

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 557 GRADE RAISE AT DUBORNE LAKE
AGREEMENT No.: 5006-E-0071
GEOCRES No. 41J-77
ASSIGNMENT No. 8**

**June 6, 2008
GS-TB-008385**

**Prepared For:
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**FOUNDATION INVESTIGATION AND DESIGN DRAFT REPORT
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PART 1: FACTUAL INFORMATION

1.0 INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation, Geotechnical Section, Northeastern Region to conduct a geotechnical investigation to evaluate the feasibility of raising the grade of Highway 557, adjacent to Duborne Lake (Upper Cranberry Lake) located 17 km north of Highway 17 at Blind River. A total of 1 testpit and 8 boreholes were advanced, 7 of which are located beyond the toe of slope staggered left and right of the centreline every 50 m and 2 are located at the edge of shoulder.

This report addresses the field investigation undertaken, laboratory test program performed and summarizes the factual information on subsurface conditions encountered and provides conclusions and recommendations for the grade raise. This work was carried out under Agreement No. 5006-E-0071.

The purpose of this investigation is to provide recommendations regarding the feasibility of raising the embankment by 1.0 m to reduce the impact of a high water level. Particular issues for this investigation are stability and settlement of the roadway embankment if supported on soft ground. The terms of reference that in the case of soft ground conditions sufficient field information is required to support a second phase of work with a more detailed evaluation on stability and settlement.

2.0 SITE DESCRIPTION

The geotechnical investigation extends for 300 m and is located 17 km north of Highway 17 on Highway 557. The culvert at the south end of the project was assigned as Sta 10+000. Along this section of highway alignment the embankment elevation is between 0.3 and 2.7 m above the elevation of the surrounding muskeg terrain. Fill from a previous Highway 557 alignment is

encountered at Sta 10+105 to the west of current alignment where it extends to Sta 10+265 and crosses to the east of current alignment progressing to the northern extent of the investigation. At Sta 10+185 a transition from swamp to higher elevation is encountered with bedrock and shallow overburden beginning at Sta 10+250. The site vegetation consists of tag alders within the muskeg terrain and mixed forest beyond the ditch line as elevations increase at the northern and southern extents.

At the time of investigation, the area of study was mostly cleared of snow to the peat layer. A layer of snow and ice of 0.4 m was only encountered at Borehole 3. The adjacent terrain was covered with 0.5 m to 1.0 m of snow. Pictures of the site from Google Earth™ and the northern and southern extents are shown below.



Satellite Imagery of Highway 557 at Duborne Lake



North end of site facing south



Highway 557 Proposed Grade Raise – At north limits looking south



South end of site facing north



Highway 557 Proposed Grade Raise – At south limits looking north, in front of rock out crop

3.0 INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between February 19th and February 25th, 2008 utilizing a CME 45 drill rig mounted on a towable chassis, equipped for geotechnical drilling and operated by DST as well as a Case 580 rubber tire backhoe operated by JI Enterprises. Six boreholes and one test pit located beyond the toe of slope were advanced to depths ranging from 2.0 to 15.5 m at 50 m spacing. Two boreholes were advanced at the edge of the paved shoulder to depths of 13 m and 2.4 m at Sta 10+100 and Sta 10+250 respectively. All boreholes and test pits were located as indicated on the Site Plan provided by the Ministry of Transportation in Agreement # 5006-E-0071, Assignment # 8 Order received in January 2008 from Jason Wright.

Boreholes 3 through 6 located from Sta 10+003 to Sta 10+200 beyond the toe of slope were advanced through expected peat and clay layers. All these boreholes encountered refusal on probable bedrock between 7.0 m and 15.0 m except Borehole 3 where drilling proceeded to a depth of 15.5 m without refusal. Borehole 2 and Test Pit 1 located at Sta 10+150 and Sta 10+250 respectively west of the current alignment and Borehole 7 located at Sta 10+300 east of the current alignment were advanced through materials which included fill from a previous highway alignment. Test pit 1 and Boreholes 2 and 7 encountered bedrock at 2.0 m, 6.3 m and 3.4 m respectively. Boreholes 8 and 9 located at Sta 10+250 and Sta 10+100 edge of paved shoulder respectively were advanced through the current embankment material. Borehole 8 was advanced to 2.3 m where refusal on bedrock was encountered. Borehole 9 was advanced to 13.0 m without encountering bedrock.

Boreholes were advanced with hollow stem augers. Soil samples were obtained from the auger flights, Shelby tube sampler and from the split spoon sampler used for the standard penetration test (SPT). The SPT involves driving a 51 mm diameter thick-walled sampler into the soil under the energy of a 63.5 kg weight falling through 760 mm. The number of blows required to drive the sampler 310 mm is known as the standard penetration blow count (N) which provides an indication of the denseness or consistency of the soil. Representative soil samples are obtained from within the sampler. A dynamic cone penetration test (DCPT) was also performed in Boreholes 3 and 4 below a 12 m depth. Borehole Logs are presented as Enclosures 1 to 9.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, supervised the drilling, sampling and in-situ testing and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included natural moisture content, gradation and plasticity limits. Laboratory results are presented on the Borehole Logs and Enclosures 10 to 11.

Ground surface elevations at the borehole locations were surveyed by DST personnel, using a benchmark with an assigned elevation of 100.00 m etched into the bedrock 9.5 m left of centreline at Sta 9+995.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Field Observations

The generalized stratigraphy beyond the toe of slope from Sta 10+003 to Sta 10+2000 consists of peat overlying a thick soft gray clay deposit which extends to bedrock at depths from 6.3 m to greater than 15.5 m below grade. The generalized stratigraphy beyond the toe of slope from Sta 10+200 to Sta 10+300 consists of a mix of fill, clay and silt deposits overlying probable bedrock at depths from 2.0 to 7.0 m below grade.

4.2 Topsoil

A topsoil layer of 0.2 m thickness was encountered at Test pit 1 and Borehole 6.

4.2 Asphalt

An asphalt (surface treated) layer of 50 mm thickness was encountered at Boreholes 8 and 9.

4.3 Fill

A sand fill of 0.9 to 2.6 m in thickness is present in Boreholes 7, 8 and 9. Occasional cobbles were encountered within this deposit.

SPT values between 9 and 17 blows per 0.3 m indicate a loose to compact condition (compactness condition). Gradation analyses conducted on a sample from Boreholes 9 indicates gravel, sand and fines contents of approximately 8%, 76% and 16% respectively. Grainsize distributions are reported on the Borehole Logs and are plotted on Enclosure 10. The moisture contents of samples ranges from 8% to 13%.

4.4 Silt

A silt layer between 0.4 and 1.8 m in thickness is present in Test pit 1 and Boreholes 7 and 8.

An SPT value of 17 blows per 0.3 m measured in Borehole 8 indicates a compact condition (compactness condition). Gradation analyses conducted on a sample from Borehole 8 indicates gravel, sand and fines contents of approximately 3%, 33% and 64% respectively. Grainsize distributions are reported on the Borehole Logs and are plotted in Enclosures 10. The moisture

contents of samples range from 12% to 19%.

4.4 Peat

Outside the embankment at Boreholes 2, 3, 4 and 5 the peat depth varies from 1.5 to 2.3 m. In general, the data indicates that the base of the peat is relatively horizontal without significant slope.

The peat was classified with respect to the modified Von Post System (see Records of Boreholes). The degree of humification varies widely from insignificant to nearly complete. The peat typically has low to moderate fine fibre content, nil to low coarse fibre content and nil to low wood or shrub remnant content. The water content of the peat was found to be from 149% to 812% for the samples collected.

4.5 Clay and Silt

In Boreholes 2, 3, 4, 5, 6, and 9 a grey clay deposit of thickness from 4.8 to greater than 13.2 m was encountered. The clay at these boreholes has a consistency of very soft to stiff as indicated by in-situ vane shear strengths varying between 7 kPa and 57 kPa. It is classified as having low sensitivity, indicated by in-situ vane test results with sensitivities of less than 10 and noted in the Borehole Logs. In situations where remolded vane test values were unattainable due to consistency of the material it is noted in the remarks on the Borehole Logs. The clay has a medium plasticity as indicated by Atterberg limit tests (Enclosure 11) conducted on samples from Boreholes 3 and 4 at depths of 4.6 and 9.1 m respectively. The moisture contents of samples clean of organics range from 28% to 97%. In Boreholes 3, 4 and 5 the moisture contents of samples contaminated with organics range from 86% to 170%.

In Boreholes 6, 7, and 8 a brown clay deposit of thickness from 0.6 to 2.8 m was encountered. The clay at these boreholes has a consistency of firm to hard as indicated by in-situ vane shear strengths varying between 44 kPa and greater than 220 kPa. It is classified as having low sensitivity, as indicated by in-situ vane test results with sensitivities of less than 10. The clay has a medium plasticity as indicated by Atterberg limit tests (Enclosure 11) conducted on samples from Boreholes 6 and 7 at depths of 0.75 and 1.5 m respectively. The moisture contents of samples range from 23% to 48%.

4.6 Groundwater

Water depths on completion of drilling are indicated on the individual borehole logs and on the soil profile. In all boreholes temporary standpipes were installed to measure the groundwater table. The groundwater level stabilized between elevations 96.85 m and 98.35 m and typically would be expected to reflect the water level in the adjacent ditches. It should be noted that groundwater levels will fluctuate seasonally and in response to climatic conditions.

Borehole No.	Water Level			
	Depth Below Grade		Elevation	
	On Completion (m)	Post Drill (m)	On Completion (m)	Post Drill (m)
TP 1	NR	NR	NR	NR
BH 2	0.30	0.30	98.35	98.35
BH 3	1.00	0.40	96.98	97.58
BH 4	0.30	0.30	97.31	97.31
BH 5	0.00	0.00	97.58	97.58
BH 6	2.00	0.40	95.99	97.59
BH 7	2.00	1.50	97.73	98.23
BH 8	2.00	1.85	98.20	98.35
BH 9	1.80	1.20	96.25	96.85

NR - Not Recorded

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PART 2: DISCUSSION AND RECOMMENDATIONS

5.0 DISCUSSION

DST Consulting Engineers Inc. (DST) has been retained by Ministry of Transportation (MTO) to conduct a foundation investigation and design to evaluate the feasibility of raising the grade of Highway 557, adjacent to Duborne Lake (Upper Cranberry Lake). The site is located 17 km north of Highway 17 (Blind River), just past Old Steel Road.

For much of this 300 m section, the road is as little as 0.3 m above the elevation of the surrounding muskeg terrain to the north and south (lake side) of the road. The purpose of the 1.0 m grade raise is to reduce water impacts on the road.

Key design criteria are that the existing road should not be unduly affected, that the new raised roadbed remains stable over the long term and that future road settlement is acceptable from an operational point of view.

The past history of the site is not well documented. The embankment was likely constructed many years ago. Given the very low elevation of the road and the deep soft clay deposits in one section of the road, it appears likely that the embankment has suffered settlement under long term consolidation of the supporting soil deposits. It is understood that in recent years this section of the road was raised 0.3 m.

The subsurface conditions below the road consist of 1.5 to 2.6 m of sand fill overlying a deep clay deposit identified at Boreholes 9 and 8. In general, the subsurface conditions beyond the existing embankment toes consist of up to 2.3 m of peat over very soft to stiff clay. Two distinctive clay deposit thicknesses are present, 8.0 to 13.2 m thick from Stations 10+000 to 10+100, and 2.1 to 6.8 m thick from Stations 10+100 to 100+300.

The subsurface conditions below the embankment at Borehole 9 indicate that the embankment was likely constructed by the displacement method over the muskeg terrain and was initially slightly shifted to the north of the existing alignment. Where the underlying clay was too weak to support the weight of the fill materials, the fill punched through the peat (see Figure 1 as a typical illustration) and displaced both peat and clay until reaching equilibrium at a depth in the clay where its strength was sufficient to support the fill. A low mud wave adjacent the embankment would have resulted. With time, the clay strength would have increased as a result of consolidation under the weight of the fill.

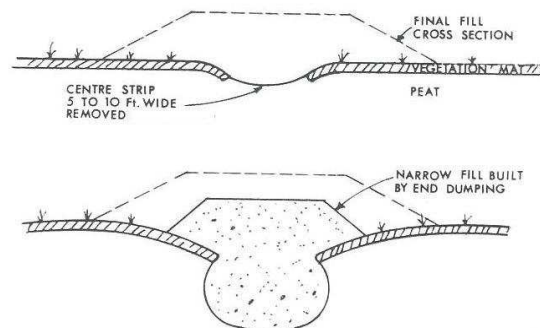


Figure 1 Typical Displacement Method

Experience with peat displacement methods is that often zones of peat remain confined within or below the fill, and also that if the base of the peat does not slope significantly, the fill remains directly under the location where it is placed as a 'bulb'. The undrained shear strengths estimated for the clay below the fill using field vane tests when compared with vertical overburden stress are also consistent with such a bearing capacity type of displacement. The thick nature of the underlying clay means that considerable consolidation settlement under the fill load is possible albeit very slowly over many years, given the thick nature of the deposit. Calculations completed using published correlations and the limited field data indicate that the clay is likely a normally consolidated clay deposit.

Preliminary analysis of the existing embankment indicates that the embankment has likely experienced gradual settlement as a result of consolidation in the deep clay layer.

In order to raise the roadway some options may be considered while providing mitigative measures for the settlement and stability concerns. In general, a grade raise conventional fill will require very careful attention to embankment stability as well as continuing long term settlement. Geosynthetics can address stability but not settlement in this case. Alternatively, lightweight fill can be used to reduce mass, associated gravitational driving forces and vertical stresses that play a key factor in stability and settlement of the final solution. Lightweight materials that have been used in embankment construction include chipped bark, sawdust, dried peat, fly ash, slag, cinders, cellular concrete, lightweight aggregates, expanded polystyrene geofoam, shredded tires, and sea shells, of these polystyrene is the only practical material. Construction considerations would include partial removal of the existing embankment to accommodate the new road structure. Another alternative is improving the shear strength and compressibility characteristics using ground improvement techniques in combination with road raise. As part of the detailed analysis these options may be considered into the assessment

Because of the very high costs associated with the lightweight fill and ground improvements, the preferred option is grade raise with conventional fill materials, on the assumption that its feasibility will be confirmed with a detailed assessment.

Grade Raise

The following options were considered for raising the existing road grade:

Option 1: Raise the existing road grade in one lift giving sufficient allowance for future settlements.

Option 2: Raise the existing road grade in increments. This method is appropriate for a 0.50 m or lower raise, or if the 1.0 m lift is to be completed in two or more increments.

For both options, a symmetrical widening of the existing road structure it is recommended to minimize the additional stresses on the existing native soils.

Using the parameters from the soil investigation a preliminary assessment was made of a grade raise of 0.50 and 1.0 m. For the 0.50 m raise the embankment widening required to achieve this is

expected to be minimal. For the 1.0 m raise the embankment widening required may produce significant settlements particularly in the organic deposits along both sides of the existing road embankment.

An immediate settlement of up to 180 mm was estimated for the clay as a result of the 1.0 m grade raise. Furthermore, the settlement from primary consolidation in the clay is expected to be greater than 150 mm over most of the embankment length. The peat consolidation will likely occur over several months, and may require some maintenance work, given the potential variable distribution of this deposit in both sides of the embankment. The sand fill consolidation will be insignificant. The deep clay consolidation may take place over several decades. Additional analyses and calculation should be carried out to accurately assess the above including time lines, secondary consolidation and stability.

At Borehole 5 a very soft clay material was found between 4.6 and 7.6 m below surface with an estimated shear strength of only between 4 and 5 kPa. However, this section of the highway may not require a full 1.0 m raise. A maximum 0.3 m raise may be feasible for the section with no significant impact to the culvert at Sta 10+000.

6.0 RECOMMENDATIONS AND CONCLUSIONS

The results of the soil investigation indicate that this 300 m long embankment is supported over very weak ground, essentially a peat deposit up to 2.3 m thick overlying a deep deposit of very soft or soft clay. Our preliminary analyses indicate that the settlement which the existing embankment has experienced over the years is likely a result of long term consolidation in the clay, perhaps still continuing today. In addition, there may have been a component caused by slow creep within overstressed zones in the clay.

A preliminary assessment of raising the grade by 0.5 m or 1.0 m using conventional fill material indicates that this is expected to be feasible with respect to stability. The new shoulders as a result of the necessary widening will likely experience considerable and variable settlement as a result of the intermittent peat layer remaining near the existing shoulders, although this effect is considerably less with a 0.5 m raise compared to a 1.0 m raise. Long term slow settlement of the entire embankment will nevertheless continue as a result of deep consolidation within the clay.

To provide a geotechnical design for the grade raise, a detailed assessment is recommended. The field data available from this investigation is considered adequate to complete this. Further laboratory testing for strength and compressibility characteristics (e.g. consolidation and direct shear tests) as well as detailed analyses of options for stability and settlement (Using computer modeling software) would be required.

Where new fill material is required over peat, a woven class II geotextile is recommended as an interface between organics and fill material to evenly distribute the load of the fill and provide high tensile strength and adequate infiltration capability (filtration opening size -F.O.S.- no less than 300 micrometres). Once the snow and ice are gone the toe of the embankment should be accurately located.

7.0 LIMITATIONS OF REPORT

A description of limitations that are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:



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Sr. Geotechnical Specialist

Reviewed by:



Mike Fabius, P. Eng.

Principal

APPENDIX 'A'
LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

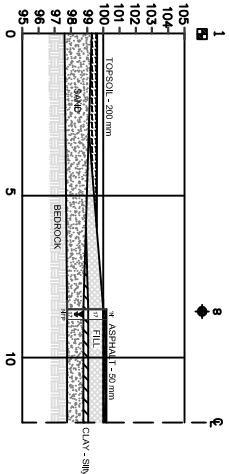
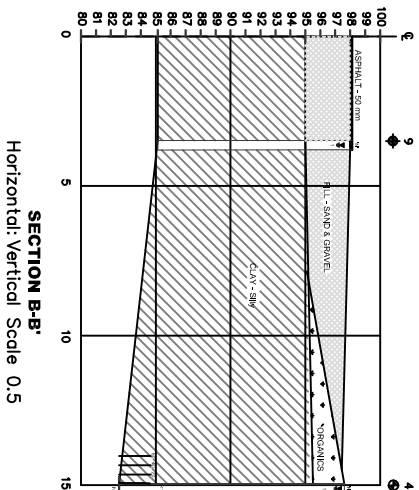
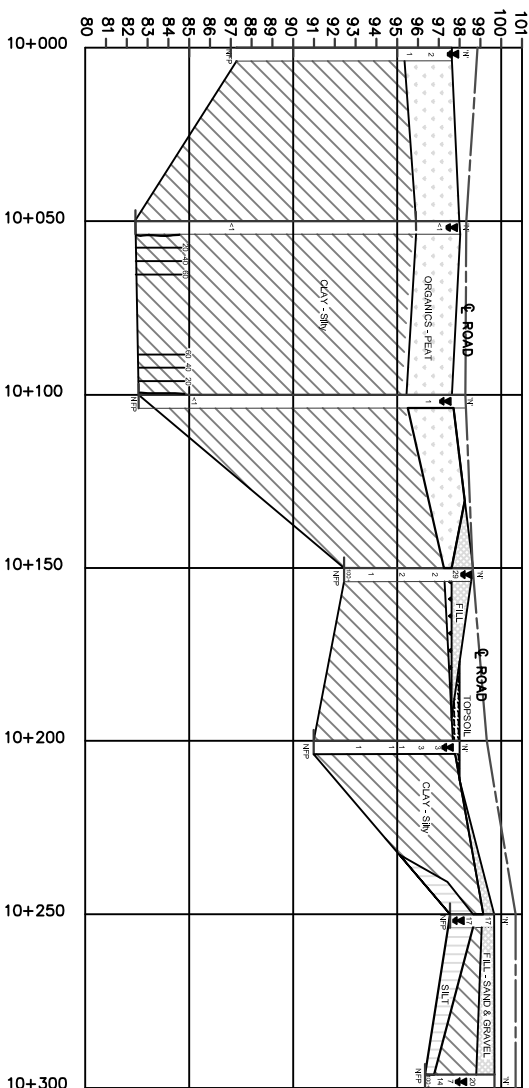
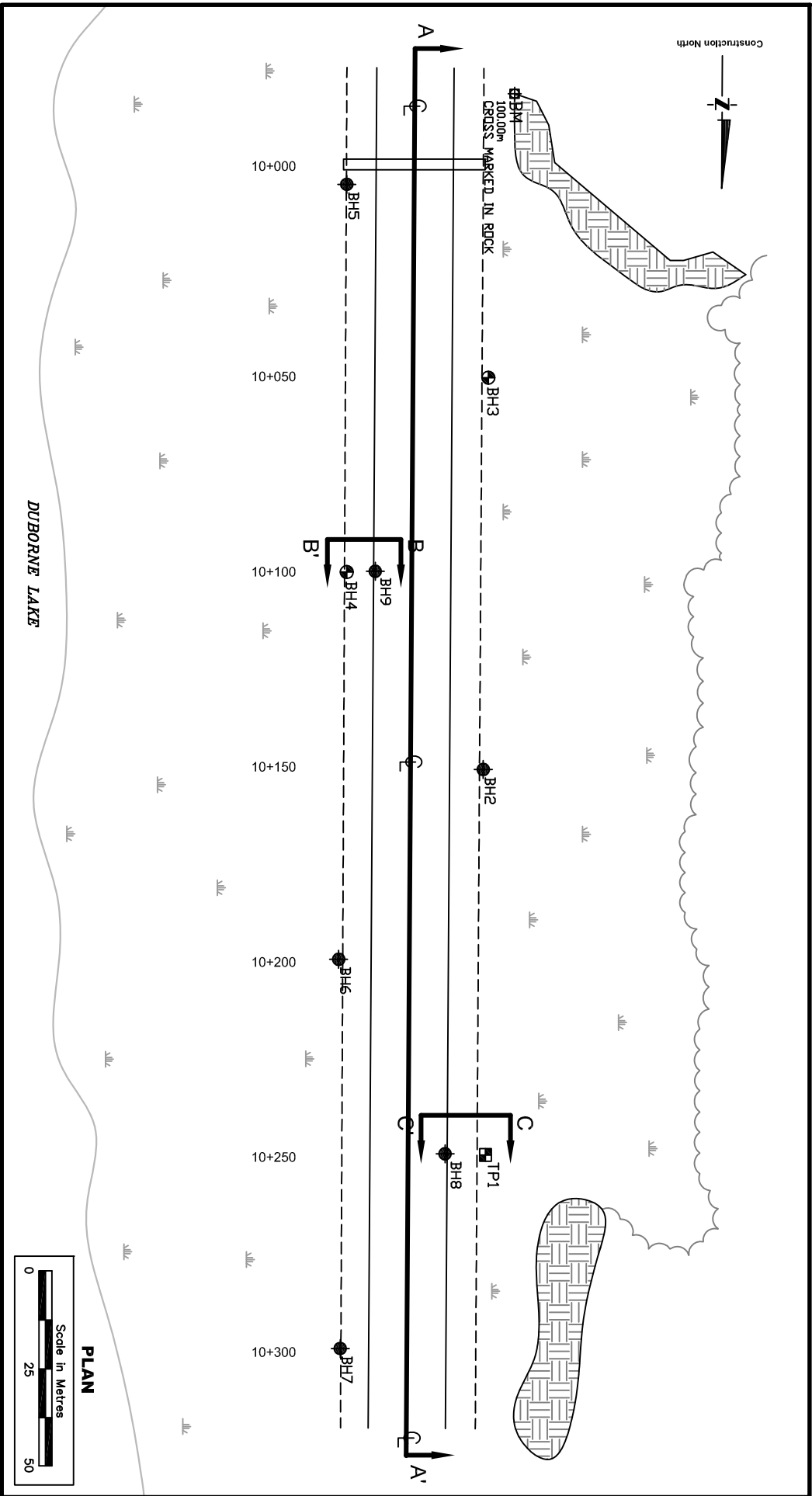
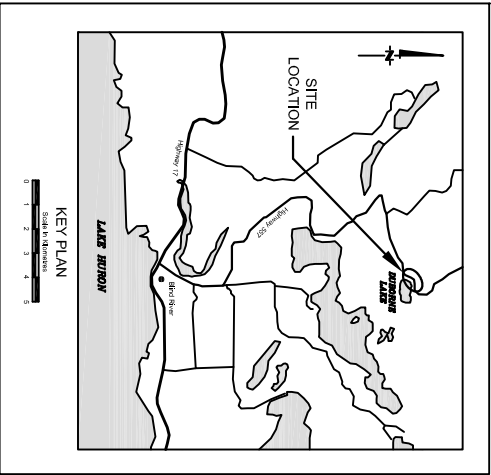
Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

D R A W I N G S

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS

GRADE RISE
Foundation Investigation & Design Report
TOWNSHIP OF BLIND RIVER
Highway 557 at Duborne Lake
10+000 to 10+300
Agreement No. 5006-E-0071
GEOCRES No. 41J-77
Assignment No. 8
BOREHOLE LOCATIONS & SOIL STRATA



LEGEND

- Borehole
- Borehole & Dynamic Cone Penetration Test
- Testpit
- Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of Investigation.
- Organics
- Fill
- Sand
- Silt
- Clay

No.	Elevation	Station	Offset
1	99.58	10+250	12.0 m Lt
2	98.65	10+150	6.5 m Lt
3	97.98	10+050	16.0 Lt
4	97.61	10+100	15.0 Rt
5	97.58	10+003	15.0 Rt
6	97.99	10+200	15.0 Rt
7	99.73	10+300	14.0 Rt
8	100.20	10+250	3.5 Lt
9	98.05	10+100	3.5 Rt

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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ENCLOSURES

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

SS SPLIT SPOON	TP THINWALL PISTON
WS WASH SAMPLE	OS OSTERBERG SAMPLE
ST SLOTTED TUBE SAMPLE	RC ROCK CORE
BS BLOCK SAMPLE	PH TW ADVANCED HYDRAULICALLY
CS CHUNK SAMPLE	PM TW ADVANCED MANUALLY
TW THINWALL OPEN	FS 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_α	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'_{v0}	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_i	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	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

Soil Descriptions

The regional soils investigation crew describes the soil in the field using the abbreviated format. As described in the *Soil Classification Manual*, the principal and secondary components are initially estimated and described, and then the minor components are identified. These minor components are described as follows:

- with describes a component having a significant effect on the sample
- trace describes a component having only a minor effect on the sample

Further refinements in identifications can be made on the basis of laboratory tests. The descriptive terms, based on percent by mass of the whole sample, are described as follows:

Descriptive Term	Example	Percent by Mass of Sample
and (with two major soil types)	sand and gravel	40-60
adjective (silty)	silty	30-40
with	silt with fine sand	20-30
some	silt, some fine sand	10-20
trace	sand, trace of gravel	0-10

The Ministry Soil Classification System describes four types of organic soils. Three of the fine-grained soil groups are described as organic (O Group). These groups are silt or clay-sized soils having a relatively low plasticity which plots below the A line on the soil plasticity chart. The O Group is differentiated from the Highly Organic Peats (Pt Group). The Pt Group is identified by its dark colour, earthy odour, spongy consistency and frequently by its fibrous texture. Peat may be subdivided into three general classes, as shown on the next page.

The engineering properties of these three types of peat are significantly different and therefore require an accurate identification. Further information on the properties and engineering significance of highly organic soils is provided in Part 7 of the *Construction Manual* [1].

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+250 12 m LT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE Backhoe COMPILED BY ML
 DATUM DATE 2008 02 20 CHECKED BY BV/MF

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
						20	40	60	80	100						
99.6																
99.4	TOPSOIL - 200 mm															
0.2	SILT - Sandy, trace gravel, occasional cobble, brown		1	BS												
97.6																
2.0	End of Testpit @ 2.0 m NFP on Bedrock															

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

ENCLOSURE 1

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+150.7 m LT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 20 CHECKED BY BV/MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE								WATER CONTENT (%)					
98.7								20	40	60	80	100									
0.0	FILL - Sand, some silt, trace gravel, brown, compact		1	AS			98										GR SA SI CL Frost to 0.2 m Water level at 0.3 m on Completion. Cave at 5.6 m.				
97.5			2	SS	29																
97.2	ORGANICS - black																				
1.5	CLAY - Silty, trace sand, grey, soft		3	SS	2				97												
			4	TW																	
			5	SS	2																
			6	SS	1		94														
92.4			7	SS	100+		93														
6.3	End of Borehole @ 6.3 m Refusal																				

\times^3, \star^3 : Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

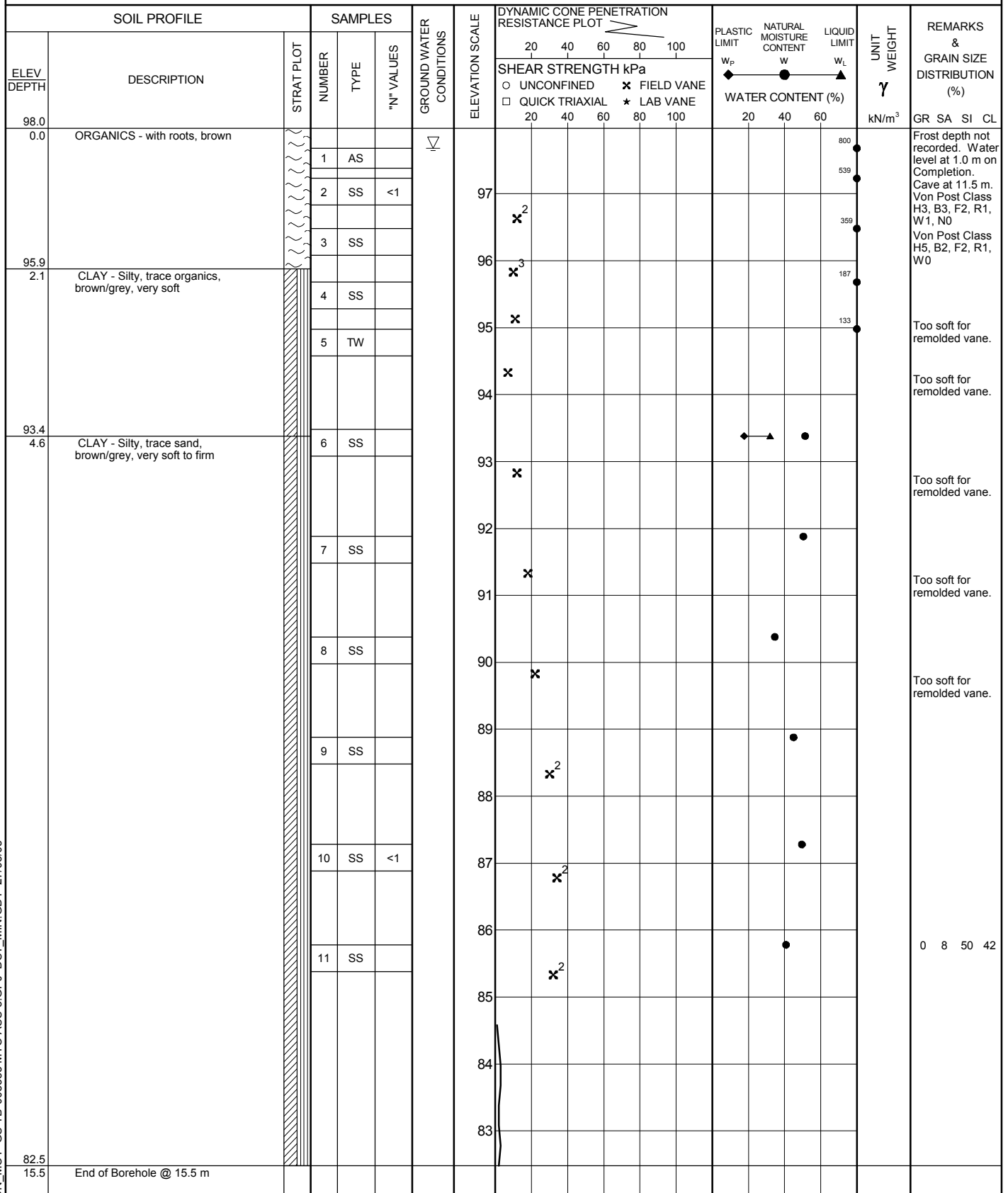
ENCLOSURE 2

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+050 16 m LT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 20 CHECKED BY BV/MF



ON MOT CS-TB-008385 MTO ASS-8.GPJ DST_MIN.GDT 27/03/08

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

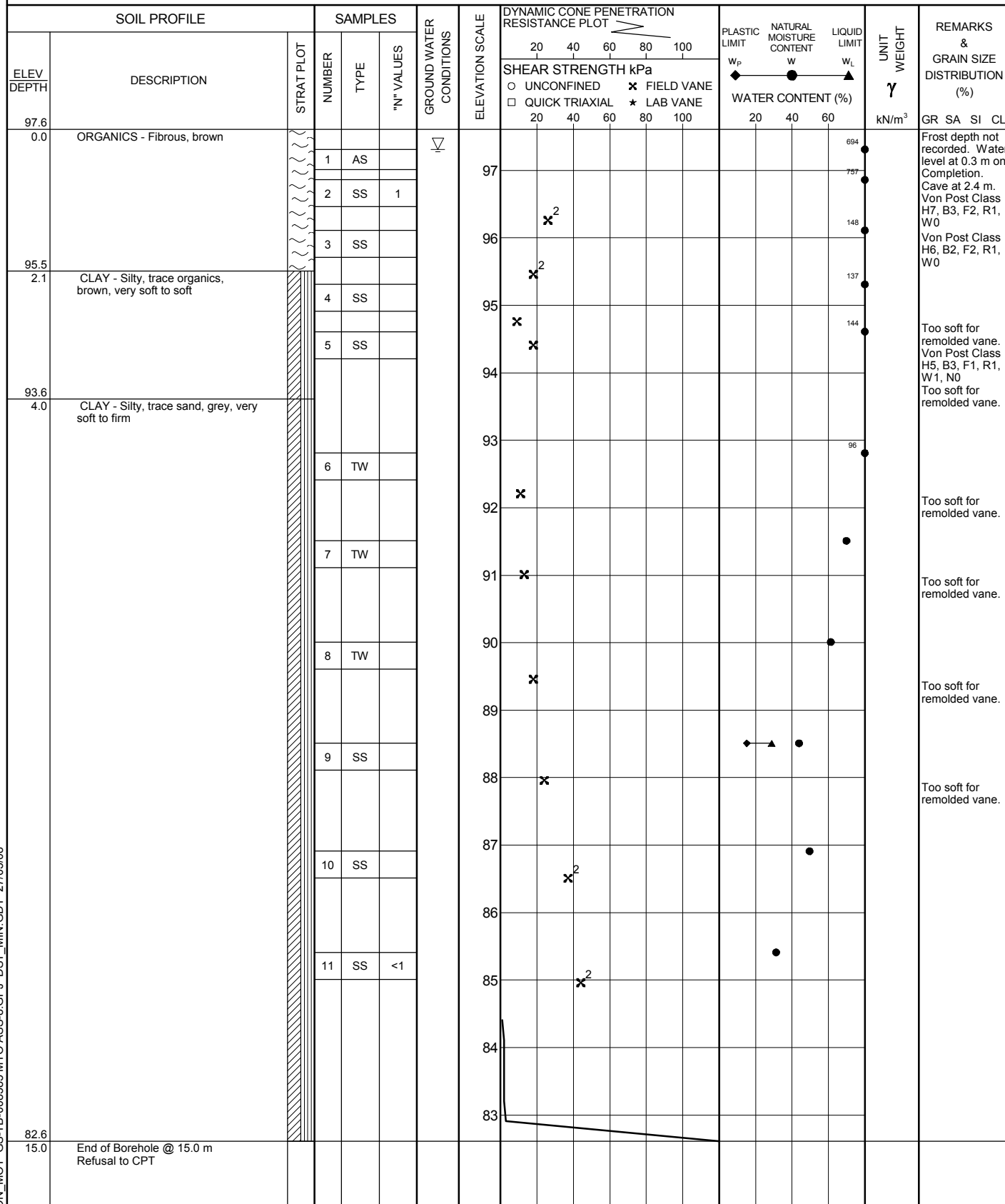
ENCLOSURE 3

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+100 15 m RT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 21 CHECKED BY BV/MF



ON_MOT_CS-TB-008385 MTO ASS-8.GPJ DST_MIN.GDT 27/03/08

x³, *³: Numbers refer to Sensitivity 0 3% STRAIN AT FAILURE

ENCLOSURE 4

METRIC

✕³, ★³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

ON MOT GS-TB-008385 MTO ASS-8.GPJ DST MIN.GDT 27/03/08

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+200 15 m RT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 22 CHECKED BY BV/MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _P	W	W _L		
98.0								20	40	60	80	100		
97.8	TOPSOIL - 200 mm		1	AS				20	40	60	80	100		
0.2	CLAY - Silty, trace sand, brown, firm to stiff		2	SS	3			20	40	60	80	100		
			3	SS	3			20	40	60	80	100		
			4	SS	1			20	40	60	80	100		
	----- - grey		5	SS	1			20	40	60	80	100		
			6	SS	1			20	40	60	80	100		
			7	TW				20	40	60	80	100		
91.0	----- - Cobbles							20	40	60	80	100		
7.0	End of Borehole @ 7.0 m Refusal							20	40	60	80	100		

\times^3, \star^3 : Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+300 14 m RT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 22 CHECKED BY BV/MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
99.7	FILL - Sand, some silt, trace gravel, brown ----- - Silty, some gravel, brown, compact CLAY - Silty, trace sand, varved, brown/grey, very stiff		1	AS			99									Frost depth not recorded. Water level at 2.0 m on Completion. Cave at 3.0 m. 0 1 57 42
98.9																
0.9			2	SS	20											
			3	SS	7											
			4	SS	14											
96.9	SILT - with sand, trace gravel, brown		5	SS	100+		97									
2.8																
96.3																
3.4	End of Borehole @ 3.4 m Refusal															

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

ENCLOSURE 7

RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+250 3.5 m LT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 23 CHECKED BY BV/MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
100.2								20	40	60	80	100					
0.05	ASPHALT - 50 mm		1	AS			100										Frost depth not recorded. Water level at 2.0 m on Completion. Cave at 2.0 m.
	FILL - Sand, some silt, trace gravel																
99.3	- some gravel, occasional cobbles, brown, compact		2	SS	17		99										
0.9	CLAY - Silty, trace sand, brown, hard																
98.9	SILT - Sandy, trace gravel, brown, compact		3	SS	17												2 33 (64)
1.3																	
97.9							98										
2.3	End of Borehole @ 2.3 m Refusal																

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

RECORD OF BOREHOLE No 9

1 OF 1

METRIC

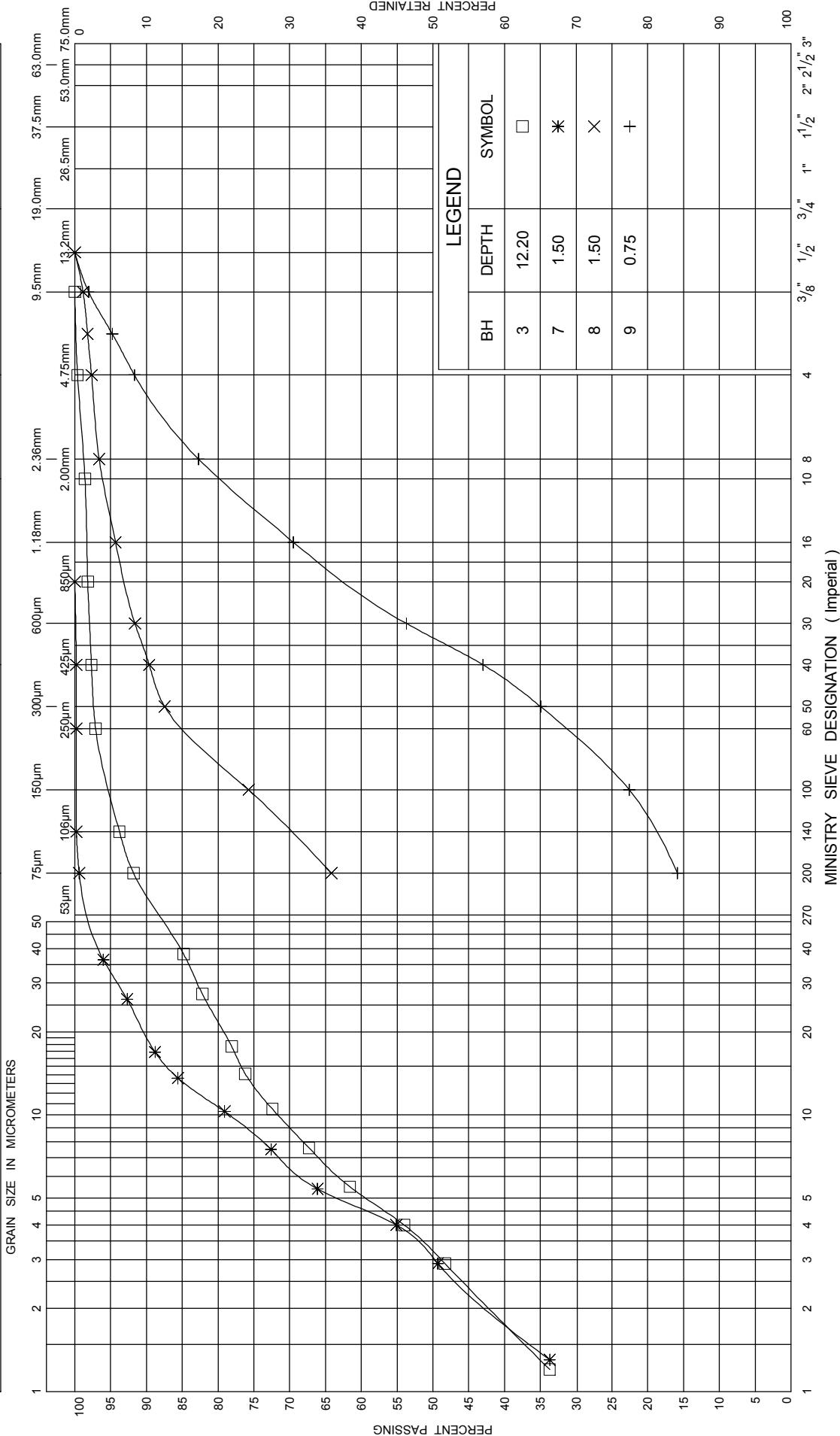
W.P. 5006-E-0071 Assignment No. 8 LOCATION 10+100 3.5 m RT ORIGINATED BY PR
 DIST HWY Highway 557 BOREHOLE TYPE HS Auger COMPILED BY ML
 DATUM DATE 2008 02 23 CHECKED BY BV/MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED	× FIELD VANE	□ QUICK TRIAXIAL					
98.1						20	40	60	80	100	20	40	60		GR SA SI CL
0.05	ASPHALT - 50 mm FILL - Sand, some silt, trace gravel, very loose to loose		1	AS											8 76 (16) Frost to 1.1 m. Water level at 1.8 m on Completion. Cave at 9.7 m.
			2	AS											
			3	SS	9										
			4	SS	2										
95.5	----- - trace organics		5	SS	1										
2.6	CLAY - Silty, grey, soft to firm														
			6	SS											
			7	TW											
			8	TW											
			9	TW											
			10	TW											
			11	TW											
			12	SS											
			13	SS											
85.1															
13.0	End of Borehole @ 13.0 m														

\times^3, \star^3 : Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse

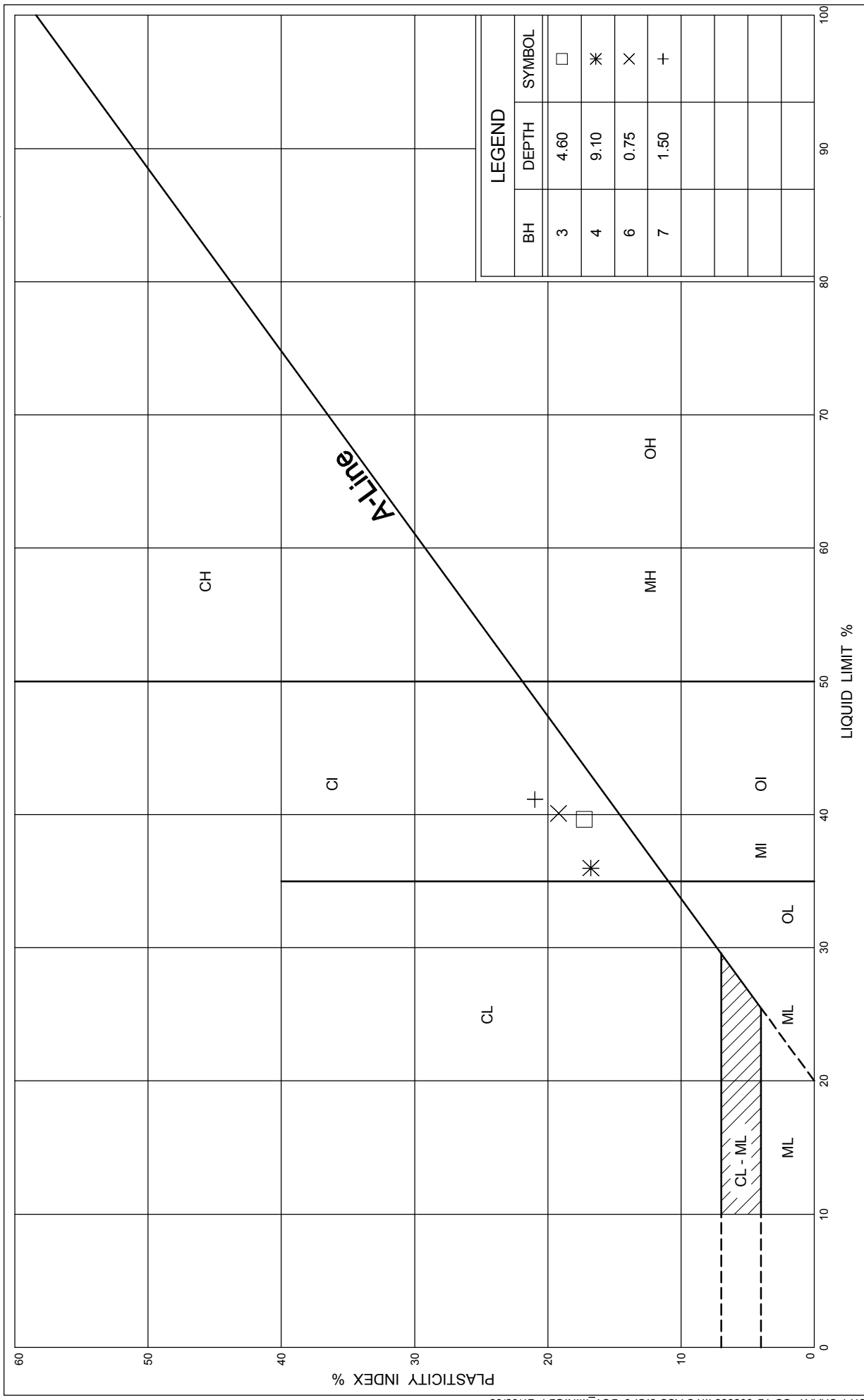


GRAIN SIZE DISTRIBUTION

ENCLOSURE 10

W P 5006-E-0071 As'nt No. 8

Highway 557 at Duborne Lake



PLASTICITY CHART

ENCLOSURE 11

W P 5006-E-0071 As'nt No. 8
Highway 557 at Duborne Lake