



**Foundation Investigation and Design Report  
Highway 17, Embankment Stabilization for Westbound Lane  
Station 10+000 to Station 10+160  
Township of Wiggins**

**GWP 6081-09-00**

**Geocres No.: 42D-27**

**Prepared for  
Ministry of Transportation, Northwestern Region**

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## **Part A - FOUNDATION INVESTIGATION REPORT**

### **1 Introduction**

TBT Engineering (TBTE) has been retained by the Ministry of Transportation (MTO) to provide foundation investigation and design services for the stabilization works on Highway 17 embankment located between Sta. 10+000 and 10+160 Township of Wiggins (approximately 40 km east of Nipigon). The foundation investigation was carried out to investigate deformations of the westbound lane (north side of the embankment) observed to have crescent cracking extending to the middle of the road indicating movement to the north.

An earlier foundation investigation was carried out by the Ministry for the widening to the north and grade raise of the highway embankment; ("Foundation Report for Hwy 17, Station 10+000 to 10+160, Grade Raise and Widening, Slope Stability Investigation, W.P. 909-76-01 (B), TWP of Wiggins, District Thunder Bay", dated August 1993, Geocres Number 42D-18). The subsurface information in the report consists of two boreholes and two dynamic cone penetration tests at the north toe of the highway embankment (on the left side of the highway Centreline). This current investigation is to augment the available subsurface information and to revisit the embankment stabilization requirements.

This investigation consisted of 4 boreholes drilled along the north toe of the embankment, laboratory testing and geotechnical analysis of the data. This report (Part A) describes the subsurface conditions encountered during the investigation.

The foundation section has assigned GEOCREs No. 42D-27 to this site.



## 2 Site Description

The foundation investigation was carried out to investigate subsurface conditions between Sta. 10+000 and Sta. 10+160 in the Township of Wiggins (approximately 40 km m east of the Town of Nipigon along Hwy.17). The highway embankment crosses a valley between two bedrock outcrops. The existing 9 m high embankment is understood to be composed of rock fill. An 8 m wide mid-height berm exists on the south side of the embankment. Extensive patching is evident along the west bound lane (north side) at two locations as illustrated below (Figure 1).



Figure 1, Patching Along West Bound Lane, Looking West

Crescent shaped cracking is evident at the patch locations.

A photograph taken along the north side guide rail indicates possible lateral shifting of the north side crest (Figure 2).





Figure 2, Guide Rail Along North Side Crest, Looking West

## 2.1 Site History

In 1993 a report was prepared by MTO Foundation Design Section; “WP 909-76-01(B), Dist 19, Hwy 17 STR Site, Station 10+000 to 10+160 Grade Raise and Widening Slope Stability Investigation, Twp. of Wiggins, August 17, 1993”. This report indicates that the existing embankment is constructed from rock fill over a silty clay subgrade. In addition, it was reported that the south side slope had experience previous slope failures requiring the placement of rock fill along the base of the slope together with slope flattening.

An 8 m wide mid-height berm was constructed on the south side of the embankment in 1995 (Contract 95-217).

It has been reported by MTO Maintenance that approximately 2 to 3 years ago (2009 to 2010) patching along the west bound lane was required. Patching was required again in October of 2011 to address settlements of up to 40 mm of the west bound travel lane.



## **2.2 Surficial Geology**

The topography consists of up to 9 m high fill embankment which appears to be composed of rock-fill with large boulders exposed on the slope faces. The surrounding valley consists of a mixture of swamp and forest wet land birch, poplar and spruce trees. The valley walls rise steeply on either end of the site, with bedrock visible at the surface.

Based on review of surface geology mapping, the site is located in an area of bedrock knob terrain with subordinate land forms consisting of till ground moraine and organic terrain over bedrock knobs.

## **3 Investigation Procedures**

A geotechnical site investigation was undertaken between December 21 and 22, 2011 which included 4 boreholes (Borehole 1-2011 to 4-2011). The 2011 borehole logs are provided in Appendix A. Previous boreholes were carried out in 1993 and have been included in Appendix E. For this report, the 1993 boreholes have been referenced as 1-1993, 2-1993 and 3-1993. The borehole locations are illustrated on the Borehole Location Plan found in Appendix C.

The 2011 boreholes were advanced using a portable power auger with solid stem augers (50 mm o.d.). A portable tripod equipped with a cat head was used to carry out standard penetration testing (SPT) and dynamic cone penetration testing (DCPT). Soil samples were obtained at the boreholes using a split spoon sampler as a part of the Standard Penetration Testing (SPT). The SPT involves driving a thick walled sampler into the soils under a standardized energy (63.5 kg, falling 760 mm). The number of blows required to drive the sampler 0.3 m is known as the SPT blow count (N). Dynamic Cone Penetrometer Testing (DCPT) was also carried out at Borehole 2 starting at a depth of 6.4 m and extending to a depth of 10.8 m. In addition, field vane testing was carried out and relatively undisturbed thin walled tube samples obtained in cohesive soils.

Surveys were conducted using North American Datum 1983, MTM CSRS Zone 14 and Canadian Geodetic Vertical Datum 1928, 1978 Adjustment. Control was established from existing published Horizontal Control Monuments and Geodetic Benchmarks. The



survey was completed using a Trimble R8 Series 3 RTK GPS with radio and an engineering level. Survey data was processed using Land Desktop 2009.

The borehole characteristics are summarized in Table 1.

**Table 1: Borehole Summary**

| BH     | Surface El. m | Station  | Offset m | End of Borehole El. m / (Depth m) | Ground Water Level * El. m / (Depth m) | Base of Peat/Organics El. m / (Depth m) | Comments                        |
|--------|---------------|----------|----------|-----------------------------------|--|---|---------------------------------|
| 1-1993 | 194.7         | 10+025   | 23 Lt    | 181.5 (13.2)                      | 194.7 (0.0)                            | 194.3 (0.4)                             | Bedrock at El. 183.1 m          |
| 2-1993 | 194.5         | 10+050   | 23 Lt    | 183.5 (11.0)                      | Wet at Surface                         | 193.5 (1.0)                             | Estimated Peat Depth, DCPT Only |
| 3-1993 | 194.6         | 10+075   | 23 Lt    | 184.9 (9.7)                       | 194.6 (0.0)                            | 193.6 (1.0)                             | 0.6 m Water at Surface          |
| 1-2011 | 194.2         | 10+074   | 27.0 Lt  | 188.1 (6.1)                       | 193.1 (1.1)                            | -                                       | No Peat                         |
| 2-2011 | 194.1         | 10+056.2 | 28.3 Lt  | 183.3 (10.8)                      | 193.7 (0.4)                            | 193.95 (0.15)                           | DCPT from El. 197.7 to 183.3m   |
| 3-2011 | 194.3         | 10+041.6 | 30.0 Lt  | 187.6 (6.7)                       | 194 (0.3)                              | 193.2 (1.1)                             |                                 |
| 4-2011 | 194.7         | 10+021.3 | 28.9 Lt  | 188.7 (6.0)                       | 194.4 (0.3)                            | 192.8 (1.9)                             |                                 |

\*Measured within 18 hrs of borehole completion

The 2011 boreholes were backfilled at the completion of the investigations using a bentonite backfill mixture to ensure the environmental integrity of the site and in compliance with Ontario Regulation 903.

Soil samples from the 2011 investigation were transported to TBT Engineering's laboratory in Thunder Bay for testing. Routine testing included moisture content, Atterberg limits and grain size analysis. The results of this testing are shown on the Borehole Logs (Appendix A) and on the laboratory data reports (Appendix B).



## **4 Sub-Surface Conditions**

Details of the subsurface conditions are provided on the borehole logs (Appendix A) and on the Soil Strata Drawings (Appendix C). The following subsurface stratigraphy pertains to the soils beyond the north side toe of the embankment.

### **4.1 Fill**

Granular fill was encountered in Boreholes 1-2011, 3-2011 and 4-2011. The fill ranged in thickness from 0.2 to 0.8 m. Grain size analyses carried out on selected sample indicates the fills can consist of 6 % gravel, 81 % sand, and 13 % silt and clay sized particles. The fill is in a very loose condition with SPT (N) values of 1 to 3 blows/0.3 m.

### **4.2 Peat/Organics**

Peat and organics with trace to some silt and sand was encountered below the above noted fills at Boreholes 3-2011 and 4-2011 and at the surface of Boreholes 2-2011, 1-1993 and 3-1993. The peat/organics range in thickness from 0.15 m to 1.6 m and extends to elevations of 192.8 to 194.3 m at the boreholes. Deeper zones may exist between and/or outside of the test hole locations. The natural moisture contents of the peat varied from 70 to 110% (dry weight basis).

### **4.3 Sand**

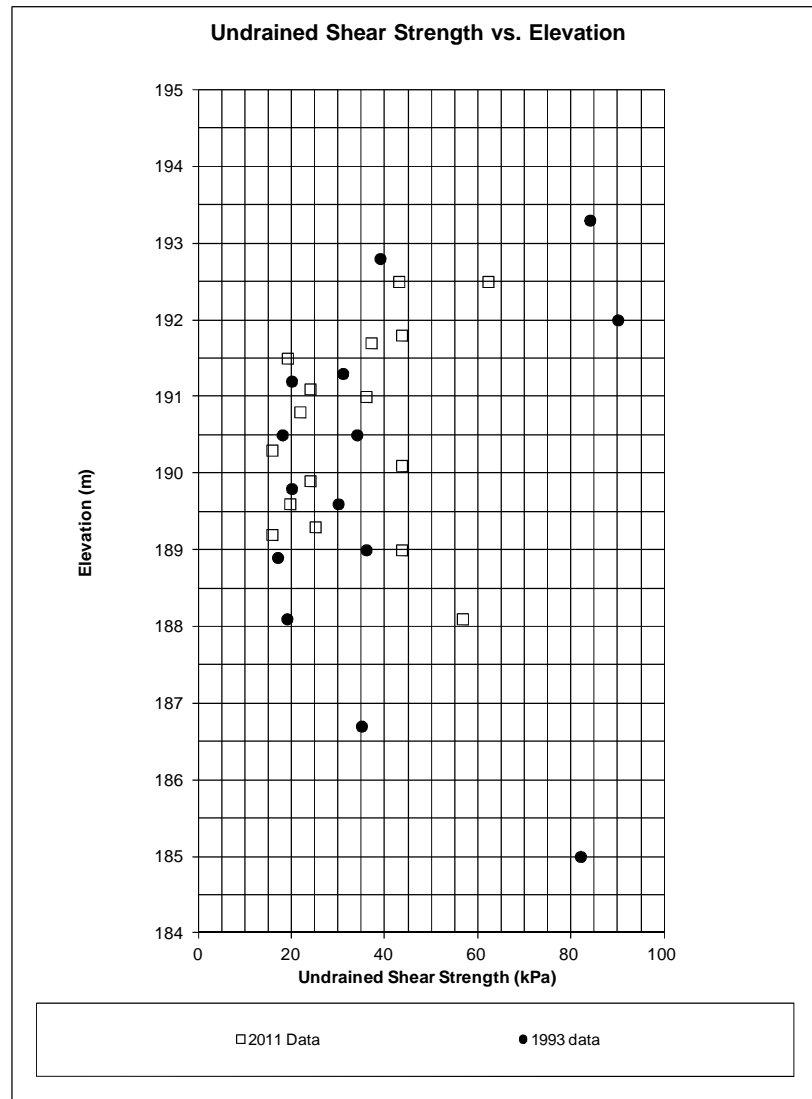
Sand was encountered below the peat in Borehole 2. The sand is 0.5 m thick and is silty with a trace of clay. The sand is in a very loose condition with SPT "N" values of 3 blows / 0.3 m.

### **4.4 Clay**

Clay was encountered underlying the fill and sand in Boreholes 1-2011 and 2-2011 and below the peat in Boreholes 3-2011, 4-2011, 1-1993, 3-1993 and at the surface of Borehole 2-1993. The top of the clay layer was encountered between elevations of 192.8 to 194.5 m (0.2 to 1.9 m below grade). In general the clay is varved, consisting of alternating layers of clay of varying plasticity, silt content and colour. The varves typically ranged in thickness from 2 to 20 mm. Occasional silt seams were also identified. The consistency of the clay varies from soft to very stiff as indicated by field vane tests between 16 and 191 kPa. There is a firm to stiffer crust overlying a soft to



stiff clay (increasing with depth). A graph of undrained shear strength vs. elevation has been illustrated in Figure 3. The undrained shear strengths have been determined based on the field vane tests corrected with respect to plasticity index (Bjerrum, 1972). SPT “N” values generally varied from 1 to 15 blows/0.3 m. The measured sensitivity of the clay varied from 3 to 10.



**Figure 3, Undrained Shear Strength vs. Elevation**

Atterberg limit testing indicates the clay is of low to medium plasticity. The natural moisture content generally exists between the liquid and plastic limits within the upper 2.5 m of the clay stratum (crust). Below a depth of 2.5 m (Elevation 192), the natural moisture contents approach and/or exceed the liquid limit.



The results of a consolidation test were reported in the 1993 report as follows:

- $e_o = 0.575$
- $C_c = 0.1702$
- $P'_c = 110 \text{ kPa}$
- $P'_o = 83 \text{ kPa}$

Two vertical silt seams were noted within the clay stratum in Borehole 1-2011 and 2-2011. The vertical seams exist between depths of 1.8 and 2.4 m.

#### **4.5 Heterogeneous Mixture of Silt/Sand/Gravel - Till**

A non – cohesive heterogeneous mixture of silt, sand and gravel with trace of Clay and numerous boulders and cobbles was encountered in one borehole (1-1993) starting at a depth of 10.1 m (el. 184.5 m) with a thickness of 1.5 m below the clay stratum. This deposit lies directly above the bedrock surface. As inferred by DCPT testing, the till exists at a depth of 10.5 m (el. 183.0 m) at Borehole 2-2001.

Two grain size distribution tests carried out in 1993 indicate this material contains primarily gravel and sand.

A standard penetration tests conducted in this layer had an 'N' value of 79 blows/0.3 m indicating a very dense condition.

#### **4.6 Bedrock / Refusal**

The overburden was underlain by dark reddish to light brown Conglomerate bedrock at depths of 11.6 m and 6.7 m in Boreholes (1-1993 and 3-1993) respectively. The rock was described as medium strong, unweathered to slightly weathered.

Auger refusal was encountered at a depth of 6.1 m (el. 188.1 m) at Borehole 1-2001. Refusal to DCPT's carried out at Boreholes 2-2011 and 2-1993 occurred at depths of 10.8 m (el. 183.3 m) and 11.0 m (el. 183.5 m), respectively. Refusals may be on cobbles, boulders, or bedrock.



#### **4.7 Ground Water**

The ground water levels observed during the 1993 and 2011 field investigations have been provided in Table 1. Ground water level readings taken upon completion of the boreholes carried out in 2011 generally varied from El. 193 to 194 m and may not have had time to stabilize. The current ground water level is likely near the peat surface at about elevation 193.5 to 194.5 m. Ground water levels measured in April of 1993 varied from El. 194.5 to 194.7 m. In 1993, 0.6 m of standing water at elevation 194.6 m was observed at Borehole 3-1993. Ground water levels will vary from season to season and from the effects of heavy precipitation events.

#### **5 Miscellaneous**

Laboratory testing for the 2011 investigation was carried out at the TBT Engineering laboratory in Thunder Bay. The drill equipment for this investigation was operated by TBT Engineering Limited. The field operations for the 2011 investigation were supervised by Allan Finke. Laboratory testing was supervised by T. Fummerton C.E.T. This report was prepared by Gordon Maki, P.Eng, and reviewed by W. Hurley, P.Eng.



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## **Part B - FOUNDATION DESIGN RECOMMENDATIONS**

### **6 Introduction**

TBT Engineering (TBTE) has been retained by the Ministry of Transportation (MTO) to provide foundation investigation and design services for the proposed stabilization works on Highway 17 embankment located between Sta. 10+000 and 10+160 Township of Wiggins. The foundation investigation was carried out to investigate deformations of the westbound lane (north side of the embankment). Settlements and pavement crescent cracking have been observed extending to the middle of the road indicating movement to the north.

The foundation investigation as described in Part A, was carried out to investigate subsurface conditions at this site. This investigation consisted of four boreholes (BH 1-2011 to 4-2011) located along the north (left) side toe of the existing embankment. Boreholes carried out during a previous investigation in 1993 were also reviewed as part of this assignment.

The foundation soils at this site consists fill overlying peat/organics which further overlies soft to very stiff clays. The clay stratum is further underlain by till and/or bedrock.

The relatively low shear strength of the native clay soil and the 9 m high existing embankment directly influence the foundation stability of the embankment. It is understood that prior to 1993, slope failures occurred along the south side of the embankment. In 1995, a south side berm was constructed to improve stability. To stabilize the north side of the embankment, construction of a berm will be required along the north toe of the embankment. Relatively shallow deposits of very loose fills overlying peat/organics were encountered along most of the north toe of the embankment.

The purpose of this section of the report (Part B) is to document the options investigated, review the geotechnical analyses undertaken and to provide specific foundation recommendations for the recommended option. These are based on the conditions encountered at the test hole locations, TBTE's interpretation of the subsurface conditions at the site and analyses of embankment stability.



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## **7 Review of Potential Causes of Settlement**

The observed settlements could be related to a number of factors which have been reviewed below.

### Consolidation of the Clay Foundation:

Consolidation of the clay foundation can lead to settlement of the embankment. However, as no significant raise in grade has been carried out after 1993, it is not expected that consolidation of the clay foundation would be significant at this point in time. The more recent settlements observed along the embankment are not expected to be attributed to consolidation of the foundation soils, although minimal consolidation due to asphalt patching loads may be ongoing.

### Soil Migration Through Existing Rock Fill:

Settlements can be related to migration of granular fills (pavement structure) into the underlying rock fill especially in cases where an open graded rock fill is used and the rock fill surface was not chinked and/or no other means of filter protection (such as a geotextile or graded filter) was provided. Soil migration usually results in non-uniform localized sink holes and/or settlement areas. The observed settlement areas are long arch shaped features with generally uniform settlement. This is not consistent with settlement patterns attributed to soil migration. Soil migration is not expected to be a significant contributing factor to the observed settlements, although some minor amounts of migration may occur and continue over time

### Slope Instability:

The observed long arch shaped and uniform settlement patterns along the west bound lane are consistent with movements associated slope instability. In addition, the observed lateral displacement (to the north) of the north side guide rail is indicative of movements associated with a low level of slope stability. Within the clay foundation, two near vertical silt seams were also identified at two borehole sample locations located near the toe of the embankment which may be indicative of a zone of slippage or soil movement.



The embankment has a history of slope instability issues along the right (south) side which was addressed in 1995 with the construction of a berm.

Stability analysis was carried out to estimate the level of stability for the embankment since construction. As with most embankments constructed over clay foundations, the level of stability is typically lowest at the end of construction when porewater pressures within the clay foundation are at their highest (due to the new embankment loading). The stability analysis was carried out for end of construction conditions assuming the porewater pressures within the clay increased by up to 80% of the weight of the embankment. The results of this analysis indicate a level of stability approaching unity at end of construction. While at a low level of stability, the embankment likely experience creep movements which have subsequently lowered the strength of the foundation soils within the zone of movement. This reduction in soil strength has likely resulted in a reduced level of stability even though excess porewater pressures have dissipated over time.

Given the above, slope instability is considered to be main cause of the observed settlements. Geotechnical analysis (Section 8) has been carried out to address slope instability and provide recommendations for a proposed stabilizing berm for the left side of the embankment. Other methods of slope stabilization such as soil reinforcement, construction of a shear key, or the use of light weights fills were not considered to be feasible for this project.

## **8 Geotechnical Analyses**

### **8.1 Geotechnical Model**

Stability analyses were carried out on a design section developed at Station 10+040 where the embankment is at its highest. Stability modeling was carried out using Slope/W software and limit equilibrium analysis using the Morgenstern-Price method. As the embankment was constructed well over 15 years ago, it is expected that any excess porewater pressures generated from the original construction would be negligible at this time. Effective stress analysis is deemed most appropriate for the current conditions.



The first phase of analysis consisted of carrying out back analyses of the existing left side of the embankment to estimate the effective residual strength parameters of the clay foundation within the zone of expected soil movement. The second phase of analyses consisted of modeling the embankment with a berm to improve the level of stability of the embankment.

## **8.2 Back Analyses Results of Geotechnical Analyses**

Back analyses of the left side of the embankment was carried out to estimate the zone of soil movement (or zone of reduced strength) within the foundation soils and to determine an appropriate effective residual angle of internal friction for this zone.

Conservatively, the back analysis was carried out assuming the peat thickness along the toe of the embankment is insignificant. In addition, no traffic loading was considered. Porewater pressure conditions within the clay foundation were modeled with zero excess head (current conditions). As the observed settlements extend to the highway centre line, the slip surfaces for the stability model were forced through this point.

The strength parameters of the clay with the expected zone of soil movement were adjusted until a factor of safety approaching unity was achieved. The results of the back analysis indicate residual effective strength parameters of  $\phi'_r = 14^\circ$ ,  $c'_r = 0$  kPa for the clay within the zone of soil movement are appropriate. The results of the back analyses also indicate the zone of soil movement extends to a depth of about 6.5 m (to el. 188 m) into the clay foundation. The zone of soil movement was not influenced by the depth to bedrock.

The design soil properties established for the embankment and foundation soils are illustrated in Table 2. The strength properties for the clay and native soils outside of the zone of movement have been based on published correlations with index tests. Typical strength properties for the fills have been selected.



**Table 2: Stability Analyses Soil Properties**

| Soil                | Effective Shear Strength Properties  |  | Unit Weight $\gamma$<br>(kN/m <sup>3</sup> ) |
|---------------------|--|--|--|
|                     | Effective Angle of Internal Friction $\phi'$<br>(degrees)                    | Effective Cohesion Intercept, $C'$ (kPa) |  |
| Rock Fill           | 45   | 0  | 19   |
| Loose Granular Fill | 30   | 0  | 20   |
| Clay                | 30 (peak – outside of movement zone)<br>14 (residual - within movement zone) | 0  | 18   |
| Peat/Organics       | 30   | 0  | 12   |
| Silt/Sand/Gravel    | 35   | 0  | 21   |

The results of the back analyses are provided in Appendix D.

### 8.3 Stability Analyses for Recommended Berm Stabilization

Stability analyses have been carried out to determine a suitable configuration for the proposed berm. The design is based on providing a minimum calculated factor of safety of 1.3 (a 30% increase in the current level of stability). The level of stability is expected to be lowest at the end of construction (construction of the berm) when excess porewater pressures will be generated within the clay by the weight of the new berm. It has been assumed that the excess porewater will reach a maximum value of 80% of the weight of the berm. In addition, a traffic loading was modeled with a uniformly distributed load of 20 kPa.

The proposed berm will be constructed across a natural drainage course and will potentially restrict flow to the existing culvert (which is damaged). Given the condition of the existing culvert, it is anticipated that seepage across the embankment is currently facilitated by seepage through the rock fill embankment. To not restrict seepage through the embankment; the use of rock fill for construction of the berm is recommended. Based on preliminary discussions with Ministry of Transportation Ontario (MTO), all existing peat below the proposed berm is to be removed to improve foundation performance for potential future widening of the embankment. The rock fill for the berm will be placed on the clay subgrade. Conservatively, the thickest peat identified from the investigation was considered to exist adjacent to the new berm location.



A maximum berm height of 196.0 m was used to avoid the existing utility (Hydro, Bell and FOTS) poles present in the left side of the embankment.

Based on the findings of the stability analyses, the berm is to be constructed 14.8 m wide with a crest elevation of 196.0 m. All existing peat and/or granular fill are to be removed from the below the berm. The berm is to be constructed using rock fill with a toe slope of 1.5H:1V. The factor of safety against instability has been calculated at 1.3 at end of construction and 1.5 under long term drained conditions. The west and east limits of the berm are to extend to Station 10+015 and 10+085, respectively. At these stations, the natural ground raises up to el. 196.0 m. The proposed layout and a typical section of the berm have been illustrated on Drawing 3 in Appendix C.

Results of the stability analyses have been included in Appendix D.

#### **8.4 Settlement Performance of Recommended Stabilization Berm**

Settlement analysis has been carried out to estimate settlements due to consolidation of the clay subgrade for the new berm and to assess potential settlements along the existing highway and utility poles. Settlements for the proposed berm have been estimated to be less than 100 mm. Settlements at the existing utility poles have been estimated to be less than 20 mm. Settlements along the existing highway pavement due to the loading from the berm have been estimated to be minimal; however, some surface maintenance may be required shortly after construction.

### **9 Culvert Extension**

The existing culvert is damaged but is not expected to be replaced or repaired in the foreseeable future. Should a new culvert be planned at some time in the future, extension of the new culvert through the berm would be required. Alternatively, a ditch may be considered through the berm. Depending on hydraulic requirements governing ditch/culvert sizing, additional fills adjacent to the ditch/culvert and restrictions on the ditch width may be required to ensure an adequate level of stability is maintained at the ditch/culvert section. Foundation details should be reviewed at that time.



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## **10 Construction Recommendations – Stabilization Berm**

The proposed stabilization measures will involve the construction of a 14.8 m wide berm located along the left side of the existing embankment between Stations 10+015 and 10+085. The berm is to be constructed to an elevation of 196.0 m. The proposed layout and a typical section of the berm have been illustrated on Drawing 3 in Appendix C.

Construction will involve excavation of existing loose granular fill and peat/organics followed by replacement with rock fill to an elevation of 196.0 m. Excavation of the existing loose granular fill and peat will require a temporary cut to be excavated along the north side toe of the existing highway embankment.

Excavation and backfilling operations are to be carried out in accordance with OPSS 209, April 2009, Excavation Method. The operations of excavating and backfilling shall be carried out simultaneously. The side slopes of the rock fill are to be constructed to 1.5H:1V. The berm design does not require the rock fill to be compacted.

The majority of the excavated material will consist of wet peat. Transporting of the wet peat may prove challenging. Stockpiling of the excavated peat over top of the berm may be considered. Where peat is to be stockpiled on top of the new berm, the use of a Class II non-woven geotextile between the top of the rock fill berm and peat will be required to minimize clogging of the voids in the rock fill. Peat should not be stockpiled against the north face (slope) of the berm (as the peat would restrict drainage through the rock fill berm).

## **11 Potential Design and Construction Issues**

Additional property will be required to facilitate construction of the berm. Sufficient property should be obtained to facilitate excavation, fill placement and construction activities required to construct the berm.

The location of the berm is located on the left side of an existing utility line (Hydro, Bell and FOTS) and associated poles. The berm is located close to one of the existing poles but does not cover it. Construction activities will need to consider protection of the



existing services. Settlements of up to 10 mm have been estimated at the pole locations.

The recommended construction methodology, OPSS 209, April 2009, Excavation Method with the operations of excavating and backfilling carried out simultaneously. Should excessive deformation occur during construction, excavation timing and methodology may need to be adjusted. Disposal of wet peat and fill needs to be considered.

## **12 Limitations**

Conclusions and recommendations presented in this report are based on the information determined at the test hole locations. Subsurface and groundwater conditions between and beyond these locations may differ from those encountered. Conditions may become apparent during construction that were not detected and could not be anticipated at the time of the site investigation.

The comments given in this report on potential construction problems and possible methods of construction are intended only for the guidance of the designer.

Groundwater levels indicated are based on the information described within the report. The presence of all conditions that could affect the type and scope of dewatering procedures which may be considered cannot readily be determined from boreholes. These include local and seasonal fluctuations of the groundwater level, changes in soil conditions between test locations, thin and/or discontinuous layers of highly permeable soils, etc.

The information contained within this report in no way reflects any environmental aspect of the site or soil.



### 13 Closure

We trust the above addresses your project requirements at this time. Should you have any questions or comments, please do not hesitate the contact us at your convenience.

Yours truly,  
For TBT ENGINEERING



Gordon Maki, P.Eng  
Manager of Geotechnical Engineering



Wayne Hurley, P.Eng.  
Vice President of Engineering



**APPENDIX A**

**Borehole Logs**



## EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

**JOINTING AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

|                                      |     |                               |
|--------------------------------------|-----|-------------------------------|
| $u_w$                                | kPa | PORE WATER PRESSURE           |
| $r_u$                                | l   | PORE PRESSURE RATIO           |
| $\sigma$                             | kPa | TOTAL NORMAL STRESS           |
| $\sigma'$                            | kPa | EFFECTIVE NORMAL STRESS       |
| $\tau$                               | kPa | SHEAR STRESS                  |
| $\sigma_1, \sigma_2, \sigma_3$       | kPa | PRINCIPAL STRESSES            |
| $\epsilon$                           | %   | LINEAR STRAIN                 |
| $\epsilon_1, \epsilon_2, \epsilon_3$ | %   | PRINCIPAL STRAINS             |
| E                                    | kPa | MODULUS OF LINEAR DEFORMATION |
| G                                    | kPa | MODULUS OF SHEAR DEFORMATION  |
| $\mu$                                | l   | COEFFICIENT OF FRICTION       |

### MECHANICAL PROPERTIES OF SOIL

|                |            |                                      |
|----------------|------------|--------------------------------------|
| $m_v$          | $kPa^{-1}$ | COEFFICIENT OF VOLUME CHANGE         |
| $C_c$          | l          | COMPRESSION INDEX                    |
| $C_s$          | l          | SWELLING INDEX                       |
| $C_a$          | l          | RATE OF SECONDARY CONSOLIDATION      |
| $c_v$          | $m^2/s$    | COEFFICIENT OF CONSOLIDATION         |
| H              | m          | DRAINAGE PATH                        |
| $T_v$          | l          | TIME FACTOR                          |
| U              | %          | DEGREE OF CONSOLIDATION              |
| $\sigma'_{vo}$ | kPa        | EFFECTIVE OVERBURDEN PRESSURE        |
| $\sigma'_p$    | kPa        | PRECONSOLIDATION PRESSURE            |
| $\tau_f$       | kPa        | SHEAR STRENGTH                       |
| $c'$           | kPa        | EFFECTIVE COHESION INTERCEPT         |
| $\phi'$        | -°         | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| $c_u$          | kPa        | APPARENT COHESION INTERCEPT          |
| $\phi_u$       | -°         | APPARENT ANGLE OF INTERNAL FRICTION  |
| $\tau_R$       | kPa        | RESIDUAL SHEAR STRENGTH              |
| $\tau_r$       | kPa        | REMOULDED SHEAR STRENGTH             |
| $S_i$          | l          | SENSITIVITY = $\frac{c_u}{\tau_r}$   |

### PHYSICAL PROPERTIES OF SOIL

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



| TBT Engineering Consulting Group |   |            | <b>RECORD OF Borehole No 1-2011</b>       |      |            | 1 OF 1                  |                 | <b>METRIC</b>  |  |
|----------------------------------|---|------------|---|------|------------|-------------------------|-----------------|--|--|
| W.P. <b>6081-09-00</b>           |   |            | PROJECT <b>Gravel River</b>               |      |            | SITE NO. _____          |                 | ORIGINATED BY <b>A.F.</b>  |  |
| DIST <b>61</b> HWY <b>17</b>     |   |            | LOCATION <b>Sta. 10+074.0 o/s 27.0 Lt</b> |      |            | TBTE JOB# <b>11-325</b> |                 | COMPILED BY <b>T.B.</b>  |  |
| DATE <b>2011 December 21</b>     |   |            | BOREHOLE TYPE <b>SS Auger - 50 mm</b>     |      |            | DATUM <b>Geodetic</b>   |                 | CHECKED BY <b>S.S.</b>   |  |
| SOIL PROFILE                     |   |            | SAMPLES                                   |      |            | GROUND WATER CONDITIONS |                 | DYNAMIC CONE PENETRATION RESISTANCE PLOT                                       |  |
| ELEV<br>DEPTH                    | DESCRIPTION   | STRAT PLOT | NUMBER                                    | TYPE | "N" VALUES |                         | ELEVATION SCALE | SHEAR STRENGTH kPa   |  |
|                                  |   |            |   |      |            |                         |                 | 20 40 60 80 100<br>○ UNCONFINED    ✕ FIELD VANE<br>■ SPT (N)        ★ LAB VANE | PLASTIC LIMIT    NATURAL MOISTURE CONTENT    LIQUID LIMIT<br>W <sub>p</sub> W                      W <sub>L</sub><br>WATER CONTENT (%) |
| 194.2                            |   |            |   |      |            |                         |                 |  |  |
| 194.0                            |   |            |   |      |            |                         |                 |  |  |
| 0.2                              | FILL - SAND/GRAVEL/CLAY - Silty, occasional cobbles, brown/CLAY - varved, occasional silt seam, trace sand, brown, very stiff |            | 1   | SS   | 7          |                         | 194             |  |  |
|                                  |   |            | 2   | SS   | 15         |                         |                 |  |  |
|                                  |   |            |   |      |            |                         | 193             |  |  |
|                                  | -----<br>- grey/brown, vertical silt seam, firm   |            | 3   | SS   | 3          |                         | 192             |  |  |
|                                  |   |            |   |      |            |                         |                 |  |  |
|                                  | -----<br>- grey/black, firm   |            | 4   | TW   |            |                         | 191             |  |  |
|                                  |   |            |   |      |            |                         |                 |  |  |
|                                  | -----<br>- soft   |            | 5   | SS   | 2          |                         | 190             |  |  |
|                                  |   |            |   |      |            |                         |                 |  |  |
|                                  |   |            | 6   | SS   | 3          |                         | 189             |  |  |
|                                  |   |            |   |      |            |                         |                 |  |  |
| 188.1                            | End of Borehole @ 6.1 m. Auger Refusal.   |            | 7   | SS   | 100+       |                         |                 |  |  |
| 6.1                              |   |            |   |      |            |                         |                 |  |  |

✕<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity  
 NP Non Plastic  
 ○ 3% STRAIN AT FAILURE

ON\_MOT\_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON\_MOT.GDT 12/3/11



|      |                         |               |                         |          |                                  |               |               |
|------|-------------------------|---------------|-------------------------|----------|----------------------------------|---------------|---------------|
| W.P. | <b>6081-09-00</b>       | PROJECT       | <b>Gravel River</b>     | SITE NO. |                                  | ORIGINATED BY | <b>A.F.</b>   |
| DIST | <b>61</b>               | HWY           | <b>17</b>               | LOCATION | <b>Sta. 10+056.2 o/s 28.3 Lt</b> | TBTE JOB#     | <b>11-325</b> |
| DATE | <b>2011 December 22</b> | BOREHOLE TYPE | <b>SS Auger - 50 mm</b> | DATUM    | <b>Geodetic</b>                  | CHECKED BY    | <b>S.S.</b>   |

ON MOT BH-10 11-325 MTO GRAVEL RIVER.GPJ ON MOT.GDT 12/3/1

Continued Next Page

✕<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity  
 NP Non Plastic  
 ○<sup>3%</sup> STRAIN AT FAILURE



| TBT Engineering Consulting Group |  | <b>RECORD OF Borehole No 2-2011</b>       |        |      |                            | 2 OF 2                  |  | <b>METRIC</b>             |                                    |                                     |                                   |  |  |  |
|----------------------------------|--|---|--------|------|----------------------------|-------------------------|--|---------------------------|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|
| W.P. <b>6081-09-00</b>           |  | PROJECT <b>Gravel River</b>               |        |      |                            | SITE NO. _____          |  | ORIGINATED BY <b>A.F.</b> |                                    |                                     |                                   |  |  |  |
| DIST <b>61</b> HWY <b>17</b>     |  | LOCATION <b>Sta. 10+056.2 o/s 28.3 Lt</b> |        |      |                            | TBTE JOB# <b>11-325</b> |  | COMPILED BY <b>T.B.</b>   |                                    |                                     |                                   |  |  |  |
| DATE <b>2011 December 22</b>     |  | BOREHOLE TYPE <b>SS Auger - 50 mm</b>     |        |      |                            | DATUM <b>Geodetic</b>   |  | CHECKED BY <b>S.S.</b>    |                                    |                                     |                                   |  |  |  |
| SOIL PROFILE                     |  | SAMPLES                                   |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE         | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |                           | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |  |
| ELEV<br>DEPTH                    | DESCRIPTION                                    | STRAT PLOT                                | NUMBER | TYPE |                            |                         | "N" VALUES   | SHEAR STRENGTH kPa        |                                    |                                     |                                   |  |  |  |
|                                  |  |   |        |      |                            |                         | <div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>✕ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>■ SPT (N)</span> <span>★ LAB VANE</span> </div> |                           |                                    |                                     |                                   |  |  |  |
| 184                              |  |   |        |      |                            |                         |  |                           |                                    |                                     |                                   |  |  |  |
| 183.3                            |  |   |        |      |                            |                         |  |                           |                                    |                                     |                                   |  |  |  |
| 10.8                             | End of DCPT Testing @ 10.8 m.<br>DCPT Refusal. |   |        |      |                            |                         |  |                           |                                    |                                     |                                   |  |  |  |

ON\_MOT\_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON\_MOT.GDT 12/3/1



TBT Engineering Consulting Group **RECORD OF Borehole No 3-2011** 1 OF 1 **METRIC**

W.P. **6081-09-00** PROJECT **Gravel River** SITE NO. \_\_\_\_\_ ORIGINATED BY **A.F.**

DIST **61** HWY **17** LOCATION **Sta. 10+041.6 o/s 30.0 Lt** TBTE JOB# **11-325** COMPILED BY **T.B.**

DATE **2011 December 22** BOREHOLE TYPE **SS Auger - 50 mm** DATUM **Geodetic** CHECKED BY **S.S.**

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  | PLASTIC<br>LIMIT<br>W <sub>P</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |  |                                    |                                     |                                   |                     |   |
| 194.3         |  |            |         |      |            |                            |                 | 20 40 60 80 100                             |  |                                    |                                     |                                   |                     |   |
| 0.0           | FILL - SAND - some silt, trace gravel, trace organics, brown, very loose |            | 1       | SS   | 1          |                            |                 | 20 40 60 80 100                             |  |                                    |                                     |                                   |                     | GR SA SI CL<br>6 81 (13)                          |
| 193.5         |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
| 0.8           | PEAT - brown   |            | 2       | SS   | 1          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
| 193.2         |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
| 1.1           | CLAY - varved, occasional silt seam, brown, stiff                        |            | 3       | SS   | 5          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               | -----<br>- grey/brown, soft  |            | 4       | SS   | 3          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            | 5       | SS   | 1          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            | 6       | SS   | 1          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               | -----<br>- trace sand, grey  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
|               |  |            | 7       | SS   | 5          |                            |                 |   |  |                                    |                                     |                                   |                     |   |
| 187.6         |  |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |
| 6.7           | End of Borehole @ 6.7 m.   |            |         |      |            |                            |                 |   |  |                                    |                                     |                                   |                     |   |

ON\_MOT\_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON\_MOT.GDT 12/3/1



| TBT Engineering Consulting Group |  |            | RECORD OF Borehole No 4-2011              |      |            | 1 OF 1                  |                 |                    | METRIC                                   |            |                   |                                       |                |                   |  |  |
|----------------------------------|--|------------|---|------|------------|-------------------------|-----------------|--------------------|--|------------|-------------------|---------------------------------------|----------------|-------------------|--|--|
| W.P. <b>6081-09-00</b>           |  |            | PROJECT <b>Gravel River</b>               |      |            | SITE NO. _____          |                 |                    | ORIGINATED BY <b>A.F.</b>                |            |                   |                                       |                |                   |  |  |
| DIST <b>61</b> HWY <b>17</b>     |  |            | LOCATION <b>Sta. 10+021.3 o/s 28.9 Lt</b> |      |            | TBTE JOB# <b>11-325</b> |                 |                    | COMPILED BY <b>T.B.</b>                  |            |                   |                                       |                |                   |  |  |
| DATE <b>2011 December 22</b>     |  |            | BOREHOLE TYPE <b>SS Auger - 50 mm</b>     |      |            | DATUM <b>Geodetic</b>   |                 |                    | CHECKED BY <b>S.S.</b>                   |            |                   |                                       |                |                   |  |  |
| SOIL PROFILE                     |  |            | SAMPLES                                   |      |            | GROUND WATER CONDITIONS |                 |                    | DYNAMIC CONE PENETRATION RESISTANCE PLOT |            |                   | REMARKS & GRAIN SIZE DISTRIBUTION (%) |                |                   |  |  |
| ELEV<br>DEPTH                    | DESCRIPTION  | STRAT PLOT | NUMBER                                    | TYPE | "N" VALUES |                         | ELEVATION SCALE | SHEAR STRENGTH kPa |  |            | WATER CONTENT (%) |                                       |                | UNIT WEIGHT       |  |  |
|                                  |  |            |   |      |            |                         |                 | 20 40 60 80 100    | UNCONFINED                               | FIELD VANE | PLASTIC LIMIT     | NATURAL MOISTURE CONTENT              | LIQUID LIMIT   | γ                 | GR SA SI CL                                  |  |
|                                  |  |            |   |      |            |                         |                 | 20 40 60 80 100    | SPT (N)                                  | LAB VANE   | W <sub>p</sub>    | W                                     | W <sub>L</sub> | kN/m <sup>3</sup> |  |  |
| 194.7<br>0.0                     | FILL - SAND - some silt, trace gravel, trace organics, brown, very loose |            | 1   | SS   | 1          |                         | 194             |                    |  |            |                   |                                       |                | 101.5             | Water level @ 0.3 m 1 hour after completion. |  |
| 194.4<br>0.3                     | PEAT - brown   |            | 2   | SS   | 1          |                         | 194             |                    |  |            |                   |                                       |                | 110.5             |  |  |
|                                  | - trace sand   |            | 3   | SS   | 5          |                         | 193             |                    |  |            |                   |                                       |                |                   |  |  |
| 192.8<br>1.9                     | CLAY - varved, occasional silt seam, brown, firm                         |            | 4   | SS   | 6          |                         | 193             |                    |  |            |                   |                                       |                |                   |  |  |
|                                  | - grey   |            |   |      |            |                         | 192             |                    |  |            |                   |                                       |                |                   |  |  |
|                                  | - soft   |            | 5   | TW   |            |                         | 191             |                    |  |            |                   |                                       |                |                   |  |  |
|                                  | - firm   |            | 6   | SS   | 3          |                         | 190             |                    |  |            |                   |                                       |                |                   |  |  |
|                                  |  |            | 7   | SS   | 5          | 189                     |                 |                    |  |            |                   |                                       |                |                   |  |  |
| 188.7<br>6.0                     | End of Borehole @ 6.0 m.   |            |   |      |            |                         |                 |                    |  |            |                   |                                       |                |                   |  |  |

x<sup>3</sup>, \*<sup>3</sup>: Numbers refer to Sensitivity  
 NP Non Plastic  
 ○ 3% STRAIN AT FAILURE

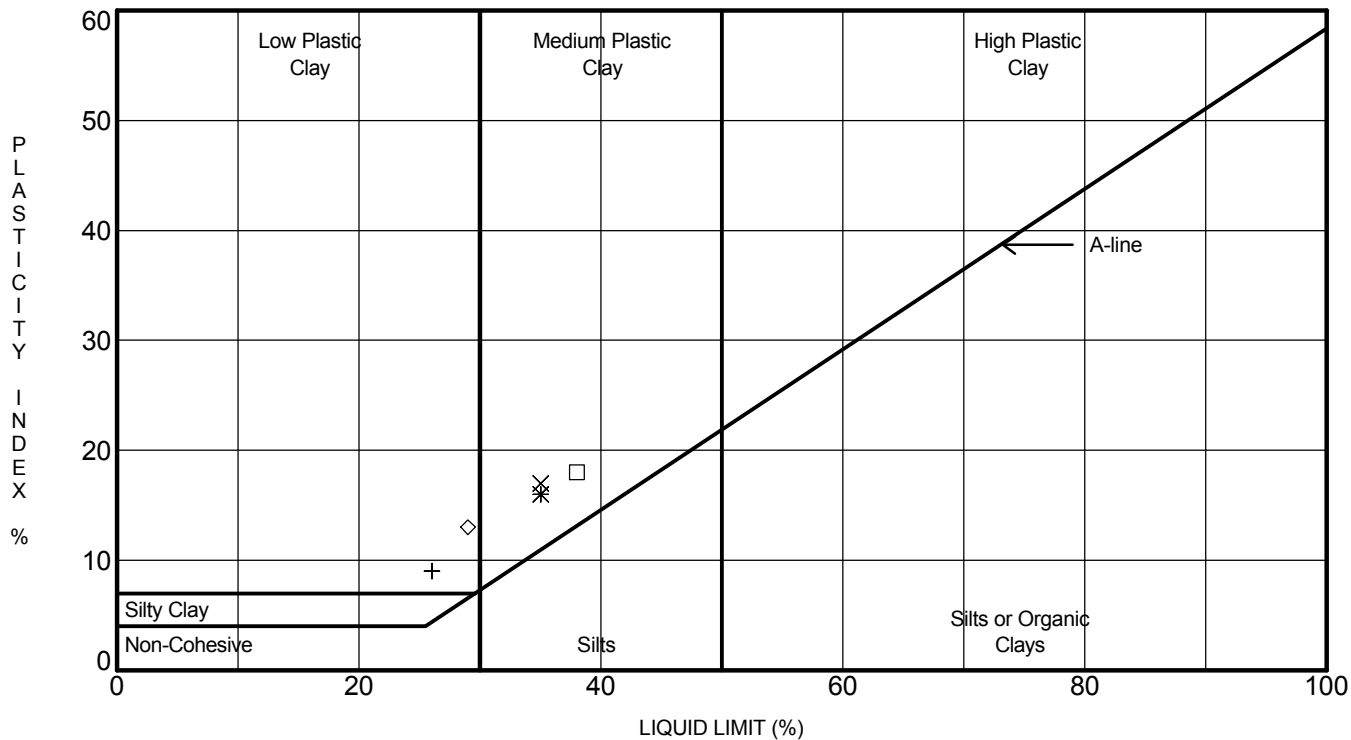
ON\_MOT\_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON\_MOT.GDT 12/3/1



## **APPENDIX B**

### **Laboratory Test Data**





| Test Hole | Sample No. | Depth (m) | LL % | PL % | PI % | M/C % |
|-----------|------------|-----------|------|------|------|-------|
| □ 1-2011  |            | 0.60      | 38   | 20   | 18   | 26    |
| * 1-2011  |            | 1.80      | 35   | 19   | 16   | 31    |
| × 2-2011  |            | 2.70      | 35   | 18   | 17   | 34    |
| + 3-2011  |            | 4.60      | 26   | 17   | 9    | 28    |
| ◇ 4-2011  |            | 4.30      | 29   | 16   | 13   | 32    |
|           |            |           |      |      |      |       |
|           |            |           |      |      |      |       |
|           |            |           |      |      |      |       |
|           |            |           |      |      |      |       |
|           |            |           |      |      |      |       |
|           |            |           |      |      |      |       |



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## ATTERBERG LIMIT RESULT

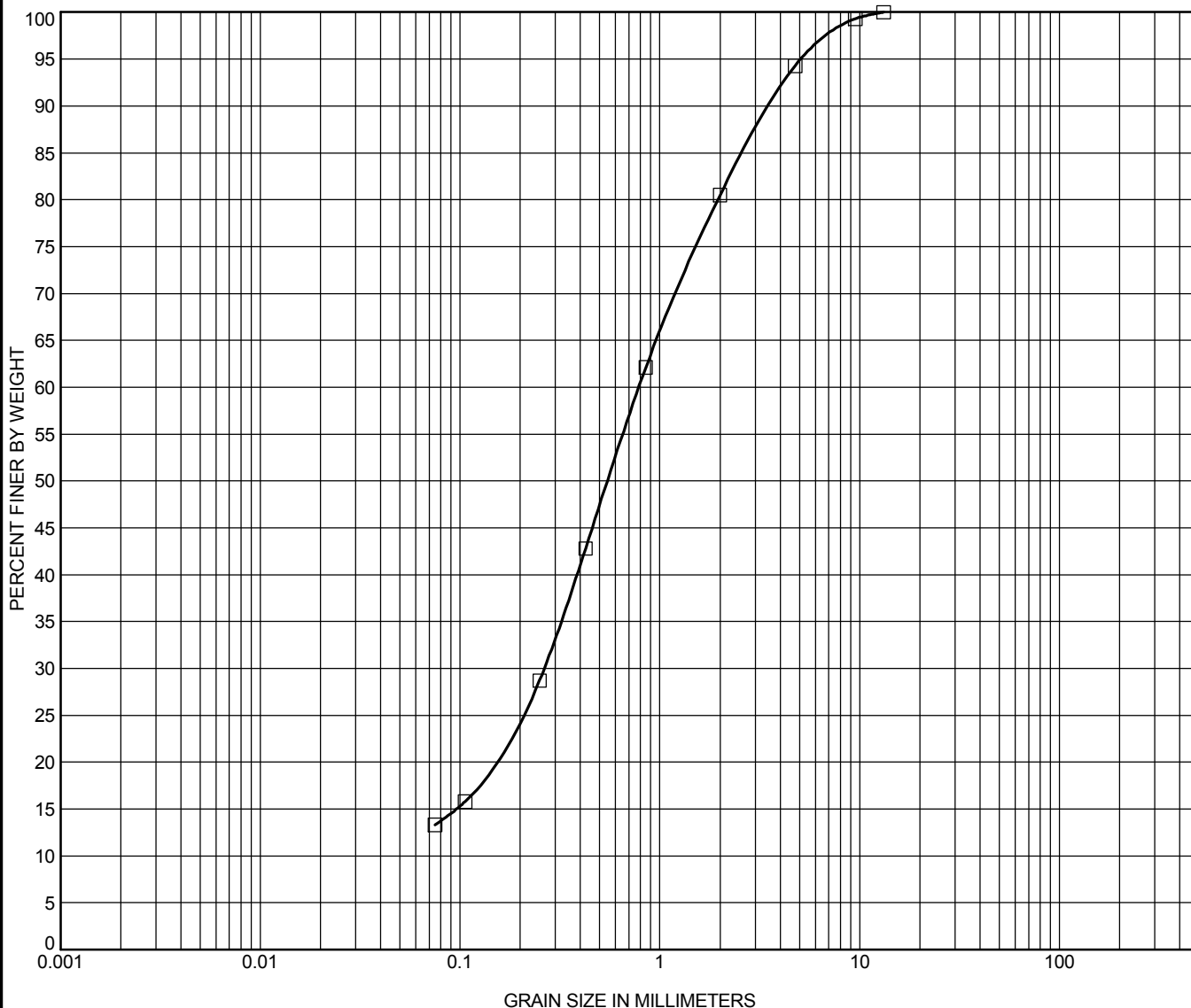
Project:

Location:

Number:

**ENCLOSURE 1**





| SILT OR CLAY | SAND |        |        | GRAVEL |        | COBBLES |
|--------------|------|--------|--------|--------|--------|---------|
|              | fine | medium | coarse | fine   | coarse |         |

Remarks:  
SAND - some silt

| Test Hole | Depth | D100 | D60   | D30   | D10 | %Gravel | %Sand | %Silt | %Clay |
|-----------|-------|------|-------|-------|-----|---------|-------|-------|-------|
| 3-2011    | 0.00  | 13.2 | 0.788 | 0.263 |     | 5.7     | 81.0  | 13.3  |       |
|           |       |      |       |       |     |         |       |       |       |
|           |       |      |       |       |     |         |       |       |       |
|           |       |      |       |       |     |         |       |       |       |
|           |       |      |       |       |     |         |       |       |       |



TBT Engineering Limited  
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Thunder Bay, Ontario P7C 6T9  
PH: 807-624-5160  
FX: 807-264-5161  
Email: [tbte@tbte.ca](mailto:tbte@tbte.ca)  
Web: [www.tbte.ca](http://www.tbte.ca)

## GRAIN SIZE DISTRIBUTION

Project: Gravel River

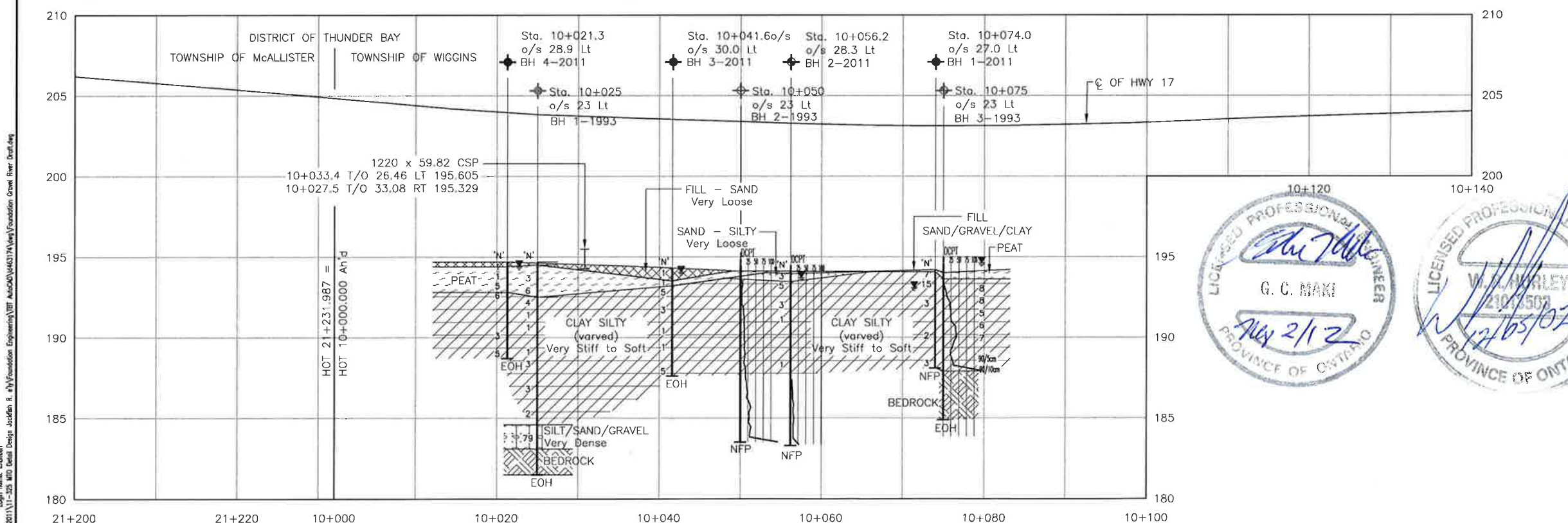
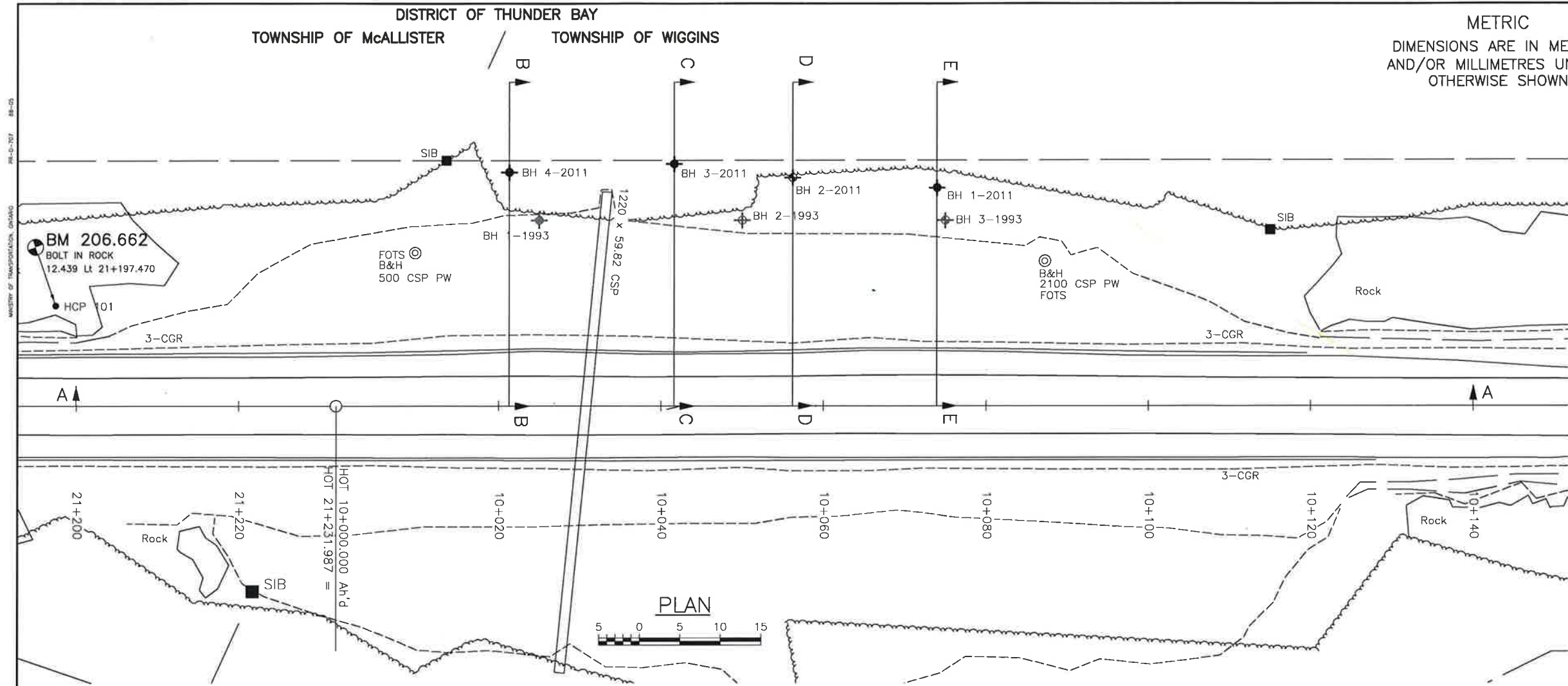
W P: 6081-09-00

DIST: 61 HWY: 17



**APPENDIX C**  
Borehole Locations, Drawings and Sections



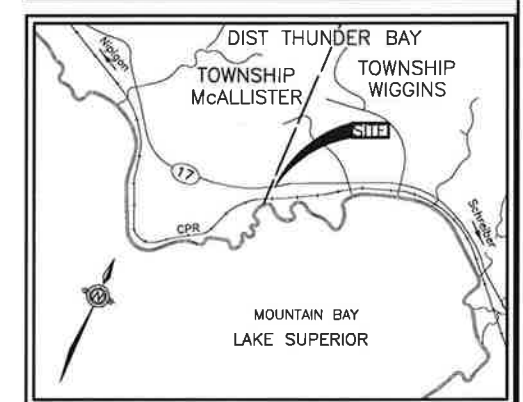


GEOCRE No. 42D-27  
CONT No. 2012-xxxx  
WP No. 6081-09-00

HWY 17, STA. 10+050 WIGGINS TOWNSHIP  
EMBANKMENT STABILIZATION  
BOREHOLE LOCATIONS AND SOIL STRATA

Ministry of Transportation  
Northwestern Region  
Structural Section

**TBT ENGINEERING**  
CONSULTING GROUP



KEY PLAN  
1.0 km 0 1.0 km  
SCALE 1:50,000

| SOIL STRATA SYMBOLS |                       |
|---------------------|-----------------------|
|                     | PEAT                  |
|                     | FILL                  |
|                     | SAND                  |
|                     | CLAY - SILTY (varved) |
|                     | SILT/SAND/ GRAVEL     |
|                     | BEDROCK               |

| LEGEND |  |
|--------|--|
|        | Borehole   |
|        | Borehole with Dynamic Cone Penetration Test (DCPT) |
|        | Borehole - Previous Investigation                  |
|        | DCPT - Previous Investigation                      |
|        | Borehole & DCPT - Previous Investigation           |
|        | Sid Pen Test (Blows/0.3m)                          |
|        | Water Level  |
|        | No Further Progress                                |

| CO-ORDINATES<br>(MTM, NAD 83 ZONE 14) |           |
|---------------------------------------|-----------|
| No                                    | ELEVATION |
| TBT BOREHOLES                         |           |
| 1-2011                                | 194.2     |
| 2-2011                                | 194.1     |
| 3-2011                                | 194.3     |
| 4-2011                                | 194.7     |
| PREVIOUS BOREHOLES                    |           |
| 1-1993                                | 194.7     |
| 2-1993                                | 194.5     |
| 3-1993                                | 194.6     |

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


| REVISIONS   |                        |
|-------------|------------------------|
| 02/05/12    | W.H. FINAL             |
| 16/04/12    | G.M. REISSUED IN DRAFT |
| 01/03/12    | G.M. ISSUED FOR DRAFT  |
| DDMMYY      | BY REVISION            |
| DESCRIPTION |                        |
| DESIGN      | CHK                    |
| DRAWN       | TB CHK                 |

REFERENCE DRAWING SUPPLIED BY CLIENT.



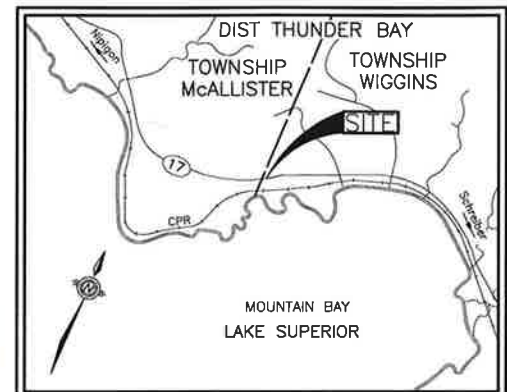


HWY 17, STA. 10+050 WIGGINS TOWNSHIP  
EMBANKMENT STABILIZATION  
SOIL STRATA CROSS-SECTIONS

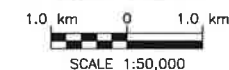

 Ontario  
 Ministry of Transportation  
 Northwestern Region  
 Structural Section









**TBT ENGINEERING**  
CONSULTING GROUP











### KEY PLAN



| SOIL STRATA SYMBOLS   |      |   |
|---|------|---|
|  | PEAT |   |
|  | FILL |   |
|  | SAND |   |
|   |      |  |
|   |      | CLAY - SILTY<br>(VARVED)  |
|   |      |  |
|   |      | SILT/SAND/<br>GRAVEL  |
|   |      |  |
|   |      | BEDROCK   |

### LEGEND

- |   |  |
|---|--|
|  | Borehole   |
|  | Borehole with Dynamic Cone Penetration Test (DCPT) |
|  | Borehole - Previous Investigation                  |
|  | DCPT - Previous Investigation                      |
|  | Borehole & DCPT - Previous Investigation           |
|  | Sid Pen Test (Blows/0.3m)                          |
|  | Water Level  |
|  | No Further Progress                                |

| No                 | ELEVATION | CO-ORDINATES<br>(MTM, NAD 83 ZONE 14) |          |
|--------------------|-----------|---------------------------------------|----------|
|                    |           | NORTHING                              | EASTING  |
| TBT BOREHOLES      |           |                                       |          |
| 1-2011             | 194.2     | 5420809.7                             | 245121.7 |
| 2-2011             | 194.1     | 5420803.8                             | 245105.0 |
| 3-2011             | 194.3     | 5420799.5                             | 245090.9 |
| 4-2011             | 194.7     | 5420790.5                             | 245072.7 |
| PREVIOUS BOREHOLES |           |                                       |          |
| 1-1993             | 194.7     | 5420786.5                             | 245078.4 |
| 2-1993             | 194.5     | 5420796.5                             | 245101.4 |
| 3-1993             | 194.6     | 5420806.4                             | 245124.3 |

-NOTE-

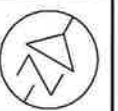
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

|             |          |      |                   |          |      |            |               |
|-------------|----------|------|-------------------|----------|------|------------|---------------|
| REVISIONS   | 02/05/12 | W.H. | FINAL             |          |      |            |               |
|             | 16/04/12 | G.M. | REISSUED IN DRAFT |          |      |            |               |
|             | 01/03/12 | G.M. | ISSUED FOR DRAFT  |          |      |            |               |
|             | XXXXXX   | BY   | REVISION          |          |      |            |               |
| DESCRIPTION |          |      |                   |          |      |            |               |
| DESIGN      |          | CHK  | CODE              | XXXXX-XX | LOAD | XX-XX-XXXX | DATE 01/03/12 |
| DRAWN       | TB       | CHK  | WH-SITE           | XXX-XXX  |      | DWG        | 2             |



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

|             |            |
|-------------|------------|
| GEOCRES No. | 42D-27     |
| CONT No.    | 2012-xxxx  |
| WP No.      | 6081-09-00 |

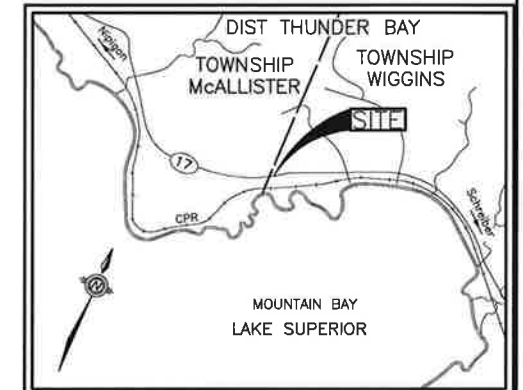


HWY 17, STA. 10+050 WIGGINS TOWNSHIP  
EMBANKMENT STABILIZATION  
PLAN OF BERM AND TYPICAL SECTION

SHEET



Ministry of Transportation  
Northwestern Region  
Structural Section



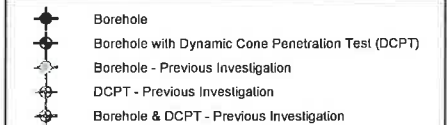
KEY PLAN



BERM CO-ORDINATES

| POINT | STATION  | OFFSET  | CO-ORDINATES<br>(MTM, NAD 83 ZONE 14) |          |
|-------|----------|---------|---------------------------------------|----------|
|       |          |         | NORTHING                              | EASTING  |
| 1     | 10+017.8 | 33.0 Lt | 5420792.8                             | 245067.8 |
| 2     | 10+020.6 | 37.1 Ll | 5420797.7                             | 245068.8 |
| 3     | 10+072.8 | 34.0 Ll | 5420815.6                             | 245117.9 |
| 4     | 10+079.5 | 27.1 Lt | 5420812.0                             | 245126.8 |

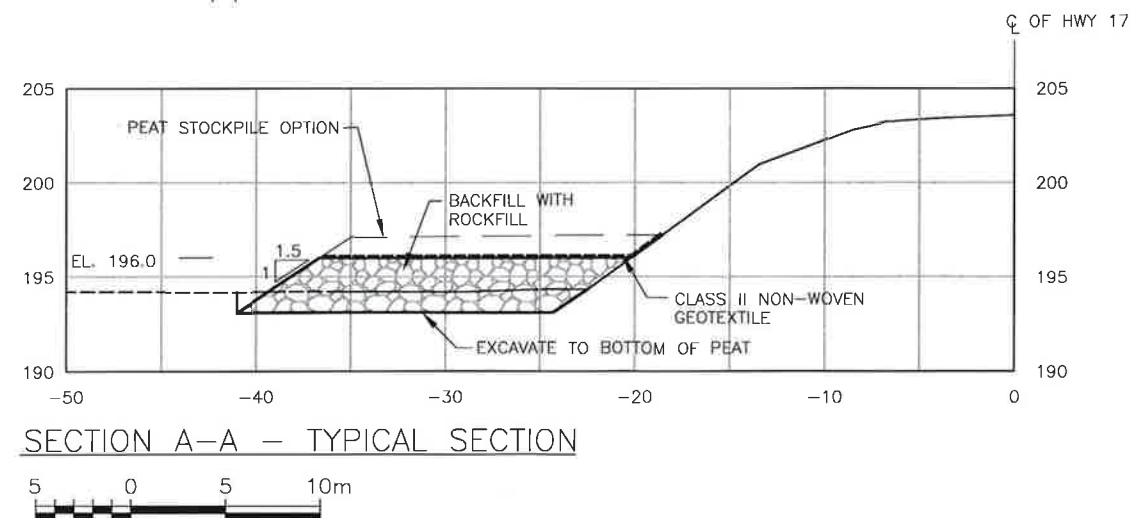
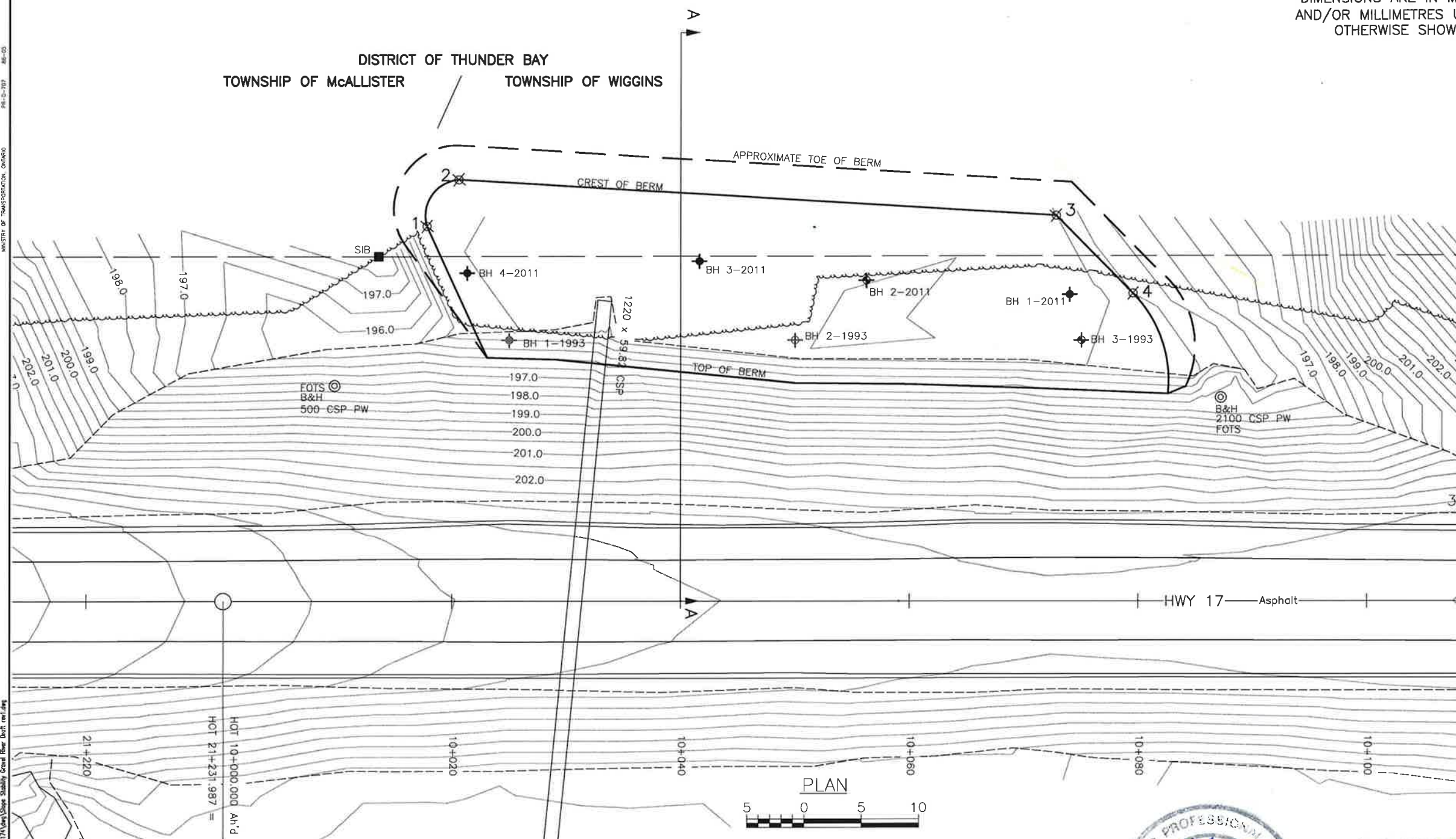
### LEGEND



| No                 | ELEVATION | CO-ORDINATES<br>(MTM, NAD 83 ZONE 14) |          |
|--------------------|-----------|---------------------------------------|----------|
|                    |           | NORTHING                              | EASTING  |
| TBT BOREHOLES      |           |                                       |          |
| 1-2011             | 194.2     | 5420809.7                             | 245121.7 |
| 2-2011             | 194.1     | 5420903.8                             | 245105.0 |
| 3-2011             | 194.3     | 5420799.5                             | 245090.9 |
| 4-2011             | 194.7     | 5420780.5                             | 245072.7 |
| PREVIOUS BOREHOLES |           |                                       |          |
| 1-1993             | 194.7     | 5420786.5                             | 245078.4 |
| 2-1993             | 194.5     | 5420796.5                             | 245101.4 |
| 3-1993             | 194.6     | 5420806.4                             | 245124.3 |

|           |          |      |                   |             |          |                 |      |          |
|-----------|----------|------|-------------------|-------------|----------|-----------------|------|----------|
| REVISIONS | 02/05/12 | W.H. | FINAL             |             |          |                 |      |          |
|           | 19/04/12 | W.H. | FOR REVIEW        |             |          |                 |      |          |
|           | 16/04/12 | G.M. | REISSUED IN DRAFT |             |          |                 |      |          |
|           | 01/03/12 | G.M. | ISSUED IN DRAFT   |             |          |                 |      |          |
|           | DDMMYY   | BY   | REVISION          |             |          |                 |      |          |
|           |          |      |                   | DESCRIPTION |          |                 |      |          |
| DESIGN    |          | CHK  |                   | CODE        | XXXXX-XX | LOAD XX-XXX-XXX | DATE | 01/03/12 |
| DRAWN     | TR       | CHK  | WH                | SITE        | XXX-XXX  |                 | DWG  | 3        |

REFERENCE DRAWING SUPPLIED BY CLIENT.





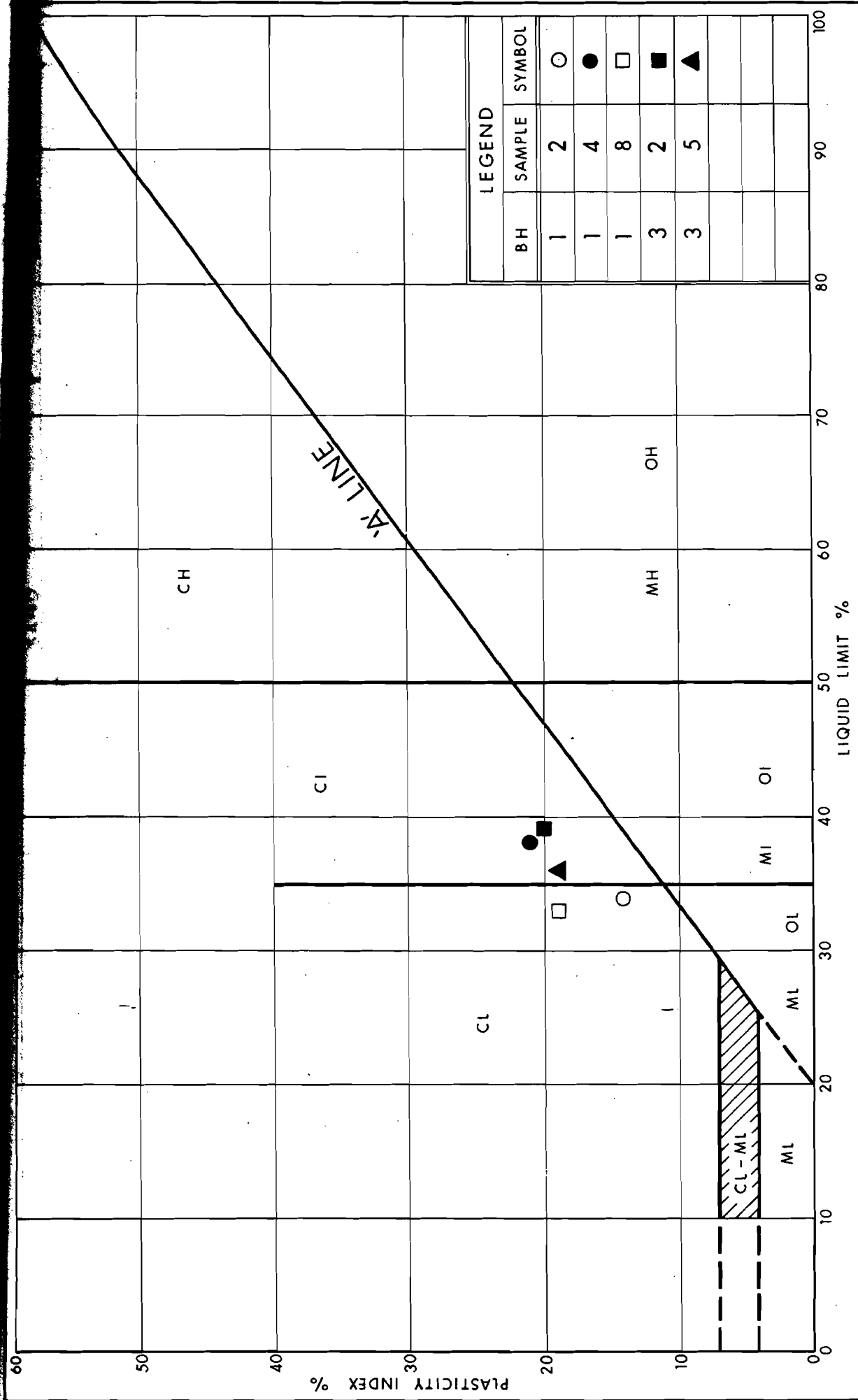
## **APPENDIX D**

### 1993 Borehole Data and Laboratory Test Data











Ministry of  
Transportation  
Ontario

## PLASTICITY CHART

### SILTY CLAY

FIG No 2

W P 909 -76-01 (B)



# CLAY & SILT

GRAIN SIZE IN MICROMETERS

Fine

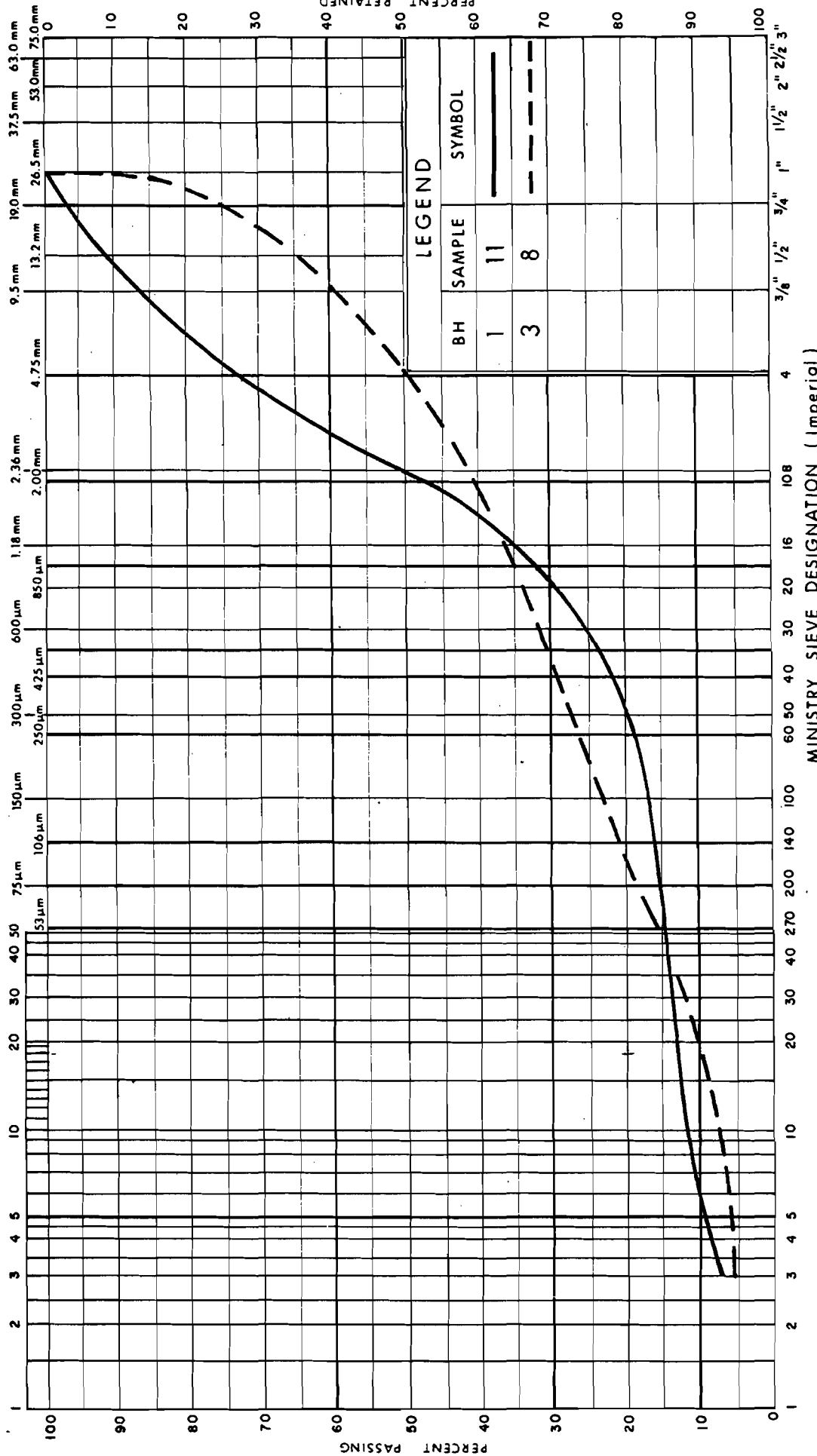
Medium

Coarse

Very Coarse

Gravel

MINISTRY SIEVE DESIGNATION (Metric)





## EXPLANATION OF TERMS USED IN REPORT

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

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

ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

**Jointing and Bedding:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

|                   |     |                            |
|-------------------|-----|----------------------------|
| SPLIT SPOON       | T P | THINWALL PISTON            |
| WASH SAMPLE       | O S | OSTERBERG SAMPLE           |
| NOTED TUBE SAMPLE | R C | ROCK CORE                  |
| ROCK SAMPLE       | P H | T W ADVANCED HYDRAULICALLY |
| TRUNK SAMPLE      | P M | T W ADVANCED MANUALLY      |
| THINWALL OPEN     | F S | FOIL SAMPLE                |

### STRESS AND STRAIN

|     |                               |
|-----|-------------------------------|
| kPa | PORE WATER PRESSURE           |
| 1   | PORE PRESSURE RATIO           |
| kPa | TOTAL NORMAL STRESS           |
| kPa | EFFECTIVE NORMAL STRESS       |
| kPa | SHEAR STRESS                  |
| kPa | PRINCIPAL STRESSES            |
| %   | TENSILE STRAIN                |
| %   | PRINCIPAL STRAINS             |
| kPa | MODULUS OF LINEAR DEFORMATION |
| kPa | MODULUS OF SHEAR DEFORMATION  |
| 1   | COEFFICIENT OF FRICTION       |

### MECHANICAL PROPERTIES OF SOIL

|                |                       |                                      |
|----------------|-----------------------|--------------------------------------|
| $m_v$          | $\text{kPa}^{-1}$     | COEFFICIENT OF VOLUME CHANGE         |
| $C_c$          | 1                     | COMPRESSION INDEX                    |
| $C_s$          | 1                     | SWELLING INDEX                       |
| $C_\alpha$     | 1                     | RATE OF SECONDARY CONSOLIDATION      |
| $c_v$          | $\text{m}^2/\text{s}$ | COEFFICIENT OF CONSOLIDATION         |
| H              | m                     | DRAINAGE PATH                        |
| $T_v$          | 1                     | TIME FACTOR                          |
| U              | %                     | DEGREE OF CONSOLIDATION              |
| $\sigma'_{v0}$ | kPa                   | EFFECTIVE OVERBURDEN PRESSURE        |
| $\sigma'_p$    | kPa                   | PRECONSOLIDATION PRESSURE            |
| $\tau_f$       | kPa                   | SHEAR STRENGTH                       |
| $c'$           | kPa                   | EFFECTIVE COHESION INTERCEPT         |
| $\phi'$        | -°                    | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| $c_u$          | kPa                   | APPARENT COHESION INTERCEPT          |
| $\phi_u$       | -°                    | APPARENT ANGLE OF INTERNAL FRICTION  |
| $\tau_R$       | kPa                   | RESIDUAL SHEAR STRENGTH              |
| $\tau_r$       | kPa                   | REMOULDED SHEAR STRENGTH             |
| $S_t$          | 1                     | SENSITIVITY = $\frac{c_u}{\tau_r}$   |

### PHYSICAL PROPERTIES OF SOIL

|                 |                                |           |      |  |           |                       |   |
|-----------------|--------------------------------|-----------|------|--|-----------|-----------------------|---|
| $\text{kg/m}^3$ | DENSITY OF SOLID PARTICLES     | e         | 1, % | VOID RATIO                                 | $e_{min}$ | 1, %                  | VOID RATIO IN DENSEST STATE                             |
| $\text{kg/m}^3$ | UNIT WEIGHT OF SOLID PARTICLES | n         | 1, % | POROSITY                                   | $I_D$     | 1                     | DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$ |
| $\text{kg/m}^3$ | DENSITY OF WATER               | w         | 1, % | WATER CONTENT                              | D         | mm                    | GRAIN DIAMETER  |
| $\text{kN/m}^3$ | UNIT WEIGHT OF WATER           | $S_r$     | %    | DEGREE OF SATURATION                       | $D_n$     | mm                    | n PERCENT - DIAMETER                                    |
| $\text{kg/m}^3$ | DENSITY OF SOIL                | $w_L$     | %    | LIQUID LIMIT                               | $C_u$     | 1                     | UNIFORMITY COEFFICIENT                                  |
| $\text{kN/m}^3$ | UNIT WEIGHT OF SOIL            | $w_p$     | %    | PLASTIC LIMIT                              | h         | m                     | HYDRAULIC HEAD OR POTENTIAL                             |
| $\text{kg/m}^3$ | DENSITY OF DRY SOIL            | $w_s$     | %    | SHRINKAGE LIMIT                            | q         | $\text{m}^3/\text{s}$ | RATE OF DISCHARGE                                       |
| $\text{kN/m}^3$ | UNIT WEIGHT OF DRY SOIL        | $I_p$     | %    | PLASTICITY INDEX = $\frac{w_L - w_p}{I_p}$ | v         | m/s                   | DISCHARGE VELOCITY                                      |
| $\text{kg/m}^3$ | DENSITY OF SATURATED SOIL      | $I_L$     | 1    | LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$    | i         | 1                     | HYDRAULIC GRADIENT                                      |
| $\text{kN/m}^3$ | UNIT WEIGHT OF SATURATED SOIL  | $I_C$     | 1    | CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$  | k         | m/s                   | HYDRAULIC CONDUCTIVITY                                  |
| $\text{kg/m}^3$ | DENSITY OF SUBMERGED SOIL      |           |      |  | j         | $\text{kn/m}^2$       | SEEPAGE FORCE   |
| $\text{kN/m}^3$ | UNIT WEIGHT OF SUBMERGED SOIL  | $e_{max}$ | 1, % | VOID RATIO IN LOOSEST STATE                |           |                       |   |



RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+025 o/s 23 m Lt. of Centerline Hwy. 17 ORIGINATED BY M.M.  
DIST 19 HWY 17 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Core COMPILED BY M.M.  
DATUM Geodetic DATE 93 04 01 CHECKED BY T.K.

| SOIL PROFILE  |  | SAMPLES       |        |      | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                 | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
|---------------|--|---------------|--------|------|----------------------------|--------------------|---|-----------------|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT<br>PLOT | NUMBER | TYPE | 'N' VALUES                 |                    | 20 40 60 80 100                             | 20 40 60 80 100 |                                    |                                     |                                   |  |  |
| 184.7         | Ground Surface - Wet Swamp   |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
| 0.0           | Organics Trace Sand<br>Dark Brown<br>Brown   |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
|               | Some Gravel<br>Some Sand   |               | 1      | SS   | 3                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 2      | SS   | 6                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 3      | SS   | 4                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 4      | SS   | 1                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 5      | SS   | 1                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               | Silty Clay<br>Soft to Stiff  |               | 6      | TW   | PH                         |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 7      | SS   | 1                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 8      | SS   | 3                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 9      | SS   | 3                          |                    |   |                 |                                    |                                     |                                   |  |  |
|               |  |               | 10     | SS   | 2                          |                    |   |                 |                                    |                                     |                                   |  |  |
| 184.6         | Brown  |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
| 10.1          | Red/Grey   |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
|               | Heterogeneous Mixture of<br>Silt, Sand and Gravel<br>Trace Clay<br>Red/Grey<br>Very Dense                  |               | 11     | SS   | 79                         |                    |   |                 |                                    |                                     |                                   |  |  |
| 183.1         | Red/Grey   |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
| 11.6          | Reddish Brown to Greenish Grey   |               | 12     | RC   | REC<br>58%                 |                    |   |                 |                                    |                                     |                                   |  |  |
|               | Bedrock<br>Conglomerate<br>Fine to Coarse Grained<br>Medium Strong<br>Unweathered to Slightly<br>Weathered |               | 13     | RC   | REC<br>100%                |                    |   |                 |                                    |                                     |                                   |  |  |
| 181.5         |  |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |
| 13.2          | End of Borehole  |               |        |      |                            |                    |   |                 |                                    |                                     |                                   |  |  |



## RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+050 a/s 23 m Lt. of Centerline Hwy. 17 ORIGINATED BY M.M.  
DIST 19 HWY 17 BOREHOLE TYPE Cone Penetration Test COMPILED BY M.M.  
DATUM Geodetic DATE 93 04 02 CHECKED BY T.K.

[illegible]

**+3, x5: Numbers refer to Sensitivity**

20  
15-5 (%) STRAIN AT FAILURE  
10



# RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+075 o/s 23 m Lt. of Centerline Hwy. 17 ORIGINATED BY M.M.  
DIST 19 HWY 17 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Core & Cone Test COMPILED BY M.M.  
DATUM Geodetic DATE 93 04 01 CHECKED BY T.K.

| SOIL PROFILE  |                                |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | PLASTIC<br>LIMIT<br>W <sub>P</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|--------------------------------|------------|---------|------|------------|----------------------------|--------------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV<br>DEPTH | DESCRIPTION                    | STRAT PLOT | NUMBER  | TYPE | 'N' VALUES |                            |                    | 20  | 40 | 60 | 80 | 100 |                                    |                                     |                                   |                     |   |
| 194.6         | Water Surface                  |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 0.0           |                                |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 194.0         | Swamp Bed                      |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 0.6           | Organics Dark Brown Brown      |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 1       | SS   | 8          |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 2       | SS   | 8          |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 3       | SS   | 5          |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 4       | SS   | 6          |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 5       | SS   | 7          |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 6       | TW   | PH         |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 7       | SS   | 90         | /5cm                       |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 187.9         | Some Gravel, Some Sand         |            | 8       | SS   | 90         | /10cm                      |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 6.7           | Reddish Brown to Greenish Grey |            | 9       | RC   | REC 100%   |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 10      | RC   | REC 100%   |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
|               |                                |            | 11      | RC   | REC 97%    |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 184.9         | End of Borehole                |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |
| 9.7           |                                |            |         |      |            |                            |                    |   |    |    |    |     |                                    |                                     |                                   |                     |   |

+3, x5: Numbers refer to 20  
Sensitivity 15-5 (%) STRAIN AT FAILURE  
10



# **ROCK CORE DESCRIPTION** **WP 909-76-01(B)**

Page 1 of 1

| CORE RECOVERY |     |              |          |           | CORE DESCRIPTION |   |
|---------------|-----|--------------|----------|-----------|------------------|---|
| BH#           | RC# | DEPTH<br>(m) | %<br>CR* | %<br>RQD* | DEPTH<br>(m)     | DESCRIPTION   |
| 1             | 12  | 11.58-11.89  | 58       | 58        | 11.58-13.18      | CONGLOMERATE, dark reddish brown to greenish grey matrix; fine to coarse grained; medium strong; unweathered to slightly weathered; fractures moderate to extremely close spaced, dipping to flat, undulating to planar, smooth to rough.       |
|               | 13  | 11.89-13.18  | 100      | 96        |                  |   |
| 3             | 9   | 6.10-6.63    | 100      | 76        | 6.10-9.14        | CONGLOMERATE, dark reddish brown to light brown to greenish grey matrix; fine to coarse grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, dipping to flat, undulating to planar, smooth to rough. |
|               | 10  | 6.63-8.21    | 100      | 95        |                  |   |
|               | 11  | 8.21-9.14    | 97       | 95        |                  |   |

\*CR = CORE RECOVERY

\*RQD = ROCK QUALITY DESIGNATION

Note: Depths are approximated where core recovery is less than 100%  
 Logged by: DAW, Soils and Aggregates Section



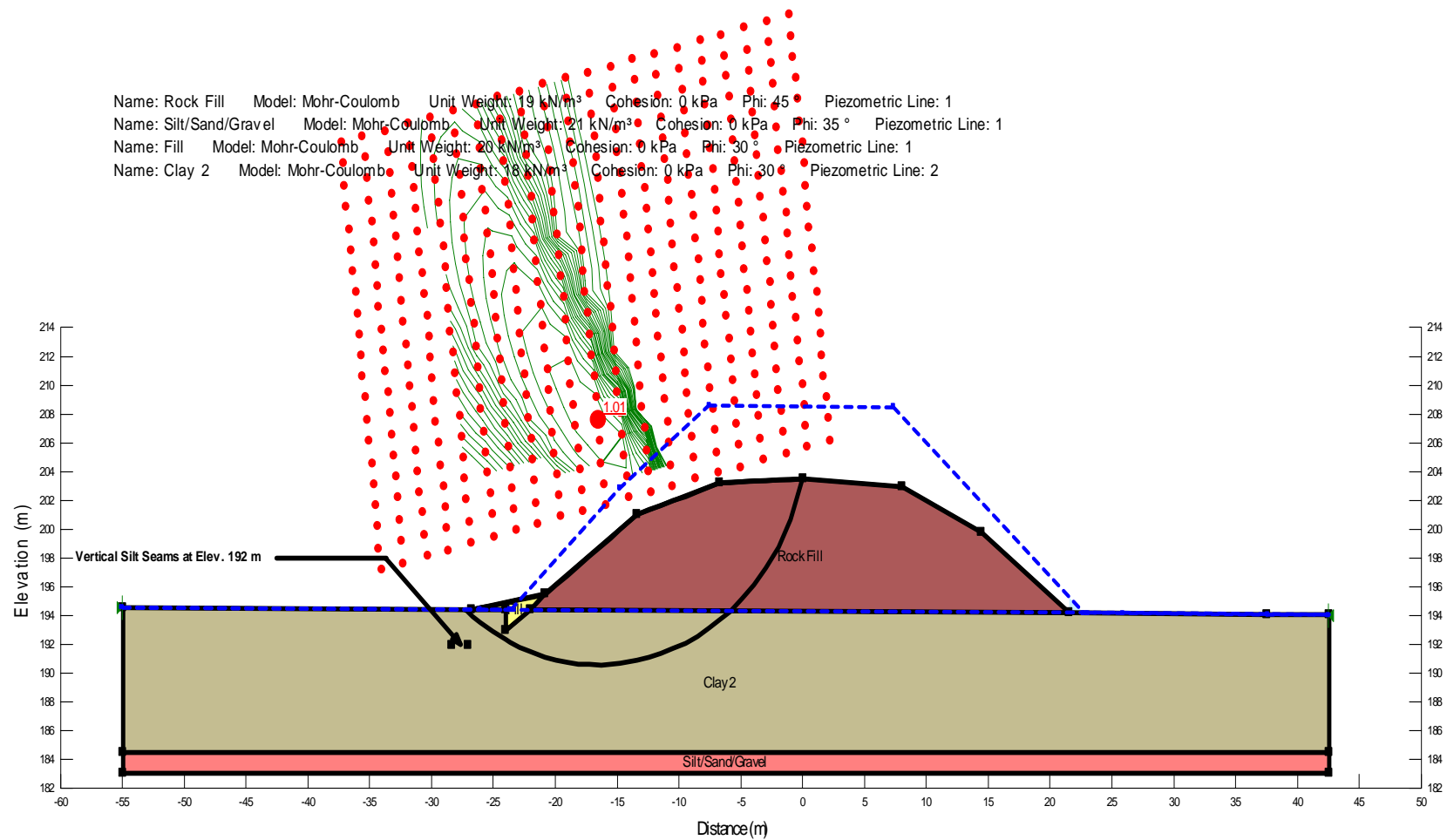
## **APPENDIX E**

### Slope Stability Analyses



Name: Station 10+040 - Drained  
Method: Morgenstern-Price  
FOS: 1.01

### Analyses of Original Construction - End of Embankment Construction

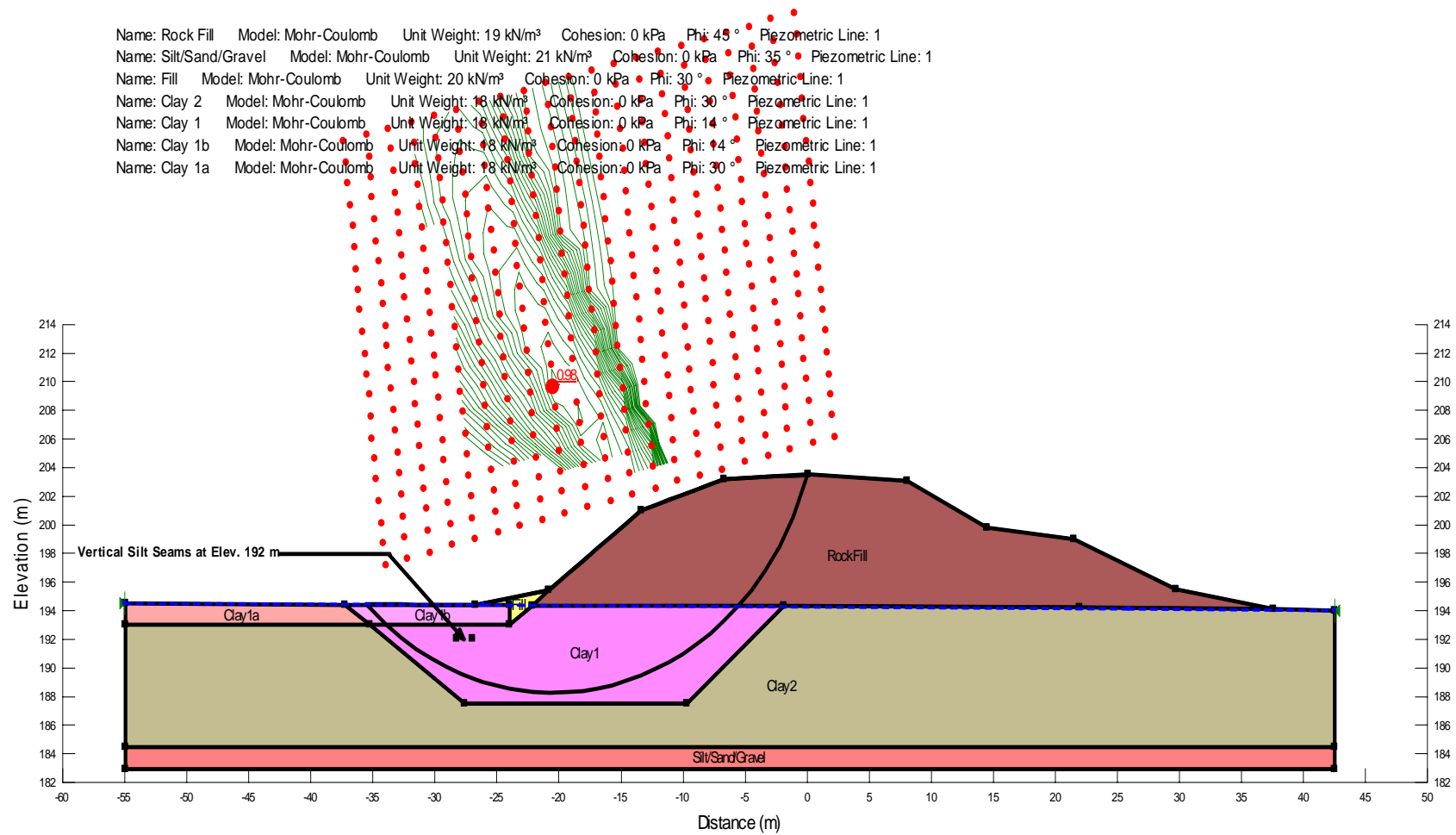


Effective Stress Analysis: Peak Angle of Internal Friction for clay foundations,  $\phi' = 30^\circ$



Name: Station 10+040 - Drained  
Method: Morgenstern-Price  
FOS: 0.98

### Back Analyses - Existing Conditions

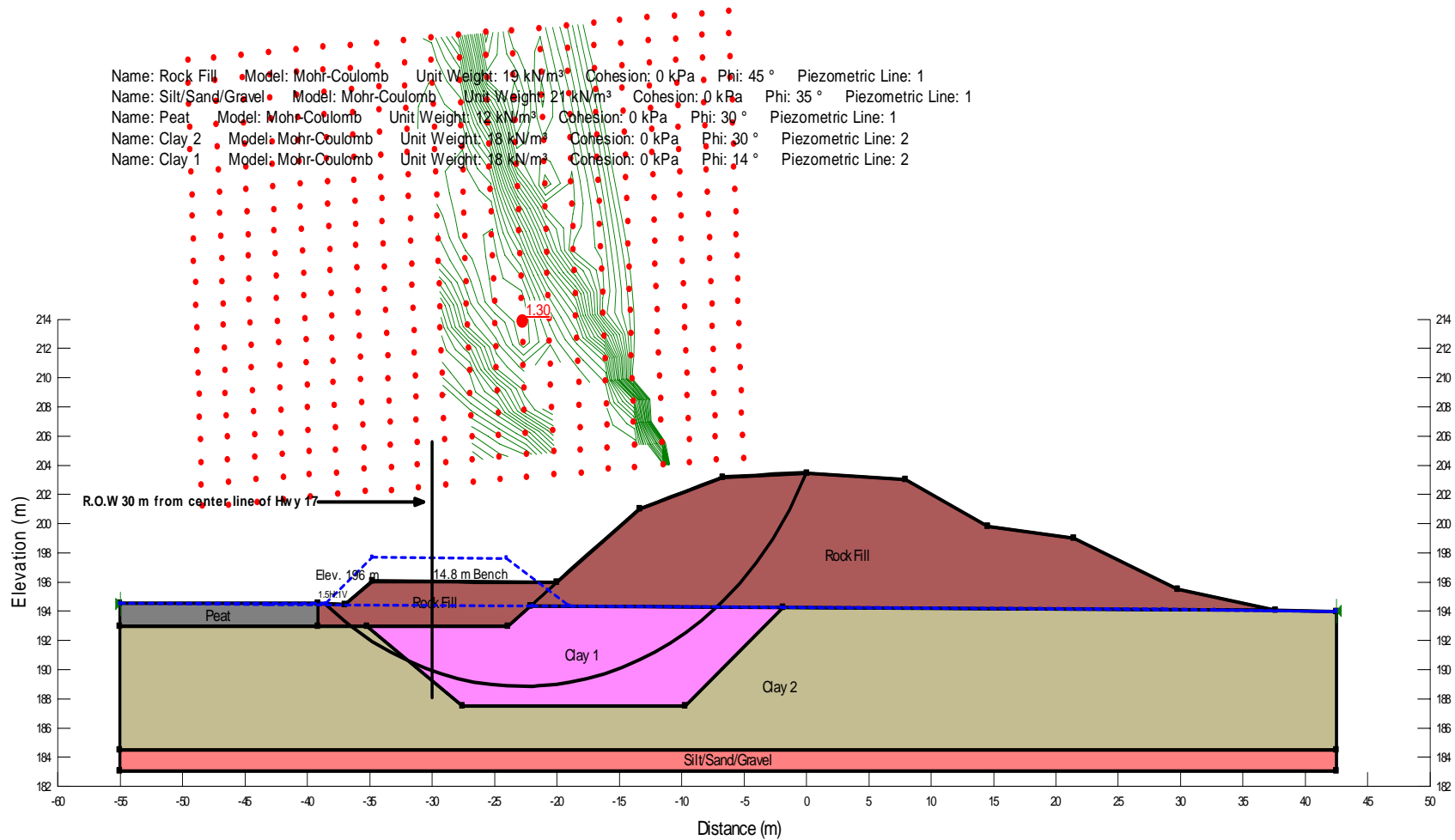


Effective Stress Analysis: Peak Internal Friction  $\phi' = 30^\circ$  Residual Angle of Internal Friction for clay foundation,  $\phi' = 14^\circ$



Name: Station 10+040 - Drained  
Method: Morgenstern-Price  
FOS: 1.30

Berm at Elev. 196 m - Effective Stress Analyses - End of Berm Construction

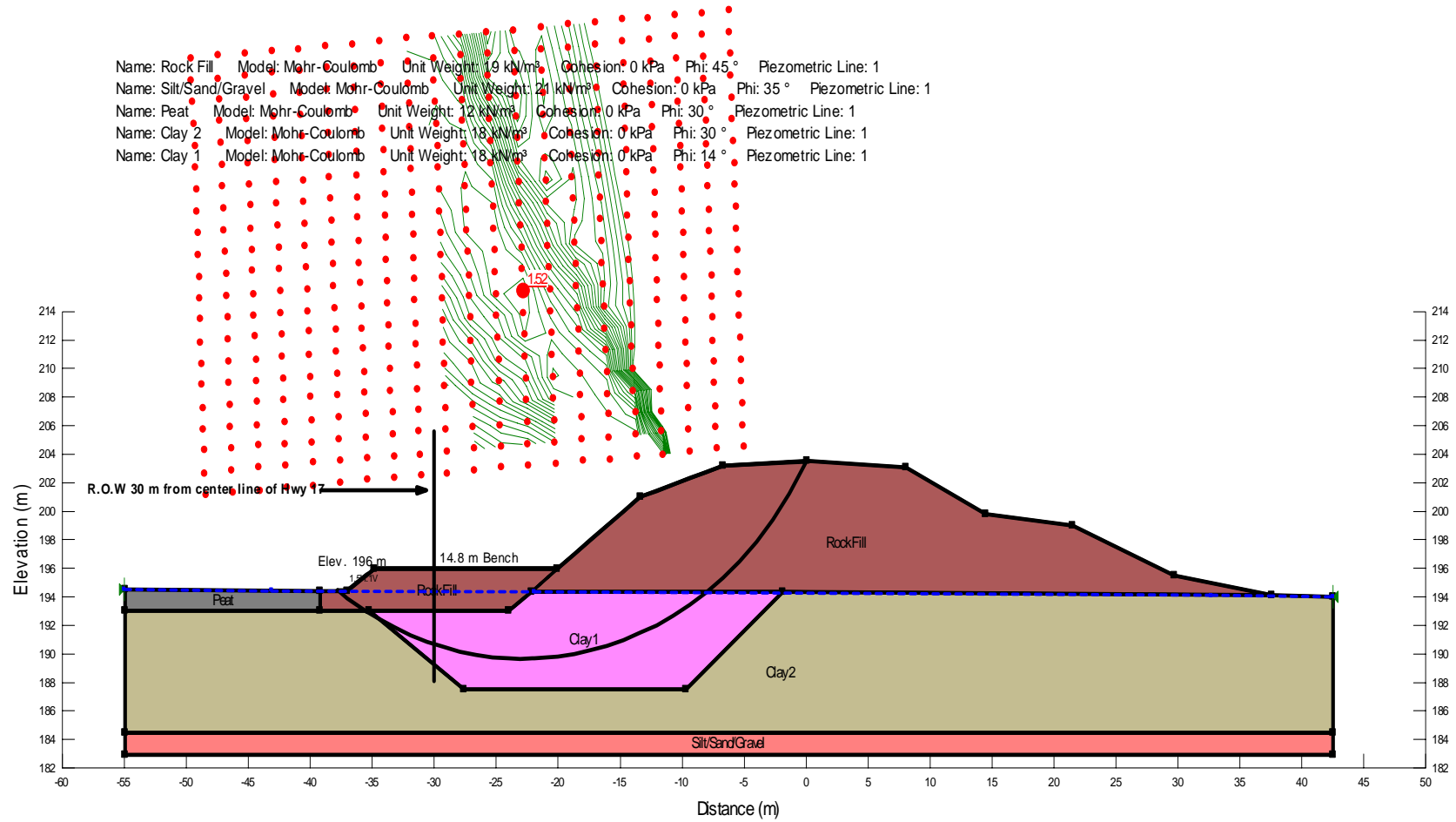


Effective Stress Analysis: Peak Internal Friction  $\phi' = 30^0$  Residual Angle of Internal Friction for clay foundation,  $\phi' = 14^0$



Name: Station 10+040 - Drained  
Method: Morgenstern-Price  
FOS: 1.52

Berm at Elev. 196 m - Effective Stress Analyses - Long Term Conditions



Effective Stress Analysis: Peak Internal Friction  $\phi' = 30^\circ$  Residual Angle of Internal Friction for clay foundation,  $\phi' = 14^\circ$