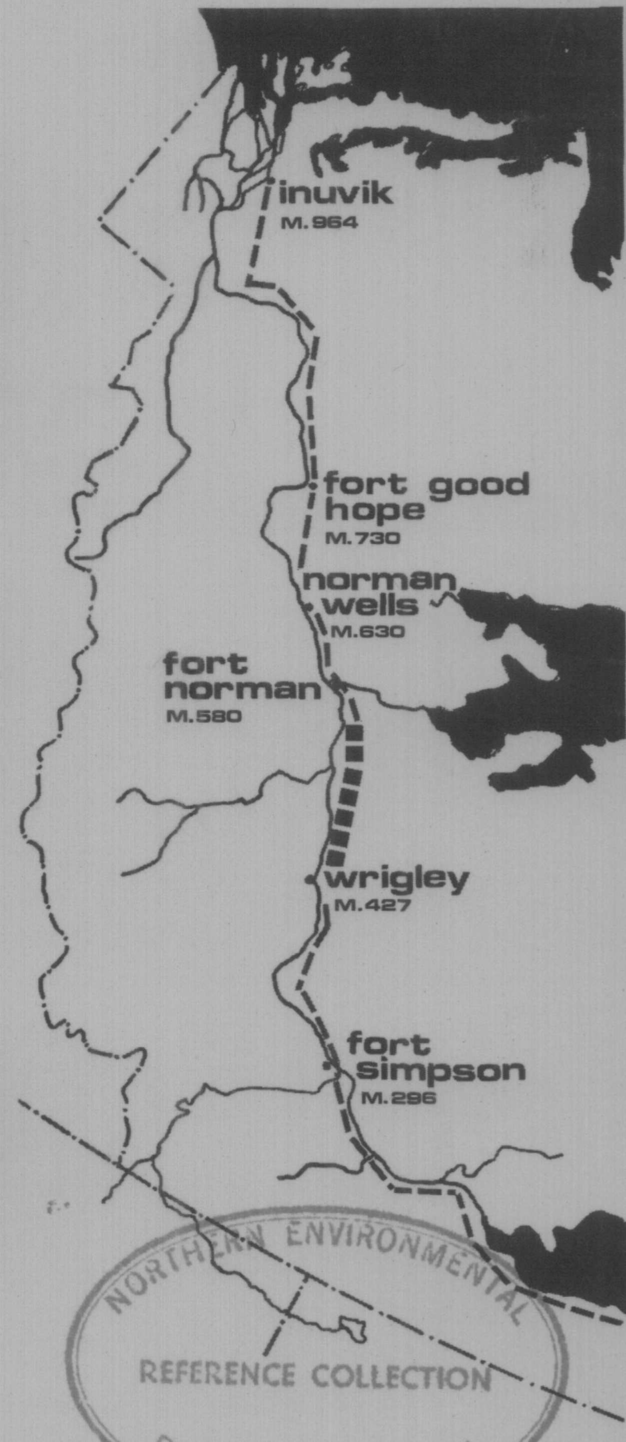

REPORT ON SUBSURFACE SOIL CONDITIONS FOR PROPOSED -

SALINE RIVER BRIDGE MILE 521.0

MACKENZIE HIGHWAY

Underwood McLellan & Associates Limited

ISSUE #39

REPORT ON
SUBSURFACE SOIL CONDITIONS
FOR
PROPOSED SALINE RIVER BRIDGE
MILE 521 MACKENZIE HIGHWAY
NORTHWEST TERRITORIES

Prepared by

Underwood McLellan & Associates Limited
Consulting Professional Engineers

Underwood McLellan & Associates Limited

2540 KENSINGTON ROAD N.W. CALGARY, ALBERTA T2N 3S3 TELEPHONE 283-4961 TELEX 038 24565

2106-032-45

April 18, 1973

Department of Public Works
P. O. Box 488
EDMONTON, Alberta.

ATTENTION: Mr. F. E. Kimball

Dear Sir:

Re: Subsurface Soil Investigation
Proposed Saline River Bridge
Mile 521, Mackenzie Highway.

Attached please find our report on the subsoil and foundation conditions for the proposed Saline River bridge at mile 521 on the Mackenzie Highway, in the Northwest Territories.

If you have any questions concerning the contents of this report, we would be pleased to discuss them with you at your convenience.

Yours very truly,

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

Per: D G Pennell

D. G. Pennell, Ph.D., P. Eng.

DGP/rr

Encl.

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APPENDIX

A. INTRODUCTION

The subsoil investigation undertaken at the Saline River forms part of the overall geotechnical investigation which was conducted from mile 450 to 550 on the Mackenzie Highway for the Department of Public Works, Government of Canada.

It was the intention of the present investigation to determine the vertical subsoil material sequence, physical and structural properties, permafrost conditions and groundwater conditions which would be expected to influence the stability of the valley slopes and embankments and the design and construction of the bridge foundation.

The included conclusions and recommendations have been based upon exploration and sample acquisition operations conducted at 10 positions adjacent to and along the proposed bridge centreline in the river channel and slopes of the bridge approaches.

In the formulation of conclusions and recommendations, the consistency and composition of the subsoil materials between and in the proximity to the individual test boring positions has been assumed, but not verified.

B. FIELD AND LABORATORY INVESTIGATION

A total of ten (10) test holes have been drilled in the Saline River valley and the adjacent uplands along and near the proposed centreline. In addition to the centreline test hole logs, borrow pit logs in the vicinity of the Saline are included in the Appendix. Test holes along the centreline were drilled to depths varying from 15 to 50 feet below existing site grades and the borrow pit test holes were generally advanced to the 15 foot level.

Centreline and structural test borings were drilled February 5, 6 and 7, 1973 by Kenting Big Indian Drilling of Calgary, utilizing a Mayhew 1000 and Heli drill and air recovery methods.

The locations of the individual test borings were selected and field located by Underwood McLellan and Associates Limited. The approximate test boring locations are graphically illustrated on the accompanying mosaic and test hole location plan.

All variations of soil, permafrost and groundwater conditions encountered during the test boring operations were noted, and representative samples of the existing subsoils were taken. The majority of samples were disturbed having been obtained by the air recovery method. Sampling and field testing were also undertaken with a two inch O.D. split spoon sampling tube and solid penetrometer.

In the laboratory the samples of materials derived from the drilling operation were subjected to standard laboratory classification procedures including particle size distribution and Atterberg index property determinations. Moisture contents were obtained for all samples returned to the laboratory. Whenever a sufficient length of intact sample was retained in the penetrometer tube, both wet and dry densities were obtained.

Permafrost samples were classified according to N.R.C. Technical Memorandum No. 79 "Guide to the

Field Description of Permafrost". The excess ice content of permafrost samples was determined by visual inspection and by measured thicknesses of ice lenses. The calculation of excess ice content was performed by the division of the ice thickness by the total sample thickness.

All soil samples were classified according to the Unified Soil Classification System.

The results of all laboratory and field tests are summarized in the Appendix on the test hole logs.

Test holes have been designated by mileage, type and number. Examples include 521B 364A, 521S 352A and 521C 469B. The letter symbols and numbers indicate:

521 - mileage.

B, S, C - between mileage and test hole numbers, indicate borrow, centreline and structure test holes, respectively.

364, 352, 469 - test hole numbers.

A, B - after test hole numbers indicate drilling performed by Mayhew 1000 or Heli drill, respectively.

C. SITE AND SUBSOIL CONDITIONS

The Saline bridge site is located at mile 521 (chainage 1190 + 00) of the Mackenzie Highway in the Northwest Territories. The Saline River is a major river flowing into the Mackenzie River and has a drainage basin which extends to Mt. Clark in the Franklin mountains.

The main Saline River channel is 140 feet deep with stable slopes of 5:1. The main channel elevation at the bridge crossing is 335 (D.P.W. datum) with an estimated high water level during flood stages of 343.

Four test holes were drilled at the stream elevation in the vicinity of the proposed piers and abutments, although three of these holes were drilled from 20 to 265 feet east of the centreline. The three holes drilled adjacent to the centreline disclosed 5 to 15 feet of surface gravel underlain by a very firm grey glacial clay till. The glacial till consisted of a high percentage of large stones and its very firm to stiff consistency was indicated by the solid penetrometer blow counts from 26 to 83. Some difficulty was experienced in identifying the soil strata in test hole 355A as a result of caving but it has been classified as gravel with some clay. Large boulders exist at the surface but at greater depths large boulders were not encountered. This test hole, 355A was drilled at the north abutment location and the solid penetrometer blow counts of 42 to 53 indicate the dense nature of the strata. The moisture content of both the glacial boulder clay till and gravel was low averaging 7% to 8% throughout the depth of the test holes. All four test holes indicated non-permafrost conditions to the lowest elevation of 310 which was attained during drilling operations. The glacial till is likely to be of Pleistocene origin with the stream gravel having been deposited since glaciation.

Test holes 356A and 357A drilled on the north approach slopes indicated dry frozen gravel and dense glacial clay till with moisture contents of

4% and 8% respectively. Test hole 469B near the top of the slope disclosed unfrozen glacial till with an average moisture content of 10 percent.

Two river terraces on the south approach, investigated with test holes 341A and 350A indicated 4 to 7 feet of gravel over clay till. The moisture content of the clay till was approximately 20% and exhibited a dry unit weight of 106.3 pcf. All materials on the south slope were frozen with some random ice. Although the moisture contents of the frozen till is relatively low, it is 10% greater than the unfrozen till found in test hole 469B on the north slope. On the valley slopes the maximum peat depth was four inches.

Free water was not encountered in the test holes and no significant sloughing occurred during air-drilling.

Bedrock materials were not encountered during drilling at the Saline River crossing although Cretaceous sandstones and shales with interbedded coal would be expected.

A soil profile with plotted test hole logs of the bridge valley site is included in the Appendix.

D. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the present investigation, we wish to offer the following generalized conclusions and recommendations relative to the design and construction of the proposed Saline River bridge foundation and approaches.

1. Pier and Abutment Foundation Design

The gravel and glacial till deposits which were described in the previous section will form the bearing strata for the proposed bridge piers and abutments. The two foundation types which may be considered include a spread footing or pile system.

Pier bases should be placed at approximately elevation 325 in the dense glacial clay till and the allowable footing bearing capacity would be 6000 psf in this material. In order to attain the elevation of the glacial till approximately 10 feet of overburden gravel must be removed.

Although a footing type foundation may be employed at this site, driven piles are preferred. The pile types available include timber, pre-cast concrete, steel H-piles and pipe piles. Timber piles may be utilized but tip protection would be necessary to drive through the gravel strata into the glacial till. Timber piles driven to "refusal" would attain allowable load bearing capacities near 40 tons but this would depend upon the pile size and energy rating of the pile driving hammer. The timber piles would be expected to attain "refusal" at a depth of approximately 15 feet from the surface.

The pre-cast concrete piles may be utilized but splicing is difficult although at this site the "refusal" depth will be in the range of 15 to 20 feet below existing channel grades, unless significant variations in the soil profile exist across the stream channel.

Steel H-piles or pipe piles are recommended for consideration based upon high driving strength, high load capacity and ease in splicing and cutting. At the Saline River site, the steel pipe or H-piles will meet refusal in the dense till at approximately the 30 foot level and the allowable capacities will be in the range of 80 tons. The capacity will depend upon the structural shape and material as well as the tip protector utilized. Wherever "refusal" is not attained in the glacial till or gravel deposits, the capacity of the pile may be estimated on the basis of the skin friction between the soil strata and pile. Approximate allowable capacities for long steel friction piles may be determined by using allowable unit adhesion of 600 psf in the dense glacial clay till and 800 psf in the gravel strata. In order to attain penetration of the steel piles around large boulders, it may be necessary to utilize vibration techniques.

It is recommended that all piles be driven to "refusal". "Refusal" will depend upon the energy rating of the hammer but is commonly 15,000 ft. lb. As an initial guide, piles should be driven to blow counts of 180 blows/ft. or 15 blows/inch. The pile capacity is largely a function of the amount of energy expended in installing the pile and not just of the recorded resistances. The pile which is driven to a sustained resistance will perform better than one which is terminated the instant a given resistance is attained. Of course, the pile must not be driven until damage occurs and whenever resistance increases greatly, the driving should be terminated.

The capacity of a pile should be established in the field by several pile-driving tests. The ultimate capacity would be calculated on the basis of a dynamic pile driving formulae such as the Hiley, Danish or Weisbach. It is recommended that the Engineering News formula not be utilized as a result of its extreme variation in factor of safety.

It is further recommended that static load tests be performed to establish more accurately the bearing capacity of a typical pile and the applicability of dynamic pile formulae for predicting pile capacity. It is emphasized that load tests at this site are important to establish pile capacity as driving formulae can only be considered a rough guide for piles in cohesive till soils.

The lateral resistance of piles can be established by recently developed methods based on beam on elastic foundation methods but the simple and more conventional approach is based on calculation of the Rankine passive earth pressure against the pile. Using Rankine theory the ultimate passive resistance force/ft.^{2} of pile can be obtained by $P = \frac{1}{2} \gamma_b K_p H^2$. The submerged unit weight of the gravel and till material may be taken as 60 pcf and the passive pressure coefficient K_p as 3.0. In order to establish the allowable lateral load a factor of safety of 2.5 should be applied to the above ultimate load. Generally, the lateral load on deep piles tends to exceed the passive resistance, consequently, the above simplified approach is on the conservative side.

Whenever the deep embankments are constructed of compacted granular fill as outlined and recommended in section D3, the abutments may be placed on spread footings in the fill. The allowable bearing pressure for the abutments will depend upon the characteristics of the fill material utilized but for initial design, 4000 psf may be used assuming a coarse compacted gravel is used. If inferior material or compaction techniques are utilized in the embankment, the abutment must be carried on piles into the insitu granular subsoils below the creek channel. Piles must be designed to carry a negative skin friction load whenever embankment fills are subject to settlement.

2. Lateral Abutment Loads.

The magnitude of the pressure applied to the abutment will depend upon the characteristics of the backfill chosen for the approach fill and upon the movements that the wall undergoes during and subsequent to fill compaction. It is recommended that granular backfill from the river terraces or borrow pits be utilized for the abutment approach embankments which will be in the order of 50 feet high.

The most common procedures for analysis of the earth pressures against gravity retaining walls include the Rankine and Coulomb methods.

Generally, it is assumed that the wall rotates sufficiently to allow mobilization of the backfill shear strength which reduces the pressure to the active case, the lowest pressure that can be realized. This assumption applies reasonably accurately when the backfill consists of uncompacted granular material but pressures greater than the active occur wherever compaction of the backfill is undertaken.

While the total yield at different elevations on the abutment may be adequate for mobilization of the full backfill strength, a gradual build-up of the backfill also results in a gradual yielding of the wall. Therefore, by the time the backfill is complete only a fraction of the total yield of the wall has become effective in decreasing the earth pressure. Recent studies have indicated that the actual earth pressure magnitude will exceed the active case and may approach the earth pressure at-rest. Pressures greater than the at-rest case may occur if heavy equipment is utilized near the concrete abutment.

If the Coulomb approach is utilized, the angle of wall friction between concrete and coarse sand and gravel would be 20 degrees. The angle of internal friction for compacted granular material would be approximately 38 degrees and the dry density may be taken as 115 pcf. For a simple verticle retaining wall abutment with horizontal backfill the Coulomb active coefficient would be .24 and the at-rest co-efficient based on $K_o = 1 - \sin \emptyset$ would be .38. The pressure distribution behind a gravity retaining wall has been shown to be non-triangular, but as a first approximation and for simplicity, the triangular pressure diagram is recommended. It is also recommended that whenever backfill is compacted in lifts by vibratory compactors the at-rest coefficient be utilized for calculation of the ultimate earth pressure.

If a pile foundation is used for the abutments it is recommended that some batter piles be utilized to ensure adequate lateral support against earth pressures. The lateral resistance of the batter piles may be taken as the horizontal component of the allowable vertical pile capacity. Whenever batter piles are utilized for lateral resistance the lateral restraint of the vertical piles is usually neglected.

Positive drainage including horizontal perforated tile and weep holes should be provided to prevent development of hydrostatic pressure against the wall. In addition, free drainage of water will prevent the development of frost heaving pressures against the walls.

3. Bridge Approach Grades and Embankments

The proposed centreline grades at the Saline bridge site will involve embankments 50 feet high. These fills will subject the stream deposited granular materials to stresses in the range of 7000 psf. Although the gravel and till at this site have high load carrying capacities, it is recommended that the deep fill be placed several months prior to foundation construction. It is also recommended that the embankments be placed in two stages of 25 feet each to allow consolidation and strength increase in unfrozen surface strata on the valley slopes which may have not been subjected to high preconsolidation. The proposed fill varying from 35 to 50 feet in depth will extend 1500 feet across the valley and will cover unfrozen and frozen soils. It can be expected that these deep fills will not allow thawing of the north-facing slopes and stability will therefore be maintained.

Embankment granular slopes should be compacted at 2:1 slopes which would allow a factor of safety of 1.5 assuming the material possesses zero cohesion. If the slopes are comprised of compacted unfrozen glacial till the side slopes should be increased to 2½:1.

It is recommended that granular fill be compacted at all deep approach fills to 95% of Standard Proctor density utilizing vibratory compaction and glacial till should be compacted with sheepsfoot rollers. Although construction may be performed during the winter, the dry nature of the granular materials will allow satisfactory compaction. It is emphasized that compaction of these deep approach fills is mandatory to ensure slope stability and prevent settlements at the bridge approach.

Common excavation will not be available from the bridge site valley slopes as the grade line has been proposed mainly to produce fill sections. Some granular embankment is available throughout the river terraces but its utilization as a construction material may be prohibited by land use regulations. The volume of fill required will necessitate the utilization of borrow material. On the uplands, two borrow pits were investigated which contained 3 to 7 feet of gravel overlying clay. It is doubtful that sufficient granular fill can be located above the river valley, therefore, pits should be developed along the river terraces.

Although the roadway gradeline through the Saline valley will primarily produce fill sections, a 15 foot cut is proposed at station 1207 + 00 on the south slope. This cut will be undertaken in 4 feet of gravel and 11 feet of frozen glacial clay till. Another cut of 30 foot depth at station 1177 + 00 on the north slope will be undertaken in a frozen high density gravel and clay mixture. Utilization of backslopes of 2:1 ensure overall stability of both cuts but some surface aggradation can be expected as a new active layer is established. After excavation of the cuts the roadway subgrade will consist of frozen glacial till. An active layer will be established but thaw settlement will be minor for this material as a result of its high bulk density.

Some ditch drainage control will be necessary to retard erosion effects on the steep cut grades.

APPENDIX

EXPLANATION OF FIELD & LABORATORY TEST DATA

The field and laboratory test results as shown for a particular test boring by the Test Hole Log Data Sheet are briefly described below:-

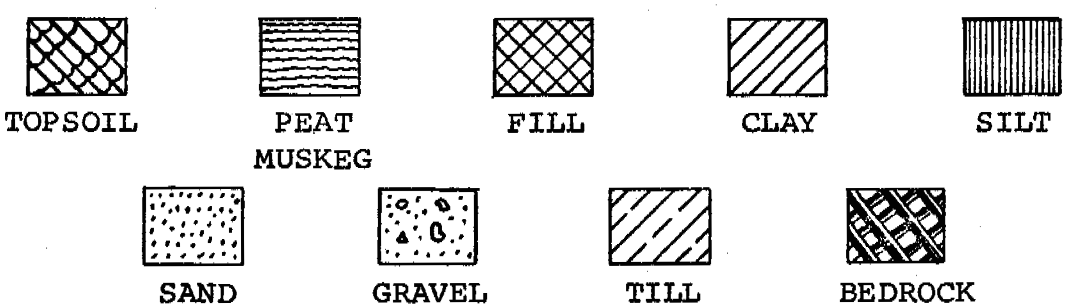
NATURAL MOISTURE CONDITIONS & ATTERBERG LIMITS

The relation between the natural moisture content and depth is significant in determining the subsurface moisture conditions. The Atterberg Limits should be compared to the Natural Moisture Content of the subsurface soil as well as plotted on the Plasticity Chart.

SOIL PROFILE & DESCRIPTION

Each soil strata is classified and described noting any special conditions. The unified classification system is used, and the soil profile refers to the existing ground elevation. When available the ground elevation is shown.

The soil symbols used are briefly shown below but are indicated in more detail in the Soil Classification Chart.



TESTS ON SOIL SAMPLES

Laboratory and field tests are identified by the following symbols:

QU - unconfined compressive strength usually expressed in tons per square foot. This value is used in determining the allowable bearing capacity of the soil.

γ_d - dry unit weight expressed in pounds per cubic foot. This value indicates the density or consistency of the in-situ soil.

C - Consolidation test. These test results are separately enclosed and provide information on the consolidation or settlement properties of the soil strata.

M.A. - grain size analysis. These test results are separately enclosed and indicate the gradation properties of the material tested.

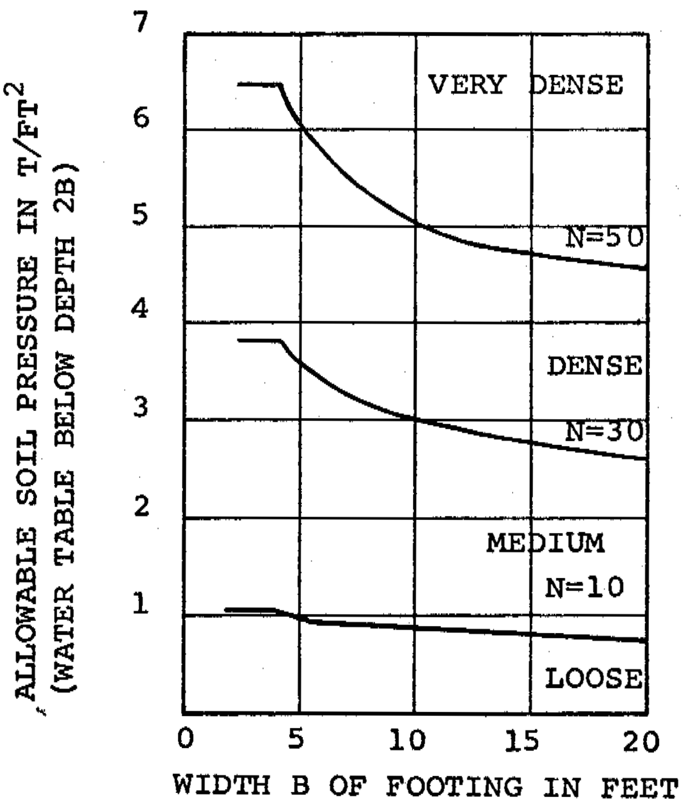
SO_4 - water soluble sulphate content is conducted primarily to determine whether sulphate resistant cement is required for the foundation structure.

N - standard penetration field test. This test is conducted in the field to determine the in-situ consistency of a soil strata. The "N" value recorded is the number of blows from a 140 lb. hammer dropped 30 inches (free fall) which are required to drive a 2" O.D. Raymond type sampler 12 inches into the soil.

The resistance and unconfined compressive strength of a cohesive soil can be related to its consistency as follows:-

N - BLOWS/Ft.	QU - $T/Ft.^2$	CONSISTENCY
2	0.25	very soft
2-4	0.25-0.50	soft
4-8	0.50-1.00	medium or firm
8-15	1.00-2.00	stiff
15-30	2.00-4.00	very stiff
30	4.00	hard

The resistance of a non-cohesive soil (sand) can be related to its consistency as follows:-



SAMPLE CONDITION AND TYPE

The depth and condition of samples are indicated by the following symbols:

UNDISTURBED   DISTURBED   LOST SAMPLE

SAMPLE TYPES

U	-	3" O.D. Shelby tube sample
D.S.	-	drive sample
M	-	moisture content sample
R.C.	-	rock core sample

PERCENTAGE WATER SOLUBLE SULPHATE CONCENTRATION

0   0.1   0.2   0.3   0.4   0.5   0.6   0.7%

Negli-gible	Posi-tive	Considerable	Severe
RELATIVE DEGREE OF SULPHATE ATTACK			

Negligible - Normal Portland Cement may be used.

Positive - Normal Portland Cement may be used, provided the strength of the concrete is increased up to 500 psi higher than the compressive strength which would normally be used.

Considerable - Type V cement must be used and the concrete compressive strength should be increased to 500 psi higher than the compressive strength which would normally be used.

Severe - Type V cement must be used and the concrete compressive strength should be increased from 500 to 1000 psi higher than the compressive strength which would normally be used.

GROUND WATER TABLE

The water table is indicated by the level of standing water in a test boring after equilibrium has been reached. This is generally taken 24 hours after the drilling operation. The water table is usually an inclined surface that is dynamic in nature with its highest level late in the winter or early spring gradually falling throughout the summer.

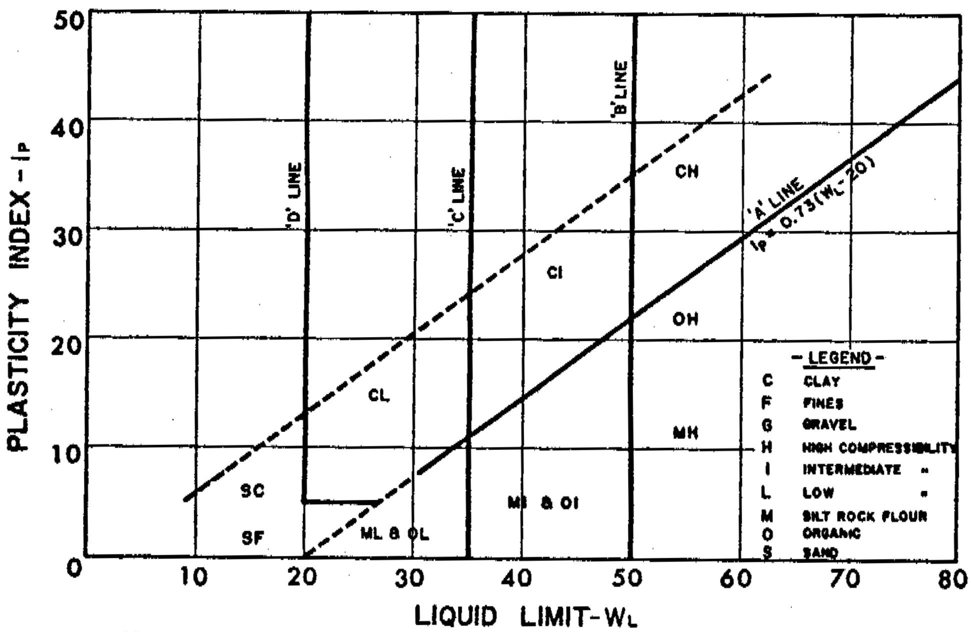
UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	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
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	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	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	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
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	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

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

PLASTICITY CHART



FOR LABORATORY CLASSIFICATION OF FINE-GRAINED SOILS

NATIONAL RESEARCH COUNCIL PERMAFROST CLASSIFICATION SYSTEM

Permafrost ground ice occurs in three basic conditions including non-visible, visible (less than one inch in thickness) and clear ice.

A. Non-visible - N

N_f - poorly bonded or friable frozen soil

N_{bn} - well bonded soil, no excess ice

N_{be} - well bonded soil, excess ice

B. Visible - V (less than 1" thick)

V_x - individual ice crystals or inclusions

V_c - ice coatings on particles

V_r - random or irregularly oriented ice formations

V_s - stratified or oriented ice formations

C. Visible Ice - (greater than 1" thick)

Ice - ice with soil inclusions

Ice + Soil - ice without soil inclusions.

A more complete description of this system is included in NRC publication TM 79.

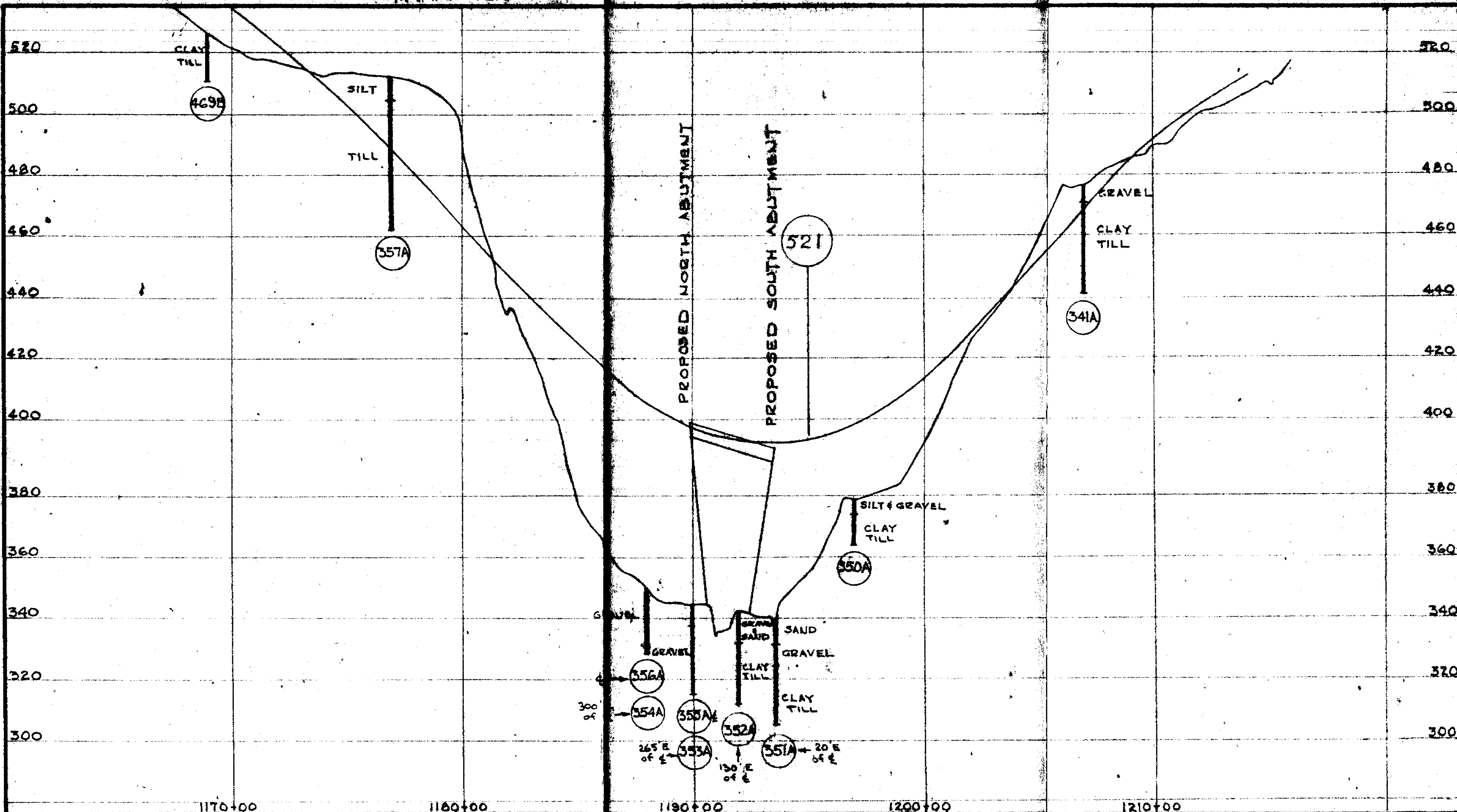
& ASSOCIATES LIMITED

CONSULTING ENGINEERS – TOWN PLANNING

Scale: 1" = 1000'

SALINE RIVER MOSAIC AND
TEST HOLE LOCATION PLAN

PLATE-1



Issue	Date	Remarks	No.	Revision	Date	By	Approved

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

CONSULTING ENGINEERS - TOWN PLANNERS

BRITISH COLUMBIA • ALBERTA • SASKATCHEWAN • MANITOBA • ONTARIO

Drawn: H.M.S.
Checked: D.G.P.
Design:
Traced:
Scale: AS SHOWN

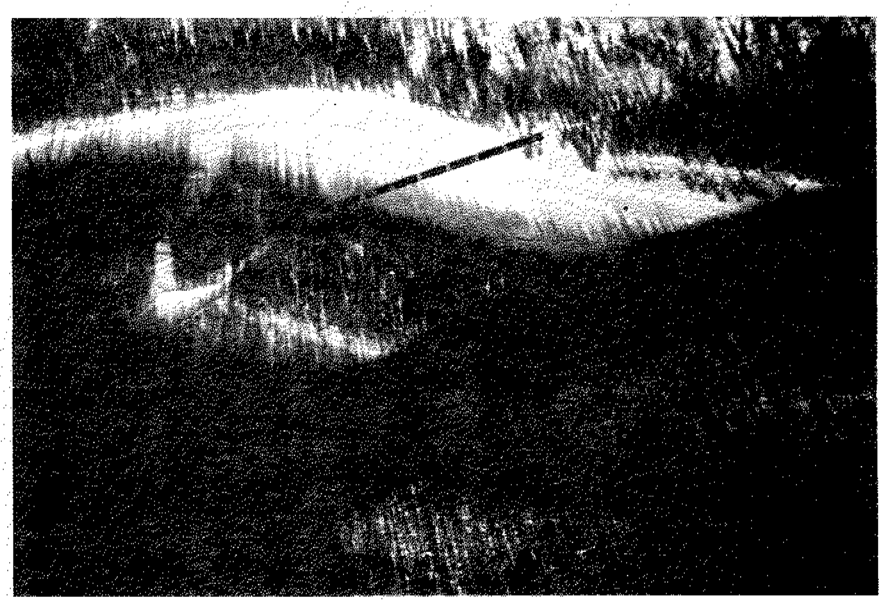
MACKENZIE HIGHWAY

SALINE RIVER BRIDGE SITE
PROFILE & SOIL CROSS SECTION

Date: MAR/73
Job:
Sheet:
Drawing: PLATE-2
Issue:

MILE 520.3

SALINE RIVER



Viewing Crossing in a
North East Direction.

Plate 3.

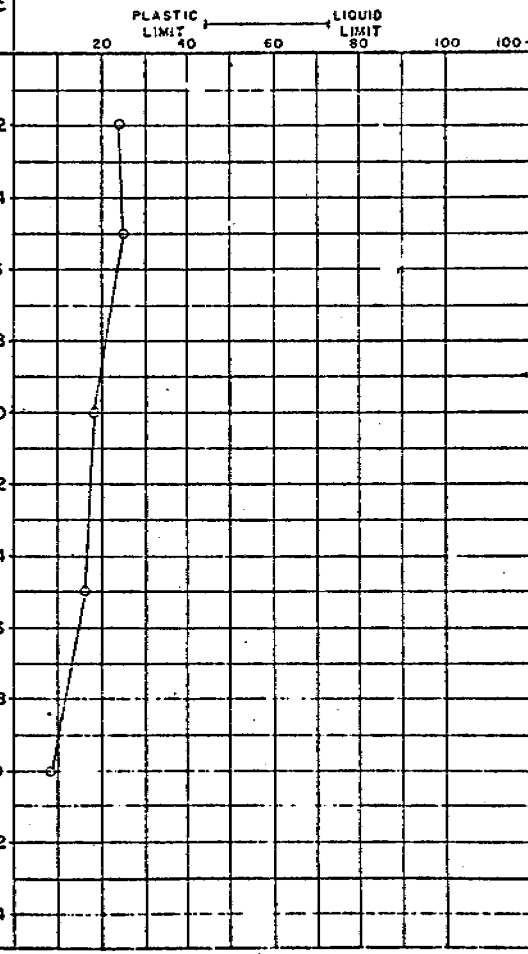
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DRN R S	FIELD ENG N. C.	DATE DRILLED 5/2/73	AIRPHOTO NO:	CHAINAGE: 1207+00	OFFSET: ℄
CKD	TECH	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: 20'-40' SPRUCE	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
520	C	341A

O = WATER CONTENT (% OF DRY WEIGHT)
Δ = 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
0–4½					GC	2" MOSS GRAVEL & CLAY SAND COBBLES BOULDERS	UF								
5					GC	CLAY TILL DARK BROWN	F	Vr.	43		19	38			
10		P			G.C			Vr.					126.0	106.3	
15					G.C										
20					G.C										
25					GC	END HOLE @ 25'	F	Vr.							

PLATE 4

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

CAN R.S.	FIELD ENG BWM.	DATE DRILLED 6/2/73	AIRPHOTO NO:	CHAINAGE: 1197+00	OFFSET: ℄
CKD	TECH	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: 30' SPRUCE	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
520	C	350A

○ = 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 (PCF)	DRY DENSITY (PCF)	REMARKS
0						4" ORGANIC									
2		⧅			GM	SILT & GRAVEL	F								
4–5		⧅			GM			Vr.							
7–10		⧅			GC	CLAY & GRAVEL MIXTURE TILL		Vr.							
14–15		⧅			G.C		F	Vr							
15						END OF HOLE									

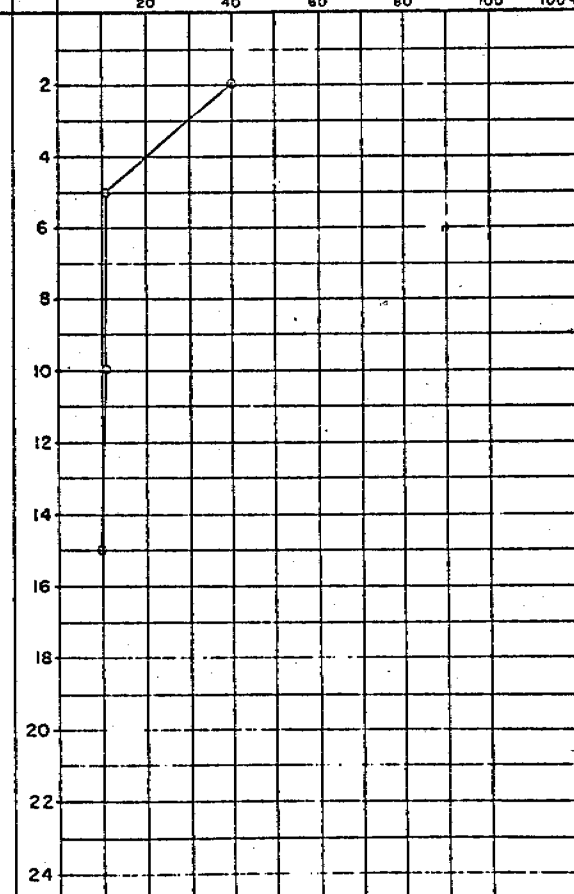


PLATE 5

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A EW	FIELD ENG: NWC	DATE DRILLED: 6/2/73	AIRPHOTO NO:	CHAINAGE: 1193+80	OFFSET: 20' E OF ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION:	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
521	S	351A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
0–12					GM	GRAVEL SAND WITH COBBLES AND BOULDERS, DRY	UF		
					GP	WET			WATER COMING OUT OF HOLE
12–35					GC	CLAY GLACIAL TILL DARK BROWN WITH SAND & GRAVEL BOULDERS			
					GC				
35						END OF HOLE			

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

GRAIN-SIZE ANALYSIS: CLAY % | SILT % | SAND % | GRAVEL % — WET DENSITY (PCF) — DRY DENSITY (PCF)

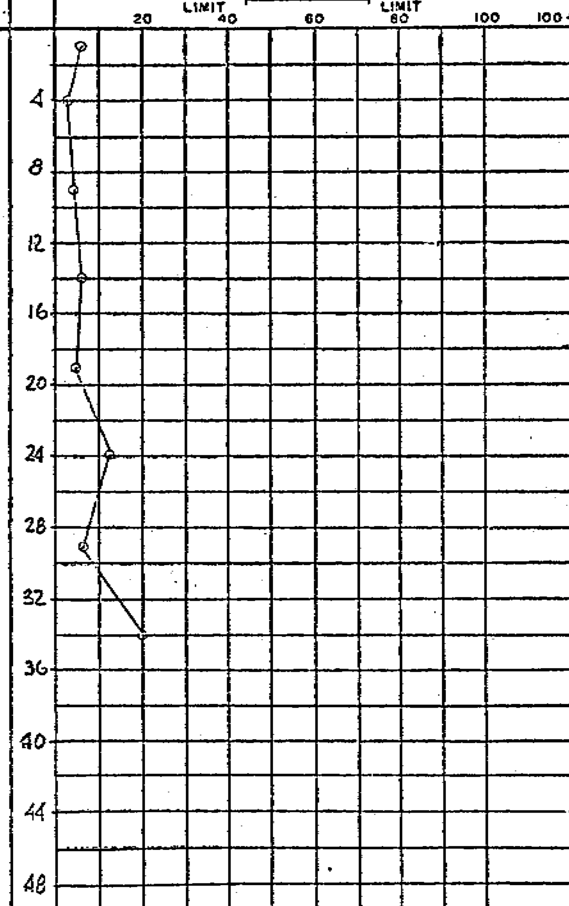


PLATE 6

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN A.E.W.	FIELD ENG NWC	DATE DRILLED 6/2/73	AIRPHOTO NO:	CHAINAGE: 1192+70	OFFSET: 130' E OF ℄
CKD D.G.P.	TECH	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: NIL	ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
521	S	352A

○ = 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	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS
0–9				26 BLS	GP	GRAVEL SAND FAIRLY DRY COBBLES AND BOULDERS	UF								
9–24				44 BLS	GC GC	CLAY GLACIAL TILL GRAVEL & SAND SOME MOISTURE COBBLES & BOULDERS WET END OF HOLE AT 30'±									

PLATE 7

UNDERWOOD McLELLAN & ASSOCIATES LIMITED — DRILL HOLE REPORT — DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: J.E.W.	FIELD ENG: N.W.C.	DATE DRILLED 6/2/73	AIRPHOTO NO:	CHAINAGE: 1190+50	OFFSET: 265' E OF ℄
CKD: S.S.P.	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: NIL	ELEV:

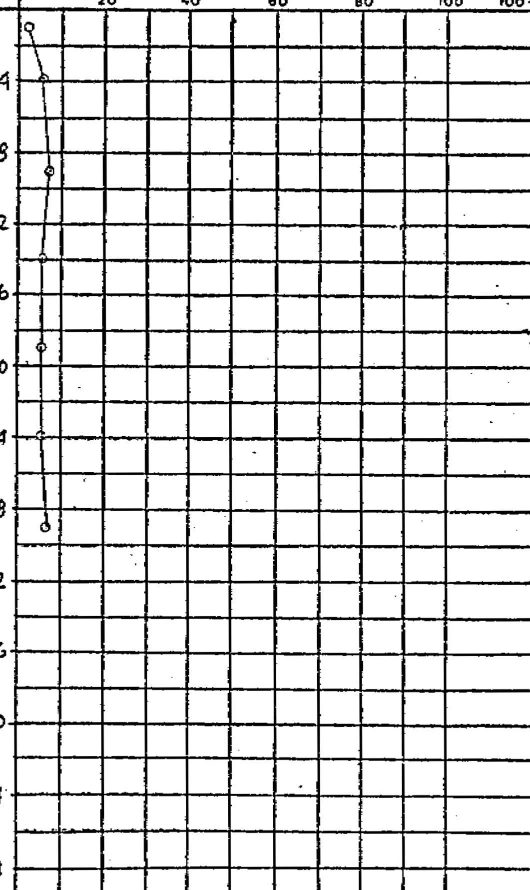
TEST HOLE

MILE	B,C,S	NUMBER
521	S	353A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–7					GP	GRAVEL, SAND, BOULDERS, ROCK FRAGMENTS	UF	
7–30				48 BLS	GC	CLAY TILL, SAND, GRAVEL AND BOULDERS. FINE, HARD, DRY		
				85 BLS	GC			
				80 BLS	SM	SILTY, SAND		
30						END OF HOLE		

DEPTH (FEET): 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48

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



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

PLATE 8

UNDERWOOD McLELLAN & ASSOCIATES LIMITED | DRILL HOLE REPORT | DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: A E W	FIELD ENG: B M	DATE DRILLED: 7/2/73	AIRPHOTO NO:	CHAINAGE: 1190+63	OFFSET: ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE TO 20'	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
521	S	355A

○ = 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 (PCF)	DRY DENSITY (PCF)	REMARKS
0					GM	GRAVEL 3" ORGANIC SILT, BOULDERS	F		3		27	70			
8							UF								
10		P		43 BLS.	GC	CLAY									
20		P		46 BLS											
24		P				SANDY CLAY, SOME POWDER PEBBLES									
28					GC										
30		P		53 BLS											
30						END OF HOLE									

DEPTH (FEET): 4, 8, 12, 16, 20, 24, 28, 32, 36, 40

PLATE 9

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN A.E.W	FIELD ENG B M	DATE DRILLED 7/2/73	AIRPHOTO NO:	CHAINAGE: 1190+00	OFFSET: 300' E of ℄	TEST HOLE
CKD DGP	TECH	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE & BIRCH TO 40'	ELEV.	

MILE	B,C,S	NUMBER
521	S	354A

○ = 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	GRAIN-SIZE ANALYSIS: CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P C F)	DRY DENSITY (P C F)	REMARKS
0–2					GM	GRAVEL 2" ORGANIC	F								
2						SILT									
4					GC	SILTY CLAY	UF								
10						SAND	F								
12					GW										
14						SAND									
15		P				END OF HOLE									

PLATE 10

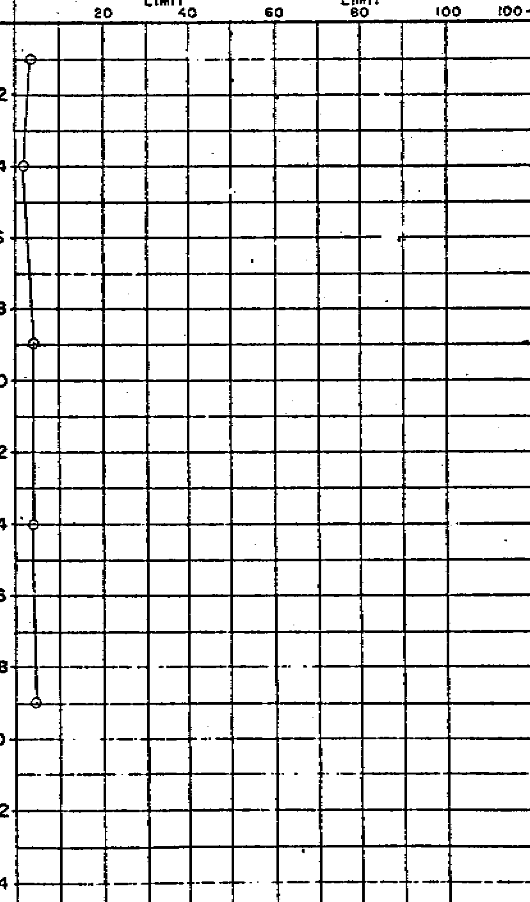
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DRN A.E.W	FIELD ENG E M	DATE DRILLED 7/2/73	AIRPHOTO NO:	CHAINAGE: 1188+00	OFFSET: ℄
CKD D.G.P	TECH	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE & BIRCH TO 35'	ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
521	S	356A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0						SILT 3" ORGANIC	F	
2					GC	GRAVEL		V
6					GW	BOULDERS		
10						BOULDERS & SAND		
12					GW			
14						SAND		
15		P		23 BLS				
19					GL	SANDY, POWDERY CLAY		V
20						END OF HOLE		

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



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

PLATE 11

UNDERWOOD McLELLAN & ASSOCIATES LIMITED | DRILL HOLE REPORT | DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

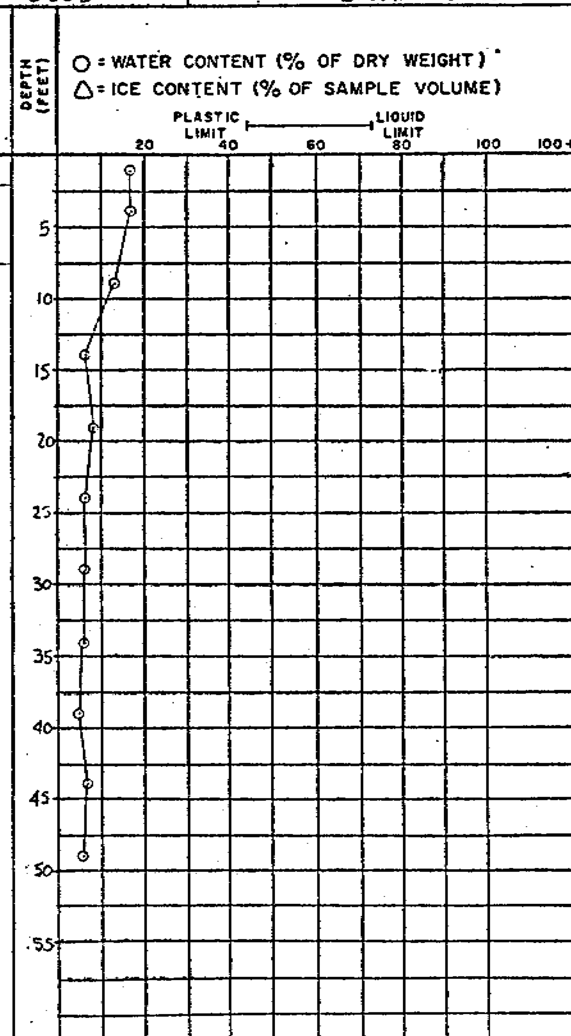
DWN: A EW | FIELD ENG B M | DATE DRILLED 7/2/73 | AIRPHOTO NO: | CHAINAGE: 1177+00 | OFFSET: ℄

CKD DGP | TECH: | RIG: AIR | SURFACE DRAINAGE: GOOD | VEGETATION: BIRCH TO 35' | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
521	C	357A

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 (PCF)	DRY DENSITY (PCF)	REMARKS
0–7					SM	SILT 4" ORGANIC; SANDY, CLAY, PEBBLES	F / UF								SO_4 = 0.08
7–38					GC	TILL; GRAVEL AND CLAY MIXTURE	F		3		54	43			
38–40						LIMESTONE									
40–50					GC	CLAY; SOME GRAVEL									
50						END OF HOLE									



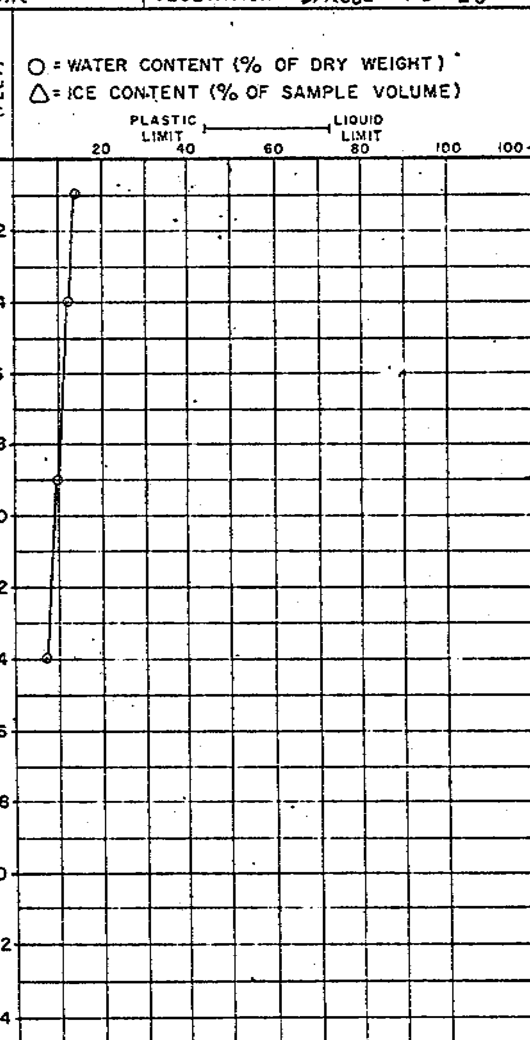
UNDERWOOD McLELLAN & ASSOCIATES LIMITED | DRILL HOLE REPORT | DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DR. AEW	FIELD ENG DR	DATE DRILLED 6/2/73	AIRPHOTO NO:	CHAINAGE: 1169+00	OFFSET ℄
CKD DGP	TECH	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE TO 25'	ELEV

TEST HOLE

MILE	E,C,S	NUMBER
521	C	469B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0						3" MOSS	F	
2		▧			GC	CLAY		
4		▧				SILTY, MED BROWN PEBBLES, TILL	UF	
10		▧						
14		▧			GC			
16–17						END OF HOLE		



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

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

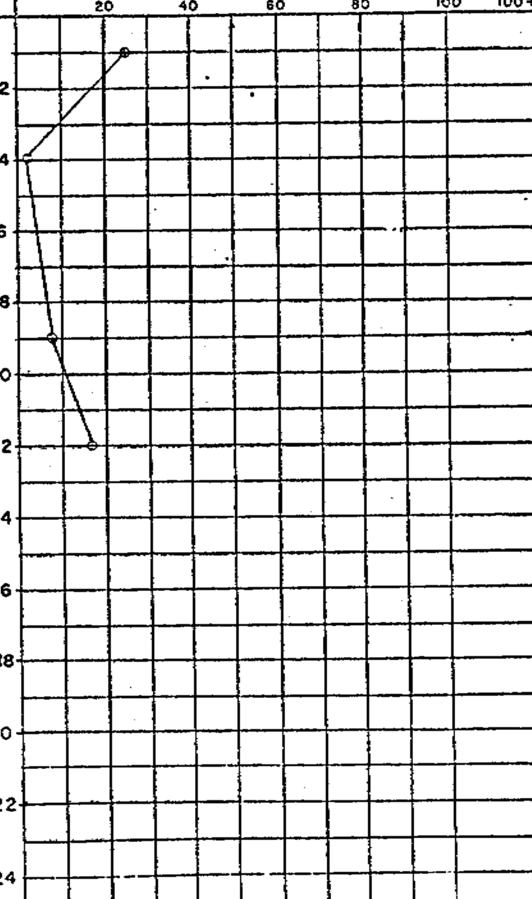
DWN: A. EW | FIELD ENG HEA | DATE DRILLED 7/2/73 | AIRPHOTO NO: | CHAINAGE: 1210+00 | OFFSET: 900' E OF ℄

CKD DGP | TECH: | RIG: AIR | SURFACE DRAINAGE: FAIR | VEGETATION: SPRUCE & BIRCH | ELEV.

TEST HOLE		
MILE	B,C,S	NUMBER
520	B	499B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–1					Pt	MUSKEG	F	
1–2						SILT ORGANIC ROCKS TO 4"		
2–7					GW	GRAVEL COARSE	UF	
7–13		P			CL	CLAY ROCK CHIPS & ROCKS SOME GRAVEL		
13						END OF HOLE		

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



GRAIN-SIZE ANALYSIS						
CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: AEW	FIELD ENG: HEA	DATE DRILLED: 7/2/73	AIRPHOTO NO:
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR

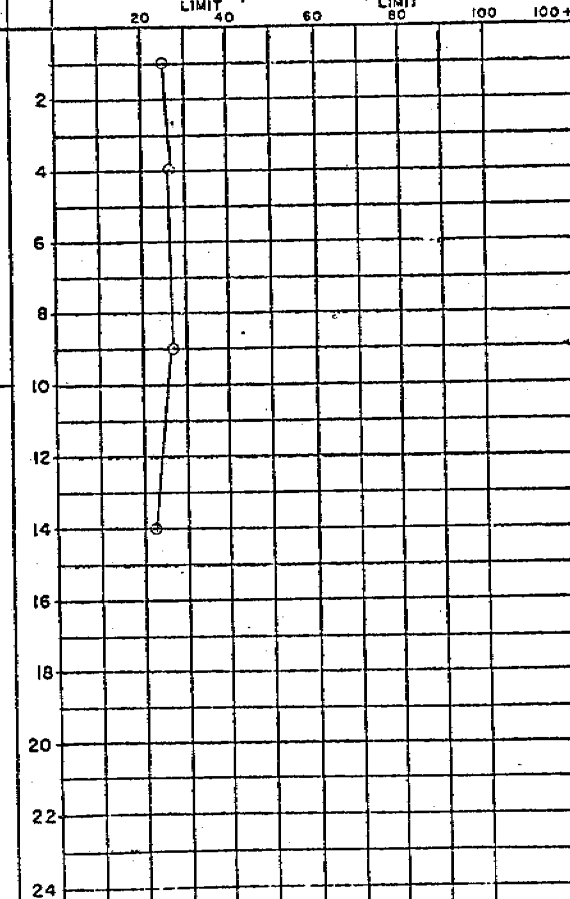
CHAINAGE: 1210+00 | OFFSET: 900' E OF ℄ | VEGETATION: SPRUCE | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
520	B	500B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0					Pt	MUSKEG	F	
0.5–2					SM	SILT ORGANIC LARGE ROCKS TO 4"		
2–5		P			CL	CLAY SILTY		
5–15		P			SM	SILT LITTLE CLAY		
10							UF	
15						END OF HOLE		

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



GRAIN-SIZE ANALYSIS: CLAY % | SILT % | SAND % | GRAVEL % | WET DENSITY (PCF) | DRY DENSITY (PCF)

REMARKS

HOLE SLOUGHING IN

PLATE 15

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A EW	FIELD ENG: HEA	DATE DRILLED: 7/2/73	AIRPHOTO NO:	CHAINAGE: 1210+00	OFFSET: 900' E OF ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE & BIRCH	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
520	B	501B

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 (PCF)	DRY DENSITY (PCF)	REMARKS
0					Pt	MUSKEG	F								
1–2					SM	SILT ROCKS TO 4" CLAYEY									
2–6					GW	GRAVEL	UF								
6–13					CL	CLAY SILTY FEW PEBBLES AND ROCK CHIPS									HOLE SLOUGHING IN
13						END OF HOLE									

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

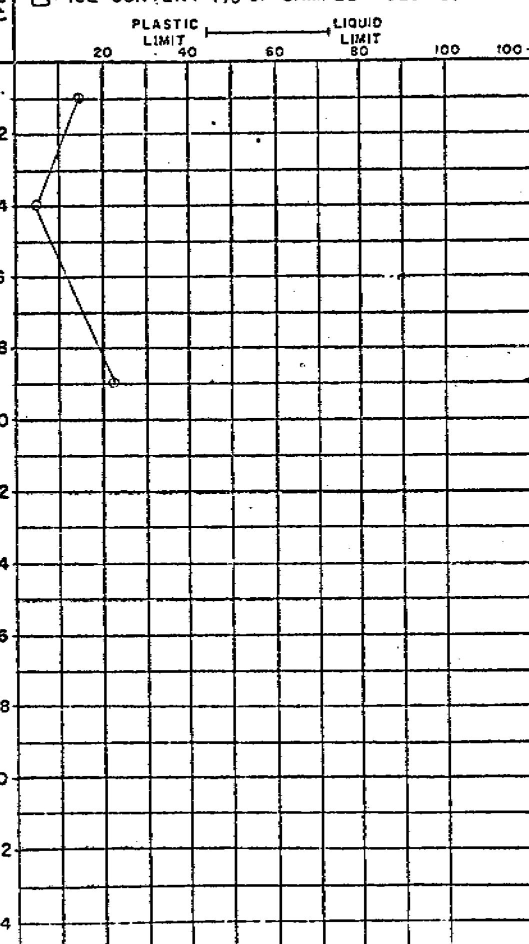


PLATE 16

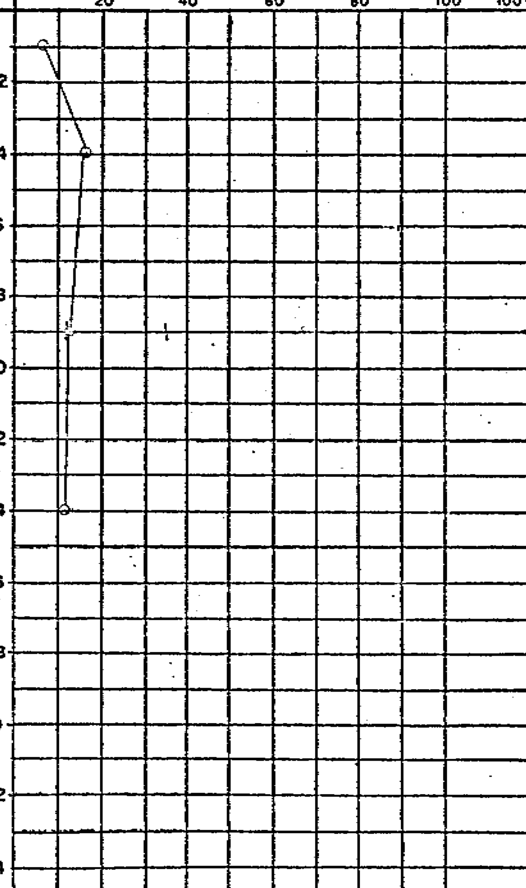
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: A E W	FIELD ENG: NWC	DATE DRILLED 7/2/73	AIRPHOTO NO:	CHAINAGE: 1177+00	OFFSET: 700' E OF ℄	TEST HOLE
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: ASPEN & BIRCH	ELEV:	

MILE	B,C,S	NUMBER
521	B	364A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0						MOSS	F	
0–3					GW	GRAVEL SAND & COBBLES		
3–15					GC	CLAY DARK BROWN GRAVEL & COBBLES		
15						END OF HOLE		

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



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

PLATE 17

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: A E W	FIELD ENG: NWC	DATE DRILLED: 7/2/73	AIRPHOTO NO:	CHAINAGE: 1177+00	OFFSET: 700' E OF ℄	TEST HOLE
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: ASPEN & BIRCH	ELEV:	

MILE	B,C,S	NUMBER
521	B	365A

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
						MOSS	F								
2		⧅				GRAVEL SAND									
4		⧅				TILL									
6						CLAY WITH SAND AND GRAVEL									
8															
10		⧅													
12						COBBLES & BOULDERS									
14		⧅													
16						END OF HOLE									
18															
20															
22															
24															

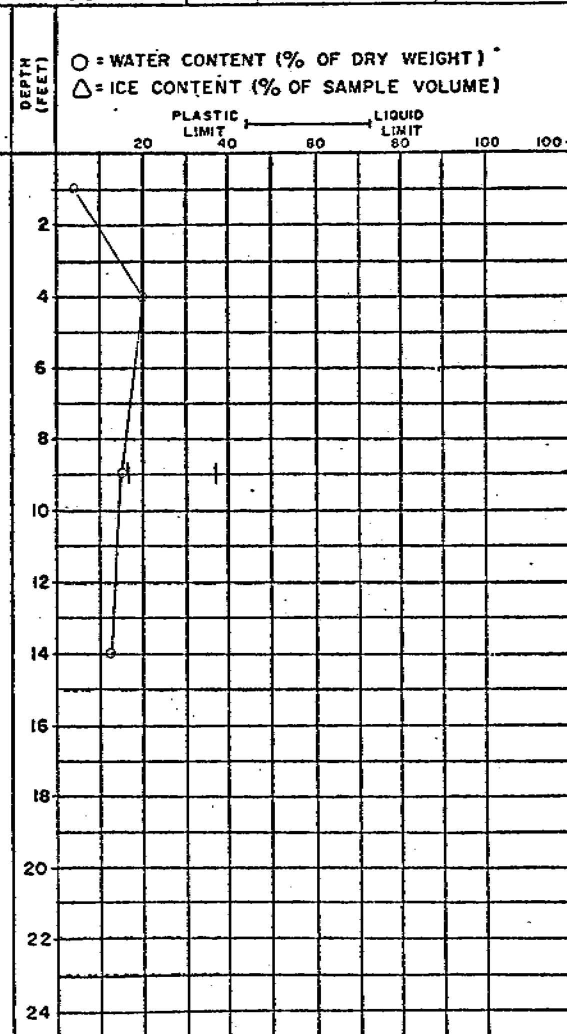


PLATE 18

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: A.E.W	FIELD ENG: N.W.C	DATE DRILLED 7/2/73	AIRPHOTO NO:	CHAINAGE: 1177+00	OFFSET: 700' E OF ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: ASPEN & BIRCH	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
521	B	366A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
0–1					Pt	MUSKEG	F		
1–15					CL	CLAY LIGHT BROWN SILT, PEBBLES COBBLES			
15						END OF HOLE			

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

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

DEPTH (FEET): 2 4 6 8 10 12 14 16 18 20 22 24

PLATE 19