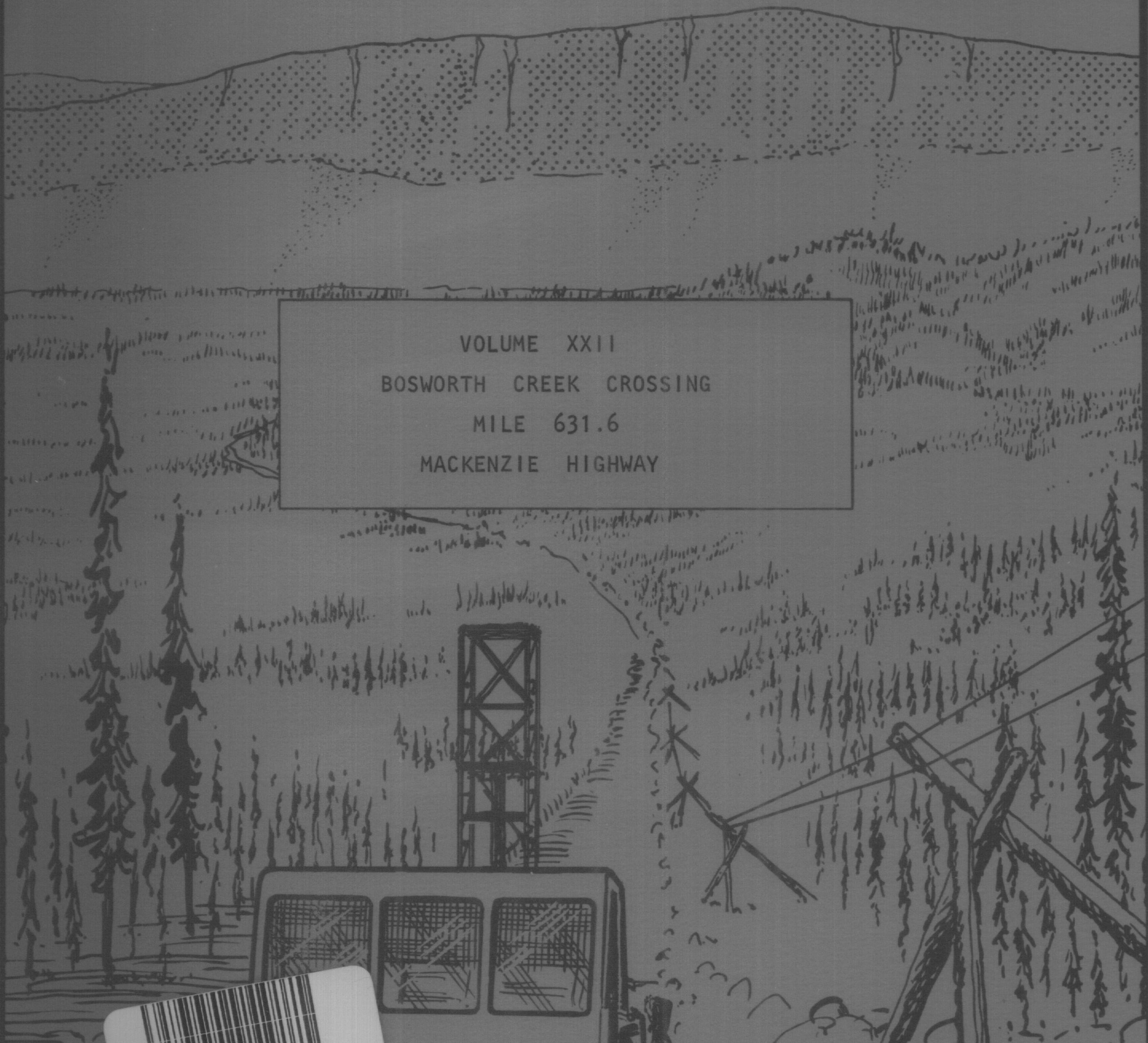
MACKENZIE HIGHWAY
GEOTECHNICAL EVALUATION



VOLUME XXII
BOSWORTH CREEK CROSSING
MILE 631.6
MACKENZIE HIGHWAY

eba Engineering Consultants Ltd.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
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ELMER W. BROOKER
& ASSOCIATES LTD.

MACKENZIE HIGHWAY

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APPENDICES

I. INTRODUCTION

As part of a geotechnical engineering study, carried out from Mile 725 to Mile 632 of the proposed Mackenzie Highway, a number of major river and stream crossings, including Bosworth Creek were investigated in detail. The general site location is indicated on the Key Plan, Drawing No. A-1, Appendix A. Details of the investigation, site conditions, geotechnical data and recommendations pertinent to the development of the creek 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 13 boreholes, drilled at the locations shown on Drawing No. A-2, Appendix A. Of the 13 boreholes drilled, one was drilled as a center line borehole (Borehole 632-C-4), in conjunction with the general route evaluation, and the remainder (Boreholes 632-S-1 to 632-S-12, inclusive) were located and drilled specifically to define subsurface conditions at the crossing. Detailed borehole logs are presented in Appendix B.

All boreholes were drilled with a track mounted Mayhew 500 rotrary drill rig, using a continuous air return circulation system. Boreholes advanced with this drill rig generally averaged about 4-3/4 inches in diameter. Borehole penetration ranged from 9 feet to 86 feet, and averaged 39 feet in depth. Sampling consisted of representative bag samples, obtained at depths of 2½, 5, 10 and 18 feet below ground surface in the center line borehole, and at depth intervals of about 5 feet, below a depth of 5 feet, in the special boreholes. Undisturbed samples were not obtained at this site because of equipment limitations.

2.2 Laboratory Testing

Laboratory testing was carried out on the disturbed soil samples to determine the natural water content profile, Atterberg limits, grain size distribution, soluble sulphate concentration and organic content of the subsoil. The moisture content tests were undertaken in the field laboratory of Elmer W. Brooker & Associates Ltd. (EBA), while all other testing was confined to the EBA Edmonton laboratory. 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.

Frozen ground was classified according to a modification of the NRC system for describing permafrost (3). The modification was necessary because the disturbed nature of the sample did not permit full usage of the NRC system with respect to describing the form of excess ice. The system used retains the main 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, Appendix C, presents a summary of laboratory test results.

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

III. SITE CONDITIONS

3.1 Surface Features

The proposed Mackenzie Highway crosses Bosworth Creek at Mile 631.6 of the highway, approximately 3 miles northwest of Norman Wells. Drawing A-1, Appendix A, is a key plan of the Norman Wells-Bosworth Creek area which shows the relative location of major features in the area. Drawing No. A-2, Appendix A, presents a detailed site plan. Plates 1 and 2, of Drawing No. A-3, Appendix A, are photographs which show the crossing as it appeared on June 7, 1973.

Bosworth Creek drains the area between the southwest side of the Discovery Ridge of the Norman Range and Kee Scarp. In the spring and after major storms, considerable volume of water is channeled through the Bosworth Creek system into the Mackenzie River. However, in the summer the flow rate of Bosworth Creek is relatively low. The creek has a well developed flood plain (AFP), shown on Drawing No. A-2 and Plates 1 and 2 of Drawing No. A-3, Appendix A. The flood plain is almost 280 feet wide at the crossing, which is the narrowest point within this reach. Except for periods of peak flow, the main channel probably is less than 50 feet wide.

The valley walls containing Bosworth Creek are steepest on the southern bank where they range from 5 degrees to 16 degrees (9% to 29% grade). On the north bank the slopes range from 5 degrees to 11 degrees (9% to 19% grade). These low to moderate slopes are expected to be stable except for surface creep. The banks bordering the flood plain, where active erosion occurs, are steeper than the valley walls. These banks are susceptible to caving due to undercutting or scour by stream action. Rip rap will be required to stabilize and protect the banks during periods of maximum runoff. The surface profile along the proposed highway center line is presented in Drawing A-4, Appendix A.

At the crossing, tree cover consists primarily of thick spruce, some of which are 40 to 50 feet in height. Locally, there are a few birch and in the flood plain a few small aspen have grown.

3.2 Subsurface Conditions

Based on observations from the boreholes, inferred stratigraphic sections have been compiled and are presented as Drawings No. A-4 and A-5, Appendix A. The generalized center line stratigraphy noted at the site is summarized in the following subsections.

3.2.1 Stratigraphy of North Valley Wall

	Material Description	Approximate Average Depth Below Existing Grade (ft)	Approximate Range of Thickness (ft)
PEAT	dark brown, silty, NB (Borehole 632-S-5 only)	0 - 1.5	0 - 1.5
GRAVEL	sandy to silty, medium grained gravel, NF, moisture content (m/c)=5% to 10% (Boreholes 632-S-2 and 632-S-3 only)	0 - 3.5	0 - 4
CLAY	light brown to grey below 7', silty with some sand to silty sand layers, NB to V-7%, (m/c)=28% to 36% (Boreholes 632-S-1, 632-S-2 and 632-S-3 only)	3.5 - 18.3	0 - 18
CLAY TO SILT (TILL)	generally clay till becoming a silt till with depth, grey, gravelly to cobbly, low plasticity, V-7% to NB, some unfrozen material, (m/c)=10% to 20%, locally to 32% (All boreholes)	0 - Depth of Penetration	Not Established

CLAY	non-gravelly, silty, V-trace, (m/c)=15% to 20% (Borehole 632-S-2 only)	49 - Depth of Penetration	Not Established

The following additional information, which may influence design or construction decisions, was also obtained during the investigation at the subject site:

1. The maximum depth of borehole penetration was 86 feet.
2. Unfrozen material was found in Borehole 632-C-4, extending from 10 feet to the bottom of the hole (18 feet); in Borehole 632-S-1, extending from 10 feet to the bottom of the hole (38 feet); in Borehole 632-S-2, extending from 25 feet to 49 feet, and in Borehole 632-S-6 (center of creek), extending to the depth of penetration (9 feet).
3. A potential source of seepage was found in Borehole 632-S-1 where a silty sand layer was encountered at a depth of 10 feet, which is the top of the unfrozen material.

3.2.2 Stratigraphy of South Valley Wall

	Material Description	Approximate Average Depth Below Existing Grade (ft)	Approximate Range of Thickness (ft)
SILT	light brown, clayey, trace of gravel, (m/c)=18%, NB (Borehole 632-S-11 only)	0 - 3	3
CLAY	light brown to grey, silty, low plastic, local traces of sand and gravel, NB to V-10%, (m/c)=25% to 45%	0 - 23.5	7 - 30+
SAND	light brown to grey, poorly graded, medium grained to gravelly, NF, (m/c)=8% to 18% (Boreholes 632-S-7, 632-S-8 and 632-S-9 only)	16.0 - 33+	Min. 12 to 13

SILT (TILL)	clayey, some gravel, low plasticity, light grey, NB, (m/c)=8% to 18% (Borehole 632-S-7 only)	20 - 39	19
CLAY	grey, silty, low plasticity, V - trace to unfrozen (m/c)= 8% to 24% (Borehole 632-S-7 only)	39 - Depth of Penetration	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 85 feet.
2. Unfrozen material was found in Borehole 632-S-7, extending from 50 feet to 68 feet, and partially frozen material extended from 68 feet to the bottom of the hole (85 feet). Borehole 632-S-11 revealed partially frozen material from 13 feet to the bottom of the hole (28 feet). Borehole 632-S-12, similarly revealed partially frozen material from 14 feet to the bottom of the hole (30 feet).
3. High ice content material was found in Borehole 632-S-10, where 40%-50% visual excess ice was recorded at depths of 10 to 11 feet from the surface.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Foundation Types

The following foundation types are believed to be feasible for a bridge structure at the subject site. At present, preference has not been given to one of the suggested systems, as final selection of a foundation system should be determined in conjunction with economic and structural design considerations.

1. Driven Steel H-Piles
2. Closed End Pipe Piles driven in pre-bored holes
3. Timber Piles driven in pre-bored holes

4.2 Foundation Design

The major factor affecting the design of pile foundations at Bosworth Creek is the noted occurrence of irregularly distributed unfrozen zones within the subsoil. Generally the near surface subsoils are frozen adjacent to the creek, where bridge abutments will most likely be founded. However, an unfrozen zone was noted at greater depth in one of the boreholes (Borehole No. 632-S-7) near a potential bridge abutment location on the south creek bank, and unfrozen zones were detected beneath the river flood plain and in several other boreholes on both sides of the creek. Unfrozen material was encountered in seven of the thirteen boreholes drilled at the crossing site.

As there does not appear to be a definite predictable distribution of frozen and unfrozen subsoil, it is believed necessary that the design of pile systems be carried out assuming thawing of frozen soil may occur and/or unfrozen soil presently exists. Consequently, 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. The existence of frozen zones is considered justification to preclude the use of dynamic 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.

Because of a lack of data, with respect to soil strength and depth to a 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 3.1, may be designed in accordance with the following preliminary design parameters. However, it is stressed that the following recommendations are presented without any knowledge of proposed highway grades, geometrics, or bridge design, at the proposed crossing site. 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 Bosworth Creek 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 86 feet, with bedrock not being encountered.

Based on a review of bedrock elevations, noted within some borings in the Norman Wells area; it is believed that shale bedrock may be expected to be encountered at a depth of about 130 to 140 feet, below existing grade at the approximate abutment locations of the proposed bridge crossing. At this depth, support is readily attainable through the use of steel piling. It is recommended that consideration be given to the use of 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 the determination of a final design pile capacity. It is believed that this could be readily achieved through the use of drilling equipment available locally in the Norman Wells area.

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. Although the design length of the piles has to be confirmed on the basis of additional field drilling, it is believed that a pile length of about 140 to 150 feet should be considered for preliminary design and estimating purposes.

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 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 is anticipated to meet with high resistance. Confirmation of this however, could be achieved through the driving of test H-piles.

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 capacity of the piles and permit a correlation to the driving records.

4.2.2 Friction Piles

Based on available geotechnical information at the Bosworth Creek crossing, it is believed that a significant 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. However, the present lack of specific information with respect to the strength of the insitu soils in an unfrozen condition, permits only a preliminary estimate of the load carrying capacity of friction pile types.

Confirmation of the suitability of friction piles, presentation of more detailed pile designs, and more precise estimates of pile capacities can only be made if detailed geotechnical information of subsurface deposits is obtained at the site. It is believed that this information could be readily obtained through the use of drilling equipment locally available in Norman Wells.

Alternatively, the following preliminary pile design parameters may be used for preliminary design and estimating purposes, with the final design to be confirmed on the basis of field installation records and load testing.

a. Driven Steel H- Piles

As a guide to the establishment of a preliminary pile design, it is recommended that standard H-piles 60 feet in length (below existing grade), with a minimum nominal size of 12 inches by 12 inches, and a minimum weight of 53 pounds per foot (CBP124), be considered for preliminary design purposes. It is believed that the suggested pile section can be driven, with an energy of 24,000 foot pounds to the full length of the pile. It is believed that piles driven to these specifications will permit an allowable static design load of 65 kips to be used. Although preboring is not considered necessary for the installation of steel H-piles through frozen ground, at this site, it may be desirable in very hard seasonally frozen ground and thick granular fills to ensure the alignment of the driven pile section. This will be particularly true if very long sections are to be driven.

It is essential that the embankment fill be placed to final grade, before the piles are driven or pre-bored, in order to prevent damage to the pile and to ensure proper compaction of the fill, which will limit negative skin friction loads on the pile. On site inspection and supervision of the driving of test piles or the initial piles of the foundation system is considered absolutely necessary in order to establish the final design bearing capacity. It is also considered essential that a pile driving record be maintained for all piles. The driving record of all piles should be reviewed as is practical, by the geotechnical consultant, to ensure the design intention has been realized.

b. Prebored Driven Closed End Steel Pipe Piles

Steel pipe piles, installed in prebored holes,may be used for foundation support. The prebored hole size should be 85 to 90 percent of the outside pile diameter to ensure a 'snug' fit, and should extend the full length of the intended pile penetration. It is essential that the fill be placed to final grade before the piles are driven or pre-bored in order to prevent damage to the pile and ensure proper compaction of the fill, which will limit negative skin friction loads on the pile.

For preliminary design purposes, it is recommended that closed end pipe piles with a minimum length of 60 feet (below existing grade), a minimum nominal diameter of 10 inches, and a minimum weight of 40 pounds per foot be considered. It is believed that the suggested pile section can be driven, with an energy of 24,000 foot pounds to the full length of the pile. It is believed that piles driven to these specifications will permit an allowable static design load of 50 kips to be used. Driven piles must penetrate to at least the full pre-bored depth. As for steel H-piles, inspection of the driving of test piles, or the first few piles of the foundation system, is considered absolutely necessary to confirm or alter the design bearing capacity recommended herein. A pile driving record must be kept for all piles for immediate review by the geotechnical consultant.

c. Pre-bored Driven Timber Piles

For preliminary design purposes, it is recommended that No. 12 Douglas Fir timber piles, with a minimum length of 60 feet (below existing grade), be considered for foundation support. The piles should be pressure treated with creosote and should have a minimum creosote retention of 12 pounds per cubic foot.

It is essential that the fill be placed to final grade before the piles are driven or pre-bored to prevent damage to the pile and to ensure proper compaction of the fill, which will limit negative skin friction loads on the pile. Prebored holes should have a maximum diameter equivalent to the pile tip diameter to permit a snug fit, and should extend for the full depth of anticipated pile penetration. If excessive driving resistance is encountered, overboring of approximately the upper half section of the hole may be required. Details of the overbore should be determined in the field, on the basis of driving records obtained from test piles.

If the suggested pile section can be driven, with an energy of 24,000 foot pounds, it is believed that an allowable static design load of 35 kips may be used. Piles must penetrate to at least the full prebored depth.

Field inspection by qualified personnel is considered necessary during the preboring and driving of test piles or the first few foundation piles, to establish or alter the preliminary design capacity and method of installation recommended herein. A driving record should be kept, for all piles installed, for immediate review by the geotechnical consulant.

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 thaw settlement within both the fill surrounding the piles and the natural subgrade material. At the subject crossing site, it is considered that all subgrade materials, which are not presently unfrozen, are thaw unstable and significant subsidence can be expected on thawing. Consequently, signficant negative skin friction effects can be anticipated in these materials if thawing is allowed. Substantial negative skin friction effects will also be mobilized in any road grade fill surrounding piles, if loss of subgrade support occurs.

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. At potential abutment locations, it is believed that about 10 feet of near surface natural soil may thaw as a result of construction and could contribute to negative skin friction effects on thawing. Table 4.3.1 presents representative values for the negative skin friction in typical soils (4).

At the Bosworth Creek site the thickness of fill will significantly effect the depth and rate of thaw wherever the soil is presently frozen. If significant amounts of frozen material degrades then settlements of 1 to 3 feet are possible, within approach fills to the proposed crossing. Sub-grade settlements will be maximum if construction occurs in late summer and minimum for late winter construction.

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.

TABLE 4.3.1

NEGATIVE SKIN FRICTION OF UNFROZEN SOIL FOR PILE DESIGN

(After Woodward Lundgren And Associates, 1971) (4)

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 a 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.

In soils containing silt and clay, this shallow surface adfreeze exerts a heaving force on the pile which must be resisted by the load on the pile, the available adfreeze bond in the permafrost, and/or the skin friction of the soils which are unfrozen or have consolidated during the summer.

The design of a pile in permafrost is controlled by the embedment required to support the applied load. However, it is necessary to check the design to ensure a factor of safety against seasonal frost-heaving. In general it has been found that a slightly deeper pile embedment is the most feasible means of resisting undesirable frost heaving stresses. Suggested design stresses for general permafrost soils are presented in Table 4.4.1 (4).

4.5 Subgrade Considerations on Center Line

4.5.1 North Valley Wall and Creek Bank

As indicated in Subsection 3.3.1, the northern banks and upper slopes at Bosworth Creek are primarily a clay to silt till overlying a considerable thickness of clay at depth. Locally, an abandoned channel exists, which parallels the present channel, approximately 450 feet to the north. A thin layer of gravel overlies approximately 15 feet of clay in this abandoned channel. Estimates of the visual excess ice were typically lower than 10% except in seasonally frozen near surface material.

Although no shear strength data for thawed or frozen soil at the site is available, qualitative evaluation of the shear strength of the various strata can be made from visual observations, ice content estimates, moisture content profiles and classification test results. Based on these factors, it is concluded that relatively low shear strengths can be expected for the till. The clay in the abandoned channel will probably have a very low shear strength and may become unstable if allowed to thaw quickly. Generally below a depth of 15 to 20 feet, the natural moisture content is lower and the soil possesses greater shear strength.

TABLE 4.4.1

FROZEN SOIL ADFREEZE BOND STRENGTH FOR PILE DESIGN

(After Woodward Lundgren And Associates, 1971) (4)

Design Category	Applicable Criteria		Design Adfreeze Bond Stress for Frost Heaving Soils[1] (PSF)
	Segregated Ice Condition	Water Content of Soil, (%)	
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

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

4.5.2 South Valley Wall and Creek Bank

The surface stratum of the southern bank of Bosworth Creek on center line is characterized by high moisture content, low to moderate ice content, alluvial clay. The clay is expected to have a low shear strength if it is allowed to thaw. Underlying the clay, between approximate elevations 360 feet and 375 feet is a low moisture content, generally poorly graded, sand stratum. The sand is expected to have a moderate to high shear strength and is likely to be the most stable stratum at the Bosworth Creek site.

4.5.3 Flood Plain Area

The river flood plain and its relationship to the present creek can be seen in Plates No. 1 and No. 2, Drawing No. A-3, Appendix A. Borehole 632-S-6, which was drilled approximately in the center of the flood plain,was unable to penetrate more than 9 feet because of free water flowing through the creek bed gravel, which resulted in sloughing conditions within the borehole.

The maximum vertical and horizontal extent of the creek bed gravel could not be ascertained. However, it is believed that the gravel underlies the entire flood plain and may grade into the sand stratum located in the south bank and valley wall. The presence of the gravel indicates that high stream velocities, at peak runoff, may cause significant scour and erosion.

The significant feature revealed by Borehole 632-S-6 was the presence of free water within the gravel. It is probable that this water will be flowing in the subsurface gravel all winter and therefore, it may contribute to a potential icing problem for winter construction and maintenance.

4.6 Settlements and Required Fill Thickness

A lack of detailed information with regard to ice contents, and a need for sophisticated testing and detailed computer analyses, make 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 total thaw settlement of about 0.5 to 1.0 feet can be expected beneath fills placed during winter, where the soils are presently frozen. This estimate assumes partial thawing, but does not take into account normal consolidation settlement of the unfrozen material 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. If a summer construction program is carried out settlements of up to 3 feet are believed possible. The higher settlements are due primarily to the rapid consolidation of the naturally thawed subgrade.

On the basis of the forgoing discussion, 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 material. 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 thickness of dry, non-plastic granular fill material of 6 feet is considered to be the minimum thickness recommended for road grade construction over frozen subgrade materials at Bosworth Creek. Local fine grained materials such as silts and clays are not considered suitable for abutment of 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 recommended that fill placement should be carried out during the late winter period to minimize thermal disturbance, and possible detrimental disturbance to the existing ground cover and slopes occasioned by the construction equipment. Snow clearing should be carried out prior to all fill placement. Placement of the fill should be carried out through 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.

4.7 Slope Stability Considerations

No evidence of recent slope instability was detected on either valley wall near the site of the river crossing. As indicated in Subsection 3.1, the valley walls are steepest on the southern side, where they range from 5 degrees to 16 degrees. On the northern side, slopes range from 5 degrees to 11 degrees.

Preliminary slope stability calculations,using assumed shear strength values for thawed materials and the known slope configuration, revealed adequate factors of safety with respect to sliding. Consequently, it is considered that approaches can be constructed on both sides of the river, on the proposed alignment, in comparative safety with respect to slope stability. However, it is recommended that excessive fill thicknesses be avoided near the crest of the slopes. In addition, cutting or excavating of slope material is not recommended and desired grades should be achieved solely through placement of fill. Placement of fill directly on underlying organic layers should be carried out.

Observations of vegetation cover, adjacent to the channel banks at the crossing, reveal that some slumping of channel banks likely occurs under the influence of channel erosion. Consequently, it is considered that rip-rap protection of the existing defined channel, upstream and downstream of the bridge crossing, may be necessary to protect the overall 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 may be eroded during times of peak runoff.

4.8 Drainage Considerations

Approach fills will concentrate runoff water on slope, along the upslope side of the fills, therefore, it is considered essential that considerable effort and care be given to minimizing erosion on the slope parallel to the fill. Every effort should be made to preserve the vegetal-lining of all designed water courses. 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. However, 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 adjacent subgrade soil and road grade fill, unless the road grade is very granular. Spacing of the flow breakers will become apparent in the field when drainage courses and gradients become accurately defined.

Culverts may be required if any fill is placed over the flood plain, because of the potential for flooding in spring and icing and flooding in the winter.

4.9 Cement Type and Corrosion Considerations

Two representative soil samples were tested to determine their soluble sulphate concentration. Positive soluble sulphate concentrations of 0.14% and 0.16% were determined from the tests. Based on these results, it is considered that Type I, Normal Portland Cement will be adequate for all concrete in contact with the subsoil. A minimum 28 day compressive strength of 3000 pounds per square inch is recommended for all concrete forming foundation elements. Further soluble sulphate concentration tests are recommended.

For steel pipe piles, extending above grade or above water level, corrosion protection may be achieved by painting or encasement with concrete. In this case, 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 the pipe piles, protective coating should be provided on the interior of the pipes to prevent possible corrosion. If practical, this may also be achieved through filling of the piles with concrete.

4.10 Additional Studies

In order to more accurately assess such factors as insitu shear strength, thaw subsidence, and slope stability, it would be 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 of value.

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 forgoing recommendations have been prepared based on our knowledge of existing conditions at Bosworth Creek 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.

However, due to the general nature of the study, 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.

Neil R. MacLeod

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Garry R. Gilchrist, P. Eng.
NRM:LAB:GRG:sjw

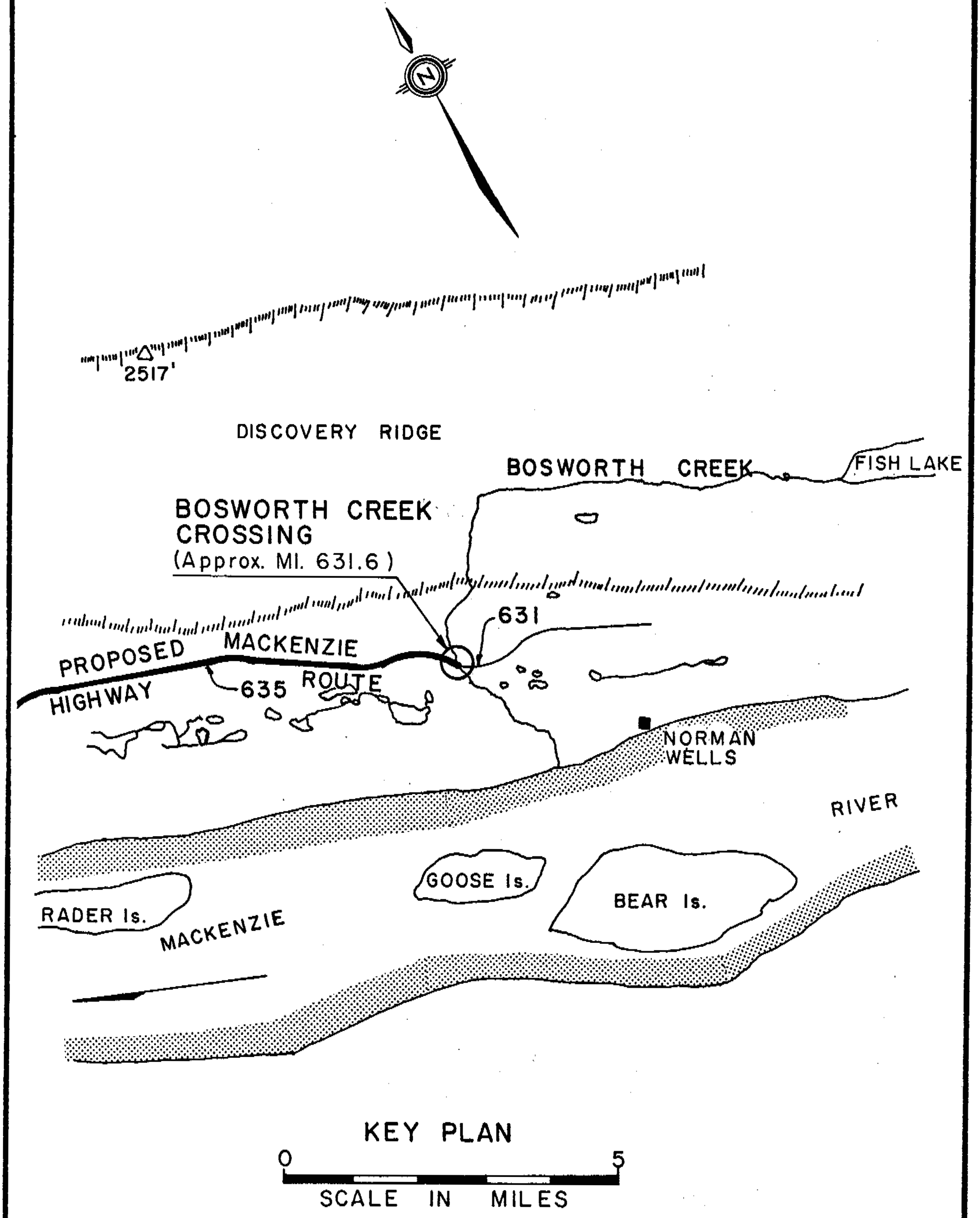
LIST OF REFERENCES

1. Yong, R.N. and Warkentin, B.P., 1966, Introduction to Soil Behavior, The MacMillan Company, New York.

2. Means, R.E. and Parcher, J.V., 1963, Physical Properties of Soils, Charles E. Merrill Books Inc., Columbus, Ohio.

3. Pihlainen, J.A., and Johnston, G.H., 1963, Guide to a Field Description of Permafrost, N.R.C. Technical Memorandum 79.

4. Woodward - Lundgren & Assocaites, 1971, Results of Pile and Anchor Installation and Load Tests and Recommended Design Procedures. Trans Alaska Pipeline System, (Unpublished).



KEY PLAN

DATE: 19 Dec.73	*SCALE:* —	*JOB NO.* E-517	*DWG. NO.* A-1

DWN BY: F.R.B.
DATE DWN.: 6 May, 73
SCALE: 1" = 200'
JOB No.: E-517

E.W. BROOKER & ASSOCIATES LTD.
civil engineers

Site and Borehole Location Plan for BOSWORTH CREEK Crossing

DWG.: A - 2
SHT. No.:

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	Alluvial Meander Plain (Mackenzie River Meander Plain)	Flat plain often with sand dunes on it	Sands and silty sands stratified or channel deposits
OW	Outwash Plains Deltas	Tabular bodies	Sand and/or gravel
RKM	Ridge-and-Knoll Moraine	Drumlinized till plain Rolling large linear features	Molded basal till low plastic silty-clay till

Topstratum Phases (Associated with Terrain Types)

Df	Thin (0 - 10 feet) of drift over bedrock surface
PT	Mixed bog and fen peats in post glacial ponded depression
SL	Slopewash or solifluction features. Topstratum of ice-rich poorly sorted silty clay and silty sand to gravel
WM	Wave modified, mainly a thin sandy to gravelly washed layer over till

Complexes are shown as combinations to 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

E.W.Brooker & Associates Ltd.

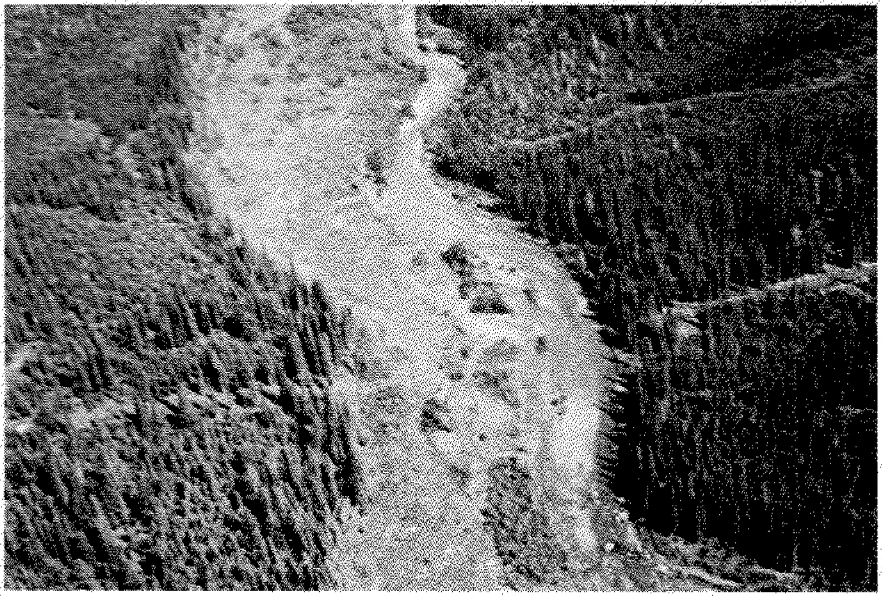


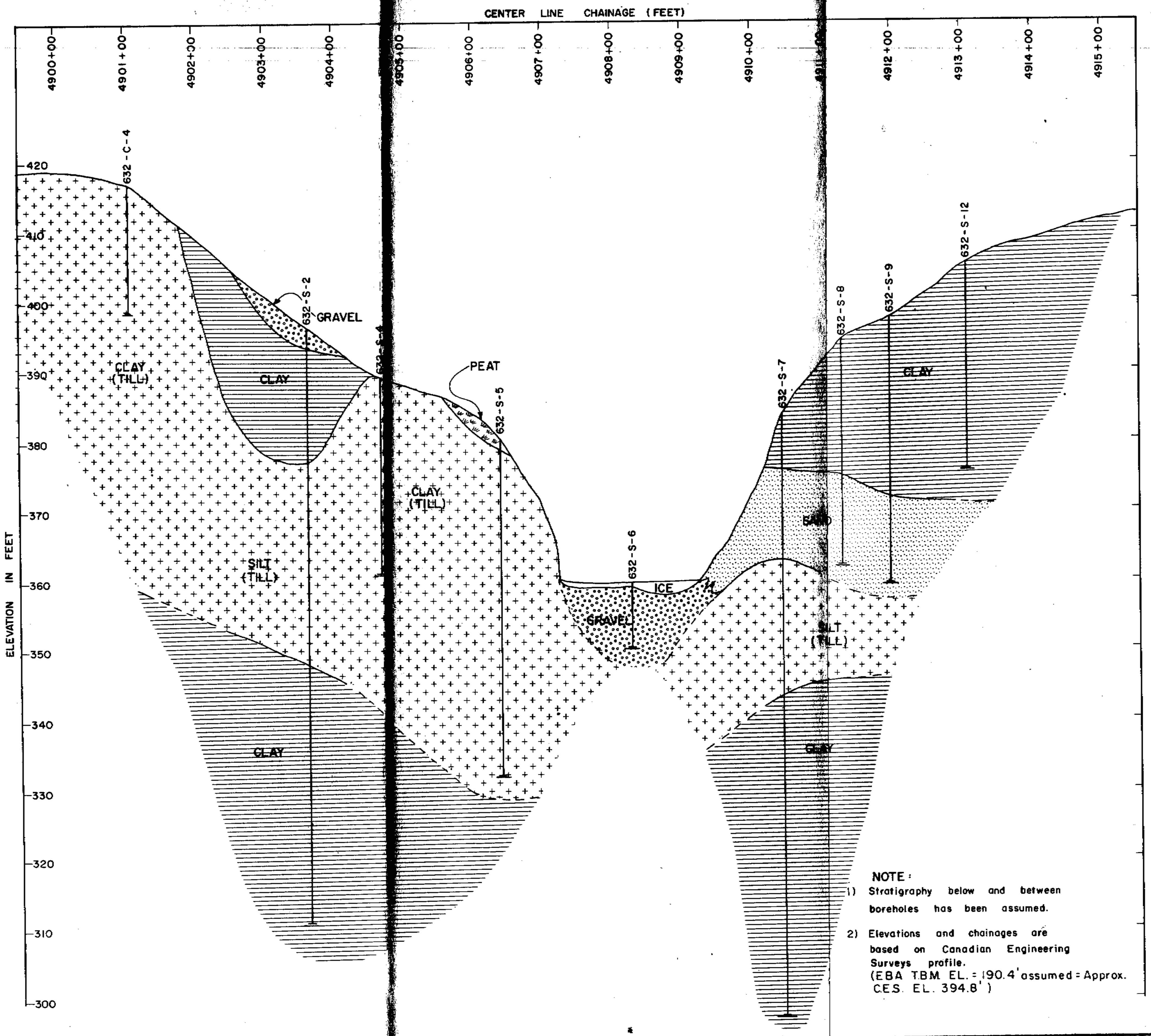
PLATE No. 1

Bosworth Creek Crossing. The cut line is the highway center line. North is to the left of the plate (June, 1973)

PLATE No. 2

Bosworth Creek Crossing Note the width of the main channel and flood plain. North is to the left of the plate. (June, 1973)

Drawing No. A-3



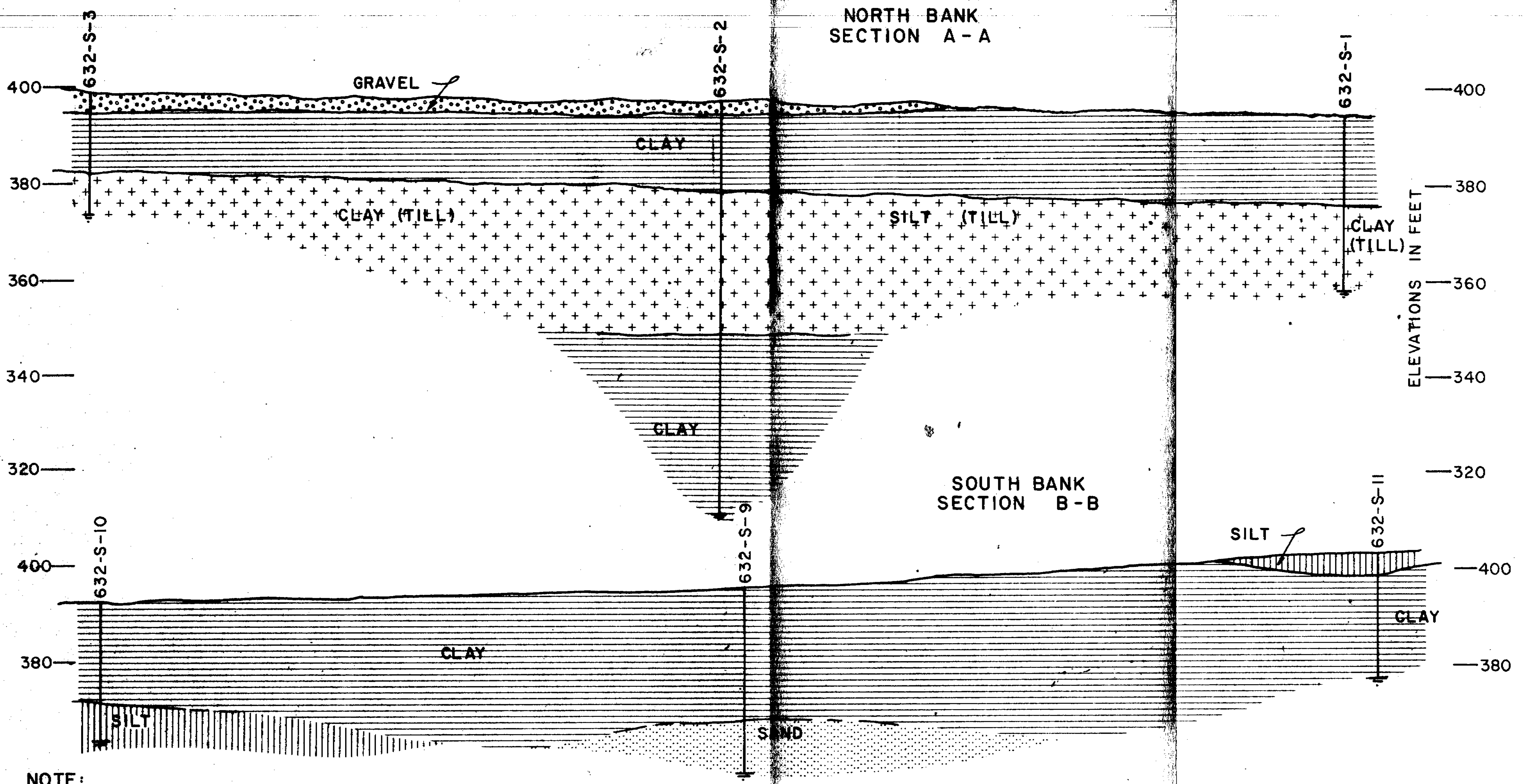
NOTE :
1) Stratigraphy below and between boreholes has been assumed.
2) Elevations and chainages are based on Canadian Engineering Surveys profile.
(EBA T.B.M. EL. = 190.4' assumed = Approx. C.E.S. EL. 394.8')

FRB
11 Dec. 73
E-317

eba Engineering Consultants Ltd.

BOSWORTH CREEK CROSSING
℄ PROFILE &
STRATIGRAPHY

A-4



NOTE:

1. Stratigraphy between boreholes has been assumed.
2. All elevations are relative to T.B.M. nail set in tree 35' east of borehole № 632-S-9. (EL. 190.4' assumed = C.E.S. EL. 394.8')
3. Scales: Horiz. 1" = 20'
   Vert. 1" = 20'

DWN.BY: FRB	Engineering Consultants Ltd.	BOSWORTH CREEK CROSSING CROSS-SECTIONS & STRATIGRAPHY	DWG.: A - 5
DATE DWN.: 19 Dec. 73			SHT.No.:
SCALE: As Noted.			
JOB No.: E-517			

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MACKENZIE HIGHWAY

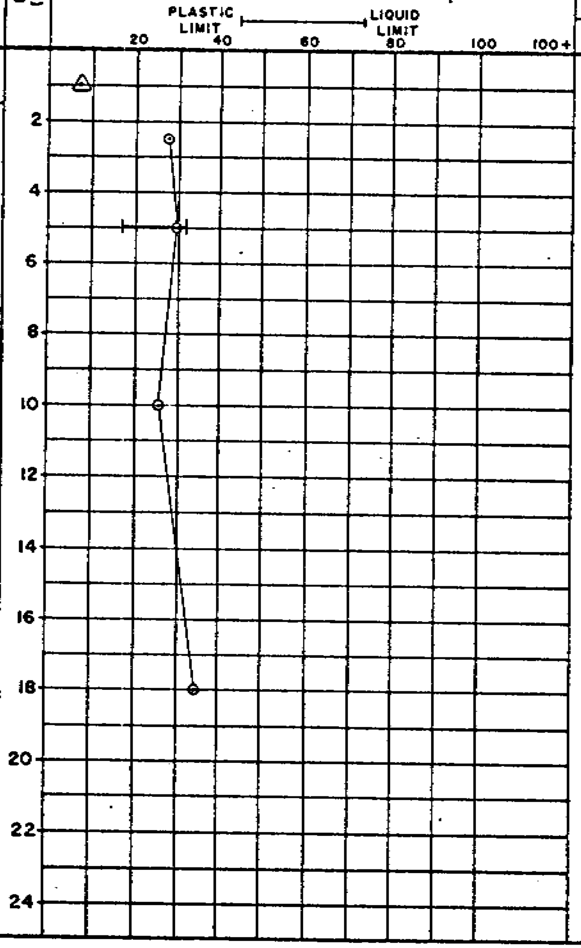
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 11/3/73 | AIRPHOTO NO: A22767 - 152 | CHAINAGE: 4901 + 00 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent S. to Creek | VEGETATION: Thick Spruce & Birch 6 - 30' | ELEV: 417.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	C	4

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0						CLAY (TILL) - Lt. Brown - Silty - Low Plasticity - Gravelly		V 5-10%
2	1	◸			CL			NB
4-5	2	◸						
10	3	◸			CL to CI	- Grey - Silty - Low-Med. Plastic	F U	Unfrozen
17-18	4	◸						
18						END OF HOLE 18'		

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



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

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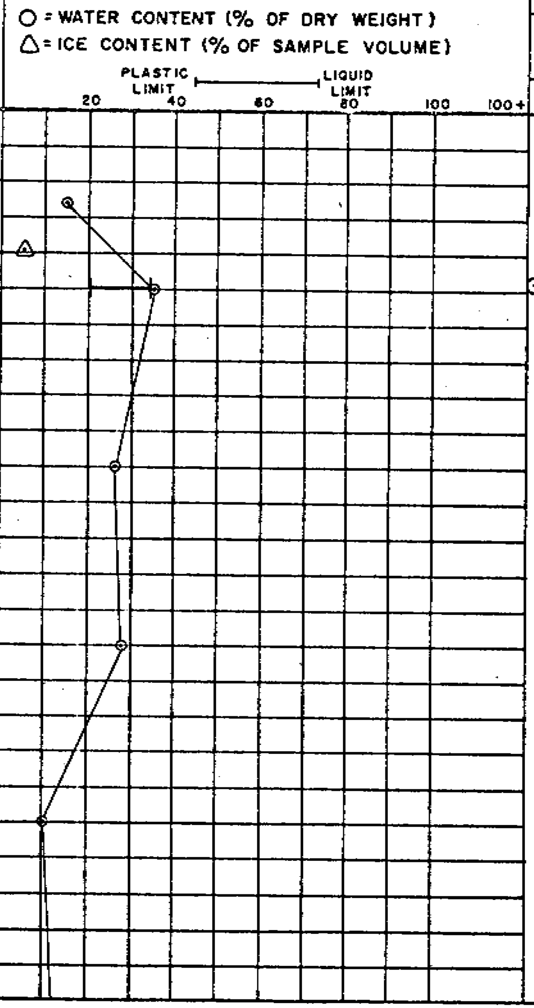
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 11/3/73	AIRPHOTO NO: A22767 - 152	CHAINAGE: 4903 + 50 (EST.)	OFFSET 120' East
CKD BD	TECH: TJ	RIG: Mayhew	SURFACE DRAINAGE: Excellent to S	VEGETATION: Thin Spruce 20 - 40'	ELEV. 396.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	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 (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0						CLAY - Lt. Brown - Silty - Med. Plasticity - Some Gravel (0-3') - Some Sand	F	NB							Bosworth Creek
2	1	⊠													
4								V 5 - 7%							
5	2	⊠			CL				34	52	12	2			
8								NB							
10	3	⊠				- Grey, silty sand	F U	Unfrozen	(18)		82	-			
15	4	⊠													
18					CL	CLAY (TILL) - Grey - Silty - Gravelly - Some Cobbles - Low Plasticity									
20	5	⊠													
24															



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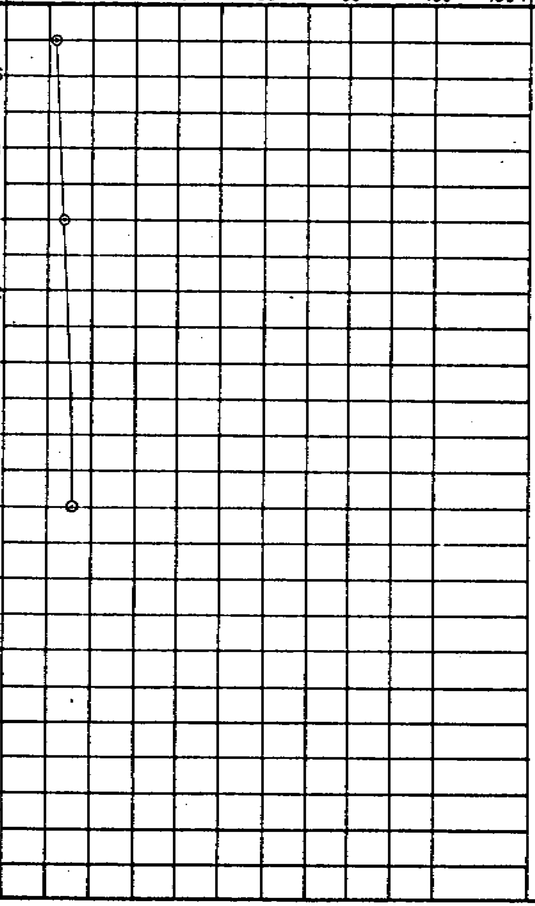
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 11/2/73 | AIRPHOTO NO: A22767 - 152 | CHAINAGE: 4903 + 50 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to S | VEGETATION: Thin Spruce 20 - 40' | ELEV: 396.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	S	1

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	○ = WATER CONTENT (% OF DRY WEIGHT) △ = ICE CONTENT (% OF SAMPLE VOLUME) PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT 20 40 60 80 100 100+	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
	6					CLAY (TILL) - Same	U	Unfrozen									
26									26								
28					CL				28								
30	7								30								
32									32								
34									34								
36									36								Hole to Crooked to Continue
38						END OF HOLE 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

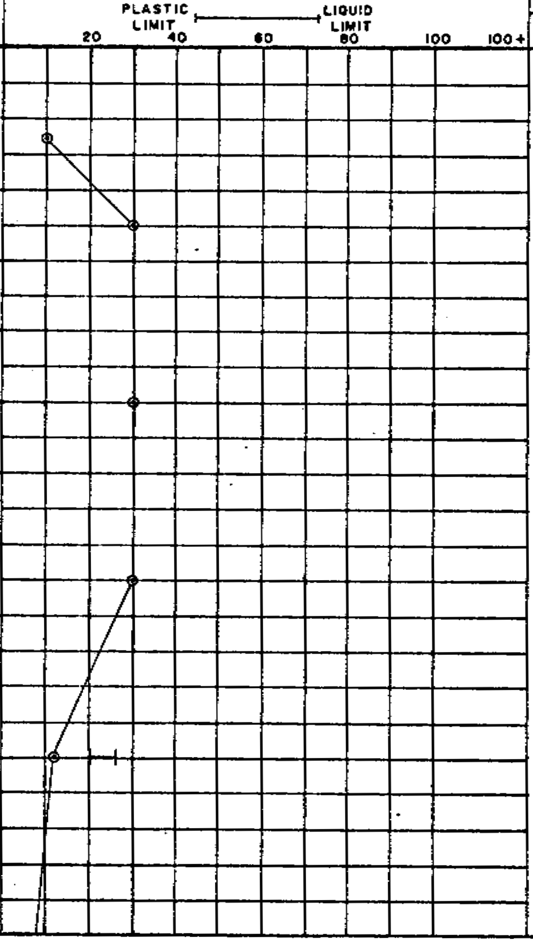
DWN: ALB
FIELD ENG: NRM
DATE DRILLED 11/3/73
AIRPHOTO NO: A22767 - 152
CHAINAGE: 4903 + 50 (EST.)
OFFSET
CKD: BD
TECH: TJ
RIG: Mayhew
SURFACE DRAINAGE: Excellent to S
VEGETATION: Thin Spruce & Birch
ELEV: 398.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	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
2	1				GM	GRAVEL - Lt. Brown - Med. - Silty	F	NF							Bosworth Creek
4 6 8 10 12 14 16 18	2 3 4				CL	CLAY - Lt. Brown - Silty - Low Plasticity - Grey		NB							
20 22 24	5				ML to CL	SILT (TILL) - Grey - Clayey - Gravelly - Some Cobbles - Low Plasticity									

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



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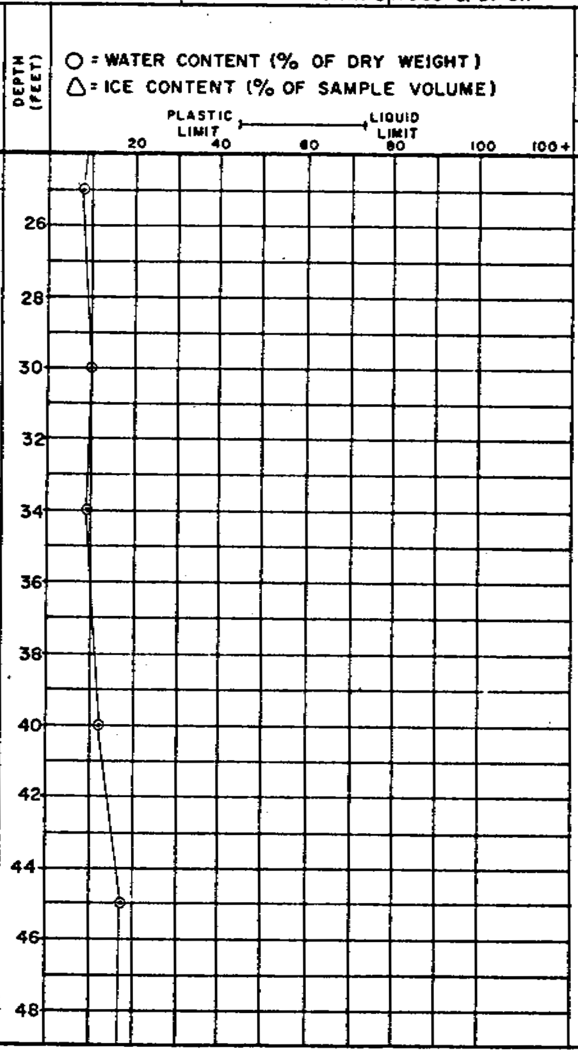
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 11/3/73	AIRPHOTO NO: A22767 - 152	CHAINAGE: 4903 + 80 (EST.)	OFFSET
CKD: BD	TECH: TJ	RIG: Mayhew	SURFACE DRAINAGE: Excellent to S	VEGETATION: Thin Spruce & Birch	ELEV: 398.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	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
	6					SILT	F	NB							
26					ML to CL	(TILL) - Same - Dry (25' - 49')	U	Unfrozen							
28															
30	7														
32															
34															
36	8														
38															
40	9														
42															
44															
46	10														
48															



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

DWN: ALB | FIELD ENG: NRM | DATE DRILLED: 11/3/73 | AIRPHOTO NO: A22767 - 152 | CHAINAGE: 4903 + 50 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to S | VEGETATION: Thin Spruce & Birch | ELEV: 398.0'

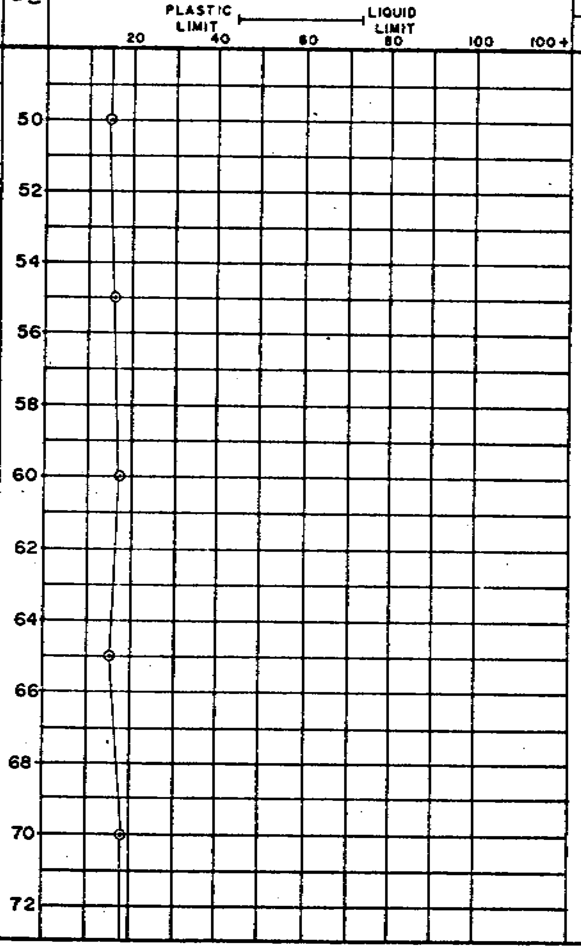
TEST HOLE		
MILE	B,C,S	NUMBER
632	S	2

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						SILT (TILL) - same	U	Unfrozen
50	11	▨			CL to CI	CLAY - silty - Low to Med. Plasticity - No Gravel - Moist	F	
52								V Trace
54								
	12	▨						
56								
58								
60	13	▨						
62								
64								
	14	▨						
66								
68								
70	15	▨						
72								

○ = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)

PLASTIC LIMIT ├───┤ LIQUID LIMIT



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

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

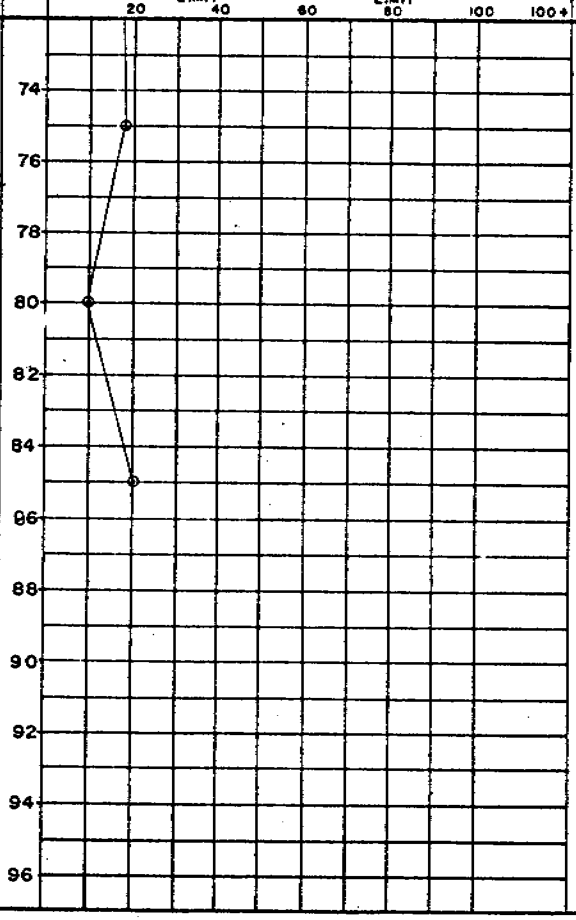
DWN: ALB
FIELD ENG: NRM
DATE DRILLED: 11/3/73
AIRPHOTO NO: A22767 - 152
CHAINAGE: 4903 + 80 (EST.)
OFFSET
CKD: BD
TECH: TJ
RIG: Mayhew
SURFACE DRAINAGE: Excellent to S
VEGETATION: Thin Spruce & Birch
ELEV: 398.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	S	2

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
74						CLAY - same	F	V- Trace	
75	16	⧅							
80	17	⧅							
85	18	⧅							Bit Plugged
86						END OF HOLE 86'			

○ = 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.)

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

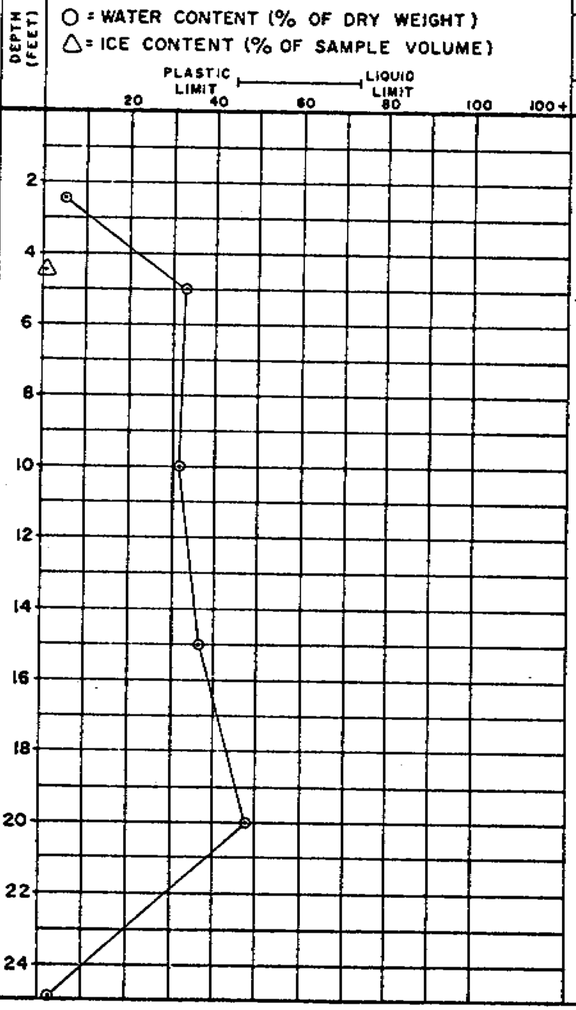
DWN: ALB	FIELD ENG: NRM	DATE DRILLED 3/11/73	AIRPHOTO NO: A22767-152	CHAINAGE: 4903 + 80 (EST.)	OFFSET 120' West
CKD BD	TECH TJ	RIG Mayhew	SURFACE DRAINAGE: Excellent to S.	VEGETATION: Thick Spruce, Willow, Birch 10' - 30'	ELEV 399.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	S	3

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
2	1	⧅			GM	GRAVEL - Lt. Brown - Sandy - Med. gravel - Some Silt	F	NF	(17)		29	54			Bosworth Creek
4	2	⧅			CL	CLAY - Lt. Brown - Silty - Low Plasticity - Grey		NB - V - 0-2%							
10	3	⧅						NB							
14	4	⧅				- Very Silty									
18					CL	CLAY (TILL) - Grey - Silty - Gravelly									
20	5	⧅						V Trace							
24	6	⧅			BL	Quartzite Boulder - 25'									Quartzite Boulder Too Hard for New Rock Bit.

END OF HOLE 25'



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DRILL HOLE REPORT

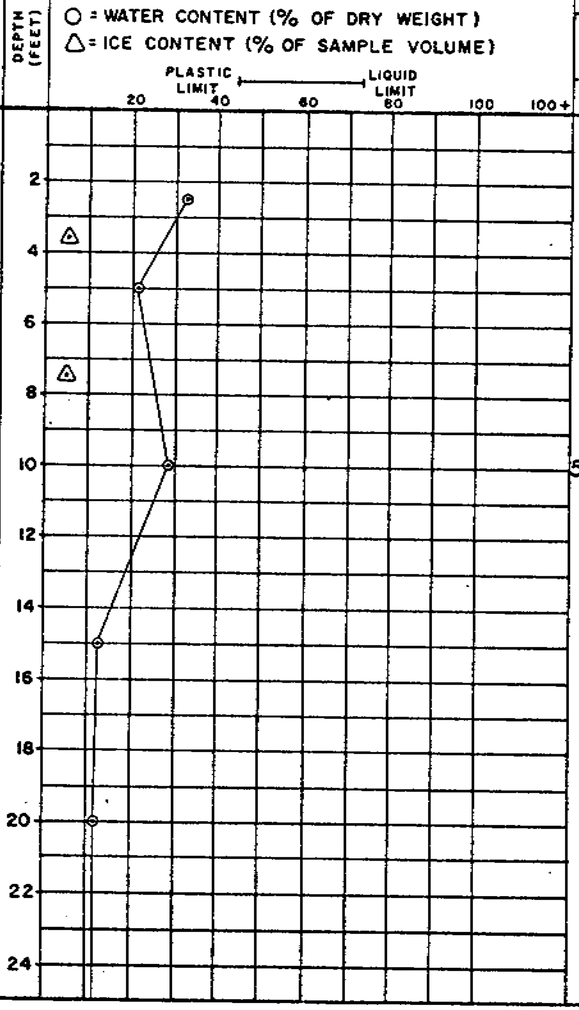
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB
CKD: BD
FIELD ENG: NRM
TECH: TJ
DATE DRILLED 11/3/73
RIG: Mayhew
AIRPHOTO NO: A22767 - 152
SURFACE DRAINAGE: Excellent to S
CHAINAGE: 4904 + 60 (EST.)
VEGETATION: Thin Spruce 40 - 50'
OFFSET
ELEV: 389.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	S	4

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.)
						CLAY (TILL)	F							
2	1	▧			CL	- Silty - Lt. Brown - Some Gravel		V 5 - 7%						
4	2	▧												
10	3	▧				- Med. Brown - Silty, trace of sand and gravel - Low - Med. Plastic		NB	54	37	8	1		
14	4	▧			CL to CI									
20	5	▧				- Grey - Low Plasticity - Gravelly								
24														



REMARKS

Bosworth Creek

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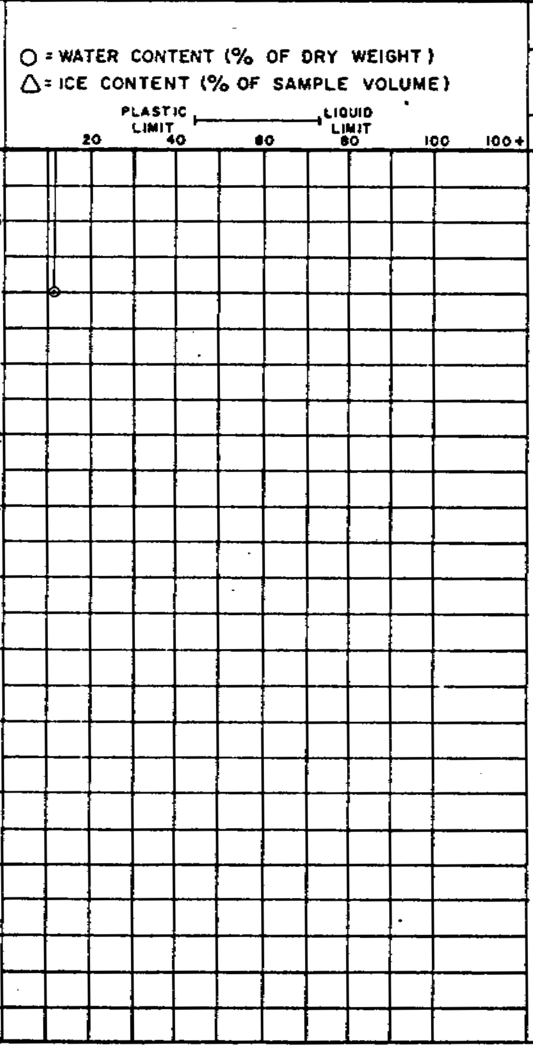
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY**

DWN: ALB | FIELD ENG: NRM | DATE DRILLED: 11/3/73 | AIRPHOTO NO: A22767 - 152 | CHAINAGE: 4904 + 60 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to S | VEGETATION: Thin Spruce 40 - 50' | ELEV: 389.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	S	4

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
						CLAY										
26					CL to CI	(TILL) - same	F	NB	26							
28	6					END OF HOLE 28'			28							
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							



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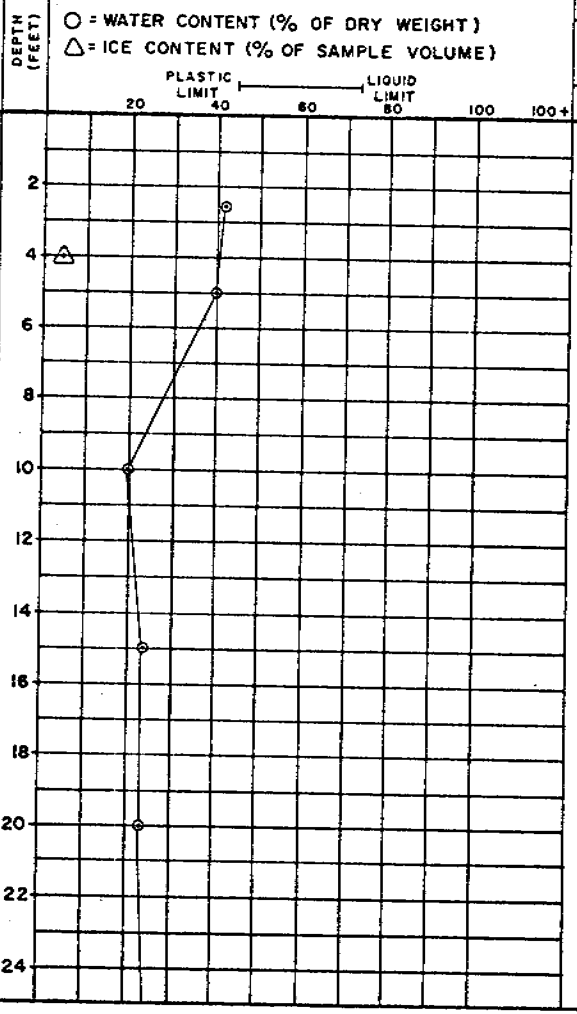
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN: ALB
CKD: BD
FIELD ENG: NRM
TECH: TJ
DATE DRILLED: 11/3/73
RIG: Mayhew
AIRPHOTO NO:
SURFACE DRAINAGE: Excellent to S
CHAINAGE: 4905 + 20 (EST.)
VEGETATION: Thick Spruce 20 - 50'
OFFSET
ELEV: 381.0'

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

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
					PT	PEAT - Dk. Brown - Silty	F								
2	1	⧅			CL	CLAY (TILL) - Lt. Brown - Silty - Some Gravel		NB V 5 - 7%							Bosworth Creek
4	2	⧅													
6															
8					CL	- Med. Brown - Silty - Low - Med. Plasticity - Some Gravel		NB							
10	3	⧅			to										
12					CI										
14	4	⧅				- Grey - Med. Plasticity - No Gravel									
16															
18															
20	5	⧅			CI to CH	- Dk. Grey - Med. to High Plasticity - Silty		NB - V Trace							Pocket Penetrometer 1.36 tsf
22															
24															



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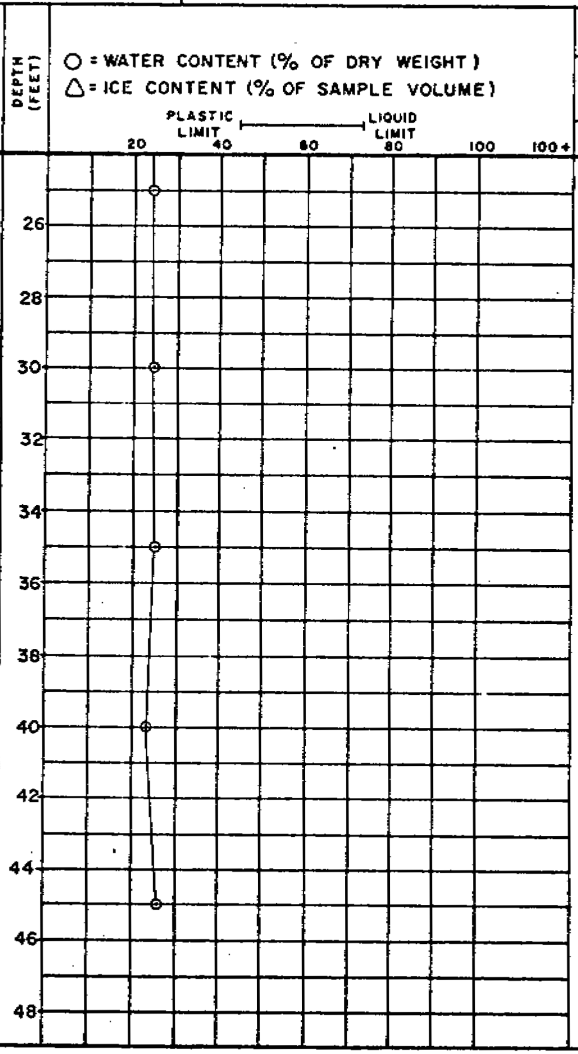
.E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN: ALB | FIELD ENG: NRM | DATE DRILLED: 11/3/73 | AIRPHOTO NO: A22767-152 | CHAINAGE: 4905 + 20 (EST.) | OFFSET
CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to S | VEGETATION: 20 - 50' | ELEV: 381.0'

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

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
	6	⧄			CI	CLAY (TILL) - Same	F	NB to V-Trace							
	7	⧄													
	8	⧄													
	9	⧄													
	10	⧄													
48						END OF HOLE 48'									



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

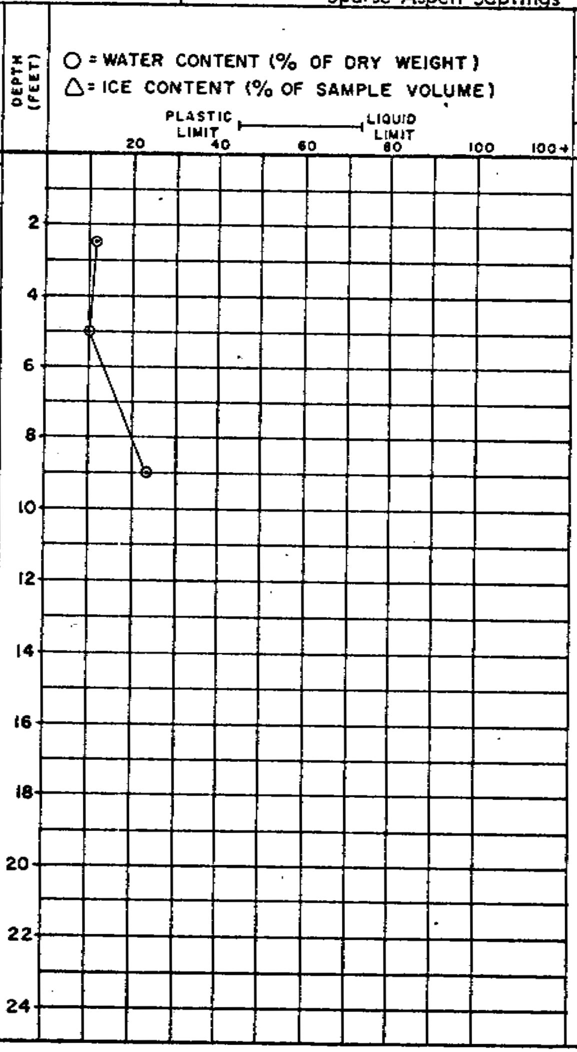
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 1/3/73 | AIRPHOTO NO: A22767 - 152 | CHAINAGE: 4908 + 20 (Est.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Fair to W | VEGETATION: Sparse Aspen Saplings | ELEV: 360.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	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
						CLEAN ICE									
2 4	1				GW	GRAVEL - Med. Brown - Sandy and clay - Some Silt	F	NF							Bosworth Creek on Flat in Middle of Valley
6	2						U		(11)		21	68			
8						- Free Water		Unfrozen							
	3														
10 12 14 16 18 20 22 24						END OF HOLE 9'									

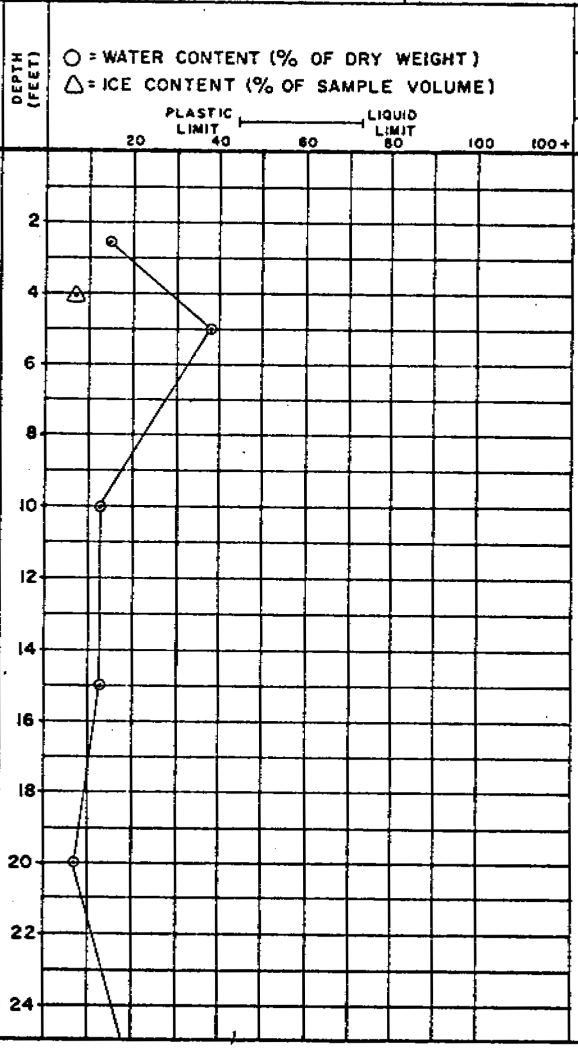


E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN: ALB | FIELD ENG: NRM | DATE DRILLED 2/3/73 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4910 + 30 (EST.) | OFFSET
CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N | VEGETATION: Thick Spruce 40 - 50' | ELEV: 384.0'

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

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
2 4 6	1 2				CL	CLAY - Lt. Brown - Silty - Low Plasticity - Grey		V 5 - 10%							Bosworth Creek
8 10 12 14 16 18 20	3 4 5				SP	SAND - Lt. Brown - Coarse - Med. - Gravelly - Trace Silt		NF							
22 24					ML	SILT (TILL) - Lt. Grey - Clayey - Some Gravel - Low Plasticity		NB							



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

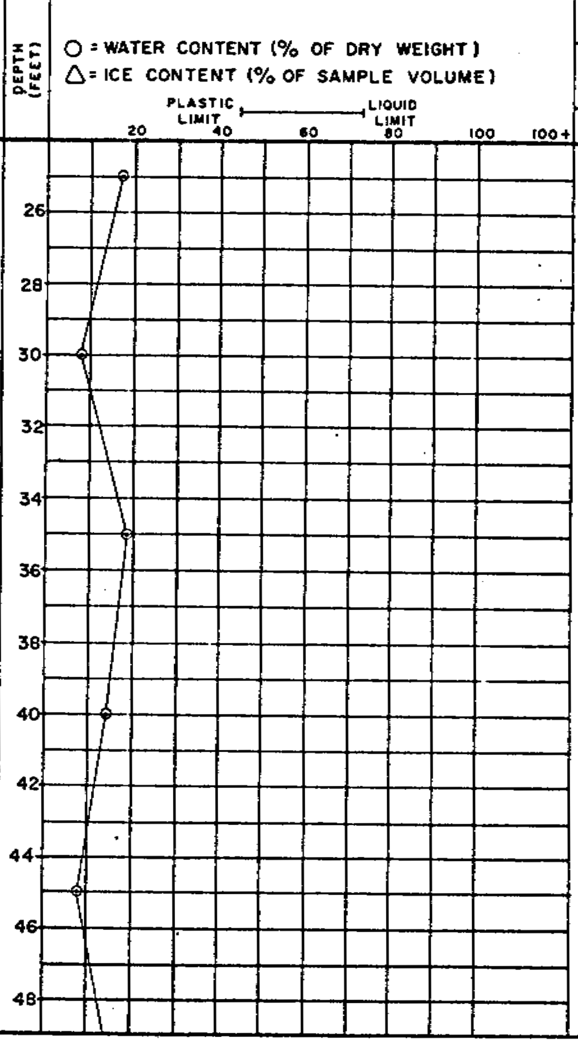
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 12/3/73 | AIRPHOTO NO: A22767 - 153 | CHAINAGE: 4910 + 30 (EST.) | OFFSET

CKD BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N | VEGETATION: Thick Spruce 40 - 50' | ELEV: 384.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	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
26	6	⧅			ML	SILT (TILL) - Light Grey - Gravelly - Dry - Non-Plastic	F	NB							
30	7	⧅													
35	8	⧅													
40	9	⧅			CL	CLAY - Grey, Silty - Low Plasticity		V Trace							
45	10	⧅													
48															



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

DWN: ALB	FIELD ENG: NRM	DATE DRILLED: 12/3/73	AIRPHOTO NO: A22767-153	CHAINAGE 4910 + 30 (EST.)
CKD: BD	TECH: TJ	RIG: Mayhew	SURFACE DRAINAGE: Excellent to N	VEGETATION: Thick Spruce 40 - 50'

OFFSET

ELEV: 384.0'

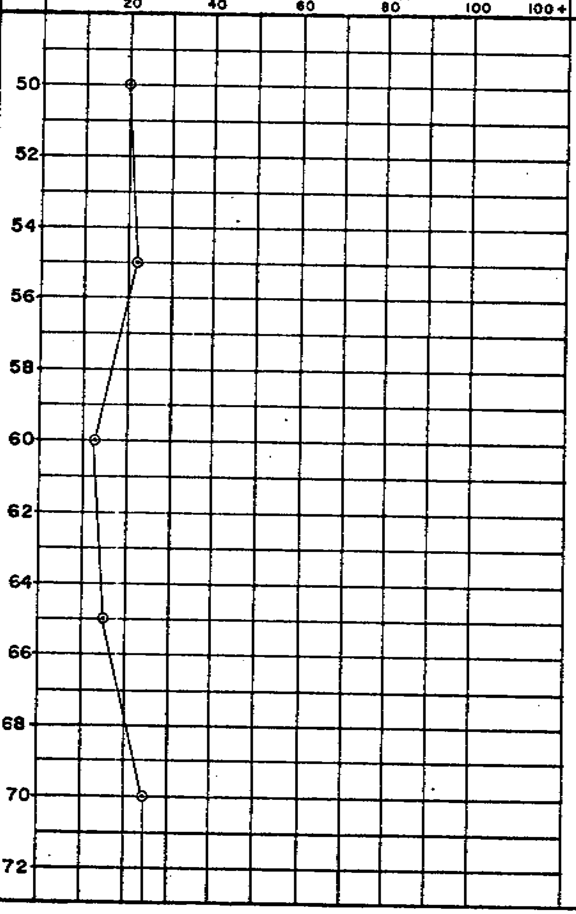
TEST HOLE		
MILE	B,C,S	NUMBER
632	S	7

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					CL	CLAY - Same	F	V-Trace
50	11	◸					U	Unfrozen
52								
54								
	12	◸						
56								
58								
60	13	◸						
62								
64								
	14	◸						
66								
68							U to F	Unfrozen- V- Trace
70	15	◸				- Grey - Silty		
72								

O = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)

PLASTIC LIMIT ├──┤ LIQUID LIMIT



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

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E.W. BROOKER & ASSOCIATES LTD.

DRILL HOLE REPORT

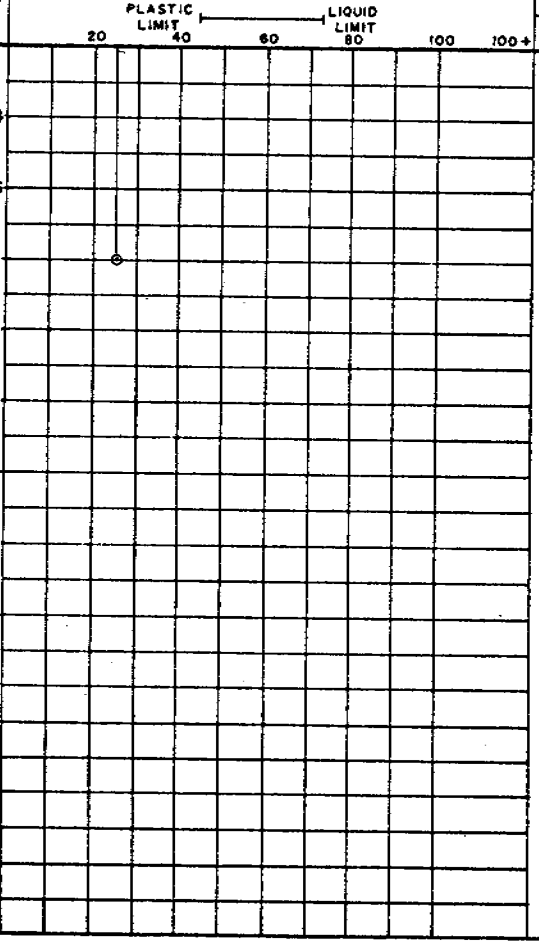
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB
CKD: BD
FIELD ENG: NRM
TECH: TJ
DATE DRILLED: 12/3/78
RIG: Mayhew
AIRPHOTO NO: A22767-153
SURFACE DRAINAGE: Excellent to N
CHAINAGE: 4910 + 30 (EST.)
OFFSET
VEGETATION: Thick Spruce 50 - 50'
ELEV: 384.0'

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						CLAY - Same	U to F	Unfrozen to V-trace
74					CL			
76								
78	16	◩						
80								
82								
84								
86						END OF HOLE 85'		
88								
90								
92								
94								
96								

○ = 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
%	%	%	%			

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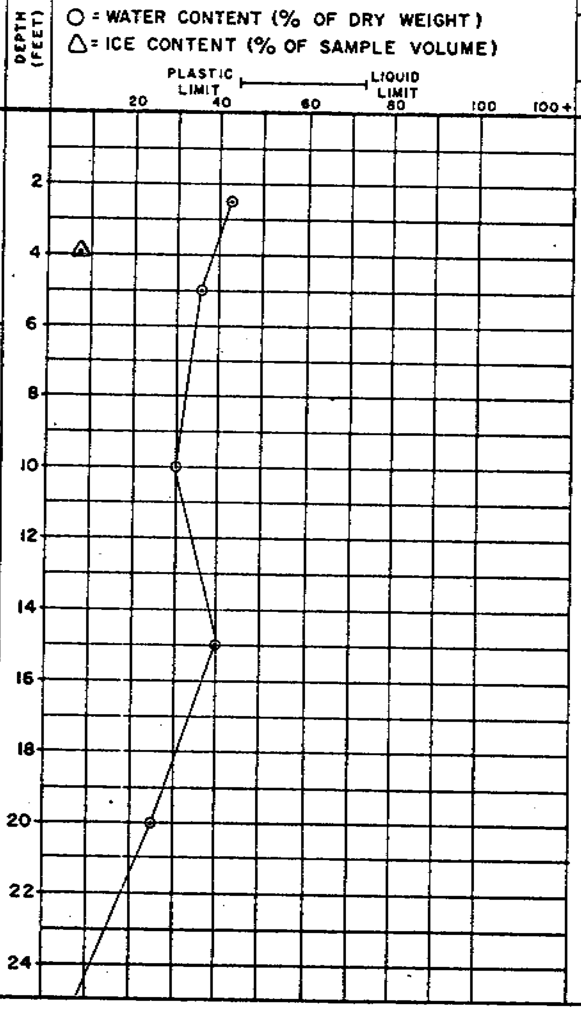
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 12/3/73	AIRPHOTO NO: A22767-153	CHAINAGE: 4911 + 20 (EST.)	OFFSET
CKD: BD	TECH: TJ	RIG: Mayhew	SURFACE DRAINAGE: Excellent to N	VEGETATION: Thick Spruce 40 - 50'	ELEV: 395.0'

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

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						CLAY	F								Bosworth Creek
2	1				CL	- Lt. Brown - Silty - Low Plasticity		V 7 - 10%							
4	2														
6								NB							
10	3				CI	- Grey, Med. Plastic									
15	4														
20	5				SP	SAND - Lt. Brown - Coarse - Med. - Gravelly - Trace Silt		NF							Samples not Representative as Gravel Stays in Hole, Sand Blows Out.



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

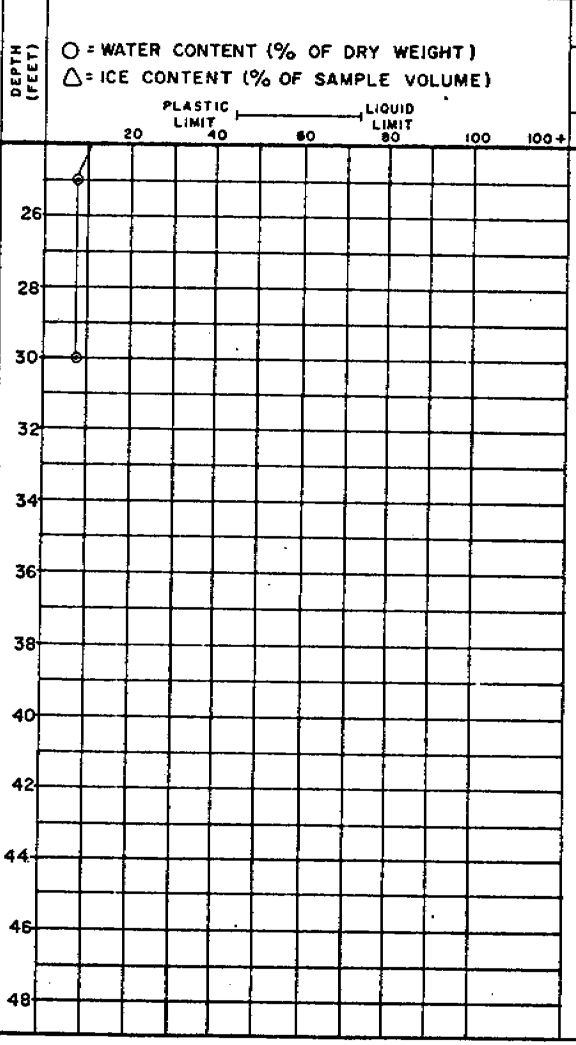
DWN: ALB | FIELD ENG: NRM | DATE DRILLED: 12/2/73 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4911 + 20 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N | VEGETATION: Thick Spruce 40 - 50' | ELEV: 395.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	S	8

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
26	6	⧅			SP	SAND - Same	F	NF							
28															
30	7	⧅													
32															Hole Caving @ 33'
34							END OF HOLE 33'								
36															
38															
40															
42															
44															
46															
48															



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

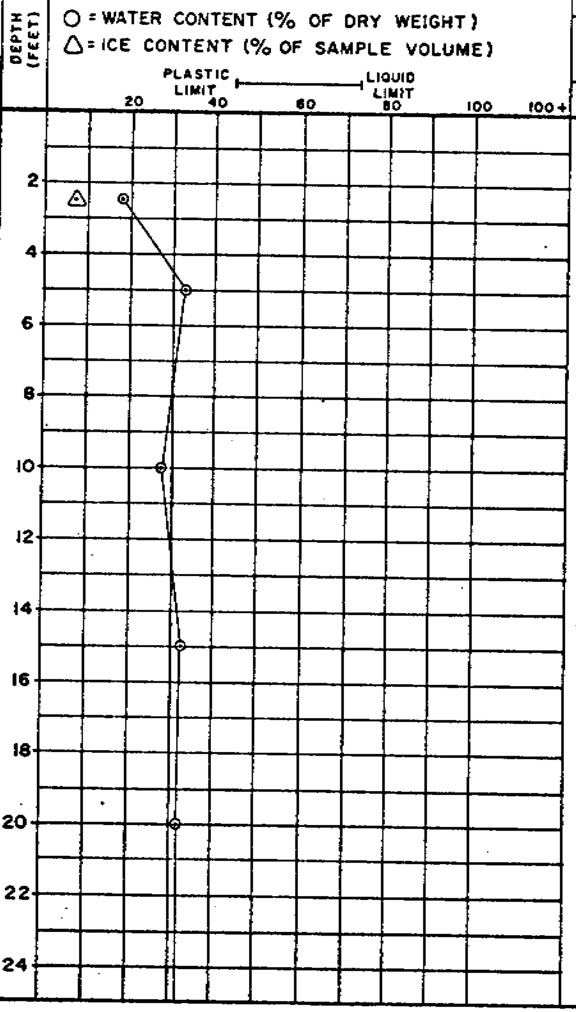
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB	FIELD ENG: NRM	DATE DRILLED 12/3/73	AIRPHOTO NO A22767-153	CHAINAGE: 4911 + 90 (EST.)	OFFSET
CKD: BD	TECH: TJ	RIG: Mayhew	SURFACE DRAINAGE: Excellent to N.	VEGETATION: Thick Spruce 40 - 50'	ELEV: 398.0'

TEST HOLE

MILE	B,C,S	NUMBER
632	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 (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
2	1	⧅			CL	CLAY - Lt. Brown - Silty - Low Plasticity - Some Gravel		V 7 - 10%							Bosworth Creek
4	2	⧅						NB							
10	3	⧅				- Grey - Silty - Low Plasticity									
14	4	⧅						V Trace							
20	5	⧅													
24															



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

DWN: ALB | FIELD ENG: NRM | DATE DRILLED 12/3/78 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4911 + 90 (EST.) | OFFSET

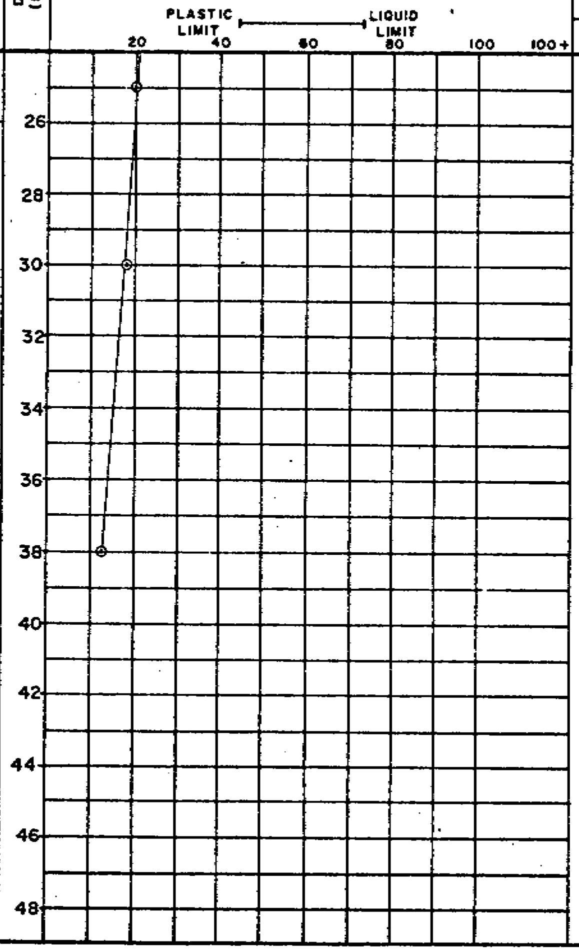
CKD BD | TECH TJ | RIG: Mayhew | SURFACE DRAINAGE Excellent to N. | VEGETATION: Thick Spruce 40-50' | ELEV: 398.0'

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6				CL	CLAY - same	F	V-Trace
26–38	7 8				SP to SM	SAND - Lt. Grey, fine grained Gravelly, silty - Non-Plastic - Dry		NB
38						END OF HOLE 38'		

○ = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)



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

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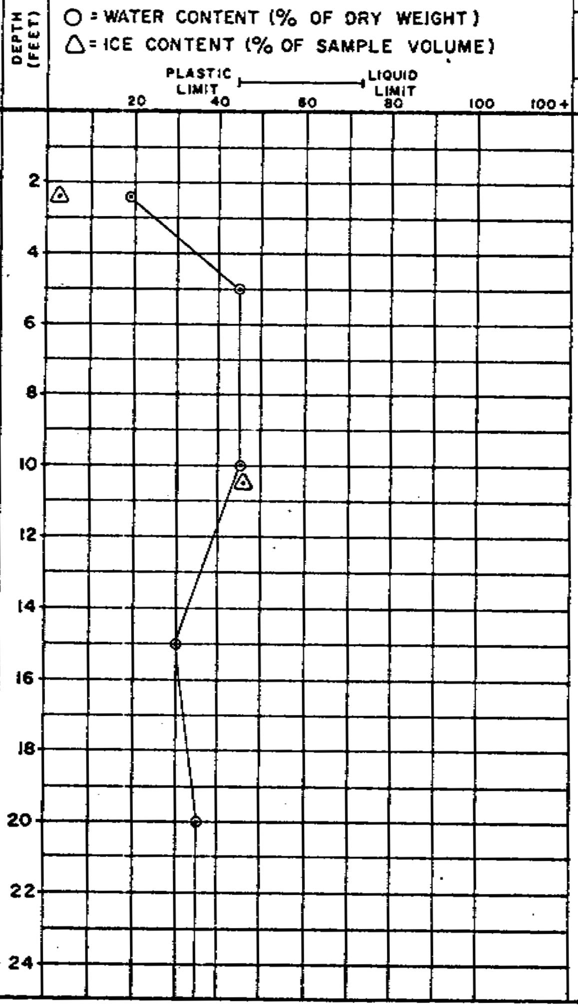
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB | FIELD ENG: NRM | DATE DRILLED 12/3/73 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4912 + 00 (EST.) | OFFSET 125' WEST

CKD BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N. | VEGETATION: Thick Spruce 40 - 50' | ELEV 396.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	S	10

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
					CL	CLAY - Lt. Brown	F	V							
2	1	⧅				- Silty, Some Grave - Low Plasticity		0 - 5%							Bosworth Creek
4								NB							
6	2	⧅			CL to CI	- Grey - Silty - Low - Med. Plasticity									
8															
10	3	⧅						V- 40-50%							
12															
14															
16	4	⧅						V - Trace							
18															
20	5	⧅													
22															
24															



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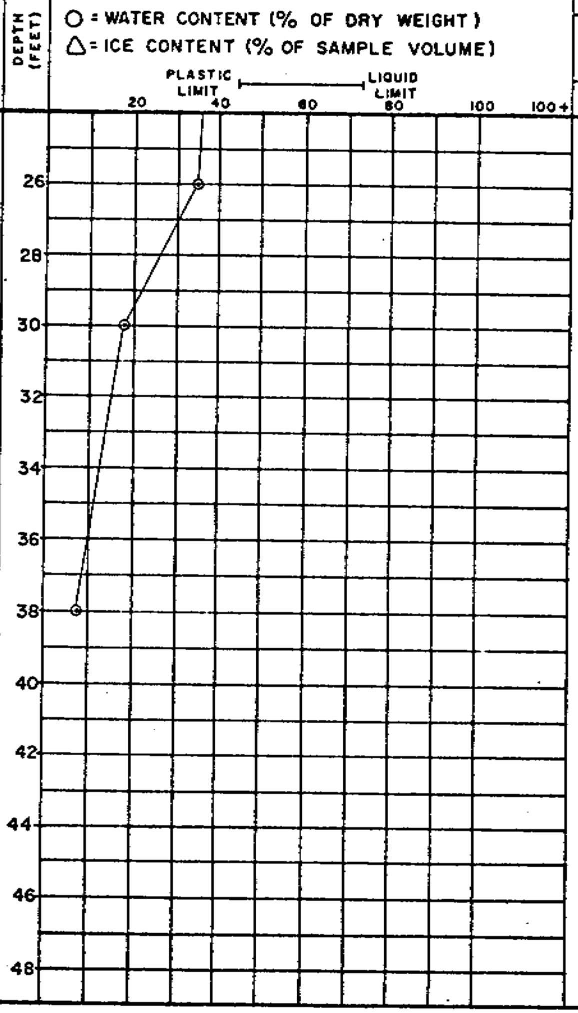
E.W. BROOKER & ASSOCIATES LTD. | DRILL HOLE REPORT | DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: ALB | FIELD ENG NRM | DATE DRILLED 12/3/73 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4912 + 00 (EST.) | OFFSET 125' West
CKD BD | TECH TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N. | VEGETATION: Thick Spruce 40 - 50' | ELEV. 396.0'

TEST HOLE		
MILE	B,C,S	NUMBER
632	S	10

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6				CL to CI	CLAY - same	F	V-Trace
	7				ML	SILT - Lt. Grey - Some Sand - Low Plasticity - Gravelly		
	8					END OF HOLE 38'		



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

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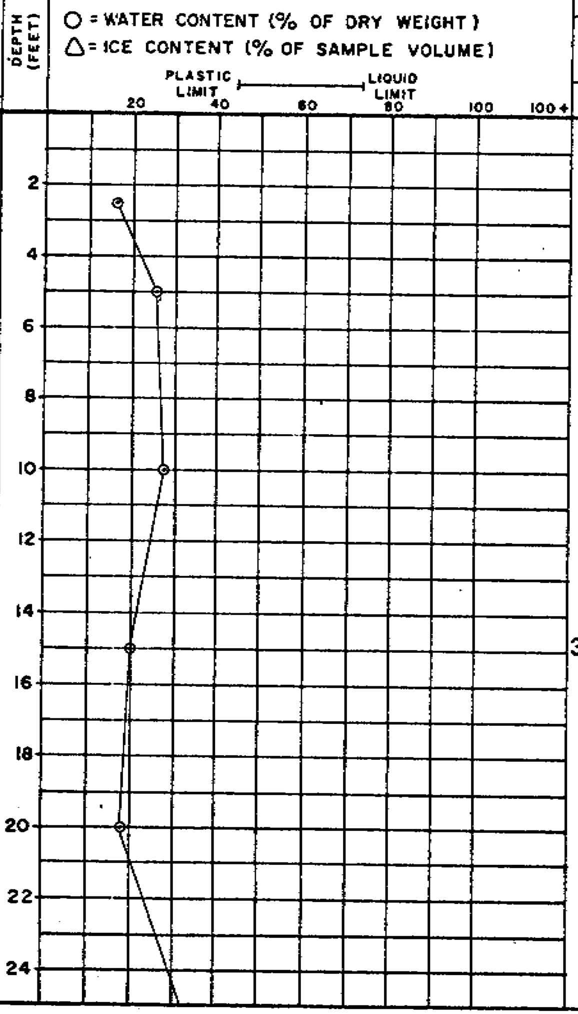
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN: ALB
CKD: BD
FIELD ENG: NRM
TECH: TJ
DATE DRILLED 12/3/73
RIG: Mayhew
AIRPHOTO NO: A22767-153
SURFACE DRAINAGE: Excellent to N
CHAINAGE: 4912 + 30 (EST.)
VEGETATION: Thick Spruce 40 - 50'
OFFSET 130' EAST
ELEV: 401.0'

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

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
2	1				ML	SILT - Lt. Brown - Low Plasticity - Trace Gravel									Bosworth Creek
4	2				CL	CLAY - Lt. Brown - Silty - Low Plasticity		NB							
6															
8															
10	3					- Grey-Brown									
12							F								
14	4				CI	- Grey, silty, some - sand and gravel - Soft - Med. Plasticity	U to F	Unfrozen - V - Trace	31	50	(19)				
16															
18															
20	5														
22															
24															



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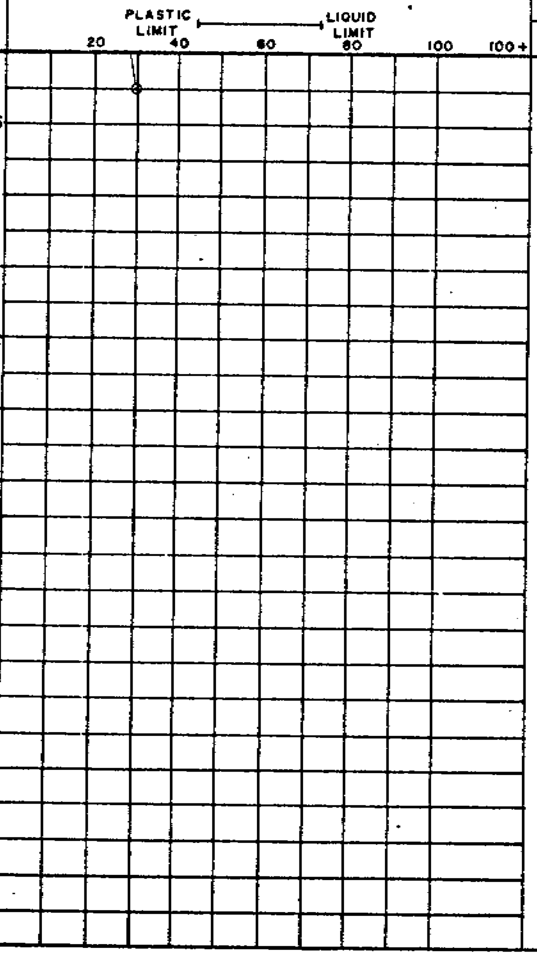
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN ALB | FIELD ENG. NRM | DATE DRILLED 12/3/73 | AIRPHOTO NO: A22767-153 | CHAINAGE: 4912 + 30 (EST.) | OFFSET 130' East
CKD BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N | VEGETATION: Thick Spruce 40-50' | ELEV: 401.0'

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

○ = 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)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
	6					CLAY - Same	U to F	Unfrozen to V-Trace								
26					CI				26							
28						END OF HOLE 28'			28							
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							



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

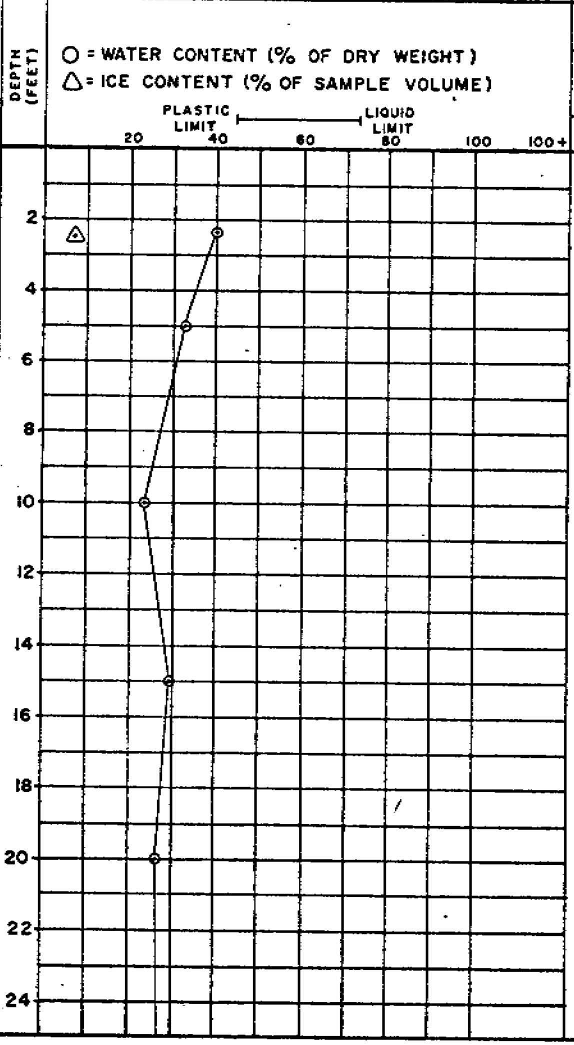
DWN: ALB | FIELD ENG: NRM | DATE DRILLED 12/3/73 | AIRPHOTO NO: A22767 - 153 | CHAINAGE: 4913 + 00 (EST.) | OFFSET

CKD: BD | TECH: TJ | RIG: Mayhew | SURFACE DRAINAGE: Excellent to N | VEGETATION: Thick Spruce 40 - 50' | ELEV: 406.0'

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

REMARKS: Bosworth Creek

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0						CLAY	F	V 5 - 10%
2	1	⧅			CL	- Lt. Brown - Silty - Low Plasticity		
3								NB
5	2	⧅						
10	3	⧅				- Grey, Low Plasticity		
14							F	
15	4	⧅			CI	- Med. Plasticity	U to F	Unfrozen - V - Trace
20	5	⧅						
24								



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

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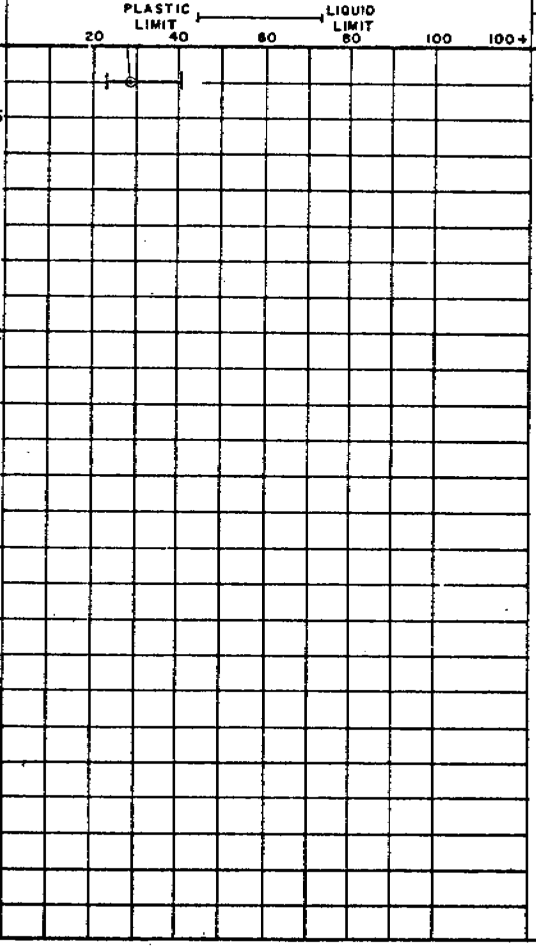
E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: ALB
FIELD ENG: NRM
DATE DRILLED 12/3/73
AIRPHOTO NO: A22767 - 153
CHAINAGE: 4913 + 00 (EST.)
OFFSET
CKD: BD
TECH: TJ
RIG: Mayhew
SURFACE DRAINAGE: Excellent to N
VEGETATION: Thick Spruce 40 - 50'
ELEV: 406.0'

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

○ = 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)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
	6					CLAY - Silty, trace of sand and gravel, med. plasticity	U to F	Unfrozen to V-Trace		34	60	5	1			
26					CI				26							
28									28							
30						END OF HOLE 30'			30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							

GRAIN SIZE DISTRIBUTION

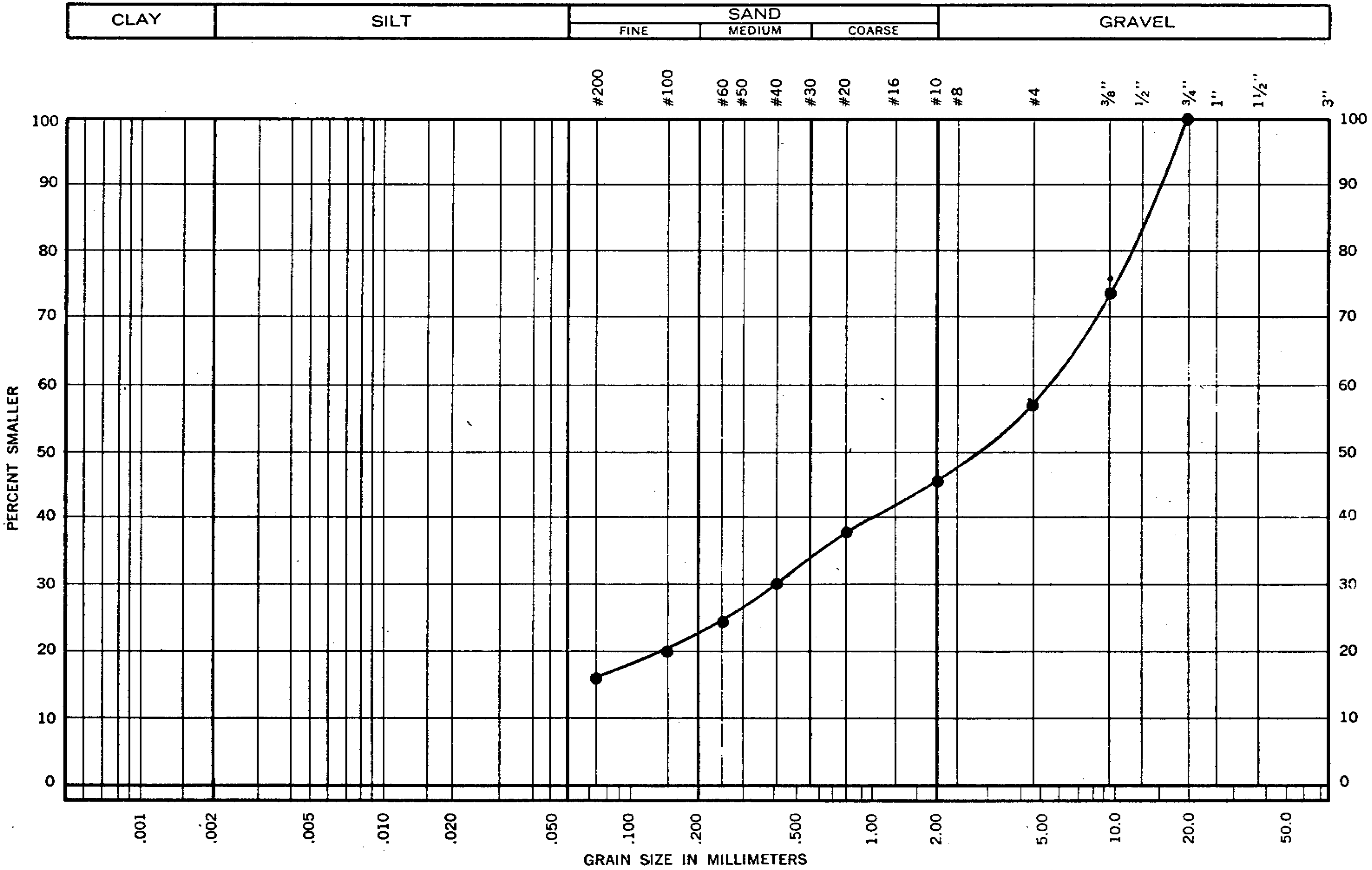


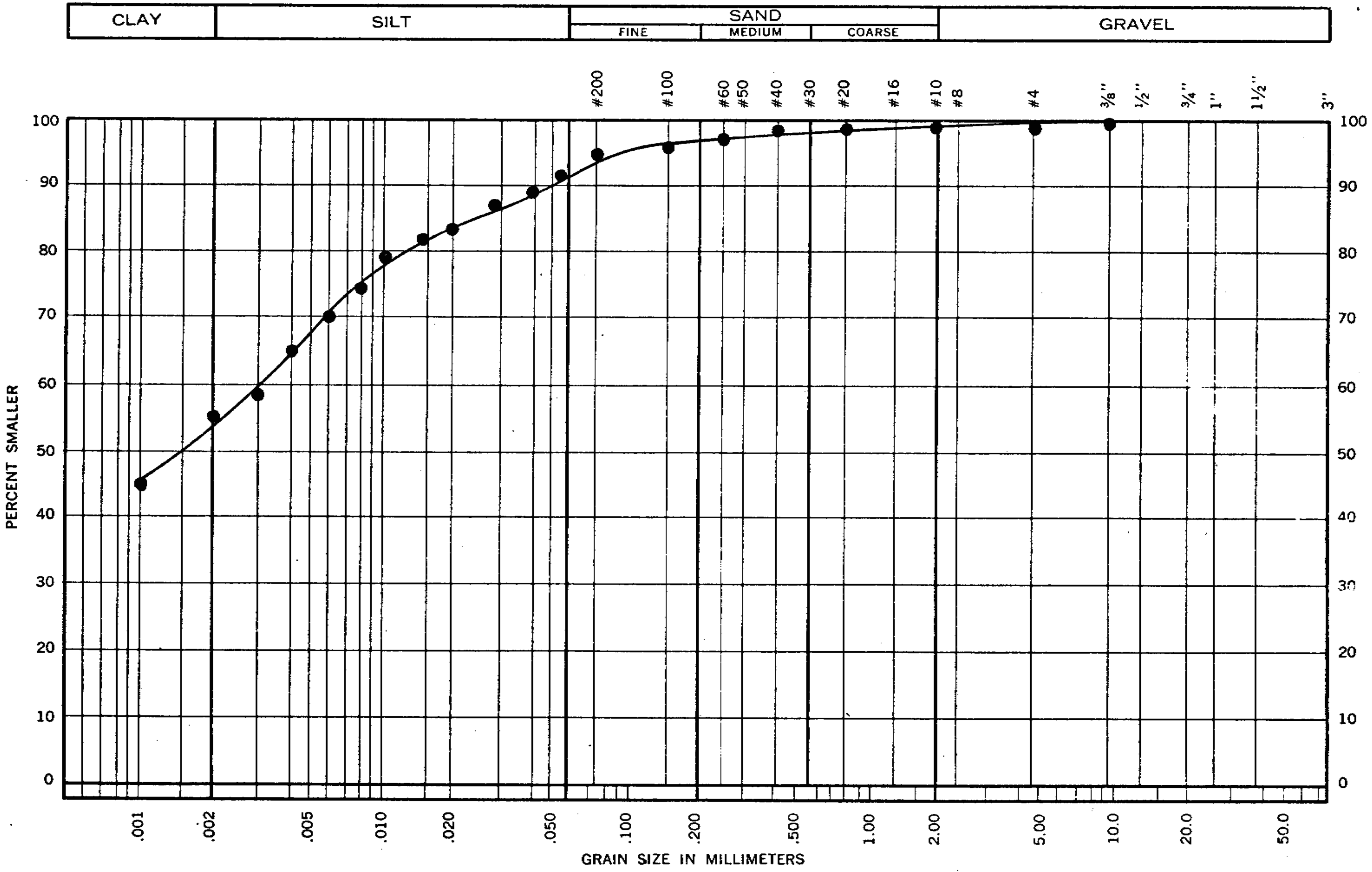
FIGURE C-1

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION GRAVEL, SANDY, SOME SILT

PROJECT Mackenzie Highway
JOB No. E-517 DATE April 12/73
SAMPLE No. 632-S-3
DEPTH 2 1/2

GRAIN SIZE DISTRIBUTION



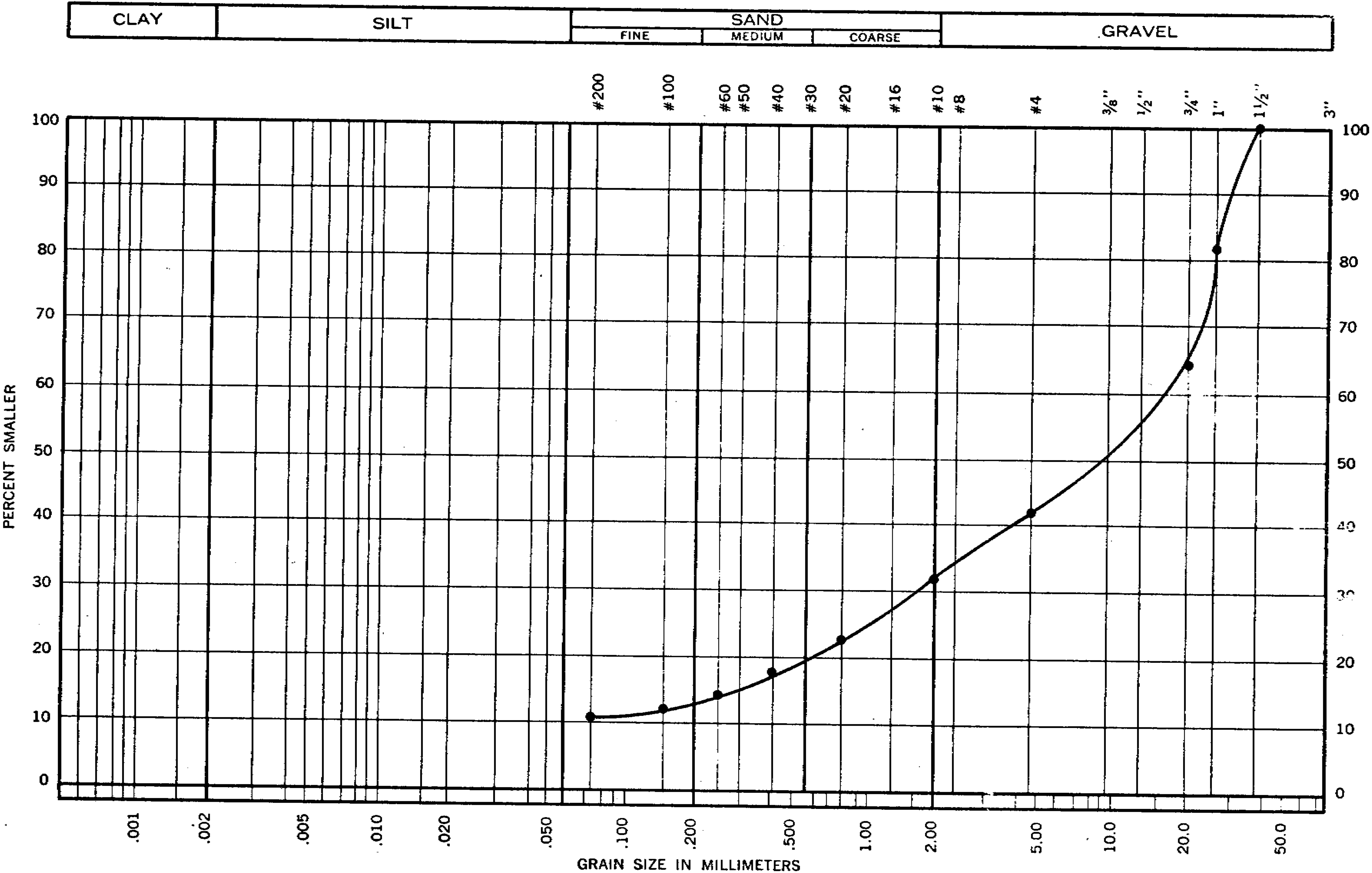
BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY, SILTY, TRACE SAND , TRACE GRAVEL

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE APRIL 8/73
SAMPLE No. 632-S-4
DEPTH 10'

FIGURE C-2

GRAIN SIZE DISTRIBUTION



BROOKER & ASSOCIATES

SAMPLE DESCRIPTION SANDY GRAVEL, SOME SILT

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE APRIL 5/73
SAMPLE No. 632-S-6
DEPTH 5'

GRAIN SIZE DISTRIBUTION

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY, SILTY, SOME SAND

PROJECT MACKENZIE HIGHWAY
JOB No. E - 517 DATE April 5/73
SAMPLE No. 632 -S- 11
DEPTH 15'

GRAIN SIZE DISTRIBUTION

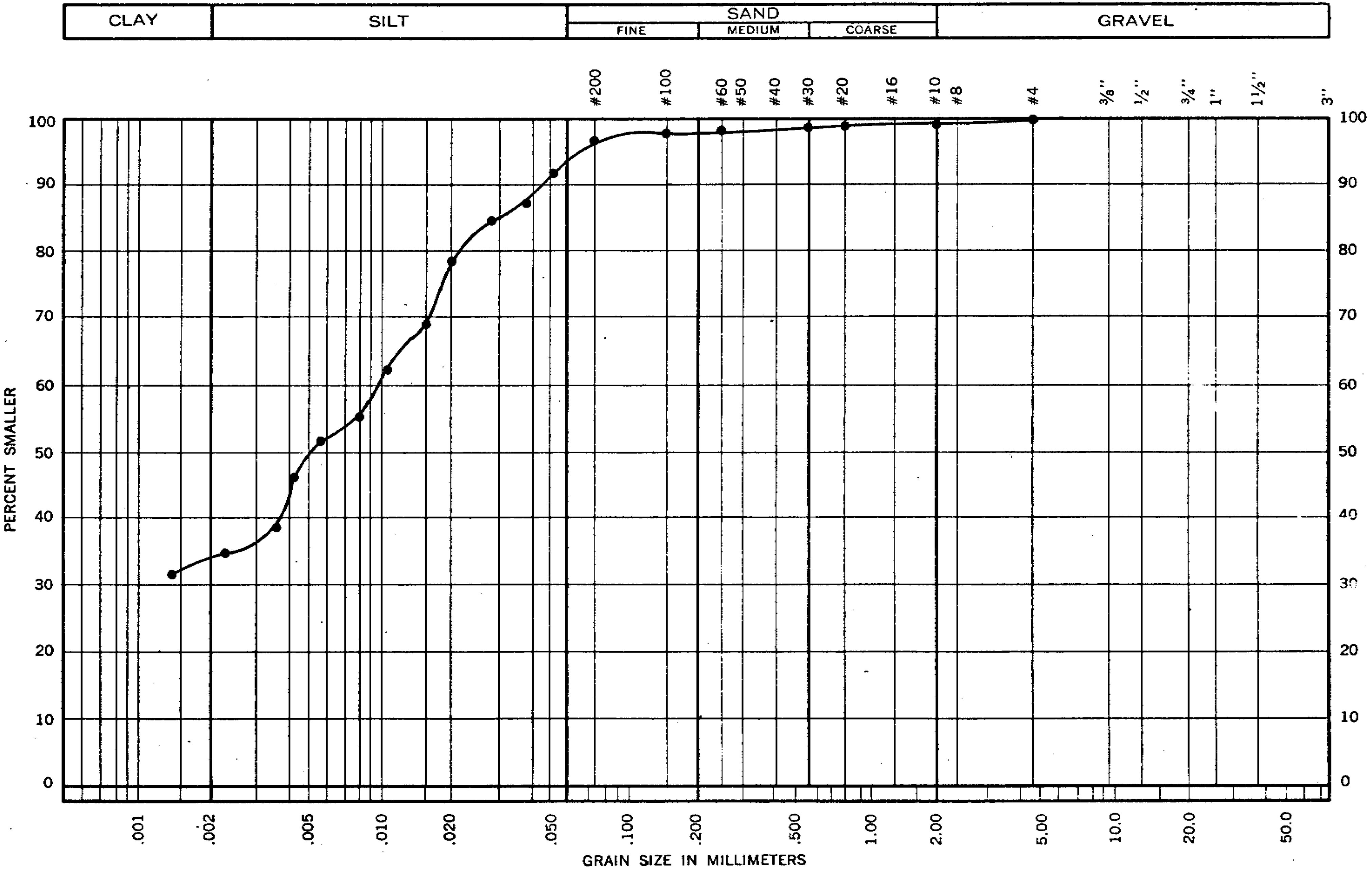


FIGURE C-5

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY, SILTY, TRACE SAND, TRACE GRAVEL

PROJECT MACKENZIE HIGHWAY
JOB No. E - 517 DATE April 9/73
SAMPLE No. 632 -S- 12
DEPTH 25'

SUMMARY OF TEST RESULTS

JOB No. E-517

BORE HOLE	DEPTH	NATURAL WATER CONTENT	Atterberg Limits			MECHANICAL ANALYSIS (M.I.T. CLASSIFICATION)				SOIL CLASSIFICATION (UNIFIED)	REMARKS
			W_L	W_P	PI						
	feet	%	%	%	%	% CLAY	% SILT	% SAND	% GRAVEL		
632-C-4	5	29.1	30.4	19.6	10.8					CL	Organic Content 12.04% SO_4 - 0.135%
632-S-1	5	35.0	34.0	20.5	13.5					CL	SO_4 - 0.158%
632-S-2	20	11.5	27.3	20.9	6.5					CL-ML	
632-S-3	2½					(1	7)	29	54	GM	
632-S-4	10					54	37	8	1	CL-CI	
632-S-6	5					(1	1)	21	68	GW	
632-S-11	15	20.9				31	50	19		CL	
632-S-12	25	29.0	40.0	24.7	15.3	34	60	5	1	CI	

DWG. No. C-6

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