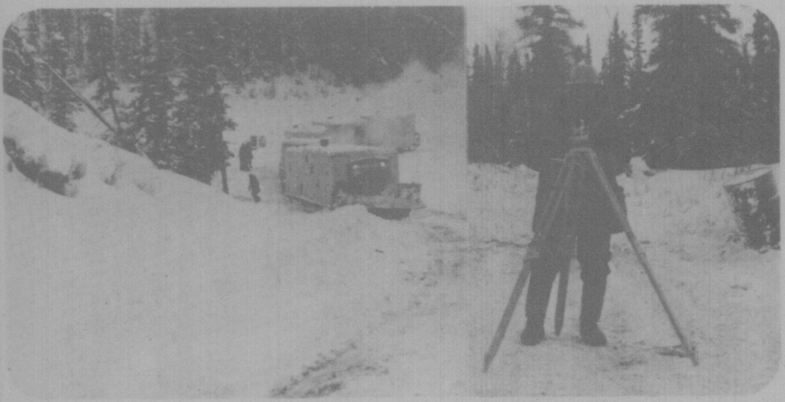
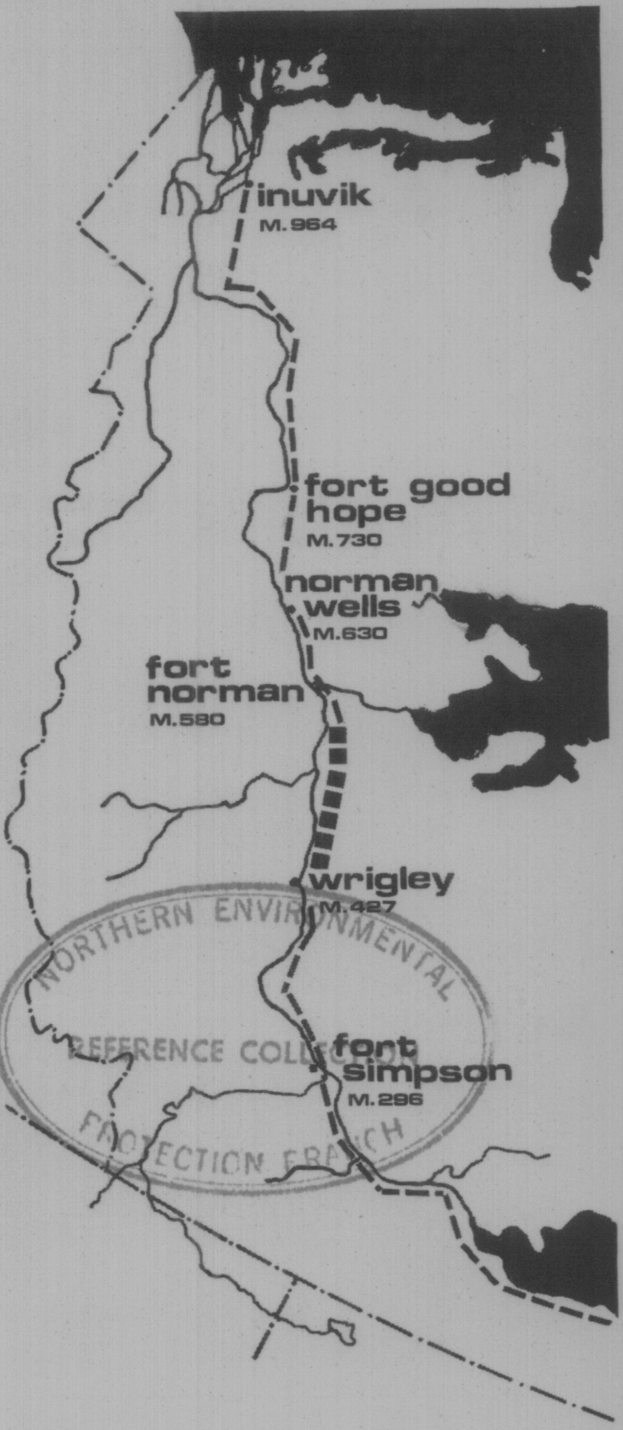
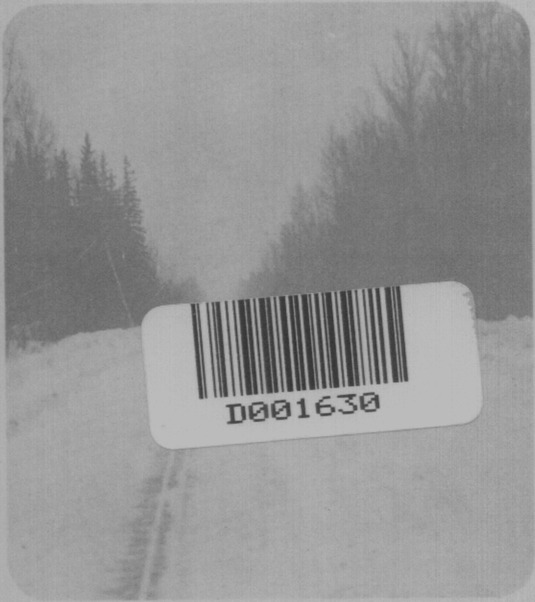






REPORT ON SUBSURFACE SOIL CONDITIONS FOR PROPOSED -

LITTLE SMITH CREEK BRIDGE MILE 533.0

MACKENZIE HIGHWAY

Underwood McLellan & Associates Limited

ISSUE #39

REPORT ON
SUBSURFACE SOIL CONDITIONS
FOR
PROPOSED LITTLE SMITH CREEK BRIDGE
MILE 533.7 MACKENZIE HIGHWAY
NORTHWEST TERRITORIES

Prepared by
Underwood McLellan & Associates Limited
Consulting Professional Engineers.

UMA Underwood McLellan & Associates Limited

2540 KENSINGTON ROAD N.W., CALGARY, ALBERTA T2N 3S3   TELEPHONE 283 4061   TELEX 038-24505

OUR FILE NO., 2106-032-45
April 25, 1973

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

Attention: Mr. F. E. Kimball

Dear Sir:

Re: Subsurface Soil Investigation
Proposed Little Smith Creek Bridge
Mile 533.7, Mackenzie Highway

Attached please find our report on the subsoil and foundation conditions for the proposed Little Smith Creek Bridge at Mile 533.7 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

D G Pennell

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

DGP/pd

Att'd.

ENGINEERING AND PLANNING CONSULTANTS

INDEX

APPENDIX

A. INTRODUCTION

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

The present report summarizes the results of subsoil investigation operations conducted in connection with the proposed Little Smith Creek bridge at mile 533.7 of the Mackenzie Highway.

It was the intention of the present investigation to determine the vertical sequence of the subsoil materials, permafrost conditions and groundwater conditions existing which would be expected to influence the stability of the valley slope and the design and construction of the proposed bridge foundations.

The included conclusions and recommendations have been based upon exploration and sample acquisition operations conducted at 10 positions 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

Ten (10) test holes have been drilled along the valley slopes and near the proposed bridge foundations in the river channel. In addition to the ten centreline test hole logs, borrow pit hole test logs in the vicinity of the bridge site have been included in the Appendix. The test holes drilled along the centreline were drilled to depths varying from 12 to 60 feet below existing site grades. The borrow pit test holes were generally advanced to the fifteen foot level.

Test borings along the centreline were drilled February 10 to 13, 1973, by Kenting Big Indian Drilling of Calgary, utilizing a Mayhew 1000 and Heli drill. Air recovery methods with "finger" bits were utilized in all test holes.

The locations of the individual test borings were selected and field located by Underwood McLellan & Associates Limited. The approximate test boring locations are graphically illustrated on the accompanying Mosaic Plot 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 was also undertaken with a two-inch O.D. split spoon sampling tube. Standard Penetration blow counts were obtained in the gravel and glacial till with a solid 2" O.D. penetrometer.

In the laboratory, the samples of materials derived from the drilling operations 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. Wherever 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 obtained by visual inspection and by measured thicknesses of ice lenses. Excess ice content was determined 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 533B 564B, 533C 397A and 533S 400A. The letter symbols and numbers indicate:

533 - mileage

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

564, 397, 400 - 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 Little Smith Creek is located at mile 533.7 (chainage 520 + 00) of the Mackenzie Highway in the Northwest Territories. The Little Smith Creek flows into the Mackenzie River from the east having a drainage basin whose origin is in the Franklin Mountains. This stream exhibits a typical sand-gravel bed which is depositing floodplain sediments at the entrance to the Mackenzie River. The main valley is pre-glacial and valley fillings in the form of glacial till were deposited during the Pleistocene Epoch. Subsequently, various levels of the creek have allowed deposition of sands, silty sands and gravels on the valley slopes and in the present main flow channel.

The Little Smith Creek bed elevation is 215 (D.P.W. plan-profile datum) with the recently recorded high water mark at elevation 223.

The main stream channel across which the creek has flowed in recent times is approximately 700 feet wide and 20 feet deep but at the present time the flow is near the south bank. Gravel and sand terraces occur immediately above the south bank and extend 1000 feet, whereas, on the north a terrace 600 feet long is present approximately 20 feet above the channel level.

Four test holes, 401A 402A, 403A and 404A were drilled across the 700 foot wide channel. All four test holes disclosed very stiff glacial clay till underlying surface deposited sands and gravels. Test holes 401A and 402A were drilled at the south and north abutment locations, respectively, and indicated 20 feet of coarse gravel, boulders and sand. These two test holes confirmed a consistent glacial till elevation of 195 at the proposed bridge location. Test hole 401A which was drilled to a depth of 60 feet did not encounter permafrost conditions, nor did the other three drill holes. Solid standard penetration blow counts from 18 to 91 were obtained in the stiff glacial till with an average count of 62 blows. Sloughing of the surface sands and gravels allowed only disturbed air returned samples to be recovered, consequently, approximate average moisture contents in the glacial till of 16% were obtained. This moisture content is near the plastic limit for the glacial till. The free water table was present at 10 feet in the gravel strata and presented severe caving conditions. Solid penetrometer blow counts in the gravel varied from 23 to 112. This range in blow count may be indicative of material variations in the surface stream deposited soils.

Test holes 399A and 400A were drilled on the south terrace at stations 531 + 00 and 525 + 00, respectively. Test hole 399A encountered 3 feet of silty clay underlain by frozen gravel with moisture contents of 5%. This test hole exhibited a similar stratigraphic sequence to that encountered across the main creek channel except 6 feet of silty clay overlies the clay till.

Near the south uplands, surface gravel and sands were found above silty clay. Permafrost was found throughout test hole 397A but test hole 398A had seasonal frost to 7 feet and then was unfrozen to the 22 foot depth where permafrost was again encountered.

On the north slopes dry sand and gravel was indicated by test borings 405A and 406A. The dry nature of the sand in test hole 405A produced extreme caving conditions.

A soil profile of the bridge valley site is included in the appendix on Plate 2.

D. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the present investigations, we wish to offer the following generalized conclusions and recommendations relative to the design and construction of the proposed Little Smith Creek bridge foundation and approaches.

1. Pier and Abutment Foundation Design

The gravel and glacial clay deposits which were described in the previous section will form the bearing strata for the proposed bridge piers and abutments. Consideration may be given for either a spread footing pier foundation or driven piles. If a pier-footing type foundation is selected, the base must be placed below the potential scour depth. It is recommended that the piers be founded in the glacial till at elevation 195 approximately 20 feet below the average existing site grades. The allowable bearing capacity for footings in undisturbed stiff till would be 6000 psf. Excavation for piers and footings will take place under caving conditions in the lower saturated gravels and will necessitate cofferdams and pumping.

Driven piles are recommended in preference to the footing type foundation, primarily based upon excavation difficulties in the gravel strata. The pile types available include timber, pre-cast concrete, steel H-piles and pipe piles. The timber piles are not recommended as a result of their low capacity and possible damage when driving through gravel strata. The pre-cast concrete piles are also not recommended primarily due to the difficulty in establishing ultimate pile lengths and unless the lengths can be predetermined considerable difficulty in splicing results.

Steel H-piles or pipe piles are, therefore, recommended for consideration primarily based on high driving strength, high load capacity and relative ease in splicing. The granular strata and glacial till at this site will provide adequate lateral support such that instability in the form of buckling of the piling will not be a problem.

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.

Steel piles driven to "refusal" can be expected to attain allowable load capacities in the range of 80 tons depending upon the cross-sectional area. False "refusal" may occur whenever extremely large boulders cannot be penetrated during driving. Although "refusal" may be attained while driving in boulders, adequate bearing capacity may not exist below the pile tip. Load tests would be required to establish allowable loads if this situation is recognized. In order to attain penetration of the steel piles around large boulders, it may be necessary to utilize vibration techniques or large diameter open pipe piles may be employed with churn-drill crushing of large boulders inside the bottom of the pipe. It is anticipated that penetration of the gravel overburden will be achieved with final refusal occurring at a depth of 30 to 40 feet below existing site grades.

Difficulty exists in establishing the depth at which refusal will be realized as no significant increasing blow count with depth was noted in the glacial till.

Conventional pile-driving tests on piles driven into the glacial clay till can only be utilized as an approximate guide in establishing load capacity. In primarily cohesive soils, the penetration resistance does not increase with depth, although load-carrying capacity of the pile is constantly increasing with depth. The common Engineering News formula should not be utilized as recent studies have indicated extreme variations in factor of safety.

Whenever piles are driven to great depths, the allowable load may be approximately determined by the adhesion between the soil and pile based on 600 psf. When "refusal" is attained, the allowable load should be based upon the pile material strength.

It is recommended that static load tests be performed to establish more accurately the bearing capacity of a typical pile.

The lateral resistance of piles can be established by recently developed methods based on the beam on elastic foundation method 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 granular material and glacial till 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 load.

Whenever the embankments are constructed of compacted granular fill or unfrozen glacial till as outlined and recommended in Section D3, the abutments may be placed on spread footings in the fill. The allowable bearing stress for the abutments should be established when the characteristics of the fill are known. If inferior materials or compaction techniques are utilized in the embankment, the abutment must be carried on piles into the insitu glacial till subsoils below the creek channel. Piles must be designed to carry a negative skin friction load whenever embankment settlement is anticipated.

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 20 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 whenever 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 buildup 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 shown 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 38 degrees and the dry density may be taken as 115 pcf. For a simple vertical retaining wall abutment with horizontal backfill the Coulomb active coefficient would be .24 and the at-rest coefficient based on $K_o = 1-\text{Sin}\ \emptyset$ 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 compaction the at-rest coefficient be utilized for calculation of the ultimate earth pressure.

If driven piles are utilized to carry the approach abutments it is recommended that some batter piles be utilized to ensure adequate lateral support against earth pressures.

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

3. Bridge Approach Embankments and Borrow Material

The proposed centreline grades at the Little Smith Creek bridge site will involve primarily fill sections. The proposed fills will vary from 20 feet at the bridge crossing to 35 feet deep approximately 1000 feet south of the main channel. Large trees should be removed from the fill areas but surface vegetation should remain in place below the proposed embankments. Wherever the fill depth becomes shallow on the valley slopes, the vegetation will provide insulation and tend to maintain permafrost conditions. The deep fills will overlie granular deposits which will provide adequate strength for the superimposed embankment loads. It is recommended that granular fill be used in all approach fills to the bridge abutments and this material should be compacted to 95% of Standard Proctor density utilizing vibratory compaction. Although fill construction may be performed during the winter with dry unfrozen gravel, it is recommended that embankments be placed in the summer. A graded gravel-sand mixture embankment should be placed at 2:1 side-slopes and it is mandatory that compaction of these fills be undertaken to ensure stability. If materials other than gravel are utilized, the strength characteristics of these materials must be evaluated to select stable side-slopes.

Common excavation will not be available from the valley slopes as the greatest portion of the grade-line has been selected to produce fill sections. Suitable granular embankment material is available throughout the valley slopes above the glacial till but its utilization as a construction material may be prohibited by land use regulations. Unfrozen glacial clay till may be utilized for embankments compacted during the summer but test holes drilled generally indicate that gravel and sand overburden are present above the till.

Suitable borrow pits were located south of the bridge site at station 531 + 00 and north at station 505 + 00. These pits contained gravel and clay till with the gravel generally, overlying the till. In order to obtain sufficient gravel for the embankments large borrow areas will likely necessitate development.

A 10 foot cut section is proposed on a north terrace at station 515 + 00 in a soil strata consisting of four feet of sand over unfrozen dry gravel. This cut, should be stable when excavated at 2:1 and no grade-line revisions are recommended.

Another 10 foot cut has been proposed on the south slope near the uplands at station 544 + 00. This cut will be undertaken in 4 feet of surface gravel and to a depth of 6 feet in unfrozen silty clay with a moisture content of 20%. It is anticipated that back-slopes of 2:1 will ensure stability of the cut section.

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:-

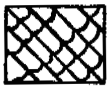
NATURAL MOISTURE CONDITIONS & ATTERBERG LIMITS

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.

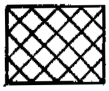
SOIL PROFILE & DESCRIPTION

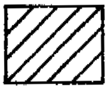
Each soil strata is classified and described noting any special conditions. The unified classification system is used, and the soil profile refers to the existing ground elevation. When available the ground elevation is shown.

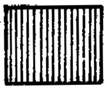
The soil symbols used are briefly shown below but are indicated in more detail in the Soil Classification Chart.

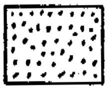

TOPSOIL


PEAT
MUSKEG


FILL


CLAY


SILT


SAND


GRAVEL


TILL


BEDROCK

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.

γd - 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.

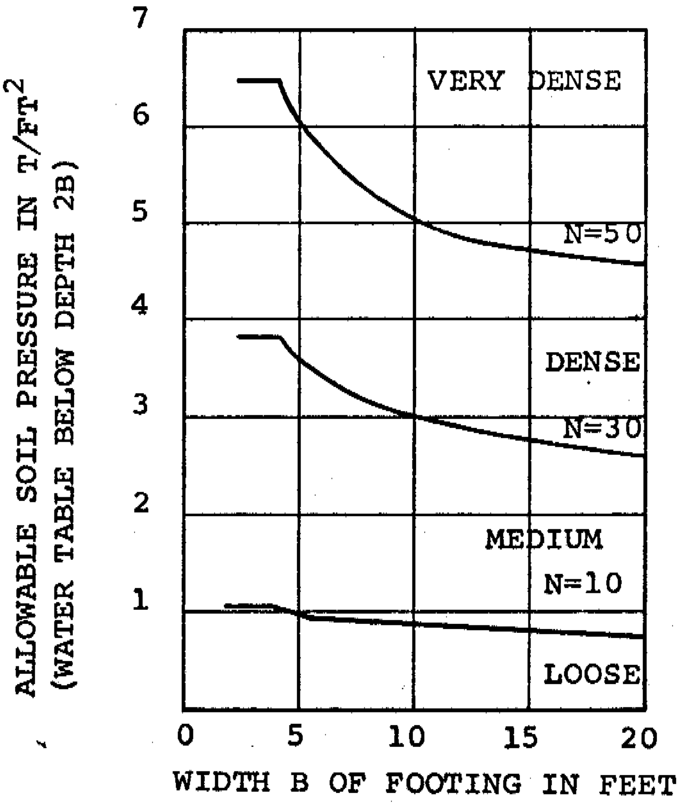
SO_4 - water soluble sulphate content is conducted primarily to determine whether sulphate resistant cement is required for the foundation structure.

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%

Negligible	Positive	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.

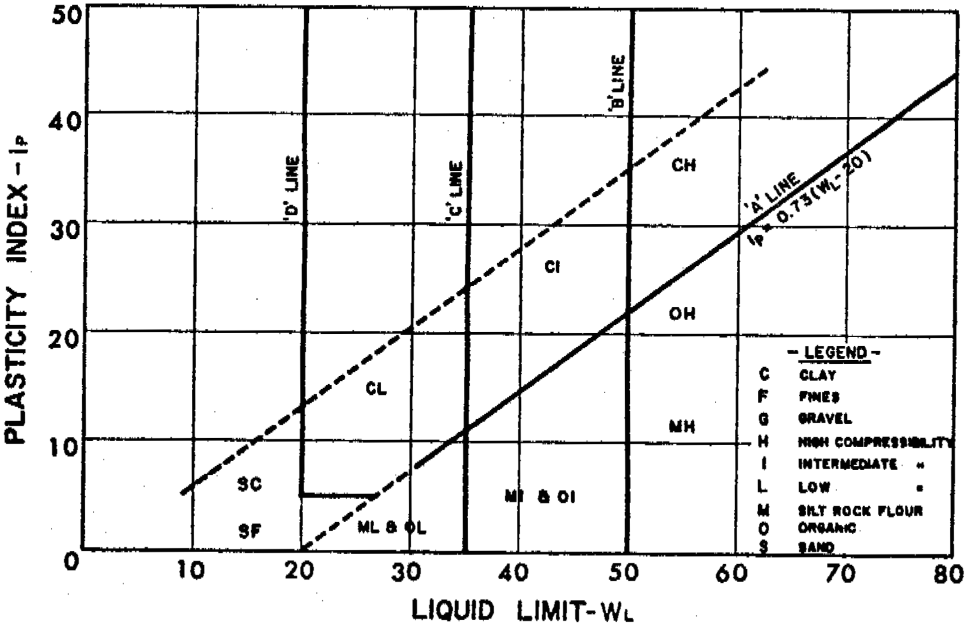
UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS 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

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

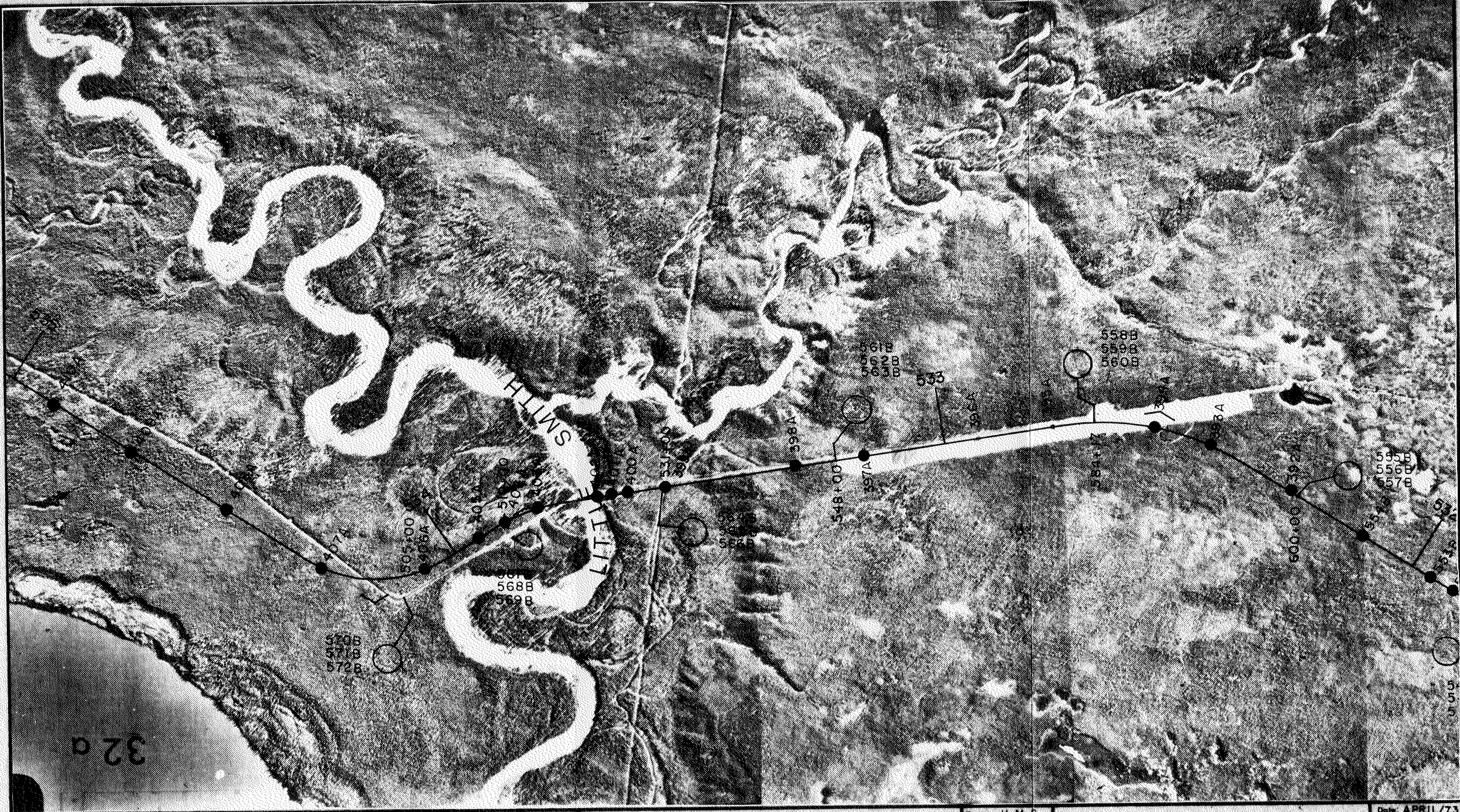
V_s - stratified or oriented ice formations

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.



32a

Issue	Date	Remarks	No.	Revision	Date	By	Approved

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

CONSULTING ENGINEERS – TOWN PLANNERS

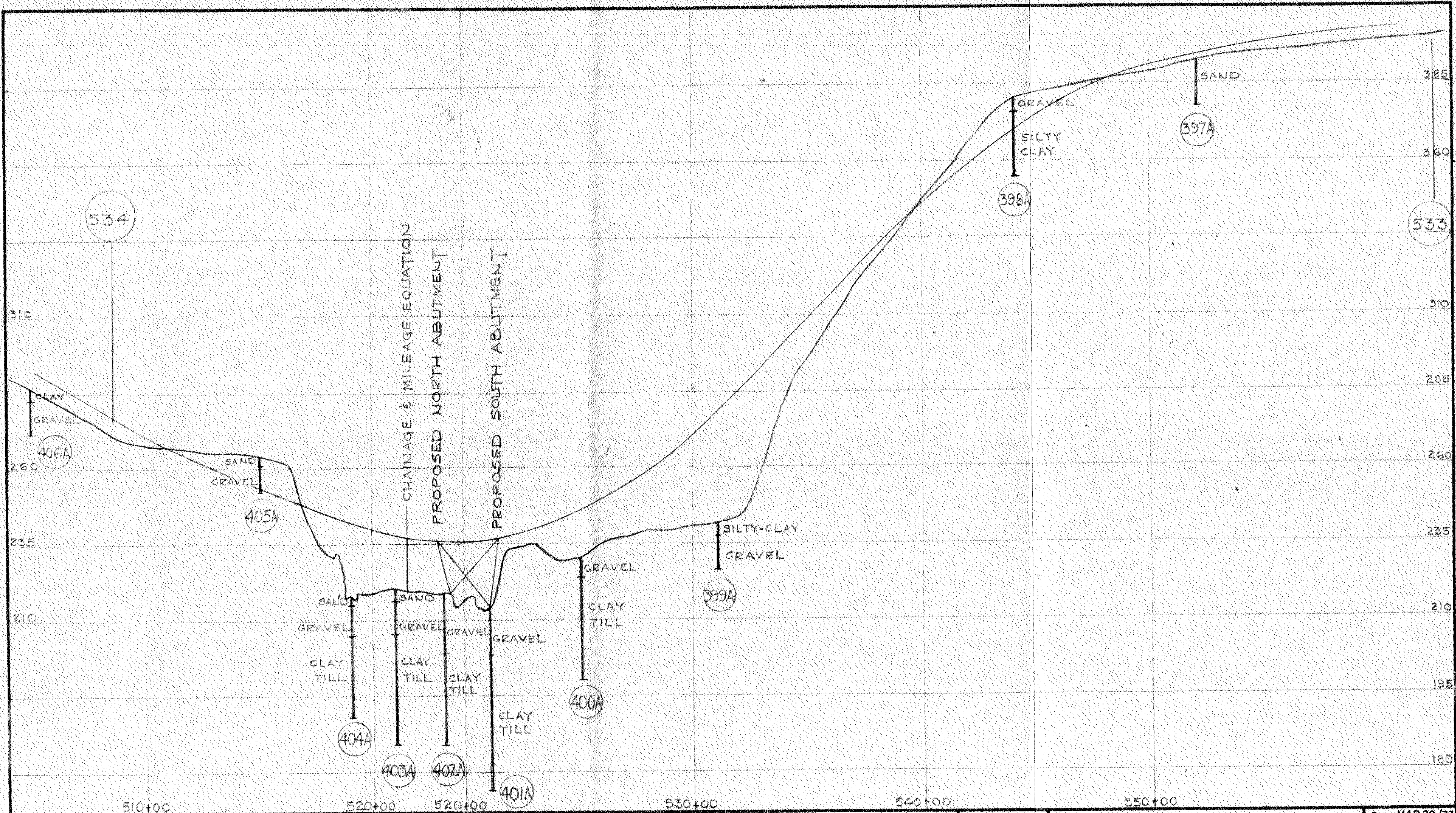
BRITISH COLUMBIA • ALBERTA • SASKATCHEWAN • MANITOBA • ONTARIO

Drawn: H.M.S.
Checked: D.G.P.
Design:
Traced:
Scale: 1" = 1000'

MACKENZIE HIGHWAY

LITTLE SMITH MOSAIC AND TEST HOLE LOCATION PLAN

Date: APRIL/73
Job:
Sheet:
Drawing: PLATE-1
Issue:



Issue	Date	Remarks	No.	Revision	Date	By	Approved

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CONSULTING ENGINEERS – TOWN PLANNERS
BRITISH COLUMBIA • ALBERTA • SASKATCHEWAN • MANITOBA • ONTARIO

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

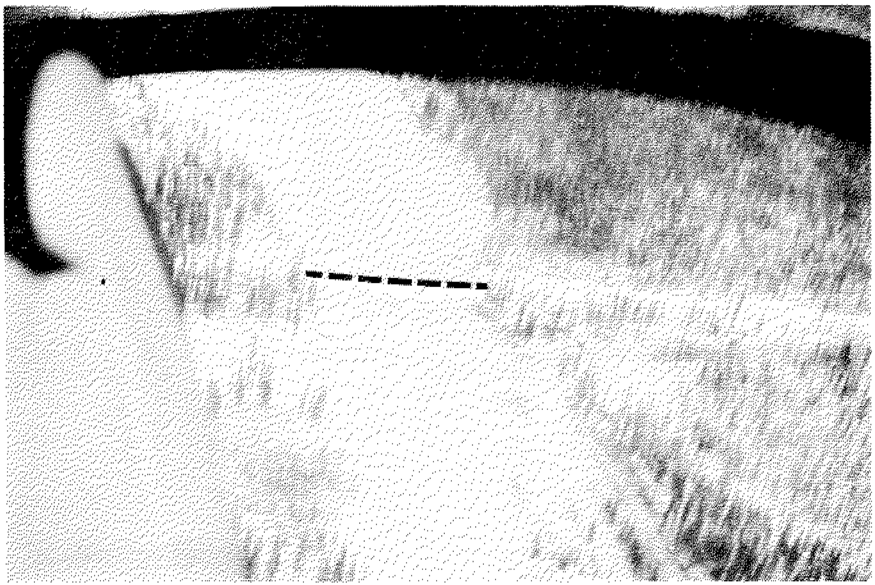
MACKENZIE HIGHWAY

LITTLE SMITH BRIDGE SITE

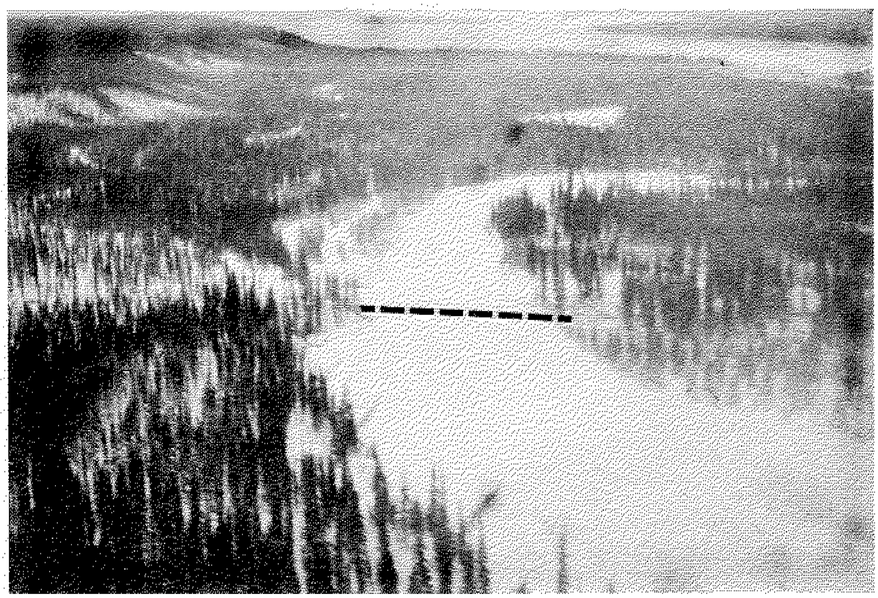
PROFILE & SOIL CROSS SECTION

Date: MAR 28/73
Job:
Sheet:
Drawing: PLATE - 2
Issue:

LITTLE SMITH CREEK CROSSING
MILE 533.0



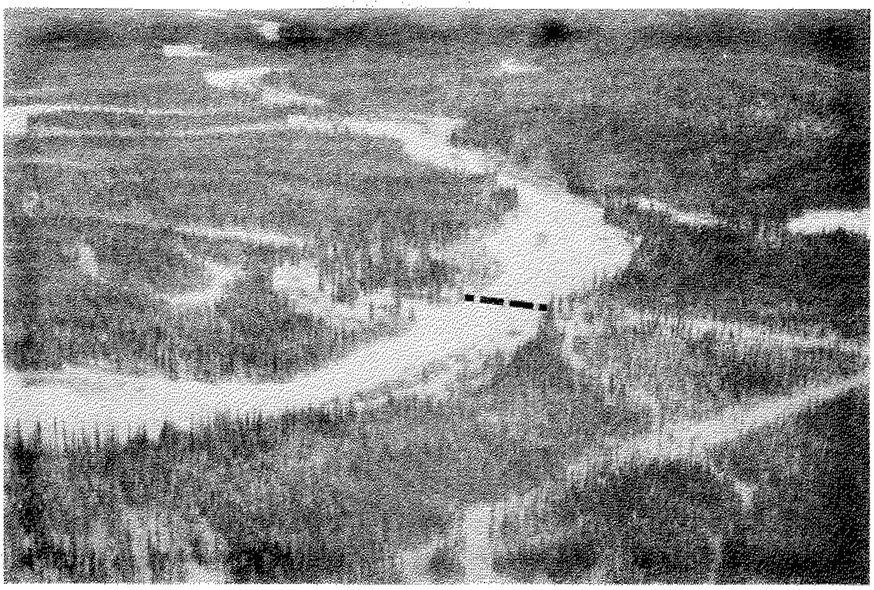
Viewing Crossing in a North Easterly Direction



Viewing Crossing in a South Westerly Direction

Plate 3

Viewing Crossing in a Southerly Direction. NOTE: Airstrip in Top Left Hand Corner.



Viewing Crossing in a Northerly Direction

Plate 3.

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN R.S
FIELD ENG R. S
DATE DRILLED 10/2/73
AIRPHOTO NO:
CHAINAGE: 552+00
OFFSET: ℄
CKD
TECH:
RIG AIR
SURFACE DRAINAGE: POOR
VEGETATION: 50' SPRUCE
ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
533	C	397A

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
2					SM	SAND GRAVEL & SOME SILT	F								
4					S.W					4	28	68			
6						SAND & PEBBLES									
8															
10		P			S.P										
12															
14					S.P		F								
16						END OF HOLE									
18															
20															
22															
24															

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

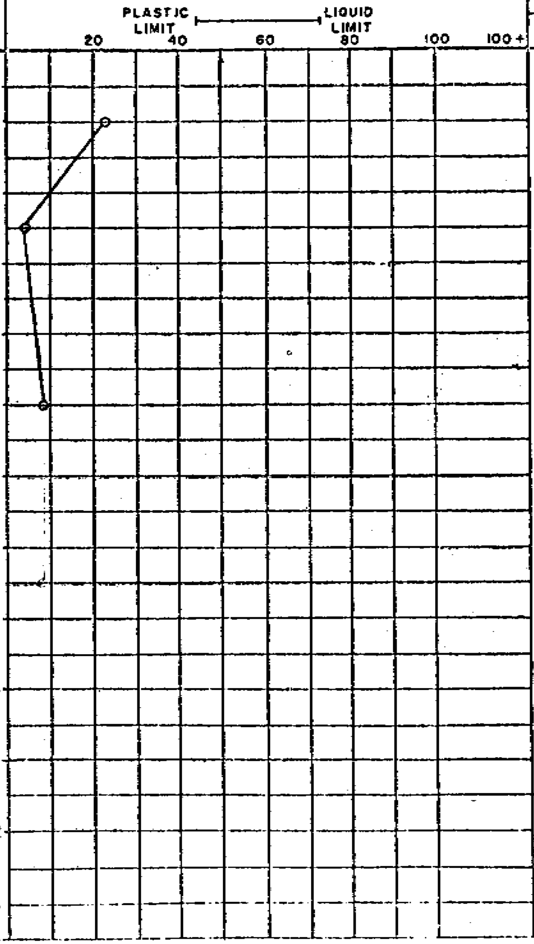


PLATE 4

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

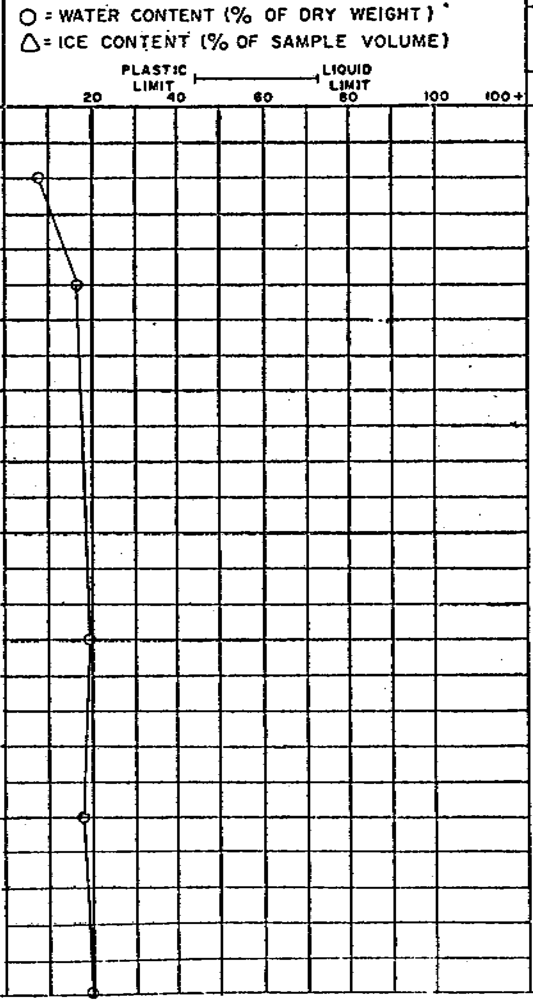
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

TEST HOLE

MILE	B,C,S	NUMBER
533	C	398A

DWN: R. S
FIELD ENG R S
DATE DRILLED 10/2/73
AIRPHOTO NO:
CHAINAGE: 544+00
OFFSET: ℄
CKD
TECH:
RIG: AIR
SURFACE DRAINAGE: SOUTH TO RIVER
VEGETATION: 30'-45' SPRUCE
ELEV:

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
2		☒			GW	GRAVEL		
4		☒			CL	SILTY CLAY	F	
8							UF	
14		☒		44 BLS	CL			
20		☒					UF	
24		☒			CL	END OF HOLE	F	



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

PLATE 5

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

DWN: R. S FIELD ENG: R S DATE DRILLED: 10/2/73 AIRPHOTO NO: CHAINAGE: 531+00 OFFSET: ℄

CKD: TECH: RIG: AIR SURFACE DRAINAGE: VEGETATION: ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	C	399A

○ = 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
						SILTY CLAY	F									
2									2							
4		▨			SW	GRAVEL			4							
6									6							
8									8							
10		▨			GW				10							
12							F		12							
14		▨			GW				14							
16						END OF HOLE			16							
18									18							
20									20							
22									22							
24									24							

PLATE 6

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: R.S
FIELD ENG: R. S
DATE DRILLED: 10/2/73
AIRPHOTO NO:
CHAINAGE: 525+00
OFFSET: ℄
CKD
TECH:
RIG: AIR
SURFACE DRAINAGE: GOOD TO RIVER
VEGETATION: 50'-80' SPRUCE
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	C	400A

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
		⊠			GW										
4		⊠			GW	GRAVEL	F		5		25	70			
8						CLAY TILL	UF								
		⊠			CL										
12															
		⊠		87 BLS	CL										
16															
20		⊠			CL										
24		⊠		110 BLS	CL										
28															
		⊠			CL										
32															
		⊠			CL		UF								
36															
40		⊠		67 BLS	CL										
						END OF HOLE									

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

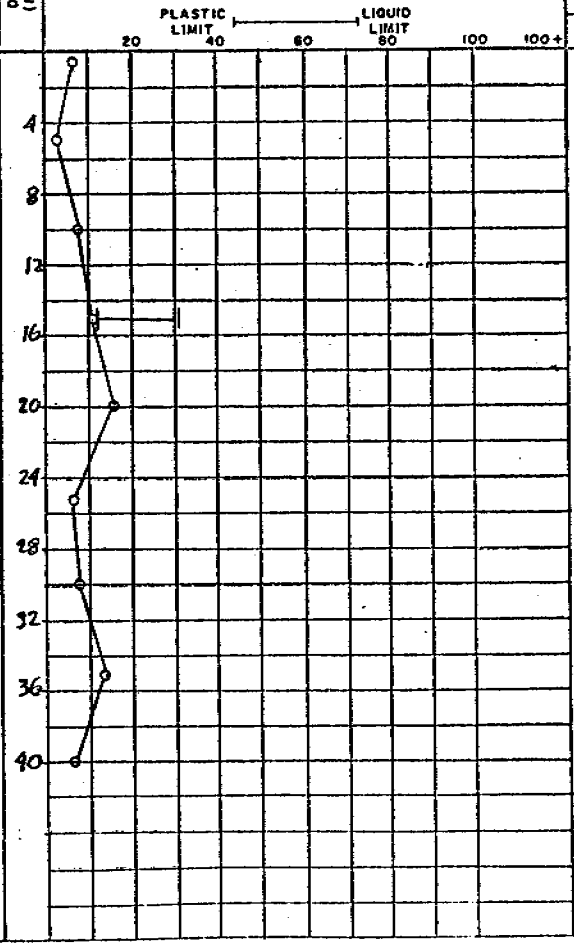


PLATE 7

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN. A EW
FIELD ENG. R S
DATE DRILLED 10/2/73
AIRPHOTO NO:
CHAINAGE: 521+00
OFFSET: ℄
CKD DGP
TECH:
RIG: AIR
SURFACE DRAINAGE: GOOD
VEGETATION: SPRUCE TO 40'
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	S	401 A

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
						GRAVEL AND COBBLES	F								
						CLAY SAND & PEBBLES									
5						GRAVEL			12		29	59			
10				40 BLS		WATER @ 9' & 12' SAND, CLAY, COBBLES	UF								
15															
20		P		48 BLS		CLAY TILL									
25															
30		P		73 BLS											
35															
40		P		75 BLS											
45						CLAY TILL SOME BOULDERS									
50		P		73 BLS		CLAY									
55															
60		P		47 BLS		END OF HOLE									

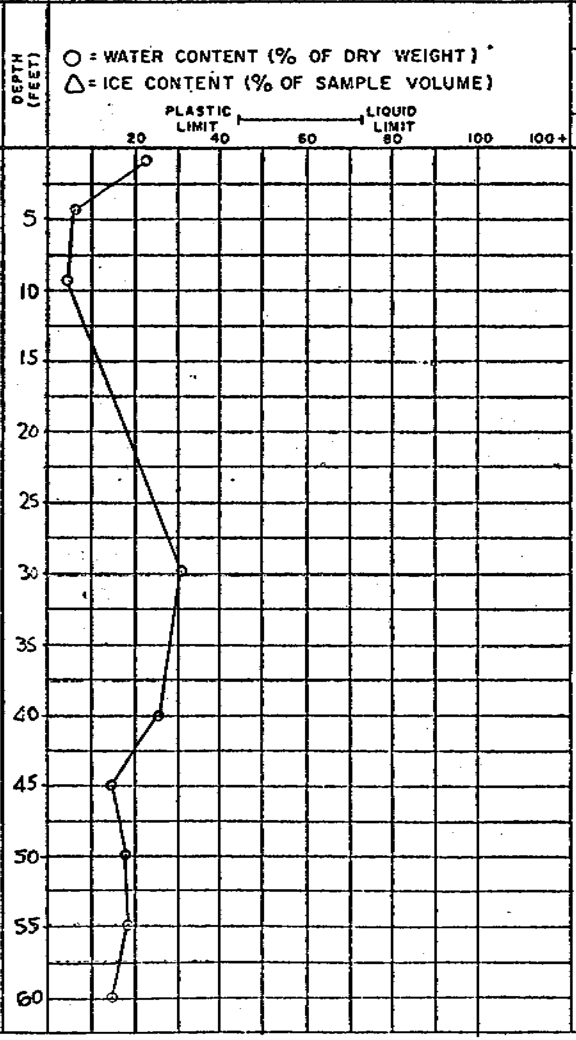


PLATE 8

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 11/2/73 | AIRPHOTO NO: | CHAINAGE: 519+00 | OFFSET: ℄

CKD DGP | TECH: | RIG: AIR | SURFACE DRAINAGE: GOOD | VEGETATION: SPRUCE TO 40' | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	S	402A

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
						GRAVEL 6" TOPSOIL	UF								SO_4 : 0.07%
5					GM										
						SAND, PEBBLES AND BOULDERS				7	34	66			
10				23 BLS											
15															HOLE SLOUGHING
20					GW										
						CLAY TILL									
25					GC	GRAVEL									
30															
35															
40		P													
45						DENSER GRAVEL CONTENT									
50		P		91 BLS	GC										
55						END OF HOLE									

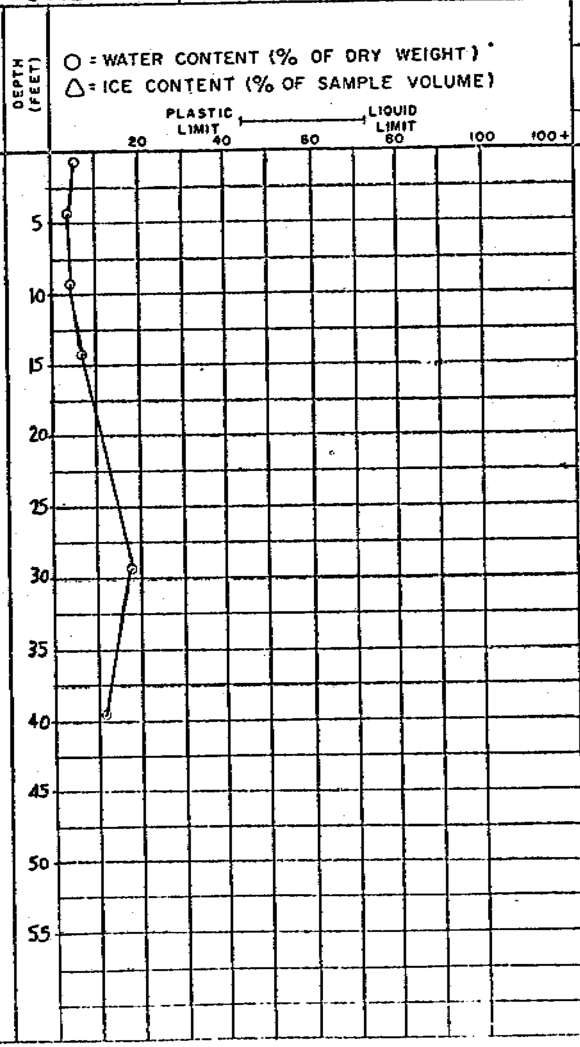


PLATE 9

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

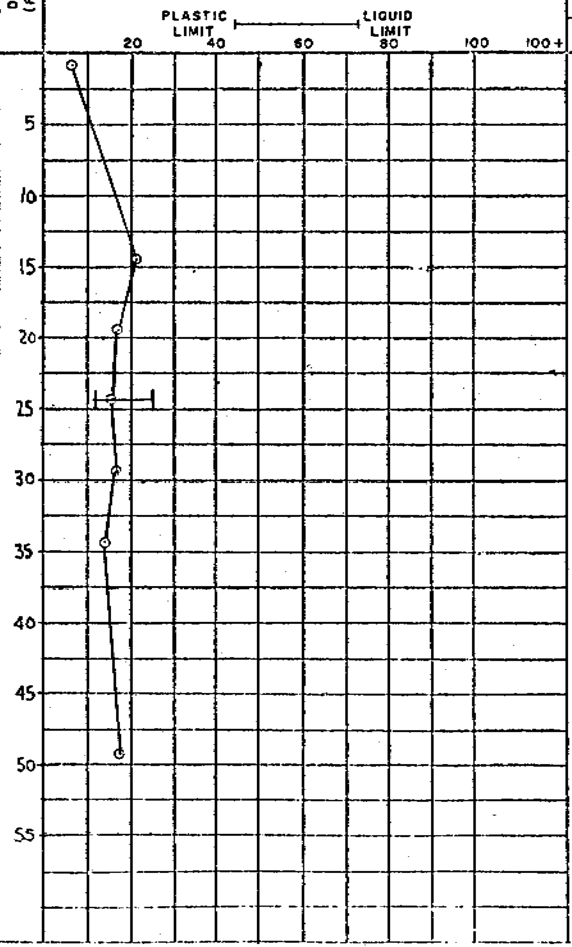
DWN. AEW	FIELD ENG NWC	DATE DRILLED 12/2/73	AIRPHOTO NO:	CHAINAGE: 521+00	OFFSET: ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE TO 50'	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	S	403A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						SAND 6" TOPSOIL	UF	
5						GRAVEL		
10				112 BLS		COARSE, DRY		
15						TILL		
20								
25				35 BLS				
30						SAND & PEBBLES		
35								
40						CLAY, SAND AND PEBBLES		
45								
50				18 BLS				
55						END OF HOLE		

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



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

REMARKS

SO_4 = 0.09%

HOLE SLOUGHING

PLATE 10

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A EW
FIELD ENG: R S
DATE DRILLED: 13/2/73
AIRPHOTO NO:
CHAINAGE: 519+00
OFFSET: ℄
CKD: DGP
TECH:
RIG: AIR
SURFACE DRAINAGE: GOOD
VEGETATION: POPLAR & SPRUCE TO 80'
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	S	404A

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
					GP	6" TOPSOIL SAND	UF								SO_4 = 0.09%
4						GRAVEL					22	78			
8				41 BLS	GC	SANDY WET			6		17	77			
12						CLAY-TILL			40		29	31			
16															
20				49 BLS											
24					GC	WET, GRAVEL, SAND									
28															
32															
36					GC										
40				109 BLS		END OF HOLE									
44															

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

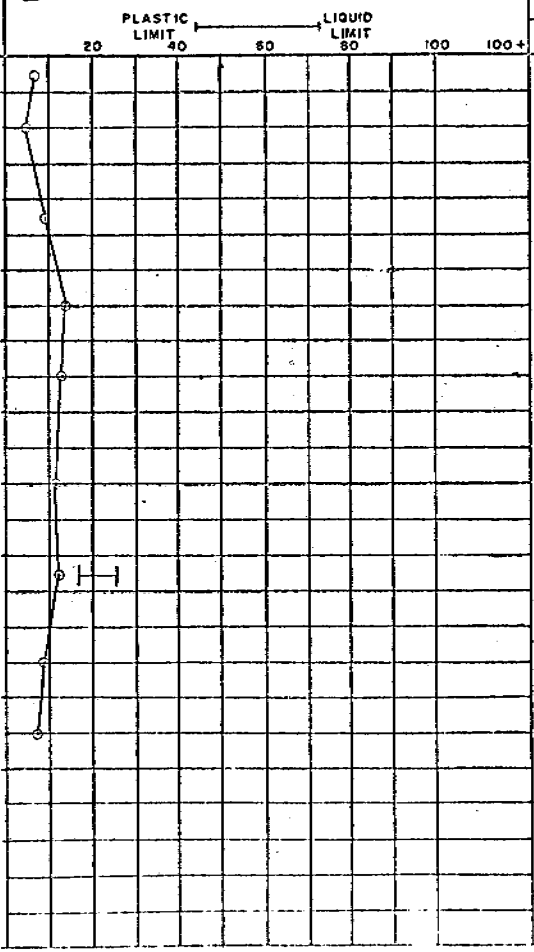


PLATE 11

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: AEW	FIELD ENG: BM	DATE DRILLED: 13/2/73	AIRPHOTO NO:	CHAINAGE: 515 +00	OFFSET: ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE & ASPEN TO 35'	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	C	405A

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
0–1						ORGANIC	F								
1–4						SAND DRY, SOME SILT									
3							UF								HOLE SLOUGHING FROM 3'
4–12						GRAVEL OCCASIONAL COBBLE CLAY									
12						END OF HOLE									

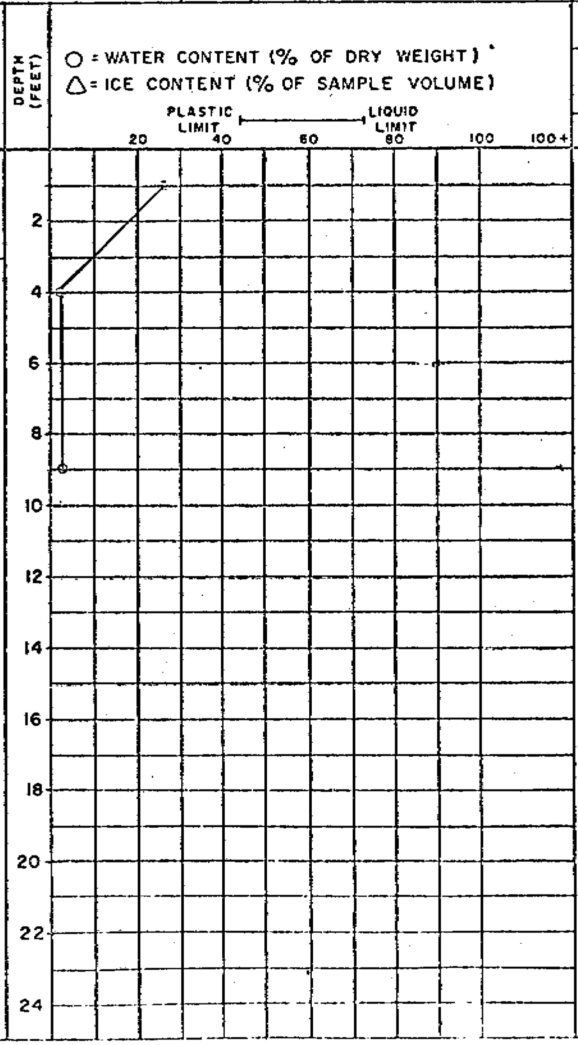


PLATE 12

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

DWN: A EW	FIELD ENG B.M	DATE DRILLED 13/2/73	AIRPHOTO NO:	CHAINAGE: 505+00	OFFSET: ℄
CKD D6P	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE TO 20'	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
534	C	406A

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
						CLAY 2" ORGINIC SILTY, TILL SOME ICE	F								
4						GRAVEL COBBLES CLAY TILL			7		22	71			
						END OF HOLE									

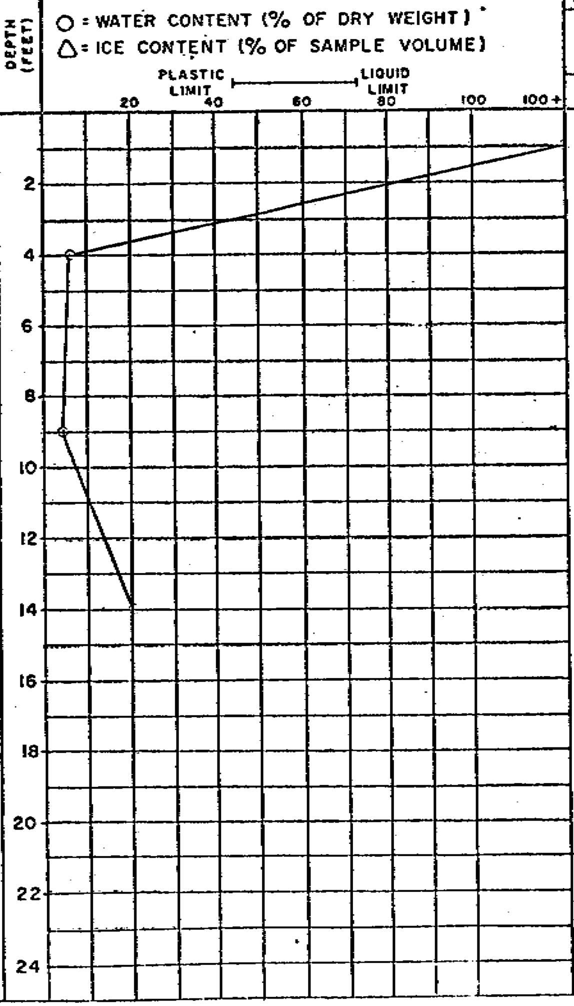


PLATE 13

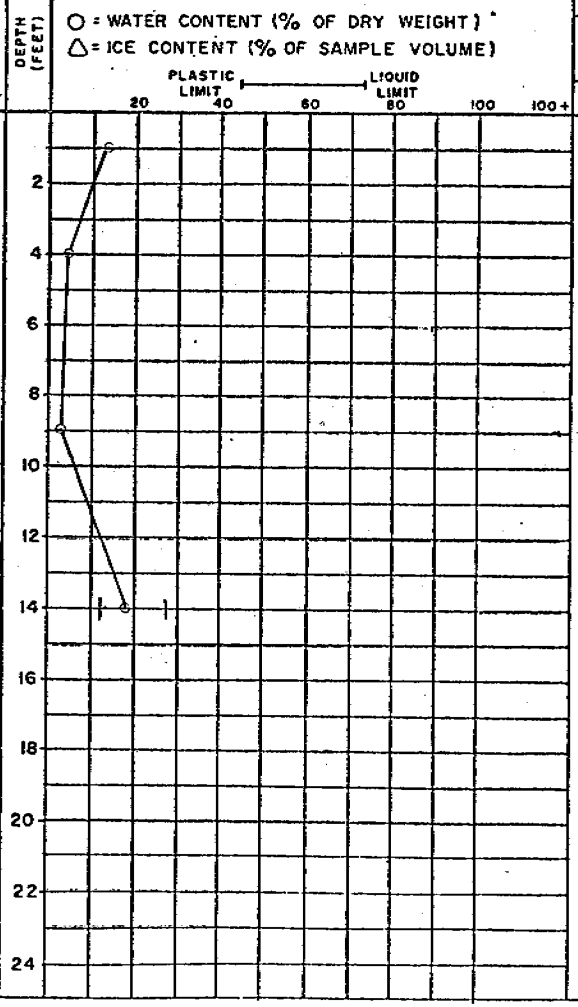
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN. A.E.W | FIELD ENG: DR | DATE DRILLED 13/2/73 | AIRPHOTO NO: | CHAINAGE: 531+00 | OFFSET: 800' W OF ℄
CKD DGP | TECH: | RIG: AIR | SURFACE DRAINAGE: FAIR | VEGETATION: SPRUCE TO 25' | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	B	564B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						SAND 3" MOSS	F	
2		▨			SW	SILT, GRAVEL, COBBLES		
						TILL		
4		▨			GW			
6						SAND. GRAVEL COBBLES, BOULDERS		
8								
10		▨				GRAVEL SEAM	UF	
12						GREY CLAY		
14		▨			GC			
16						END OF HOLE		
18								
20								
22								
24								



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

PLATE 14

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

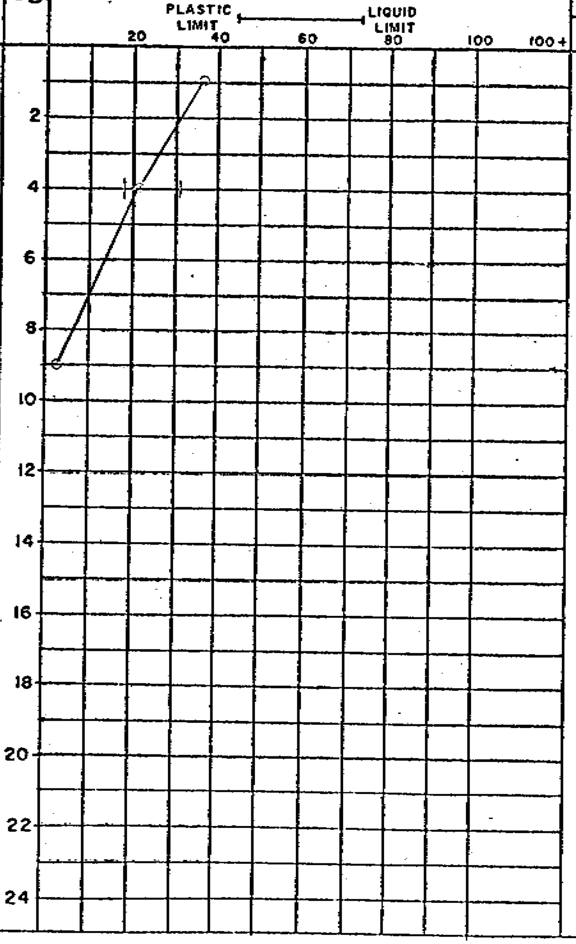
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A.E.W
FIELD ENG: DR
DATE DRILLED 13/2/73
AIRPHOTO NO:
CHAINAGE: 531+00
OFFSET: 800' W OF ℄
CKD: DG P
TECH:
RIG: AIR
SURFACE DRAINAGE: FAIR
VEGETATION: SPRUCE TO 25'
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	B	565B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					Pt ML	CLAY 3" MOSS ORGANIC, SILTY	F	
					GC GW	TILL SILTY CLAY, MOIST MED. BROWN SAND, GRAVEL, COBBLES	UF	
						END OF HOLE		



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

REMARKS

PLATE 15

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

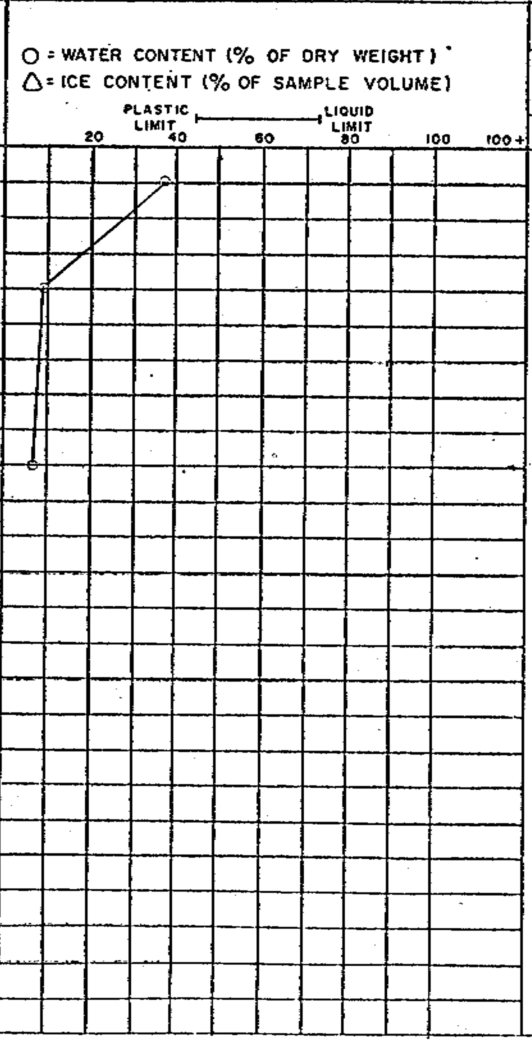
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN AEW
FIELD ENG DR
DATE DRILLED 13/2/73
AIRPHOTO NO:
CHAINAGE: 531+00
OFFSET: 800' W OF ℄
CKD DGP
TECH:
RIG: AIR
SURFACE DRAINAGE: FAIR
VEGETATION: SPRUCE TO 25'
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
533	B	566B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					Pt	CLAY 3" MOSS	F	
2					CL	SILTY		
						SILT MOIST	UF	
4					GC	GRAVEL		
6						SAND, CLAY, MOIST		
8						PEBBLES		
					SW			
10								
12						END OF HOLE		
14								
16								
18								
20								
22								
24								



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

PLATE 16

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

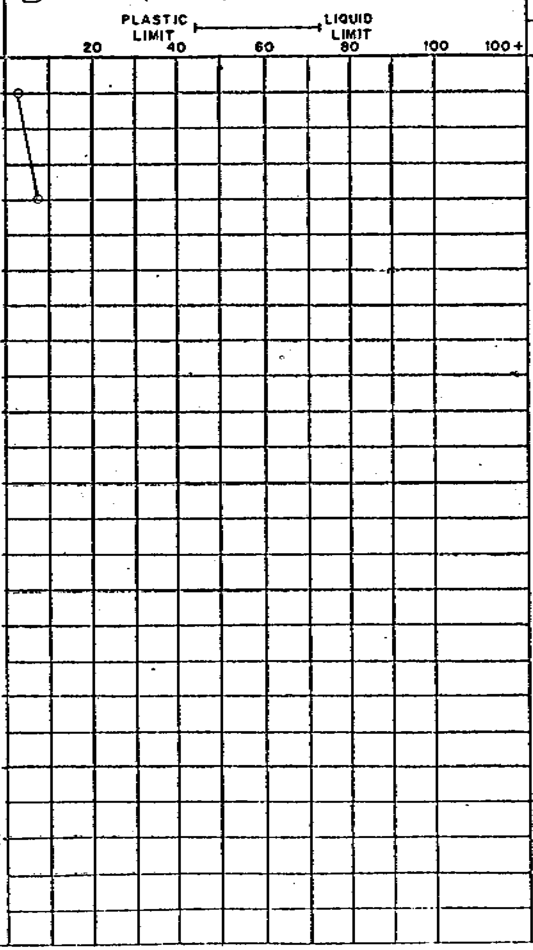
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A E W
FIELD ENG H E A
DATE DRILLED 13/2/73
AIRPHOTO NO:
CHAINAGE: 505+00
OFFSET: 700' W OF ℄
CKD D G P
TECH:
RIG: AIR
SURFACE DRAINAGE: GOOD
VEGETATION: SPRUCE, BIRCH, POPLAR
ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
534	B	570B

○ = 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	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P C F)	DRY DENSITY (P C F)	REMARKS
		▧			SW	SAND 4" PEAT	F									
2						GRAVEL	UF		2							
4		▧							4		45	40	15			
6					SM				6							
8						END OF HOLE			8							
10									10							
12									12							
14									14							
16									16							
18									18							
20									20							
22									22							
24									24							

PLATE 17

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A EW
FIELD ENG H.E.A
DATE DRILLED 13/2/73
AIRPHOTO NO:
CHAINAGE: 505+00
OFFSET: 700' W OF ℄
CKD DGP
TECH:
RIG: AIR
SURFACE DRAINAGE: GOOD
VEGETATION: SPRUCE & BIRCH
ELEV:

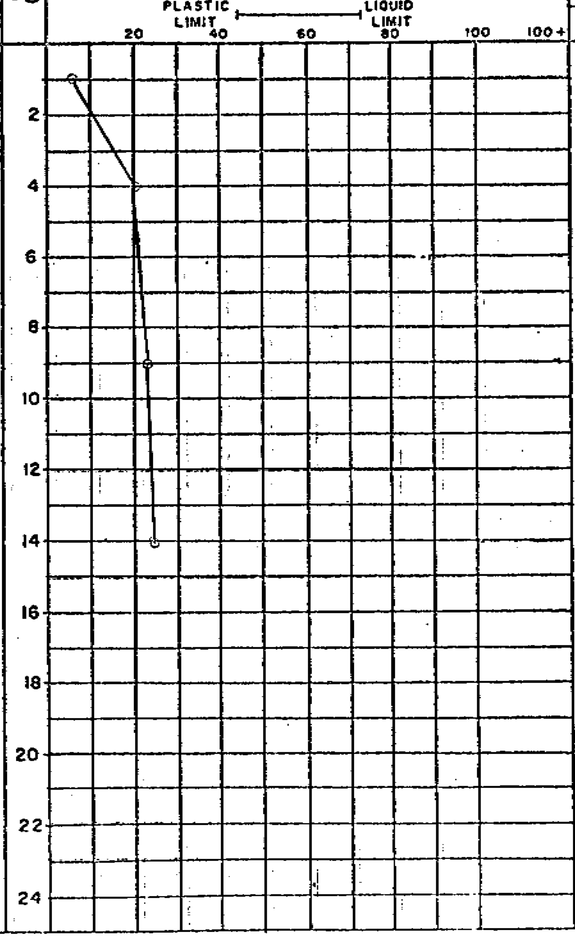
TEST HOLE

MILE	B,C,S	NUMBER
534	B	571B

REMARKS

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					PL	PEAT	F	
					SP	SAND		
						GRAVEL		
					GC	CLAY TILL		
						CLAY, FEW PEBBLES	UF	
					GC	CLAYEY SILT WITH LOTS OF PEBBLES		
						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)
%	%	%	%		

PLATE 18

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A.E.W
CKD: DGP
FIELD ENG: H E A
TECH:
DATE DRILLED: 13/2/73
RIG: AIR
AIRPHOTO NO:
SURFACE DRAINAGE: GOOD
CHAINAGE: 505+00
VEGETATION: SPRUCE & BIRCH
OFFSET: 700' W OF ℄
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
534	B	572B

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						TOPSOIL PEAT	F								
1		⧅			Pt	SILT ORGANIC									
2–4						GRAVEL		Vc							
4		⧅			GW				16		16	68			
6–8					GP	DRY COARSE FINE SAND LARGE ROCKS									
9		⧅													
14		⧅			GC	CLAY TILL		Vc							
15						END OF HOLE									

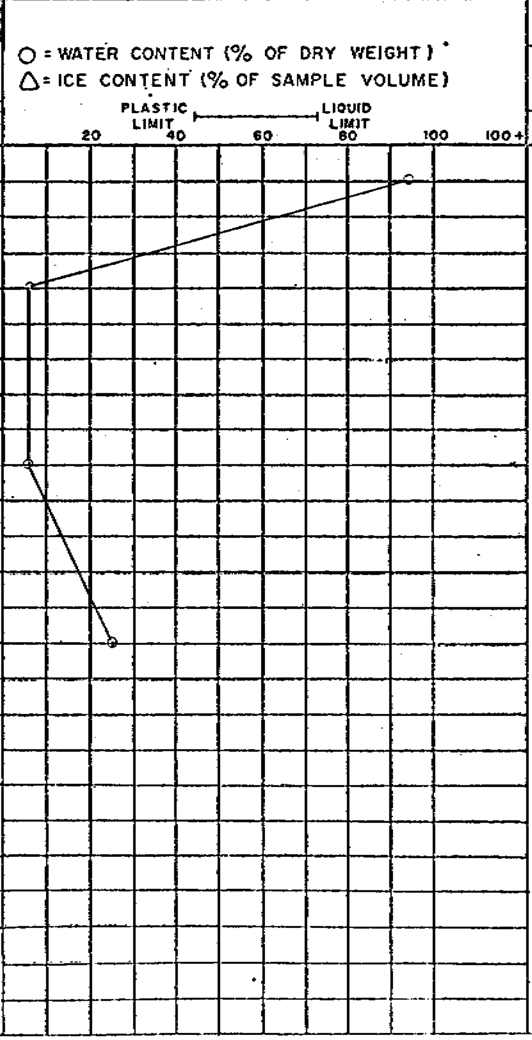


PLATE 19