

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
SERVICE ROAD OVER HIGHWAY 7
HIGHWAY 7-NEW, KITCHENER TO GUELPH
G.W.P. 408-88-00**

Geocres Number: 40P8-156

Report to

**Ministry of Transportation Ontario
West Region**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation conducted at the site of the proposed underpass structure to carry a proposed Service Road over Highway 7-New in the Regional Municipality of Waterloo, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions under the potential foundation footprint was developed from the data obtained in the course of the investigation.

The information collected in the course of the investigation and presented in this report is intended for preliminary design purposes only. Additional site investigation, field testing and engineering analysis will be required at the detail design stage. The extent of the additional investigation will depend, in part, on the final location and General Arrangement of the structure.

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

2 SITE DESCRIPTION

At the site, the Highway 7-New alignment runs parallel to the existing Highway 7 alignment, approximately 1.1 km to the north. The site is located approximately 2.6 km east of the Kitchener-Waterloo Expressway and Wellington Street interchange. The site lies approximately 1.5 km northeast of a developed area of the City of Kitchener. The Grand River is approximately 350 m to the south.

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 site lies within an area of active farms and agricultural lands. There are farmsteads/residential dwellings to the east and west of Service Road, north of the existing Highway 7 alignment.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at this site was carried out from July 23 to 25, 2008. Three boreholes, 08-070, 08-071 and 08-072, were drilled approximately at the north abutment, pier and south abutment of a possible two-span structure arrangement. The depths of the boreholes ranged from 18.7 m to 21.5 m (Elevations 290.3 to 293.7). The Record of Borehole sheets for the boreholes are included in Appendix A. The approximate locations of the three boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix E.

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area.

The boreholes were drilled using hollow stem auger equipment mounted on a CME75 truck-mounted drill rig. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In Borehole 08-071, drilled at the proposed pier location, a standpipe piezometer consisting of 25 mm diameter PVC pipe with a slotted screen was installed and enclosed in filter sand to permit longer term groundwater level monitoring. The location and completion details of the piezometer are shown in Table 3.1. Boreholes without piezometer installations were grouted with bentonite upon completion. The borehole completion details are shown in Table 3.1.

The completion of the boreholes and the standpipe piezometer was carried out in accordance with the requirements of O. Reg. 903 (as amended by O. Reg. 372/07).

Table 3.1 – Borehole Completion Details

Foundation Unit	Borehole Location	Piezometer Tip Depth/Elevation (m)	Completion Details
North Abutment	08-070	No Installation	Bentonite benseal to 0.2 m, then holeplug to ground surface.
Pier	08-071	18.2/294.2	Piezometer with 1.5 m slotted screen installed with sand filter to 16.3 m, holeplug from 16.3 m to 15.9 m, benseal grout from 15.9 m to 1.8 m, holeplug from 1.8 m to 0.6 m, then benseal from 0.6 m to ground surface.
South Abutment	08-072	No Installation	Bentonite from bottom of borehole to ground surface

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) 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 also subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained 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 E. 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, the site is underlain by topsoil overlying compact to dense sand, sand and gravel and silty sand layers, very stiff to hard silty clay till and very dense sandy silt till. Lower layers of very dense sand were encountered in boreholes drilled at the pier and south abutment.

5.1 Topsoil

Topsoil was contacted surficially in the three boreholes. Thickness of the topsoil ranged from 125 mm to 150 mm.

The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities

5.2 Sand and Gravel

A native brown sand and gravel layer containing trace silt, trace clay and occasional cobbles was contacted in Borehole 08-070 below the topsoil. Thickness of this sand and gravel layer was 2.3 m.

The depth to the base of the sand and gravel layer was 2.4 m (Elevations 312.5).

SPT 'N' values measured in the sand and gravel layer were 35 and 54 blows per 0.3 m of penetration indicating a dense to very dense relative density. Moisture content was 11%.

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

Soil Particles	(%)
Gravel	36
Sand	55
Silt and Clay	9

5.3 Sandy Silt

Native brown sandy silt containing some clay and trace gravel was contacted below the topsoil in Borehole 08-071. Thickness of this sandy silt layer was 1.3 m.

The depth to the base of this sandy silt layer was 1.5 m (Elevation 311.0).

SPT 'N' value measured in the sandy silt was 12 blows per 0.3 m of penetration, indicating a compact relative density. Moisture content was 8%.

5.4 Upper Sand

Native brown sand containing trace silt and occasional rootlets was contacted in Borehole 08-072 below the topsoil. Thickness of this upper sand layer was 0.9 m.

The depth to the base of the upper sand layer was 1.1 m (Elevation 309.4).

SPT 'N' value measured in the upper sand layer was 11 blows per 0.3 m of penetration indicating a compact relative density. Moisture content varied from 18% to 20%

5.5 Silty Clay Till

An extensive deposit of native brown to grey silty clay till containing trace sand and occasional cobbles was contacted in all the boreholes below the native sand, sand and gravel and sandy silt layers, at depths and elevations indicated in Table 5.1.

Table 5.1 – Depths and Elevations of Silty Clay Till

Foundation Unit	Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)
North Abutment	08-070	2.4 to 17.8	312.5 to 297.2	15.4
Pier	08-071	1.5 to 14.7	311.0 to 297.8	13.2
South Abutment	08-072	1.1 to 14.0	309.4 to 296.4	12.9

A 200-mm thick layer of silt was contacted within the silty clay till at 3.6 m depth (Elevation 306.8) in Borehole 08-072.

SPT 'N' values measured in the silty clay till ranged from 12 to 57 blows per 0.3 m of penetration, indicating a stiff to hard consistency. The natural moisture contents generally lay in the range of 10 to 25%.

Grain size distribution curves for selected silty clay till samples are presented on the Record of Borehole sheets and on Figures B2 and B3 of Appendix B. Atterberg Limits test results are presented on Figures B6 and B7 of Appendix B.

The results of grain size distribution tests are summarized as follows:

Soil Particles	(%)
Gravel	0
Sand	1 to 10
Silt	16 to 45
Clay	45 to 83

Liquid Limit	36 to 59
Plastic Limit	15 to 21

The above results show that the silty clay till is of medium to high plasticity with a group symbol of CI-CH.

It should be noted that glacial tills are known to contain cobbles and boulders.

5.6 Sandy Silt Till

Grey sandy silt till containing some clay to clayey, trace of gravel and occasional cobbles were observed at 17.8 m, 14.7 m and 14.0 m depths (Elevations 297.2, 297.8 and 296.4) in Boreholes 08-070, 08-071 and 08-72 respectively.

Thickness of the sandy silt till varied from 2.4 m to 3.0 m in Boreholes 08-071 and 08-072. The depth to the base of the sandy silt till ranged from 16.4 m to 17.7 m (Elevations 294.0 and 294.8) in Boreholes 08-071 and 08-072. Borehole 08-070 was terminated within the sandy silt till at 21.5 m depth (Elevation 293.5).

The sandy silt till layer encountered in Boreholes 08-070 and 08-071, is classified as very dense, based on SPT 'N' values higher than 100 blows per 0.15 m of penetration. In Borehole 08-072, SPT 'N' values were 12 and 15 blows per 0.3 m of penetration, indicating a compact relative density.

The natural moisture contents generally lay around 8 to 19%.

Grain size distribution curves for three sandy silt till samples, are presented on the Record of Borehole sheets and on Figure B4 of Appendix B. The results of the laboratory are summarized as follows:

Soil Particles	(%)
Gravel	1 to 11
Sand	34 to 51
Silt	28 to 40
Clay	10 to 26

Although not specifically identified in the boreholes, this layer may contain cobbles and boulders which may account for some high blow counts and resistance to augering.

5.7 Lower Sand

Lower layers of grey sand were contacted in Boreholes 08-071 and 08-072 at 17.7 m and 16.4 m depths (Elevations 294.8 and 294.0), respectively. Both boreholes were terminated within the lower sand layer.

A 700-mm thick layer of sand was also encountered within the sandy silt till at 14.9 m depth (Elevation 295.5) in Borehole 08-072.

SPT 'N' values measured in the lower sand were 100 blows per 0.3 m of penetration to higher than 100 blows per 0.125 m of penetration, indicating a very dense relative density. The natural moisture contents generally lay in the range of 17 to 19%.

Grain size distribution curves for two sand samples tested are presented on the Record of Borehole sheets and on Figure B5 of Appendix B. The results of the laboratory are summarized as follows:

Soil Particles	(%)
Gravel	0
Sand	85 to 89
Silt & Clay	11 to 15

5.8 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling. A standpipe piezometer was installed in Borehole 08-071 (at the proposed pier) to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.2.

Table 5.2 – Water Level Measurements

Foundation Unit	Borehole	Date (2008)	Water Level (m)		Comment
			Depth	Elevation	
Pier	08-071	August 6	12.8	299.6	In piezometer
		August 20	12.4	300.0	

The piezometric reading indicates that the groundwater level is near Elevation 300.0 m.

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

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

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Stephane Loranger, C.E.T. of Thurber, under the direction of Mr. Alastair E. Gorman, P.Eng.

The coordinates for the boreholes and the ground surface elevations were obtained by Thurber Engineering Ltd. using GPS equipment.

Overall supervision of the field program was conducted by Mr. Alastair E. Gorman, P.Eng. Interpretation of the data and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng. 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 new structure.

Based on the Plates 3 and 5 of the E.A:

- The existing ground surface within the proposed Service Road (connection to Bridge Street) varies from north to south from approximate Elevations 315.0 to 310.4.
- The proposed Highway 7 grade will be at Elevations 308.8. Hence, Highway 7 will be in a 6.2 m deep cut at the north abutment, 3.6 m cut at the pier and 1.6 m deep cut at the south abutment.
- The proposed grade of Service Road (connection to Bridge Street) will be at Elevation 316.8, with approach embankments 1.8 m to 6.4 m high relative to the existing ground surface and 8.0 m high relative to proposed Highway 7 grade.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of this investigation.

It is anticipated that a two-span structure will be constructed at this site.

8 STRUCTURE FOUNDATIONS

The stratigraphy identified in the preliminary investigation consisted primarily of topsoil overlying native compact to dense upper sand, sand and gravel and sandy silt layers, an extensive deposit of very stiff to hard silty clay till and compact to very dense sandy silt till. Lower layers of very dense sand were encountered in boreholes drilled at the proposed pier and south abutment.

Groundwater level measured in the piezometer was 12.4 m (Elevation 300.0) below the ground surface.

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

- Spread footings bearing on native soil
- Spread footings on engineered fill
- Steel H-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

Spread footings bearing on native soil generally are the least expensive form of construction.

The design of spread footings bearing on native undisturbed compact to dense sand, sand and gravel or very stiff to hard silty clay till must be in accordance with the elevations and bearing resistances given in Table 8.1.

Table 8.1 – Bearing Resistances for Spread Footings

Element	Depth (m)	Elev.	ULS _r (kPa)	SLS (kPa)
North Abutment (BH 08-070)	0.8	314.2	375	250
Pier (BH 08-071)	2.9	309.5	375	250
	4.4	308.0	450	300
South Abutment (BH 08-072)	1.6	308.8	300	200
	4.4	306.0	375	250

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 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.

Founding elevations presented in Table 8.1 are generally above the groundwater level observed during the investigation. However, if temporary excavations required to construct these footings extend below the water table, local groundwater control will be required to construct the footing in the dry and to prevent disturbance of the footing base.

8.2 Spread Footings on Engineered Fill

Spread footings can also be founded on Granular “A” engineered fill pads. These would be most useful in the case of perched abutments on footings.

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. Subexcavation of existing native loose sands will be required. The engineered fill will bear on native compact to dense sand and gravel, sandy silt and sand the highest permitted founding elevations at which engineered fill pads may be founded, are given in Table 8.2.

Table 8.2 – Founding Elevations for Engineered Fill Pads

North Abutment (BH 08-070)	Pier (BH 08-071)	South Abutment (BH 08-072)
314.5	311.5	309.5

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.

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.

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

8.3 Steel H-Piles

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

It is recommended that the H-piles be driven to achieve resistance in the very dense sandy silt till glacial soils and very dense sand encountered at this site.

The elevations at which the H-piles are expected to develop the required resistance are given in Table 8.3.

Table 8.3 – Estimated Pile Tip Elevation

Foundation Unit	Pile Tip Depth (m)	Pile Tip Elevation	Soil
North Abutment (BH 08-070)	19.5	295.5	Very dense sandy silt till
Pier (BH 08-071)	16.4	296.0	
South Abutment (BH 08-072)	18.9	291.5	Very dense sand

8.3.1 Axial Resistance

For preliminary design, the vertical, axial, factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS) for two pile sections when driven into the very dense soil are presented in Tables 8.4.

Table 8.4 – Axial Resistance of Two Pile Sections Founded on Very Dense Soils

Pile Section	Geotechnical Resistance (kN)	
	Factored ULS	SLS
HP 310 X 110	1,600	1,400
HP 360 X 132	1,800	1,600

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

Installation of the piles must be in accordance with SP 903S01 and must be controlled using the Hiley Formula and an ultimate resistance of 3,200 kN for an HP 310 X 110 and 3,600 kN for the HP 360 X 132.

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 glacial sandy silt till layer 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

Due to the presence of stiff to hard cohesive soils, downdrag on the piles is not an issue at this site. However, it is recommended that construction of the approach fills be carried out at least three months in advanced of pile driving.

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.

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 current information, the recommended abutment foundation consists of steel H-piles driven into the very dense native sand and sandy silt till, despite the higher cost noted in Appendix C.

The recommended foundation at the pier is a spread footing on hard silty clay till. Spread footings on engineered fill is feasible, but does not offer any cost advantage over spread footings on native soils.

9 BRIDGE APPROACHES AND EMBANKMENTS

Based on the three boreholes drilled at the site, the approach embankments will be constructed over compact, non-cohesive sand, sand and gravel and sandy silt and the cohesive very stiff silty clay till.

No long term settlement or global stability issues are anticipated for approach embankments built at this site. However, further settlement analysis should be conducted during the detail phase design. The 8.0 m high embankments likely to be constructed will be stable at side slopes of 2H:1V if constructed using SSM or granular fill.

Where earth fill embankments are higher than 8 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive grade to shed run-off water.

The mainline cut shown on EA Plates 3 and 5 may be at approximately 8.8 m above the groundwater table. During detail design, when the grade has been finalized, permanent drainage (if necessary) and slope protection requirements must be addressed. Subject to drainage control, the cut slopes will be stable at slopes with a maximum inclination of 2H: 1V.

10 CONSTRUCTION CONCERNS

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

1. Pile refusal at higher elevation.

Although there was little direct evidence of their presence during drilling, glacial till deposits inherently contain boulders. It is possible that a pile will achieve refusal at a higher elevation than anticipated due to encountering a boulder. If it is suspected that this is happening, the QVE must immediately bring it to the attention of the CA. If the CA cannot resolve the issue, it must be referred to the design team for resolution.

2. Pile fails to develop specified resistance.

If a pile has not developed the specified resistance after being driven 3 m beyond the anticipated pile tip elevation, stop driving and check the Hiley calculation and all input values. If the calculation still shows that the pile has not reached the specified resistance, the following procedure should be implemented:

- a) Stop driving in that pile group for 48 hours (minimum)
- b) After 48 hours, warm up the hammer on another pile then commence re-driving the subject pile and measure the resistance.
- c) If the pile still does not reach the specified resistance, the QVE must immediately advise the CA who, in turn, should refer the issue to the design team.

3. 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.

11 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. Boreholes for structure foundations.

Additional boreholes may be required for the structure foundations, especially if the structure is built off the current Service Road alignment and thus removed from the alignment of the current investigation. Particular attention should be paid to groundwater levels and exploration off the existing road embankment is recommended.

2. Boreholes for approaches.

A minimum of one borehole is recommended in each approach fill on Service Road. Similarly, at least one borehole is required in the mainline cut to either side of the structure. The boreholes in the cut must include piezometers for groundwater monitoring.

12 CLOSURE

Engineering analysis and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng. and 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.

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Appendix A

Record of Borehole Sheets

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.
TERMS		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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 0.3 m of core run.				

RECORD OF BOREHOLE No 08-070

1 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 816 095.20 E 227 943.38 ORIGINATED BY SLL
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG
 DATUM Geodetic DATE 2008.07.23 - 2008.07.23 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			SHEAR STRENGTH kPa					WATER CONTENT (%)
								20 40 60 80 100					
315.0													
0.0													
0.1	TOPSOIL, occasional organics, roots and rootlets: (125mm)												
	SAND and GRAVEL, trace silt, trace clay Dense to Very Dense Brown Moist		1	SS	35								
	occasional cobbles Wet		2	SS	54								
312.5													
2.4	Silty CLAY, trace sand Very Stiff to Hard Brown to Grey (TILL)		3	SS	22								
			4	SS	23								
			5	SS	42								
			6	SS	30								
			7	SS	22								
			8	SS	44								

Continued Next Page

+ 3 x 3 Numbers refer to
Sensitivity 20
15 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-070

3 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 816 095.20 E 227 943.38 ORIGINATED BY SLL
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG
 DATUM Geodetic DATE 2008.07.23 - 2008.07.23 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
	Sandy SILT, trace to some gravel, trace clay Very Dense Grey Wet (TILL)		15	SS	100/ .150		295										
	Layer of sand: (400mm)						294										
293.5			16	SS	100/ .150												
21.5	END OF BOREHOLE AT 21.5m. BOREHOLE BACKFILLED WITH BENTONITE BENSEAL TO 0.2m, THEN HOLEPLUG TO SURFACE.				.150												

ONTMT4S 6417R.GPJ 9/10/08

RECORD OF BOREHOLE No 08-071

1 OF 2

METRIC

G.W.P. 408-88-00 LOCATION N 4 816 060.14 E 227 953.28 ORIGINATED BY SLL
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG
 DATUM Geodetic DATE 2008.07.24 - 2008.07.24 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	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
312.4												
0.0	TOPSOIL: (125mm)											
0.2	Sandy SILT, some clay, trace gravel Compact Brown Wet		1	SS	12		312					
311.0												
1.5	Silty CLAY, trace sand Very Stiff Brown (TILL)		2	SS	16		311					
			3	SS	14		310					
	Brown to Grey		4	SS	22		309					
			5	SS	28		308					
			6	SS	34		307					
	Hard Grey		7	SS	46		306					
			8	SS	37		305					
							304					
							303					

Continued Next Page

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

RECORD OF BOREHOLE No 08-071

2 OF 2

METRIC

G.W.P. 408-88-00 LOCATION N 4 816 060.14 E 227 953.28 ORIGINATED BY SLL
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY LG
 DATUM Geodetic DATE 2008.07.24 - 2008.07.24 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		
	Continued From Previous Page							SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
								WATER CONTENT (%)						
								20	40	60	80	100		
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
								w _p w w _L						
								20 40 60						
297.8	Silty CLAY, trace sand Very Stiff to Hard Grey (TILL)		9	SS	25		302							
							301							
			10	SS	42		300							
							299							
			11	SS	25		298							0 1 16 83
14.7	Sandy SILT, some clay to clayey, trace gravel Very Dense Grey Moist (TILL)		12	SS	100/ .250		297							1 34 39 26
							296							
			13	SS	100/ .125		295							
294.8							294							
17.7	SAND, trace to some silt, trace gravel Very Dense Grey Wet		14	SS	100/ .250		294							
293.7														
18.7	END OF BOREHOLE AT 18.7m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2008.08.06 12.8 299.6 2008.08.20 12.4 300.0													

ONTMT4S 6417R.GPJ 9/10/08

METRIC

+ ³ × ³: Numbers refer to Sensitivity

METRIC

+ 3, × 3: Numbers refer to Sensitivity

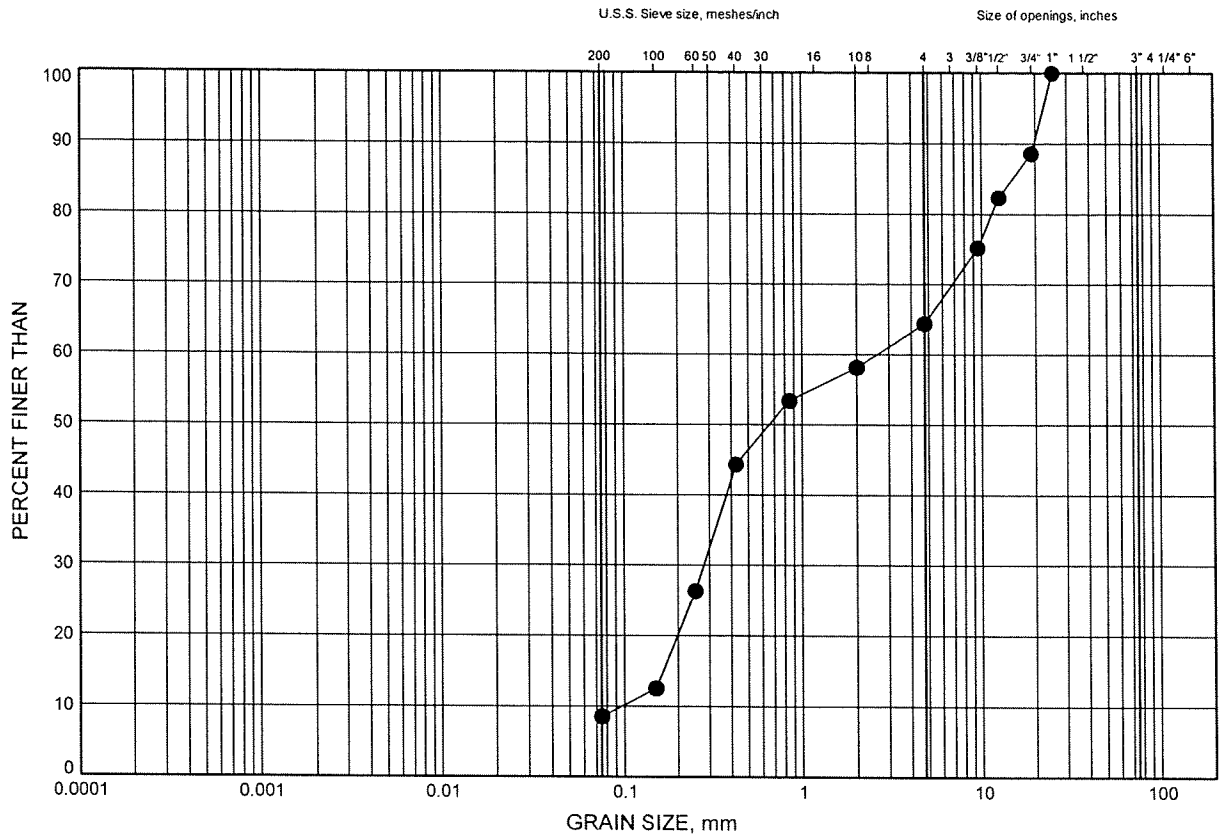
Appendix B

Laboratory Test Results

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-070	1.83	313.13

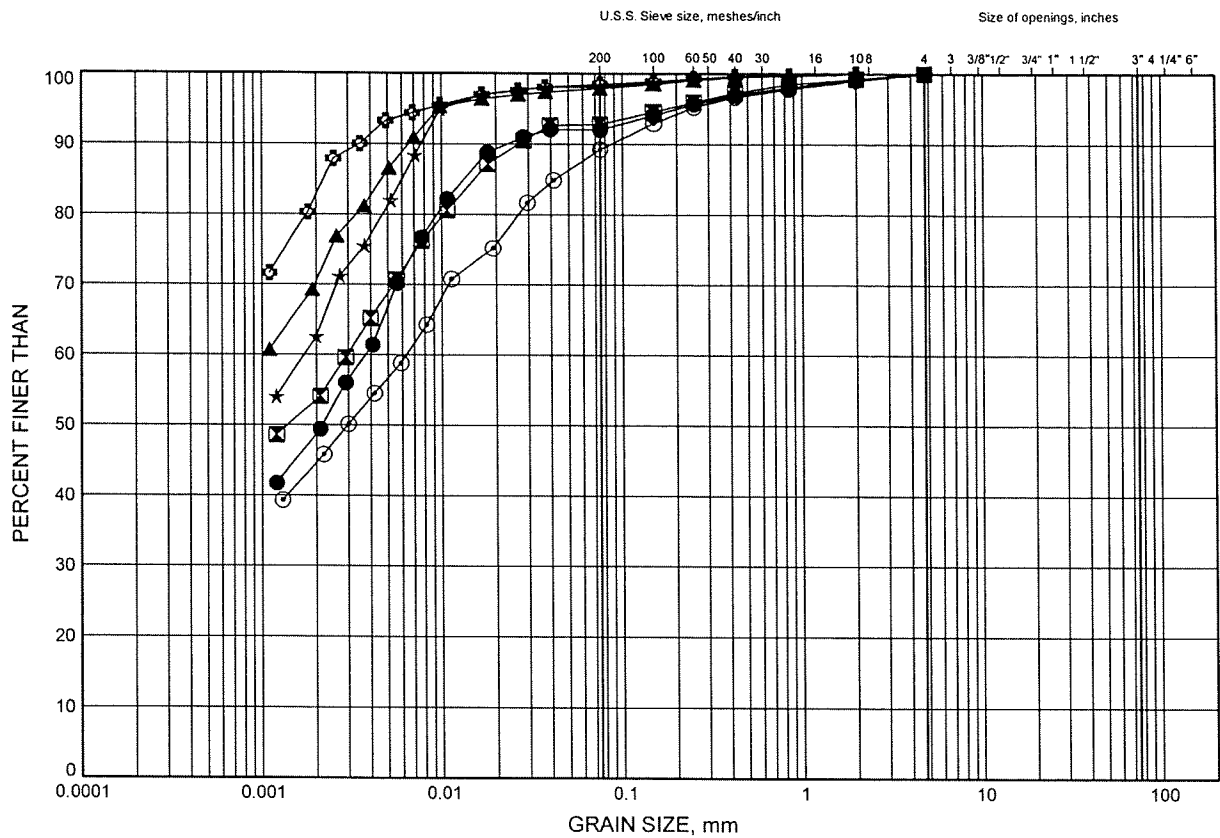


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-070	4.88	310.09
⊠	08-070	10.97	303.99
▲	08-070	17.07	297.89
☆	08-071	2.59	309.85
⊙	08-071	7.92	304.52
⊛	08-071	13.96	298.49

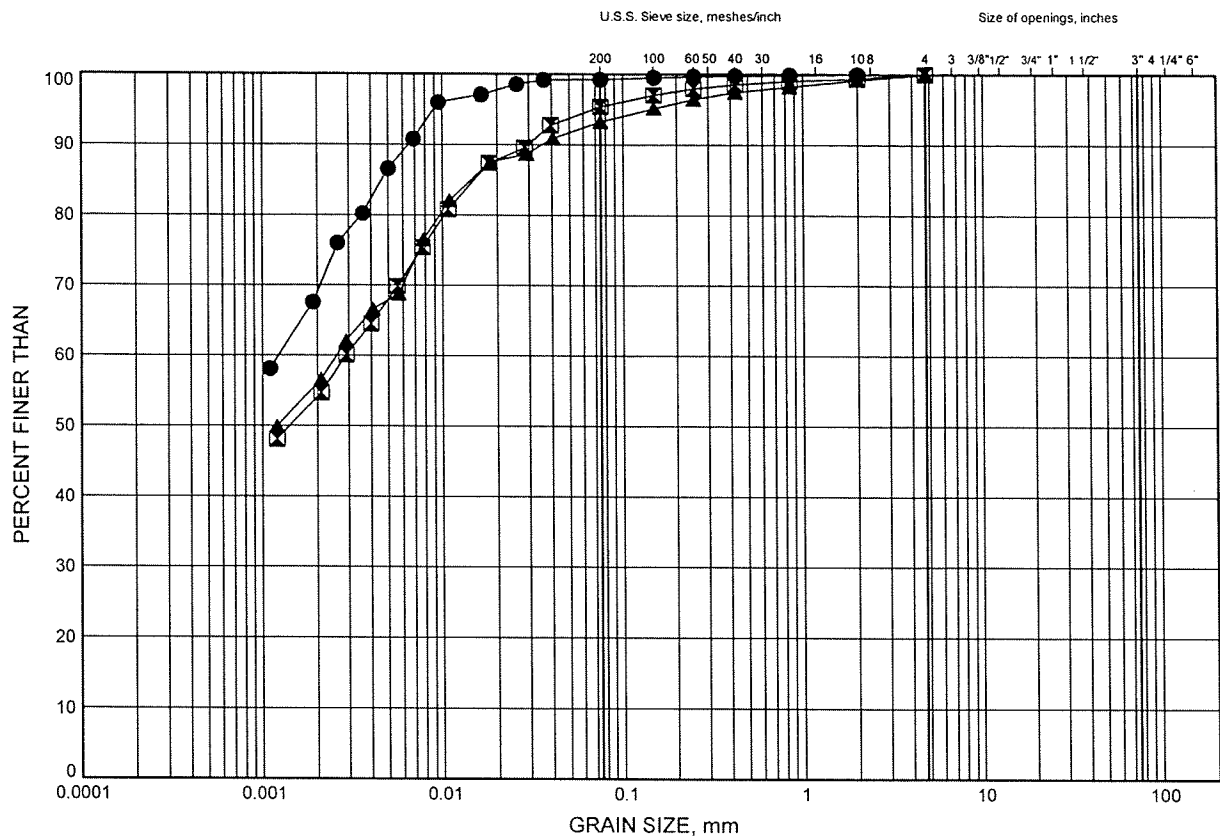


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-072	2.59	307.84
⊠	08-072	4.88	305.55
▲	08-072	10.97	299.46

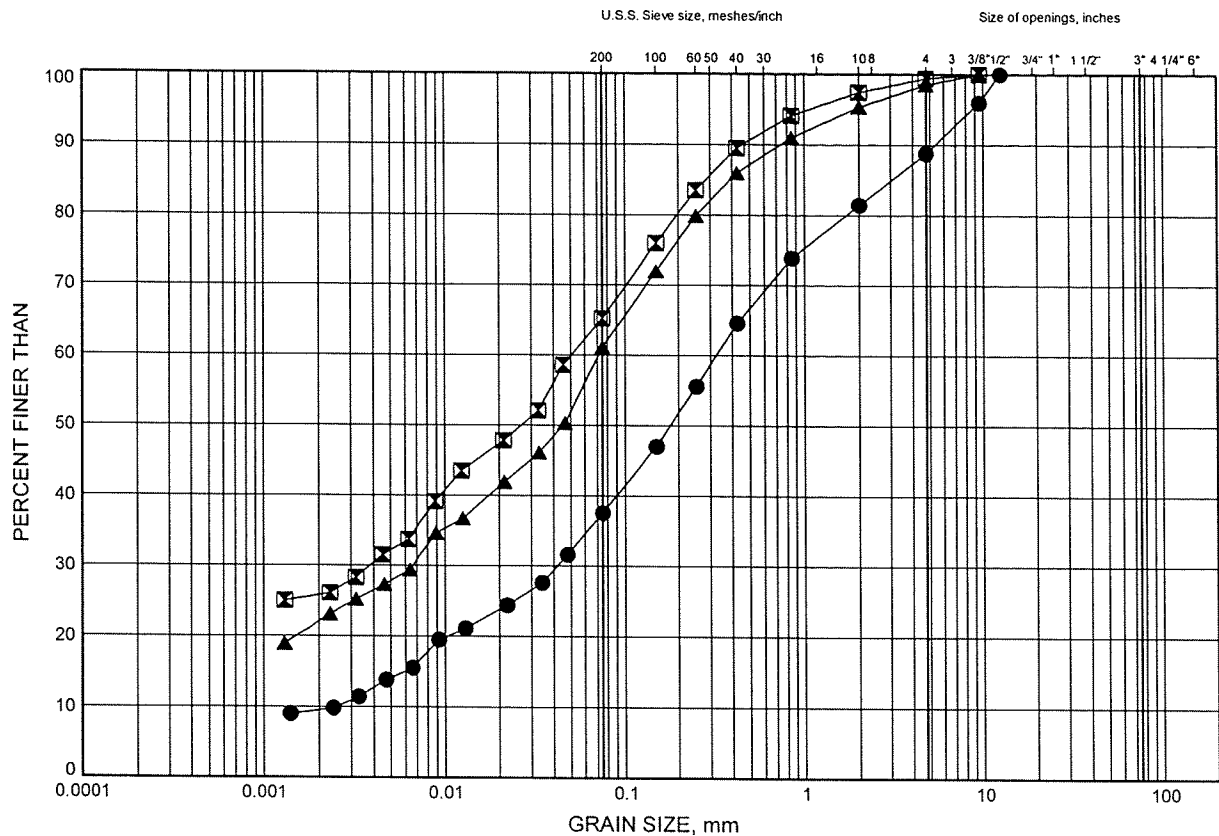


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B4

Sandy Silt Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-070	19.96	295.00
⊠	08-071	15.49	296.95
▲	08-072	14.23	296.21

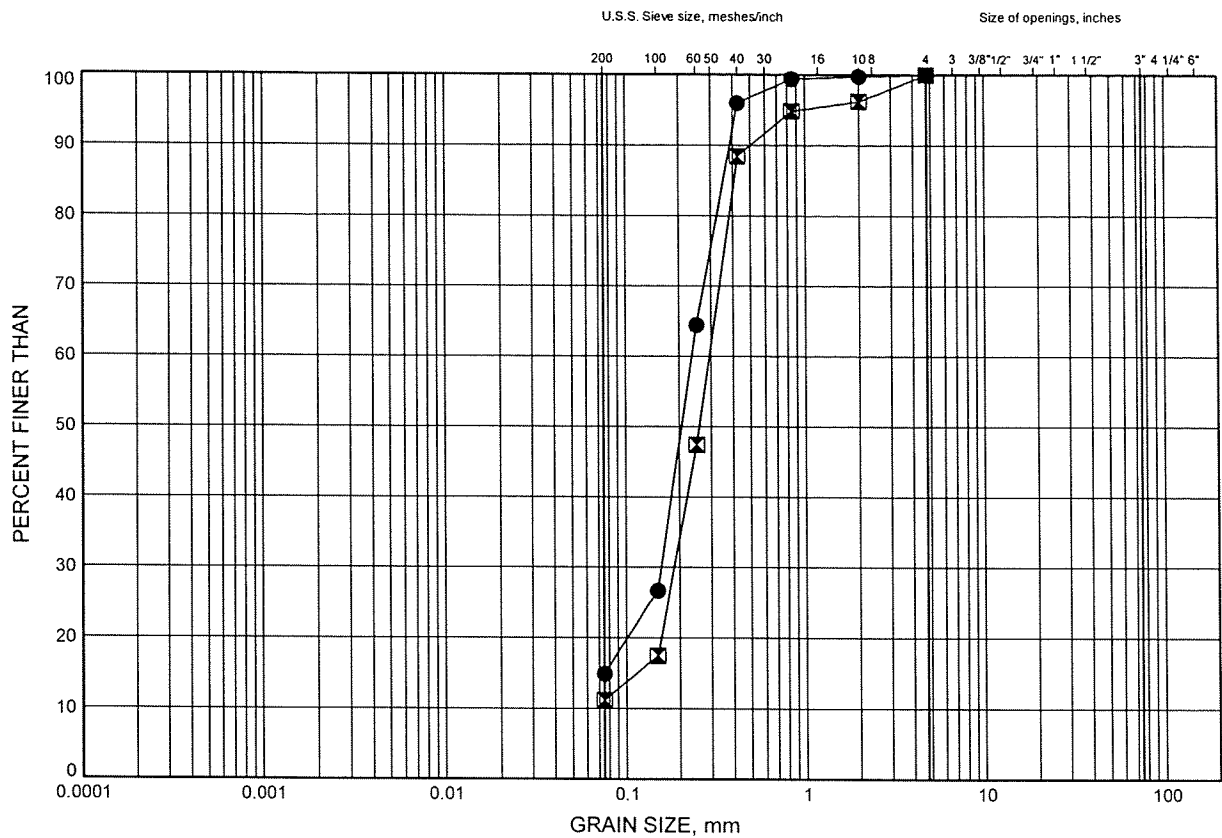


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B5

Lower Sand Layer



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-072	15.44	294.99
⊠	08-072	18.38	292.05

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 9/4/08

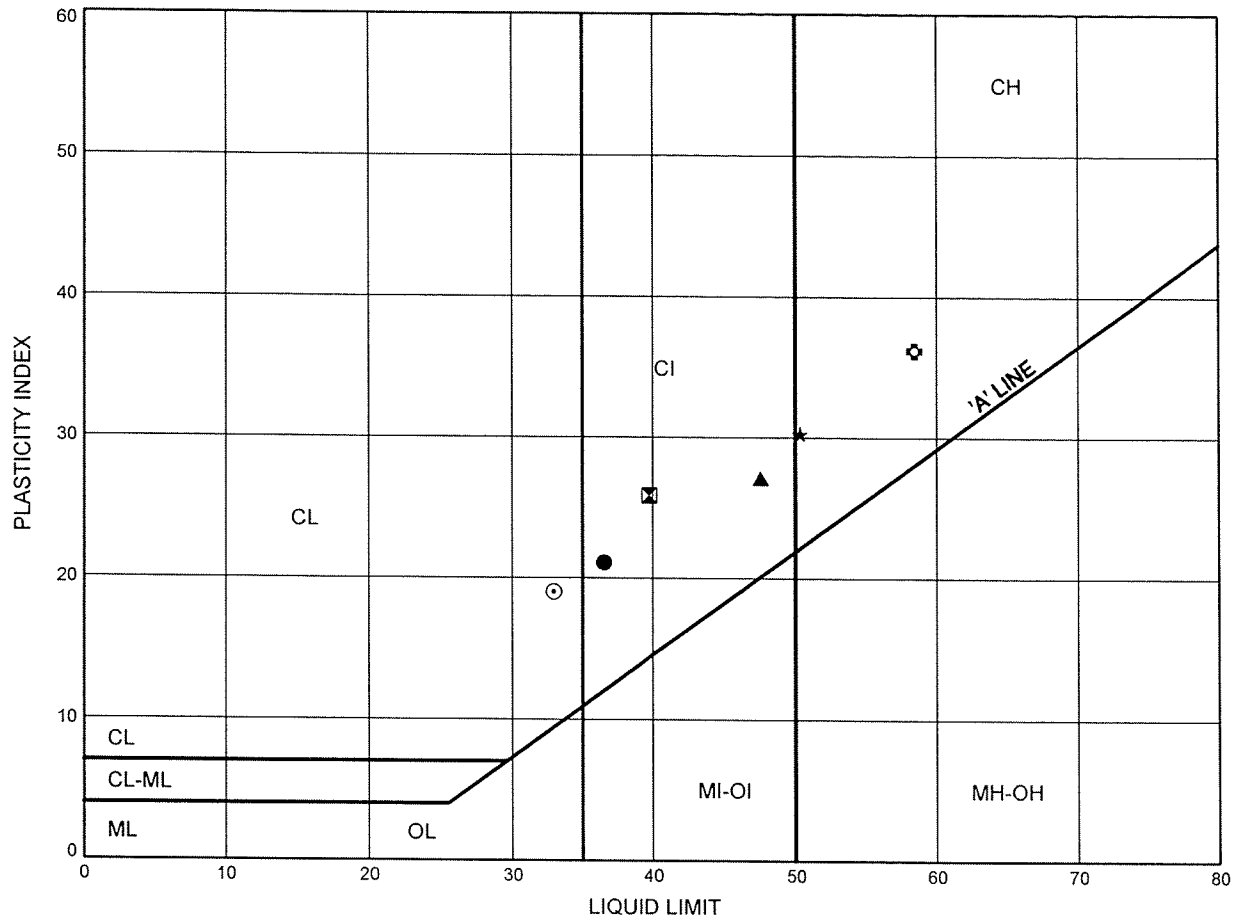
W.P.# 408-88-00
Prepared By MFA
Checked By RPR



Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty Clay Till



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-070	4.88	310.09
⊠	08-070	10.97	303.99
▲	08-070	17.07	297.89
★	08-071	2.59	309.85
⊙	08-071	7.92	304.52
⊕	08-071	13.96	298.49

Date September 2008
 Project 408-88-00

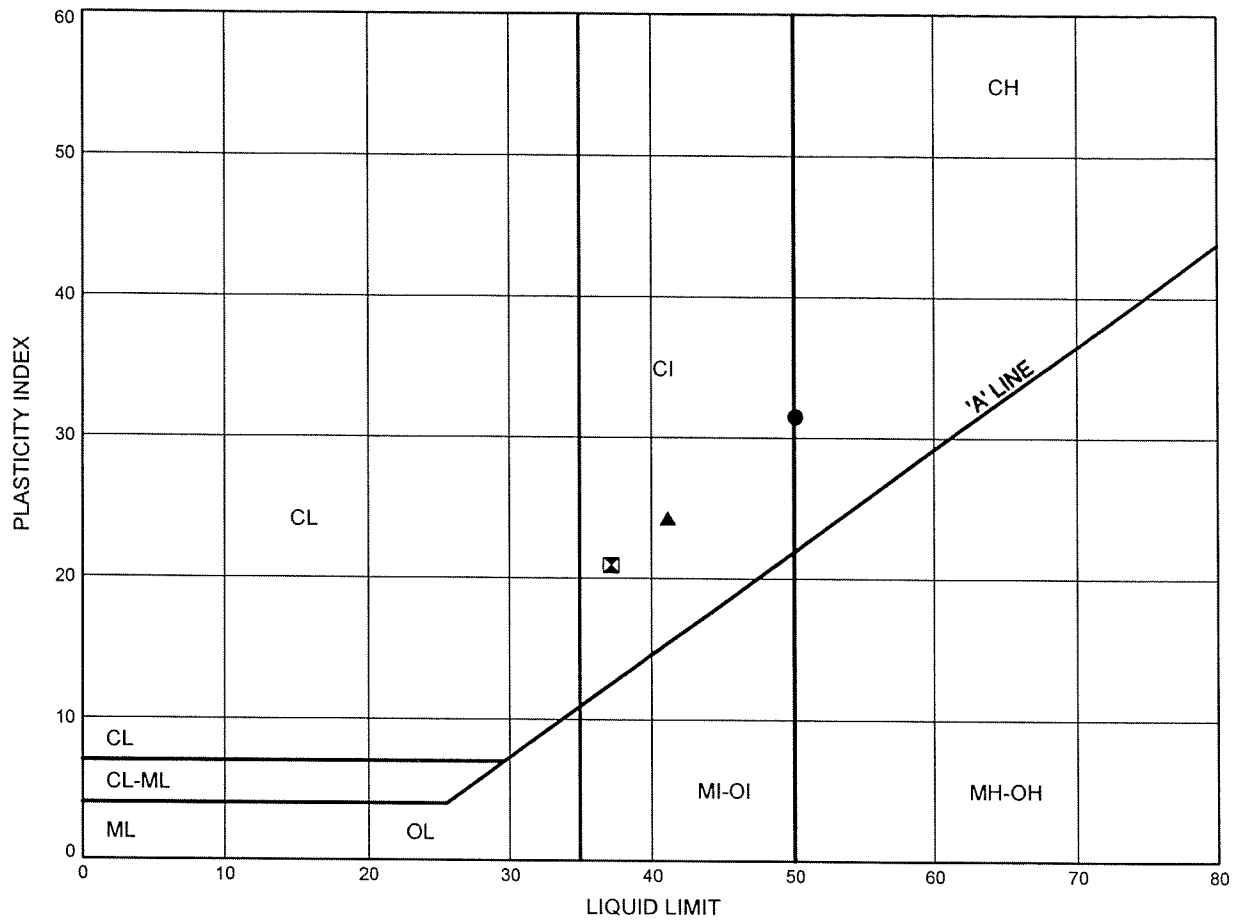


Prep'd MFA
 Chkd. RPR

Highway 7 - New ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty Clay Till



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-072	2.59	307.84
⊠	08-072	4.88	305.55
▲	08-072	10.97	299.46

Date September 2008
Project 408-88-00



Prep'd MFA
Chkd. RPR

Appendix C

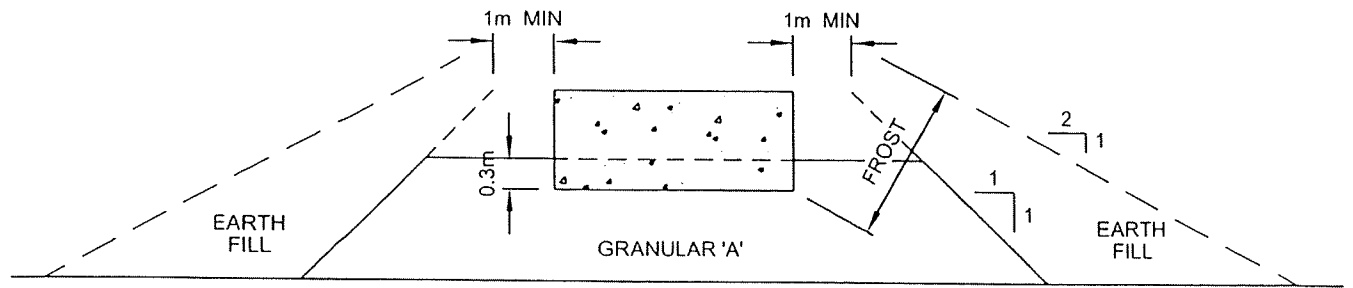
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

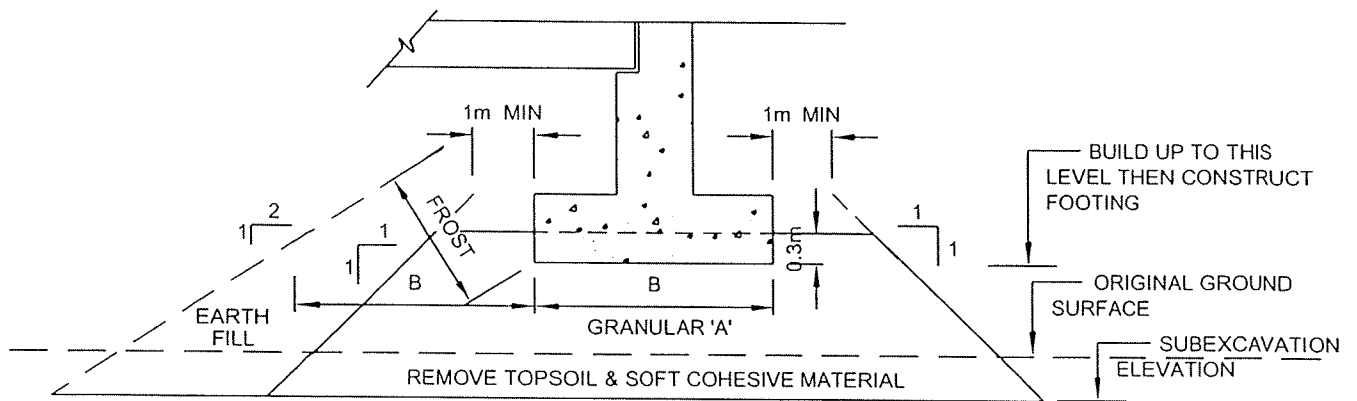
Foundation Element	Spread Footings	Spread Footings on Engineered Fill	Driven Piles
Abutments	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Lower geotechnical resistance available due to founding on compact soils near the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Better geotechnical resistance than spread footings on native, but still influenced by the compact soils at the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense soils. ii. Comparatively short abutment stem possible iii. Permits integral abutment design <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense/hard soils at shallow depth will limit length of pile and geotechnical resistance that can be developed. <p>RECOMMENDED</p>
	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation. <p>RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation. <p>NOT REQUIRED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense soils. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense soils at shallow depth will limit length of pile and geotechnical resistance that can be developed. <p>NOT RECOMMENDED</p>

Appendix D

Figure



CROSS-SECTION



LONGITUDINAL SECTION

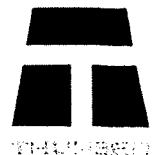
NOT TO SCALE

NOTES:

1. REMOVE TOPSOIL AND SOFT SILTY CLAY SUBSOIL UNDER FOOTPRINT OF COMPACTED GRANULAR 'A'.
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

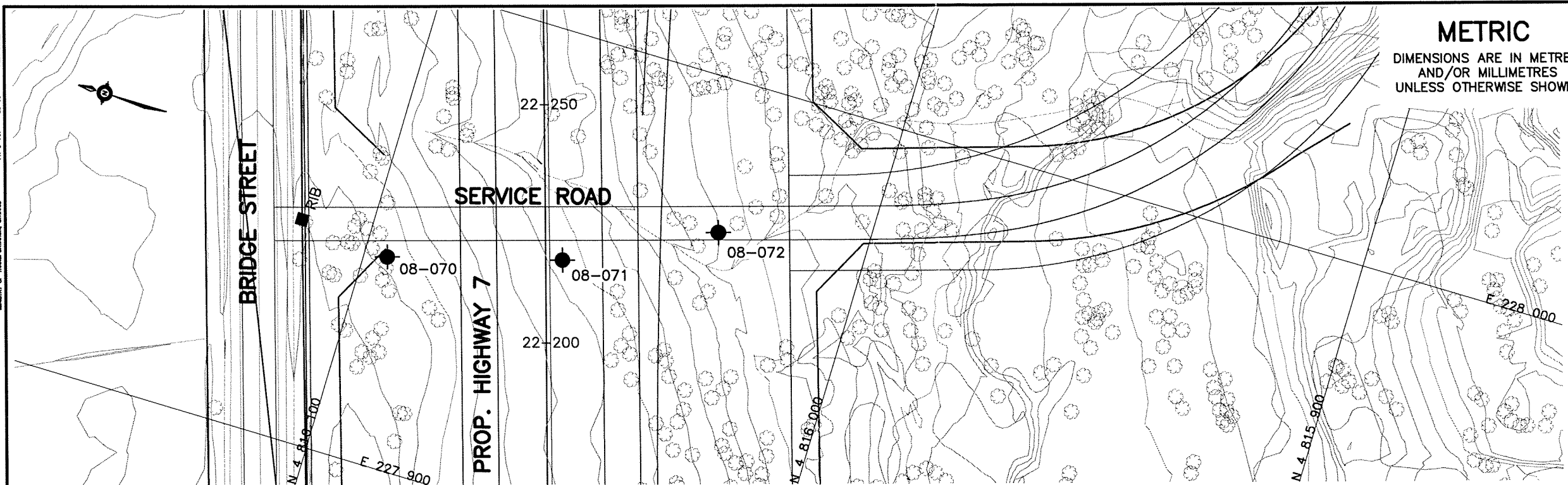


DWG. NO.

FIGURE 1

Appendix E

Drawing titled “Borehole Locations and Soil Strata”



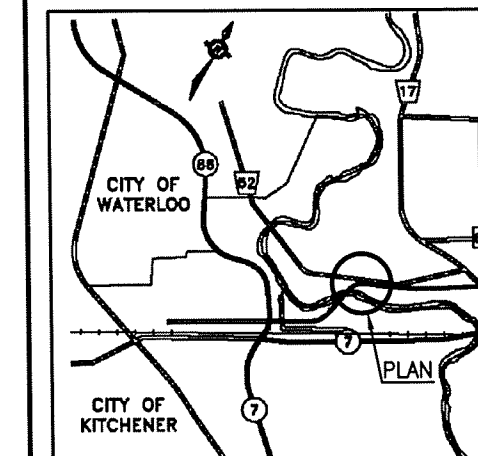
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 408-88-00

HIGHWAY 7
RECOMMENDED ROUTE
SERVICE ROAD OVER PROP. HWY 7
BOREHOLE LOCATIONS AND SOIL STRATA








SHEET



KEYPLAN

LEGEND

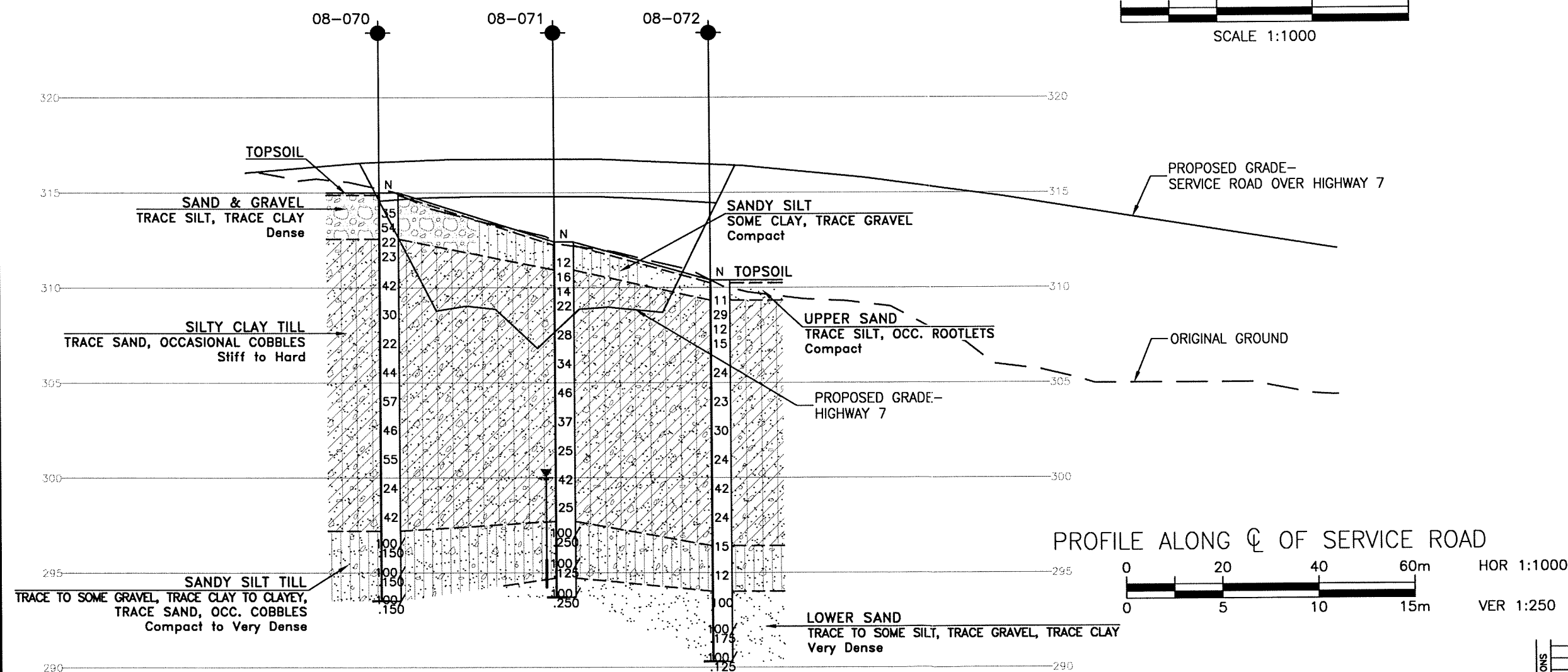
- | | |
|---|---------------------------------------|
|  | Borehole |
|  | Borehole and Cone |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60° Cone, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level |
|  | Head Artesian Water |
|  | Piezometer |
| 90% | Rock Quality Designation (RQD) |
| A/R | Auger Refusal |

[illegible]

-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.
- 3) Proposed grades are from Plate 3 of the E.A. Study.

GEOCRES No. 40P8-156



DRAWING NOT TO BE SCALED
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