Foundation Investigation and Design Report

Culvert Replacement at Samuel Creek

GWP 146-98-00

Highway 11
25 km west of Hearst, Ontario

Site No.: 39W-130/C
Geocres No.: 42F-16

Prepared for:

Engineering Northwest Ltd.
200 South Syndicate Avenue
Thunder Bay, Ontario
P7E 1E9

Prepared By:

TBT Engineering
Thunder Bay Testing & Engineering Limited
314-101 Syndicate Ave. N
Thunder Bay, ON., P7C 3V4

August 10, 2006

Ref. No. 05-101

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Part A FOUNDATION INVESTIGATION REPORT

1 Introduction

TBT Engineering has been retained by Engineering Northwest Ltd. to carry out a Foundation Investigation for the replacement of Samuel Creek Culvert at Hwy 11, in the District of Cochrane and Township of Studholme.

The site is located on Highway 11, approximately 25 km west of Hearst.

A foundation investigation was carried out to investigate subsurface conditions at the site. This investigation consisted of a number of boreholes drilled in the vicinity of the proposed new structure location, laboratory testing and geotechnical analysis of the data. This report provides a summary of that work and of the conditions encountered.

The foundation section has assigned GEOCRES No. 42F-16 to this site.

2 Site Description

The site is located on Highway 11, approximately 25 km west of Hearst. At this location Highway 11 runs generally in an east-west direction. Samuel Creek crosses the highway generally in a north-south direction and flows to the south. The existing culvert consists of a 3.00 X 1.92, 33.8 m long Concrete Box Culvert.

The area surrounding the culvert site consists of low lying terrain within the creek flood plane with grassy vegetation and shrubbery. Beyond the floodplain spruce trees were noted.

The creek and its flood plain are about 3 m below the current road grade. The creek width is the order of 2 m. At the culvert inverts, the visible creek bed consists of coarse sands and gravels. The water level in the creek was approximately at elevation 250.6 m at the time of this investigation.

The mapped surficial geology based on The surficial geology for the area is mapped as a zone of ground moraine consisting of clay till with subordinate terrain units consisting of either rock knob and/or organic terrain. In general, the clay till is underlain by varved clay and silt. (1 - Northern Ontario Engineering Geology Terrain Study 30)

The topography is generally of low local relief areas of plains and undulating to rolling terrain.

The road embankment is about 3 metres high with fore slopes varying from 4 h:1v to 5 h:1v.

South Side of Samuel Creek Culvert, Looking North-West (downstream side)

North Side of Samuel Creek Culvert, Looking North (upstream side)

3 Investigation Procedures

A site investigation was undertaken in two phases between November 6, 2005 and April 29, 2006. Various investigation techniques were used depending on the conditions encountered. Both a truck mounted CME 55 and a track mounted Star100 drill rig were used for geotechnical sampling and testing. A total of 5 boreholes were completed to depths varying between 15 and 21 m below grade.

Soil samples were obtained at the boreholes with 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, known as the SPT blow count (N), was recorded. In addition, field vane testing and relatively undisturbed thin walled tube sampling was carried out at selected depths within clay soils.

Borehole locations were referenced in the field and ground surface elevations were surveyed and referenced to BM 525.764, top of "T" Rail, 56.5 RT, 18+722.4 (Reference: Horizontal & Vertical Control, Plate No. 847-11 / 30-0, CONT NO 90-235, WP NO 318-85-00, Sheet 44).

The borehole characteristics and drill techniques utilized are summarized in Table 1.

Table 1. Drill Summary

Location	Surface Elevation (metres)	Bedrock / Refusal (Elevation/Depth) (metres)	Bottom of Hole (Elevation/Depth) (metres)	Comments
BH 1	253.9	N/A	233.2 / 20.7	Casing used to advance hole beyond 13 m
BH 2	252.6	N/A	236.7 / 15.9	
BH 3	254.0	N/A	238.2 / 15.9	
BH 4	252.1	N/A	236.9 / 15.2	
BH 5	253.7	N/A	237.8 / 15.9	

The boreholes were backfilled at the completion of the investigations using a cement/bentonite backfill to ensure the environmental integrity of the site.
Soil samples were transported to TBT Engineering's laboratory in Thunder Bay for testing. Routine testing included moisture content, grain size analysis and Atterberg Limits. The results of this testing are shown on the Borehole Logs (Appendix A) and on the laboratory data reports (Appendix B). In addition, two consolidation tests were carried out on selected thin walled tube samples. The results of this testing has been included in Appendix B.

4 General Site Geology and Sub-Surface Conditions

4.1 Site Geology

The surficial geology of the area consists predominantly of clay till ground moraine with subordinate land forms consisting of rock knob and organic terrain. The clay till is generally underlain with varved clay and silt. The varved clay and silt deposit was identified through the field investigation carried out at this site. It is likely that the upper clay till is not present within the localized flood plain of the creek.

4.2 Subsurface Conditions

Details of the subsurface conditions are provided on the Borehole Logs, Appendix A, and on the Section Plans, Drawing 1. In general, the subsurface stratigraphy consists of variable fills and/or organics overlying a stratum of layered silts and clays which is further underlain by a deep silt stratum to the depth of the investigation.

Groundwater levels within the boreholes at the time of drilling were similar to the level of the Samuel Creek at the time of the investigation.

4.2.1 Fill

Fill was encountered at Boreholes 1, 3 and 5 which were put down within the shoulders and fore slopes of the highway embankment. The fill is variable and consists of either sands with trace gravel, silt, clay with trace sand and gravel. At the borehole locations, the fill was found to vary from 1.3 to 2.1 m in thickness and generally extends to elevations of 252.0 to 252.5 m. The granular fill was generally found to be in a very loose condition, or have of stiff consistency in the case of cohesive soils..

The pavement investigation boreholes for this project encountered fills consisting of sands and gravels with variable proportions of silt to depths of approximately 3.6 -3.9 m (elevation 251.4- 251.2 m) below the paved road surface.

4.2.2 Peat

Peat was encountered below the fill at Boreholes 3 and 5. The sample of peat at Borehole 3 contained silt. The thickness of the peat layer was approximately 0.3 m. The natural moisture content varied from 53 to 255 %.

4.2.3 Silt / Clay - Layered

An upper stratum of layered silts and clays was found to vary from about 3.5 to 5 m in thickness and extends to elevations of 246.9 to 248.9 m. This stratum extends approximately 1.4 to 3.4 m below the invert of the existing culvert (250.27 m). The alternating layers of silts and clays were observed to vary in thickness from 10 to over 600 mm. The clay layers are soft to stiff while the silt layers vary from very loose to compact. SPT "N" values varied from 3 to 19 blows / 0.3 m. Field vane testing results varied from 20 to 55 kPa. Shear strength sensitivities as indicated by field vane testing varied from 2 to 4.

Atterberg limit testing (Appendix B, Enclosure 1) carried indicate the silt layers are non-cohesive while the clay layers were found to vary from medium to high plastic. The natural moisture content of the clay layers exceeds the liquid limit.

Grainsize analyses carried out on selected silt layers (Appendix B, Enclosure 2) indicates the silt layers contain from 1 to 26 % sand and from 12 to 20 % clay sized particles. This material is considered to be susceptible to frost heave.

Consolidation testing (Appendix B, Enclosures 5 and 6) carried out on clay layers within this stratum indicate the clay is normally consolidated. Within the anticipated design stress range, the volume compressibility (m_v) varies from $6.7x10^{-4}$ to $8.3x10^{-4}$ m^2/kN ($1/m_v$ = 1.2 to 1.5 MPa).

Based on grain size analyses, the hydraulic conductivity of the silt layers has been estimated to be 10^{-5} cm/sec or less. Based on consolidation testing, the hydraulic conductivity of the clay layers is less than 10^{-6} cm/sec.

4.2.4 Sand

A 0.3 m thick sand layer with some silt was encountered below the above noted layered clays and silts at Borehole 4. The hydraulic conductivity of this sand layer is estimated to be in the order of 10^{-2} to 10^{-3} cm/sec.

4.2.5 Silt

The lower silt stratum was found to start at elevation 246.9 to 248.9 m and is in a compact to very dense condition as indicated by SPT "N" values of 11 to 77 blows / 0.3 m.

Grainsize analyses carried out on selected samples of this stratum (Appendix B, Enclosures 3 and 4) indicates the gravel content varies from 0 to 6 %, the sand content varies from 2 to 32 %, the silt content varies from 52 to 92%, and there is 3 to 13 % clay sized particles. The hydraulic conductivity has been estimated to be 10^{-5} cm/sec or less. This material is considered to be susceptible to frost heave.

4.2.6 Ground Water

The ground water levels observed were generally at or above (within 1 m) of the water levels within the Samuel Creek at the time of the investigation (Elevation 250.6 m).

5 Miscellaneous

The field drilling services for this project were provided by TBT Engineering. Laboratory testing was carried out at the TBT Engineering laboratory in Thunder Bay. The field operations were supervised by T. Dupuis, rcji. This report was prepared by G. Maki, P.Eng. and reviewed by W. Hurley, P.Eng.

PART B FOUNDATION DESIGN RECOMMENDATIONS

6 Discussions and Engineering Recommendations

6.1 Introduction

The existing culvert\ at Samuel Creek, across Highway 11 is to be replaced. The new culvert is now anticipated to be an open footing concrete, or steel multi-plate structure with a span of approximately 5.5 m and a rise of 3 m above the footings. The design of the culvert will be conducted in accordance with the Canadian Highway Bridge Design Code (CHBDC).

The horizontal and vertical alignment of the Highway will remain essentially unchanged. It is also understood that the approach embankments will be restored to the current configuration upon completion of construction.

The foundation investigation as described in Part A, was carried out to investigate subsurface conditions at the site. This investigation consisted of a number of boreholes advanced in the vicinity of the new structure, laboratory testing and geotechnical analysis of the data. The purpose of this section of the report (Part B) is to provide geotechnical design recommendations for the project. These are based on the conditions encountered at the test locations and our interpretation of the subsurface conditions at the site.

6.2 Culvert Foundations

The foundation system for the proposed structure must support the design loads within acceptable settlement tolerances and must accommodate all anticipated loadings. The soil conditions at this site include variable fills and/or organics overlying a stratum of layered silts and clays which is further underlain by a deep silt stratum.

The design configuration involves the use of an open bottom culvert structure. Various foundation options were reviewed during the design process. The use of shallow foundations founded within the upper weak/compressible layered silts and clays was reviewed in addition to footings founded on the lower compact to dense silt stratum.

Given the design frost depth of 2.6 m and the low bearing capacity and poor settlement performance for footings founded within the upper layered silts and clays, it recommended that structural loads be founded on the lower compact to dense silt stratum. A cross section prepared by Hatch Mott MacDonald (Structural Designers) illustrating the proposed foundation configuration has been included (Appendix “C”). The proposed foundation elevation is 247.7 m which provides a minimum depth of cover of 2.6 m.

With a proposed foundation (footing) width of 1.5 m, it is understood that the proposed foundation resistances in the order of 200 kPa (ULS) and 100 kPa (SLS) will be required.

The design frost depth for this project is 2.6 m.

6.3 Foundation Design - Culvert

The culvert will be supported by concrete footings founded below the invert level. Footings founded directly on the compact to dense silt stratum, or founded on a granular pad extending to the compact to dense silt stratum may be designed using the capacities shown in Table 3.

Table 3, Strip Footing Design Capacities

Strip Footings	Min. Depth of Cover (m)	Footing Width (m)	Factored Geotechnical Resistance At ULS (kPa)	Design Capacity at SLS (kPa) for 25 and 50 mm settlement	
				25 mm	50 mm
Founded on compact to dense silt stratum with, or without granular pad	1.5	0.6–0.9	185	185	> 185
		1.0-1.5	205	110	> 205
Founded on compact to dense silt stratum with, or without granular pad	2.6	0.6–0.9	300	185	> 300
		1.0-1.5	320	110	> 320

Where a granular pad is considered, it may be constructed using either Granular “B”, Type III, fill compacted to 95% of standard Proctor maximum dry density, or “self compacting” 19 mm clear stone completely wrapped with a heavy non-woven geotextile. The base of the pad should extend beyond the edge of footing a distance equal to the thickness of fill placed below the footing. Alternatively, the zone between the bottom of the footing and the top of the compact to dense silt may be filled using lean concrete.

6.4 Soil Backfill

Design of the Samuel Creek culvert is to be carried out by the designer. Construction shall conform to the supplier's requirements, where applicable. Fill placed outside of the culvert should be sloped using a frost taper, with d=450 mm and f=2.6 m (similar to frost taper shown on OPSD 3501.000).

Design unit weights for granular backfill are applicable as follows:

Granular A	22 kN/m3
Granular B (Type III)	21 kN/m3

Backfill behind the culvert must be free draining. The fill may be specified as Granular A or Granular B, Type III depending on the culvert supplier's requirements.

6.5 Embankment Stability- Longitudinal

Global stability of the culvert was completed using SLOPE/W software (GeoStudio 2004 by Geo-Slope International Ltd.). The Morgenstern-Price method of analysis was used with a half sine function for distribution of inter-slice shear forces which satisfies both moment and force equilibrium. For the geometry assessed, the software computes numerous possible slip surfaces with the associated factor of safety to identify the slip surface with the lowest calculated factor of safety.

The inclusion of an open bottom structure within the highway embankment has a potential to induce soil failures into the base of the channel. The primary driving force of the failure is the weight of the embankment fill adjacent to and above the culvert. The driving forces must be resisted by the mobilized shear strength of the embankment fill and base materials. The culvert provides limited lateral support.

Stability analyses were carried out utilizing both un-drained soil strength parameters and drained soil strength parameters. The design soil properties were derived through in-situ field testing, laboratory testing and correlations were applicable. The parameters listed in Table 4 were used for the stability analyses.

Table 4- Soil Parameters used in Stability Analyses

Soil	Unit Weight (kN/m³)	Un-drained Analysis (kPa) φ = 0	Drained Analysis c'=0
Existing Embankment Fill	20	-	28°
Silt/Clay Layered	18	20	28°
Silt	18	-	32°
New Construction Fill	20	-	35°

The stability analysis provides a minimum factor of safety of 1.3 for the final configuration of the culvert with foundations extending to a minimum elevation of 247.7 m.

All fill soils used to restore the embankment should consist of Granular A, Granular B, Type III or rock fill. Embankment fill must be placed and compacted in accordance with OPSS requirements.

6.6 Approach Embankments

The final geometry including horizontal and vertical highway alignment is to remain essentially unchanged. As such, no stability or settlement related issues are anticipated.

No camber of the culvert profile is required.

Exposed granular slopes should be seeded to provide protection from erosion and surficial sloughing.

The embankment fill used to restore the roadway to the pavement sub-grade level should consist of Granular A, Granular B, Type III. Above this the pavement fill structure should be placed as per the Geotechnical Design Report.

6.7 Lateral Loadings - Headwalls

Culvert headwalls (if utilized) should be designed to resist lateral loadings induced by backfill adjacent to the walls at appropriate deformation conditions. Backfill should consist of free draining granular materials such as Granular B. Earth pressures may be calculated using the methods provided in Canadian Highway Bridge Design Code, or using a triangular pressure distribution as provided in the Canadian Foundation Engineering Manual and the parameters provided in Table 5. Active soil loadings are appropriate where sufficient deformation of the headwall can occur. For rigid designs, the at-rest condition should be used.

Table 5 - Embankment Soil Parameters (unfactored) Level Backfill

Soil	Active Earth Pressure Coefficient (Ka)	At-Rest Earth Pressure Coefficient (Ko)	Passive Earth Pressure Coefficient (Kp)	Unit Weight (KN/m^3)	Phi (Degrees)
Granular A	0.27	0.43	3.7	22	35
Granular B	0.30	0.46	3.4	21	33

Weeping tile and/or weep holes should be provided to prevent development of hydrostatic pressures behind the abutments. The weep holes should be protected with a granular filter or non-woven geotextile to prevent migration of fines. Positive drainage of the weeping tiles should be provided.

6.8 Staging

Construction staging may be used accommodate highway traffic during construction of the culvert. Stability analyses were carried out to assess suitable slope configurations for staging. Design soils properties used for the stability analyses are provided in Table 4.

The effects of negative porewater pressures from the excavation were conservatively neglected in our analyses. This is due to the unpredictability of estimating the initial negative porewater pressure response and time effects as well as the contractor's schedule.

Based on the results of the stability analyses, temporary fills utilizing compacted Granular B fill compacted to 95% of standard Proctor maximum dry density, may be constructed with slopes of 1.5h:1v, or flatter.

Temporary cuts above the groundwater table are to be sloped at 2.h:1v, or flatter. Due to presence of loose silts, temporary cuts or excavations below the water table are expected to be unstable and subject to excessive sloughing. As such, shoring and/or braced excavation are recommended for cuts and/or excavation below the groundwater level (see Section 5.10).

6.9 Temporary Road Protection

In addition to, or as an alternative to construction staging, the use of temporary road protection may be required for support of the parts of the embankment and/or pavement structure. Details of the temporary road protection are normally the responsibility of the contractor. Special provisions for Temporary Road Protection (539S01) and RSS (599S22) should be reviewed for inclusion in contract documents.

It is anticipated that temporary road protection, if considered, may consist of some form of gravity wall, reinforced earth system, or sheet pile system. The use of conventional sheet piling may be considered as some form of shoring will also be required for excavations below the groundwater level. Due to the presence of very dense silts at depth, heavy driving can be expected for driven sheet piles.

These temporary road protection systems may be designed using the methods provided in the Canadian Highway Bridge Design Code. Lateral loads should include active or at-rest pressures as appropriate for the soil support systems and traffic loadings, embankment configuration and the applicable compaction surcharge. Active loads are appropriate for yielding conditions while at-rest pressures should be used for non-yielding cases. Soil pressure coefficients are provided in Table 7.

Table 7 - Embankment Soil Parameters for Design of Temporary Road Protection (unfactored), Level Backfill

Soil	Active Earth Pressure Coefficient (Ka)	At-Rest Earth Pressure Coefficient (Ko)	Unit Weight (KN/m^3)	Phi
Existing Embankment Granular Fills (drained)	0.40	.53	20	28°
Existing Embankment Clay Fills (drained)	$Pa=\sigma_z'-2\,C_u$	0.6	20	C_u = 30 kPa
Granular A	0.27	0.43	22	35°
Granular B	0.30	0.45	21	33°
Silt/Clay Layered (drained)	0.40	0.53	17(7*)	28°
Silt/Clay Layered (undrained)	$Pa=\sigma_z'-2\,C_u$	0.6	17(7*)	C_u = 20 kPa
Compact to Dense Silt	0.31	0.48	18(8*)	31°

* indicates submerged value

6.10 Temporary Shoring - De-watering

Temporary shoring should be considered for foundation excavations below the groundwater level. It is understood that the existing culvert is to be left in-place during construction, and as such the shoring should be designed to prevent undermining and/or support of the existing culvert.

Temporary shoring should be designed to resist lateral loadings and to minimise deformations. The use of sheet piling and/or anchored or braced shoring may be considered. There may be some use for trench box type retaining systems for some areas of this project, depending on the configurations used. Site-specific design is required.

Due to the presence of very dense silts at depth, heavy driving can be expected for driven piles.

Temporary shoring may be designed using the methods provided in the Canadian Foundation Engineering Manual. The loading configurations will depend on the type of shoring system used. In general, temporary shoring may be designed using the following parameters:

Table 8 - Embankment Soil Parameters for Design of Temporary Shoring (unfactored), Level Backfill

Soil	Active Earth Pressure Coefficient (Ka)	Passive Earth Pressure Coefficient (Kp)	Unit Weight (KN/m^3)	Phi
Existing Embankment Granular Fills (drained)	0.40	2.8	20	28°
Existing Embankment Clay Fills (drained)	$Pa=\sigma_z'-2\ C_u$	$Pp=\sigma_z'+2\ C_u$	20	C_u = 30 kPa
Granular A	0.27	3.7	22	35°
Granular B	0.30	3.4	21	33°
Silt/Clay Layered (drained)	0.40	2.8	17(7*)	28°
Silt/Clay Layered (undrained)	$Pa=\sigma_z'-2\ C_u$	$Pp=\sigma_z'+2\ C_u$	17(7*)	C_u = 20 kPa
Compact to Dense Silt	0.31	3.1	18(8*)	31°

* indicates submerged value

The estimated hydraulic conductivity of the silt soils below the groundwater is generally 10^{-5} cm/sec, or less. However, a sand layer was identified with an estimated hydraulic conductivity in the order of 10^{-2} to 10^{-3} cm/sec. Where sheeting is used, the sheeting should penetrate to a sufficient depth prevent piping of the excavation base during dewatering. Alternatively, or in addition, dewatering in the form of well points and/or relief wells may be considered. The contractor should retain the services of personnel experienced in the design of the shoring and dewatering systems.

6.11 Scour Protection

The footings should be provided with sufficient scour protection to ensure the footings are not undermined and the design minimum depth of cover is maintained. Scour protection should be in accordance with Section 1.10 of the CHBDC.

6.12 Red Flag Issues

As the existing culvert is to be temporarily left in-place to control and maintain the creek flow during construction of the new foundations, special attention to foundation excavation will be require to prevent undermining and destabilization of the existing culvert. The design of sheet piling, braced shoring must consider the stability of the existing culvert.

Excavations within the loose soils below the groundwater table will be subject to sloughing even at flat slope angles. As such, the use of temporary shoring is recommended.

The above comments are not intended to include all critical issues that may become apparent during the construction of this project. The responsibility to deliver acceptable construction quality remains with the contractor.

7 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 design recommendations provided in this report are based on the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

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

Benchmarks and elevations referred to in this report are used primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

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 be 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.

8 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

Prepared by:

Gordon Maki, P.Eng
Manager of Geotechnical Engineering

Reviewed By

Wayne Hurley, P.Eng
Vice-President, Engineering

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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/0.3 m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

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

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

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

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	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_U	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX $= w_L - w_P$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL				k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE			

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No 1

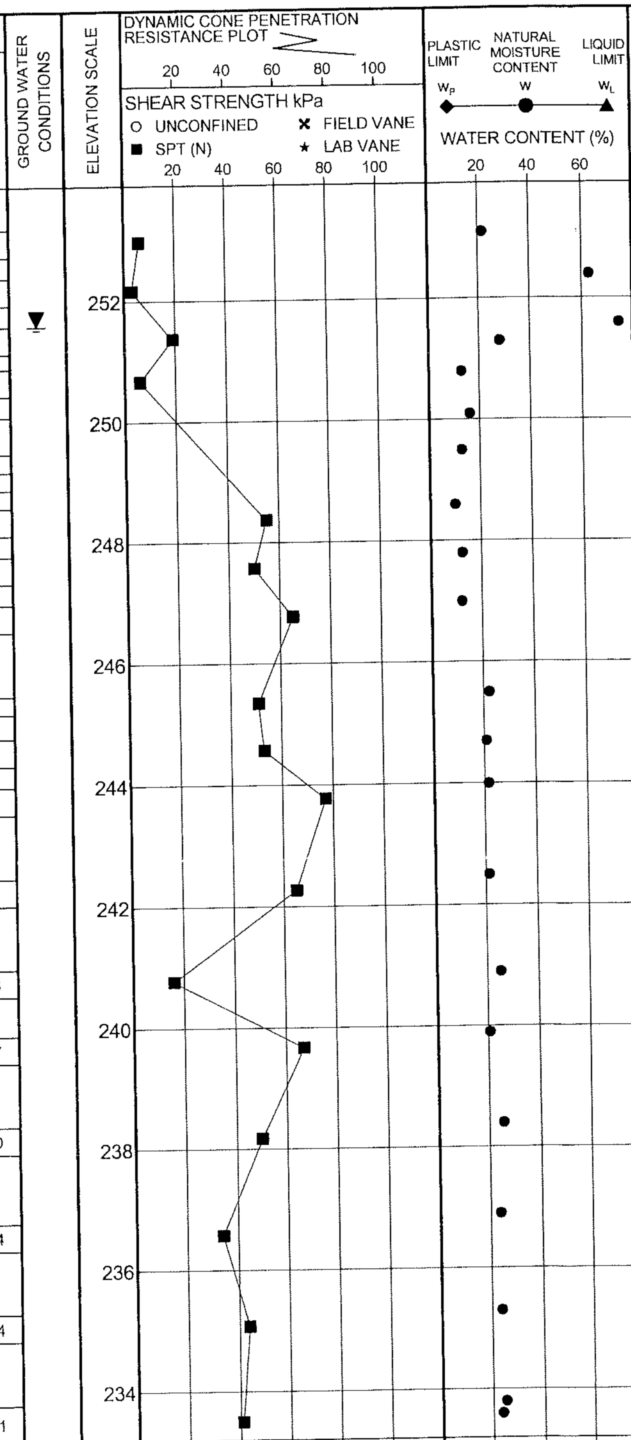
METRIC

W.P. **GWP 146-98-00** LOCATION **Samuel Creek Sta 18+719 8.8m RT, Twp Studhome** ORIGINATED BY **T.D.**

DIST **Cochrane** HWY **11** BOREHOLE TYPE **HSA/N Casing** COMPILED BY **T.B.**

DATUM **Geodetic** DATE **06/11/2005** CHECKED BY **G.M.**

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
253.9 / 0.0	- 150mm TOPSOIL FILL - CLAY - Silty, trace sand & gravel, trace organics, brown, firm	1	SS	6	
252.4 / 1.5	SILT/CLAY - layered, trace sand to Sandy, grey/brown, layers from 10 to 60 mm, very loose /soft to compact/firm	2	SS	3	
		3	SS	19	
		4	SS	6	
		5	TW		
		6	VANE		
248.9 / 5.0	SILT - trace sand to Sandy, trace clay, occasional cobbles, grey, moist, compact to very dense				0 30 60 10
		7	SS	55	
		8	SS	50	
		9	SS	65	
		10	SS	51	0 2 92 6
		11	SS	53	
		12	SS	77	
		13	SS	65	
		14	SS	16	
		15	SS	67	
		16	SS	50	
		17	SS	34	
		18	SS	44	
		19	SS	41	
233.2 / 20.7	End of Borehole @ 20.7m below grade.				



UNIT WEIGHT γ kN/m³

$\times^3, \star^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

ON_MOT_BH LOG 2 05-101-1.GPJ ON_MOT.GDT 8/10/06

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 2

METRIC

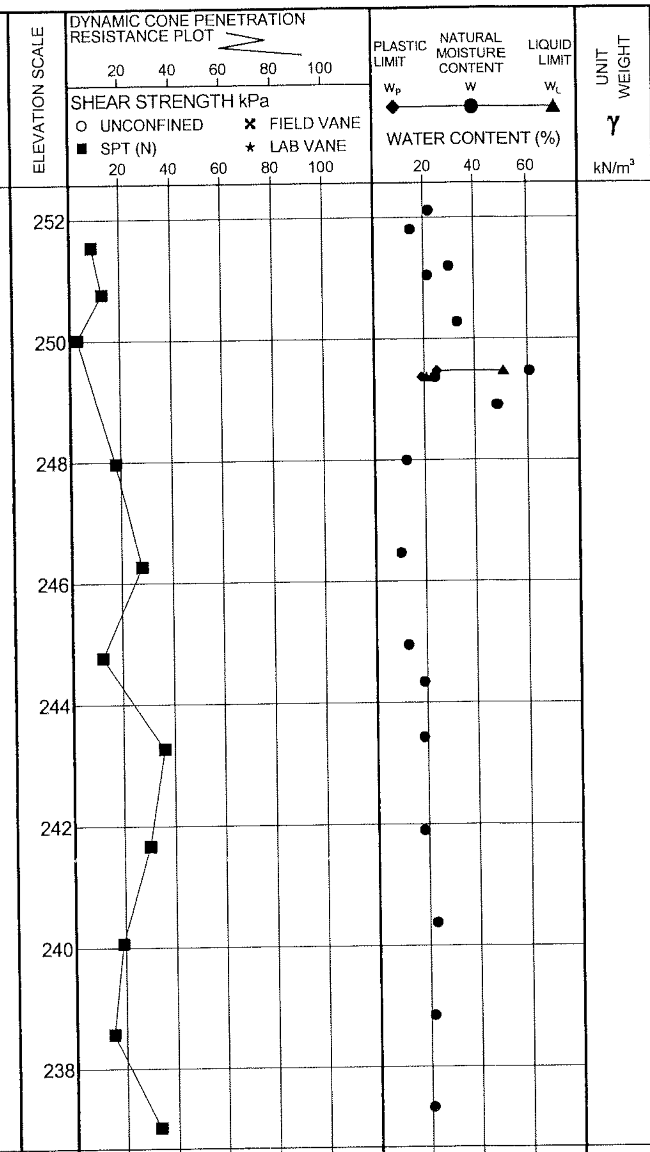
TBT Engineering

W.P. **GWP 146-98-00** LOCATION **Samuel Creek Sta 18+742 16.3m RT, Twp Studhome** ORIGINATED BY **T.D.**

DIST **Cochrane** HWY **11** BOREHOLE TYPE **HSA/N Casing** COMPILED BY **T.B.**

DATUM **Geodetic** DATE **27/04/2006** CHECKED BY **G.M.**

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
252.6 / 0.0	- 150 mm TOPSOIL SILT/CLAY - layered, trace sand to Sandy, grey/brown, layers from 10 to 60 mm, very loose /soft to compact/stiff, trace to some organics within upper 2.1 m	1	AS		
		2	SS	9	
		3	SS	13	
		4	SS	3	
		5	TW		
			VANE		
248.3 / 4.3	SILT - trace sand to Sandy, trace clay, occasional cobbles, grey, moist, compact to very dense	6	SS	18	6 32 53 10
		7	SS	28	
		8	SS	12	
		9	SS	36	
		10	SS	30	
		11	SS	19	
		12	SS	15	0 5 91 4
		13	SS	33	
236.7 / 15.9	End of Borehole @ 15.9m below grade.				



×3, ★3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

TBT Engineering

RECORD OF BOREHOLE No 3

METRIC

W.P. GWP 146-98-00	LOCATION Samuel Creek Sta 18+744 9.8m RT, Twp Studhome		ORIGINATED BY T.D.
DIST Cochrane HWY 11	BOREHOLE TYPE HSA/N Casing		COMPILED BY T.B.
DATUM Geodetic	DATE 27/04/2006		CHECKED BY G.M.

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
254.0 / 0.0	- 150 mm TOPSOIL FILL - SAND - some gravel, trace silt, brown - - - - - - SILT - trace sand, brown, loose
251.9 / 2.1	PEAT - some silt, black
251.6 / 2.4	SILT/CLAY - layered, trace sand to Sandy, grey/brown, layers from 10 to 60 mm, very loose /soft to compact/firm, trace organics within upper 0.3m
246.9 / 7.1	SILT - trace sand to Sandy, trace clay, occasional cobbles, grey, moist, compact to very dense
238.1 / 15.9	End of Borehole @ 15.9m below grade.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	AS	
2	SS	3
3	SS	3
4	SS	3
5	SS	13
6	SS	3
7	TW	
	VANE	
8	SS	5
9	SS	33
10	SS	11
11	SS	41
12	SS	46
13	SS	44

GROUND WATER CONDITIONS: water level symbol at approx. elevation 252

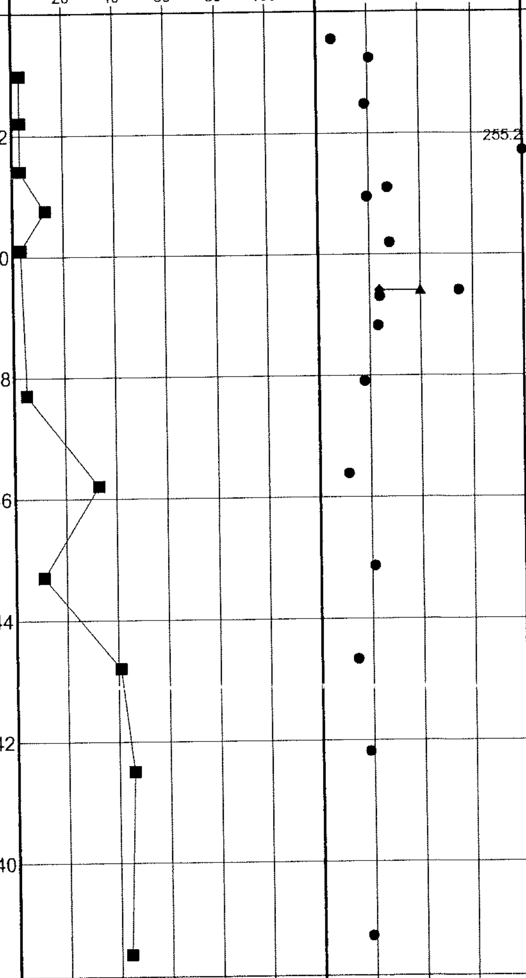
ELEVATION SCALE: 252, 250, 248, 246, 244, 242, 240

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)

SHEAR STRENGTH kPa: O UNCONFINED; ✖ FIELD VANE; ■ SPT (N); ★ LAB VANE (20, 40, 60, 80, 100)

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%) (20, 40, 60)



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Sample	GR	SA	SI	CL
7	0	1	86	13
12	0	8	88	4

✖ 3, ★ 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Ministry of Transportation
Ontario

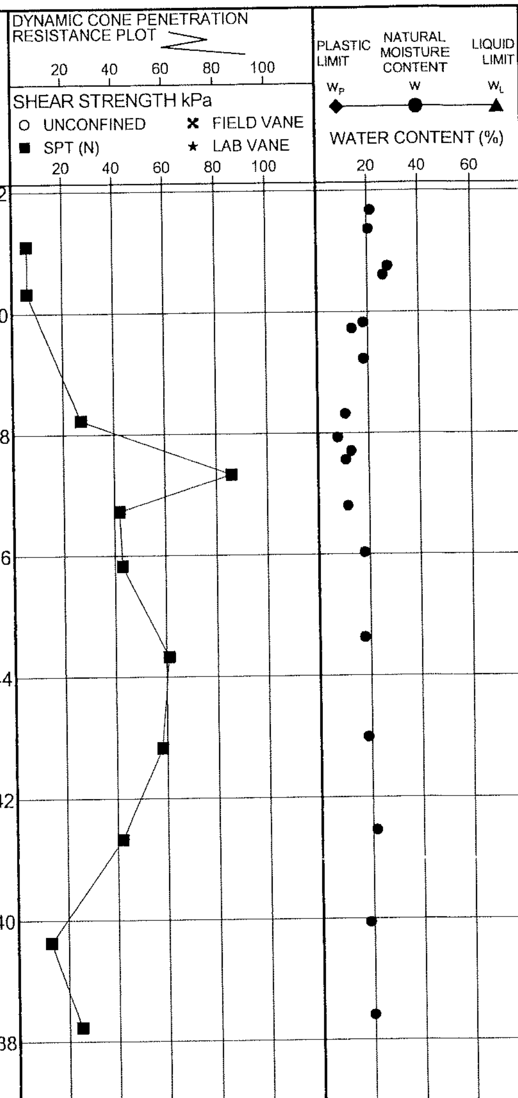
TBT Engineering

RECORD OF BOREHOLE No 4

METRIC

W.P.	GWP 146-98-00	LOCATION	Samuel Creek Sta 18+724 18.0m LT, Twp Studhome	ORIGINATED BY	T.D.
DIST	Cochrane HWY 11	BOREHOLE TYPE	HSA/N Casing	COMPILED BY	T.B.
DATUM	Geodetic	DATE	28/04/2006	CHECKED BY	G.M.

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
252.1 / 0.0	- 150 mm TOPSOIL SILT/CLAY - layered, trace sand to Sandy, grey/brown, layers from 10 to 60 mm, loose/firm, trace organics within upper 2 m	1	AS		
		2	SS	6	
		3	SS	6	
		4	TW		0 26 63 11
			VANE		
248.4 / 248.2	SAND - some silt, grey	5	SS	27	
4.0	SILT - trace sand to Sandy, trace clay, occasional cobbles, grey, moist, compact to very dense				4 27 57 12
		6	SS	86	
		7	SS	42	
		8	SS	43	
		9	SS	61	
		10	SS	58	
		11	SS	42	
		12	SS	13	
		13	SS	25	
236.9 / 15.2	End of Borehole @ 15.2m below grade.				



GROUND WATER CONDITIONS; ELEVATION SCALE; UNIT WEIGHT γ kN/m³

×³, ★³. Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 5

METRIC

TBT Engineering

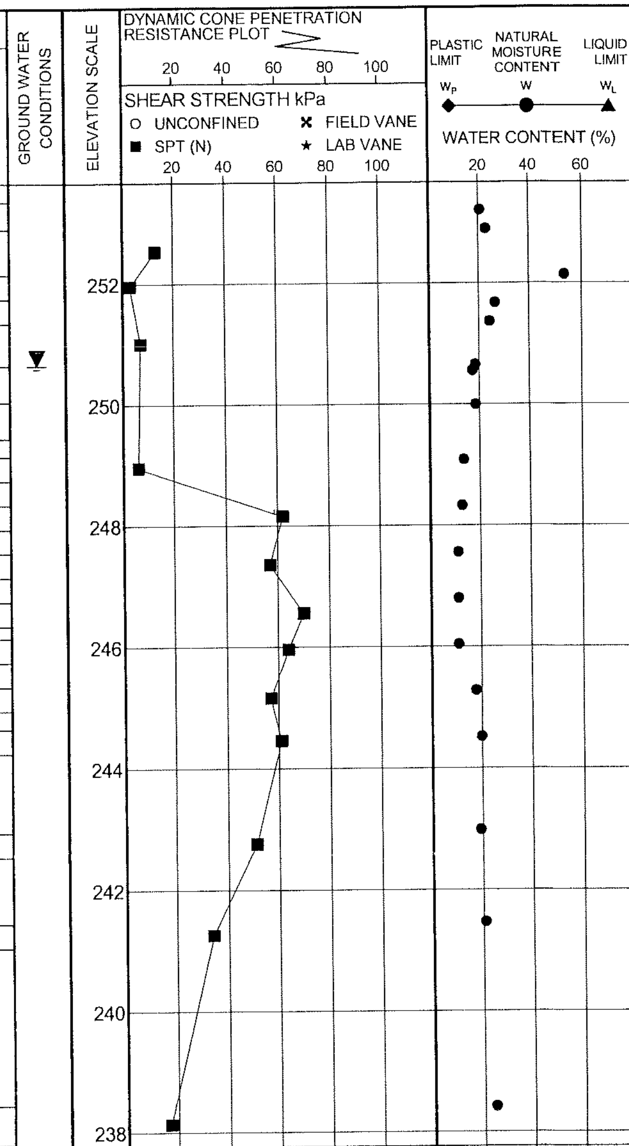
W.P.	**GWP 146-98-00**	LOCATION	**Samuel Creek Sta 18+724 10.0m LT, Twp Studhome**	ORIGINATED BY	**T.D.**
DIST	**Cochrane** HWY **11**	BOREHOLE TYPE	**HSA/N Casing**	COMPILED BY	**T.B.**
DATUM	**Geodetic**	DATE	**29/04/2006**	CHECKED BY	**G.M.**

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
253.7 / 0.0	FILL - CLAY - Silty, trace sand & gravel, brown, stiff
252.4 / 1.3	PEAT - black
252.1 / 1.6	SILT/CLAY - layered, trace sand to Sandy, grey/brown, layers from 10 to 60 mm, very loose /soft to loose/stiff, trace organics within upper 2.7m
248.6 / 5.1	SILT - trace sand to Sandy, trace clay, occasional cobbles, grey, moist, compact to very dense
237.8 / 15.9	End of Borehole @ 15.9m below grade.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	AS	
2	SS	13
3	SS	3
4	SS	7
5	TW	
	VANE	
6	SS	6
7	SS	62
8	SS	57
9	SS	70
10	SS	64
11	SS	57
12	SS	61
13	SS	51
14	SS	34
15	SS	17



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

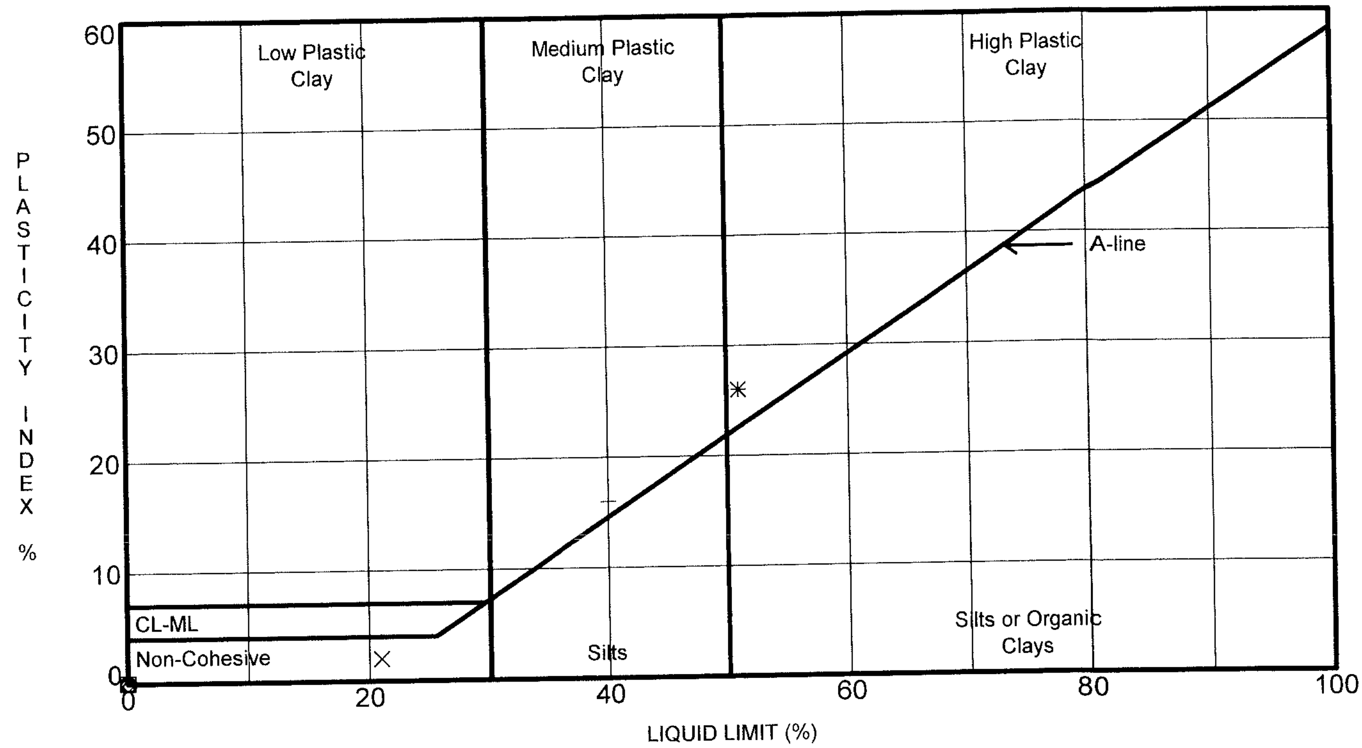
GR	SA	SI	CL
0	26	55	19
0	11	83	6
0	18	78	4

ON_MOT_BH LOG 2 05-101-1.GPJ ON_MOT.GDT 8/10/06

✕³, ★³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

APPENDIX B

Laboratory Test Data



	Borehole No.	Sample No.	Depth (m)	LL%	PL%	PI%	M/C%
□	1		3.10	NP	NP	NP	13
✳	2		3.10	51	25	26	61
×	2		3.20	21	19	2	24
+	3		4.60	40	24	16	55
◇	3		4.70	NP	NP	NP	24
△	4		2.40	NP	NP	NP	14
○	5		3.10	NP	NP	NP	17

TBT Engineering
314-101 Syndicate Ave. N
Thunder Bay, Ontario P7C 3V4
Telephone: 807-624-5160
Fax: 807-624-5161

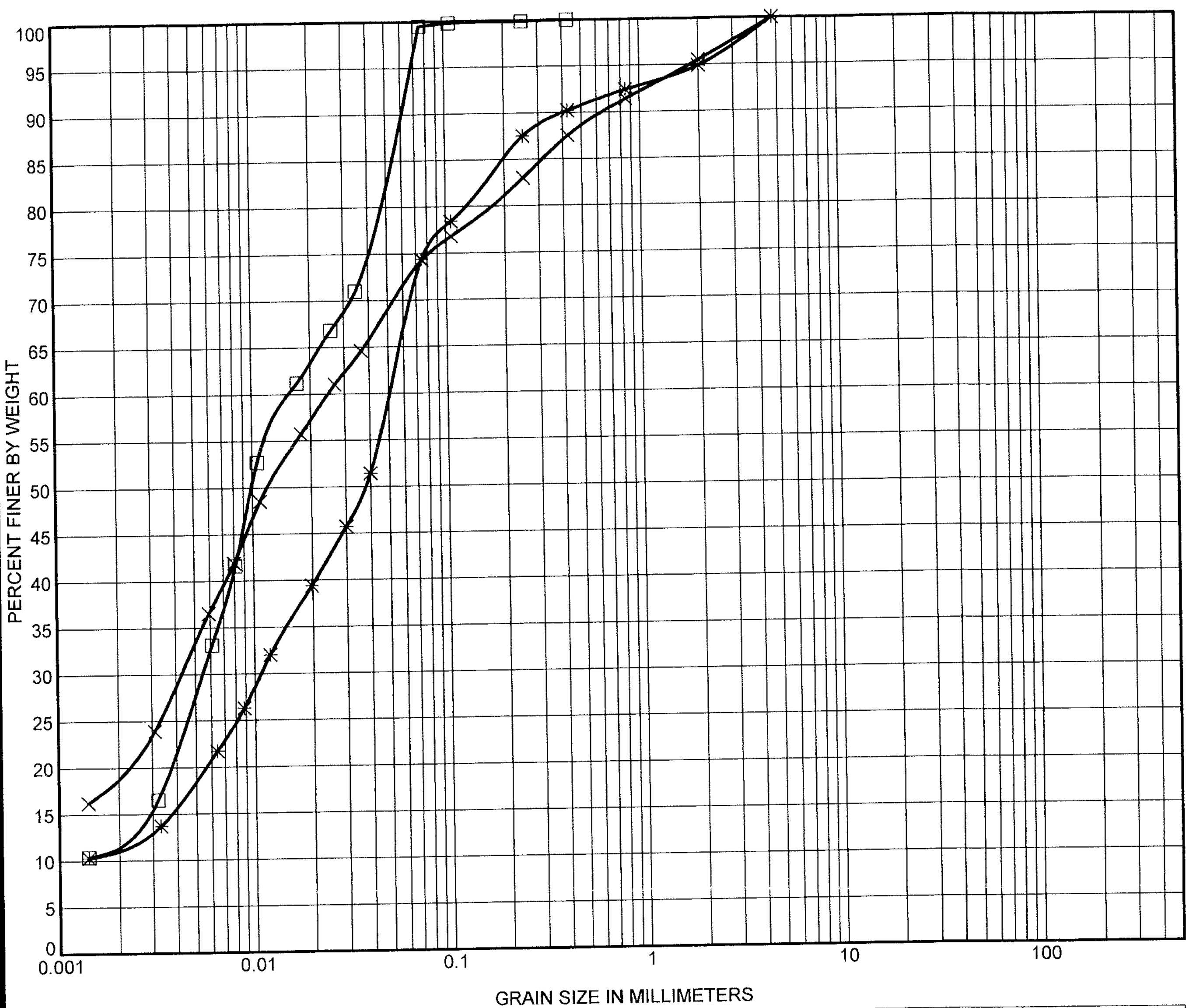
ATTERBERG LIMIT RESULTS

W P: GWP 146-98-00

District: Cochrane

Highway: 11

ENCLOSURE 1



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:

Test Hole		Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□	3	4.70	0.425	0.016	0.005		0.0	0.5	99.5	
✳	4	2.40	4.75	0.051	0.011		0.0	25.6	74.4	
×	5	3.10	4.75	0.025	0.004		0.0	25.7	74.3	

MTO_GS 05-101-1.GPJ CAN_LAB.GDT 6/19/06

TBT Engineering
314-101 Syndicate Ave. N
Thunder Bay, Ontario P7C 3V4
Telephone: 807-624-5160
Fax: 807-624-5161

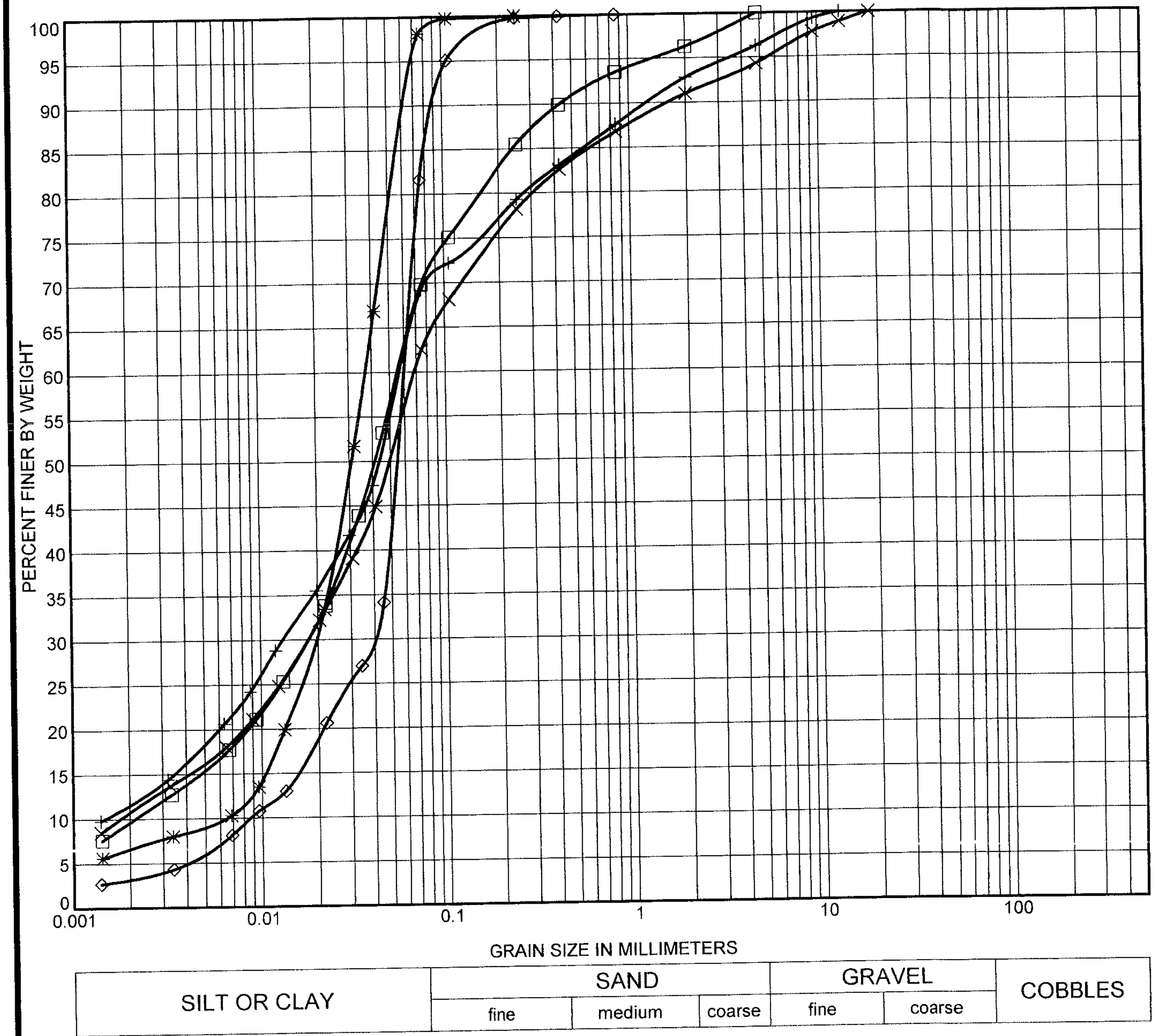
GRAIN SIZE DISTRIBUTION

Project:

Location:

Number:

ENCLOSURE 2



Remarks:

	Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□	1	5.30	4.75	0.056	0.017	0.002	0.0	30.2	69.8	
✳	1	9.10	0.25	0.037	0.019	0.006	0.0	1.9	98.1	
×	2	4.60	19	0.069	0.018	0.002	5.7	31.8	62.5	
+	4	4.60	13.2	0.058	0.013	0.001	3.7	27.1	69.2	
◇	5	12.20	0.85	0.059	0.038	0.009	0.0	18.4	81.6	

MTO_GS_05-101-1.GPJ_CAN_LAB.GDT 6/19/06

TBT Engineering
314-101 Syndicate Ave. N
Thunder Bay, Ontario P7C 3V4
Telephone: 807-624-5160
Fax: 807-624-5161

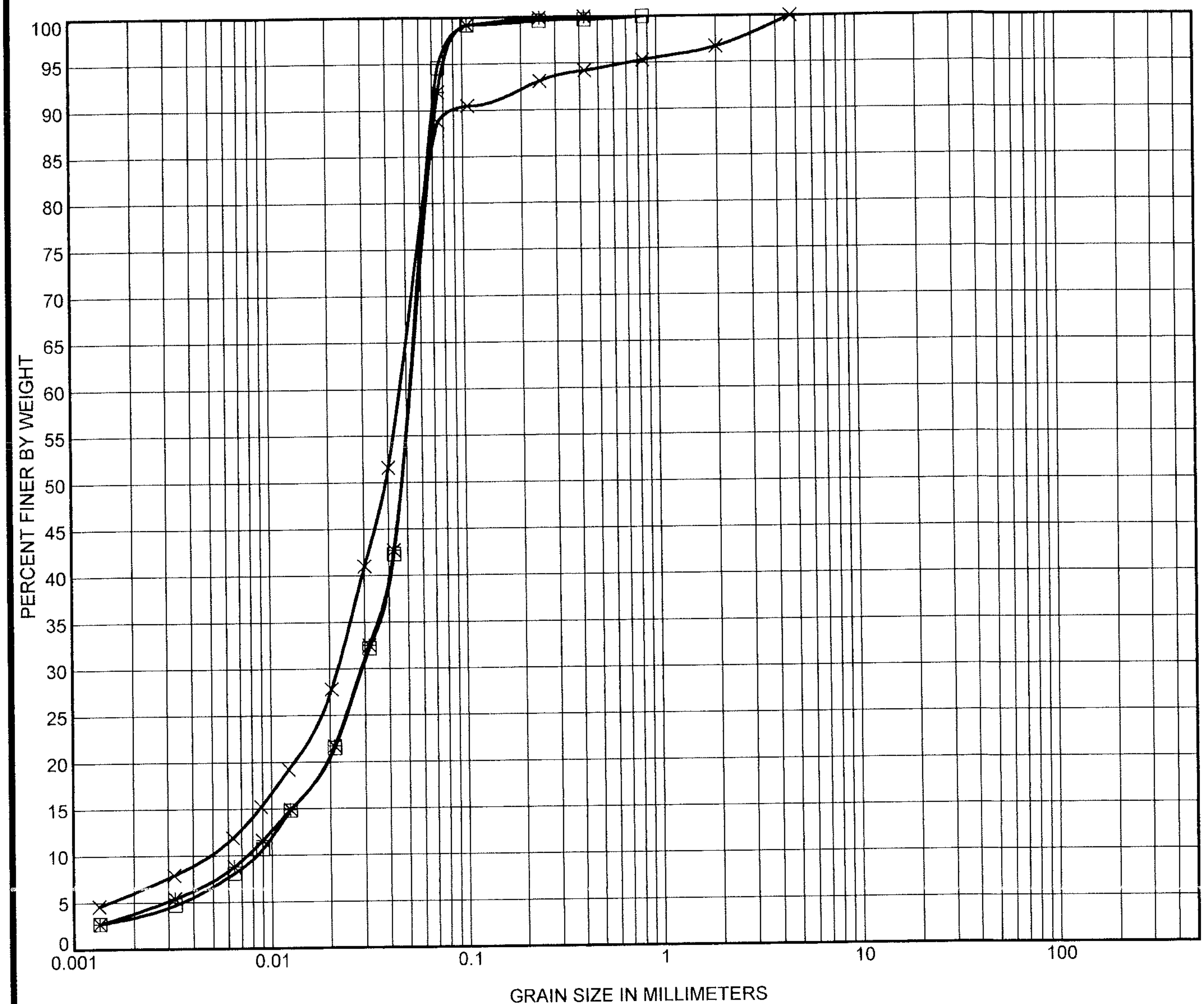
GRAIN SIZE DISTRIBUTION

Project:

Location:

Number:

ENCLOSURE 3



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:

Test Hole		Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□	2	13.72	0.85	0.052	0.029	0.008	0.0	5.4	94.6	
✳	3	12.19	0.425	0.052	0.029	0.007	0.0	8.0	92.0	
×	5	9.14	4.75	0.046	0.022	0.005	0.0	11.2	88.8	

TBT Engineering
314-101 Syndicate Ave. N
Thunder Bay, Ontario P7C 3V4
Telephone: 807-624-5160
Fax: 807-624-5161

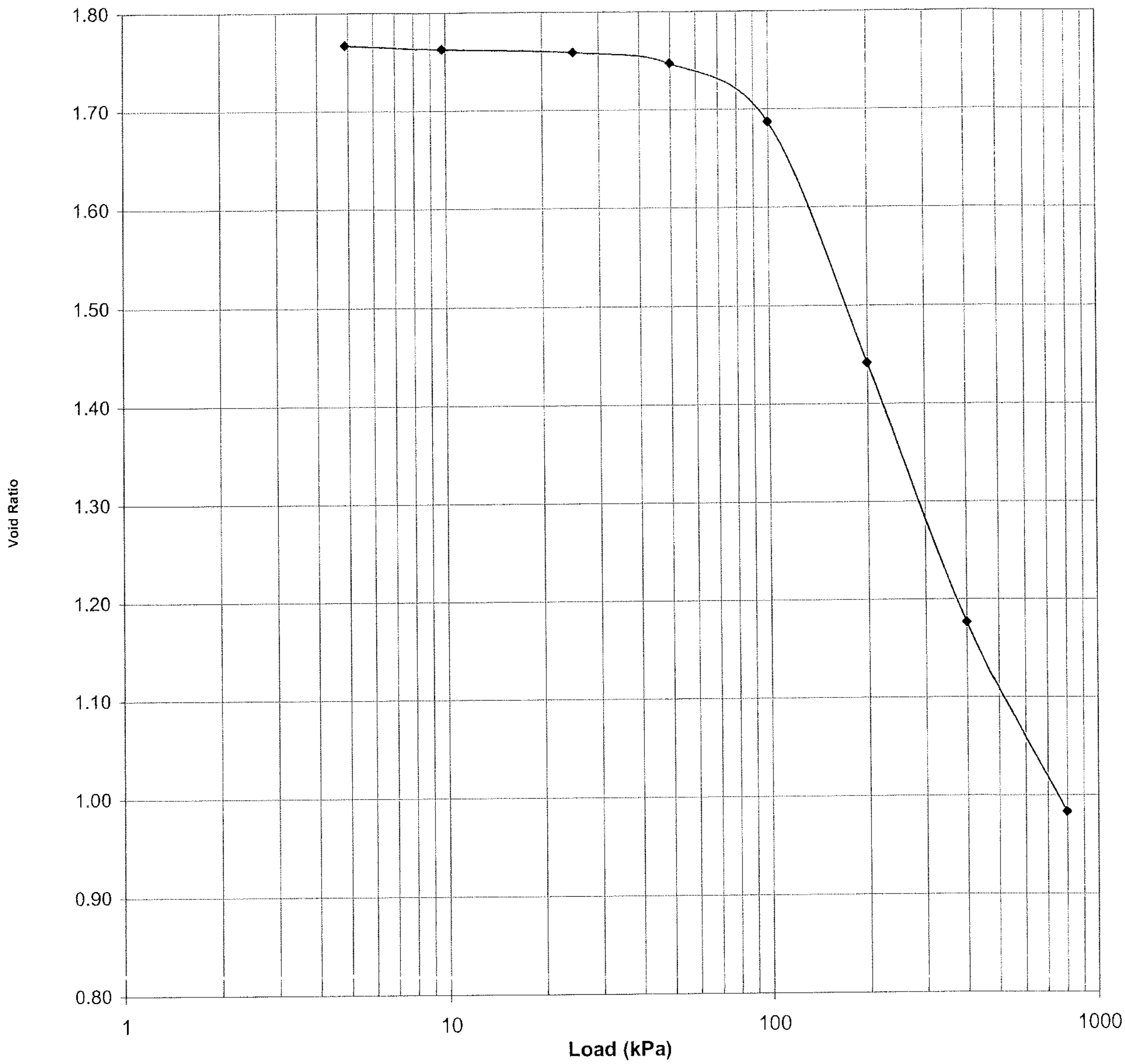
GRAIN SIZE DISTRIBUTION

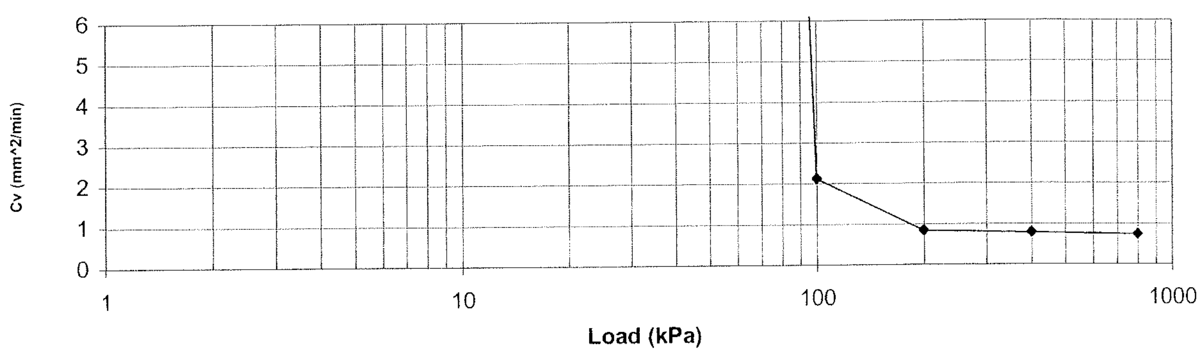
Project:

Location:

Number:

ENCLOSURE 4



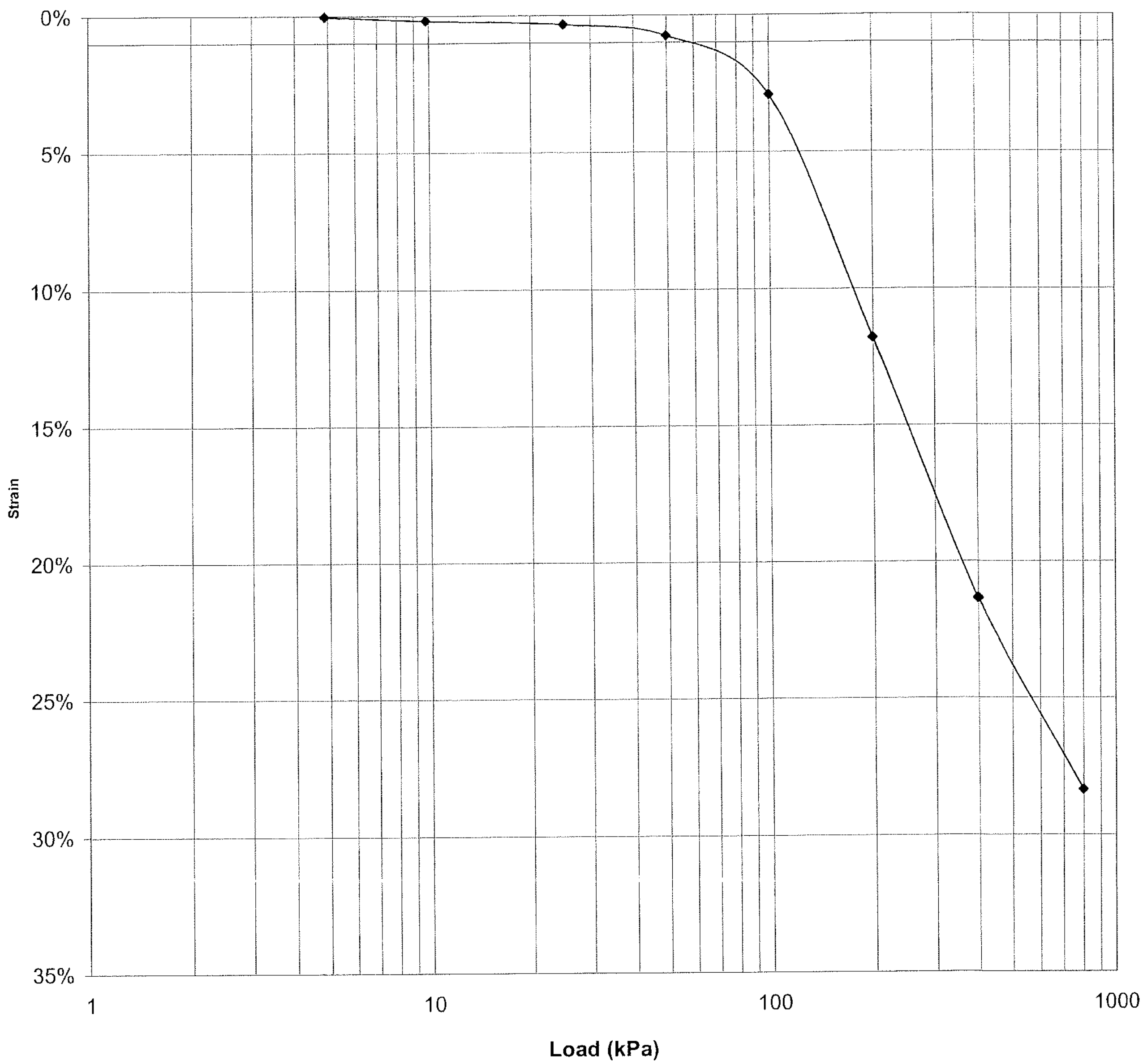


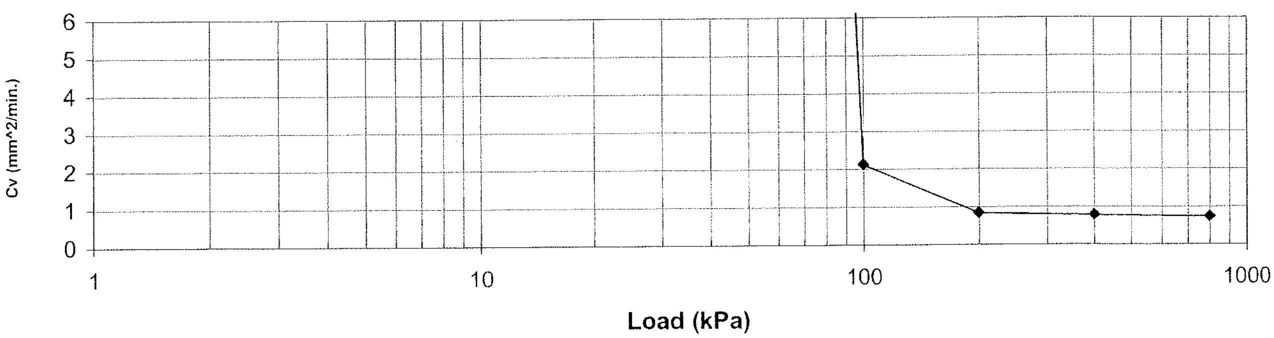
CONSOLIDATION TEST
Calstock

Borehole 2 Depth: 3.1 m Lab No. 06-293

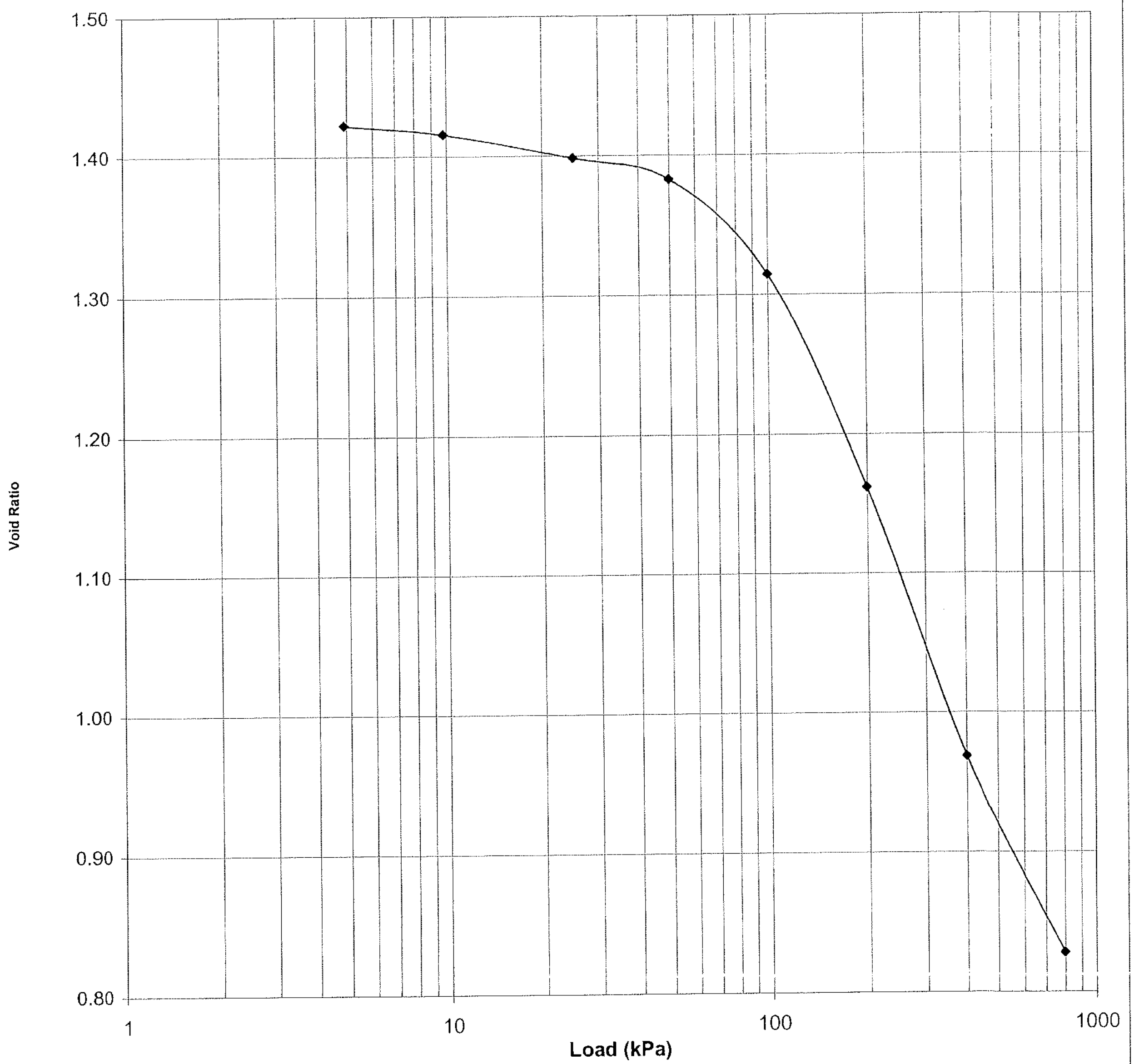
Project No.: 05-101

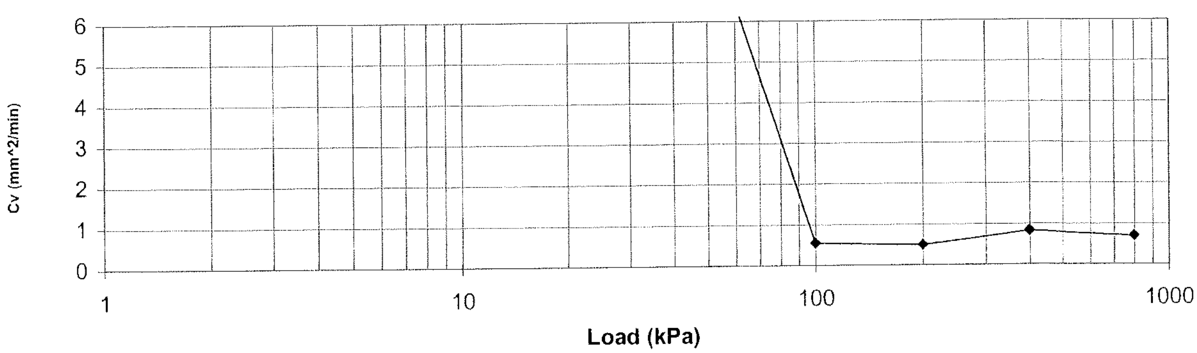
Enclosure No.5



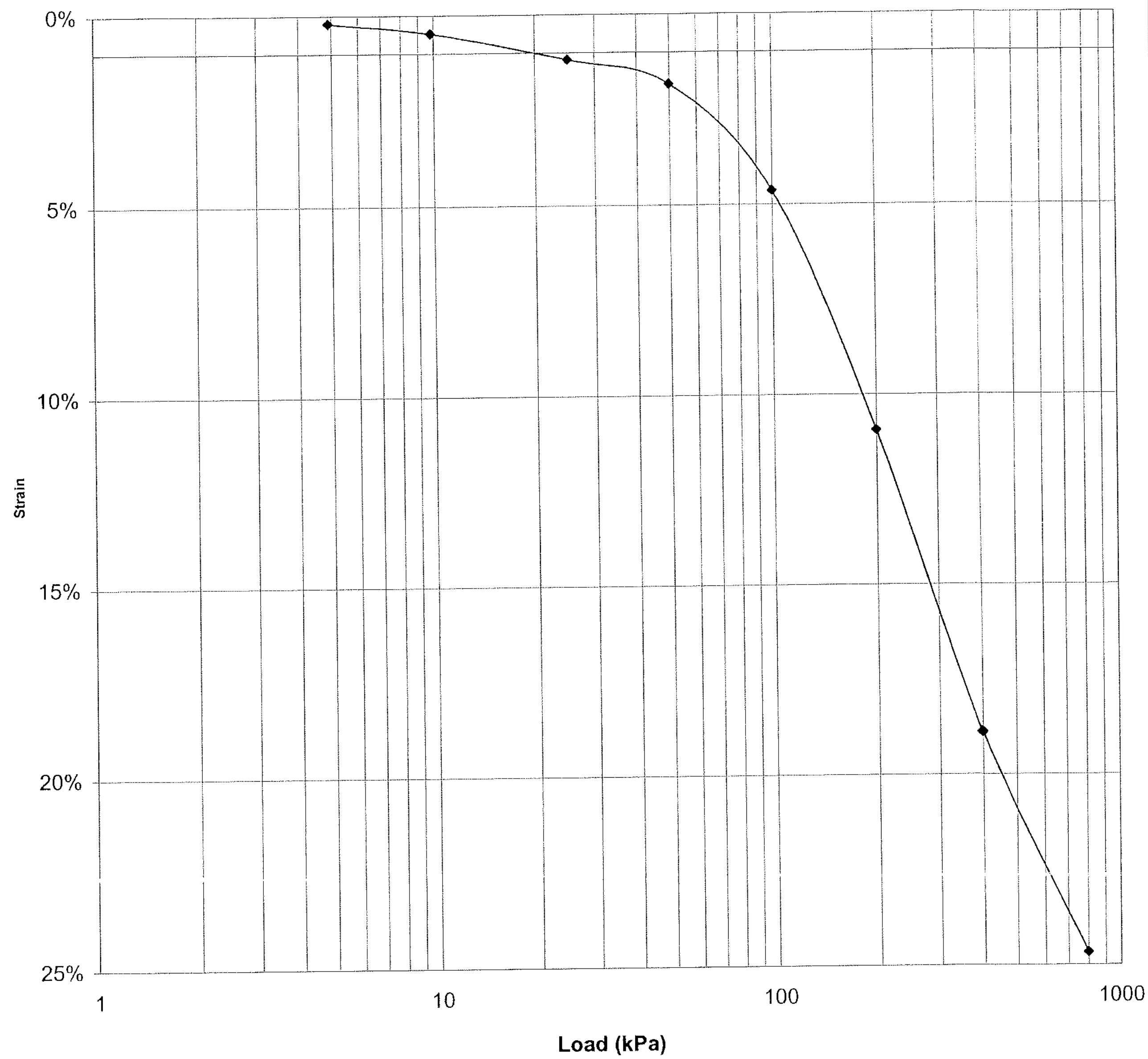


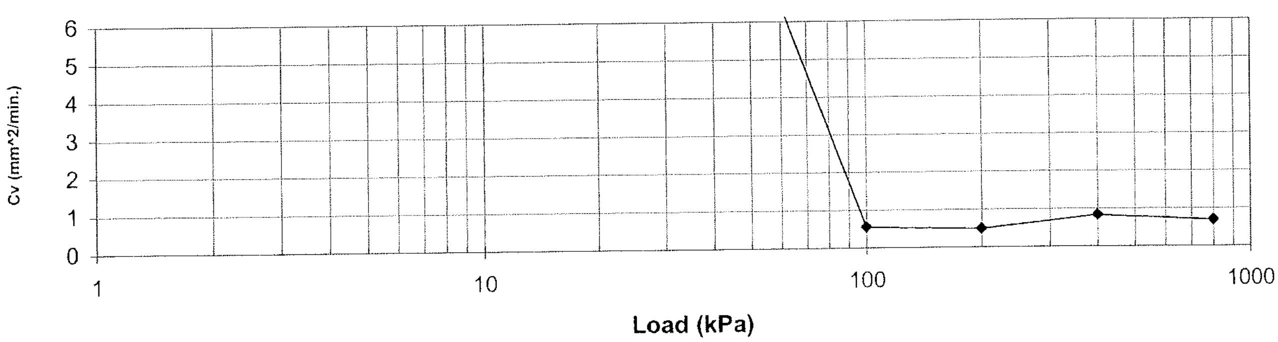
	CONSOLIDATION TEST **Calstock**	Project No.: 05-101
	Borehole 2 Depth: 3.1 m Lab No.: 06-293	Enclosure No.6





	CONSOLIDATION TEST **Calstock**	Project No.: 05-101
	Borehole 3 Depth: 5.18 m Lab No. 06-310	Enclosure No.7





CONSOLIDATION TEST
Calstock

Borehole 3 Depth: 5.18 m Lab No.: 06-310

Project No.: 05-101

Enclosure No.8

APPENDIX C

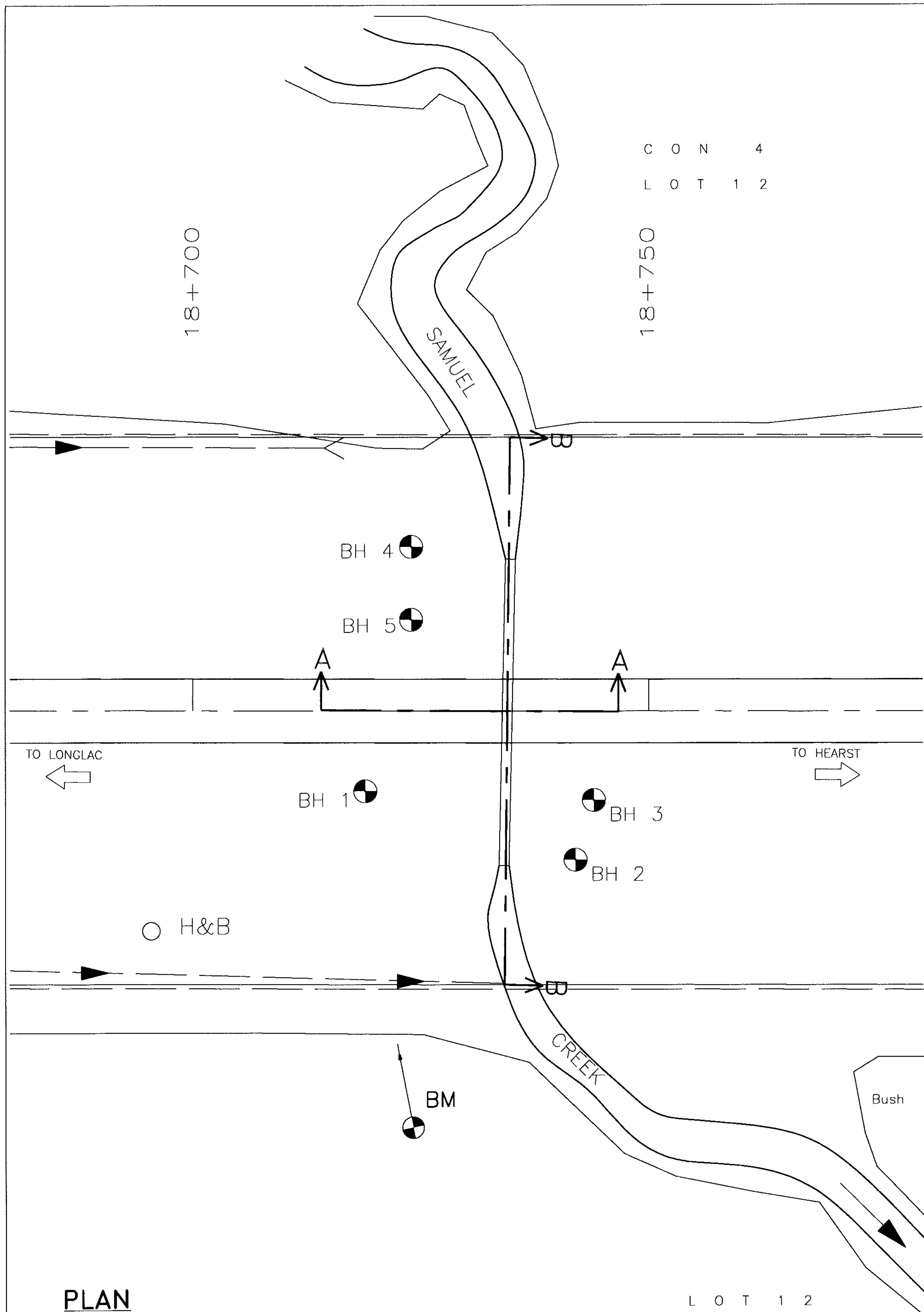
DRAWINGS AND FIGURES

CONT No
GWP NO 146-98-00

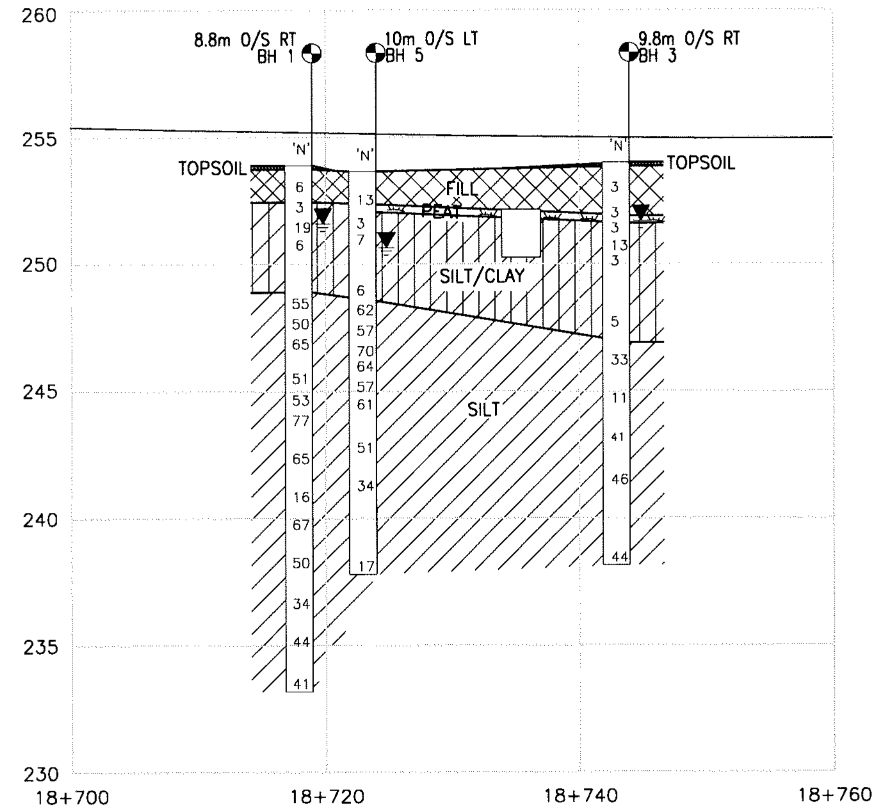
SAMUEL CREEK CULVERT
HWY 11, 25km WEST OF HEARST
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

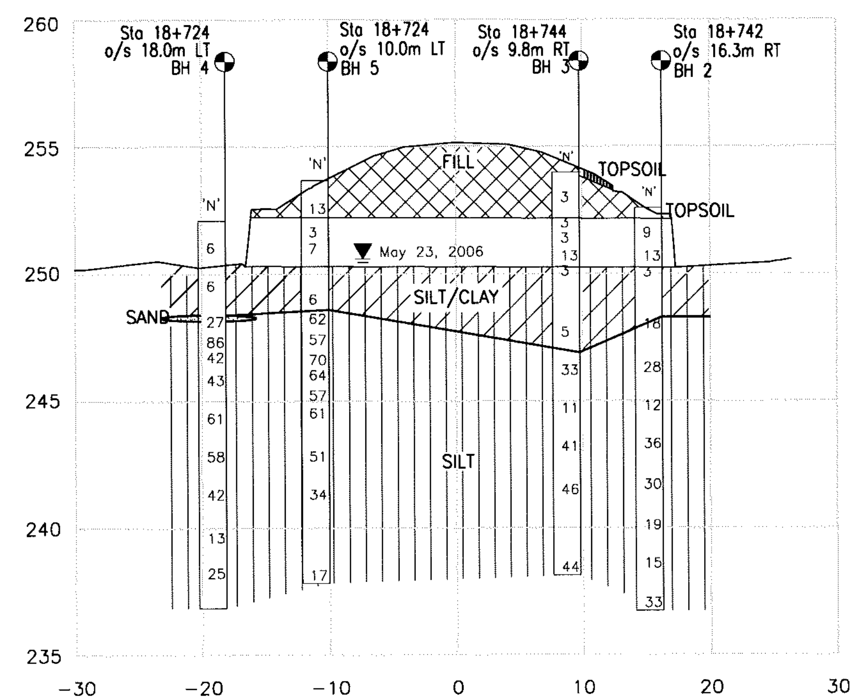
TBT ENGINEERING



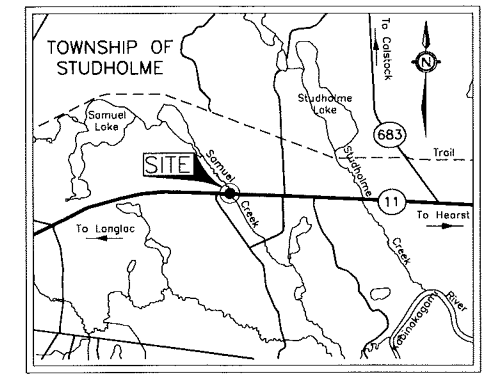
PLAN
SCALE
0 2 4 6 8 10 20m



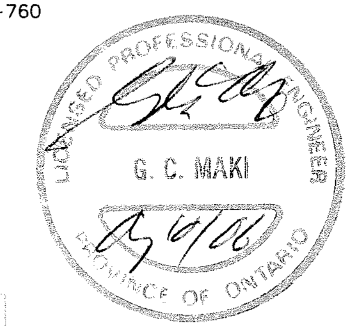
PROFILE A-A
SCALE
HOR 0 2 4 6 8 10 20m
VERT 0 2 4 6 8 10m



SECTION B-B
SCALE
HOR 0 2 4 6 8 10 20m
VERT 0 2 4 6 8 10m



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



SOIL STRATA SYMBOLS

TOPSOIL
SILT
PEAT
FILL
SILT/CLAY

LEGEND

Borehole
'N' Std Pen Test (Blows/0.3m)
WL at time of investigation April 2006

No	ELEVATION	STATION	OFFSET
1	253.9	18+719	8.8m RT
2	252.6	18+742	16.3m RT
3	254.0	18+744	9.8m RT
4	252.1	18+724	18.0m LT
5	253.7	18+724	10.0m LT

Borehole Elevations referenced from:

BM 252.764
TOP OF "T" RAIL
Sta 18+722.4, o/s 36.5RT
Elev. 252.764m Geodetic

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

REVISIONS

SECTION B-B REFERENCED FROM ENL SAMUEL-SECTIONS-MAY 23-2006.dwg.
PLAN & PROFILE REFERENCED FROM FILE 08470011018.jpg MAY 1988.

HWY 11 SAMUEL CREEK			DIST SUDHOLME
SUBM'D WH	CHECKED	DATE MAY 2006	SITE
DRAWN T.B.	CHECKED	APPROVED	DWG