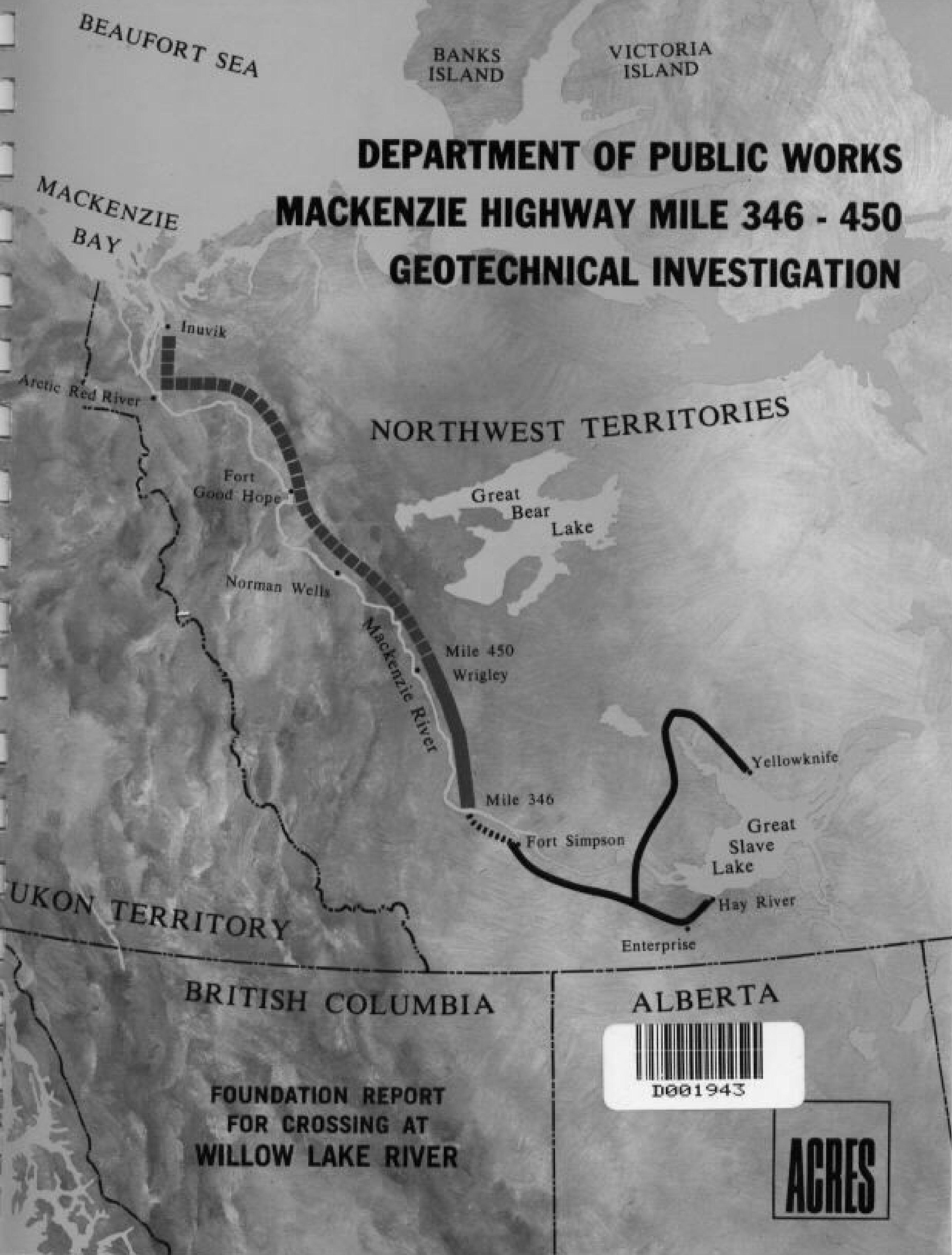
DEPARTMENT OF PUBLIC WORKS
MACKENZIE HIGHWAY MILE 346 - 450
GEOTECHNICAL INVESTIGATION



FOUNDATION REPORT FOR CROSSING AT WILLOW LAKE RIVER

ACRES

FOUNDATION REPORT FOR CROSSING
AT
WILLOW LAKE RIVER
MILE 394 MACKENZIE HIGHWAY
NORTHWEST TERRITORIES

ACRES CONSULTING SERVICES LIMITED
Suite 990 - 125 - 9 Ave. S.E.
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T2G OP6

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1.0 INTRODUCTION

This report contains the results of the foundation investigation and recommendations for foundation and embankment design for the Willow Lake River crossing at Mile 394 on the Mackenzie Highway, Northwest Territories. The field investigation at this site was part of an overall geotechnical investigation conducted by Acres Consulting Services from Mile 346 to Mile 450 of the Mackenzie Highway for the Department of Public Works, Government of Canada.

The purpose of the investigation was to determine the site foundation, permafrost and groundwater conditions and to provide recommendations on the design and construction of the proposed bridge abutments, piers and approach embankments.

2.0 SITE AND GEOLOGY

The Willow Lake River crossing site is located at Mile 394.7 (chainage 985 + 00) on the Mackenzie Highway. This site is approximately one mile upstream from the junction of Willow Lake River with the Mackenzie River.

The stream bed elevation at the proposed crossing site is approximately 250 ft. (D.P.W. datum). The length of the bridge is 900 feet and 4 spans are proposed.

The crossing site is located in a shallow valley approximately 3/4 mile wide and 50 feet deep, incised into

2.0 SITE AND GEOLOGY - Continued

the fluvial sands and glacial tills which mantle the Mackenzie River valley in this section of the project.

The deepest boring, to a depth of 101 feet, did not encounter bedrock at this site, although shale is encountered at shallow depth several miles to the north along the highway centreline. Bedrock in the area is horizontally bedded shale, sandstone and limestone of the Fort Simpson Formation of Devonian age.

3.0 FIELD INVESTIGATION AND LABORATORY TESTING

A total of seven testholes were drilled at the bridge site along centreline to depths ranging from 15 to 101 feet at the locations shown in Figure 1. Figure 2 shows a centreline section of the valley.

Two testholes were drilled at the abutment locations to depths of 101 and 55 feet and three holes were drilled at pier locations to depths of 51, 71 and 66 feet respectively.

The drilling and sampling at the bridge site was done between January 30 and February 7, 1973 by Kenting Big Indian Drilling of Calgary utilizing a Gardner-Denver 200 "helidrill" mounted on a Foremost 60 tracked vehicle.

Sampling was done using the air recovery percussion method for disturbed samples, 3 inch thin-walled Shelby tubes for undisturbed cohesive soil samples, and the standard split spoon for granular soil samples. Standard Penetration blow counts were taken with the split spoon sampler.

Samples were logged in the field and classified according to the Unified Soil Classification System as shown in Figure 3. Ice contents were classified according to the N.R.C. Technical Memorandum No. 75 "Guide to the Field Description of Permafrost" as shown in Figure 4.

Moisture contents were obtained for all samples returned to the laboratory and the samples were subjected to routine classification tests including grain size distribution and Atterberg limits. The results of all laboratory and field tests are included in the testhole logs appended to this Report.

4.0 FOUNDATION CONDITIONS

The following boreholes were drilled to investigate the foundation conditions at the bridge abutment and pier locations.

HOLE NUMBER	LOCATION
394-C-B	South Abutment
394-S-C	South Pier
394-S-D	Centre Pier
394-S-E	North Pier
394-S-F	North Abutment

4.0 FOUNDATION CONDITIONS - Continued

The detailed soil descriptions for these holes are given in the borehole logs appended to this Report.

The boreholes drilled for the three piers showed unfrozen, medium density, silty-sands and gravel to a depth of about 20 feet. Blow counts ranged from 20 to 59 and averaged 30.

This stratum is underlain by approximately 20 feet of dense, dark grey, sandy-silt with minor clay, having W_L = 45 percent, W_p = 20 percent and an average water content of 30 percent. Blow counts from the Standard Penetration test ranged from 22 to 52 and averaged 32 indicating that the silt consistency ranges from very stiff to hard.

Below a depth of about 45 feet, the soil is a clayey-silt with blow counts ranging from 22 to 39 and averaging 32 indicating a very stiff to hard consistency.

No frozen ground was encountered in the three pier testholes.

Testhole 394-C-B, drilled on the south abutment location, showed silty-sand and sandy-silt to a depth of 46 feet. The soil was frozen to a depth of 33 feet. Moisture contents varied from 20 to 30 percent in the lower section of the hole but increased to a maximum of 45 percent in the upper 10 feet of the hole. Blow counts of 46 and 19 were recorded at depths of 35 and 40 feet respectively, in the unfrozen soil, indicating a very stiff to hard consistency.

4.0 FOUNDATION CONDITIONS - Continued

Testhole 394-S-F, drilled on the north abutment location, showed loose to medium dense silty-sand to a depth of 18 feet. Standard Penetration Test blow counts ranged from 4 to 33. This stratum is underlain by dense sand and gravel to a depth of approximately 60 feet with an average blow count of 44. Dense grey clayey-sandy-silt occurs to a depth of 101 feet. A thaw-consolidation test on a sample from a depth of 16 feet in this hole showed a consolidation of 0.34 percent.

The two testholes drilled on the centreline of the approach embankments some 500 feet back from the river (394-C-G and 394-C-K) showed silty-sand and clayey-silt with moisture contents in excess of 20 percent in the top 20 feet. The soil sampled in these holes was frozen throughout.

5.0 RECOMMENDATIONS AND CONCLUSIONS

The following conclusions and recommendations are made, based upon the results of the investigation program, for the design and construction of the Willow Lake River bridge foundations and approach fills.

5.1 Pier and Abutment Foundation Design

The subsurface investigation program described previously shows the piers to be underlain by unfrozen, medium density, silty-sands and gravels to a depth of 20 feet. Very stiff to hard, unfrozen, sandy and clayey-silt underlies this stratum with the clay content increasing with depth. Under the abutments, some 20 feet of frozen silty-sand overlies silty sands and gravels. The upper 20 feet of the abutment holes are characterized by relatively high water contents and standard penetration blow counts in 394-S-F of 4 to 7 indicate a loose relative density in at least part of this stratum.

In view of the subsurface conditions under the abutments and of scour considerations, a driven friction pile foundation is recommended for all piers and abutments at this site. The suitable types include pre-cast reinforced concrete, and steel pipe and H piles. Steel H piles are recommended for use at this site in view of their high driving strength, high load capacity and ease of splicing.

It is recommended that all piles used for pier foundations should be driven to a depth of not less than 50 feet or "refusal". As an initial guide, it is recommended that "refusal" be considered to be 240 blows per foot (20 blows per inch) under a hammer rated at 15,000 ft-lb.

Ultimate pile capacity should be established in the field by use of dynamic pile driving formulae. The Janbu formula (Terzaghi and Peck, 1967[1]) is recommended with the use of a factor of safety of 3 to establish an allowable load per pile. Design loading should not exceed 40 tons per pile for a minimum H pile size of HP 10 x 57.

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[1] Terzaghi, K., and Peck, R.B., 1967. Soil Mechanics in Engineering Practice, John Wiley and Sons, 2nd edition, p. 229.

5.1 Pier and Abutment Foundation Design - Continued

It is recommended that all piles used for abutment foundations should be driven to a depth not less than 60 feet into the existing soil or to "refusal". The recommendations for "refusal", establishment of allowable load per pile, and design loading limits are as outlined previously for the pier foundations.

The abutment foundations may be placed on pile-supported footings located in the embankment. If this procedure is adopted, it is recommended that the abutments be placed on select, well-compacted granular fill. Settlement of the foundation under the weight of the approach embankments would subject the piles supporting the abutments to significant negative skin friction which must be allowed for in the pile design. It is recommended, as an alternative, that the abutment sites be preloaded for a minimum of 2 summer months with the full height of the approach embankment to allow consolidation of the foundation soil, then a portion of the embankment fill be removed to allow pile driving and construction of the bridge abutments.

5.2 Lateral Abutment Loads

The approach fills will have a maximum height of approximately 30 feet and it is recommended that they be constructed of well-compacted granular fill from the approach cuts or the adjacent borrow pits. Thus earth pressures against the concrete abutment and wing walls will be larger than the active case and will approach the earth pressure at-rest case.

5.2 Lateral Abutment Loads - Continued

It is recommended that the lateral earth pressure design should use a triangular load distribution using a coefficient of earth pressure at-rest (K_o) of 0.40 with due allowance for any surcharges or live loads acting near the wall.

Either the Coulomb or the Rankine method of calculation of earth pressure against the wall can be used. It is recommended that the angle of shearing resistance of the granular fill be taken as 38 degrees and the dry density of the granular fill be taken as 125 pcf. If the Coulomb method of analysis is adopted, the angle of wall friction between the concrete and the granular fill should be taken as 20 degrees.

The use of extensive measures to ensure proper drainage of the backfill behind the abutment is recommended to prevent the development of hydrostatic pressure against the wall. The measures adopted should include the use of perforated steel pipe drains at the base of the wall, weep holes through the wall and the use of select, free-draining granular fill immediately behind the wall.

The use of batter piles to ensure sufficient lateral support against lateral earth pressure is recommended in view of the nature of the upper 20 feet of the abutment foundations.

5.3 Bridge Approach Embankments

The grade presently proposed for the Willow Lake River bridge will result in embankments with a maximum height

5.3 Bridge Approach Embankments - Continued

of approximately 30 feet. These embankments will overlie the upper silty-sand and sandy-silt deposits which have a relatively high water content.

Some settlement of the embankments will occur and, to allow consolidation to take place prior to abutment construction, it is recommended that the abutments be constructed a minimum of two months prior to bridge construction.

The embankment should be compacted to a minimum density of 98 percent Standard Proctor density utilizing vibrating rollers. The maximum recommended lift thickness is 9 inches.

Data from the project hydrology consultants (Bolter, Parish, Trimble Ltd. of Edmonton) shows that occasional abnormally high water levels will occur due to ice jams on the Mackenzie River. Hence, the approach embankments must be designed for stability against rapid drawdown conditions. If the embankments are constructed from free-draining granular fill containing a minimum of fines, embankment sideslopes as steep as 2.5 horizontal to 1 vertical can be used. If the embankment fill is not free-draining, the maximum recommended embankment sideslopes are 3.5 horizontal to 1 vertical.

It is recommended that the embankment sideslopes be armoured with a minimum thickness of 18 inches of rip-rap having a minimum diameter of 6 inches. Size and thickness of the rip-rap should be increased in those areas of the embankment subject to high velocity water flow. Sufficient cobbles and boulders to

5.3 Bridge Approach Embankments - Continued

satisfy this requirement, as well as to provide riprap protection for the abutments, should be available in the adjacent borrow pits (392-No. 1 and 396-No. 1) at haul distances of approximately 1-1/2 miles.

APPENDIX

LEGEND

PHOTOGEOLOGIC AND BOREHOLE MAPPING

F	- Frictional soils (sand, gravel)
T	- Transitional soils (silt, mixed silty soils)
C	- Cohesive soils (clay)
O	- Organic soils (peat)
R	- Bedrock, outcrop or under shallow overburden
ICE	- Massive ground ice
/	- Example - O/T organics overlying transitional soils
( )	- Example - (ICE) possible or occasional ground ice
	- Beach
	- Slides or slumping of slopes
X	- Spring
 421-BT-1	- Test Trenches
• 421-C-D	- Centreline boreholes
• 421-B-J	- Borrow source boreholes
	- Outline of potential borrow sources

NOTES RELATING TO PHOTOMOSAICS

1. The drill hole locations marked on the photomosaics are transferred from the locations marked on the airphotos used in the field and have been plotted relative to the topographic features and not in accordance with the actual mile posts. In some instances the borehole chainages as determined from field surveys do not agree with the mileages noted on the drawings.

2. The photomosaics on which the data has been plotted were those supplied to Acres by D.P.W. on February 8, 1973.

DEFINITIONS

SYMBOL

w_l	- Liquid limit
w_p	- Plastic limit
w_n	- Natural water content
I_p	- Plasticity index
psf	- pounds per square foot
pcf	- pounds per cubic foot
K_o	- Coefficient of earth pressure at rest

MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS more than 50% of material is LARGER than no. 200 sieve size	GRAVEL AND GRAVELLY SOILS more than 50% of coarse fraction RETAINED on no. 4 sieve	CLEAN GRAVELS (little or no fines)	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (appreciable amount of fines)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS more than 50% of coarse fraction PASSING no. 4 sieve	CLEAN SAND (little or no fines)	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (appreciable amount of fines)	SM	SILTY SANDS, SAND-SILT MIXTURES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS more than 50% of material is SMALLER than no. 200 sieve size	SILTS AND CLAYS	liquid limit LESS than 50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	liquid limit GREATER than 50	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 3

<table>
<tr><th rowspan="2"></th><th colspan="2">MAJOR GROUP</th><th colspan="3">SUB-GROUP</th></tr>
<tr><th>DESCRIPTION</th><th>DESIGNATION</th><th colspan="2">DESCRIPTION</th><th colspan="2">DESIGNATION</th></tr>
<tr><td rowspan="7">DESCRIPTION OF FROZEN SOIL</td><td rowspan="3">SEGREGATED ICE IS NOT VISIBLE BY EYE</td><td rowspan="3">N</td><td colspan="2">POORLY BONDED OR FRIABLE</td><td colspan="2">Nf</td></tr>
<tr><td rowspan="2">WELL BONDED</td><td>NO EXCESS ICE</td><td rowspan="2">Nb</td><td>n</td></tr>
<tr><td>EXCESS ICE</td><td>e</td></tr>
<tr><td rowspan="4">SEGREGATED ICE IS VISIBLE BY EYE (ICE 1 INCH OR LESS IN THICKNESS)</td><td rowspan="4">V</td><td colspan="2">INDIVIDUAL ICE CRYSTALS OR INCLUSIONS</td><td colspan="2">Vx</td></tr>
<tr><td colspan="2">ICE COATINGS ON PARTICLES</td><td colspan="2">Vc</td></tr>
<tr><td colspan="2">RANDOM OR IRREGULARLY ORIENTED ICE FORMATIONS</td><td colspan="2">Vr</td></tr>
<tr><td colspan="2">STRATIFIED OR DISTINCTLY ORIENTED ICE FORMATIONS</td><td colspan="2">Vs</td></tr>
<tr><td rowspan="2">DESCRIPTION OF SUBSTANTIAL ICE STRATA</td><td rowspan="2">ICE (GREATER THAN 1 INCH IN THICKNESS)</td><td rowspan="2">ICE</td><td colspan="2">ICE WITH SOIL INCLUSIONS</td><td colspan="2">ICE + SOIL TYPE</td></tr>
<tr><td colspan="2">ICE WITHOUT SOIL INCLUSIONS</td><td colspan="2">ICE</td></tr>
</table>

ICE CLASSIFICATION CHART

NRC/ACFEL ICE CLASSIFICATION SYSTEM

FIGURE 4

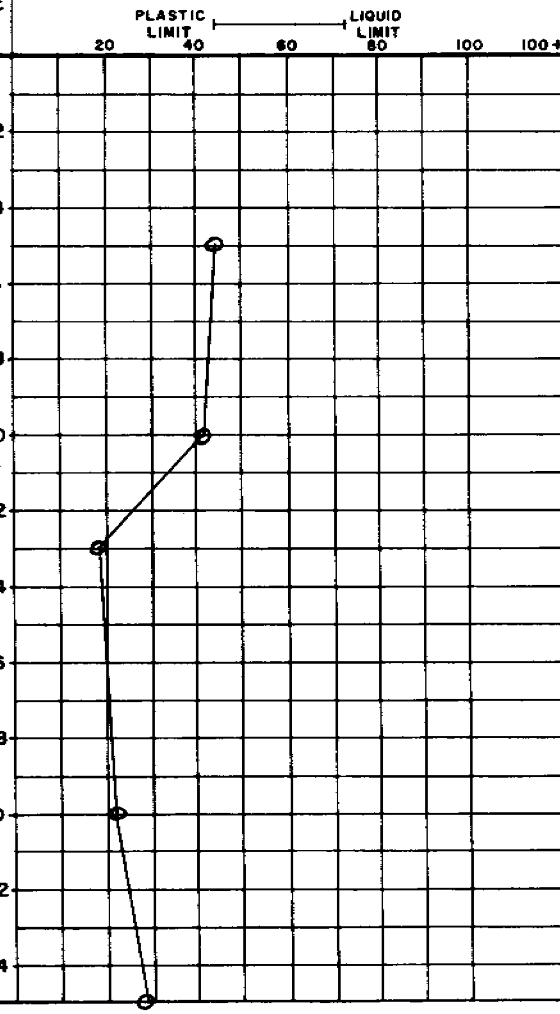
ACRES CONSULTING SERVICES LIMITED CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 30/1/73	AIRPHOTO NO: A22771-71	CHAINAGE: 979+25	OFFSET:		
CKD:	TECH: W.R.	RIG: 1	SURFACE DRAINAGE: GOOD	VEGETATION: D. B.	ELEV: 271		

TEST HOLE		
MILE	B,C,S	NUMBER
394	C	B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–8						FINE SILTY SAND WITH A TRACE OF CLAY BROWN GREY									
	1	P		50	SM			N_{bn}'	6	27	67	0			
8							F								
8–12						SILTY WITH SOME CLAY AND A TRACE OF SAND									
	2	P	90	38	ML				16	76	8	0			
12–24	3	P	10	38	SP	SAND WITH A TRACE OF SILT AND GRAVEL									
								V_x							
	4	P		126	SP				0	8	91	1			
					SP										

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

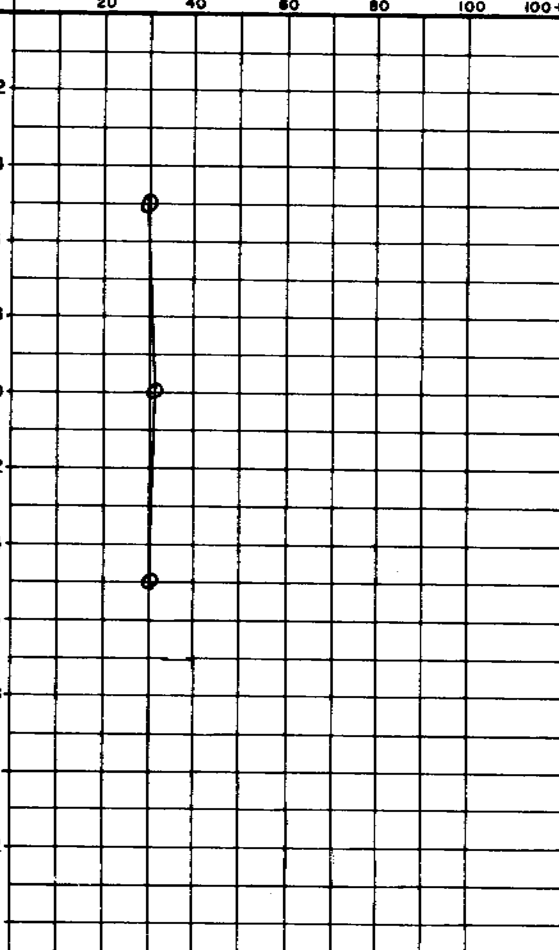
DWN:	FIELD ENG:	DATE DRILLED: 30/1/73	AIRPHOTO NO: A22771-71	CHAINAGE: 979+25	OFFSET:
CKD:	TECH: W.R.	RIG: 1	SURFACE DRAINAGE: GOOD	VEGETATION: D B	ELEV: 271

TEST HOLE

MILE	B,C,S	NUMBER
394	C	B

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT; 20, 40, 60, 80, 100, 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25	6	P		112	SM	GREY SAND WITH SOME SILT	F	N_f	0	12	88	0			
30	7	P	90	93	SM				2	22	76	0			
35	8	P		46	SM		UF								
40	9	P		19	ML	GREY SILT WITH SOME FINE SAND AND A TRACE OF CLAY			3	84	13	0			
45	10	T			ML										
50					CL	GREY CLAYEY SILT WITH A TRACE OF SAND									



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 30/1/73	AIRPHOTO NO: A22771-71	CHAINAGE: 979+25	OFFSET:
CKD:	TECH: R.S.	RIG: 1	SURFACE DRAINAGE: GOOD	VEGETATION: D B	ELEV: 291

TEST HOLE

MILE	B,C,S	NUMBER
394	C	B

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
2							UF		2							
4									4							
55 6					11	END OF DRILLED HOLE AT 55'			6							
					20											
8					49				8							
					36											
60 10					45				10							
					44											
12					57				12							
					65											
14					115				14							
65					146											
16						END OF DYNAMIC PENETRATION TEST AT 65'			16							
18									18							
20									20							
22									22							
24									24							

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CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 5/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 981 + 31	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: RIVER (NIL)	ELEV: 258

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	C

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT —— LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–5	1					GRAVELLY SAND	F	N_{bn}	0	3	65	32			
9	2	P		20	GP		UF		0	8	64	28			
14	3	P		59	GP										
19						DARK GREY SANDY SILT WITH A TRACE OF CLAY									
21	4	P		31	ML										

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CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

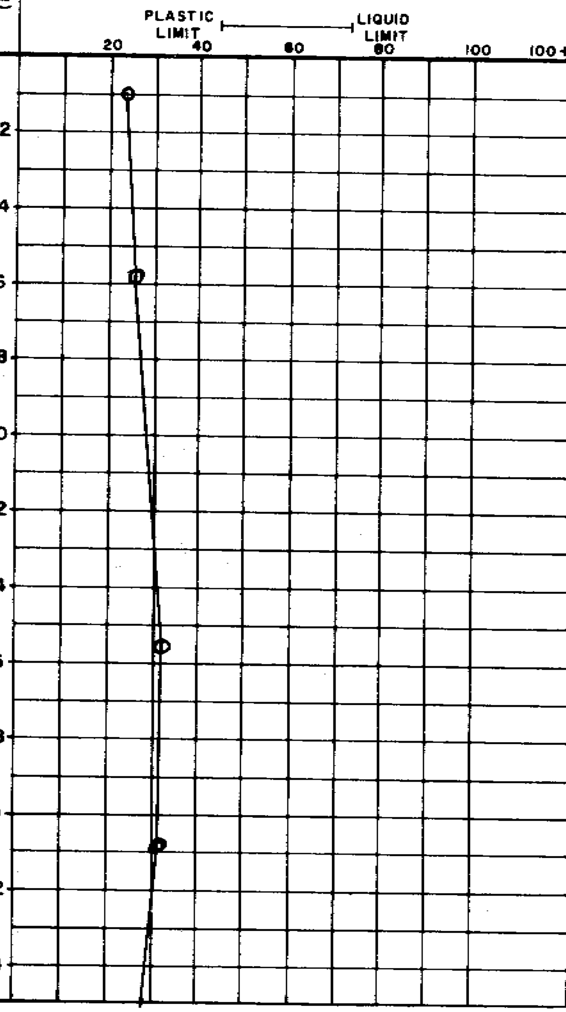
DWN:	FIELD ENG:	DATE DRILLED: 5/2/73	AIRPHOTO NO: A2271-71
CKD:	TECH: R.G.	RIG: 2	SURFACE DRAINAGE: ON RIVER

CHAINAGE: 981 + 31 | OFFSET: | VEGETATION: RIVER | ELEV: 258

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	C

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25	5	P	70	41	ML										
30	6	P		49	ML										
35	7	P		33	ML		UF								
40	8	P		32	ML										
45	9	P		46	ML										
50															

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



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DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 5/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 981 + 31	OFFSET:
CKD:	TECH: R.G.	RIG: 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: RIVER	ELEV: 258

TEST HOLE

MILE	B,C,S	NUMBER
394	S	C

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	○ = WATER CONTENT (% OF DRY WEIGHT) △ = ICE CONTENT (% OF SAMPLE VOLUME) PLASTIC LIMIT — LIQUID LIMIT 20 40 60 80 100 100+	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
	10	P		41													
2						END OF HOLE AT 51-5'			2								
4									4								
6									6								
8									8								
10									10								
12									12								
14									14								
16									16								
18									18								
20									20								
22									22								
24									24								

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CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 7/2/73	AIRPHOTO NO: A 22771-71	CHAINAGE: 984 + 05	OFFSET: 27' E
CKD: B.P.S	TECH: R.G.	RIG: No. 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: Nil	ELEV: 256.5

TEST HOLE

MILE	B,C,S	NUMBER
394	S	D

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P C F)	DRY DENSITY (P C F)	REMARKS
0–6						ICE AND WATER									
3															
6						RIVER BOTTOM									
6–24						DARK GREY SILT WITH A TRACE OF CLAY AND OF SAND									
21	1	P	90	23	ML		UF		6	84	10	0			

ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED 7/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 984 + 05	OFFSET 27'E
CKD B.P.S.	TECH R.G.	RIG #2	SURFACE DRAINAGE ON RIVER	VEGETATION NIL	ELEV 256.5

TEST HOLE

MILE	B,C,S	NUMBER
394	S	D

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
2									2							
4									4							
6									6							
8							UF		8							
30 (10)									10							
	2	P		22	ML					4	90	6	0			
12									12							
14									14							
16									16							
18									18							
40 (20)									20							
	3	P		35	ML					5	79	16	0			
22									22							
24									24							

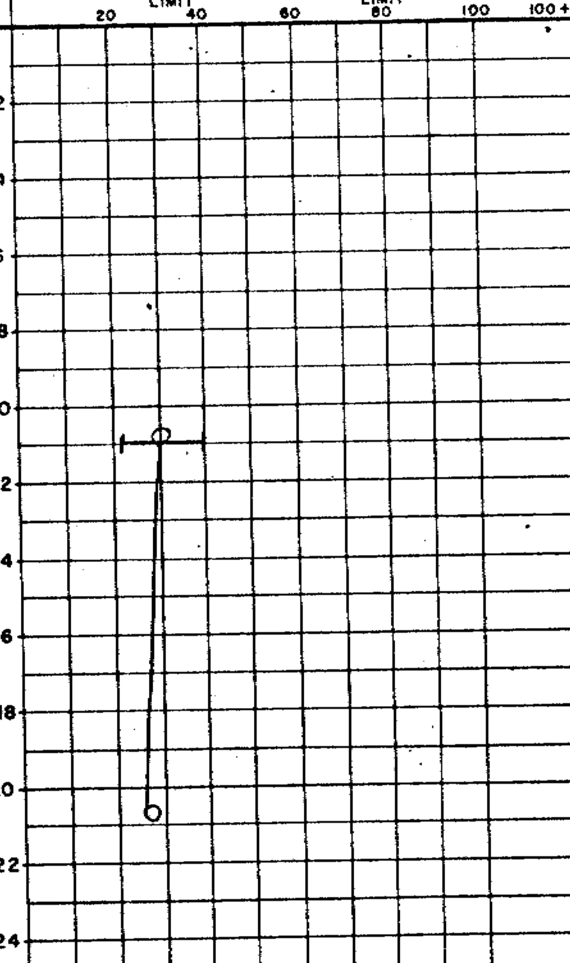
ACRES CONSULTING SERVICES LIMITED CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 7/2/7[illegible]	AIRPHOTO NO: A22771-71	CHAINAGE: 984+05	OFFSET: 27' E
CKD: B.P.S.	TECH: R.G.	RIG: #2	SURFACE DRAINAGE: ON RIVER	VEGETATION: NIL	ELEV. 256.5

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	D

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
45						DARK GREY CLAY AND SILT	UF								
50	4	P	70	36	CL				48	51	1	0			
					CL										
60	5	P	90	22	CL				43	56	1	0			
						END OF HOLE AT 61.5'									



ACRES CONSULTING SERVICES LIMITED, CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 6/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 986 + 27	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: RIVER (NIL)	ELEV: 256

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	E

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT; scale 20, 40, 60, 80, 100, 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–6						ICE AND WATER RIVER BOTTOM									
6–22						GREY SAND WITH A TRACE OF SILT									
15.5	1	P		30	SP		NF		0	6	94	0			
22–24						GREY SANDY SILT WITH SOME CLAY									

ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

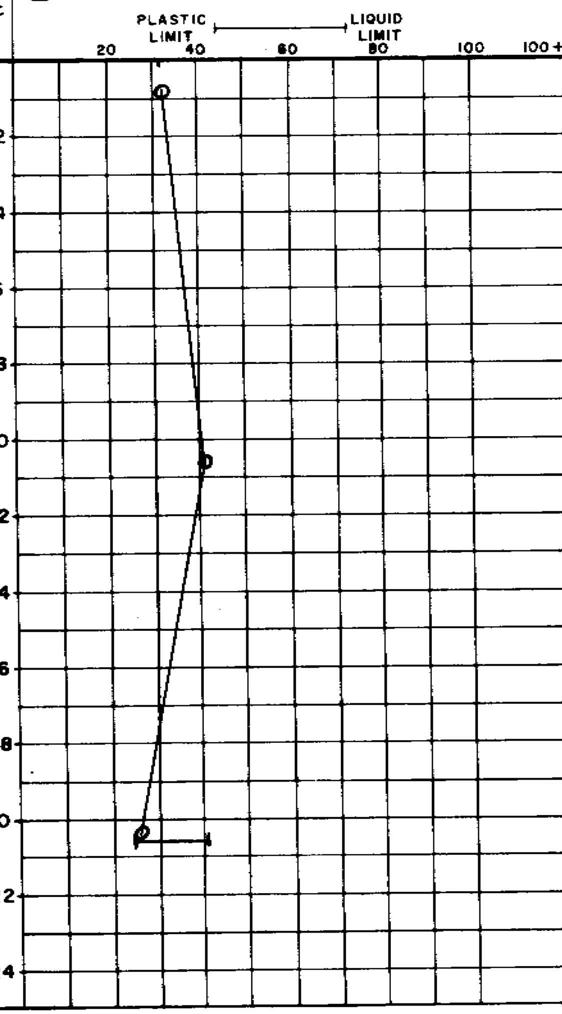
DWN:	FIELD ENG:	DATE DRILLED: 6/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 986 + 27	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: RIVER (NIL)	ELEV: 256

TEST HOLE

MILE	B,C,S	NUMBER
394	S	E

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25	2	P		52	CL				16	71	13	0			
30							UF								
35	3	P		32	ML				5	47	48	0			
40						GREY CLAY AND SILT									
45	4	P		31	CL				54	46	0	0			

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



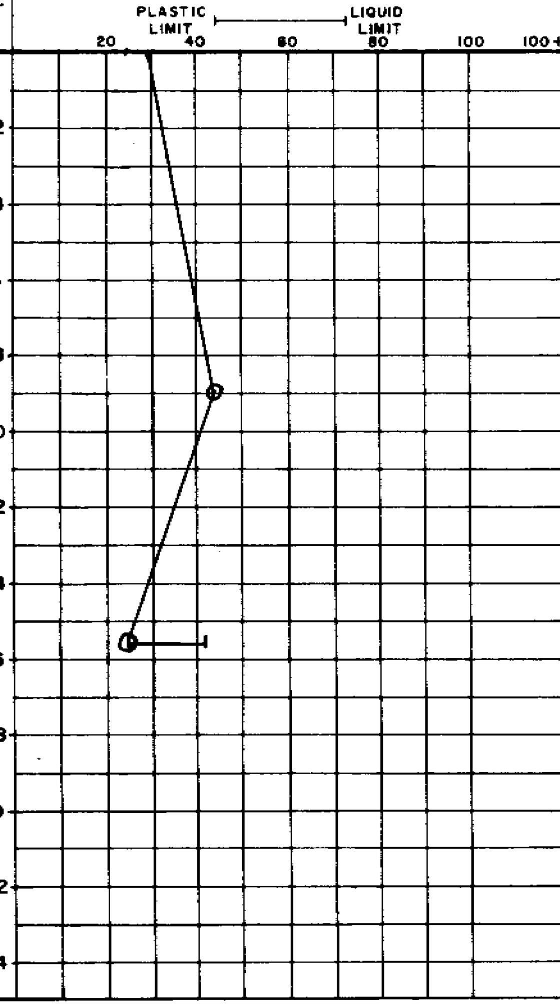
ACRES CONSULTING SERVICES LIMITED CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED:	AIRPHOTO NO: A22771-71	CHAINAGE: 986 + 27	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: ON RIVER	VEGETATION: RIVER (NIL)	ELEV: 256

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	E

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
50															
52															
55					ML	GREY SILT WITH SOME FINE SAND AND A TRACE OF CLAY	UF		8	56	36	0			
60	5														
63															
65	6	P	39		CL	GREY SILT AND CLAY			47	52	1	0			
						END OF HOLE AT 66'-5"									



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

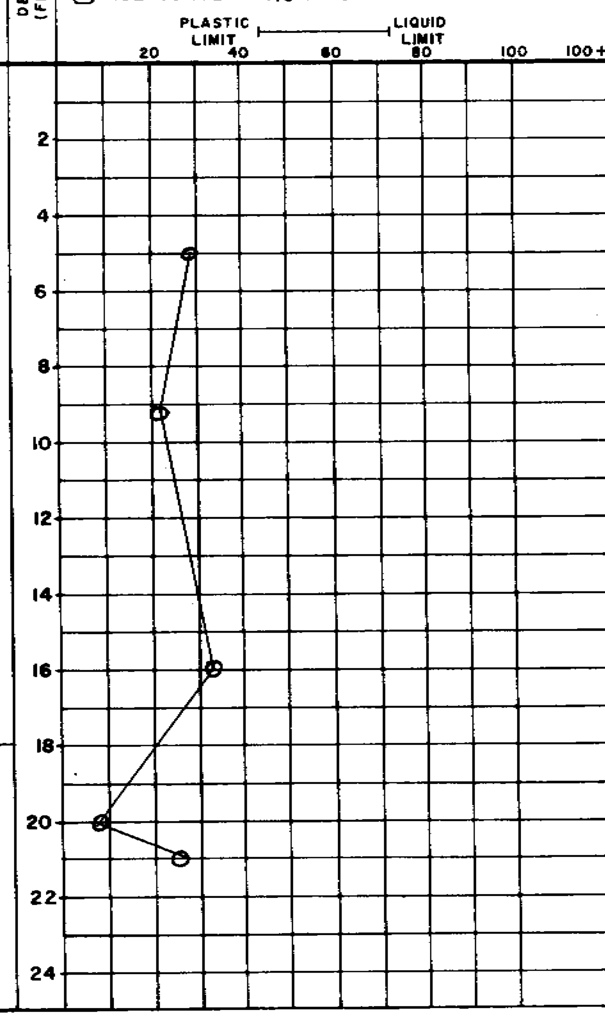
DWN:	FIELD ENG:	DATE DRILLED: 6/2/73	AIRPHOTO NO: A22771-71	CHAINAGE: 988+25	OFFSET:
CKD:	TECH: R.G.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 284

TEST HOLE

MILE	B,C,S	NUMBER
394	S	F

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
4–5	1	P		33	SC	BROWN SILTY SAND WITH SOME CLAY			12	43	45	0			
8							F	N_{bn}							
10–11	2	P		4	SC				13	40	47	0			
16	3	P		7	ML										
18						----------		----------							
20–21	4	P		37		BROWN SAND WITH SOME GRAVEL AND A TRACE OF SILT			0	6	78	16			
22								N_f							

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 7/2	AIRPHOTO NO: A22771-73	CHAINAGE: 998 + 25	OFFSET:
CKD:	TECH: R.G.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 284

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	F

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ├──┤ LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25	5	P		43					0	7	56	37			
					SW	SANDY GRAVEL WITH MINOR SILT	F	N_f							
30	6	P		44					0	8	67	25			
35							UF								
40	7								0	4	23	73			
							UF								
45	8	P		58	ML				16	36	48	-			
50															

ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

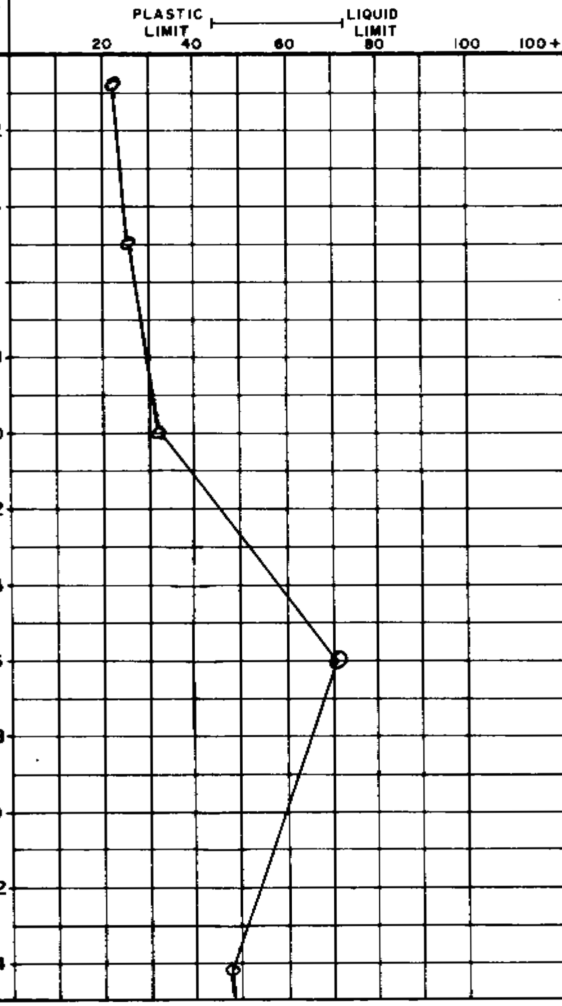
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 3/2	AIRPHOTO NO: A22771-73	CHAINAGE: 988 + 25	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 284

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	F

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
1	9	P		39	ML	SILTY SANDY GRAVEL, MINOR CLAY			22	30	16	32			
55															
6	10	T			ML										
60							UF		6	87	7	0			
11	11	P		48	ML										
65															
16	12														
18					SM	GREY SILTY SAND, MINOR CLAY AND GRAVEL									
70									13	37	46	4			
23	13														

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

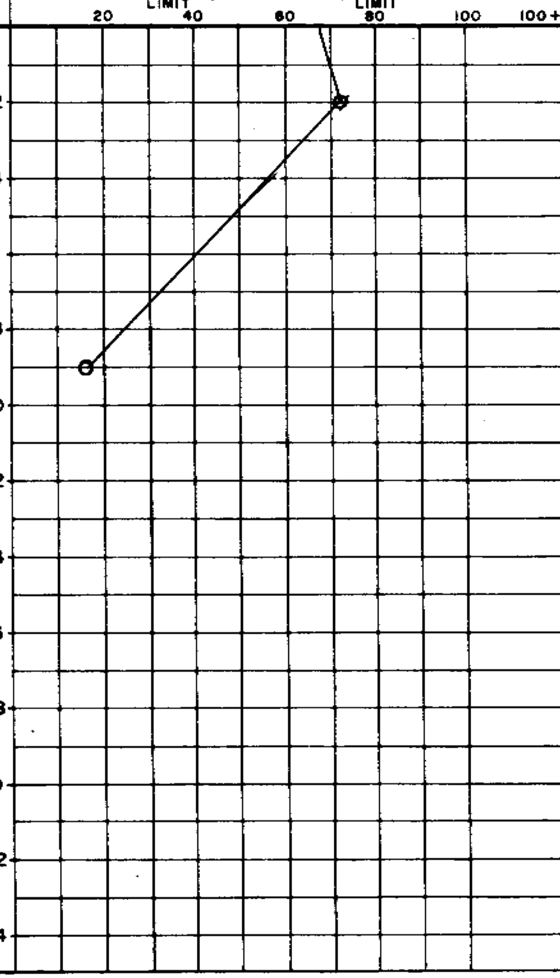
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 7/3	AIRPHOTO NO: A22771-73	CHAINAGE: 988 + 25	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 284

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	F

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ├──┤ LIQUID LIMIT

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
						GREY, CLAYEY, SANDY SILT, MINOR GRAVEL										
2	14				CL				2							
4									4							
80										20	45	31	4			
6									6							
8									8							
85	15				CL				10							
12									12							
14									14							
90																
16									16							
18									18							
95					CL				20							
22									22							
24									24							



ACRES CONSULTING SERVICES LIMITED CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 7/2/73	AIRPHOTO NO: A22771-73	CHAINAGE: 988 + 25	OFFSET:
CKD:	TECH: M.H.R.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 284

TEST HOLE		
MILE	B,C,S	NUMBER
394	S	F

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
100	16	P		38	CL				40	58	2	0			
2						END OF HOLE AT 101'-5"									

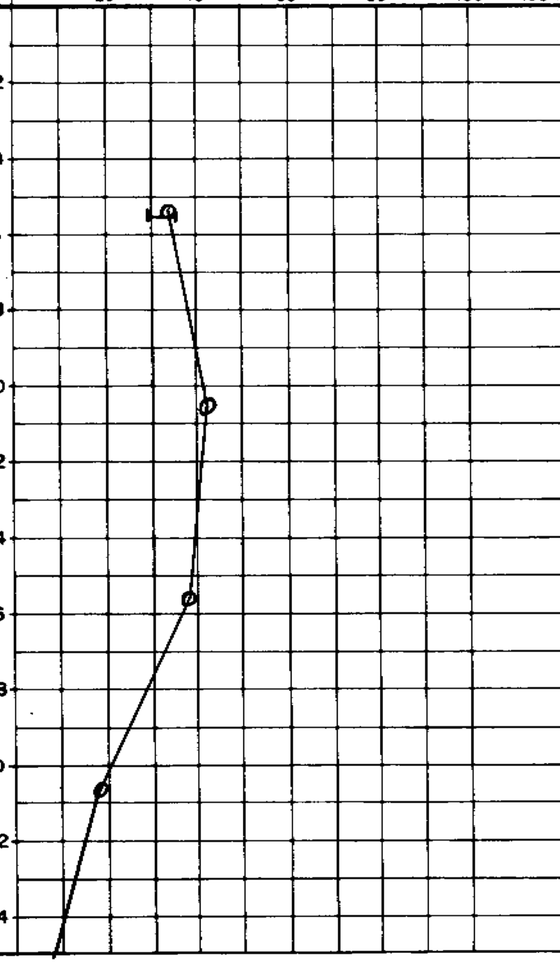
ACRES CONSULTING SERVICES LIMITED CALGARY, ALBERTA	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED: 30/1/73	AIRPHOTO NO: A22771-71	CHAINAGE: 969+65	OFFSET:
CKD:	TECH: W.R.	RIG: 1	SURFACE DRAINAGE: GOOD	VEGETATION: A B D	ELEV: 293

TEST HOLE		
MILE	B,C,S	NUMBER
394	C	G

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–1						SILTY SAND									
1–13						BROWN SAND WITH SOME SILT AND A TRACE OF CLAY	F	N_{bn}							
5.5	1	P	80	49	SM				2	10	88	0			
10.5	2	P	90	70	SM				3	14	83	0			
13–25						SAND WITH SOME GRAVEL AND A TRACE OF SILT		N_f							
15.5	3	P		136	SW				0	6	78	16			
20.5	4	P		151	SW				0	6	87	7			

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ├──┤ LIQUID LIMIT



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: | FIELD ENG: | DATE DRILLED: 30/1/73 | AIRPHOTO NO: A22771-71 | CHAINAGE: 969+65 | OFFSET:

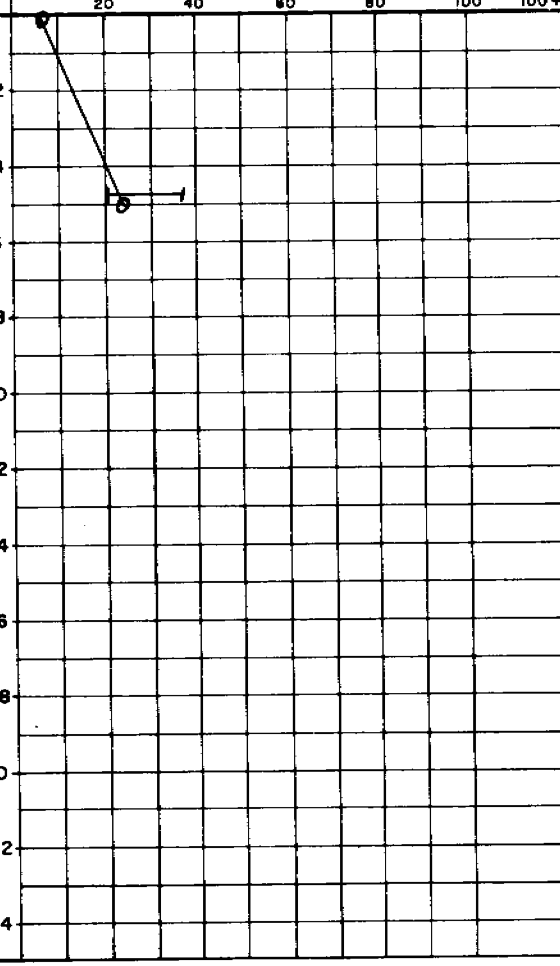
CKD: | TECH: W.R. | RIG: 1 | SURFACE DRAINAGE: LOW & FLAT | VEGETATION: A B C E | ELEV: 293

TEST HOLE

MILE	B,C,S	NUMBER
394	C	G

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ├──┤ LIQUID LIMIT

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25	5	P					F	N_f	1	7	74	18			
29								V_x							
30	6	P	90	61	CL	GREY CLAYEY SILT			40	59	1	0			
						END OF HOLE AT 30'									



ACRES CONSULTING SERVICES LIMITED
CALGARY, ALBERTA

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN:	FIELD ENG:	DATE DRILLED 31/1/73	AIRPHOTO NO: A22771-71	CHAINAGE: 994+50	OFFSET:
CKD:	TECH: V.S.	RIG: 2	SURFACE DRAINAGE: GOOD	VEGETATION: A G	ELEV: 288

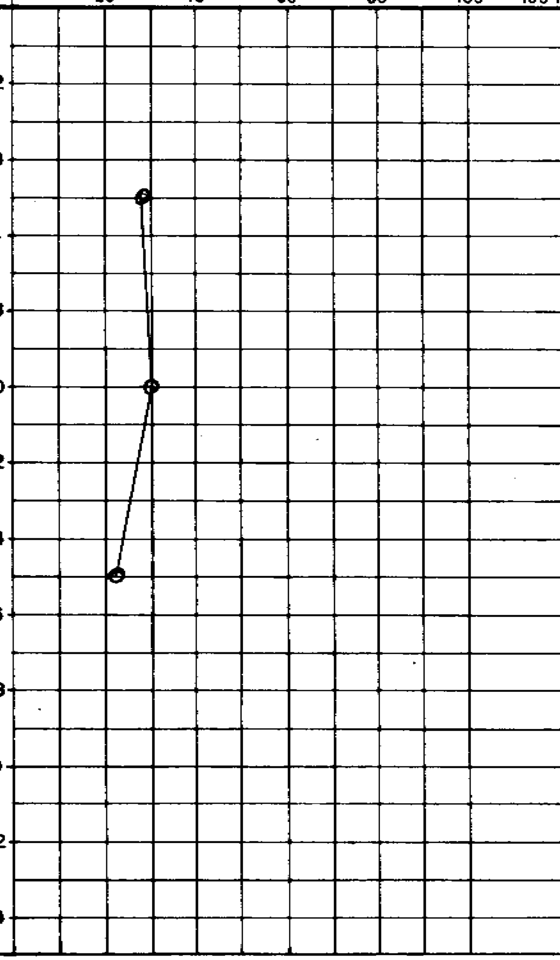
TEST HOLE

MILE	B,C,S	NUMBER
394	C	K

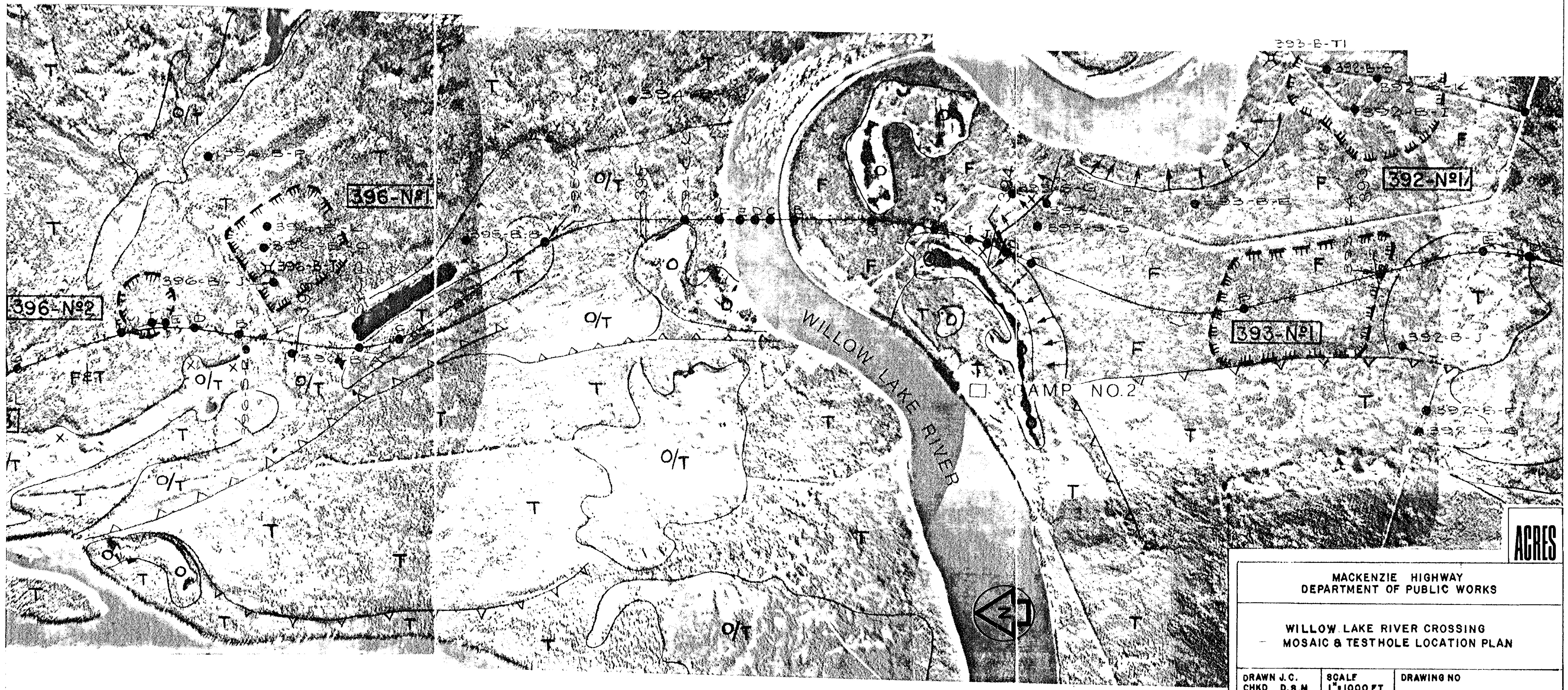
DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–13						GREY CLAYEY SILT WITH A TRACE OF SAND		
6	1	P	100	120	ML		F	
8–9								V_r
10–11	2	P	90	136	ML			
13–16.4						GREY SILTY SAND		N_f
16	3			200	SC			
16.4						END OF HOLE AT 16'-5"		

DEPTH (FEET)

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



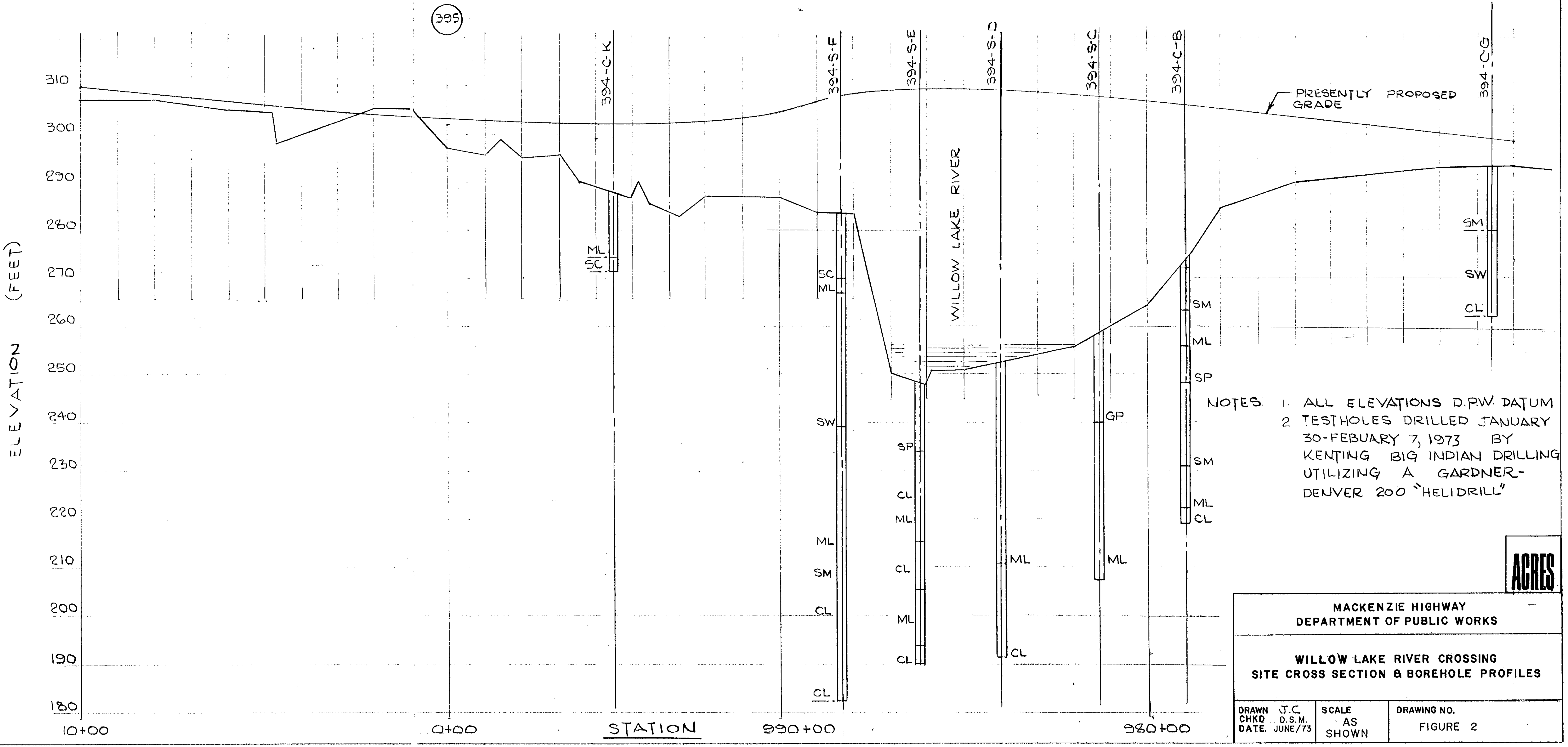
GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS



MACKENZIE HIGHWAY
DEPARTMENT OF PUBLIC WORKS

WILLOW LAKE RIVER CROSSING
MOSAIC & TESTHOLE LOCATION PLAN

DRAWN J.C. CHKD D.S.M DATE 12 JUNE 73	SCALE 1"=1000 FT. (APPROX.)	DRAWING NO FIGURE 1.



NOTES
1. ALL ELEVATIONS D.P.W. DATUM
2. TESTHOLES DRILLED JANUARY 30-FEBUARY 7, 1973 BY KENTING BIG INDIAN DRILLING UTILIZING A GARDNER-DENVER 200 "HELIDRILL"

ACRES

MACKENZIE HIGHWAY
DEPARTMENT OF PUBLIC WORKS

WILLOW LAKE RIVER CROSSING
SITE CROSS SECTION & BOREHOLE PROFILES

DRAWN J.C. CHKD D.S.M. DATE. JUNE/73	SCALE AS SHOWN	DRAWING NO. FIGURE 2