

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
VICTORIA STREET UNDERPASS
HIGHWAY 7-NEW, KITCHENER TO GUELPH
G.W.P. 408-88-00**

Geocres Number: 40P8-202

Report to

**Ministry of Transportation Ontario
West Region**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents factual information that may be used in the preliminary design of the foundations of a new structure that will carry Victoria Street over the Kitchener-Waterloo Expressway (KWE) in the Regional Municipality of Waterloo. The new underpass structure will incorporate two new ramps, S-E ramp on the east end of the underpass and E-S ramp and Edna Street connector at the west end of the underpass. The proposed new underpass structure is part of the Highway 7-New project.

It is understood that an alternate design is being considered for this site and consists of extending the existing structure on both sides (west and east) to accommodate the two new ramps: S-E ramp on the east end and E-S ramp/Edna Street connector at the west end.

For preparation of this report, no boreholes were drilled within the footprint of the proposed structure. This report is based on information on subsurface conditions contained in previous foundation reports prepared in 1966 and 2009. The titles of the reports are listed as follows:

- Foundation investigation report for Victoria Street Underpass, Kitchener-Waterloo Expressway, District #4 (Hamilton), W.J. 66-F-36, W.P.635-64, Geocres No. 40P8-44, dated June 17, 1966, prepared by DHO (Department of Highways Ontario, Reference 1).
- Preliminary foundation investigation and design report, E-S ramp and connector street under Victoria Street, Highway 7-New, Kitchener to Guelph, G.W.P. 408-88-00, Geocres No. 40P8-158, prepared by Thurber, dated November 10, 2009. (Reference 2).

Records of boreholes from the previous reports are attached in Appendix A for reference.

A site investigation, field testing and engineering analysis will be required at the detail design stage. The detailed design must be based on site-specific investigation at the foundation elements.

Thurber carried out the investigation for the Ministry of Transportation Ontario, West Region (MTO) under Purchase Order Number 3006-E-0123.

2 SITE DESCRIPTION

The site is located near the eastern limits of the City of Kitchener, approximately 380 m south of the Kitchener-Waterloo Expressway (KWE) and Wellington Street interchange. At this location, an underpass structure carries Victoria Street over the northbound and southbound lanes (NBL and SBL) of the KWE and existing E-S and S-E ramps. The existing underpass at KWE and Victoria Street is a four-span structure supported on two abutments and three piers.

The site lies within an area of industrial and commercial lands and is generally flat.

Based on the Ontario Geological Survey Special Volume 2, The Physiography of Southern Ontario, Third Edition by Chapman and Putnam, the site lies within the physiographic region known as the Waterloo Hills, characterized by ridges of sandy till and kames or kame moraines, with outwash sands occupying the intervening hollows.

The following photographs of the site are included in Appendix E and show the general nature of the surrounding lands:

1. An aerial view of Kitchener-Waterloo Expressway and Victoria Street.
2. A view looking at the south side of the existing structure at Kitchener-Waterloo Expressway and Victoria Street underpass.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at this site was carried out by DHO from April 21 to 29, 1966 (Reference 1) and consisted of drilling and sampling a total of eight boreholes within the underpass area. Eight dynamic cone penetration tests (DCPTs) were conducted adjacent to the boreholes and seven DCPTs were conducted at various locations covering the underpass area. The Boreholes and DCPTs were identified as Boreholes 1 to 15.

Boreholes 1, 4, 5, 8, 9, 12, 13 and 15 were terminated at depths ranging from 11.2 m to 14.2 m (elevations 305.9 to 309.5). DCPTs were terminated upon refusal at 3.0 m to 6.1 m depth (elevations 315.5 to 319.5).

Two boreholes (numbered 08-047 and 08-048) were drilled by Thurber near the proposed west extension of the existing bridge on June 17, 25 and 26, 2008. The depths of Boreholes 08-047 and 08-048 were 18.7 m and 21.6 m (Elevations 305.0 and 301.7), respectively.

The Record of Borehole sheets and DCPTs are included in Appendix A. The approximate locations of the boreholes and DCPTs relative to the Victoria Street Underpass GA are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix F.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Selected samples were subjected to gradation analysis and Atterberg Limits testing. The results of this testing program are shown on the Record of Borehole sheets in Appendix A. Grain size analysis distribution curves and Atterberg Limits testing results are included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy along the proposed alignment are presented in this appendix and on the “Borehole Locations and Soil Strata” drawing in Appendix F. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

It should be recognized that since these boreholes were drilled in 1966, it is possible that the current ground surface elevations may differ and the actual subsurface stratigraphy may have been modified by construction of cuts and addition of fills.

In general, at the time of the 1966 investigation, the site was underlain by topsoil overlying native layers of loose to dense sand and sandy silt/silty sand, and very stiff to hard clayey silt/silty clay.

Boreholes 08-47 and 08-48, drilled at the west end of the existing underpass, revealed topsoil or pavement structure and granular fill overlying native loose to dense sand, very stiff to hard silty clay till and silty clay and very dense silt till.

5.1 Topsoil and organics

Topsoil and soft organics were encountered surficially at the following boreholes:

| <u>Boreholes</u> | <u>Thickness</u> |
|------------------|-------------------|
| 1 | 760 mm (organics) |
| 13 and 15 | 300 mm |
| 08-48 | 200 mm |

5.2 Pavement structure

Pavement structure consisting of approximately 65 mm of asphalt overlying granular (sand and gravel) fill was encountered in Borehole 08-047 drilled on a residential drive way, in close proximity to the Victoria Street lane.

5.3 Fill

Fill was encountered surficially in Boreholes 4, 5, 8, 9, and 12 and below the pavement structure and topsoil in Boreholes 08-47 and 08-48. The fill consists of silty sand

containing trace gravel to gravelly, trace clay to clayey, occasional organics, some rubbish, layer of asphalt and numerous cobbles

The thickness of the fill varied from 1.7 m to 4.6 m. The base of the fill was encountered between elevations 316.9 and 320.7.

The fill is classified as very loose to very dense based on SPT 'N' values of 3 to 90 blows for 0.3 m of penetration. The 90 blows may represent spoon bouncing on cobbles or rock piece.

The natural moisture content ranged from 5% to 25%.

Grain size distribution curve for a gravelly sand fill sample is presented on the Record of Borehole sheets and on Figure B1 of Appendix B. The results of the laboratory tests are summarized as follows:

| Soil Particles | (%) |
|----------------|-----|
| Gravel | 44 |
| Sand | 42 |
| Silt & Clay | 14 |

5.4 Silty Sand

Native silty sand was encountered below the fill in Boreholes 4, 8, and 12, and below the topsoil in Boreholes 1, 13, and 15. The thickness of the silty sand varied from 0.8 m to 5.6 m.

The depth to the base of the silty sand varied from 3.2 m to 6.4 m (elevations 318.4 and 315.8).

SPT 'N' values recorded in the silty sand ranged from 1 blow for 0.3 m penetration to 70 blows for 0.15 m penetration, indicating a very loose to very dense condition. The natural moisture content ranged from 7% to 25%.

The results of grain size distribution testing of selected samples of the silty sand are presented on the Record of Borehole sheets in Appendix A. The results of these laboratory tests are summarized as follows:

| Soil Particles | (%) |
|----------------|----------|
| Gravel | 1 |
| Sand | 55 to 90 |
| Silt | 30 to 42 |
| Clay | 1 to 2 |
| Silt & Clay | 9 |

5.5 Sand

Native brown sand containing trace silt and trace gravel was encountered below the fill in Boreholes 08-47 and 08-48. The depths to the base of the native sand were 5.6 m and 8.1 m (Elevations 318.2 and 315.3), in Boreholes 08-047 and 08-048, respectively.

A 300-mm layer of sand was encountered in Borehole 08-048 at 10.7 m depth (Elevation 312.7).

The sand is classified as loose to dense, based on SPT 'N' values of 6 to 37 blows for 0.3 m of penetration. The natural moisture content ranged from 8 to 19%.

Grain size distribution curves for three selected samples of sand are presented on the Record of Borehole sheets and on Figure B2 of Appendix B. The results of the laboratory tests are summarized as follows:

| Soil Particles | (%) |
|----------------|----------|
| Gravel | 0 to 1 |
| Sand | 89 to 94 |
| Silt & Clay | 6 to 11 |

5.6 Clayey Silt/Silty Clay and Silty Clay Till

Native brown to grey silty clay/clayey silt and silty clay till containing some sand to sandy, trace gravel and occasional sand seams were contacted below the native sand and silty sand layers. The clayey silt/silty clay and silty clay till were contacted at depths ranging from 3.1 m to 8.1 m (elevations 315.3 to 318.7).

The silty clay and silty clay till extended to 17.8 m and at least 21.6 m (Elevations 306.0 and 301.7) in Boreholes 08-047 and 08-048, respectively.

Boreholes 1, 4, 5, 8, 9, 12, 13 and 15 were terminated within the clayey silt/silty clay at depths ranging from 11.2 m to 14.2 m (elevations 305.9 to 309.5). Borehole 08-048 was terminated within the silty clay till layer at 21.6 m (elevation 301.7).

The cohesive layer is very stiff to hard in consistency, based on SPT 'N' values ranging from 22 blows for 0.3 m penetration to 60 blows for 0.1 m penetration. SPT 'N' values higher than 100 blows per 0.3 m of penetration, indicating a hard consistency, were measured below 15.2 m and 18.3 m depth (Elevations 308.6 and 305.1) in Boreholes 08-047 and 08-048, respectively.

The moisture content varied from 8% to 29%.

Grain size distribution curves for selected samples of silty clay and silty clay till are presented on the Record of Borehole sheets and on Figure B3 of Appendix B. Atterberg

Limits test results are presented on Figure B5 of Appendix B. The results of these laboratory tests are summarized as follows:

| Soil Particles | (%) |
|-----------------------|------------|
| Gravel | 0 to 15 |
| Sand | 0 to 36 |
| Silt | 31 to 78 |
| Clay | 18 to 63 |

| | |
|---------------|----------|
| Liquid Limit | 21 to 43 |
| Plastic Limit | 12 to 20 |

The above results show that the silty clay/clayey silt and silty clay till are of low to medium plasticity with group symbols of CL-CI.

Although not encountered in the boreholes, this glacial till layer may contain cobbles and boulders which may account for some high SPT 'N' values.

5.7 Silt Till

Grey silt till was contacted below the silty clay in Borehole 08-047, at 17.8 m (Elevation 306.0). Borehole 08-047 was terminated within the silt till at 18.7 m depth (Elevation 305.0).

SPT 'N' value in this layer was 103 blows per 0.3 m of penetration, indicating a very dense relative density. Moisture content was 18%.

Grain size distribution curve for a silt till sample is presented on the Record of Borehole sheets and on Figure B4 of Appendix B. The results of the laboratory tests are summarized as follows:

| Soil Particles | (%) |
|-----------------------|------------|
| Gravel | 0 |
| Sand | 5 |
| Silt | 89 |
| Clay | 6 |

Although not encountered in the boreholes, this glacial till layer may contain cobbles and boulders which may account for the high SPT 'N' value.

5.8 Groundwater Conditions

In 1966, water levels were observed during drilling at depths ranging from 0.5 m to 1.7 m below ground surface (elevations 319.3 to 321.8). These water levels may have been affected by subsequent construction of the underpass.

Water levels were observed at 16.8 m and 5.5 m depth (Elevations 307.0 and 317.9) in Boreholes 08-047 and 08-048, respectively, during and upon completion of drilling in 2008 (Reference 2).

The water level condition at this site should be confirmed during additional field investigation required for the detailed design.

Seasonal fluctuations of the groundwater level are to be expected, in particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

6 MISCELLANEOUS

All-Terrain Drilling of Waterloo, Ontario supplied a truck-mounted CME75 drill rig and conducted the drilling, sampling and in-situ testing operations in 2008.

The coordinates and the ground surface elevations for Boreholes 08-47 and 08-48 were determined by Thurber Engineering Ltd. using GPS equipment.

Interpretation of the 1966 and 2008 borehole data and preparation of the report were carried out by Ms. Lindsey Blaine, E.I.T. and Ms. R. Palomeque Reyna, P.Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects, reviewed the report.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents preliminary geotechnical design recommendations to assist the design team to select and design a suitable foundation system for the proposed underpass structure.

The existing Victoria Street underpass at KWE is a four-span structure supported on two abutments and three piers.

Two design alternatives are proposed for the underpass structure at this site:

1. Replacement of the existing underpass structure.

A new four-span structure supported on three piers and two abutments is proposed. The total length of the bridge is 129 m. The lengths of the spans will be 35 m, 37 m, 34 m and 23 m. The new structure will incorporate two new ramps: S-E ramp at the east end of the structure and E-S ramp/Edna Street connector at the west end of the structure.

Based on the GA drawing, the proposed Victoria Street grade will be approximately at elevation 325.2. The proposed road grades for the new S-E and E-S ramps are near elevations 317.8 and 319.0, respectively. Previous boreholes drilled in 1966 near the existing east abutment (S-E ramp) indicated that the ground surface elevation was near elevation 321.8. Based on these elevations, a cut of approximately 6.0 m depth will be required at the east end of the underpass to construct the proposed S-E ramp under Victoria Street. Boreholes drilled in 2008 at the west end of the structure (E-S ramp), revealed that the ground surface elevation ranged from elevations 323.4 to 323.8. At the west end of the underpass, a cut of 5.6 m to 6.0 m will be required to construct the E-S ramp under Victoria Street.

2. Extensions of the existing underpass structure to the east and west to accommodate the new ramps.

Maintain the existing structure and extend it on both sides, east and west, to accommodate the new S-E and E-S ramps. The new underpass extensions will carry Victoria Street over the proposed ramps. The GA drawing indicates that at the existing abutments, the existing expansion joints, ballast wall, wingwalls, approach slab and part of the parapet wall and railing will be removed. The existing east and west abutments and footings will be maintained. New abutment and associated foundations will be required for the proposed bridge extensions. Each underpass extension will be founded on two new abutments.

The proposed bridge extensions are approximately 22.0 m and 30.0 m long on the east and west sides, respectively. The width of Victoria Street underpass will be approximately 18.9 m.

Cuts on the east and west sides of the underpass will also be required for this alternative. Cuts to pass both ramps under Victoria Street will be in the order of 6.2 m depth at the east end and 5.6 m to 6.0 m depth at the west end.

Preliminary geotechnical/foundation recommendations for the proposed E-S ramp and Edna Street connector under Victoria Street, on the west end of the underpass, were addressed in a previous foundation report prepared by Thurber in 2009, Geocres No. 40P8-158, Reference 2.

The discussion and recommendations presented in this report are based on the bridge design alternative information available from the MMM Group and on the factual data obtained in the previous investigations.

8 STRUCTURE FOUNDATIONS

The stratigraphy at this site consists primarily of topsoil, pavement structure and fill overlying native layers of loose to dense silty sand/sand and, very stiff to hard clayey silt, silty clay and silty clay till.

In 1966, water levels were observed during drilling at depths ranging from 0.5 m to 1.7 m below ground surface (elevations 319.3 to 321.8). In 2008, water levels were observed at 16.8 m and 5.5 m depth (Elevations 307.0 and 317.9).

In the preparation of the preliminary foundation design recommendations, consideration was given to the following foundation types:

- Spread footings bearing on native soil
- Spread footings on engineered fill
- Steel H-piles or steel pipe piles driven into hard soils

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix C.

8.1 Spread Footings on Native Soil

The new underpass structure or the proposed bridge extensions may be supported on spread footings bearing on competent undisturbed native soils.

Provided a minimum footing width of 3 m is maintained, the design of spread footings bearing on native undisturbed compact to dense sand or very stiff silty clay till should be in accordance with the elevations and bearing resistances given in Table 8.1.

Table 8.1 – Bearing Resistances for Spread Footings

| Foundation Unit | Borehole | Depth (m) | Elevation | ULS _f (kPa) | SLS (kPa) | Soil |
|---|----------------|--------------------------|----------------------------|------------------------|-----------|--|
| East Abutment of the replacement structure option Or New abutments for S-E ramp for bridge extension option | 13 | 2.0 ⁽¹⁾ | Below 317.0 ⁽¹⁾ | 450 | 300 | Hard clayey silt/silty clay |
| | | 3.5 ⁽¹⁾ | 315.5 ⁽¹⁾ | 600 | 400 | |
| Pier 3 Pier 2 | 12 | 1.5 ⁽²⁾ | Below 317.0 ⁽²⁾ | 450 | 300 | Hard silty clay/clayey silt |
| | 8 | 3.0 ⁽²⁾ | 315.5 ⁽²⁾ | 600 | 400 | |
| Pier 1 | 4 | 1.5 ⁽²⁾ | Below 317.0 ⁽²⁾ | 450 | 400 | |
| West abutment of the replacement structure option or New abutments for E-S ramp and Edna Street connector | 08-47 08-48 | Below 0.5 ⁽³⁾ | Below 317.0 ⁽³⁾ | 450 | 300 | Compact to dense sand/very stiff silty clay till |

⁽¹⁾ Depths/elevations below the proposed S-E ramp grade shown in GA (elevation 319.0).

⁽²⁾ Depths/elevations below the existing KWE grade shown in GA (approx. elevation 318.5).

⁽³⁾ Depths/elevations below the proposed E-S ramp grade shown in GA (approx. elevation 317.8).

The bearing resistances in Table 8.1 are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be adjusted as shown in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4.

The ultimate friction factor for sliding resistance on the native soils may be assumed to be 0.45 for sand and 0.4 for silty clay/clayey silt or silty clay till.

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction. Differential settlement is not expected to exceed 20 mm across the width of the structure or between foundation elements.

If extensions of the existing underpass to the east and west are the selected design option, the footings of the existing east and west abutments will be maintained and new foundations (spread footings) for the two new west and east abutments will be constructed. In this case, it is recommended that all new footings adjacent to an existing footing, be founded at similar elevations as the existing footings, where possible, such that the latter will not be undermined. It is critical for the designer to have accurate information on footing base elevations and outlines of existing footing footprints to avoid interference between new and existing footings.

In 1966, water levels were observed during drilling at depths ranging from 0.5 m to 1.7 m below ground surface (elevations 319.3 to 321.8). However, the construction of the highway, installation of drainage, etc., may have impacted the groundwater level. In 2008, water levels were observed at 16.8 m and 5.5 m depth (Elevations 307.0 and 317.9). These elevations show a wide range, therefore further investigation is required to establish the present water level at this site.

If temporary excavations required to construct these footings extend below the water table, dewatering and groundwater lowering and control will be required prior to excavation to construct the footings in the dry.

8.2 Spread Footings on Engineered Fill

Spread footings can also be founded on Granular “A” engineered fill pads. These may be useful in the case of perched abutments on footings for the bridge replacement option.

If an engineered fill pad is used, all topsoil, or other deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material. The engineered fill must bear on native dense sand or very stiff to hard silty clay/clayey silt and silty clay till. The highest permitted founding elevation at which engineered fill pads may be placed is 317.0.

Typically, spread footings on pads of engineered granular fill at least 2 m thick may be designed for the following geotechnical resistances:

- Factored ULS 900 kPa
- SLS 350 kPa

These resistance values are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be calculated as illustrated in the CHBDC Clause 6.7.3 and Clause 6.7.4.

The ultimate friction factor for sliding resistance between the footing concrete and the Granular A pad may be assumed to be 0.55.

For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is expected to not exceed 25 mm. Differential settlements are not expected to exceed 20 mm across the width of the structure or between foundation elements.

The Granular A pad must be compacted to 100% of Standard proctor maximum dry density (SPMDD) at optimum moisture content of $\pm 2\%$. The geometry of the fill pad must conform to the general requirements shown in Figure 1 in Appendix D.

8.3 Steel H-Piles and Steel Pipe Piles

The soil stratigraphy encountered at this site is considered to be suitable for the support of foundations on driven steel piles.

The boreholes drilled in the 1966 investigation are generally 11.2 m to 14.2 m deep (elevations 305.9 to 309.5), revealing a soil stratigraphy that is mostly loose to dense silty sand underlain by very stiff to hard cohesive soils. Deeper boreholes (Boreholes 08-47 and 08-48), extending to approximately 19.0 m to 22.0 m (elevations 302 to 305), drilled by Thurber in 2008 for a proposed E-S ramp and connector street under Victoria Street (located at the west abutment and Pier 1 of the proposed underpass), revealed the presence of 100 blow clay and silt tills generally below elevation 308 to 305 near borehole termination depths. Additional field investigation involving deeper boreholes is required at the detailed design stage at all of the foundation elements.

8.3.1 Axial Resistance

For preliminary design, the axial, factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS) for two H-pile sections (HP 310x110 and HP 360x132) and two pipe pile section (324 mm x 9.5 mm and 356 mm x 9.5 mm) when driven into the hard silty clay/clayey silt and silty clay till are presented in Table 8.2.

For preliminary design purposes, the recommendations for driven steel H-piles at the abutments and piers are based on the data from the deeper boreholes (08-47 and 08-48). Pile capacities are provided for an assumed 11.0 m and 20.0 m deep piles driven to Elevations 305.0 and 296.0.

Table 8.2 – Axial Resistance of Pile Sections Founded on Hard Soils

| Replacement Structure Foundation Unit | Estimated Pile Tip Elevation | Pile Length (m) | Pile Section | Geotechnical Resistance (kN) | |
|--|------------------------------------|-----------------------|----------------|---------------------------------|-------|
| | | | | Factored ULS | SLS |
| West and east abutments Piers 1, 2 and 3 | 305.0 | 11 | HP 310 X 110 | 950 | 800 |
| | | | HP 360 X 132 | 1,200 | 1,000 |
| | | | Pipe 324 x 9.5 | 800 | 650 |
| | | | Pipe 356 x 9.5 | 900 | 750 |
| | 296.0 | 20 | HP 310 X 110 | 1,600 | 1,400 |
| | | | HP 360 X 132 | 1,800 | 1,600 |
| | | | Pipe 324 x 9.5 | 1,350 | 1,150 |
| | | | Pipe 356 x 9.5 | 1,500 | 1,250 |

-Average underside cap elevation: 316.0

The pile capacities for piles founded on hard soils at elevation 305.0 (11.0 m long) are relatively low. If higher pile capacities are required for this structure, the piles will have to be extended deeper. The actual pile tip elevations and capacities should be confirmed after additional geotechnical investigation involving deeper boreholes, is completed at the detailed design stage.

The structural resistance of the pile must be checked by the structural designer.

Pile installation should be in accordance with OPSS 903.

Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance to be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The Hiley formula need not be used until the piles are within 2.0 m of the bearing stratum. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of “R” kN per pile”. “R” must have a minimum value of twice the design load at ULS.

These are preliminary recommendations and may change during detail design based on the final alignment, final bridge arrangement and the results of the site investigation and field testing to be completed at that time.

Due to the possible presence of cobbles and boulders in the silty clay till at the expected founding layer, the tips of all driven piles should be fitted with steel H-Pile driving shoes in accordance with OPSD 3000.100.

8.3.2 Downdrag

Downdrag on the piles is not an issue at this site.

8.4 Abutment Design Considerations

From a geotechnical perspective, the conditions at this site are considered to be suitable for the design of conventional, semi-integral or integral abutments for both the bridge replacement or extension option.

8.5 Frost Cover

The design depth of frost penetration for this site is 1.4 m. All footing bases and undersides of pile caps/abutment stems must be provided with at least 1.4 m of soil cover.

8.6 Recommended Foundation

From a geotechnical perspective, and based on available information, the recommended foundations for each underpass design alternative are as follows:

- **Replacement of the existing underpass structure**

The recommended foundation system for the abutments and pier for a new structure consist on steel H-piles driven into the hard silty clay/clayey silt and silty clay till.

Additional field investigation is required at the detailed design stage to confirm soil stratigraphy at deeper depth and the pile tip elevation that will develop the required resistance

- **Extension of the existing underpass structure to the east and west**

For this design alternative, the recommended foundation for the bridge extensions is spread footings founded on native soils.

Driven piles are also feasible. However, pre-augering may be required to mitigate vibration due to pile driving having an adverse impact on the adjacent footings.

Settlement monitoring of the existing east and west abutment footings must be conducted before, during and after construction of the adjacent foundations. Existing footings at the abutments should not be undermined or damaged during new footing construction.

9 BRIDGE APPROACHES AND EMBANKMENTS

The approach embankments will be constructed over compact to dense sand and very stiff to hard silty clay/clayey silt, silty clay till or and may incorporate the sand fill of the existing embankment.

Permanent earth cuts are required to build the proposed S-E and E-S ramps under Victoria Street for either alternative: underpass extensions or construction of a new underpass. Cuts will be in the order of 6.0 m depth at the east end and 5.6 m to 6.0 m at the west end, and will be formed predominantly through sand fill and native loose to dense sand/silty sand.

The proposed bases of the cuts (below elevation 319) are below the groundwater table observed at elevations 319.3 to 321.8 during the investigation conducted in 1966.

During detail design, when the ramp and connector grades have been finalized, construction drainage as well as permanent drainage of the cut and erosion protection of the cut slopes must be addressed. Subject to depressing the groundwater level below the base of the cut and implementing permanent drainage, the cut slopes will be stable at slopes with a maximum inclination of 2H: 1V.

The existing abutment footings must not be undermined during excavation of the cut.

10 RETAINING WALL

GA drawing indicates that Retained Soil System (RSS) walls are incorporated in the design at the east and west abutments for the structure replacement option.

The soil conditions encountered at the site are considered suitable for the support of Retained Soil System (RSS) walls at the east and west approaches/abutments.

To provide an acceptable foundation performance, the RSS mass must be founded on the native undisturbed soils. The highest base levels for the underside of the wall, the soil type at the base levels and bearing resistances are indicated in Table 10.1.

Table 10.1 – Maximum Elevation at Underside of Wall Base or Granular A Fill

| Location | Borehole | Elevation | ULS _r (kPa) | SLS (kPa) | Soil |
|---------------------------------------|----------------|----------------|---------------------------|--------------|---|
| S-E ramp | 13 | 317.5 | 450 | 300 | Hard clayey silt/silty clay |
| E-S ramp and Edna Street connector | 08-47 08-48 | Below 317.0 | 450 | 300 | Dense sand/very stiff silty clay till |

Alternatively, the RSS may be founded on engineered fill founded on the native soils at elevation provided in Table 10.1.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC 2006 Section 6.7.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning.

If a RSS wall system is selected, the global stability must be analyzed after the location of the wall is known. Global stability of the RSS wall is not expected to be an issue at this site.

For the design of the RSS walls, reference must be made to the MTO RSS Design Guidelines.

11 EARTH PRESSURE

Earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K \cdot (\gamma h + q)$$

Where:

P_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 11.1)

γ = unit weight of retained soil (see Table 11.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 11.1.

The factors in Table 11.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the Canadian Highway Bridge Design Code.

Table 11.1 – Earth Pressure Coefficient (K)

| Condition | Earth Pressure Coefficient (K) | | | |
|--------------------------------------|---|--|--|---|
| | OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | | OPSS Granular B Type I Existing sand fill and native sand $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$ | |
| | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) |
| Active (Unrestrained Wall) | 0.27 | 0.40* | 0.31 | 0.48* |
| At rest (Restrained Wall) | 0.43 | - | 0.47 | - |
| Passive (Movement Towards Soil Mass) | 3.7 | - | 3.3 | - |

*For wing walls.

12 ROADWAY PROTECTION

It is anticipated that roadway protection will be required to facilitate construction at this site. Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2.

The geotechnical design requirements should be addressed during the detail design stage, at which time the construction and staging requirements would be better defined.

13 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

1. Footing construction adjacent to the existing east abutment footings.

If the selected design alternative consists of extension of the underpass on both sides, special attention should be paid to the following issues:

- New footing construction for the bridge extensions to accommodate the proposed E-S and S-E ramps must not undermine the existing abutment footings.
- Settlement monitoring of the existing east abutment and footings should be conducted before, during and after construction of the new footings.

2. Destabilization of excavations

If excavation is carried out in cohesionless soil without prior implementation of adequate measures to control groundwater and surface water, there is a risk that the sides and or base

of the excavation will be destabilized. This could lead to a risk to personnel working on site, or to a loss of bearing resistance in the soil.

Accordingly, it must be emphasized to the contractor that proper groundwater and surface water control measures must be in place prior to commencing excavation.

14 INVESTIGATION FOR DETAIL DESIGN

During the detail design phase of the project, additional site investigation and field testing will be required. The following minimum program is recommended:

1. Proposed boreholes

For the detail field investigation, boreholes should be drilled for the structure foundations, cuts and retaining walls.

- Boreholes for structure foundations: A minimum of 2 boreholes at each foundation element should be drilled. One borehole shall extend to refusal and another shall extend to 3.0 m below refusal.
- Boreholes for Cut Stability: Boreholes are required in the roadway cut to either side of the structure. The boreholes in the cut must include piezometers for groundwater monitoring. Stability of cuts must be investigated during detail design phase.
- Boreholes for Approaches: A minimum of one borehole is required at each bridge approach within 20 m of the abutment.
- Boreholes for Retaining Walls: Boreholes are required at the proposed retaining wall structures. One borehole is required at each end of the structure, and the minimum number of intermediate boreholes shall meet the criteria: the maximum borehole spacing is 50 m for a retaining structure less than 100 m long and maximum borehole spacing is 75 m for a retaining wall structure longer than 100 m. The retaining wall boreholes could be combined with the foundation or cut boreholes.

The location and number of boreholes should be selected based on the MTO Foundation Office guidelines and terms of reference.

2. Pile Design

A greater depth of exploration is required for finalization of pile design during the detail design phase.

3. Groundwater impacts.

Currently, there is no information available of the water level at the site after construction of KWE and existing Victoria Street underpass. Further investigation is required to establish the new water level as it could have been impacted due to highway construction.

The need for a Permit to Take Water should be assessed during detailed design.

4. Impacts to adjacent structure or traffic lanes

Detail design must address potential impacts on adjacent structures and roads.

15 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. R. Palomeque Reyna, P.Eng.

The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Rocío Palomeque Reyna, P.Eng., M.Eng.
Geotechnical Engineer



P. K. Chatterji, P.Eng.,
Review Principal



Appendix A

Record of Borehole Sheets

Previous Investigations:

- Victoria Street Underpass, Kitchener-Waterloo Expressway, District #4 (Hamilton), W.J. 66-F-36, W.P.635-64, Geocres No. 40P8-44, dated June 17, 1966 prepared by DHO
- E-S ramp and connector street under Victoria Street, Highway 7-New, Kitchener to Guelph, G.W.P. 408-88-00, Geocres number 40P8-158, prepared by Thurber, dated November 10, 2009.

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS:-

| <u>CONSISTENCY</u> | <u>'N' BLOWS / FT.</u> | <u>c LB. / SQ. FT.</u> | <u>DENSENESS</u> | <u>'N' BLOWS / FT.</u> |
|--------------------|------------------------|------------------------|------------------|------------------------|
| VERY SOFT | 0 - 2 | 0 - 250 | VERY LOOSE | 0 - 4 |
| SOFT | 2 - 4 | 250 - 500 | LOOSE | 4 - 10 |
| FIRM | 4 - 8 | 500 - 1000 | COMPACT | 10 - 30 |
| STIFF | 8 - 15 | 1000 - 2000 | DENSE | 30 - 50 |
| VERY STIFF | 15 - 30 | 2000 - 4000 | VERY DENSE | > 50 |
| HARD | > 30 | > 4000 | | |

TYPE OF SAMPLE

| | | | |
|------|------------------------------------|------|-------------------|
| S.S. | SPLIT SPOON | T.W. | THINWALL OPEN |
| W.S. | WASHED SAMPLE | T.P. | THINWALL PISTON |
| S.B. | SCRAPER BUCKET SAMPLE | O.S. | OESTERBERG SAMPLE |
| A.S. | AUGER SAMPLE | F.S. | FOIL SAMPLE |
| C.S. | CHUNK SAMPLE | R.C. | ROCK CORE |
| S.T. | SLOTTED TUBE SAMPLE | | |
| | P.H. SAMPLE ADVANCED HYDRAULICALLY | | |
| | P.M. SAMPLE ADVANCED MANUALLY | | |

SOIL TESTS

| | | | |
|-----------------|---------------------------------|------|-----------------|
| Q _u | UNCONFINED COMPRESSION | L.V. | LABORATORY VANE |
| Q | UNDRAINED TRIAXIAL | F.V. | FIELD VANE |
| Q _{cu} | CONSOLIDATED UNDRAINED TRIAXIAL | C | CONSOLIDATION |
| Q _d | DRAINED TRIAXIAL | S | SENSITIVITY |

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

| | |
|------------|--|
| γ | UNIT WEIGHT OF SOIL (BULK DENSITY) |
| γ_s | UNIT WEIGHT OF SOLID PARTICLES |
| γ_w | UNIT WEIGHT OF WATER |
| γ_d | UNIT DRY WEIGHT OF SOIL (DRY DENSITY) |
| γ' | UNIT WEIGHT OF SUBMERGED SOIL |
| G | SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$ |
| e | VOID RATIO |
| n | POROSITY |
| w | WATER CONTENT |
| S_r | DEGREE OF SATURATION |
| w_L | LIQUID LIMIT |
| w_p | PLASTIC LIMIT |
| I_p | PLASTICITY INDEX |
| s | SHRINKAGE LIMIT |
| I_L | LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$ |
| I_C | CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$ |
| e_{max} | VOID RATIO IN LOOSEST STATE |
| e_{min} | VOID RATIO IN DENSEST STATE |
| I_D | DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$ |
| | RELATIVE DENSITY D_r IS ALSO USED |
| h | HYDRAULIC HEAD OR POTENTIAL |
| q | RATE OF DISCHARGE |
| v | VELOCITY OF FLOW |
| i | HYDRAULIC GRADIENT |
| k | COEFFICIENT OF PERMEABILITY |
| j | SEEPAGE FORCE PER UNIT VOLUME |
| m_v | COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$ |
| c_v | COEFFICIENT OF CONSOLIDATION |
| C_α | COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$ |
| T_v | TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH) |
| U | DEGREE OF CONSOLIDATION |
| τ_f | SHEAR STRENGTH |
| c' | EFFECTIVE COHESION INTERCEPT |
| ϕ' | EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION |
| c_u | APPARENT COHESION |
| ϕ_u | APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION |
| μ | COEFFICIENT OF FRICTION |
| S_t | SENSITIVITY |

GENERAL

| | |
|---------------------------|-----------------------------------|
| π | = 3.1416 |
| e | BASE OF NATURAL LOGARITHMS 2.7183 |
| $\log_e a$ OR $\ln a$ | NATURAL LOGARITHM OF a |
| $\log_{10} a$ OR $\log a$ | LOGARITHM OF a TO BASE 10 |
| t | TIME |
| g | ACCELERATION DUE TO GRAVITY |
| V | VOLUME |
| W | WEIGHT |
| M | MOMENT |
| F | FACTOR OF SAFETY |

STRESS AND STRAIN

| | |
|----------------|--|
| u | PORE PRESSURE |
| σ | NORMAL STRESS |
| $\bar{\sigma}$ | NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED) |
| τ | SHEAR STRESS |
| ϵ | LINEAR STRAIN |
| γ | SHEAR STRAIN |
| ν | POISSON'S RATIO (μ IS ALSO USED) |
| E | MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS) |
| G | MODULUS OF SHEAR DEFORMATION |
| K | MODULUS OF COMPRESSIBILITY |
| η | COEFFICIENT OF VISCOSITY |

EARTH PRESSURE

| | |
|----------|---|
| d | DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE |
| δ | ANGLE OF WALL FRICTION |
| K | DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS |
| K_0 | COEFFICIENT OF EARTH PRESSURE AT REST |

FOUNDATIONS

| | |
|-------|--|
| B | BREADTH OF FOUNDATION |
| L | LENGTH OF FOUNDATION |
| D | DEPTH OF FOUNDATION BENEATH GROUND |
| N | DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY |
| k_s | MODULUS OF SUBGRADE REACTION |

SLOPES

| | |
|---------|--|
| H | VERTICAL HEIGHT OF SLOPE |
| D | DEPTH BELOW TOE OF SLOPE TO HARD STRATUM |
| β | ANGLE OF SLOPE TO HORIZONTAL |

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

JOB 66-F-36

W.P. 635-64

DATUM 1027.00

LOCATION N 201, 943.152; E 210, 780-802

BORING DATE April 25, 1966

BOREHOLE TYPE WashBoring NX Casing

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

ORIGINATED BY W.W.K.

COMPILED BY W.E.

CHECKED BY dl

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W | BULK DENSITY P.C.F. | REMARKS |
|----------------|---|---------|------|-------------|--|--|------------------------|---|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1057.0 | Ground Level | | | | | | | |
| 1054.5 | Soft Org. Muck | 1 | SS | 1.5 | | | | Sand 87% Silt 13% W.L. El. 1052.9 Observed in Casing |
| 2.5 | Silty Sand Very Loose to Very Dense | 2 | SS | 1 | | | | |
| | | 3 | SS | 12 | | | | |
| | | 4 | SS | 35 | | | | |
| 1036.0 | | 5 | SS | 22 | | | | |
| 21.0 | Silty Clay | 6 | SS | 24 | | | | Sand 4% Silt 46% Clay 50% |
| | With traces of Sand Very Stiff to Hard | 7 | SS | 47 | | | | |
| 1015.5 | | 8 | SS | 70 | | | | |
| 41.5 | End of Borehole | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 66-F-36 LOCATION N202.019-244; E210.780.990 ORIGINATED BY W.W.K.
 W.P. 635-64 BORING DATE April 26, 1966 COMPILED BY W.E.
 DATUM 1059.10 BOREHOLE TYPE Penetration Only CHECKED BY SKR

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS |
|--------------|--------------------|---------|------|-------------|--|---|------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1059.10 | Ground Level | | | | | | | |
| 0.0 | Penetration Only | | | | | | | |
| 1048.10 | | | | 1050.0 | | | | |
| 11.0 | End of Penetration | | | 1040.0 | | | | |

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 66-P-36 LOCATION N201, 956.644; E210, 820.195 ORIGINATED BY W.W.K.
 W.P. 635-64 BORING DATE April 25, 1966 W.E.
 DATUM 1059.17 BOREHOLE TYPE Penetration Only CHECKED BY AK

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WP — WL | BULK DENSITY P.C.F. | REMARKS |
|--------------|--------------------|---------|------|-------------|--|---|------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1059.17 | Ground Level | | | | | | | |
| 0.0 | Penetration Only | | | 1050 | | | | |
| 1043.17 | | | | 1040 | | | | |
| 16.0 | End of Penetration | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

| DEPARTMENT OF HIGHWAYS - ONTARIO | | | RECORD OF BOREHOLE NO. 5 | | | FOUNDATION SECTION | | | |
|----------------------------------|---------------------------------|------------|---------------------------------------|------|-------------|---|---|------------------------|---------|
| MATERIALS & TESTING DIVISION | | | LOCATION N201, 982-013; E210, 876.200 | | | ORIGINATED BY W.W.K. | | | |
| JOB 66-F-36 | | | BORING DATE April 26, 1966 | | | COMPILED BY W.E. | | | |
| W.P. 635-64 | | | BOREHOLE TYPE Washboring NX Casing | | | CHECKED BY <i>HL</i> | | | |
| DATUM 1055.83 | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT SHEAR STRENGTH P.S.F. | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS |
| ELEV. DEPTH | DESCRIPTION | STRAT. PLG | NUMBER | TYPE | | | | | |
| 1055.83 | Ground Level | | | | | | | | |
| 1045.63 | Fill - Dirt with Org. matter | SS | 1 | SS | 6 | | | | |
| | Loose | SS | 2 | SS | 4 | | | | |
| 10.2 | Clayey Silt with traces of Sand | SS | 3 | SS | 45 | | | | |
| | Hard | SS | 4 | SS | 133 | | | | |
| | | SS | 5 | SS | 64 | | | | |
| | | SS | 6 | SS | 71 | | | | |
| 1014.3 | | SS | 7 | SS | 93 | | | | |
| 41.5 | End of Borehole | | | | | | | | |

W.L. El. 1050.6
Observed in casing
Gravel 2%
Sand 16%
Silt 55%
Clay 26%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 66-F-36 LOCATION N202, 072.140; E210, 867.300
W.P. 635-64 BORING DATE April 27, 1966
DATUM 1052.31 BOREHOLE TYPE Penetration Only
ORIGINATED BY W.W.K.
COMPILED BY W.E.
CHECKED BY [Signature]

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F. | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WP — WL WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS |
|----------------|---------------------|---------|------|-------------|--|--|---------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1052.31 0.0 | Ground Level | | | 1050 | | | | |
| 1042.31 | Penetration Only | | | 1040 | | | | |
| 10.0 | End of Penetration | | | | | | | |

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

JOB 66-F-36

LOCATION N202,008.745 ; E210,928.182

ORIGINATED BY W.W.K.

W.P. 635-64

BORING DATE April 25, 1966

COMPILED BY W.E.

DATUM 1055.45

BOREHOLE TYPE Penetration Only

CHECKED BY *[Signature]*

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS |
|-----------------|--------------------|---------|------|-------------|--|---|------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1055.45 0.0 | Ground Level | | | | | | | |
| | Penetration Only | | | 1050 | | | | |
| | | | | 1040 | | | | |
| | | | | 1030 | | | | |
| 1035.45 20.0 | End of Penetration | | | | | | | |

| DEPARTMENT OF HIGHWAYS - ONTARIO | | | RECORD OF BOREHOLE NO.8 | | | FOUNDATION SECTION | | |
|----------------------------------|--|---------|--------------------------------------|-------------|---|--|------------------------|---------|
| MATERIALS & TESTING DIVISION | | | LOCATION N202.097.448 : E210.924.627 | | | ORIGINATED BY W.W.K. | | |
| JOB 66-F-36 | | | BORING DATE April 27, 1966 | | | COMPILED BY | | |
| W.P. 635-64 | | | BOREHOLE TYPE Washboring NX Casing | | | CHECKED BY | | |
| DATUM 1050.32 | | | | | | | | |
| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRAT-ON RESISTANCE BLOWS / FOOT SHEAR STRENGTH P.S.F. | LIQUID LIMIT PLASTIC LIMIT WATER CONTENT W.P. W. WL | BULK DENSITY P.C.F. | REMARKS |
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1050.32 0.0 | Ground Level | | | 1050 | | | | |
| 1040.12 10.2 | Fill - dirt, Sand Gravel, Silt Org. matter | 1 | SS 17 | | | | | |
| 1037.62 12.7 | Silty Sand Dense | 2 | SS 8 | | | | | |
| | | 3 | SS 44 | 1040 | | | | |
| | | 4 | SS 60 | | | | | |
| | | 5 | SS 52 | 1030 | | | | |
| | | 6 | SS 67 | | | | | |
| | | 7 | SS 83 | 1020 | | | | |
| | | 8 | SS 77 | | | | | |
| | | 9 | SS 83 | 1010 | | | | |
| 1003.7 46.5 | End of Borehole | | | | | | | |

W.L. El.
1048.1
Observed in
Casing 1%
Gravel 1%
Sand 55%
Silt 42%
Clay 2%

WATER CONTENT 30%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 9

FOUNDATION SECTION

JOB 66-F-36 LOCATION N202.027.085 : E210.978.412 ORIGINATED BY W.W.K.
W.P. 635-64 BORING DATE April 22, 1966 COMPILED BY W.T.E.
DATUM 1054.65 BOREHOLE TYPE Washboring NX Casing CHECKED BY AK

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE | | LIQUID LIMIT PLASTIC LIMIT WATER CONTENT | | BULK DENSITY γ P.C.F. | REMARKS |
|-----------------|--|---------|------|-------------|--------------------------------|-----------------------|--|----|------------------------------------|---|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | BLOWS / FOOT | SHEAR STRENGTH P.S.F. | WL | WP | | |
| 1054.65 0.0 | Ground Level | 1 | SS | 1050 | | | | | | |
| | | 2 | SS | | | | | | | |
| | | 3 | SS | | | | | | | |
| 1039.65 15.0 | Fill - Dirt, Sand Gravel, Silt, Clay and Org. Matter | 4 | SS | 1040 | | | | | | M.L. El. 1049.1 Observed in casing Gravel 4% Sand 6% Silt 31% Clay 59% |
| | | 5 | SS | | | | | | | |
| | | 6 | SS | 1030 | | | | | | |
| | | 7 | SS | | | | | | | |
| | | 8 | SS | 1020 | | | | | | Sand 15% Silt 59% Clay 26% |
| 1008.7 46.5 | End of Borehole | 9 | SS | 1010 | | | | | | |

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

BOB

66-F-36

!

635-64

DATE:

1047.16

LOCATION

N202.127.811 : E210.968.988

BORING DATE

April 27, 1966

BOREHOLE TYPE

Penetration Test Only

RECORD OF BOREHOLE NO. 10

FOUNDATION SECTION

ORIGINATED BY W.K.

COMPILED BY W.E.

CHECKED BY

[illegible]

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO.11

FOUNDATION SECTION

JOB 66-P-36 LOCATION N 202,047.765 ; E 211,023.985 ORIGINATED BY W.W.K.
W.P. 635-64 BORING DATE April 22, 1966 COMPILED BY W.E.
DATUM 1055.14 BOREHOLE TYPE Penetration Test Only CHECKED BY AK

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F. | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WP — WL WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS |
|--------------|--------------------|---------|------|-------------|--|--|------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1055.14 | Ground Level | | | | | | | |
| 0.0 | Penetration Only | | | 1050 | | | | |
| 1037.14 | | | | 1040 | | | | |
| 18.0 | | | | 1030 | | | | |
| | End of Penetration | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 12

FOUNDATION SECTION

JOB 66-P-36 LOCATION N 202, 137.137 ; E 211, 029.292 ORIGINATED BY W.W.K.
 W.P. 635-64 BORING DATE April 28, 1966 COMPILED BY W.E.
 DATUM 1055.20 BOREHOLE TYPE Washboring NX Casing CHECKED BY [Signature]

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE | | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W | | BULK DENSITY γ P.C.F. | REMARKS | | |
|--------------|------------------------------|---------|------|--------------|--------------------------------|----|--|----|------------------------------------|---------|----|-----|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | BLOWS / FOOT | FOOT | 20 | 40 | 60 | | | 80 | 100 |
| 1055.20 | Ground Level | | | | | | | | | | | |
| 0.0 | Fill - Dirt with Org. matter | 1 | SS | 10 | | | | | | | | |
| 1049.7 | Loose | | | | | | | | | | | |
| 5.5 | Silty Sand | 2 | SS | 11 | | | | | | | | |
| 1044.7 | Compact | | | | | | | | | | | |
| 10.5 | Clayey Silt to Silty Clay | 3 | SS | 30 | | | | | | | | |
| | With traces of Sand | 4 | SS | 88 | | | | | | | | |
| | Very Stiff to Hard | 5 | SS | 85 | | | | | | | | |
| | | 6 | SS | 52 | | | | | | | | |
| 1013.7 | | 7 | SS | 105 | | | | | | | | |
| 41.5 | End of Borehole | | | | | | | | | | | |

W.L. El
1050.9
Observed in
Casing
Gravel 3%
Sand 30%
Silt 43%
Clay 24%

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 12

FOUNDATION SECTION

JOB 66-P-36 LOCATION N 202, 137.137 ; E 211, 029.292 ORIGINATED BY W.W.K.
 W.P. 635-64 BORING DATE April 28, 1966 COMPILED BY W.E.
 DATUM 1055.20 BOREHOLE TYPE Washboring NX Casing CHECKED BY [Signature]

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W | BULK DENSITY γ P.C.F. | REMARKS |
|--------------|------------------------------|---------|------|-------------|--|--|------------------------------------|---------|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1055.20 | Ground Level | | | | | | | |
| 0.0 | Fill - Dirt with Org. matter | 1 | SS | 10 | | | | |
| 1049.7 | Loose | | | | | | | |
| 5.5 | Silty Sand | 2 | SS | 11 | | | | |
| 1044.7 | Compact | | | | | | | |
| 10.5 | Clayey Silt to Silty Clay | 3 | SS | 30 | | | | |
| | With traces of Sand | 4 | SS | 88 | | | | |
| | Very Stiff to Hard | 5 | SS | 85 | | | | |
| | | 6 | SS | 52 | | | | |
| 1013.7 | | 7 | SS | 105 | | | | |
| 41.5 | End of Borehole | | | | | | | |

W.L. El
1050.9
Observed in
Casing
Gravel 3%
Sand 30%
Silt 43%
Clay 24%

| DEPARTMENT OF HIGHWAYS - ONTARIO | | | | RECORD OF BOREHOLE NO. 14 | | | | FOUNDATION SECTION | | | |
|----------------------------------|--------------|---------|------|--|---|---|------------------------|----------------------|--------------|--|--|
| MATERIALS & TESTING DIVISION | | | | LOCATION N 202, 169.581 ; E 211, 097.176 | | | | ORIGINATED BY W.W.K. | | | |
| JOB 66-F-36 | | | | BORING DATE April 29, 1966 | | | | COMPILED BY W.B. | | | |
| W.P. 635-64 | | | | BOREHOLE TYPE Penetration Test Only | | | | CHECKED BY <i>sk</i> | | | |
| DATUM 1055 - 68 | | | | | | | | | | | |
| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT SHEAR STRENGTH P.S.F. | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WATER CONTENT % | BULK DENSITY P.C.F. | REMARKS | | | |
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | | BLOWS / FOOT | | |
| 1055.68 0.0 | Ground Level | | | | | | | | | | |
| Penetration Only | | | | | | | | | | | |
| 1037.43 18.25 | | | | | | | | | | | |
| End of Penetration | | | | | | | | | | | |

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 15

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-P-36 LOCATION N 202, 142.976 ; E 210, 823.216 ORIGINATED BY W.W.K.
W.P. 635-64 BORING DATE April 26, 1966 COMPILED BY W.E.
DATUM 1049.47 BOREHOLE TYPE Washboring NX Casing CHECKED BY [Signature]

| SOIL PROFILE | | SAMPLES | | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F. | LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W W.P. — W — WL WATER CONTENT % 10 20 30 | BULK DENSITY P.C.F. | REMARKS |
|---------------------------|---|-----------------|-------------------------|-------------|--|--|------------------------|--|
| ELEV. DEPTH | DESCRIPTION | NUMBER | TYPE | | | | | |
| 1049.47 1048.47 1.0 | Ground Level Black Org. Topsoil Silty Sand Compact to very Dense | 1 2 3 | SS 40 SS 25 SS 80 | | | | | W.L. El. 1047.7 Observed in Casing Gravel 3% Sand 36% Silt 40% Clay 21% |
| 1036.47 13.0 | Clayey Silt to Silty Clay with Traces of Sand Hard | 4 | SS 80 | | | | | |
| | | 5 | SS 60/L | | | | | |
| | | 6 | SS 100 | | | | | |
| | | 7 | SS 97 | | | | | |
| 1012.8 36.6 | | End of Borehole | | | | | | |

Appendix B

Laboratory Test Results

Previous Investigations:

- Victoria Street Underpass, Kitchener-Waterloo Expressway, District #4 (Hamilton), W.J. 66-F-36, W.P.635-64, Geocres No. 40P8-44, dated June 17, 1966 prepared by DHO
- E-S ramp and connector street under Victoria Street, Highway 7-New, Kitchener to Guelph, G.W.P. 408-88-00, Geocres number 40P8-158, prepared by Thurber, dated November 10, 2009.

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

| CLASSIFICATION | PARTICLE SIZE | VISUAL IDENTIFICATION |
|----------------|--------------------|---|
| Boulders | Greater than 200mm | same |
| Cobbles | 75 to 200mm | same |
| Gravel | 4.75 to 75mm | 5 to 75mm |
| Sand | 0.075 to 4.75mm | Not visible particles to 5mm |
| Silt | 0.002 to 0.075mm | Non-plastic particles, not visible to the naked eye |
| Clay | Less than 0.002mm | Plastic particles, not visible to the naked eye |

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

| TERMINOLOGY | PROPORTION |
|---------------------------------|---------------|
| Trace or Occasional | Less than 10% |
| Some | 10 to 20% |
| Adjective (e.g. silty or sandy) | 20 to 35% |
| And (e.g. sand and gravel) | 35 to 50% |

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

| DESCRIPTIVE TERM | UNDRAINED SHEAR STRENGTH (kPa) | APPROXIMATE SPT ⁽¹⁾ 'N' VALUE |
|------------------|--------------------------------|--|
| Very Soft | 12 or less | Less than 2 |
| Soft | 12 to 25 | 2 to 4 |
| Firm | 25 to 50 | 4 to 8 |
| Stiff | 50 to 100 | 8 to 15 |
| Very Stiff | 100 to 200 | 15 to 30 |
| Hard | Greater than 200 | Greater than 30 |

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

| DESCRIPTIVE TERM | SPT "N" VALUE |
|------------------|-----------------|
| Very Loose | Less than 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | Greater than 50 |

5. LEGEND FOR RECORDS OF BOREHOLES

| SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE | SS Split Spoon Sample | WS Wash Sample | AS Auger (Grab) Sample |
|---|---|--|------------------------|
| | TW Thin Wall Shelby Tube Sample | TP Thin Wall Piston Sample | |
| | PH Sampler Advanced by Hydraulic Pressure | PM Sampler Advanced by Manual Pressure | |
| | WH Sampler Advanced by Self Static Weight | RC Rock Core | SC Soil Core |

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

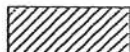
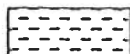



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

| MAJOR DIVISIONS | | GROUP SYMBOL | TYPICAL DESCRIPTION |
|----------------------|---------------------------------|--------------|---|
| COARSE GRAINED SOILS | GRAVEL AND GRAVELLY SOILS | GW | Well-graded gravels or gravel-sand mixtures, little or no fines. |
| | | GP | Poorly-graded gravels or gravel-sand mixtures, little or no fines. |
| | | GM | Silty gravels, gravel-sand-silt mixtures. |
| | | GC | Clayey gravels, gravel-sand-clay mixtures. |
| | SAND AND SANDY SOILS | SW | Well-graded sands or gravelly sands, little or no fines. |
| | | SP | Poorly-graded sands or gravelly sands, little or no fines. |
| | | SM | Silty sands, sand-silt mixtures. |
| | | SC | Clayey sands, sand-clay mixtures. |
| FINE GRAINED SOILS | SILTS AND CLAYS $W_L < 50\%$ | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity. |
| | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$). |
| | | CI | Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$). |
| | | OL | Organic silts and organic silty-clays of low plasticity. |
| | SILTS AND CLAYS $W_L > 50\%$ | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts. |
| | | CH | Inorganic clays of high plasticity, fat clays. |
| | | OH | Organic clays of medium to high plasticity, organic silts. |
| HIGHLY ORGANIC SOILS | | Pt | Peat and other highly organic soils. |
| CLAY SHALE | | | |
| SANDSTONE | | | |
| SILTSTONE | | | |
| CLAYSTONE | | | |
| COAL | | | |

EXPLANATION OF ROCK LOGGING TERMS

| ROCK WEATHERING CLASSIFICATION | | SYMBOLS | |
|--------------------------------|---|---|-------------------|
| Fresh (FR) | No visible signs of weathering. | | |
| Fresh Jointed (FJ) | Weathering limited to the surface of major discontinuities. |  | CLAYSTONE |
| Slightly Weathered (SW) | Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material. |  | SILTSTONE |
| Moderately Weathered (MW) | Weathering extends throughout the rock mass, but the rock material is not friable. |  | SANDSTONE |
| Highly Weathered (HW) | Weathering extends throughout the rock mass and the rock is partly friable. |  | COAL |
| Completely Weathered (CW) | Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved. |  | Bedrock (general) |

| DISCONTINUITY SPACING | | STRENGTH CLASSIFICATION | | | |
|-----------------------|-----------------------|-------------------------|---|---------------------|--|
| Bedding | Bedding Plane Spacing | Rock Strength | Approximate Uniaxial Compressive Strength | | Field Estimation of Hardness* |
| | | | (MPa) | (psi) | |
| Very thickly bedded | Greater than 2m | Extremely Strong | Greater than 250 | Greater than 36,000 | Specimen can only be chipped with a geological hammer |
| Thickly bedded | 0.6 to 2m | | | | |
| Medium bedded | 0.2 to 0.6m | Very Strong | 100-250 | 15,000 to 36,000 | Requires many blows of geological hammer to break |
| Thinly bedded | 60mm to 0.2m | | | | |
| Very thinly bedded | 20 to 60mm | Strong | 50-100 | 7,500 to 15,000 | Requires more than one blow of geological hammer to break |
| Laminated | 6 to 20mm | | | | |
| Thinly Laminated | Less than 6mm | Medium Strong | 25.0 to 50.0 | 3,500 to 7,500 | Breaks under single blow of geological hammer. |
| | | Weak | 5.0 to 25.0 | 750 to 3,500 | Can be peeled by a pocket knife with difficulty |
| | | Very Weak | 1.0 to 5.0 | 150 to 750 | Can be peeled by a pocket knife, crumbles under firm blows of geological pick. |
| | | Extremely Weak (Rock) | 0.25 to 1.0 | 35 to 150 | Indented by thumbnail |

| TERMS | |
|-------------------------------------|--|
| Total Core Recovery: (TCR) | Core recovered as a percentage of total core run length. |
| Solid Core Recovery: (SCR) | Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run. |
| Rock Quality Designation: (RQD) | Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length. |
| Uniaxial Compressive Strength (UCS) | Axial stress required to break the specimen |
| Fracture Index: (FI) | Frequency of natural fractures per 0.3m of core run. |

RECORD OF BOREHOLE No 08-047

1 OF 2

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 014.67 E 226 147.74 ORIGINATED BY GA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.06.25 - 2008.06.26 CHECKED BY RPR

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|-----------------|--|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | |
| | | | | | | | | 20 40 60 80 100 | | 20 40 60 80 100 | | | |
| 323.8 0.0 | ASPHALT, (65mm) | | | | | | | | | | | | |
| 0.2 | SAND and GRAVEL Dense Brown Moist (FILL) | | 1 | SS | 48 | | | | | | | | |
| 323.2 0.6 | SAND, trace gravel, trace silt Very Loose to Compact Brown Moist to Damp (FILL) | | 2 | SS | 10 | | | | | | | | |
| | | | 3 | SS | 4 | | | | | | | | |
| | | | 4 | SS | 4 | | | | | | | | |
| 320.7 3.0 | SAND, fine grained, trace silt Compact Brown Damp | | 5 | SS | 27 | | | | | | | | |
| | | | 6 | SS | 24 | | | | | | | | |
| 318.2 5.6 | Silty CLAY, trace to some sand, trace gravel Very Stiff Brown (TILL) | | 7 | SS | 25 | | | | | | | | |
| | Hard | | 8 | SS | 44 | | | | | | | | |
| | occasional sandy silt seams | | | | | | | | | | | | |
| | Brown to Grey | | 9 | SS | 43 | | | | | | | | |
| | | | | | | | | | | | | | |

Continued Next Page

+ 3 × 3: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-047

2 OF 2

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 014.67 E 226 147.74 ORIGINATED BY GA
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
DATUM Geodetic DATE 2008.06.25 - 2008.06.26 CHECKED BY RPR

| 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 kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|--------------|------------------|------------|------------------------------------|-------------------------------------|-----------------------------------|--|--|-------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | WATER CONTENT (%) |
| | | | | | | | | ○ UNCONFINED | + FIELD VANE | ● QUICK TRIAXIAL | × LAB VANE | | | | | | |
| | Continued From Previous Page | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| | Silty CLAY, trace to some sand, trace gravel Very Stiff to Hard Brown (TILL) | | 10 | SS | 38 | | | | | | | | | | | | |
| 312.1 | | | | | | | | | | | | | | | | | |
| 11.7 | Silty CLAY, occasional sand Very Stiff Grey | | 11 | SS | 22 | | | | | | | | | | | 0 1 44 55 | |
| | | | | | | | | | | | | | | | | | |
| | | | 12 | SS | 27 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | Hard | | 13 | SS | 107 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | occasional silty sand seams | | 14 | SS | 101 | | | | | | | | | | | 0 0 52 48 | |
| | | | | | | | | | | | | | | | | | |
| 306.0 | | | | | | | | | | | | | | | | | |
| 17.8 | SILT, trace sand Very Dense Grey Wet (TILL) | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 305.0 | | | 15 | SS | 103 | | | | | | | | | | | 0 5 89 6 | |
| 18.7 | END OF BOREHOLE AT 18.7m. WATER LEVEL OBSERVED AT 16.8m DURING DRILLING. BOREHOLE BACKFILLED WITH GROUT TO 1.8m, HOLEPLUG TO 1.2m, CONCRETE TO 0.1m THEN ASPHALT PATCH TO SURFACE. | | | | | | | | | | | | | | | | |

ONTMT4S 6417R.GPJ 11/12/09

+³, ×³: Numbers refer to Sensitivity 15 20 10 (% STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-048

1 OF 3

METRIC

W.P. 408-88-00 LOCATION N 4 814 022 96 E 226 174.52 ORIGINATED BY SA
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
DATUM Geodetic DATE 2008.06.17 - 2008.06.17 CHECKED BY RPR

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|---|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 | 40 | 60 | 80 | 100 | | |
| 323.4 | | | | | | | | | | | | | | |
| 0.0 | TOPSOIL, occasional roots (200mm) | | | | | | | | | | | | | |
| 0.2 | SAND and SILT, some gravel, trace clay Loose to Very Dense Brown to Grey Moist (FILL) | | 1 | SS | 20 | | 323 | | | | | | | |
| | Layer of asphalt and gravel: (200mm) Brown to Dark Brown | | 2 | SS | 7 | | | | | | | | | |
| | | | | | | | 322 | | | | | | | |
| | | | 3 | SS | 70 | | | | | | | | | |
| | gravelly, numerous cobbles | | 4 | SS | 24 | | 321 | | | | | | | 44 42 14 (SI+CL) |
| | Clayey, occasional black stains, organics | | 5 | SS | 7 | | 320 | | | | | | | |
| 319.1 | | | | | | | | | | | | | | |
| 4.3 | SAND, trace gravel, trace silt Loose Brown Moist | | 6 | SS | 6 | | 319 | | | | | | | |
| | | | | | | | 318 | | | | | | | |
| | | | 7 | SS | 37 | | 317 | | | | | | | 1 93 6 (SI+CL) |
| | Dense Wet | | | | | | 316 | | | | | | | |
| 315.3 | | | 8 | SS | 25 | | | | | | | | | |
| 8.1 | Silty CLAY, some sand to sandy, trace gravel Very Stiff to Hard Grey (TILL) | | | | | | 315 | | | | | | | |
| | occasional silty sand seams | | 9 | SS | 31 | | 314 | | | | | | | 2 20 51 27 |

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity
20
15 5
10 (%) STRAIN AT FAILURE

METRIC

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | | | | |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|----|---|----|-----|--|---|-------------------|---|----------------|----|----|----|----|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 | 40 | 60 | 80 | 100 | | | W _P | W | W _L | GR | SA | SI | CL |
| | | | | | | | | SHEAR STRENGTH kPa | | | | | | | WATER CONTENT (%) | | | | | | |
| | Continued From Previous Page | | | | | | | | | | | | | | | | | | | | |
| | Silty CLAY , some sand to sandy, trace gravel Hard Grey (TILL) Layer of sand: (300mm) | | 10 | SS | 33 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | 11 | SS | 30 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | 12 | SS | 48 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | 13 | SS | 45 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | 14 | SS | 46 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | Layer of clayey silt | | 15 | SS | 103 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | occasional cobbles | | 16 | SS | 104/ | | | | | | | | | | | | | | | | |

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 08-048

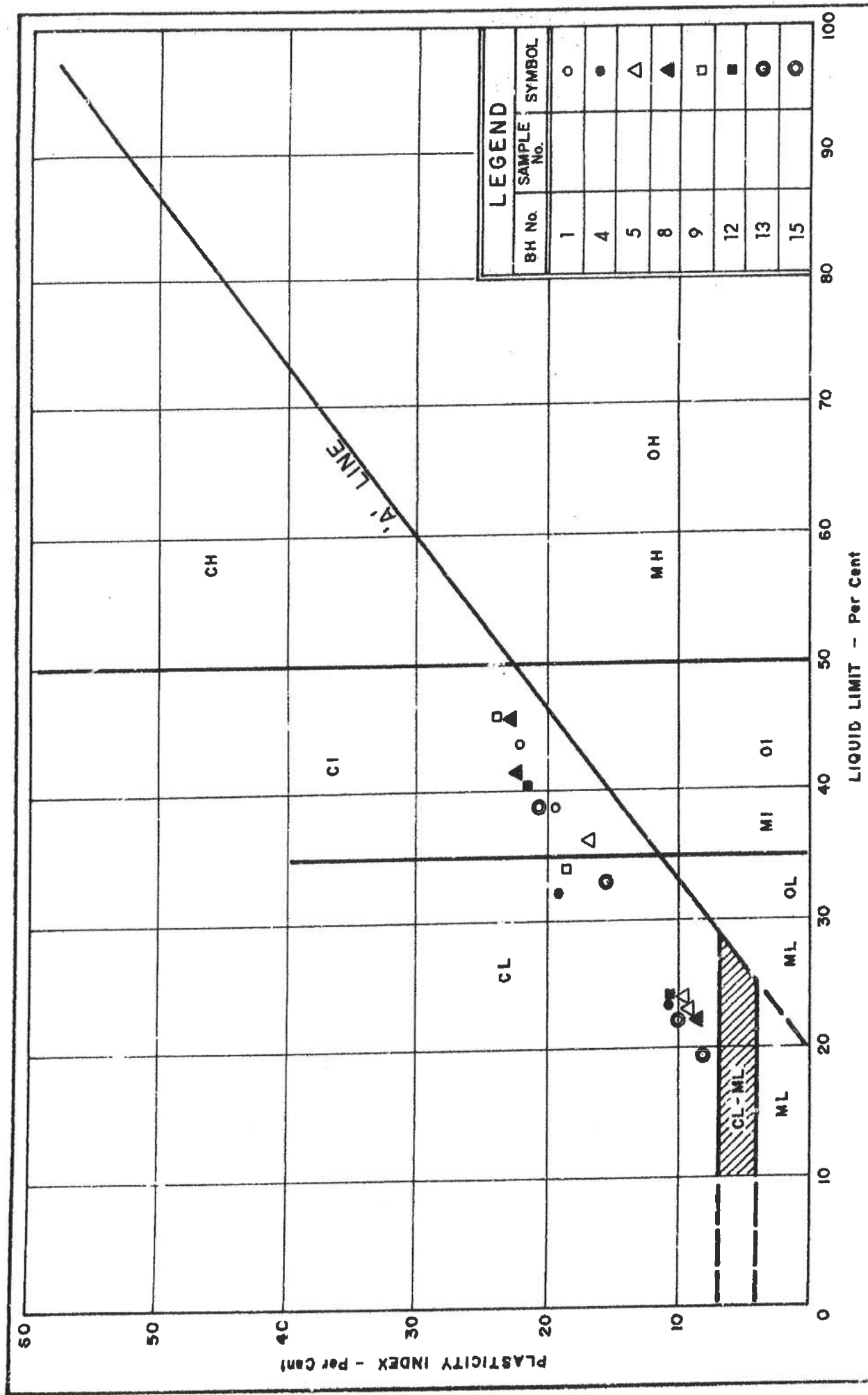
3 OF 3

METRIC

W.P. 408-88-00 LOCATION N 4 814 022 96 E 226 174.52 ORIGINATED BY SA
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
DATUM Geodetic DATE 2008.06.17 - 2008.06.17 CHECKED BY RPR

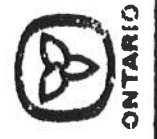
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|---|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | WATER CONTENT (%) | | | | |
| | Continued From Previous Page | | | | 200 | | | 20 40 60 80 100 | | 20 40 60 | | | | |
| | Silty CLAY , trace sand Hard Grey (TILL) | | | | | | 303 | | | | | | | |
| 301.7 | | | 17 | SS | 112 | | 302 | | | | | | | |
| 21.6 | END OF BOREHOLE AT 21.6m. BOREHOLE OPEN AND DRY TO BOTTOM UPON COMPLETION. WATER LEVEL OBSERVED AT 5.5m DURING DRILLING. BOREHOLE BACKFILLED WITH GROUT TO 0.9m, HOLE PLUG TO 0.05m THEN AUGER CUTTINGS TO SURFACE. | | | | | | | | | | | | | |

ONTMT4S 6417R.GPJ 11/6/12

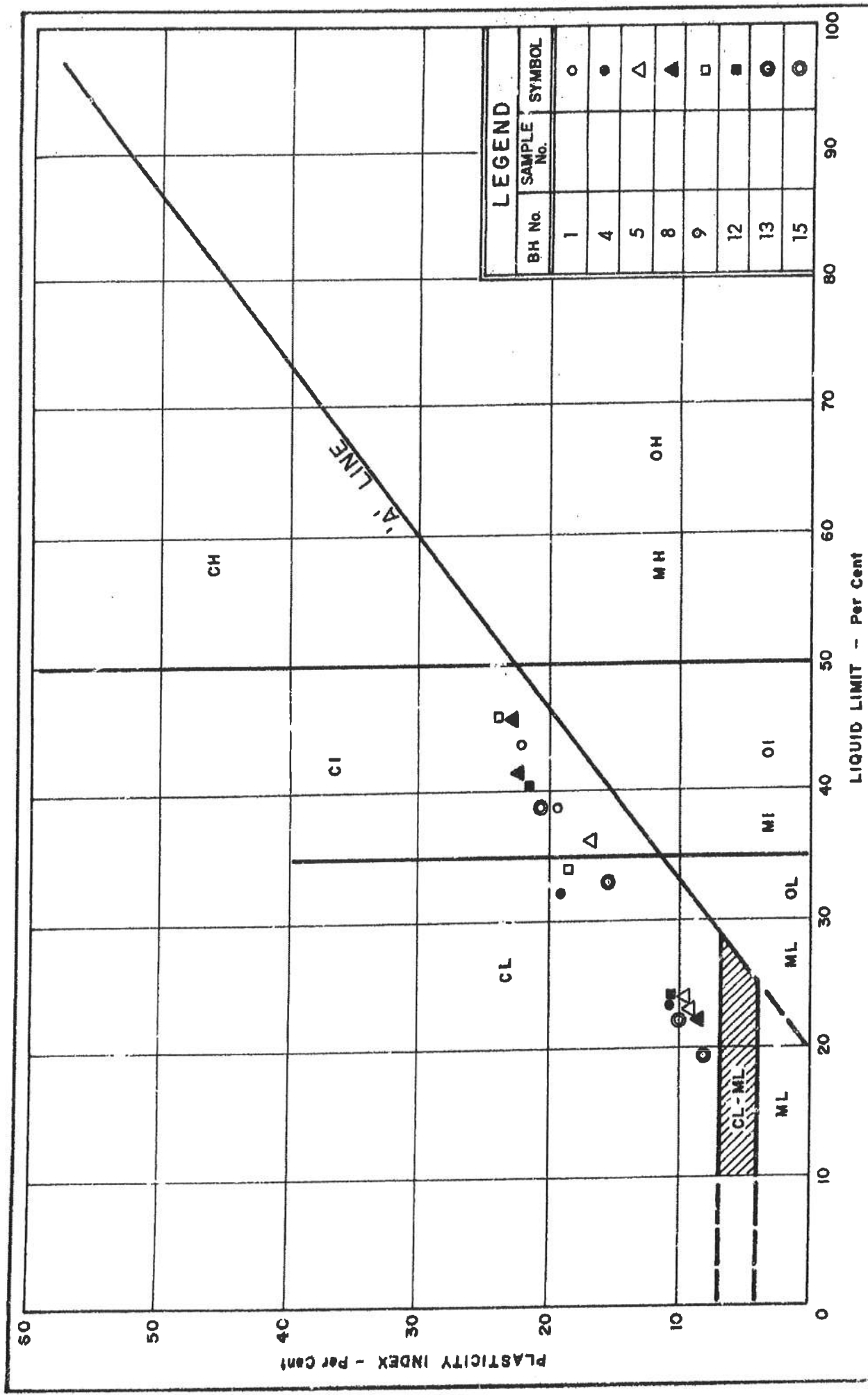


PLASTICITY CHART

DEPARTMENT OF HIGHWAYS
 MATERIALS and
 TESTING
 DIVISION



W.P. No. 635-64
 JOB No. 66-F-36



PLASTICITY CHART

DEPARTMENT OF HIGHWAYS
 MATERIALS and
 TESTING
 DIVISION



ONTARIO

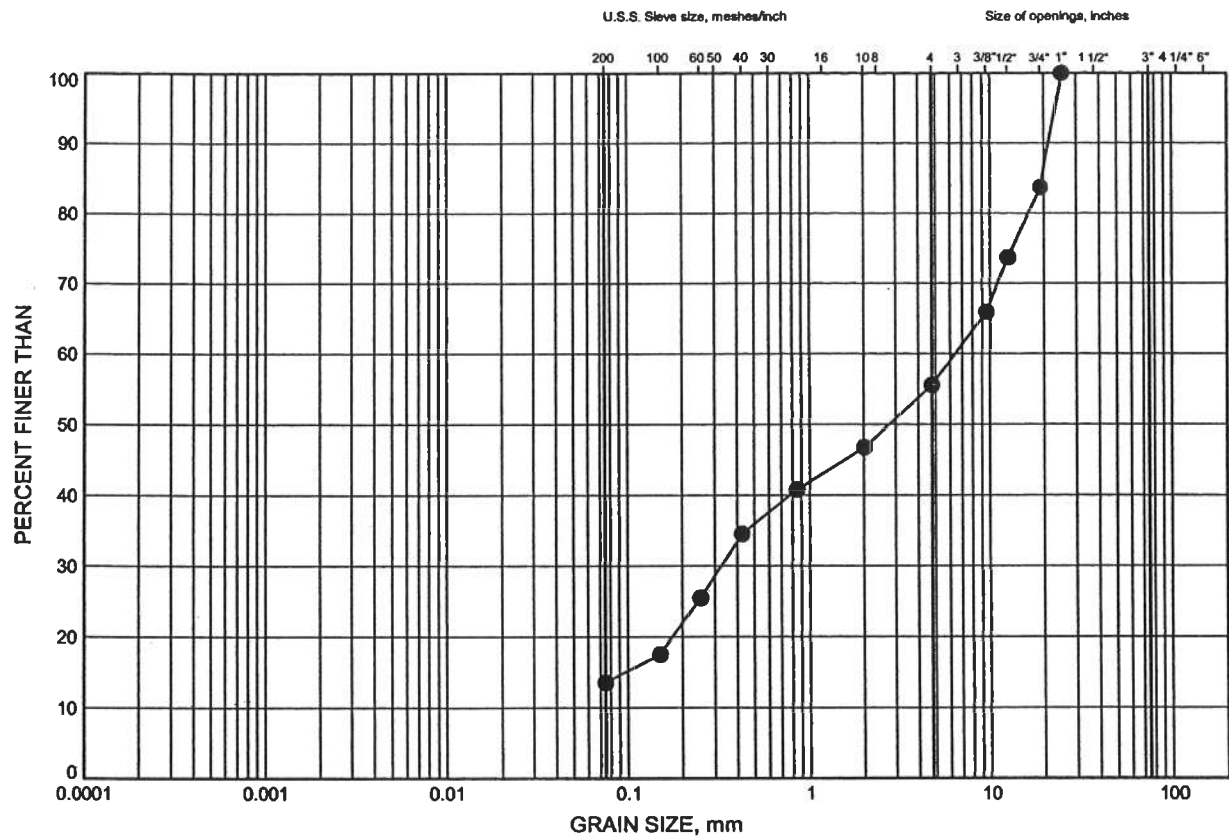
WP. No. 635-64

JOB No. 66-F-36

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly Sand Fill



| | | | | | | |
|---------------|------|--------|--------|--------|--------|-------------|
| SILT and CLAY | FINE | MEDIUM | COARSE | FINE | COARSE | COBBLE SIZE |
| FINE GRAINED | SAND | | | GRAVEL | | |

LEGEND

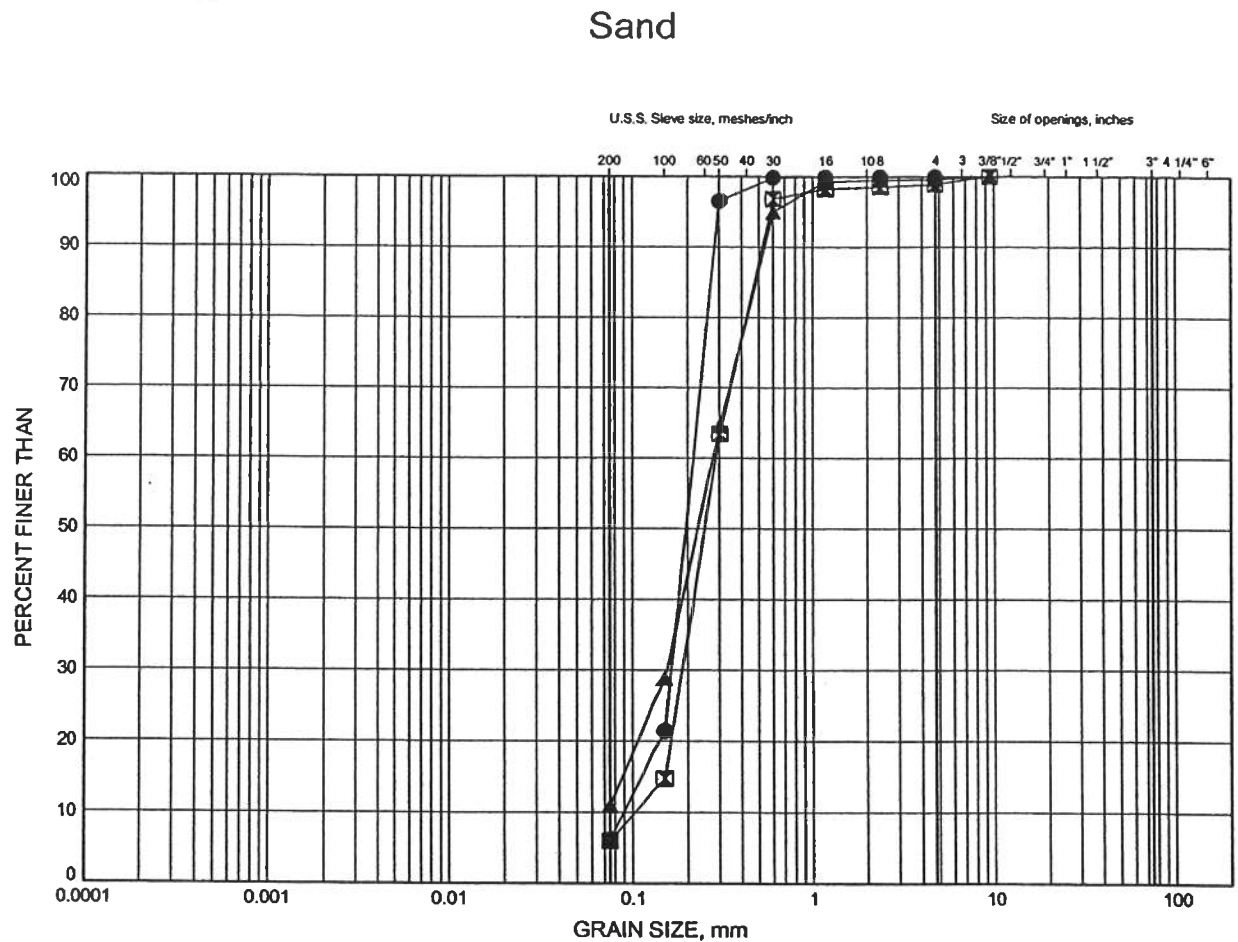
| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-048 | 2.47 | 320.88 |



W.P.# 408-88-00
Prepared By .AN.
Checked By .RPR.

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2



| | | | | | | |
|---------------|------|--------|--------|--------|--------|-------------|
| SILT and CLAY | FINE | MEDIUM | COARSE | FINE | COARSE | COBBLE SIZE |
| FINE GRAINED | SAND | | | GRAVEL | | |

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-047 | 3.35 | 320.44 |
| □ | 08-048 | 6.40 | 316.95 |
| ▲ | 08-048 | 10.90 | 312.46 |

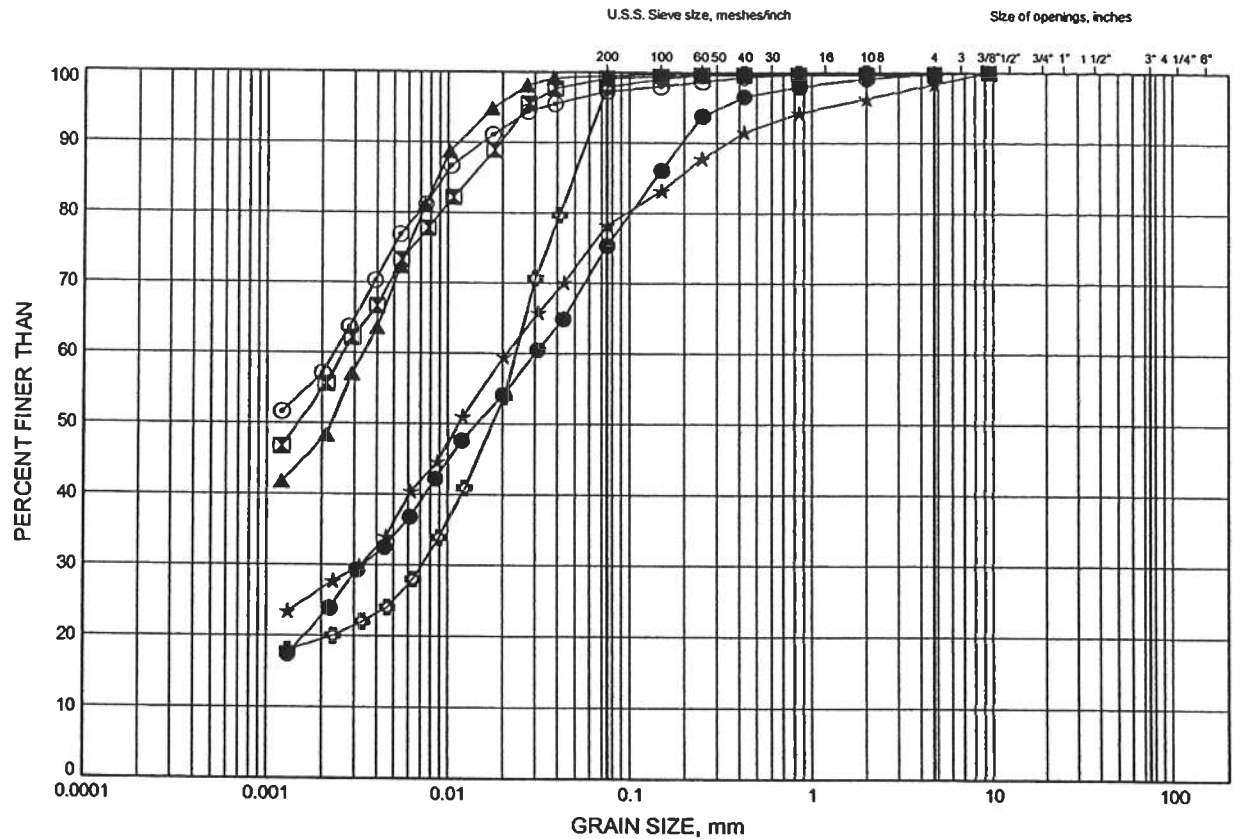


W.P.# 408-88-00
Prepared By SA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty Clay and Silty Clay Till



| | | | | | | |
|---------------|------|--------|--------|--------|--------|-------------|
| SILT and CLAY | FINE | MEDIUM | COARSE | FINE | COARSE | COBBLE SIZE |
| FINE GRAINED | SAND | | | GRAVEL | | |

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-047 | 7.92 | 315.86 |
| ⊠ | 08-047 | 12.50 | 311.29 |
| ▲ | 08-047 | 17.07 | 306.72 |
| ☆ | 08-048 | 9.45 | 313.90 |
| ⊙ | 08-048 | 14.02 | 309.33 |
| ⊕ | 08-048 | 18.52 | 304.84 |

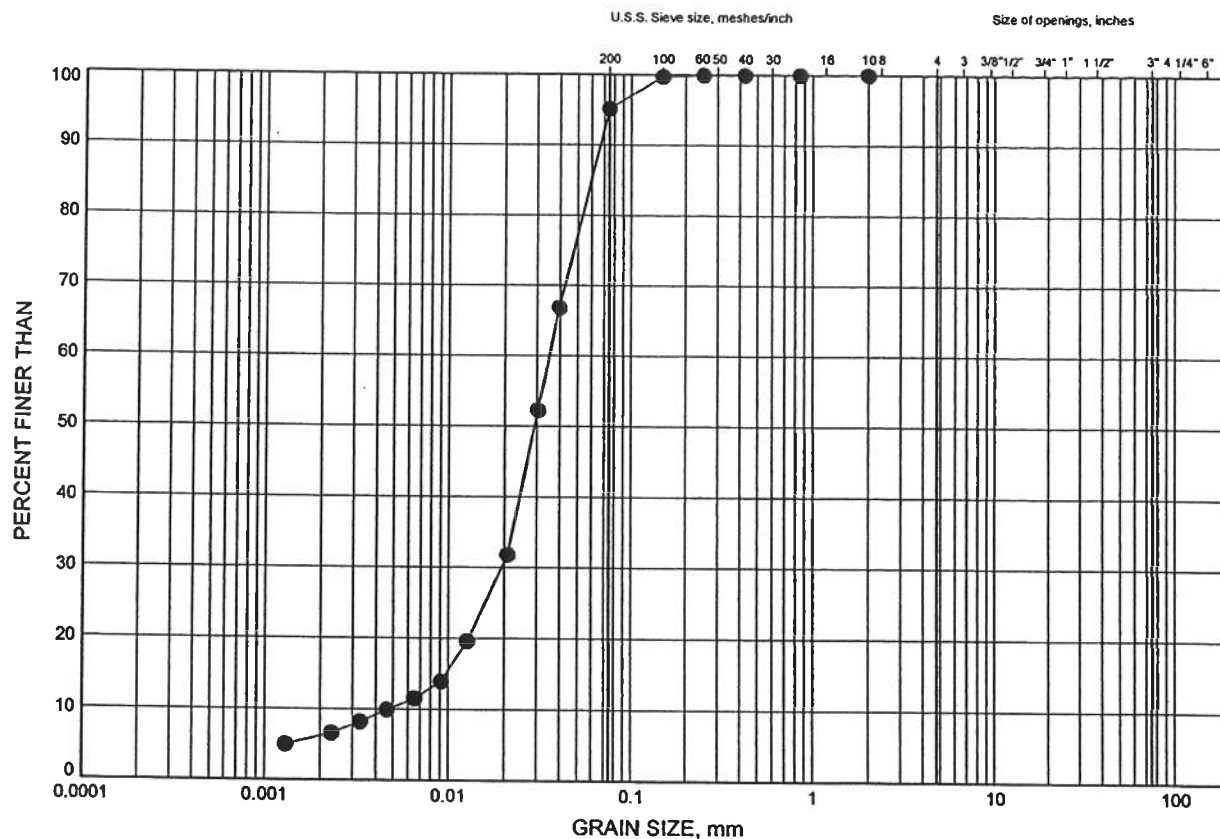


W.P.# 408-88-00
Prepared By SA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B4

Silt Till



| | | | | | | |
|---------------|------|--------|--------|--------|--------|-------------|
| SILT and CLAY | FINE | MEDIUM | COARSE | FINE | COARSE | COBBLE SIZE |
| FINE GRAINED | SAND | | | GRAVEL | | |

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-047 | 18.59 | 305.20 |

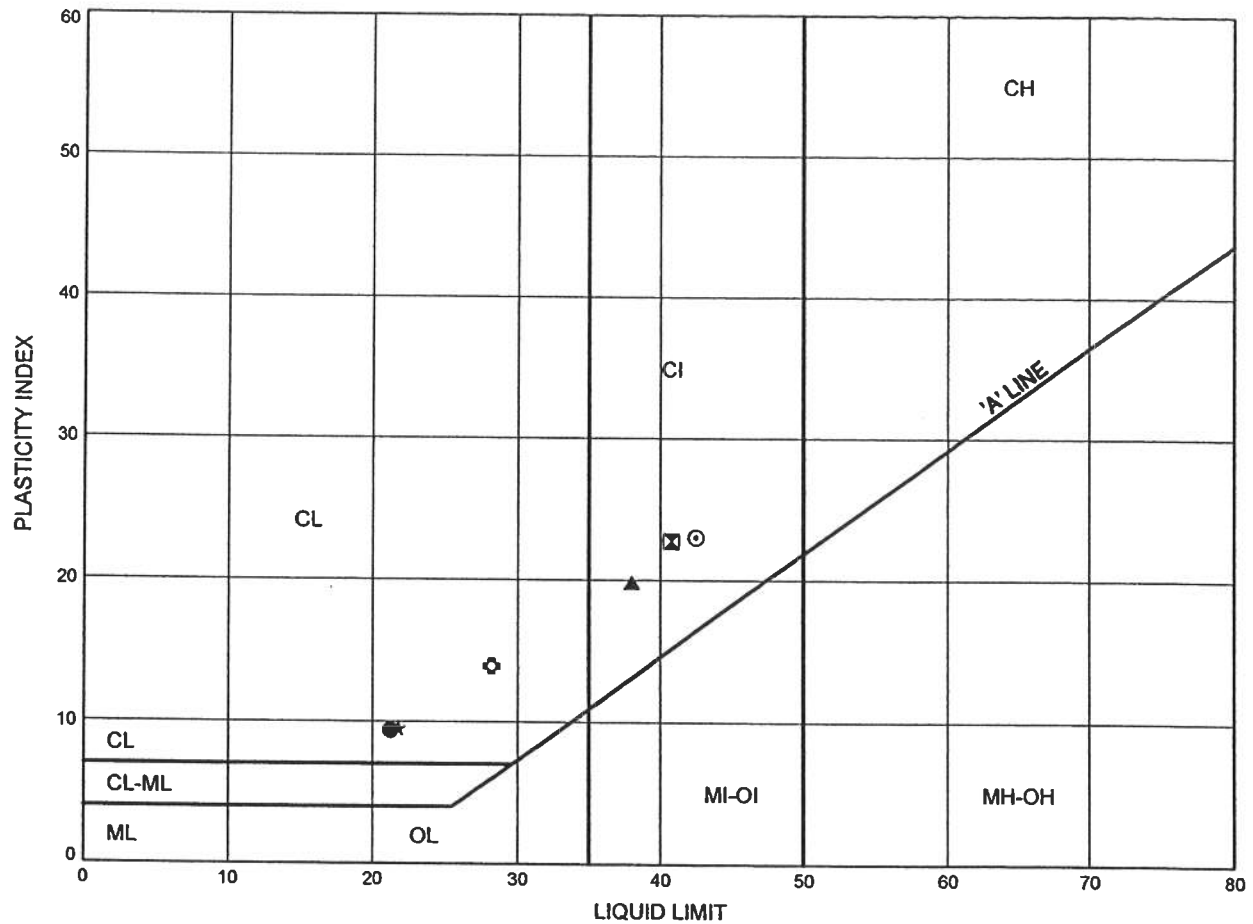


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay and Silty Clay Till



| SYMBOL | BH | DEPTH (m) | ELEV. (m) |
|--------|--------|-----------|-----------|
| ● | 08-047 | 7.92 | 315.86 |
| ⊠ | 08-047 | 12.50 | 311.29 |
| ▲ | 08-047 | 17.07 | 306.72 |
| ★ | 08-048 | 9.45 | 313.90 |
| ⊙ | 08-048 | 14.02 | 309.33 |
| ⊕ | 08-048 | 18.52 | 304.84 |

Date August 2008
 Project 408-88-00



Prep'd MFA
 Chkd. RPR

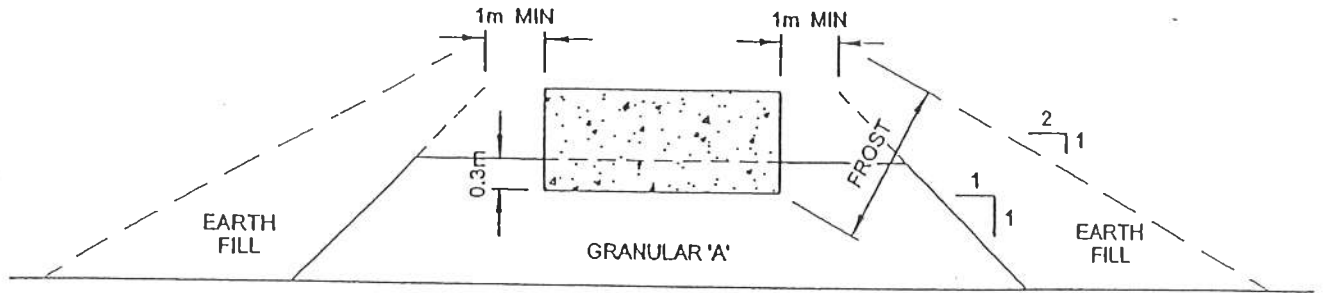
Appendix C

Foundation Comparison

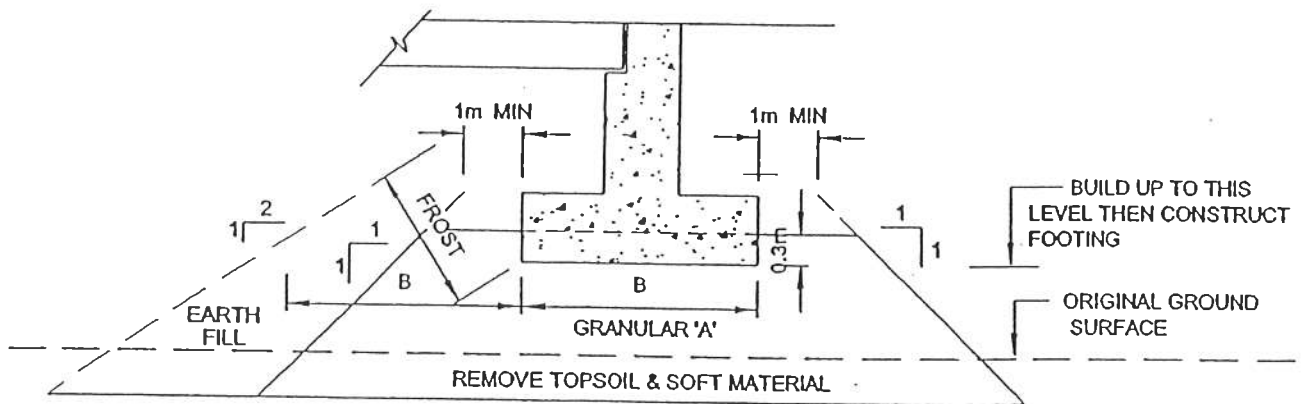
COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

| Foundation Element | | Spread Footings | Spread Footings on Engineered Fill | Driven Piles |
|---------------------------------|---------------|--|--|--|
| | | Advantages: <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. ii. Relatively simple construction method | Advantages: <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. | Advantages: <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense soils. ii. Permits integral abutment design |
| | | Disadvantages: <ul style="list-style-type: none"> i. Lower geotechnical resistance available due to founding on compact soils near the surface. ii. Dewatering may be required, depending on depth of excavation. | Disadvantages: <ul style="list-style-type: none"> i. Better geotechnical resistance than spread footings on native soil, but still influenced by the presence of compact soils. ii. Dewatering may be required, depending on depth of excavation. iii. Cost of engineered fill placement | Disadvantages: <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. No deep excavation required. iii. Pile vibration may induce settlement on the existing footings. |
| | New underpass | FEASIBLE | FEASIBLE | RECOMMENDED |
| | Pier | FEASIBLE | FEASIBLE | RECOMMENDED |
| Extension of existing underpass | Abutments | RECOMMENDED | FEASIBLE | FEASIBLE |

DRAFT



CROSS-SECTION



LONGITUDINAL SECTION

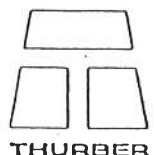
NOT TO SCALE

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

| | |
|----------|-------------|
| ENGINEER | AEG |
| DRAWN | SS |
| DATE | April, 2004 |
| APPROVED | PKC |
| SCALE | NTS |

ABUTMENT ON COMPACTED FILL SHOWING
GRANULAR A CORE



THURBER

DWG. NO.

FIGURE 1

Appendix E

Site Photographs





Photo 1. Aerial view of KWE and Victoria Street



Photo 2. KWE and Victoria Street (South Side)

Appendix F

Drawings titled “Borehole Locations and Soil Strata”



CONT No
WP No 408-88-00

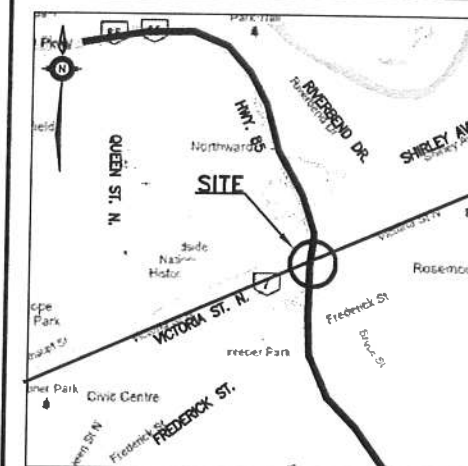


VICTORIA STREET
UNDERPASS
BOREHOLE LOCATIONS PLAN






SHEET



THURBER ENGINEERING LTD.



KEYPLAN
LEGEND

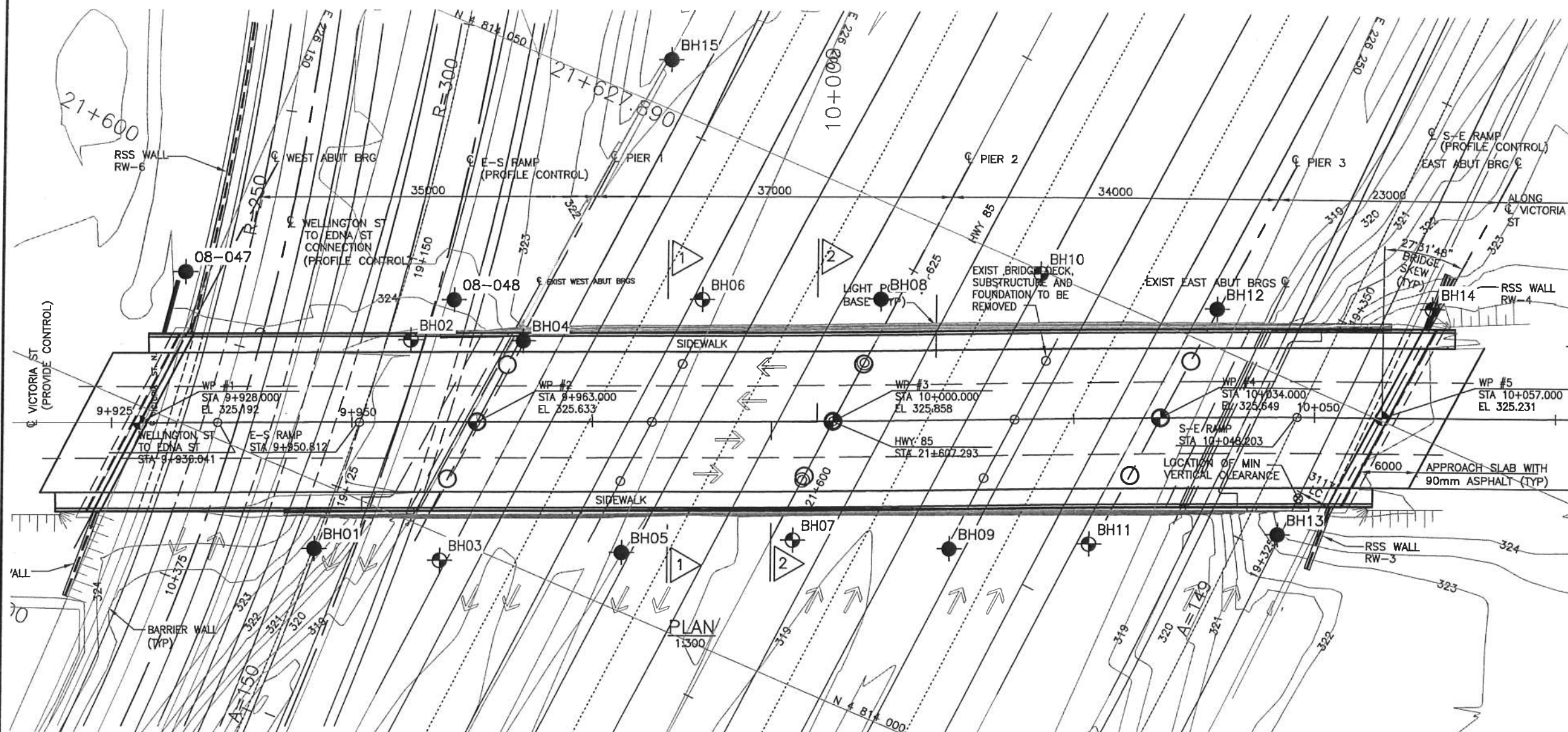
- | | |
|---|---|
|  | Borehole & Cone (Previous Investigation) |
|  | Cone Penetration Hole (Previous Investigation) |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level |
|  | Head Artesian Water |
|  | Piezometer |
| 90% | Rock Quality Designation (RQD) |
| A/R | Auger Refusal |

| NO | ELEVATION | NORTHING | EASTING |
|------|-----------|----------|---------|
| BH01 | 322.2 | | |
| BH02 | 322.8 | | |
| BH03 | 322.8 | | |
| BH04 | 322.5 | | |
| BH05 | 321.8 | | |
| BH06 | 320.7 | | |
| BH07 | 321.7 | | |
| BH08 | 320.1 | | |
| BH09 | 321.5 | | |
| BH10 | 319.2 | | |
| BH11 | 321.6 | | |
| BH12 | 321.6 | | |
| BH13 | 321.9 | | |

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 40P8-202

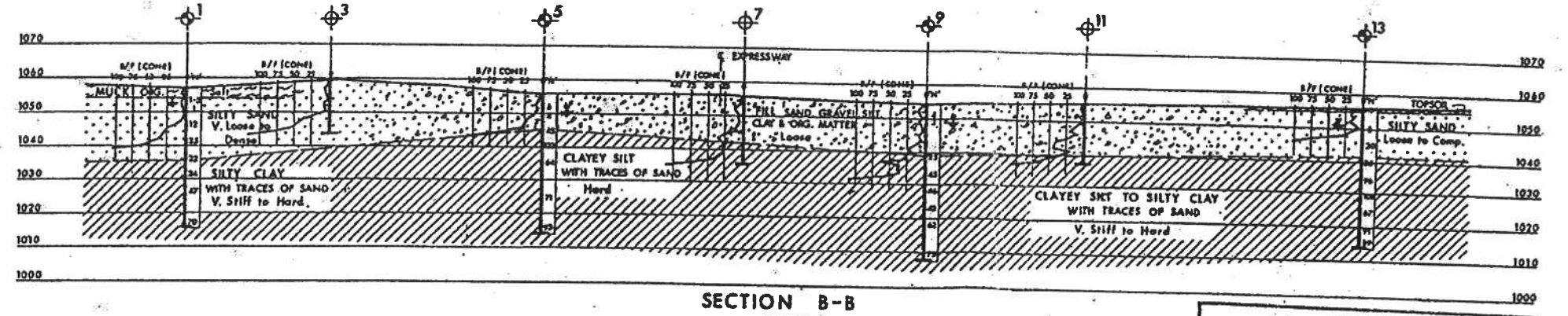
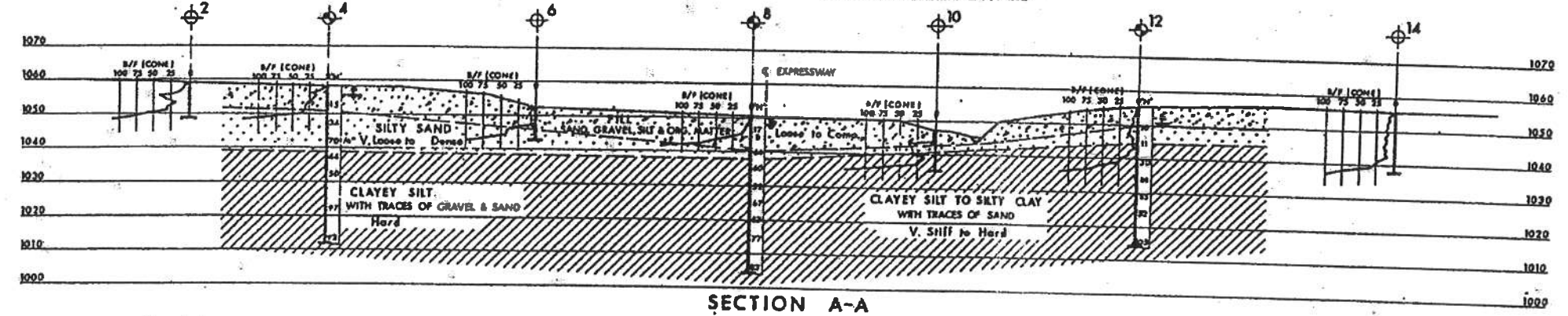
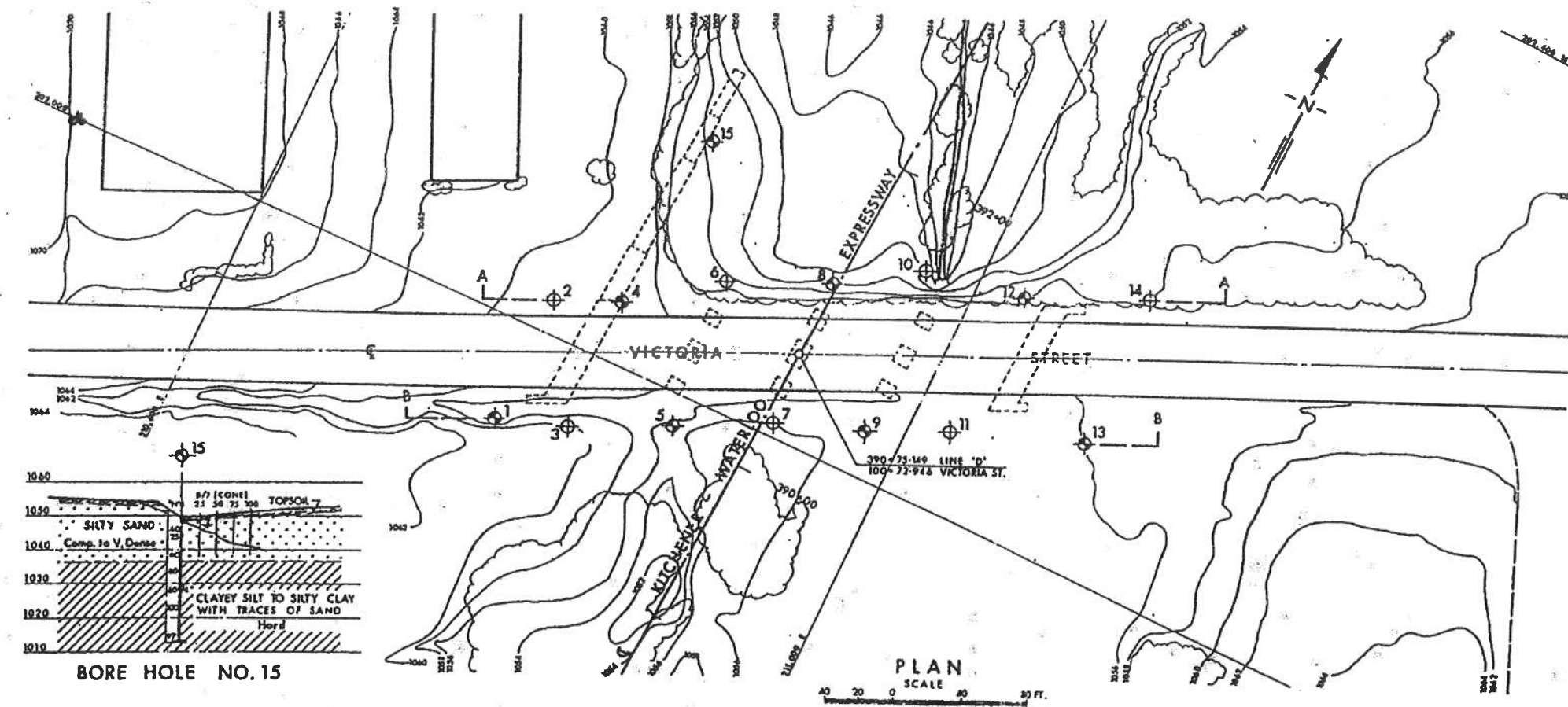
[illegible]

PLAN

SCALE 1:500



| | | | |
|--------|-------|-------------|----------|
| BH14 | 321.8 | | |
| BH15 | 319.9 | | |
| 08-047 | 323.8 | 4 814 014.6 | 226 147. |
| 08-048 | 323.4 | 4 814 022.9 | 226 174. |



NOTE
The complete soil investigation report for this structure may be examined at the Bridge Office and Foundation Office, Downsview, and at the Hamilton District Office.



- LEGEND**
- Bore Hole
 - Cone Penetration Hole
 - Bore & Cone Penetration Hole
 - Water Levels established at time of field investigation, APRIL 1964

| NO. | ELEVATION | CO-ORDINATES | |
|-----|-----------|--------------|---------|
| | | NORTH | EAST |
| 1 | 1037-00 | 201,943 | 210,780 |
| 2 | 1039-10 | 202,019 | 210,780 |
| 3 | 1039-17 | 201,956 | 210,820 |
| 4 | 1038-14 | 202,033 | 210,817 |
| 5 | 1035-83 | 201,982 | 210,874 |
| 6 | 1032-31 | 202,072 | 210,867 |
| 7 | 1035-45 | 202,008 | 210,928 |
| 8 | 1030-32 | 202,097 | 210,924 |
| 9 | 1034-65 | 202,027 | 210,978 |
| 10 | 1047-14 | 202,127 | 210,968 |
| 11 | 1035-14 | 202,047 | 211,023 |
| 12 | 1033-20 | 202,137 | 211,029 |
| 13 | 1036-18 | 202,074 | 211,099 |
| 14 | 1035-68 | 202,169 | 211,097 |
| 15 | 1049-47 | 202,142 | 210,822 |

NOTE
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.

| REVISION | DATE | BY | DESCRIPTION |
|----------|------|----|-------------|
| | | | |
| | | | |
| | | | |

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION - FOUNDATION SECTION

VICTORIA STREET

KING'S HIGHWAY NO. KITCHENER-WATERLOO EXPR. DIST. NO. 4
CO. WATERLOO CITY OF KITCHENER
TWP. LOT CON.

BORE HOLE LOCATIONS & SOIL STRATA

| | | | |
|-----------------------------|---|-----------------|--------------------|
| SUBM'D. W.K. | CHECKED <input checked="" type="checkbox"/> | DR. NO. 633-64 | M.S.T. DRAWING NO. |
| DRAWN S.O. | CHECKED <input checked="" type="checkbox"/> | JOB NO. 66-F-36 | 66-F-36A |
| DATE 17 JUNE 1966 | | SITE NO. 33-235 | BRIDGE DRAWING NO. |
| APPROVED <i>[Signature]</i> | | CONT. NO. C8-62 | D-8000-2 |