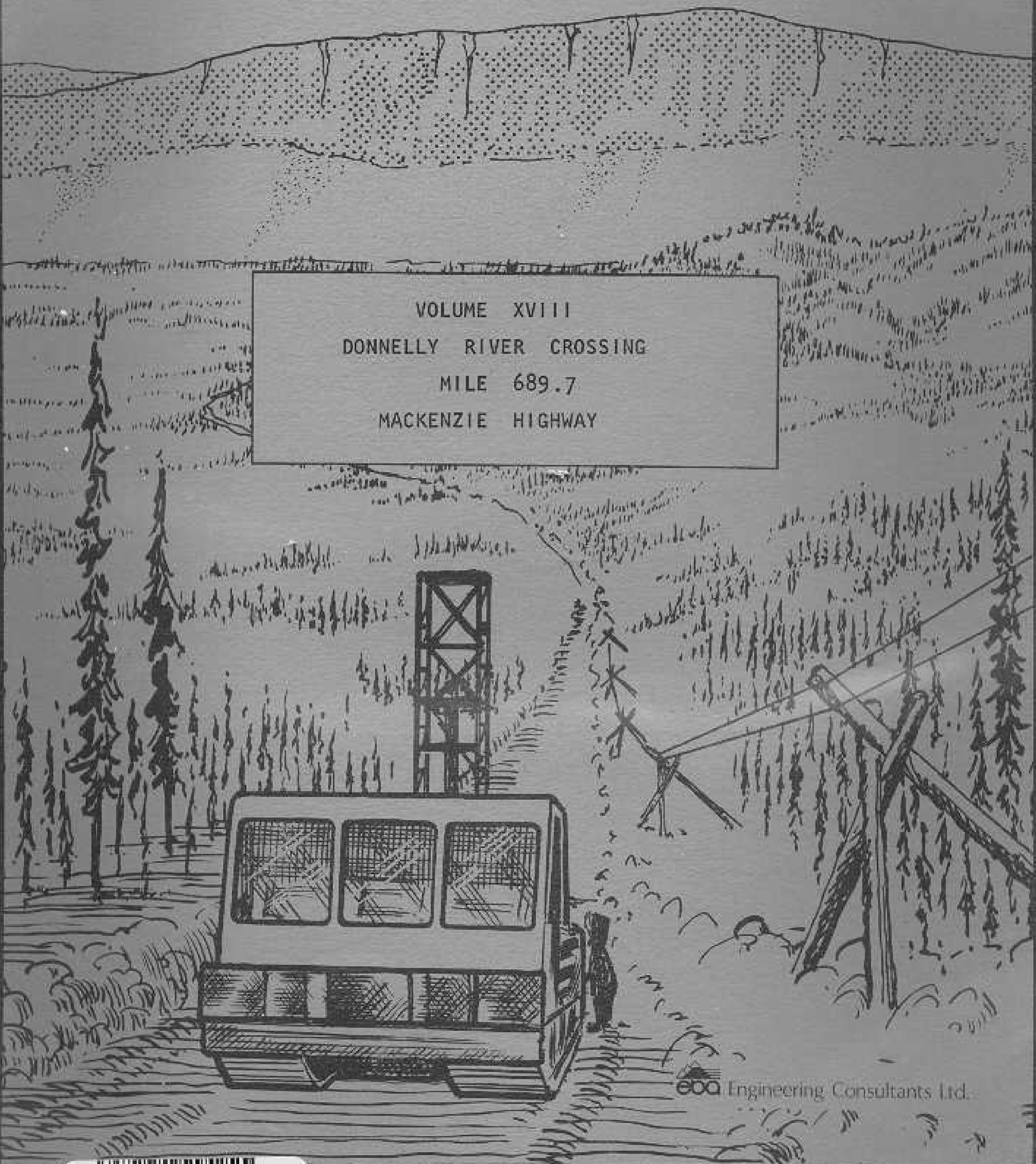
MACKENZIE HIGHWAY
GEOTECHNICAL EVALUATION



VOLUME XVIII
DONNELLY RIVER CROSSING
MILE 689.7
MACKENZIE HIGHWAY

eba Engineering Consultants Ltd.

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THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
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& ASSOCIATES LTD.

MACKENZIE HIGHWAY
GEOTECHNICAL EVALUATION
VOLUME XVIII
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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, a number of bridge sites at major river and stream crossings were investigated. The Donnelly River Crossing, is one such site investigated in detail. Details of the investigation, together with geotechnical data and recommendations pertinent to bridge construction at 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. SITE CONDITIONS

2.1 Surface Features and Geology

The proposed river crossing is approximately 1000 feet downstream of where the Donnelly River exits from Chick Lake and is at approximately Mile 689.7 of the proposed Mackenzie Highway. The approximate geographic location of the crossing is shown on the Key Plan, Drawing No. A-1, Appendix A, and the crossing site is shown on the Site Plan, Drawing No. A-2, Appendix A. Plates 1, 2, and 3, Drawing No. A-3, and Plate 5, Drawing No. A-4, Appendix A are low angle oblique photographs of the crossing area.

The valley of the Donnelly River has been formed in and is controlled by the local bedrock, which consists of Cretaceous (1)* silty clay shale. Except for the crossing area, the valley walls are relatively

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

steep and the river channel is well defined. Very steep slope sections occur adjacent to meander bends where active erosion of the toe of most slopes is presently occurring. In some of these meander bends recent slide activity is apparent. A typical slide area, is located just downstream of the crossing site, as shown on Drawing No. A-2, and in Plates No. 2 and 3, Drawing No. A-3, Appendix A. Drawing No. A-2, Appendix A, shows the approximate extent of the flood plain which has developed primarily on the north bank of the present channel in the area proposed for the crossing.

Slope gradients of both north and south valley walls are relatively gentle in this area, with a maximum slope angle of about 11 degrees existing over approximately the upper third of the south valley wall. The overall slope angles of north and south valley walls are about 2 and 5 degrees, respectively. Plates 4 and 6, Drawing No. A-4, Appendix A, show north and south valley walls, respectively, at the crossing site.

An aerial photographic interpretation of the surficial geology, of the immediate area of the Donnelly River crossing, is shown in Drawing No. A-2, Appendix A. The surficial deposits are believed to be primarily glacial lake basin sediments that have been reworked to some degree by slope wash action (GLB-1-(SL)) (2). A terrain legend, which describes the symbols used in the terrain analysis, is presented as Drawing No. A-2a, Appendix A. The soils consist of glaciolacustrine silty clays and clayey silts. This type of deposit has been confirmed, by subsurface borings, to be generally present both north and south of the Donnelly River. However, some of the borings revealed that glacial deposits, which have been classified as ground moraine with a shallow peat covering (GM(PT)), exist on the north bank of the Donnelly River in close proximity to the crossing. In this area the lacustrine clays appear to be absent. In addition, an area of near surface bedrock with thin drift covering (BR(Df)) is present a short distance to the west of the crossing. Silt, sand and gravel was noted in the flood plain area, within the present river valley.

Tree cover at the crossing consists primarily of sparse to medium dense black spruce. Some deciduous trees, such as poplar and willow are present along the Donnelly River channel, Chick Lake shoreline, and high ground areas adjacent to the river crossing site. Surficial drainage of the area is generally well developed toward the Donnelly River and Chick Lake.

2.2 Field Drilling and Laboratory Testing

Evaluation of subsurface conditions was based on field data obtained from 20 boreholes, drilled at the locations shown on Drawing No. A-2, Appendix A. Of the 20 boreholes drilled,3 were centerline boreholes, drilled in conjunction with the general route evaluation, and the remainder were located and drilled specifically to define subsurface conditions at the crossing.

The centerline boreholes were designated Boreholes 689-C-1 to 689-C-3, inclusive, and the special boreholes consisted of Boreholes 689-S-1 to 689-S-17, inclusive. Detailed borehole logs are presented in consecutive order in Appendix B.

With the exception of Boreholes 689-C-1 and 689-C-2, all holes were drilled with a track mounted Mayhew 500 rotary drill rig, using a continuous air return circulation system. Boreholes 689-C-1 and 689-C-2, were dry augered, utilizing a track mounted, Texoma Super Economatic power auger. Boreholes advanced with the rotary drill rig generally averaged about 4-3/4 inches in diameter, while the augered holes averaged about 12 inches in diameter. Borehole penetration ranged from 5 feet to 88 feet, and averaged 34 feet in depth. Sampling consisted of representative bag samples, obtained generally at depths of 2½, 5, 10 and 18 feet below ground surface in the shallow holes; and at depth intervals of 5 feet, after a depth of 10 feet below ground surface in the deep boreholes. Undisturbed samples were not obtained, other than a few fragmented core samples of silt, which is believed to be a weathered shale material. These cores were taken from two boreholes (Boreholes 689-S-6 and 689-S-8).

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 pH range of the subsoil. The moisture content tests were undertaken in the field laboratory of Elmer W. Brooker and 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 (3) and on textural classification according to U.S. Engineers Department (4) textural classification triangle. Frozen ground was classified according to a modification of the NRC system for describing permafrost (5). The modification consisted of dropping the modifying symbol describing the form of excess ice. This was necessary because the disturbed nature of the samples obtained from both rigs prevented accurate description of 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 observation, and based on previous experience are believed to be relatively accurate. 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-6, inclusive, Appendix C. Drawing No. C-7, Appendix C, presents a summary of laboratory results.

2.3 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 centerline stratigraphy noted at the site is summarized in the following Sub-Sections.

2.3.1 Stratigraphy on Centerline - North Valley Wall

Material Description		Approximate Average Depth Below Existing Grade (FT)	Approximate Range of Thickness (FT)
ORGANIC SILT, ORGANIC CLAY, PEAT,	- black to dark brown, organic, fibrous, clayey and silty, V - (5% to 15%), moisture content (M.C.) avg. = 85%	0 - 3.2	0.5 - 7.0
CLAY OR SILT (TILL)	- medium to dark brown, silty or clayey, sandy and gravelly, low plastic, V - (0 to 10%), M.C. (avg.) = 35%	3.2 - 9.0	4.0 - 6.0
SILT (WEATHERED SHALE)	- grey, clayey, shale fragments, soft, low to medium plastic, NB, M.C(avg.) = 14%	9.0 - 21.6	10 - 17
SHALE	- grey, clayey silt to silty clay shale, weathered, soft, low to medium plastic, NB, M.C. (avg.) = 9.7%	21.6 - 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 88 feet.

2. A grey silty clay layer was encountered in Boreholes 689-S-5 and 689-S-1, beneath the organic layer, and overlying the silt (weathered shale) and shale, respectively. The clay layer averaged 4.75 feet in thickness and exhibited excess ice contents estimated up to 30 percent (NB to V). The moisture content of the clay stratum averaged 27.3 percent. At the location of Boreholes 689-S-5 and 689-S-1, the shale was noted at depths of 8.5 feet and 12.5 feet, respectively.

3. Due to a lack of downhole temperature measuring equipment and the absence of visible ice at depths greater than an average of about 6 feet in the boreholes, it was difficult to accurately determine to what depth permafrost extended in the borings. However, it is believed that all borings encountered frozen material to the maximum depth of penetration and that NB is the correct ice classification for the silt (weathered shale) and shale strata.

4. Borehole 689-S-1 was the only borehole in which an unfrozen zone could be positively identified. This zone was noted at a depth of about 8 feet, where free water was noted to be entering the borehole.

2.3.2 Stratigraphy on Centerline - South Valley Wall

Material Description		Approximate Average Depth Below Existing Grade (FT)	Approximate Range of Thickness (FT)
PEAT	- dark brown to black, clayey, silty, organic, fibrous, V-(15% - 20%), M.C. (avg.) = 53%	0 - 2.7	1.0 - 4.0
CLAY	- medium brown to grey, silty, some sand, low plastic, V-(10% - 15%) to NB, M.C. (avg.) = 31.9%	2.7 - 14	4 - 14.0
SHALE	- grey, clay-silt shale, some sand, weathered, soft, low plasticity, NB, M.C. (avg.) = 10.6%	14 - 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 38 feet.

2. A medium brown to grey, silty, fine grained sand layer, was noted in Boreholes 689-S-2 and 689-S-12, overlying the shale stratum.

3. All boreholes are believed to have encountered frozen material to the maximum depth of penetration.

III. CONCLUSIONS AND RECOMMENDATIONS

3.1 Foundation Types

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

1. Driven 'H' Piles.
2. Closed End Pipe Piles Driven in Prebored Holes.
3. Timber Piles Driven in Prebored Holes.

3.2 Foundation Design Parameters

The recommended foundation types listed in Subsection 3.1, may be designed in accordance with the following parameters.

3.2.1 Driven Steel H-Piles

The design of steel H-piles is dependent upon the type of support that is provided the pile in or on the bearing material. In the case of the Donnelly River bridge crossing, it is considered that the shale bedrock material provides the only suitable bearing support for foundation elements. However, as the insitu density or consistency of the shale has not been precisely established; nor have the thermal conditions of the shale been accurately determined, only tentative pile designs or driving criteria can be provided at this time.

As a guide to the establishment of a pile design, it is recommended that standard H-piles 50 feet in length, with a minimum nominal size of 12 inches by 12 inches, and a minimum weight of 53 pounds per foot (12BP53), 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 a set of 1 inch per blow, measured over the last foot of driving. It is believed that piles driven to these specifications will permit an allowable static design load of 70 kips to be used. Although preboring is not considered necessary for the installation of steel H-piles in frozen ground, at this site, it may be desirable in very hard seasonally frozen ground 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 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.

3.2.2 Prebored Driven Closed End Pipe Piles

As in the case of steel H-piles, pipe pile design is based on the means of support achieved. Preboring of closed end pipe piles, driven into the shale stratum, is considered necessary to facilitate the driving operation and maintain alignment of the piles. 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 50 feet, 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 a set of 1 inch per blow, measured over the last foot of driving. It is believed that piles driven to these specifications will permit an allowable static design load of 60 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.

3.2.3 Prebored Driven Timber Piles

For preliminary design purposes, it is recommended that Number 12 Douglas Fir timber piles, with a minimum length of 50 feet, 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. Preboring into the shale stratum, is considered essential to limit pile damage in frozen ground. 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.

As the pile capacity will depend on the preboring and overboring of the pile holes, which remains to be proven in the field, the set to which the piles can be driven cannot be predicted. However, if the suggested pile section can be driven, with an energy of 24,000 foot pounds, to a set of 1 inch per blow, measured over the last foot of driving; it is believed that an allowable static design load of 40 kips may be used. Piles must penetrate to at least the full prebored depth.

If timber piles cannot be driven to the foregoing specifications, their design bearing capacity must be determined on the basis of field driving records or load tests. Field inspection by qualified personnel is considered necessary during the preboring, overboring 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 consultant.

3.3 Negative Skin Friction

The effect of negative skin friction, on individual piles and pile groups, will be dependent upon the occurrence and magnitude of settlement within both the fill surrounding the piles and the natural subgrade materials. At the crossing site, it is considered that all subgrade materials, with the exception of the silt (weathered shale) and shale strata are thaw unstable and significant subsidence can be expected if thawing occurs. Consequently, significant 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.

As 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, no allowance has been made for skin friction in the design pile capacities quoted in Subsection 3.2 of this report. However, Table 3.3.1 is presented as an aid to the design of pile foundation systems at the site. As is evident from the borehole logs, soils in the vicinity of probable pile installations fall in the CL to CI category. Therefore a negative skin friction value of 800 pounds per square foot for the subgrade soils at the site, is believed to be maximum negative skin friction value applicable to pile design. It is believed that the maximum load attributable to skin friction can be obtained by assuming that the entire depth of thaw sensitive material plus the depth of granular fill at the pile locations will contribute to negative skin friction.

3.4 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. Ice segregation in soils containing silt and clay causes a heaving force on the pile which must be resisted by the

TABLE 3.3.1

NEGATIVE SKIN FRICTION OF UNFROZEN SOIL FOR PILE DESIGN (AFTER WOODWARD LUNDGREN AND ASSOCIATES, 1971) (6)

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

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* 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.

available adfreeze bond in the permafrost or the skin friction in unfrozen soils which the piles may be imbedded in.

The design of a pile in permafrost is often controlled by the embedment required to resist the heave stress. In general it has been found that a slightly deeper pile embedment is the cheapest means of overcoming undesireable frost heaving stresses. Increasing the pile length will only be necessary, however, if the pile loads will be less than the frost heave force anticipated. Suggested design adfreeze bond stresses for general permafrost soils are presented in Table 3.4.1. These design stresses may be used in conjunction with an assumed or measured frost penetration depth to determine the frost heave force.

3.5 Subgrade Considerations on Centerline

3.5.1 North Valley Wall

As indicated in Subsection 2.1, the subsurface borings generally revealed a succession of peaty organic topsoil, underlain by a silt or clay till, a layer of silt or weathered shale, and shale bedrock to the depth of borehole penetration. Visual observations revealed that generally only the organic and till strata possessed visible excess ice (V) but that all strata appeared to be frozen.

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, based on visual observations, ice content estimates, moisture content profiles and classification test results. Based on these factors, it is concluded that low shear strengths can be expected for the organic and till strata if these materials were

TABLE 3.4.1

FROZEN SOIL ADFREEZE BOND STRENGTH FOR PILE DESIGN (AFTER WOODWARD LUNDGREN AND ASSOCIATES, 1971) (6)

	APPLICABLE CRITERIA		DESIGN ADFREEZE BOND STRESS, PSF
DESIGN CATEGORY	SEGREGATED ICE CONDITION	WATER CONTENT OF SOIL, %	FROST HEAVING SOILS[1]
I -Above Average Soil-ice Condition	No Visible Ice, 1%	<15	5000
		15-40	4000
II -Average Soil-ice Condition	Little Visible Ice, 1-10%	<15	4000
		15-40	2000
III -Below Average Soil-ice Condition	Occasional Visible Ice, 11-20%	<15	2000
		15-40	
		>40	1350
IV -Poor Soil-ice Condition	Some Visible Ice, 21-35%	15-40	1350
		>40	900
V -Very Poor Soil-ice Condition	Considerable Visible Ice, >35%	Any	700

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

allowed to thaw. Consequently, these materials will provide poor subgrade support in a thawed condition. The silt (weathered shale) and shale possess lower moisture contents and substantially greater shear strength in a thawed condition.

To accurately predict settlement of fill placed on permafrost soils containing excess ice,detailed knowledge of ground ice distribution together with an assessment of the thermal disturbance caused by fill placement are required. 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 15 and 10 percent of the original thickness of the strata, can be expected in the organic and till layers, respectively. This estimate assumes complete thawing of the strata, but does not take into account normal consolidation settlement of the unfrozen material under the influence of the surcharge load of road fills. 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 the thaw settlement, occur fairly rapidly. Normal consolidation settlement of the till would be much less and would likely be in the order of 1 or 2 percent of the thickness of the strata, under the influence of the surcharge load. Consolidation of the underlying silt (weathered shale) and shale strata, due to thaw subsidence and normal consolidation under loading, is anticipated to be much less significant, except where visible excess ice may occur.

3.5.2 South Valley Wall

The succession of strata on the south valley wall, consisted of peat or organic topsoil, clay and shale. Generally, the noted ice contents and moisture profiles indicate that the near surface subgrade soils on the south valley wall are slightly more stable than on the north wall. However, as on the north wall, the high excess ice and moisture contents infer low shear strength for the peat and clay strata when these materials thaw. The shale stratum, existing in the south valley wall, has the same characteristics as that present in the north wall. The silt (weathered shale) stratum, which was noted on the north valley wall, appears to be absent on the south wall, with the more resistant shale being present directly beneath the clay stratum. However, the clay stratum has properties very much similar to the silt (weathered shale) and may in fact be the same stratum, but with a higher average moisture content.

Qualitative estimates of thaw subsidence, assuming the entire strata thaw, are about 15 and 10 percent of the peat and clay strata thicknesses respectively. The subsidence potential on the south valley wall is considered to be of the same magnitude as on the north wall.

3.5.3 Flood Plain Area

The river flood plain area is outlined on Drawing No. A-2, Appendix A. On the north side of the river, organic silt and clay overlie clay and silt (weathered shale) or shale. On the south side of the river peat overlies clay, silty sand and shale. The excess ice content and moisture content of the peat and organic layers are fairly erratic. The ice classification varies from non visible well bonded (NB) to visible (V, 5 to 10 percent). The average moisture content is approximately 80 percent. Ice distribution within the clay is also varied and ranges from non visible, well bonded (NB) to visible (V, 25 to 30 percent). The moisture content of the clay is about 30 percent. Some silty sand was observed to overlie the shale in the south river bank, adjacent to the river edge. This sand stratum possessed low ice contents which generally ranged from non-visible, well bonded (NB) to visible (V, 0 to 5 percent). Moisture contents were high and ranged from 20 to 40 percent. The remaining underlying strata (silt and shale) were similar to that encountered beneath both valley walls. Some seepage water was, however, noted at a depth of 8 feet within the silt (weathered shale) stratum, at the location of Borehole 689-S-1. It was also observed, within this borehole, that the moisture content of the shale was higher than in the other boreholes, for a depth extending to about 35 feet below ground surface. However, it is believed that the higher moisture content is not representative and is due to sample contamination from free seepage water from above.

Based on the foregoing observations it is concluded that subgrade support within the flood plain area is essentially the same as that found further upslope. Ice contents and moisture contents are similar and thaw subsidence of the same magnitude is anticipated.

3.6 Fill Placement

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 granular fill material (gravel or quarried rock) of about 4 to 5 feet is considered to be the minimum recommended for road grade construction on underlying frozen subgrade materials. Local fine grained materials such as silts and clays 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 analyses, which are 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 detrimental effects on the existing slopes, occassioned by the construction equipment. The fill should be placed before preboring of piles. Placement of fills on layers of snow, either on the existing subgrade or on subsequent layers of the grade is not recommended. Snow clearing should be carried out prior to fill placement. Placement of the fill should be carried out through end dumping with subsequent spreading by dozing equipment. Minimum initial lift thicknesses of 2 feet are suggested. Depending on construction completion schedules, construction of fills may be staged for several seasons or carried to completion as construction progresses.

3.7 Slope Stability Considerations

3.7.1 North Valley Wall

No evidence of recent slope instability was detected on the north valley wall, in the immediate vicinity of the proposed river crossing and approach fills. Based on available survey information, plotted on Drawing No. A-5, Appendix A, the slope gradient along centerline averages about 2 degrees (about 3.5 percent). Rudimentary 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 the north side of the river, on the proposed alignment, in comparative safety with respect to slope instability. However, it is recommended that excessive fill thicknesses be avoided near the crest of the slope. 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, and the underlying organic layers should be disturbed as little as possible.

3.7.2 South Valley Wall

Evidence of recent slope instability has been observed on the south valley wall adjacent to the proposed crossing of the Donnelly River channel. Drawing No. A-2, and Plates No. 2 and 3, Drawing No. A-3, Appendix A, show a recent slide that has occurred 200 to 300 feet downstream of the proposed bridge crossing. It appears, from visual observations, that this is a shallow slide, concentrated in surficial materials. Other shallow seated slides further downstream, have been detected through aerial photographic interpretation. These slides, including the one near the Donnelly River crossing, generally occur at meander bends where river flow results in active toe erosion of the slope. Another common feature of the slides is their occurrence on steep slopes, estimated to be in the order of 20 to 30 degrees.

For purposes of slope stability calculations, assumed strength parameters for thawed soils were used in conjunction with the slope profile determined from survey information. The maximum slope angle on the south valley wall appears to be about 11 degrees. This slope gradient extends over a section of the slope, approximately from Borehole 689-S-3 to a point between Boreholes 689-S-14 and 689-C-3, as shown on Drawing No. A-5, Appendix A. The average overall slope of the south valley wall is about 5 degrees.

Using the foregoing slope data and assumed soil strength parameters, it was determined that adequate factors of safety exist for this slope gradient, assuming a shallow failure surface. Factors of safety for deep seated movements within the shale are expected to be even greater.

3.7.3 General

Based on observations of local failures, and rudimentary slope stability calculations, using assumed strength parameters for thawed soils, it is considered that the slopes on centerline are presently stable, and that an approach road grade may be constructed upon them. However, it is recommended that large fills be limited to lower slope sections, where they will act as a toe load and assist in maintaining slope stability. Cutting of slope material is not recommended. Placement of fill directly on the organic surface material is advocated.

Observations of vegation 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.

3.8 Drainage Considerations

As approach fills will concentrate runoff water on slope, along the upslope sides of the fills, 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 natural water courses. However, where this is impossible, coarse gravel should be used as channel lining. Transverse flow breakers at frequent intervals may be required to reduce the flow velocities along the fill and thereby reduce the potential for erosion by running water. Spacing of the 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 adjacent subgrade soil and road grade fill, unless the road grade is a very competent granular material.

3.9 Cement Type and Corrosion Considerations

Two representative soil samples were tested to determine their soluble sulphate concentration and general range of acidity. The soluble sulphate concentrations determined from the tests, ranged from negligible to severe (0.52%) and the pH of the samples was found to be about 6.5, which indicates slight acidity.

Although these results are inconclusive, it is recommended that Type V Sulphate Resistant Cement be used 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.

In view of the low acidity of the subsoil, it is considered that corrosion of steel piles embedded within the soil, will not be greater than normal. Consequently, special protective measures are not believed necessary. For 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 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.

3.10 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 stable and failed 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. It is believed that most of this information could be readily acquired during the summer season, and it is recommended that consideration be given to the acquisition of some of this information.

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 desirable, these tests need not be carried out at actual bridge crossing sites, but may be carried out in areas where materials and conditions would be representative of general foundation conditions at most of the proposed bridge sites. Such tests would provide invaluable design data on which future designs of pile foundation systems could be established.

IV. LIMITATIONS

The foregoing recommendations have been prepared based on our knowledge of existing conditions along the Donnelly River Valley, at 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,

ELMER W. BROOKER & ASSOCIATES LTD.

L. A. BALANKO

Lawrence

Lawrence A. Balanko, P. Eng.

G. R. Gilchrist

G. R. GILCHRIST

Garry R. Gilchrist, P. Eng.

LAB:lmh

LIST OF REFERENCES

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2. Canadian Arctic Gas Study Limited; Gas Pipeline Route Alignment and Terrain Data, prepared by J.D. Mollard and Associates Ltd. (unpublished)

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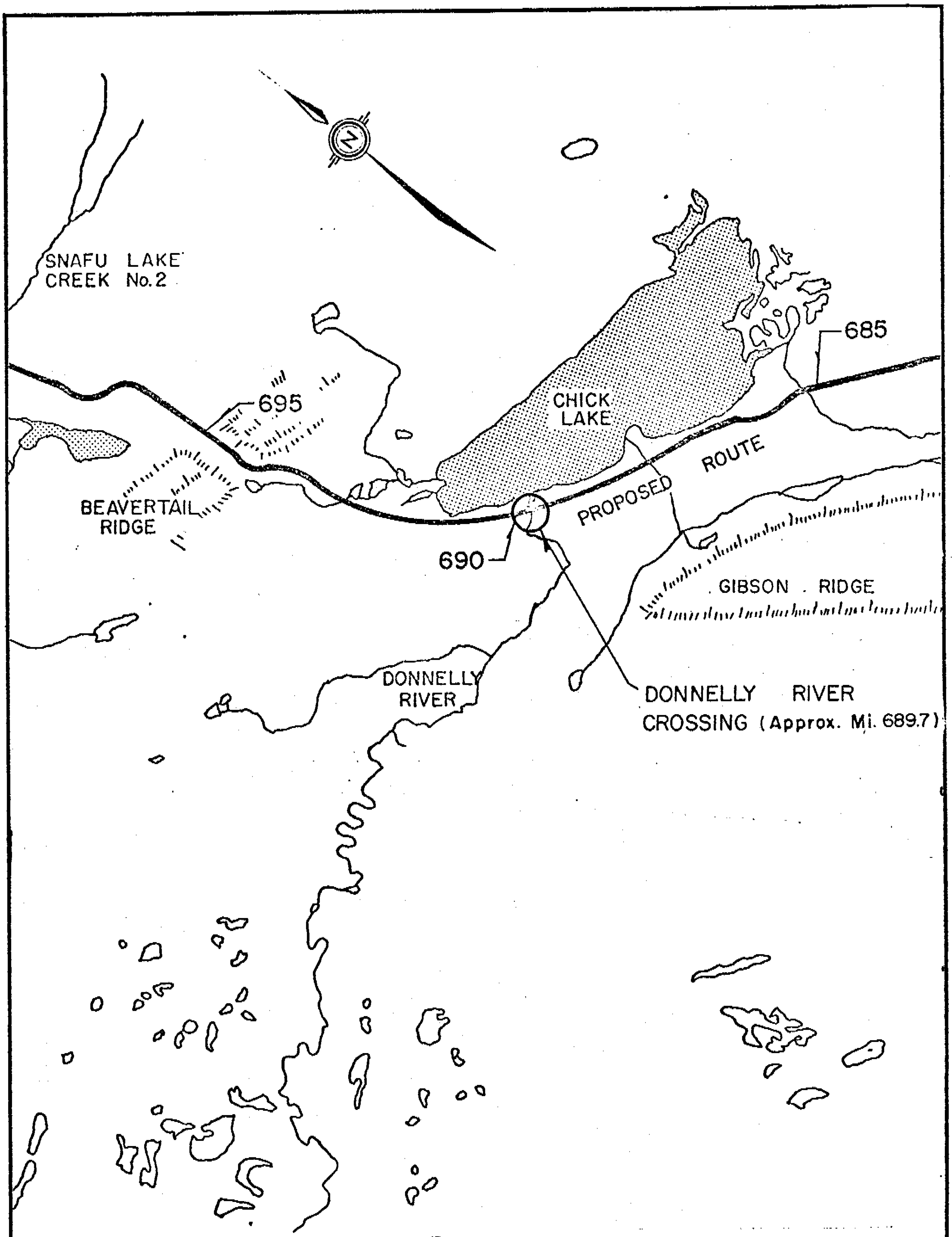
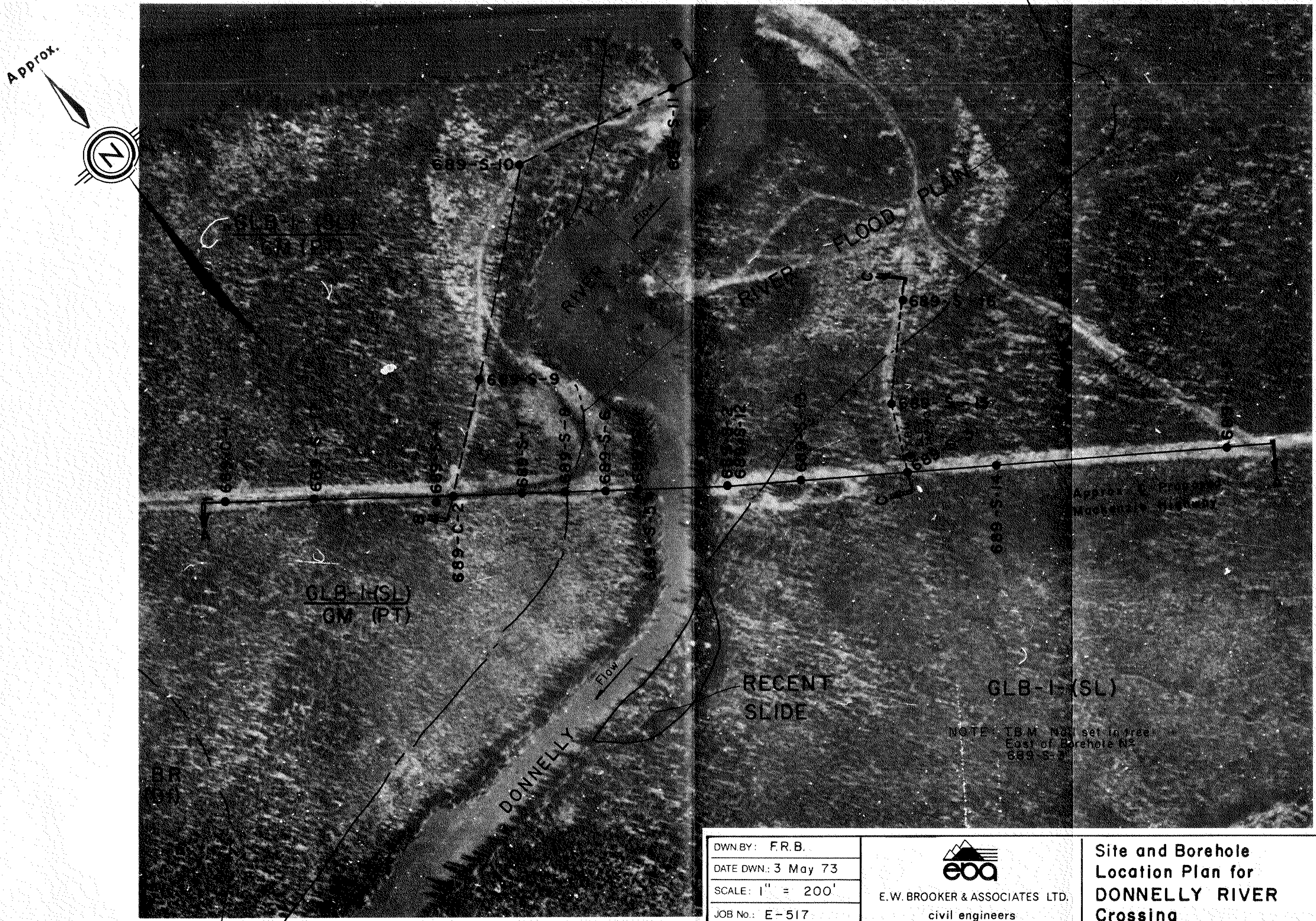
6. Woodward - Lundgren & Associates, 1971. - Results of Pile and Anchor Installation and Load Tests, and Recommended Design Procedures. Trans Alaska Pipeline System, (unpublished).



KEY PLAN

DATE: 23/08/73	*SCALE:* 1" = 2 mi.	*JOB NO.* E 517	*DWG. NO.* A-1



DWN.BY: F.R.B.
DATE DWN.: 3 May 73
SCALE: 1" = 200'
JOB No.: E-517

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civil engineers

Site and Borehole Location Plan for DONNELLY RIVER Crossing

DWG.: A - 2
SHT.No.:

PLATE No. 1

North easterly view of Donnelly River Crossing & Chick Lake (February, 1973)

PLATE No. 2

Southwesterly view of Donnelly River Crossing NOTE SLIDE AREA (February, 1973)

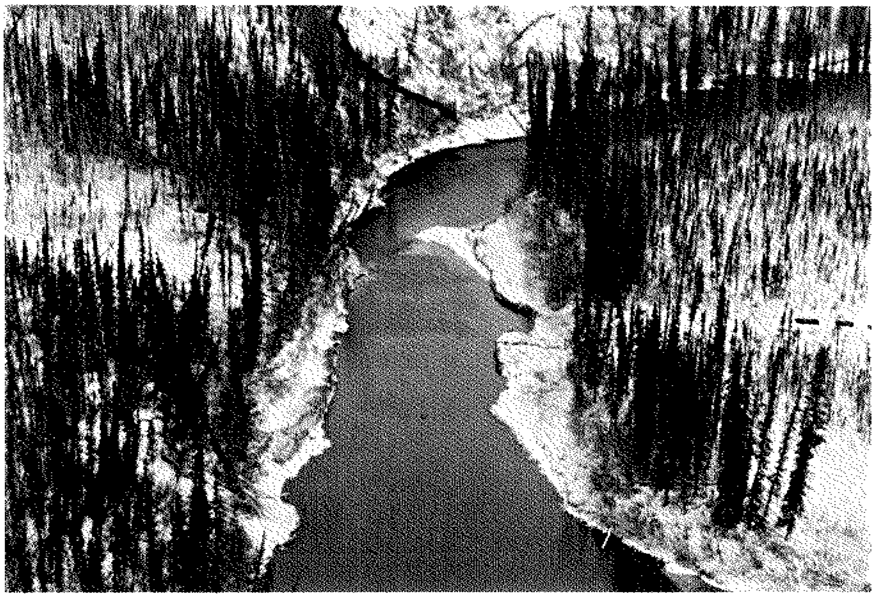


PLATE No. 3

Close up view of Donnelly River Crossing NOTE SLIDE AREA. (Late September 1972)

Drawing No. A-3

E.W. Brooker & Associates Ltd.

PLATE No. 4

Donnelly River Crossing North approach. Plate taken approximately 15 feet north of the river. (June, 1973)

PLATE No. 5

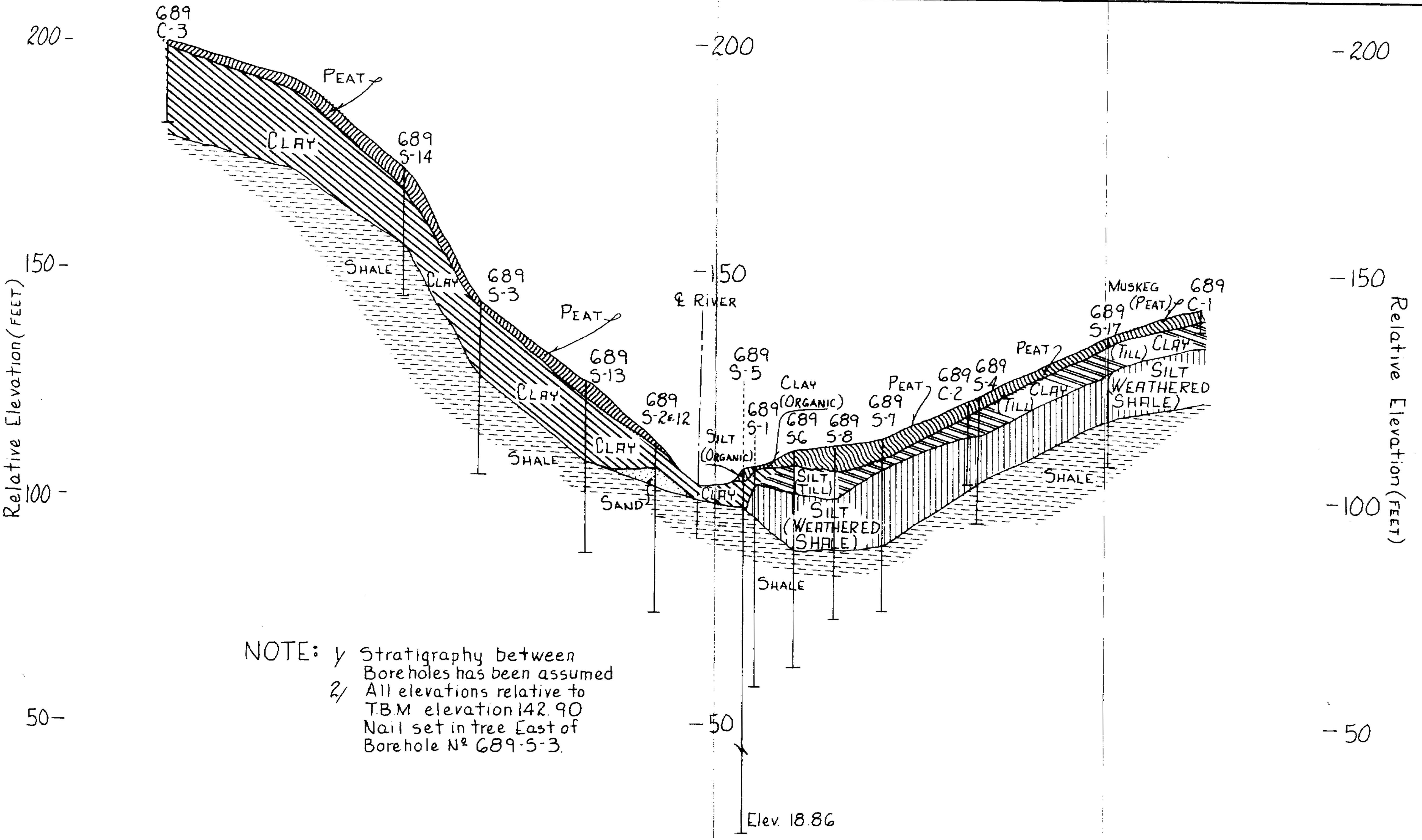
Donnelly River Crossing North is to the bottom left. (June, 1973)

PLATE No. 6

Donnelly River Crossing View from north side towards the south approach. (June, 1973)

Drawing A-4

E.W. Brooker & Associates Ltd.



NOTE: 1/ Stratigraphy between Boreholes has been assumed
2/ All elevations relative to T.B.M. elevation 142.90 Nail set in tree East of Borehole Nº 689-S-3.

DWN BY: FRB
DATE DWN: 3 May, 73
SCALE: Vert. 1" = 20'
Hor. 1" = 200'
JOB No.: E-517

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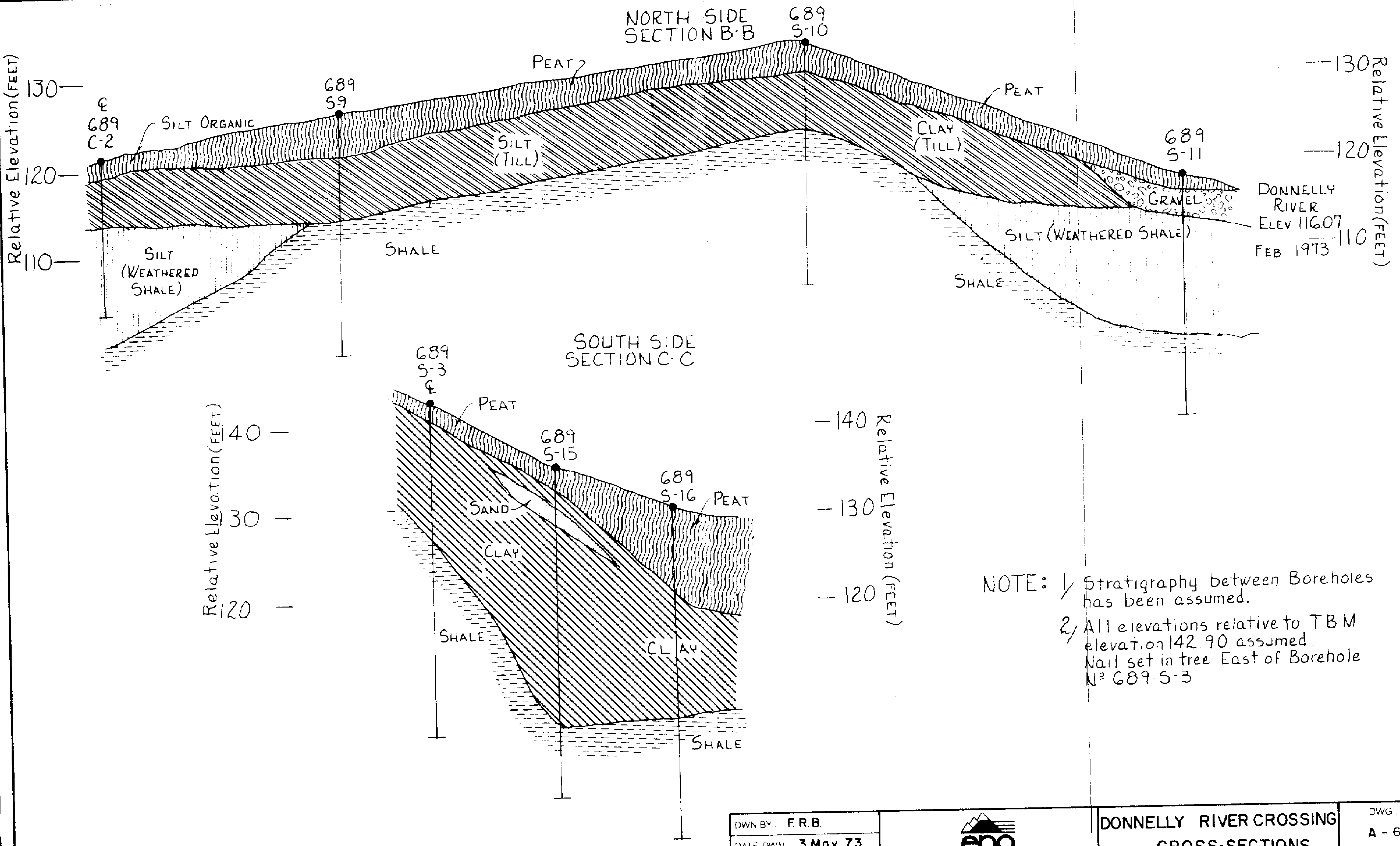
DONNELLY RIVER CROSSING
℄ PROFILE &
STRATIGRAPHY

DWG.: A - 5
SHT. No.:



NOTE: 1/ Stratigraphy between Boreholes has been assumed.

2/ All elevations relative to T.B.M elevation 142.90 assumed. Nail set in tree East of Borehole № 689-S-3

DWN BY	F.R.B.
DATE DWN	3 May, 73
SCALE	Vert. 1" = 10' Hor. 1" = 100'
JOB No.	E-517

eba
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DONNELLY RIVER CROSSING
CROSS-SECTIONS
AND STRATIGRAPHY

DWG. A-6

SHT No.

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MACKENZIE HIGHWAY 283

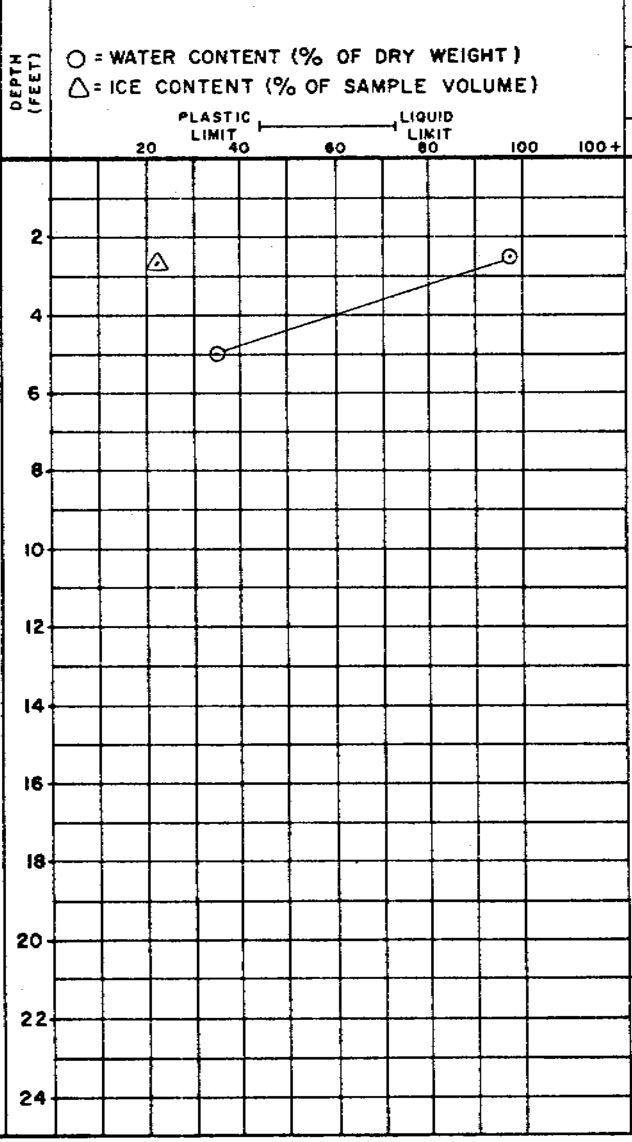
DWN: BL | FIELD ENG: LAB | DATE DRILLED 30/1/73 | AIRPHOTO NO: A-22774-861 | CHAINAGE: 1836 + 36 | OFFSET

CKD: NRM | TECH: HC | RIG Texoma | SURFACE DRAINAGE: Very Good South | VEGETATION: Black Spruce Dense 10'-12' | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	C	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
2	1				PT	PEAT - Organic, Black									
4	2				CL to CI	CLAY (TILL) - Rocky, Silty, Dark Brown, Low to Medium Plastic	F	V 20-25%							
						END OF HOLE @ 5' ON ROCKS									



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

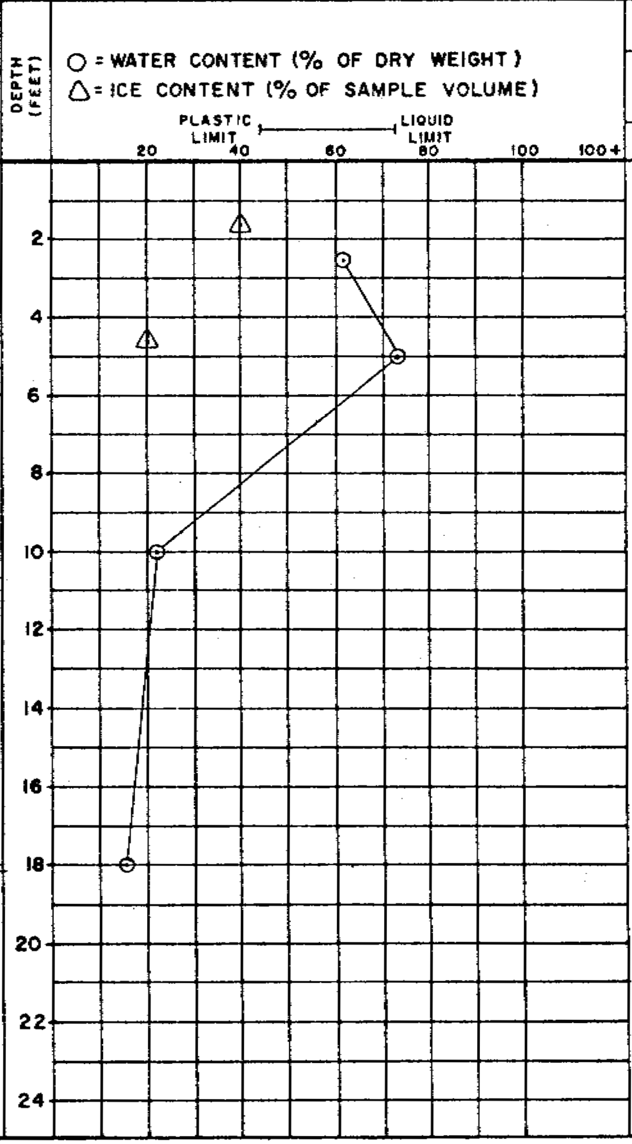
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: BL	FIELD ENG: LAB	DATE DRILLED: 30/1/73	AIRPHOTO NO: A-27774-86	CHAINAGE: 1841 + 47.1	OFFSET
CKD NRM	TECH: HC	RIG: Texoma	SURFACE DRAINAGE: Very Good S	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	C	2

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
2	1				PT to OL	SILT - Peaty Black, Organic		V -40%
4–6	2				CL	SILT (TILL) - Dark Brown, Gravelly, Sandy, Clayey, Low Plastic		V -20%
10	3				CL	SILT (Weathered Shale) - Grey, Shale pieces, Some Clay, More Shale With Depth, Hard - Mottled to 16- - Grey	F	NB
18	4							
						End of Hole @18'		



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

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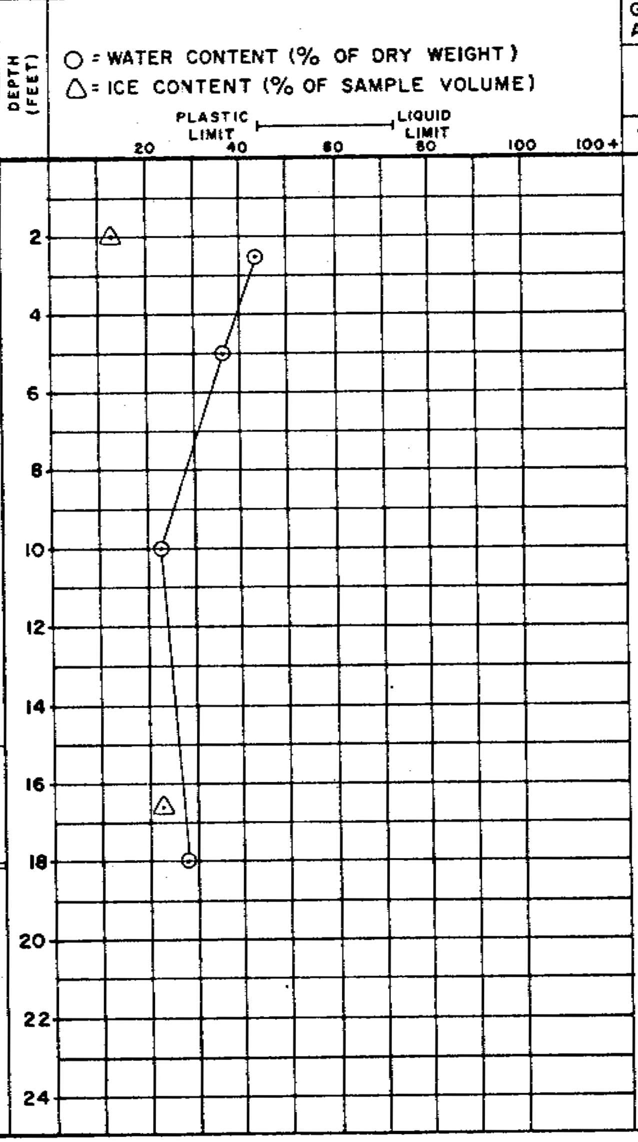
MACKENZIE HIGHWAY

DWN: BL | FIELD ENG: LAB | DATE DRILLED 7/2/73 | AIRPHOTO NO: A22861-134 | CHAINAGE: 1859 + 12.1 | OFFSET
CKD: NRM | TECH: DY | RIG: Mayhew 500 | SURFACE DRAINAGE: Well Drained | VEGETATION: Black Spruce | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	C	3

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–1					PT	PEAT - Medium Brown, Fibrous									
2	1					CLAY - Medium Brown, Silty, Medium Plasticity		V 10-15%							
4–6	2				CI		F	NB							
10	3					- Grey, Silty, Medium Plasticity									
16								V 20-25%							
18	4														
						END OF HOLE 18'									



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DRILL HOLE REPORT

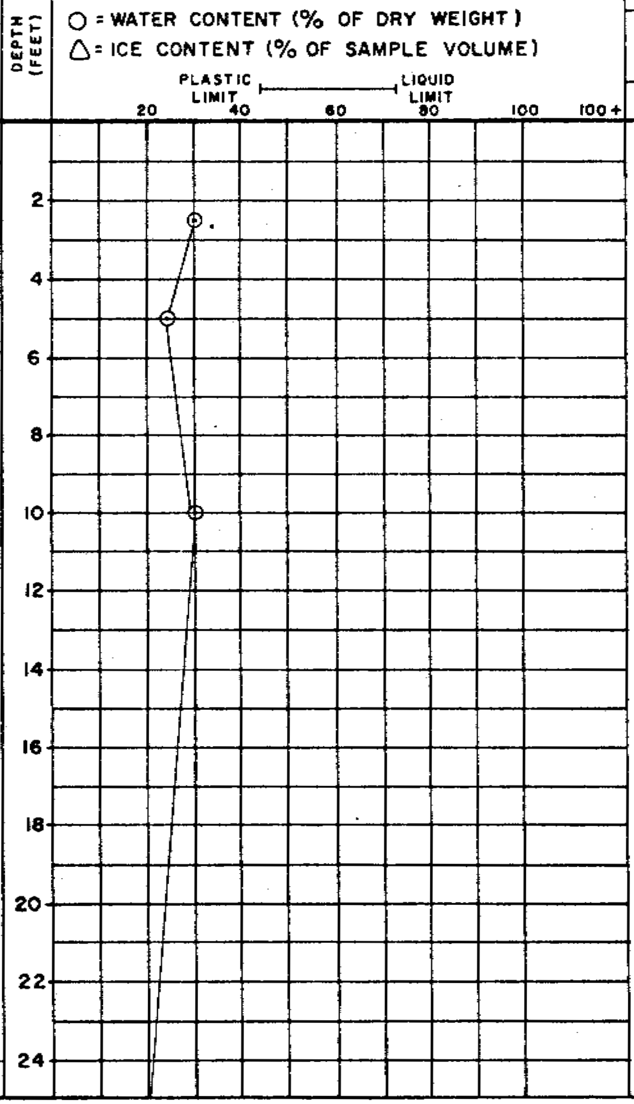
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

Page 1 of 2

DWN: BL
CKD: NRM
FIELD ENG: LAB
TECH: DY
DATE DRILLED 6/2/73
RIG: Mayhew 500
AIRPHOTO NO: A22816-134
SURFACE DRAINAGE: Well Drained
CHAINAGE: 1846 + 08.9
VEGETATION: Black Spruce
OFFSET
ELEV:

TEST HOLE 245		
MILE	B,C,S	NUMBER
689	S	1

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					OH	CLAY - Black, Organic	F	NB
2	1	⧅			CI	CLAY - Grey, Silty - Medium Plasticity	U	Unfrozen
4								
	2	⧅			CL to CI	SILT (Weathered Shale) - Grey, Clay-Silt, Low to Medium Plastic, Wet - Water entering Hole		
6								
8							F	NB
10	3	⧅						
12								
14					SH (CL)	SHALE - Grey, Clay-silt, Shale, Wet, Low, Plastic		
16								
18								
20								
22								
24								



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

REMARKS

N. Bank of Donnelly River

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DRILL HOLE REPORT

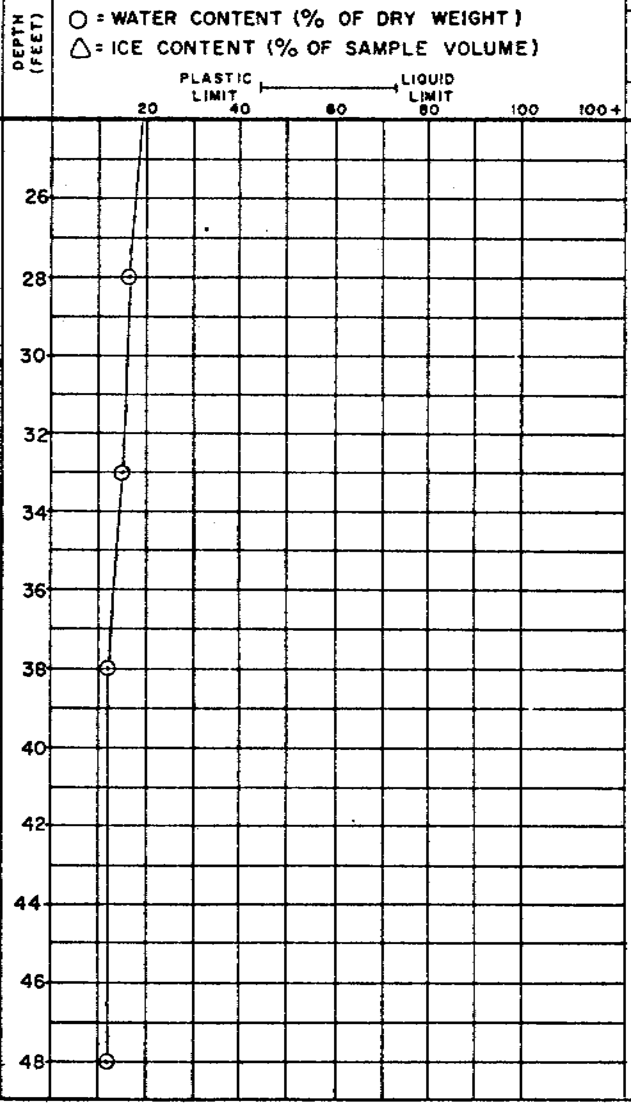
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY
Page 2 of 2

DWN: BL
FIELD ENG: LAB
DATE DRILLED 6/2/73
AIRPHOTO NO: A22816 - 134
CHAINAGE: 1846 + 08.9
OFFSET
CKD: NRM
TECH: DY
RIG: Mayhew 500
SURFACE DRAINAGE: Well Drained
VEGETATION: Black Spruce
ELEV:

TEST HOLE 245

MILE	B,C,S	NUMBER
689	S	1

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
26						SHALE - Grey, Clay-Silt Shale, Dry, Low Plastic, Soft		
28	4	◸						
30					SH (CL)			
32								
34	5	◸					F	NB
36								
38	6	◸						
40								
42								
44								
46								
48		◸				End of hole @ 48'		



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

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MACKENZIE HIGHWAY

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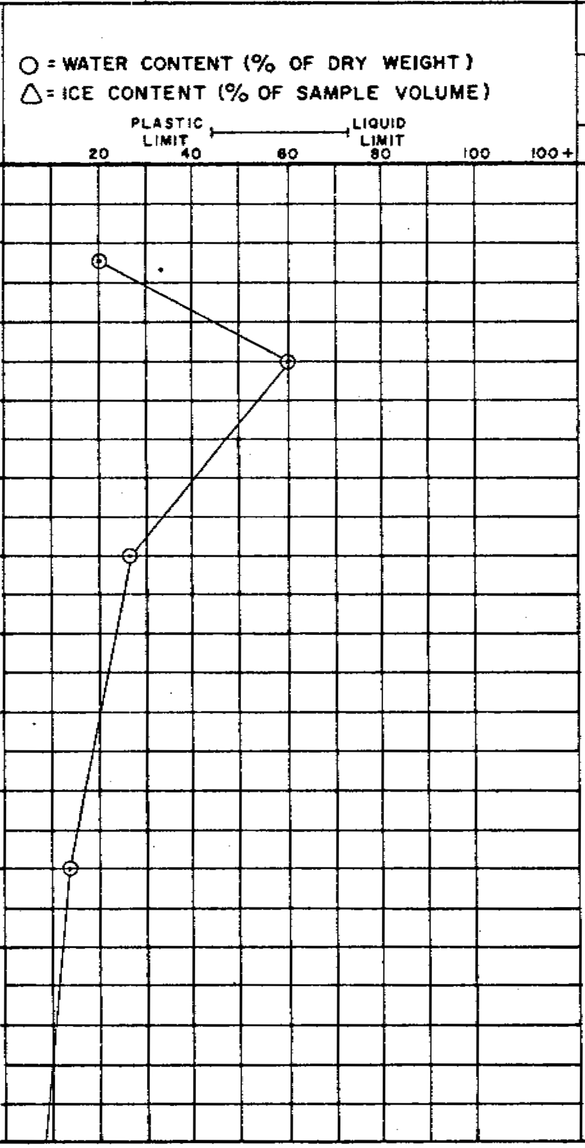
DWN: BL	FIELD ENG: LAB	DATE DRILLED 6/2/73	AIRPHOTO NO: A22861-134	CHAINAGE: 1848 + 27.4	OFFSET	TEST HOLE: 246
CKD: NRM	TECH: DY	RIG: Mayhew 500	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV:	

MILE	B,C,S	NUMBER
689	S	2

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2					PT	PEAT - Medium Brown - Woody	F	
2	1	◸				CLAY - Dark Brown, Silty, Some Organics, Gravel Particles, Medium Plasticity - Traces of Fine Sand		NB
4					CI			
5	2	◸						
6						SAND - Light Brown - Fine, Silty		
9					SM			
10	3	◸						
11						SHALE - Grey, Clay & Silt Shale, Dry, Soft		
14					SH (CL)			
18	4	◸						
24								



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

REMARKS

South Bank of Donnelly River

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DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY
Page 2 of 2

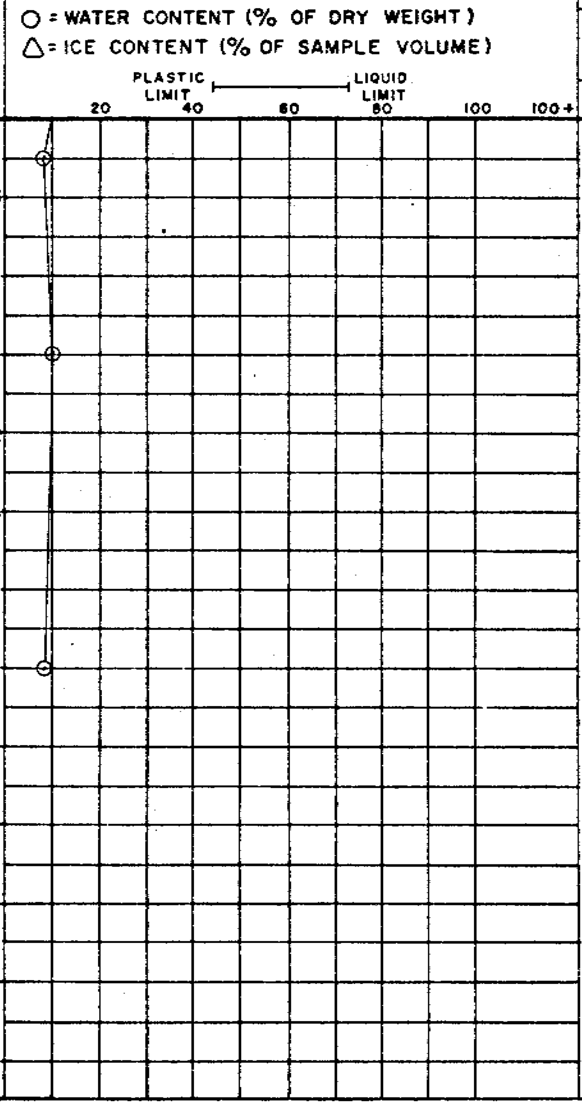
DWN: BL | FIELD ENG: LAB | DATE DRILLED: 6/2/73 | AIRPHOTO NO: A22861-134 | CHAINAGE: 1848 + 27.4 | OFFSET

CKD: NRM | TECH: DY | RIG: Mayhew 500 | SURFACE DRAINAGE: Well Drained | VEGETATION: Black Spruce | ELEV:

TEST HOLE 246

MILE	B,C,S	NUMBER
689	S	2

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
	5	⧅				SHALE - Grey, Clay & Silt Shale, Dry, Soft										
26									26							
28					SH (CL)				28							
30	6	⧅					F	NB	30							
32									32							
34									34							
36									36							
	7	⧅														
38									38							
						END OF HOLE 38'										
40									40							
42									42							
44									44							
46									46							
48									48							



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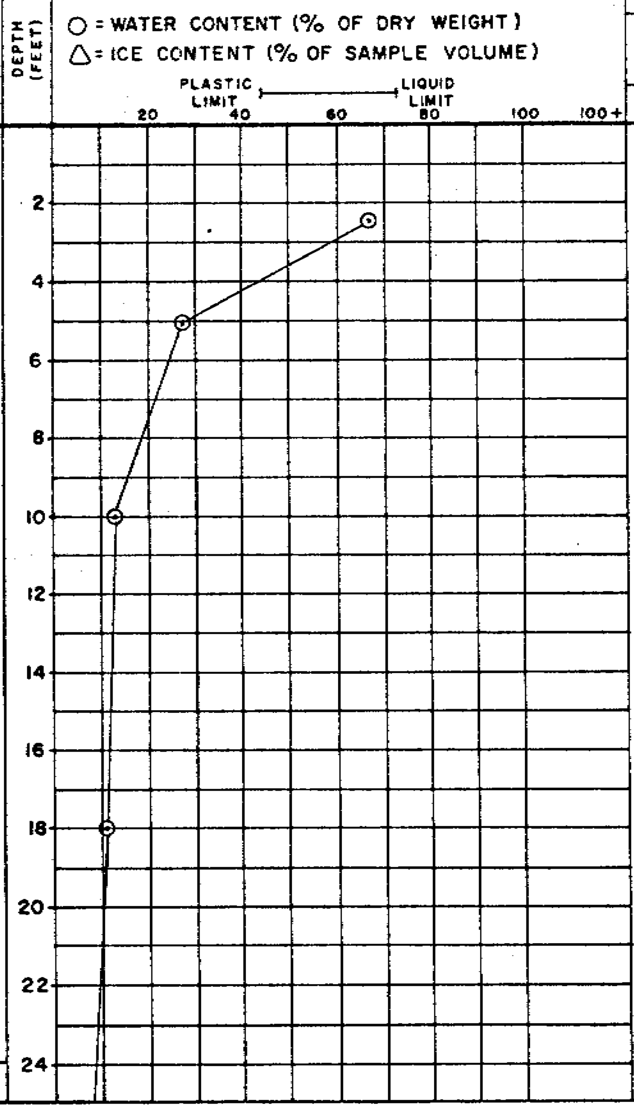
MACKENZIE HIGHWAY
Page 1 of 2

DWN: BL | FIELD ENG: LAB | DATE DRILLED: 7/2/73 | AIRPHOTO NO: A22861-134 | CHAINAGE: 1852 + 19.2 | OFFSET

CKD: NRM | TECH: DY | RIG: Mayhew 500 | SURFACE DRAINAGE: Well Drained | VEGETATION: Black Spruce | ELEV:

TEST HOLE MVPL 9		
MILE	B,C,S	NUMBER
689	S	3

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					PT	PEAT - Medium Brown - Fibrous		
2	1				ML to CL	CLAY - Medium Brown to Grey, Sandy (coarse), some Clay to Clayey, Some Shale Fragments, Low Plastic	F	NB
4	2							
6								
8								
10	3					- Shale Fragments		
12								
14								
16								
18	4				SH (CL)	SHALE- Grey, Clay-Silt Shale	F	NB
20								
22								
24								



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

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MACKENZIE HIGHWAY

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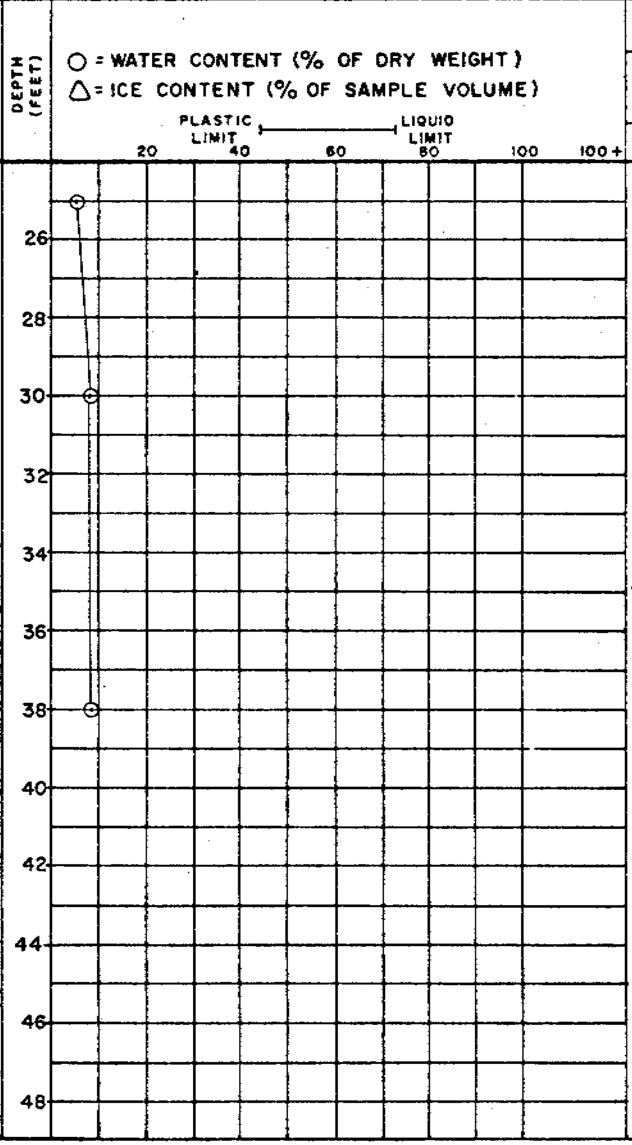
DWN: BL	FIELD ENG: LAB	DATE DRILLED 7/2/73	AIRPHOTO NO: A22861-134	CHAINAGE: 1852 + 19.2	OFFSET		TEST HOLE MVPL 9
CKD: NRM	TECH: DY	RIG: Mayher 500	SURFACE DRAINAGE: Well Drained	VEGETATION: Black Spruce	ELEV:		

MILE	B,C,S	NUMBER
689	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
25	5	⧅				SHALE - Grey, Clay-Silt Shale									
29					SH										
30	6	⧅			(CL)										
31							F	NB							
37	7	⧅													
38						END OF HOLE 38'									



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MACKENZIE HIGHWAY

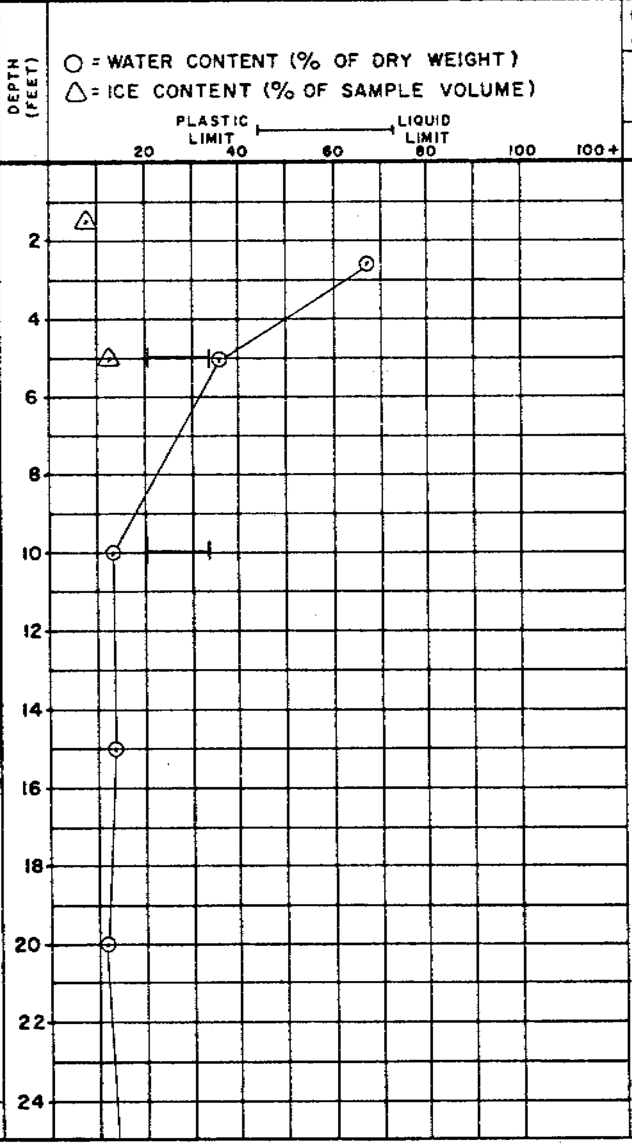
DWN: BL | FIELD ENG: LAB | DATE DRILLED: 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1841 + 22.1 | OFFSET:

CKD: NRM | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	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.)	REMARKS
2	1	▨			PT to OL	PEAT - Black - Fibrous - Silty		V-5-10%							Donnelly River Crossing
4 6 8	2	▨			CL	CLAY SILT (TILL) - Medium Brown, Some Sand, Trace Gravel - Low Plasticity		V 10-15%	22	57	17	4			
10 12 14	3	▨			ML to CL	SILT (Weathered Shale) - Medium Brown - Clayey - Low Plasticity	F	NB							
16 18	4	▨				- Grey									
20 22 24	5	▨			SH (CL)	SHALE - Grey, Silty-Clay, - Weathered, Soft									



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Page 2 of 2

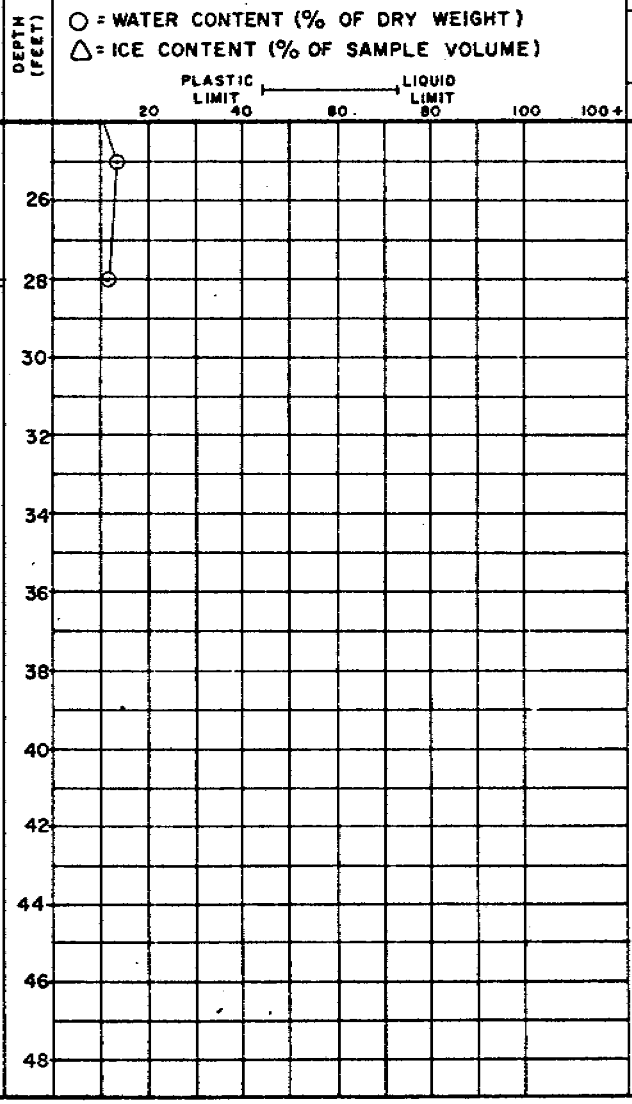
DWN: BL | FIELD ENG: LAB | DATE DRILLED: 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1841 + 22. 1 | OFFSET

CKD: NRM | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	4

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6				SH (CL)	SHALE - Grey, Silty-Clay, Weathered, Soft	F	NB
26								
	7							
28								
						END OF HOLE @ 28'		
30								
32								
34								
36								
38								
40								
42								
44								
46								
48								



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

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

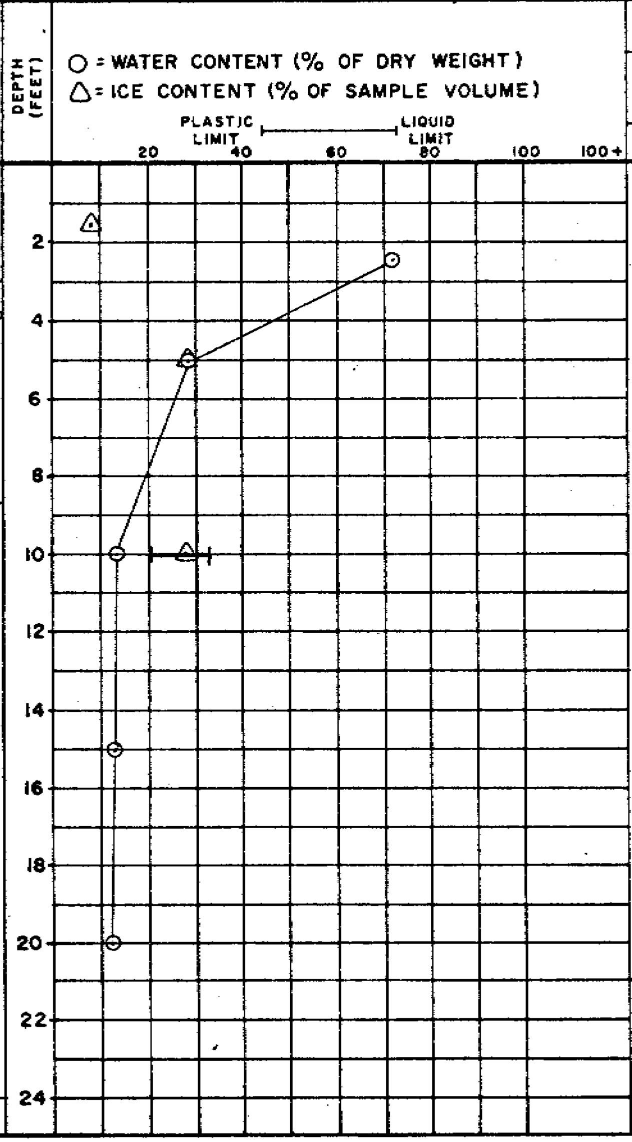
Page 1 of 4

DWN: BL
FIELD ENG: NRM
DATE DRILLED: 27/2/73
AIRPHOTO NO: A22861-133
CHAINAGE: 1846 + 33.9
OFFSET
CKD: LAB
TECH: JK
RIG: Mayhew
SURFACE DRAINAGE: Good to S
VEGETATION: Black Spruce
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	5

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	⧅			PT to OL	SILT - Organic - Black to Dark Brown - Fibrous, Woody		V-5-10%							Donnelly River Crossing
4	2	⧅			CL	CLAY - Grey - Silty - Low Plasticity	F	V- 25-30% (very thin layers)							
10	3	⧅			SH (CL)	SHALE - Grey, Silty Clay Shale, Sandy, Low Plasticity, Weathered, very Soft		NB	31	41	28	-			
15	4	⧅				- Grey, Silty-Clay Shale, Low Plasticity, Soft, Weathered									
20	5	⧅			SH (CL)										
24															



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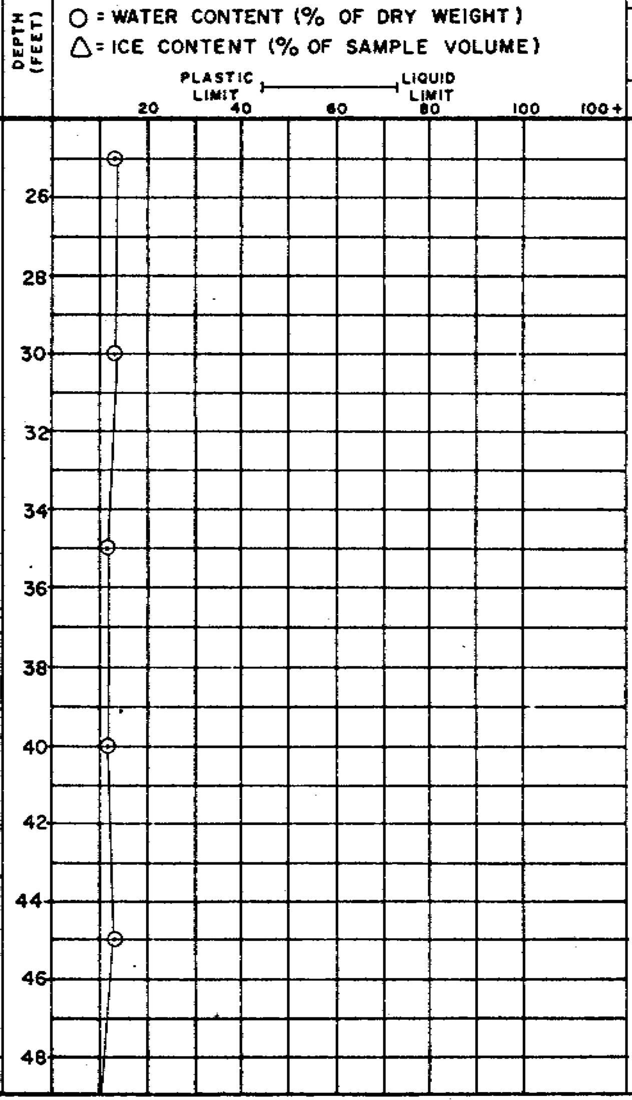
DWN: BL	FIELD ENG: NRM	DATE DRILLED 27/2/70	AIRPHOTO NO: A22861-133	CHAINAGE: 1846 + 33.9	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to S	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	5

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
	6	⧅				SHALE - Grey, Silty-Clay Shale, Low Plasticity, Soft, Weathered									
26					SH (CL)										
28															
30	7	⧅													
32							F	NB							
34															
	8	⧅													
36															
38															
40	9	⧅													
42															
44															
		⧅													
46															
48															



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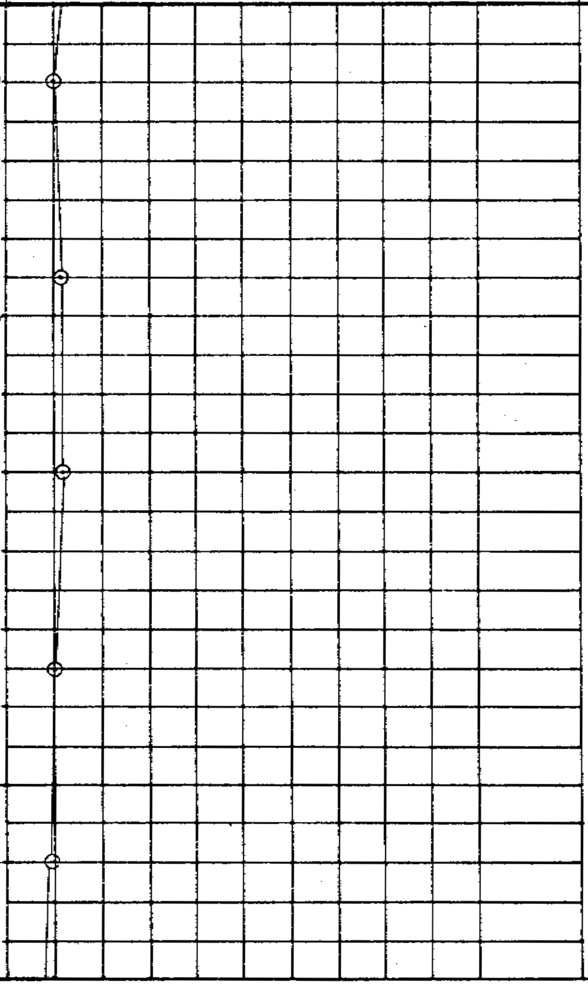
DWN: BL | FIELD ENG: NRM | DATE DRILLED 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1846 + 33.9 | OFFSET

CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	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	DEPTH (FEET)	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
50	10	▧				SHALE - Grey, Silty-Clay Shale, Low Plasticity, Soft			50								
52							F	NB	52								
54	11	▧			SH (CL)				54								
56									56								
58									58								
60	12	▧							60								
62									62								
64	13	▧							64								
66									66								
68									68								
70		▧							70								
72									72								

E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY
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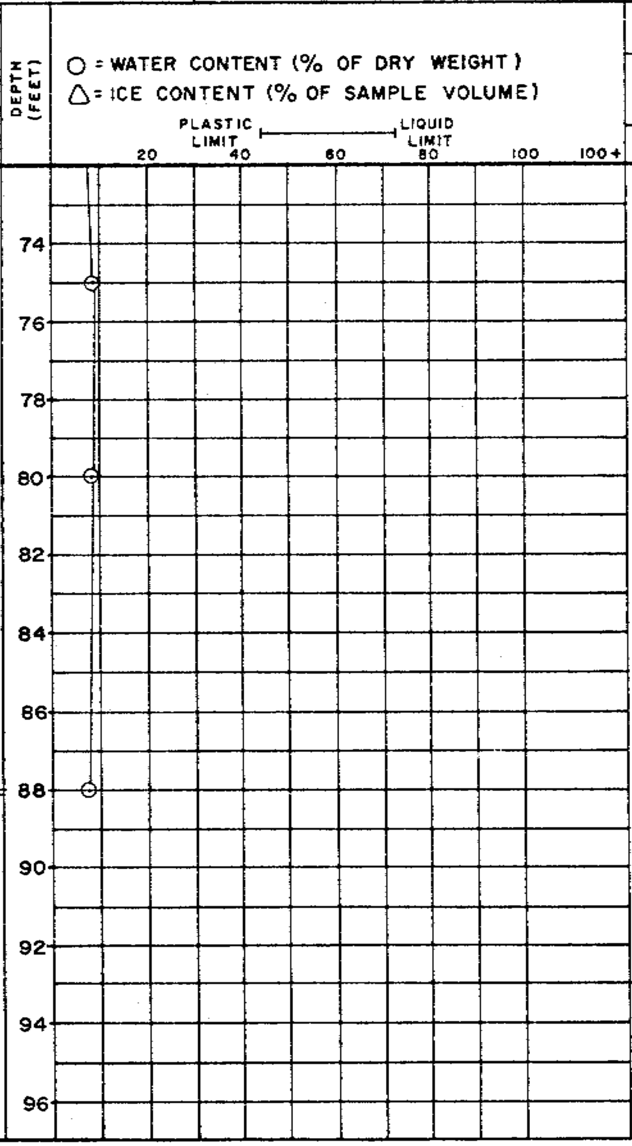
DWN: BL | FIELD ENG: NRM | DATE DRILLED 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1846 + 33.9 | OFFSET
CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						SHALE - Grey, Silty-Clay Shale, Low Plasticity, Soft		
74							F	NB
	16							
76					SH (CL)			
78								
80	17							
82						- Grey, Silty Clay Shale, Low Plasticity, Soft		
84					SH (CL)			
86								
88	18							
						END OF HOLE 88'		
90								
92								
94								
96								



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

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MACKENZIE HIGHWAY

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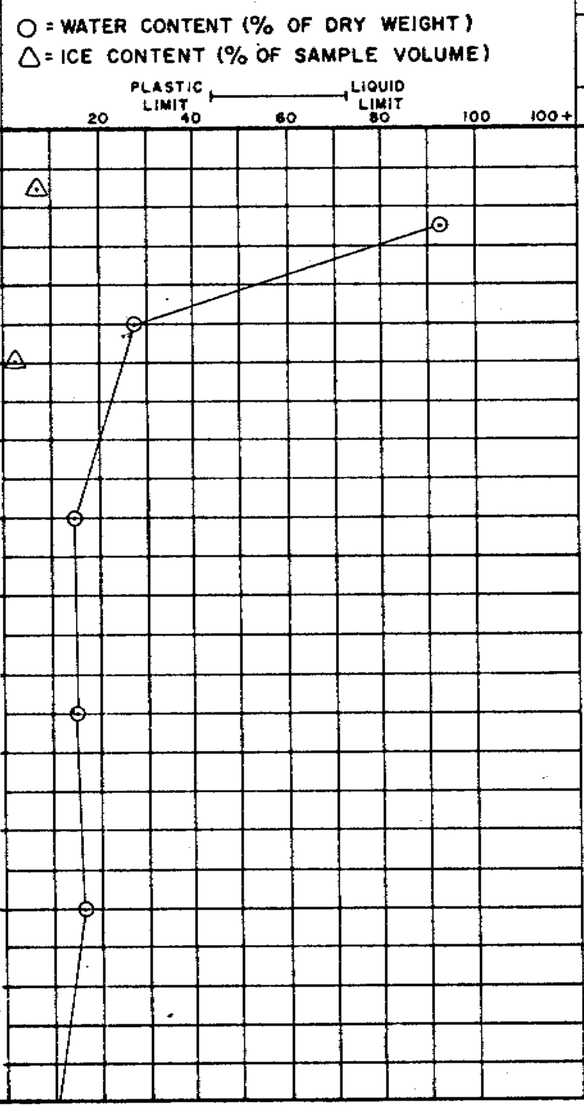
DWN: BL	FIELD ENG: NRM	DATE DRILLED 27/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: 1845 + 21.2	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to S	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	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
2	1	▧			PT	PEAT - Black to Dark Brown - Fibrous (Fine)		V-5-10%							Donnelly River Crossing
4 6 8	2	▧			SM	SILT (TILL) - Dark Brown, Clayey, Sandy, Trace of - Gravel, - To Gravelly Low Plasticity	F	V-0-5%							
10 12 14 16 18 20	3 4 core 6	▧ ▧ ■ ▧			ML to CL	SILT (Weathered Shale) - Grey, Some Clay, Low to Medium Plasticity, - Weathered, Very Soft Shale Fragments Throughout - Clay-silt, trace of sand		NB	27	66	7	-			
22 24						SHALE - Grey, clay-silt, weathered, low to medium plastic									

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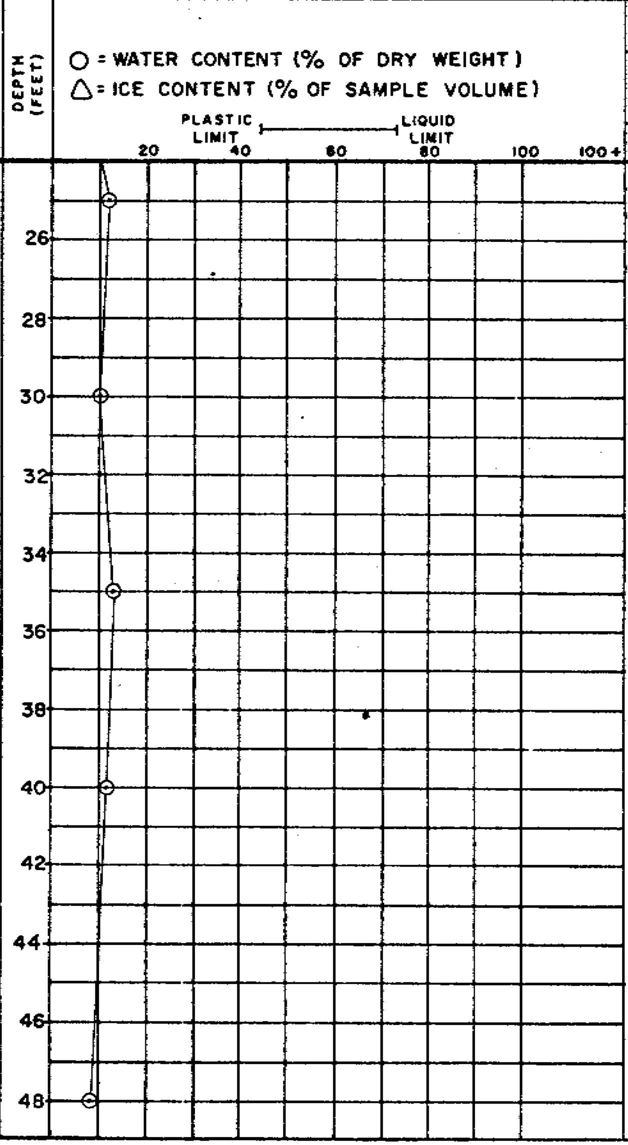
DWN: BL | FIELD ENG: NRM | DATE DRILLED 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1845 +21.2 | OFFSET

CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	6

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	7					SHALE - Grey, Clay-silt, Weathered, Low to Medium Plasticity		
26								
28								
30	8							
32					SH (CL)			
34								
	9					- Grey, Silty-Clay Shale - Weathered - Soft	F	NB
36								
38								
40	10							
42						- Grey, Silt-Clay Shale, Weathered, Soft	F	
44								
46								
48	11					END OF HOLE @ 48'		



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

REMARKS

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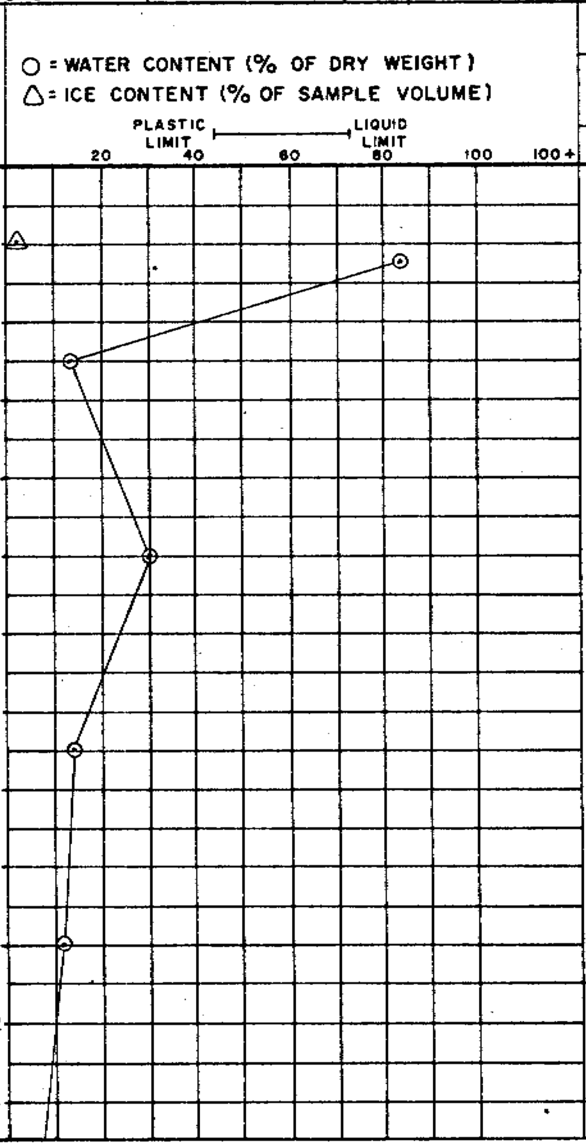
DWN: BL	FIELD ENG: NRM	DATE DRILLED 27/2 73	AIRPHOTO NO: A22861-133	CHAINAGE: 1843 + 28.6	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to S	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	7

SAMPLE NUMBER	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
1	PT to OL	PEAT - Black - Fibrous - Silty		V-0-5%
2	CL	CLAY (TILL) - Silty - Medium Brown - Low Plasticity - Gravelly - Sandy		
3 4 5	ML to CL	SILT (Weathered Shale) - Grey, Low Plasticity - Some Clay	F	NB



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

REMARKS

Donnelly River Crossing

E.W. BROOKER & ASSOCIATES LTD.

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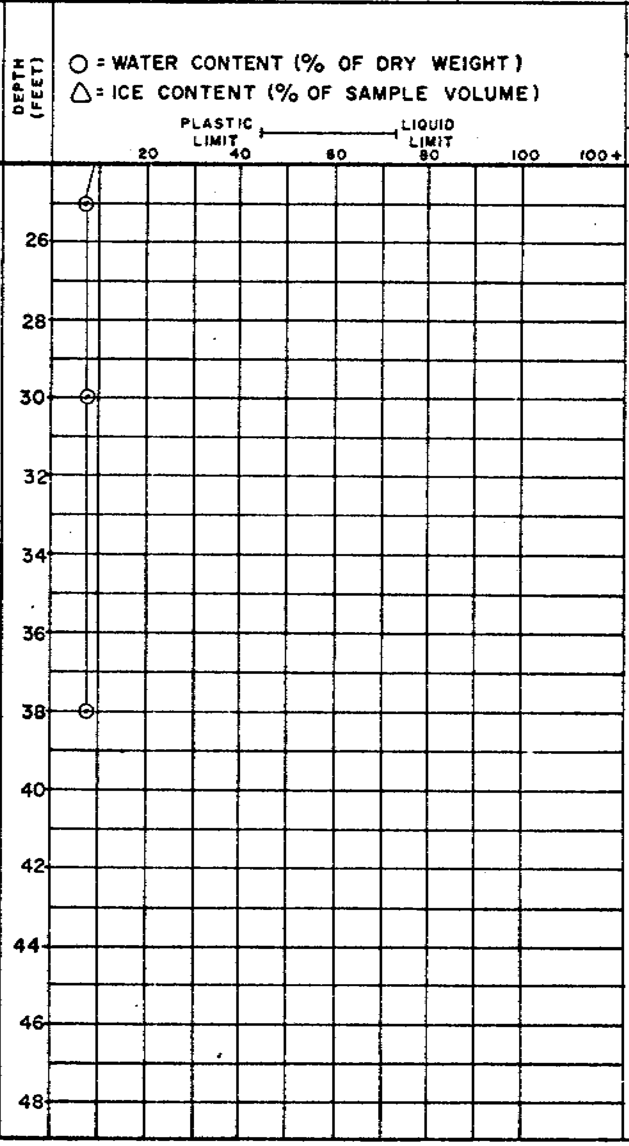
DWN: BL | FIELD ENG: NRM | DATE DRILLED 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1843 + 28.6 | OFFSET

CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6	⧅				SHALE - Grey, Silty, Some Clay, Low Plasticity, Weathered		
26								
28					SH (CL)		F	NB
30	7	⧅						
32								
34								
36								
38	8	⧅						
						END OF HOLE @ 38'		
40								
42								
44								
46								
48								



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

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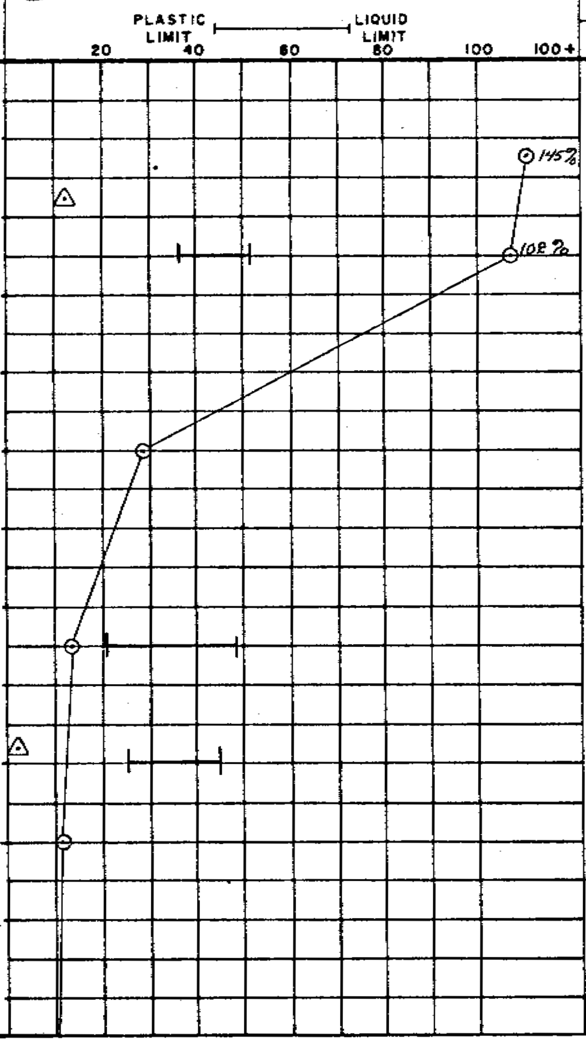
DWN: BL
FIELD ENG: NRM
DATE DRILLED: 28/2/73
AIRPHOTO NO: A22861-133
CHAINAGE: 1844 + 33
OFFSET:
CKD: LAB
TECH: JK
RIG: Mayhew
SURFACE DRAINAGE: Good to S
VEGETATION: Black Spruce
ELEV:

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	REMARKS
2 4 6	1 2				OH to MH	CLAY - Organic, Black to Dark Brown, Fibrous, Clayey, Silty		V-10-15%	2 4 6	Donnelly River Crossing
8 10 12	3				CL	CLAY (TILL) - Medium Brown - Silty - Low Plasticity - Some Sand & Gravel	F	NB	8 10 12	
14 16 18 20 22	core core				CI	SILT (Weathered Shale) - Grey - Clayey - Med. Plastic - Clayey - Medium Plastic		V-0-5% (≈1/8") layers NB	14 16 18 20 22	
24					SH (CI)	SHALE - Grey, Weathered, Silty, Clayey			24	

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

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



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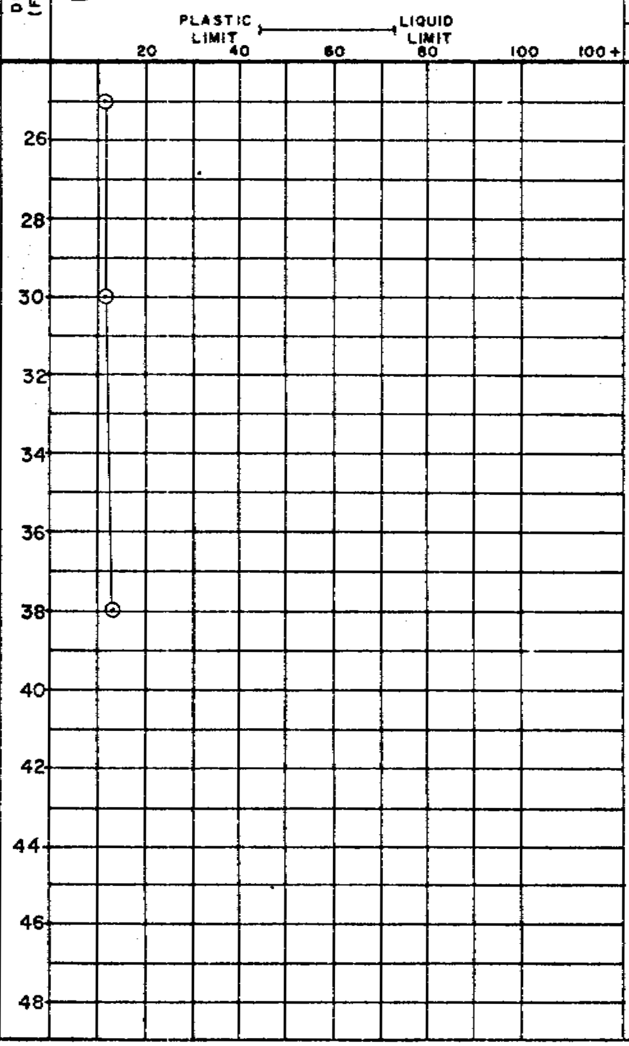
DWN: BL | FIELD ENG: NRM | DATE DRILLED: 28/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1844 + 33 | OFFSET
CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
	4					SHALE - Weathered, Grey, Silty, Clayey									
26					SH										
28					(CI)										
30	5						F	NB							
32															
34															
36															
38	6					END OF HOLE @ 38'									
40															
42															
44															
46															
48															

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



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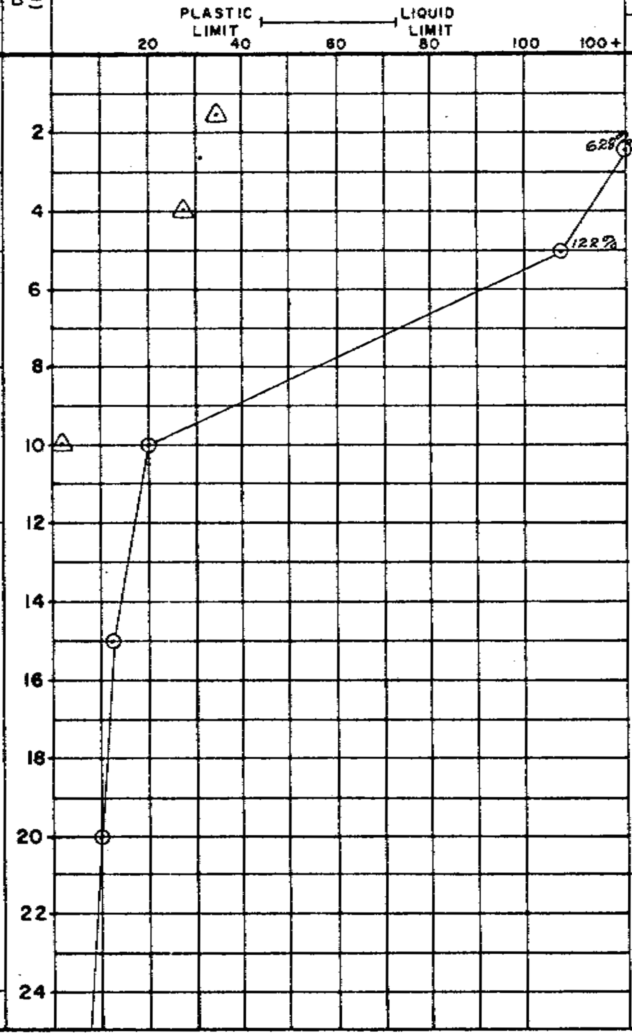
DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to W	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	9

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				PT to OL	PEAT - Black, Fibrous, Silty		V-30-40%							Donnelly River Crossing
4	2				OL	ORGANIC SILT - Medium Brown		V-25-30%							
6 8					CL	SILT (TILL) - Medium Brown, Clayey, Low Plasticity		N.B							
10	3						F	V-0-5%							
12 14 16 18	4				SH (CL) to (CI)	SHALE - Grey, Clayey - Weathered - Soft		NB							
20 22 24	5														

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



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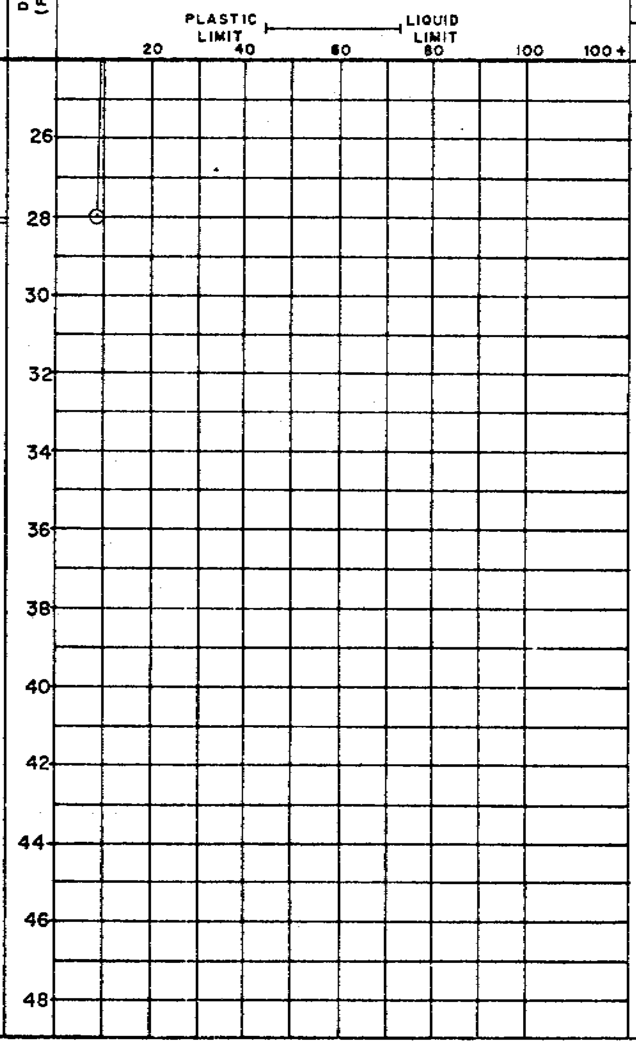
DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to W	VEGETATION: Black Spruce	ELEV:	

TEST HOLE		
MILE	B,C,S	NUMBER
689	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
26					SH (CL to CI)	SHALE - Grey, Clayey - Weathered	F	NB							
28	6	⧅													
30						END OF HOLE @ 28'									
32															
34															
36															
38															
40															
42															
44															
46															
48															

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



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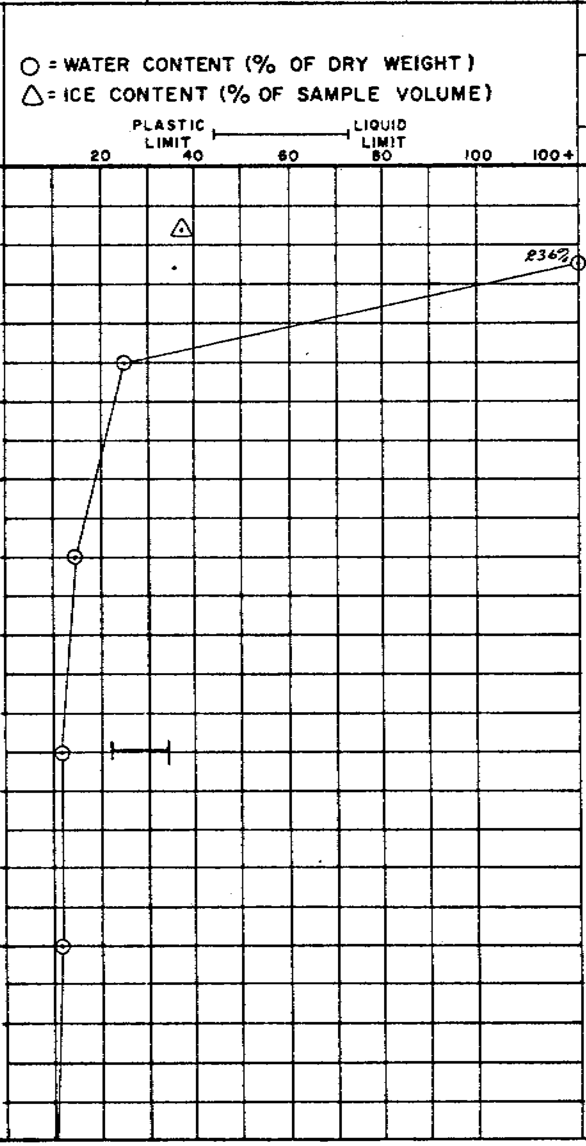
DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to S	VEGETATION: Black Spruce		ELEV:

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
2	1				PT to OL	PEAT - black, fibrous - silty, clayey		V- 35-40%	Donnelly River crossing.
4	2				CL	CLAY- medium brown (TILL)- silty - low plasticity	F	NB	
10	3								
12					SH (CL)	SHALE - grey - weathered - soft, low plasticity			
14	4								
20	5								
24									



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

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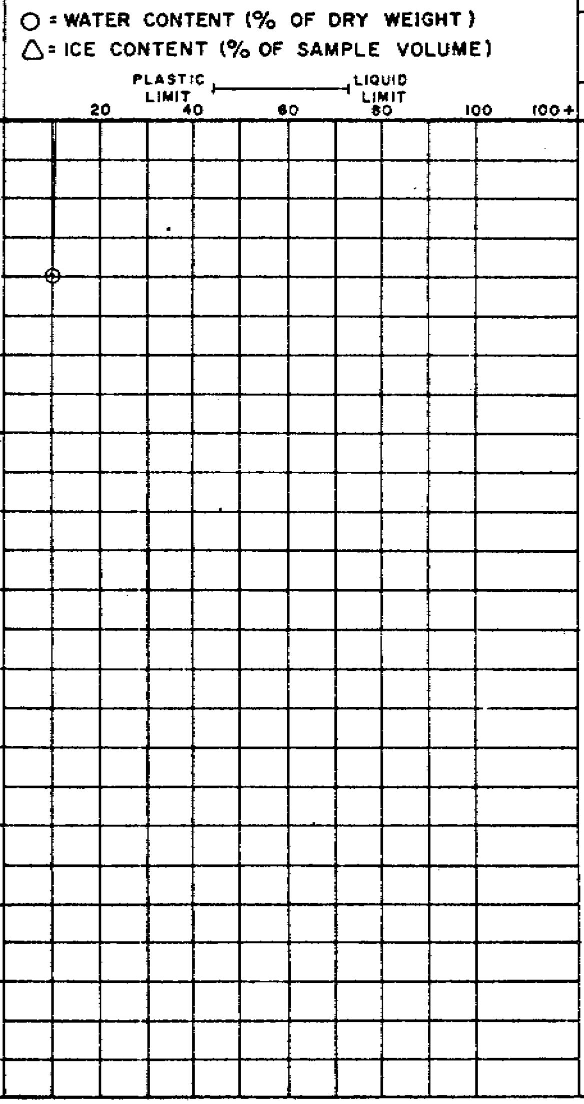
DWN: BL | FIELD ENG: NRM | DATE DRILLED 28/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: Off Line | OFFSET

CKD LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

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

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
26					SH (CL)	SHALE - Grey - Weathered - Low Plasticity	F	NB	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							

GRAIN-SIZE ANALYSIS



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DWN: BL | FIELD ENG: NRM | DATE DRILLED 28/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: Off Line | OFFSET

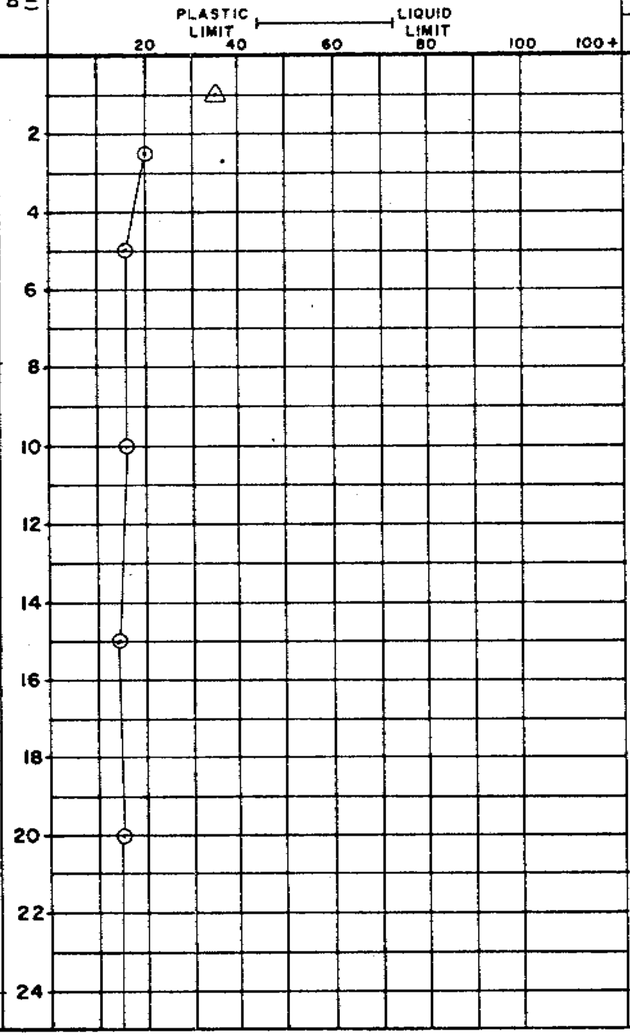
CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to SE | VEGETATION: BLACK SPRUCE & Birch | ELEV:

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

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
					PT	PEAT - Black, Fibrous		V-30-40%							Donnelly River Crossing
2	1	⧅			GP to GM	GRAVEL - Greyish Brown - Dense - Sandy, Silty - Poorly Graded									
4	2	⧅													
6						SILT to SHALE - Grey, Clayey - Low Plasticity	F	NB							
8					ML to SH (ML)										
10	3	⧅													
12															
14	4	⧅				- With Weathered Shale, Soft									
16															
18															
20	5	⧅			SH (CL) to (ML)	SHALE - Grey, Clayey & Silty, Soft, Low Plasticity									
22															
24															

GRAIN- SIZE ANALYSIS

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

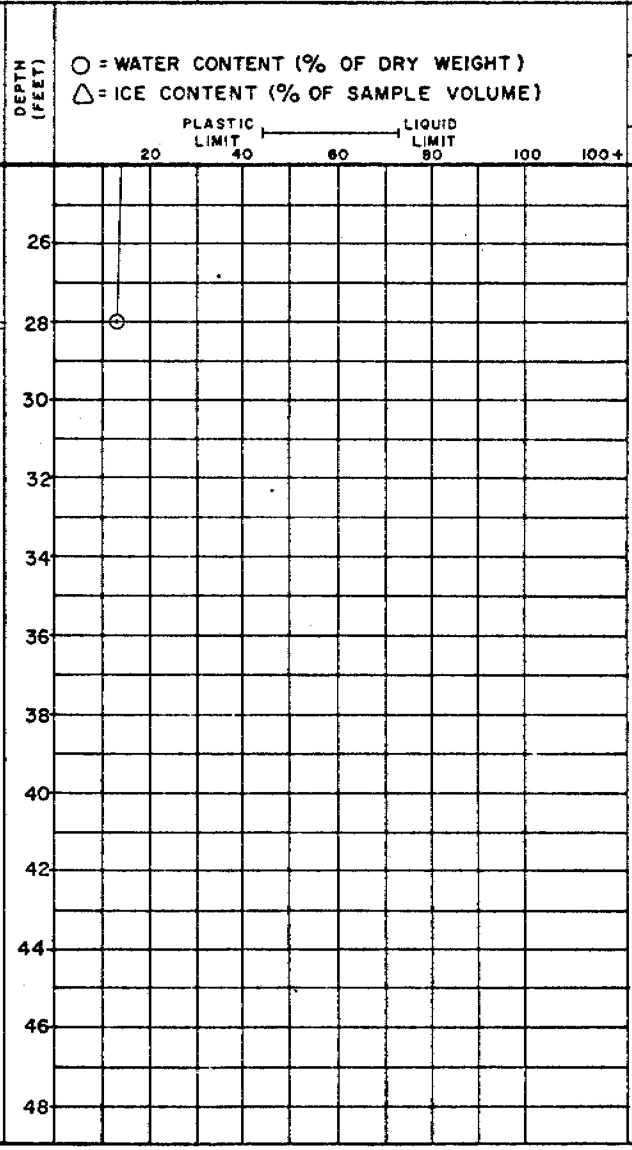


E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY Page 2 of 2

DWN: BL
FIELD ENG: NRM
DATE DRILLED 28/2/73
AIRPHOTO NO: A22861-133
CHAINAGE: Off Line
OFFSET
CKD: LAB
TECH: JK
RIG: Mayhew
SURFACE DRAINAGE: Good to SE
VEGETATION: Black Spruce & Birch
ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	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 (PCF)	DRY DENSITY (PCF)	REMARKS
26					SH (CL) to (ML)	SHALE - Grey, Clayey & Silty, Soft, Low Plasticity	F	NB							
28	6														
						END OF HOLE @ 28'									
30															
32															
34															
36															
38															
40															
42															
44															
46															
48															

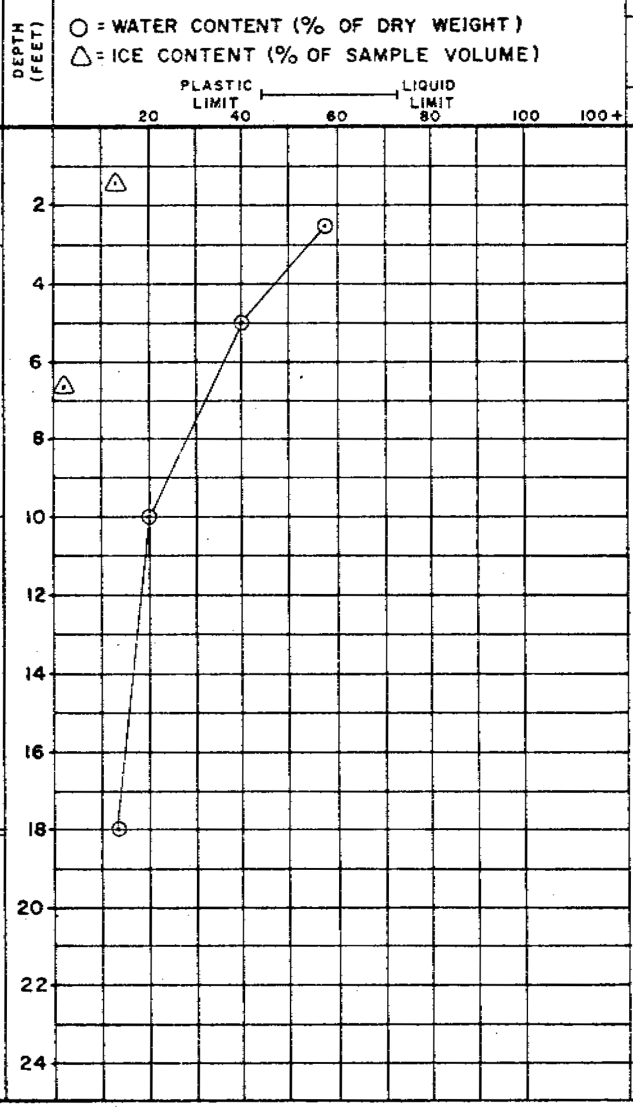


E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY**

DWN: BL
FIELD ENG: NRM
DATE DRILLED 28/2/73
AIRPHOTO NO: A22861-133
CHAINAGE: 1848 + 27.4
OFFSET
CKD: LAB
TECH: JK
RIG: Mayhew
SURFACE DRAINAGE: Good to N
VEGETATION: Bl. Spruce
ELEV:

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

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				PT to OL	PEAT - Black, Fibrous, Silty, Some Clay & Gravel		V-10-15							Donnelly River Crossing
4	2				SM	SAND - Medium Brown, Fine Grained, Silty, Some Clay,		V-0-5%	16	33	51	-			
10	3				SH (CL)	SHALE - Grey, Silty Clay, Weathered		N B							
18	4					END OF HOLE @ 18'									



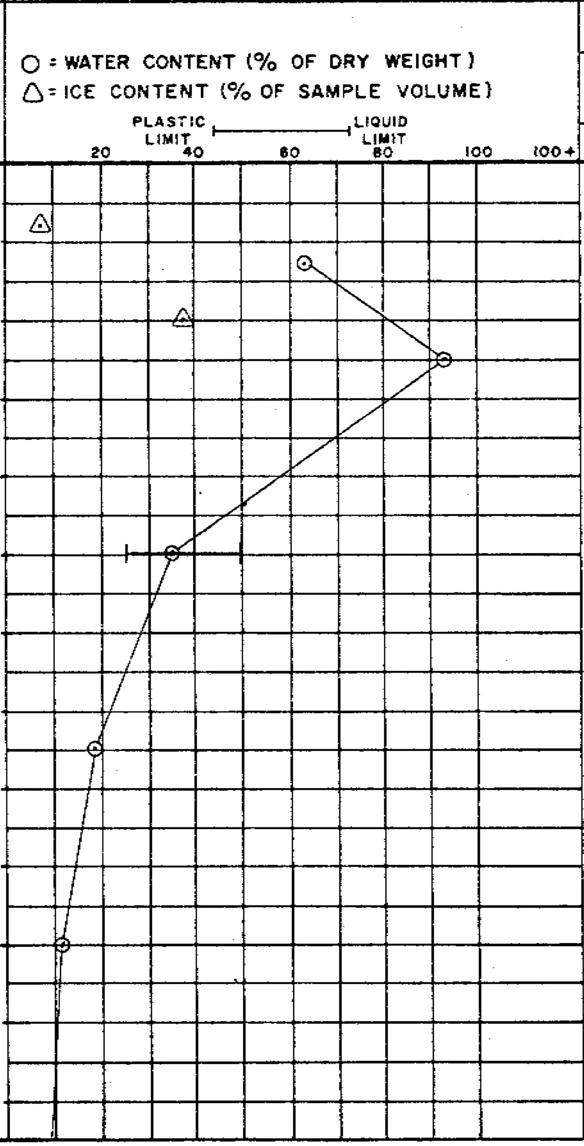
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

DWN: BL
FIELD ENG: NRM
DATE DRILLED 28/2/73
AIRPHOTO NO: A22861-133
CHAINAGE: 1849 + 80.9
OFFSET
CKD: LAB
TECH: JK
RIG: Mayhew
SURFACE DRAINAGE: Good to N.
VEGETATION: Black Spruce
ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	13

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				PT to OH	PEAT - Black Fibrous - Silty - Clayey		V-5-10%							Donnelly River Crossing
4								V-35-40%							
6	2				CI to CH	CLAY - Dark Brown - Silty - Medium to High Plasticity									
10	3					- Silty, Clay, Trace of Sand, Medium to High Plasticity	F	NB	33	57	10	-			
16	4					- Greyish Brown									
20	5				SH (CL)	SHALE - Grey, Clayey - Weathered, Soft									
24															



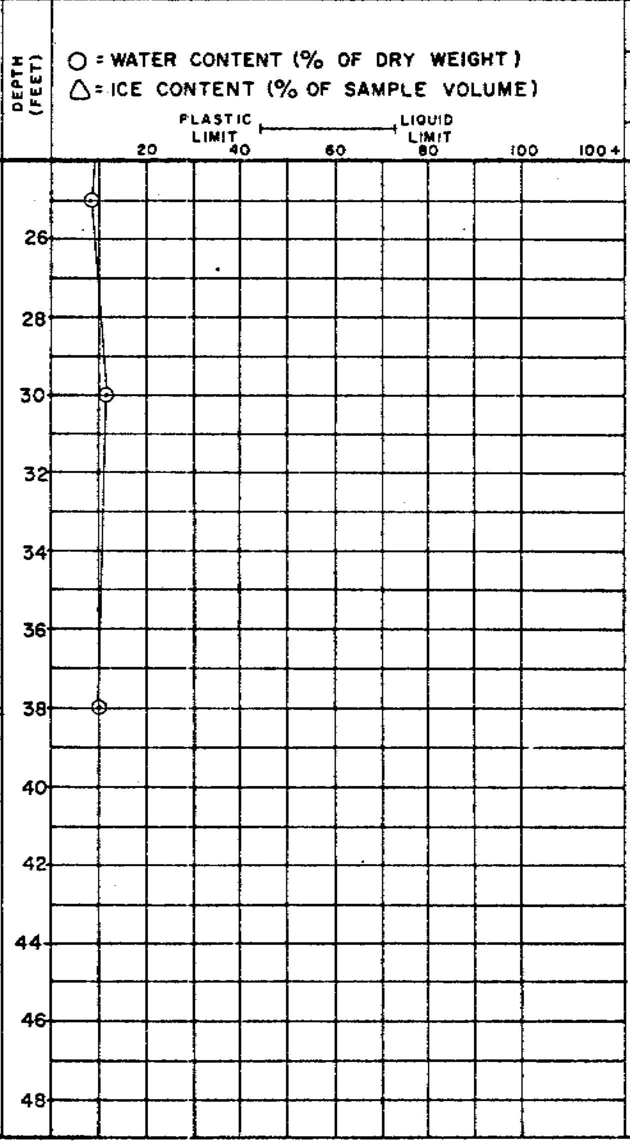
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY

Page 2 of 2

DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: 1849 + 80.9	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to N	VEGETATION: Black Spruce	ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	S	13

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	6	⧅			SH (CL)	SHALE - Grey, Clayey - Weathered, Soft									
30	7	⧅					F	NB							
38	8	⧅													
						END OF HOLE @ 38'									



E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA**
MACKENZIE HIGHWAY Page 1 of 2

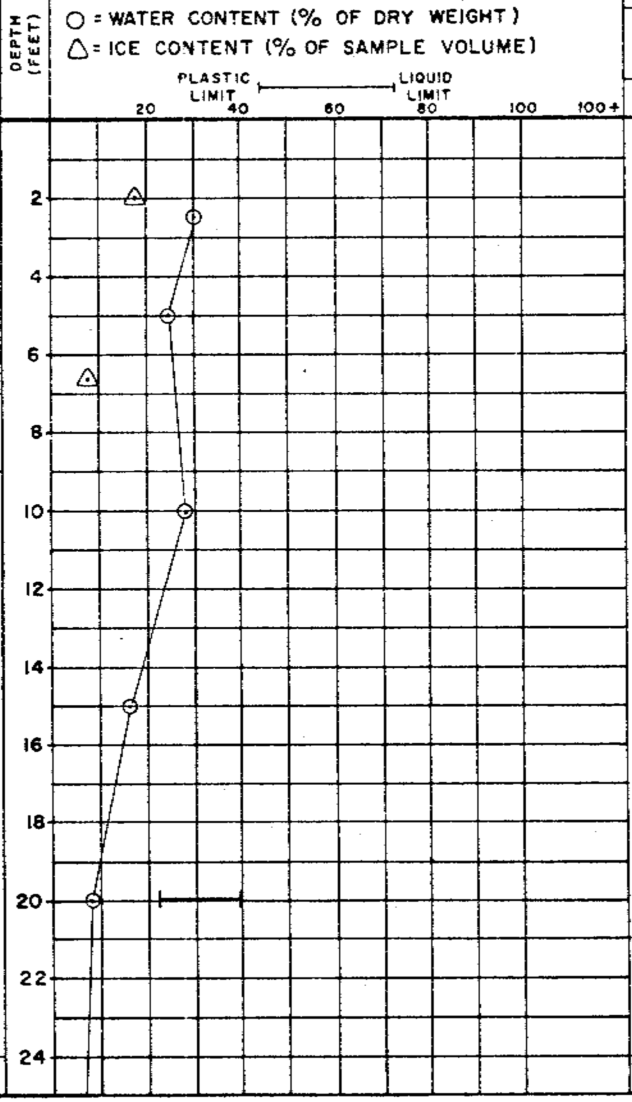
DWN: BL | FIELD ENG: NRM | DATE DRILLED 28/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1853 + 87.8 | OFFSET

CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to N | VEGETATION: Black Spruce | ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	14

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				PT to OL	PEAT - Black - Fibrous - Clayey - Silty		V-15-20%							Donnelly River Crossing
4	2					CLAY - Greyish Brown - Low Plasticity - Silty									
6								V-5-10%							
8					CL	- Sandy from 9' to 11'									
10	3														
12							F								
14	4							NB							
16						SHALE - Grey, Clay-Silt, Some Sand - Weathered, Soft									
18															
20	5				SH (CI)	- Med.Plasticity			30	57	13	-			
22															
24															



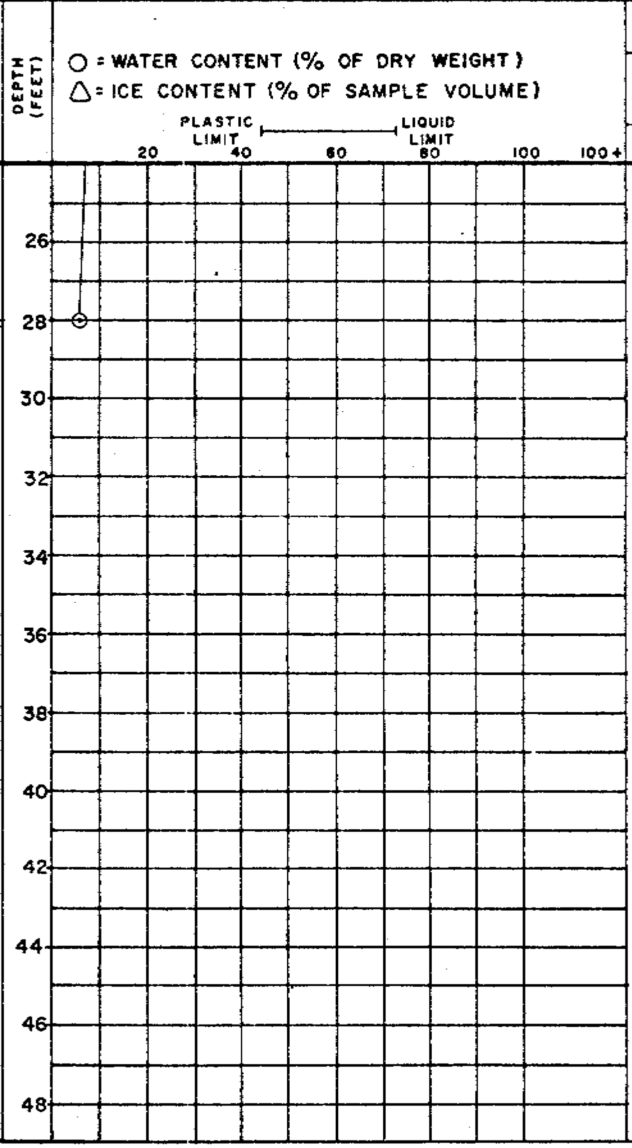
E.W. BROOKER & ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY** Page 2 of 2

DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: 1853 + 87.8		OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to N		VEGETATION: Black Spruce	ELEV:	

TEST HOLE

MILE	B,C,S	NUMBER
689	S	14

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
26					SH (CI)	SHALE - Grey, Clay-Silt, Some Sand - Weathered, Soft	F	NB							
28	6														
						END OF HOLE @ 28'									
30															
32															
34															
36															
38															
40															
42															
44															
46															
48															



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DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

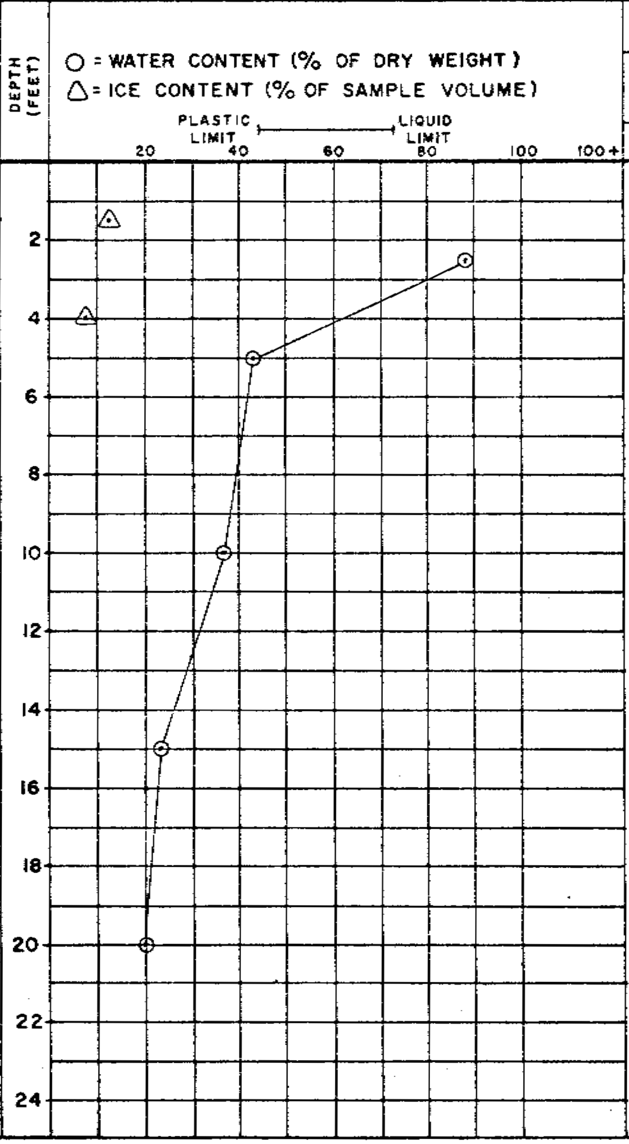
Page 1 of 2

DWN: BL	FIELD ENG: NRM	DATE DRILLED: 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to NE	VEGETATION: Black Spruce	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
689	S	15

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				PT	PEAT - Black - Fibrous		V-10-15%							Donnelly River Crossing
4	2				OH	CLAY - Medium Brown - Organic, Silty		V-5-10%							
6					SM to SP	SAND - Medium Brown - Fine, Silty - Dense - Uniform									
8 10 12 14 16 18 20 22 24	3 4 5				CL	CLAY - Greyish Brown, Sandy (fine), Silty - Low Plasticity	F	NB							



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DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

Page 2 of 2

DWN: BL	FIELD ENG NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to NE	VEGETATION: Black Spruce	ELEV:	

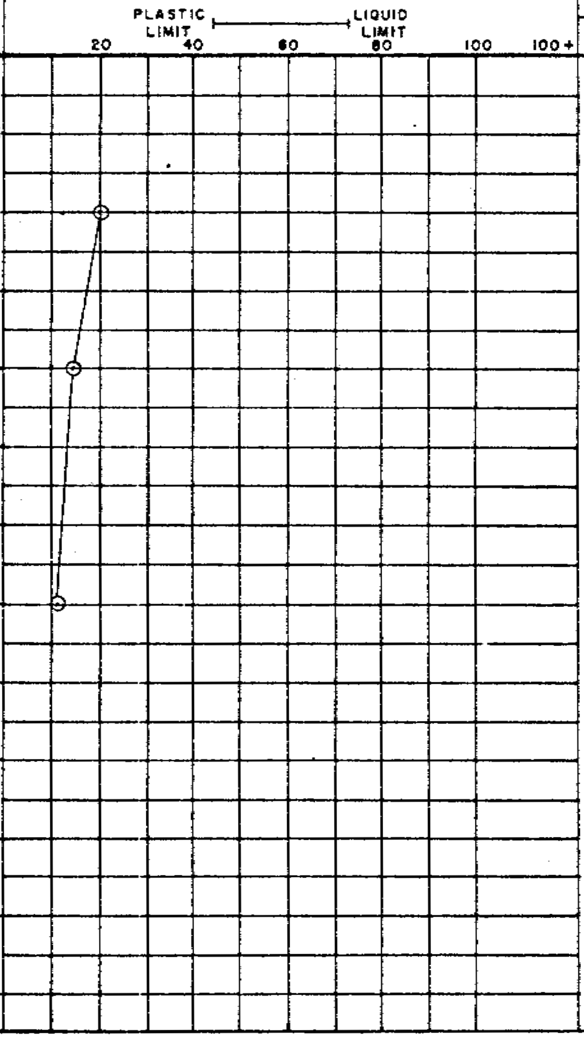
TEST HOLE

MILE	B,C,S	NUMBER
689	S	15

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	CLAY - Grey-Brown, Sandy (fine), silty, Low Plasticity			26							
28	6	⧄					F	NB	28							
30						SHALE - Weathered, Clayey, Grey			30							
32	7	⧄			SH (CL)				32							
34									34							
36									36							
38	8	⧄				END OF HOLE @ 38'			38							
40									40							
42									42							
44									44							
46									46							
48									48							

○ = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)



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DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

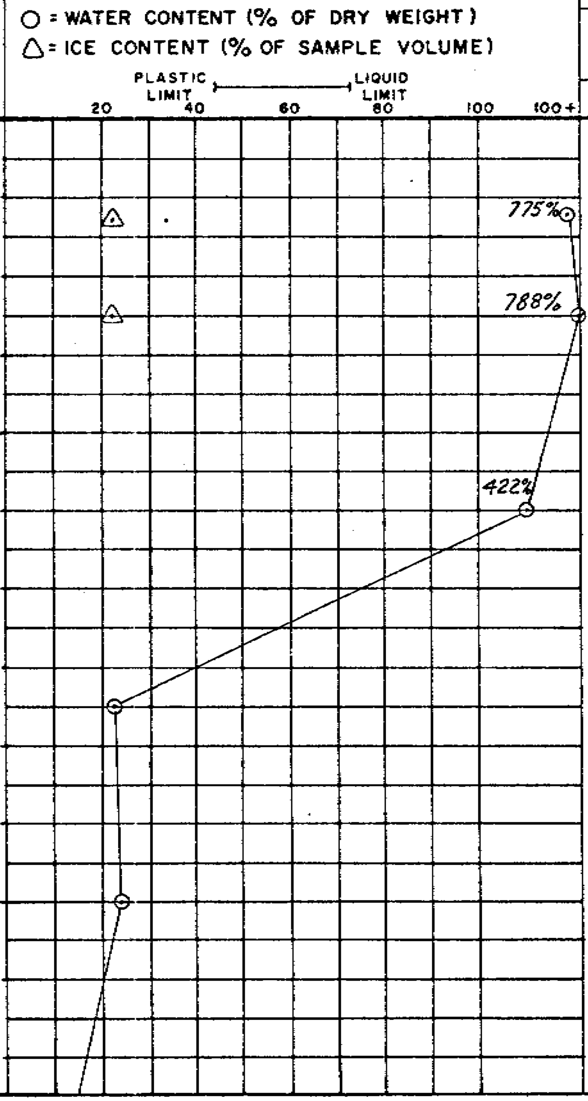
Page 1 of 2

DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Fair to NE	VEGETATION: Black Spruce	ELEV:	

TEST HOLE

MILE	B,C,S	NUMBER
689	S	16

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
						PEAT - Reddish Brown - Fibrous									Donnelly River Crossing
2	1	⧄			PT			V-20-25%							
4	2	⧄			to										
6					OL										
8						- Silty	F								
10	3	⧄				CLAY - Grey, Silty, Low Plastic									
12															
14					CH			NB							
16	4	⧄													
18															
20	5	⧄				- Boulder									
22															
24															



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

DWN: BL	FIELD ENG: NRM	DATE DRILLED 28/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: Off Line	OFFSET	
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Fair to NE	VEGETATION: Black Spruce	ELEV:	

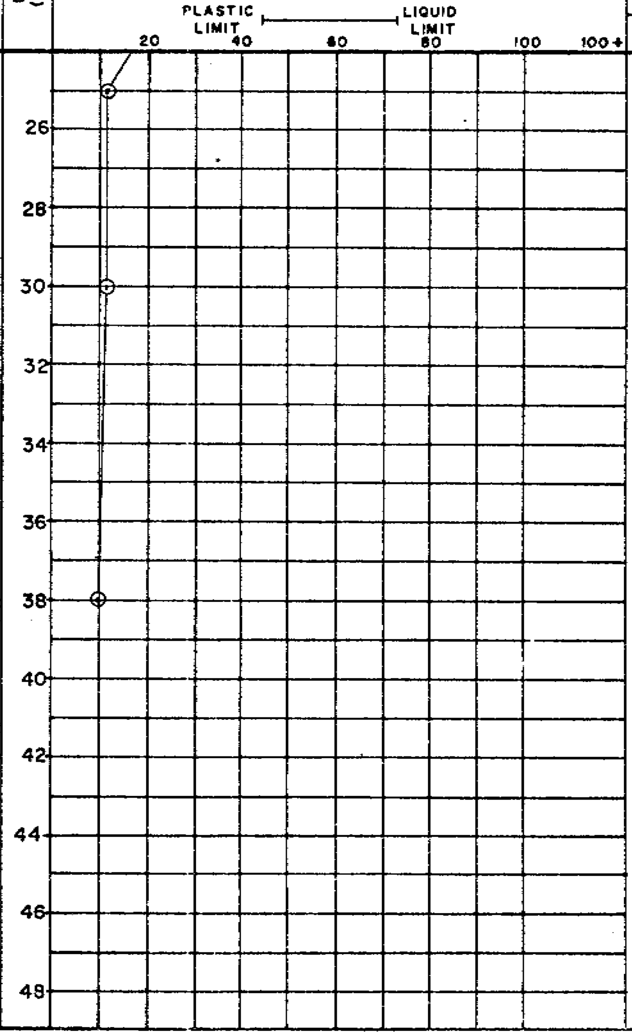
TEST HOLE

MILE	B,C,S	NUMBER
689	S	16

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
	6	⧅				SHALE - Grey, Silty-Clay, Weathered, Soft		
26								
28					SH (CL)		F	NB
30	7	⧅						
32								
34								
36								
38	8	⧅						
						END OF HOLE @ 38'		
40								
42								
44								
46								
48								

○ = 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			
%	%	%	%			

E.W. BROOKER & ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY Page 1 of 2

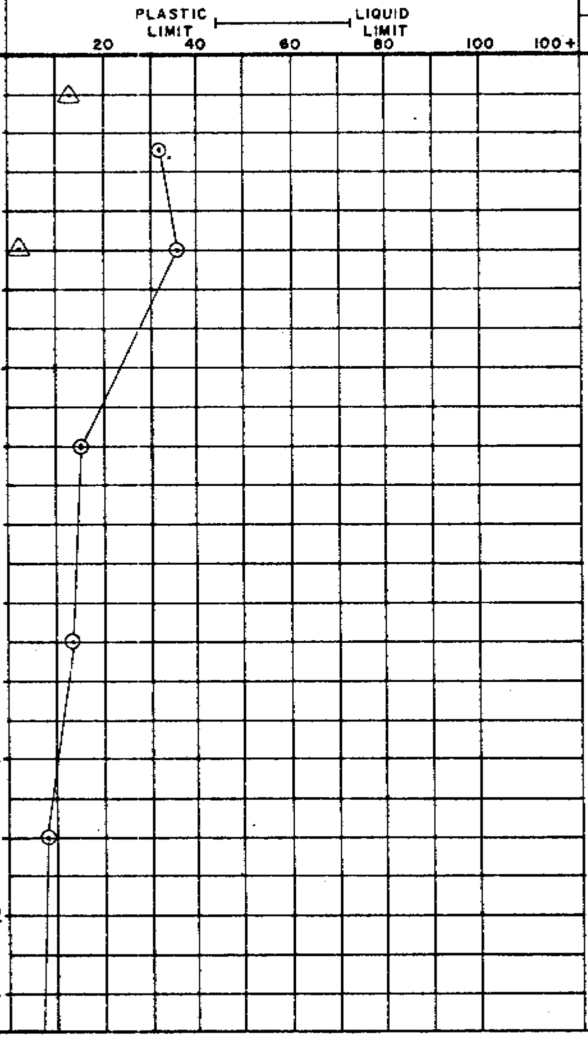
DWN: BL	FIELD ENG: NRM	DATE DRILLED 27/2/73	AIRPHOTO NO: A22861-133	CHAINAGE: 1838 + 35.3	OFFSET
CKD: LAB	TECH: JK	RIG: Mayhew	SURFACE DRAINAGE: Good to S	VEGETATION: Black Spruce	ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	S	17

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 - Black, Fibrous, Silty		V-10-15%							Donnelly River Crossing
2	1	⧅			CL	CLAY (TILL) - Medium Brown, Silty, Medium Plasticity - Organics near Top		V-0-5%							
4	2	⧅													
6															
8					ML to CL	SILT (Weathered Shale) - Medium Brown, Clayey, Low Plasticity, Soft									
10	3	⧅					F								
12															
14						- Grey		NB							
16	4	⧅													
18															
20	5	⧅			SH (CL)	SHALE - Weathered, Grey, Silty, Clay, Hard									
22															
24															

○ = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)



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MACKENZIE HIGHWAY

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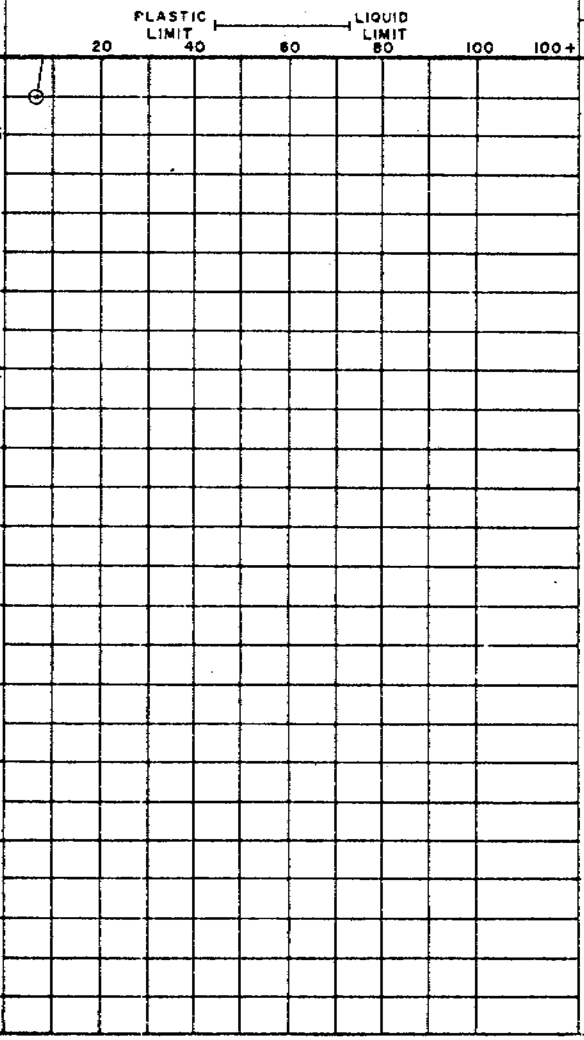
DWN: BL | FIELD ENG: NRM | DATE DRILLED 27/2/73 | AIRPHOTO NO: A22861-133 | CHAINAGE: 1838 + 35.3 | OFFSET

CKD: LAB | TECH: JK | RIG: Mayhew | SURFACE DRAINAGE: Good to S | VEGETATION: Black Spruce | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
689	S	17

○ = 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	▨				SHALE - Grey, Silty Clay, Weathered										
26					SH (CL)	- Harder	F	NB	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							



GRAIN SIZE DISTRIBUTION

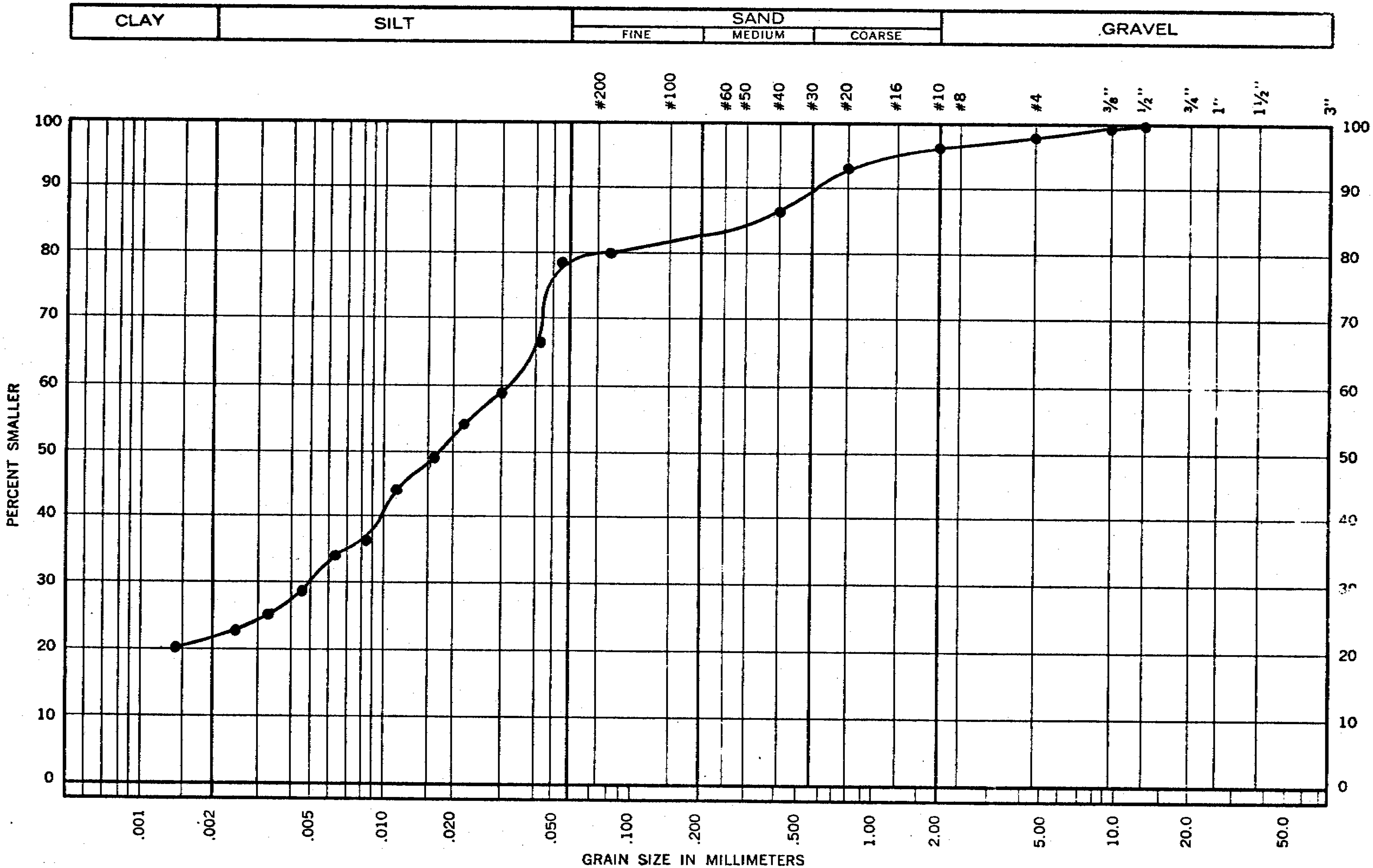


FIGURE C-1

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY-SILT (TILL)
SOME SAND, TRACE OF GRAVEL

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE MARCH 23/73
SAMPLE No. 689-S-4
DEPTH 5'

GRAIN SIZE DISTRIBUTION

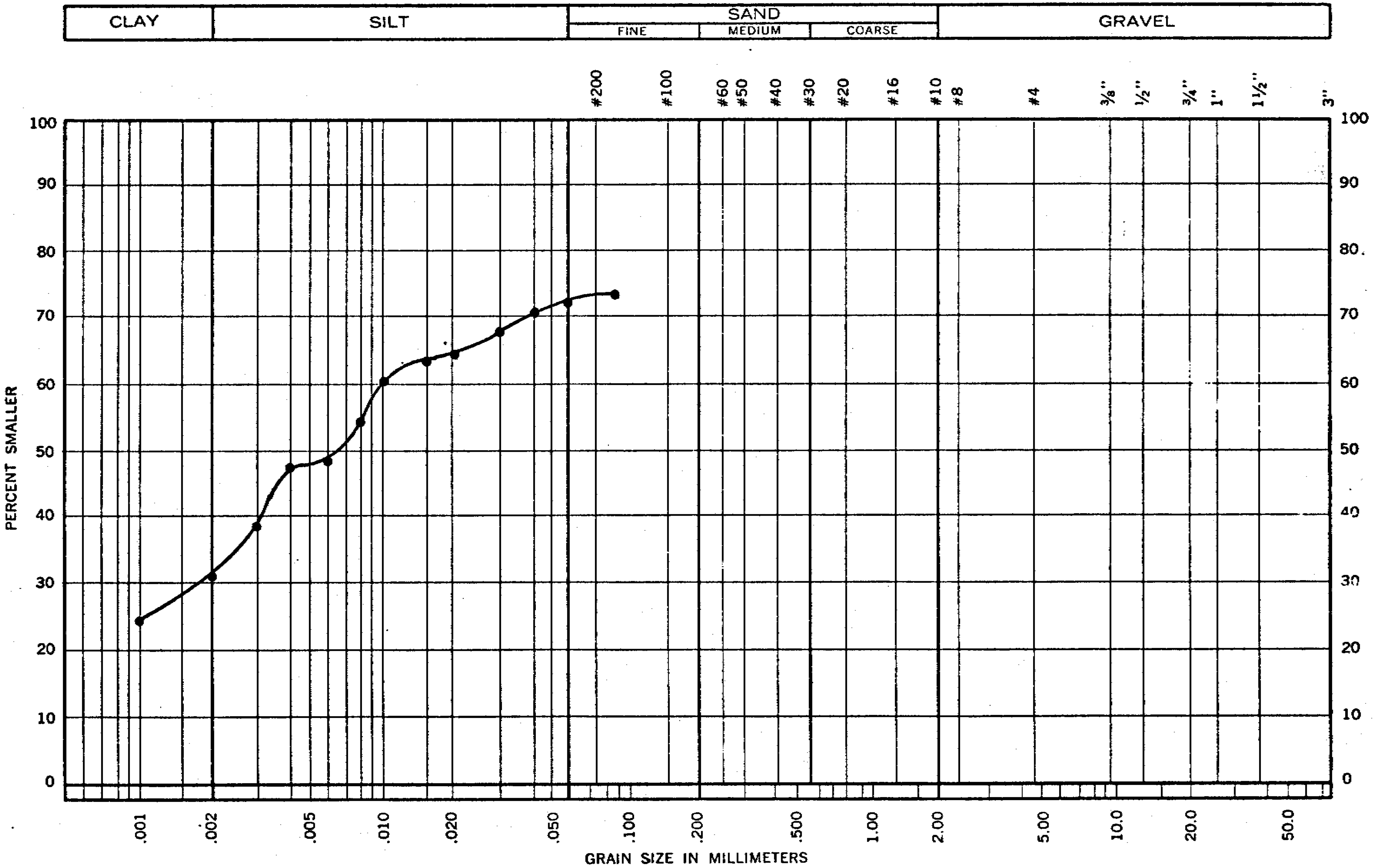


FIGURE C-2

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION SHALE, SILTY CLAY, SANDY

PROJECT MACKENZIE HIGHWAY

JOB No. E-517 DATE APRIL 5/73

SAMPLE No. 689-S-5

DEPTH 10'

GRAIN SIZE DISTRIBUTION

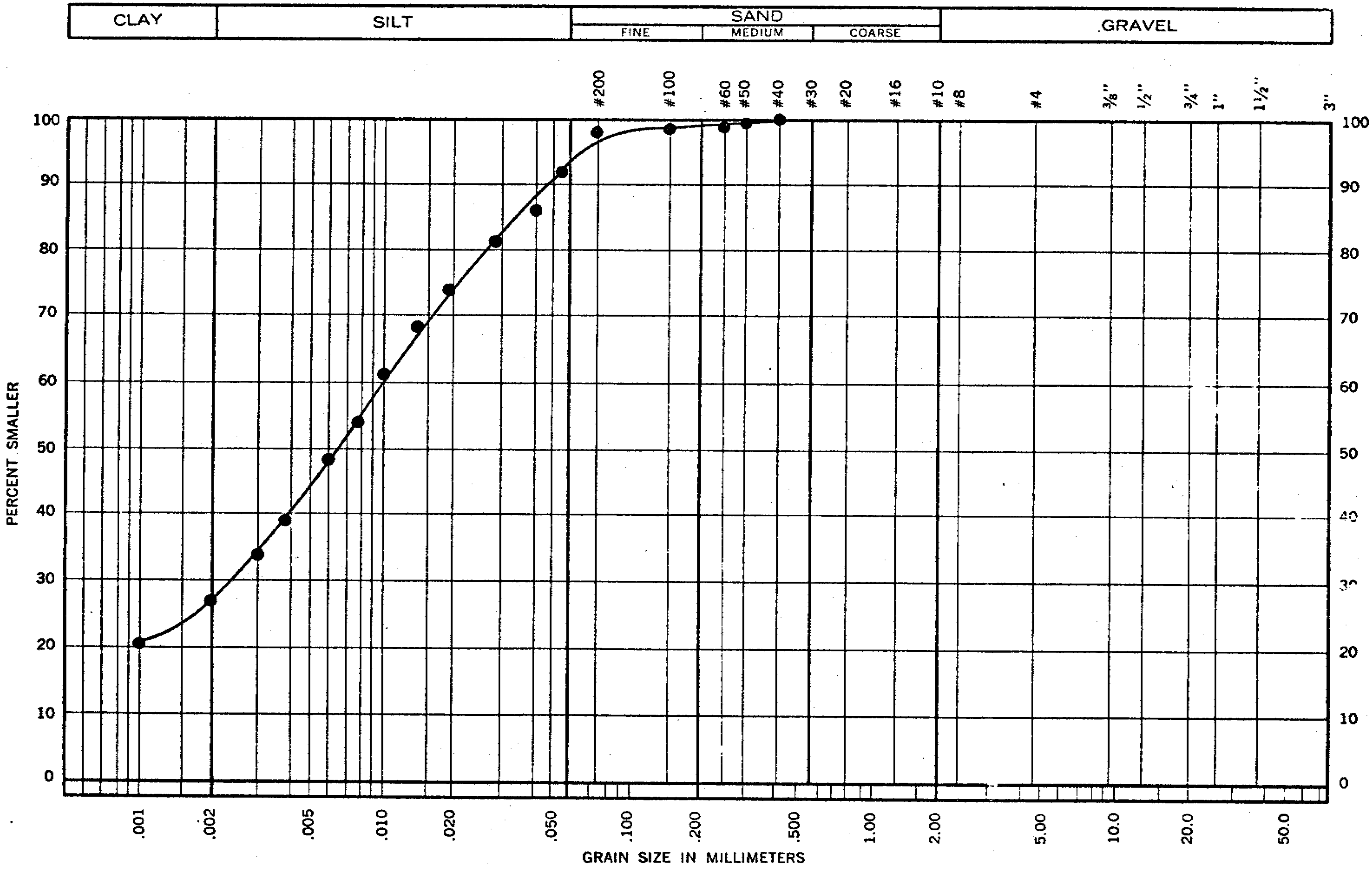


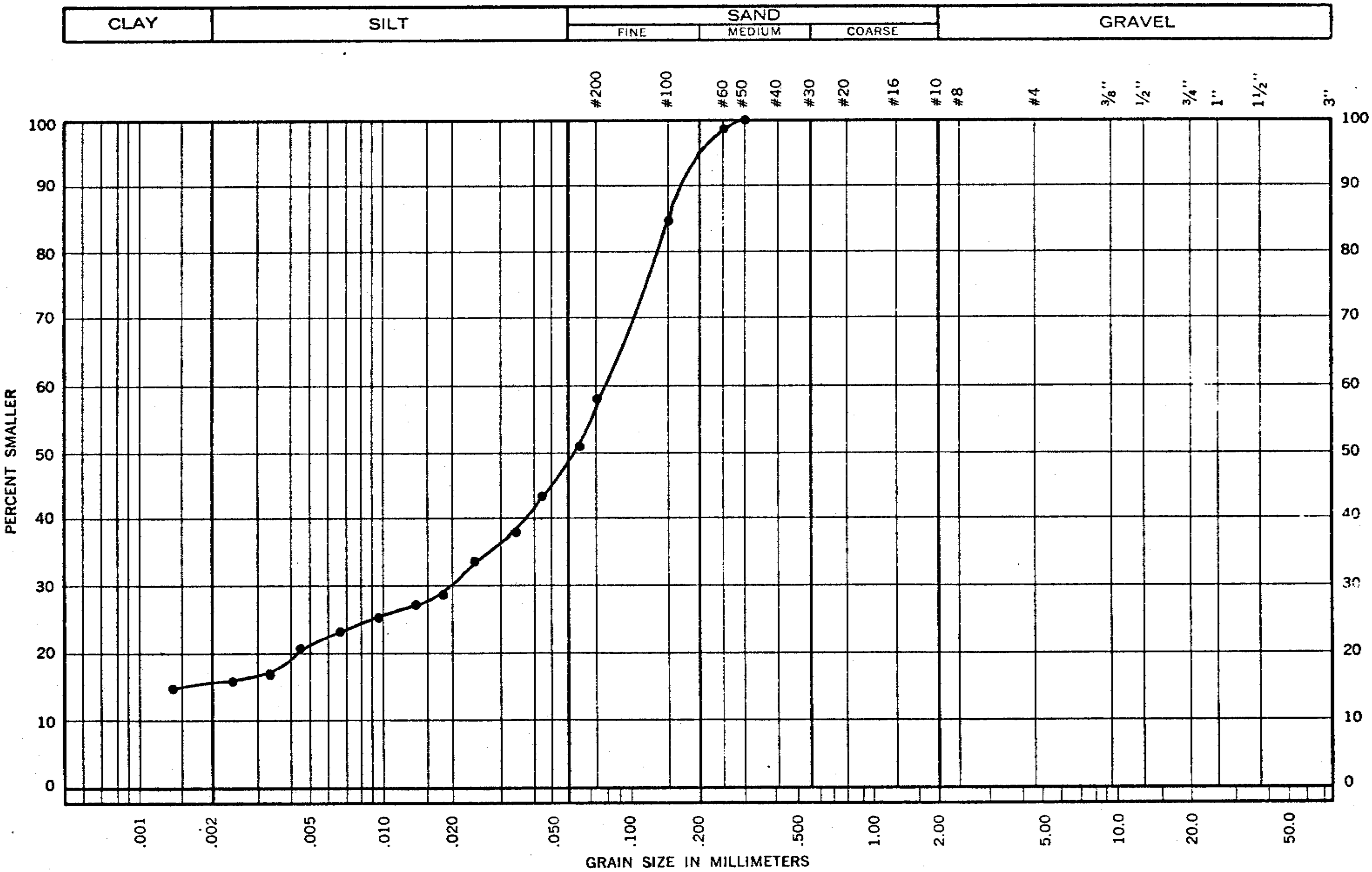
FIGURE C-3

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION (WEATHERED SHALE)
CLAY-SILT, TRACE OF SAND.

PROJECT MACKENZIE HIGHWAY
JOB No. E-517 DATE APRIL 8/73
SAMPLE No. 689 - S - 6
DEPTH 18-20' AVERAGE OF ALL SAMPLES TAKEN

GRAIN SIZE DISTRIBUTION



BROOKER & ASSOCIATES

SAMPLE DESCRIPTION SILTY SAND, SOME CLAY

PROJECT MACKENZIE HIGHWAY
JOB No. E - 517 DATE April 9/73
SAMPLE No. 689 -S- 12
DEPTH 5'

FIGURE C-4

GRAIN SIZE DISTRIBUTION

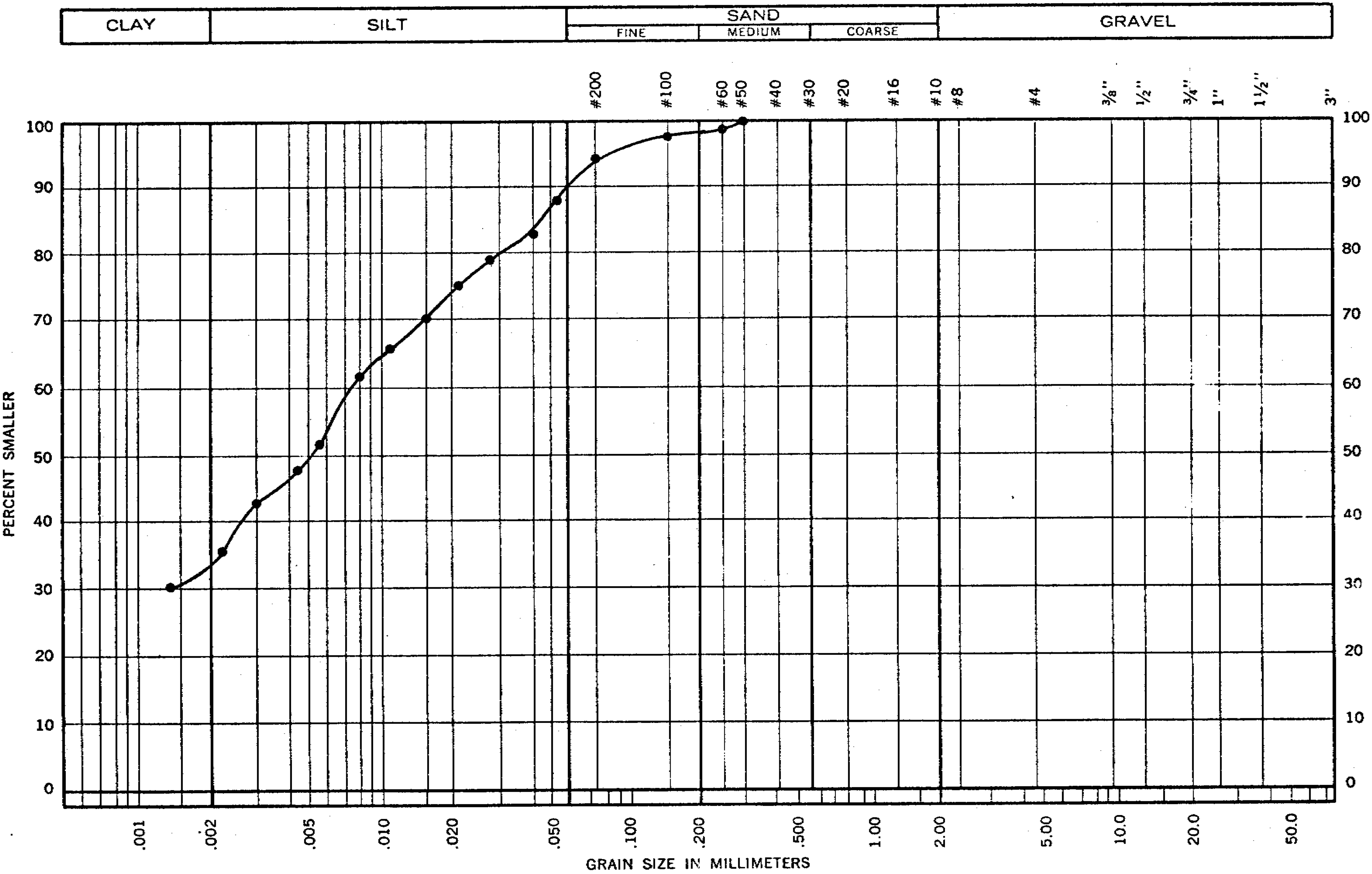


FIGURE C-5

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY, SILTY, SOME SAND

PROJECT MACKENZIE HIGHWAY
JOB No. F - 517 DATE April 9/73
SAMPLE No. 689 -S- 13
DEPTH 10'

GRAIN SIZE DISTRIBUTION

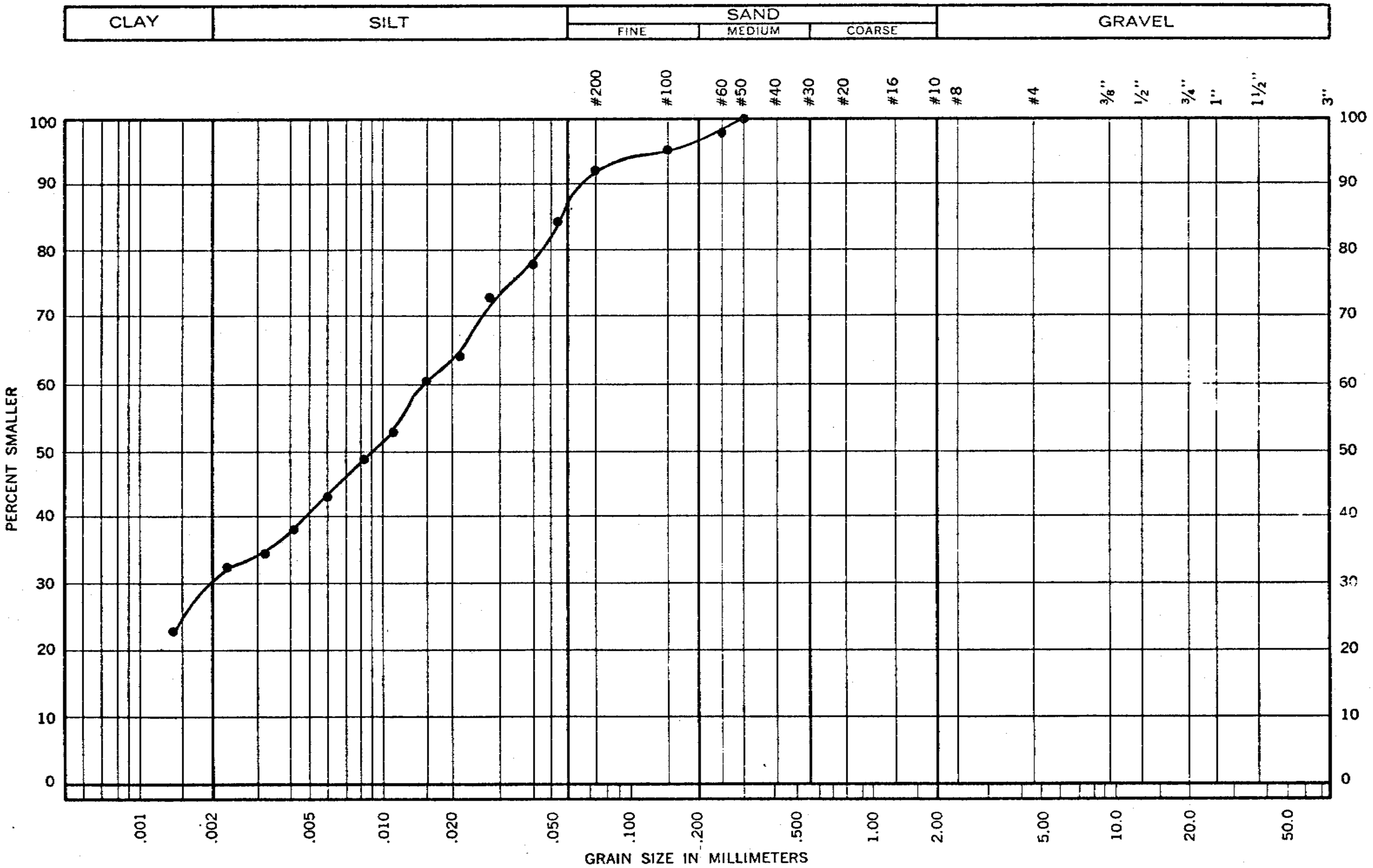


FIGURE C-6

BROOKER & ASSOCIATES

SAMPLE DESCRIPTION CLAY - SILT (SHALE)
SOME SAND

PROJECT MACKENZIE HIGHWAY
JOB No. E - 517 DATE April 9/73
SAMPLE No. 689 -S- 14
DEPTH 20'

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		
689-S-4	5		34.2	20.6	13.6	22	87	17	4	CL	
689-S-5	10		32.8	20.1	12.7	31	41	(28)		CL	
689-S-6	18-20					27	66	7	0		
689-S-8	5		SOLUBLE SULPHATES - 0.52% - pH = 6.5 SEVERE CONCENTRATION								
689-S-12	5					16	33	51	0	SM	
689-S-12	5		SOLUBLE SULPHATES - NEGLIGIBLE - pH = 6.5								
689-S-13	10					33	57	10	0		
689-S-14	20					30	57	13	0		

DWG. No. C-7

EBA ENGINEERING CONSULTANTS LTD.