#69-F-218C

W.P. 178-64

BEECH RIVER

BRIDGE

November 27th, 1969.

GEOTECHNICAL INVESTIGATION

BEECH RIVER BRIDGE

69-F-218C

ONTARIO DEPARTMENT OF HIGHWAYS

W.P. 178-64

SUBMITTED BY

Professional Services Division

WARNOCK HERSEY INTERNATIONAL LIMITED

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1.0 - INTRODUCTION

The Professional Services Division of Warnock Hersey International Limited was authorized by Mr.A.Rutka, Ontario Department of Highways to carry out a Geotechnical study of the subsoils at the site of the proposed Beech River Bridge.

The site is located on Lot 14, Concession III, Township of Stanhope, County of Haliburton on the King's Highway No. 35, as shown on the enclosed site plan.

The purpose of the investigation was to evaluate the ultimate bearing capacity of round steel and H-piles using the in situ pressuremetric test method.

Therefore the anticipated behaviour of the piles are presented in graphical form to facilitate comparison at a later stage with the actual pile load tests.

All results calculated in this report are a direct function of pressuremetric values as obtained from the tests and are presented in the form of Limit Pressure and Standard Pressuremetric Modulus of Deformation. No attempt has been made to break down the paramaters into the normal components used in standard soil mechanics terminology (ϕ, K_o etc).

The field work was carried out as a joint venture by Warnock Hersey International Limited and Geoprobe (Quebec) Limited.

Boreholes 1 and 2 were drilled to 100 and 101.5 feet respectively. The results varied significantly between holes 1 and 2 and from the Standard Penetration tests, it was noted that the material in Borehole 1 was considerably denser. An additional hole (2A) was drilled to verify some of the tests at higher elevations.

Only the results from holes 2 and 2A have been used in the calculations of ultimate bearing capacity.

2.0 - FIELD TESTING PROGRAMME

2.1 - Soil Borings

A sketch showing the locations of the boreholes may be found in the Appendix of this report.

The boreholes were advanced according to standard wash boring procedures using a Boyles Brothers screw feed type drill. Standard BX casing was advanced in 5 foot lengths with a 350 lb. hammer and then washing inside the casing followed. The hole was kept full of Bentonite at all times to prevent caving.

Some Standard Penetration tests were taken and split spoon samples recovered to facilitate description of soil stratigraphy.

Surface elevations of the boreholes were taken with respect to an assumed benchmark at the mid-span of existing Beech River Bridge (100.0').

2.2 - Geoprobe Pressuremetric Test

The Geoprobe test is an in situ pressuremetric test that is performed inside a borehole at various elevations.

After the probe is set at a test elevation, the expandable rubber pressure cell is inflated with gas pressure to a given value and held for a sufficient length of time, such that the change in diameter versus time is very small (at pressures below the creep pressure). In stiff to hard soils, it is usually necessary to hold the test pressure for only one minute before increasing pressure to a higher value. By performing the tests at various pressures, a stress-deformation curve can be plotted and a number of soil properties may be derived, such as the lateral earth pressure at rest, the modulus of deformation, the creep pressure, the limit pressure and the shear strength of the soil. Normally, the pressuremeter test is performed at a number of elevations in the borehole so that a complete profile of the aforementioned properties may be determined.

The modulus of deformation of the soil is determined mathematically as a function of the slope of the stress-deformation curve.

The limit pressure, P_L is the pressure at which complete failure of the soil occurs if the tests are carried to this point. This is the pressure at which an infinite expansion of the borehole takes place.

The creep pressure P_f, is limit of pseudo-elastic zone where the soil ceases to behave as a nearly elastic material and plastic deformations take place.

Geoprobe tests were carried out in Boreholes 1, 2 and 2A and representative test curve samples are included in Appendix C of this report.

3.0 - SOIL CONDITIONS

The site was covered with approximately six inches of topsoil. Underlying the topsoil was various stratified layers of fine and medium sand deposit with some small gravel.

In Borehole 1 the N-values varied between 14 and 30 blows per foot. In Borehole 2 the N-values were somewhat lower and varied between 6 and 12 to a depth of 80 feet where they increased to 18 - 22 blows per foot.

While a considerable difference was noted between the boreholes in relation to N-values, the soil strata encountered are felt to be of the same origin.

Water levels were recorded in Boreholes 1 and 2 at 40.0 and 20.0 feet below grade respectively.

4.0 - GEOTECHNICAL DISCUSSION

4.1 - General

Figure 1 in Appendix C illustrates the variation in Limit Pressure with depth. From the surface to a depth of 30 feet the P_L value decreases at a constant rate from 8.5 tsf to 2.2 tsf. From 30 feet to 65 feet the P_L remained constant and then increased rapidly to 11.0 tsf at 90 feet.

The standard pressuremetric modulus of deformation, E, decreased on a similar trend from 85 near the surface to 20 at 30 feet and up to 50 at 70 feet.

The ratio $E/P_L = 8$ indicates that the material is normally consolidated.

4.2 - Bearing Capacity of Piles

Most of the correlation data available is based on concrete piles and therefore in the calculations for steel H-piles and round steel piles, some assumptions have been made.

In all cases the contribution from the first five feet from the surface has been neglected in the calculation of friction.

The ultimate bearing capacity (q_{ult}) referred to in this report corresponds to a deflection of, approximately 1 cm and corresponds further to a load exceeding the pseudo-elastic zone by 33%.

4.2.1 - Round Steel Piles

The end bearing value is taken as equivalent to that of a concrete pile and the formulae used is as follows: (Menard, Sept. 1965).

$$q_{ult} = P_o + K (P_L - P_o) \qquad (1)$$

Where K is coefficient which varies with depth of embedment and nature of the soil. In the case of the sands at this site, the value of K varied between 3.6 and 4.0.

The friction factor between soil and steel is assumed to be 80 percent of the soil/concrete value (So).

Therefore the skin friction values for steel ($\frac{S_o}{0.8}$) were derived as follows: (Menard, Sept. 1965)

when

$$P_L < 5.2 \qquad \frac{S_o}{0.8} = \frac{P_L - P_o}{8} \qquad (2)$$

$$5.2 < P_L < 9 \qquad \frac{S_o}{0.8} = \frac{P_L}{20} + 0.28 \qquad (3)$$

$$9 < P_L \qquad \frac{S_o}{0.8} = 0.8 \qquad (4)$$

except for area within 3 diameters of the pile tip where:

$$P_L < 5.2 \qquad \frac{S_o}{0.8} = \frac{P_L - P_o}{8} \qquad (5)$$

$$5.2 < P_L < 9 \qquad \frac{S_o}{0.8} = \frac{P_L}{7} - 0.10 \qquad (6)$$

$$9 < P_L \qquad \frac{S_o}{0.8} = 1.2 \qquad (7)$$

4.2.4 - <u>Steel H-Piles</u>

For steel H-piles the skin friction value along the pile is calculated by the same formulae as with the round steel piles (Equations No.1-4) with the exception of the area within ten feet of the tip of the pile.

Within 10 feet of the pile tip the formulae becomes

$$\frac{So}{0.8} = \frac{P_L - Po}{8} \qquad (8)$$

It is assumed that over a 10 to 20 foot length from the pile tip, the sand will form a plug between the flanges of the H-pile and an end bearing capacity based on a cross-section equivalent to the maximum dimensions of the pile will be developed and carried, within limits, by the sand plug.

4.2.3 - Timber Piles

It is assumed that timber piles would behave approximately the same as concrete piles.

4.3 - Settlement

The anticipated settlements have been calculated from formulae proposed by M.Cassan based on a study by H.Cambefort (Sols-Soils No. 18-19).

4.3.1 - Round Piles

The following is the formulae used in calculating total settlement of round piles.

$$\text{Settlement } (w) = P \, \frac{4}{\pi D} \; \frac{1 + \frac{R}{E_s} \, \frac{h}{D}}{R + 4Bh} \qquad (9)$$

Where R and B are coefficients based on the modulus of deformation (E) and in the case of driven piles:

P = Total load on pile head in tons.

R = 13.5E Tons/m^2

B = 1.25E Tons/m^3

D = pile diameter or width of base in meters.

h = Useful height of pile in meters.

E_s = Modulus of pile material.

E = harmonic mean of standard pressuremetric modulus.

<u>Note</u>: In this formula the unit "Tons" is "Metric" (1000 kilograms). Whereas on the graphs, conversion has been made to Short English Tons (2000 pounds).

4.3.2 - Square Pile

$$W = \frac{P}{d} \quad \frac{1 + \frac{R}{Es} \; \frac{h}{d}}{R + 4\,Bh} \qquad (10)$$

Where d = width of pile

4.4 - RESULTS & CONCLUSIONS

Using the above formulae and assumptions, the results are presented in the form of five graphs on the following pages. Figure 1 is the ultimate bearing capacity of the different types of piles in function of depth from the existing ground surface.

It can be seen from the figure that the rate of increase of the ultimate bearing capacity, (qult) is nearly constant between 50 and 67 feet at which depth a marked increase in the rate becomes evident.

Figures 2A-D illustrate the calculated settlement of the various types of piles at two different depths (50 ft. & 73'6").

Total rupture values have been indicated on the curves, however it is preferrable to base the recommendations for working loads of the piles on q_{ult} as defined previously, or better still, on the pseudo-elastic zone which can be determined with greater accuracy.

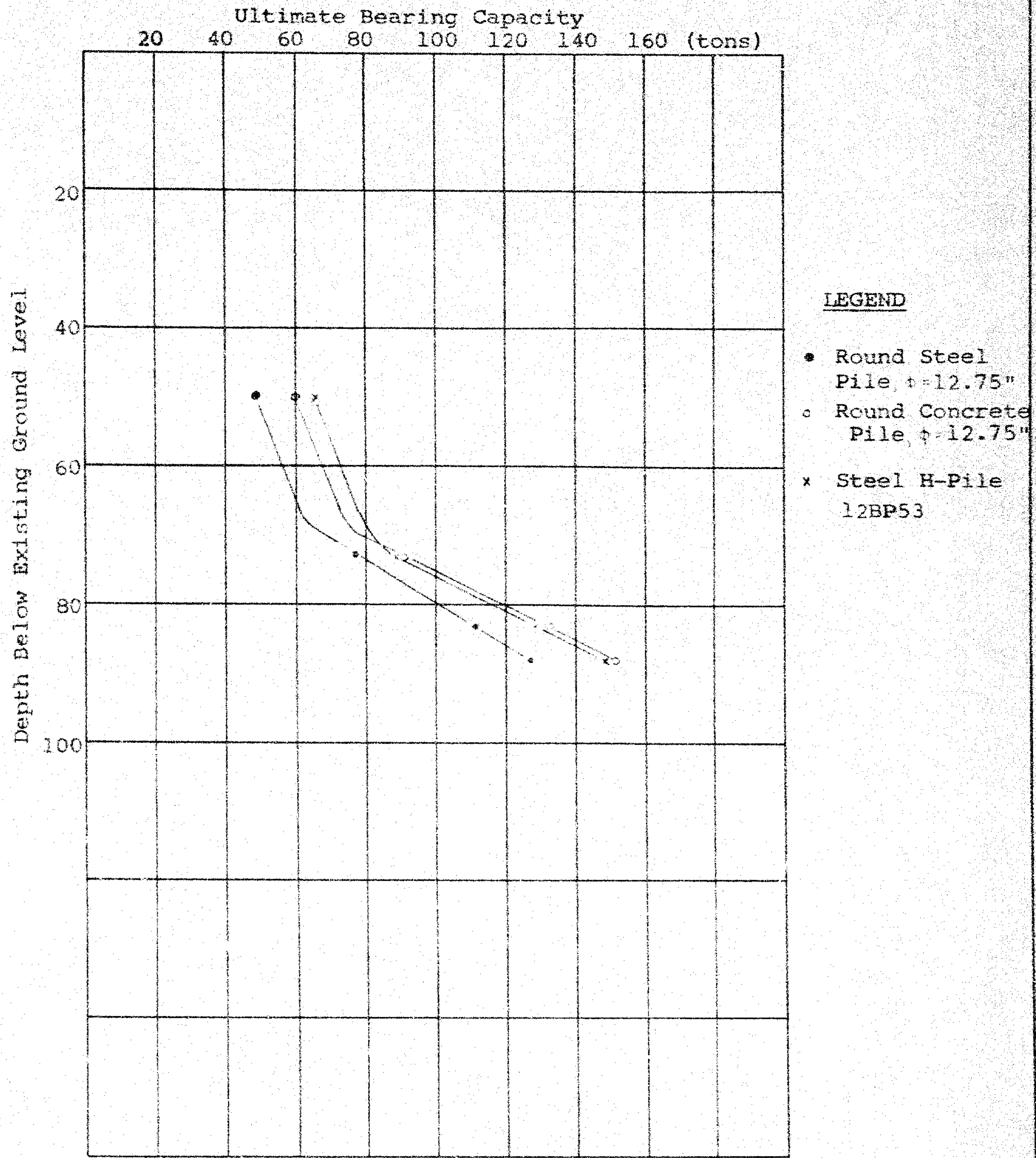
The final choice of pile type will obviously be one of economics.

Ontario Department of Highways

BEECH RIVER BRIDGE

Fig 1

230-514

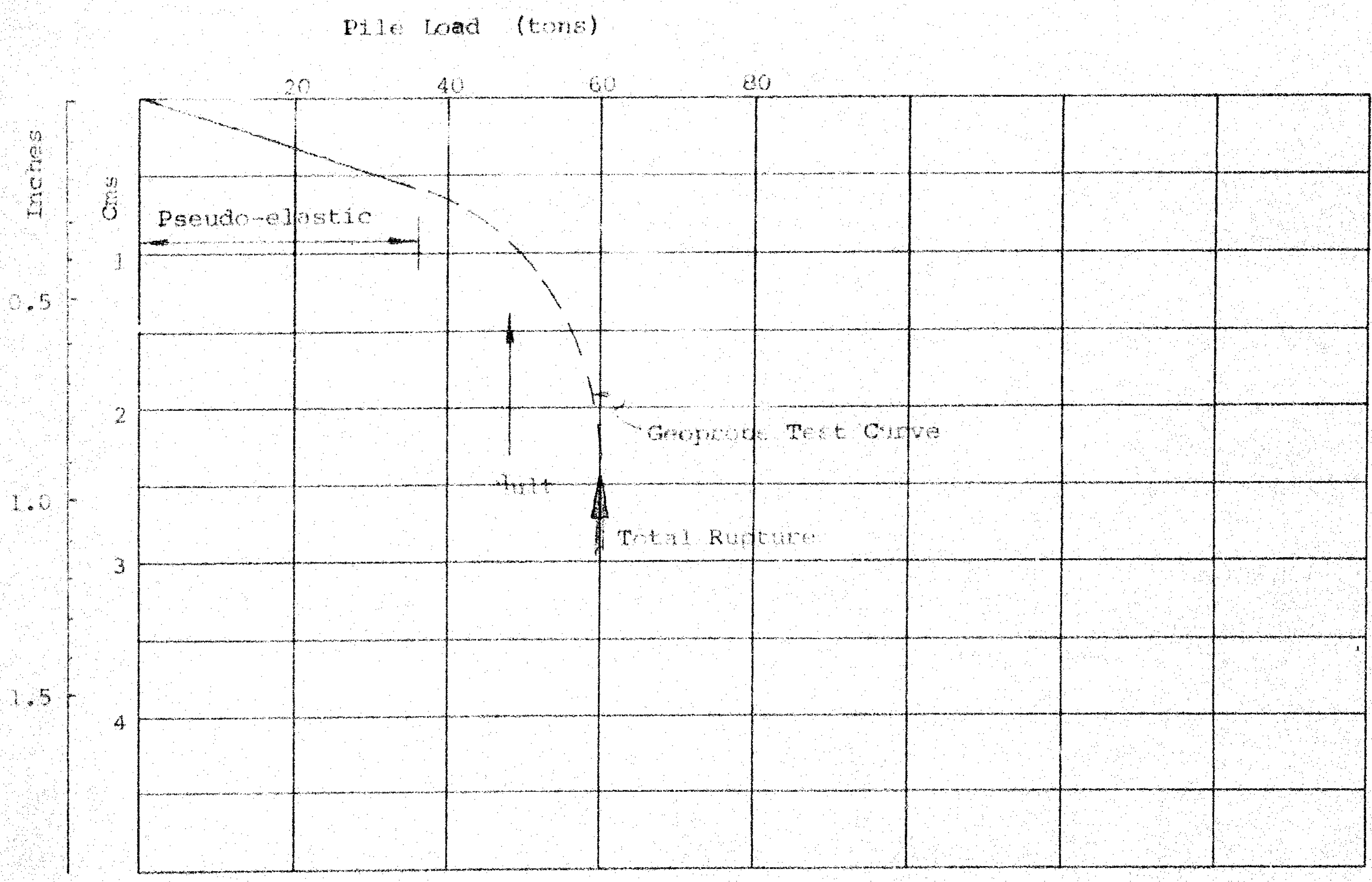


Ontario Department of Highways

BEECH RIVER BRIDGE

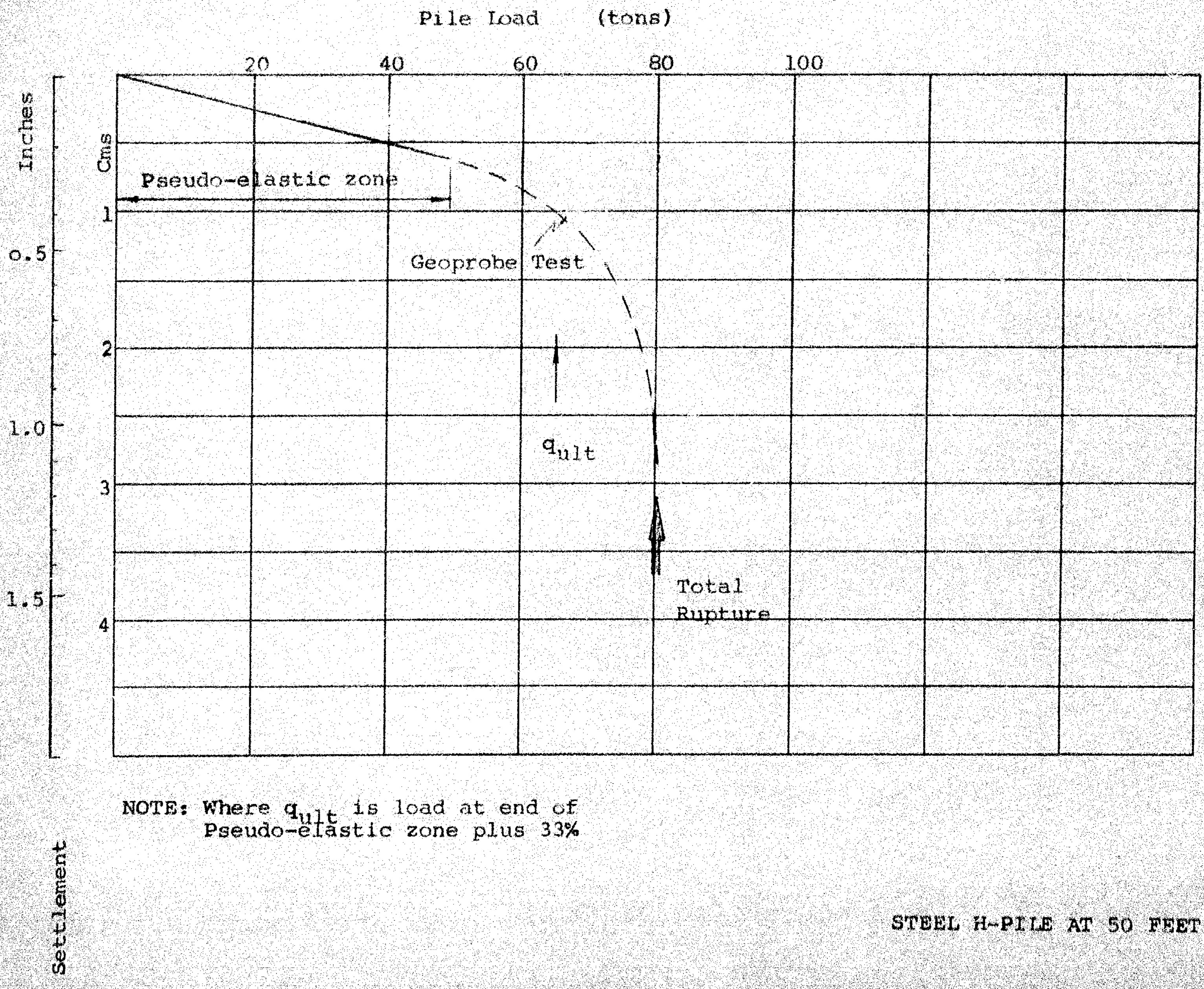
Fig 2A

230-514



NOTE: Where q_{ult} is load at end of Pseudo-elastic zone plus 33%

ROUND STEEL PILE AT 50 FEET



NOTE: Where q_{ult} is load at end of Pseudo-elastic zone plus 33%

STEEL H-PILE AT 50 FEET

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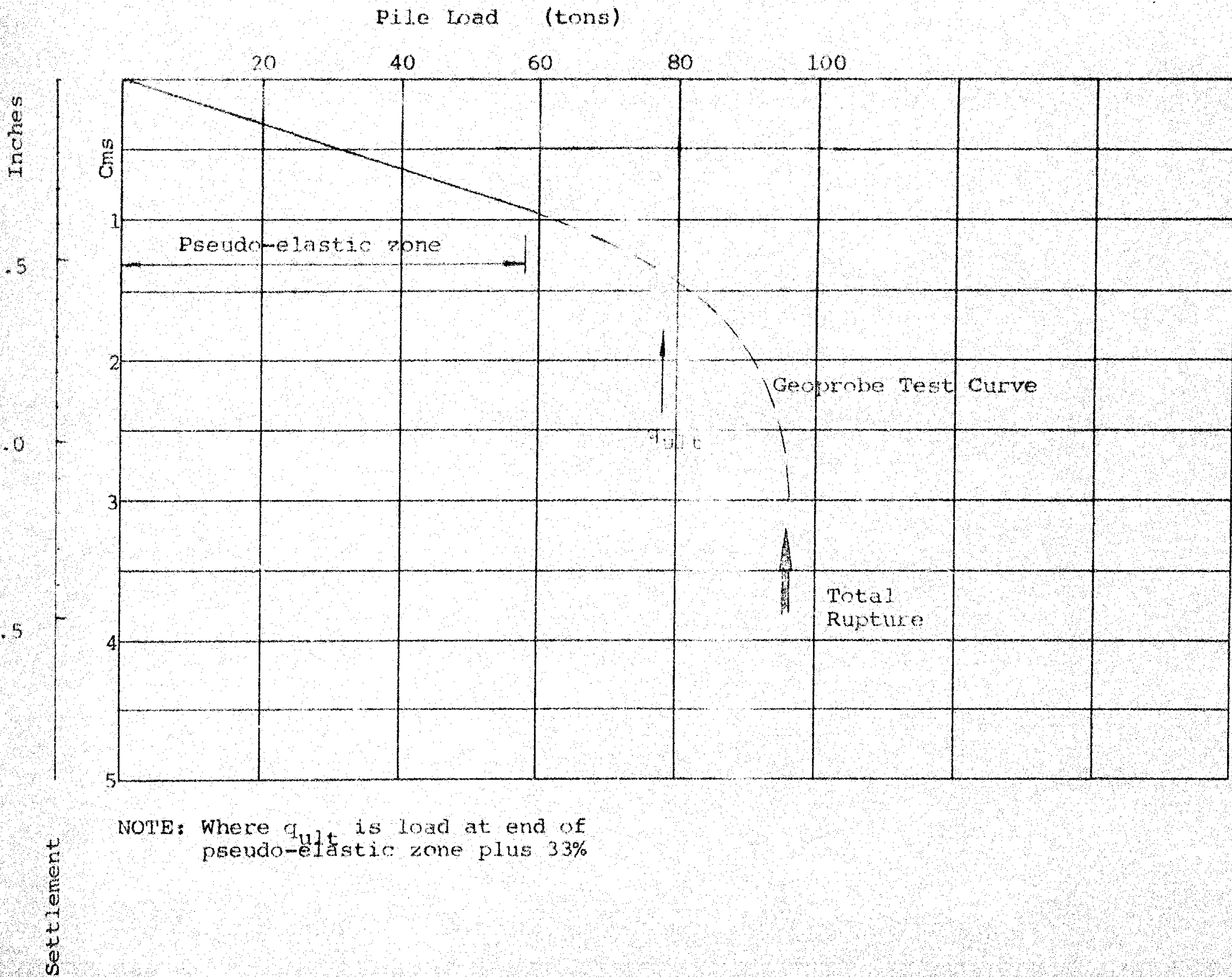
BEECH RIVER BRIDGE

Fig 2B

230-514



NOTE: Where q_{ult} is load at end of pseudo-elastic zone plus 33%

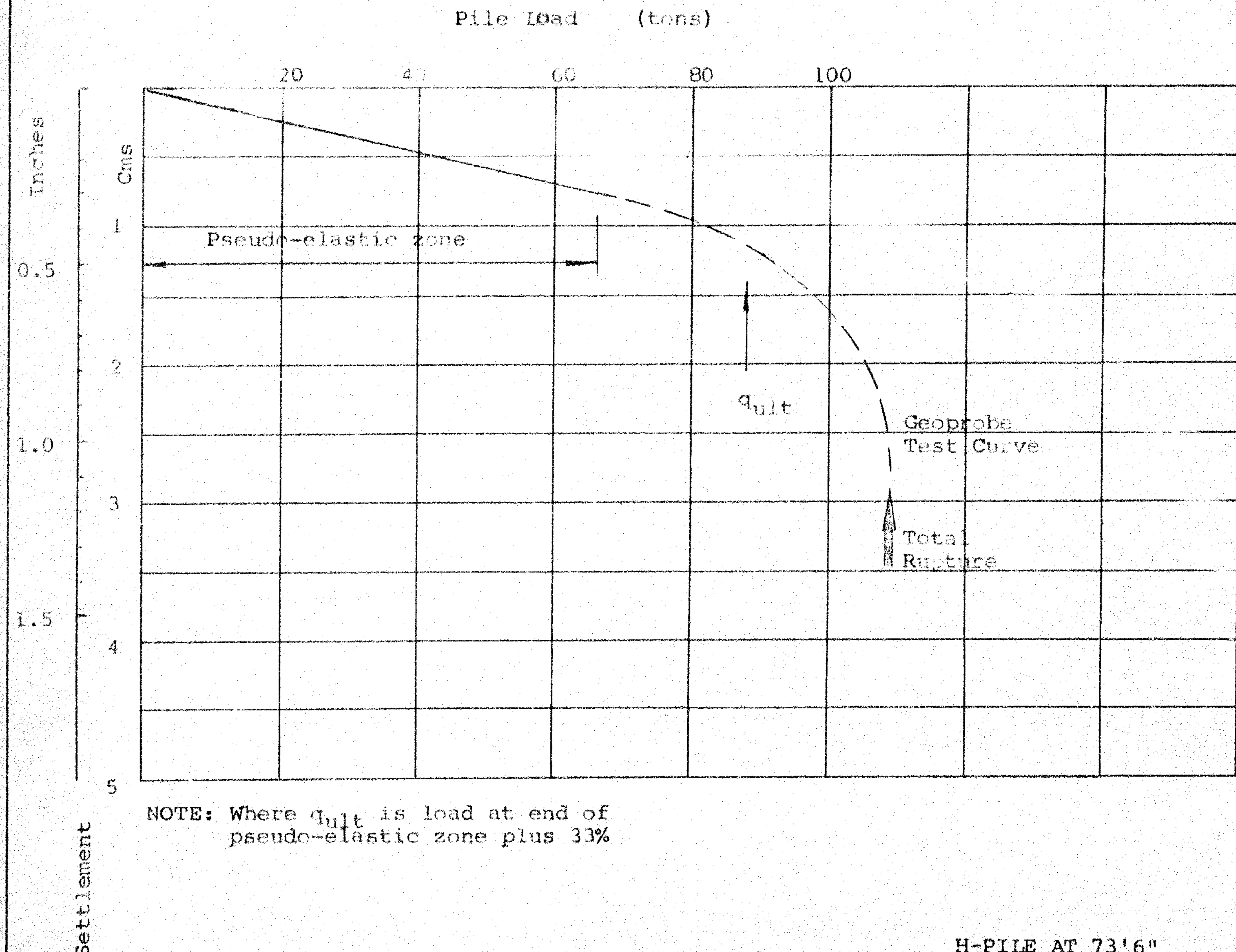
ROUND STEEL PILE AT 73' 6"

Ontario Department of Highways

BEECH RIVER BRIDGE

Fig 2C

230-514



NOTE: Where q_{ult} is load at end of pseudo-elastic zone plus 33%

H-PILE AT 73'6"

Ontario Department Of Highways

BEECH RIVER BRIDGE

Fig 2D

230-514

This report is respectfully submitted to

Mr.A.Rutka, Ontario Department of Highways.

Yours very truly

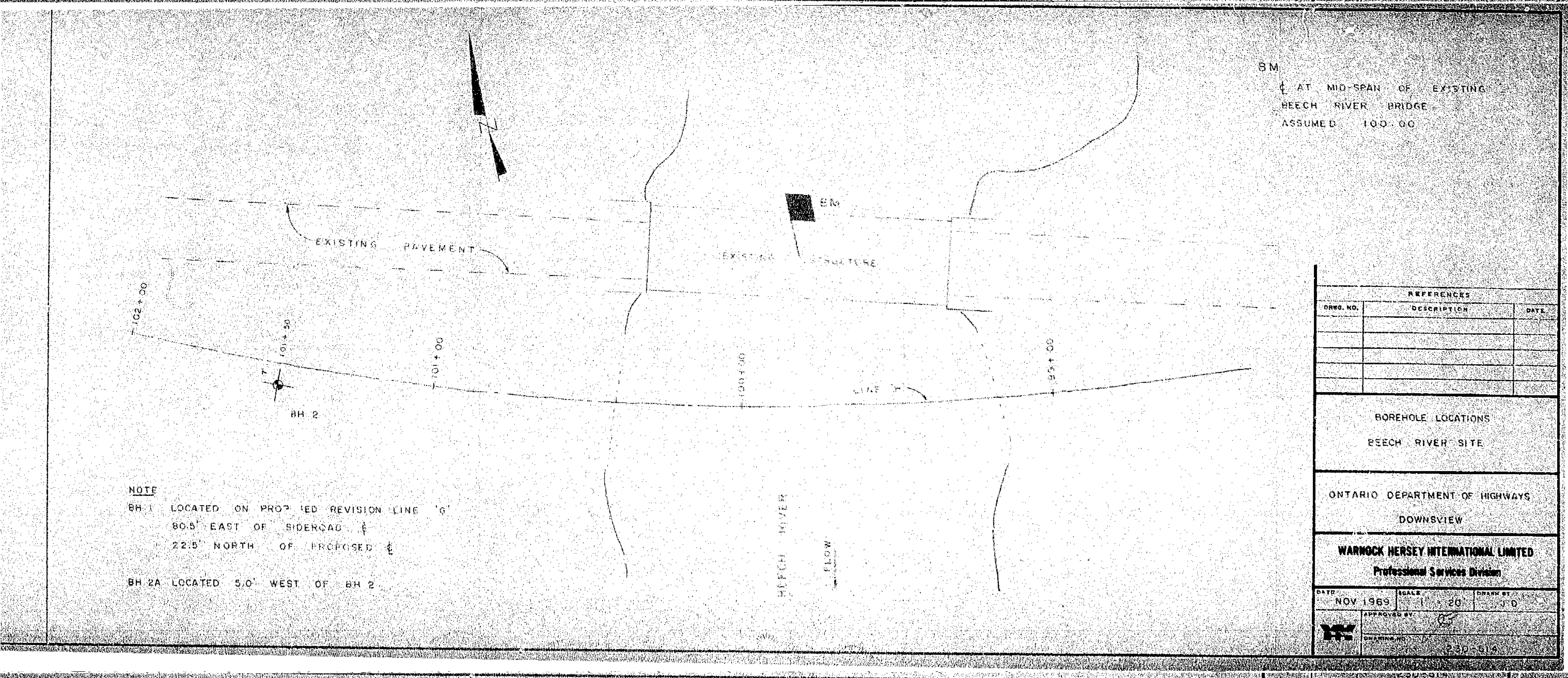
Professional Services Division
WARNOCK HERSEY INTERNATIONAL LIMITED

John C. Beam

John C.Beam,P.Eng.,
Special Projects Engineer,
Geotechnical Department.

REGISTERED PROFESSIONAL ENGINEER
J. C. BEAM
PROVINCE OF ONTARIO

APPENDIX



BM
℄ AT MID-SPAN OF EXISTING
BEECH RIVER BRIDGE
ASSUMED 100.00
N
BM
EXISTING PAVEMENT
EXISTING STRUCTURE
102+00
101+50
101+00
100+00
99+00
LINE 'F'
BH 2
BEECH RIVER
FLOW
NOTE
BH 1 LOCATED ON PROPOSED REVISION LINE 'G'
80.5' EAST OF SIDEROAD ℄
22.5' NORTH OF PROPOSED ℄
BH 2A LOCATED 5.0' WEST OF BH 2
REFERENCES
DRWG. NO.
DESCRIPTION
DATE
BOREHOLE LOCATIONS
BEECH RIVER SITE
ONTARIO DEPARTMENT OF HIGHWAYS
DOWNSVIEW
WARNOCK HERSEY INTERNATIONAL LIMITED
Professional Services Division
DATE
NOV 1969
SCALE
1" = 20'
DRAWN BY
J D
APPROVED BY
DRAWING NO.
230-614

OFFICE BOREHOLE RECORD

APPENDIX B

PROJECT NO. 230-514
BOREHOLE NO. 1
CASING BX
DATUM Assumed

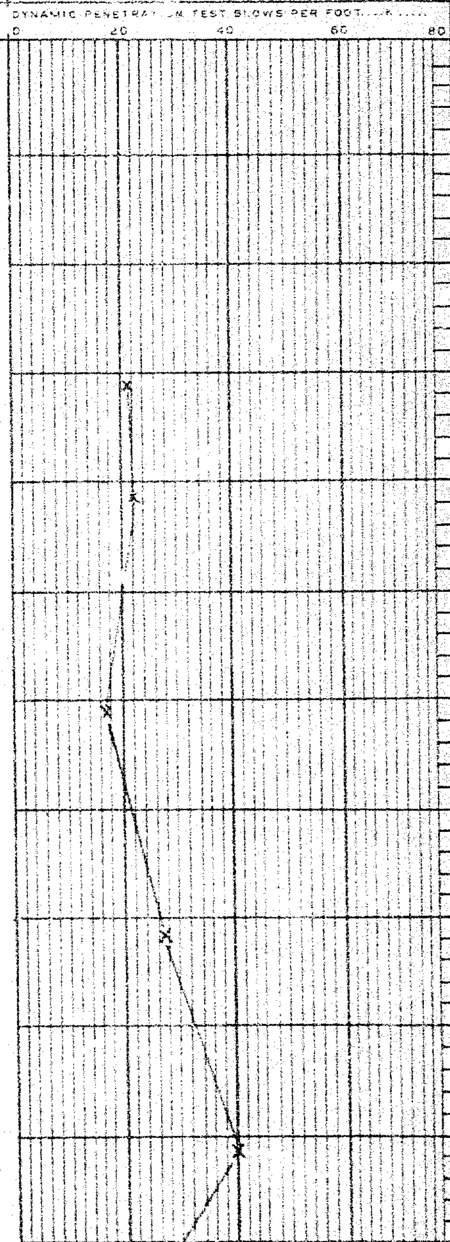
CLIENT Ontario Department of Highways
LOCATION Beech River
DATE OF BORING Sept.4,5,6, & 9
DATE OF WL READING Sept. 11/69.

SOIL PROFILE						SAMPLES						
DEPTH	ELEVATION DEPTH	SOIL DESCRIPTION	STRAT. PLOT	WATER CONDITIONS	CONDITION	TYPE	NUMBER	RECOVERY	N-VALUE	LABORATORY TESTS PERFORMED
0	129.0							%		
		6" TOPSOIL								
10		SAND Brown Medium with some small gravel moist								
					X	SS	1	100	21	G
20					X	SS	2	100	22	G
30	99.0 30.0	SAND Brown Fine Compact			X	SS	3	100	17	G
40	89.0 40.0			▼	X	SS	4	100	27	G
50					X	SS	5	100	30	G
55	55.0	Continued								

LAB TEST RESULTS

WATER CONTENT & ATTERBERG LIMITS. WP W WL

DYNAMIC PENETRATION TEST BLOWS PER FOOT



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OFFICE BOREHOLE RECORD

APPENDIX B

PROJECT NO. 230-514

CLIENT Ontario Department of Highways

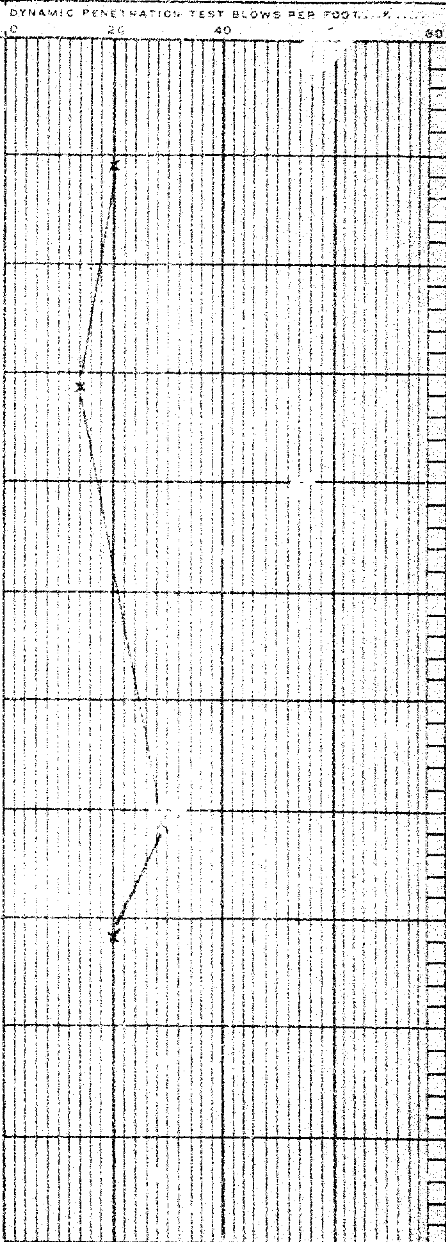
BOREHOLE NO. 1 cont'd

LOCATION Beech River

CASING BX

DATE OF BORING Sept. 4,5,6 & 9, DATE OF WL READING Sept. 11/69. DATUM Assumed

SOIL PROFILE					SAMPLES						
DEPTH	ELEVATION / DEPTH	SOIL DESCRIPTION	STRAT. PLOT	WATER CONDITIONS	CONDITION	TYPE	NUMBER	RECOVERY	N-VALUE	LABORATORY TESTS PERFORMED	LAB TEST RESULTS — WATER CONTENT & ATTERBERG LIMITS W_P W W_L
55								%			DYNAMIC PENETRATION TEST BLOWS PER FOOT 0 20 40 60
60		SAND Brown Fine Compact Wet				SS	[illegible]	[illegible]	20	G	
70	59.0 70.0	SAND Brown Medium with some small gravel changes to grey brown at 80.0 ft.				SS	7	100	14	G	
80		wet				WS	8			G	
90	39.0 90.0	SAND Grey brown Medium Wet				SS	9	100	29		
						SS	10	100	20		
100	29.0 100.0	End of Hole 100.0 ft. NOTE: Water level 40.0 ft. Drove BX casing 70.0 ft. and wash bored using Bentonite Continuous Geoprobe testing from 7' - 90' from 70' - 100' drilled ahead with AX casing									



OFFICE BOREHOLE RECORD

APPENDIX B

PROJECT NO. 230-514

CLIENT Ontario Department of Highways

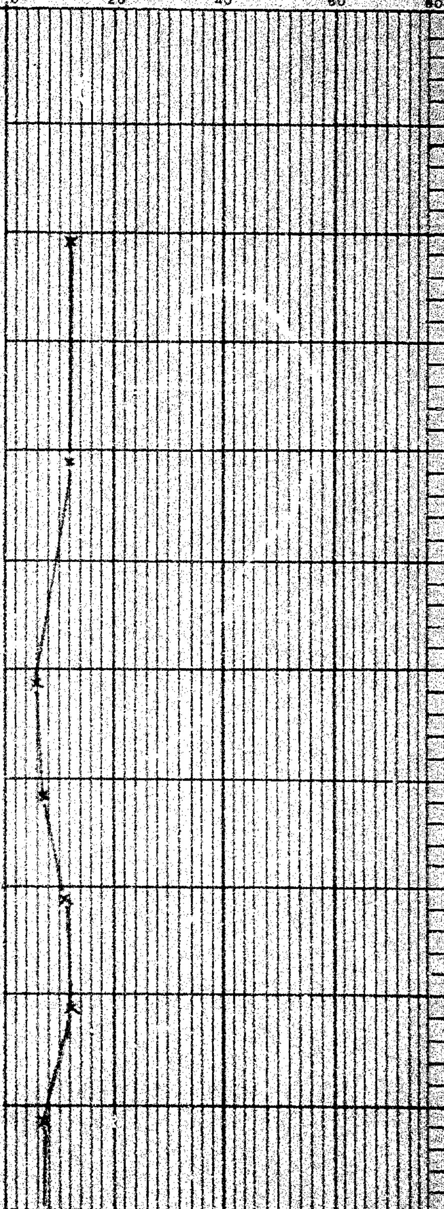
BOREHOLE NO. 2

LOCATION Beech River

CASING BX

DATE OF BORING Sept. 9,10,11,14. DATE OF WL READING Sept. 15/69. DATUM Assumed

SOIL PROFILE						SAMPLES						LAB TEST RESULTS
DEPTH	ELEVATION / DEPTH	SOIL DESCRIPTION	STRAT. PLOT	WATER CONDITIONS		CONDITION	TYPE	NUMBER	RECOVERY	N VALUE	LABORATORY TESTS PERFORMED	WATER CONTENT & ATTERBERG LIMITS Wp W Wl / DYNAMIC PENETRATION TEST BLOWS PER FOOT 0 20 40 60 80
0	108.0								%			
		6" TOPSOIL										
		SAND Brown Medium with some small gravel moist										
10						X	SS	1	100	12	G	
20	88.0 20.0	SAND Brown Medium Wet		▼		X	SS	2	100	12	G	
30	78.0 30.0	SAND Brown Fine				X	SS	3	100	6	G	
						X	SS	4	100	7	G	
40		Changes to grey brown at 40.0 ft. Loose to compact Wet				X	SS	5	100	11	G	
	63.0 45.0	SAND Grey Fine with some silt Compact				X	SS	6	100	12	G	
50	58.0 50.0	SAND Brown Fine Changes to grey at 60.0 ft. loose to wet				X	SS	7	100	7	G	
55												
		continued										



OFFICE BOREHOLE RECORD

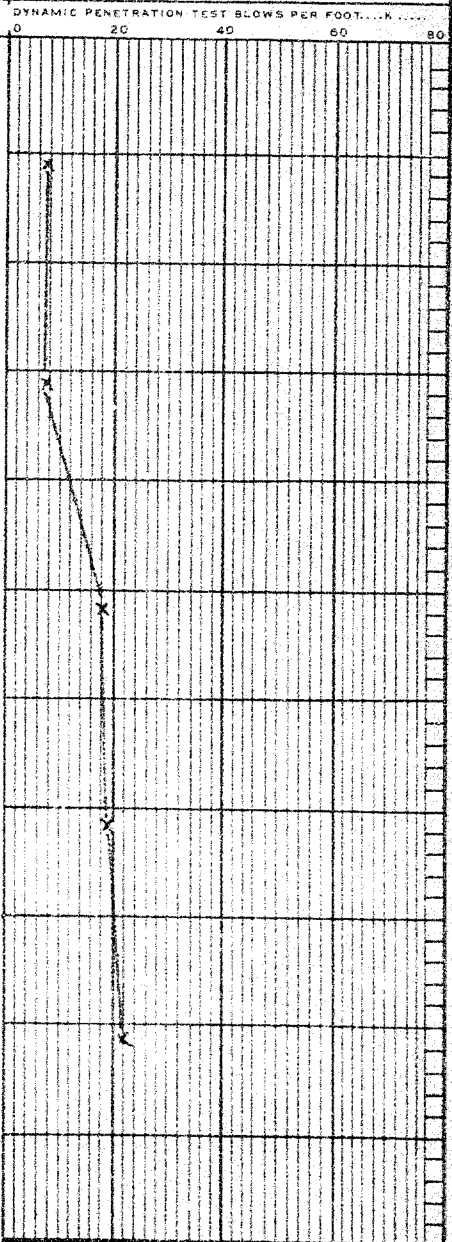
APPENDIX B

CLIENT: Ontario Department of Highways
LOCATION: Beech River
DATE OF BORING: Sept.9,10,11,14
DATE OF WL READING: Sept. 15/69.,
PROJECT NO.: 230-514
BOREHOLE NO.: 2 cont'd
CASING: BX
DATUM: Assumed

DEPTH	ELEVATION / DEPTH	SOIL DESCRIPTION	STRAT. PLOT	WATER CONDITIONS	CONDITION	TYPE	NUMBER	RECOVERY %	N-VALUE	LABORATORY TESTS PERFORMED
55		SAND Brown Fine Changes to Grey Brown at 60.0 ft. Loose Wet								
60					X	SS	8	100	7	G
70					X	SS	9	100	7	G
80	28.0 80.0	SILTY SAND Grey Fine Compact Wet			X	SS	10	100	18	G
90					X	SS	11	100	19	G
					X	WS	12	100		G
100	6.5 101.5				X	SS	13	100	22	G
		End of Hole 101.5 ft. NOTE: Water level 20.0 ft. Drove BX casing and wash bored using Bentonite Losing Bentonite after 25.0 ft. and between 81.0 ft - 84.0 ft. Hole caved 41'6" and 45' - 50' Continuous Geoprobe testing to 100 ft.								

LAB TEST RESULTS

WATER CONTENT & ATTERBERG LIMITS. Wp W WL



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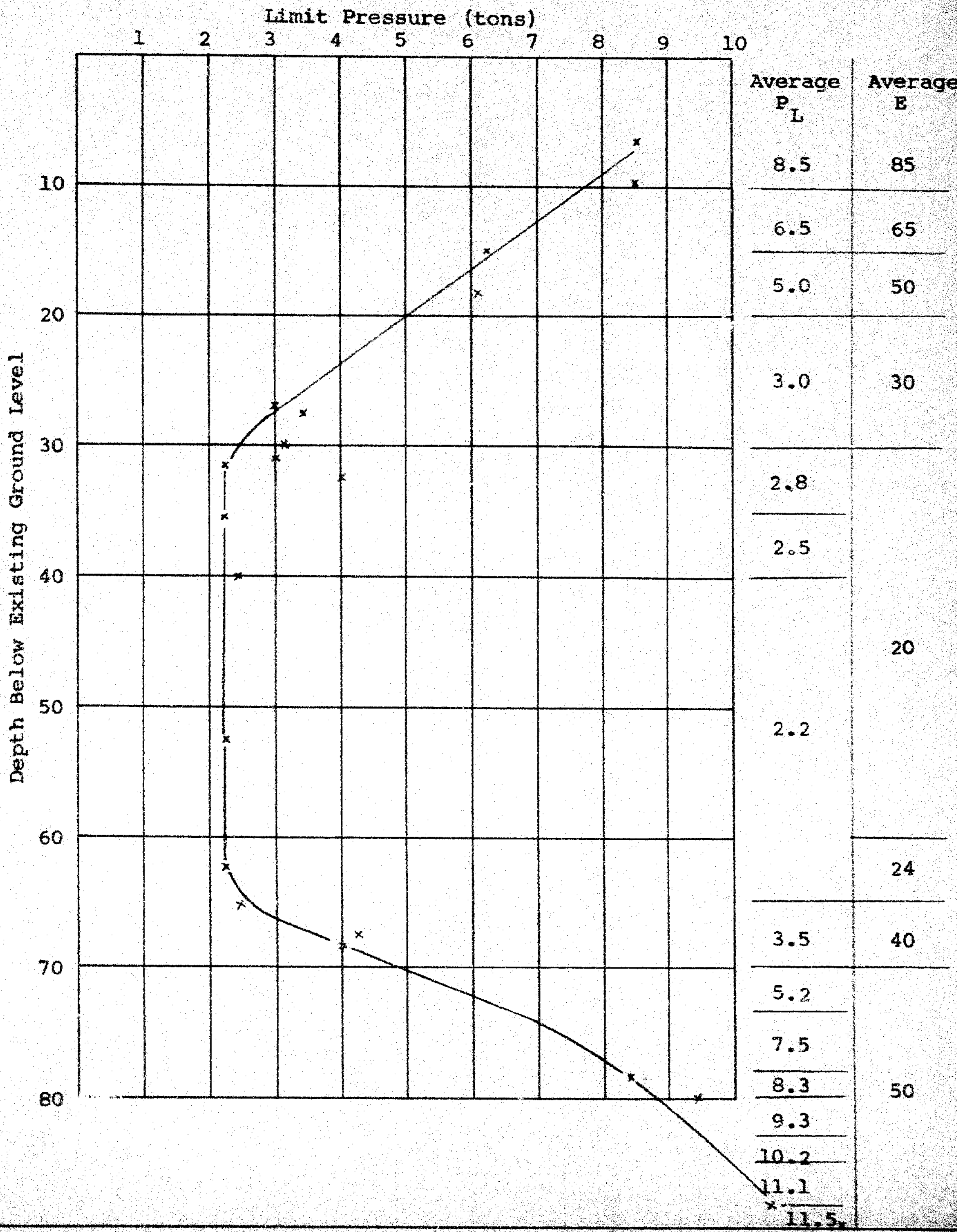
Ontario Department of Highways

BEECH RIVER BRIDGE

App C Fig 1

230-514



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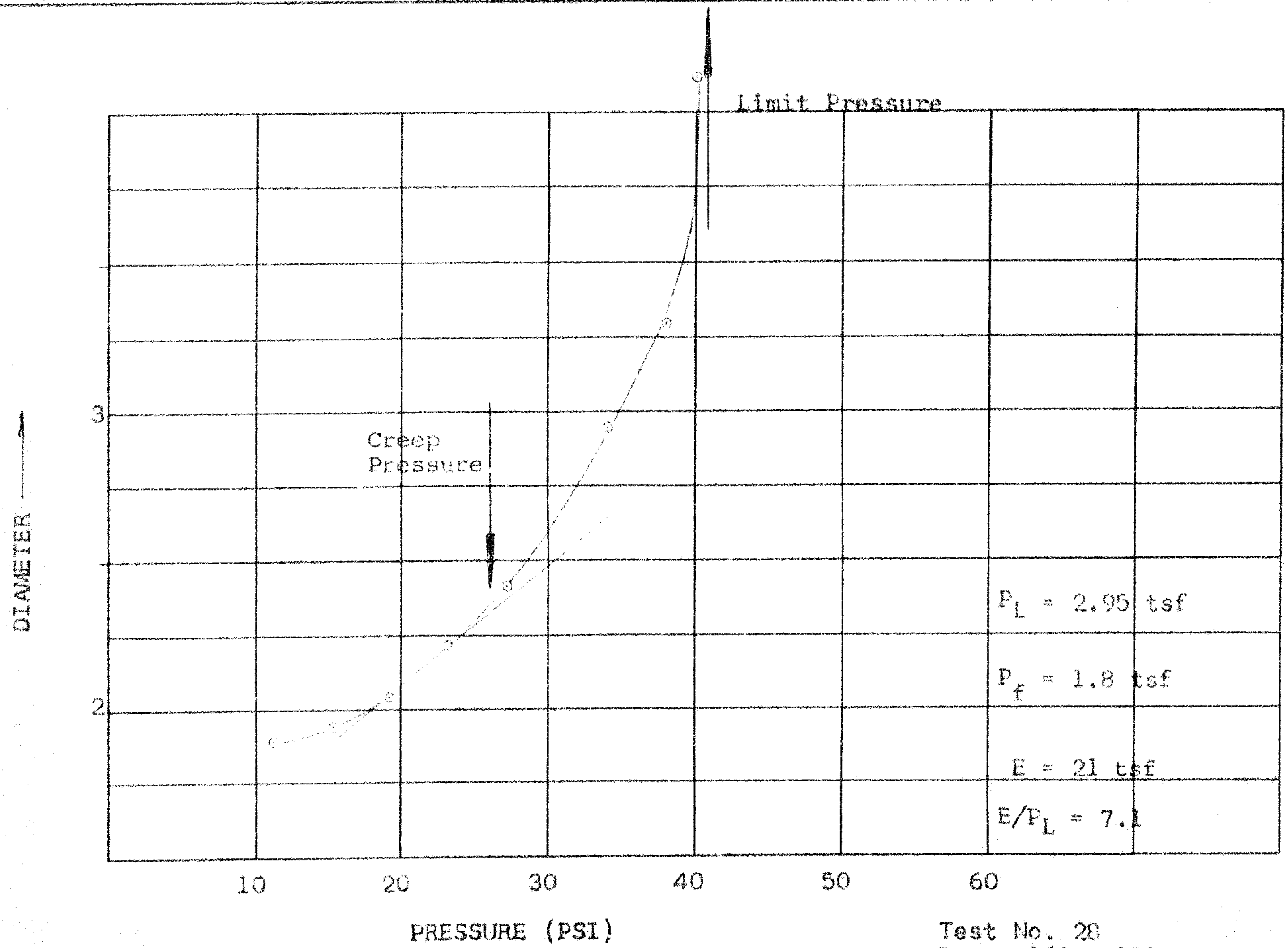
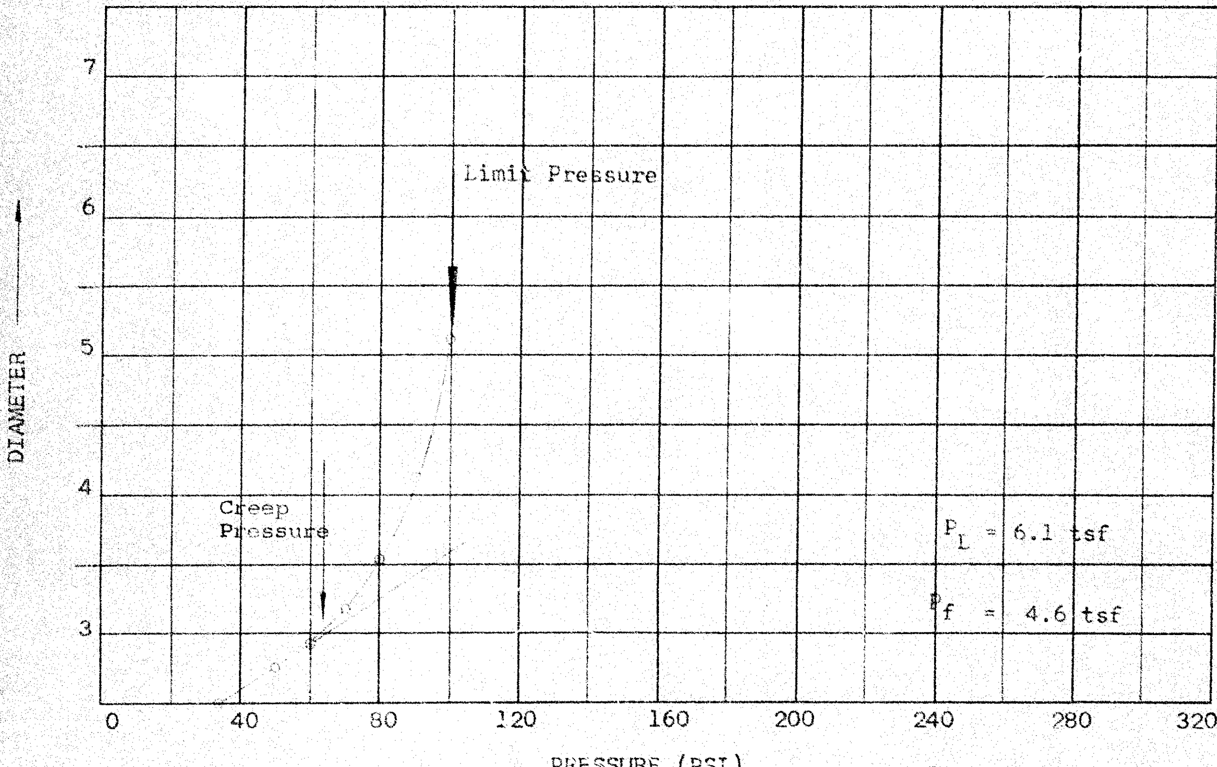


Test No. 28
Depth 16' - 19'
Borehole No. 2

ONTARIO DEPARTMENT OF HIGHWAYS
BEECH RIVER

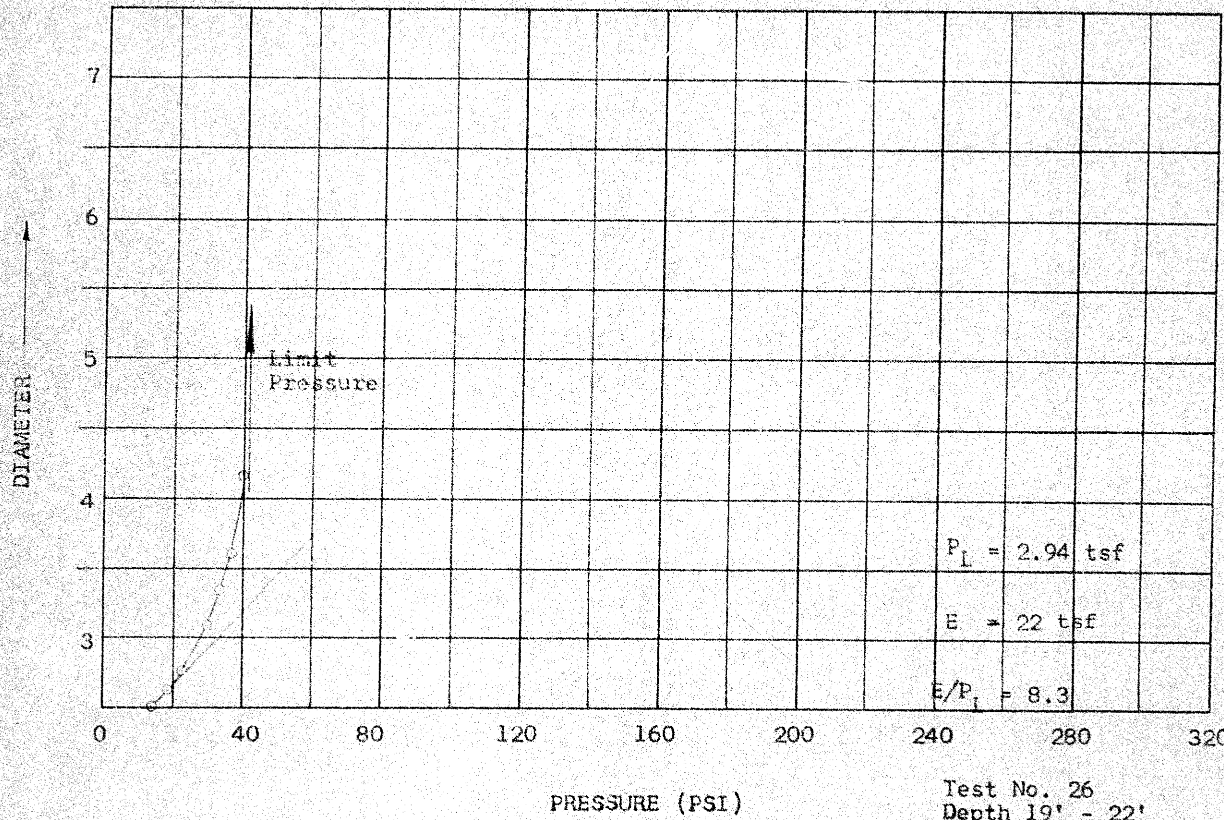
APP C Fig 2
230-514



Test No. 50
Depth 17' - 20'
Borehole 2A

ONTARIO DEPARTMENT OF HIGHWAYS
BEECH RIVER BRIDGE

APP C Fig 3
230-514



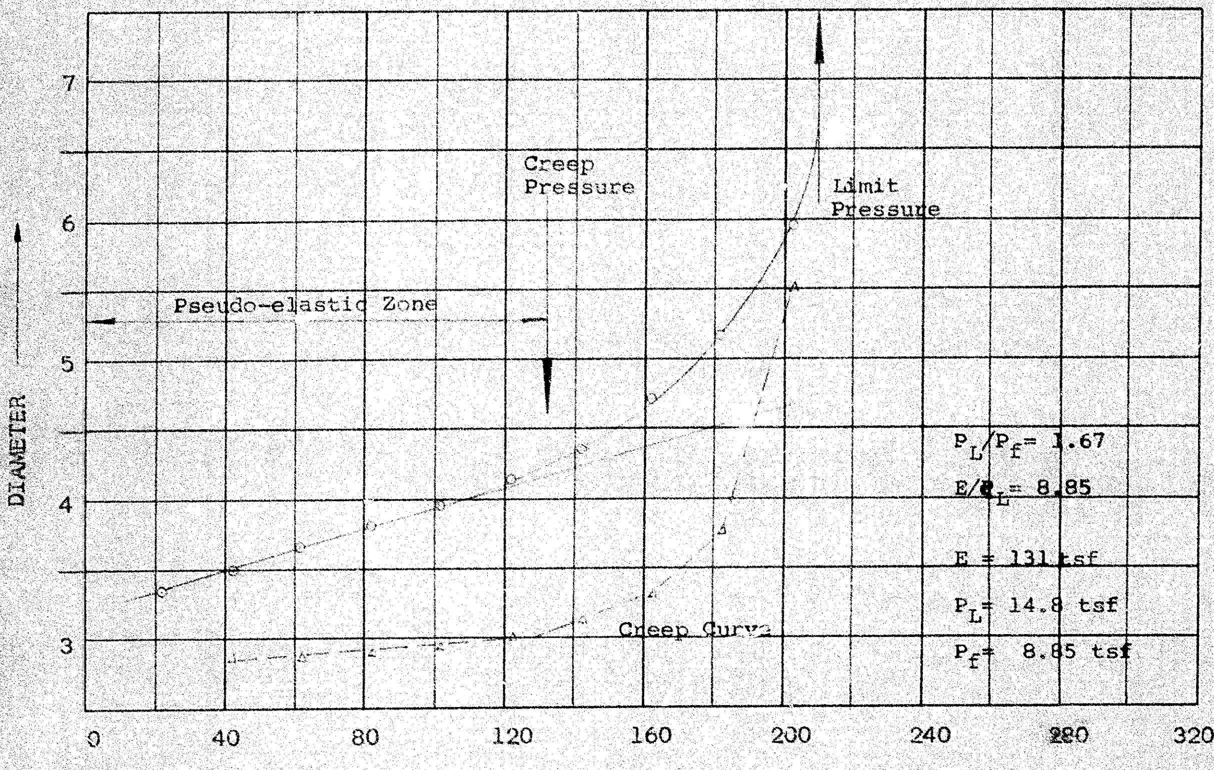
Test No. 26
Depth 19' - 22'
Borehole No. 2

ONTARIO DEPARTMENT OF HIGHWAYS
BEECH RIVER BRIDGE

APPC Fig 4
230-514

ONTARIO DEPARTMENT OF HIGHWAYS

BEECH RIVER BRIDGE



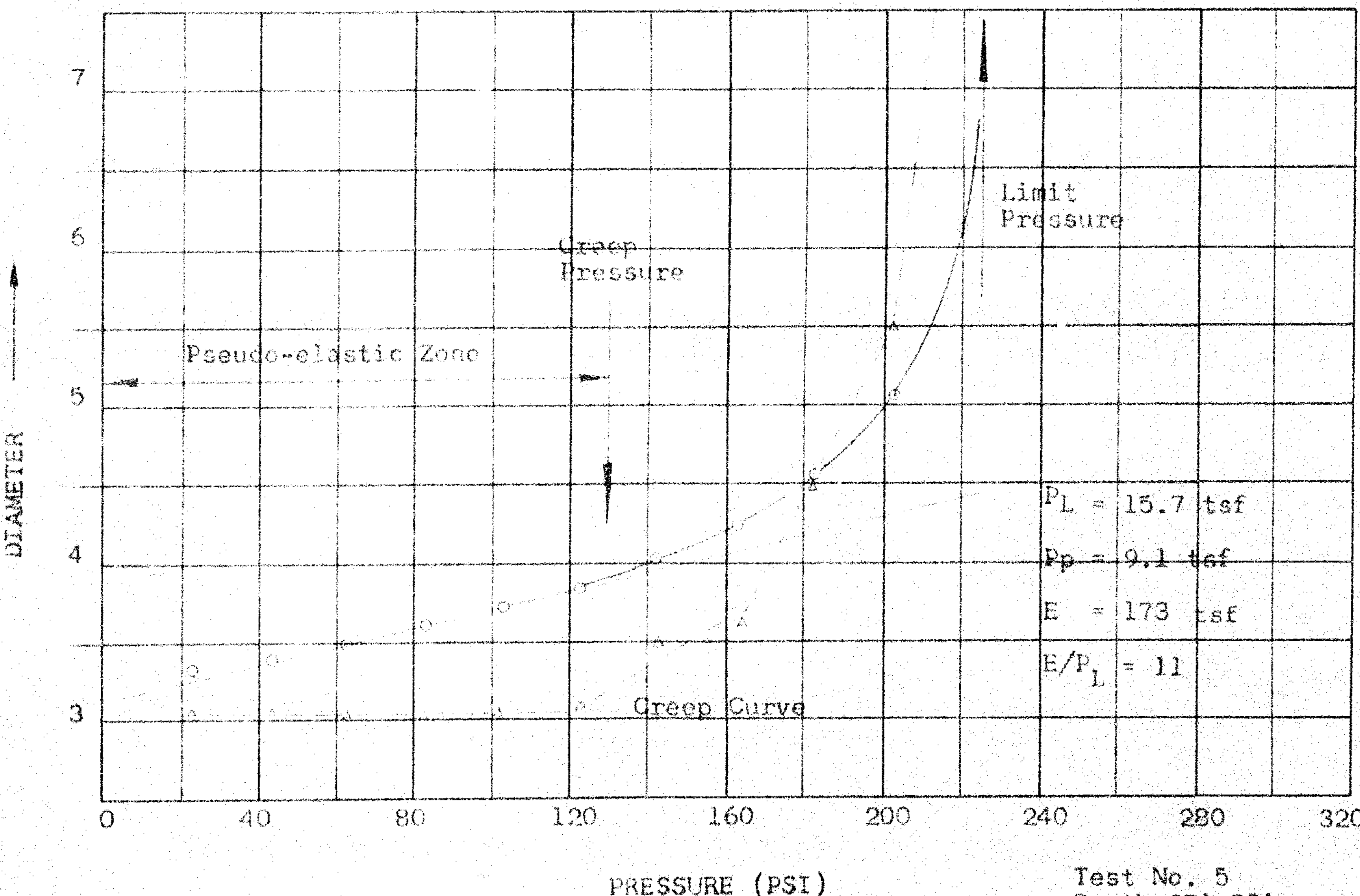
PRESSURE (PSI)

Test No 6
Depth 24'-27'
Borehole No 1

App C Fig 5

230-514

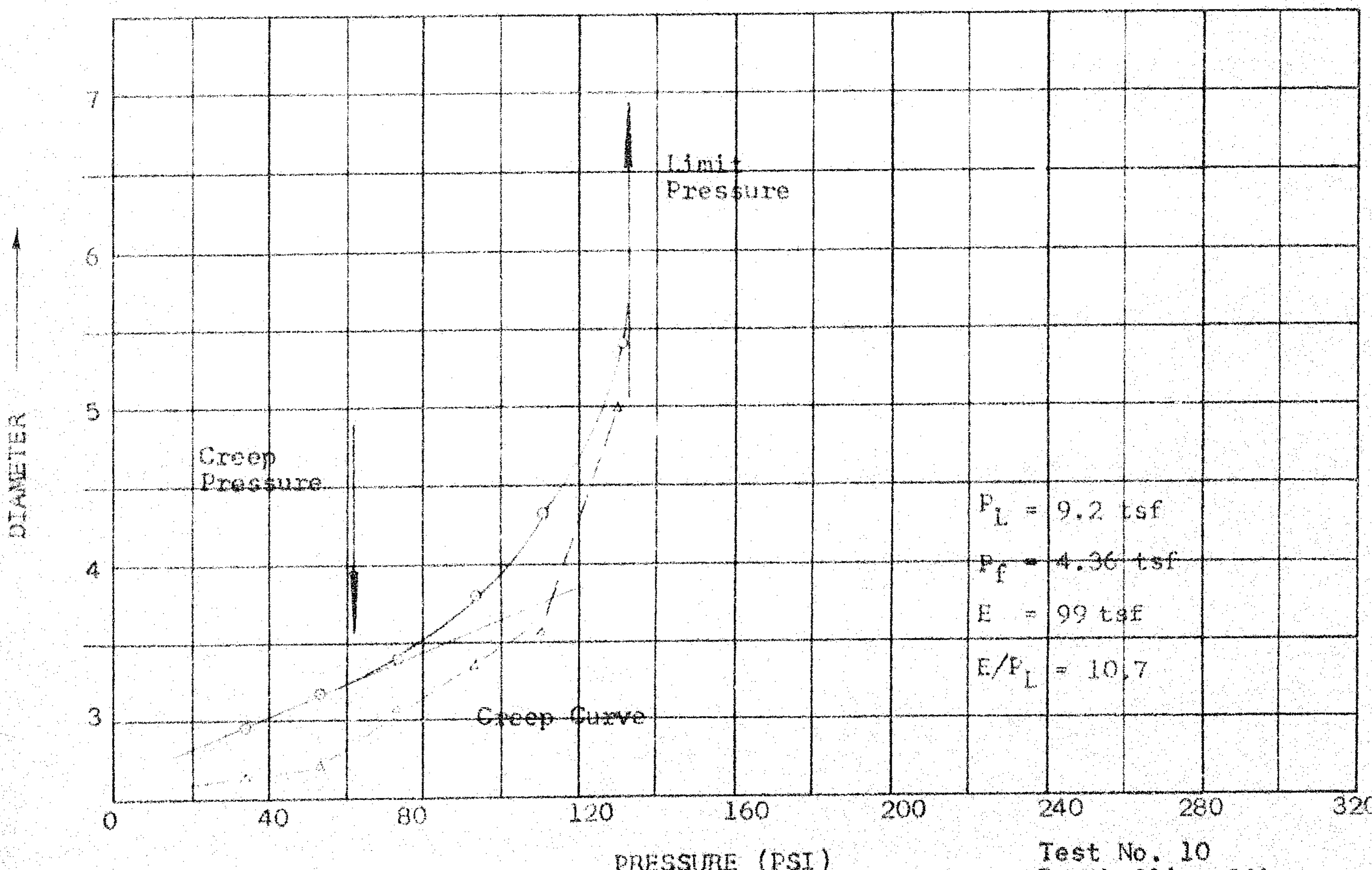
CANADA BLUE PRINT 104



Test No. 5
Depth 27'-30'
Borehole No. 1

ONTARIO DEPARTMENT OF HIGHWAYS
BEECH RIVER BRIDGE

APP C Fig 6
230-514



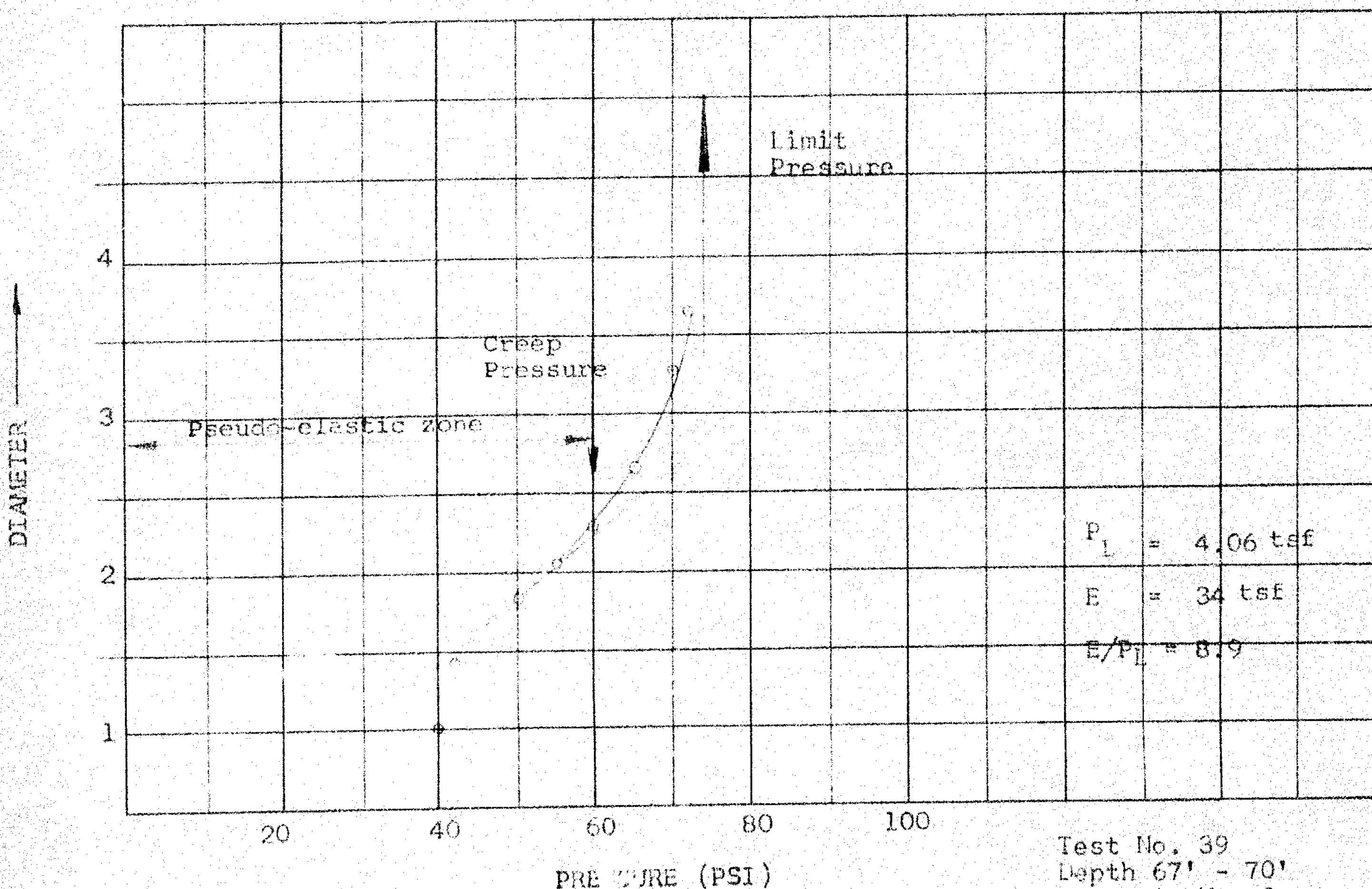
Test No. 10
Depth 31' - 34'
Borehole No. 1

ONTARIO DEPARTMENT OF HIGHWAYS

BEECH RIVER BRIDGE

APPC Fig 7

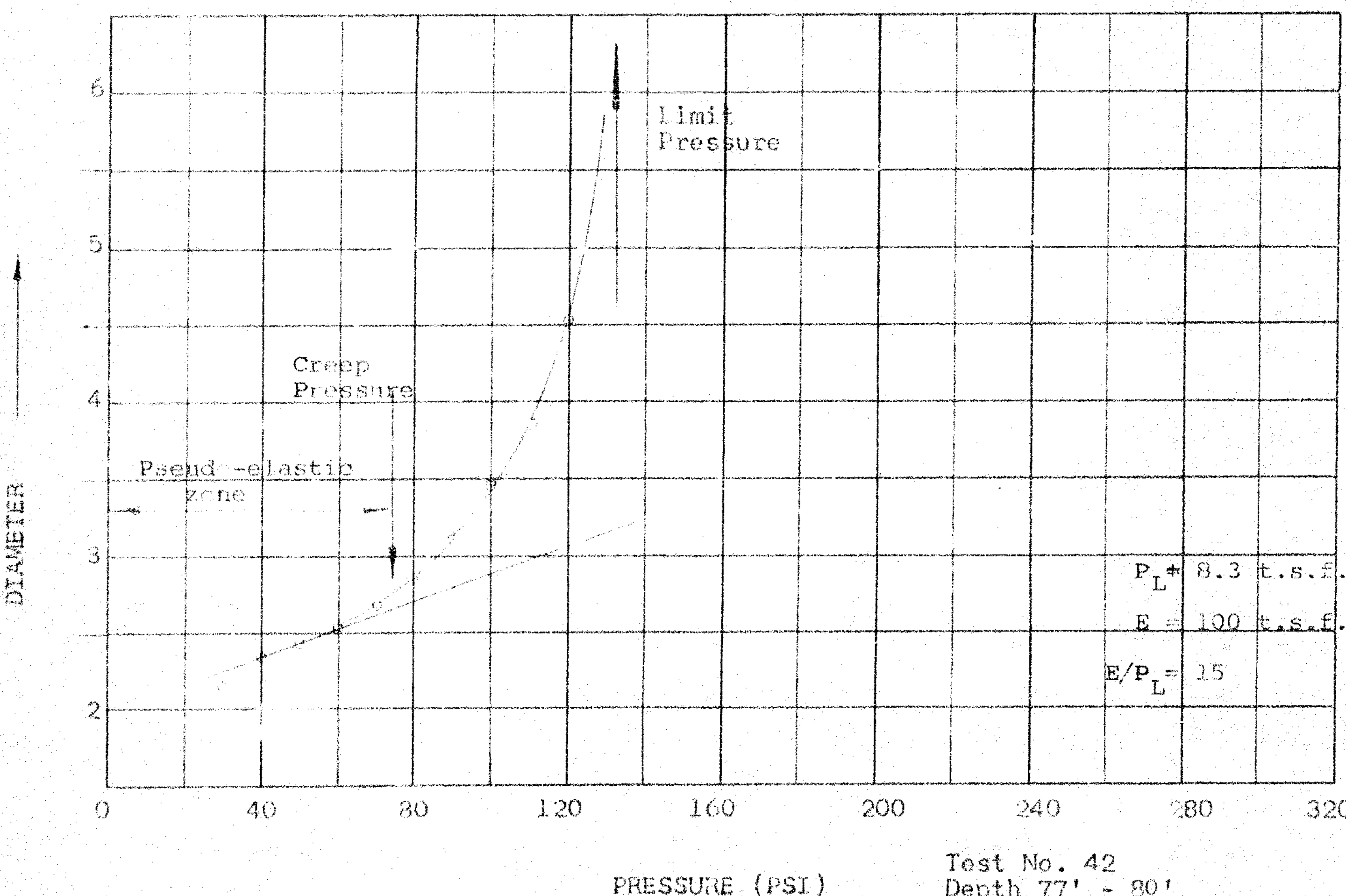
230-514



Test No. 39
Depth 67' - 70'
Borehole No. 2

ONTARIO DEPARTMENT OF HIGHWAYS
BEECH RIVER BRIDGE

APP C Fig 8
230-514



Test No. 42
Depth 77' - 80'
Borehole No. 2

ONTARIO DEPARTMENT OF HIGHWAYS

BEECH RIVER BRIDGE

APP C Fig 9

230-514

HON. GEORGE E. GOMME
MINISTER

A. T. C. McNAB
DEPUTY MINISTER

Hwy. 401 & Keele St.,
Downsview 464, Ontario.
Tel. 248-3282
(Area Code 416)

DEPARTMENT OF HIGHWAYS
Materials and Testing Office

August 13, 1969

Warnock Hersey International Limited,
Professional Services Division,
250 Madison Avenue,
Toronto 7, Ontario.

Attention: Mr. J. Beam, P. Eng.,
Special Projects Engr. - Geotechnical Services

Re: LETTER OF AUTHORITY - FOUNDATION INVESTIGATION
Beach River Bridge on Hwy. 35, approx. 2 Miles
North of Carnarvon - District #11 (Huntsville)
W.P. 178-64

Dear Sirs:

This is to authorize you to carry out a foundation investigation at the above mentioned site using the Geoprobe equipment.

Your investigation will be confined to the immediate area of Station 101+00, and not more than two holes should be drilled.

The plans and other pertinent information were given to you by Mr. K. G. Selby on May 30, 1969.

You are requested to submit eleven (11) copies of the report on completion of the work.

7800
93090
17

Charges for the drilling and sampling work will be in accordance with your Schedule of Rates, effective on July 14, 1969. Charges for field and laboratory testing and analysis will be in accordance with your Schedule of Prices dated July 7, 1969. Invoices for this work should be submitted, in triplicate, to the attention of the undersigned.

Yours very truly,

A. Rutka

A. Rutka
MATERIALS & TESTING ENGINEER

KGS/MdeF
cc: Messrs. S. McCombie
H. McArthur
J. McAllister
W. Aitken
W. Fry
E. R. Saint
D. A. Barr

Foundations Files (Rm. 110)
Gen. Files