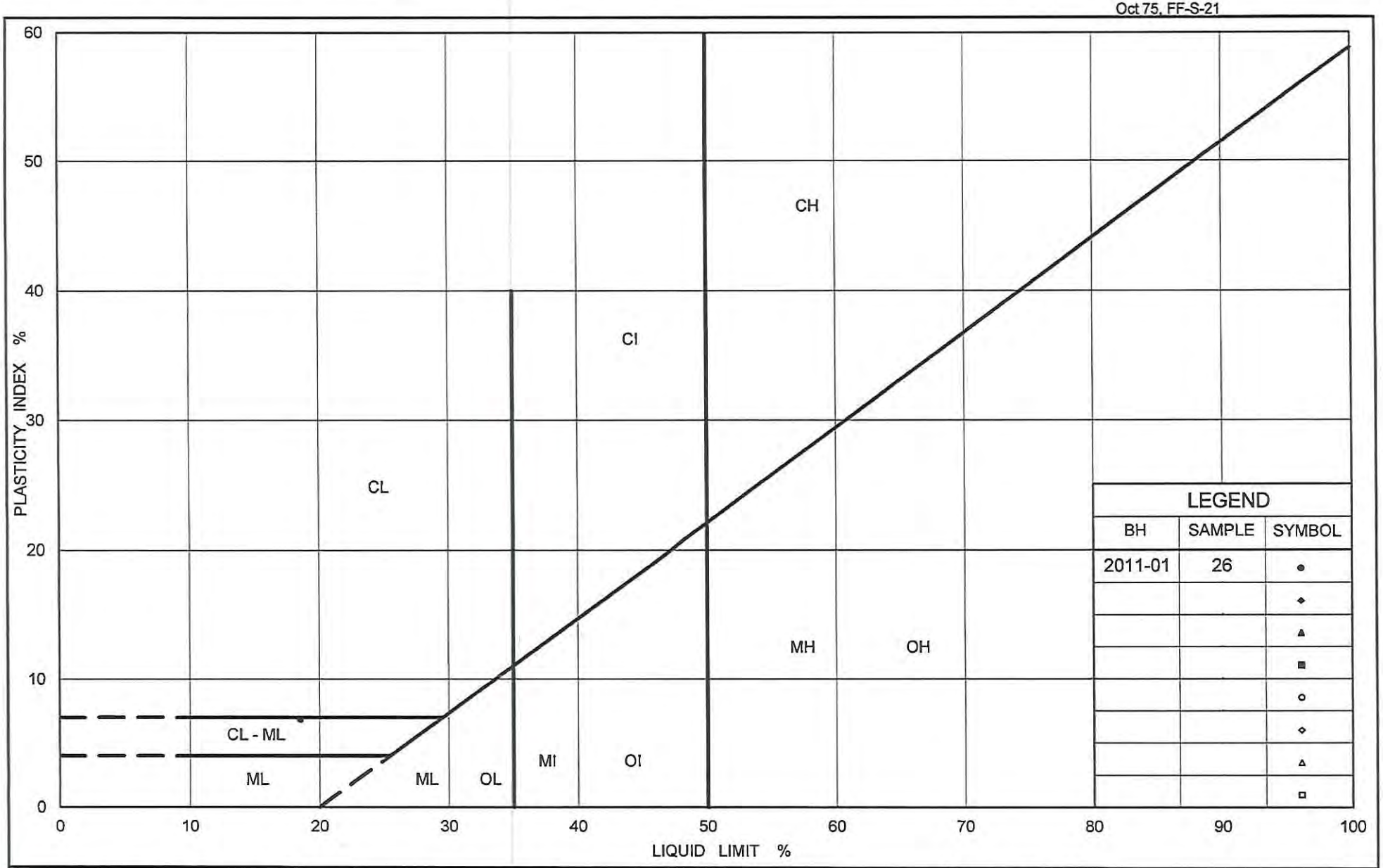
Project Number: 09-1111-6055

Checked By: _____

Golder Associates

Date: 21-Dec-11

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Lower Clayey Silt Till

Figure No. D6

Project No. 09-1111-6055

Checked By:

APPENDIX E

Midland Avenue Overpass

April 2012
Report No. 09-1111-6055-1

Golder Associates

Structure Description: Highway 401 WBL - Midland Avenue Overpass, North Widening
Site No.: 37-216

Existing Highway 401 Grade: ~172 m to 173 m
Local Road Elevation: ~166 m
Original Ground Surface Elevation: ~166 m

Approximate Station: 13+760

FOUNDATION INVESTIGATION

Site Description:

The site is located on the north side of Highway 401 WBL at the Midland Avenue overpass (Structure Site No. 37-216) in the City of Toronto, Ontario. Industrial parks are located south and northeast of the highway, while a residential zone is located northwest of the highway. See key plan on Drawing 1.

Borehole Information:

Boreholes 74-1 to 74-4 (including Boreholes 74-1A and 74-2A) were drilled as part of a 1966 investigation at this site by others (MTO GEOCRES No. 30M14-74).

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
74-1	East Abutment	4,848,650.4	322,931.3	166.1	36.6
74-1A	East Abutment	4,848,615.6	322,957.3	171.3	14.2
74-2	West Abutment	4,848,645.5	322,914.7	165.6	11.1
74-2A	West Abutment	4,848,601.5	322,911.9	170.9	15.7
74-3	West Abutment	4,848,561.5	322,923.5	165.2	11.1
74-4	East Abutment	4,848,573.7	322,966.5	166.1	11.1

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Probable Fill:** A layer that has been interpreted by Golder as fill (due to its elevation relative to the natural ground surface in the area) was encountered immediately below the ground surface in Boreholes 74-1A and 74-2A. The fill consists of sand to sandy silt containing trace clay. The measure Standard Penetration Test (SPT) 'N' values vary from 8 to 42 blows per 0.3 m of penetration, indicating a loose to dense relative density.
- **Sand to Sandy Silt:** A deposit of sand to sandy silt containing trace gravel and clay and occasional clayey silt layers was encountered immediately below the ground surface in all boreholes except Boreholes 74-1A and 74-2A, where it was encountered underlying the probable fill. The deposit is 22.6 m in thick as encountered in Borehole 74-1, the only borehole in which the deposit was fully penetrated. All other boreholes terminated within this deposit after penetrating it for 8.1 m to 11.1 m. The measured SPT'N' values vary from 14 blows per 0.3 m of penetration to 100 blows per 0.04 m of penetration. However, in general, the SPT 'N' values are greater than 100 blows per 0.3 m of penetration below a depth of approximately 5 m (Elevation 161.5 m), indicating a compact to dense relative density in the upper portion, and a very dense relative density in the lower portion of the deposit.
- **Clayey Silt**: A deposit of clayey silt was encountered underlying the sandy silt to silty sand in Borehole 74-1. This borehole terminated within this deposit, penetrating it for a thickness of 14.0 m. The measured SPT 'N' values vary from 91 to 106 blows per 0.3 m of penetration, suggesting a hard consistency.

Groundwater Conditions:

The groundwater level was measured in the open boreholes upon completion of drilling, as summarized in the following table:

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)
74-1	1.8	164.3
74-2	2.5	163.1
74-3	1.1	164.1
74-4	1.6	164.6

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site.

The groundwater levels at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 WBL - Midland Avenue Overpass, North Widening
Site No.: 37-216

Existing Highway 401 Grade: ~172 m to 173 m
Local Road Elevation: ~166 m
Original Ground Surface Elevation: 166 m

Approximate Station: 13+760

FOUNDATION RECOMMENDATIONS

Note: The site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Preliminary Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

It is understood that up to 2.3 m of northward widening is proposed for the existing Highway 401 WBL-Midland Avenue overpass. In addition, the superstructure may be replaced, using the existing foundations.

ASSESSMENT OF EXISTING FOUNDATIONS

The existing Midland Avenue overpass consists of a single-span structure. Based on available drawings, the existing west and east abutments are supported on 3.7 m wide spread footings founded at Elevation 163.4 m. Golder has assessed the factored axial geotechnical resistance at Ultimate Limit States (ULS) and the axial geotechnical resistance at Serviceability Limit States (SLS) for the existing abutment foundations, using the existing founding elevations, foundation geometry, and subsurface conditions to complete bearing capacity and settlement analyses. The following table summarizes the assessed geotechnical resistances for the existing abutment footings:

Founding Stratum	Geotechnical Resistance	
	Factored ULS	SLS
Dense to very dense sandy silt to silty sand	500 kPa	300 kPa

FOUNDATION OPTIONS

Based on the existing subsurface information, both shallow and deep foundation options have been considered for support of the widened abutments at this site. A summary of the advantages and disadvantages associated with each option is presented below:

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense sandy silt to silty sand	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • Allows for semi-integral abutment design	• Requires excavations to a depth of up to about 3.0 m below Midland Avenue grade to match existing founding level; this will extend below the groundwater level, and dewatering will be required • Protection system may be required along Highway 401 to facilitate removal or cutting down of existing wing walls and excavation through embankment fill • Potential for up to 15 mm to 20 mm of differential settlement to occur between existing and new portions of structure; construction joint required to accommodate differential movement
"Perched" footings founded in the widened approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the footings above the groundwater level at the site	• Poor compatibility with existing closed abutment configuration and existing spread footings founded on native soils below Midland Avenue grade • Potential for differential settlement
Steel H-piles driven into "100-blow" sandy silt to silty sand deposit	• Pile caps may be perched in widened approach embankments, or founded at minimum frost protection depth, minimizing depth of excavation as compared with shallow foundation option • Allows for integral abutment design with H-piles, and semi-integral abutment design with pipe piles; may be compatible if the existing structure can be converted to semi-integral abutments • Minimal differential settlement between existing and widened portions of structure	• Requires driving shoes to facilitate driving through very dense soils (possibly containing cobbles/boulders) • Pre-augering is expected to be required if pile caps are located below the Midland Road grade, due to the relatively shallow depth to "100-blow" soil • Potential vibration impacts on existing overpass; however, vibrations are anticipated to have a peak particle velocity of less than 100 mm/s • Protection systems may still be required along the edge of Highway 401 to facilitate the removal or cutting down of the existing wing walls/retaining walls before constructing the widening

Recommended Foundation Option: From a geotechnical/foundations perspective, the preferred option for support of the abutment widening is driven steel H-piles or pipe piles. This will minimize differential settlement between the existing and new portions of the structure and minimize dewatering requirements, as compared with a shallow foundations constructed to match the existing footings. This may also permit the use of integral abutments with reduced maintenance costs. However, it is noted that for the relatively small width of widening, this configuration may not be aesthetically compatible with the existing structure; in this case, spread footings are considered an acceptable alternative to support the abutment widening.

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the widening may be founded on the dense to very dense sandy silt to silty sand at the same level as the existing footings (Elevation 163.4 m). This founding level satisfies the minimum depth of 1.2 m for frost protection purposes. Alternatively, spread footings for the widened abutments and associated wing walls could be founded at higher elevations within the approach embankments on a compacted Granular 'A' pad; however, as noted above, this may not be compatible with the existing structure which has a closed configuration.

The factored geotechnical resistance at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) for preliminary design may be taken as the same as the existing capacity (provided in table at left), assuming the new footings will match the existing footings in width and founding elevation. If "perched" footings are adopted on a compacted granular pad in the approach embankments, the factored geotechnical resistance at ULS and geotechnical resistance at SLS may be taken as 800 kPa and 350 kPa, respectively.

Structure Description: Highway 401 WBL - Midland Avenue Overpass, North Widening
Site No.: 37-216

Existing Highway 401 Grade: ~172 m to 173 m
Local Road Elevation: ~166 m
Original Ground Surface Elevation: 166 m

Approximate Station: 13+760

Steel H-Piles

Steel HP 310x110 piles driven to found within the very dense soils (where SPT "N" values exceed 100 blows per 0.3 m of penetration) can be used for support of the northward abutment widening. For preliminary design, the following pile tip elevation may be assumed:

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
North widening of abutments	159.0 m	1,600 kN	1,400 kN

Due to the presence of very dense soils at a shallow depth, pre-augering of the piles may be required if the pile caps are founded below the Midland Road grade. Additional investigation is required during the detail design stage to confirm the subsurface conditions, pile tip elevations and requirements for pre-augering.

Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.), founded at the same design pile tip elevation.

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments. However; the existing structure is supported on spread footings and an integral abutment system for the widening will not be compatible unless the existing structure can be converted to semi-integral abutments.

Approaches and Backfill

- Height: Approximately 7.5 m at the abutments.
- Stability: Approach embankments up to 7.5 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) will have a factor of safety of greater than 1.3 against deep-seated slope instability.
- Settlement: Assuming the use of conventional earth fill or granular fill, it is expected that approximately 25 mm of settlement will occur under the footprint of the widened approach embankments. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).
- The widened approach embankment fill should be keyed into the existing fill as per MTO standards.

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt deposit is classified as a Type 2 soil, assuming appropriate dewatering, while the existing embankment fill would be classified as Type 3 soil according to OHSA. The side slopes for temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

If shallow foundations are adopted, it is anticipated based on available information that excavations will extend below the groundwater table (approximately Elevation 164 m based on observations during the 1966 borehole investigation). In this case, dewatering will be required in the silty sand to sandy silt deposit to lower the groundwater level to approximately 1 m below the founding elevation. It is expected that pumping from filtered sumps alone would not be sufficient, and that it would be necessary to use a well-point system to assist in lowering the groundwater level in the silty sand to sandy silt soils.

Protection Systems

It is anticipated that temporary protection systems could be required along the north edge of Highway 401 to facilitate excavation through the existing fill and removal or cutting down of the existing wing walls or retaining walls. However, it is also understood that consideration is being given to northward widening of the highway in this area without removal of the existing retaining walls (this is addressed in a separate Preliminary Foundation Report for the retaining walls on this project), which could reduce the requirement for temporary protection along this section of Highway 401.

Temporary protection systems would also likely to be required along the edge of Midland Avenue due to the depth of excavation required to match the existing footings, where shallow foundations are adopted for the north widening of the abutments. These temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.

Obstructions During Pile Driving

It is recommended that driving shoes be used to facilitate pile driving into the very dense silty sand to sandy silt, if deep foundations are adopted.

RECOMMENDATIONS FOR ADDITIONAL WORK

Further subsurface investigation should be carried out during detail design to confirm the shallow subsoil conditions and the groundwater level in the widening area, to refine the founding elevations and geotechnical resistances, as well as to assess the dewatering requirements associated with the use of shallow foundations constructed to match the existing founding levels.

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

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

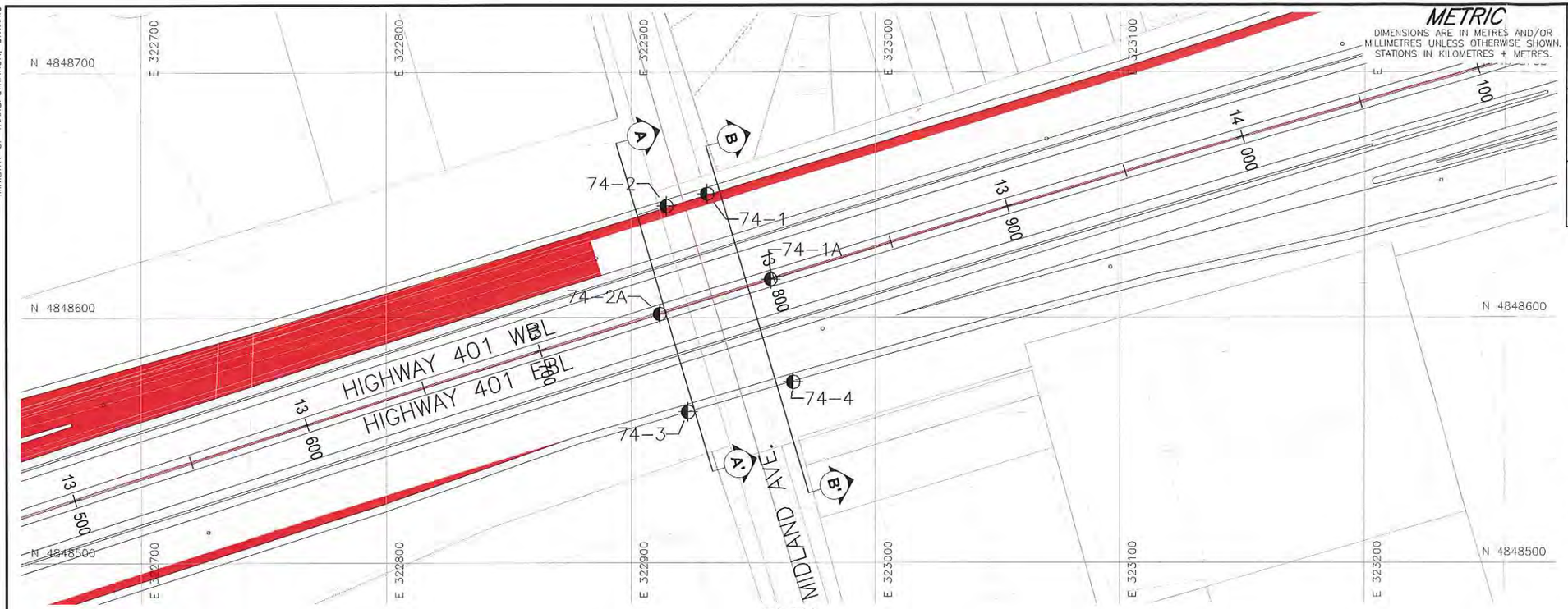
CONT No.
WO No. 07-20012

MIDLAND AVENUE OVERPASS
HIGHWAY 401 WIDENING

BOREHOLE LOCATIONS AND SOIL STRATA

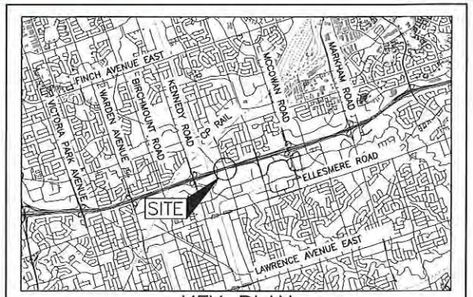
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

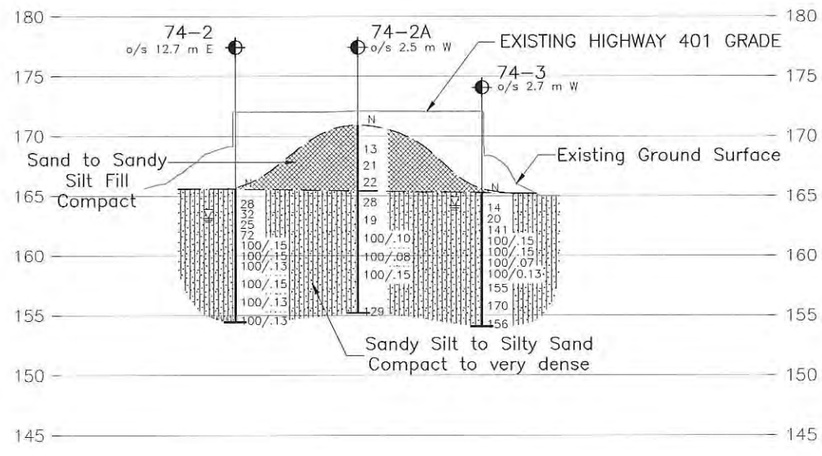
SCALE
20 0 20 40 m



KEY PLAN
SCALE
1.5 0 1.5 3 km

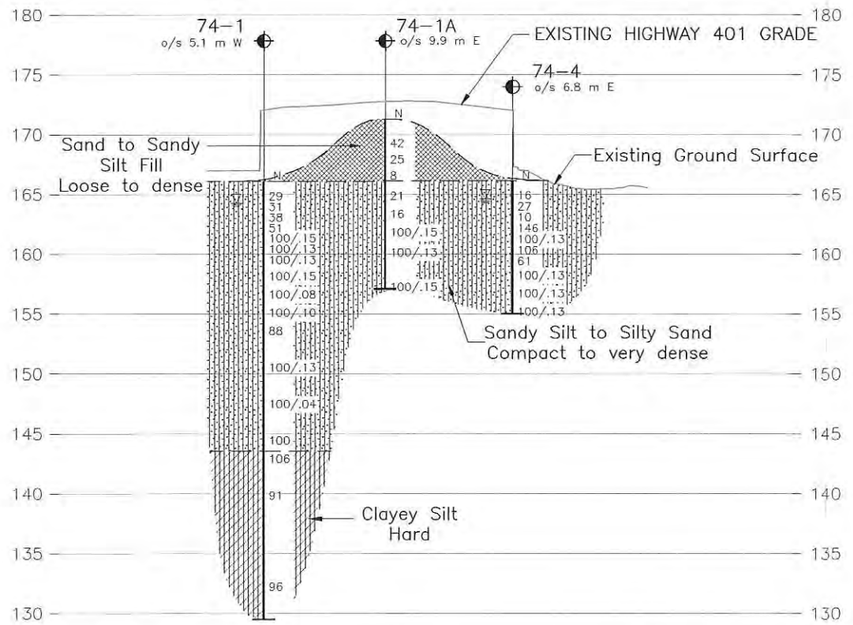
LEGEND

- Borehole – Current Investigation
- Borehole – 1966 Investigation (Geocres 30M14-74)
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling



A-A' WEST ABUTMENTS

HORIZONTAL SCALE
20 0 20 40 m
VERTICAL SCALE
5 0 5 10 m



B-B' EAST ABUTMENTS

HORIZONTAL SCALE
0 20 40 m
VERTICAL SCALE
5 0 5 10 m

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
74-1	166.1	4848650.4	322931.3
74-1A	171.3	4848615.6	322957.3
74-2	165.6	4848645.5	322914.7
74-2A	170.9	4848601.5	322911.9
74-3	165.2	4848561.5	322923.5
74-4	166.1	4848573.7	322966.5

NOTES

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

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE PROVINCE OF ONTARIO

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHK'D. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD	CHK'D. NK	APP'D. LCC	DWG. E1

PLOT DATE: April 12, 2012
PLOTTED BY: Richard Dowsett
FILENAME: N:\Projects\2009\09-1111-6055 (URS, GTA)\-CO-Foundation Conditions and Recommendations\09111160550CO021.dwg

FORM 99-MT-136
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 74-1

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 371 +10; 134' Lt. of ℄ ORIGINATED BY A.K.B.
W.P. 260-61 BORING DATE Sept. 29-Oct. 5, 1966 COMPILED BY A.K.B.
DATUM Geodetic BOREHOLE TYPE Washboring, BX & NX Casing CHECKED BY AKL

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
544.9	GROUND LEVEL									
0.0	Grey and Brown Sand to Silty Sand Traces of Gravel & clay. Compact to very dense.		1	SS	29	540				W.L. El.538.9
			2	SS	31					
			3	SS	38					
			4	SS	51	530				
			5	SS	100/6"					
			6	SS	100/5"					
			7	SS	100/5"					
			8	SS	100/6"	520				
			9	SS	100/3"					
			10	SS	100/4"	510				Sa. 91% Si.&Cl. 9%
			11	SS	88					
						500				
			12	SS	100/5"					
						490				
			13	SS	100/1.5"					
						480				
			14	SS	100					
470.9						470				
74.0	Grey Clayey Silt Hard		15	SS	106					
						460				
			16	SS	91					
						450				
			17	SS	96					
						440				
						430				
424.9										
20.0	End of Borehole					420				

JRM -126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 74-1A

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1A

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 371 +59.5; 1.5' Lt. ℄ ORIGINATED BY A.K.B.
W.P. 260-61 BORING DATE Oct. 31, 1966 COMPILED BY A.K.B.
DATUM Geodetic BOREHOLE TYPE Washboring, BX Casing CHECKED BY

SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT (20 40 60 80 100) SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L PLASTIC LIMIT w_P WATER CONTENT w (w_P — w — w_L) WATER CONTENT % (10 30)	BULK DENSITY γ P.C.F.	REMARKS
ELEV / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE				
(w) 171.3 562.0	GROUND LEVEL									
0.0	Brown & Grey Sandy Silt with traces of clay. Loose to very dense		1	SS	42	560				Gr. 3% Sa. 44% Si. 42% Cl. 11%
			2	SS	25	550				
			3	SS	8			NP		
			4	SS	21	540				
			5	SS	16					Gr. 4% Sa. 39% Si.&Cl. 57%
			6	SS	100/6"	530				
			7	SS	100/5"					
						520				
157.1 515.5			8	SS	100/5"					
14.2 46.5	End of Borehole									

FORM OB-M-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 74-2

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 370 + 52: 134' Lt. of ℄ ORIGINATED BY A.K.B.
W.P. 260-61 BORING DATE Oct. 6, 1966 COMPILED BY A.K.B.
DATUM Geodetic BOREHOLE TYPE Washboring, BX Casing CHECKED BY AK

(W)	ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
165.6	543.2	GROUND LEVEL					
	0.0						540
		Brown & Grey Sandy Silt with occasional layer of clayey silt		1	SS	28	
				2	SS	32	
				3	SS	25	
				4	SS	72	530
				5	SS	100/6"	
				6	SS	100/6"	
		Very Dense		7	SS	100/5"	520
				8	SS	100/6"	
				9	SS	100/5"	510
154.4	506.7			10	SS	100/5"	
11.1	36.5	End of Borehole					

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT — 20 40 60 80 100
SHEAR STRENGTH P.S.F.

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY
γ P.C.F.

REMARKS

▼ W.L. = El. 535.2

Gr. 5%
Sa. 50%
Si. 42%
Cl. 3%

Gr. 1%
Sa. 30%
Si. 59%
Cl. 10%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2A

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 370 +03.5; 1' Rt. of ℄ ORIGINATED BY AKB

W.P. 260-61 BORING DATE November 2, 1966 COMPILED BY AKB

DATUM Geodetic BOREHOLE TYPE Washboring, BX Casing CHECKED BY [signature]

(w)	ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
17.9	560.7	GROUND LEVEL					560
	0.0	Brown & Grey Silt with occ. layers of clayey silt. Compact		1	SS	13	
				2	SS	21	550
				3	SS	22	
				4	SS	28	540
				5	SS	19	
				6	SS	100/4"	530
		Silty Sand to Sand. Very Dense		7	SS	100/3"	
				8	SS	100/6"	520
155.2	509.2			9	SS	129	510
15.7	51.5	End of Borehole					

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F. — ○

LIQUID LIMIT —— w_L

PLASTIC LIMIT —— w_P

WATER CONTENT —— w

w_P w w_L

WATER CONTENT % — 10 20 30

○ N.P.

BULK DENSITY γ P.C.F.

REMARKS

Org. 2.6%

M 01 26
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 74-3

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 370 + 05; 139' Rt. of ℄ ORIGINATED BY AKB
W.P. 260-61 BORING DATE Oct. 7, 1966 COMPILED BY AKB
DATUM Geodetic BOREHOLE TYPE Washboring, BX Casing CHECKED BY AKB

(m) ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
165.2 542.0	GROUND LEVEL					
0.0	Brown & Grey Silty Sand with traces of gravel. Compact to very dense.		1	SS	14	540
			2	SS	20	
			3	SS	141	
			4	SS	100/6"	530
			5	SS	100/6"	
			6	SS	100/3"	
			7	SS	100/5"	520
			8	SS	155	
			9	SS	170	510
154.1 505.5			10	SS	156	
11.1 36.5	End of Borehole					

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100
SHEAR STRENGTH P.S.F.

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_p
WATER CONTENT —— w
w_p w w_L
WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

▽W.L. = El.538.5

Gr. 21%
Sa. 47%
Si.&Cl.32%

FORM T-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 74-4

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 66-F-87 LOCATION Sta. 371 + 50; 139' Rt. of ℄ ORIGINATED BY AKB
W.P. 260-62 BORING DATE Oct. 12, 1966 COMPILED BY AKB
DATUM Geodetic BOREHOLE TYPE Washboring, BX Casing CHECKED BY

(m) ELEV.	ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE
166.1	545.1	GROUND LEVEL					
	0.0						
		Brown & Grey Silty sand with traces of clay		1	SS	16	540
				2	SS	27	
				3	SS	10	
				4	SS	146	
				5	SS	100/5"	530
		Compact to very dense		6	SS	106	
				7	SS	61	
				8	SS	100/5"	520
				9	SS	100/5"	
155.0	508.6			10	SS	100/5"	510
11.1	36.5	End of Borehole					

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT: 20 40 60 80 100
SHEAR STRENGTH P.S.F.

LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY P.C.F.

REMARKS

▼ W.L. El. 540.0

Gr. 1%
Sa. 70%
Si. & Cl. 29%

APPENDIX F

Markham Road Overpass

Structure Description: Highway 401 WBL - Markham Road Overpass, North Widening
Site No.: 37-218

Existing Highway 401 Grade: ~164 m to 165 m
Local Road Elevation: ~158 m to 159 m
Original Ground Surface Elevation: 159 m to 160 m

Approximate Station: 17+100

FOUNDATION INVESTIGATION

Site Description:

The site is located on the north side of Highway 401 WBL at the Markham Road overpass (Structure Site No. 37-212) in the City of Toronto, Ontario. The interchange is surrounded by commercial development. See key plan on Drawing 1.

Borehole Information:

Boreholes 32-1 to 32-6 were drilled as part of a 1967 investigation at this site by others (MTO Geocres No. 30M14-32). Borehole 2011-05 was drilled as part of the 2011 investigation by Golder.

Borehole No.	Borehole Location	MTM NAD 83 Northing (m)	MTM NAD 83 Easing (m)	Borehole Elevation (m)	Borehole Depth (m)
32-1	East Abutment	4,849,502.2	326,139.3	157.7	9.6
32-2	Centre Pier	4,849,511.6	326,117.1	157.4	9.6
32-3	West Abutment	4,849,489.1	326,104.6	157.3	9.6
32-4	West Abutment	4,849,574.8	326,078.3	158.5	7.6
32-5	Centre Pier	4,849,566.6	326,099.6	158.1	9.1
32-6	East Abutment	4,849,588.9	326,113.2	160.2	7.6
2011-05	East Abutment	4,849,605.9	326,125.8	163.5	15.9

Subsurface Conditions:

Borehole records and geotechnical laboratory test results are included within this appendix, and are summarized as follows:

- **Topsoil:** Approximately 200 mm of topsoil was encountered immediately below the ground surface in Borehole 2011-05, which was drilled within the ramp loop in the northeast quadrant of the interchange.
- **Silty Sand to Clayey Silt Fill:** Approximately 5.8 m of silty sand to clayey silt fill was encountered below the topsoil in Borehole 2011-05.
- **Silty Sand to Sandy Silt:** A deposit of silty sand to sandy silt was encountered underlying the topsoil and fill in Borehole 2011-05, and immediately below ground surface in Boreholes 32-3 to 32-6. The cohesionless deposit ranges in thickness from 2.9 m to 4.9 m. The measured Standard Penetration Test (SPT) 'N' values vary from 11 blows per 0.3 m of penetration to 102 blows per 0.06 m of penetration. However, in general the SPT 'N' values are between 35 blows and 70 blows per 0.3 m of penetration, indicating a dense to very dense relative density.
- **Clayey Silt:** A deposit described as "clayey silt with sand, trace gravel" was encountered immediately below ground surface in Boreholes 32-1 and 32-2 and underlying the silty sand to sandy silt in all other boreholes. The deposit ranges in thickness from approximately 1.2 m to 9.6 m, with Boreholes 32-1 to 32-4 terminating within this deposit. The measured SPT 'N' values vary from 17 blows per 0.3 m of penetration to 50 blows per 0.01 m of penetration, however; in general the SPT 'N' values are over 100 blows per 0.3 m of penetration, suggesting a hard consistency.
- **Sand:** A deposit of sand containing some gravel and trace silt was encountered underlying the clayey silt in Boreholes 2011-05, 32-5 and 32-6. These boreholes terminated within this deposit, penetrating it for a thickness of approximately 1.0 m to 2.0 m. The measured SPT 'N' values vary from 10 blows to 94 blows per 0.3 m of penetration, indicating a compact to very dense relative density. However, the lower SPT 'N' values in Borehole 2011-05 are considered have been affected by sample disturbance due to groundwater inflow.

Groundwater Conditions:

The groundwater level was measured in the open boreholes immediately following completion of drilling as part of the 1967 investigation. The groundwater level was also measured in a standpipe piezometer installed in Borehole 2011-05 as part of the 2011 investigation. The measured water levels are summarized in the following table.

Borehole No.	Depth to Groundwater (m)	Groundwater Elevation (m)	Date of Reading
2011-5	8.4 8.0	161.1 161.5	On completion (April 11, 2011) April 21, 2011
32-1	0.5	157.3	On completion
32-2	0.6	156.8	On completion
32-3	1.5	155.8	On completion
32-4	0.6	157.9	On completion
32-5	0.5	157.6	On completion
32-6	1.2	159.0	On completion

As these water levels (with the exception of the measurement made in the piezometer in Borehole 2011-5) were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site. The water level measured in the standpipe piezometer in Borehole 2011-05 was at Elevation 161.5 m on April 21, 2011, ten days following completion of drilling.

The groundwater level(s) at the site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.

Structure Description: Highway 401 WBL - Markham Road Overpass, North Widening
Site No.: 37-218

Existing Highway 401 Grade: ~164 m to 165 m
Local Road Elevation: ~158 m to 159 m
Original Ground Surface Elevation: 159 m to 160 m

Approximate Station: 17+100

FOUNDATION RECOMMENDATIONS

Note: The site-specific foundation recommendations are for planning purposes only. Refer to Section 6.0 of the Preliminary Foundation Design Report for the project-wide foundation recommendations, design assumptions and limitations.

GENERAL

It is understood that up to 2.0 m of northward widening is proposed for the existing Highway 401 WBL - Markham Road overpass. In addition, the superstructure may be replaced, using the existing foundations.

ASSESSMENT OF EXISTING FOUNDATIONS

The existing Markham Road overpass is a two-span structure, with span lengths of 18.6 m between the abutments and the centre pier. Based on the available drawings, the existing west and east abutments are supported on 3.7 m wide spread footings founded at Elevation 155.7 m, and the existing center pier is supported on a 3.4 m wide footing founded at Elevation 155.8 m. Golder has assessed the factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limit States (SLS) for the existing abutment and pier foundations, using the existing founding elevations, foundation geometry, and subsurface conditions to complete bearing capacity and settlement analyses. The following table summarizes the assessed geotechnical resistances for the existing footings:

Foundation Element	Founding Stratum	Geotechnical Resistance	
		Factored ULS	SLS
Abutments/ Wing Walls	Dense to very dense silty sand to sandy silt	500 kPa	300 kPa
Pier	Dense to very dense silty sand to sandy silt	500 kPa	300 kPa

FOUNDATION OPTIONS

Based on the existing subsurface information, both shallow and deep foundation options have been considered for support of the northward widening of the Markham Road overpass structure. A summary of the advantages and disadvantages associated with each option is provided below.

Foundation Option	Advantages	Disadvantages
Spread footings founded on dense to very dense silty sand to sandy silt	• Lower cost than deep foundations • Conventional construction • Existing structure supported on shallow foundations, and has performed well • Allows for semi-integral abutment design	• Requires excavations to a depth of about 2.2 m to 3.3 m below Markham Road grade to match existing founding level; this will extend below the groundwater level, and dewatering will be required • Protection system may be required along Highway 401 to facilitate removal of existing wing walls and excavation through embankment fill, as well as along Markham Road • Potential for up to about 15 mm of differential settlement to occur between existing and new portions of structure; construction joint required to accommodate differential movement
"Perched" abutment footings founded in widened approach embankments on a compacted granular pad	• Minimizes depth of excavation through existing embankment fill, and maintains the abutment footings above the groundwater level at the site	• Poor compatibility with existing closed abutment configuration and existing spread footings founded on native soils below Markham Road grade • Potential for differential settlement between existing and widened portions of structure
Steel H-piles or pipe (tube) piles driven into "100-blow" silty sand to sandy silt deposit	• Pile caps may be perched in widened approach embankments, or founded at minimum frost protection depth, minimizing depth of excavation as compared with shallow foundation option • Allows for integral abutment design with H-piles, and semi-integral abutment design with pipe piles; may be compatible if the existing structure can be converted to semi-integral abutments • Minimal differential settlement between existing and widened portions of structure	• Requires driving shoes to facilitate driving through very dense soils (possibly containing cobbles/boulders) • Native soils are very dense/hard and pre-augering of piles is expected to be necessary to achieve target depths/ resistances if pile caps are located below the Markham Road grade (for example for widening of the centre pier) • Potential vibration impacts on existing overpass structure; however, vibrations are anticipated to have a peak particle velocity of less than 100 mm/s • Protection systems may still be required along the north edge of Highway 401 to facilitate the removal of the existing wing walls/retaining walls before constructing the widening

Recommended Foundation Option: From a geotechnical/foundations perspective, the preferred option for support of the abutment widening is driven steel H-piles or pipe piles, with the pile caps for the abutments perched within the approach embankments. This will minimize differential settlement between the existing and new portions of the structure and minimize dewatering requirements, as compared with shallow foundations constructed to match the existing footings. This may also permit the use of integral abutments with reduced maintenance costs. However, it is noted that for the relatively small width of widening, this configuration may not be aesthetically compatible with the existing structure; in this case, spread footings are considered an acceptable alternative to support the abutment widening.

For the northward widening of the centre pier, spread footings are preferred from a foundations perspective, although there is potential for up to approximately 15 mm of differential settlement between the existing and new portions of the structure. Deep foundations are an acceptable alternative at the centre pier, although pre-augering is likely to be necessary to facilitate pile installation, owing to the relatively shallow depth to "100-blow" soil.

FOUNDATION RECOMMENDATIONS

Spread Footings

Spread footings for the northward widening may be founded on the dense to very dense silty sand to sandy silt deposit at the same level as the existing footings (Elevation 155.7 m and 155.8 m for the abutments and pier, respectively). This founding level will satisfy the minimum depth of 1.2 m for frost protection purposes. Alternatively, spread footings for the widened abutments and associated wing walls could be founded at higher

Structure Description: Highway 401 WBL - Markham Road Overpass, North Widening
Site No.: 37-218

Existing Highway 401 Grade: ~164 m to 165 m
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Original Ground Surface Elevation: 159 m to 160 m

Approximate Station: 17+100

elevations within the approach embankments on a compacted Granular 'A' pad; however, as noted above, this may not be compatible with the existing structure.
For preliminary design purposes, the factored geotechnical resistance at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) may be taken as the same as the assessed existing capacity (provided in the table above) assuming the new footings will match the existing footings in width and founding elevation. If "perched" footings are adopted on a compacted granular pad, the factored geotechnical resistance at ULS and geotechnical resistance at SLS may be taken as 800 kPa and 350 kPa, respectively.

Steel H-Piles or Steel Pipe (Tube) Piles

Steel HP 310x110 piles founded within the very dense/hard soils (where SPT 'N' values exceed 100 blows per 0.3 m of penetration) can be used for support of the northward abutment widening. It is assumed that the pile caps at the abutments would be perched within the approach embankment fill to minimize excavation and dewatering requirements. For northward widening at the centre pier, pre-augering may be required to reach the design pile tip elevation as presented in the table below, due to the presence of very dense/hard soil at shallow depths.

Location	Design Pile Tip Elevation	Geotechnical Resistance	
		Factored ULS	SLS
Northwest abutment widening	153.0 m	1,600 kN	1,400 kN
Northeast abutment widening	151.0 m	1,600 kN	1,400 kN
North widening of centre pier	151.0 m	1,600 kN	1,400 kN

Due to the presence of very dense soils at a shallow depth, pre-augering of the piles may be required if the pile caps are founded below the Markham Road grade (as, for example, at the centre pier). Additional investigation is required during the detail design stage to confirm the subsurface conditions at the site and further assess the design pile tip elevations and requirements for pre-augering.

Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.), founded at the same design pile tip elevation.

Abutment Type

The site soils are suitable for construction of conventional, integral or semi-integral abutments. However; the existing structure is supported on spread footings and an integral abutment system for the widening will not be compatible unless the existing structure can be converted to semi-integral abutments.

Approaches and Backfill

- Height: Approximately 7 m to 7.5 m high at the abutments.
- Stability: Approach embankments up to 7.5 m high with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V) will have a factor of safety of greater than 1.3 against deep-seated slope instability.
- Settlement: Assuming the use of conventional earth fill or granular fill, it is expected that approximately 25 mm of settlement will occur under the footprint of the northward widening of the approach embankments. The majority of the settlement is expected to occur during and immediately after construction (i.e. elastic settlement).

CONSTRUCTION CONSIDERATIONS

Excavation

The silty sand to sandy silt deposit and the clayey silt deposit are classified as Type 2 soil, assuming appropriate dewatering in the cohesionless deposit, while the existing embankment fill would be classified as Type 3 soil according to OHSA. The side slopes for temporary excavations (i.e., those open for a relatively short time period) should be sloped at 1 horizontal to 1 vertical (1H:1V).

Groundwater/Surface Water Control

If shallow foundations are adopted, it is anticipated that excavations will extend below the existing groundwater table in the silty sand to sandy silt deposit at the site (approximately Elevation 161.5 m as measured in the piezometer installed as part of the 2011 investigation – this is above the Markham Road grade). In this case, some dewatering would be required in the silty sand to sandy silt deposit to lower the groundwater level to approximately 1 m below the founding elevation; it is expected that pumping from filtered sumps alone would not be sufficient, and that it would be necessary to use some well-points to assist in lowering the groundwater level in the silty sand to sandy silt soils.

Protection Systems

It is anticipated that temporary protection systems could be required along the edge of Highway 401 to facilitate excavation through the existing fill and removal or cutting down of the existing wing walls or retaining walls. However, it is also understood that consideration is being given to northward widening of the highway in this area without removal of the existing retaining walls (this is addressed in a separate Preliminary Foundation Report for the retaining walls on this project), which could reduce the requirement for temporary protection along this section of Highway 401.

Temporary protection systems are also likely to be required along the edge of Markham Road and at the centre pier if shallow foundations are adopted, due to the depth of excavation required to match the existing footings. These temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.

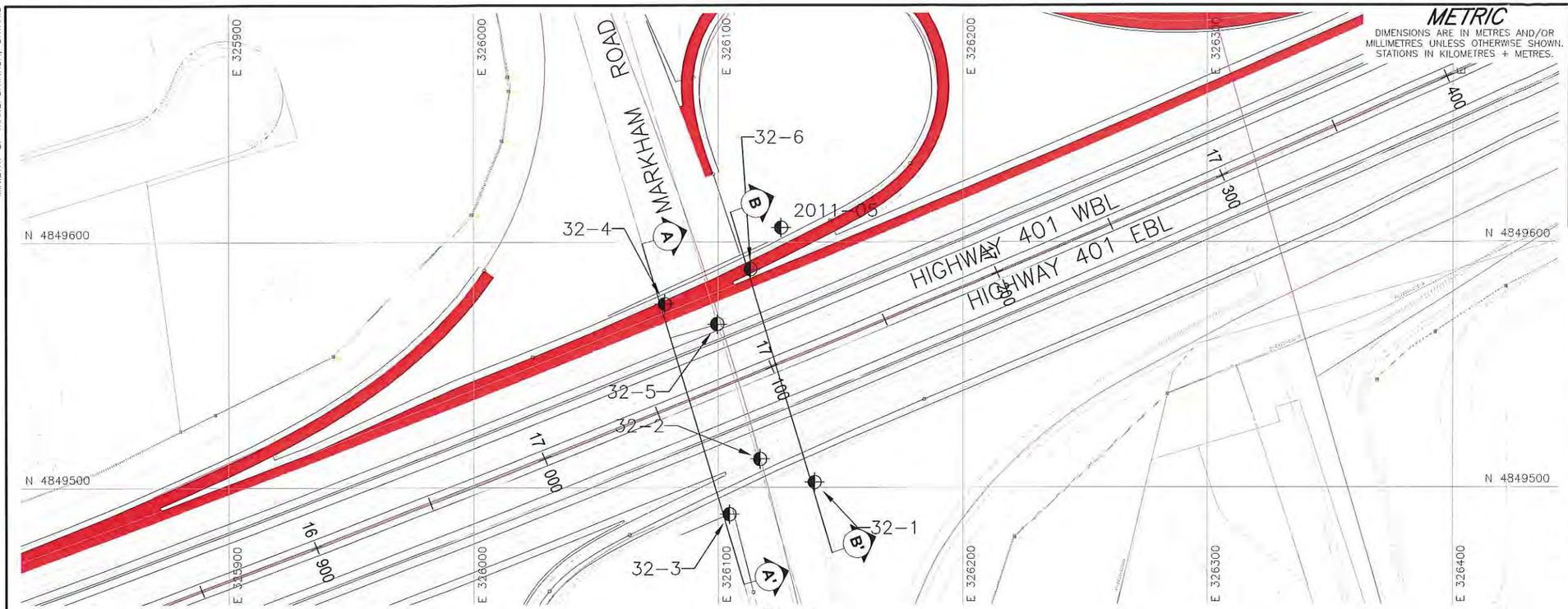
Obstructions During Pile Driving

If deep foundations are adopted for the northward widening of the centre pier, pre-augering may be required due to the presence of very dense soil at shallow depths. In addition, it is recommended that driving shoes be used to facilitate pile driving into the very dense silty sand to sandy silt and hard clayey silt deposits.

RECOMMENDATIONS FOR ADDITIONAL WORK

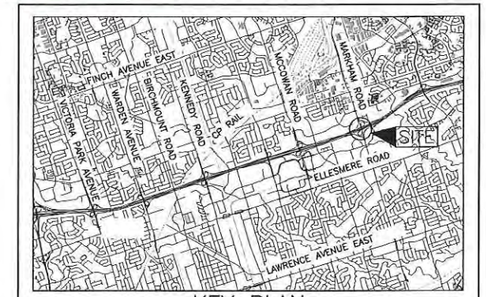
Further subsurface investigation should be carried out during detail design to confirm the shallow subsoil conditions and the groundwater level in the widening area, to refine the founding elevations and geotechnical resistances, as well as to assess the dewatering requirements associated with the use of shallow foundations constructed to match the existing founding levels.

MINISTRY OF TRANSPORTATION, ONTARIO

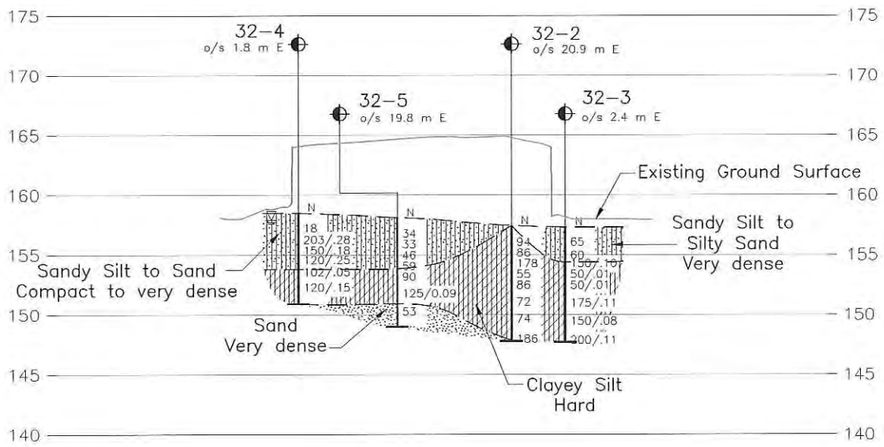


PLAN

SCALE
20 0 20 40 m

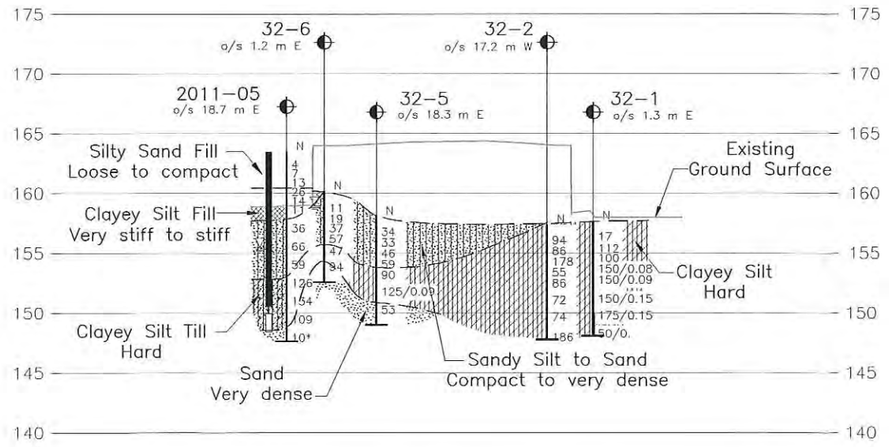


KEY PLAN
SCALE
1.5 0 1.5 3 km



WEST ABUTMENTS (A-A')

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE



EAST ABUTMENTS (B-B')

HORIZONTAL SCALE
20 0 20 40 m
5 0 5 10 m
VERTICAL SCALE

REGISTERED PROFESSIONAL ENGINEER
F. J. HEFFERNAN
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
L.C. COYNE
PROVINCE OF ONTARIO

CONT No.
WO No. 07-20012

SHEET

MARKHAM ROAD OVERPASS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

LEGEND

- Borehole – Current Investigation
- Borehole – 1966 Investigation (Geocres 30M14-75)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
32-1	157.7	4849502.2	326139.3
32-2	157.4	4849511.6	326117.1
32-3	157.3	4849489.1	326104.6
32-4	158.5	4849574.8	326078.3
32-5	158.1	4849566.6	326099.6
32-6	160.2	4849588.9	326113.2
2011-05	163.5	4849605.9	326125.8

NOTES

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

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. Base_Mapping_and_Promising_Mainline_Alternatives.dwg, dated Oct. 4, 2010 received Dec. 22, 2010.

Geocres No. 30M14-338

HWY. 401	PROJECT NO. 09-1111-6055		DIST.
SUBM'D. NK	CHK'D. LCC	DATE: 2/24/2012	SITE:
DRAWN: CD/JFC	CHK'D. NK	APP'D. LCC	DWG. F1

PLOT DATE: February 24, 2012
FILENAME: C:\Projects\09-1111-6055 (URS, GTA)\-CD-Foundation Conditions and Recommendations\09111160552C001.dwg

Golder Associates

RECORD OF BOREHOLE No 2011-05

1 OF 2 **METRIC**

PROJECT 09-1111-6055 | LOCATION N 4849605.9 ;E 326125.8 | ORIGINATED BY SB

G.W.P. 07-20012 | BOREHOLE TYPE CME 55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers | COMPILED BY MAS

DIST Central HWY 401 | DATUM Geodetic | DATE April 11, 2011 | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
163.5	GROUND SURFACE										
0.0	TOPSOIL										
0.2	Silty sand, trace clay, trace gravel, containing organics (FILL) Loose to compact Brown to grey-brown Moist		1	SS	4		163		○		
			2	SS	7		162				
			3	SS	13		161		○		
160.5											
3.1	Clayey silt with sand, trace gravel, containing organics (FILL) Very stiff to stiff Grey Moist		4	SS	26		160				
			5	SS	14				○		5 45 33 17
			6	SS	11		159				
157.7							158				
5.8	SAND and SILT, trace clay, trace gravel Dense to very dense Grey Moist		7	SS	36		157				
			8	SS	66	▽	156		○		0 42 49 9
	Becoming wet below a depth of 9.1 m		9	SS	59		155				
152.8							154				
10.7	CLAYEY SILT with sand, trace gravel (TILL) Hard Grey Moist		10	SS	126		153		○		
			11	SS	134		152				
			12	SS	109		151		⊖		1 26 60 13
148.6							150				
							149				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No 2011-05

2 OF 2 **METRIC**

PROJECT 09-1111-6055 | G.W.P. 07-20012 | LOCATION N 4849605.9 ;E 326125.8 | ORIGINATED BY SB

DIST Central HWY 401 | BOREHOLE TYPE CME 55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers | COMPILED BY MAS

DATUM Geodetic | DATE April 11, 2011 | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
14.9	SAND, some gravel, trace silt Compact Brown Wet		13	SS	10*		148		○		
147.7											
15.9	END OF BOREHOLE										

NOTES:

* SPT "N" value considered to have been affected by sample disturbance due to groundwater inflow to borehole.

1. Water level in piezometer at a depth of 8.4 m (Elev. 161.1 m) on completion of installation.

2. Water level in piezometer at a depth of 8.0 m (Elev. 161.5 m) on April 21, 2011.

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

OFFICE REPORT ON SOIL EXPLORATION

BH 32-1

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 67-F-40 LOCATION Co-ordinates 62,143 N, 102,822 E. ORIGINATED BY SMS

W.P. 262-61 BORING DATE May 15, 1967 COMPILED BY AMS

DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY

(m) ELEV.	DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % (10, 20, 30)	BULK DENSITY γ P.C.F.	REMARKS
157	517.5	GROUND LEVEL									Gr.Sa.Si.Cl
	0.0	Clayey silt with sand and trace of gravel.									▼516.0
				1	SS	17			o		
				2	SS	112	510		o		0 25 62 13
		Very Stiff to Hard		3	SS	100			o		
				4	SS	150/3"			o		
				5	SS	150/3½"	500		o		
				6	SS	150/6"			o		
				7	SS	175/6"	490		o⊢		
148.1	486.0			8	SS	50/¾"			o		
9.6	31.5	End of Borehole									

RM (-126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 32-2

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 67-F-40 LOCATION Co-ordinates 62,170 N; 102,750 E. ORIGINATED BY AMS
W.P. 262-61 BORING DATE May 15, 1967 COMPILED BY AMS
DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY

(m) ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRAT. PLOT	SAMPLES: NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % (10 20 30)	BULK DENSITY P.C.F.	REMARKS
157.4 516.4	GROUND LEVEL									Gr.Sa.Si.Cl
0.0	Clayey silt with some sand and trace of gravel.		1	SS	94	510				▽ 514.4
			2	SS	86					0 35 51 14
			3	SS	178					
			4	SS	55					
	"Hard		5	SS	86	500				
			6	SS	72					
			7	SS	74	490				0 3 81 16
147.8 484.9			8	SS	186					
9.6 31.5	End of Borehole									

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OFFICE REPORT ON SOIL EXPLORATION

BH 32-3

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 67-F-40 LOCATION Coordinates 62,098 N; 102,710 E. ORIGINATED BY AMS

W.P. 262-61 BORING DATE May 16, 1967 COMPILED BY AMS

DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY

(m) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
157.3 516.0	GROUND LEVEL									Gr.Sa.Si.Cl
0.0	Fine sandy silt to silty fine sand and trace of gravel. Very Dense.		1	SS	65	510		o		2 50 (48) ▼511.0
			2	SS	60					
154.4 506.5			3	SS	150/4"			o		
2.9 9.5	Clayey silt with sand and trace of gravel. Hard.		4	SS	50/½"			o		
			5	SS	50/½"	500		o		0 10 73 17
			6	SS	175/4½"			o		
			7	SS	150/3"	490		o		0 24 59 17
147.7 484.5			8	SS	200/4½"			o		
9.6 31.5	End of Borehole									

FORM -126
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 32-4

DEPARTMENT OF HIGHWAYS -- ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 67-F-40 LOCATION Co-ordinates 62,377 N; 102,628 E. ORIGINATED BY AMS
W.P. 262-61 BORING DATE May 17, 1967 COMPILED BY AMS
DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY

(M) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
158.5 520.0	GROUND LEVEL									
0.0	Sand with some gravel									
154.0 515.0	Compact		1	SS	18					▽518.6
1.5 5.0	Sandy silt to sand with traces of clay and gravel.		2	SS	203/11"					19 75 (6)
			3	SS	150/7"	510				9 55 (36)
	Very Dense.		4	SS	120/10"					
153.8 504.5										
4.7 15.5	Clayey silt with sand & trace of gravel.		5	SS	102/2½"					
			6	SS	120/6"	500				0 26 59 15
150.9 495.0	Hard									
7.6 25.0	End of Borehole									

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66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 32-5

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

JOB 67-F-40 LOCATION Co-ordinates 62,370 N; 102,694 E. ORIGINATED BY AMS

W.P. 262-61 BORING DATE May 16, 1967 COMPILED BY AMS

DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY [illegible]

(m) ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE
158.1 518.7	GROUND LEVEL					
	0.0 Fine sand with some silt and traces of clay and gravel. Dense to V.Dense.		1	SS	34	
			2	SS	33	510
			3	SS	46	
153.7 504.2			4	SS	59	
4.4	14.5 Clayey silt to silt with some sand. Hard.		5	SS	90	
						500
150.9 495.2			6	SS	125/3½"	
7.2	23.5 Fine sand Very dense		7	SS	53	
149.0 488.7						490
9.1	30.0 End of Borehole					

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.

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

w_P w w_L

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

Gr.Sa.Si.Cl

▽517.2

1 36 54 9

0 29 56 15

RM (126)
66-4546

OFFICE REPORT ON SOIL EXPLORATION

BH 32-6

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

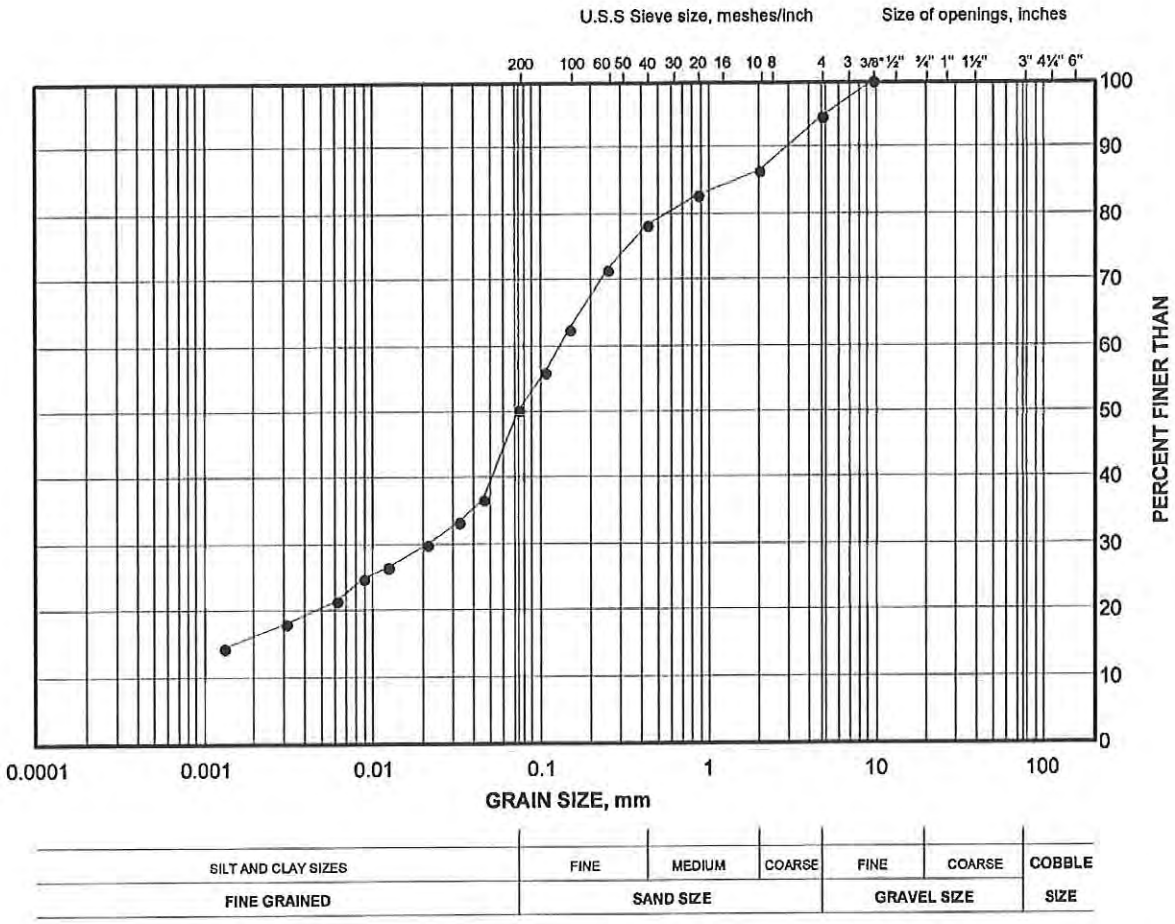
JOB 67-F-40 LOCATION Co-ordinates 62,422N; 102,470 E. ORIGINATED BY AMS
W.P. 262-61 BORING DATE May 16 & 17, 1967 COMPILED BY AMS
DATUM Geodetic BOREHOLE TYPE Continuous Flight Auger CHECKED BY

(M)	ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % (10 20 30)	BULK DENSITY γ P.C.F.	REMARKS
160.2	525.5	GROUND LEVEL									Gr.Sa.Si.Cl
	0.0	Silty sand to sand, Traces of gravel & clay. Compact to V.Dense.		1	SS	11	520				▽521.5
				2	SS	19					2 44 45 9
				3	SS	37					
153.8	511.0			4	SS	57					
4.4	14.5	Clayey silt with sand. Hard.		5	SS	41	510				0 35 55 10
154.5	507.0										
5.6	18.5	Fine sand. Very Dense.		6	SS	94					
152.6	500.5										
7.6	25.0	End of Borehole									

GRAIN SIZE DISTRIBUTION TEST RESULT

Clayey Silt Fill

FIGURE F1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-05	5	159.4

Project Number: 09-1111-6055

Checked By: Mayne

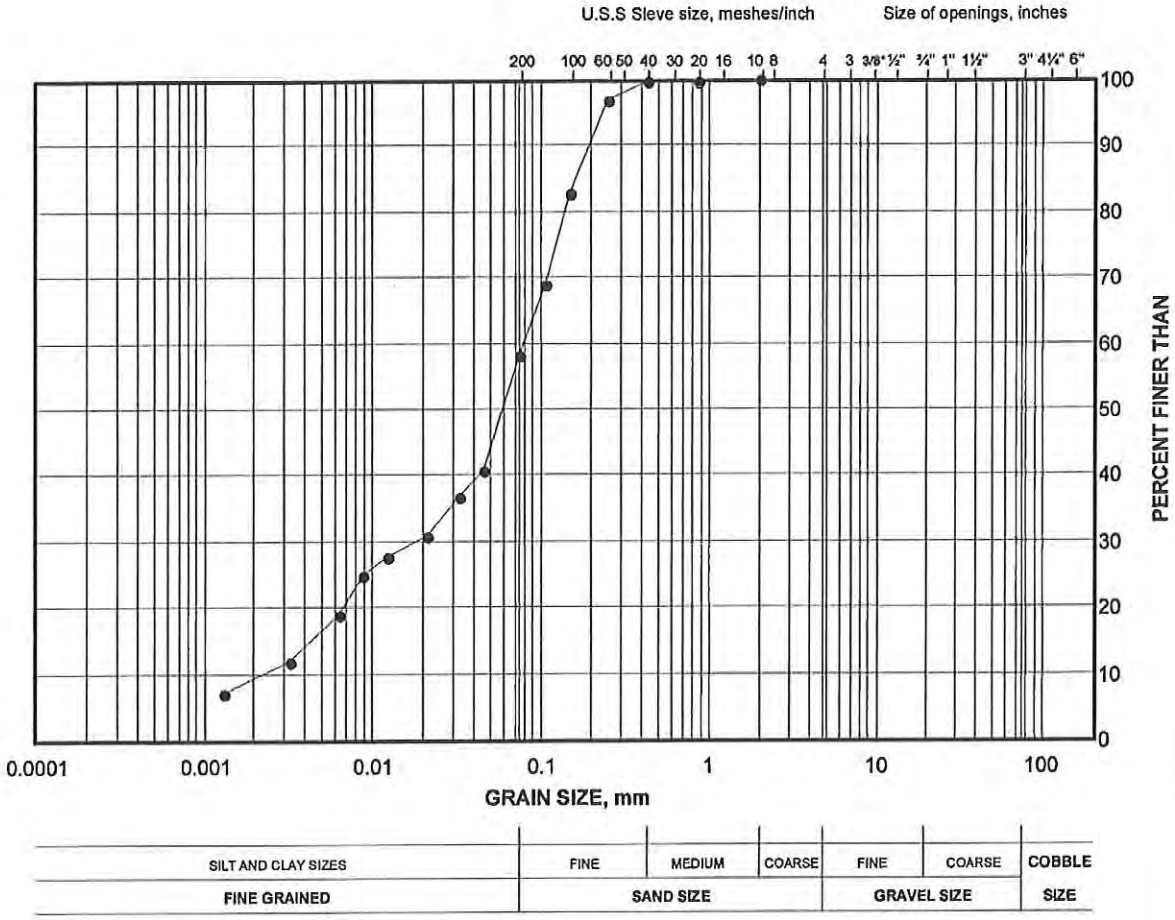
Golder Associates

Date: 21-Dec-11

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand to Sandy Silt

FIGURE F2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-05	8	155.6

Project Number: 09-1111-6055

Checked By: _____

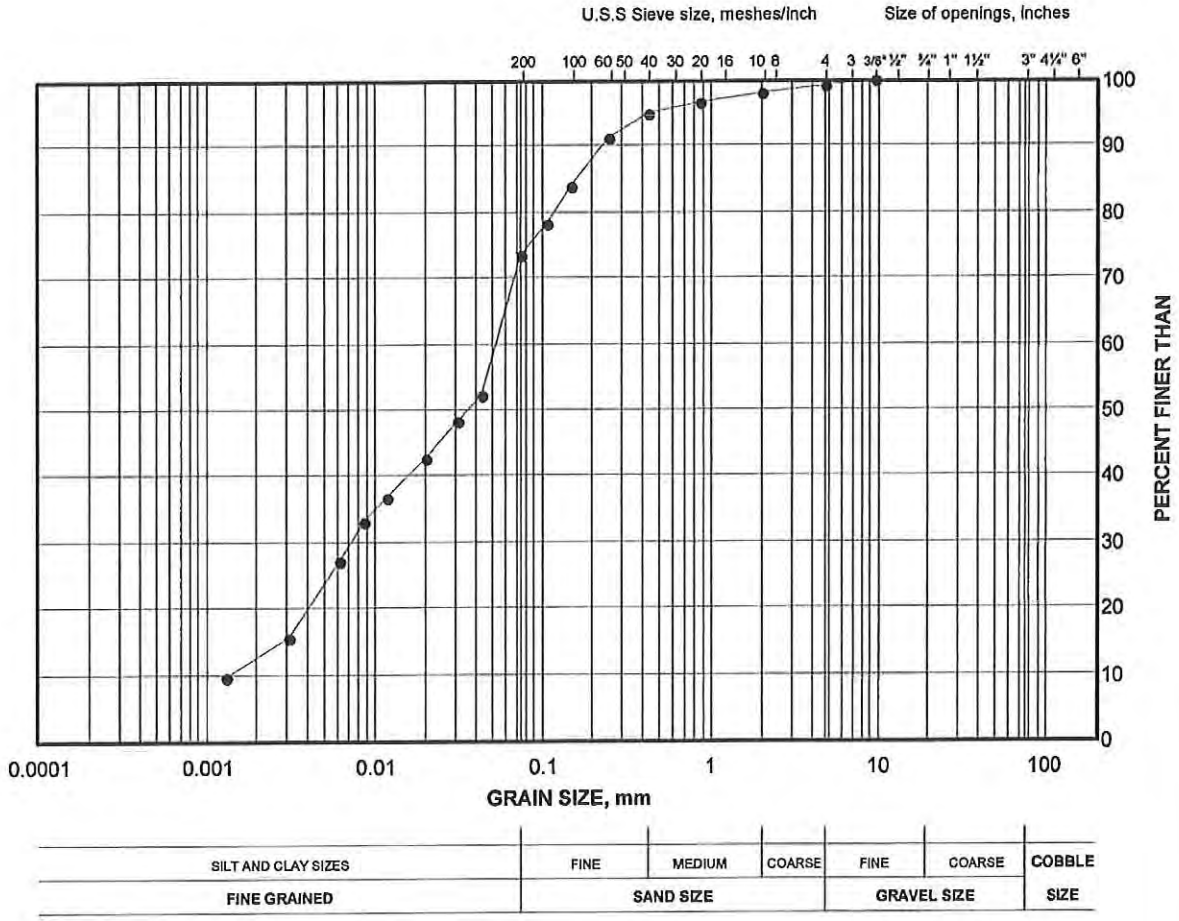
Golder Associates

Date: 21-Dec-11

GRAIN SIZE DISTRIBUTION TEST RESULT

Clayey Silt Till

FIGURE F3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2011-05	11	151.1

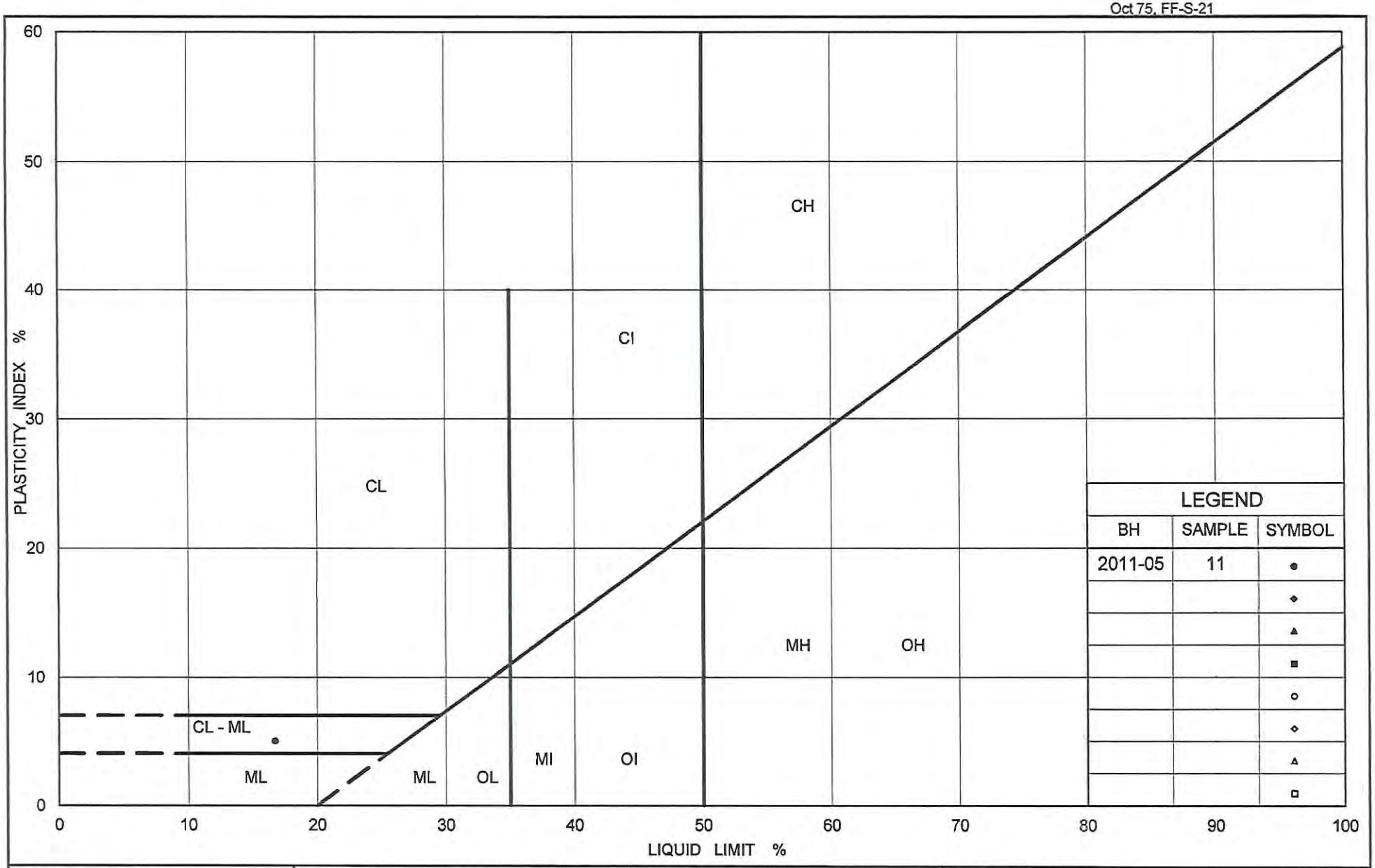
Project Number: 09-1111-6055

Checked By: _____

Golder Associates

Date: 21-Dec-11

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt Till

Figure No. F4

Project No. 09-1111-6055

Checked By:

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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