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HWY. No. 400

LOCATION HWY 400 AT HOLLAND MARSH
(EMBANKMENT DISTRESS STUDY)

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

ENGINEERING MATERIALS OFFICE
PAVEMENT & FOUNDATION DESIGN SECTION

WP 7-82-01

DIST 6

Hwy. 400 Over Holland Marsh
Embankment Distress Study

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TABLE OF CONTENTS

	Page No.
Introduction	1
Site Description and Geology	1 - 2
Review of Previous Construction and Maintenance Activity	2 - 3
Subsurface Conditions	4
General	4
Pavement and Embankment Fill	5 - 6
Peat	6 - 7
Silty Clays.....	7 - 8
Groundwater Conditions	8
Pavement Condition	9
Discussion and Recommendations	10
Details of Settlement	10 - 11
Remedial Measures	11
A) Continued Annual Maintenance	11
B) Pavement Removal	11
C) Fill Replacement.....	12
D) Subexcavation and Replacement	12
Miscellaneous	13

APPENDIX A

Test Results - Peat	Chart 1
Test Results - Silty Clays	Chart 2
Records of Boreholes	
Grain Size + Plasticity Charts	Fig. 1-4
Void Ratio - Pressure Curves	Fig. 5
Terminology and Abbreviations	
Plan and Stratigraphical Sections	Drawing A
Longitudinal Stratigraphical Profiles	Drawing B

APPENDIX B

Previous Design/Construction Details	Fig. 6-8
Pavement Condition Survey	Fig. 9
Comparison of Profile Grades	Fig. 10
Photographs of Pavement Distress	

FOUNDATION INVESTIGATION REPORT
FOR
HWY. 400 OVER HOLLAND MARSH
EMBANKMENT DISTRESS STUDY
W.P. 7-82-01, DISTRICT 6, TORONTO

INTRODUCTION:

Widening of the Hwy. 400 embankment over the Holland Marsh peats some 12 years ago has resulted in severely distressed pavement conditions and ongoing maintenance concerns. The Pavement and Foundation Design Section was requested to carry out a subsurface investigation for the above mentioned 2.3 km portion of Hwy. 400 to establish the extent and properties of the subsoils, to assess the causes of the apparent settlements and predict future movements, and to provide engineering recommendations for remedial measures to minimize future distress. This report summarizes the factual data obtained from a geotechnical investigation of the site and provides detailed design recommendations for future pavement /embankment reconstruction.

The fieldwork for the investigation commenced on 82 11 15 and continued to 82 11 19. A total of 12 sampled boreholes were advanced, 10 through the paved highway shoulders and 2 at the base of the embankments in the unstressed areas, using truck and track mounted auger machines equipped with continuous flight hollow stem augers. In addition, 8 pavement core holes located within the outside driving lanes adjacent to the sampled boreholes were put down to ascertain actual pavement structure depths. Both 'disturbed' and 'undisturbed' samples were retained for visual classification and laboratory testing. A total of 84 metres of sampled borings were advanced to depths ranging from 5.8 to 8.1 metres.

SITE DESCRIPTION AND GEOLOGY

The project site is located on Highway 400, some 55 km north of Toronto, where it crosses the Holland Marsh, in the Townships of King and West Gwillimbury, County of Simcoe and Regional Municipality of York. Specifically, the site encompasses the twin N.B. and S.B. embankments extending 2.3 kilometres between the South and North Canal Structures.

Physiographically, the site is located in the Lake Simcoe basin of the Simcoe Lowlands region.

The marsh is situated in a broad valley that extends from Cook Bay at the south end of Lake Simcoe in a southwesterly direction. Two rivers, the Schomberg and the Holland, occupy this valley. The valley is surrounded by hills of interlobate origin. It has been suggested that the valley was formed by an advancing ice lobe during the Lake Schomberg stage of deglaciation. Subsequently, this area was submerged under glacial Lake Algonquin. As the ice receded further north, rebound of the north end of Lake Simcoe prevented proper drainage at Cook Bay, thus creating the wet stagnant environment for the development of the marsh and peat forming vegetation.

In due course, the entire basin became infilled to form peat bogs overlying any glaciolacustrine deposits pre-existing in the basin. At the present time, Holland Marsh is enclosed by perimeter dykes constructed from drainage canal excavation spoil. The dykes are reinforced with interlocking sheet piling at the weaker points. The reclamation scheme intercepted the Schomberg river which now serves as a drainage waterway.

The Schomberg river channel was realigned and a 1.5 m high by 3.0 m wide concrete box culvert was provided to connect the two portions of the marsh across the highway.

REVIEW OF PREVIOUS CONSTRUCTION AND MAINTENANCE ACTIVITIES

Initial construction of the twin embankments, designed to carry two 3.4 metre wide traffic lanes each, was carried out under Contract #46-14 which included organic subexcavation and backfilling. A profile of Hwy. 400 across the Holland Marsh, indicating peat depths taken from a 1945 route survey sounding, are shown on Figure 6, in Appendix B. This peat was excavated for its full depth under most of the alignment to limits shown on Figure 7. Native earth backfill was dumped into the excavation without compaction until the level of the fill approached the elevation of the surrounding terrain. In the area of the Schomberg River channel, due to peat thicknesses up to 10 metres, underfill blasting and toe shooting displacement techniques were used with limited success. A 30 m wide median was provided between the embankments to accommodate disposal of the peat on site. Final grading, granular base and paving work was completed in 1952.

In less than two decades after its construction, traffic capacity problems made it necessary to widen the freeway to six lanes, although no serious distress was evident for the original 4 lanes.

Design criteria necessitated three lanes of 3.7 metres in each direction requiring a total widening of 4.3 metres. Due to structural, traffic, design economy and possible existing embankment stability concerns, the decision was made to widening the embankments to the outside without subexcavation of the underlying peats. The pavement structure for the widening as constructed is shown on Figure 8, Appendix B. This work was carried out during the summer of 1971 under Contract #71-12, with hot mix asphalt being placed in the fall. Immediately, longitudinal cracking developed and within 6 months (spring of 1972) these cracks had widened to 25 mm with differential settlements of up to 50 mm measured across some of these cracks. Ongoing corrective pavement treatment consisting crack filling, levelling with a sand asphalt course, and hot mix patching and repaving have been carried out since widening. The following table summarizes major contract patching work in recent years.

<u>Year</u>	<u>Contract No.</u>	<u>Quantities</u>	<u>Costs</u>
1977	77-588	265T-H.L.3	\$3,434
1978	78-548	216T-H.L.3	\$3,128
1979	79-542	926T-H.L.1	\$26,622
1980	80-508	1055T-H.L.1	\$30,648

These figures do not include costs associated with specific safety demand work being carried out on an annual basis.

SUBSURFACE CONDITIONS

In general, borings revealed reasonably uniform subsurface conditions across the site. Existing fill material was found to extend for a maximum 3.3 metres under the widened portion and 5.0 metres under the subexcavated portion of the highway embankment. The fill varied from , a gravelly sand through a silty sand to silty clay with sand. Underlying the widened portion and surficial beyond the embankment is a highly compressible fine fibrous peat encountered to an average thickness of 2.1 metres. Underlying this organic deposit and explored to a maximum thickness of 4.3 metres is a glaciolacustrine deposit consisting of interbedded silty clays of low and intermediate plasticity with occasional silt and sand layers throughout.

The boundaries between the various soil types as well as insitu and laboratory test results are shown on the attached Record of Borehole Sheets, Appendix A. A plan showing the locations and elevations of the borings, along with two typical transverse stratigraphical sections are shown on Drawing No. 78201-A, Appendix A. Two longitudinal sections along the outside pavement edge of the northbound and southbound alignments showing detailed soil stratigraphy and existing profile grade are presented on Drawing No. 78201-B.

The various subsoil types encountered across the site are described in detail on the following pages:

PAVEMENT AND EMBANKMENT FILL

As a result of borings taken in the outside shoulder and adjacent driving lane, plus two borings in the inside shoulders, the following asphalt pavement thicknesses were encountered.

<u>Borehole No.</u>	<u>Outside Shoulder (cm)</u>	<u>Outside Driving Lane (cm)</u>	<u>Inside Shoulder (cm)</u>
1	21	36	
2	28	36	
3	13	31	
4	25	42	
5	21	30	
6	16	21	
7	8	25	
8	9	23	
9			16
10			26

These compare with theoretical "as constructed" asphalt thicknesses of:

Outside Shoulders	8 cm
Outside Driving Lane	21 cm
Inside Shoulders	16 cm (minimum)

Borings advanced through the existing embankment indicated fill to extend for depths ranging from 1.4 to 3.3 metres beneath the outside widened portion and between 3.7 and 5.0 metres for the subexcavated portion.

This fill material ranged from a coarse granular gravelly sand in the upper portion (granular base) to a silty sand or sand with silt and gravel representing the compacted native earth fill. Typical gradation curves of representative samples taken from the fill are shown on the Grain Size Distribution Charts, Figures 1 and 2. In addition, cohesive fill consisting of silty clay with sand was encountered in many of the borings.

Based on interpretation of Standard Penetration Test 'N' values and augering operation, the majority of the fill has undergone a moderately high degree of compactive effort. The exception being the fill used to backfill the original peat excavation which was just end-dumped, accounting for its very loose to loose denseness.

PEAT

Underlying the widened portion of the embankment and surficial beyond the fill limits is the characteristic organic deposit of the Holland Marsh described as a uniform fine textured fibrous peat with occasional decomposed wood fragments. Total depths of peat encountered within the borings ranged from 1.4 metres to 3.2 metres. Unlike the muskeg deposits of northern Ontario, no noticeable change in the character of the peat was discernable with depth within this deposit.

The results of laboratory testing consisting of water content, organic content, weight, strength and compressibility testing are detailed in tabular form in Chart 1, Appendix A, and summarized as follows for peats underlying the embankment widening.

<u>Index Properties</u>			<u>Range</u>	<u>Mean</u>
Water Content	(w)	%	131-472	295
Organic Content	(O _m)	%	55-95	76
Unit Weight	(γ)	kN/m ³	9.1-11.2	10

Undrained Shear Strength (Cu) as performed by:

Quick Triaxial	kPa	19-87	40
Field Vane	kPa	42-65	54

Consolidation Testing

Initial Void Ratio	(e ₀)	4.3-7.0	5.6
Compression Index	(C _c)	2.6-4.0	3.4
Coefficient of Consolidation (C _v)	m ² /s	.08-.17	0.14

Results of laboratory testing of the 'virgin' peat, outside the embankment influence, are detailed for comparison in Chart 1. Typical consolidation curves for two samples are plotted on Figure 5.

Based on these results, the peats underlying the embankment widening can be described as highly compressible, exhibiting large magnitudes and short duration for the primary consolidation stage and continuous long-term deformation for the secondary compression stage. The long-term compression/deformation appears to be a continuous process showing an almost linear relation with log time. This agrees with current literature, suggesting the fine fibrous peats show the highest compressibility and the coarse-fibrous peats the least.

In consideration of the uniform fine fibrous texture of the peat and based on interpretation of insitu vane and laboratory quick triaxial testing, the consistency of the embankment loaded peat is assessed as firm. Based on limited testing, the consistency of the virgin peat is assessed as ranging from soft to firm, indicating some strength gain as a result of consolidation.

SILTY CLAYS

Immediately below the peat and underlying the fill where the peat was originally subexcavated is a glaciolacustrine deposit consisting of interbedded silty clays of low to intermediate plasticity. Layers and seams of silt and silty sand were present throughout this deposit. Typical gradation curves in envelope form for the silty clays and individual curves for the fine granular seams are shown on Figure 3, Appendix A.

Details of insitu and laboratory testing of this silty clay deposit are shown in Table form in Chart 2, and summarized as follows for the embankment loaded samples:

			Range		Mean	
			CL	CI	CL	CI
<u>Index Properties</u>						
Water Content	(w)	%	18-29	30-41	24	35
Liquid Limit	(w _L)	%	19-34	36-42	25	39
Plastic Limit	(w _p)	%	15-18	16-20	16	18
Plasticity Index	(I _p)	%	5-17	18-23	9	19
Unit Weight	(γ)	kN/m ³	17.4-20.6		18.9	

Undrained Shear Strength (Cu) as performed by:

Insitu vane	(kPa)	36-92	61
Unconfined compression	(kPa)	19-57	40
Quick Triaxial	(kPa)	21-37	26

Consolidation Testing

Initial Void Ratio	(e _o)	0.808-1.093	0.953
Compression Index	(C _c)	0.179-0.269	0.221
Preconsolidation Pressure	(P _c) kPa	65-128	105

The results of index testing are plotted on the plasticity chart, Figure 4. A typical void ratio V.S. pressure curve representative of the consolidation behaviour for the silty clay deposit is plotted on Figure 5.

These results indicate the deposit to consist of inorganic, moderately compressible, interbedded silty clays of low to intermediate plasticity (CL-CI).

Based on interpretation of insitu and laboratory undrained shear strength testing, the consistency for this deposit is assessed as ranging from soft to stiff, but generally in the firm range.

GROUNDWATER CONDITIONS

In view of the lowlying marshy terrain across the site, groundwater levels are assumed to approximate the native ground surface (elevation 218±) and reflect existing levels in the north and south canals. These levels are expected to show seasonal fluctuations and affected by the intensive agricultural operations in the area.

PAVEMENT CONDITION

As part of the investigation program a comprehensive pavement condition survey was undertaken across the Holland Marsh Crossing. Details of the survey, showing all major distress features, are presented in schematic form on Figure 9. In addition, outside lane edge of pavement profile elevations were taken for comparison against the "as constructed" profile grades and plotted on Figure 10 to illustrate the amount of longitudinal distortion evident. Repaving operations have actually raised the existing profile grade along the southern portion of the northbound lanes. Photographs illustrating the various types of cracking and pavement distress encountered are appended to the back of this report.

Briefly, the long term differential consolidation settlements between the original and widened portions of Hwy. 400 have predominately manifested themselves in severe continuous longitudinal cracking (photos 7 & 8) generally between the middle and outside lanes and severe stepped meandering cracks through the outside paved shoulders and driving lane. (Photos 1 to 4). Distortions indicative of differential settlements range up to ± 50 mm across the major cracks. In addition, moderate to severe random and transverse cracking (Photos 5 & 6) is apparent throughout most of the paved surface. Sectional remedial patching has resulted in an undulating longitudinal grade (refer to Figure 10, for profiles) with pavement edge stepping of up to ± 50 mm. (Photos 11 & 12). This extensive patching has resulted in an uneven, non-uniformly textured wearing surface exhibiting reduced driver comfort and safety characteristics.

DISCUSSION AND RECOMMENDATIONS

In view of the major ongoing differential settlements in both the north and southbound lanes where Hwy. 400 crosses the Holland Marsh and the continuous patching program carried out to ensure driver safety, it is proposed to perform the necessary remedial work required to alleviate the previously mentioned distress. The existing Hwy. 400 profile grades encompasses fill heights averaging 1.5 to 3 metres over peat deposits having a mean thickness of 2.1 metres across a majority of the alignment. Considering the strength/deformation characteristic of these peats and the underlying silty clay deposit, the following paragraphs will address the magnitude and causes of this settlement and present alternative recommendations for remedial treatment.

DETAILS OF SETTLEMENT

Settlements of the pavement surface atop the embankment fills are clearly shown on profile grades sketch (Figure 10) and the appended photos. Based on these grade elevations and the thickness of asphalt pavement encountered, the total amount of settlement resulting from long-term secondary consolidation of the peats underlying the widened portion can be summarized as follows:

	Outside Paved Shoulder (mm)	Outside Driving Lanes (mm)	Differential between Outside Shoulder & Lane (mm)
Range	30-320	50-360	0-150
Mean (\bar{x})	173	140	53

These values represent the actual settlement which has occurred since paving was completed, however higher values are expected in the area of the old Schomberg River where much greater peat depths are present and where excavation and/or displacement techniques were only partially successful.

Correlating field performance to laboratory consolidation testing behaviour and assuming a linear rate of settlement with the logarithm of time for long term (secondary) compression, it is anticipated that the

peat deposit will experience further secondary compression. Differential settlements, between the original and widened embankment sections, in the order of 50 mm are estimated to occur in the next 10 years as a result of this compression. Additional settlements of 20%, are anticipated if asphalt is placed to maintain the highway grade.

Due to the behaviour of peat and distortions resulting not only from vertical loading (compression) but lateral yielding (shear strain), these predictions of field settlements are at best, approximate.

REMEDIAL MEASURES

In consideration of the anticipated magnitude of future differential settlements between the widened and subexcavated portions of the embankment; costs associated with continuing patching versus major reconstruction; and acceptable quality of driver safety and comfort, the following recommendations for alternative remedial measures are presented:

A) Continued Annual Maintenance

One approach is simply to continue ongoing patching and resurfacing to maintain an acceptable level of safety and comfort. This method would impose additional loads maximizing the magnitude of continuing consolidation settlements and lateral deformation. The approach would necessitate escalating maintenance costs and probable major rehabilitation work within 5 years.

B) Pavement Removal

Under this alternative, the existing asphalt pavement would be removed and recycled with some levelling of the subbase material carried out as required. Essentially, this would unload the peats in the order of 4 kPa (approximately 9% of the existing average embankment loading) and result in minor profile grade lowering. This approach will provide short term relief from a driver's safety and comfort view point, but will not significantly affect the long term secondary compression settlements occurring within the peats. Differential cracking and distortions will reappear, requiring patching measures and resulting in progressive stress increments and increased settlements.

C) Fill Replacement

In order to significantly unload the compressible peat deposit so as to reduce settlements to an acceptable level, it is proposed to partially excavate the widened portion of the existing embankment and replace with a light weight fill. Removal of 2 metres of existing native fill material and replacement with a lightweight fill such as bottom ash, water cooled slag, etc. (unit weight of 14 kN/m^3) will result in a 30% removal of vertical stresses and a major reduction in the long term differential settlements anticipated. All fill within the original widening should be removed for the recommended depth and replaced, necessitating temporary traffic detouring onto the inside shoulder to insure two lanes of traffic. A further reduction of vertical stresses can be achieved through the use of specialty fills such as air-dried slag ($\gamma = 11 \text{ kN/m}^3$) or a combination of light weight fill and rigid board styrofoam, however the additional benefits of this last sandwich treatment may not warrant the increased costs.

D) Subexcavation and Replacement

As a final alternative to insure no differential performance between the original and widened portion of the embankments, subexcavation of the underlying peat within the limit of the widening and replacement with engineered fill is recommended. The replacement fill material should consist of a combination of normal and light weight fill to insure no increase in imposed vertical stresses on the underlying silty clay deposit. That is, for each metre of peat thickness removed, one and a half metres of light weight fill height must be placed in the fill. Based on preliminary analysis, temporary excavation slopes of 1:1 will remain stable provided the longitudinal base of the excavation is limited to 8 metres.

Excavation and filling operations must be carried out on a continuing basis to insure the integrity of the embankment. Additional borings will be necessary to establish where the limits of the original peat removal occurs under the widened portion. This information can then be used to estimate the excavation geometry, and design temporary inside shoulder widening to accomodate detoured traffic.

In the area of the old Schomberg River where peat depths are greatest, a combination of partial subexcavation and replacement with light weight fill will be required. Although the costs and disruption to traffic for this work are significantly higher than those associated with the previous alternatives, this technique will insure the long term distortion-free performance expected from a high volume freeway such as Hwy. 400.

In summary, although various design alternatives are technically viable at this site, a comprehensive cost benefit analysis taking into account current pavement management and maintenance concepts should be carried out to insure acceptable long term performance.

MISCELLANEOUS

The fieldwork for this investigation was supervised by Mr. A. Ragula, Field Technician under the direction of Mr. T. J. Kazmierowski, Foundation Engineer. The drawings and figures were prepared by Mr. J. A. PetruzzIELLO of the drafting unit. This report was written by T. J. Kazmierowski and reviewed by Mr. M. Devata, Senior Foundation Engineer.



A handwritten signature in black ink, appearing to read "T. J. Kazmierowski".

T. J. Kazmierowski, P. Eng.,
Foundations Engineer



A handwritten signature in black ink, appearing to read "M. Devata".

M. Devata, P. Eng.,
Senior Foundations Engineer

A P P E N D I X A

Detailed Lab Test Results – PEAT

	B.H. #	S #	W %	Q_m %	γ kN/m ³	UU kPa	e_o	C_c	P_c kPa
PEAT UNDER EMBANKMENT LOADING	1	4	266	79	-	-	-	-	-
	1	5	387	-	9.83	18.8	5.91	3.66	81
	1	6	267	-	11.2	25.9	-	-	-
	2	4b	215	56	-	-	-	-	-
	2	5	267	87	-	-	-	-	-
	3	2	131	55	-	-	-	-	-
	4	5	310	85	10.2	86.9	6.43	3.64	98
	5	4	241	76	10.4	60.8	4.35	2.62	162
	5	5	219	73	-	-	-	-	-
	6	4b	334	84	-	-	-	-	-
	6	5	472	91	9.7	30.3	4.84	3.47	55
	7	3	341	95	9.1	31.1	5.01	2.81	60
	7	4	267	92	10.2	39.0	-	-	-
	8	2	137	44	-	-	-	-	-
	8	4	447	91	9.7	48.2	7.0	4.04	56
	8	5	398	87	10.2	21.1	-	-	-
Mean \bar{x} =			295	76	10	40	5.59	3.37	70
Standard Deviation S =			102	16	0.6		1.02	0.54	18.9
VIRGIN PEAT	11	1	227	53	-	-	-	-	-
	11	2	177	71	9.7	24.7	4.50	3.02	63
	11	3	524	54	10.1	13.8	4.44	2.29	35
	12	1	328	85	10.3	49.4	8.43	7.84	109
		Mean \bar{x} =		66	10	29			

Detailed Lab Test Results - SILTY CLAYS

	B.H. #	S #	W %	W _L %	W _P %	I _P %	γ kN/m ³	U kPa	UU kPa	e ₀	C _c	P _c kPa
SILTY	1	7	40.5	42	19.5	22.5	17.4	19.0	-	-	-	-
	1	10	25	27	18	9	-	-	-	-	-	-
	2	6	35	40	18	22	18.1	-	24.7	1.093	0.269	65
	3	5	29.5	36	18.5	17.5	19.0	-	27.2	-	-	-
CLAYS	4	7	28.5	30	16	14	19.3	-	36.8	0.808	0.179	122
	4	8	19.5	23	17.5	5.5	20.6	40.4	-	-	-	-
	5	6	29	27.5	16.5	11	19.2	33.4	-	-	-	-
	6	6	-	-	-	-	18.1	-	23.9	-	-	-
UNDER	6	8	21.5	20	15	5	-	-	-	-	-	-
	7	5	27.3	34.5	18	16.5	19.2	-	23.2	-	-	-
EMBANKMENT	7	6	18	19	14.5	4.5	-	57.0	21.1	-	-	-
	7	7	23	27.5	16	11.5	20.1	28.7	-	-	-	-
	8	6	27	36	16	20	17.9	-	18.5	-	-	-
	10	7	25	27	17	10	-	-	-	-	-	-
LOADING	10	8	31	39	19.5	19.5	18.9	38.6	28.6	0.959	0.216	128
	10	9	21.5	24.5	16.5	8	-	-	-	-	-	-
		CL	23.6	24.9	16.3	8.8	18.9	40	26	0.953	0.221	
	Mean \bar{x} =	C I	34.6	38.6	18.2	19.4						
VIRGIN	11	7	23	20	14.5	5.5	-	-	-	-	-	-
	12	2	31	30.5	16.5	13.5	18.9	-	16.2	-	-	-
SILTY	12	3	28	32.5	18.5	14	-	-	-	-	-	-
	12	4	23	23	17.5	5.5	20.1	31.9	-	0.816	0.132	-
CLAY	Mean \bar{x} =		26	26	17	9.6	19.5					



RECORD OF BOREHOLE No 1

METRIC

W P 7-82-01 LOCATION Sta. 10 + 301.3 N.B. Chainage o/s 2.2 m Rt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 15 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100								
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE								
221.3	N.B.L. Paved Shoulder															
0.0	21 cm Asphalt															
	Brown Fill		1	SS	79		220							40 45 (15)		
	Gravelly Sand to Silty Sand		2	SS	35									6 42 44 8		
218.9	Wood		3	SS	47											
2.4	Black Fine Fibrous Peat with wood fragments Soft		4	SS	PH		218					W = 266 %		0 _m = 79%		
			5	TW	PH							W = 387 %	9.8	e ₀ = 5.91 C _c = 3.66		
216.6			6	TW	PH							W = 267 %	11.2			
4.7			7	TW	PH		216						17.4	0 4 68 28		
	Grey Interbedded Silty Clays and Silts of Slight plasticity Firm to V. Stiff		8	SS	21							N.P.		0 16 79 5		
			9	SS	10		214					I				
213.2			10	SS	6											
8.1	End of Borehole															

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2

METRIC

W P 7-82-01 LOCATION Sta. 10 + 684.8 N.E. Chainage o/s 2.3 m Rt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 15 CHECKED BY

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			20	40	60	80	100					
220.6	N.B.I. Paved Shoulder																
0.0	28 cm Asphalt																
	Fill Sand with Silt and Gravel		1	SS	59		220										25 50 (25)
			2	SS	11												
	Brown Silty Clay		3	SS	7		218										
	Grey Some Sand																
217.3			4	SS	7												0 19 60 21 Om = 56%
3.3	Black Fine Fibrous Peat Occ. wood fragments Firm		5	SS	7												Om = 87%
215.9							216										
4.7	Grey Silty Clay with Silt and Sand Seams		6	TW	PH												0 3 69 28 e _o = 1.04 C _c = 0.269 P _c = 65 kPa
214.5	Stiff to V. Stiff		7	SS	25												
6.1	End of Borehole																

+³, x⁵: Numbers refer to Sensitivity

20
15
10

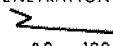
5 (%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 3

METRIC

W P 7-82-01 LOCATION Sta. 11 + 163.2 N.B. Chainage o/s 1.8 m Rt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 15 CHECKED BY SP

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			20	40	60	80	100					
220.0	N.B.L. Paved Shoulder																
	13 cm Asphalt																
0.0	Fill Sand with Silt and Gravel		1	SS	7												
218.5																	
1.5	Black Fine Fibrous Peat Occ. Silty Clay and Silty Sand Layers Firm		2	SS	9												
			3	SS	PH												
			4	SS	5												
216.3																	
3.7	Grey Silty Clays of low to Intermediate Plasticity Firm to V. Stiff		5	TW	PH												
			6	TW	PH												
			7	SS	28												
214.2																	
5.8	End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15
10
5
0
5
10
15
20
(%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 4

METRIC

W P 7-82-01 LOCATION Sta. 11 + 905.8 N.B. Chainage o/s 1.4 m Rt. E.P. Driving Lane ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TJK
DATUM Geodetic DATE 82 11 16 CHECKED BY CF

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
221.3	N.B.L. Paved Shoulder																
0.0	25 cm Asphalt																
	Fill Silty Sand to Gravelly Sand		1	SS	73		220										18 40 35 7
	Brown		2	SS	55												
	Grey Silty Clay with Sand		3	SS	19												
218.2			4	SS	13		218							W = 70 %			Om = 28%
3.1	Black Fine Fibrous Peat Firm to Stiff		5	TW	PH									W = 310 %		10.2	Om = 85% e _o = 6.43 C _c = 3.64
216.4			6	TW	PH												
4.9			7	TW	PH		216									19.3	0 2 81 17 e _o = 0.808 C _c = 0.179
	Grey Silty Clay of low to Intermediate Plasticity Occ. Silt and Fine Sand Seams Firm to V. Stiff		8	TW	PH		214									20.6	
213.2			9	SS	36												
8.1	End of Borehole																

RECORD OF BOREHOLE No 5

METRIC

W P 7-82-01 LOCATION Sta. 11 + 904.4 S.B. Chainage o/s 1.4 m Lt. E.P. Driving ORIGINATED BY AR
 DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
 DATUM Geodetic DATE 82 11 16 CHECKED BY

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			20	40	60	80	100					
221.4	S.B.L. Paved Shoulder																
0.0	21 cm Asphalt																
	Fill Silty Sand to Gravelly Sand		1	SS	41		220										
	Brown Grey		2	SS	24												
218.8	Silty Clay some Sand		3	SS	8												
2.6			4	TW	PH		218									10.4	Om = 76% e _o = 4.35 C _c = 2.62
	Black Fine Fibrous Peat Non-woody Firm		5	SS	PH												Om = 73%
216.8			6	TW	PH		216									19.2	0 3 76 21
4.6	Grey Silty Clays of low to Intermediate Plasticity Occ. Silty Sand Layers Firm to V. Stiff		7	SS	43												0 70 25 5
214.9	End of Borehole																
6.5																	

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

RECORD OF BOREHOLE No 6

METRIC

W P 7-82-01 LOCATION Sta. 11 + 460.7 S.B. Chainage o/s 1.7 m Lt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 17 CHECKED BY *SP.*

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			20	40	60	80	100					
220.1	S.B.L. Paved Shoulder																
0.0	16 cm Asphalt						220										
	Fill Sand		1	SS	30												7 87 (6)
	Brown Grey		2	SS	13												
	Silty Clay some Sand		3	SS	20		218										
216.9			4	SS	3												
3.2	Black Fine Fibrous Peat Firm		5	TW	PH		216										Om = 84%
			6	TW	PH												Om = 91%
215.3																	Om = 91%
4.8																	Om = 91%
	Grey Silty Clays of low to Intermediate Plasticity Firm to V. Stiff		7	TW	PH												Om = 91%
			8	SS	8		214										Om = 91%
			9	SS	12												Om = 91%
212.0			10	SS	22												Om = 91%
8.1	End of Borehole																Om = 91%

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

METRIC

W P 7-82-01 LOCATION Sta. 11 + 133.9 S.B. Chainage o/s 1.6 m Lt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 17 CHECKED BY GP

[illegible]

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 8

METRIC

W P 7-82-01 LOCATION Sta. 10 + 310.5 S.B. Chainage o/s 2.0 m Lt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 17 CHECKED BY EP

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			20	40	60	80	100					
220.7	S.B.L. Paved Shoulder																
0.0	9 cm Asphalt																
	Brown Fill		1	SS	23		220										
219.3	Sand Some Silt																
1.4			2	SS	7										W = 137 %		Om = 44%
	Black Fine Fibrous Peat with wood fragments Firm		3	TW	PH												
			4	TW	PH		218								W = 447 %	9.7	Om = 91% e ₀ = 7.0 C _c = 4.04
216.6			5	TW	PH										W = 398 %	10.2	Om = 87%
4.1	Grey Silty Clay Stiff		6	TW	PH		216										
216.0																	
4.7			7	SS	24												
	Grey Sandy Silt to Silt Compact		8	SS	20										N.P.		0 11 84 5
214.1																	
6.6	End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 9

METRIC

W P 7-82-01 LOCATION Sta. 10 + 301.0 N.B. Chainage o/s 11.5 m Lt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 18 CHECKED BY ep

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			20	40	60	80	100					
220.9	N.B.L. Median Shoulder																
0.0	16 cm Asphalt																
	Gravelly Sand		1	SS	100	10 cm	220										
	Boulder																
	Silty Clay with Sand		2	SS	85												
	Fill																
	Silty Sand to Sandy Silt		3	SS	21		218										4 53 38 5
	Traces of Clay		4	SS	6												3 41 49 7
217.2																	
3.7			5	SS	2												
	Grey Silty Clay with interbedded Sandy Silt Layers		6	SS	10		216										
	Soft to Very Stiff		7	SS	17												
214.3			8	SS	22												0 18 67 15
6.6	End of Borehole																

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 10

METRIC

W P 7-82-01 LOCATION Sta. 11 + 905.5 N.B. Chainage o/s 15.4 m Lt. E.P. Driving ORIGINATED BY AR
 DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
 DATUM Geodetic DATE 82 11 18 CHECKED BY EP

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 Y 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 (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE												
221.6	N.B.L. Median Shoulder							20	40	60	80	100	10	20	30					
0.0	26 cm Asphalt																			
Fill	Gravelly Sand		1	SS	28															
	Silty Clay and Sand Trace Gravel		2	SS	63		220													
			3	SS	40															
			4	SS	40		218										2 37 41 20			
	Brown Grey		5	SS	9															
216.6			6	SS	3												1 83 12 4			
5.0	Grey Silty Clays of low to Intermediate Plasticity Soft to Firm		7	SS	6		216													
			8	TW	PH											18.9	e ₀ = 0.96 C _c = 0.22			
			9	SS	10															
			10	SS	36		214													
213.5	Sand																			
8.1	End of Borehole																			



RECORD OF BOREHOLE No 11

METRIC

W P 7-82-01 LOCATION Sta. 10 + 301.8 N.B. Chainage o/s 10.4 m Rt. E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 19 CHECKED BY EP

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
219.5	Ground Surface																			
0.0	Brown to Black Fine Fibrous Peat with occasional wood fragments Soft to Firm		1	SS	5															
			2	TW	PH		218									9.7	Om = 71% e _o = 4.5 C _c = 3.02			
			3	TW	PH											10.1	Om = 54% e _o = 4.44 C _c = 2.29			
216.3			4	SS	PH															
3.2	Grey Silty Clay with interbedded Sandy Silt and Silt Layers Stiff to V. Stiff		5	SS	17		216									0 14 81 5				
			6	SS	13															
213.7			7	SS	14		214									0 1 80 19				
5.8	End of Borehole																			



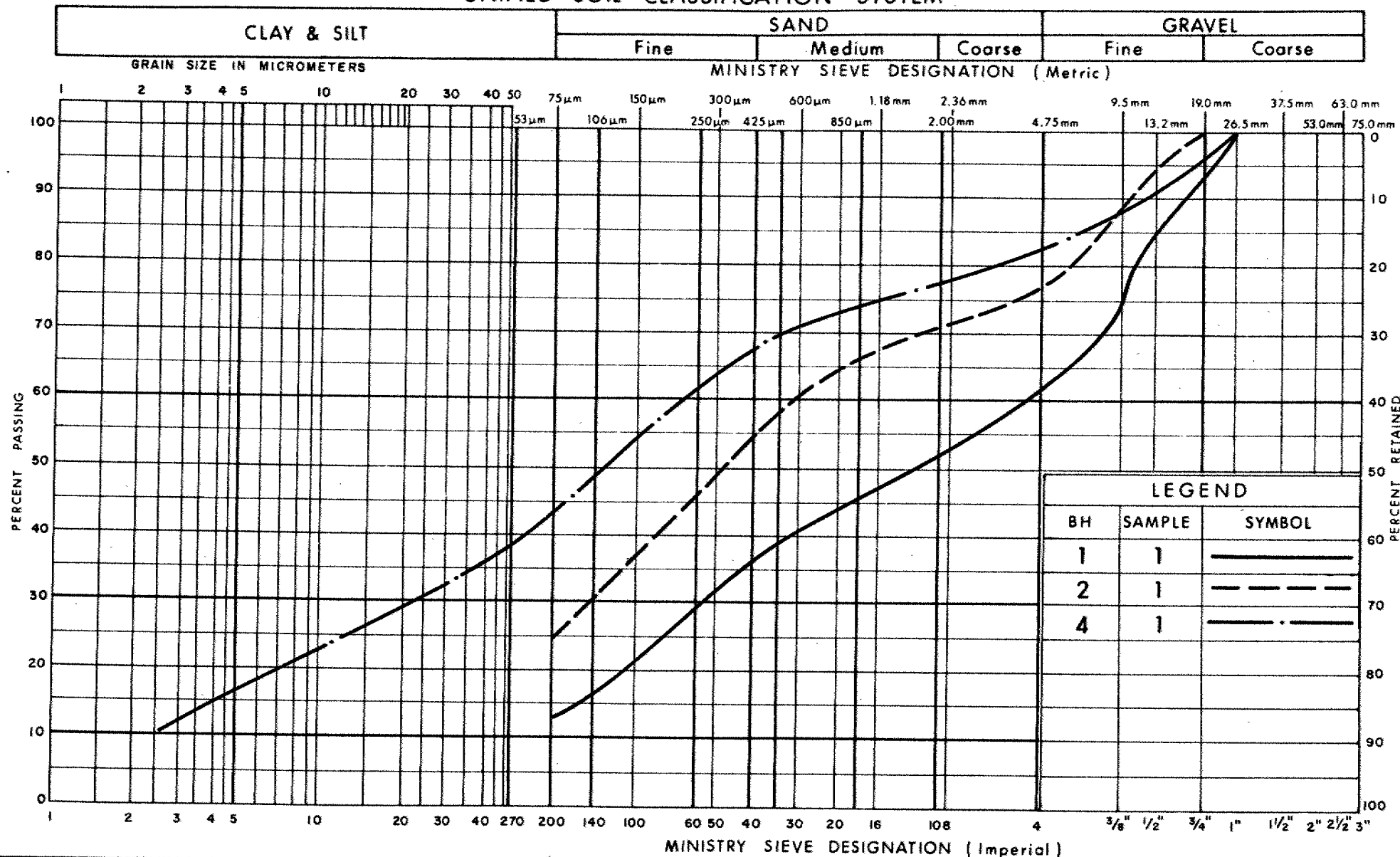
RECORD OF BOREHOLE No 12

METRIC

W P 7-82-01 LOCATION Sta. 11 + 905.8 N.B. Chainage o/s 13.4 m Rt.E.P. Driving ORIGINATED BY AR
DIST 6 HWY 400 BOREHOLE TYPE Hollow Stem Auger Lane COMPILED BY TJK
DATUM Geodetic DATE 82 11 19 CHECKED BY EP

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								WATER CONTENT (%)				
218.4	Ground Level							20	40	60	80	100								
0.0	Black Fine Fibrous Peat Occ. wood fragments Soft to Firm					218														
			1	TW	PH															
216.7			2	TW	PH															
1.7	Organics																			
	Grey Silty Clays of low to Intermediate Plasticity with interbedded Sandy Silt and Silt Layers Soft to V. Stiff		3	SS	4		216													
			4	TW	PH															
			5	SS	13															
		6	SS	18		214														
		7	SS	25																
212.6																				
5.8	End of Borehole																			

UNIFIED SOIL CLASSIFICATION SYSTEM



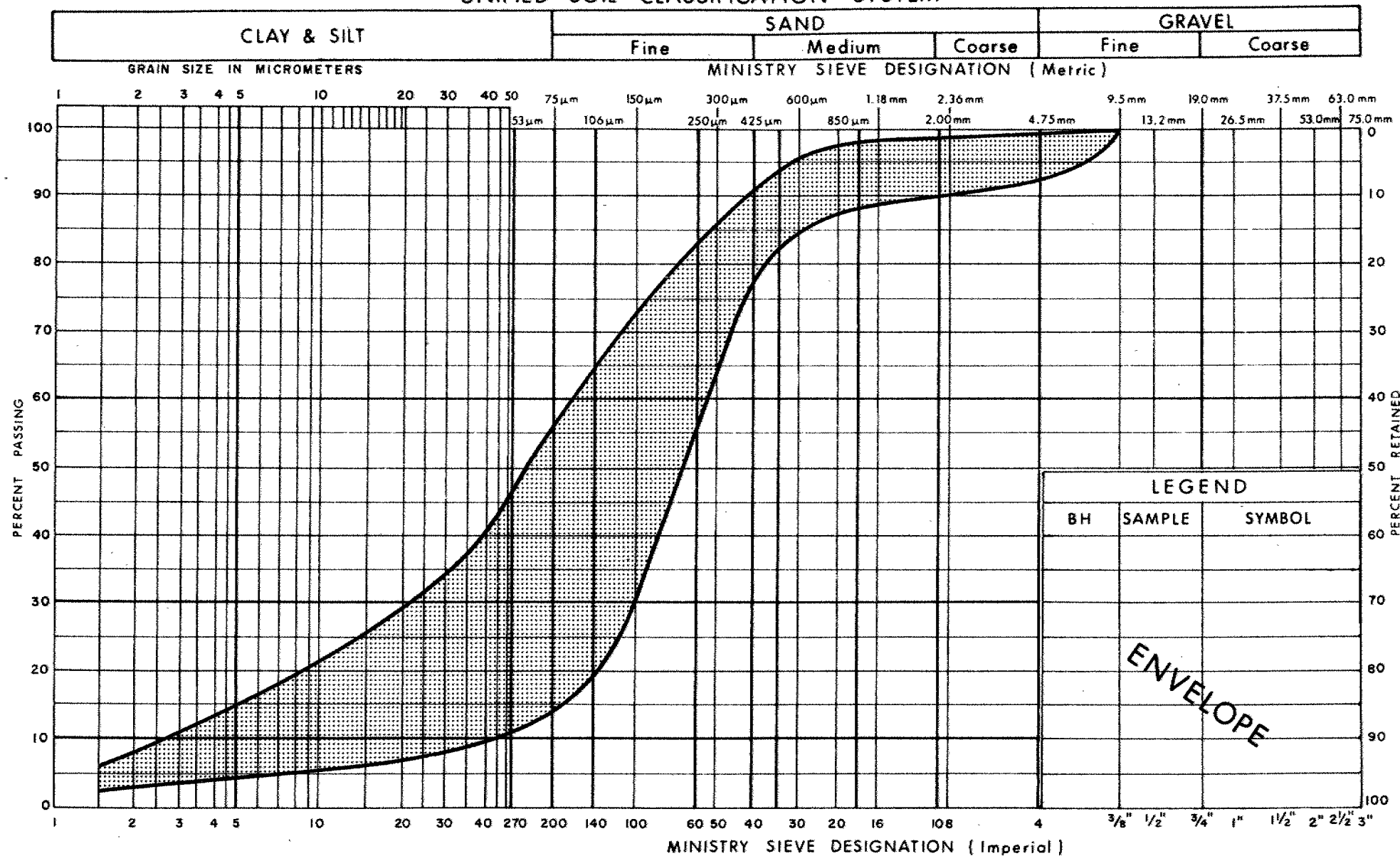
Ministry of
Transportation and
Communications

GRAIN SIZE DISTRIBUTION
FILL
GRAVELLY SAND TO SAND WITH SILT & GRAVEL

FIG No 1

W P 7-82-01

UNIFIED SOIL CLASSIFICATION SYSTEM

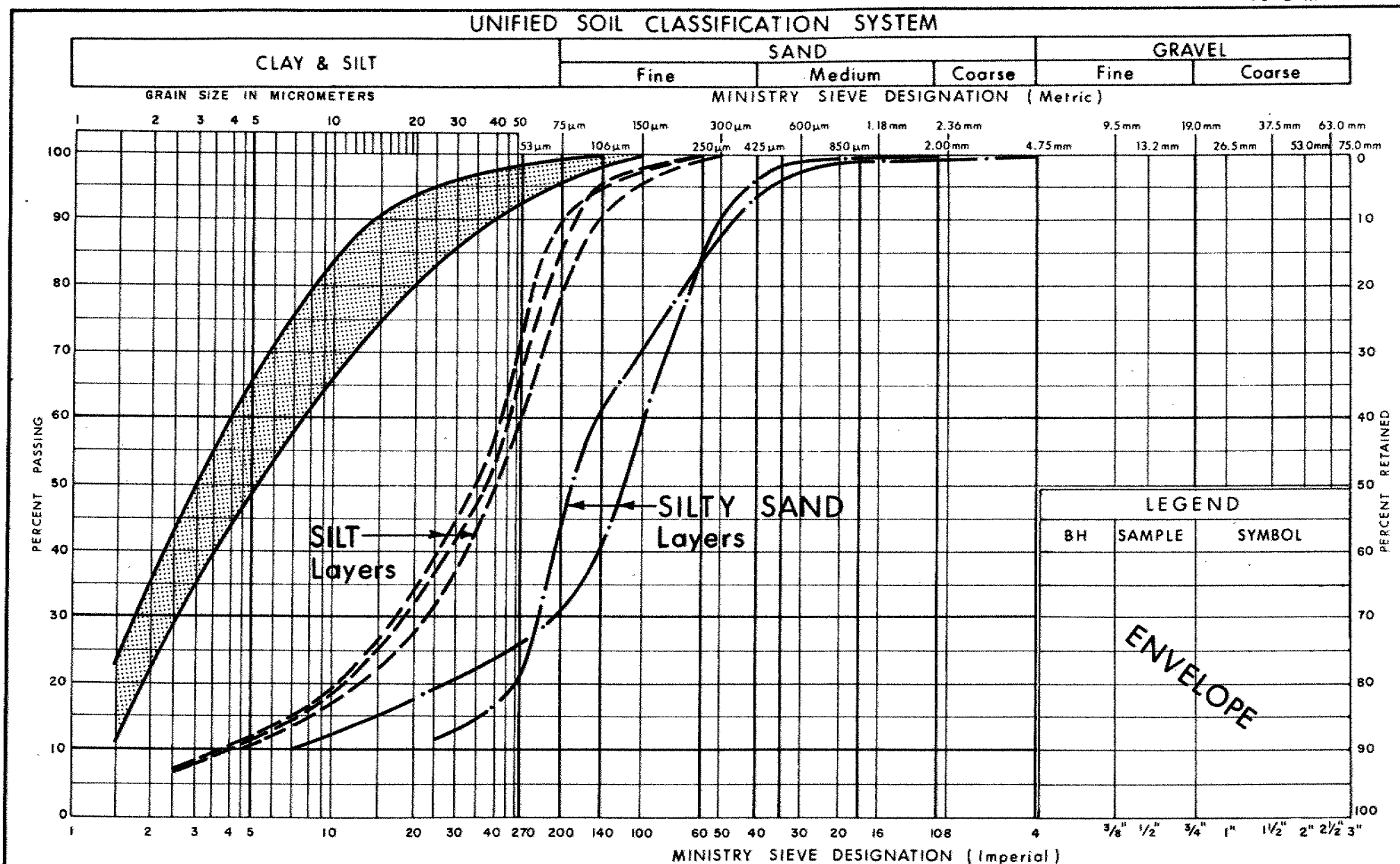


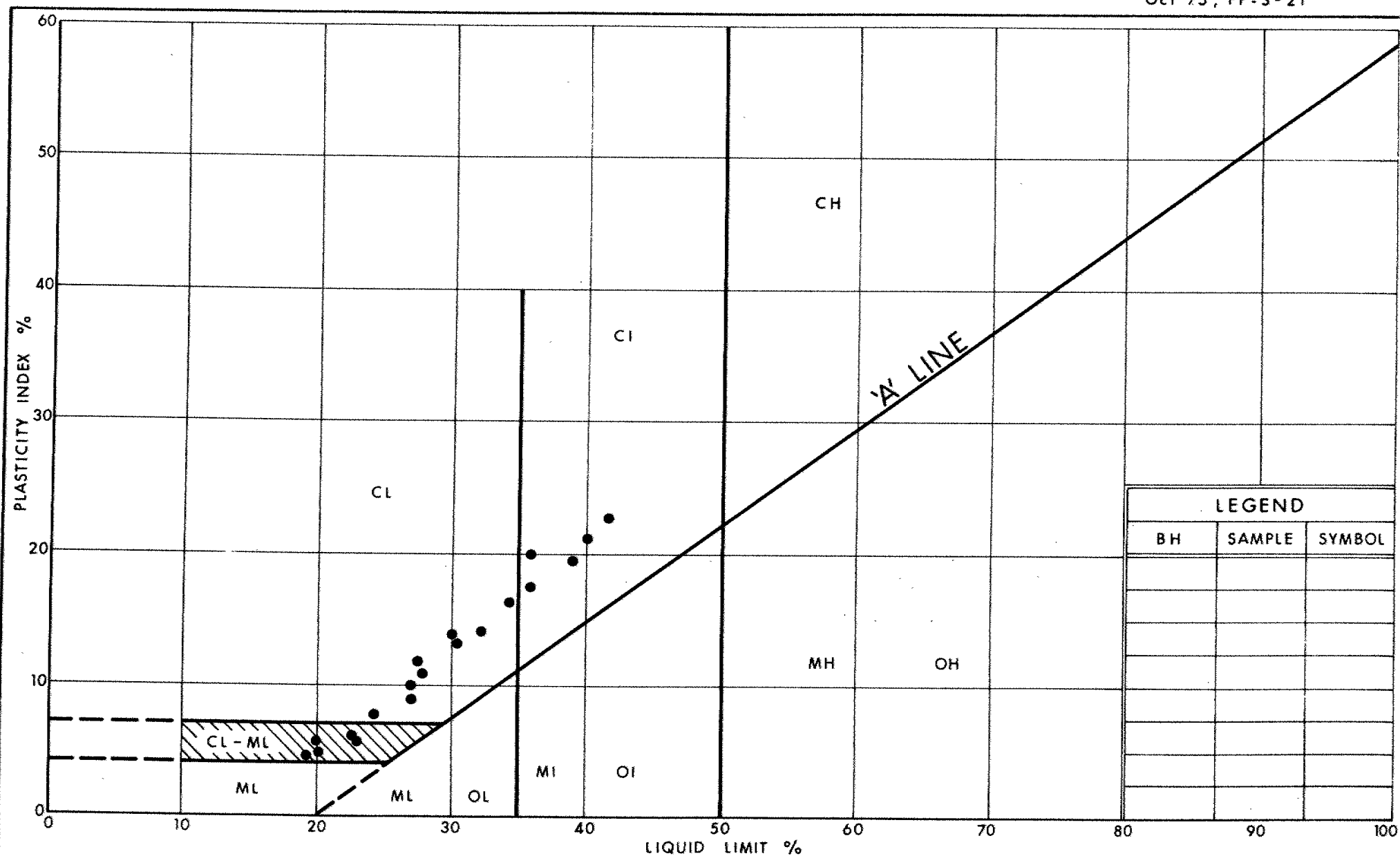
Ministry of
Transportation and
Communications

GRAIN SIZE DISTRIBUTION
FILL
SAND TO SILTY SAND

FIG No 2

WP 7-82-01





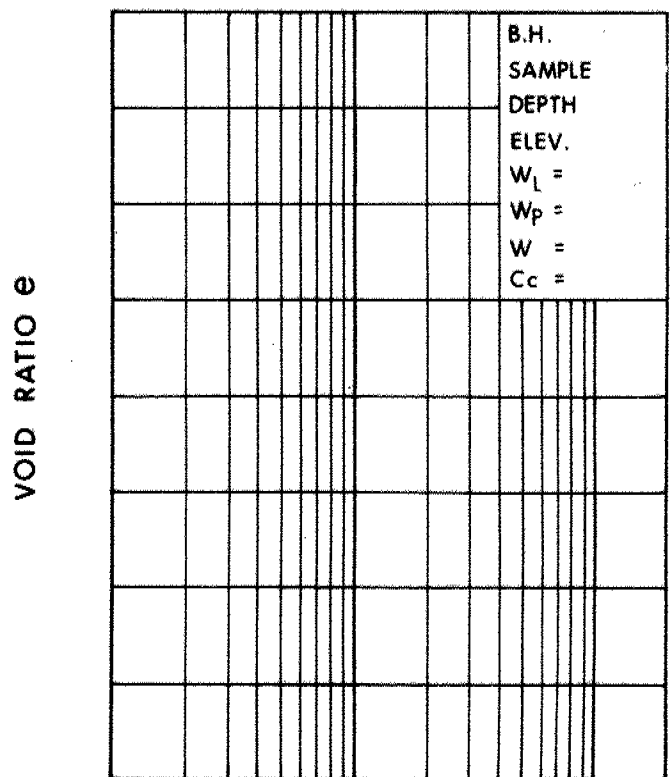
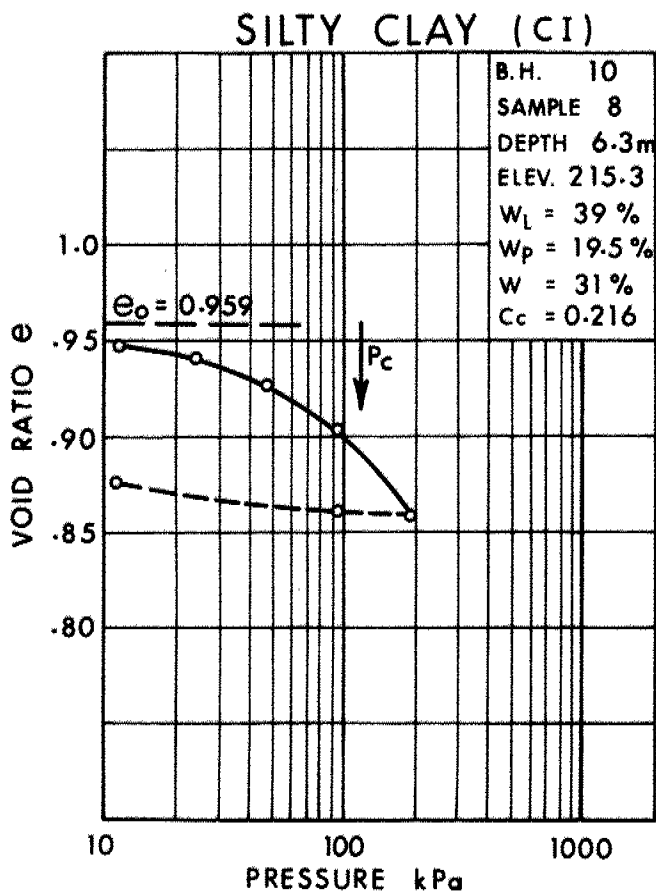
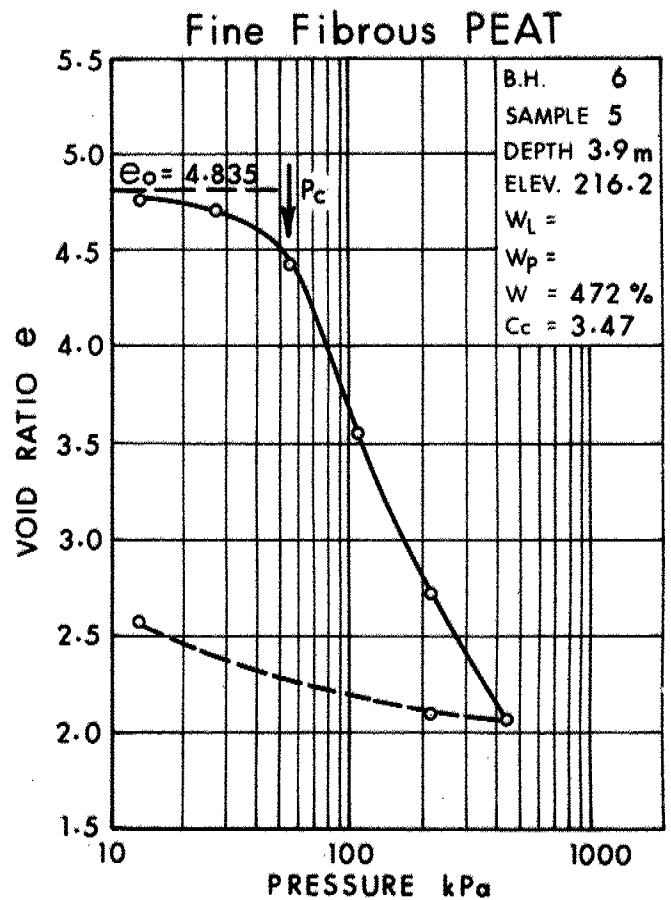
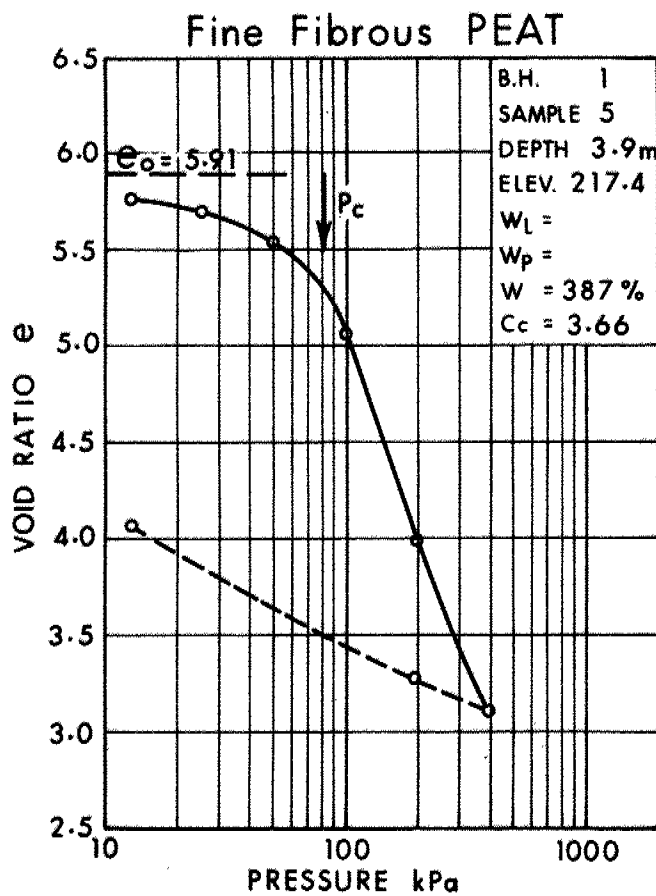
Ministry of
Transportation and
Communications

PLASTICITY CHART
INTERBEDDED SILTY CLAYS
OF LOW TO INTERMEDIATE PLASTICITY

FIG No 4

W P 7-82-01

VOID RATIO - PRESSURE CURVES



NOTE:

All samples have undergone embankment loading

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

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 = $\frac{c_u}{\tau_r}$

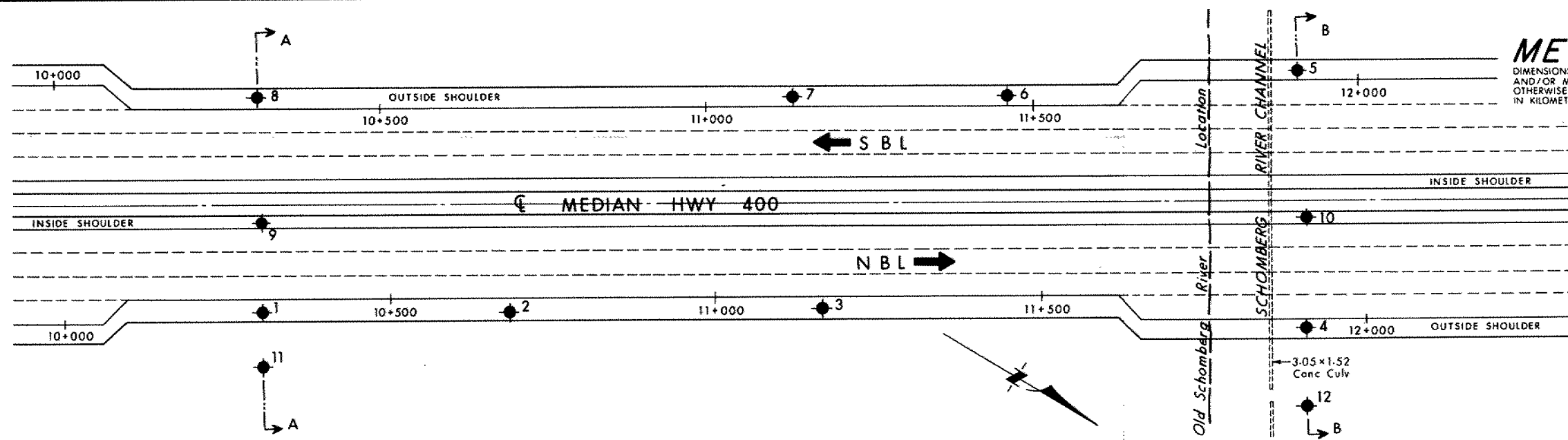
STRESS AND STRAIN

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

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^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

A P P E N D I X B



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES.

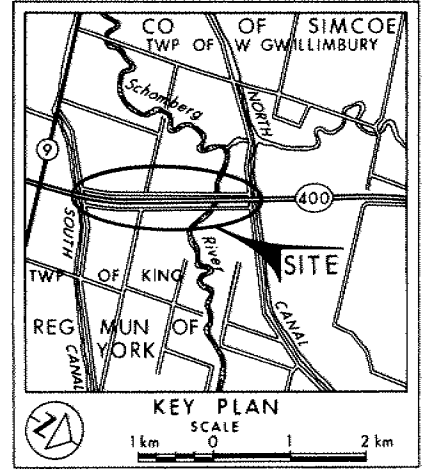
CONT No
WP No 7-82-01

HWY 400 OVER HOLLAND MARSH

BORE HOLE LOCATIONS & SOIL STRATA

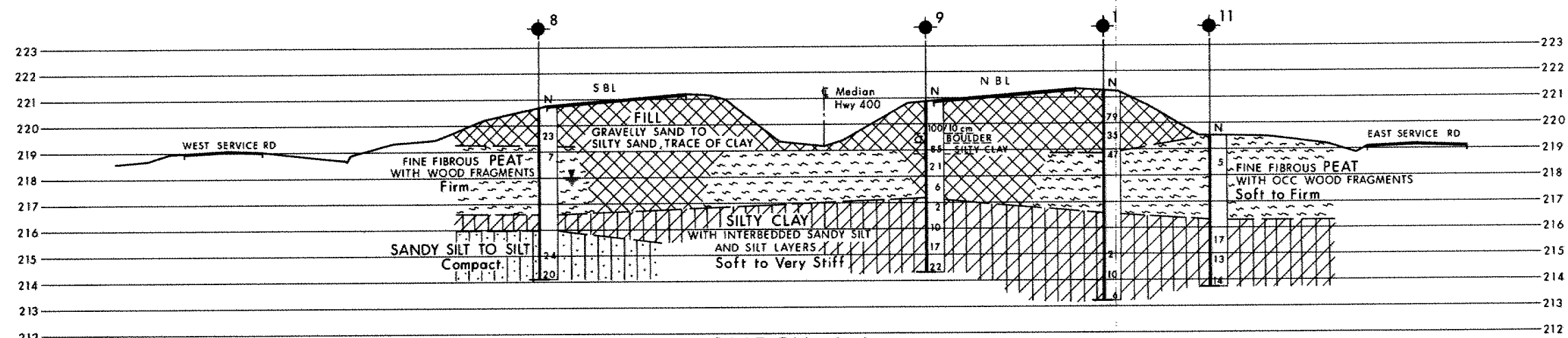


SHEET

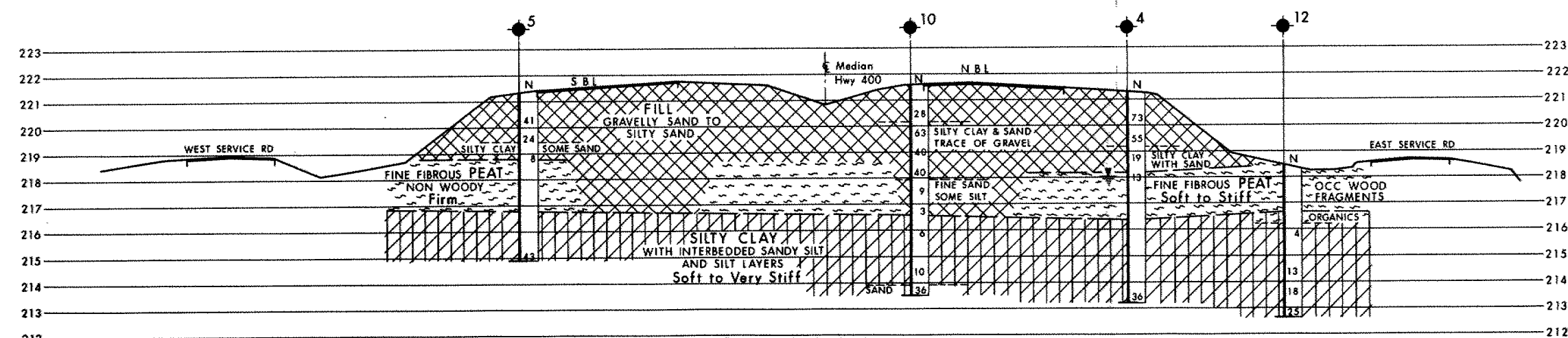
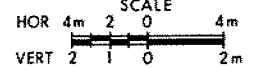


NOTE

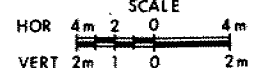
For Profiles Refer to
Dwg No 78201-B



SECTION A-A



SECTION B-B



LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊙ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation

No	ELEVATION	NORTH BOUND STATION	LANE E P OFFSET
1	221.3	10+301.3	2.2m Rt
2	220.6	10+684.8	2.3m Rt
3	220.0	11+163.2	1.8m Rt
4	221.3	11+905.8	1.4m Rt
9	220.9	10+301.0	11.5m Lt
10	221.6	11+905.5	15.4m Lt
11	219.5	10+301.8	10.4m Rt
12	218.4	11+905.8	13.4m Rt
SOUTH BOUND LANE E P			
No	ELEVATION	STATION	OFFSET
5	221.4	11+904.4	1.4m Lt
6	220.1	11+460.7	1.7m Lt
7	220.1	11+133.9	1.6m Lt
8	220.7	10+310.5	2.0m Lt

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV.	DATE	BY	DESCRIPTION
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MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, ONTARIO PH-000000-2.04

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES.

CONT No
WP No 7-82-01

HWY 400 OVER HOLLAND MARSH

SHEET

BORE HOLE LOCATIONS & SOIL STRATA

SEE DWG No 78201-A

KEY PLAN
SCALE

LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊙ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation

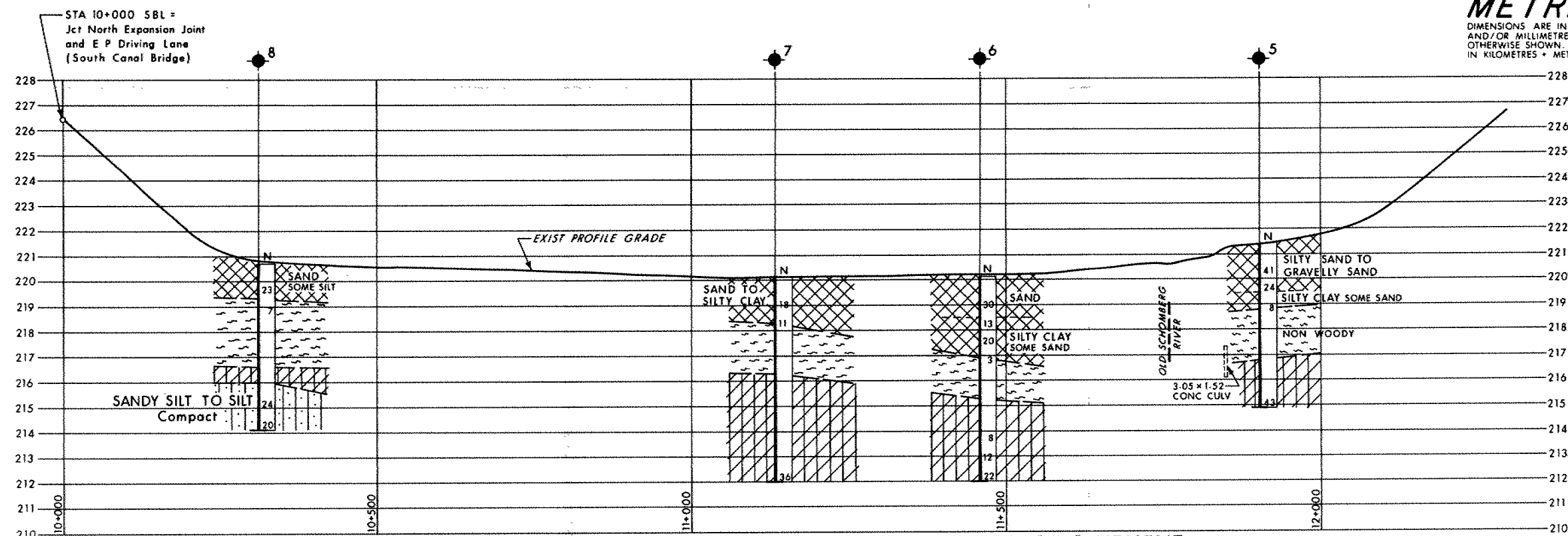
No	ELEVATION	NORTH BOUND LANE STATION	E P OFFSET
1	221.3	10+301.3	2.2m Rt
2	220.6	10+684.8	2.3m Rt
3	220.0	11+163.2	1.8m Rt
4	221.3	11+905.8	1.4m Rt
SOUTH BOUND LANE E P OFFSET			
5	221.4	11+904.4	1.4m Lt
6	220.1	11+460.7	1.7m Lt
7	220.1	11+133.9	1.6m Lt
8	220.7	10+310.5	2.0m Lt

NOTE

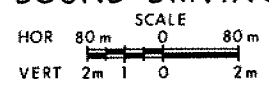
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

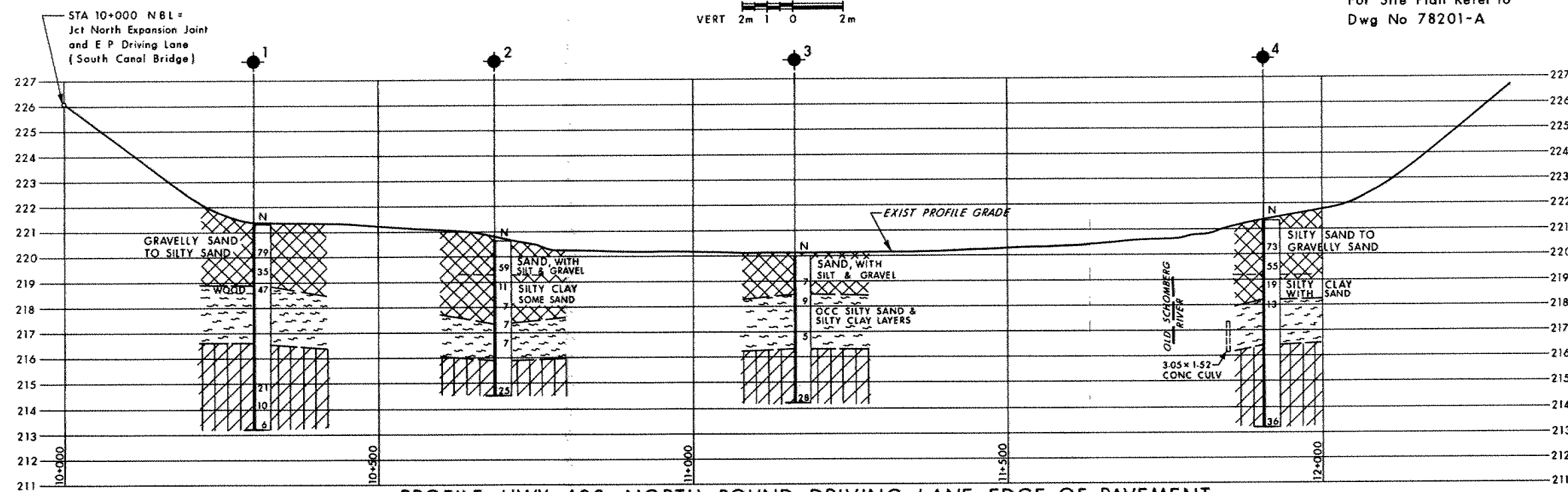
REV	DATE	BY	DESCRIPTION
1			
Geocres No 31D-298			
HWY No 400			DIST 6
SUBMITTAL CHECKED			DATE 1983 01 25 SITE N/A
DRAWN BY			DWG 78201-8



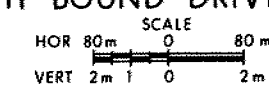
PROFILE HWY 400 SOUTH BOUND DRIVING LANE EDGE OF PAVEMENT



NOTE
For Site Plan Refer to
Dwg No 78201-A



PROFILE HWY 400 NORTH BOUND DRIVING LANE EDGE OF PAVEMENT



LEGEND FOR SOIL STRATIGRAPHY

- FILL MATERIAL
- FINE FIBROUS PEAT WITH OCC WOOD FRAGMENTS Soft to Firm
- SILTY CLAYS (OF LOW & INTERMEDIATE PLASTICITY) OCC SILT AND SAND LAYERS Soft to Very Stiff



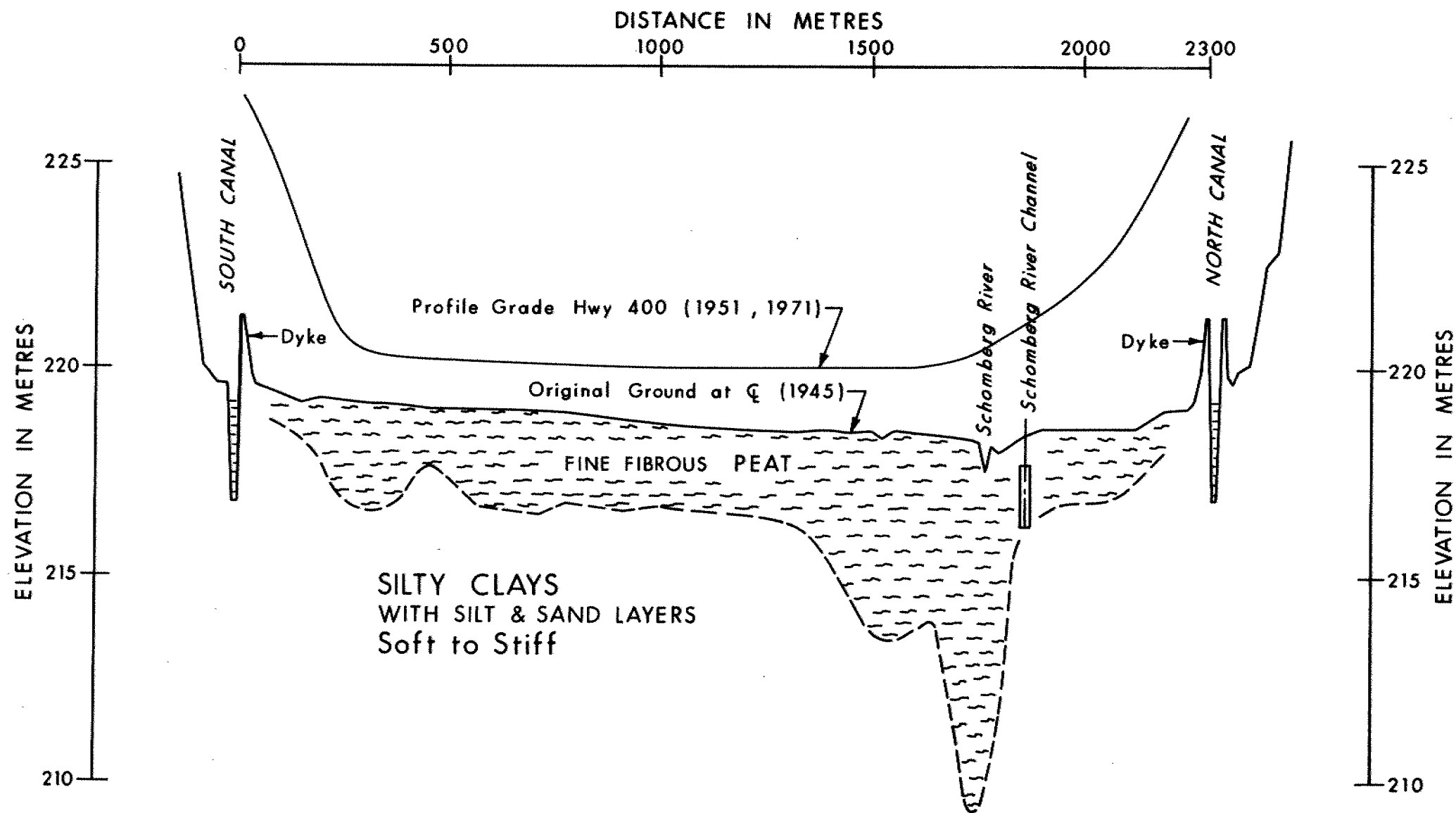


Fig 6 : Hwy 400 Profile Showing Peat Depths (1945 Soundings)

☐ DITCH & DIVIDED HIGHWAY

☐ PAVEMENT

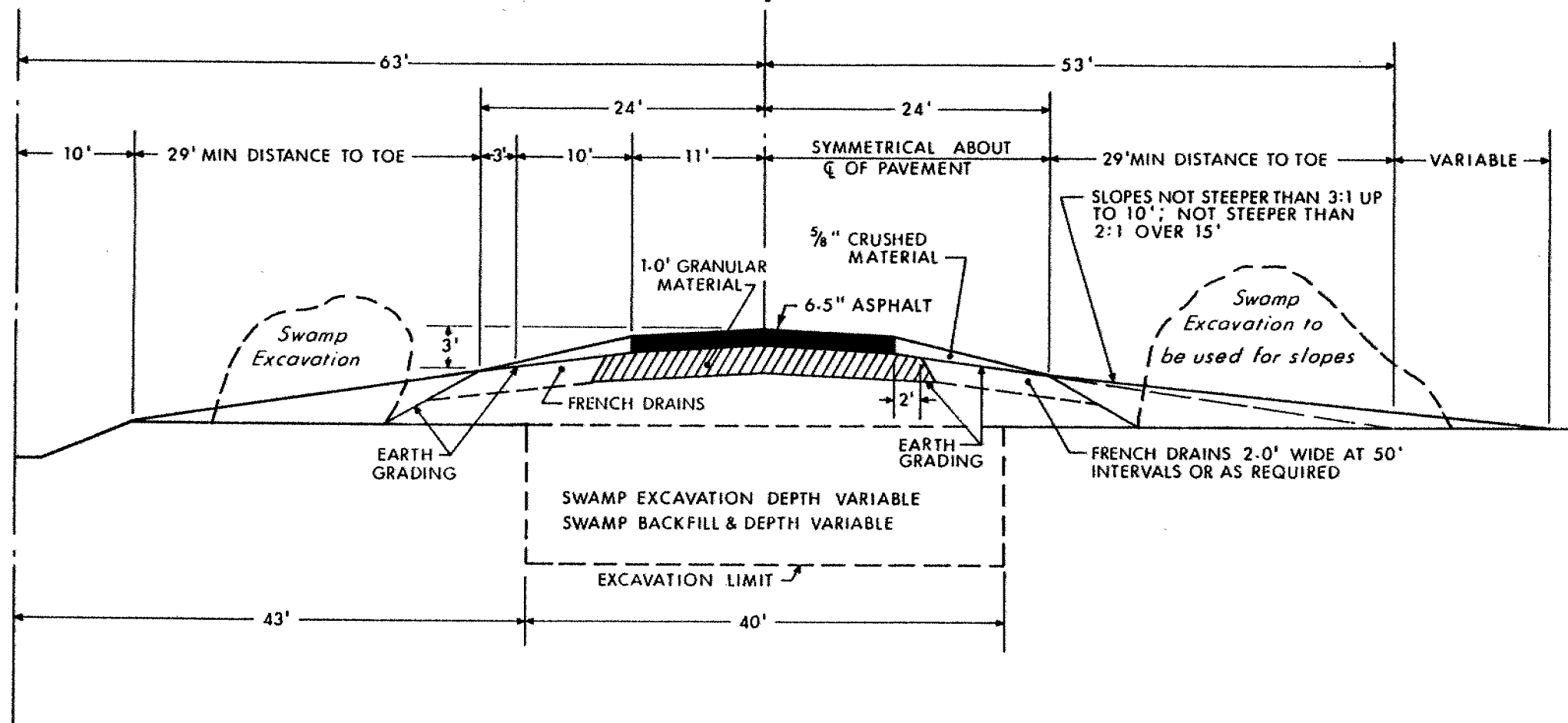


Fig 7 : Cross-Section Showing Limits of Peat Excavation and Pavement Structure under Contract 46-14

WP 7-82-01

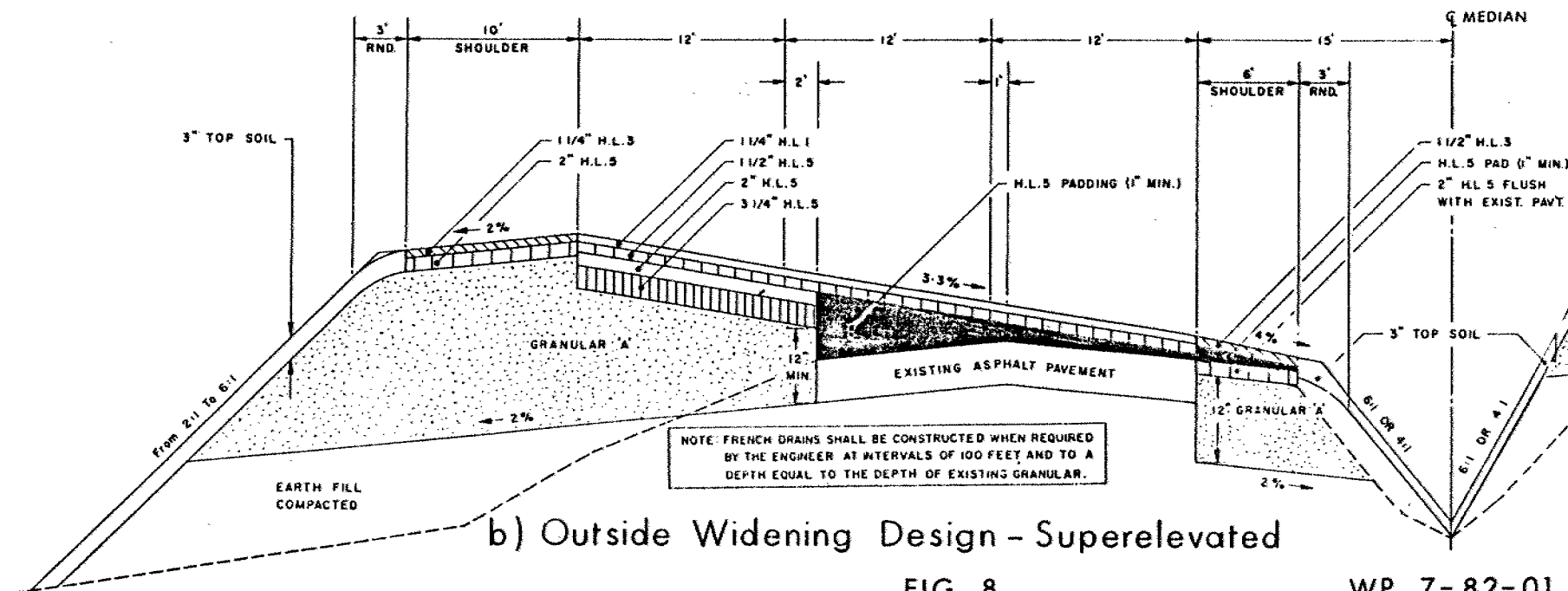
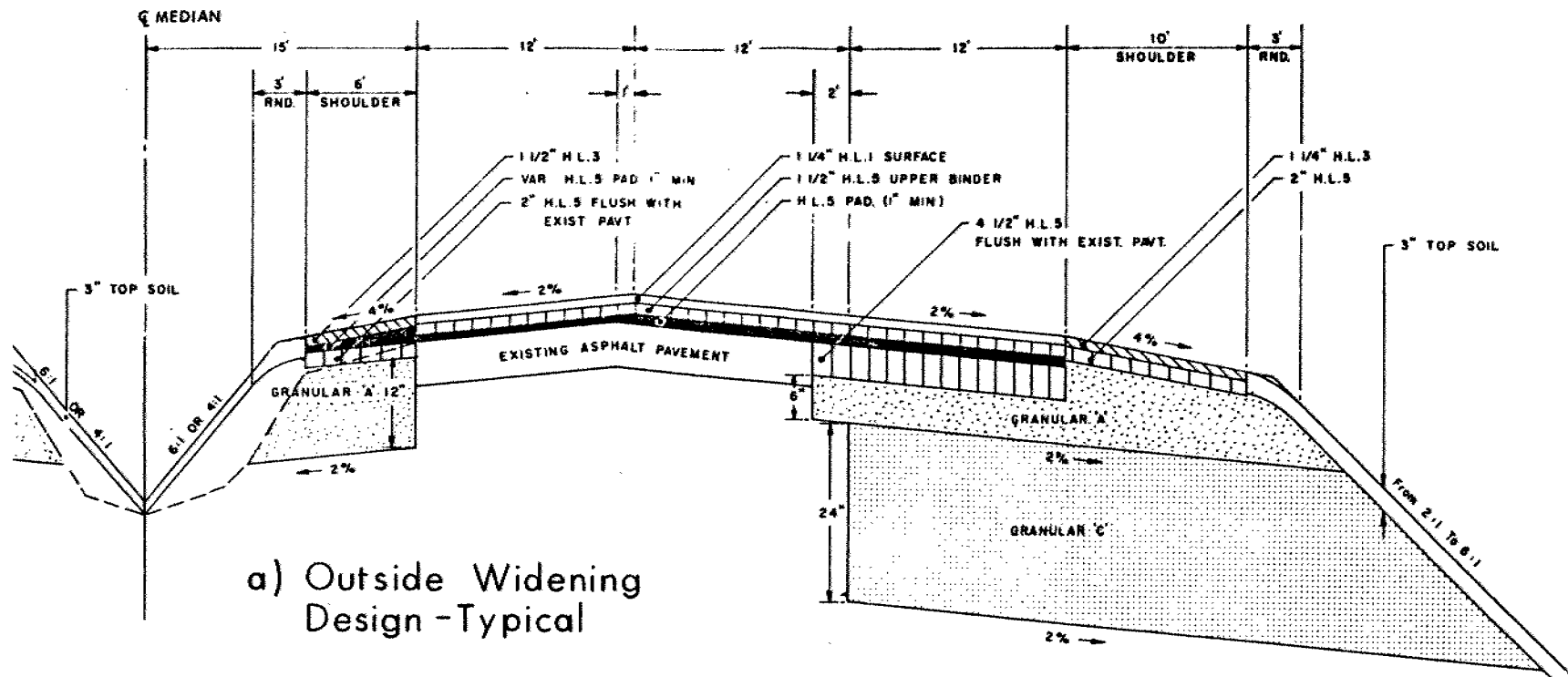


FIG 8

WP 7-82-01

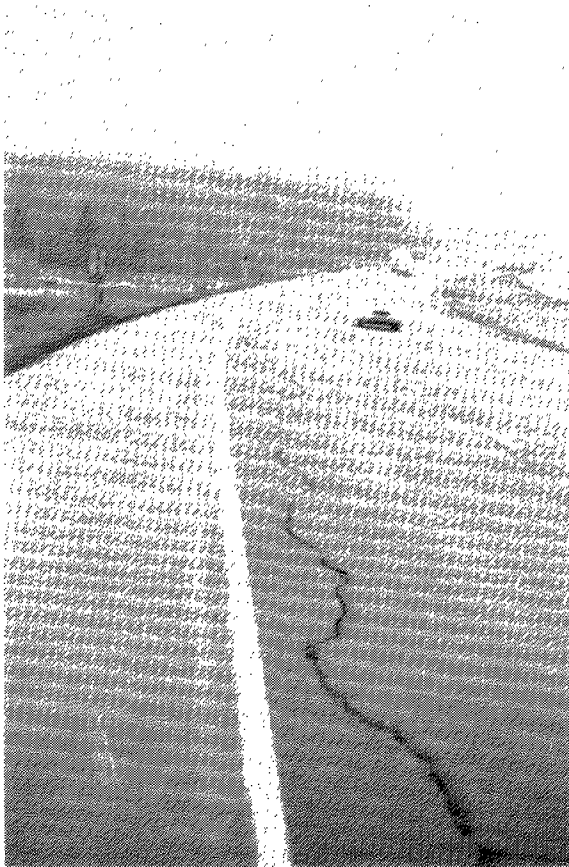


Photo 1

Very severe
meandering crack

Sta. 10 + 360 N.B.L.
looking south.

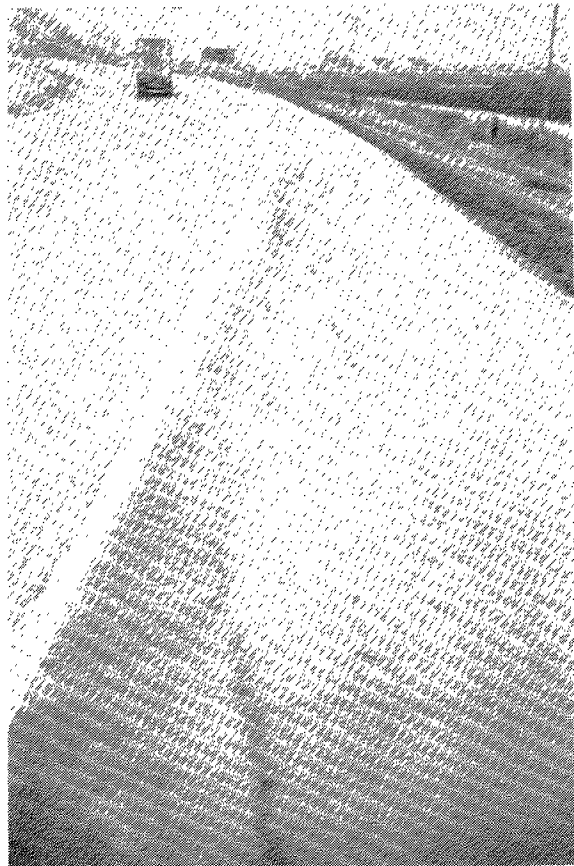


Photo 2

Severe to very severe
multiple meandering
cracks along shoulder

Sta. 10 + 220 N.B.L.
looking north.

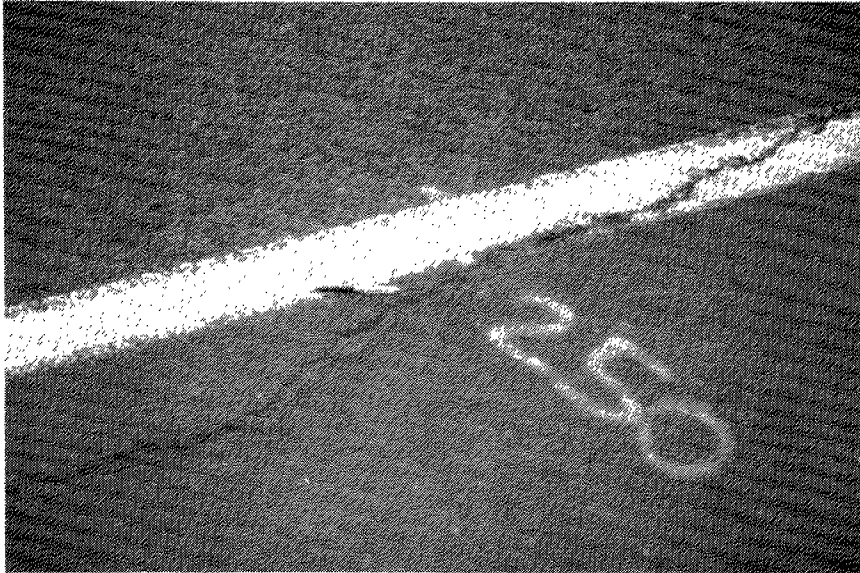


Photo 3

Very severe meandering outside edge crack

Sta. 10 + 250 N.B.L.



Photo 4

Very severe single meandering outer wheel track crack

Sta. 10 + 400 N.B.L.

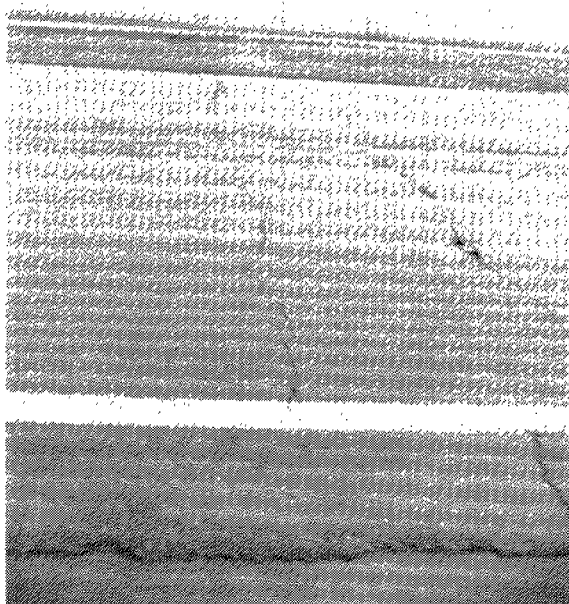


Photo 5

Severe to very
severe transverse
cracking with
moderate outside
lane distortion

Sta. 11 + 250 N.B.L.

Photo 6

Severe transverse
crack beside pavement
core hole.

Note, moderate
ravelling of pavement
surface.

Sta. 11 + 110 S.B.L.



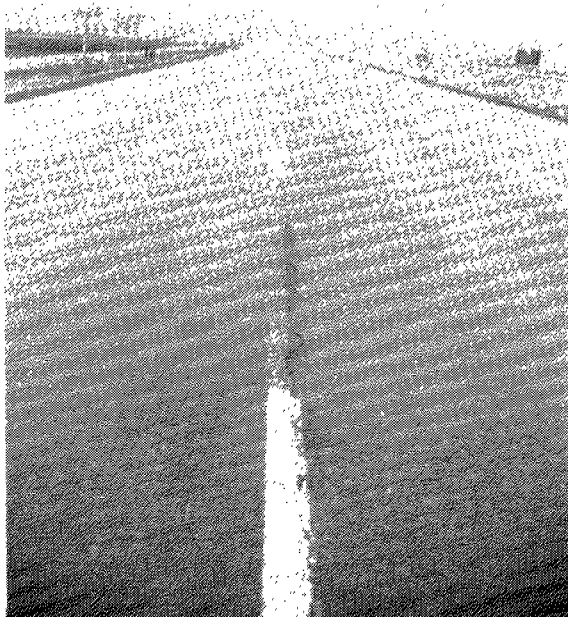


Photo 7

Very severe
longitudinal outside
centreline crack

Sta. 10 + 900 N.B.L.
looking south

Photo 8

Very severe multiple
outside centreline
cracking

Sta. 11 + 280 S.B.L.
looking north

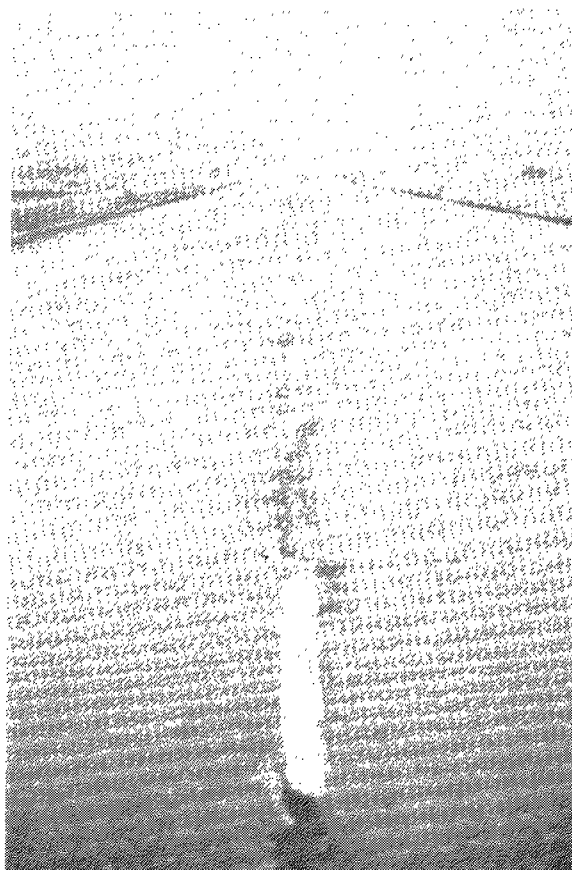




Photo 9

Moderate to severe multiple longitudinal
outer wheel track and pavement edge cracking
(map cracking)

Sta. 10 + 980 N.B.L. looking north

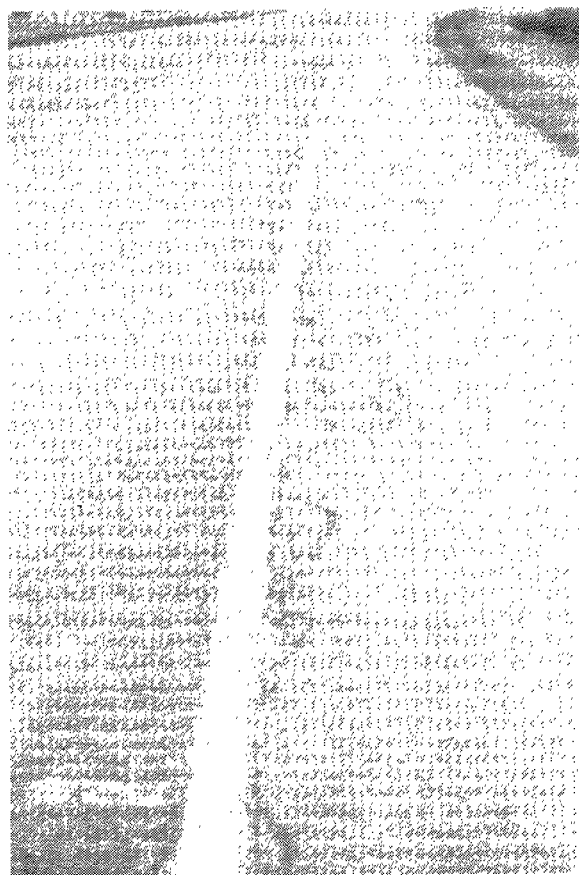


Photo 10

Severe multiple
longitudinal
outside edge
cracking

Sta. 10 + 520 S.B.L.
looking south

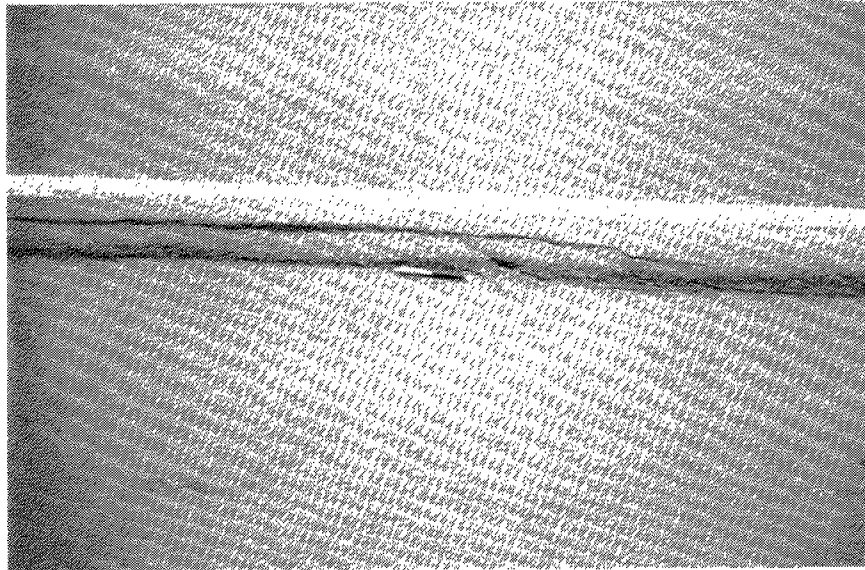


Photo 11

Severe stepping along outside edge of recently patched pavement section

Sta. 10 + 665 N.B.L.

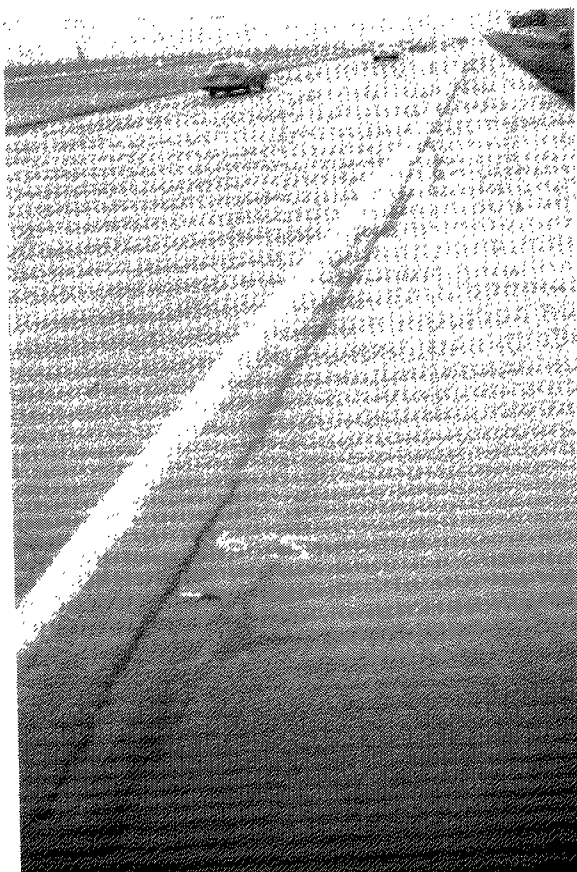
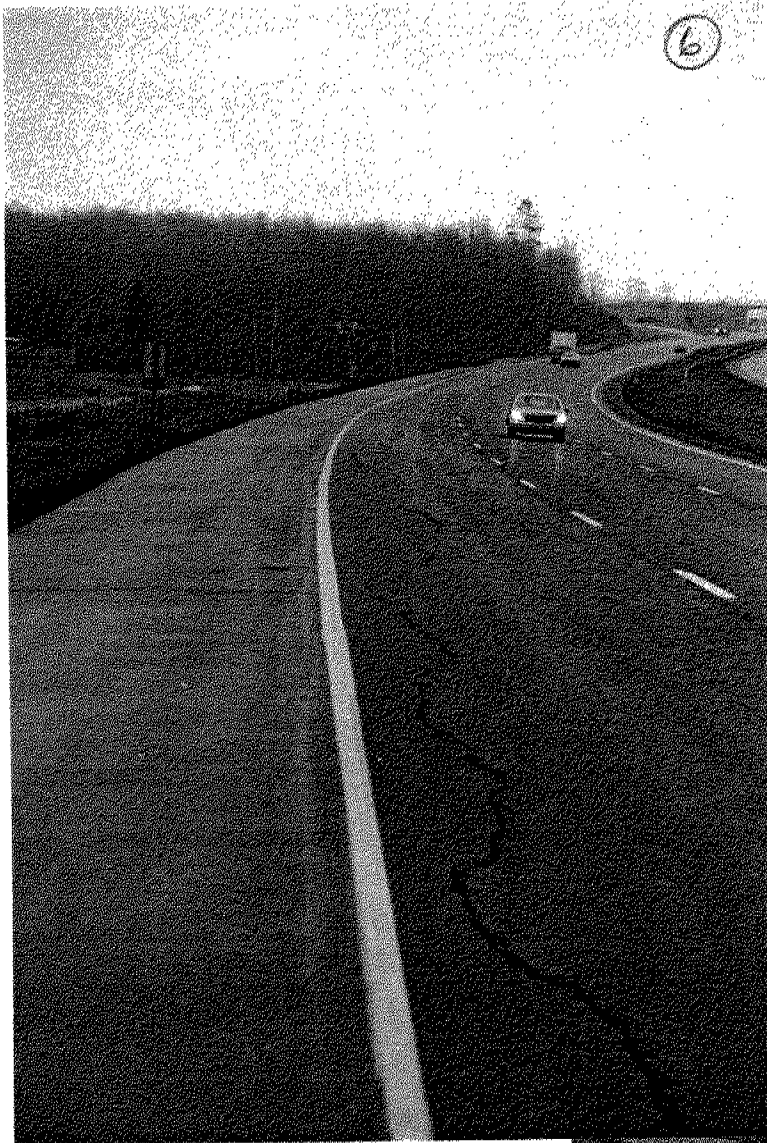


Photo 12

Hot mix patched section showing edge stepping

Note, reflection cracking through recent patch.

Sta. 10 + 675
N.B.L.



Very severe
Meandering Crack
Sta 10+360 N.B.L
looking south.



Severe ^{to very severe} multiple
meandering cracks
along shoulder
Sta 10+700 N.B.L.
looking north



Very severe longitudinal meandering
outside edge cracking
Sta 10+250 N.B.L



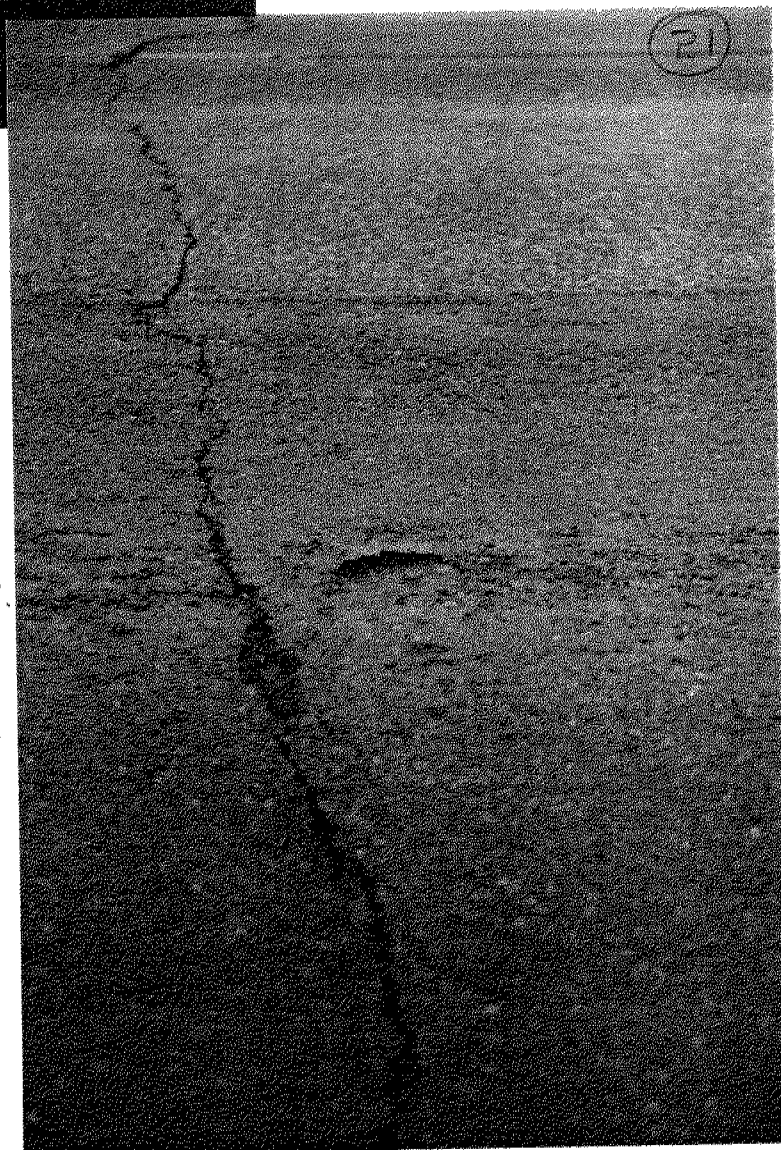
Very Severe Single Longitudinal Meandering
Outer Wheel Track Crack
Sta 10+400 N.B.L

(13)

5



Severe to very
severe transverse
cracking with
moderate outside
lane distortion
Sta 11 + 250 N.B.L.

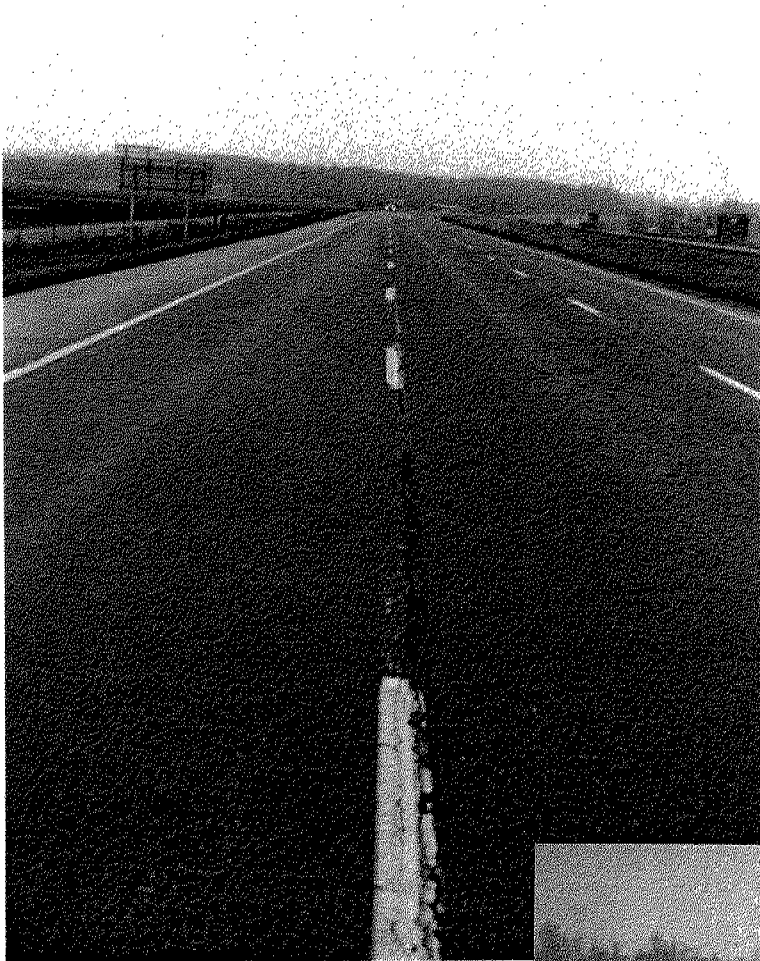


Severe transverse
crack beside
pavement core hole.
Note, moderate
ravelling of pavement
surface.

Sta 11 + 110 S.B.L.

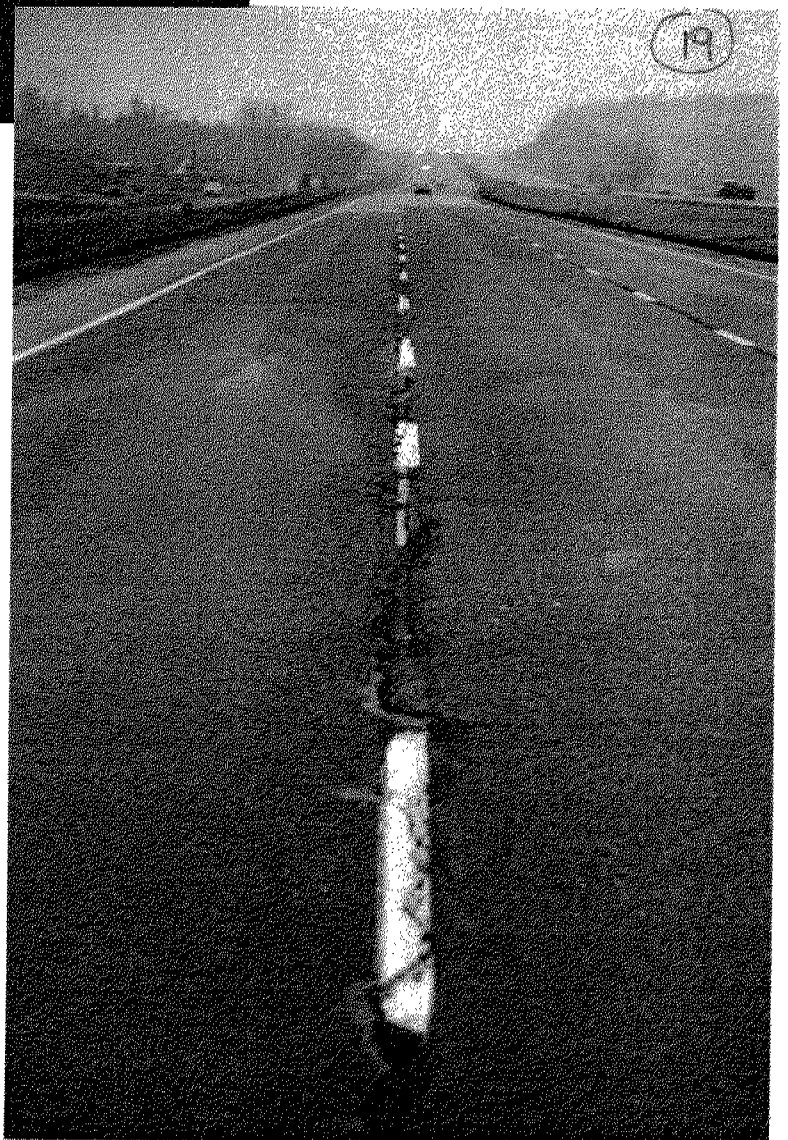
⑪

7



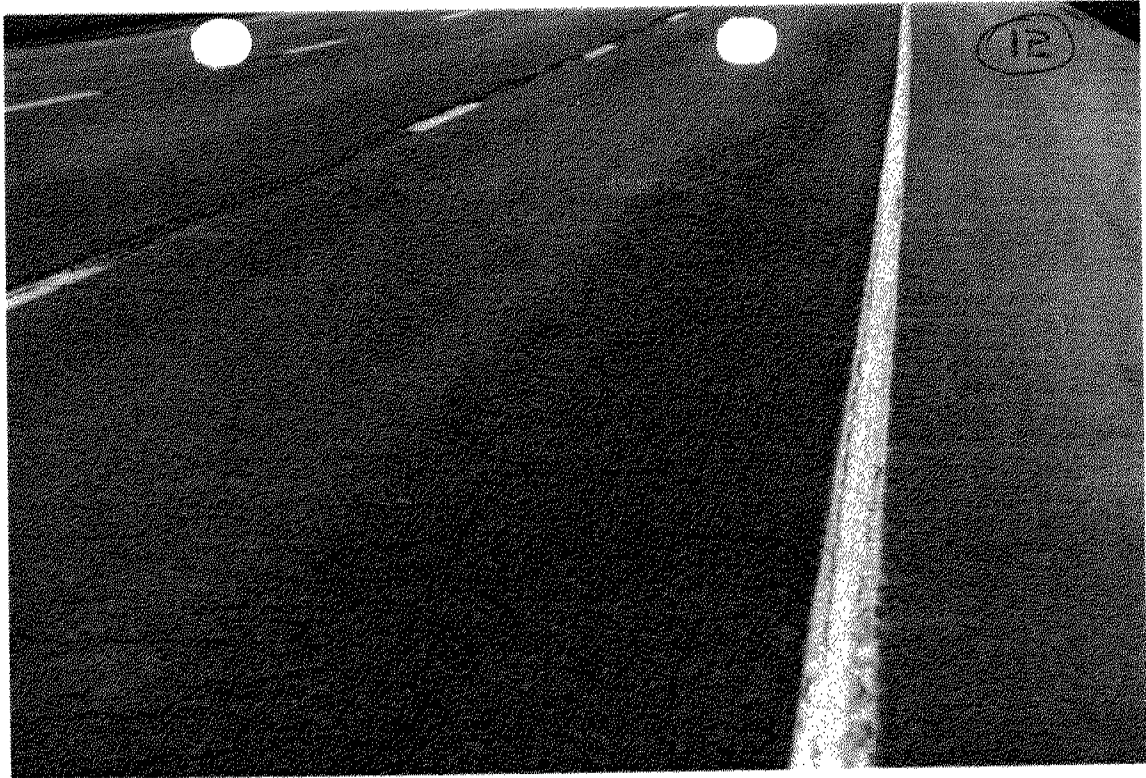
Very Severe
longitudinal outside
center line crack

Sta 10+900 N.B.L.
looking south



⑪

Very severe
multiple outside
center line cracking
Sta 11+280 S.B.L.
looking north.



trap (cracking)

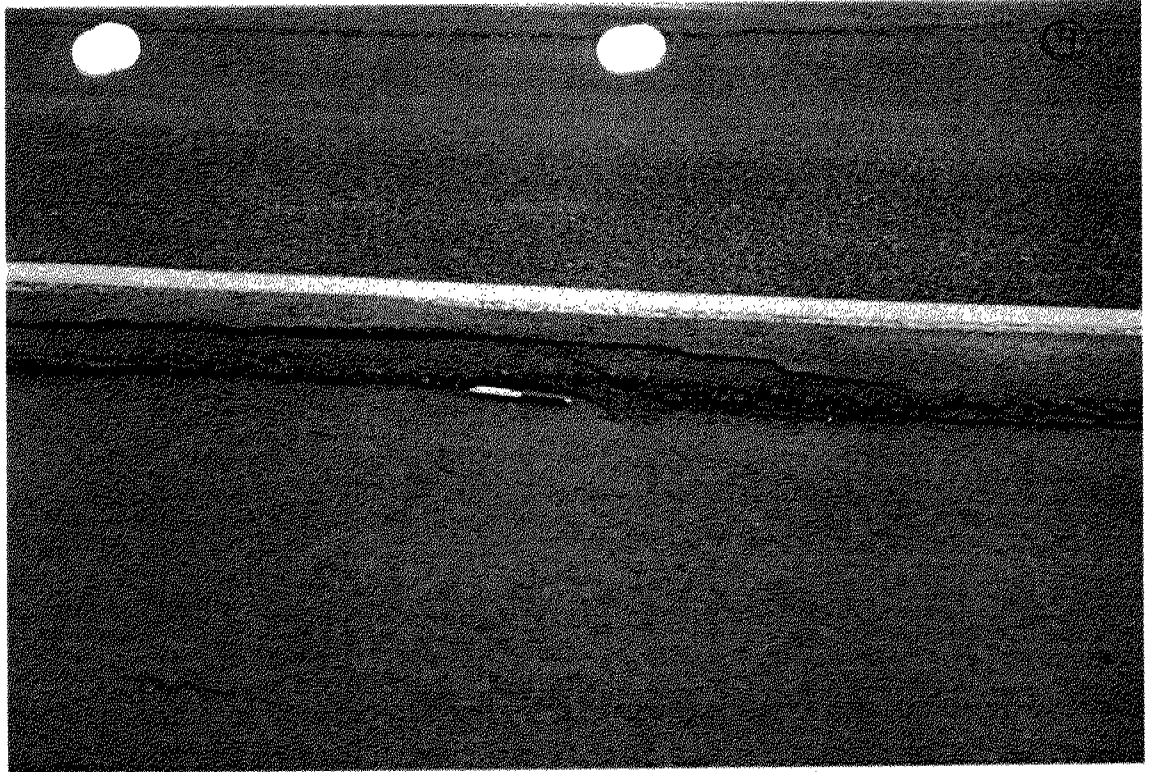
Moderate to severe multiple longitudinal
outer wheel track and pavement edge cracking
(map cracking) Sta 10+980 N.B.L. looking north



10

Severe multiple
longitudinal
outside edge
cracking

Sta 10+520 S.B.L.
looking south



Severe stepping along outside edge
of recently patched pavement section
Sta. 10+665 N.B.L



12

Photo 12.

Hot mix patched
section showing
edge stepping
Note reflection
cracking through
recent patch

Sta 10+675 +
N.B.L.

memorandum



To: Mr. D. Aspinwall
District Maintenance Engineer
Maintenance Section
District 6
5000 Yonge St.

Date: 82 12 17

Attn: B. Thompson

From: Pavement & Foundation Design Section
Room 315, Central Building
Downsview

Re: Hwy. 400/Holland Marsh Embankment Study
W.P. 7-82-01

As per discussions with Mr. A. Ragula, we are requesting a summary of all major pavement maintenance work (i.e. patch date, length, thickness, location, etc.) carried out on the above-mentioned highway section between the North and South Channel structures since the completion of Contract 71-12. This information is vital in comparing the actual performance and settlement characteristics versus the anticipated/theoretical behaviour based on field and laboratory study for this embankment.

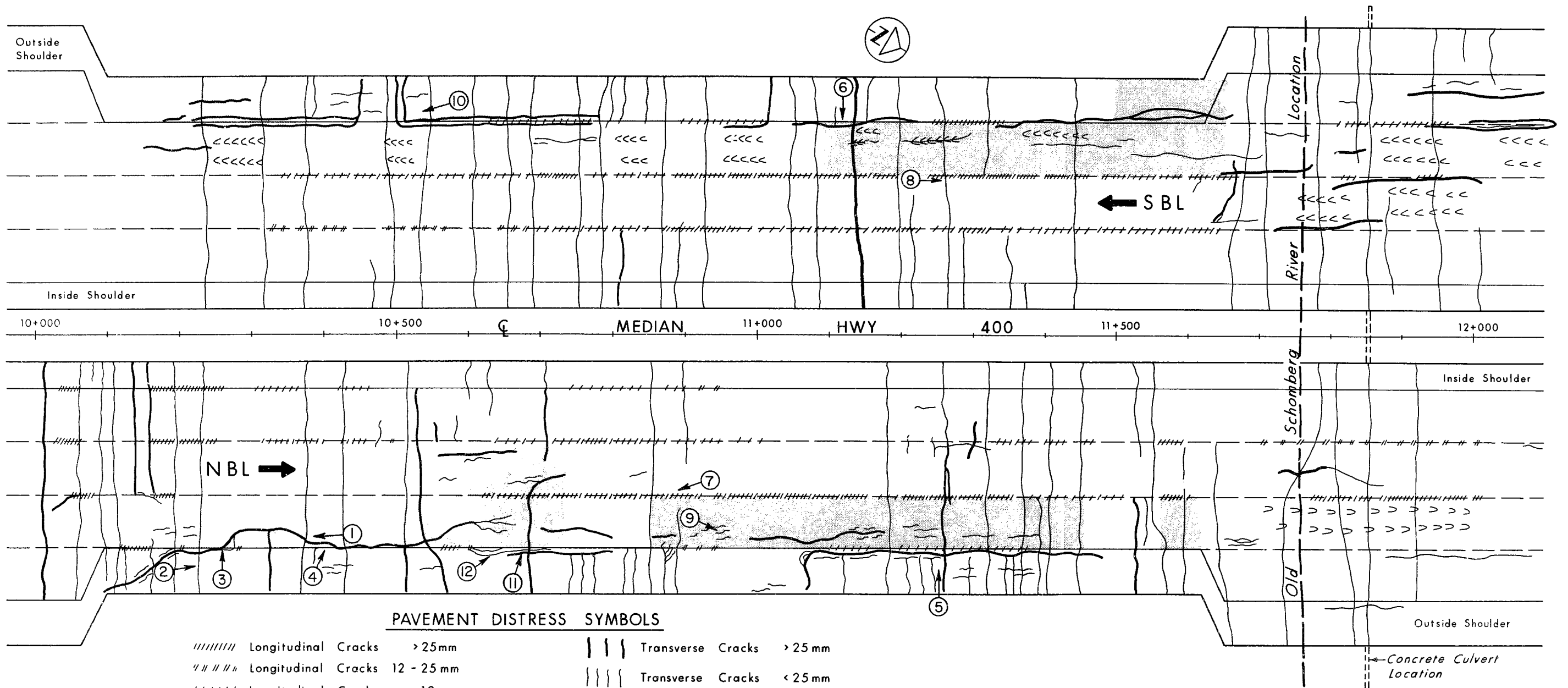
Please contact this Section if further details are required.

Thanking you in advance.

A handwritten signature in dark ink, appearing to read "Tom Kazmierowski".

for Tom Kazmierowski, P. Eng.
Foundations Engineer

TK:syc



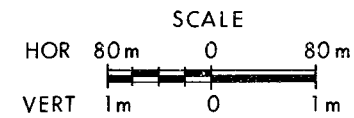
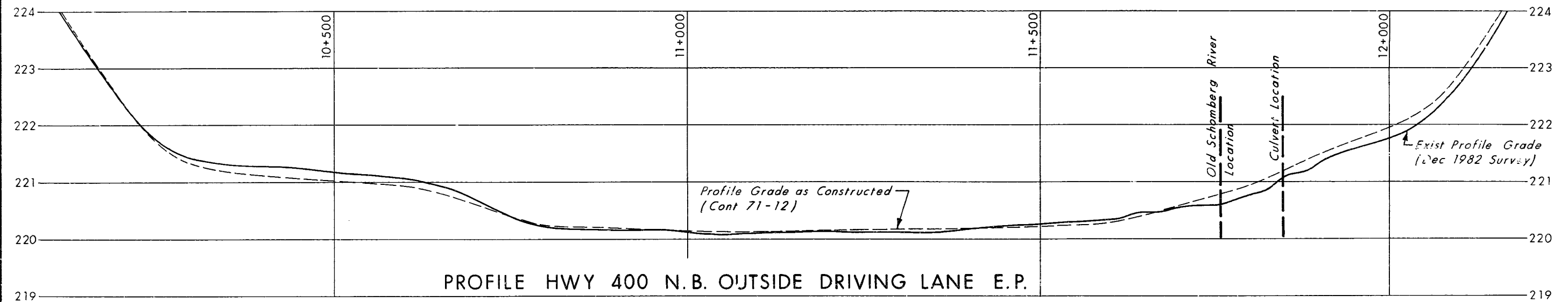
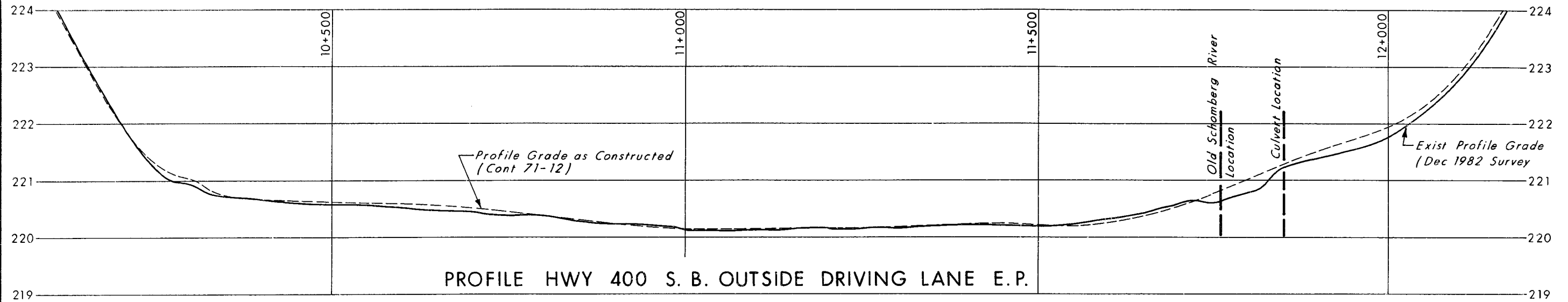
PAVEMENT DISTRESS SYMBOLS

////////	Longitudinal Cracks	> 25mm		Transverse Cracks	> 25mm
"" ""	Longitudinal Cracks	12 - 25 mm		Transverse Cracks	< 25 mm
/////	Longitudinal Cracks	< 12 mm		Rutting	
~~~~~	Random Cracks	> 25mm		Recent Patching	
~~~~~	Random Cracks	< 25mm			
~~~~~	Meandering Cracks	> 25mm	⑦ →	Photograph number and location	(refer to appendix for photos)
~~~~~	Meandering Cracks	< 25mm			

Geocres No 31D-298



HWY 400 OVER HOLLAND MARSH PAVEMENT CONDITIONS SURVEY	
CO OF SIMCOE TWP OF W GWILLIMBURY	REG MUN OF YORK TWP OF KING
DATE 1983 01 26	WP 7-82-01 DIST 6 Figure 9



Geocres No 31D-298



COMPARISON OF EXISTING AND AS
CONSTRUCTED PROFILE GRADES

CO OF SIMCOE REG MUN OF YORK
TWP OF W GWILLIMBURY TWP OF KING

DATE 1983 01 26 WP 7-82-01 DIST 6 Figure 10