FOUNDATION INVESTIGATION AND DESIGN REPORT

HYDRO ONE TOWER RELOCATION AT HODDER AVENUE

HIGHWAY 11/17 FOUR-LANING FROM 1.0 KM WEST OF HODDER AVENUE/COPENHAGEN ROAD EASTERLY FOR 5.8 KM THUNDER BAY, ONTARIO

W.P. 334-94-00

Geocres Number: 52A-145

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed relocation of a Hydro One tower in the southwest quadrant of the intersection of Hodder Avenue and Highway 11/17 in Thunder Bay, Ontario. An existing tower will be relocated 32 m to the west of the current tower location to accommodate construction of a new W-N/S ramp during interchange development.

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, record of borehole sheets, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed to describe the geotechnical conditions influencing design and construction of the tower foundations.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin Corporation, under the Ministry of Transportation Ontario (MTO) Agreement Number 6008-E-0005.

2 SITE DESCRIPTION

The site lies on the southwest quadrant of the intersection of Highway 11/17 and Hodder Avenue at the northeast limit of the City of Thunder Bay. An existing Hydro One corridor runs east-west at the site, crossing Hodder Avenue to the east and Highway 11/17 to the west of the site.

The existing ground surface at the proposed tower location slopes down to the Current River situated approximately 200 m to the west. The hydro corridor is grass covered and bordered by tress on the north and south.

Geologically, the site area is located within the physiographic region known as the Canadian Shield, characterized by Pre-Cambrian bedrock typically occurring as rounded knobs and ridges where exposed. At this site, the bedrock consists of the Gunflint Formation, a sequence of limestone, chert-carbonate, graphitic shale, tuff, taconite and chert. Intrusions/sills of diorite are present locally. The bedrock is overlain by a discontinuous layer of glacial till comprising a heterogeneous mixture of clayey silt, silt, sand and gravel.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation for the new tower foundations was carried out between January 9 and 13, 2010 and consisted of four boreholes, numbered 10-81 to 10-84, located near the corners of the proposed tower location. Five additional boreholes were drilled in the vicinity of the tower location, as follows:

- Boreholes 09-01 and 09-03 were drilled on June 29, 2009 in connection with the foundation investigation for the proposed W-N/S Ramp cut.
- Boreholes 10-86 and 10-87 were drilled to the north and east of the existing hydro tower to determine foundation parameters for a possible retaining wall along the W-N/S Ramp required if the existing tower were not relocated. These boreholes were drilled on January 6 and 14, 2010.
- Borehole 10-85 was drilled to the northwest of the proposed tower location on January 8 to 9, 2010 to confirm subsurface conditions downslope from the proposed tower location.

The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix F. The borehole elevations, locations and depths are summarized in Table 3.1. The boreholes were advanced to depths of 9.3 to 19.4 m, at least 3.0 m into bedrock in all but one of the boreholes.

Table 3.1 – Borehole Summary

Borehole	Ground Surface Elevation (m)	Location		Total Depth (m)	Length of Core in Bedrock (m)
		Northing	Easting		
09-01	260.4	5 371 905.0	365 060.4	9.3	-
09-03	263.1	5 371 893.1	365 081.2	10.7	3.1
10-81	256.9	5 371 883.6	365 036.8	17.9	3.7
10-82	258.6	5 371 883.1	365 043.8	18.0	3.1
10-83	256.8	5 371 875.9	365 036.6	19.4	4.5
10-84	258.4	5 371 876.5	365 043.0	17.5	4.1
10-85	255.4	5 371 889.1	365 032.3	14.8	3.0
10-86	261.8	5 371 898.8	365 071.6	10.9	3.6
10-87	264.4	5 371 883.3	365 102.6	10.4	3.5

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area. Hydro One was contacted to confirm the required clearance between the drilling equipment and overhead wires.

Hollow-stem augers were used to advance the boreholes to auger refusal encountered at depths of 2.7 to 6.3 m. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Below the refusal depths, the boreholes were advanced a further 4.0 to 13.8 m, including 3.0 to 4.5 m into bedrock, by BQ and NQ size diamond coring techniques.

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

All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In three boreholes (Nos. 09-03, 10-81 and 10-84), standpipe piezometers consisting of 19 mm PVC pipe with a slotted screen were installed and enclosed in filter sand to permit longer term groundwater level monitoring. The completion details of the piezometers are shown in Table 3.2. Following the final water level reading, the piezometers were decommissioned in accordance with MOE Regulation 903.

The boreholes in which no piezometers were installed were backfilled with bentonite and cuttings. The borehole completion details are shown in Table 3.2.

Table 3.2 – Borehole Completion Details

Borehole	Piezometer Tip		Completion Details
	Depth (m)	Elevation (m)	
09-01	-	-	Borehole backfilled with bentonite to surface
09-03	10.7	252.4	Piezometer with 1.5 m slotted screen installed with sand filter below 5.6 m depth, and bentonite seal to ground surface.
10-81	10.7	246.2	Piezometer with 1.5 m slotted screen installed with sand filter below 4.9 m depth, and bentonite seal to ground surface.
10-82	-	-	Borehole backfilled with bentonite to surface
10-83	-	-	Borehole backfilled with bentonite to surface
10-84	13.7	244.7	Piezometer with 1.5 m slotted screen installed with sand filter below 9.0 m depth, and bentonite seal to ground surface.
10-85	-	-	Borehole backfilled with bentonite to surface
10-86	-	-	Borehole backfilled with bentonite to surface
10-87	-	-	Borehole backfilled with bentonite to surface

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 and 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.

Point load testing was conducted on rock core samples retrieved from the boreholes. The results of the point load tests are shown on the borehole logs in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil and rock stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawings 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, the site is underlain by compact to very dense sandy silt to silty sand till underlain by very dense sand and gravel with cobbles and boulders. The till, sand and gravel is underlain by bedrock. Surficial topsoil, clayey silt fill, sand and sandy silt layers were encountered in individual boreholes.

5.1 Silt Fill

Silt fill, trace clay to clayey, was encountered surficially in borehole 10-86 located northeast of the tower. The lower boundary of the fill was encountered at 2.1 m depth (elevation 259.7 m). The fill is firm to loose with SPT 'N' values of 7 and 3 blows/0.3 m recorded. Moisture contents ranged from 12 to 22% in the fill.

5.2 Topsoil

A 1.1 m thick layer of topsoil was encountered in borehole 09-01 located north of the proposed tower site. The topsoil thickness may vary beyond the borehole location and this data should not be used to estimate topsoil quantity.

5.3 Sand and Sandy Silt

A 0.3 m thick layer of dark brown sand with trace organics was encountered below the topsoil in borehole 09-01. An 'N' value of 21 blows/0.3 m (compact) and moisture content of 10% were obtained in this layer. The lower boundary of the sand was at 1.4 m depth (elevation 258.9 m).

A surficial sandy silt deposit was encountered in borehole 10-87 located east of the existing tower. An 'N' value of 8 blows/0.3 m indicates that the sandy silt is loose. A moisture content of 22% was obtained. The sandy silt layer was 1.4 m thick.

5.4 Sandy Silt to Silty Sand Till

A heterogeneous glacial till deposit consisting of sandy silt to silty sand with variable content of clay and gravel was encountered surficially or below the fill, sand or silt in all boreholes. The till contains frequent cobbles and boulders. The thickness of the till layer varies from 1.7 to at least 7.9 m, and the lower boundary ranges from elevation 249.6 to 261.7 m.

The results of laboratory grain size distribution tests carried out on samples of the till are illustrated in Figures B1 to B3, Appendix B. The results for all but one sample are summarized below. A piece of gravel was included in the sample tested from borehole 10-85, resulting in a higher gravel content of 39%.

Gravel (%)	0 to 14
Sand (%)	17 to 57
Silt (%)	26 to 69
Clay (%)	5 to 15

The till is generally loose to dense with 'N' values of 5 to 44 blows/0.3 m in the upper 1.5 to 3.0 m of this deposit, and becomes dense to very dense below this level with 'N' values exceeding 40 blows/0.3 m penetration. Below 4.4 to 5.9 m depth in boreholes 09-01, 09-03 and 10-86, the till became very dense and/or bouldery, requiring coring procedures to penetrate.

The moisture content of samples from this deposit ranged from about 5 to 25%, typically 10 to 20%.

5.5 Silty Sand and Gravel

Further penetration by augering and split spoon sampling was refused at depths of 2.7 to 6.3 m in all boreholes. Below these depths, the boreholes were advanced using rock coring methods, resulting in limited recovery until bedrock was encountered at depths of 6.9 to 14.9 m.

Based on the limited samples recovered, the material penetrated during the coring operations was described as very dense silty sand and gravel with occasional to frequent cobbles and boulders. The sand and gravel is underlain by bedrock.

5.6 Bedrock

Bedrock was encountered below the silt/sand till and sand and gravel in all boreholes except borehole 09-01. The depths to bedrock proved by coring are summarized in Table 5.1.

Table 5.1 – Depth to Bedrock at Borehole Locations

Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
09-03	7.6	255.5
10-81	14.2	242.7
10-82	14.9	243.7
10-83	14.9	241.9
10-84	13.4	245.0
10-85	11.8	243.6
10-86	7.3	254.5
10-87	6.9	257.5

The bedrock recovered in the cores consisted of a complex interbedding of various rock types considered to be part of the Gunflint Formation. Varying with depth and location, the rock was described as chert carbonate, grainstone, calcareous siltstone, shale, and wackestone. Shale laminations, calcite veining, pyrite veining, chert nodules and fossiliferous bands were also noted.

The bedrock is typically described as thinly banded and fresh to slightly weathered. The colour is dark to charcoal grey with light grey bands.

Core recovery in the bedrock was between 80% and 100%. RQD values typically ranged from 77 to 100% indicating good to excellent rock quality. Lower RQD values of 35 to 60% were obtained in boreholes 10-84 and 10-87, indicating poor to fair quality. An RQD value of 0 (very poor quality) was recorded for one run of thinly bedded material recovered from borehole 10-82.

The unconfined compressive strength of the rock is highly variable depending upon the actual bedding layer of rock tested. Strength values estimated from the results of point load tests conducted on the core samples ranged from 31 to 302 MPa, indicating a medium strong to extremely strong intact rock. The point load test results are included on the borehole logs in Appendix A.

5.7 Groundwater

Groundwater was not observed in the boreholes while advancing using augers. Water was introduced into all boreholes as part of the coring operations and therefore groundwater levels could not be recorded immediately upon completion.

The groundwater depths and elevations measured in the piezometers two to five months subsequent to drilling are shown in Table 5.2.

Table 5.2 – Groundwater Depths and Elevations in Piezometers

Borehole	Installation Date	Groundwater Levels in Piezometers		
		Date	Depth (m)	Elevation (m)
09-03	29-Jun-09	23-Nov-09	10.4	252.7
10-81	10-Jan-10	01-Mar-10	9.8	247.1
10-84	13-Jan-10	01-Mar-10	11.2	247.2

The above water levels reflect the piezometric head at the level of the piezometer tips at the time of the readings. The measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.

6 MISCELLANEOUS

J.D. Barnes Limited determined the co-ordinates and ground elevations at the boreholes following completion of the site investigation.

Eastern Ontario Diamond Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling and sampling equipment for the current field program. Full time supervision of the field activities, including obtaining utility clearances, was carried out by Mr. Stephane Loranger and Mr. Luke Gilarski of Thurber.

Supervision of the field program, interpretation of the field data, and preparation of the report was performed by Mr. Murray Anderson, 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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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist the design team to select and design a suitable foundation system for the relocated tower. Recommendations for design of a retaining wall to the east of the existing tower are also provided for completeness in the event that the tower is not relocated.

It is understood that the tower will be relocated 32 m to the west of the existing tower to accommodate construction of the new W-N/S ramp to the Highway 11/17 – Hodder Avenue interchange. The new ramp will be constructed in a cut of approximately 10 m depth with a slope crest located at least 6 m from the tower base.

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 the investigation.

8 TOWER FOUNDATIONS

In general, the site is underlain by compact to very dense glacial till consisting of sand and silt with cobbles and boulders. Very dense sand and gravel was encountered below the till at depths of 5.6 to 6.3 m, and bedrock was encountered at depths of 13.4 to 14.9 m at the proposed tower location.

Groundwater was not observed in the boreholes during drilling. Groundwater levels measured in the piezometers at the proposed tower location were 9.8 to 11. 2 m below the ground surface, at elevation 247.1 to 247.2 m.

Hydro tower foundations typically consist of augered caissons (drilled piers) designed to provide vertical, lateral and uplift resistance to the applied tower loads. Geotechnical parameters for design of caisson foundations are provided in the following section.

If the caissons will extend into the sand and gravel encountered below depths of 5.6 to 6.3 m, caisson installation may be difficult due to the very dense conditions and presence of cobbles and boulders at this site. Alternative foundation schemes (spread footings, grillage foundations, and micropiles) are therefore discussed in addition to caissons. A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix C.

8.1 Caisson Foundations

The use of augered caisson foundations may be considered at this site. However, selection of caisson foundations must recognize the presence of very dense glacial till containing cobbles and boulders which may impact installation.

Caisson installation equipment must be able to penetrate the very dense till and sand and gravel deposits, and dislodge, handle, remove or otherwise penetrate the cobbles and boulders. Rock coring methods may be necessary if large or frequent boulders are encountered. Further discussion regarding caisson installation is presented in a subsequent section.

Geotechnical parameters for design of the caissons were interpreted from the investigation results and are provided in Table 8.1.

Table 8.1 – Recommended Geotechnical Design Parameters

Depth (m)	Stratum	SPT 'N' Values	c_u (kPa)	ϕ' (deg.)	n_h (kPa/m)	γ' (kN/m^3)	K_p
0 – 2.2	Compact to dense till	10 to 22	0	30°	5,000	20	3.0
2.2 – 6.0	Dense to very dense till	40 to 70	0	35°	10,000	21	3.7
6.0 – 14.5	Very dense sand and gravel	Cored	0	38°	18,000	22	4.2

In the above table:

c_u = undrained shear strength = unconfined compressive strength, $q_u / 2$
ϕ' = angle of internal friction
n_h = a coefficient related to soil density
γ' = bulk unit weight
K_p = coefficient of passive earth pressure (values are for level ground)

The coefficient of horizontal subgrade reaction (k_s) can be estimated as follows:

$$k_s = n_h \cdot z / D \qquad (\text{kN/m}^3)$$

where z = depth of embedment of caisson in metres
D = caisson width in metres

At this site, bedrock and the groundwater level are expected to be below the base of the caisson and will not impact foundation design.

For a typical caisson with a diameter of 0.9 to 1.2 m, a length of 6.0 m, and founded in dense to very dense silt/sand till or sand and gravel, the following resistance values are recommended:

	End-Bearing	Unit Shaft Resistance
Factored Resistance at ULS	1,000 kPa	30 kPa
Resistance at SLS	800 kPa	25 kPa
Allowable (working stress design)	800 kPa	25 kPa

Where downward sloping ground exists in front of a caisson, reduction of lateral passive resistance should be taken into account during design. For foundation design at the caissons, it can be assumed that full lateral resistance can only be mobilized where the width of the soil in front of the caisson is equal to or greater than approximately 4 times the diameter of the caissons. For sloping ground in front of a caisson, the magnitude of the mobilized passive resistance can be estimated using the following reduction factors:

Table 8.2 Slope Reduction Factors

Slope Inclination	**Passive Resistance Reduction Factor**
2H : 1V	0.60
2.5H : 1V	0.65
3H : 1V	0.70
4H : 1V	0.75

The depth of frost penetration at the site is 2.2 m. Accordingly all adhesion/skin friction or ultimate passive resistance within the upper 2.2 m should be neglected in foundation design.

8.2 Shallow Foundations on Native Soil

As an alternative to caisson foundations, consideration may be given to the use of spread footings or grillage foundations. Grillage foundations consist of steel beams laid in a grid on the founding surface and backfilled with granular materials to form a pad behaving like a mat foundation. Hydro One Network has indicated that the existing tower is likely supported on a grillage foundation, however design details were not available.

Spread footing or grillage foundations should be constructed on native, undisturbed dense to very dense glacial till at or below elevation 255.0 m. The following resistance values are recommended for design of 2.0 to 3.0 m square foundations constructed on dense to very dense till at this level:

Factored Bearing Resistance at ULS	600 kPa
Bearing Resistance at SLS	400 kPa
Allowable Bearing Capacity (working stress design)	400 kPa

The resistance values are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced accordingly.

The lateral resistance of the foundations may be computed using an unfactored friction coefficient of 0.55 on dense to very dense till. This is an "ultimate" value and requires a degree of sliding movement to occur to fully mobilize the resistance.

The bearing surfaces should be prepared by removing all loose/disturbed material. The exposed till surface should be protected from deterioration by placing a minimum 75 mm thick working mat of concrete of the same class as the footing within 4 hours of completing excavation. Areas requiring subexcavation beneath the underside of footing should be backfilled with the same class of concrete as used in the footing.

Uplift resistance for spread footings can be provided by the mass of the concrete in the footings and supplemented by anchors extended into the very dense till/sand and gravel or underlying bedrock. The anchors should be designed using the following values for bond strength in the very dense granular soils or bedrock:

	Very dense till or sand and gravel	Bedrock
Factored Resistance at ULS	90 kPa	350 kPa
Allowable (working stress design)	75 kPa	300 kPa

The above bond values are provided for design purposes only. To confirm the design values, selected anchors must be performance tested and all remaining anchors must be proof tested in accordance with OPSS 942.

8.3 Micropiles

Micropiles are considered a suitable option for support of the tower at this site. Micropile installation techniques such as rotary percussive duplex methods should be capable of penetrating the very dense till, sand and gravel with cobbles and boulders.

The hole diameter for micropiles is typically 175 to 250 mm. This diameter is much less than for caissons and therefore the potential for encountering boulders and the resulting risk of delays and increased costs would be reduced by the use of micropiles.

The design of the micropile system should be carried out by an experienced micropile contractor. It is envisioned that each tower leg would be supported on several micropiles developing resistance within the very dense sand and gravel.

8.4 Recommended Foundation

Augered caisson foundations are commonly used to support hydro towers and are considered feasible at this site. However, if the caissons will extend below approximate elevation 252 m, installation in the very dense soils with cobbles and boulders may be difficult, and the potential exists for production loss and cost escalation due to these conditions.

If deeper caissons (extending below elevation 252 m) are required, the use of micropile foundations is preferred as a means of managing the risks associated with foundation construction. Spread footing or grillage foundations with anchors may also be considered.

8.5 Frost Cover

The depth of frost penetration at this site is 2.2 m. The base of footings and pile caps on earth must be provided with a minimum of 2.2 m of earth cover as protection against frost action.

9 FOUNDATION EXCAVATION AND DEWATERING

Excavation for foundation and pile cap construction will be carried out within compact to dense sandy silt to silty sand till. It is anticipated that a hydraulic excavator will be suitable. Provision must be made for possible arduous excavation in the dense till materials and handling of cobbles and boulders.

A NSSP should be included in the contract alerting the Contractor to the presence of cobbles and boulders in the till deposits, possible arduous excavation, and potential issues during establishment of the founding surface. Suggested wording is provided in Appendix D, "Foundation Excavation".

All excavations must be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA) and in accordance with Special Provision 902S01. For the purposes of the OHSA, the soils may be classed as Type 3 within the upper 2.2 m and Type 2 below this depth.

Caisson installation should generally be carried out in accordance with SP 903S01. Caisson installation equipment must be able to penetrate the dense to very dense soils at the site and dislodge, handle, remove or otherwise penetrate any cobbles and boulders encountered. Rock coring methods may be necessary if large or frequent boulders are encountered, notably below a depth of about 6 m indicated by the boreholes. A suggested text for an NSSP on this subject is provided in Appendix D.

The selection of the method of excavation or installation of caissons/micropiles is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions.

The groundwater level on site is expected to be below the caisson/footing depth and is not expected to impact caisson installation or foundation excavation procedures. Pumping from the caisson/foundation excavation should be suitable for removal of any accumulating seepage. A temporary liner must be maintained on site to support the caisson sidewalls if any seepage zones or less stable cohesionless materials are encountered.

Excavations should be inspected regularly for evidence of instability if they have been left open for extended periods of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to ensure the stability of the excavation and the safety of workers.

10 RETAINING WALL DESIGN

This section provides geotechnical recommendations for design of a new retaining wall between the existing hydro tower and the proposed W-N/S Ramp. We understand that the retaining wall concept and design have not been developed as current plans call for relocation of the tower, and therefore the wall will not be required. This section is provided for completeness only, in the event that tower relocation is not carried out.

The distance from the edge of the proposed ramp cut to the nearest hydro tower leg is approximately 20 m. A minimum 15 m wide platform around the tower is preferred by Hydro One Networks for access and maintenance purposes. The retaining wall alignment will therefore be located between 15 and 20 m from the tower.

The subsurface stratigraphy along the anticipated wall alignment generally consists of an upper 1.5 to 2.1 m thick zone of loose/firm silt fill, sandy silt or till underlain by dense to very dense silt and sand till, and silty sand and gravel with cobbles and boulders. Bedrock was encountered at depths of 6.9 to 7.6 m (elevation 254.5 to 257.5 m).

10.1 Wall Type Feasibility

Three alternative wall designs are considered in this report: a permanent soldier pile wall with no excavation behind the wall, a conventional cantilever wall with granular backfill, and an RSS wall. The feasibility of each wall type was reviewed in terms of geometry with respect to the tower foundations and the associated constructability of the wall.

A cross-section of the ramp cut at the closest point to the hydro tower is provided in Figure E1, Appendix E, showing the anticipated wall location, the bedrock surface level and the probable limits of excavation for wall construction. This cross-section was prepared based on the following assumptions:

- Based on the borehole data and cut/tower proximity, it is anticipated that the base of the wall will be at the bedrock surface. A concrete cantilever wall or RSS will therefore be founded on the bedrock surface, and a soldier pile wall will require socketing of the piles into the bedrock.

- The wall height will be a maximum of 7.6 m above the bedrock surface.
- The excavation limits for a cantilever wall and RSS were assumed to extend upwards from the base of the excavation at an inclination of 1H:1V towards the tower.
- The RSS block was assumed to have a width of approximately 0.7 times the wall height.
- Excavation will not be required behind the soldier pile wall.

To avoid disturbance of the existing hydro tower foundations, the excavation for wall construction should not extend below a line inclined downwards from the tower foundation at 1.25H:1V.

It is noted that the design of the existing hydro tower foundation has not been confirmed, may extend closer to the wall than anticipated, and may be highly sensitive to disturbance of the founding soils. From this perspective, selection of a wall type that minimizes excavation and maintains the largest separation between the tower and excavation is preferred.

Based on the above assessment, the recommended retaining wall type at this site is a soldier pile and lagging wall. Recommendations for design of a soldier pile wall are presented below.

10.2 Soldier Pile and Lagging Wall

A soldier pile and lagging wall design is considered feasible at this site. The soldier piles should consist of steel H-piles installed in predrilled holes cut in the bedrock and backfilled with concrete.

Resistance to axial loads will be developed through a combination of shaft resistance and end bearing of the caisson in the bedrock. The recommended values for design, assuming a typical 0.5 m diameter by 2 m length socket, are as follows:

	End-Bearing	Unit Shaft Resistance
Factored Resistance at ULS	5,000 kPa	350 kPa
Resistance at SLS	Will not govern	Will not govern

Resistance to lateral movement of a soldier pile retaining wall will be provided by the passive earth pressure developed on the face of the caisson in the bedrock. An ultimate lateral resistance, p_{ult}, of 1,000 kPa may be assumed for a minimum 0.5 m wide socket extending at least 2 m into rock. Lateral deflection in a bedrock socket is expected to be negligible.

A minimum 3 m distance between the soldier piles and the rock cut face is recommended.

10.3 Backfill And Lateral Earth Pressures

Earth pressures acting on the walls may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC (2006) 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 below)

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

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

q = value of any surcharge (kPa),
including foundation loads from the existing hydro tower

The lateral earth pressure coefficients to be employed during wall design are dependent on the type of material used as backfill, provision of drainage, and the relative movement between the wall and adjacent soil. The recommended earth pressure coefficients for granular backfill and a fully drained condition are provided in Table 10.1.

If a cantilever wall with backfill is employed, the backfill should consist of Granular A or Granular B material, and corresponding lateral earth pressure coefficients for granular material should be used for design. The coefficients for native till should be employed where excavation will not be carried out behind the wall (ie., soldier pile wall supporting native material) or where the back face of the excavation behind the wall is inclined steeper than 1H:2V from the heel of the wall.

Table 10.1 – Earth Pressure Coefficients

Condition	**Earth Pressure Coefficient (K)**			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8\ kN/m^3$		OPSS Granular B Type I or Native Sand/Silt Till $\phi = 32°, \gamma = 21.2\ kN/m^3$	
	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	0.38	0.31	0.46
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 10.1 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.

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.

In general, loads from hydro tower foundations located closer to the wall than a line inclined upwards at 1.25H:1V from the base of the wall should be accounted for during computation of the lateral pressures on the wall.

Compaction equipment to be used adjacent to retaining structure must be restricted in accordance with OPSS 501.07.

The backfill must be in accordance with OPSS 902 as amended by Special Provision 902S01, and placed to the extents shown in OPSD 3121.150 where applicable. The design of the retaining walls must incorporate a subdrain as shown in OPSD 3121.150 and 3190.100, or as per the RSS supplier specifications.

10.4 Global Stability

Global stability of a concrete cantilever, soldier pile or RSS wall founded on the bedrock at this site is not considered to be an issue.

11 SEISMIC CONSIDERATIONS

11.1 Seismic Design Parameters

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.02

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.0 should be used in seismic design.

11.2 Liquefaction Potential

The foundation soils at the site are assessed as not being prone to liquefaction.

11.3 Retaining Wall Dynamic Earth Pressures

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls, the coefficients of horizontal earth pressure in Table 11.1 may be used:

Table 11.1 – Earth Pressure Coefficient for Earthquake Loading

Condition	Earth Pressure Coefficient (K) for Earthquake Loading			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I or Native Sand/Silt Till $\phi = 32°$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (K_{AE})*	0.28	0.41	0.32	0.49
At rest (K_{OE})**	0.45	-	0.50	-
Passive (K_{PE})	3.7	-	3.2	-

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.
** After Woods

12 CONSTRUCTION CONCERNS

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

- Augering for installation of caissons may be slow and laborious due to the presence of dense to very dense till with cobbles and boulders. Coring may be required to penetrate large or frequent boulders.
- Excavation for footing construction, if required, is expected to encounter compact to dense till containing cobbles and boulders. Excavation may be laborious and require removal of large boulders.
- Provision of a level foundation base in the till may be difficult if large boulders are encountered at the excavation base level. Excavation should be carried out in a manner that minimizes disturbance to the subgrade.

13 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.
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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

C_{pen} 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			

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 09-001

METRIC

G.W.P. 334-94-00
LOCATION N 5 371 905.0 E 365 060.4
ORIGINATED BY LG

HWY 11/17
BOREHOLE TYPE Hollow Stem Augers/BQ Coring
COMPILED BY AN

DATUM Geodetic
DATE 2009.06.29 - 2009.06.29
CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
260.4 / 0.0	**TOPSOIL**, roots, organics				260		
259.3 / 1.1	**SAND**, trace silt, trace gravel, trace organics, Compact, Dark brown, Moist	1	SS	21		o	
258.9 / 1.4	**SAND and SILT**, trace clay, trace to some gravel, Compact to Very Dense, Brown, Moist (TILL)	2	SS	29	259	o	
		3	SS	42	258	o	6 54 34 6
		4	SS	66	257	o	
	with frequent cobbles and boulders	5	SS	83/ ~~200~~	256	o	12 47 35 7
	Auger refusal on boulder at 5.3m. Began coring.	1	RUN		255		RUN 1# TCR=53%, SCR=28%, RQD=28%
		2	RUN		254		RUN 2# TCR=30%, SCR=0%, RQD=0%
		3	RUN		253, 252		RUN 3# TCR=40%, SCR=0%, RQD=0%
251.1 / 9.3	END OF BOREHOLE AT 9.3m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.						

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 09-003

METRIC

G.W.P.	334-94-00	LOCATION	N 5 371 893.1 E 365 081.2
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers/BQ Coring
DATUM	Geodetic	DATE	2009.06.29 - 2009.06.29

ORIGINATED BY LG
COMPILED BY AN
CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.1 / 0.0	**SILT** and **SAND**, trace to some clay, trace gravel Loose to Very Dense Brown Moist (TILL)	1	SS	5	263		
		2	SS	8	262		2 30 52 15
		3	SS	28	261		
	with cobbles and boulders	4	SS	63	260		
		5	SS	67			9 48 35 8
		6	SS	100/ 0.150	259		
	Auger refusal on boulder at 4.4m. Began coring. Frequent cobbles and boulders	1	RUN			FI	
		2	RUN		258		RUN 2# TCR=2%, SCR=0%, RQD=0%
		3	RUN		257 256		RUN 3# TCR=52%, SCR=2%, RQD=2%
255.4 / 7.6	**GUNFLINT FORMATION**, strong (chert carbonate), thinly banded, slightly weathered, charcoal grey, sub-horizontal fractures, calcite veining	4	RUN		255	0 3 1 0 1	RUN 4# TCR=100%, SCR=100%, RQD=100% UCS=73MPa
		5	RUN		254	2 0 0	RUN 5# TCR=100%, SCR=100%, RQD=100% UCS=99MPa

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 09-003

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 893.1 E 365 081.2 ORIGINATED BY LG

HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/BQ Coring COMPILED BY AN

DATUM Geodetic DATE 2009.06.29 - 2009.06.29 CHECKED BY TH

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
						▼	253			2	
252.4										1	
10.7	END OF BOREHOLE AT 10.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2009.11.23 10.4 252.7										

ONTMT4S 1156.GPJ 3/17/10

$+^3, \times^3$: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 10-081

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 883.6 E 365 036.8 ORIGINATED BY LG

HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2010.01.09 - 2010.01.10 CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.9 / 0.0	**SAND** and **SILT**, trace clay, trace gravel Compact to Very Dense Brown Moist (TILL)					
		1	SS	11	256	
		2	SS	42	255	
		3	SS	27	254	
	Occasional cobble	4	SS	64	253	4 36 52 9
		5	SS	44	252	
	Auger refusal at 5.8m. Began coring.					
251.1 / 5.8	Silty **SAND** and **GRAVEL**, with frequent cobbles	1	RUN		251 250	RUN 1# TCR=61%, SCR=9%, RQD=0%
		2	RUN		249	RUN 2# TCR=58%, SCR=12%, RQD=0%
		3	RUN		248 247	RUN 3# TCR=3%, SCR=0%, RQD=0%

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-081

METRIC

G.W.P. 334-94-00
LOCATION N 5 371 883.6 E 365 036.8
ORIGINATED BY LG
HWY 11/17
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
COMPILED BY AN
DATUM Geodetic
DATE 2010.01.09 - 2010.01.10
CHECKED BY TH

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT (FI)	REMARKS
	Silty **SAND** and **GRAVEL**, with frequent cobbles	4	RUN		246		RUN 4# TCR=0%, SCR=0%, RQD=0%
		5	RUN		245, 244		RUN 5# TCR=75%, SCR=5%, RQD=0%
242.7		6	RUN		243		RUN 6# TCR=82%, SCR=45%, RQD=20% UCS=186MPa
14.2	**GUNFLINT FORMATION**, strong to extremely strong (grainstone), dark grey, slightly weathered					FI 2 0	
		7	RUN		242, 241	3 1 0 0	RUN 7# TCR=100%, SCR=97%, RQD=97% UCS=175MPa
239.0		8	RUN		240	0	RUN 8# TCR=100%, SCR=100%, RQD=100% UCS=256MPa
17.9	END OF BOREHOLE AT 17.9m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³
GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2010.03.01	9.8	247.1

ONTMT4S 1156.GPJ 3/17/10

+ ³, × ³: Numbers refer to Sensitivity

15-20-5-10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 10-082

METRIC

G.W.P. 334-94-00	LOCATION N 5 371 883.1 E 365 043.8	ORIGINATED BY LG
HWY 11/17	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	COMPILED BY AN
DATUM Geodetic	DATE 2010.01.12 - 2010.01.12	CHECKED BY TH

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
258.6 0.0	Sandy **SILT**, trace to some gravel, trace clay, occasional cobbles Compact to Very Dense Brown Moist (TILL)				258		
		1	SS	14		~20	
		2	SS	22	257	~22	
		3	SS	59	256	~18	10 31 54 5
		4	SS	78/.225	255	~16	
		5	SS	39	254	~21	0 32 64 5
252.5	Auger refusal at 6.1m. Began coring.				253		
6.1	Silty **SAND** and **GRAVEL**, frequent cobbles and boulders Very Dense Brown	1	RUN		252		RUN 1# TCR=92%, SCR=8%, RQD=0%
		2	RUN		251 / 250		RUN 2# TCR=95%, SCR=47%, RQD=0%
		3	RUN		249		RUN 3# TCR=68%, SCR=42%, RQD=0%

Column headings also include: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-082

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 883.1 E 365 043.8 ORIGINATED BY LG

HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2010.01.12 - 2010.01.12 CHECKED BY TH

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT (FI)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	Continued From Previous Page						
		4	RUN		248 / 247		RUN 4# TCR=68%, SCR=65%, RQD=0% UCS=217MPa
		5	RUN		246		RUN 5# TCR=97%, SCR=17%, RQD=0%
243.7		6	RUN		245 / 244	FI	RUN 6# TCR=53%, SCR=0%, RQD=0%
14.9	**GUNFLINT FORMATION**, very strong (grainstone), with interbedded calcareous siltstone shale at 15.9 to 16.6 and 17.1 to 17.4m, dark grey, some pyrite veining	7	RUN		243	>3, 1, 4, 5, 11	RUN 7# TCR=84%, SCR=77%, RQD=77% UCS=194MPa
		8	RUN		242	0, 0, 0	RUN 8# TCR=100%, SCR=76%, RQD=0% UCS=77MPa
240.6		9	RUN		241	0, 0, 0	RUN 9# TCR=100%, SCR=96%, RQD=96% UCS=222MPa
18.0	END OF BOREHOLE AT 18.0m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.						

Column headings also printed: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; γ kN/m^3; GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity   15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-083

METRIC

G.W.P. 334-94-00 | LOCATION N 5 371 875.9 E 365 036.6 | ORIGINATED BY LG
HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers/NQ Coring | COMPILED BY AN
DATUM Geodetic | DATE 2010.01.10 - 2010.01.11 | CHECKED BY TH

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
256.8 / 0.0	Sandy **SILT**, trace to some gravel, trace clay; Compact to Very Dense; Brown; Moist; (TILL)						
	Occasional cobbles	1	SS	10	256	o	
		2	SS	34	255	o	
		3	SS	58	254	o	
		4	SS	41	253	o	
		5	SS	50/ .075	252	o	
251.2 / 5.6	Auger refusal at 5.6m. Began coring.						
	Silty **SAND** and **GRAVEL**, with occasional cobbles and boulders; Very Dense; Brown; (TILL)	1	RUN		251, 250		RUN 1# TCR=32%, SCR=6%, RQD=0%
		2	RUN		249		RUN 2# TCR=0%, SCR=0%, RQD=0%
		3	RUN		248, 247		RUN 3# TCR=27%, SCR=20%, RQD=0%

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³; GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 10-083

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 875.9 E 365 036.6 ORIGINATED BY LG
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2010.01.10 - 2010.01.11 CHECKED BY TH

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	Silty **SAND** and **GRAVEL**, with occasional cobbles	4	RUN		246		RUN 4# TCR=28%, SCR=0%, RQD=0%
		5	RUN		245, 244		RUN 5# TCR=50%, SCR=33%, RQD=33%
241.9		6	RUN		243		RUN 6# TCR=17%, SCR=0%, RQD=0%
14.9	**GUNFLINT FORMATION**, strong to very strong (interbedded laminated shale and calcareous siltstone with occasional chert nodules), dark grey with occasional thin light grey fossiliferous bands, sub-horizontal fractures	7	RUN		242, 241	FI 0 0 0 0	RUN 7# TCR=80%, SCR=80%, RQD=80% UCS=129MPa
		8	RUN		240	0 0 0 0	RUN 8# TCR=100%, SCR=100%, RQD=100% UCS=92MPa
237.4		9	RUN		239, 238	0 0	RUN 9# TCR=100%, SCR=100%, RQD=100% UCS=63MPa
19.4	END OF BOREHOLE AT 19.4m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.						

Column headings also printed: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; γ kN/m³; GR SA SI CL

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 10-084

METRIC

G.W.P. 334-94-00
HWY 11/17
DATUM Geodetic

LOCATION N 5 371 876.5 E 365 043.0
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
DATE 2010.01.13 - 2010.01.13

ORIGINATED BY LG
COMPILED BY AN
CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
258.4 / 0.0	Sandy SILT, trace gravel, trace to some clay, occasional cobbles. Compact to Very Dense. Brown. Moist. (TILL)				
		1	SS	44	
		2	SS	13	2 17 69 12
		3	SS	50/.125	
		4	SS	77	
		5	SS	40	1 32 61 6
252.1	Auger refusal at 6.3m. Began coring.				
6.3	Silty SAND and GRAVEL, with cobbles and boulders. Very Dense. Brown. (TILL)	1	RUN		RUN 1# TCR=50%, SCR=38%, RQD=0%
		2	RUN		RUN 2# TCR=38%, SCR=50%, RQD=0%
		3	RUN		RUN 3# TCR=70%, SCR=50%, RQD=0%

Elevation scale: 258, 257, 256, 255, 254, 253, 252, 251, 250, 249

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-084

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 876.5 E 365 043.0 ORIGINATED BY LG
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2010.01.13 - 2010.01.13 CHECKED BY TH

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						
	Silty **SAND** and **GRAVEL**, with cobbles and boulders				248		
		4	RUN		247		RUN 4# TCR=55%, SCR=0%, RQD=0%
		5	RUN		246		RUN 5# TCR=17%, SCR=0%, RQD=0%
245.0 / 13.4	**GUNFLINT FORMATION**, strong to very strong (interbedded laminated shale and calcareous siltstone with occasional chert nodules), dark grey with occasional thin light grey fossiliferous bands, sub-horizontal fractures	6	RUN		245, 244	FI >5 >5	RUN 6# TCR=67%, SCR=17%, RQD=0% UCS=83MPa
		7	RUN		243, 242	>6 >6 1 0 3	RUN 7# TCR=100%, SCR=83%, RQD=35% UCS=186MPa
241.0		8	RUN			4 5 5	RUN 8# TCR=100%, SCR=113%, RQD=45% UCS=83MPa
17.5	END OF BOREHOLE AT 17.5m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						

Groundwater level symbol shown at approx. elev. 247.2.

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; STRAT PLOT; GROUND WATER CONDITIONS.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2010.03.01	11.2	247.2

ONTMT4S 1156.GPJ 3/17/10

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-085

METRIC

G.W.P.	334-94-00	LOCATION	N 5 371 889.1 E 365 032.3	ORIGINATED BY	LG
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2010.01.08 - 2010.01.09	CHECKED BY	TH

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) | SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100) | PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.4 0.0	Silty **SAND**, some gravel, trace clay Compact to Very Dense Brown Moist (TILL)				255	
		1	SS	21	254	
	Pocket of clayey silt, trace sand	2	SS	16		
		3	SS	23	253	
		4	SS	79/ .225	252	39 46 15 (SI+CL)
		5	SS	50/ .075	251	
249.6	Auger refusal at 5.8m. Began coring.				250	
5.8	Silty **SAND** and **GRAVEL**, frequent cobbles and boulders (TILL)	1	RUN		249	RUN 1# TCR=82%, SCR=73%, RQD=0%
		2	RUN		248 247	RUN 2# TCR=68%, SCR=53%, RQD=0%
		3	RUN		246	RUN 3# TCR=80%, SCR=7%, RQD=0%

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

15 -⊕- 5 (20 above, 10 below) (%) STRAIN AT FAILURE

ONTMT4S 1156.GPJ 3/17/10

RECORD OF BOREHOLE No 10-085

METRIC

G.W.P. 334-94-00	LOCATION N 5 371 889.1 E 365 032.3	ORIGINATED BY LG
HWY 11/17	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	COMPILED BY AN
DATUM Geodetic	DATE 2010.01.08 - 2010.01.09	CHECKED BY TH

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **SAND** and **GRAVEL**, frequent cobbles and boulders (TILL)						245				
			4	RUN							RUN 4# TCR=63%, SCR=42%, RQD=0%
243.6							244				
11.8	**GUNFLINT FORMATION**, strong (interbedded calcareous wackestone, siltstone and occasional shale laminations), light to dark grey, sub-horizontal fractures									FI	RUN 5# TCR=100%, SCR=83%, RQD=83% UCS=54MPa
			5	RUN			243			1	
										0	
										0	
							242			1	RUN 6# TCR=100%, SCR=100%, RQD=100% UCS=73MPa
										0	
			6	RUN						0	
							241			0	
240.5										0	
14.8	END OF BOREHOLE AT 14.8m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.									0	

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 10-086

METRIC

G.W.P. 334-94-00 | LOCATION N 5 371 898.8 E 365 071.6 | ORIGINATED BY LG

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2010.01.06 - 2010.01.06 | CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
261.8 / 0.0	Clayey **SILT**, some sand, trace gravel, trace organics; Firm; Brown; Moist; (FILL)	1	AS			o		
		1	SS	7	261	o		
260.4 / 1.4	**SILT**, some sand, trace gravel, trace organics; Loose; Brown; Moist; (FILL)	2	SS	3	260	o		
259.7 / 2.1	Silty **SAND**, some gravel, trace clay, occasional cobbles; Very Dense; Brown; Moist; (TILL)	3	SS	62/ .250	259	o		
		4	SS	83/ .250	258	o		14 47 33 6
		5	SS	76/ .225	257	o		
	Auger refusal at 5.9m. Began coring.	1	RUN		256			RUN 1# TCR=100%, SCR=0%, RQD=0%
	Numerous cobbles	2	RUN		255			RUN 2# TCR=67%, SCR=11%, RQD=0%
254.5 / 7.3	**GUNFLINT FORMATION**, medium strong to very strong (interbedded fine grained wackestone and siltstone), dark grey, sub-horizontal fractures	3	RUN		254		0, 0, 0, 1	RUN 3# TCR=100%, SCR=100%, RQD=100% UCS=146MPa
	675mm vertical fractures at 9.7m	4	RUN		253, 252		2, 0, 0, 0	RUN 4# TCR=100%, SCR=100%, RQD=100% UCS=64MPa

Continued Next Page

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3.

$+^3, \times^3$: Numbers refer to Sensitivity

15-20-5-10 (%) STRAIN AT FAILURE

ONTMT4S 1156.GPJ 3/17/10

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 10-086

METRIC

G.W.P. 334-94-00	LOCATION N 5 371 898.8 E 365 071.6	ORIGINATED BY LG
HWY 11/17	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	COMPILED BY AN
DATUM Geodetic	DATE 2010.01.06 - 2010.01.06	CHECKED BY TH

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page									0	
250.9			5	RUN			251			0 0	RUN 5# TCR=100%, SCR=100%, RQD=100% UCS=31MPa
10.9	END OF BOREHOLE AT 10.9m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.										

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

$+^3, \times^3$: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 10-087

METRIC

G.W.P. 334-94-00 LOCATION N 5 371 883.3 E 365 102.6 ORIGINATED BY LG

HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2010.01.14 - 2010.01.14 CHECKED BY TH

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
264.4 / 0.0	Sandy **SILT**, trace gravel, Loose, Brown, Moist	1	SS	8	~21		
263.0 / 1.4	Silty **SAND**, some gravel, trace clay, occasional cobbles, Compact to Very Dense, Brown, Moist (TILL)	2	SS	34	~14		12 56 26 6
	Auger refusal at 2.7m. Began coring.	3	SS	50/ 0.075	~15		
261.7 / 2.7	Silty **SAND** and **GRAVEL**, frequent cobbles, Very Dense, Brown	1	RUN				RUN 1# TCR=29%, SCR=10%, RQD=0%
		2	RUN				RUN 2# TCR=25%, SCR=0%, RQD=0%
		3	RUN			>3	RUN 3# TCR=77%, SCR=73%, RQD=73% UCS=302MPa
257.5 / 6.9	**GUNFLINT FORMATION**, very strong to extremely strong (interbedded calcareous siltstone and fine grained wackestone), dark grey, sub-horizontal fractures					1, 1	
		4	RUN			>3, >2, 3, 2, 2	RUN 4# TCR=83%, SCR=52%, RQD=52% UCS=255MPa
		5	RUN			>3, 2, >2, >3	RUN 5# TCR=100%, SCR=60%, RQD=60% UCS=243MPa

Elevation scale: 264, 263, 262, 261, 260, 259, 258, 257, 256, 255

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 10-087

METRIC

G.W.P. 334-94-00 | LOCATION N 5 371 883.3 E 365 102.6 | ORIGINATED BY LG

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2010.01.14 - 2010.01.14 | CHECKED BY TH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
254.0										2	
10.4	END OF BOREHOLE AT 10.4m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.						254				

+³, ×³: Numbers refer to Sensitivity

15-20-5-10 (%) STRAIN AT FAILURE

ONTMT4S 1156.GPJ 3/22/10

Appendix B

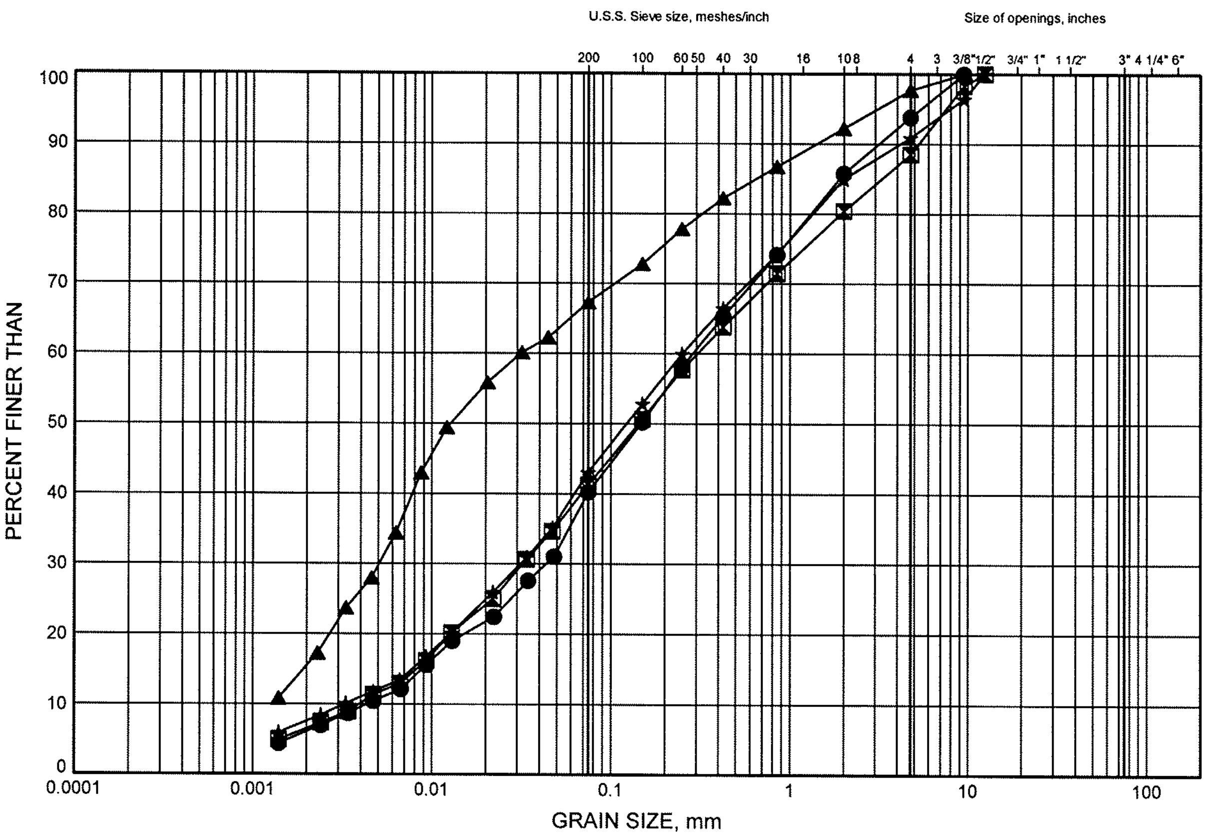
Laboratory Test Results

Hwy 11/17 Hodder Avenue

GRAIN SIZE DISTRIBUTION

FIGURE B1

SANDY SILT TO SILTY SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	09-001	2.53	257.84
⊠	09-001	4.75	255.62
▲	09-003	1.07	262.00
★	09-003	3.35	259.72

GRAIN SIZE DISTRIBUTION - THURBER 1156.GPJ 3/12/10

W.P.# 334-94-00

Prepared By MFA

Checked By MRA

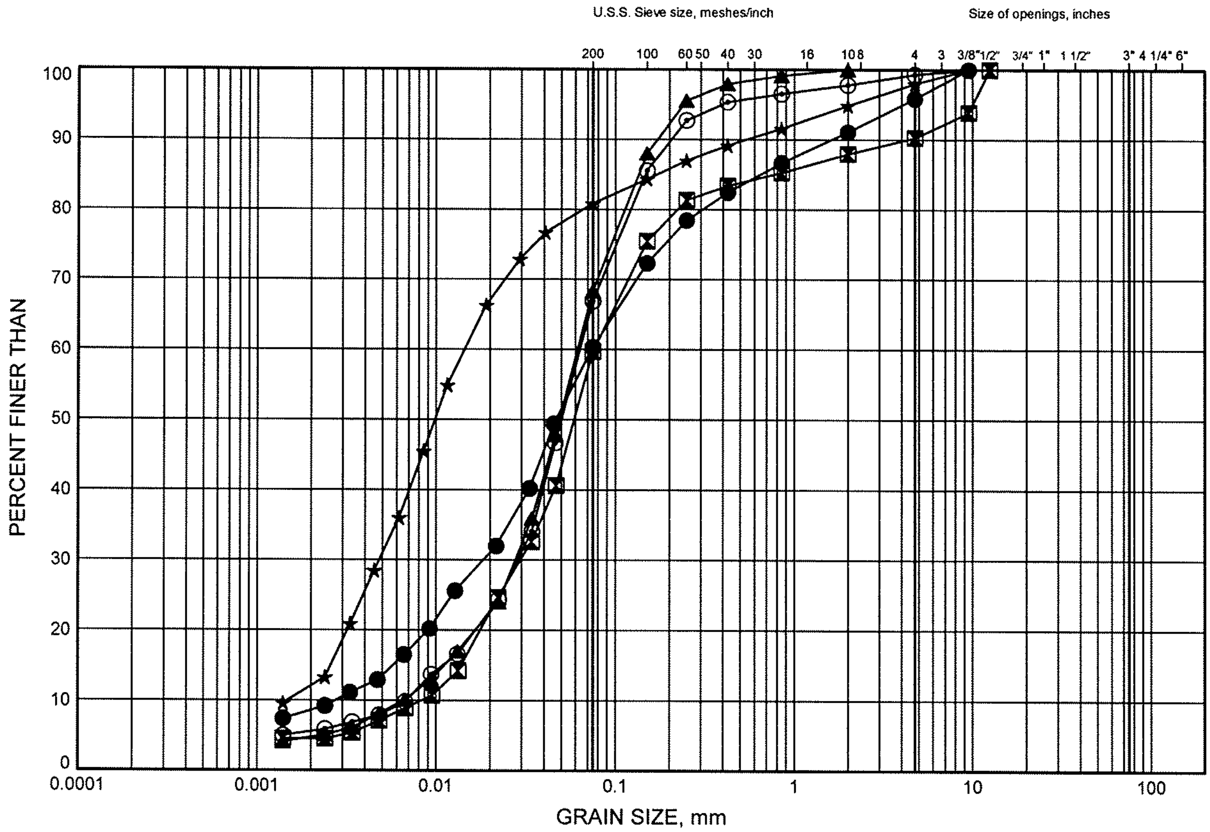
THURBER

Hwy 11/17 Hodder Avenue

GRAIN SIZE DISTRIBUTION

FIGURE B2

SANDY SILT TO SILTY SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	10-081	3.23	253.67
⊠	10-082	2.59	255.97
▲	10-082	4.88	253.68
★	10-084	1.83	256.60
⊙	10-084	4.88	253.55

GRAIN SIZE DISTRIBUTION - THURBER 1156.GPJ 3/12/10

W.P.# 334-94-00

Prepared By MFA

Checked By MRA

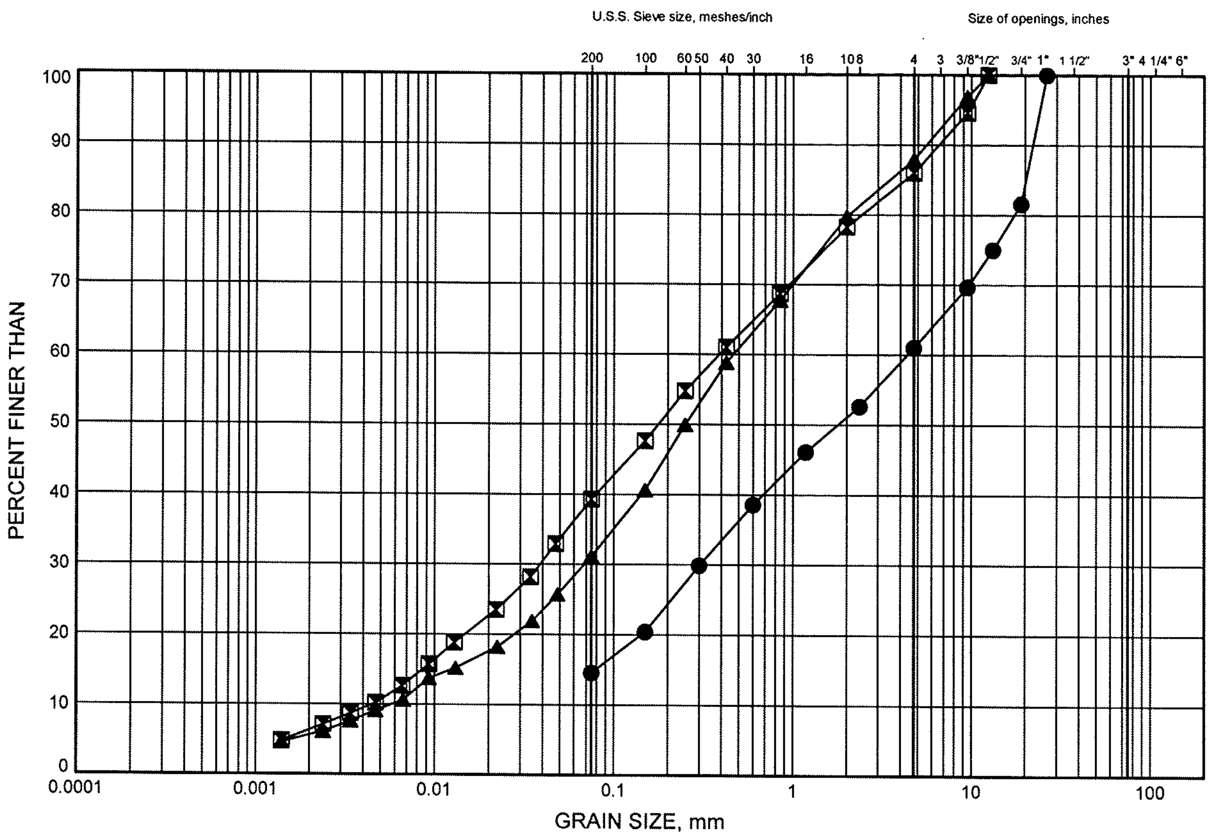
THURBER

Hwy 11/17 Hodder Avenue

GRAIN SIZE DISTRIBUTION

FIGURE B3

SANDY SILT TO SILTY SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	10-085	3.24	252.11
⊠	10-086	3.25	258.57
▲	10-087	1.83	262.57

W.P.# 334-94-00

Prepared By MFA

Checked By MRA

THURBER

Appendix C

Comparison of Foundation Alternatives

COMPARISON OF HYDRO TOWER FOUNDATION ALTERNATIVES

Caissons	Footings or Grillage on Native Soil	Micropiles
Advantages: i. High resistance is available for caissons founded in very dense till or sand and gravel. ii. Conventional design for hydro towers. iii. Construction of caissons could continue in freezing weather. *Disadvantages:* i. Higher cost than shallow foundations. ii. High potential for encountering cobbles and boulders during augering. iii. May require rock coring methods to penetrate boulders and bedrock if encountered. iv. Temporary liners may be required if seepage zones or loose zones of cohesionless soil are encountered. v. Potential difficulty in cleaning and inspecting bases. **FEASIBLE**	*Advantages* i. Ease of construction. ii. High geotechnical resistance is available on the till deposits. iii. Lower cost than deep foundations. *Disadvantages:* i. May require soil or rock anchors to provide uplift resistance. ii. Potential for subgrade disturbance during excavation of bouldery material. iii. Potential for freezing conditions to impact construction. **FEASIBLE**	*Advantages:* i. Micropiles will develop relatively high geotechnical resistance in very dense soils and bedrock. ii. Smaller diameter than caissons, presenting less potential for encountering boulders. iii. Rotary percussive methods should penetrate very dense, bouldery material. iv. Installation of micropiles could continue in freezing weather. v. Foundation construction may require less volume of excavation than footings. *Disadvantages:* i. Potentially higher costs than caissons and shallow foundations. ii. Specialist contractor required, limiting competitive bidding. iii. Limited local experience with micropiles. **RECOMMENDED**

THURBER

Appendix D

Special Provisions

1. List of Special Provisions and OPSS Documents Referenced in this Report

- SP 902S01
- SP 903S01
- OPSS 501
- OPSS 902
- OPSD 3121.150
- OPSD 3190.100

2. Suggested Text for NSSP on "Foundation Excavation"

The glacial till at the site is dense to very dense and contains cobbles, boulders and slabs of rock. Accordingly, equipment suitable for excavation of this material and handling and removal of cobbles, boulders and rock slabs should be provided. Arduous excavation should be expected in the very dense till and sand and gravel.

Provision of a level foundation base in the till may be difficult if large boulders are encountered at the excavation base level. Excavation should be carried out in a manner that minimizes disturbance to the subgrade.

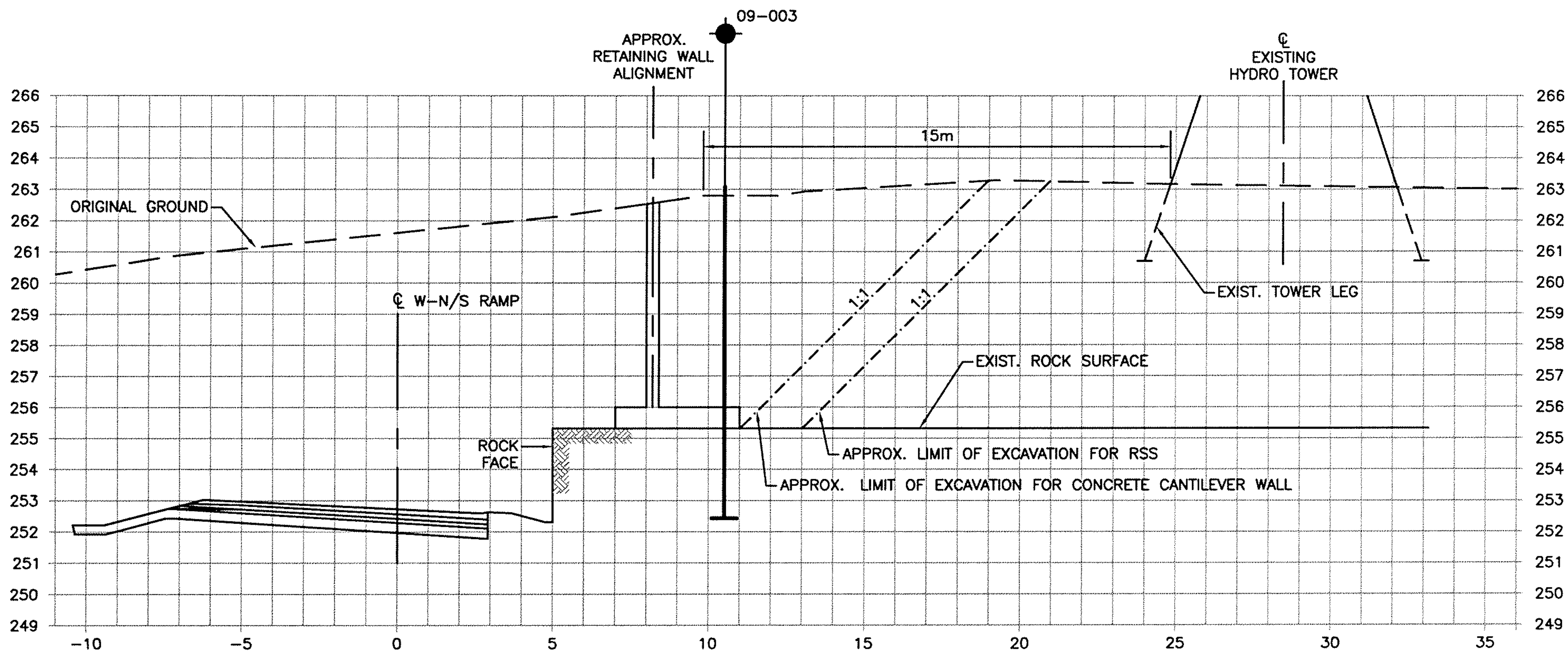
3. Suggested Text for NSSP on "Caisson Installation"

The glacial till soils at this site are dense to very dense and contain cobbles and boulders. Augering in the till might be laboured. Caisson installation equipment must be able to penetrate this very dense material and dislodge, handle, remove or otherwise penetrate the cobbles and boulders. Rock coring methods may be necessary if large or frequent boulders are encountered.

Appendix E

Cross-Section at Existing Hydro Tower

D:\Drafting\19\1351\156\ted1156-RampSectionatHydroTower.dwg - Layout1 - Apr. 21, 2010 1:22pm



THURBER PROJECT #

McCORMICK RANKIN CORPORATION

RAMP CROSS-SECTION
AT EXISTING HYDRO TOWER

19-1351-156

THURBER ENGINEERING LTD.
GEOTECHNICAL ■ ENVIRONMENTAL ■ MATERIALS

ENGINEER : MRA	DRAWN : MFA	APPROVED : -
DATE : APRIL 2010	SCALE : 1:200	DRAWING No. FIGURE E1

Appendix F

Borehole Locations and Soil Strata Drawings

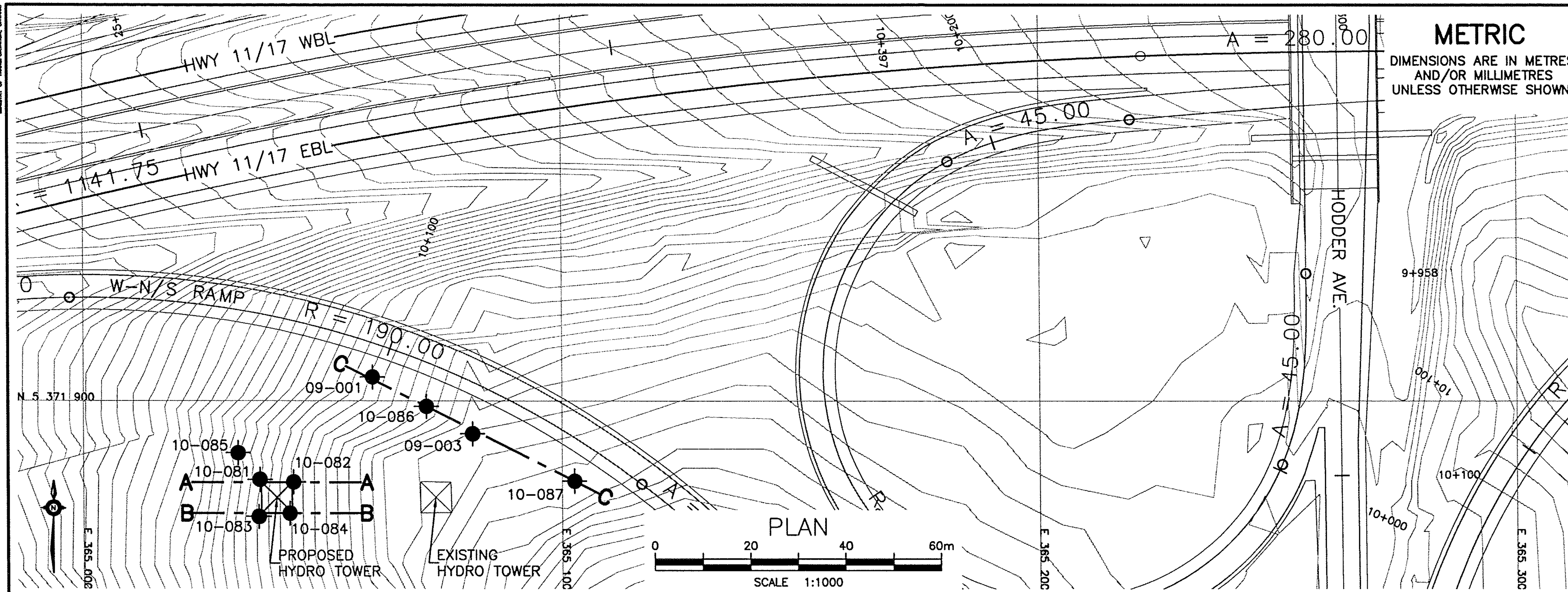
CONT No	
GWP No	SHEET

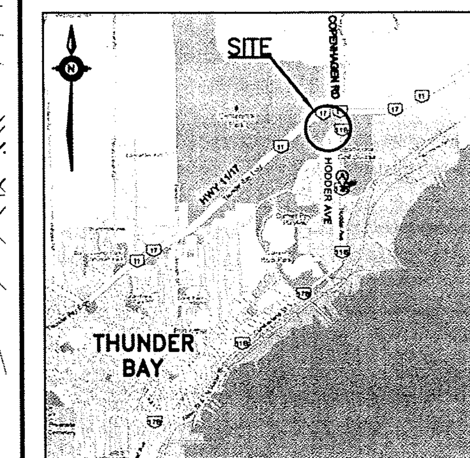
HIGHWAY 11/17
AT HODDER AVENUE
HYDRO TOWER AND RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

McCORMICK RANKIN CORPORATION

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS

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

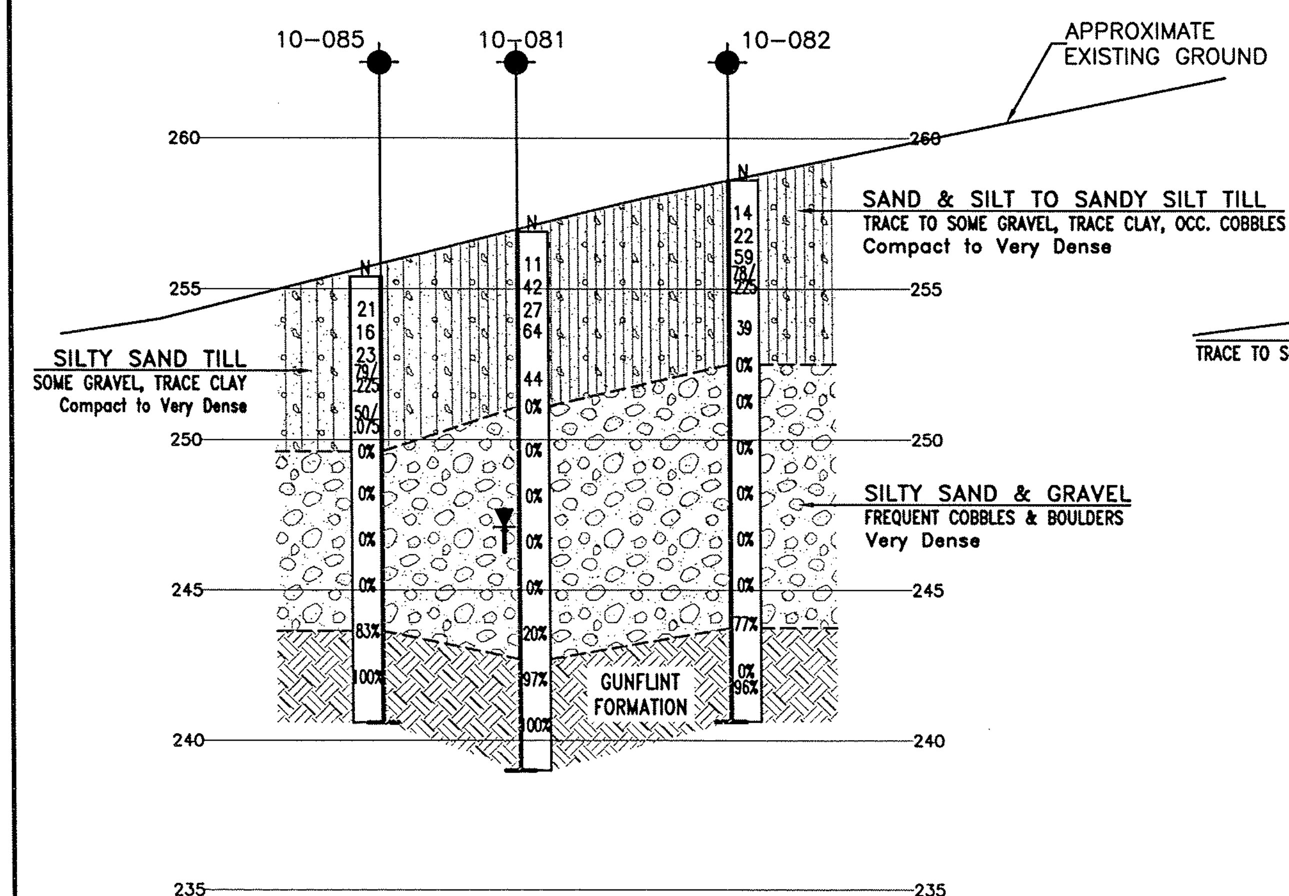




KEYPLAN

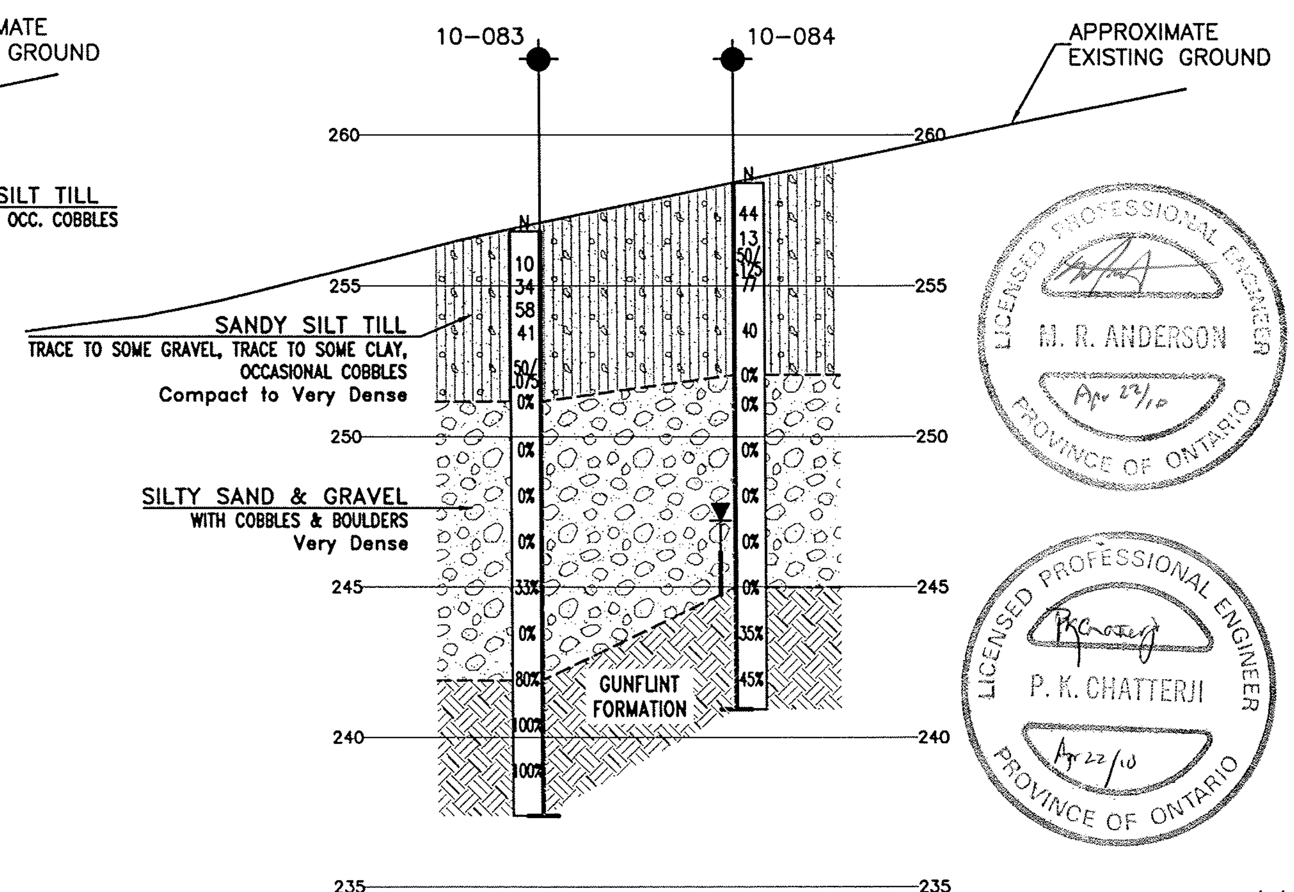
	LEGEND
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
09-001	260.4	5 371 905.0	365 060.4
09-003	263.1	5 371 893.1	365 081.2
10-081	256.9	5 371 883.6	365 036.8
10-082	258.6	5 371 883.1	365 043.8
10-083	256.8	5 371 875.9	365 036.6
10-084	258.4	5 371 876.5	365 043.0
10-085	255.4	5 371 889.1	365 032.3
10-086	261.8	5 371 898.8	365 071.6
10-087	264.4	5 371 883.3	365 102.6



SECTION A–A

SCALE 1:250



SECTION B–B

SCALE 1:250

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Apr 22/10
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Apr 22/10
PROVINCE OF ONTARIO

-NOTES-

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

GEOCRES No. 52A-145

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN MRA	CHK AEG	CODE	LOAD	DATE APR. 2010	
DRAWN MFA	CHK PKC	SITE	STRUCT	DWG 1	

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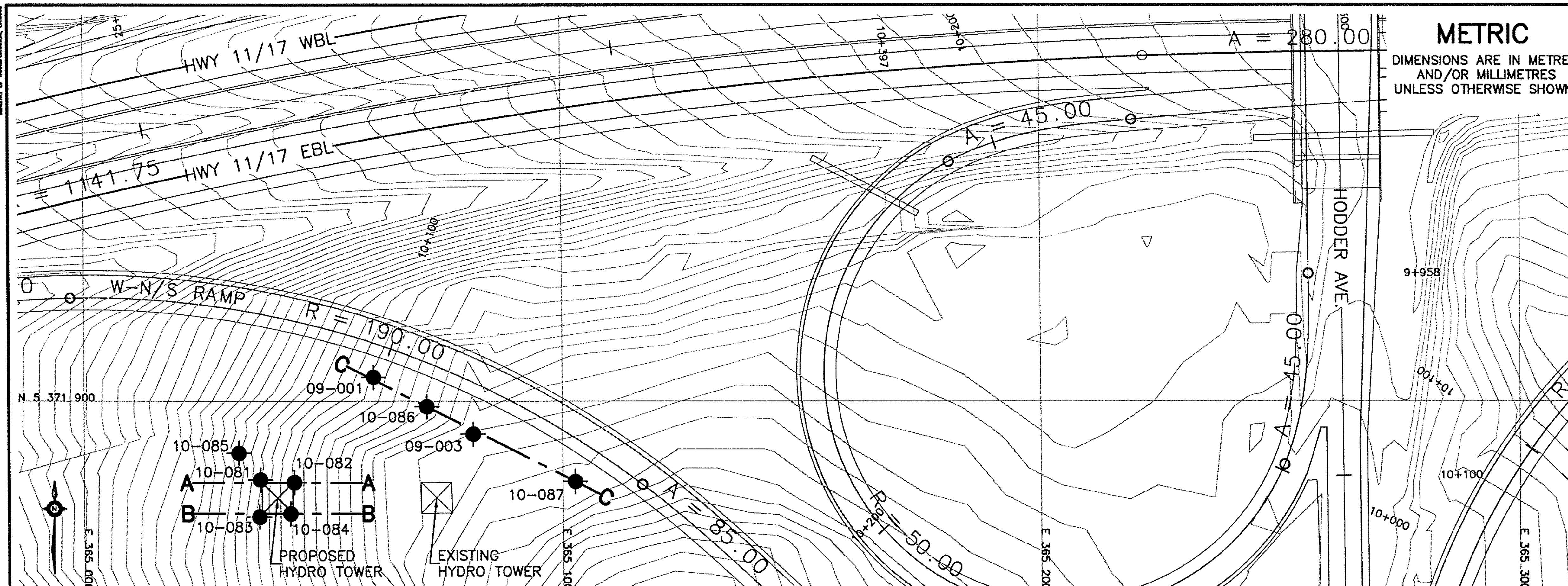
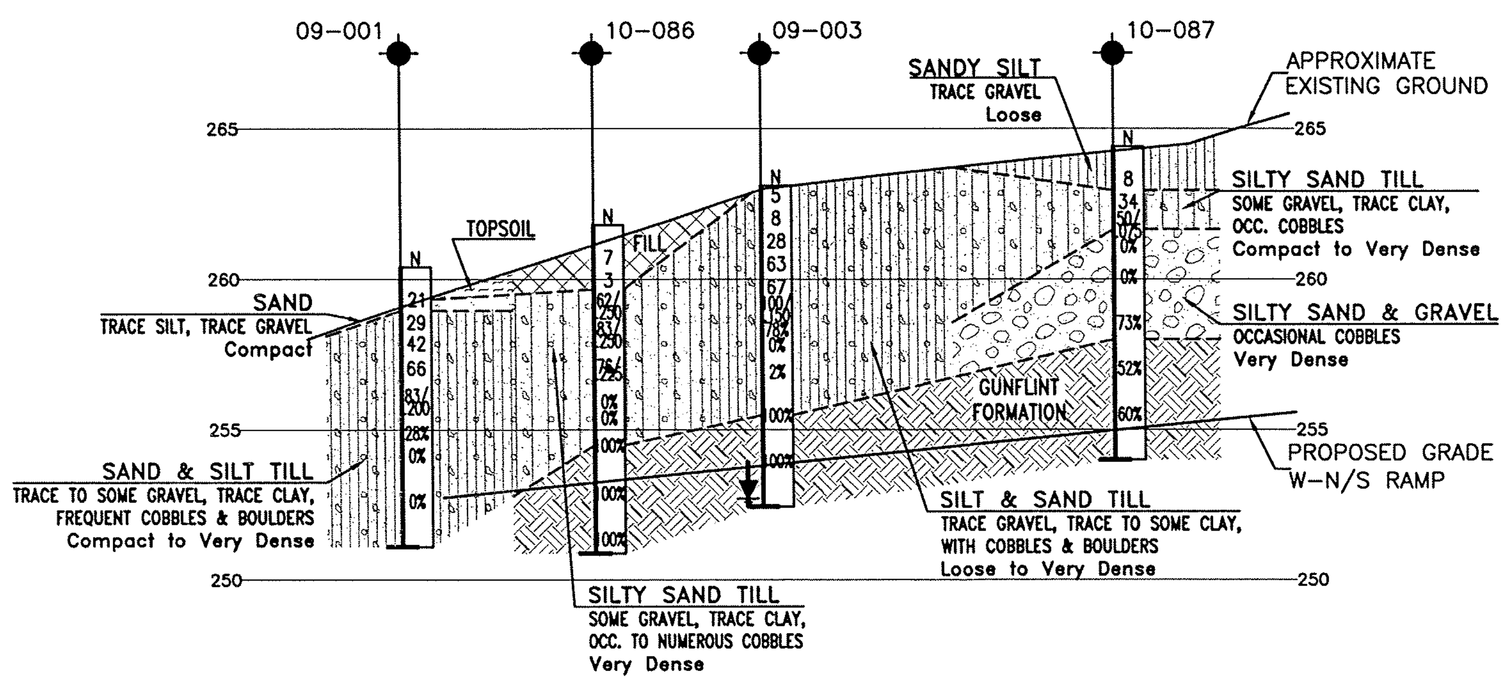
PLOTDATE: Apr 22, 2010 - 9:19am



PLAN

0 20 40 60m

SCALE 1:1000



SECTION C-C

0 10 20 30m H 1:500

0 5 10 15m V 1:250

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

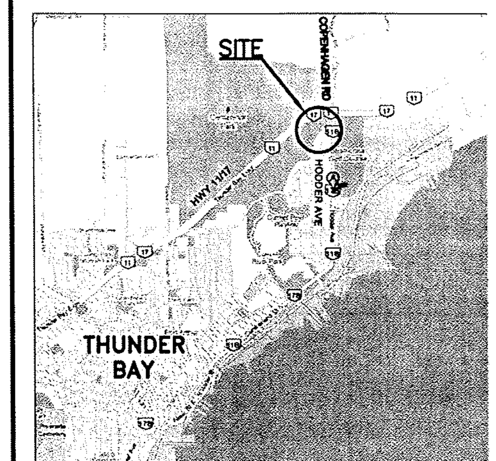
CONT No
GWP No

SHEET

HIGHWAY 11/17
AT HODDER AVENUE
HYDRO TOWER AND RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

McCORMICK RANKIN CORPORATION

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



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

NO	ELEVATION	NORTHING	EASTING
09-001	260.4	5 371 905.0	365 060.4
09-003	263.1	5 371 893.1	365 081.2
10-081	256.9	5 371 883.6	365 036.8
10-082	258.6	5 371 883.1	365 043.8
10-083	256.8	5 371 875.9	365 036.6
10-084	258.4	5 371 876.5	365 043.0
10-085	255.4	5 371 889.1	365 032.3
10-086	261.8	5 371 898.8	365 071.6
10-087	264.4	5 371 883.3	365 102.6

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GEOCRES No. 52A-145

REVISIONS DATE	BY	DESCRIPTION

DESIGN MRA	CHK AEG	CODE	LOAD	DATE APR. 2010
DRAWN MFA	CHK PKC	SITE	STRUCT	DWG 2

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