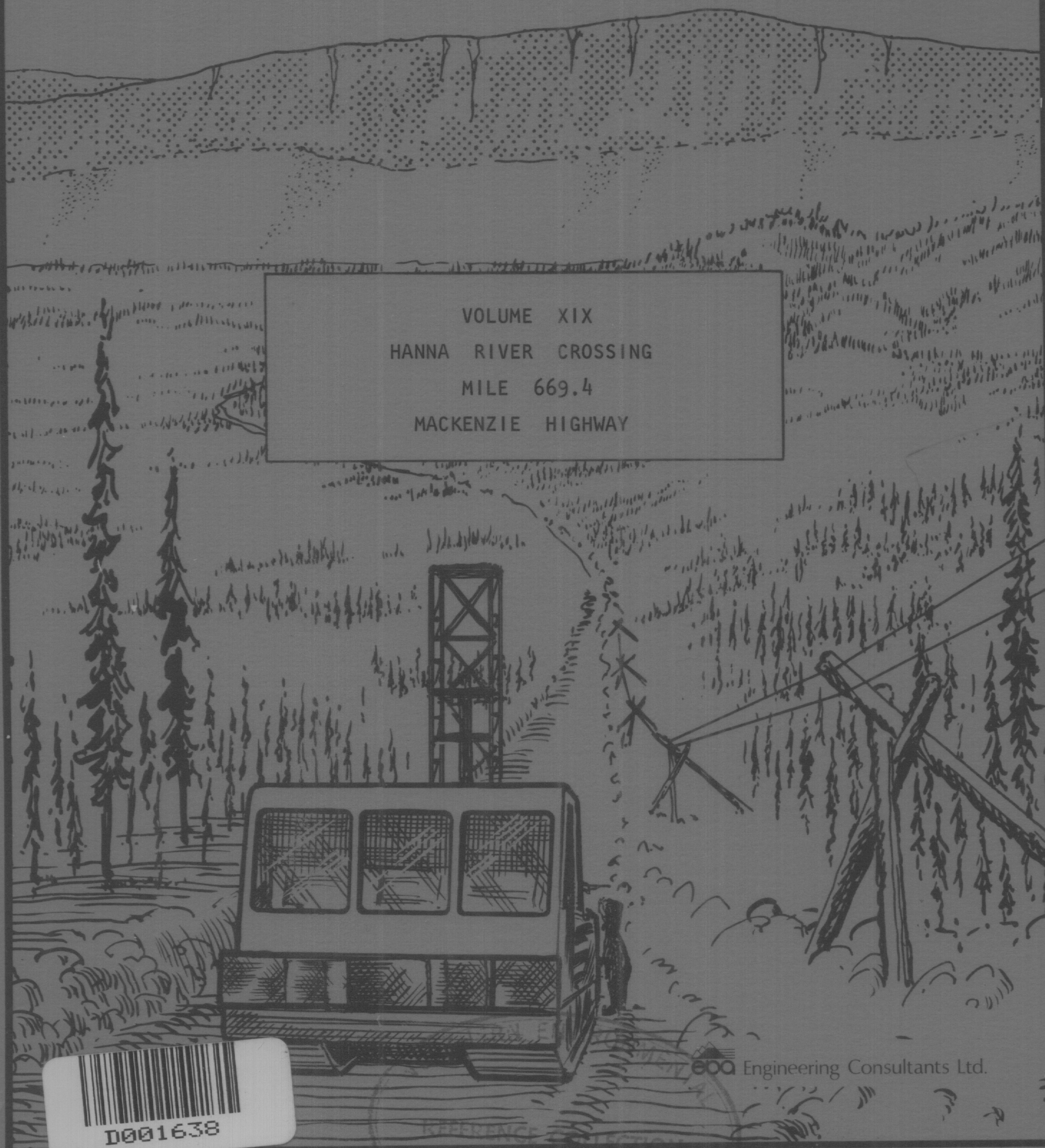
MACKENZIE HIGHWAY
GEOTECHNICAL EVALUATION



VOLUME XIX

HANNA RIVER CROSSING

MILE 669.4

MACKENZIE HIGHWAY

EBA Engineering Consultants Ltd.

MACKENZIE HIGHWAY
GEOTECHNICAL EVALUATION
VOLUME XIX
HANNA RIVER CROSSING
MACKENZIE HIGHWAY

Submitted To:

GOVERNMENT OF CANADA
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EBA Engineering Consultants Ltd.

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I. INTRODUCTION

In conjunction with a geotechnical engineering study carried out from Mile 725 to Mile 632 of the proposed Mackenzie Highway, several major river and stream crossings were investigated. The Hanna River Crossing, whose geographic location is shown on the Key Plan, Drawing No. A-1, Appendix A, is one such site investigated in detail. Details of the investigation, site conditions, geotechnical data and recommendations pertinent to the development of the river crossing, are reported herein.

This work was carried out for the government of Canada, Department of Public Works, and was authorized by Contract Number A10/73, File No. 9305-52-307.

II. GEOTECHNICAL DATA AQUISITION

2.1 Field Testing

The evaluation of subsurface conditions has been based on field data obtained from thirteen boreholes, drilled at the locations shown on the Site Plan, Drawing No. A-2, Appendix A. Of the thirteen boreholes advanced, two were drilled as center line boreholes, in conjunction with the general route evaluation, and the remainder were located and drilled specifically to define subsurface conditions at the river crossing.

The special boreholes consisted of Boreholes 669-S-1, 669-S-2, and 669-S-4 to 669-S-12, inclusive. The two center line boreholes were designated Boreholes 669-C-6 and 669-C-7. Detailed borehole logs are presented in consecutive order in Appendix B.

The center line boreholes were drilled with a Texoma Super Economatic power auger, fitted with a 12 inch diameter stub auger. All special boreholes were drilled with a track mounted Mayhew 500 rotary drill rig, using a continuous air return circulation system. Boreholes advanced with this drill rig generally were 4-3/4 inches in diameter. Borehole penetration ranged from 15 feet to 51 feet, and averaged 30 feet in depth. Sampling consisted of representative bag samples, obtained at depths of 2-1/2 and 5 feet, and at depth intervals of about 5 feet, thereafter, to the bottom of each borehole. Two core samples and one Shelby tube sample were obtained from Boreholes 669-S-9 and 669-S-12, respectively.

2.2 Laboratory Testing

Laboratory testing was carried out on disturbed soil samples to determine the natural water content profile, Atterberg limits, grain size distribution, soluble sulphate concentration, and pH of the subsoil. The moisture content tests were undertaken in the field laboratory of EBA Engineering Consultants Ltd., while all other testing was confined to the EBA Edmonton laboratory. One unconfined compression test was performed on thawed undisturbed clay, the result of which is noted on Drawing No. C-6, Appendix C. In addition to the laboratory testing outlined above, all samples were visually classified in both the EBA field and Edmonton laboratories. Soil classification was based on plasticity, according to the extended Unified Classification System [(1)*], and on textural classification according to U.S. Engineers Department [(2)] textural classification triangle.

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* Superscripted numbers in parentheses refer to the List of References presented at the end of this report.

Frozen ground was classified according to a modification of the NRC system for describing permafrost [3]. This modification was necessary because the disturbed nature of the samples obtained did not permit full usage of the NRC system; especially in describing the form of the excess ice. The system used retains the symbols V and N for visible and non-visible ice, respectively, and the modifying symbols B and F for well bonded and poorly bonded non-visible ice, respectively. Excess ice quantities were estimated from visual observations. The results of laboratory tests are presented on the borehole logs (Appendix B), where applicable, and on grain size distribution curves, Drawings No. C-1 to C-5, inclusive, Appendix C. Drawing No. C-6 presents a partial summary of laboratory results.

III. SITE CONDITIONS

3.1 Surface Features and Geology

The proposed Mackenzie Highway crosses the Hanna River at Mile 669.4, approximately 38 miles north-west of Norman Wells, N.W.T., Drawing A-1, Appendix A, is a Key Plan of the Hanna River area and Drawing No. A-2, Appendix A, presents a detailed Site Plan. Plates 1, 2 and 3, of Drawing No. A-3, Appendix A, show the crossing from the air in both February and June, 1973.

The Hanna River drains a large area extending east of Paige Mountain and south-east of Brokenoff Mountain. Moon Lake appears to be the principle reservoir of the Hanna River system, but several smaller lakes may also contribute substantial base flow, as they are probably spring fed throughout the entire year. The large watershed of the Hanna River results in a substantial stream flow throughout the summer and fall. In the winter there is probably a continuous flow of water under the ice.

Aerial photographic interpretation of the surficial geology of the immediate area of the Hanna River Crossing, is shown on Drawing No. A-2, Appendix A. The surficial materials are believed to be glacial lake basin sediments, with peat being noted in depressions. Active flood plain and alluvial meander plain deposits exist in the immediate vicinity of the Hanna River channel. A terrain legend, which describes the symbols used in the terrain analysis, is presented as Drawing No. A-2a, Appendix A.

3.2 Subsurface Conditions

Based on observations from the boreholes, inferred stratigraphic sections along center line and on two cross-section lines have been compiled and are presented as Drawings No. A-4 and A-4a, respectively, Appendix A. The generalized center line stratigraphy noted at the site is summarized in Table 3.2.1, following.

TABLE 3.2.1
STRATIGRAPHY AT HANNA RIVER CROSSING

MATERIAL	DESCRIPTION	APPROXIMATE AVERAGE DEPTH BELOW EXISTING GRADE (FT)	AVERAGE RANGE OF THICKNESS (FT)
PEAT (BH's 669-S-6 & 669-S-12, only)	black, fibrous, silty V 35% - 40%	0-1.5	1 - 2
CLAY -SILT	low to medium plasticity, brown to grey, some sand, M/C 21% - 284% (avg. 48%), unfrozen to frozen, V 0% - ice	Below 0	Not Established

The following additional information, which may influence design or construction decisions, was also obtained during the field investigation.

1. The maximum depth of borehole penetration was 51 feet.

2. Partially unfrozen material was observed below 12 feet in depth in Borehole 669-S-6, 30 feet in depth in Borehole 669-S-7, 30 feet in depth in Borehole 669-S-8 and 25 feet in depth in Borehole 669-S-11.

3. A silt layer, 9 feet in thickness, was noted at and below the ground surface at the location of Borehole 669-S-2.

4. Ice was recorded in the upper 3 feet of Boreholes 669-C-6, 669-C-7 and 669-S-7.

5. No borehole information is available in the bottom of the creek channel to indicate the type and nature of underlying subsoil materials.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Foundation Types

At present, preference is given to pile foundation systems supported on bedrock. However, final selection of a foundation system should be determined in conjunction with economic and structural design considerations. The following foundation types are believed to be feasible for a bridge structure at the subject site.

1. Closed end pipe piles driven in pre-bored holes.
2. Driven steel H-Piles.

4.2 Foundation Design

Major factors affecting the design of pile foundations at the Hanna River Crossing are the occurrence of unfrozen zones within the subsoil, a high percentage of visible ice, and high natural moisture content at or near the assumed abutment locations of the proposed bridge. Generally, the subsoil was noted to be frozen near the creek. However, the noted unfrozen zones, in the general area of bridge construction, and the possibility of unfrozen subsoil beneath the river flood plain and channel, renders pile design, based on soil adfreeze principles, hazardous. Consequently, it is considered that allowable pile bearing capacities must be determined on the basis of available end bearing support, and/or available skin friction support of existing subsoil material in the unfrozen state. In addition, the existence of frozen zones is considered to preclude the use of dyanamic pile formulae as a rational approach to the determination of pile capacities. However, placement of piles through pile driving techniques will likely be the most expedient method of installation.

Because of a lack of data with respect to soil strength and depth to a frost stable bearing surface, pile designs presented herein are largely based on empirical data, and must be considered, only preliminary in nature. Confirmation of the design parameters presented herein through additional field and/or laboratory testing is considered necessary.

The recommended foundation types listed in Subsection 4.1, may be designed in accordance with the following preliminary design parameters. However, it is stressed that the following recommendations are presented without knowledge of final design highway grades, geometrics, or bridge design. Consequently, the recommendations presented may require reconsideration when these factors become known.

4.2.1 End Bearing Piles

It is considered that the only positive method of foundation support, that will permit relatively high loads without excessive settlements at the Hanna River Crossing, is an end bearing pile system achieving support on bedrock existing beneath the site. However, due to equipment limitations the maximum depth of drill penetration was 51 feet, with bedrock not being encountered.

Based on a review of bedrock geology of the area, it is believed that shale and/or sandstone bedrock of Upper to Middle Devonian Age [4] may be expected at an unknown depth below the approximate abutment locations of the proposed river crossing. It is recommended that consideration be given to the use of steel end bearing piles for bridge foundation support. However, determination of bedrock depth and properties, at the locations of bridge abutments and piers, is a necessary prerequisite to determination of a final design pile capacity.

For preliminary design purposes, it is believed that consideration should be given to the use of closed end pipe piles to provide end bearing support in bedrock. It is recommended that piles with a minimum nominal diameter of 12 inches and a minimum weight of 65 pounds per foot be used. The design length of piles must be confirmed on the basis of additional field drilling.

Installation of pipe piles will require the use of both drilling and pile driving equipment. It is recommended that the piles be installed in pre-bored holes having a diameter of about 95% of the pile diameter to permit a snug fit. The pile holes should be prebored at least 5 to 10 feet into the bedrock, or until drilling refusal is met, whichever is shallower, and the piles should be driven to at least the full prebored depth. A minimum driving energy of 24,000 foot pounds is recommended. Steel H-piles are presently believed to be less feasible, as preboring would result in loss of lateral support, and installation without preboring to the anticipated depth is expected to meet with high driving resistance. Confirmation of this, however, could be achieved through the driving of test H-piles at the site.

A preliminary design load capacity of about 170 kips may be used for the foregoing recommended pipe pile section, if the piles can be driven to 'refusal' in bedrock. It is considered that 'refusal' will constitute a penetration of less than 0.1 inch per blow, measured over the last foot of driving with the recommended pile driving energy. It is recommended that pile driving records be kept for all piles, for immediate review by the geotechnical consultant. A pile load test is also recommended, prior to or at the outset of pile installation, to confirm the load carrying capacity of the piles and permit a correlation to the driving records.

4.2.2 Friction Piles

Based on available geotechnical information at the Hanna River Crossing, it is believed that limited probability exists for the successful installation of piles at the site, achieving their load carrying capacity primarily through skin friction between pile and embedding soil. Hence, the present lack of specific information, with respect to the strength of insitu soils in an unfrozen condition, in combination with the above belief that long term satisfactory performance is a remote possibility, precludes the recommending of skin friction piles.

Confirmation of the suitability of friction piles, presentation of more detailed pile designs, and estimates of pile capacities can only be made if additional more detailed geotechnical information of subsurface deposits is obtained at the site.

4.3 Negative Skin Friction

The effect of negative skin friction, on individual piles and pile groups, will be dependent upon the occurrence and magnitude of both consolidation settlement and thaw settlement within the fill surrounding the piles and the natural subgrade soils. At the crossing site, it is considered that all clay and silt materials are thaw unstable and consequently significant negative skin friction effects can be anticipated in these materials if thawing occurs. Substantial skin friction effects will also be mobilized in any road grade fill surrounding piles if loss of subgrade support occurs. To limit the amount of thawing of the subgrade, the loss of subgrade support, and the magnitude of negative skin friction, fills should be placed during the winter season. In order to further limit potential negative skin friction, due to settlement of the fill itself, it is recommended that fills be placed to final grade and pre-boring and installation of piles be carried out through the fill. The maximum time period possible should be allowed between these two phases of construction.

It is extremely difficult to accurately predict the anticipated total magnitude of negative skin friction loads on any pile or pile group that may be installed at the subject site. Negative skin friction develops due to the downdrag effect of the soil around the pile as it thaws and consolidates. Table 4.3.1 presents suggested values [5] for negative skin friction in typical soils. At the Hanna River Crossing, the thickness of fill placed and method of placement will significantly effect the depth and rate of thaw wherever the soil is presently frozen.

TABLE 4.3.1

NEGATIVE SKIN FRICTION OF UNFROZEN SOIL FOR PILE DESIGN
(After Woodward Lundgren And Associates, 1971) (5)

Description of Soil Categories	Design Negative Skin Friction
Clean sands and gravels with little or no silt or clay. Typically: GW, GP, SW, SP	$P_s = 30d\ (X^2 + 2HX)$*
Silty or clayey sand and gravel mixtures with considerable amounts of silt and clay. Typically: GM, SM, GC, SC, SF	700 PSF
Moderately plastic to highly plastic inorganic clays. Typically: CL, CH	800 PSF
Non-plastic to slightly plastic inorganic silts and lean clays. Typically: ML, MH	350 PSF
Organic silts and clays. Typically: OL, OH	150 PSF

*Load developed on that portion of a pile embedded in granular stratum.

P_s = Load developed, lbs.
d = Diameter of pile, ft.
H = Depth of overburden to top of granular stratum, ft.
X = Length of pile embedded in granular stratum, ft.

However, for preliminary design purposes and an assumed depth of abutment fill of about 10 feet, it is believed that about 5 feet of thaw may take place in the natural subgrade which will contribute to negative skin friction. This estimate assumes that the fill is placed during the winter on a frozen subgrade.

4.4 Frost Heave of Piles

Frost heaving of piles can occur as the active layer freezes each winter. During the cold winter months, the surface soils freeze and bond to the pile at low temperatures. In soils containing silt and clay this shallow surface adfreeze, if accompanied by ice lens formation, exerts a heaving force on the pile which must be resisted by the dead load on the pile, the available adfreeze bond in the permafrost, and/or pile skin friction within unfrozen soil zones in which the pile is embedded.

In order to prevent pile heave, it is necessary to check the pile design to ensure that the available resisting forces provide an adequate factor of safety against seasonal frost heaving. In general, it has been found that slightly deeper pile embeddment is the most feasible means of overcoming undesirable frost heaving stresses, if they exceed the sum of the total resisting forces divided by the factor of safety. Suggested design stresses for general permafrost soils are presented in Table 4.4.1 [(5)] and may be used for preliminary design purposes.

TABLE 4.4.1

FROZEN SOIL ADFREEZE BOND STRENGTH FOR PILE DESIGN
(After Woodward Lundgren And Associates, 1971) (5)

Design Category	Applicable Criteria: Segregated Ice Condition	Applicable Criteria: Water Content of Soil %	Design Adfreeze Bond Stress, for Frost Heaving Soils[1] (PSF)
I -above average soil-ice condition	No visible ice, (< 1%)	15 15 - 40	5000 4000
II -average soil-ice condition	Little visible ice, (1 - 10%)	15 15 - 40	4000 2000
III -below average soil-ice condition	Occasional visible ice, (11 - 20%)	15 15 - 40	2000 1500
IV -poor soil-ice condition	Some visible ice (21 - 35%)	40 15 - 40	1350 1350
V -very poor soil-ice condition	Considerable visible ice, (>35%)	40 Any	900 700

[1] Applies only for soils containing 5% or more of silt or clay size particles.

4.5 Subgrade Considerations On Center Line

As indicated in Table 3.2.1, the stratigraphy on center line, on both sides of the creek, is similar. Generally, clay and/or silt were noted from existing grade to the maximum depth of borehole penetration. A thin organic cover was noted at one center line borehole location. Estimated visual excess ice contents are generally high near the surface, becoming lower with increasing depth. Moisture contents are high and it is expected that very soft conditions will probably exist in unfrozen soils during the summer season. A winter construction program is, therefore, advocated to limit undesirable disturbance to the sub-grade thermal regime.

Qualitative evaluation of shear strength of the silt and/or clay can be made, from visual observations, ice content estimates, moisture content profiles, and classification test results. In addition, limited quantitative evaluation of shear strength can be made, based on the single laboratory strength test on thawed undisturbed clay. Based on these factors, it is concluded that on thawing, low shear strength will exist in the silt and/or clay. Generally, below 25 feet from existing grade, the moisture content in the silt and/or clay is low enough that it is expected to have a moderate shear strength on thawing.

A lack of detailed information, with regard to ice contents, and a need for sophisticated testing and detailed computer analyses, makes it impossible to accurately predict thaw settlement of fill on frozen materials with excess ice contents. Therefore, only qualitative estimates of thaw settlement can be made at this time. Based on visual estimates of excess ice content, it is believed that a total thaw settlement on center line (approach fill about 6 feet in thickness) of about 1 to 2 feet can be expected for winter construction, and 2 to 3 feet for summer construction. This estimate assumes thawing of subgrade soils, but does not take into account normal consolidation settlement of the unfrozen subgrade soils due to the surcharge effects of the road bed fill. In the case of peat soils, normal consolidation settlement can easily reach 50 percent of the original thickness of the deposit and can, as with thaw settlement, occur fairly rapidly.

It is considered that the conventional northern construction practice of placing fill material directly on the organic subgrade is desirable at this site. Fills for bridge approaches should be constructed with allowance being made for the occurrence of thaw subsidence, if sufficient thickness of fill is not placed to preserve the frozen subgrade. Allowance for expected subsidence can be made by either providing extra fill to compensate for the anticipated settlement, or to upgrade as subsidence occurs, or both. A 6 foot thickness of granular fill material (non-plastic) is considered to be the minimum depth for road grade construction on underlying frozen subgrade materials at the Hanna River Crossing. Local fine grained materials, such as silt and silty clay, are not considered suitable for abutment or approach fills. The thickness of road grade material required to prevent degradation of the permafrost can only be predicted after detailed theoretical analysis, which is considered to be beyond the scope of this investigation. It is believed that fill placement should be carried out during the late winter period to minimize thermal disturbance, and possible damage to the existing ground cover and slopes by the construction equipment. Snow clearing should be carried out prior to all fill placement. Placement of the fill should be undertaken by end dumping with subsequent spreading by dozing equipment. A minimum initial lift thickness of 2 feet is suggested. Depending on construction completion schedules, placement of fills may be staged for several seasons or carried to completion as construction progresses.

It was not possible to drill through the ice into the creek bed. Therefore, the extent and characteristics of the creek bed gravel could not be determined. However, it is believed that gravel underlies the active stream channel. It is impossible to estimate the maximum depth of scour based on the available data.

It was noted at the time of drilling (first week of March, 1973) that the river was covered with ice but there was water flowing under the ice cover. It is probable that water continues to flow throughout the winter. Therefore, a potential icing problem may develop with respect to winter construction and maintenance.

4.6 Slope Stability Considerations

No evidence of recent slope instability was detected on either valley wall in the immediate vicinity of the proposed crossing. The slope gradient along center line ranges from about 11 to 22 degrees (about 20 to 40 percent grade) in the immediate vicinity of the Hanna River.

Cursory slope stability calculations, utilizing implied shear strength parameters for thawed materials and the surveyed slope configuration, indicates a marginal factor of safety with respect to slope stability. Consequently caution is advised when constructing on or in the vicinity of slopes immediately adjacent to the Hanna River at the crossing site. Detailed consideration of slope stability conditions at this site are recommended. In any event, it is recommended that excessive fill thicknesses be avoided near the crest of slopes. In addition, cutting or excavating of slope material is not recommended and desired grades should be achieved solely through the placement of fill.

It is considered that rip-rap protection of the existing defined river channel, upstream and downstream of the bridge crossing, may be necessary to protect the stability of the crossing site. Bridge abutments should be set as far back from the channel banks as is practicable. Fine grained fills should not be used for subgrade construction on the flood plain as they are easily eroded.

4.7 Drainage Considerations

Approach fills will concentrate runoff water along the upslope sides of fills. Therefore, it is considered essential that significant effort and care be taken to minimize erosion on the slope parallel to the fill. Every effort should be made to preserve the vegetal lining of all designed water courses and wherever this is impossible, coarse gravel should be used as channel lining. Transverse flow breakers should be provided at frequent intervals to reduce the rate of runoff along the fill and thereby reduce the potential for erosion by running water. Spacing of flow breakers will become apparent in the field when drainage courses and gradients become accurately defined. Ponding of water adjacent to fills should be discouraged as ponded water will act as a heat source for rapid degradation of permafrost. It will also tend to reduce the shear strength of the subgrade soil and road grade fill, unless the road grade is very granular.

4.8 Cement Type and Corrosion Considerations

A representative sample from the crossing area was tested to determine the soluble sulphate concentration and soil acidity. The soluble sulphate concentration determined rates as positive and the pH test result indicates a slightly acidic condition. It is recommended that the use of Type V Sulphate Resistant Cement be considered, for preliminary design purposes, for all concrete in contact with the soil, until further test results are available. Confirmation soil sulphate analyses can be performed prior to construction. A minimum '28 day' compressive strength of 3000 pounds per square inch is recommended for all concrete forming foundation elements.

For steel pipe piles, extending above grade or above the groundwater level, corrosion protection may be achieved by painting or encasement with concrete. In this instance, the protective coating should extend to a minimum distance of 2 feet below final grade or minimum anticipated low water level, whichever is deeper. In the case of pipe piles, protective coating should be provided on the interior of the pipes to prevent possible corrosion. If practical, this may be achieved through filling of the piles with concrete.

4.9 Additional Studies

In order to more accurately assess such factors as insitu shear strength, thaw subsidence, and slope stability, it is desirable to obtain additional detailed geotechnical information at the site. Such items as acquisition of representative undisturbed samples of the various soil types, a thorough study of existing local slopes, refined field and laboratory tests to determine shear strength and thaw subsidence factors, and a refined theoretical analysis of these factors, constitute the additional detailed geotechnical information that is considered to be desirable.

In addition to the desirability of obtaining further detailed geotechnical information, it is recommended that consideration be given to establishment of a series of closely supervised and documented pile driving and pile load tests. Although preferable, these tests need not be carried out at actual bridge crossing sites, but may be carried out in areas and materials that would be representative of general foundation conditions at most of the proposed bridge sites. Such tests would provide valuable design data on which future designs of pile foundation systems could be established.

V. LIMITATIONS

The foregoing recommendations have been prepared based on our knowledge of existing conditions at the Hanna River and the proposed highway crossing. This knowledge has been derived from visual, physical and analytical considerations of existing soil and slope conditions, which were obtained from our field investigation. The findings and comments presented are believed to accurately reflect conditions as they are known to exist.

Due to the general nature of the study, reported herein, the findings cannot be considered to be a comprehensive assessment of slope and foundation conditions at the crossing. Should conditions be encountered other than described herein, the geotechnical consultant should be contacted so that recommendations may be evaluated in light of new findings.

Respectfully Submitted,

EBA Engineering Consultants Ltd.

G.R. Gilchrist, P. Eng.

L.A. Balanko, P. Eng.

GRG:lmh

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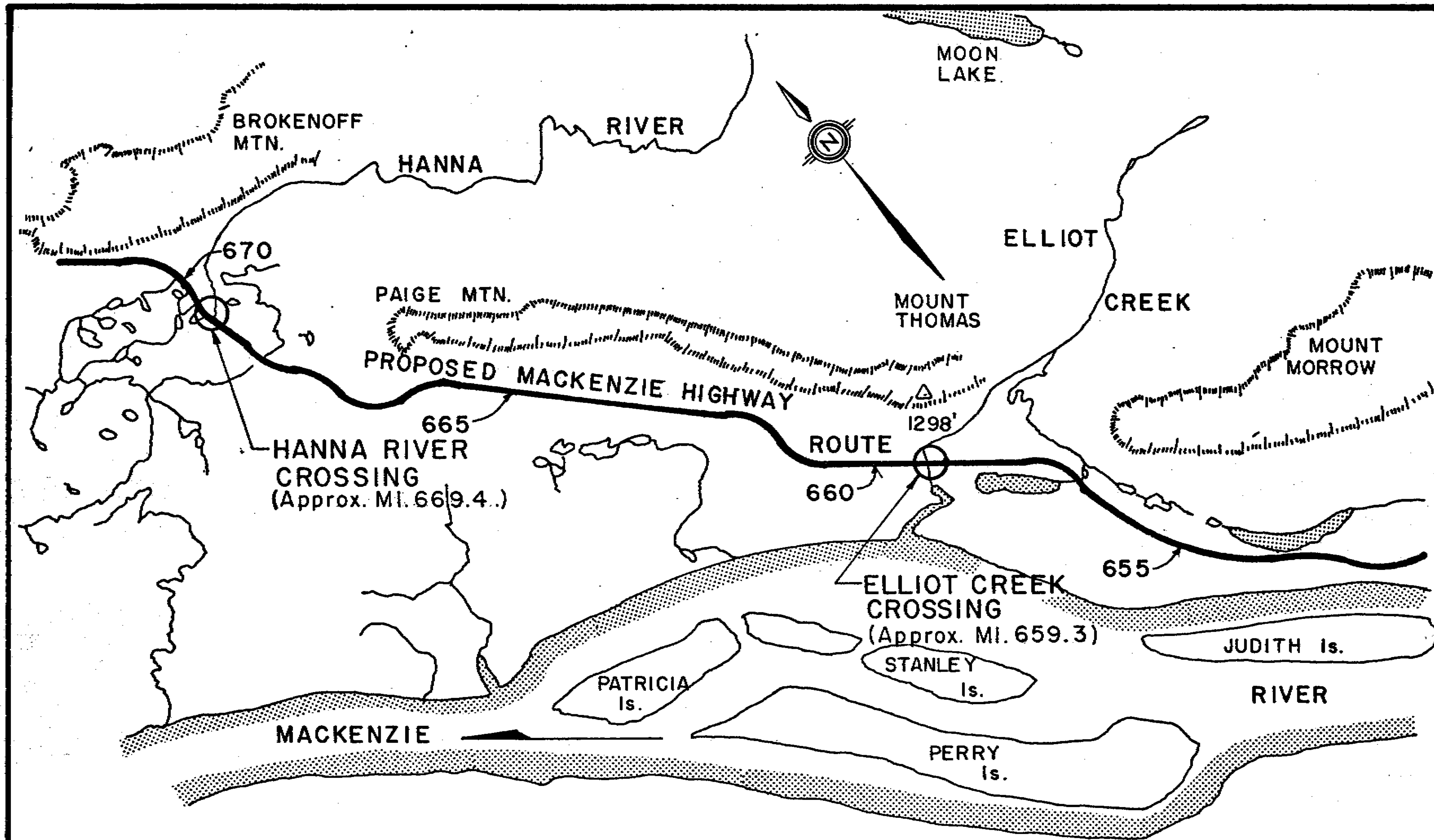

KEY PLAN

	DATE	SCALE	JOB No.	DWG No.
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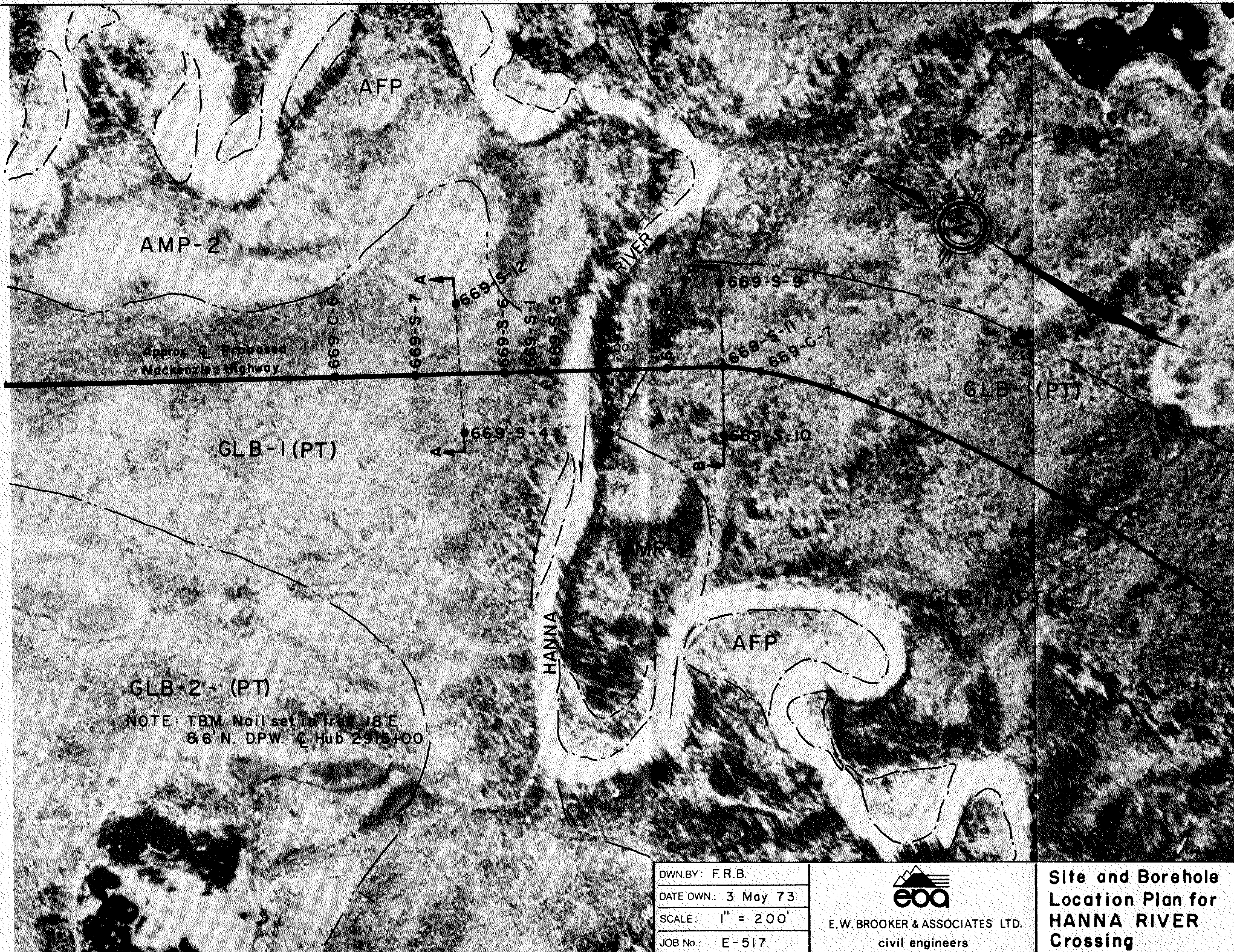


DWN.BY: F.R.B.	E.W. BROOKER & ASSOCIATES LTD. civil engineers	Site and Borehole Location Plan for HANNA RIVER Crossing	DWG.: A - 2
DATE DWN.: 3 May 73			
SCALE: 1" = 200'			SHT.No.:
JOB No.: E-517			

TERRAIN LEGEND

SYMBOL	TERRAIN TYPE	PHYSIOGRAPHIC FEATURES	MATERIALS DESCRIPTION
AFP	Active Flood Plain	Exposed bars in stream or river channel	Sand and gravel in high energy streams to silt and sand in low energy streams
AMP-2	Alluvial Meander Plain (excluding the Mackenzie River Plain)	Flood plains filling bottom of the stream	Fine silt, sand or gravel as channel deposits
GLB-1	Glacial Lake Basin (Better drained type)	Lowland occasionally swampy areas	Ice-rich to medium plastic silty clay, occasionally with a trace of sand
GLB-2	Glacial Lake Basin (thermo-karst type)	Lowlands usually swampy with thaw lakes	Usually peat covered glacio-lacustrine silty clay

Topstratum Phases (Associated with Terrain Types)

PT	Mixed bog and fen peats in post glacial ponded depression

Complexes are shown as combinations of two terrain types with or without phases that pertain to the parent type.

Terrain Symbols are modified from Canadian Gas Arctic Study Limited Terrain Study for this area.

Drawing No. A-2a

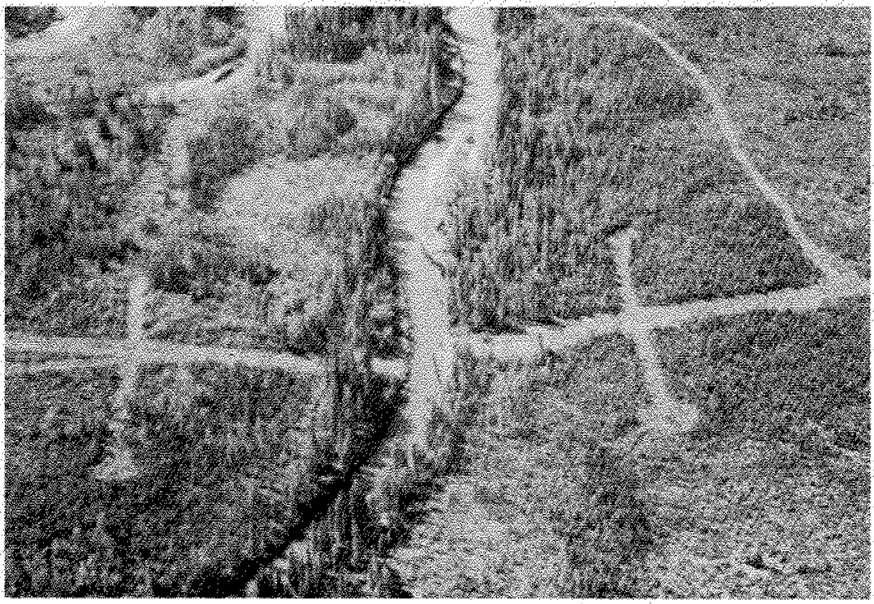


PLATE No. 1

General Site plan of the Hanna River Crossing. North is to the right of the plate. (June, 1973)

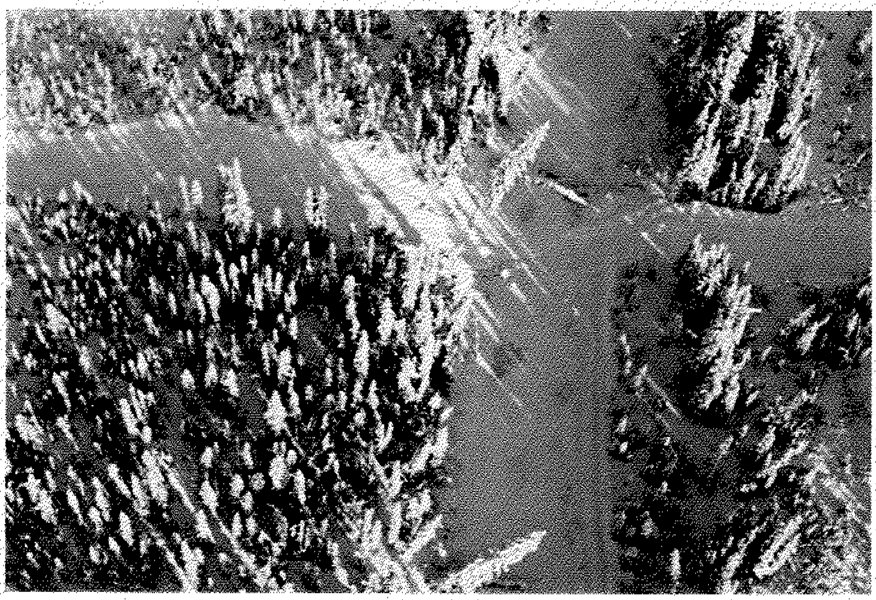


PLATE No. 2

Hanna River Crossing. North is to the left of the plate. (Feb., 1973)

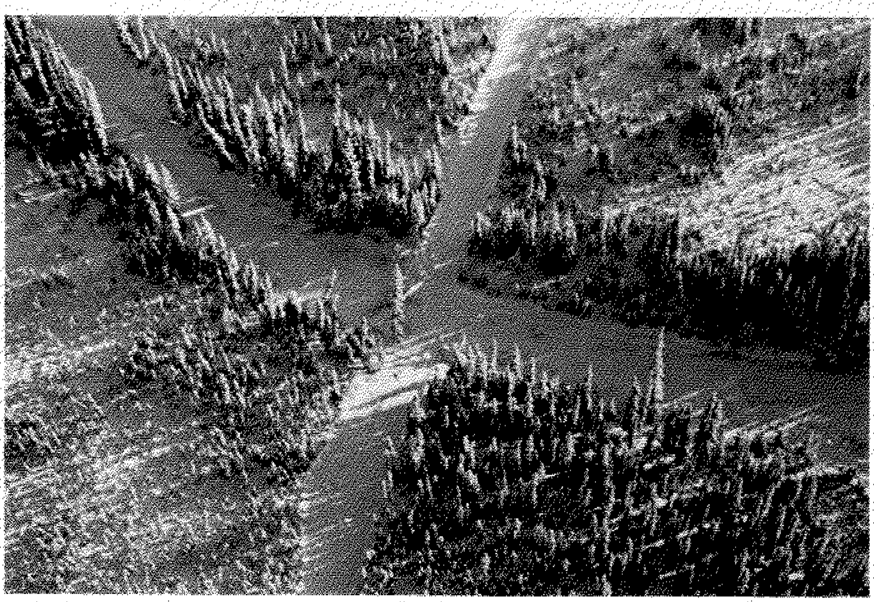
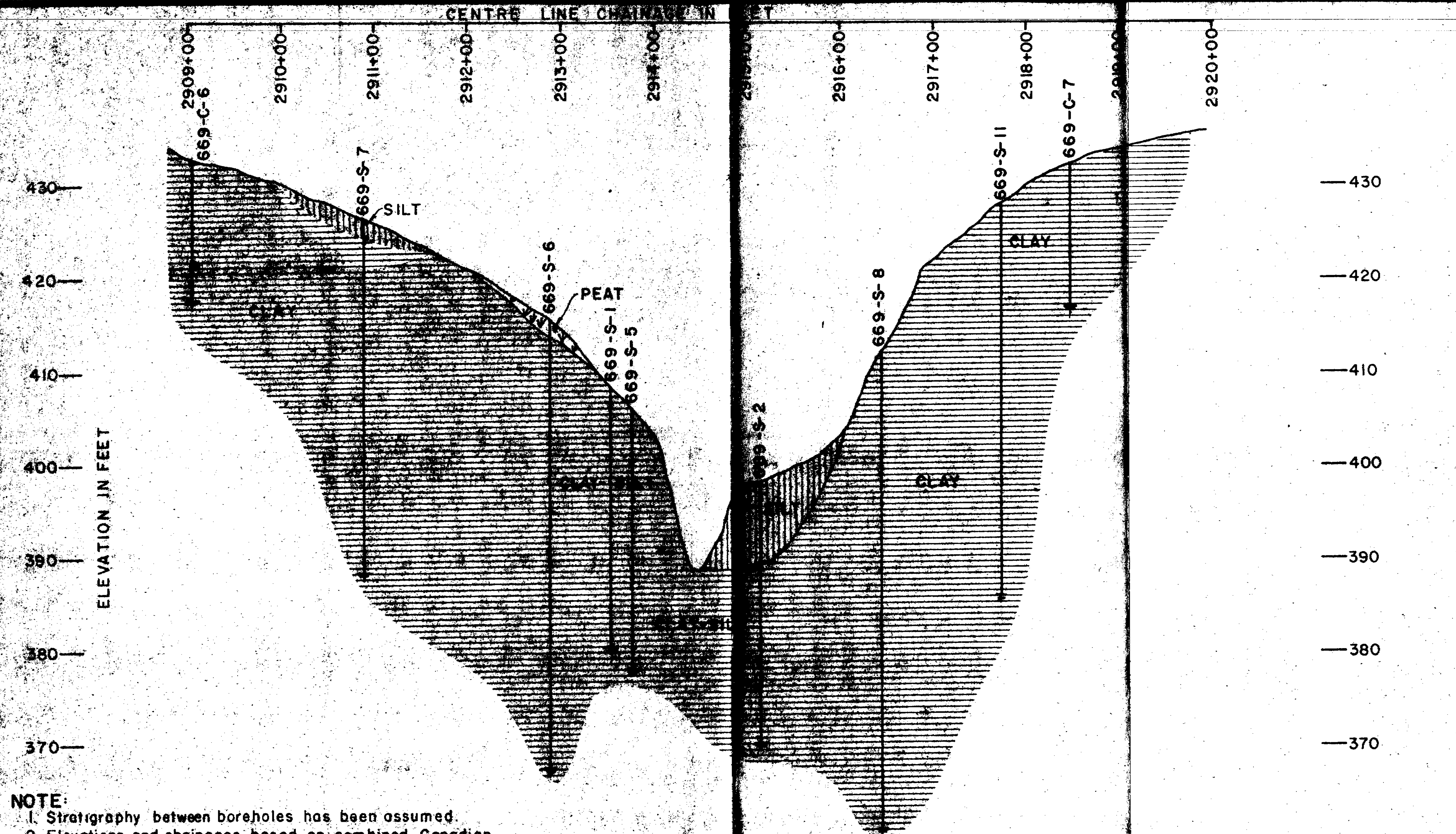


PLATE No. 3

Hanna River Crossing. North is to the bottom of the plate. (Feb., 1973)

Drawing No. A-3

E.W. Brooker & Associates Ltd.



NOTE:

1. Stratigraphy between boreholes has been assumed.
2. Elevations and chainages based on combined Canadian Engineering Surveys (CES) and EBA Surveys and related to CES datum.

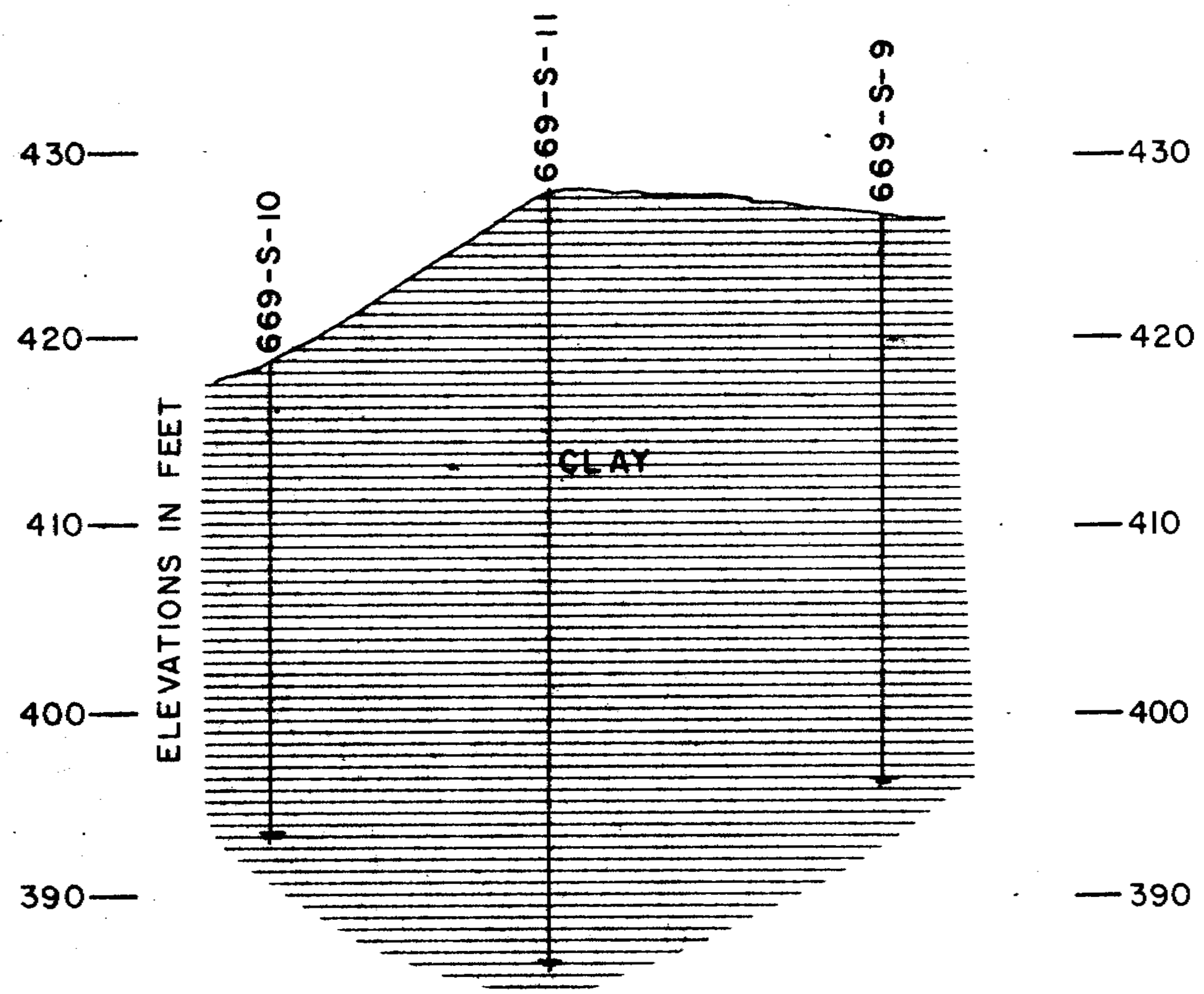
DWN BY: F.R.B.	
DATE DWN:	
SCALE: AS NOTED	
JOB No.: E-517	

EBA Engineering Consultants Ltd.

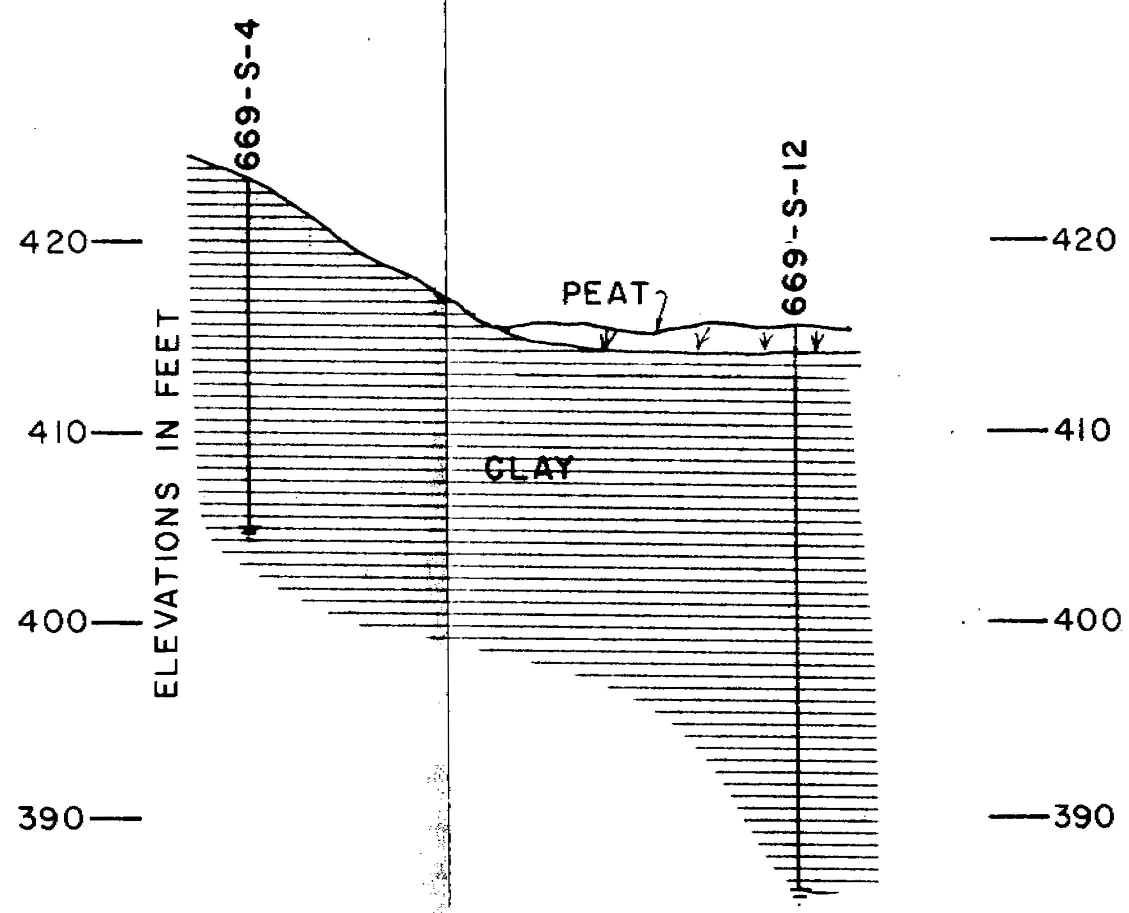
HANNA RIVER CROSSING
℄ PROFILE & STRATIGRAPHY

DWG.: A-4

SHT. No.:



SOUTH BANK
SECTION B-B



NORTH BANK
SECTION A-A

NOTE

1. Stratigraphy between boreholes has been assumed.
2. Elevations and chainages based on combined Canadian Engineering Surveys (CES) and EBA Surveys and to CES datum.
3. Scales: Horiz. 1" = 100'
   Vert. 1" = 10'

DWN.BY: F.R.B.	EBA Engineering Consultants Ltd.	HANNA RIVER CROSSING CROSS-SECTIONS & STRATIGRAPHY	DWG.: A-4,a
DATE DWN.:			
SCALE: As Noted			SHT.No.:
JOB No.: E-517			

E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

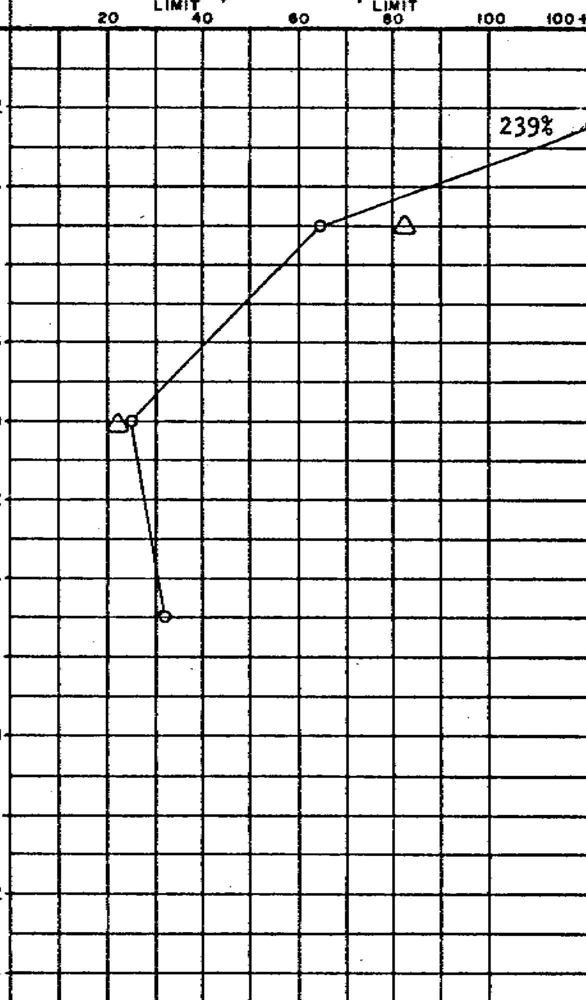
DWN: ALB	FIELD ENG: GRG	DATE DRILLED 12/2/73	AIRPHOTO NO: A22763-45 10	CHAINAGE: 2909 + 15		OFFSET	
CKD: NRM	TECH: HC	RIG: Texoma	SURFACE DRAINAGE: Good - South	VEGETATION: Bl. Sp. 10-20' Dense to Sparse		ELEV: 432.7'	

TEST HOLE		
MILE	B,C,S	NUMBER
669	C	6

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2						CLAY - Silty - Med. Brown		
2	1				CL	- Low Plasticity		ICE
4–6	2							V' 80-85%
8							F	V 20-25%
10	3				CI	- Dark Brown - Silty - Med. Plasticity		
12								NB
14	4					- Grey,		
15						END OF HOLE 15'		

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

PLASTIC LIMIT ├──┤ LIQUID LIMIT



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

REMARKS

Top of N. Bank of Hanna River.

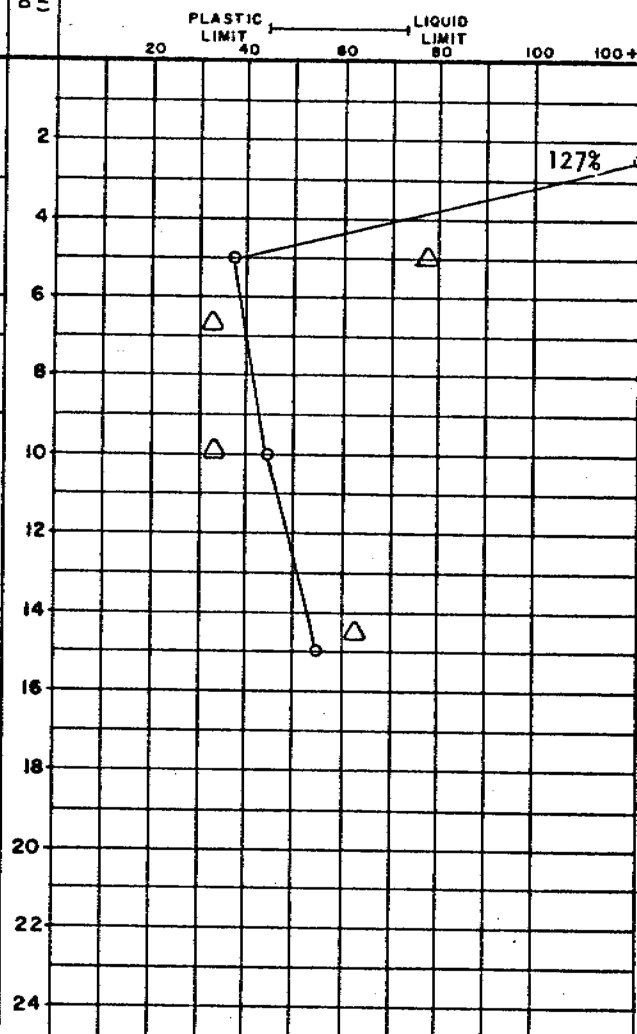
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: GRG	DATE DRILLED 12/2/73	AIRPHOTO NO: A22763-45	CHAINAGE: 2918 + 55	OFFSET
CKD NRM	TECH: HC	RIG: Texoma	SURFACE DRAINAGE: Very Good to North	VEGETATION: Bl. Sp. 5-10' Sparse	ELEV: 431.8'

TEST HOLE		
MILE	B,C,S	NUMBE
669	C	7

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2					CL	CLAY - Silty - Med. Brown - Low Plasticity	F	
2–3	1							ICE
3–6	2							V 75-80%
6–7								V 30-35%
7–9								NB
9–14	3				CI	- Grey - Med. Plasticity		V 30-35% to NB
14–15	4							V 60-65%
15						END OF HOLE 15'		

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



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

E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY**

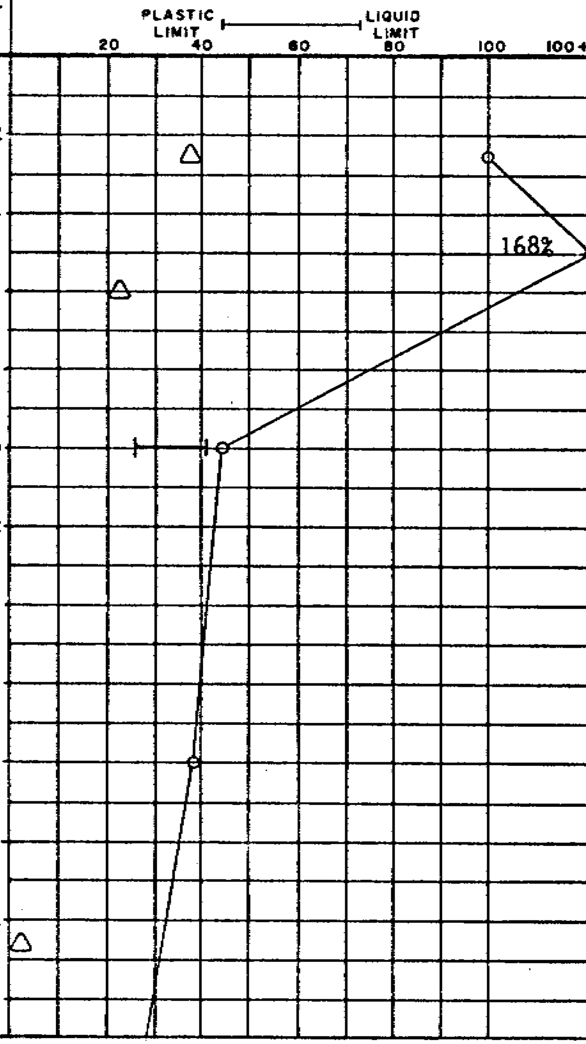
DWN: ALB	FIELD ENG: GRG	DATE DRILLED: 18/2/73	AIRPHOTO NO: A22763-45	CHAINAGE: 2913 + 60	OFFSET
CKD: NRM	TECH: DY	RIG: Mayhew	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV: 409.1

TEST HOLE

MILE	B,C,S	NUMBER
669	S	1

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2					OL to ML	CLAY - Dark Brown SILT - - Sandy (Fine) - Organic Trace of Gravel	F	V 35-40%
3	1							
4–5	2							V 20-25%
10	3					- Grey - Clayey, Sandy		
12					CI	- Med. Plasticity - (TILL - LIKE)		
16						- Some Fine Sand		NB
18	4							
21–22								V 1-5%
24								

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



DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
10	20	52	24	4		

REMARKS

North Bank of Hanna River

E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

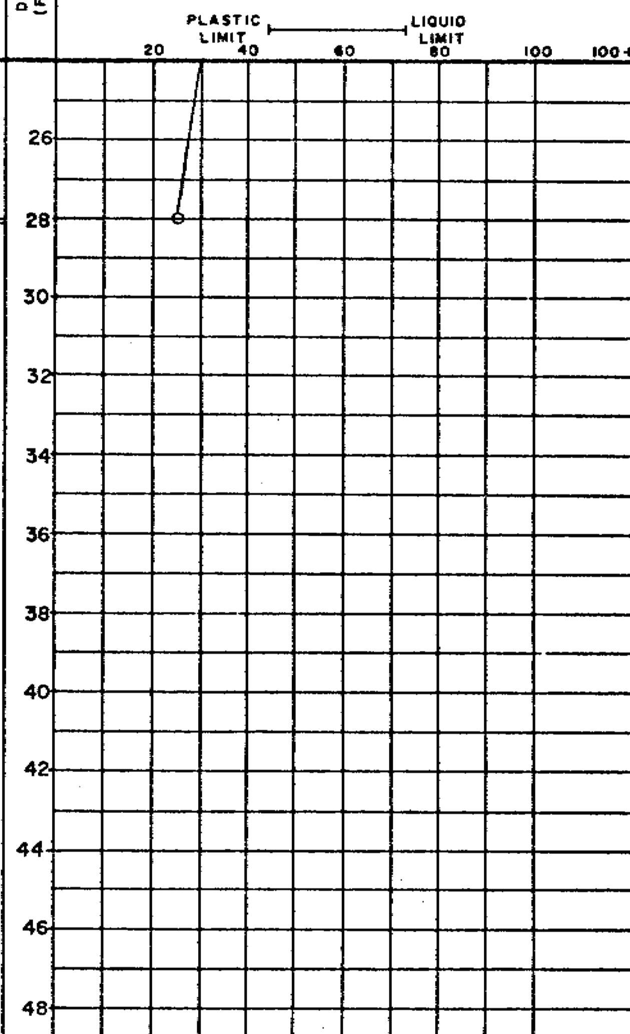
DWN: ALB	FIELD ENG: GRG	DATE DRILLED 18/2/73	AIRPHOTO NO: A22763-45	CHAINAGE: 2913 + 60	OFFSET
CKD: NRM	TECH: DY	RIG: Mayhew	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV: 409.1'

TEST HOLE

MILE	B,C,S	NUMBER
669	S	1

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
26					CI	CLAY SILT - Same as Above	F	V-1-5%							
28	5														
						END OF HOLE 28'									

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



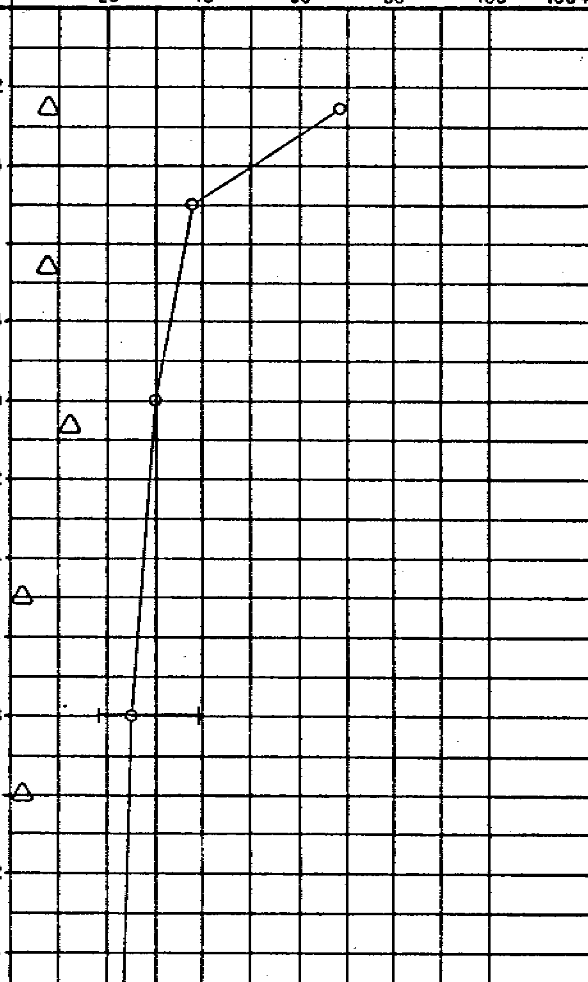
E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT — DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: GRG	DATE DRILLED 18/2/73	AIRPHOTO NO: A22763-45	CHAINAGE 2915 + 15	OFFSET
CKD: NRM	TECH: DY	RIG: Mayhew	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV: 398.3'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	2

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
0–9	1, 2				ML	SILT - Dk. Brown - Sandy - Some Clay - Low Plasticity - Fine to Med. Sandy	F	V 5-10%							South Bank of Hanna River
9–13	3				CL to CI	CLAY SILT - Grey - Silty - Low to Med. Plasticity		V 10-15%							
13–24	4					- Med. Plasticity		V 1-5%							

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



E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY	Page 2 of 2

DWN: ALB	FIELD ENG: GRG	DATE DRILLED 18/2/73	AIRPHOTO NO:	CHAINAGE: 2915 + 15	OFFSET
CKD NRM	TECH DY	RIG Mayhew	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV: 398.3'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	2

○ = 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
26					CL to CI	CLAY - SILT - Same as Above	F	V-1-5%	26							
28		5							28							
						END OF HOLE 28'										
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							

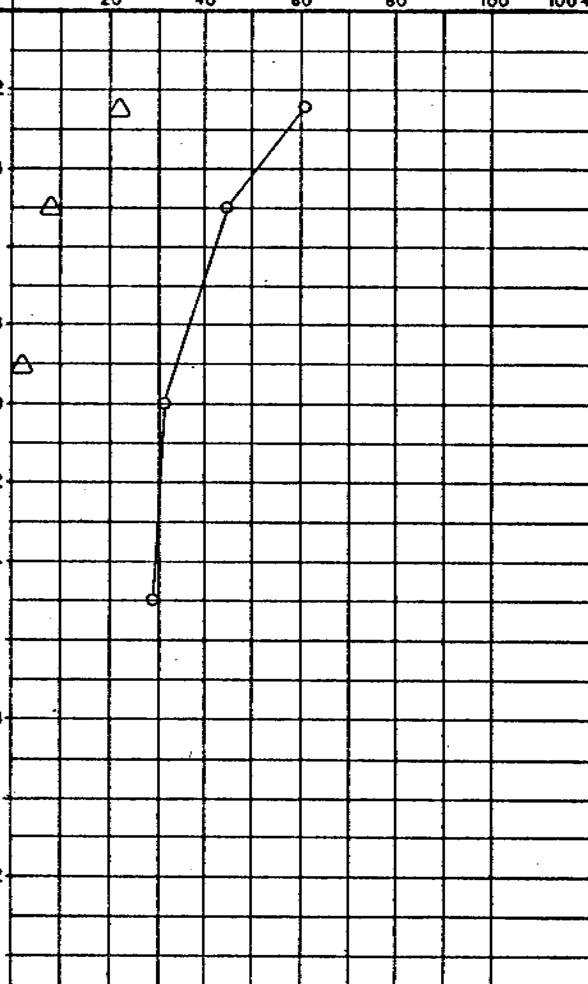
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2912 + 25	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 423.3'

TEST HOLE

MILE	B,C,S	NUMB
669	S	4

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.)
0–4	1				CL to CI	CLAY - Med. Brown - Silty, - Lowto Med. Plasticity - Trace of sand		V 20-25%						
4–7	2							V 5-10%						
7–11	3					- Grey - Silty	F	V 0-5%						
11–18	4					- Silty, Trace of sand		NB	49	44	7			
18						END OF HOLE 18'								



REMARKS

Hanna River West of ℄

E.W. BROOKER & ASSOCIATES LTD.

DRILL HOLE REPORT

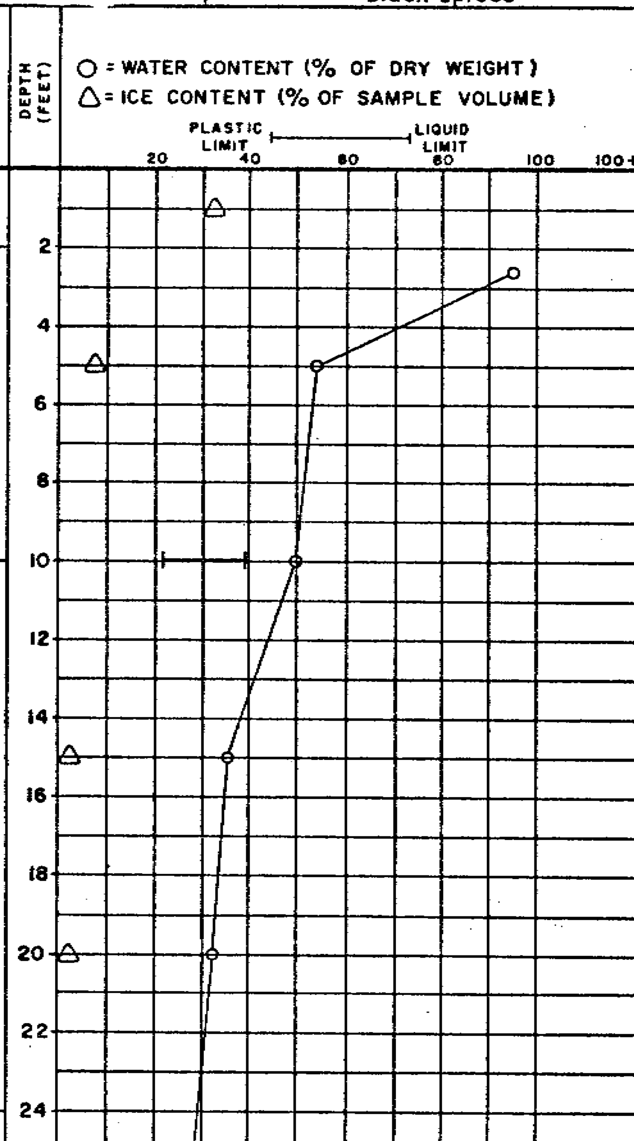
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG. NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 – 45	CHAINAGE: 2913 + 80	OFFSET
CKD NRM	TECH JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 406.3′

TEST HOLE

MILE	B,C,S	NUMBER
669	S	5

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2						SILT – Med. Brown CLAY – Low Plasticity – Trace of Fine Sand Near Top		V 30-35%
3	1							
2–10								V 5-10%
5	2				CL to CI			
10	3					– Clay-silty, Trace of Sand, Med. Plasticity		
15	4					– Grey – Low to Med. Plasticity	F	V 0-5%
20	5							



DEPTH (FEET)	GRAIN-SIZE ANALYSIS: CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0							Hanna River
10	30	65	5				

E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2913 + 80	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 406.3'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	5

○ = 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	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
25–28	6				CL to CI	SILT - CLAY - Same as Above	F	V- 0-5%							
28						END OF HOLE 28'									

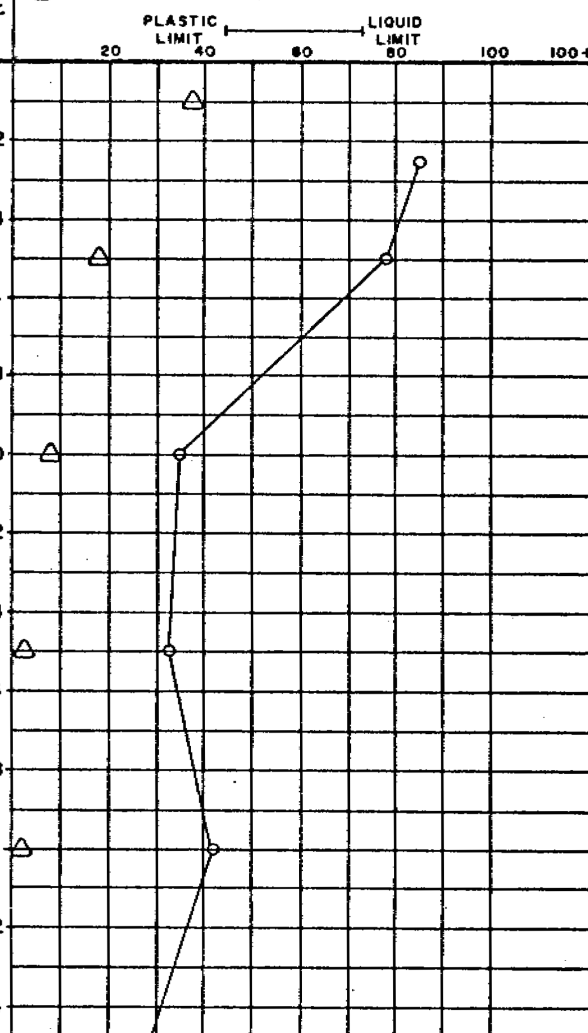
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2912 +85	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 417.3'

TEST HOLE		
MILE	B,C,S	NUMBE
669	S	6

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					Pt	PEAT - Black - Fibrous, Silty		V 35-40%							Hanna River
2–4	1					CLAY - Med. Brown - Clayey - Low to Med. Plasticity									
4–9	2				CL to CI			V 15-20%							
10	3					- Piece of Wood @ 10' - Grey	F	V 5-10%							
15	4						F to U								
18–20	5							V 0-5% to Unfrozen							
24															

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



E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

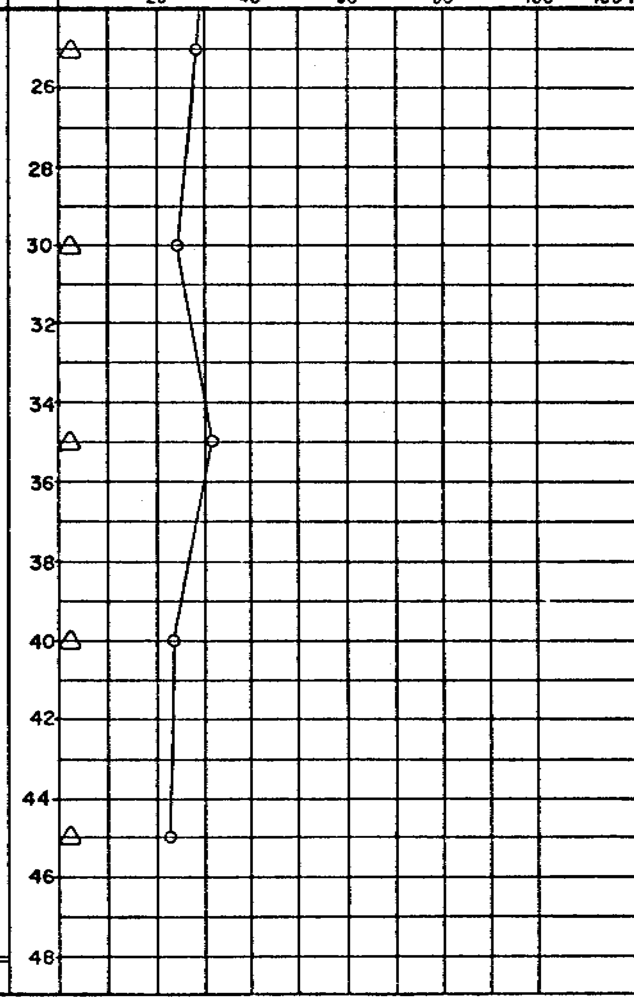
DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2912 + 85	OFFSET	
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 417.3'	

TEST HOLE

MILE	B,C,S	NUMBER
699	S	6

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					CLAY - Same as Above									
30	7				CL to CI		F to U	V'-0-5% to Unfrozen							
35	8														
40	9														
42															Hole terminated at 48' due to drill bit mudding up
48						END OF HOLE 48'									

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



E.W. BROOKER & ASSOCIATES LTD.

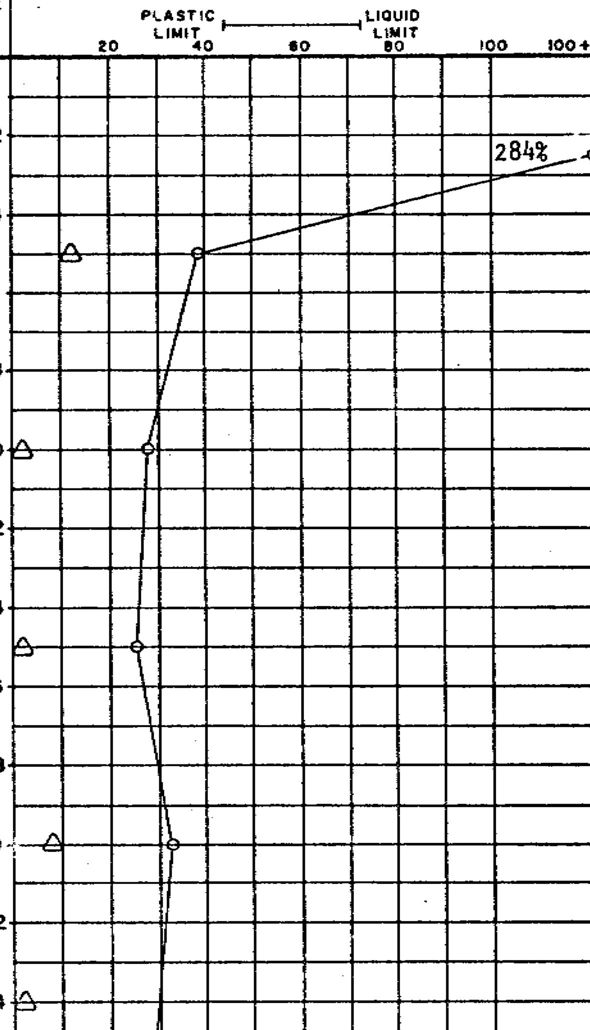
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2911 + 00	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 424.2'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	7

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
0–3	1				ML	SILT - Clayey - Med. Brown - Organic		ICE							Hanna River
3–24	2, 3, 4, 5				CL to CI	CLAY - Med. Brown - Silty - Low to Med. Plasticity; - Grey (at 15 ft)	F	V 10-15% (3–9 ft); V 0-5% (9–18 ft); V 5-10% (18–22 ft); V 0-5% (22–24 ft)							



E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2911 + 00	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to South	VEGETATION: Black Spruce	ELEV: 424.2'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	7

○ = 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 (PCF)	DRY DENSITY (PCF)	REMARKS
25–38	6, 7, 8				CL to CI	CLAY - Same as Above	U to F	V-0-5% to Unfrozen							Hole terminated at 38' due to drill bit mudding up
38						END OF HOLE 38'									

E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

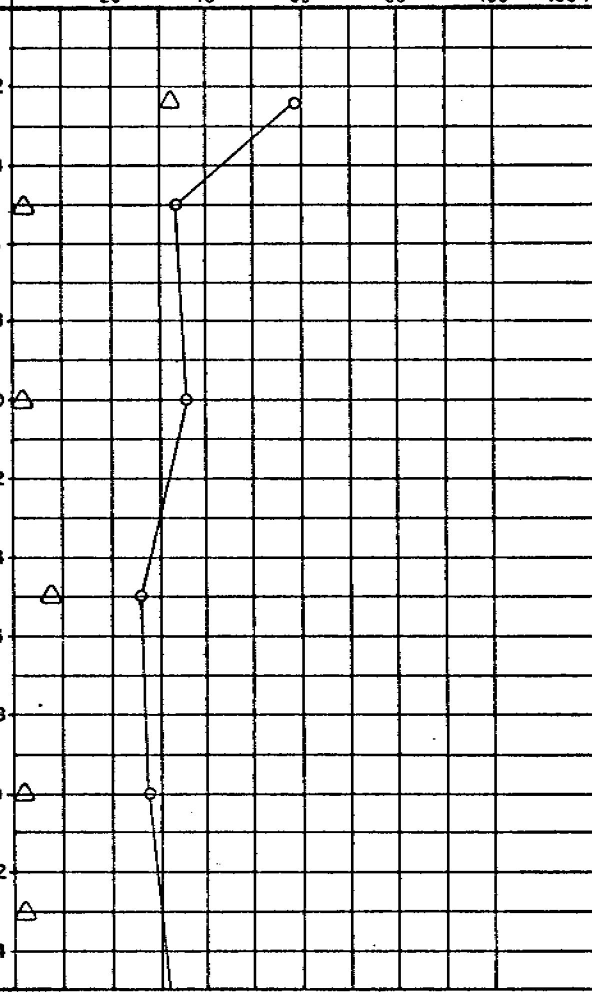
DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2916 + 55	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV: 413.4

TEST HOLE

MILE	B,C,S	NUMBER
669	S	8

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
0–3	1				CL to CI	CLAY - Med. Brown - Silty - Low to Med. Plasticity	F	V 35-40%	Hanna River
3–13	2, 3							V 0-5%	
13–16	4					- Grey		V 5-10%	
16–24	5							V 0-5%	

○ = 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)

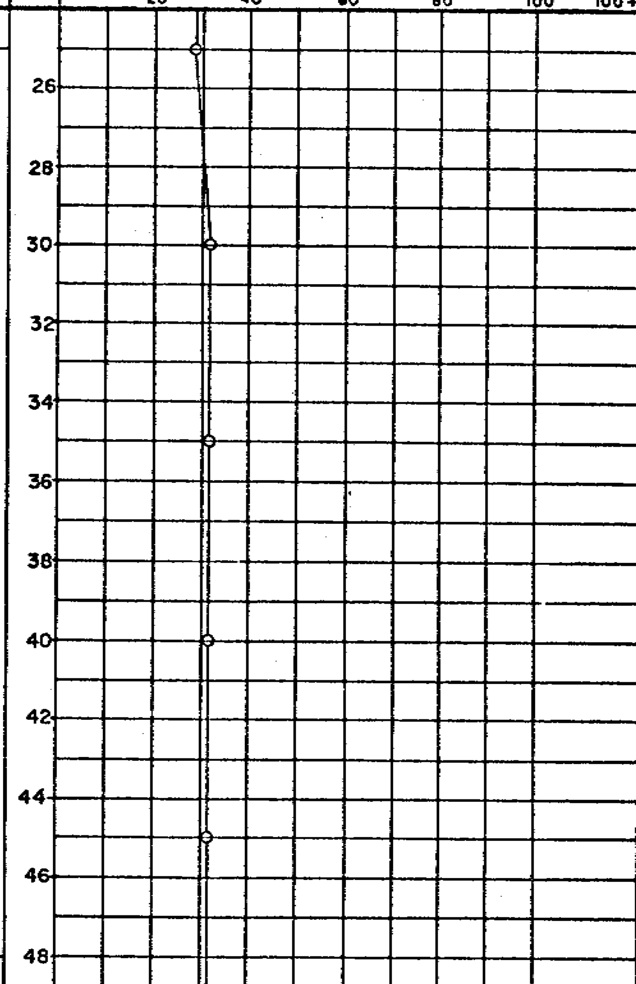
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2916 + 55	OFFSET
CKD NRM	TECH JK	RIG Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV 413.4

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	8

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6					CLAY - Same as Above		V - 0-5%
26								
28					CL to CI			
30	7						F to U	NB to Unfrozen
32								
34	8							
36								
38								
40	9							
42								
44	10							
46								
48								

○ = 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

E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB | FIELD ENG: NRM | DATE DRILLED: 3/1/73 | AIRPHOTO NO: A22763 - 45 | CHAINAGE: 2916 + 55 | OFFSET

CKD: NRM | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to North | VEGETATION: Black Spruce & Birch | ELEV: 413.4'

TEST HOLE

MILE	B,C,S	NUMBER
669	S	8

○ = 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
50	11				CL to CI	CLAY - Same as Above	F to U	NB to Unfrozen							Hole drilled to 51' with bit mudding up excessively. Over bored hole with larger bit, but unable to penetrate beyond 51' due to mudding conditions.
						END OF HOLE 51'									

E.W. BROOKER & ASSOCIATES LTD.

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

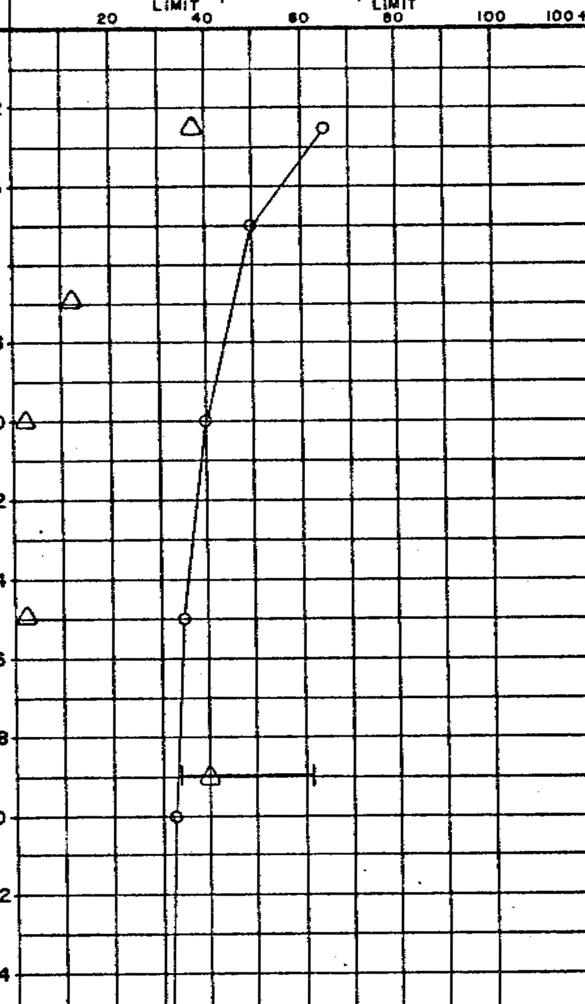
DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2917 + 70	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV: 426.7'

TEST HOLE

MILE	B,C,S	NUMBER
669	S	9

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
0–2						CLAY - Med. Brown - Some Silt - Med. Plasticity									Hanna River
2–4	1				CL			V 35-40%							East of ℄
5	2							V 10-15%							
10	3				CI	- Grey - Silty - Med. Plasticity									
13							F	V 0-5%							
15	4														
16–18					CH	- Silty. - Trace of Sand									
18–20	CORE							V 40%	68	31	1	-			
20	5														
22								V 0-5%							
24															

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



E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2917 + 70	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV: 426.7'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	9

○ = 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
25	6					CLAY - Same as Above	F	V 0-5%							
28	CORE				CI	- Med. Plasticity		NB	41	55	4	-			
30						END OF HOLE 30'									

E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

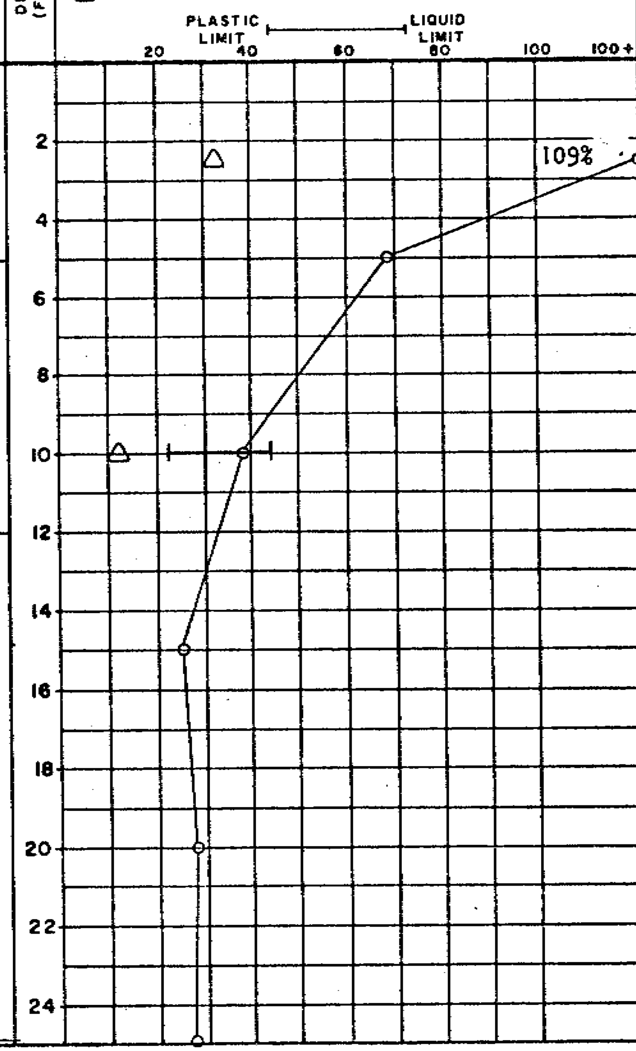
DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2917 + 70	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV 418.9'

TEST HOLE		
MILE	B,C,S	NUMB
669	S	10

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–3						CLAY - Med. Brown - Silty - Low Plasticity - Organics to 3'		
2.5	1				CL			V 35-40%
5	2							
7.5					CI	- Med. Plasticity		
10	3							V 10-15%
11.5							F	
12.5						- Grey - Silty		
15	4							NB
20	5							

END OF HOLE 25'

○ = 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

Hanna River
West of ℄

E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

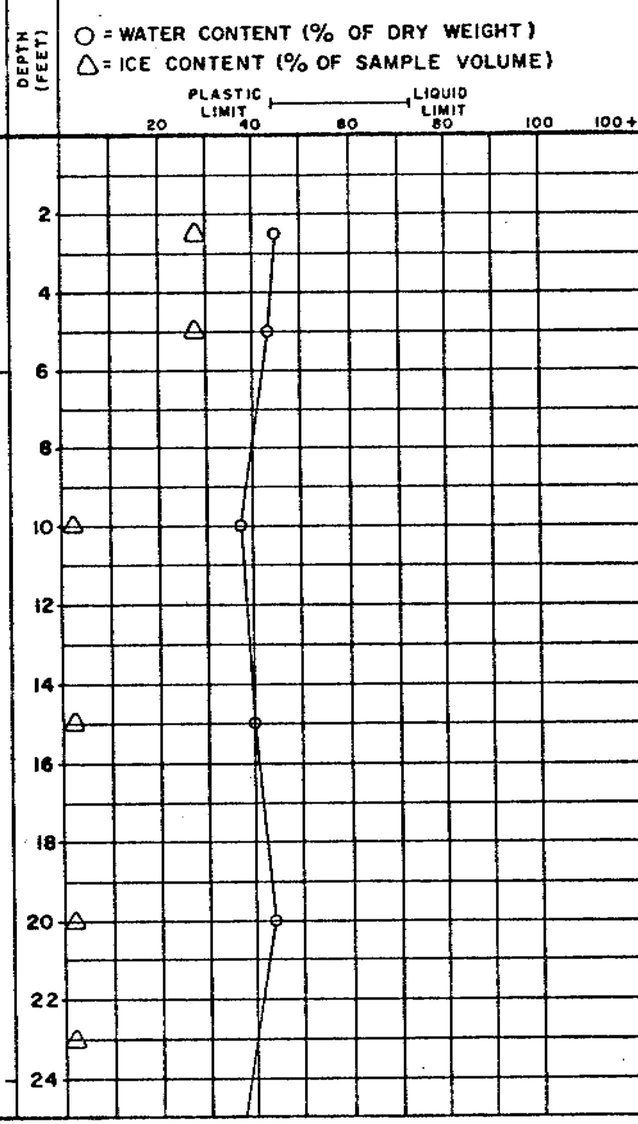
DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2917 + 80	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to North	VEGETATION: Black Spruce & Birch	ELEV: 427.5'

TEST HOLE

MILE	B,C,S	NUMBER
669	S	11

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
0						CLAY - Med. Brown - Silty - Low Plasticity			Hanna River
2–3	1				CL			V 25-30%	
5	2								
7					to				
10	3					- Grey	F	V 0-5%	
11					CI				
15	4								
20	5								
24									

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



E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT — DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

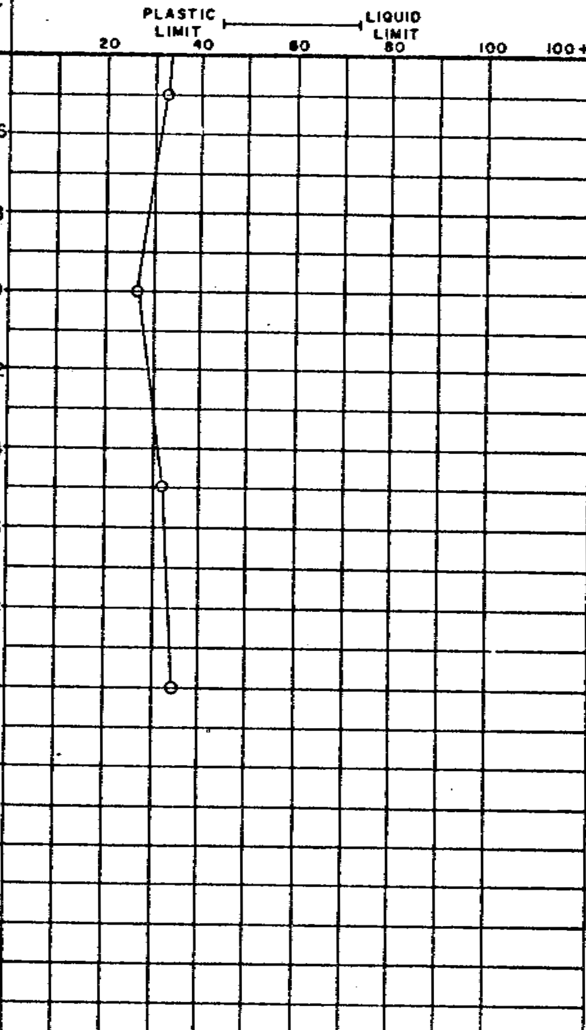
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 3/1/73 | AIRPHOTO NO: A22763 - 45 | CHAINAGE: 2917 + 80 | OFFSET

CKD: NRM | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to North | VEGETATION: Black Spruce & Birch | ELEV: 427.5'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	11

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
25	6				CL	CLAY - Same As Above		V-0-5
30	7				CI		F to U	NB to Unfrozen
35	8							
40	9				CL	- Low Plasticity		
42						END OF HOLE 42'		

○ = 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

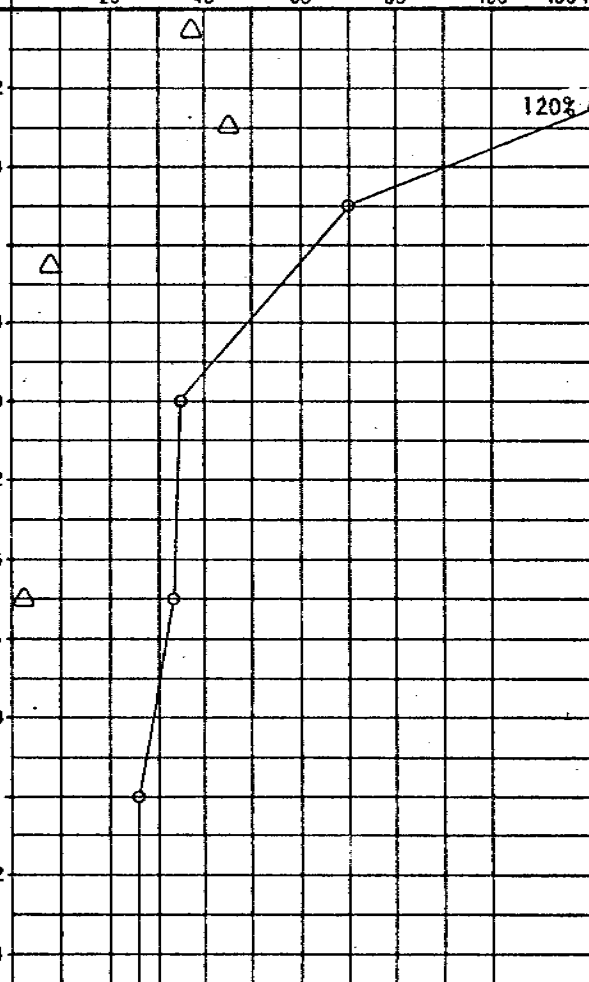
E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT — DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2912 +'25	OFFSET
CKD: NRM	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Fair to South East	VEGETATION: Black Spruce & Birch	ELEV: 415.8'

TEST HOLE

MILE	B,C,S	NUMBER
669	S	12

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–1					Pt	PEAT - Black, Fibrous		V 35-40%
1–5	1 (≈3)				CL	CLAY - Med. Brown - Silty - Trace of Fine Sand - Low Plasticity		V 40-50%
5–8	2 (≈5)							V 5-10%
8–24	3 (10)						F	V 0-5%
	4 (15)					- Shaley		
	5 (20)					- Grey - Low Plasticity		
24								



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

E.W. BROOKER & ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

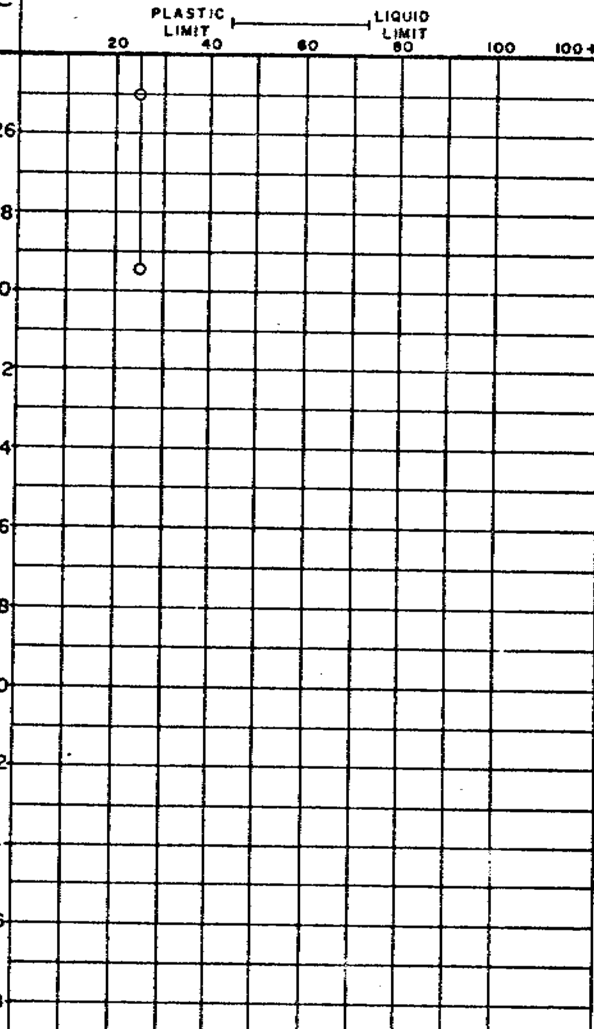
DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/1/73	AIRPHOTO NO: A22763 - 45	CHAINAGE: 2912 + 25
CKD NRM	TECH: JK	RIG Mayhew	SURFACE DRAINAGE: Fair to South East	VEGETATION: Black Spruce & Birch

OFFSET
ELEV: 415.8'

TEST HOLE		
MILE	B,C,S	NUMBER
669	S	12

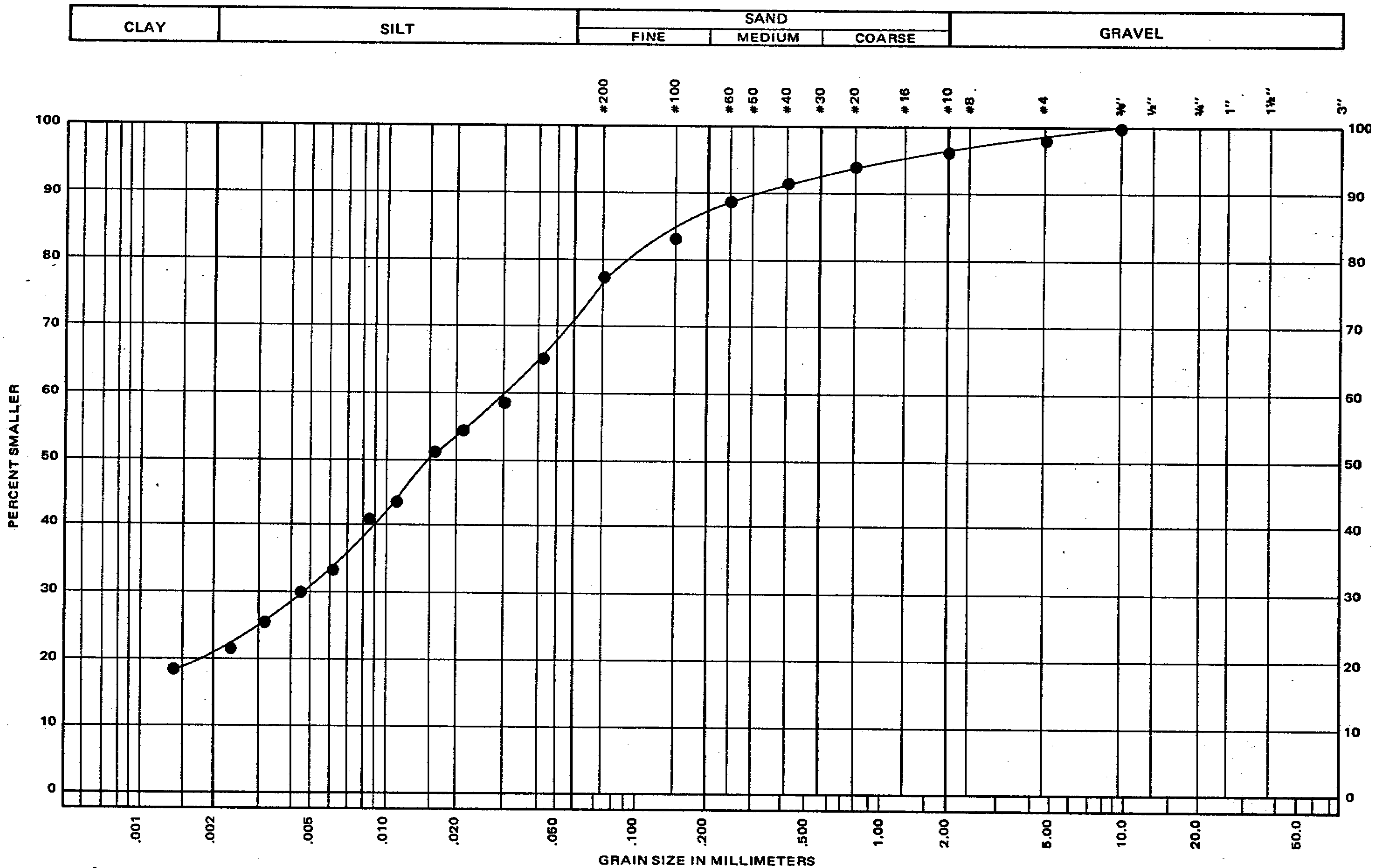
DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
26–29½	6	TUBE			CL	CLAY - Same As Above	F	V 0-5%	qu = 0.11 tsf
29½						END OF HOLE 29½'			

○ = 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.)

GRAIN SIZE DISTRIBUTION



E. W. Brooker & Associates Ltd.

SAMPLE DESCRIPTION CLAY, SILT, SANDY TRACE OF GRAVEL

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE April 2/73
SAMPLE No. 669 - S - 1
DEPTH 10'

FIGURE C - 1

GRAIN SIZE DISTRIBUTION

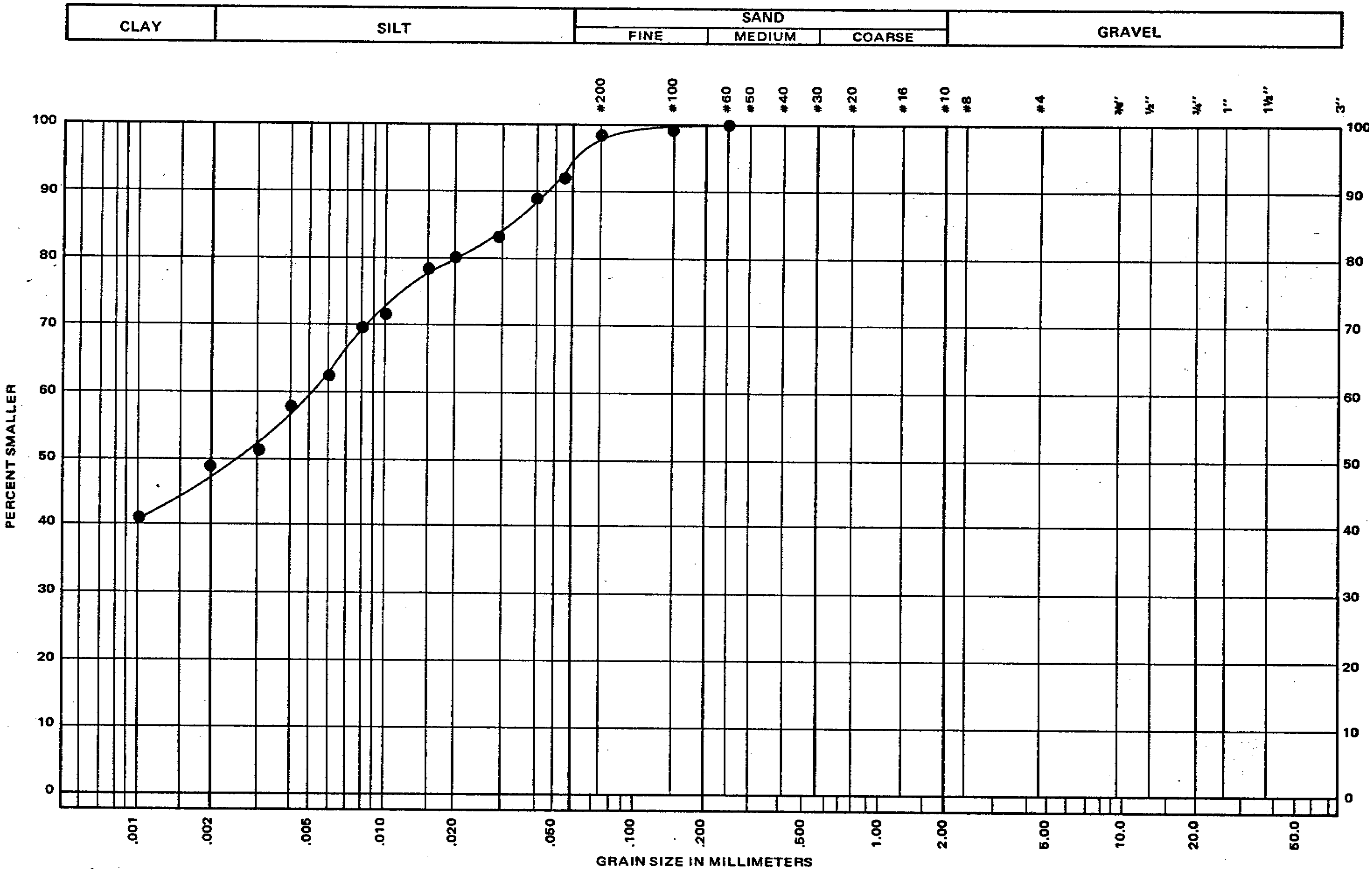


FIGURE C - 2

E. W. Brooker & Associates Ltd.

SAMPLE DESCRIPTION CLAY, SILTY, TRACE OF SAND

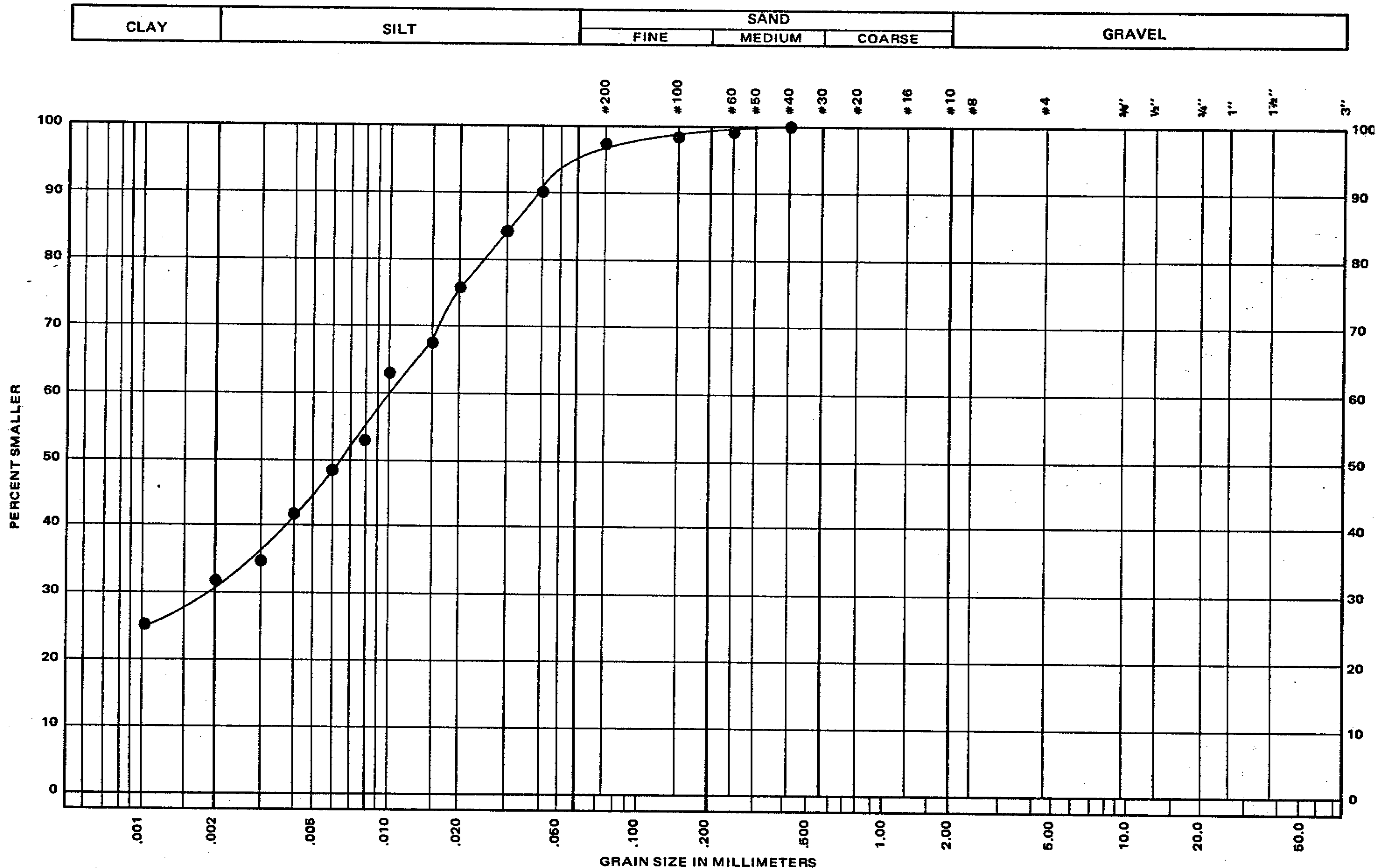
PROJECT MACKENZIE HIGHWAY

JOB No. E-517 DATE April 8/73

SAMPLE No. 669 - S - 4

DEPTH 15'

GRAIN SIZE DISTRIBUTION



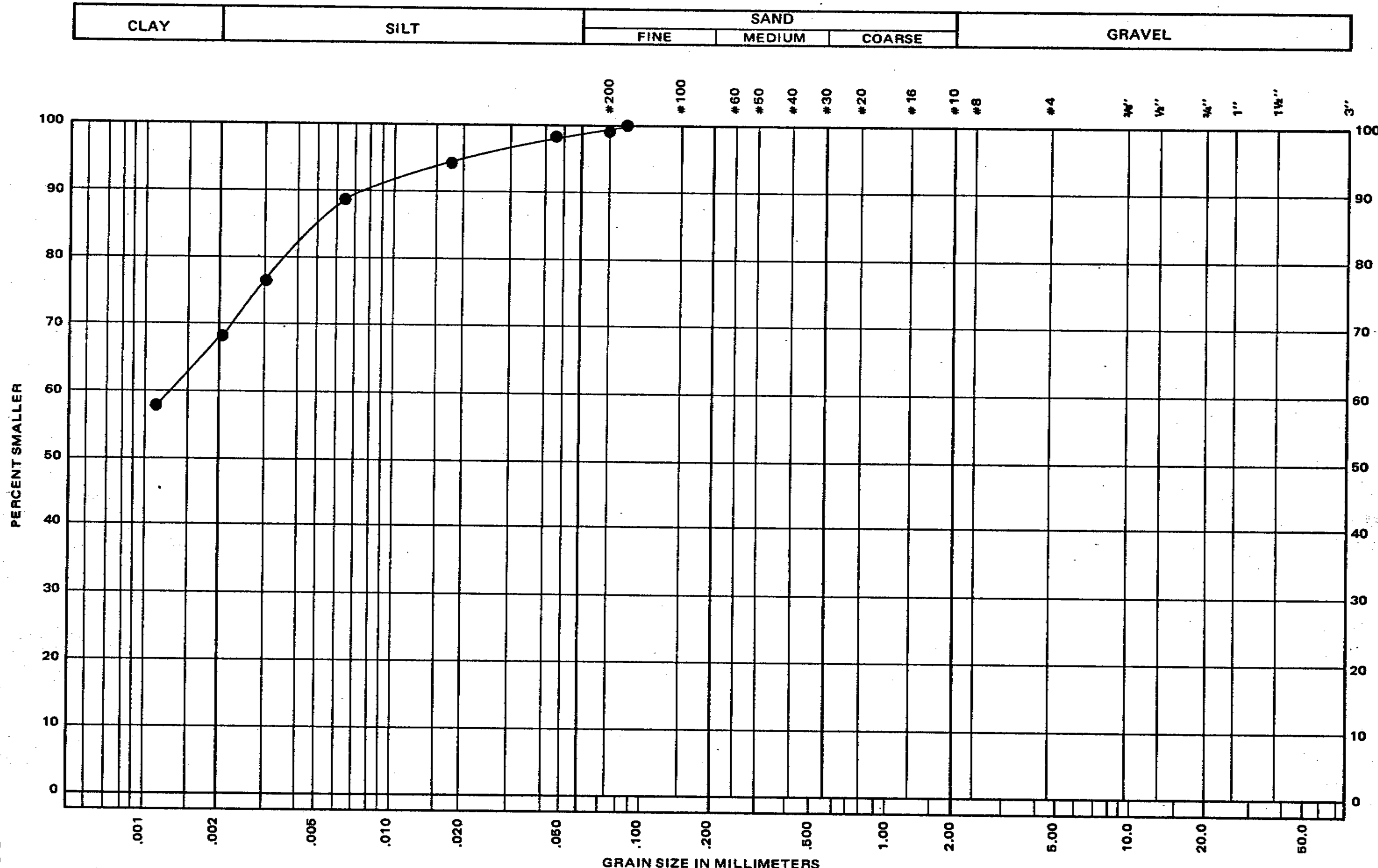
E. W. Brooker & Associates Ltd.

SAMPLE DESCRIPTION SILT, CLAY, TRACE OF SAND

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE April 11/73
SAMPLE No. 669 - S - 5
DEPTH 10'

FIGURE C - 3

GRAIN SIZE DISTRIBUTION



E. W. Brooker & Associates Ltd.

SAMPLE DESCRIPTION CLAY, SILTY

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE May 15/73
SAMPLE No. 669 - S - 9
DEPTH AVERAGE (18'-20')

FIGURE C - 4

GRAIN SIZE DISTRIBUTION

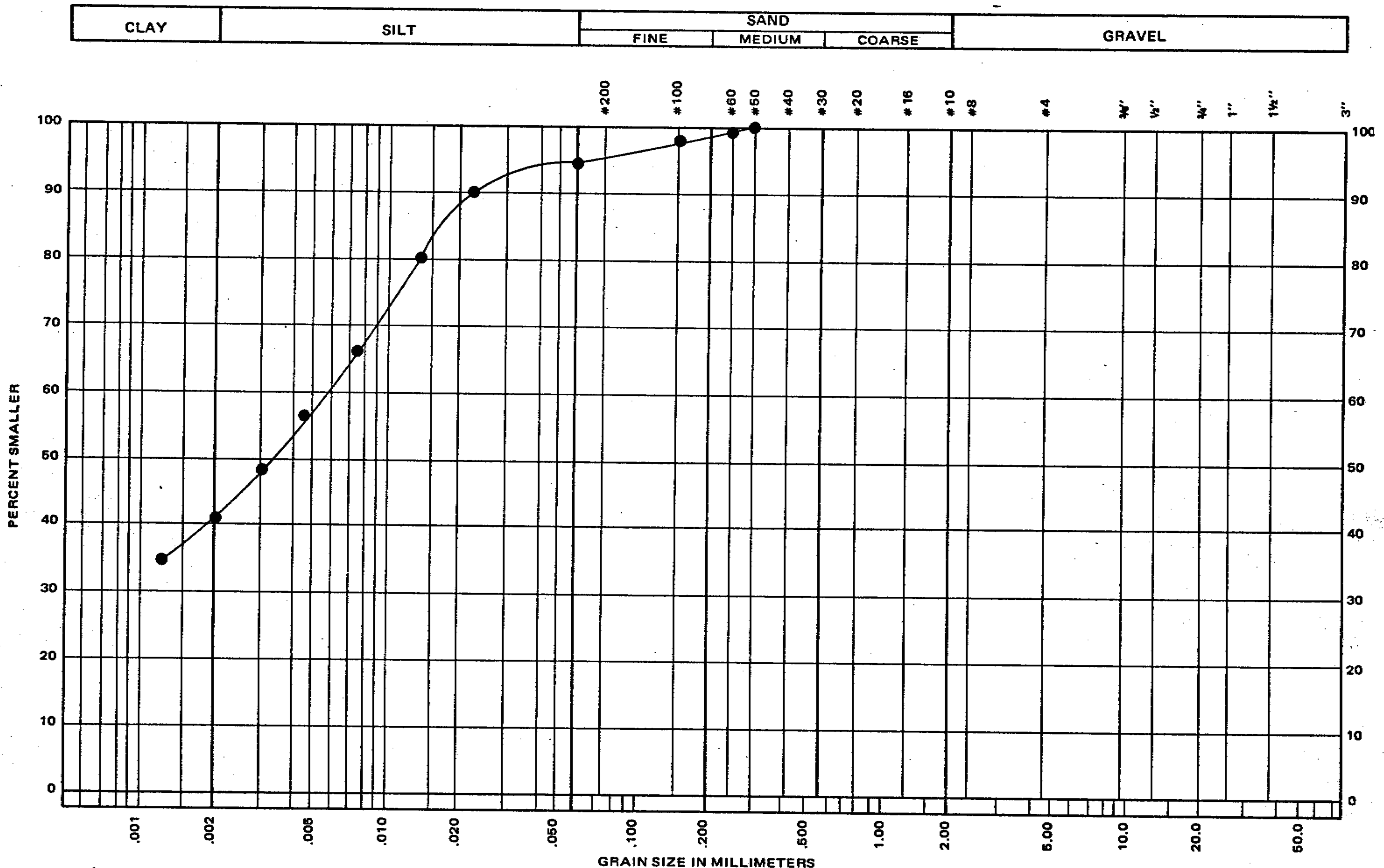


FIGURE C - 5

E. W. Brooker & Associates Ltd.

SAMPLE DESCRIPTION CLAY, SILTY, TRACE OF SAND

PROJECT MACKENZIE HIGHWAY

JOB No. E-517 DATE May 15/73

SAMPLE No. 669 - S - 9

DEPTH AVERAGE (28'-30')

SUMMARY OF TEST RESULTS

JOB No. E-517

BORE HOLE	DEPTH	NATURAL WATER CONTENT	Atterberg Limits W_L	W_P	PI	MECHANICAL ANALYSIS (M.I.T. CLASSIFICATION) % CLAY	% SILT	% SAND	% GRAVEL	SOIL CLASSIFICATION (UNIFIED)	REMARKS
	feet	%	%	%	%						
669-S-1	10	44.0	40.1	26.4	13.7	20	52	24	4	CI	
-2	18	25.0	38.5	18.4	20.1					CI	
-3	10	26.0	56.8	27.9	28.9					CI	
-4	15					49	44	7	0	CL - CI	
-5	10	50.0	38.8	21.6	17.2	30	65	5	0	CI	
-9	18-20	33.5	61.0	32.1	28.9	68*	31*	1*	0	CH	*Average of Five Test Results
-9	28-30		43.5	25.8	17.7	41*	55*	4*	0	CI	*Average of Five Test Results
-10	10	26.0	41.4	24.1	17.3					CI	
-12	28-29 1/2	31.8									qu = 0.11 tsf.

DWG. No. C-6

EBA ENGINEERING CONSULTANTS LTD.