

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

Geocres Number: 40P8-203

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 Frederick Street over the Kitchener-Waterloo Expressway (KWE) in the Regional Municipality of Waterloo. The new structure will incorporate a proposed S-E ramp on the east end. 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 to the east to carry Frederick Street over the proposed S-E ramp (Bruce St. ramp) of the KWE.

No boreholes were drilled within the footprint of the proposed structure for preparation of this report. This report is based on information on subsurface conditions contained in a previous foundation report prepared in 1966. The title of the report is listed as follows:

- Foundation investigation report for Frederick Street Underpass, Kitchener-Waterloo Expressway, District #4 (Hamilton), W.J. 66-F-53, W.P. 634-64, Geocres No. 40P8-48, prepared by DHO (Department of Highways Ontario), dated July 21, 1966, (Reference 1).
- Foundation investigation and design report for Northeast Corner Retaining Wall, Frederick Street Underpass, Site No. 33-234, G.W.P. 3110-09-00, City of Kitchener, Ontario, prepared by Peto MacCallum Ltd., PML Ref. 10KF079C, Geocres No. 40P8-199, dated May 31, 2012, (Reference 2).

Records of boreholes from the previous report 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 700 m south of the Kitchener-Waterloo Expressway (KWE) and Wellington Street interchange. At this location, an underpass structure carries Frederick Street over the northbound and southbound lanes (NBL and SBL) of the KWE and existing ramps (E-S and S-E). The existing underpass at KWE and Frederick 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 Frederick Street.
2. A view of the south side of the existing structure at Kitchener-Waterloo Expressway and Frederick Street underpass.

3 SITE INVESTIGATION AND FIELD TESTING

A site investigation and field testing at this site was carried out by DHO from May 26 to June 6, 1966 and consisted of drilling and sampling a total of nine boreholes (numbered 2, 3, 6, 7, 10, 11, 14, 16 and 17) and sixteen dynamic cone penetration tests (DCPTs). Nine DCPTs were conducted adjacent to the boreholes and seven DCPTs were conducted at various locations within the underpass area. Boreholes were terminated at depths ranging from 17.0 m to 25.5 m (elevations 301.4 to 309.0). DCPTs were terminated upon refusal between 3.4 m and 8.2 m depth (elevations 317.1 to 323.1).

An investigation was conducted in 2011 by Peto MacCallum (Reference 2) for the northeast corner retaining wall of the Frederick Street on Highway 7/85 (Kitchener-Waterloo Expressway). This investigation consisted of drilling and sampling four boreholes (numbered RW-1 to RW-4) advanced to depths ranging from 6.4 m to 9.8 m (elevations 309.9 to 316.5).

For description of the subsurface soil conditions, only the boreholes and DCPTs drilled in 1966 near the proposed structure were considered (Boreholes 2, 3, 6, 7, 10, 11 and 14 and DCPTs 1 to 14). A summary is presented for the boreholes drilled in 2012 (RW-1 to RW-4).

The Record of Borehole sheets and DCPTs from the previous investigations are included in Appendices A and B. The approximate locations of the boreholes and DCPTs are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix F.

4 LABORATORY TESTING

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

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendices A and B. 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.

In general, at the time of the 1966 investigation, the site was underlain by topsoil overlying native layers of loose to very dense sand and sandy silt/silty sand and hard clayey silt/silty clay. The silty clay is underlain by very dense sandy silt to silty sand underlain by hard clay. Fill was encountered in one borehole drilled at the east end of the underpass. It should be recognized that since the deeper 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.

Boreholes drilled in 2011, at the northeast corner retaining wall revealed surficial asphalt and/or generally cohesionless fill overlying layers of native compact sand and stiff to hard silty clay.

5.1 Data from previous investigation, 1966 (Reference 1)

5.1.1 Topsoil

Sandy topsoil was encountered surficially in Boreholes 2, 3, 6, 7, 11, and 14. The thickness of the topsoil ranges from 0.9 m to 2.0 m.

SPT ‘N’ values recorded in the sandy topsoil ranged from 2 to 11 blows for 0.3 m penetration, indicating a very loose to compact relative density.

5.1.2 Fill

A 900-mm thick layer of gravelly sand fill was encountered surficially in Borehole 10, drilled near KWE northbound lane.

5.1.3 Sand

Native sand containing trace to some silt and trace gravel was encountered below the topsoil and fill in Boreholes 2, 3, 6, 7, 10, 11, and 14. The thickness of the native sand ranged from 2.3 m to 11.0 m.

Thin layers (approximately 0.9 m to 1.8 m thick) of silty fine sand, gravelly sand and silty clay were encountered within the sand in Boreholes 3, 11, and 14.

The depth to the base of the sand ranged from 4.3 m to 12.5 m (elevations 312.8 to 321.6).

Most of the SPT 'N' values recorded in the sand ranged from 9 to 36 blows for 0.3 m penetration, indicating a loose to dense relative density. Higher SPT 'N' values ranging from 45 blows for 0.3 m of penetration to 100 blows for less than 0.3 m of penetration, indicating a dense to very dense relative density, were measured near the base of the sand deposit in Boreholes 3, 11, and 14.

Moisture contents measured in Borehole 14 ranged from 12% to 28%.

Grain size distribution results from sand and gravelly sand samples are presented on the Record of Borehole sheets and in Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Sand (%)	Gravelly sand (%)
Gravel	2	47
Sand	80 to 97	46
Silt	1 to 20	7

5.1.4 Clayey Silt to Silty Clay

Native layers of clayey silt to silty clay containing some to trace sand and gravel were encountered in all of the boreholes at the depths and elevations indicated in Table 5.1. In most boreholes a lower layer of clayey silt to silty clay was encountered below a layer of sandy silt to silty sand.

Table 5.1 – Depths and Elevations of Clayey Silt to Silty Clay

Borehole	Depth below existing ground surface (m)	Thickness (m)	Elevation (m)
2	6.1 to 13.4	7.3	320.8 to 313.5
	18.0 to 25.5 (borehole termination depth)	7.5	308.9 to 301.4
3	6.1 to 11.9	5.8	320.6 to 314.8
6	4.3 to 6.1	1.8	321.2 to 319.3
	7.7 to 15.8	8.1	317.8 to 309.6
7	4.3 to 7.0	2.7	321.6 to 318.9
	10.1 to 14.0	3.9	315.8 to 311.8
10	6.1 to 17.2	11.1	319.4 to 308.3
11	4.3 to 7.0	2.7	321.3 to 318.6
	8.8 to 18.0	9.2	316.7 to 307.6
14	12.5 to 15.8	3.3	312.8 to 309.4
	18.6 to 20.3 (borehole termination depth)	1.7	306.7 to 305.0

SPT ‘N’ values measured in the clayey silt to silty clay generally ranged from 16 blows for 0.3 m penetration to greater than 100 blows for less than 0.3 m penetration, indicating a very stiff to hard consistency.

The natural moisture contents generally lay in the range of 9 to 29%.

Grain size distribution results for the clayey silt/silty clay samples tested are presented on the Record of Borehole sheets in Appendix A and in Appendix B. The results of Atterberg Limits tests for the clayey silt/silty clay samples are presented on the Record of Borehole sheets in Appendix A.

The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	7 to 14
Sand	1 to 28
Silt	41 to 80
Clay	15 to 57

Index Property	(%)
Liquid Limit	17 to 56
Plastic Limit	10 to 22

The silty clay ranges in plasticity from low to high.

5.1.5 Sandy Silt to Silty Sand

Native deposits of sandy silt to silty sand were encountered in all of the boreholes at depths and elevations indicated in Table 5.2. In general, an upper layer of sandy silt to silty sand was encountered within the clayey silt/silty clay deposit and a lower layer of sandy silt to silty sand was encountered below the clayey silt/silty clay deposit.

Table 5.2 – Depths and Elevations of Native Sandy Silt to Silty Sand

Borehole	Depth below existing ground surface (m)	Thickness (m)	Elevation (m)
2	13.4 to 18.0	4.6	313.5 to 308.9
3	11.9 to 18.1 (borehole termination depth)	6.2	314.8 to 308.6
6	6.1 to 7.7	1.6	319.3 to 317.8
	15.9 to 17.2 (borehole termination depth)	1.3	309.6 to 308.3
7	7.0 to 10.1	3.1	318.9 to 315.8
	14.0 to 17.0 (borehole termination depth)	3.0	311.8 to 308.8
10	4.3 to 6.1	1.8	321.2 to 319.4
	17.2 to 17.5 (borehole termination depth)	0.3	308.3 to 308.0
11	7.0 to 8.8	1.8	318.6 to 316.7
	18.0 to 18.6 (borehole termination depth)	0.6	307.6 to 307
14	15.8 to 18.6	2.8	309.4 to 306.7

SPT ‘N’ values measured in the sandy silt to silty sand ranged from 29 blows for 0.3 m penetration to greater than 100 blows for less than 0.3 m penetration, indicating a compact to very dense relative density.

The natural moisture contents generally lay in the range of 10% to 18%.

Grain size distribution results for the sandy silt to silty sand samples tested are presented on the Record of Borehole sheets Appendix A. The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Sand	5 to 67
Silt	32 to 95

5.1.6 Groundwater Conditions

In 1966, water levels were observed during drilling operations at depths ranging from 2.6 m to 4.0 m below ground surface (elevations 321.3 to 322.9). These water levels may have been affected by subsequent construction of the underpass. The depth to water level 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.

5.2 Data from the 2012 investigation at Northeast Corner Retaining Wall (Reference 2)

Boreholes RW-1 to RW-4 were drilled at the northeast corner retaining wall at this site. The 2011 boreholes were advanced through the embankment fill and into the underlying native materials. The subsurface conditions encountered were as follows:

- Asphalt was encountered surficially in Boreholes RW-1 and RW-2 drilled on the existing Highway 7 speed change lane in front of the retaining wall.
- Fill was contacted below the asphalt in Boreholes RW-1 and RW-2 and surficially in Boreholes RW-3 and RW-4. The fill consisted of various soils: very loose sand with some silt and some gravel, compact sand and crushed gravel, compact silty sand and silt and very stiff clayey silt. The thickness of the fill ranged from 1.4 m to 2.3 m, with a base elevation of 318.3 to 321.2.
- Native brown sand containing trace to some gravel to gravelly, trace to some silty and trace clay was contacted below the fill at 2.3 m depth (elevations 320.0 and 321.2) in Boreholes RW-3 and RW-4. The sand was compact in density. The thickness of the sand layer was 2.1 and 3.6 m in Boreholes RW-3 and RW-4, respectively.
- Stiff to hard dark brown to grey silty clay containing trace sand and trace gravel was contacted below the fill in Boreholes RW-1 and RW-2 at 1.4 m depth (elevations 318.3) and below the sand in Boreholes RW-3 and RW-4 at 4.4 m and 5.9 depth (elevations 317.9 and 317.6). Layers of silty sand and gravelly sand were encountered within the silty clay in Borehole RW-3. Cobbles were noted in the silty clay in Boreholes RW-3 and RW-4. The silty clay is low to medium plastic. The boreholes were terminated within the silty clay at depths ranging from 6.4 m to 9.8 m (elevations 309.9 to 316.5).
- Water levels measured during, upon completion of drilling and in the piezometers are indicated in Table 5.3.

Table 5.3 – Water Level Measurements

Borehole	Date	Water Level (m)		Comments
		Depth	Elevation	
RW-1	April 8, 2011	2.9	316.8	In piezometer
RW-2	April 8, 2011	7.3	312.4	Upon completion of drilling
RW-3	April 8, 2011	3.0	319.3	During drilling
	July 19, 2011	Dry	-	In piezometer
	September 23, 2011	3.3	319.0	In piezometer
	October 8, 2011	3.3	319.0	In piezometer
RW-4	April 8, 2011	4.2	319.3	During drilling

Cave-in was observed in Boreholes RW-1, RW-2 and RW-4 at 5.0 m to 8.7 m depth (elevations 311.0 to 318.5).

The above values are short-term readings and 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

Interpretation of the 1966 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 Frederick 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 2-span structure supported on one pier and two abutments is proposed. The lengths of the spans will be 46 m and 56 m. The new structure will incorporate a new S-E ramp (Bruce Street ramp) at the east end of the structure.

Based on the GA drawing, the proposed Frederick Street grade will vary from west to east (across KWE) from elevations 329.6 to 327.7. The proposed grade of the S-E ramp is near elevation 319.0. Previous boreholes drilled at the proposed east abutment indicated that the ground surface elevation was near elevation 325.2. Based on these elevations, a cut of approximately 6.0 m depth will be required to construct the proposed S-E ramp under Frederick Street. Placement of 2 m of fill will be necessary to achieve the proposed Frederick Street grade. The heights of the west and east approaches will be approximately 7.0 m to 8.0 m.

2. Extension of the existing underpass structure to the east.

Maintain the existing structure (abutment, wingwall and footing) and extend it to the east to carry Frederick Street over the proposed S-E ramp (Bruce Street ramp). GA drawing indicates that the existing expansion joints, ballast wall, wingwalls, approach slab and part of the parapet wall and railing will be removed. The existing east abutment and footings

will be maintained. New foundations will be required for the proposed bridge extension which will be founded on two new west and east abutments.

The length of the bridge extension is approximately 22.0 m. The span of the rigid frame will be approximately 12.0 m and the width of bridge deck will be approximately 18.9 m.

The proposed Frederick Street grade will vary from west to east (across the S-E ramp) from elevations 325.4 to 325.1. The proposed grade of the S-E ramp is near elevation 319.0. Previous boreholes drilled near the existing east abutment indicated that ground surface elevation was near elevation 325.4. Based on these elevations, a cut of approximately 6.1 m to 6.4 m depth will be required to construct the S-E ramp under Frederick Street.

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

8 STRUCTURE FOUNDATIONS

For preparation of geotechnical recommendation in this report, the deeper boreholes drilled in 1966 were used.

The stratigraphy identified in the 1966 investigation consisted primarily of topsoil overlying native layers of loose to dense sand, hard silty clay/clayey silt and compact to very dense sandy silt/silty sand.

During the 1966 investigation, groundwater level was observed at elevations ranging from 321.3 to 322.9. Groundwater level measured in October 2011 at the northeast side of the underpass was at elevation 319.0.

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 the very dense soil

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 structure or the proposed bridge extension 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 very dense sand or very stiff to hard silty

clay/clayey silt 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)	Highest Elevation	ULS _r (kPa)	SLS (kPa)	Soil
East Abutment of the replacement structure option	11 14	Below 1.0 ⁽¹⁾	At or below 318.0 ⁽¹⁾	375	250	Compact sand
Or New east and west abutments for S-E ramp (Bruce St. ramp) for bridge extension option		Below 2.0 ⁽¹⁾	At or below 317.0 ⁽¹⁾	600	400	Very dense sand
Pier	7 10	2.0 ⁽²⁾	319.0 ⁽²⁾	600	400	Hard clayey silt/ Dense silty sand
West Abutment	2 3	3 ⁽³⁾	318.5 ⁽³⁾	600	400	Hard silty clay

⁽¹⁾Depths/elevations below the base of the 6-m cut for the proposed S-E ramp (elevation 319.0).

⁽²⁾Depths/elevations below the existing KWE grade shown in GA (approx. elevation 321.0).

⁽³⁾Depths/elevations below the existing KWE grade shown in GA (approx. elevation 321.5).

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 of footing concrete on the native soils may be assumed to be 0.45 for sand/silt and 0.4 for silty clay/clayey silt.

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 extension of the existing underpass to the east is the selected design option, the footings of the existing east abutment 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

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 17.0 m to 25.5 m deep (elevations 301.4 to 309.0), revealing a soil stratigraphy that consists of loose to dense sand over very stiff to hard cohesive soils, with a few layers of dense to very dense sandy silt. Preliminary geotechnical capacities for piles were estimated based on the available data.

For preliminary design purposes, a pile length of 25.0 m below the pile cap has been assumed. The estimated pile tip elevations are provided in Table 8.2.

Table 8.2 – Estimated Pile Tip Elevation

Foundation Unit	Borehole	Pile Tip Depth (m)	Estimated Pile Tip Elevation
East Abutment for the replacement structure option or New east and west abutments for S-E ramp (Bruce St. ramp) for bridge extension option	11 14	25	297.0 ⁽¹⁾
Pier	7 10	25	292.5 ⁽²⁾
West Abutment	2 3	25	300.0 ⁽³⁾

⁽¹⁾ Pile tip depths/elevations from underside of pile cap indicated in GA, approx. elevation 322.0.

⁽²⁾ Pile tip depths/elevations from underside of pile cap indicated in GA, approx. elevation 317.5.

⁽³⁾ Pile tip depths/elevations from underside of pile cap indicated in GA, approx. elevation 325.0.

The estimated pile tip elevations are below the depth of exploration in the 1966 investigation. Additional field investigation including deeper boreholes is required at the detailed design stage to confirm the pile tip elevation that will develop the required resistance.

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 are presented in Table 8.3. The assumed pile length is 25.0 m.

Table 8.3 – Axial Resistance of Pile Sections Founded on Very Dense/Hard Soils

Foundation Unit	Pile Length	Pile Section	Geotechnical Resistance (kN)	
			Factored ULS	SLS
Abutments Piers	25.0	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

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

Pile installation should be in accordance with OPSS 903. Tip protection should be provided for both H-piles and pipe piles.

The pipe piles should be driven open ended. The pipe piles are more prone to damage when driven into dense/hard soils, particularly if they encounter obstructions such as a layer of cobbles and boulders.

Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance should 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.

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 the bridge replacement 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 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 abutment and pier foundations for a new structure consist of steel H-piles driven into the hard soils at or below the elevation of 297.0 at the east abutment, 292.5 at the pier and 300.0 at the west abutment.

Additional field investigation is required at the detailed design stage to confirm the pile tip elevation that will develop the required resistance.

- **Extension of the existing underpass structure to the east.**

For this design alternative, the recommended foundation for the bridge extension is spread footings founded on dense 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 existing footing.

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

9 BRIDGE APPROACHES AND EMBANKMENTS

Permanent earth cut is required to build the proposed S-E ramp (Bruce Street ramp) under Frederick Street for both alternatives. The cut will be formed predominantly through 6.0 m of possibly compact sand and hard clayey silt. The proposed base of the cut (below elevation 319), is below the groundwater table observed at elevations 321.3 to 322.0 during the investigation conducted in 1966.

During detail design, when the S-E ramp grade has 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 east abutment footings must not be undermined during excavation of the cut.

10 RETAINING WALL

GA drawing indicates that retaining walls are incorporated in the design at the east and west abutments.

10.1 Cantilever wall

Cantilever walls could be founded on native compact to very dense sand. The founding elevations and geotechnical resistances for the wall foundations are provided in Table 10.1 below. Design earth pressure parameters are provided in Section 11 of this report.

10.2 Retained soil system

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	Depth (m)	Elevation	ULS _r (kPa)	SLS (kPa)	Soil
East Abutment of the replacement structure option or New east and west abutments for S-E ramp for bridge extension option (Bruce St. ramp)	11 14	2.0 ⁽¹⁾	Below 318.0 ⁽¹⁾	375	250	Compact sand
West Abutment	2 3	1.5 ⁽²⁾	320.0 ⁽²⁾	375	250	Very stiff to hard clayey silt

⁽¹⁾Depths/elevations below the base of the 6-m cut for the proposed E-S ramp (elevation 319.0).

⁽²⁾Depths/elevations below the existing KWE grade shown in GA (approx. elevation 321.5).

Alternatively, the RSS may be founded on engineered fill founded on the native soils at elevations 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 walls 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 dated September 2008.

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:

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

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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	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 extension of the bridge is the selected option special attention should be paid to the following issues:

- New footing construction for the bridge extension to accommodate the proposed E-S Ramp must not undermine the existing east abutment footings.
- Settlement monitoring of the existing east abutment and footing 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 water level information available only at the northeast side of the site after construction of KWE and existing Frederick Street underpass. Further investigation is required to establish the new water level across the site 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 and Laboratory Test Results (Previous Investigation, Geocres No. 40P8-48 – Reference 1)

Foundation investigation report for Frederick Street Underpass, Kitchener-Waterloo Expressway, District #4 (Hamilton), W.J. 66-F-53, W.P. 634-64, Geocres No. 40P8-48, prepared by DHO (Department of Highways Ontario), dated July 21, 1966.

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

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	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_c	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
σ'	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

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION
JOB 66-F-53
W.P. 634-64
DATUM Geodetic

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

LOCATION N 200,786.159, E210,719.093
BORING DATE May 31, 1966.
BOREHOLE TYPE Dynamic Cone Penetration

ORIGINATED BY D.W.
COMPILED BY D.W.
CHECKED BY K.G.S.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL		BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	SHEAR STRENGTH P.S.F.	PLASTIC LIMIT — WP	WATER CONTENT — W		
1072.7	Groundlevel											
0.0						1070						
						1060						
1058.8	End of borehole.											
13.9												
						1050						

103/11"

DEPARTMENT OF HIGHWAYS - ONTARIO
 MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 66-F-53 LOCATION N 200,887.525, E 210,709.963 ORIGINATED BY D.W.
 W.P. 634-64 BORING DATE May 26, 1966. COMPILED BY D.W.
 DATUM Geodetic BOREHOLE TYPE Penetration & Washboring. CHECKED BY K.G.S.

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	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		20	40	60	80	100	WP	W	WL		
1072.4	Groundlevel															
0.0	Sand (Topsoil) Loose					1070										
1068.4			1	SS	8											
4.0			2	SS	24											
	Sand occasional trace of silt. Compact.		3	SS	20											
			4	SS	25	1060										
			5	SS	10											
			6	SS	30											
1052.4			7	SS	28	1050										
20.0	Clayey silt with some sand and gravel Stiff to hard.		8	SS	15											
			9	SS	57											
1045.4			10	SS	71											
27.0			11	SS	44	1040										
	Silty clay Hard Brownish grey.		12	SS	194											
			13	SS	88	1030										
1028.4			14	SS	100/11"											
44.0			15	SS	85/6"	1020										
	Fine sandy silt to silty fine sand. Very dense.															
1013.4			16	SS	120	1010										
59.0																
	Silty clay Hard Brownish grey.		17	SS	92	1000										
			18	SS	46	990										
988.9			19	SS	130											
83.5	End of borehole.					980										

 Sa 80%
 Si 20%

 G. W. L.
 1059.4
 Sa 96% Si 4%

 Gr 14%
 Sa 27%
 Si 44%
 Cl 15%

[illegible]

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200.821.407. E210.811.176

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE May 31, 1966.

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Dynamic Cone Penetration

CHECKED BY K.G.S. *AK*

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL		BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.	PLASTIC LIMIT — WP	WATER CONTENT — W		
1069.8	Groundlevel										
0.0											
					1060						
					1050						
1049.8	End of borehole.										
20.0					1040						

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53 LOCATION N 200.844.706, E 210.861.156ORIGINATED BY D.W.W.P. 634-64BORING DATE May 31, 1966.COMPILED BY D.W.DATUM GeodeticBOREHOLE TYPE Penetration & Washboring.CHECKED BY K.G.S.

SOIL PROFILE		STRAT. PLOT	SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W		BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	SHEAR STRENGTH P.S.F.	WATER CONTENT %	WATER CONTENT %		
1069.1	Groundlevel											
0.0	Sand (Topsoil) Loose											Sa 88% Si 12%
1062.6			1	SS	6							
6.5	Sand with trace of silt. Compact.		2	SS	20	1060						GWL El. 1058.6
1055.1			3	SS	19							
14.0	Clayey silt with trace of sand and gravel. Very stiff to hard.		4	SS	16	1050						
1046.1	Grey		5	SS	34							Sa 67% Si 32%
23.0			6	SS	100/11"							
	Silty fine sand.		7	SS	100/9"	1040						
	Very dense.		8	SS	52/2"							
1036.1			9	SS	80							
33.0	Silty clay. Hard. Brownish grey.		10	SS	61	1030						
1023.1			11	SS	97							
46.0						1020						
	Fine sandy silt. Very dense.											Sa 28% Si 72%
1013.2			12	SS	110/5"							
55.9	End of borehole.					1010						

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 8

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200,939.749, E 210.847.402

ORIGINATED BY D.W.

W.P. 634-64

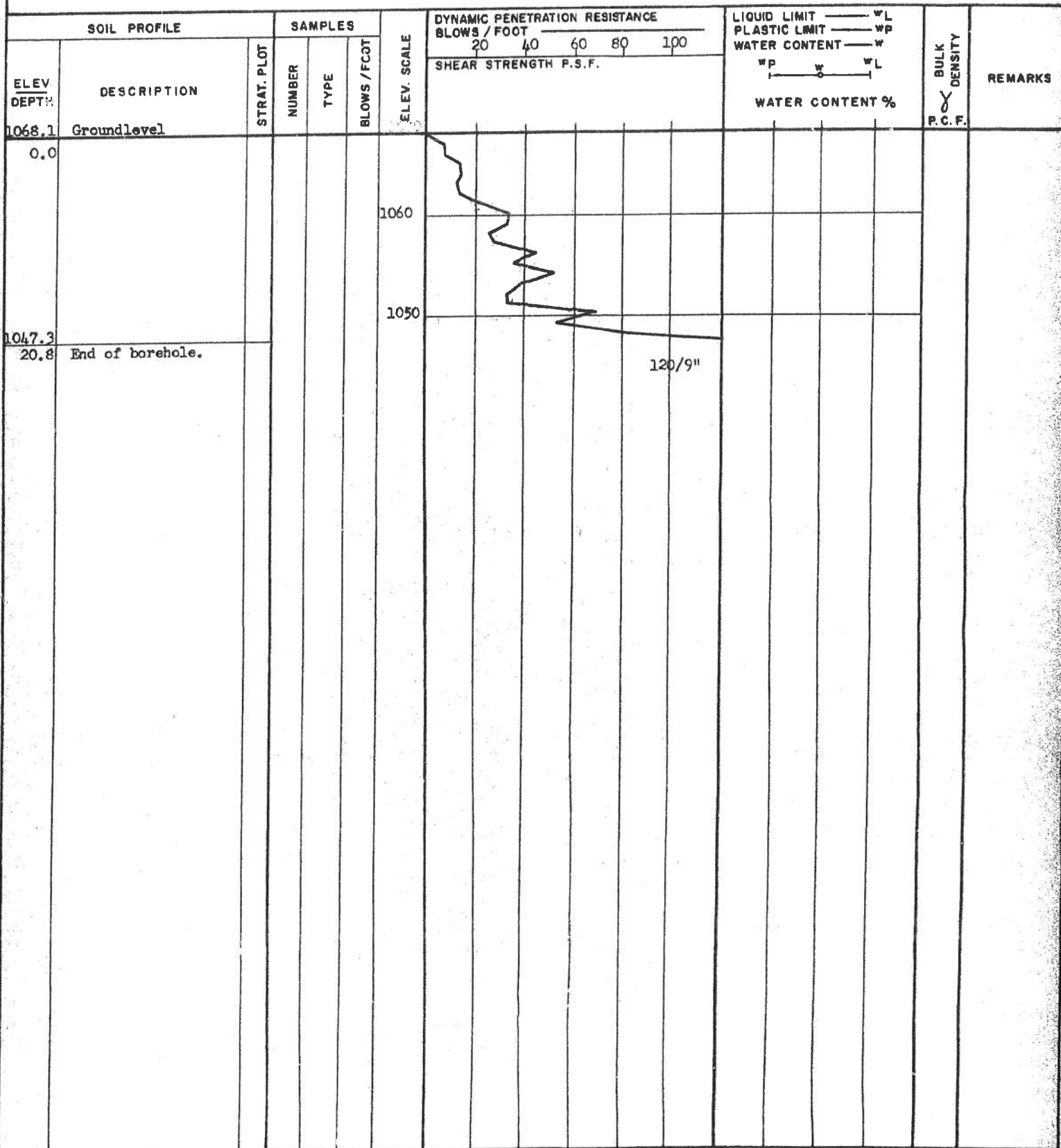
BORING DATE June 6, 1966.

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Dynamic Cone Penetration.

CHECKED BY K.G.S.



DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 9

FOUNDATION SECTION

JOB 66-F-53 LOCATION N 200,873.400, E 210,912.942 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE June 2, 1966 COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Dynamic Cone Penetration. CHECKED BY K.G.S. *AK*

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL		BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.	PLASTIC LIMIT — WP	WATER CONTENT — W		
1069.0	Groundlevel										
1046.5											
22.5	End of borehole.										

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 10

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200,955.200, E 210,895.815

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE June 3, 1966.

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Penetration & Washboring

CHECKED BY K.G.S.

SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL		BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. LOT	NUMBER	TYPE	BLOWS / FOOT	BLOWS / FOOT	WATER CONTENT — W	WATER CONTENT — W			
1067.9	Groundlevel										
0.0	Fill gravelly sand.										
1064.9											
3.0	Sand with trace of silt. Loose to compact.		1	SS	9	1060					
			2	SS	29						
1053.9											
14.0	Fine sandy silt. Dense		3	SS	34	1050					
1047.9			4	SS	29						
20.0	Clayey silt with some sand & gravel. Hard.		5	SS	54						
1044.9			6	SS	99						
23.0			7	SS	77	9"1040					
			8	SS	64						
	Clayey silt to silty clay. Hard. Brownish grey.		9	SS	73	1030					
			10	SS	41						
			11	SS	45	1020					
1011.4	Fine sandy silt. Very dense.		12	SS	70	1010					
1010.8			13	SS	123	6"					
57.5	End of borehole.										

Sa 90%
S1 10%GWL EL.
1056.3Sa 5%
S1 95%

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200,883.088. E 210,947.710

ORIGINATED BY D.W.

W. P. 634-64

BORING DATE MAY 31, 1966.

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Penetration & Washboring

CHECKED BY K.G.S.

[illegible]

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 12

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200.967.693, E 210.949.158

ORIGINATED BY D.W.

W. P. 634-64

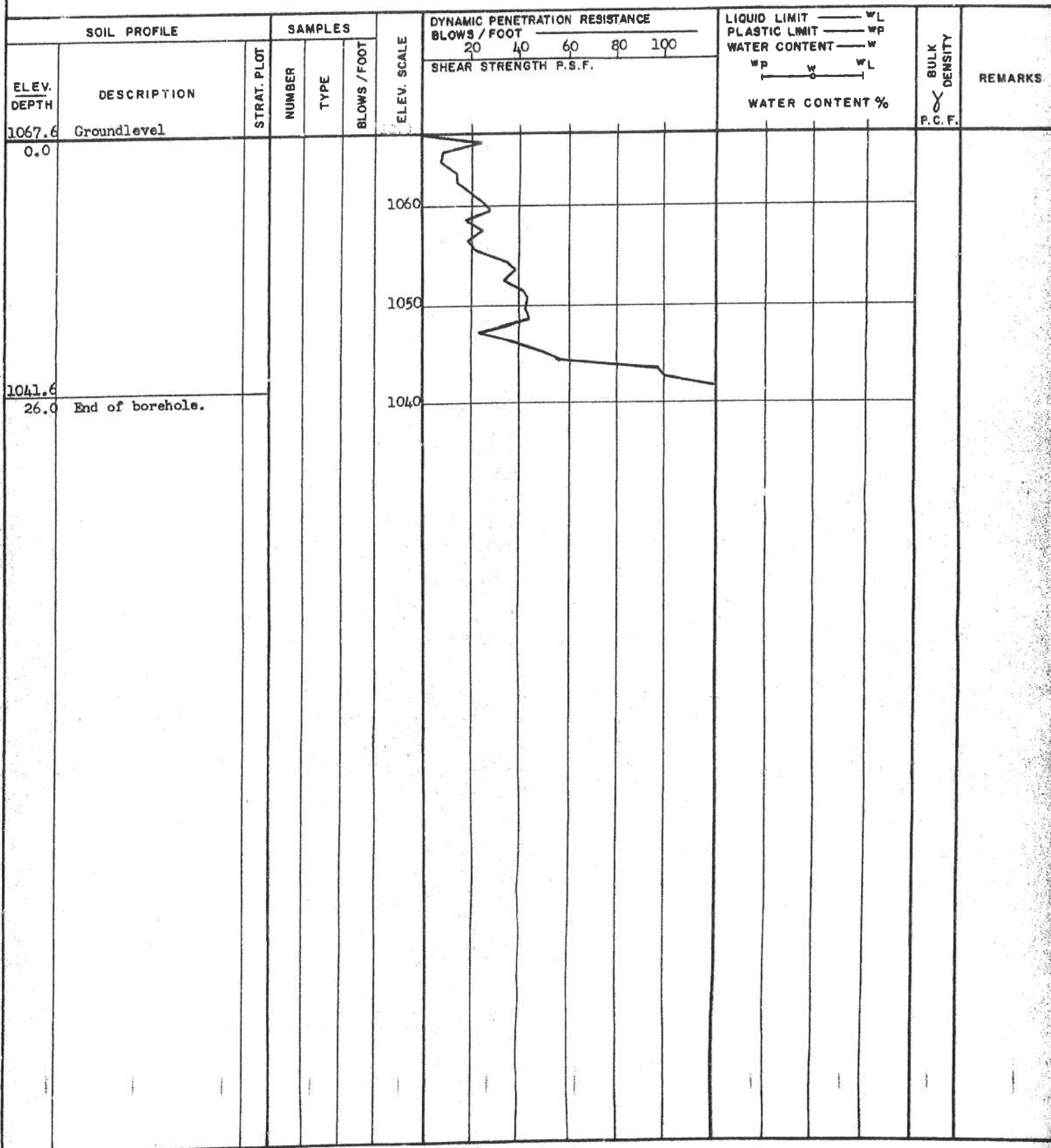
BORING DATE June 6, 1966

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Dynamic Cone Penetration.

CHECKED BY K.G.S. *[Signature]*



DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 13

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200.914.762. E 211.000.220

ORIGINATED BY D.W.

W.P. 634-64

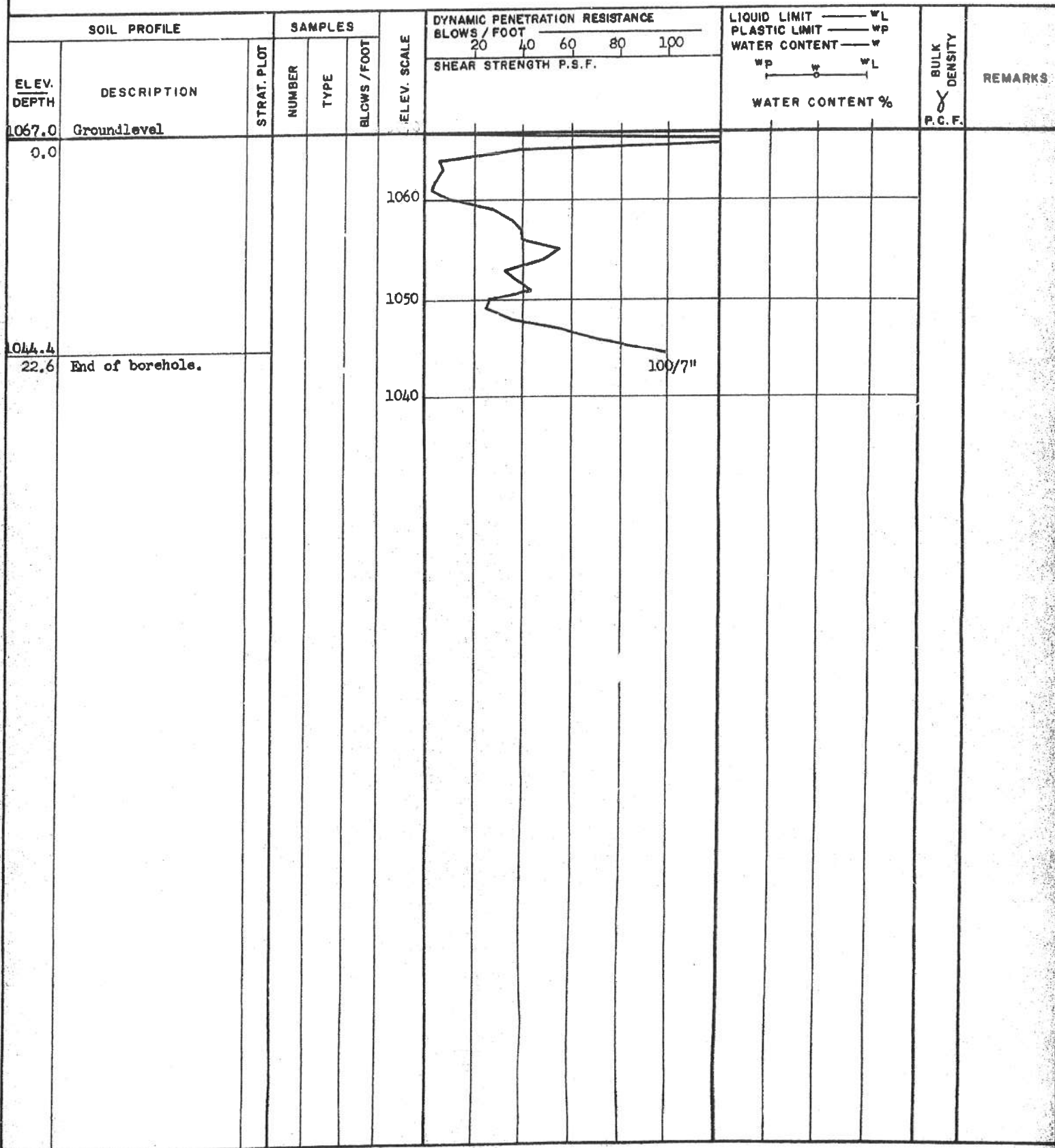
BORING DATE June 2, 1966

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Dynamic Cone Penetration

CHECKED BY K.G.S.



DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 14

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 200,997.938, E 210,999.324

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE June 2, 1966

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Penetration & Washboring.

CHECKED BY K.G.S. *JK*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT					WATER CONTENT %				
							20	40	60	80	100	15	30	45		
SHEAR STRENGTH P.S.F.												WP — W — WL				
1067.2	Groundlevel															
0.0	Sand (Topsoil)															
1062.2	Compact		1	SS	11											
5.0			2	SS	14	1060										
	Sand with trace of silt.		3	SS	18											
			4	SS	15											
	Compact.		5	SS	15	1050										
			6	SS	17											
			7	SS	20											
			8	SS	28											
1041.2	Silty clay with trace of sand. Hard.		9	SS	130	1040										
1038.2			10	SS	100/9"											
29.0	Sand with some silt. Very dense.		11	SS	62	1030										
1026.2			12	SS	93											
41.0	Silty clay. Hard.		13	SS	47	1020										
1015.2	Fine sandy silt. Very dense.		14	SS	109	1010										
1006.2	Silty clay Hard															
61.0	Brownish grey		15	SS	120	1000										
1000.7																
66.5	End of borehole.															

Sa 89%
 Si 11%
 GWL El.
 1054.2
 Sa 93%
 Si 7%
 Gr 2%
 Sa 97%
 Si 1%

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 16

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53

LOCATION N 201,116.543, E 210,741.917

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE June 3, 1966

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Penetration & Washboring

CHECKED BY K.G.S. *JK*

SOIL PROFILE		STRAT. PLOT	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 % 15 30 45	BULK DENSITY P.C.F.	REMARKS
E-EV. DEPTH	DESCRIPTION		NUMBER	TYPE					
1065.0	Groundlevel								
0.0	Sand	[Pattern]	1	SS	17	1060			
	Compact								
1056.0			2	SS	26				
9.0	Clayey silt to silty clay with some sand and gravel.	[Pattern]	3	SS	62	1050			Gr 7%
	Very stiff to hard		4	SS	111				Sa 26%
	Brownish grey.		5	SS	126				Sl 46%
			6	SS	87	1040			Cl 19%
1036.0			7	SS	85				
29.0	Silty clay	[Pattern]	8	SS	83				Sa 2%
	Hard								Sl 41%
1024.0	Brownish grey.		9	SS	39	1030			Cl 57%
41.0			10	SS	105				
	Silty fine sand,	[Pattern]	11	SS	91/8"	1020			
	Very dense								
1008.5			12	SS	116	1010			
56.5	End of borehole.					1000			

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 17

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 66-F-53 LOCATION N 200,754.293, E 210,935.966ORIGINATED BY D.W.W.P. 634-64 BORING DATE June 2, 1966COMPILED BY D.W.DATUM Geodetic BOREHOLE TYPE Penetration & WashboringCHECKED BY K.G.S.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	20	40	60	80	100	WP	WL		
1069.6	Groundlevel															
0.0	Sand															
	Loose to v. dense		1	SS	9											
			2	SS	70	1060										
1054.6			3	SS	28											
15.0	Clayey silt		4	SS	34											
	Very stiff to hard.		5	SS	22	1050										
1049.1			6	SS	27											
20.5	Fine sandy silt, v. dense		7	SS	53											
1046.6			8	SS	150/7"	1040										
23.0	Clayey silt to silty clay.		9	SS	60/6"											
	Hard.		10	SS	88											
	Brownish grey.		11	SS	76	1030										
1025.4			12	SS	68/6"											
	re sandy silt.					1020										
	very dense															
1013.8			13	SS	50/3"											
55.8	End of borehole.					1010										

Sa 91%
 Si 9%
 GWL
 El.
 1057.8

Sa 1%
 Si 80%
 Cl 19%

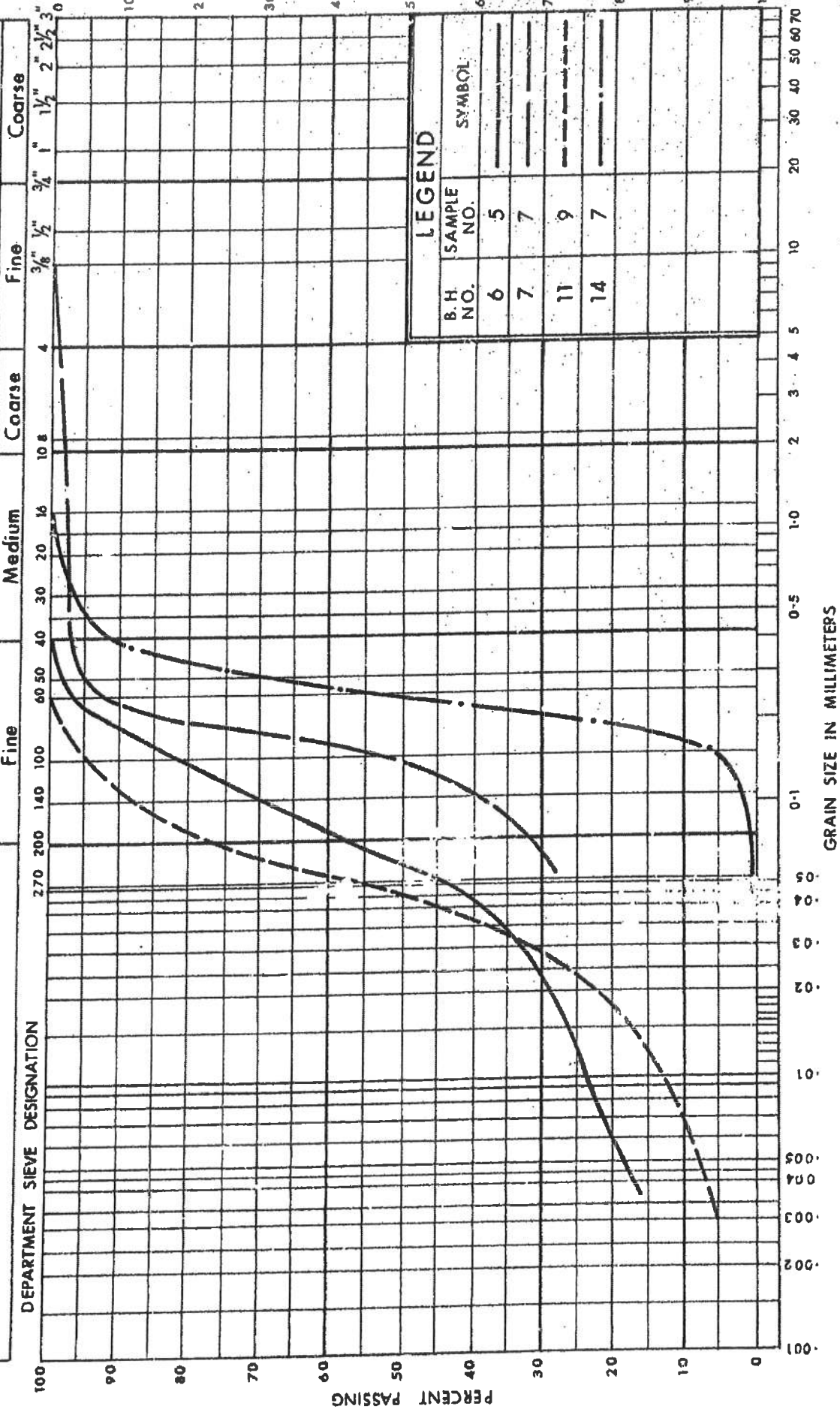
Sa 28%
 Si 72%

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT

SAND

GRAVEL



LEGEND

B.H. NO.	SAMPLE NO.	SYMBOL
6	5	—
7	7	—
11	9	—
14	7	—

DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION



GRAIN SIZE DISTRIBUTION

W.P. No. 634-64
JOB No. 66-F-53

Appendix B

Record of Borehole Sheets and Laboratory Test Results (Previous Investigation, Geocres No. 40P8-199 – Reference 2)

Foundation investigation and design report for Northeast Corner Retaining Wall, Frederick Street Underpass, Site No. 33-234, G.W.P. 3110-09-00, City of Kitchener, Ontario, prepared by Peto MacCallum Ltd., PML Ref. 10KF079C, Geocres No. 40P8-199, dated May 31, 2012.

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 'A' 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.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

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 (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	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
F V FIELD VANE	

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
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_l	l	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No RW-1

1 of 1

METRIC

G.W.P. 3110-09-00 LOCATION Coords: 4 813 701.9 N; 226 222.6 E ORIGINATED BY R.E.
 DIST London HWY 7/ 65 BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY N.S.E.
 DATUM Geodetic DATE April 08, 2011 CHECKED BY E.R.G.

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	20 40 60 80 100	20 40 60 80 100					
319.7	Ground Surface														
0.0	Asphalt over sand some silt, some gravel Very loose Brown Wet		1	AS	-										
	(FILL)		2	SS	3										
318.3	Silty clay, trace sand		3	SS	17										
1.4	Very stiff Brown Moist		4	SS	34										
	sand layers to 4.9m		5	SS	25										
	Hard to Greyish very stiff brown.		6	SS	26										
	Hard		7	SS	37										
			8	SS	31										
			9	SS	33										
			10	SS	39										
309.9	End of borehole														
9.8	* Borehole dry (**) Base of footing -El.318.2 Note: Borehole cave-in at 8.5m C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers Water Level Readings: Date Apr. 08, '11 Depth (m) 2.9 Elev. 316.8 Piezometer Legend: Bentonite seal Filter sand 19mm dia. PVC screen Bentonite grout														

RECORD OF BOREHOLE No RW-2
1 of 1
METRIC

G.W.P. 3110-C9-00 **LOCATION** Coords: 4 813 710.4 N; 226 223.0 E **ORIGINATED BY** R.E.
DIST London **HWY** 7/ 85 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** N.S.B.
DATUM Geodetic **DATE** April 08, 2011 **CHECKED BY** E.R.G.

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		
319.7	Ground Surface													
0.0	Asphalt over sand and crushed gravel, trace silt Compact Brown Moist (FILL)		1	AS	-		319							
318.3			2	SS	11									
1.4	Silty clay, trace gravel sand layers Stiff Dark Moist brown sand layers to 3.7m Hard Greyish brown		3	SS	9		318							(**)
			4	SS	31		317							1 4 43 52
			5	SS	23		316							
			6	SS	44		315							
			7	SS	43		314							
			8	SS	35		313							
			9	SS	29		312							
309.9	End of borehole						310							
9.8														

* 2011 04 08

 Water level measured
after drilling

 (***) Base of footing
-El. 318.2

 Note: Borehole cave-in at
8.7m

RECORD OF BOREHOLE No RW-3

1 of 1

METRIC

G.W.P. 3110-09-00 LOCATION Coords: 4 E13 719.3 N; 226 229.5 E ORIGINATED BY F.P.
DIST London HWY 7/ 85 BOREHOLE TYPE Dynamic Ram Sounder COMPILED BY N.S.E
DATUM Geodetic DATE July 19, 2011 CHECKED BY B.R.G.

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		
322.3	Ground Surface													
0.0	Silty sand some clay, trace gravel organic inclusions		1	SS	14		322							8 37 37 18
	Compact Grey Moist (FILL)		2	SS	27		321							3 50 34 13
	clayey silt layers													4 26 45 25
	gravelly sand		3	SS	20		320							23 39 27 11
320.0	Compact Brown Damp clayey silt layers													4 25 42 29
2.3	Sand trace to some gravel trace clay		4	SS	21		319							15 76 6 3
	Compact Brown Moist to wet		5	SS	16		318							10 76 10 4
317.9			6	SS	14		317							(*) 73 12 4
4.4	Silty clay trace sand, trace gravel silty sand and gravelly sand layers, cobbles		7	SS	36		316							3 23 50 24
	Hard Grey Moist		8	SS	67									
315.9			9	SS	70/15cm									
6.4	End of borehole													
	Sample 9: Sampler bouncing													
	* 2011 07 19													
	▽ Water level observed during drilling													
	(**) Base of footing -El. 318.2													
	Water Level Readings:													
	Date Depth Elev.													
	July 19, '11 (m) Dry ----													
	Sept. 23, '11 3.3 319.0													
	Oct. 08, '11 3.3 319.0													
	Piezometer Legend:													
	■ Bentonite seal													
	□ Filter sand													
	□ 30mm dia. PVC screen													
	□ Filter bed													

RECORD OF BOREHOLE No RW-4
1 of 1
METRIC

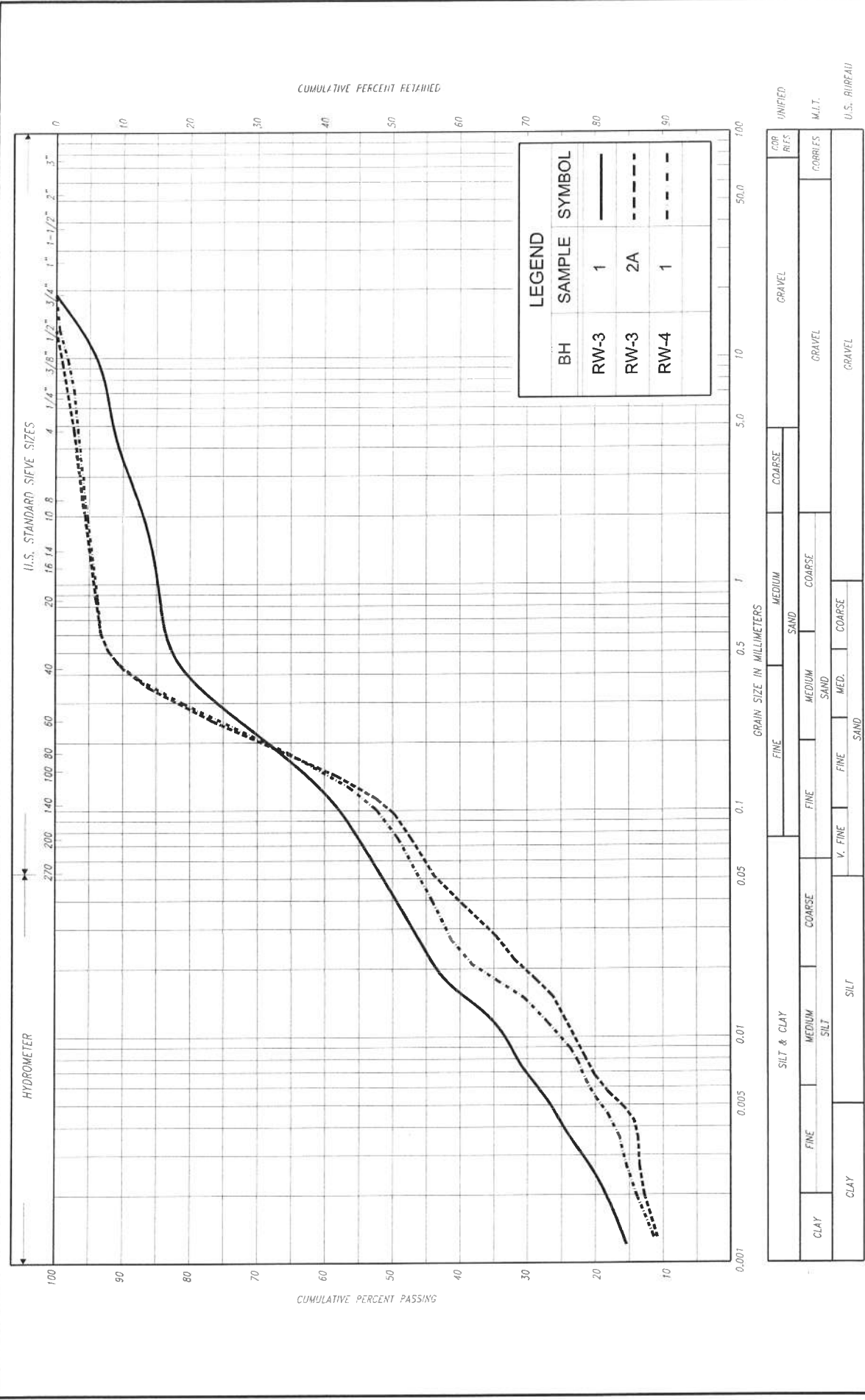
G.W.P. 3110-09-00 **LOCATION** Ccords: 4 813 705.4 N; 226 228.2 E **ORIGINATED BY** A.L.
DIST London **HWY** 7/ 65 **BOREHOLE TYPE** Dynamic Ram Sounder **COMPILED BY** N.S.P
DATUM Geodetic **DATE** July 20, 2011 **CHECKED BY** E.R.G.

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					
323.5	Ground Surface																
0.0	Silty sand, some clay trace gravel, rootlets		1	SS	21		323										4 47 35 14
	Compact Brown Moist (FILL)																
	Silt with sand, trace gravel		2	SS	21												22 20 54 4
	Compact Grey Sand, some silt some gravel, trace clay		3	SS	21		322										15 68 11 6
321.2	Compact Brown Clayey silt, trace sand																
2.3	Very stiff Grey Sand trace to some gravel trace to some silt trace clay		4	SS	20		321										9 63 (8)
	Compact Brown Moist to wet		5	SS	13		320										11 73 12 4
	Gravelly to with gravel		6	SS	13		319										38 43 13 6
			7	SS	9		318										26 68 3 3
317.6			8	SS	14												(**)
5.9	Silty clay, trace gravel cobbles		9	SS	49												
	Stiff to Grey Moist hard		10	SS	52/15cm		317										
316.5			11	SS	50/13cm												
7.0	End of borehole																
	Samples 10 and 11: Sampler bouncing																
	* 2011 07 20																
	▽ Water level observed during drilling																
	(**) Base of footing -El.318.2																
	Note: Borehole cave-in at 5.0m																



TABLE A-1
LIST OF ATTERBERG LIMITS RESULTS

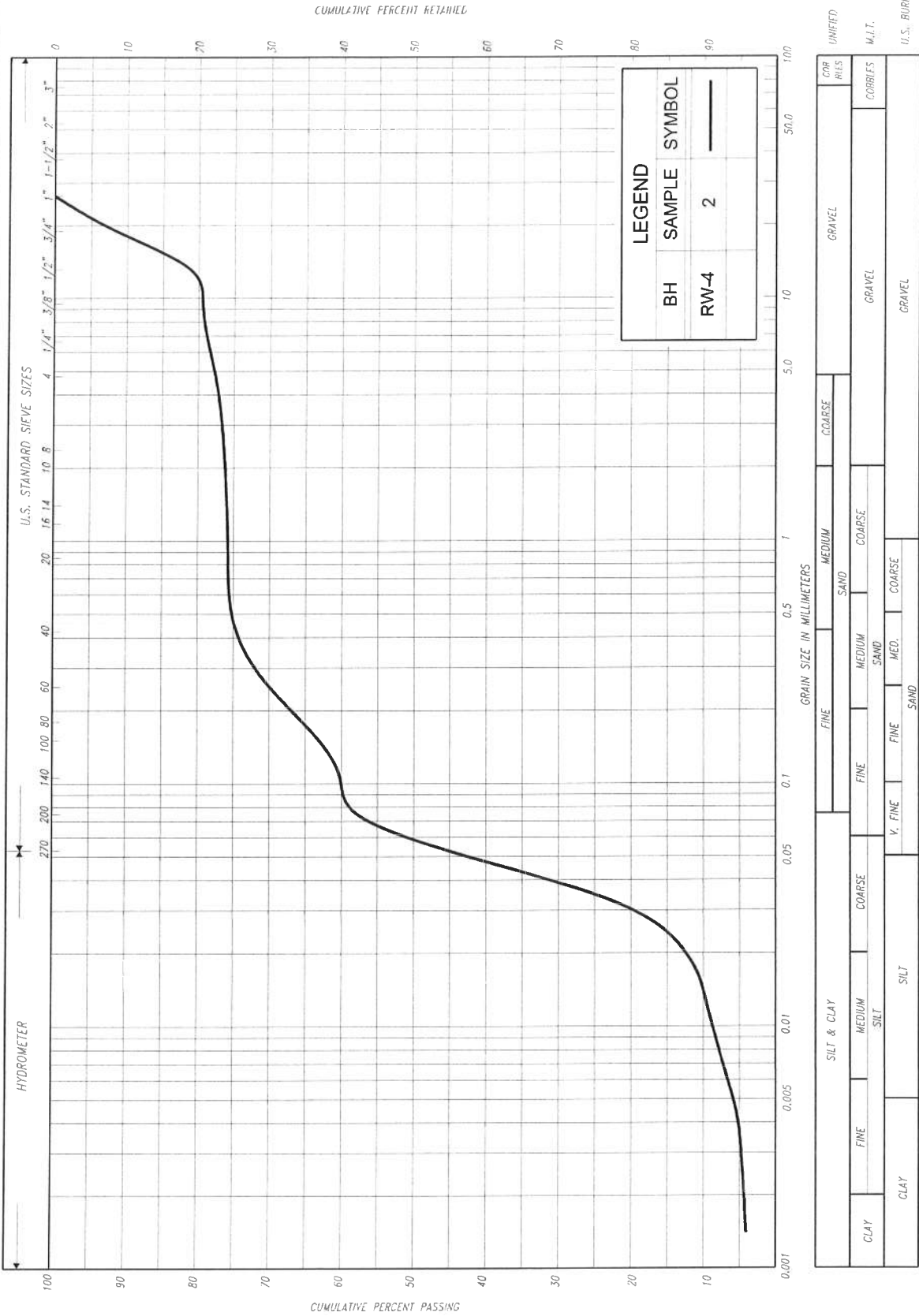
SOIL TYPE	BOREHOLE NO.	SAMPLE NO.	DEPTH / ELEVATION (m)	MOISTURE CONTENT (W %)	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)
Clayey Silt Fill	RW-3	3B	2.1 / 320.2	-	22	12	10
Silty Clay	RW-2	3	1.9 / 317.8	19	36	18	18
	RW-2	5	3.3 / 316.3	19	35	17	18
	RW-2	7	6.3 / 313.4	21	45	23	22



GRAIN SIZE DISTRIBUTION
SILTY SAND, some clay, trace gravel
(FILL)

FIG No. RW-GS-1
HWY: 7 / 85
G.W.P. No. 3110-09-00





GRAIN SIZE DISTRIBUTION

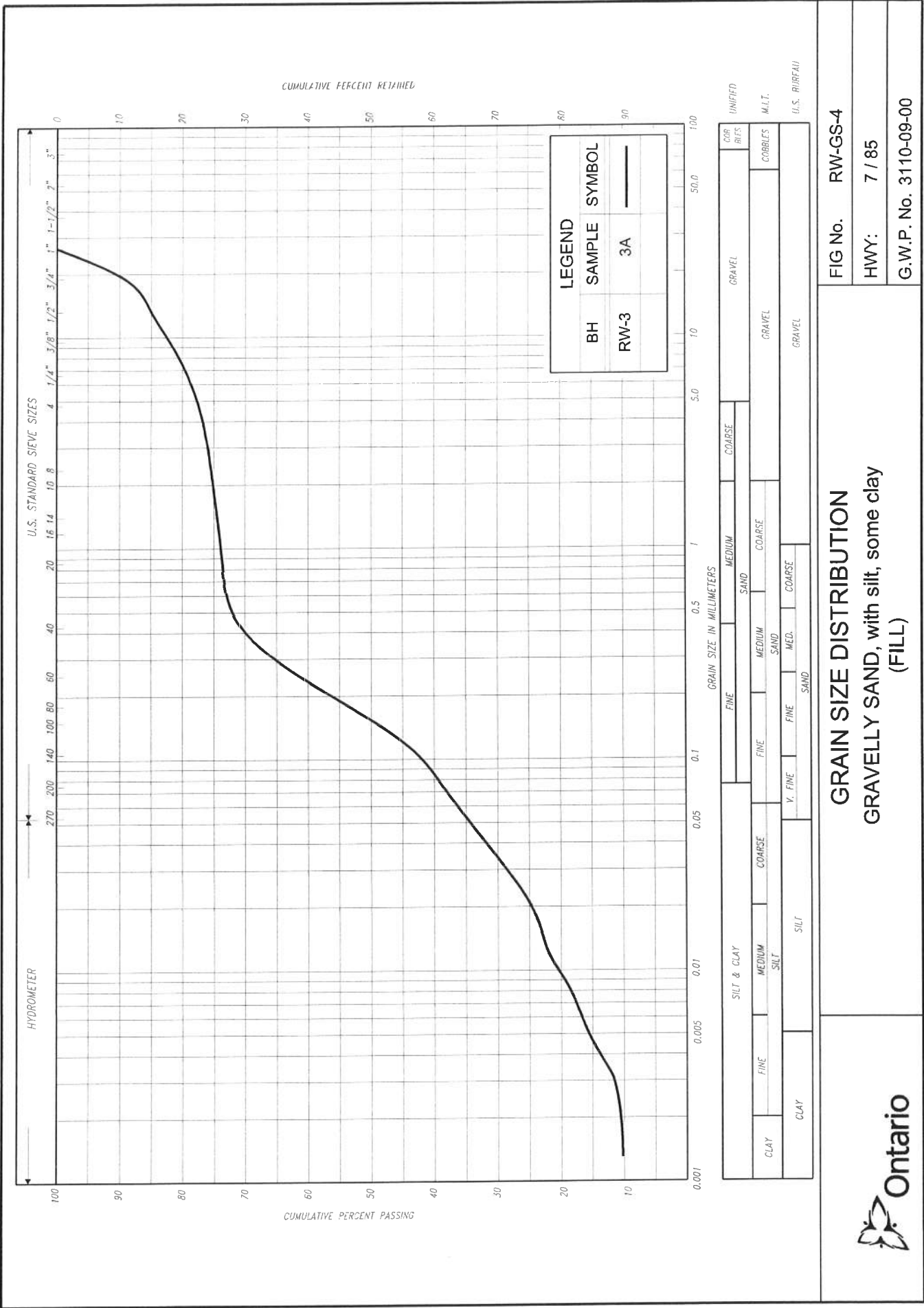
SILT, some sand, some gravel, trace clay
(FILL)

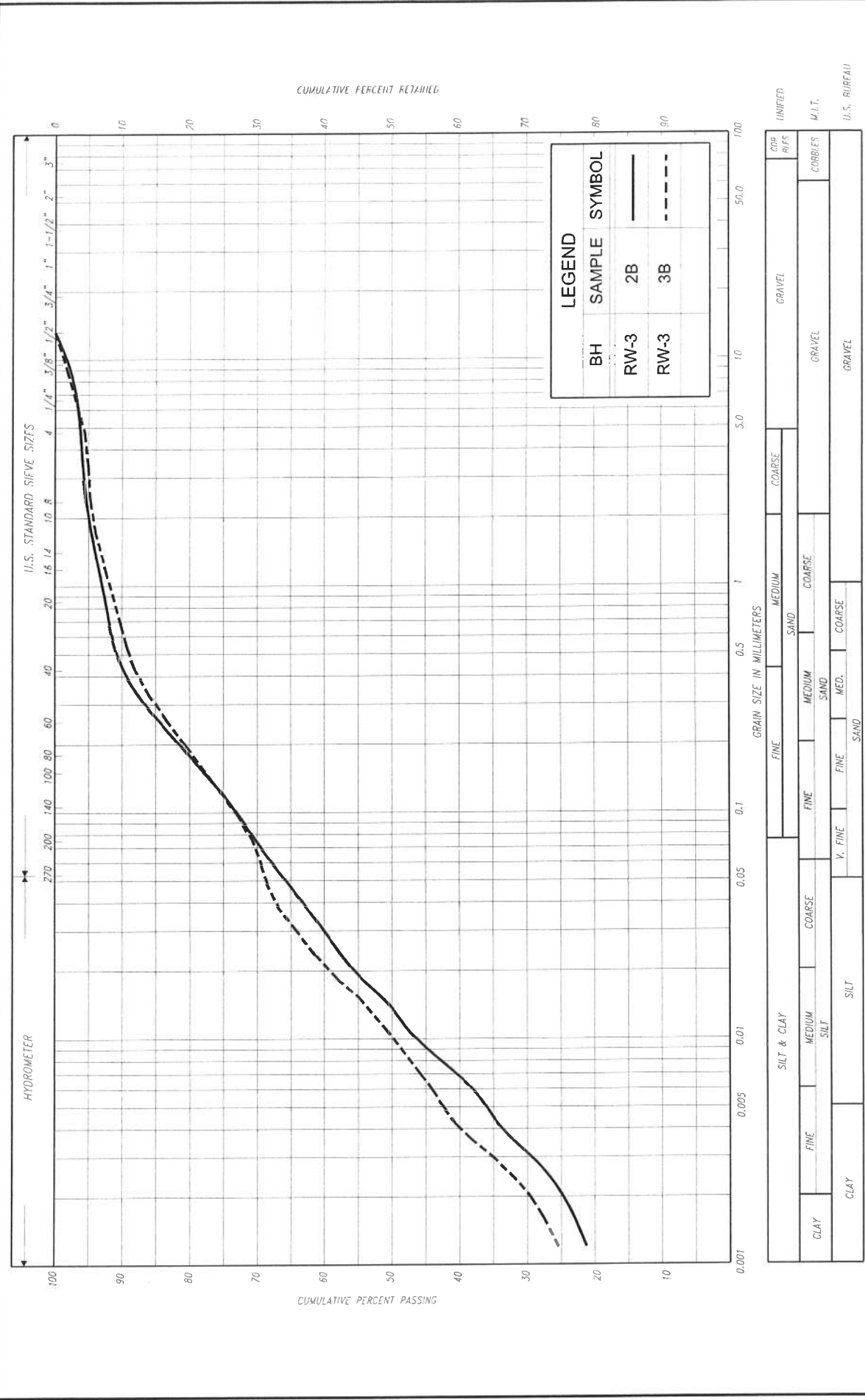
FIG No. RW-GS-2

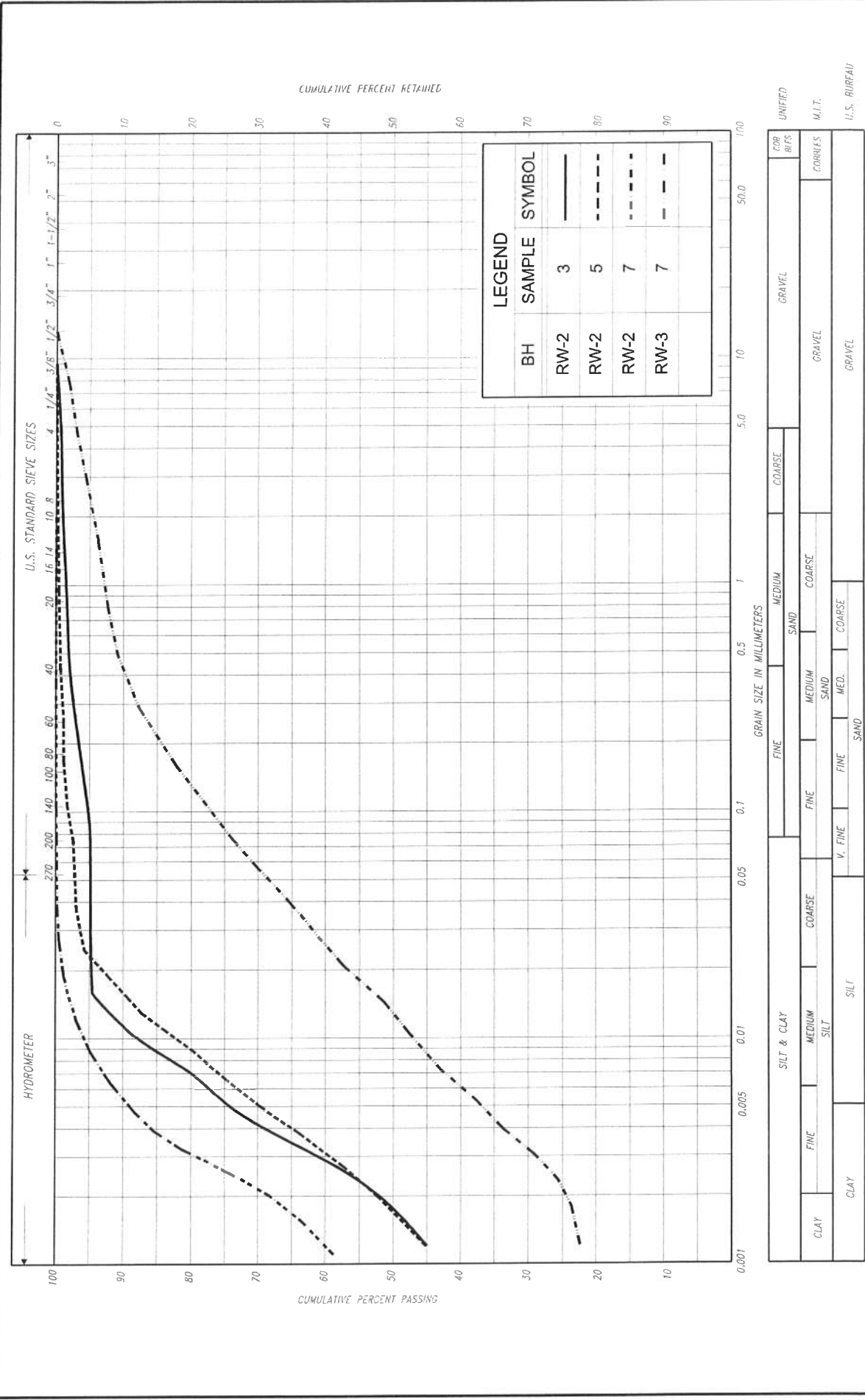
HWY: 7 / 85

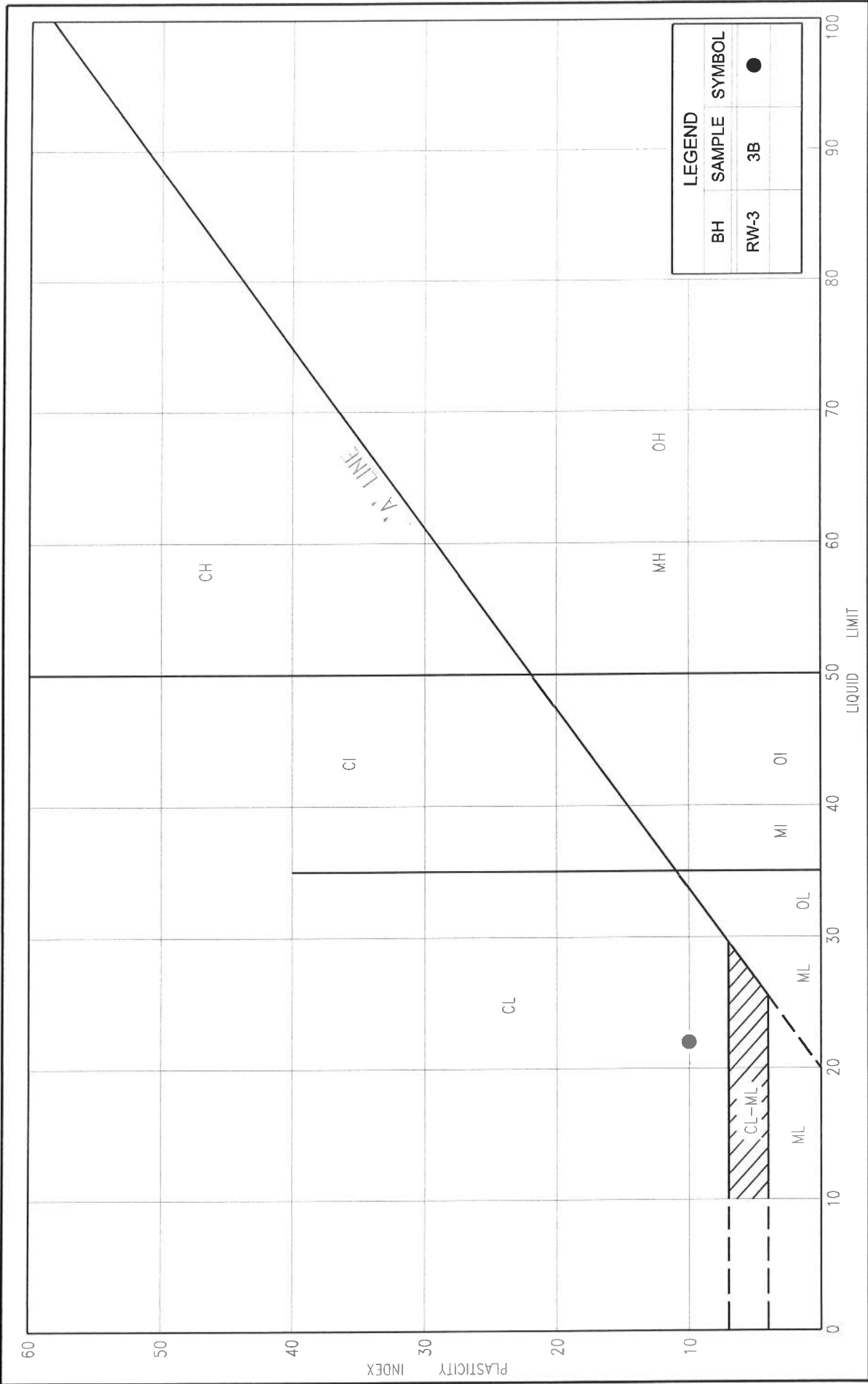
G.W.P. No. 3110-09-00











PLASTICITY CHART

CLAYEY SILT, with sand, trace gravel (CL)
(FILL)

FIG No. RW-PC-1

HWY: 7 / 85

G.W.P. No. 3110-09-00



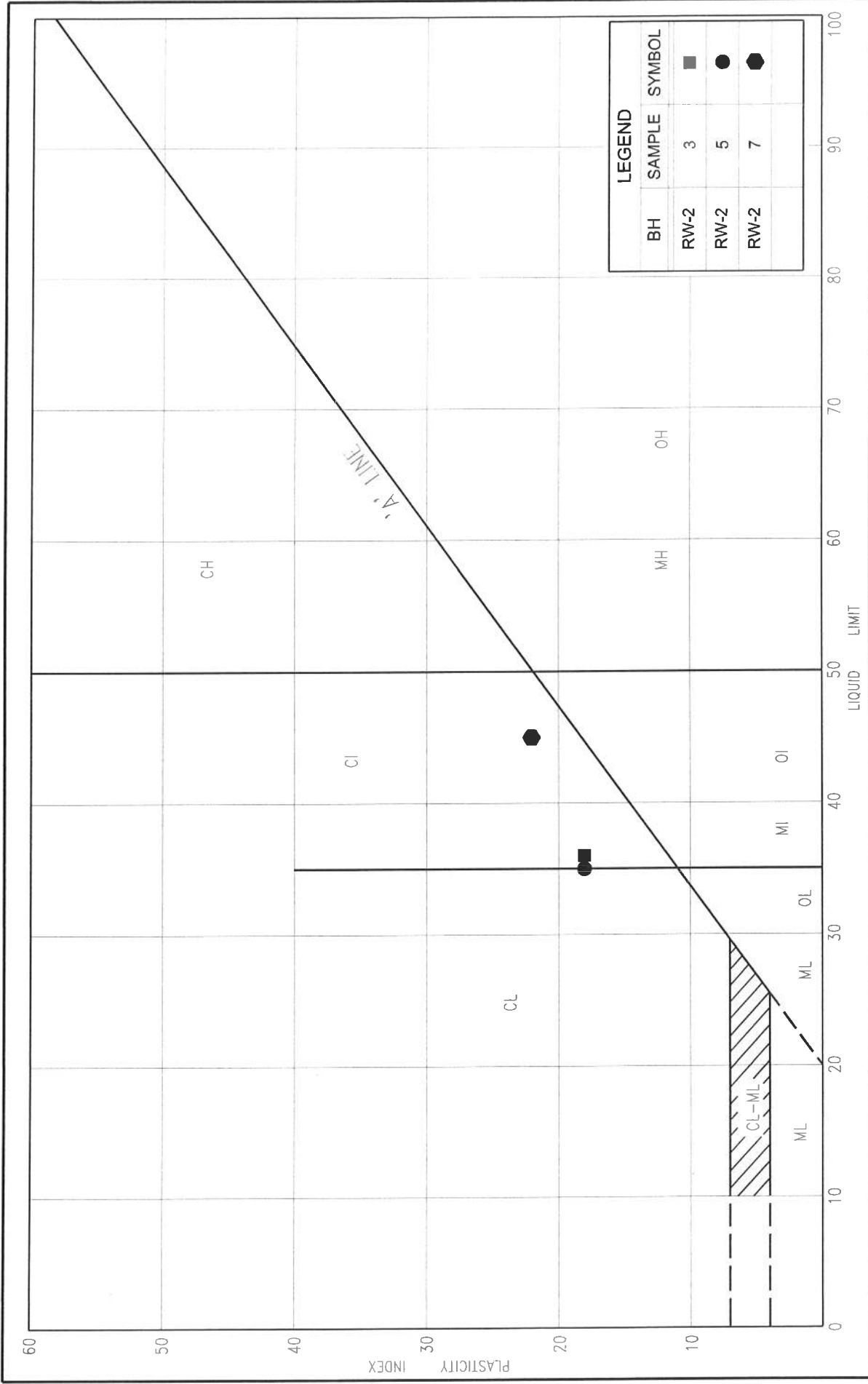


FIG No. RW-PC-2

HWY: 7 / 85

G.W.P. No. 3110-09-00

PLASTICITY CHART

SILTY CLAY, trace to with sand, trace gravel (CI)



Appendix C

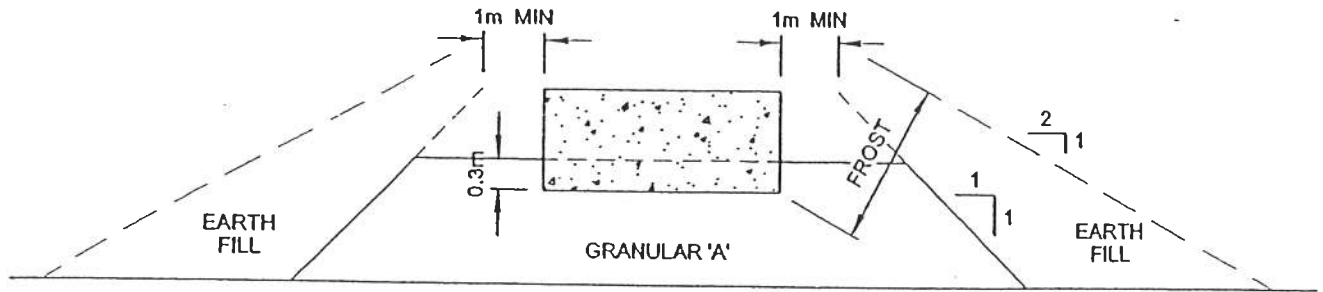
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

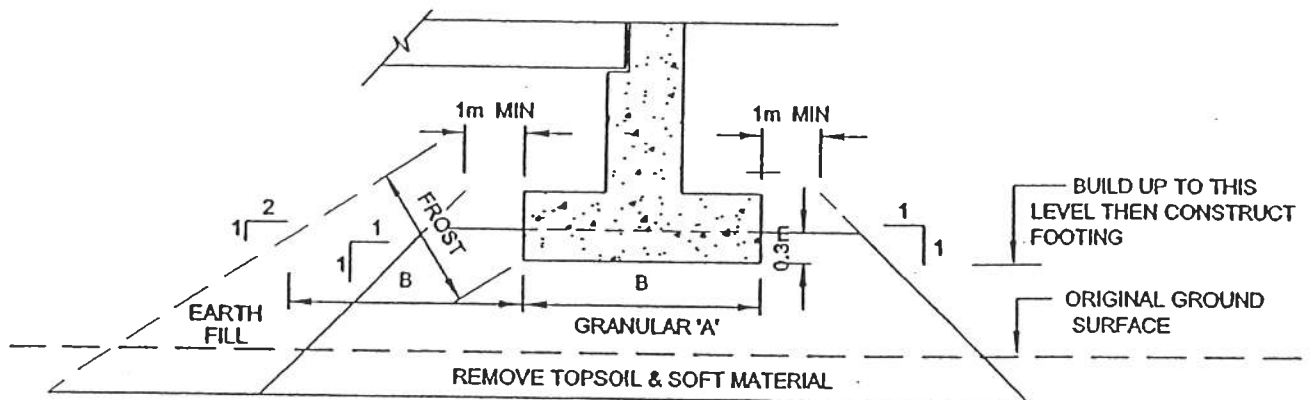
Foundation Element		Spread Footings	Spread Footings on Engineered Fill	Driven Piles
New underpass	Abutments	Advantages: i. Generally less costly construction than deep foundation elements. ii. Relatively simple construction method	Advantages: i. Generally less costly construction than deep foundation elements.	Advantages: i. High geotechnical resistance may be developed by driving the piles into very dense soils. ii. Permits integral abutment design
		Disadvantages: 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: i. Higher 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: i. Higher unit cost compared to footings. ii. No deep excavation required. iii. Pile vibration may induce settlement on the existing footings.
		FEASIBLE	FEASIBLE	RECOMMENDED
Extension of existing underpass	Pier	FEASIBLE	FEASIBLE	RECOMMENDED
	Abutments	RECOMMENDED	FEASIBLE	FEASIBLE

Appendix D

Figure



CROSS-SECTION



LONGITUDINAL SECTION

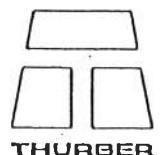
NOT TO SCALE

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

Frederick Street Underpass
Highway 7-New, Kitchener to Guelph



Photo 1. Aerial view of Kitchener-Waterloo Expressway and Frederick Street

Frederick Street Underpass
Highway 7-New, Kitchener to Guelph



Photo 2. Existing Frederick Street Underpass at Kitchener-Waterloo Expressway (south view)

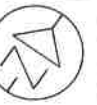
Appendix F

Drawing titled “Borehole Locations and Soil Strata”

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 408-88-00

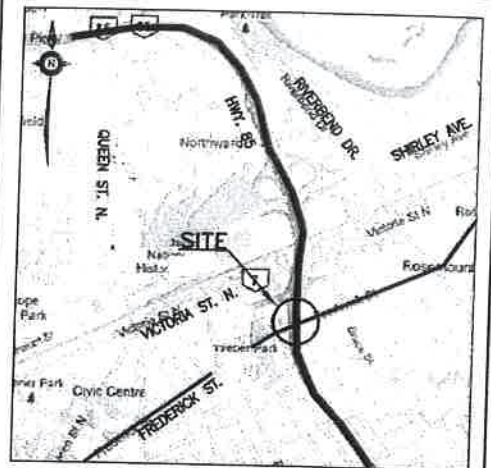
FREDERICK STREET
UNDERPASS
BOREHOLE LOCATIONS PLAN



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

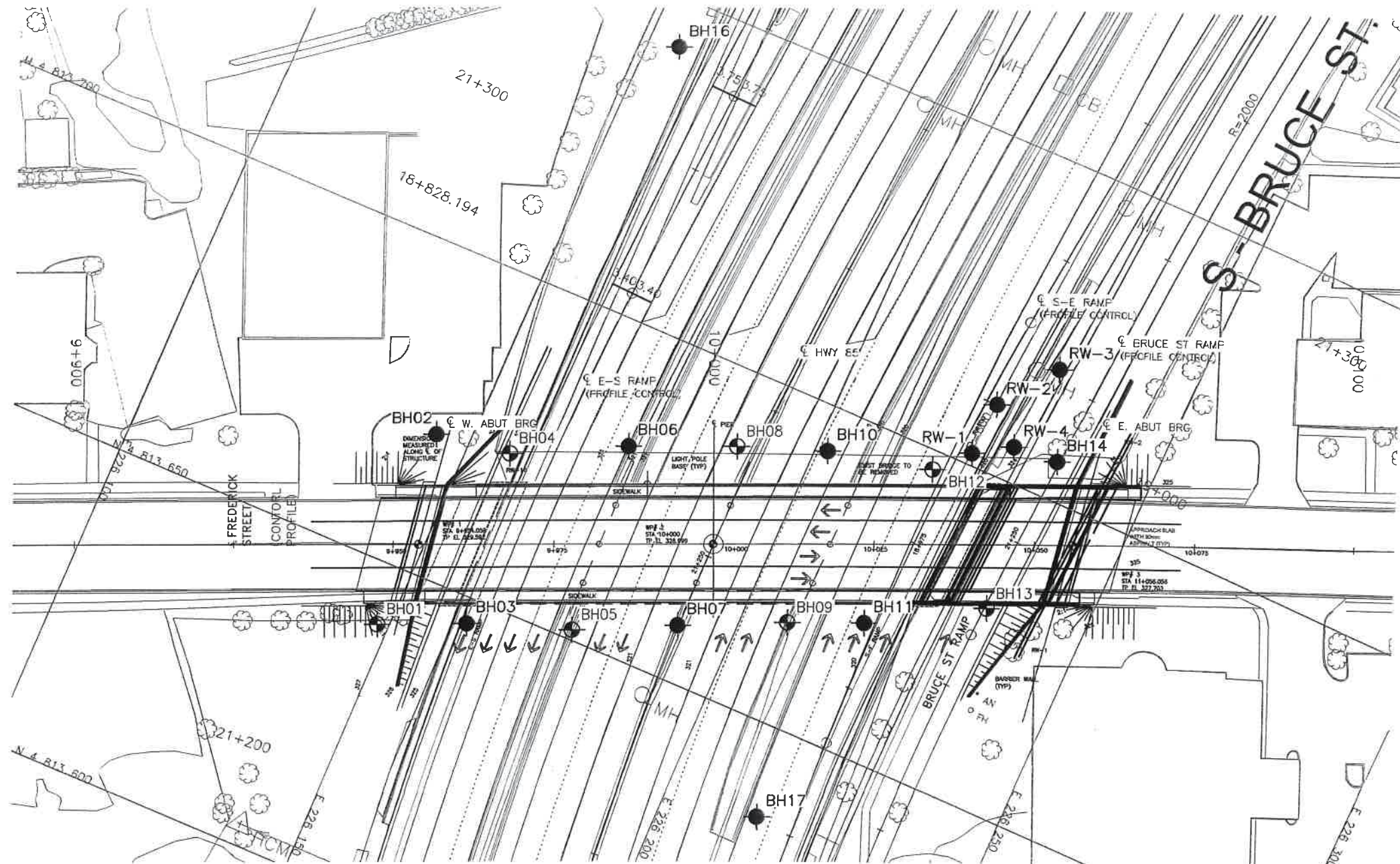
- ◆ Borehole & Cone (Previous Investigation)
- ◆ Cone Penetration Hole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- P Piezometer
- 90° Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RW-1	319.7	4 813 701.9	226 222.6
RW-2	319.7	4 813 710.4	226 223.0
RW-3	322.3	4 813 719.3	226 229.5
RW-4	323.5	4 813 705.4	226 228.2
BH01	327.0		
BH02	326.9		
BH03	326.7		
BH04	325.9		
BH05	326.1		
BH06	325.4		
BH07	325.9		
BH08	325.6		
BH09	325.8		

-NOTES-

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

GEOCREs No. 40P8-203



BH10	325.5		
BH11	325.6		
BH12	325.4		
BH13	325.2		
BH14	325.3		
BH15	-		
BH16	324.6		
BH17	326.0		

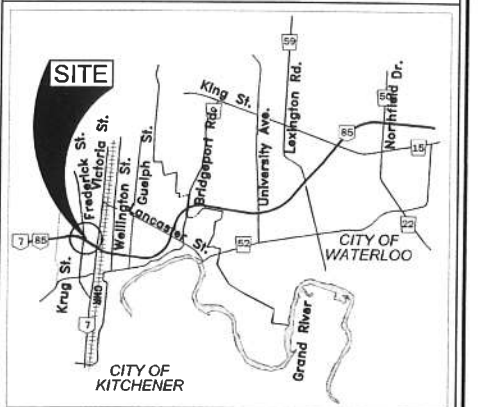
REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	SITE
STRUCT			
DWG			
DATE	NOV. 2012		

CONT No
GWP No 3110-09-00



FREDERICK STREET UNDERPASS
RETAINING WALL
HIGHWAY 7/85
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



LEGEND

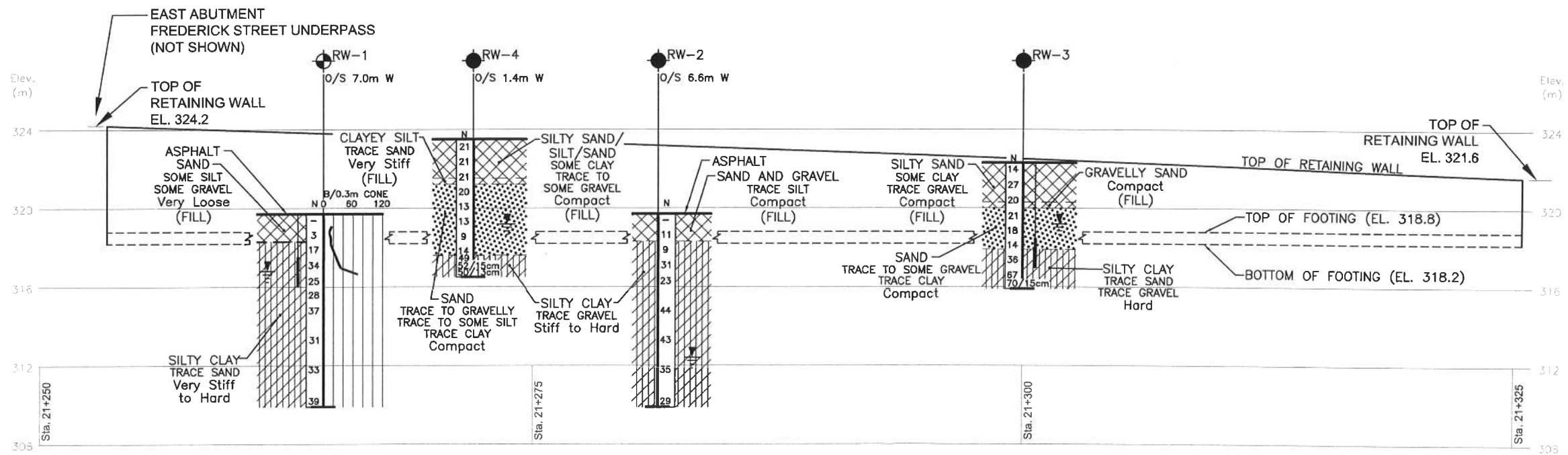
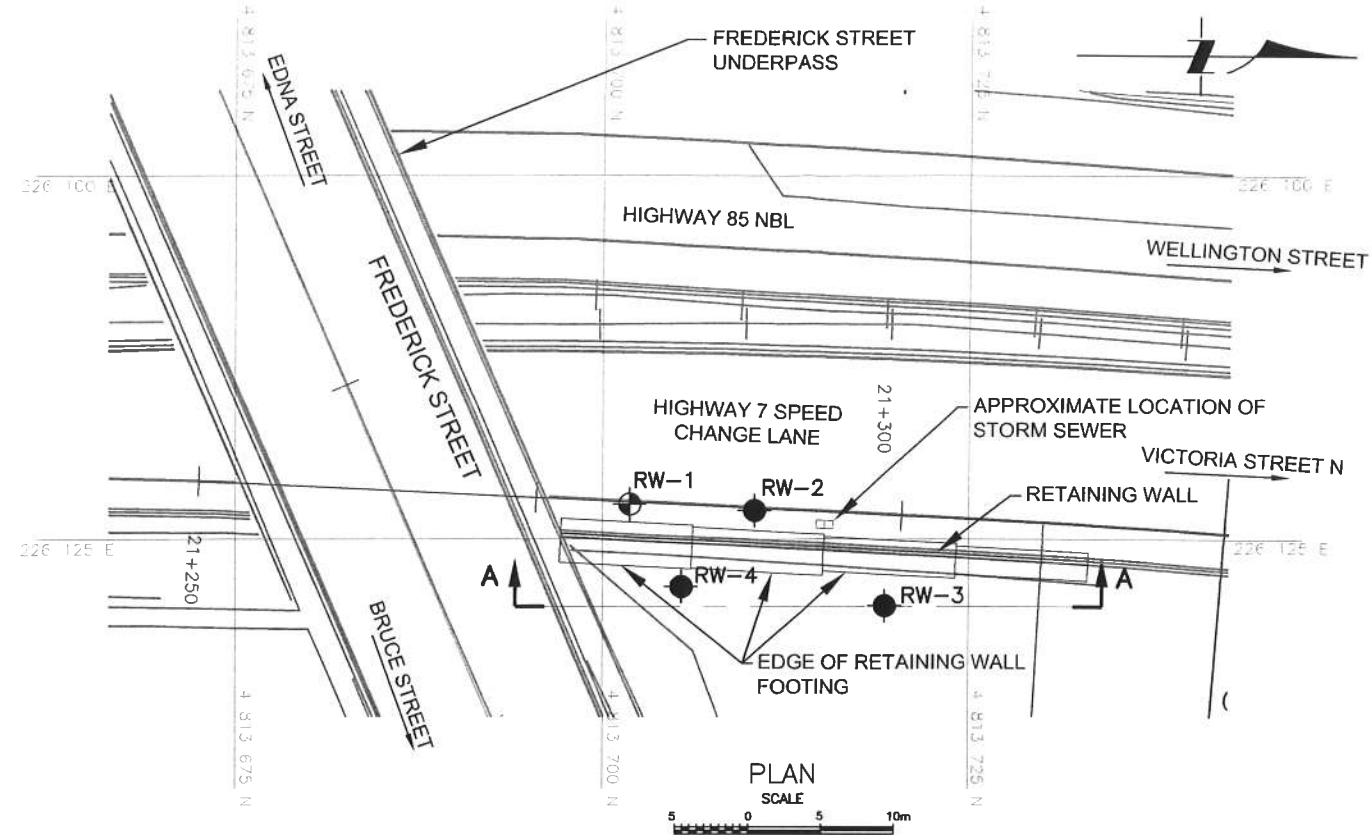
- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation April and July 2011
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
RW-1	319.7	4 813 701.9	226 222.6
RW-2	319.7	4 813 710.4	226 223.0
RW-3	322.3	4 813 719.3	226 229.5
RW-4	323.5	4 813 705.4	226 228.2

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 40PB-199	HWY No 7 / 85	DIST London
SUBM'D NA	CHECKED NSB	DATE MAY 28, 2012
DRAWN NA	CHECKED CN	APPROVED BRG
		DWG RW-1



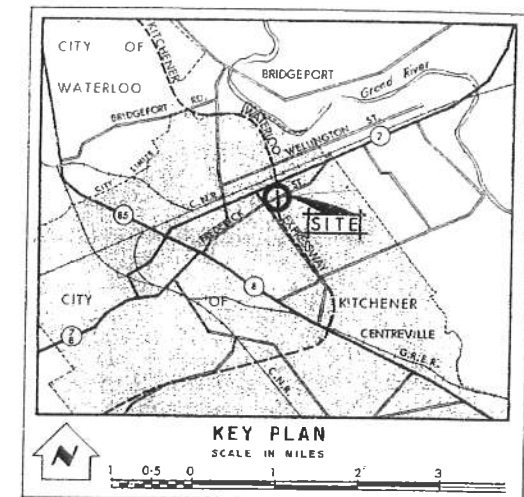
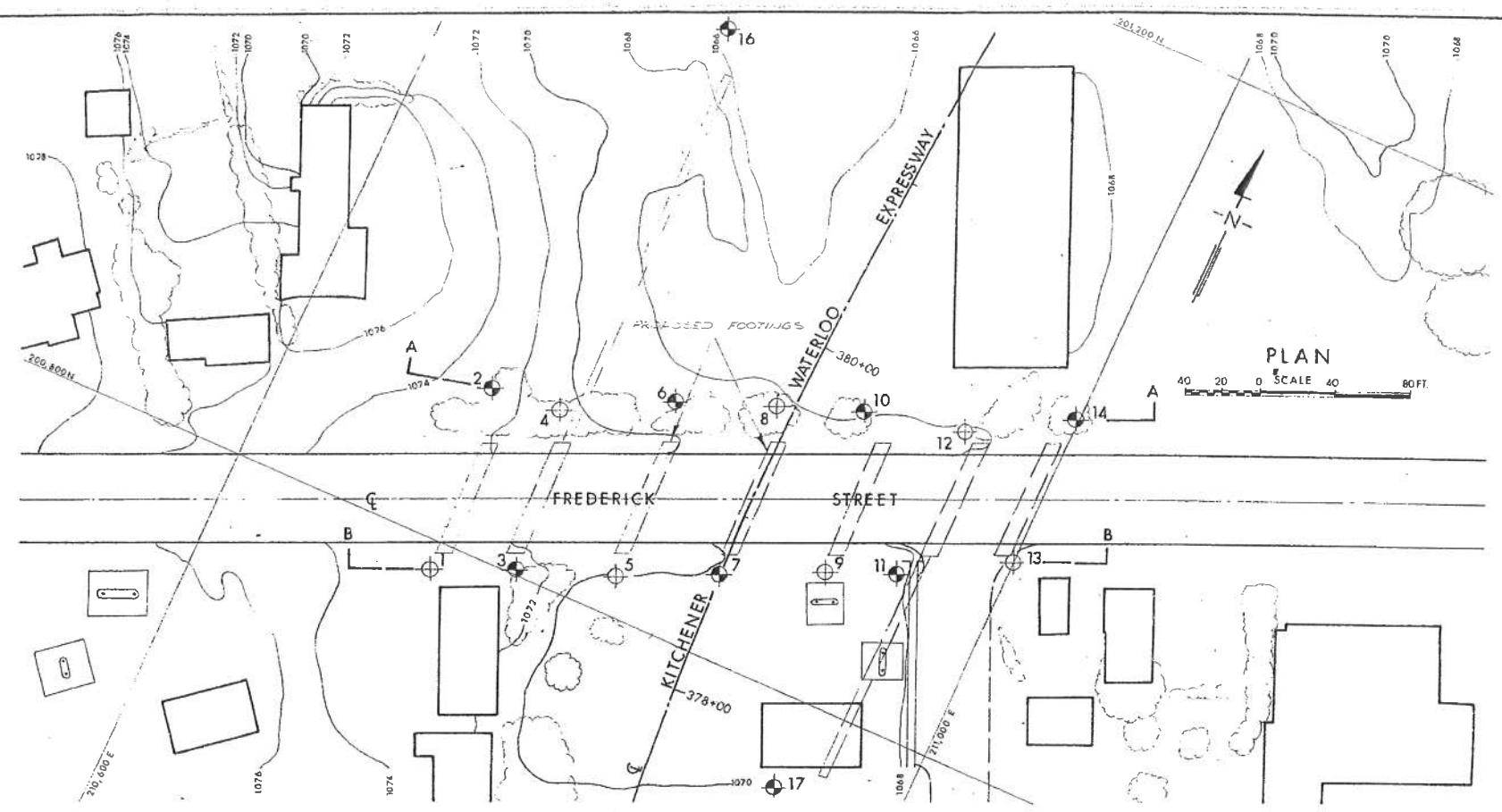
PROFILE A - A

NOTES:

- DRAWING RW-1 SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND THE RECORD OF LOG OF BOREHOLES.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



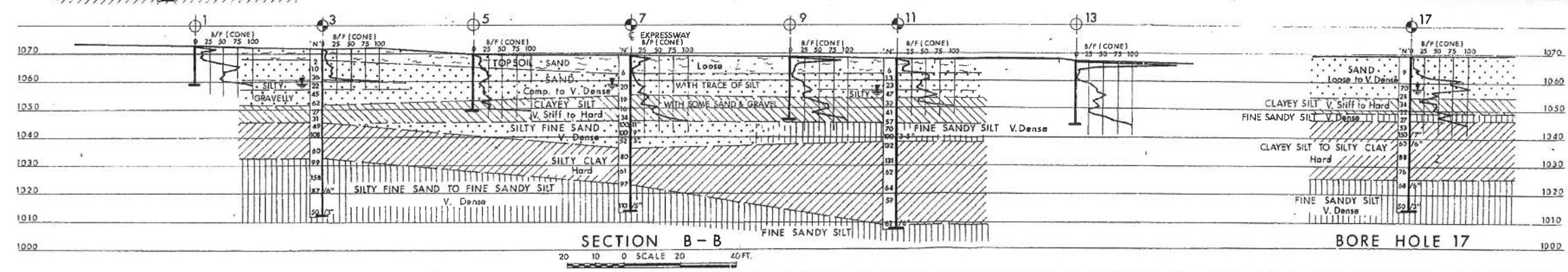
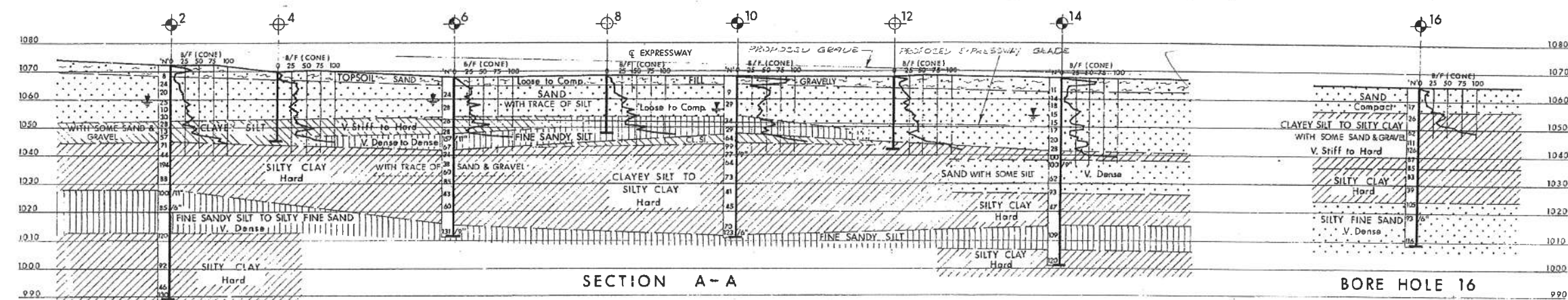
REF MRC Drawing: 2010362_Alignment.dwg; CONTRACT
DRAWINGS - CONTRACT No. 68-62



- LEGEND**
- Bore Hole
 - ⊕ Cons. Penetration Hole
 - ⊙ Bore & Cone Penetration Hole
 - Water Levels established at time of field investigation, MAY & JUNE 1966

NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	1072.7	200,785	210,719
2	1072.4	200,887	210,709
3	1071.9	200,803	210,761
4	1069.3	200,890	210,747
5	1069.8	200,821	210,811
6	1067.7	200,919	210,802
7	1069.1	200,844	210,861
8	1068.1	200,939	210,847
9	1069.0	200,873	210,912
10	1067.9	200,955	210,895
11	1068.2	200,883	210,947
12	1067.6	200,967	210,949
13	1067.0	200,914	211,000
14	1067.2	200,797	210,999
16	1065.0	201,116	210,741
17	1069.6	200,754	210,935

- 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.



PRINT RECORD

NO.	FOR	DATE

REVISIONS

NO.	DATE	BY	DESCRIPTION

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

FREDERICK STREET

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

BORE HOLE LOCATIONS & SOIL STRATA

SUB'D. D.W. CHECKED	W.P. NO. 634-68	M.B.T. DRAWING NO.
DRAWN S.O. CHECKED	JOB NO. 66-F-53	66-F-53A
DATE 16 AUG. 1966	SITE NO.	BRIDGE DRAWING NO.
APPROVED	CONT. NO.	