



PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

for

16TH AVENUE OVERPASS STRUCTURES

HIGHWAY 404 HOV LANE EXPANSION

FROM HIGHWAY 407 TO GREEN LANE

WO 03-20024

REGIONAL MUNICIPALITY OF YORK, ONTARIO

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PML Ref.: 14TF003A-16
Index No.: 037FIDR
Geocres No.: 30M14-417
May 27, 2015



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PRELIMINARY FOUNDATION INVESTIGATION REPORT

for
16th Avenue Overpass Structures
Highway 404 HOV Lane Expansion
From Highway 407 to Green Lane
WO 03-20024,
Regional Municipality of York, Ontario

1. INTRODUCTION

The Foundation Engineering Services required for this project include preparation of a preliminary design level Foundation Investigation and Design Report for the proposed Highway 404 High Occupancy Vehicle (HOV) lanes expansion from Highway 407 to Green Lane, 26 km, in the Regional Municipality of York.

This report addresses the proposed widening into the median of both the existing Highway 404 NBL and SBL Overpasses over 16th Avenue. The report was prepared for the MMM Group Limited on behalf of the Ontario Ministry of Transportation.

The Terms of Reference for this assignment required a Preliminary Foundation Investigation and Design Report in two parts – Preliminary Foundation Investigation Report and Preliminary Foundation Design Report, to be based on existing information only. An excerpt from the RFP defining the scope of services follows:

Preliminary Foundation Investigation Report

For bridges, the Preliminary Foundation Investigation Report shall present a subsurface model under the plan limits of foundation elements, and at the immediate approaches within 20 m of the structure.

This portion of the report shall consist of factual information only, with no reference to recommendations or project proposals, and present details of subsurface conditions to justify preliminary recommendations.



The Preliminary Foundation Investigation Report shall consist of

- *Site Description.*
- *Investigation Procedures including site investigation and lab testing procedures.*
- *Description of Subsurface Conditions including soil, rock and groundwater conditions.*

Preliminary Foundation Design Report

The Preliminary Foundation Design Report shall present discussion and recommendations for planning purposes. Recommendations shall be presented in accordance with the requirements of the most recent edition of the Canadian Highway Bridge Design Code in effect for MTO projects. The Service Provider shall analyse field data and test results and make preliminary recommendations, including but not limited to:

- *Structure foundations design (shallow or deep) including anticipated axial resistances, approximate founding elevations of potential foundation options.*
- *Embankment settlement and stability.*
- *Construction concerns of potential geotechnical problems associated with the site, including the need for shoring, dewatering.*
- *Scope of work required for detail design.*

The Service Provider shall identify and present a comprehensive overview of the advantages, disadvantages, costs and risks/consequences of viable alternative foundation schemes in tabular format. The Report should conclude a preferred alternative from a foundation technical and cost effectiveness perspective.

This Preliminary Foundation Investigation Report summarizes the subsurface conditions based on review and compilation of information from available relevant reports for this site and provides preliminary design level recommendations. The report is intended for preliminary design and planning purposes. Detail design level foundation engineering services will be required for the detail design phase of the project.

The elevations in this report are expressed in meters, unless otherwise noted.



2. SOURCES OF INFORMATION

The following reports, including drawings, were available for the 16th Avenue Overpass Structures. Reference 1 is the original report for the site. The Reference 2 report essentially summarizes the information from the Reference 1 report. The Reference 3 report is a pile load test and will be pertinent to the detail design phase of the project. Pertinent excerpts from the Reference 2 report are presented in Appendix A. The General Arrangement drawing for Reference 2 is presented in Appendix B.

REFERENCE 1:

- Foundation Investigation and Design Report For Proposed Twin Overpass Structures, Highway 404 and 16th Avenue, Site, 37-666, W.P. 160-74-25, District 6, Toronto, by Soil Mechanics Section – Ministry of Transportation and Communications, dated April 5, 1977, GEOCRE 30M14-54.
- General Layout, Drawing 1, Highway 404 Overpass at 16th Avenue, Site No. 37-666, Cont. No. 78-45, W.P. 160-74-25 by McCormick, Rankin & Associates Limited Consulting Engineers, dated June 1977.

REFERENCE 2:

- Foundation Investigation Report for Highway 404 Overpass Widening at 16th Avenue, W.P. 38-87-01, Site No. 37-666, District 6, Toronto, by Foundation Design Section – Engineering Materials Office – Ministry of Transportation Ontario, dated October 27, 1988, GEOCRE 30M14-192.
- General Arrangement, Drawing 1, Highway 404 Overpass Widening at 16th Avenue, Site No. 37-666, District 6, Cont. No. 90-64, W.P. No. 38-87-01 by Morrison Hershfield Limited Consulting Engineers, dated October 1988.

REFERENCE 3:

- Pile Driving Analysis, M.T.C Pile Load Test Program, Sixteenth Avenue and Proposed Highway No. 404, Buttonville, Ontario by The Trow Group Limited for Birmingham Construction Limited, Project: J9642, dated February 28, 1978, GEOCRE 30M14-54.

In addition to the above GEOCRE reports, the following documents were also reviewed:

- Ministry of Northern Development and Mines. 1991. Bedrock Geology of Ontario – Southern Sheet, Map 2544, Scale 1:1,000,000.
- Chapman and Putnam. 1984. The Physiography of Southern Ontario, 3rd Edition.
- Ontario Geological Survey. 1984. Physiography of Southern Ontario, Map 2715, Scale 1:600,000.



3. SITE DESCRIPTION AND GEOLOGY

The site is located approximately 1.7 km west of Woodbine Avenue on 16th Avenue near Buttonville at the boundary of the Towns of Richmond Hill and Markham in the Regional Municipality of York.

Each of the Highway 404 overpass structure carries four lanes of traffic over the 16th Avenue. The topography of the site area is generally flat to gently undulating with the industrial lands in the immediate vicinity of the site location. The Toronto Buttonville Municipal Airport is located approximately 400 m east of the site.

Physiographically, the site is located in a region known as the Peel Plain. The subsoil in the area is characterized by moraine till layers and silty sand deposits. Coarse grained granular deposits of variable thickness are interbedded in the till at random locations. Upper Ordovician shale bedrock of Georgian Bay Formation underlies the overburden in the area.

4. INVESTIGATION PROCEDURES

This Preliminary Foundation Investigation Report is based on existing subsurface information. No current subsurface investigation was carried out at the site location for this project. Previous MTO GEOCRETS reports, listed in Section 2, were reviewed to gather subsoil and groundwater data.

The original foundation investigation field work (Reference 1) was carried out during the periods of December 4, 1970 to January 31, 1971, August 24 to 31, 1971 and an additional investigation was carried out from February 22 to 25, 1977. A total of ten boreholes were investigated to depths between 12.2 to 40.4 m (40.0 to 132.5 ft.) below the ground surface. At that time, it was proposed to construct twin single span structures where Highway 404 would cross the 16th Avenue in the Regional Municipality of York. It was anticipated that the proposed grade elevation of Highway 404 would be at approximate elevation 196.0 (643.0 ft.) requiring fills up to 1.5 m (5.0 ft.) and the grade of the 16th Avenue would be at approximate elevation 189.9 (623.0 ft.) requiring



cuts up to 4.6 m (15.0 ft.). At that time, the original ground was at approximate elevation 194.2 (637.0 ft.).

The foundation investigation conducted by Foundation Design Section (Reference 2) was carried out between June 6 and 21, 1988. A total of four additional boreholes (Boreholes 13 to 16) were investigated to depths between 36.8 and 38.6 m to supplement the information in the Reference 1 report. Groundwater conditions in the open boreholes were observed throughout the drilling operations. The purpose of the foundation investigation was to determine the subsoil and groundwater conditions for the proposed widening of the twin overpass structures at Highway 404 and 16th Avenue.

5. SUMMARIZED SUBSURFACE CONDITIONS

The subsurface and groundwater conditions encountered are summarized below based on the Foundation Investigation Report on overpass widening at 16th Avenue.

5.1 General

Refer to the Record of Borehole sheets (Appendix A) for the details of the subsurface conditions including soil classifications, inferred stratigraphy, and groundwater observations for the median of the Highway 404 NBL and SBL.

The depositional characteristics of the subsoil at this site are complex. The stratigraphy revealed in the boreholes generally included irregular layers of clayey silt and silt to silty sand to a depth in excess of 39.0 m below the ground surface. The water levels measured in the open boreholes was found to be at depths between 0.5 to 0.8 m (elevations 188.7 to 189.5).

The two major types of subsoil at the site are discussed below:

5.2 Layers of Clayey Silt with some/traces of Sand and Gravel

Varying thicknesses ranging from 1.9 (in borehole 15) to 13.8 m (in borehole 13), of cohesive soft to hard layers of clayey silt were encountered in the borehole locations. N values ranged from 2 to



greater than 100 blows for 300 mm penetration. The field vane shear test results obtained 46 to 96 kPa with sensitivity ranging from 2 to 7. Undrained shear strengths based on laboratory unconfined compression test ranged from 25 to 86 kPa.

The grain size distribution results obtained from samples of this deposit were presented in Figure 2 of the appended report. The Atterberg liquid limit ranged from 16.5 to 49.0 with corresponding plastic limit ranging from 10.5 to 19.5. The plasticity indices ranged from 6 to 30. The Atterberg test results indicated that the cohesive stratum is inorganic, with the plasticity in the low range. The natural moisture contents measured ranged from 7 to 38%.

5.3 Layers of Silt to Silty Sand with Some Gravel

Varying thicknesses ranging from 1.5 (in borehole 14) to 9.3 m (in borehole 4) of very loose to very dense silt to silty sand were randomly interstratified with layers of clayey silt at random depths. Occasional clayey silt seams up to 50 mm in thickness were encountered within these non-cohesive soils. N values recorded ranged between 1 to greater than 100 blows for 300 mm penetration.

A grain size envelope presenting the results of the grain distribution analyses were presented in Figure 4 of the appended report. Moisture content determination results ranged from 8 to 25%.

5.4 Groundwater

Groundwater levels were noted in the open boreholes during and upon completion of augering. The water levels measured in the open boreholes was found to be at depths between 0.5 to 0.8 m, elevations 188.7 to 189.5, below ground surface.

Groundwater levels are subjected to fluctuations due to seasonal and rainfall patterns.



6. MISCELLANEOUS

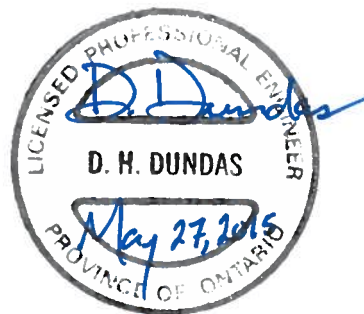
The Preliminary Foundation Investigation portion of this report was prepared by Mr. N. Rahman, P.Eng., and reviewed by Mr. D. Dundas, P.Eng. The report was independently reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



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Appendix A - Foundation Investigation Report for Highway 404 Overpass Widening at 16 th Avenue, W.P. 38-87-01, Site No. 37-666, District 6, Toronto, by Foundation Design Section – Engineering Materials Office – Ministry of Transportation Ontario, dated October 27, 1988, GEOCRE 30M14-192.	
Appendix B - General Arrangement, Drawing 1, Highway 404 Overpass Widening at 16th Avenue, Site No. 37-666, District 6, Cont. No. 90-64, W.P. No. 38-87-01 by Morrison Hershfield Limited Consulting Engineers, dated October 1988.	

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for
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Highway 404 HOV Lane Expansion
From Highway 407 to Green Lane
WO 03-20024,
Regional Municipality of York, Ontario

7. ENGINEERING RECOMMENDATIONS

7.1 General

This portion of the report provides the preliminary foundation design recommendations for the proposed widening of the existing 16th Avenue Overpass structures, associated with the proposed widening of Highway 404 in the Regional Municipality of York. The recommendations are intended for preliminary design and planning purposes only and are based on the factual subsurface and groundwater conditions obtained from previous investigations. Further foundation engineering services will be required to provide detail design level recommendations.

It is expected that the existing highway platform will be widened throughout the project length and will require the widening of the existing 16th Avenue Overpass structures. It is understood that the widening will be achieved by adding one HOV lane in each direction of the Highway 404 NBL and SBL lanes in the existing median area. This will require filling of the median and possibly construction of a new barrier along the centreline of the median.

The grades for Highway 404 and 16th Avenue are at about elevation 196.0 and elevation 189.9, respectively.

Based on the available General Arrangement drawing (Appendix B) for the existing overpass structures, the abutment and retaining walls are founded on end bearing steel 'H' piles (HP 310 x 110) driven into the hard clayey silt layer to terminate near elevation 155.0.



7.2 Foundation Options

The following table summarizes the foundation types considered, their advantages and disadvantages as well as relative cost and risks/consequences are tabulated below:

Foundation Type	Advantages	Disadvantages	Relative Cost	Risks/Consequences
Spread Footings (placed on native soils or structural fill)	Ease of installation. No vibration concerns from pile driving.	Higher groundwater level at the site could require dewatering and shoring. The required size of the footing may be larger than for a pile cap. Possible differential settlement between the existing and proposed structures.	Low	Differential settlement between widened and existing portions of structure.
Driven H-Piles	Driven H-piles cause small soil displacement and less risk to disturbing existing foundations. Same type as existing foundation.	Vibration induced during pile driving. Potential interference with existing piles. Possible presence of cobbles and boulders in the glacial till soils.	Moderate	Disturbance to existing foundations through physical contact with existing piles during driving of new piles could cause settlement of existing structure. Pile driving induced vibrations could cause disturbance to ground supporting existing piles and subsequent settlement of existing structure.
Caissons	Larger bearing capacity than for other options.	Challenging installation due to the presence of noncohesive soil and high groundwater table, which could require liners, mud drilling techniques and tremie concreting methods. Liners could be impractical because of the length of liner required in view of the noncohesive deposits to depth at the site. Construction difficulties due to possible presence of cobbles and boulders in the glacial till soils	High	Loss of ground during installation that could cause settlement of existing foundations. Flowing soils under along shaft and base could cause necking of concrete in caisson and subsequent reduction in resistance of caisson foundation.



A foundation system consisting of steel H-piles driven into the hard clayey silt layer is the recommended means of supporting the abutments and retaining walls of the widening structures in view of the need to preserve the existing pile foundations during construction. This is consistent with the existing foundations. An extensive pile loading testing program with evaluation of foundation alternatives was carried out during the period of October 20 to November 2, 1977 (Reference 3). It was concluded that the most suitable type of pile foundation would be 'H' end bearing piles driven into the lower hard clayey silt till.

The locations of retaining walls have not been indicated at this stage. It is presumed that the only locations could be at the inside of widenings at each abutment. Currently, the embankments are in the order of 6 to 8 m high and sloped at 2H:1V at these locations. Embankment slopes after median widening should maintain geometry of 2H:1V or flatter. However, if 2H:1V slopes cannot be realized, retaining walls will be required. If retaining walls are required, spread footings could be considered for RSS type walls. The retaining walls may be restricted to the median and may be aligned along the Highway 404 lanes or parallel to the abutments.

Caissons were given consideration as a foundation option, but it was concluded that the noncohesive deposits present at the site present challenging conditions and high risk for loss of ground during caisson installation. In view of practical difficulties in implementing mitigation techniques such as installing full depth liners or employing mud drilling in close proximity to existing structures, it is recommended that driven H-piles are the preferred options for foundations for the proposed widenings.

7.3 Pile Foundation

Based on the general arrangement drawing (Reference 2), the existing top and bottom of the 0.9 m thick pile cap are at about elevation 189.0 and 188.1, respectively. It is anticipated that the new pile cap will match the elevations of the existing one at the site location.

Further, it is anticipated that the driven steel H-Piles will encounter practical refusal at elevation near 155.0 yielding a pile length of approximately 10.0 m.



Preliminary design level values for factored axial resistance at ultimate limit states (ULS) and factored axial reaction at serviceability limit states (SLS) are provided below:

PILE SECTION	FACTORED AXIAL RESISTANCE AT ULS (kN)	FACTORED AXIAL REACTION AT SLS (kN)
HP 310 x 79	1150	850
HP 310 x 110	1600	1150

The resistance at SLS normally allows for 25 mm of compression of the pile and founding medium.

The H-piles would have to be equipped with driving shoes and pile installation would be in accordance with OPSS 903. The existing piles would have to be located and avoided during driving of new piles.

In order to avoid undermining the adjacent existing abutments, all excavations for pile cap construction would have to be adequately supported by protection systems.

Vibration and settlement monitoring of the existing foundations would have to be considered in the detail design phases of the project and specified for construction. Vibration and noise, as a result of piling, should also be monitored in order to confirm that MTO and other by-law requirements are met. This issue should be addressed during detailed design.

The approach embankment fill as well as any fill placed below grade to deal with unsuitable/compressible soils within the limits of the pile foundation should comprise Granular A or Granular B Type II with a maximum nominal size of 75 mm to enable driving of the piles and minimise the potential for damage during pile installation. Granular B Type I is recommended below the water table if required.

As per OPSD 3090.101, a minimum of 1.2 m of soil cover or the equivalent thermal insulation should be provided for frost protection to the pile caps.

Resistance to lateral loads may be provided in part by mobilization of passive resistance along the pile.



It is recommended that the design value used for lateral pile resistance should not exceed 150 kN for Factored Resistance at ULS and 100 kN for SLS. If greater lateral resistance is required, it can be provided by the horizontal component of battered piles.

7.4 Approach Embankments

Based on the available general arrangement drawing (Reference 2), the existing earth embankment side and front slopes are constructed at 2H:1V slope. The height of the embankment is about 6 to 8 m. Embankment slopes after median widening should maintain geometry of 2H:1V or flatter. However, if 2H:1V slopes cannot be realized, retaining toe walls will be required at the toe of the slopes. The retaining toe walls locations and height should be such to permit 2H:1V slope geometry above the retaining wall. Further, where the height of the embankments is greater than 8 m for earth fill, a 2.0 m wide mid-height bench will be required in accordance with OPSD 202.010.

The existing compressible materials within the 20 m of the abutments should be excavated prior to placement of the embankment fill and backfill. Benching of the existing embankment front slopes (at the abutments) should be carried out to key in the new fill. The new fill should be keyed into the existing fill as per MTO standards.

It is anticipated that there will be no slope stability issues and that settlements of the approach embankments will be negligible.

7.5 Abutments and Retaining Walls

The abutment and wing walls should be designed to resist the unbalanced lateral earth pressure imposed by the backfill adjacent to the wall. Recommendations for earth pressures should be provided in the detail design phase. Conventional or RSS walls may be considered.



7.6 Construction Considerations

7.6.1 Excavation

All excavation at the structure foundation sites should be carried out in accordance with the Occupational Health and Safety Act (OHSA), local and MTO regulations.

According to OHSA criteria, very loose to loose and soft soils are classified as Type 4 soils, compact non-cohesive and stiff to firm cohesive soils are classified as Type 3 soils. The very stiff cohesive and dense non-cohesive soils are considered as Type 2 soils. The hard cohesive soil is classified as Type 1 soil. Since open cut procedures are governed by soils with the highest soil type number, temporary cut slopes over the full depth of excavation inclined at 3 horizontal to 1 vertical should be provided assuming adequate drainage measures are in place. Flatter slopes may be required at locations where water seepage affects stability of an excavation. If steeper geometries are required, shoring will be necessary.

The selection of the method of excavation is the responsibility of the Contractor and a provision must be made for the handling of pavement materials, potential obstructions in the fill, and potential presence of cobbles and boulders.

7.6.2 Roadway Protection

Temporary roadway protection will probably be required to permit excavation between the existing highway lanes and the proposed widenings. A minimum performance level of 2, according to OPSS 539 is recommended. The contractor is responsible for selection, preparation of a detailed design and performance for the roadway protection system. Several protection scheme alternatives such as sheet piling, sheeting supported by rakers or bracing, cantilever or anchored soldier piles and lagging may be considered.



7.6.3 Groundwater Control

Based on previous investigations, the water levels measured in the open boreholes was found to be at depths between 0.5 to 0.8 m, elevations 188.7 to 189.5, below ground surface.

The groundwater regime has undoubtedly been changed with the lowering of 16th Avenue by 4.6 m (15.0 ft.) to approximately 189.9 (623.0 ft.) to facilitate construction of the Highway 404 NBL and SBL Structures.

Due to the presence of high water levels observed in the boreholes, it is considered that the soil may become susceptible to disturbance under conditions of unbalanced hydrostatic head and thus, the contractor should be required to lower the groundwater level to at least 0.5 m below the bottom of the excavation depth.

Although the method for dewatering should remain the responsibility of the Contractor, more positive groundwater control, other than conventional sump pumping, may be required. Consideration could be given to using adequate perimeter ditching or cofferdams if necessary. Surface water run-off should be diverted away from excavation to ensure that the foundation is constructed in the dry.



8. SCOPE OF ADDITIONAL INVESTIGATION AND DESIGN SERVICES

The recommendations in this report are preliminary. Detailed foundation engineering services will be required during the Detail Design phase of the project.

The extent of further investigations at this site may be limited to 1 borehole in the Highway 404 median at each of the north and south abutments extending to depth sufficient to provide information for shoring and dewatering plus 1 additional borehole in the median at each of the north and south structure approaches within 20 m of the abutments to determine the extent of compressible material to be removed for the widened highway lanes. Further, it is recommended to install piezometers at the proposed abutment and approach embankment borehole locations to monitor and establish a stabilized groundwater level at the site location during the detailed design of the widening structures.

Detail design recommendations would be required for all aspects including slope stability, settlement, axial and lateral pile resistance, seismic design, temporary roadway protection, dewatering, construction specifications and liaison with the design team.



9. CLOSURE

The Preliminary Foundation Design portion of this report was prepared by Mr. N. Rahman, P.Eng., and reviewed by Mr. D. Dundas, P.Eng. The report was independently reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



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APPENDIX A

Previous Foundation Investigation Report

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

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WP *38* 87-01

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at 16th Avenue

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FOUNDATION INVESTIGATION REPORT
For
Highway 404 Overpass Widening at 16th Avenue
W.P. 38-87-01, Site No. 37-666
District 6, Toronto

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above mentioned site during the periods of June 7 to June 21, 1988.

As described in our previous Foundation Investigation Report (W.P. 160-74-25, April 1977) and the Report for Pile Load Capacity Evaluation (July 1978), twelve boreholes (Boreholes 1 to 12) were advanced and sampled during the various time as part of foundation investigation and pile load tests for the Hwy. 404 over the 16th Avenue. These boreholes extended to depths between 12.2 and 40.4 metres below the ground surface. The results obtained from these boreholes are utilized in this report (Boreholes 3, 4, 9 and 10).

During the June of 1988, four boreholes (Boreholes 13 to 16) were advanced and sampled as part of this project by means of hollow stem augers and washboring techniques or using a conventional diamond drill (NX Casing) adapted for soil sampling purposes. These boreholes extended down to depths between 36.8 and 38.6 metres below the existing ground surface.

This report contains factual information together with recommendations pertaining to the structure widening of Hwy. 404 bridges at 16th Avenue.

SITE DESCRIPTION

This site is located on Hwy. 404 where it crosses the existing 16th Avenue at the boundary of the Towns of Richmond Hill and Markham, in the Regional Municipality of York. The existing structures are twin 11.9 x 20.5 m single span rigid frame bridges constructed with earth embankments approximately 6.0 metres in height. Buttonville Airport is located approximately 400 m east of this site. The topography of the area is flat to gently undulating with the land in the immediate vicinity being used for farming purposes.

Physiographically the site is located in the Region known as the "Peel Plain". The underlying glacial material of the plain is a till or boulder clay containing large amounts of Palaeozoic shale and limestone. The subsoil is characterized by Moraine till layers and silty sand deposits. In much of the "Peel Plain" this material has been modified by the veneer of clay which, when deep enough, is varved. In various places the stream valleys are bordered by trains of sandy alluvium.

SUBSURFACE CONDITIONS

The subsoil at this site was found to consist of irregular layers of clayey silt and silt to silty sand, extending to a depth in excess of 39 metres below the existing ground surface. Detailed description of various soil types encountered in each borehole are given on the Record of Borehole Sheets. Location and elevations of the boreholes, together with the estimated subsurface sections inferred from the borehole data are shown on Drawing No. 388701-A. Due to the complex depositional characteristics of the subsoil at this site, it is very difficult to define the stratigraphical profile across the site. In view of this, the two types of subsoil will be discussed separately.

Layers of Clayey Silt with Some/Traces of Sand and Gravel

Cohesive layers of clayey silt with some/traces of sand and gravel of varying thickness were encountered at various depths at the site. The minimum thickness of these layers varies from 1.9 m at BH #15 to a maximum thickness of 13.8 m at BH #13.

Typical grain-size distribution results obtained from samples of this deposit are plotted on Figure 2 in Appendix.

The various laboratory and field results obtained in these cohesive layers, are summarized in the following table (see details in Report WP160-74-25):

	<u>Range</u>
Liquid Limit (w_L , %)	16.5-49
Plastic Limit (w_p , %)	10.5-19.5
Plasticity Index (I_p , %)	6-30
Natural Moisture Content (w , %)	7-38
'N' value (blows/0.3 m)	2-over 100
Undrained Shear Strength-Cu (kPa)	
-Field Vane Tests	46-96
-Laboratory Unconfined Compression Tests	25-86

The Atterberg Limit tests, carried out on representative samples of cohesive layers, are summarized on Figure 1, and the results indicate that the cohesive stratum is inorganic, with the plasticity in the low range (CL-Clayey Silt).

The results from the Standard Penetration tests showed that the consistency ranged from soft to hard.

Layers of Silt to Silty Sand with Some Gravel

The layers of silt to silty sand are randomly interbedded with layers of clayey silt. These layers of silt to silty sand were found to be of varying thickness and were located at random depths. The granular layers range from a minimum thickness of 1.5 m at BH #14 to a maximum thickness of 9.3 m at BH #4. Occasional thin layers up to 50 mm in thickness were encountered with these non-cohesive layers (refer to BH #3 and #15). Grain size curves from samples of these granular layers are shown in an envelope form (Figure 4).

Standard Penetration resistance tests carried out in this material, ranged from 1 blow/0.3 m to in excess of 100 blows/0.3 m. Based on these results, it is estimated that the relative density of the granular layers of the subsoil varies randomly from very loose to very dense.

GROUNDWATER CONDITIONS

The groundwater level across the site, during the period of investigations was observed by taking readings in the open boreholes. The observations indicated that the water level in the open boreholes was found to be between elevations 188.7 and 189.5 metres, which corresponds to depths of from 0.5 to 0.8 metres below existing ground surface.

DISCUSSION AND RECOMMENDATIONS

The existing structures are twin 11.9 metres wide single span bridges over 16th Avenue. It is proposed to widen the east side of the existing northbound structure by about 8 metres from the existing edge of the deck. In addition, it is also proposed to widen the west side of the existing southbound structure by about 3 metres from the existing west edge of the deck.

The existing structure retaining walls are founded on end bearing Steel 'H' Piles (HP 310 x 110) driven into the hard clayey silt layer. For the existing structures, extensive pile loading tests were carried out during the period of October to November 1977. The results were submitted in a report form (See MTO Report EM-20, July 1978). At that time, it was concluded that the most suitable type of pile foundation would be Steel 'H' end bearing piles driven into the lower clayey silt till. Approximate tip elevation was 160.0 metres.

In view of the performance of the existing structures, it is our recommendation that the widening of the structures should be also supported on similar type foundation of the existing structure.

ABUTMENT AND RETAINING WALLS

The proposed widened portion of the structures and retaining walls may be supported on end bearing 'H' piles driven into the hard clayey silt layer using the following design values and tip elevations:

<u>Structure</u>	<u>Pile Type</u>	<u>Estimated Tip Elev. (m)</u>	<u>Factored Capacity at U.L.S. (kN)</u>	<u>Allowable Capacity at S.L.S. Type II (kN)</u>
Northbound Bridge	HP 310 x 79	155.0 m	1150	850
	HP 310 x 110	155.0 m	1600	1150
Southbound Bridge	HP 310 x 79	157.0 m	1150	850
	HP 310 x 110	157.0 m	1600	1150
Retaining Walls	HP 310 x 79	155.0 m	1150	850
	(N.B.)			
	HP 310 x 110 (S.B.)	157.0 m	1600	1150

It should be noted that the pile driving in the field should be controlled by employing the Hiley Dynamic pile Driving Formula, as per current MTO Standards.

Other Considerations

The following recommendations should be taken into consideration during construction:

- Base of pile cap foundations should be at the existing level.
(Structures, 188.4 metres, retaining walls, 189.6 metres).
- During excavation care must be taken to avoid undermining the existing foundation.
- Pile cap foundations must have a minimum earth cover of 1.2 metres for frost protection.

Backfill to abutments and retaining walls should consist of Granular 'A' or Granular 'B' for which the following properties are recommended:

Granular 'A' $\gamma = 22.8 \text{ kN/m}^3$ $\phi = 35^\circ$ $K_A = 0.27$

Granular 'B' $\gamma = 21.2 \text{ kN/m}^3$ $\phi = 30^\circ$ $K_A = 0.33$

Dewatering

Dewatering for the footing excavations may be a problem, since excavation will be carried out about 1 metre below the groundwater level in granular subsoil. One method of achieving this is carrying out excavations by means of oversize perimeter ditches and constantly pumping out water from the ditches.

Approaches

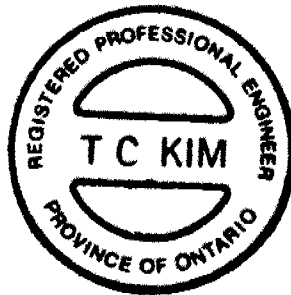
Approach fills and cuts should be constructed with standard 2:1 side and forward slopes in which even in general no major stability problems are anticipated. The new fill should be keyed into the existing fill as per MTO Standards.

Some differential settlement can be anticipated between the consolidated portion of existing fill and new fill. In view of this, it is suggested that the new fill should be left in place as long as possible in order to minimize differential movement prior to paving operations. The settled portion of the embankment should be brought up to grade with fill material prior to commencement of paving.

MISCELLANEOUS

The field work for this recent investigation was carried out during the period of 88 06 07 to 88 06 21 1988, under the supervision of Ken Zasitko (Technician). The equipment was owned and operated by Master Soil Investigation Toronto.

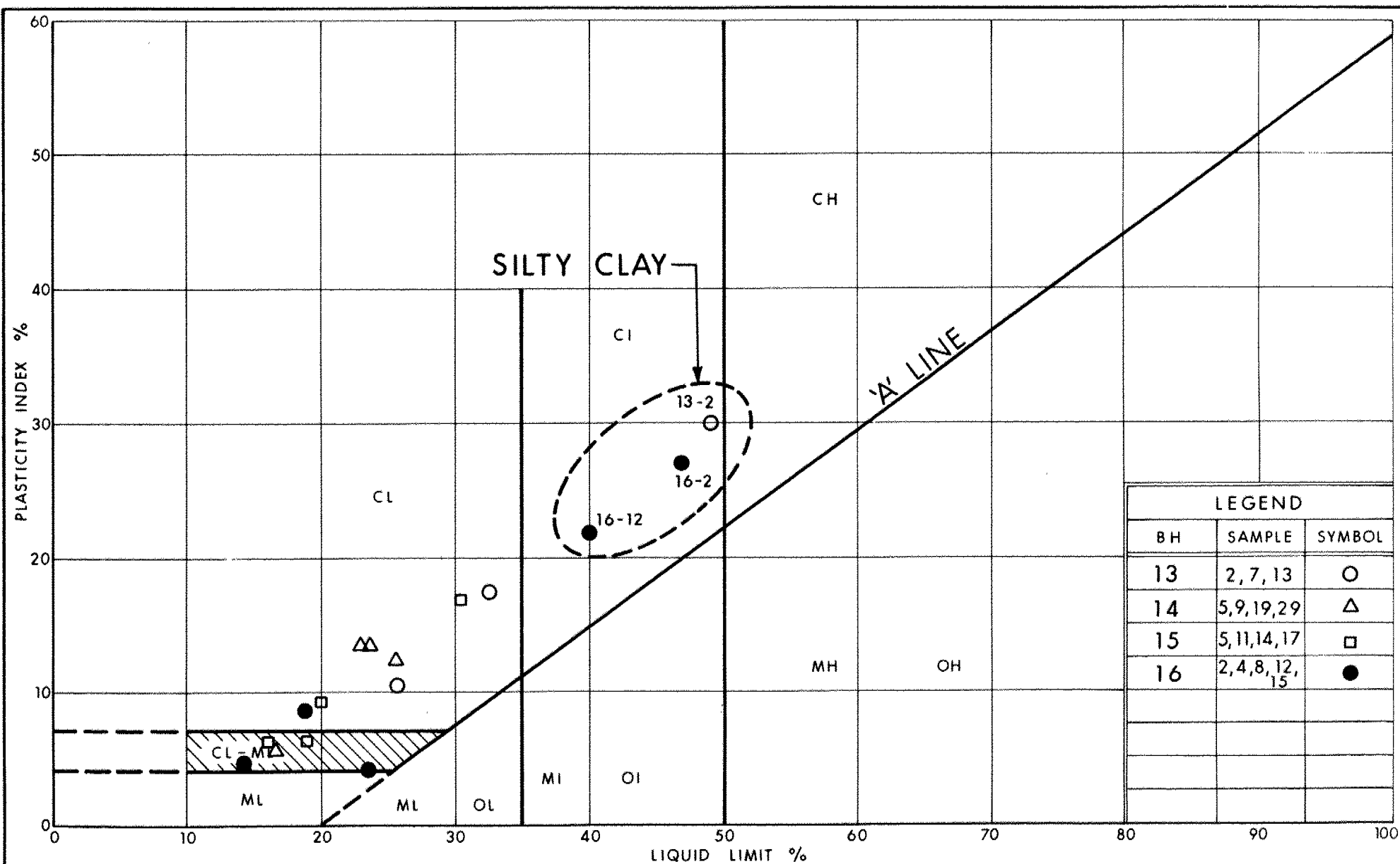
This report was written by T.C. Kim, Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.



Tae C. Kim
Tae C. Kim, P.Eng.
Foundation Engineer

M. Devata
Murty Devata, P.Eng.
Chief Foundation Engineer

APPENDIX



Ministry of
Transportation

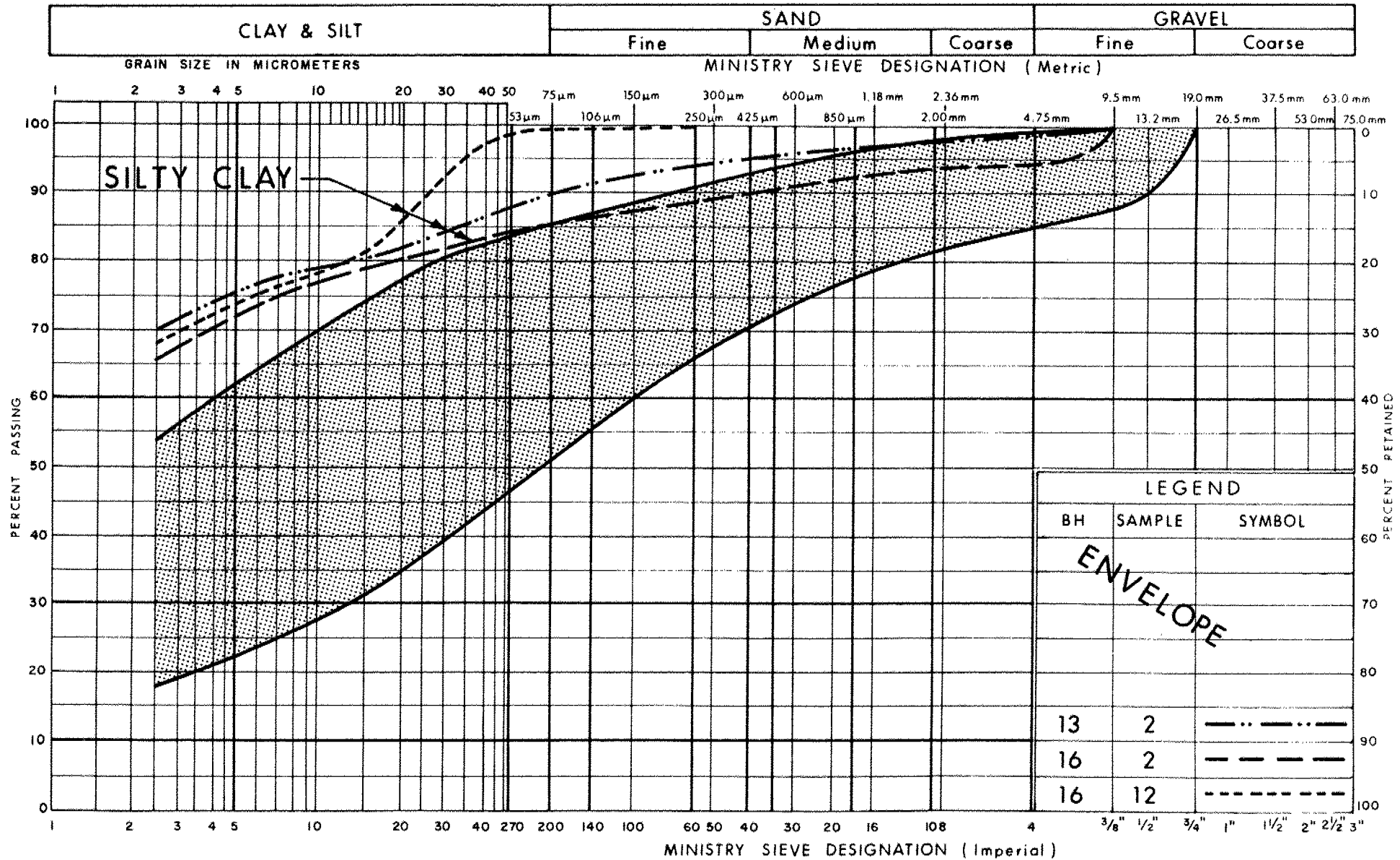
Ontario

PLASTICITY CHART
CLAYEY SILT TO SILT (Glacial Till)
SOME SAND, TRACE OF GRAVEL

FIG No 1

W P 38-87-01

UNIFIED SOIL CLASSIFICATION SYSTEM



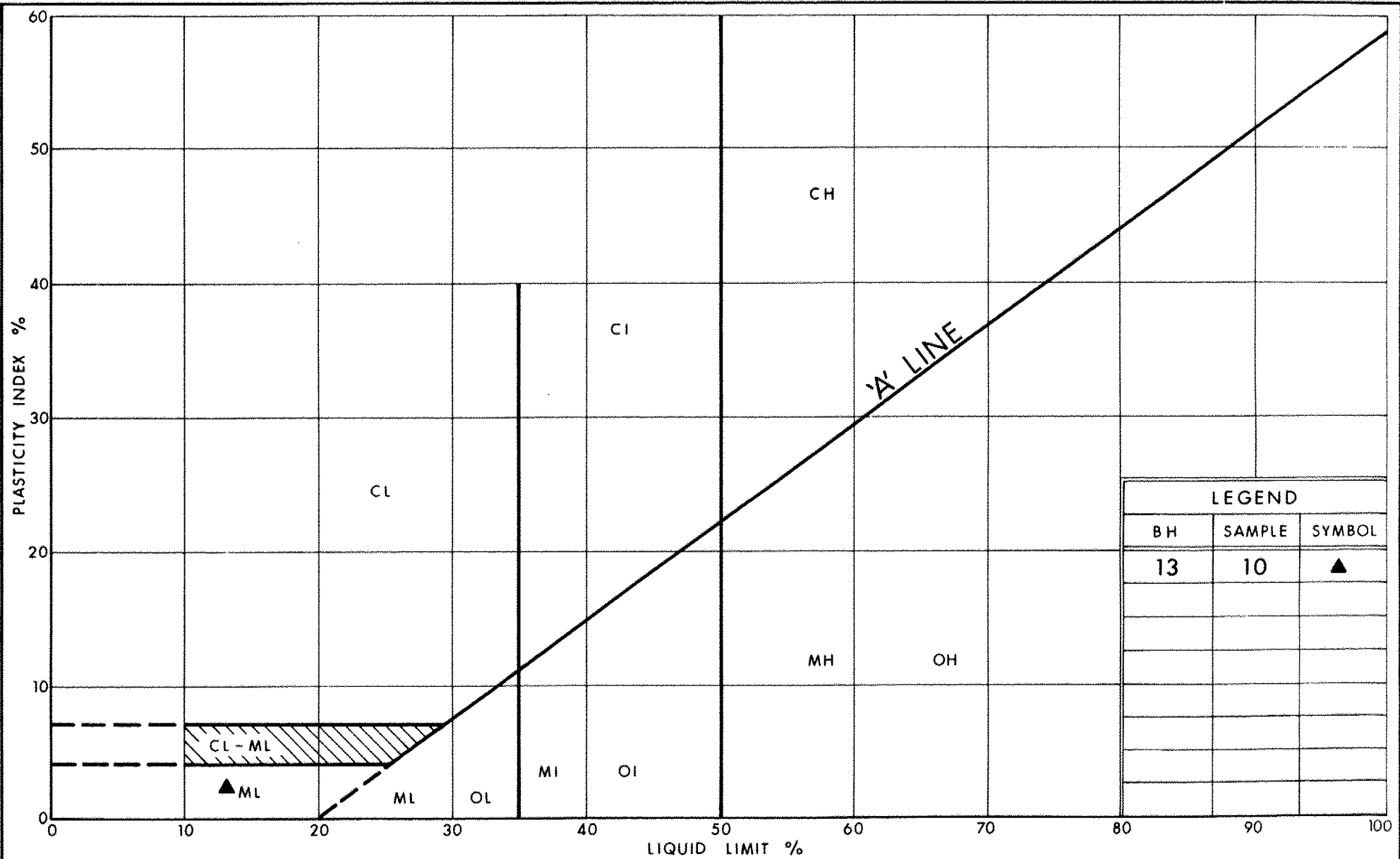
Ministry of
Transportation

Ontario

GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILT (Glacial Till)
 SOME SAND, TRACE OF GRAVEL

FIG No 2

W P 38-87-01



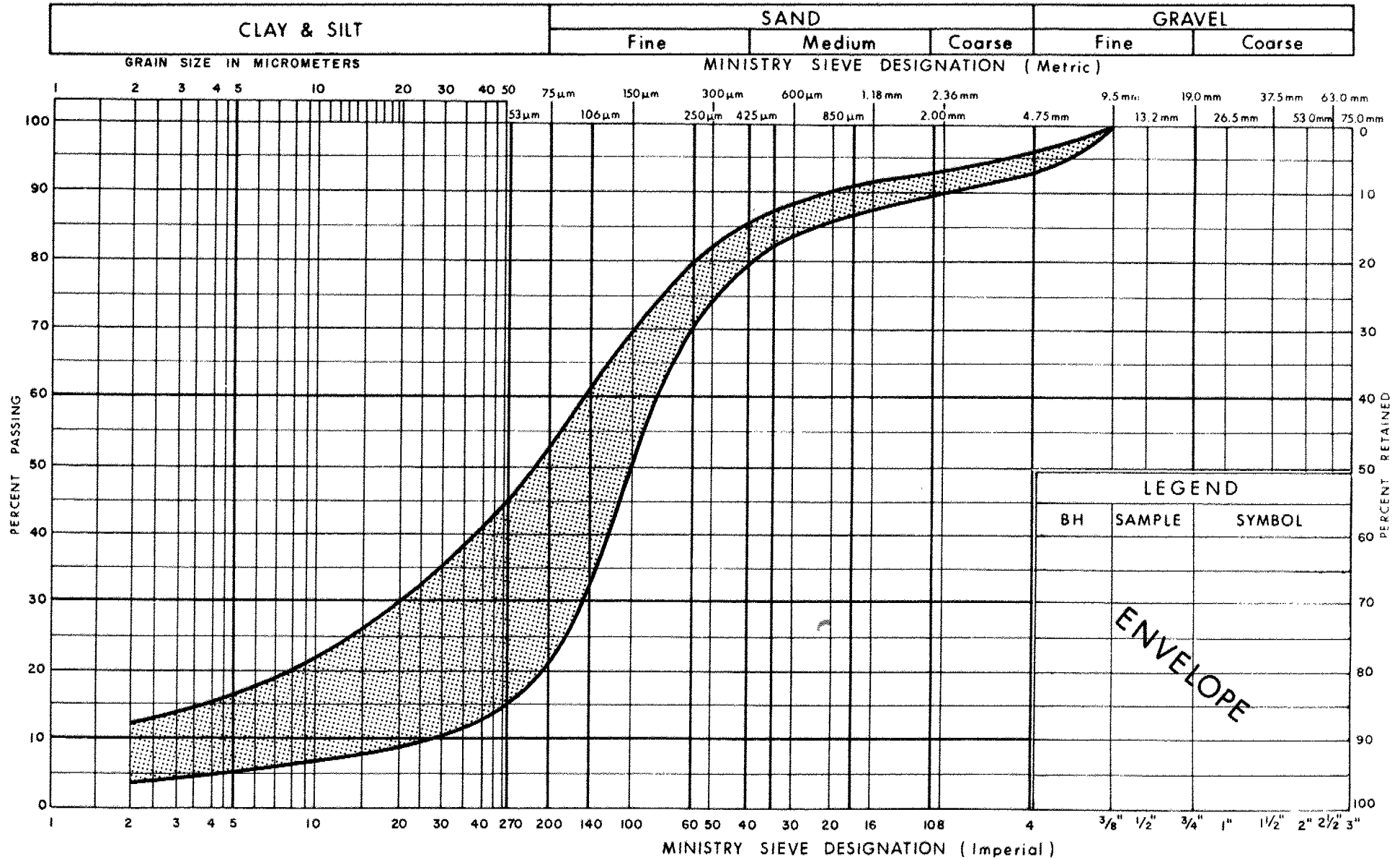
Ministry of
Transportation

PLASTICITY CHART
SILTY SAND, TRACE GRAVEL, CLAY
(Glacial Till)

FIG No 3

W P 38-87-01

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
SILTY SAND, TRACE GRAVEL, CLAY
 (Glacial Till)

FIG No 4

W P 38-87-01

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 1" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	l	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	l	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	l	COMPRESSION INDEX
C_s	l	SWELLING INDEX
C_α	l	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	l	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	l	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	l, %	VOID RATIO	e_{\min}	l, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	l, %	POROSITY	I_D	l	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	l, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	l	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	l	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	l	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	l	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	l, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 3 (Formerly WP 160-74-25) METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 125.5; E 314 812.4 ORIGINATED BY VK
DIST 6 HWY 404 BOREHOLE TYPE Washboring, NX, BX Casing & Cone Test COMPILED BY VK
DATUM Geodetic DATE 1971 01 15 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT Y kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa				Wp	W	WL		
								20 40 60 80 100								
							20 40 60 80 100				10 20 30					
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE				WATER CONTENT (%)					
194.2	Ground Level						194									
0.0	Silty Sand Trace of Clay Compact	Brown Grey	1	SS	24											
			2	SS	27											
191.3			3	SS	15											
2.9	Clayey Silt to Silt Trace of Sand (Till)		4	TW	PM											
189.3	Firm to Stiff		5	TW	PM											
4.9	Silt to Silty Sand Compact		6	SS	22											
186.9			7	SS	14											
7.3	Clayey Silt to Silt Stiff to Very Stiff (Till)		8	SS	12											
			9	TW	PM											
			10	TW	PM											
			11	SS	22											
178.7			12	SS	71											
15.5	Silty Sand Some Gravel Trace of Clay Very Dense															
176.8			13	SS	31											
17.4	Clayey Silt to Silt Trace of Sand and Gravel (Till) Hard		14	SS	165											
168.9			15	SS	71											
25.3	Silty Sand Some Gravel Occ. Clayey Silt Seams (Till) Dense to Very Dense		16	SS	36											
164.0																

Continued

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

Continued



RECORD OF BOREHOLE No 3 Continued METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 125.5; E 314 812.4 ORIGINATED BY VK
DIST 6 HWY 404 BOREHOLE TYPE Washboring, NX, BX Casing & Cone Test COMPILED BY VK
DATUM Geodetic DATE 1971 01 15 CHECKED BY TCK

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 x LAB VANE	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
164.0	Continued										
30.2	Silty Sand, Some Gravel, Occ. Clayey Silt Seams, Dense to Very Dense (Till)										
162.2			17	SS	68		162				
32.0	Clayey Silt to Silt Some Sand (Till) Hard		18	SS	240		160				1 22 60 17
159.2	Silty Sand										
158.7	(Till) Very Dense		19	SS	316						
35.5	End of Borehole										

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 4 (Formerly WP 160-74-25) METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 144.1; E 314 790.4 ORIGINATED BY VK
 DIST 6 HWY 404 BOREHOLE TYPE Washboring, BX Casing and Cone Test COMPILED BY VK
 DATUM Geodetic DATE 1970 12 09 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPo						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE							
194.0	Ground Level														GR SA SI CL
0.0	Sand to Silty Sand Loose to Compact		1	SS	6										
	Brown Grey		2	SS	17		192								2 54 32 12
191.0			3	SS	26										
3.0			4	SS	21		190								
	Clayey Silt to Silt Some Sand Stiff to Hard (Till)		5	SS	13										
			6	SS	15		188								0 16 40 44
			7	SS	17		186								
183.9			8	SS	35										
10.1	Silt to Silty Sand Compact to Dense		9	SS	19		184								
			10	SS	39		182								0 11 82 7
180.9			11	SS	49		180								
13.1	Clayey Silt to Silt Some Sand Trace of Gravel Very Stiff to Hard (Till)		12	SS	184		178						22.5	3	23 52 22
			13	SS	94		176								
			14	SS	29		174								
173.6															
20.4	Silty Sand Some Gravel Compact to Dense (Till)		15	SS	16		172								
							170								
	Clayey Silt		16	SS	30		168								
							166								
			17	SS	34										
164.3							164								
29.7	Clayey Silt to Silt (Till) Hard		18	SS	138										

Continued

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 4 Continued METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 144.1; E 314 790.4 ORIGINATED BY VK
 DIST 6 HWY 404 BOREHOLE TYPE Washboring, BX Casing and Cone Test COMPILED BY VK
 DATUM Geodetic DATE 1970 12 09 CHECKED BY TCK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100				
163.8	Continued														
30.2	Clayey Silt to Silt Trace of Sand and Gravel Hard (Till)					162									
159.9						160									
34.1	Silty Sand Some Gravel Very Dense (Till)		19 SS	150	8 cm	158									
155.9						156									
38.1	End of Borehole														

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 9 (Formerly WP 160-74-25) METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 160.5; E 314 808.1 ORIGINATED BY VK
 DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem Auger and Cone Test COMPILED BY VK
 DATUM Geodetic DATE 1977 02 22 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	Wp W WL	10 20 30		
194.2	Ground Level						194						GR SA SI CL
0.0	Topsoil												
193.4													
0.8	Sandy Silt		1	SS	8								
192.1	Compact		2	SS	11								0 26 72 2
2.1			3	SS	12								
			4	SS	11								
	Silty Sand		5	SS	8								
			6	SS	8								
	Clayey Silt to Silt		7	TW	PM								0 0 55 45
	Stiff to Very Stiff		8	SS	8								
	(Till)		9	SS	7								
			10	SS	8								
185.1													
9.1	Silty Sand to		11	SS	4								0 80 (20)
	Sandy Silt												
182.9	Loose to Compact		12	SS	12								0 55 41 4
	(Till)												
11.3	Clayey Silt to Silt												
	Trace of Sand, Gravel												
181.5	Hard (Till)		13	SS	28								
12.7	End of Borehole												

RECORD OF BOREHOLE No 10 (Formerly WP 160-74-25) METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 120.9; E 314 793.8 ORIGINATED BY VK
DIST 6 HWY 404 BOREHOLE TYPE Solid Stem Auger and Cone Test COMPILED BY VK
DATUM Geodetic DATE 1977 02 25 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
194.2	Ground Level													
0.0	Topsoil						194							GR SA SI CL
	Clayey Silt to Silt (Till)		1	SS	19									0 0 78 22
	Stiff to Silty Sand		2	SS	33		192							0 9 87 4
191.0	Very Stiff		3	SS	13									
3.2	Silty Sand		4	SS	8									0 22 63 15
189.3	Loose to Compact Clayey Silt		5	SS	10		190							
4.9	Clayey Silt to Silt Occ. Silty Clay Layers		6	SS	7									0 13 39 48
	Firm to Stiff (Till)		7	SS	6		188							0 1 29 70
186.2			8	TW	PM									
8.0	Silt to Silty Sand Loose to Dense (Till)		9	SS	13		186							0 39 56 5
			10	SS	9									
			11	SS	13		184							
182.9	Clayey Silt to Silt Some Sand		12	SS	39									
11.3	Hard (Till)		13	SS	42									0 15 42 43
182.0														
12.2	End of Borehole													

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF BOREHOLE No 13

METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 163.3; E 314 826.8 ORIGINATED BY KZ
DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem Auger, NX-Casing, Washboring & Cone Test COMPILED BY KZ
DATUM Geodetic DATE 88 06 17, 20, 21 CHECKED BY TCK

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			NATURAL MOISTURE CONTENT LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	W	LIQUID LIMIT W _L		
189.5	Ground Level												
0.0 188.9	Sand & Gravel (Fill)												
0.6	Fine Sand Trace of Silt and Gravel Very Loose		1	SS	2		188						
186.3	Brown Grey		2	SS	2		186					49%	1 10 23 66
3.2	Silty Sand Trace of Clay and Gravel		3	SS	8		184						
	Clayey Silt to Silt Some Sand Trace of Gravel Occ. Silty Clay Layers Soft to Hard (Till)		4	SS	16		182						
			5	SS	14		180						
			6	SS	68		178						
			7	SS	51		174						0 11 57 32
172.5	Silty Sand Trace of Clay (Lacustrine) Very Loose		8	SS	1		172						
17.0			9	SS	9		170						
169.5	Silty Sand Trace of Gravel and Clay Occ. Silt Layers Loose to Compact (Till)		10	SS	11		168						
20.0			11	SS	62		166						5 44 40 11
161.8	Silty Sand Very Dense (Lacustrine)						164						
27.7							162						
159.3							160						
30.2													

Continued

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 13 Continued METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 163.3; E 314 826.8 ORIGINATED BY KZ
 DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem Auger, NX-Casing, Washboring, Cone Test COMPILED BY KZ
 DATUM Geodetic DATE 88 06 17, 20, 21 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
159.3	Continued														
30.2	Silty Sand (Lacustrine)						158								
156.5			11A	WS	-										
33.0	Clayey Silt to Silt Some Sand Trace of Gravel (Till) Hard		12	SS	118/	23cm	156								
152.7							154								
36.8	End of Borehole		13	SS	60/	10cm									3 18 38 41

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 14

METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 144.8; E 314 831.3 ORIGINATED BY KZ
 DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem, NX-Casing, Washboring, Cone Test COMPILED BY KZ
 DATUM Geodetic DATE 88 06 7 - 10 CHECKED BY TCK

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W		
189.6	Ground Level											
0.0	Sand and Gravel											
188.7	(Fill) Brown		1	SS	5							
0.9	Grey		2	SS	14							
	Sand		3	SS	8							
	Trace of Silt		4	SS	14							
	Clayey Silt to Silt		5	SS	16							
	Some Sand		6	SS	19							
	Trace of Gravel		7	SS	41							
	Occ. Silt Layers		8	SS	64							
	(Till)		9	SS	43							
	Stiff to Hard		10	SS	36							
176.4			11	SS	17							
13.2	Silt, Trace of		12	SS	15							
174.9	Clay and Sand		13	SS	8							
14.7	Compact		14	SS	10							
	Silty Sand		15	SS	11							
	Trace of Clay		16	SS	22							
	and Gravel		17	SS	18							
	(Till)		18	SS	41							
	Loose to Compact		19	SS	53							
170.3			20	SS	49							
19.3	Clayey Silt to Silt		21	SS	31							
	With/Some Sand											
	Some Gravel											
	Occ. Silt and Sand											
	Layers											
	(Till)											
	Stiff to Hard											
162.7	Clayey Silt											
26.9	(Lacustrine)											
161.2	Hard											
28.4	Silty Sand											
	(Lacustrine)											
159.4	Dense to Very Dense											
30.2												

Continued

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

Continued



RECORD OF BOREHOLE No 14 Continued METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 144.8 E 314 831.3 ORIGINATED BY KZ
DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem, NX-Casing, Washboring, Cone Test COMPILED BY KZ
DATUM Geodetic DATE 88 06 7, 8, 9, 10 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPa					
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL x LAB VANE						
</														

RECORD OF BOREHOLE No 15

METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 142.9; E 314 771.9 ORIGINATED BY KZ
 DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem, NX Casing, Washboring, Cone Test COMPILED BY KZ
 DATUM Geodetic DATE 88 06 15, 16 CHECKED BY TCK

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W		
189.3	Ground Level											
0.0	Sand and Gravel (Fill)											
188.7	Brown Grey											
0.6	Clayey Silt		1	SS	6		188					
186.8	Some Sand											
2.5	Firm		2	SS	23		186					
	Clayey Silt											
	Silty Sand to		3	SS	6		184					0 12 77 11
183.7	Sand Silt											
5.6	Loose to Dense		4	SS	3		182					4 14 31 51
	Clayey Silt to Silt		5	SS	5		180					
179.2	Some Sand		6	SS	15							
10.1	Trace Gravel		7	SS	1		178					
	Occ. Silt Pockets		8	SS	29							
176.1	(Till)		9	SS	16		176					
13.2	Soft to Stiff		10	SS	12		174					
	Clayey Silt to Silt		11	SS	34		172					2 22 49 27
	Some Sand		12	SS	20		170					
	Trace of Gravel											
	(Till)		13	SS	1		168					
167.7	Stiff to Hard											
21.6	Silty Sand		14	SS	40		166					4 28 43 25
	Trace of Gravel											
164.7	(Till)		15	SS	7		164					
24.6	Very Loose						162					
	Clayey Silt to Silt											
161.6	with Sand						160					
27.7	Trace of Gravel											
	(Till)											
	Hard											
	Fine Sand											
	Loose											
159.1												
30.2												

Continued

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

Continued



RECORD OF BOREHOLE No 15 Continued METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 142.9; E 314 771.9 ORIGINATED BY KZ
DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem, NX Casing, Washboring, Cone Test COMPILED BY KZ
DATUM Geodetic DATE 88 06 15, 16 CHECKED BY TCK

SOIL PROFILE		STRAT PLOT	SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION		NUMBER	TYPE			'N' VALUES	20 40 60 80 100					
159.1	Continued												GR SA SI CL
30.2													
156.3													
33.0	Clayey Silt to Silt With Sand Some Gravel (Till) Hard		15A	WS	-								10 38 37 15
			16	SS	128								
152.4													
36.9	End of Borehole		17	SS	176								

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 16

METRIC

W P 38-87-01 LOCATION Co-ords. N 4 858 122.3; E 314 777.1 ORIGINATED BY KZ
 DIST 6 HWY 404 BOREHOLE TYPE Hollow Stem, NX-Casing, Washboring, Cone Test COMPILED BY KZ
 DATUM Geodetic DATE 88 06 10, 13, 14 CHECKED BY TCK

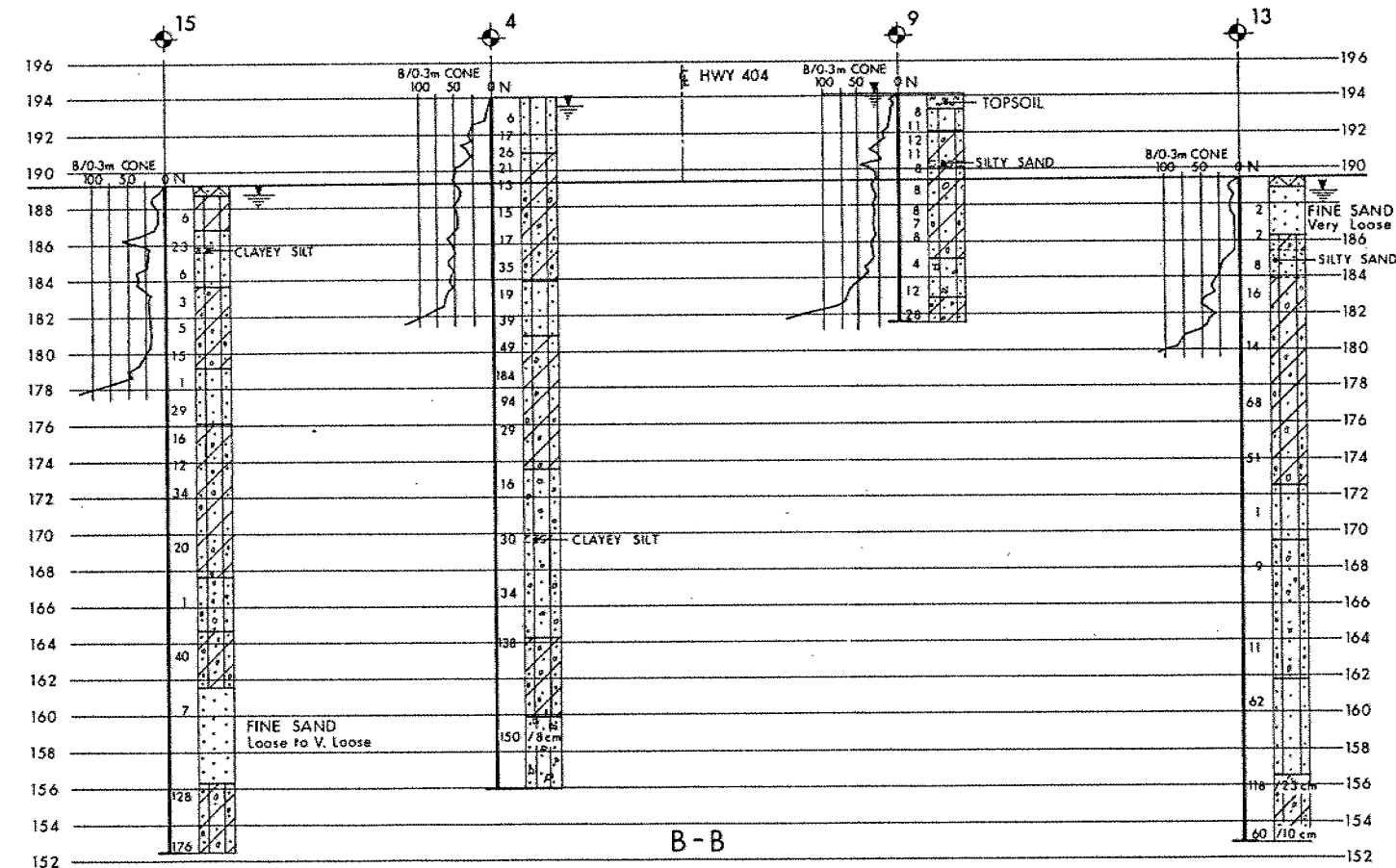
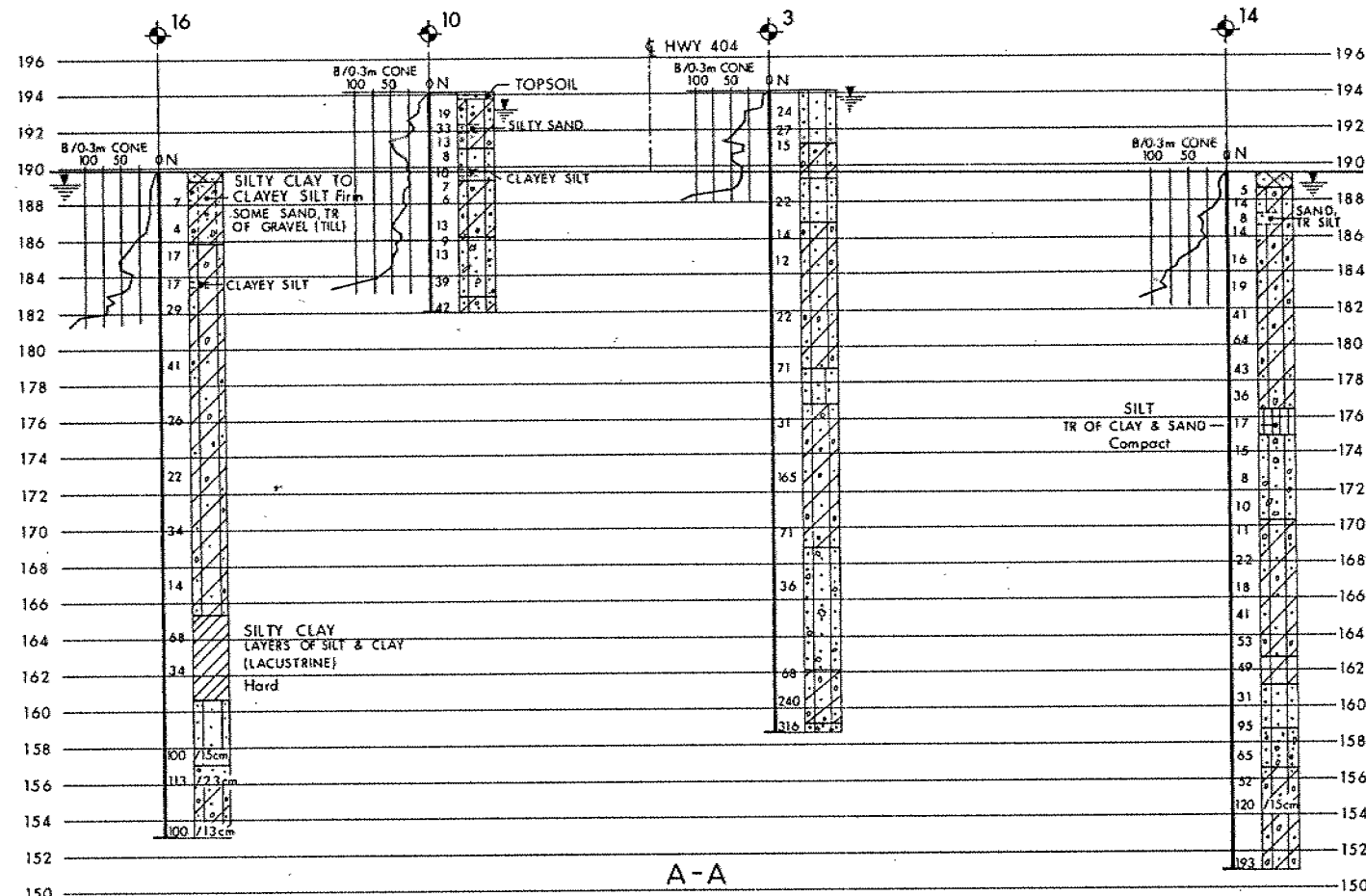
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
189.9	Ground Level											
189.3 0.6	Sand and Gravel (Fill) Brown Grey											
	Silty Clay to Clayey Silt Some Sand Trace of Gravel (Till) Firm		1	SS	7		188					
185.9 4.0			2	SS	4		186					5 10 21 64
	Clayey Silt		3	SS	17		184					0 0 95 5
			4	SS	17		182					
			5	SS	29		180					
	Clayey Silt to Silt		6	SS	41		178					
	Some Sand						176					
	Trace of Gravel (Till)		7	SS	26		174					
	Occ. Silt and Sand Pockets						172					
	Stiff to Hard		8	SS	22		170					6 34 45 15
			9	SS	34		168					
			10	SS	14		166					
165.3 24.6	Silty Clay (Lacustrine) Layers of Silt and Clay Hard		11	SS	68		164					
			12	SS	34		162					0 0 33 67
160.7 29.2	Fine Sand to Silty Sand						160					
159.7 30.2	(Lacustrine)											

Continued

+3, x5: Numbers refer to
Sensitivity

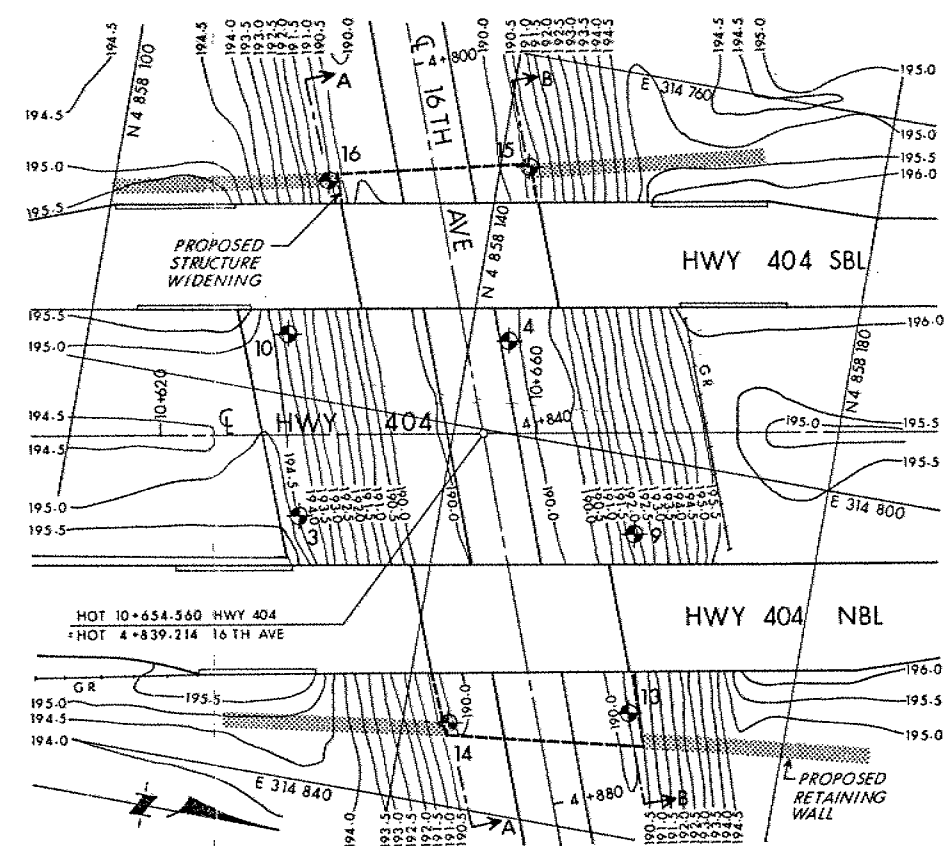
20
15 \div 5 (%) STRAIN AT FAILURE
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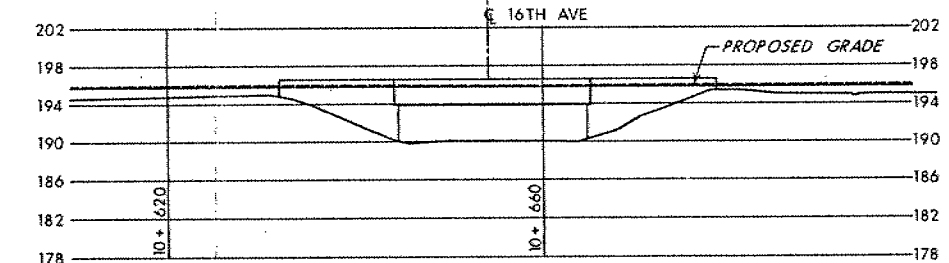
SECTIONS

SCALE
4m 2 0 4m



PLAN

SCALE
8m 4 0 8m



PROFILE HWY 404

SCALE
8m 4 0 8m

SOIL STRATIGRAPHY LEGEND

- SAND & GRAVEL (FILL)
- CLAYEY SILT TO SILT
TRACE OF SAND
TRACE OF GRAVEL
OCCASIONAL SILT & SILTY CLAY
LAYERS, OCCASIONAL SILT & SAND
POCKETS
Soft to Hard
(TILL)
- SILTY SAND TO SANDY SILT
TRACE GRAVEL, CLAY
Very Loose to Very Dense
(LACUSTRINE)
- SILTY SAND
TRACE OF CLAY
TRACE/SOME GRAVEL
Very Loose to Very Dense
(TILL)
- CLAYEY SILT
SOME SAND
Firm to Hard
(LACUSTRINE)

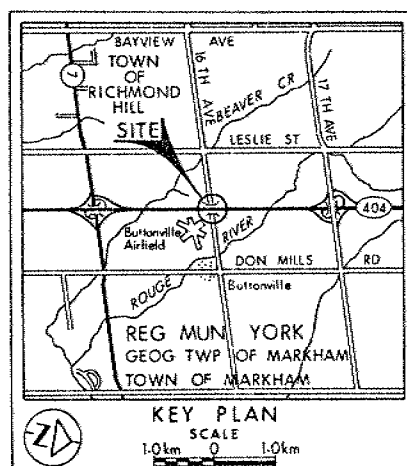
CONT No
WP No 38-87-01

16TH AVE

BORE HOLE LOCATIONS & SOIL STRATA



SHEET



LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation
70 12, 71 01, 77 02 and 88 06

No	ELEVATION	CO-ORDINATES NORTH	EAST
71 01	3	194.2	4 858 125.5 314 812.4
70 12	4	194.0	4 858 144.1 314 790.4
77 02	9	194.2	4 858 160.5 314 809.1
	10	194.2	4 858 120.9 314 793.8
	13	189.5	4 858 163.3 314 826.8
	14	189.6	4 858 144.8 314 831.3
88 06	15	189.3	4 858 142.9 314 771.9
	16	189.9	4 858 122.3 314 777.1

NOTE

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

Geacres No 30M14-192	HWY No 404	DIST 6
SUBMITTAL CHECKED	DATE 88 09 14	SITE 37-666
DRAWN BY	CHECKED	DWG 388701-A



APPENDIX B

Previous General Arrangement Drawing

