G.I.-30 SEPT. 1976

GEOCRES No. 41K-49

DIST. 18 REGION

W.P. No. 7814-91-01

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 548

LOCATION Hwy 548 — 6.7 Km South of Catherine St., St. Joseph Island

No. of PAGES - —

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

Ministry
of
Transportation
Ontario

FILE No. _____ **DATE** _____

REMARKS

DOUG COOPER 807-473-2145

LISA WINTER (PROPERTIES) 807-473-2000 (EX 2057)

LINDA CAZUBA 473-2059

MASTER SOIL - HAROLD (416) 749-1062

RAY WRIGHT - (705) 248-2641 (ECHO BAY PATROL)

DISTRICT ENGINEER R. VAN VEEN

705-942-8102

FAX 705-945-6830

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP	7814-91-01	DIST	62
HWY	548	STR SITE	

Highway 548 - 6.7 km South of Catherine St.
(Richards Landing) St. Joseph Island

DISTRIBUTION

R.J. Krisciunas
W. Prystanski (3)
G. Gombola
F.A. Adams (2)
M. Holowka
A. Carriere
G. Norman (Cover Only)
F. Bacchus (Cover Only)
File ✓

GEOCRES 41K-49

DATE APR 09 1996

FOUNDATION INVESTIGATION REPORT
WP 7814-91-01
STA. 23+776 - STA. 24+320
HWY 548 - 6.7 KM SOUTH OF CATHERINE ST.(Richards Landing)
St. Joseph Island District 62, Sault Ste. Marie

INTRODUCTION

This report was written in response to a request by the Northwestern Regional Geotechnical Section concerning cut stabilization along Hwy. 548 where road improvements necessitated the flattening of the grade. Cuts of up to 7.0 metres will be required within the existing embankment.

The longitudinal limits that pertain to this investigation and recommendation extend from STA. 23+950 to STA. 24+070 along highway. 548.

A foundation investigation was carried out at the above site consisting of four boreholes of 6.6 to 14.2 metres. Three boreholes were placed along the length of the highway approximately at the toe of the proposed cut embankments and one borehole placed at the crest. Due to difficulties obtaining property clearance, the investigation had to be limited to the existing right of way.

The report contains factual information obtained from this investigation pertaining to roadway embankments along highway 548.

SITE DESCRIPTION

The site is located approximately 5 km west of the Two Tree Creek along Highway 548 in the Township of St. Joseph County of Algoma. This region is also known as Sailors Encampment. The existing highway roadway is an asphalt covered two lane road with gravel shoulders. The highway curves up a steep incline over a natural embankment which appears to be composed of sands and boulder outcrops. Along the length of the existing highway embankment some natural erosion seems to have taken place due to surficial run-off.

The topography consist of a 16 metre hill which is heavily forested, containing residential homes on either side of the highway approximately 500 metres north and south. Drainage runs down the highway into the St. Marys River located near by.

SUBSURFACE CONDITIONS

The subsoil throughout the site primarily consists of a non-cohesive Silty Sand, some Gravel containing numerous boulders. Auger grinding was quite frequent and penetration became difficult due to the presence of boulders. Upon reaching the water table, quick conditions were encountered as sand blew up into the augers.

The locations of borings are shown on Dwg. No. 78149101-A in the attached appendix of this report. The field and laboratory test results are plotted on the Record of Borehole Logsheets.

Specific descriptions of the material encountered is given below.

Silty Sand, Some Gravel, Numerous Boulders

As could be observed from the surface the substrata encountered throughout the site consisted of a non-cohesive Silty Sand, some Gravel. Numerous boulders were encountered within all boreholes throughout the investigation. This material reaches beyond the scope of this investigation which had a maximum depth of 14.2 metres.

Results of grain size distribution tests carried out on select samples indicate that the material contains 1-32 % Gravel, 39-89 % Sand, 7-33 % Silt and 1-8 % Clay. Figure 1 illustrate grain size distribution curves for this material based on representative samples within this layer in an envelope form.

Standard penetration tests indicate this layer ranged from 30 Blows/0.3 m to > 120 Blows/0.3 m. Due to the presence of boulders and quick conditions these values may be misleading. Generally the material had a very dense state.

Groundwater Conditions

Observations of the groundwater level was carried out utilizing two standpipes and by measuring the water level in open boreholes. Groundwater levels determined at the time of the investigation indicated it to be at a depth of 6.3 - 8.1 m. Observations at the site indicated drainage of surfical water present through the region.

Groundwater levels are subject to seasonal fluctuations and may therefore vary accordingly.

Discussion and Recommendations

General

It is proposed to flatten the existing grade of Hwy. 558, raising it (Fill) from Sta. 23+600 to 23+900 and lowering it (Cut) from Sta. 23+900 to Sta. 24+240. Maximum Fill heights are expected to be 4.0 metres with cut slopes reaching 7.0 metres in height.

The following recommendations apply to the highway cut regions.

Stability Considerations

Stability analysis was carried out to evaluate the overall stability of the embankment and the internal stability of the proposed cut slopes.

A total stress analysis was applied for calculations of slope stability of the embankment cuts using the limit equilibrium method of stability developed by Sarma (1973, Stability Analysis of Embankment and Slopes, Geotechnique, Vol. 23, No. 3). A minimum factor of safety of 1.3 was incorporated for the analysis. It should be noted that all stability calculations were made for the static condition only.

The design parameters, subgrade geometry and groundwater level used in the analysis are as follows:

Soil Type	Cu (kPa)	Phi (deg.)	Gamma (kN/m^3)
Silty Sand	0	32	18.9

Water level at the existing ground surface at the toe of the embankment.

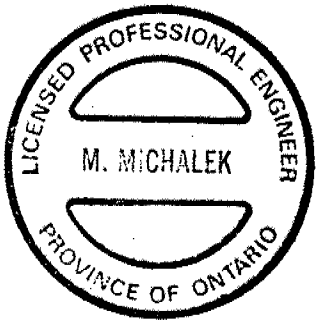
As shown on Figures 2,3 the analysis of generalized embankment conditions indicate that stability of embankments with a maximum height of 7 m may be controlled by providing of 2H:1V slopes.

As surfical run-off may be a problem, it is additionally recommended to provide granular sheeting, shown on the attached drawing along the length of the slopes to provide protection against sloughing. This condition has already been observed at various locations on the Island already.

Miscellaneous

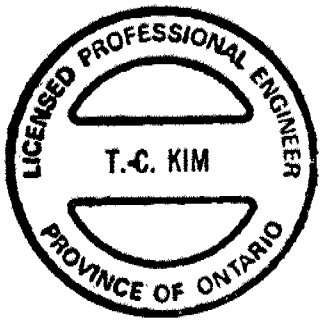
The fieldwork for this investigation was carried out under the supervision of M. Michalek, Jr. Foundation Engineer. The equipment was owned and operated by Master Soils Investigations, Toronto.

The report was written by M. Michalek and reviewed by T.C. Kim, Sr. Foundation Engineer.

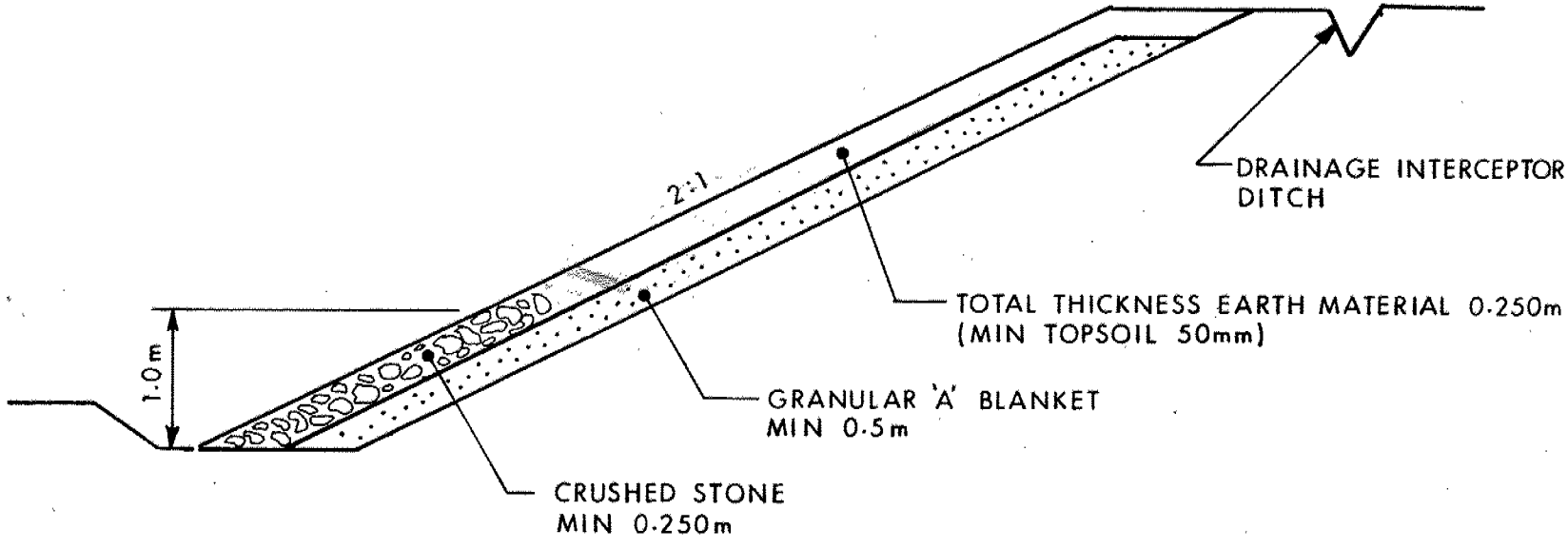


M. Michalek, P. Eng.
Jr. Foundation Engineer

T. C. Kim, P. Eng.
Sr. Foundation Engineer



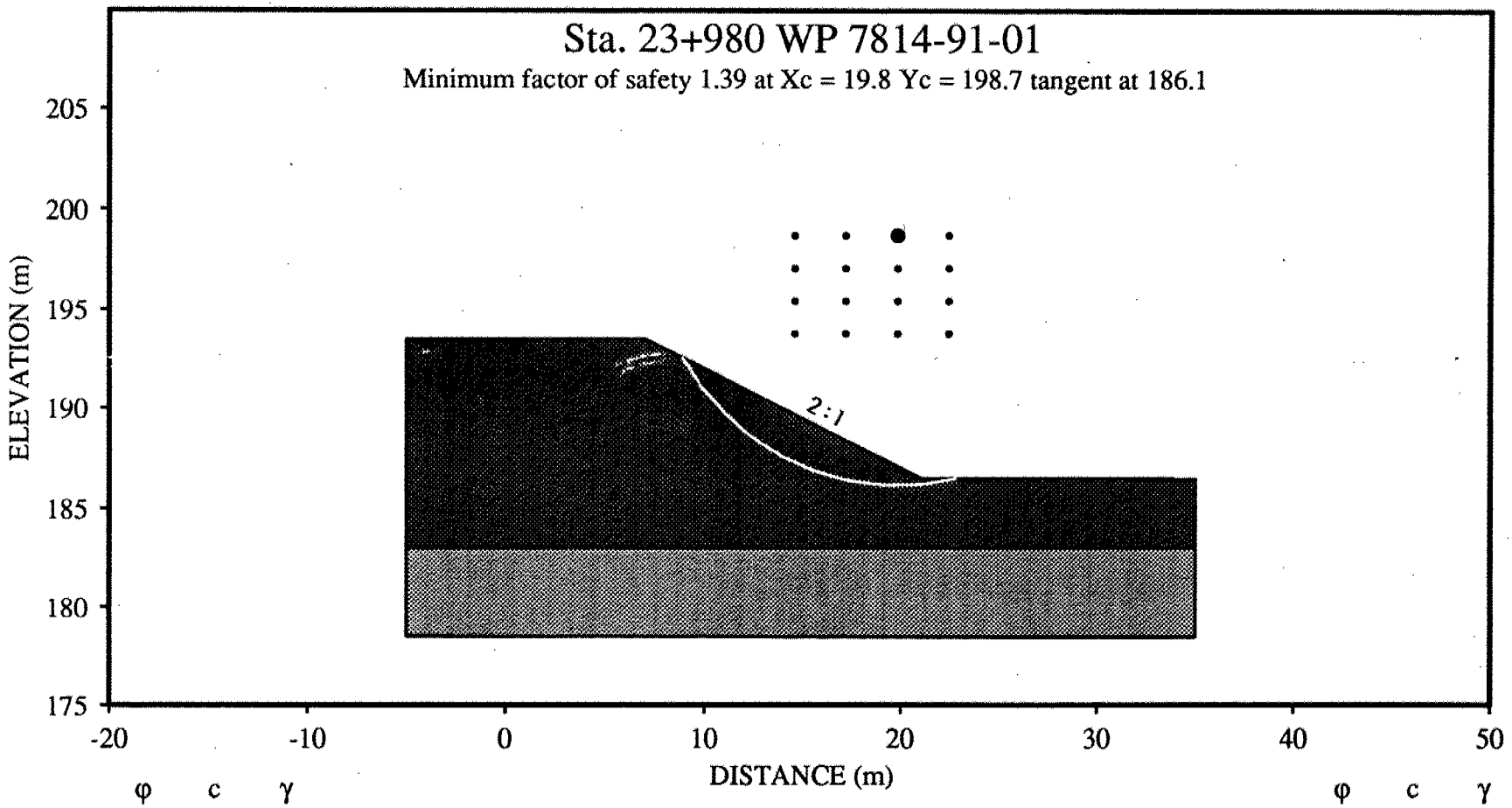
APPENDIX



GRANULAR BLANKET

Sta. 23+980 WP 7814-91-01

Minimum factor of safety 1.39 at Xc = 19.8 Yc = 198.7 tangent at 186.1

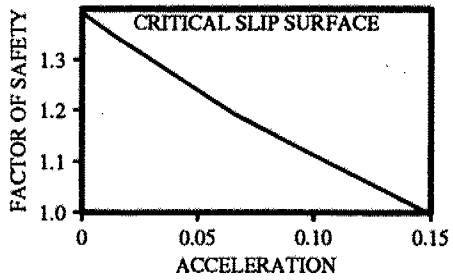


φ	c	γ	
32.0	0.0	18.9	Sandy Silty

φ	c	γ	
32.0	0.0	18.9	Sandy Silt

CRITICAL ACCELERATIONS

0.255	0.178	0.149	0.193
0.249	0.178	0.152	0.216
0.248	0.189	0.157	0.251
0.269	0.205	0.163	0.309

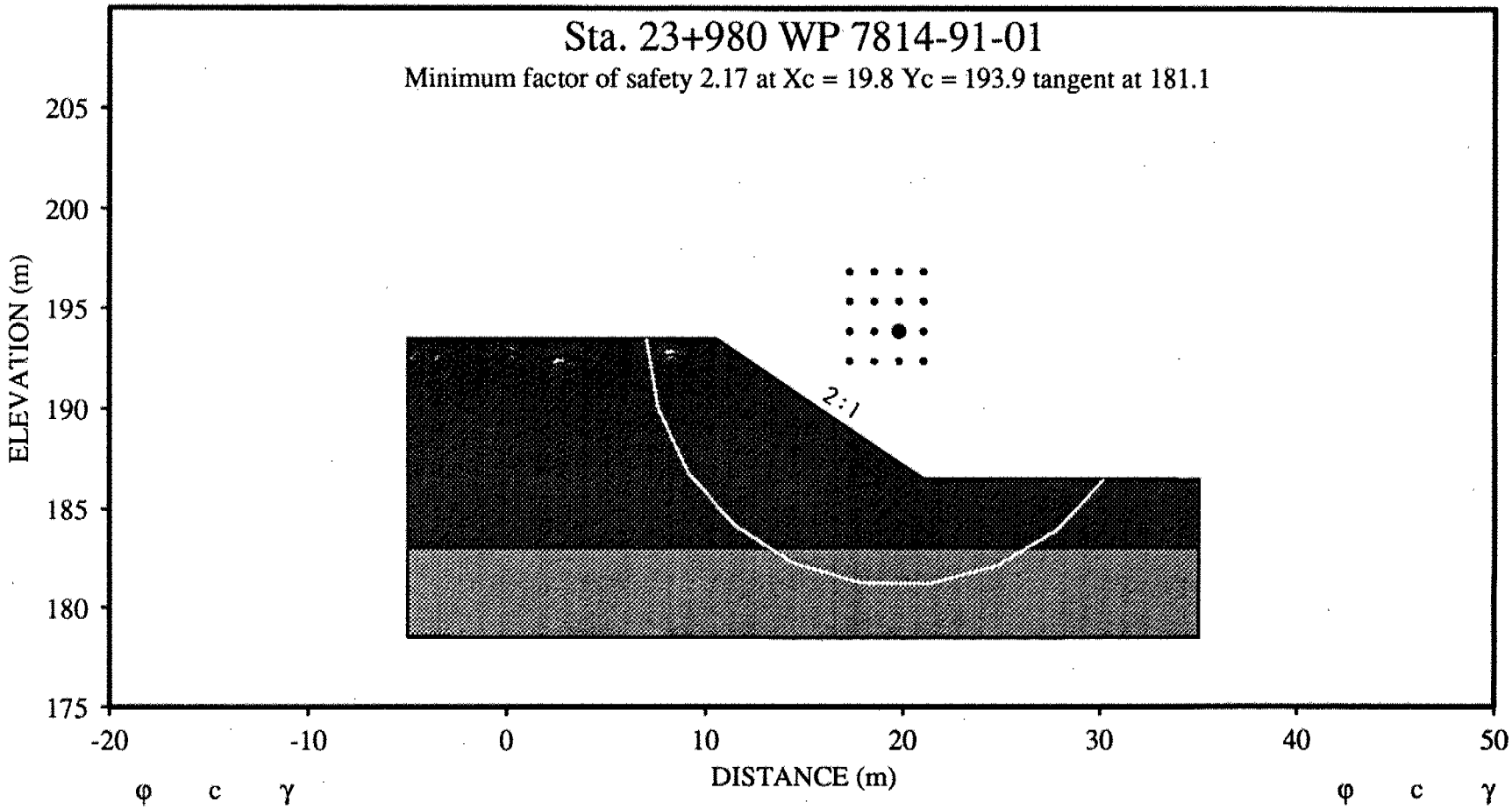


FACTORS OF SAFETY

1.774	1.477	1.393	1.566
1.715	1.464	1.402	1.659
1.677	1.493	1.414	1.818
1.707	1.537	1.429	2.145

Sta. 23+980 WP 7814-91-01

Minimum factor of safety 2.17 at Xc = 19.8 Yc = 193.9 tangent at 181.1

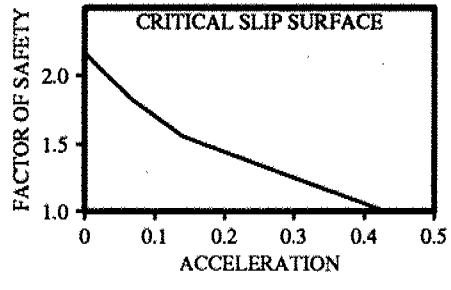


φ	c	γ	
32.0	0.0	18.9	Sandy Silty

φ	c	γ	
32.0	0.0	18.9	Sandy Silt

CRITICAL ACCELERATIONS

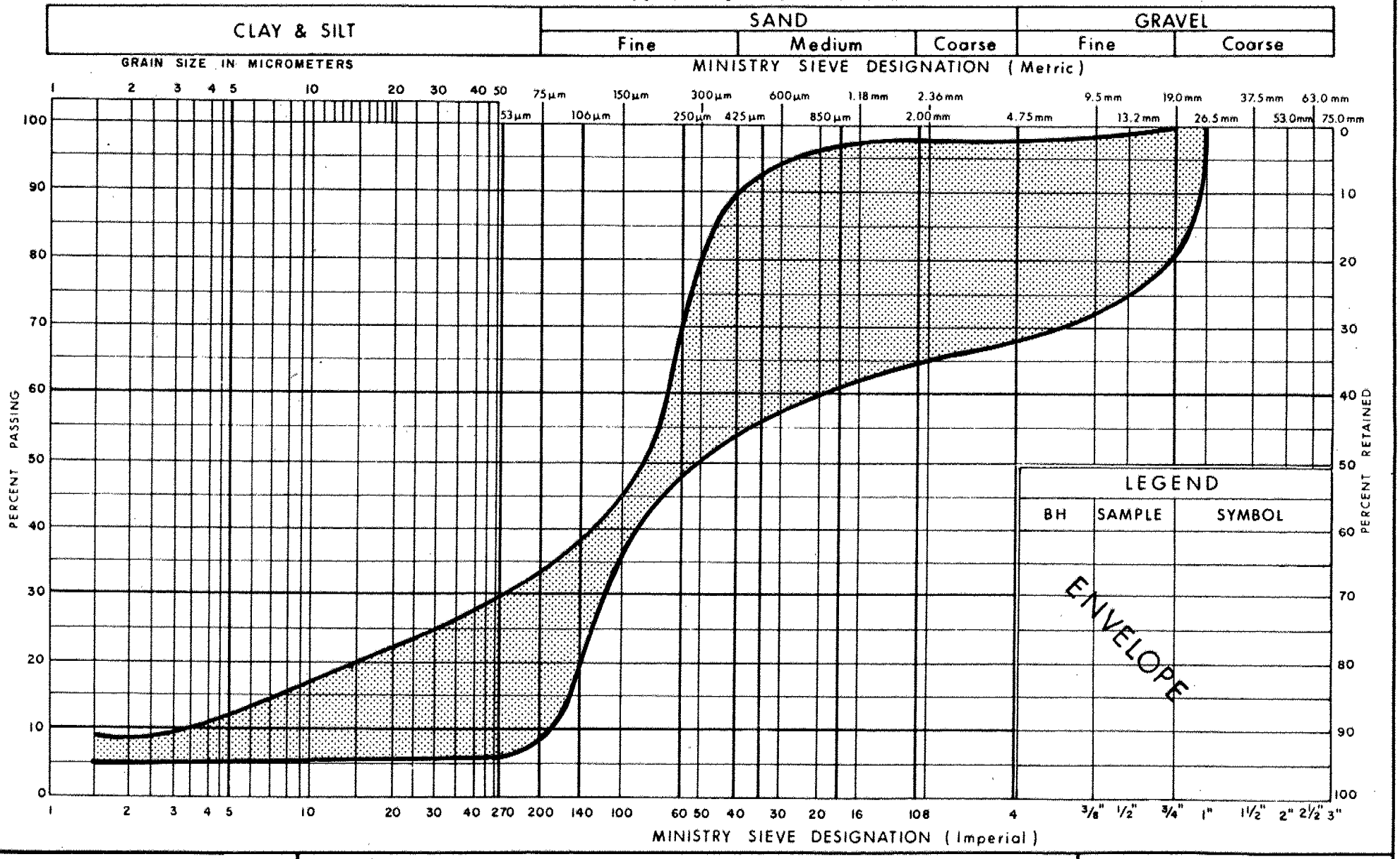
0.391	0.386	0.387	0.393
0.402	0.399	0.402	0.412
0.425	0.424	0.431	0.448
0.478	0.481	0.496	0.525



FACTORS OF SAFETY

2.288	2.238	2.218	2.230
2.243	2.196	2.183	2.210
2.216	2.173	2.173	2.222
2.235	2.199	2.222	2.318

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SILTY SAND
TRACE / WITH GRAVEL, NUMEROUS BOULDERS

FIG No 1

W P 7814 - 91 - 01

RECORD OF BOREHOLE No 1 — 1 OF 1 — METRIC

W.P. 7814-91-01 LOCATION Sta. 24+061.4 – 17.2 m Rt of CL Hwy 548 ORIGINATED BY M.M.

DIST 62 HWY 548 BOREHOLE TYPE Hollow/Solid Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 09 08 95 CHECKED BY T.K.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.5	Ground Surface										
0.0	Silty Sand some Gravel Numerous Boulders Very Dense		1	SS	44	DRY	196				
			2	SS	64		195				
			3	SS	106		194				
			4	SS	120		193		o		14 45 33 8
			5	SS	90 /23cm		192				
			6	SS	50 /18cm		191				
189.9			7	SS	120		190				
6.6	End of Borehole Auger Refusal Probable Boulder										

$+^3$, $\times^5$: Numbers refer to Sensitivity

$\frac{20}{15}\diamond\frac{}{10}$-5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2 1 OF 1 METRIC

W.P. 7814-91-01 LOCATION Sta. 24+067.5 – at CL Hwy 548 ORIGINATED BY M.M.

DIST 62 HWY 548 BOREHOLE TYPE Hollow/Solid Stem Augers COMPILED BY M.M.

DATUM Geodetic DATE 09 08 95 CHECKED BY T.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
193.9	Ground Surface – Hwy. 548										
0.0	Silty Sand some Gravel Numerous Boulders Very Dense		1	SS	34		193				
			2	SS	58		192		○		32 39 23 6
			3	SS	50	/5cm	191				
			4	SS	45		190		○		
			5	SS	69	/8cm	189				
			6	SS	30		188				
			7	SS	60	/3cm ▼	187				
			8	SS	92		186		○		15 48 31 6
			9	SS	35	/3cm	185				
			10	SS	50	/13cm	184				
			11	SS	50	/5cm	183				
179.7						PI	182				
14.2	End of Borehole						181				
	* Ground Water Conditions 3:00 pm Aug. 9/95 – 181.4 m 9:00 am Aug. 10/95 – 185.7 m 4:30 pm Aug. 10/95 – 184.7 m						180				

$+^3$, $\times^5$: Numbers refer to Sensitivity

$\frac{20}{15 \diamond 5}$ (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3 1 OF 1 METRIC

W.P. 7814-91-01 LOCATION Sta. 24+021.5 – 2.3 m Rt. of CL Hwy 548 ORIGINATED BY M.M.

DIST 62 HWY 548 BOREHOLE TYPE Hollow Stem Auger, Tri-Cone COMPILED BY M.M.

DATUM Geodetic DATE 10 08 95 CHECKED BY T.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
193.3	Ground Surface – Hwy. 548										
0.0							193				
			1	SS	55		192				
			2	SS	67				○		20 47 25 8
			3	SS	74		191				
			4	SS	41		190				
			5	SS	94	/28cm	189				
	Silty Sand some Gravel Numerous Boulders Very Dense		6	SS	76	/20cm	188				
			7	SS	60	/5cm	187		○		5 82 12 1
			8	SS	30	/3cm	186				
							185				
							184				
							183				
							182				
180.7			9	SS	60	/8cm	181				
						P1					
12.6	End of Borehole										

* Ground Water Conditions
12:00 pm Aug. 10/95 – 186.7 m
6:00 pm Aug. 10/95 – 187.2 m

$+^{3}$, $\times^{5}$: Numbers refer to Sensitivity

$\frac{20}{15}\diamond\frac{5}{10}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 4 — 1 OF 1 — METRIC

W.P. 7814-91-01 LOCATION Sta. 23+980 – 8.7 m Lt of CL Hwy 548 ORIGINATED BY M.M.

DIST 62 HWY 548 BOREHOLE TYPE Hollow Stem Auger, Tri-Cone COMPILED BY M.M.

DATUM Geodetic DATE 10 08 95 CHECKED BY T.K.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
189.8	Ground Surface – Hwy. 548										
0.0											
			1	SS	35		189				
			2	SS	61	/15cm	188		o		
			3	SS	61	/28cm	187				
			4	SS	104	/20cm	186				
	Silty Sand some Gravel Numerous Boulders Very Dense		5	SS	50	/15cm	185				
			6	SS	59	/15cm	184				
						▼	183				
			7	SS	100	/20cm	182		o		1 89 7 3
			8	SS	70	/15cm	181				
			9	SS	70	/23cm	180				
							179				
177.2			10	SS	100	/8cm	178				
12.6	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

$\frac{20}{15}\diamond 5$ (%) STRAIN AT FAILURE

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 (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

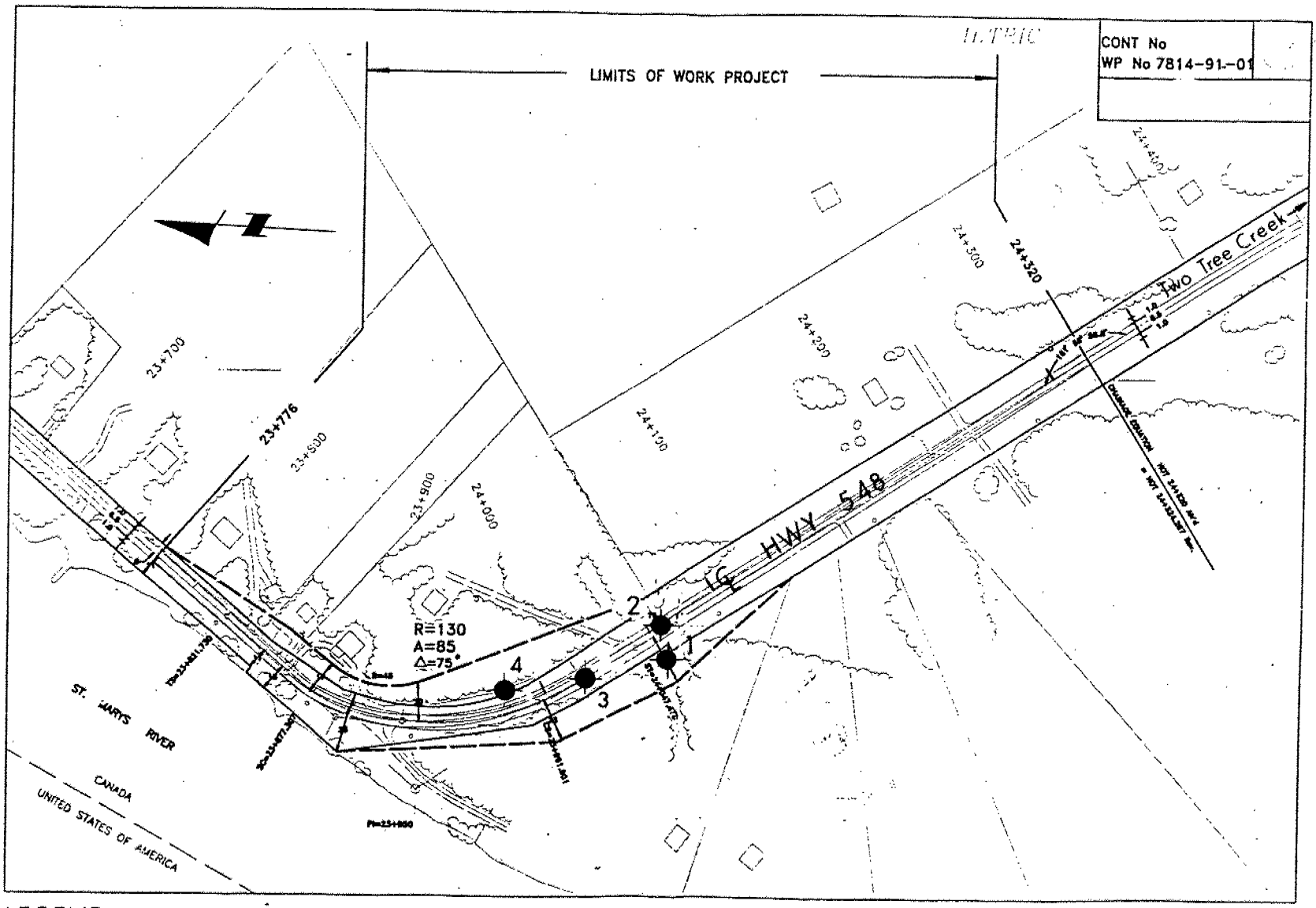
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
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
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_p	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_p	%	PLASTICITY INDEX = $w_L - w_p$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE

e_{min}	1, %	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE



LEGEND

● BOREHOLE

NOTE

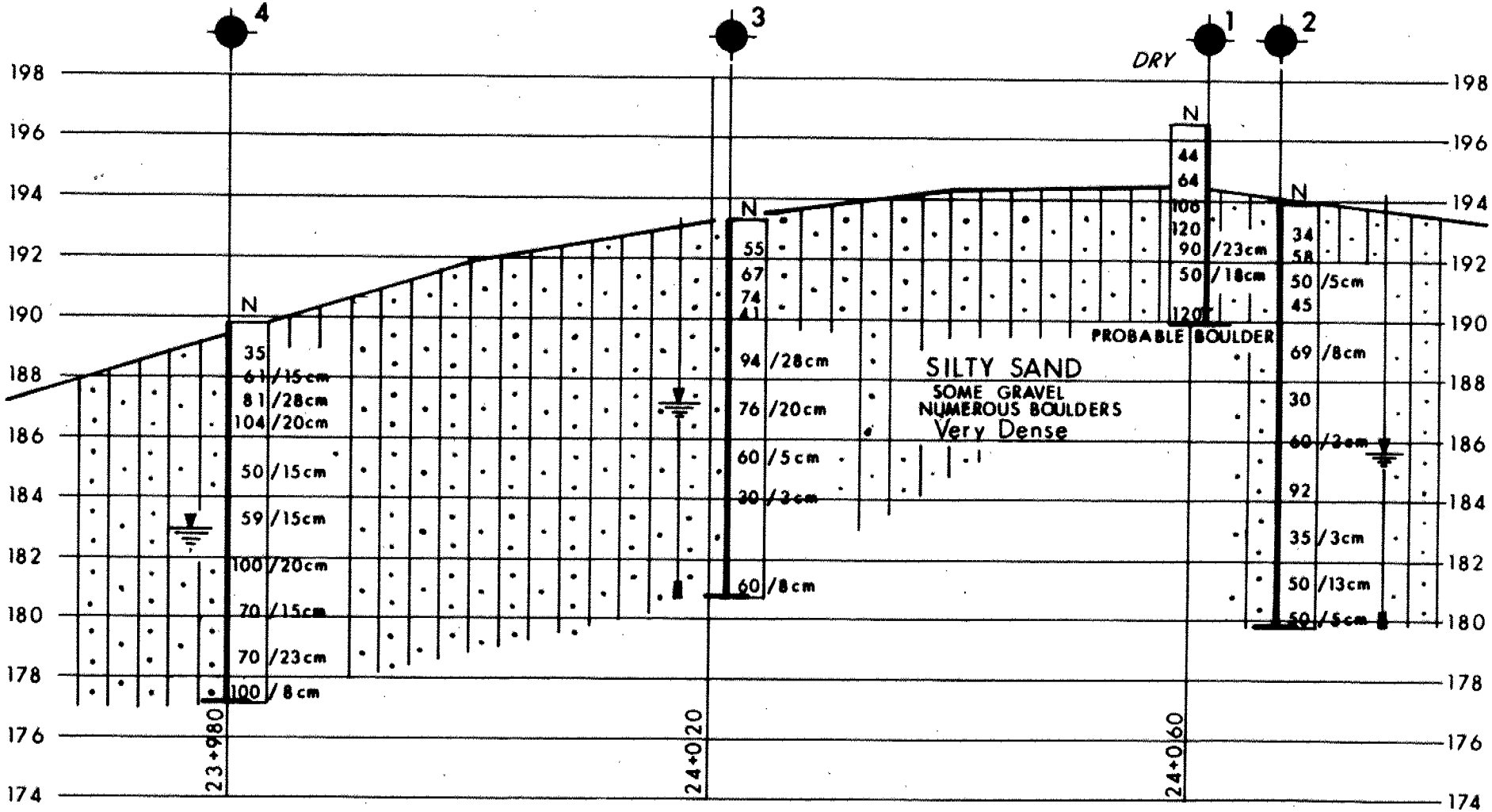
FOR PROFILE REFER TO DWG No 78149101-B

PLAN

SCALE

40m 0 40m

WP 7814-91-01
Dist 62, Hwy 548
Geocres No 41K-49
Dwg No 78149101-A



LEGEND

- BOREHOLE
- WATER LEVEL
- PIEZOMETER

NOTE
FOR PLAN REFER TO
DWG 78149101-A

℄ PROFILE HWY 548

SCALE
5m 0 5m Hor
2m 0 2m Vert

WP 7814-91-01
Dist 62, Hwy 548
Geocres No 41K-49
Dwg No 78149101-B