Geocon Inc.

Geotechnical Consultants

Set No. 2

July 86

DEMPSTER HWY.

TERRAIN EVALUATION :

POTENTIAL ICE WEDGE AREAS

0- N.W.T BORDER

85- GOING N into N.W.T.

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1.0 INTRODUCTION

In September 1985, a section of the Dempster Highway at km 8.5 collapsed because an ice wedge in frozen over burden deposits beneath the road fill melted out.

In December 1985, the Government of the Northwest Territories (GNWT), Department of Public Works and Highways retained an engineering consultant (EBA Engineering Consultants Ltd.) to carry out field investigations including drilling and geophysical surveys at km 8.5 and at seven other locations along the Northwest Territories portion of the Dempster Highway. At all locations existing or predicted maintenance problems related to the thawing of permafrost had been identified. The results of the EBA study were presented in a December 1985, report to the GNWT entitled, "Geotechnical Evaluation Dempster Highway, N.W.T. (Selected Sites)".

In May 1986, GNWT, Department of Public Works and Highways decided to undertake further work to identify and assess potential ice wedge areas on the Dempster Highway between kilometres 0 and 85. This study consisted of an airphoto interpretation study which was awarded to Geocon Inc. on July 11, 1986, by Mr. L. Elkin, P.Eng., Deputy Minister of the Department of Public Works and Highways. The results of this study are presented in this report. Section 2.0

describes the Scope of Work; Section 3.0, The Methodology; Section 4.0, The Geological Setting; Section 5.0, Results of the Airphoto Study; Section 6.0, The Recommendations for Further Investigations; and Section 7.0, Closure.

2.0 SCOPE OF WORK

The terms of reference for the airphoto study are as follows:

- Carry out a medium level (1:15,000 scale) airphoto study within a 300 m corridor along the Dempster Highway (km 0-85) which identifies potential ice wedge areas.

- Prepare a suggested priority schedule and plan for a field testing program based on the severity of the potential ice wedge areas within the corridor.

- Submit six copies of the written report which includes good quality xerox copies of the annotated airphotos. The original annotated airphotos and "as-built" drawings will also be returned with the report.

3.0 METHODOLOGY

The contract was awarded July 11, 1986, and work was completed between July 25 and August 10, 1986, after airphotos arrived from the government airphoto library in Ottawa.

The project was undertaken by:

- Meeting with GNWT employees, R. Doerries and A. Aderichin, to obtain information on the failure of the highway at km 8.5.

- Reviewing existing published and unpublished reports on terrain conditions along the highway.

- Carrying out terrain analysis on 1:15,000 scale airphotos.

- Compiling tables showing (a) a summary of terrain characteristics by kilometre post, and (b) a ranking of terrain types for massive ice potential.

- Preparing recommendations for future geophysical and geotechnical work to be undertaken to further delineate ice-rich areas including buried ice wedges,

ice wedge polygons, and terrain units with high ice contents because of interstitial ice.

3.1 Meeting with Government

G. Minning and S. Dufour of Geocon Inc. met on July 31, 1986, with R. Doerries and A. Aderichin in GNWT offices at Yellowknife to discuss the failure of the highway at km 8.5 and to obtain background reports on the project available in the GNWT offices. The 1985 EBA report mentioned previously in Section 1.0 was obtained at this time.

3.2 Review Existing Information

Foothills Pipeline alignment sheets, Geological Survey of Canada (GSC) bedrock and surficial geology maps, and high level coloured airphotos borrowed from the GSC were reviewed prior to the July 31, Yellowknife meeting with GNWT personnel. A discussion regarding ice contents of typical terrain units was also held with O. L. Hughes, GSC, Calgary, Alberta. Dr. Hughes has undertaken detailed surficial geology mapping projects along the Dempster corridor.

During airphoto interpretation studies, drilling logs from the 1985 EBA report, "Geotechnical Evaluation Dempster

Highway, N.W.T." and logs for holes drilled by Klohn Leonoff Consultants Ltd. in the 1978, "Dempster Lateral Drilling Program", report for Foothills Pipelines were reviewed and their locations indicated on the airphotos, (e.g. EBA BH and FPL 78-174).

An attempt was made to obtain test pit logs and relevant drillhole logs from PWC, Edmonton but they could not be made available in time to complete this work according to the schedule.

3.3 Airphoto Interpretation

Airphoto interpretation was undertaken on stereo pairs ordered from the Government of Canada airphoto library in Ottawa. The low level airphotos are from 1978 rolls A25005 and A25006 and are at an approximate scale of 1:15,000. The study area was covered by 92 airphtos but some extra airphotos were obtained to ensure complete coverage.

Airphoto interpretation of principal terrain units or landforms and their visible permafrost characteristics was undertaken between July 25 and August 4, 1986. Each terrain unit or landform identified on stereo airphoto pairs has distinctive topographic and geomorphic expression, geologic origin and material, drainage,

vegetation, and permafrost characteristics (including the presence of ice wedges, ice-rich polygons and interstitial ice).

A legend which describes the environment of deposition of the terrain units and their specific properties was prepared after terrain units were classified and mapped on the airphotos. This legend appears with the airphotos in Appendix I.

3.4 Compilation of Airphoto Study Results

After airphoto interpretation was completed, two tables were prepared which summarize the terrain and permafrost characteristics of kilometres 0-85 of the Dempster Highway. The original survey mileages (chainage distances) were taken from the "as-built" drawings, converted to kilometres and transferred to the airphotos so that a kilometre by kilometre summary of terrain characteristics could be made. This summary appears as Table 1 in Section 5.0. Table 2 in Section 5.0, summarizes the terrain units and ranks their potential for containing massive ice. This chart also shows the total number of km of terrain within each ranking.

3.5 Prepare Recommendations for Future Work

The results of the airphoto study have been considered in association with available geotechnical and geophysical methods to determine the most effective course of future work.

Mr. Tony Sartorelli of Geophysicon Ltd. and Mr. Jean Pilon of the Permafrost Research Section, Terrain Sciences Division, GSC, were consulted regarding appropriate geophysical techniques. Recommendations are contained in Section 5.0.

4.0 GEOLOGIC SETTING

The study area (km 0-85) of the Northwest Territories portion of the Dempster Highway is located within three physiographic subdivisions. The subdivisions from west to east include: 1) the Richardson Mountains which extend from 20 km north of Eagle River in the Yukon to 40 km west of Peel River in the Northwest Territories, 2) the Peel Plateau which extends from 40 km west of Peel River to 2 km west of Peel River, and 3) the Peel Plain which extends from 2 km west of the Peel River to the Mackenzie River.

4.1 The Richardson Mountains

The Richardson Mountains and the Porcupine Plateau to the west have undergone erosion and weathering from Tertiary time until the present. No Cordilleran or Laurentide ice-sheets covered the area except for a tongue of Laurentide ice which entered MacDougall Pass from the east. Also peaks south of MacDougall Pass with elevations of 1525 m supported restricted circque glaciers. Because the Richardson Mountains and southern Porcupine Plateau were not glaciated, the character of the local terrain is determined mainly by the lithology and structure of subadjacent bedrock. In the Richardson Mountains this bedrock is largely the Imperial Formation which consists of sandstone, shale, mudstone, and siltstone and the Road River shales. Mountain slopes are covered by colluvial detritus ranging from silty gravel to coarse blocky debris which appears to have little segregated ice. Lower slopes are mantled by fine grained colluvial slopewash sediments which form pediment deposits. These pediment deposits vary in thickness from 1-12 m and often have high ice contents. Organic deposits occur on pediment slopes where fine grained materials are present. Alluvial plain and terrace deposits consisting of sand and gravel are often found along mountain valley streams.

4.2 Peel Plateau and Peel Plain

The Peel Plateau and Peel Plain subdivisions are part of the Interior Plains physiographic region. These areas (and MacDougall Pass in the Richardson Mountains) underwent erosion from Tertiary until Quatenary time and were glaciated twice during the Pleistocene by continental or Laurentide ice-sheets moving from the south and east. Drift associated with the last glacial advance and retreat is commonly at ground surface throughout these areas. Drift includes all rock and soil material deposited directly from glacier ice and by water associated with the melting of ice-sheets. Till derived directly from glacier ice and deposited in morainal landforms or terrain units is the major type of drift which covers bedrock in Peel Plain and portions of Peel Plateau.

Stratified drift including ice contact stratified drift (eskers, kames, kame terraces), and proglacial sediments (glaciofluvial plains and terraces, glaciolacustrine plains and terraces) have been deposited from water associated with the melting of the ice-sheet.

Laurentide ice moved generally northwestward across the Interior Plains during the last Wisconsin glaciation. However, during its retreat the development of minor lobations controlled by low relief features in the

Mackenzie lowlands produced a complicated pattern of ice-flow features (Hughes, 1972). Major halts or re-advances are inferred from moraines like the one near Fort McPherson. In these ridged and hummocky moraine landforms, drift can be up to 30 m thick. However, in large areas of Peel Plain, and Peel Plateau morainal deposits can be less than 2 m thick.

After the glacial retreat and draining of glacial lakes, weathering processes continued to erode bedrock and soil materials. Alluvial plains and terraces formed along rivers and streams. Water erosion and mass wasting resulted in the formation of colluvial deposits along river and stream valleys. Fine grained sediments from slopewash and small streams were deposited in topographic lows. Organic deposits also accumulated in these low areas. Permafrost formed in surficial materials and in some areas where permafrost thawed, thermokarst features developed.

5.0 RESULTS OF THE AIRPHOTO STUDY

Terrain unit boundaries and letter symbols representing the names of the individual units have been indicated on the airphotos which are contained in Appendix I. A legend which describes the characteristics of the individual terrain units is also included in this appendix.

The study area lies within the continuous permafrost zone and all terrain units mapped on the airphotos could contain high ice content permafrost.

High ice content permafrost according to the NRC classification is greater than 20% ground ice by volume. Visible ground ice less than 25 mm thick can occur as individual crystals or inclusions, ice coatings or particles, random or irregularly oriented ice formations, and stratified or oriented ice formations. Visible ground ice greater than 25 mm thick can occur as thick ice with or without soil inclusions (see NRC classification system for Ice in Appendix II).

High ice content permafrost which occurs as visible ice between particles of soil and thin layers less than 25 mm thick is found in most of the terrain units. In Tables 1 and 2 this ice is referred to as interstitial ice. When this ice melts, settlement over broad areas occurs. Thicker visible ice (> 25 mm) forms distinct lenses and wedges or massive ice bodies like the lens present at km 8.5 and ice which cores hills in hummocky moraine deposits near Fort McPherson. If these ice bodies melt out, localized settlement occurs over the wedge or lens. If sloping terrain is present, e.g. hummocky moraine, slope failures can occur.

TABLE 1
SUMMARY OF TERRAIN CHARACTERISTICS BY
KM POST

KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
0-1.0	Cb(P)-G	Colluvial Blanket (pediment slope) - Gullied	Fine grained slope material and residual rock over shale and mudstone	1-12m	lenses and wedges	3b	--	Colluvium is probably 2m or less - some shallow rock - Lower chance of wedges than in thicker colluvium
1.0-1.3	smR-S	Shale and mudstone (solifluction features)	Rock	At Surface	--	--	--	--
1.3-2.3	Cb(P)-G	Colluvial Blanket (pediment slope) - Gullied	Fine grained slope material and residual rock over shale and mudstone	1-12m	lenses and wedges	3b	--	Colluvium is probably 2m or less. Lower chance of wedges than in thicker colluvium
2.3-3.2	smR-S	Shale and mudstone (solifluction features)	Rock	At Surface	--	--	--	--
3.2-4.0	Cb(P)-G	Colluvial Blanket (pediment slope) - Gullied	Fine grained slope material and residual rock over shale and mudstone	1-12m	lenses and wedges	3b	--	Colluvium is probably 2m or less. Lower chance of wedges than in thicker colluvium
4.0-5.8	smR-S	Shale and mudstone	Rock	At Surface	--	--	--	--
6.8-7.96	Cb(P)-G	Colluvial Blanket (pediment slope) - Gullied	Fine grained slope material and residual rock over shale and mudstone	1-12m	lenses and wedges	3a	--	Colluvium is 2-12m. Good chance for wedges

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KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
7.96-8.22	Ap	Alluvial Plain	Sand, silt gravel	>5m	mostly interstitial minor wedges	6	—	Fairly low chance for wedges
8.22-9.9	Cb(P)-G	Colluvial Blanket (Pediment Slope) Gullied	Fine grained slope material over shale and mudstone	1-12m	lenses and wedges	3a	8.5-9.35 9.5-9.7 9.8-9.9	Thick colluvium. Good ice wedge potential, especially where * is shown
9.9-10.03	At	Alluvial Terrace	Sand, silt, gravel	>5m	mostly interstitial ice	6	—	Low chance for wedges
10.03-10.1	Ap	Alluvial Plain	Sand, silt, gravel	>5m	mostly interstitial ice	6	—	Low chance for wedges
10.1-10.4	ss,smR	Sandstone, shale and mudstone	Rock	At Surface	--	--	--	--
10.4-11.1	Cb(P)-G	Colluvial Blanket - Pediment Slope	Fine grained slope material over bedrock	1-12m	lenses and wedges	3a	10.8	Thick colluvium. Good ice wedge potential where * is shown
11.1-11.4	ss,smR	Sandstone, shale and mudstone	Rock	At Surface	--	--	--	--
11.4-12.0	Cb(P)-G	Colluvial Blanket - Pediment Slope	Fine grained slope material	1-12m	lenses and wedges	3a	—	Thick colluvium. Good ice wedge potential
12.0-12.5	ss,smR	Sandstone, shale and mudstone	Rock	At Surface	--	--	--	--

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KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
12.5-12.8	Av+Cv / ss,smR	Alluvial and colluvial veneer over shale and mudstone	Fine grained material over shale and mudstone	<2m / rock	minor lenses and wedges	3b	--	Thin colluvium 2m. Lower chance of ice wedges than in thick colluvium
12.8-13.0	ss,smR	Sandstone, shale and mudstone	Rock	At Surface	--	--	--	--
13.0-13.5	Av+Cv / ss,smR	Alluvial and colluvial veneer over sandstone shale and mudstone	Fine grained material over shale and mudstone	<2m / rock	minor wedges	3b	13.3-13.5	Thin colluvial and alluvial veneer. Lower chance of wedges than the thicker colluvium. Greatest ice wedge potential in * along slope
13.5-14.0	Ap_2	Upper alluvial plain	Sand, silt, gravel	>5m	mostly interstitial ice; minor wedges	6	--	--
14.0-14.5	Ap_1	Lower alluvial plain	Sand, silt, gravel	>5m	mostly interstitial ice; minor wedges	6	--	--
14.5-17.8	Mv+Cv / ss,smR	Morainal and colluvial veneer over shale and sandstone	Till; some fine grained colluvium	<2m / rock	lenses and wedges; some interstitial ice	3b	14.7-14.8 14.95-15.35 15.6 15.9 16.25 16.6-16.8 17.5-17.7	Thin colluvium and till; greatest potential in * area along slope
17.8-19.0	ss,smR	Shale and mudstone	Rock	At Surface	--	--	--	--

SUMMARY OF TERRAIN CHARACTERISTICS BY
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KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
18.0-19.0	Mv+Cv / ss,smR	Morainal and colluvial veneer over shale and mudstone	Till; some fine grained colluvium	< 2m / rock	lenses and wedges; some interstitial ice	3b	18.0-18.2	Thin colluvium and till; greatest potential in * area
19.0-19.9	ss,smR	Sandstone, shale and mudstone	Rock	At Surface	--	--	--	--
19.9-20.5	Cv /Ap / ss,smR	Colluvial veneer over sandstone. Road on alluvial plain	Mostly rock; minor sand, silt, gravel	< 2m; rock mostly < 1m in Cv unit; >1 in Ap	possibility of interstitial ice in Ap beneath road	6 in Ap only	--	--
20.5-22.1	ss,smR/Cv /Ap ssR	Colluvial veneer and shallow rock; some alluvial plain beneath road	Mostly rock; minor colluvium and alluvial sand, silt	< 2m; rock mostly < 1m in Cv unit; >1m in Ap	possible interstitial ice in Ap beneath road	6 in Ap only	--	--
22.1-23.3	ss,smR (minor Ap)	Sandstone, siltstone shale; minor Ap - not always beneath road	Mostly rock	At Surface	possible ice in Ap only	6 in minor Ap along this stretch	--	--
23.3-29.5	Cb(P)	Colluvial blanket - pediment slope	Fine grained slope material; minor till	1-12m	possible ice wedges and lenses	3a	23.3-23.8 24.7-26.1 26.35-27.2 27.3-28.1	Colluvium and till is thick - Good chance of wedges and lenses, especially in * areas

SUMMARY OF TERRAIN CHARACTERISTICS BY KM POST

KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
28.5-29.2	ss,smR	Sandstone, siltstone, shale	Mostly rock	At Surface	--	--	--	--
29.2-31.8	Cb(P)-G	Colluvial blanket - pediment slope	Till and fine grained slope materal; gullied	1-12m	possible ice wedges and lenses	3a	29.4 29.75-30.0 30.7-30.9 30.95-31.45 31.6 31.7-31.8	Colluvium and till is thick Good chance of wedges and lenses, especially in * areas
31.8-31.9	On ss,smR-G	Thick colluvium and rock	Valley with rock and fine grained slope material	>5m	possible ice wedges and lenses	3a	31.8-31.85	Thick colluvium on slopes; potential for wedges and lenses
31.9-34.2	Cb(P)-G	Colluvial blanket - Pediment slope	fine grained slope material and till	1-12m	lenses and wedges	3a	32.0-32.2 32.4 32.8-33.1 33.25-33.3	Fairly visible patterned ground meaning high ice content at 32.96 km
34.2-34.7	Ap+Lb	Alluvial and lacustrine plain	Silt and clay; alluvial and lacustrine material	>5m	mostly interstitial ice - possible lenses and wedges	4	--	More chance of settlement over broader area

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34.7-40.1	Cb(P)-G	Colluvial blanket - Pediment Slope	Fine grained slope material and till	1-12m	lenses and wedges	3a	35.2-35.45 36.0 36.15 36.4-36.5 36.6-36.7 37.2-37.3 37.5 37.65-37.8 37.9-38.05 38.95 39.6-40.1	Thick till and colluvium; chance of lenses and wedges - especially in * areas
40.1-40.15	Mp	Moraine plain	Till	>5m	mostly interstitial ice	--	--	Settlement over broad area if at all - very low chance of wedges

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40.15-47.9	Cb(P)-G	Colluvial blanket - Pediment slope	Fine grained slope material and till	1-12m	possible wedges and lenses	3a	40.15-40.4 40.5-40.6 41.0-41.15 41.2-41.35 41.55-41.7 41.8 41.9 42.05 42.5 43.0-43.2 43.35-43.5 45.9 46.3 47.5 47.65 47.75	Thick till and colluvium chances of wedges and lenses - especially in * areas
47.9-57.3	Cv ss,smR	Colluvial veneer over sandstone, shale and mudstone	Thin, fine grained material	< 2m rock locally thicker	wedges only in areas where colluvium is thicker	3b	48.75-48.95 49.3 49.7 49.9 49.95 51.0 52.3-52.4 52.65-52.8 54.1-54.2 55.8-55.9 56.3-56.6	Possible wedges and lenses in thicker colluvium where * is present

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KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
57.3-59.9	Mv+Cv / smR — R	Morainal and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained colluvium	<2m / rock	lenses and wedges; some interstitial ice	3b	57.5-57.6 59.0-59.1	Thin till and colluvium - chance of ice greatest in * areas
59.9-60.9	Cb(P)-G	Colluvial blanket (pediment slope) - Gullied	Fine grained slope material and till	1-12m	lenses and wedges	3a	60.8-60.9	Thick till and colluvium - chance of wedges and lenses
60.9-62.0	Mv+Cv / smR — R	Morainal and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained colluvium	<2m / rock	lenses and wedges; some interstitial ice	3b	--	Thin till and colluvium - best chance of wedges in * areas (none in this section)
62.0-62.2	pO+fO	Organic deposits	Peat and fen	>5m / till and colluvium	lenses and wedges	2	--	Lenses and wedges in organics and in underlying till and colluvium
62.2-63.5	Mv+Cv / smR — R	Morainal and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained colluvium	<2m / rock	lenses and wedges; some interstitial ice	3b	62.2-62.4 62.55-62.6 63.2-63.3	Thin till and colluvium; best chance of wedges in * areas only
63.5-63.6	pO+fO	Organic deposits	Peat and fen	>5m / till and colluvium	lenses and wedges	2	--	Lenses and wedges in organics and underlying material
63.6-63.7	Mv+Cv / smR — R	Morainal and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained colluvium	<2m / rock	lenses and wedges; some interstitial ice	3b	--	Thin till and colluvium; chance of wedges in * areas (none in this section)

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63.7-63.9	pO+fO	Organic deposits	Peat and fen	>5m till and colluvium	lenses and wedges	2	--	Lenses and wedges in organics and in underlying material
63.9-64.6	Mv+Cv / smR — R	Moraine and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained slope material	<2m rock	lenses and wedges; some interstitial ice	3b	--	Thin till and colluvium; chance of wedges in * areas only (none this section)
64.6-64.7	Lp	Lacustrine	Silt and sand	>5m	Interstitial ice	4	--	Settlement over broad area
64.7-64.8	pO+fO	Organic deposits	Peat and fen	>5m lacustrine	lenses and wedges	2		Lenses and wedges in organics and underlying material
64.8-66.2	Mv+Cv / smR — R	Moraine and colluvial veneer over shale and mudstone (Rilled)	Till; some fine grained slope material	<2m rock	lenses and wedges some interstitial ice	3b	65.2-65.7 65.9-66.2	Thin till and colluvium - best chance of wedges in * areas
66.2-71.6	Mv / smR — R	Moraine veneer over shale and mudstone (Rilled)	Till	<2m rock	lenses and wedges; some interstitial ice	3b	66.2-66.7 67.15-67.4 67.9 69.9-70.1 70.3 70.5 71.0	Thin till; best chance of wedges in * areas
71.6-72.5	Cm+ss, smR-G	Colluvial mantle and sandstone and shale (Gullied)	Fine grained slope material and rock	>5m	lenses and wedges	3a		Colluvium may be thick or thin. Thicker colluvium has more chance of ice

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KM POST	TERRAIN TYPE	LANDFORM	MATERIAL	THICKNESS	ICE	RATING OF MASSIVE ICE POTENTIAL	km OF * SECTIONS (AREAS OF GREATEST PROBABILITY OF MASSIVE ICE)	COMMENTS
72.5-75.1	Ap_2-K	Upper alluvial plain (Thermokarst)	Sand and silt	>5m	Interstitial ice - high ice content	5	--	Settlement over broad area
75.1-75.8	Ap_2	Alluvial plain	Sand and silt	>5m	Interstitial ice	6	--	Settlement over broad area
75.8-76.9	Ap_2-K	Alluvial plain (Thermokarst)	Silt and sand	>5m	Interstitial ice - high ice content	5	--	Settlement over broad area
76.9-77.6	Mp	Moraine plain	Till	>5m	Interstitial ice (higher ice content in rises on plain)	7	--	Low potential for wedges - Settlement over broad area
77.6-77.7	fO+pO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plain
77.7-77.9	Mp	Moraine plain	Till	>5m	Interstitial ice	7	--	Low potential for wedges - settlement over broad area
77.9-78.1	pO+fO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plan
78.1-78.4	Mp	Moraine plain	Till	>5m	Interstitial ice	7	--	Low potential for wedges - Settlement over broad area
78.4-78.5	pO+fO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plain

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78.5-79.3	Mp	Moraine plain	TIII	>5m	Interstitial ice	7	--	Low potential for wedges
79.3-79.4	pO+fO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plain
79.4-79.9	Mp	Moraine plain	TIII	>5m	Interstitial ice	7	--	Low potential for wedges
79.9-80.1	pO+fO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plan
80.1-81.6	Mp	Moraine plain	TIII	>5m	Interstitial ice	7	--	Low potential for wedges
81.6-81.7	pO+fO	Organics	Peat and fen	>5m moraine plain	Lenses and wedges	2	--	Lenses and wedges in organics and underlying moraine plain
81.7-95.0	Mm	Rolling moraine	TIII	>5m	Interstitial ice	1	83.45-83.75 83.9-84.1 84.55-85.0	Lenses and wedges in hills of rolling moraine.

During terrain classification and mapping activities numerical symbols, e.g. 3a, were assigned to the terrain units along the highway to rank their potential for containing various types of high ice content permafrost, especially ice wedges and lenses. A line with arrows drawn beneath the number $\overset{3a}{\longleftrightarrow}$ indicates the lateral extent of each ranking. A * or a $\overset{*}{\longleftrightarrow}$ shows a specific location with each ranking where there is the most chance for massive ice to occur. Dotted lines also outline areas where ice wedge polygons and other surface permafrost features are present.

The terrain with the highest potential for massive ice is ranked number 1 and the lowest potential is number 7. A total of 7 categories or rankings have been identified and are indicated along with terrain unit and ice descriptions on a kilometre by kilometre basis (see Table 1). Table 2 summarize 7 rankings or categories and identifies the total number of kilometres in each of the 7 categories. Table 2 shows the type of ice expected in terrain units of the seven different categories. Bedrock at ground surface has not been assigned a ranking because it is considered to have very low potential for massive ice. However, isolated ice wedges have been reported in bedrock exposures near the Yukon border. Bedrock accounts for 9.9 km or 11.6% of the route.

TABLE 2:
RANKING OF TERRAIN TYPES FOR MASSIVE ICE POTENTIAL

Potential for Massive Ice (From Worst Case #1 to Least Case #7)	Total km	Terrain Type	Material	Thickness	Ice Description	Reaction To Disturbance
(1)	3.3	Mm - (Rolling Moraine)	Till (silty clay)	>5m	Interstitial ice; ice wedges and lenses especially in hills	Local settlement and slope failures
(2)	1.4	pO+fO (Organics)	Peat and fen	3-5m; often >5m	Ice lenses and wedges in organics and in underlying material	Settlement over broad areas
(3a)	28.39	Cb(P) (Pediment slope; thicker colluvium >2m)	Fine grained (silt and clay) colluvium; minor gravel; weathered rock	1-12m colluvium / Rock	Some interstitial ice; ice wedges and lenses	Settlement over wedges and lenses
(3a)	1.0	Cm (Colluvial Mantle) >5m	Fine grained (silt and clay) colluvium; minor gravel; weathered rock	>5m colluvium / Rock	Same as above	Same as above
(3b)	2.8	Cb(P) (Pediment slope; thin colluvium <2m)	Fine grained (silt and clay) colluvium; minor gravel; weathered rock	1-12m colluvim / Rock	Some interstitial ice; thin wedges and lenses	Settlement over wedges and lenses
(3b)	9.4	Cv (Colluvial veneer) <2m	Same as above	<2m colluvium / Rock	Same as above	Same as above
(3b)	5.4	Mv (Morainal veneer) <2m	Till	<2m	Same as above	Same as above

TABLE 2: (CONT'D)
RANKING OF TERRAIN TYPES BY MASSIVE ICE POTENTIAL

Potential for Massive Ice	Total km	Terrain Type	Material	Thickness	Ice Description	Reaction To Disturbance
(3b)	11.5	Mv+Cv (Morainal and colluvial veneer) <2m	Till and fine grained colluvium; minor gravel; weathered rock	<2m till and colluvium / Rock	Same as above	Same as above
(3b)	.8	Av+Cv (Alluvial and colluvial <2m)	Silt and sand and fine grained colluvium; minor gravel; weathered rock	<2m alluvium and colluvium / rock	Same as above	Same as above
(4)	0.1	Lp (Lacustrine Plain)	Lacustrine sand; silt and clay	>5m	Mostly interstitial ice	Settlement over broad areas
(4)	.5	Lp+Ap (Lacustrine plain and alluvial plain	Lacustrine and alluvial sand; silt and clay	>5m	Same as above	Same as above
(5)	3.7	Ap_2-K (Alluvial Floodplain - Thermokarst)	Alluvial sand, silt, clay and minor gravel	>5m	Interstitial ice	Settlement over broad areas; Thermokarst lakes
(6)	.93	Ap (Alluvial Floodplain - Undifferentiated)	Alluvial sand, silt, clay and minor gravel	>5m	Interstitial ice	Settlement over broad areas
(6)	1.2	Ap_2 (Alluvial Floodplain - Inactive)	Same as above	>5m	Same as above	Same as above

TABLE 2: (CONT'D)
RANKING OF TERRAIN TYPES BY MASSIVE ICE POTENTIAL

Potential for Massive Ice	Total km	Terraine Type	Material	Thickness	Ice Description	Reaction To Disturbance
(6)	0.5	Ap_1 (Alluvial Floodplain - Active)	Same as above	>5m	Interstitial ice; sometimes unfrozen	Same as above
(6)	0.13	At (Alluvial Terrace)	Same as above	>5m	Interstitial ice; minor lenses	Same as above
(7)	4.05	Mp (Moraine Plain)	Till (silty clay)	>5m	Interstitial ice	Same as above
(-)	9.9	sm,ssR Bedrock	Conglomerate, arcillite, sandstone, siltstone, shale and mudstone	At surface	Frozen but little ice or isolated wedges only	Usually none
	85					

Rankings 1, 2, 3a, and 3b have the greatest chance of containing massive ice, in the form of wedges and lenses. Terrain units with these rankings underlie 64 km or 75% of the highway from km 0 to 85.

The most massive ice is present in the hummocky portions of hummocky moraine deposits (ranking #1 on Table 2) in the vicinity of Fort McPherson. These deposits account for 3.3 km or 3.8% of the route. Ice wedge polygons are visible in hummocky moraine deposits just east of the study area between km 117 and 121.

Ice lenses are also present in peat and fen organic deposits and in overburden materials beneath these deposits. These deposits (ranking #2 on Table 2) account for 1.4 km or 1.6% of the route. These deposits are quite visible on airphotos and settlement over broad areas would probably occur if the ice in these deposits melted out.

Thick colluvial deposits at the base of mountain slopes also have high potential for ice wedges. These thicker colluvial deposits have been ranked as 3a and account for 29.39 km or 34.5% of the route.

Thinner colluvial deposits ranked as 3b also have fairly high potential for ice wedges, although not as high as the thicker colluvium with 3a classification. In the thinner

colluvial units bedrock is usually only 2 m from ground surface. Areas marked within 3b units with $\overset{*}{\longleftrightarrow}$ or * have the greatest potential for massive ice. Colluvial units with a 3b ranking account for 29.9 km or 35.1% of the route.

The terrain units with ranking of 4 to 7 have high ice content permafrost but ice generally is interstitial to the soil grains and wedges and lenses are not as common. Terrain with rankings of 4 to 7 account for 11.11 km or 13% of the route.

Foothills Pipelines borehole logs shown in Appendix II give some idea of ice contents in the various types of terrain. Table 3 summarizes key factors relative to these holes.

TABLE 3
FOOTHILLS PIPELINES BOREHOLE LOGS

NUMBER	TERRAIN TYPE	AIRPHOTO #	PERMAFROST CLASSIFICATION
174	Cb(P) 3b ranking	A25006-55 (Our #1)	Organic silt with ice lenses at surface; Gravel with interstitial ice at depth
175	Cb(P) 3b ranking	A25006-55 (Our #1)	Interstitial ice; some lenses at silt/gravel interface
176	Cb(P)	Off Road alignment	Interstitial ice and ice lenses in 5 m of silt and clay overburden overlying shale and siltstone
177	ss,smR boundary of Mv+Cv / ss,smR	A25006-24 (our #20)	Minor ice lenses in clay and silt colluvial veneer 2 m thick which overlies siltstone
178	Cv -C / ss,smR boundary of Cb(P)	A25005-140 (Our #34)	Ice lenses and thick ice & soil or massive ice
179	Ap+Lp	A25005-132 (Our #39)	Interstitial ice in silts and gravels. Thin lenses in surface organics and some of the buried silt and clay layers
180	Mp with organic cover	A25005-126 (Our #45)	Thin lenses in organic cover; some thin lenses in underlying silt and clay till - Also interstitial ice
181	Cb(P)	A25005-120 (Our #51)	Interstitial ice and ice lenses
182	Area of Flow Slide Cb(P) or Cv / ss,smR	Off Photo	Interstitial ice and thick ice lenses
183	Mm-K	A25005-52 (Our #62)	Interstitial ice and thick ice wedge at 4 m depth

TABLE 3 (Cont'd)
FOOTHILLS PIPELINES BOREHOLE LOGS

NUMBER	TERRAIN TYPE	AIRPHOTO #	PERMAFROST CLASSIFICATION
184	Mv+Cv -R / smR	A25005-62 (Our #69)	Interstitial ice - thin lenses in 2 m of silt which overlies bedrock
185	Mv / smR	Off Photo	Thin lenses in organic cover; interstitial ice; lens at 6 m depth
186	Ap_2-K	Off Photo	Interstitial ice - small lenses Rock at 6 m
187	Mv / smR	Off Photo	Thin ice lenses in organic silt at surface; interstitial ice in till beneath organics; Rock at 3 m
188	Mm	Off Photo	Interstitial ice and thin ice lenses in 8.5 m of till

6.0 RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

The air photo study presented in this report should be confirmed by field investigations. The terrain unit boundaries, unit names, and descriptions, and surface permafrost features shown on airphotos should be verified during a truck traverse along the highway. During this traverse, sections consisting of overburden and rock located in existing road cuts, borrow pits, and other natural exposures would be closely examined. In areas where ice wedges and lenses are anticipated or permafrost features have been identified, detailed observations of the ground surface and the condition of the road would be made. The traverse should be made jointly by the geologist who did the terrain mapping and a geotechnical engineer familiar with permafrost and northern highway construction. This ground truthing should be done before the ground is covered by snow.

Geophysical surveys using electromagnetic methods (EM31) and the newest generation of radar equipment (in use by the GSC) should be carried out at selected locations in terrain units with the highest potential for massive ice, particularly in areas which are ranked as 1, 2, 3a, or 3b on the airphotos. The EM31 will show areas with high ice contents, but will not necessarily delineate the shape or thickness of individual ice wedges and lenses. EM31

equipment is available commercially at Geophysicon Inc., Calgary, Alberta.

Mr. Tony Sartorelli of Geophysicon has worked successfully with this equipment for Foothills Pipelines along the Dempster Highway. His familiarity with the Dempster area makes him best suited to carry out the EM-31 studies.

The newest generation of radar equipment which is used experimentally by the Geological Survey of Canada, Terrain Sciences division, and is available commercially from "A-Cubed", Mississauga, Ontario, may complement the information obtained with EM-31 equipment. This new generation of radar equipment may in fact be able to delineate the shape and thickness of the ice wedges. Peter Ananan, of A-Cubed is one of the leading experts on shallow radar geophysics in North America and has done radar work on high ice content permafrost along the Norman Wells oil pipeline. Both types of geophysics, particularly the new radar, can be expensive if done over every location where ice wedges are expected. For this reason, it is our recommendation that the geophysics be calibrated in areas with known high ice contents and massive ice (e.g. km 117 or km 8.5) and then run in selected localities where massive ice bodies are anticipated. It is

also important to bear in mind that geophysics is only as good as the interpreter's experience. It is for this reason that we are identifying herein individuals in whom we have confidence.

If geophysics supports the terrain mapping identification of areas with high potential for massive ice, drilling and geotechnical logging can be undertaken to confirm that massive ice is present. This combined approach could then be used to cut back on the amount of drilling in areas with expected massive ice. Alternatively drilling without geophysics can be undertaken at all or selected localities where massive ice is anticipated.

Geophysical surveys and drilling are carried out most successfully after the active layer is frozen in autumn.

Investigation of highway construction procedures in the vicinity of the ice wedge at km 8.5 may also provide clues as to the melting out of the ice wedge and failure in the road fill at this locality. Along the southern Dempster Highway, melting of ice wedges usually occurs within the first three years after construction (O.L. Hughes, GSC., personal communication). Evidence of ice wedges melting out is usually observed and repaired prior to collapse.

It is possible the drainage system along the highway or the condition and thickness of the fill at km 8.5 may have contributed to the collapse which gave rise to these investigations.

7.0 CLOSURE

The General Conditions and Limitations contained in Appendix III are deemed to apply to this geotechnical report.

The air photo interpretation presented herein was conducted by Ms. G. Minning, M.Sc. P. Geol. Ms. Minning prepared the report which was reviewed by Dr. G. Hollingshead, P. Eng., and Mr. Dufour. Mr. T. Sartorelli, P. Geoph. of Geophysicon Ltd. contributed to the discussion of geophysical methods as did Mr. Jean Pilon, Geological Survey of Canada. O.L. Hughes, Geological Survey has also provided useful insight into the ice contents of certain terrain units.

We will be pleased to provide further design assistance or field services as you may require. Please do not hesitate to contact the undersigned.

Respectfully yours,

GEOCON INC.

Prepared by

Gretchen Minning

G.V. Minning M.Sc. P.Geol.

G. Hollingshead PhD. P.Eng.

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G. W. HOLLINGSHEAD
LICENSEE

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 078
GEOCON
INC.

APPENDIX I

LEGEND FOR TERRAIN TYPES

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas with high ice content
- pO - Peat: peat; flat to depressional; poor drainage; generally frozen, areas with high ice content

C - Colluvial

- Cb(P) - Pediment: silt, sand and clay, with some organics and angular coarse material, overlying bedrock; depth to bedrock from 1 to 12 m, depending on location on pediment surface; gently to moderately sloping; fair drainage; medium to high ice content
- Cm - Colluvial Mantle Slopewash: predominantly silt, clay and sand; gently to steeply sloping; fair to good drainage; medium to high ice content
- Ct - Talus: angular bedrock fragments, silt and sand matrix; steeply sloping; good drainage; low ice content
- Cv - Colluvial Veneer: predominantly silt, clay and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

A - Alluvial

- Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to undulating, channelled; fair to good drainage, high water table; unfrozen or low ice content
- Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat to undulating, channelled; fair drainage with open water, frequently inundated; generally unfrozen
- Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; fair to good drainage, periodically inundated; low ice content
- At - Alluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; low ice content
- Av - Alluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying material; good drainage; low ice content

G - Glaciofluvial

Gp - Glaciofluvial Plain: stratified sand and gravel, minor silt; level to gently undulating; good drainage; low ice content

M - Morainal

Mm - Rolling Moraine: silty clay till, organic veneer common in depressions; undulating to rolling; fair to good drainage; medium to high ice content - especially in hills

Mp - Moraine Plain: silty clay till; flat to gently undulating; fair to good drainage; low to high ice content, mostly medium

Mv - Moraine Veneer: silty clay till; topography reflects underlying bedrock; fair to good drainage; low to high ice content, mostly medium

R - Bedrock

R - Bedrock with little or no cover. Lower case prefix indicates rock type, where known, e.g.

- s - Sedimentary rock (undifferentiated)
- sm - Siltstone, mudstone, shale, argillite
- ss,sm - Sandstone and conglomerate; some shale, siltstone, mudstone and argillite

Modifiers

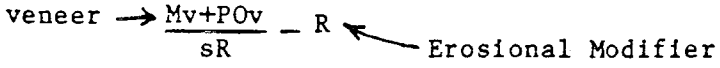
- K - Thermokarst features
- G - Gullied
- R - Rills
- S - Solifluction

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

pO+fO	or	ss,sm R/Ap
50% + 50%		75% 25%

Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:



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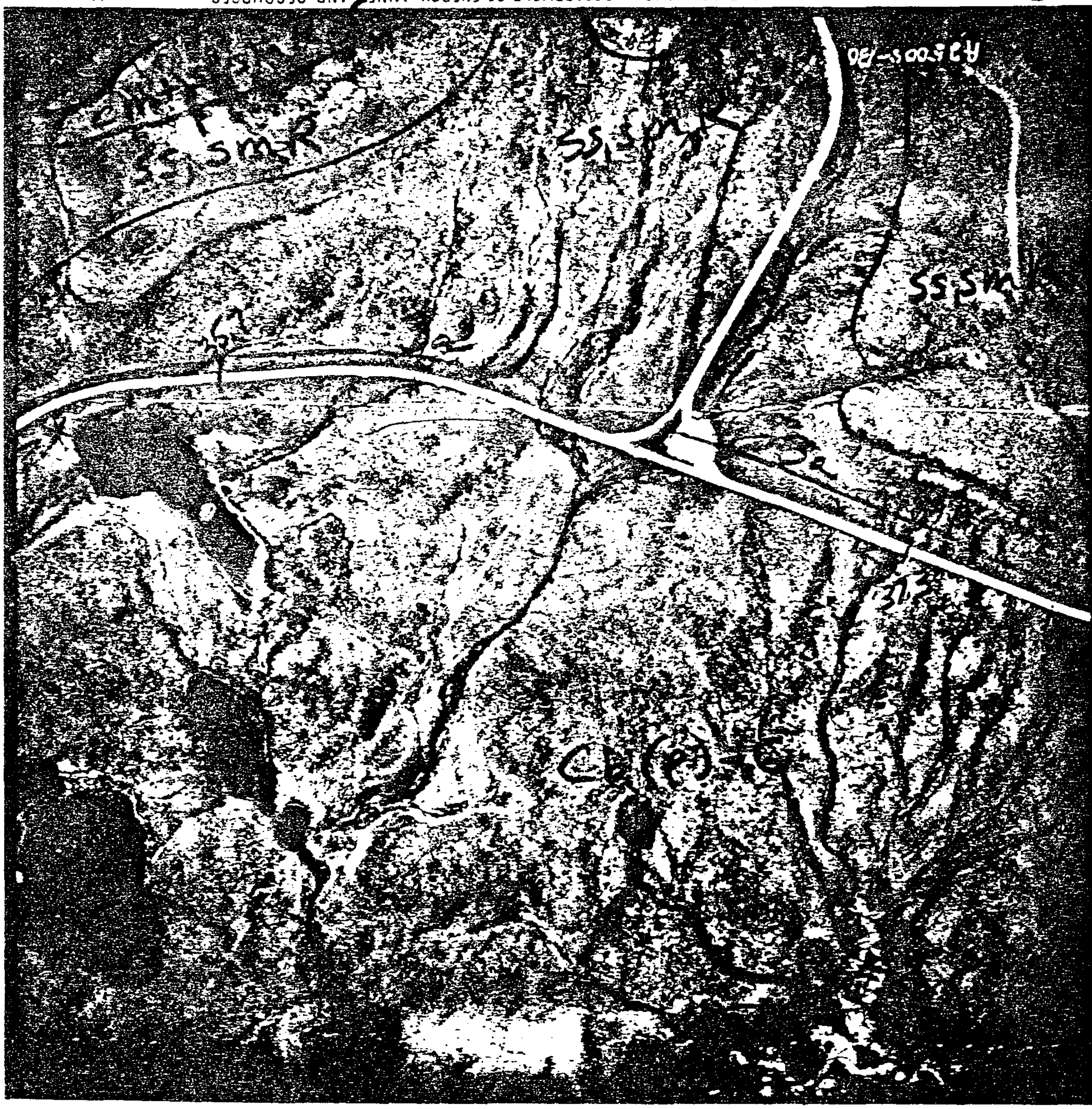
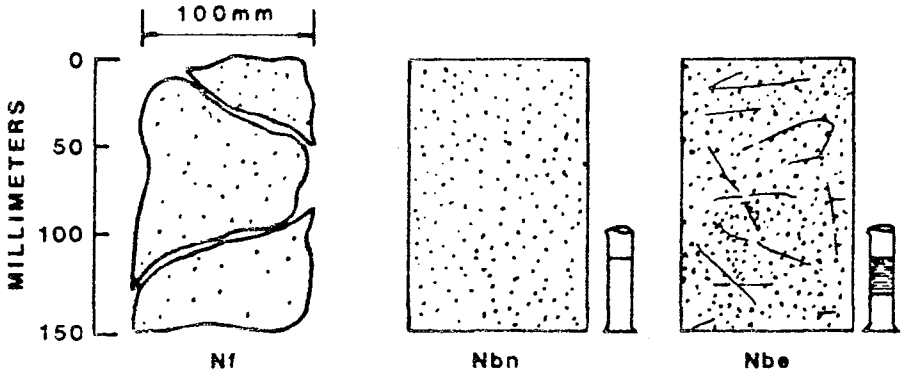


APPENDIX II

Geocon

GROUND ICE DESCRIPTION

ICE NOT VISIBLE



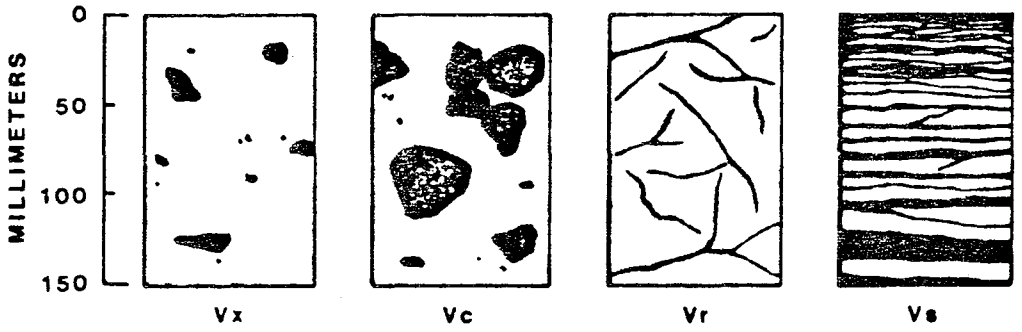
POORLY BONDED OR FRIABLE

WELL BONDED - NO EXCESS ICE

WELL BONDED - EXCESS ICE

LEGEND: SOIL - ICE - OR

VISIBLE ICE LESS THAN 25mm THICK



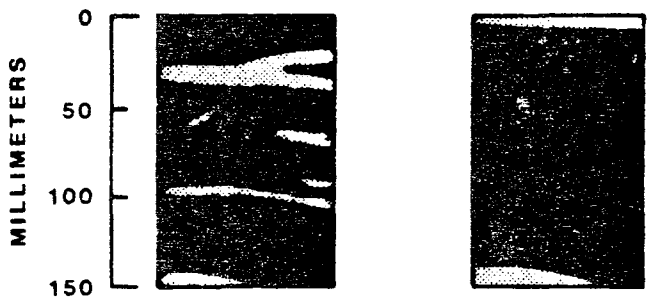
INDIVIDUAL ICE INCLUSIONS

ICE COATINGS ON PARTICLES

RANDOM OR IRREGULARLY ORIENTED ICE FORMATIONS

STRATIFIED OR DISTINCTLY ORIENTED ICE FORMATIONS

VISIBLE ICE GREATER THAN 25mm THICK



ICE & SOIL

ICE WITH SOIL INCLUSIONS

ICE

ICE WITHOUT SOIL INCLUSIONS

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA: DEPTH | TYPE | BLOW/15cm. | No.
SYMBOL
PERMAFROST: N.R.C. CLASS | N.F. or F.
LOCATION
ELEVATION
DESCRIPTION OF MATERIAL
COHESION - Kg./Sq. cm. 0.2 0.6 1.0 1.4 1.8 ● FIELD VANE △ LAB VANE ■ UNCONF
PLASTIC LIMIT | WATER CONTENT | LIQUID LIMIT
x — — — — — 0 — — — — — x
10 30 50 70 90%

2. Vegetation is comprised of a thick growth of shrub and conifers to 15m tall.
3. Peat tussocks cover the surface.
4. Poorly drained.
5. Hole augered to 0.3m, cored to 5.4m and then drilled with air to 8.5m.

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-188
DATE	Aug.14/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg. | HT. DROP 76 cm. | SAMPLE DATA | SYMBOL | PERMAFROST | LOCATION | ELEVATION | COHESION - Kg./Sq.cm. (0.2, 0.6, 1.0, 1.4, 1.8; ● FIELD VANE △ LAB VANE ▮ UNCONF.)

DEPTH	TYPE	BLOW/15 cm.	No.	N.R.C. CLASS	N.F. or F.	DESCRIPTION OF MATERIAL	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10, 30, 50, 70, 90%)
	B				NF	0.10m ORGANIC COVER	
	B		1		0.35M	PEAT - dark brown	
	C		2	Nbe			431%
1	C		3	Vr		1.00m	467%
	C		4	Vr Vs	gravel layer	ORGANIC SILT AND CLAY - trace to little sand - low plasticity - peat pockets - greyish brown - ice lenses 1/2mm-3mm spaced @ 1mm-10mm	181%
2	C		5			1.80m	114%
	C		6	Nbe Vs		←trace cobbles and boulders	
3	C		7	Vr Vx		CLAY AND SILT - and sand - sand, coarse to fine - little to some gravel - low to medium plasticity - rusty specks - massive structure - brown to 6.0m, grey below - ice lenses 1/4mm-3mm spaced @ 1mm-20mm	
4	C		8				
5	C		9				
6	C		10				
	B		11			(TILL)	
7	B		12				
	B		13				
8	B		14				
	B		15				
	B		16			8.50m	
9						END OF HOLE	

Notes:
1. Hole located on a hummocky surface sloping 1% to north.

(Cont'd.)

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JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-188
DATE	Aug. 14/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15cm.	No.
	B		1
	B		
	C		2
1	C		3
	C		4
2	C		5
	C		6
	C		7
3	C		8
	C		9
	C		10
4	C		11
	C		12
5	B		13
	B		14
6	B		15
	B		16
7			

SYMBOL

PERMAFROST

N.R.C. CLASS	N.F. or F.
	NF
Vs	
ICE+	
Vr ICE+	
Vr	
Vs	
Nbe	
Nbn	

LOCATION Peel River
ELEVATION

DESCRIPTION OF MATERIAL

0.1m ORGANIC COVER
0.3m

ORGANIC SILT AND CLAY
- trace fine sand
- trace gravel
- low plasticity
- silt laminations
- peat layer
- greyish brown
- ice lenses 1/4mm-7mm spaced @ 1mm-12mm

1.70m

CLAY AND SILT
- trace to little sand
- trace gravel
- medium to high plasticity
- greyish brown

3.30m (TILL)

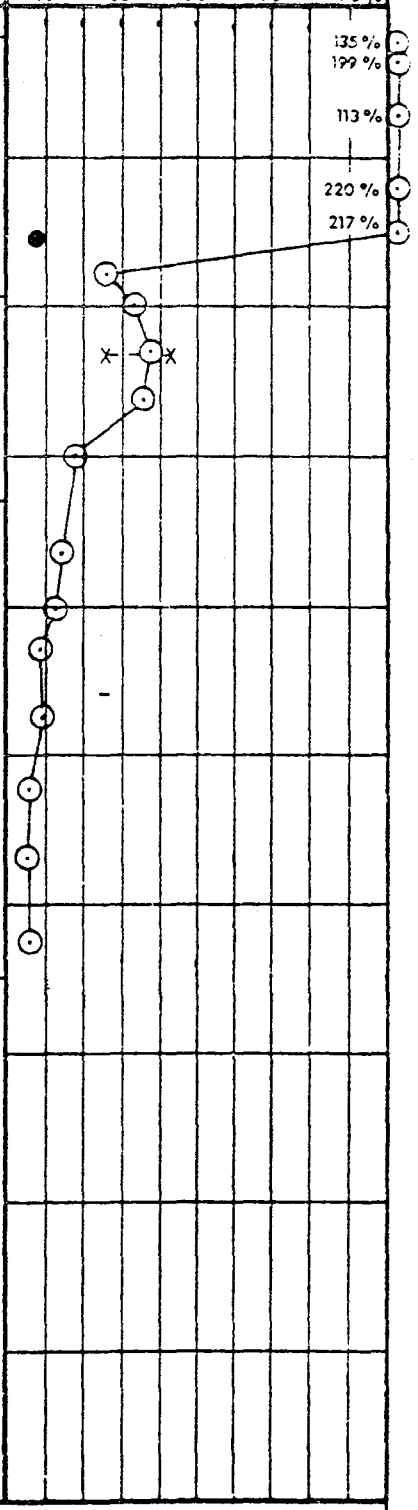
SHALE - SILTSTONE
- medium to high plasticity
- laminated
- white specks
- upper 1.0m is highly weathered & fractured

6.50m

END OF HOLE

Notes:
1. Hole located north of Peel River.
2. Vegetation consists of shrubs to 2m and birch and conifers to 10m in the vicinity.
3. Frost mounds and peat tussocks cover the surface.
4. Drainage is poor.
5. Hole augered to 0.3m, cored to 4.5m then drilled with air to 6.5m.

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
ORGANIC CONTENT % UNCONF.
PLASTIC LIMIT WATER CONTENT LIQUID LIMIT
10 30 50 70 90%



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-187
DATE Aug. 14/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.
	B		1
	B		
	C		2
1	C		3
	C		4
2	C		5
	C		6
3	C		7
	C		8
	C		9
4	B		10
	B		11
5	B		12
	B		13
6			

SYMBOL

PERMAFROST

N.R.C. CLASS	N.F. or F.
	NF
Vr	
Vs	
Nbe	
Vr	
Vs	

LOCATION Peel River
ELEVATION

DESCRIPTION OF MATERIAL

0.2m ORGANIC COVER

0.3m ORGANIC SILT & CLAY
- dark brown

CLAY AND SILT
- little to some sand
- little gravel
- low to medium plasticity
- gravel comprised mostly of siltstone
- rusty brown
- ice lenses 1/4mm-5mm spaced @ 1mm-8mm

2.50m (TILL)

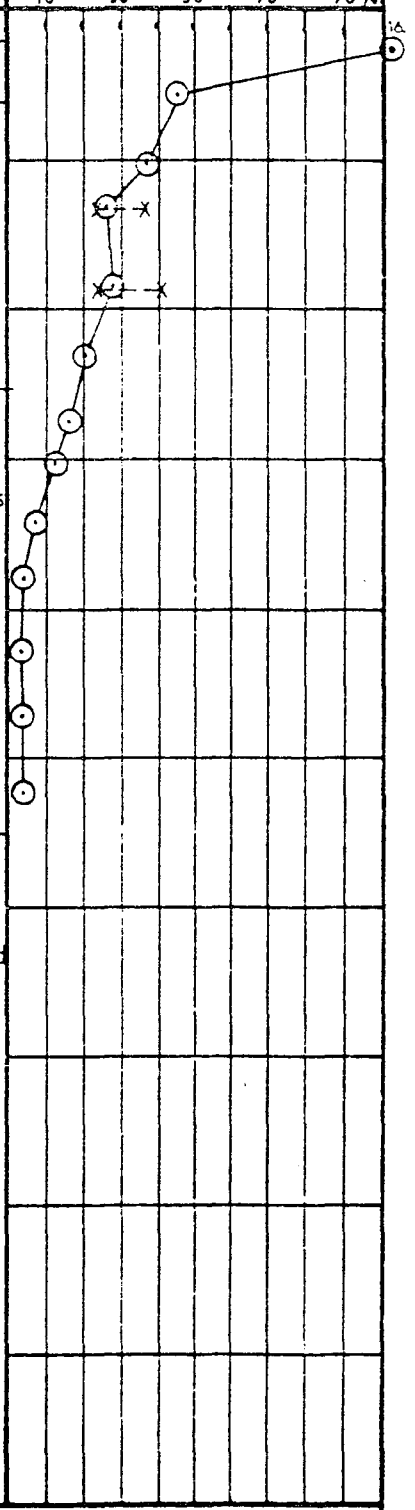
SHALE
- concretions and interbeds of hard siltstone
- low to medium plasticity
- fractured
- rusty brown
- ice lenses 1/2mm-1mm spaced @ 5mm-10mm

5.50m

END OF HOLE

Notes:

1. Hole located on Peel River flood plain on a small peninsula surrounded by water on north, east and west.
2. Surface is flat, but irregular with frost mounds and peat tussocks.
3. Vegetation consists of shrubs and grasses with occasional conifers to 10m tall.
4. Poor drainage.
5. Hole augered to 0.3m, cored to 3.6m, then drilled with air to 5.5m.



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-186
DATE	Aug. 14/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5Kg
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B		23				
	B		24		Vr Vs		As above
11							
	B		25				
	B		26				
12							11.90m
	B		27				
	B		28		Nbn Vr Vs		SHALE - SILTSTONE - low to medium plasticity - grey
13							
	B		29				
	B		30				
14							
	B		31				
							14.5m
15							END OF HOLE

LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
ORGANIC CONTENT % UNCONF

PLASTIC LIMIT | WATER CONTENT | LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%

Notes:

1. Hole located 30m south of south bank of Peel River. Terrain slopes 2% easterly.
2. Vegetation comprised of shrubs and bushes 2-3m tall and birch to 10m tall along river bank.
3. Moderate to poor drainage.
4. Hole augered to 0.5m, cored to 9.3m and then drilled with air to 14.5m.
5. Thermistors installed to a depth of 0.2, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 5.0 and 8.0m.

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-185
DATE	Aug. 14/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.
	B		
	B		1
1	C		2
	C		3
2	C		4
	C		5
3	C		6
	C		7
	C		8
4	C		9
	C		10
5	C		11
	C		12
6	C		13
	C		14
	C		15
7	C		16
	C		17
8	C		18
	C		19
9	C		20
	C		21
10	B		22

SYMBOL

PERMAFROST

N.R.C. CLASS	N.F. or F.
	NF
	0.5M
Vx Vr Vs	
Vs Vr Vx Nbe	
ICE+	
Nbe Vr Vs	

LOCATION Peel River
ELEVATION

DESCRIPTION OF MATERIAL

0.10m ORGANIC COVER

ORGANIC SILT AND CLAY
- trace fine sand
- low to medium plasticity
- peat laminations
- brown with rusty zones
- ice lenses 1mm-7mm spaced @ 1mm-10mm

1.20m

CLAY AND SILT
- trace to little gravel to 6.0m, some gravel below
- little sand, fine to coarse
- trace cobbles & boulders
- low to medium plasticity
- greyish brown with rusty zones
- extensive lenses 1mm-18mm spaced @ 1mm-20mm to a depth of 5.0m
- below 5.0m, ice lenses 1/4mm-10mm spaced @ 3mm-45mm

(TILL)

6.55m

ICE & CLAY & SILT

7.30m

CLAY AND SILT
- as above

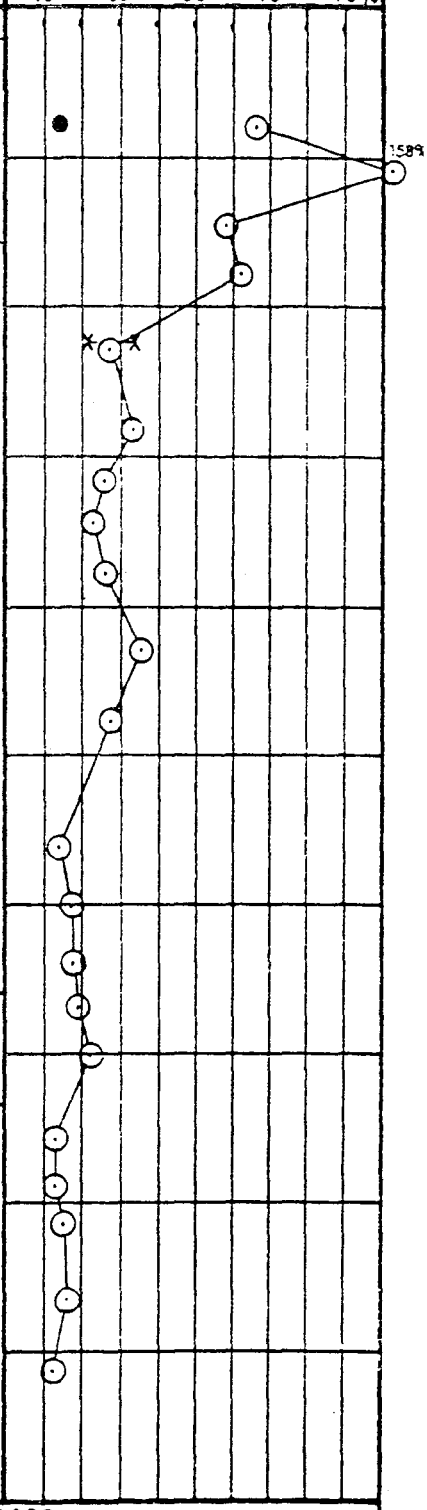
← ICE+ (20mm layer)
- ice lenses 1mm-10mm spaced @ 1mm-60mm

←cobbles

(Cont'd.)

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● ORGANIC CONTENT % ■ UNCONF.

PLASTIC LIMIT | WATER CONTENT | LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%



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CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-185
DATE	Aug. 14/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

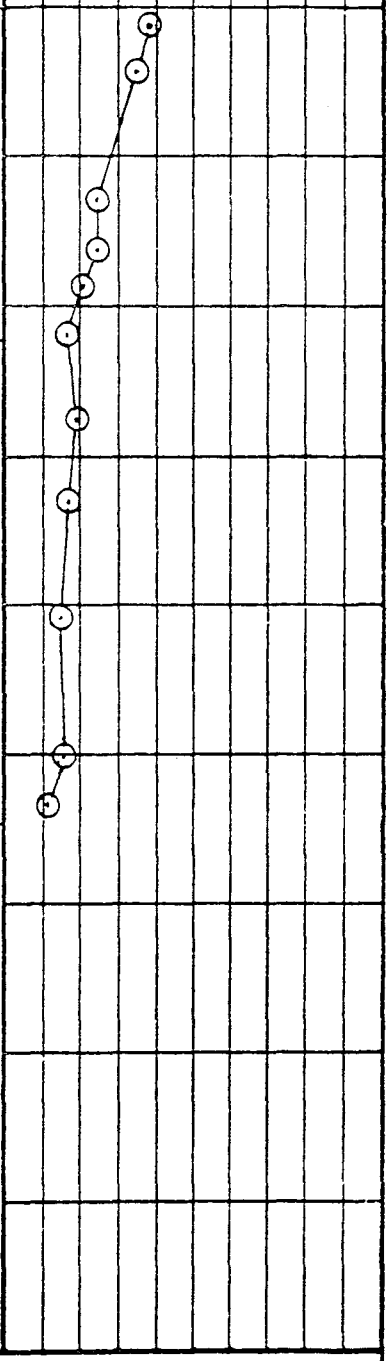
DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B					NF	0.25m PEAT - dark brown
	B				ICE		0.35m ICE
1					Vr		PEAT AND ORGANIC SILT - dark brown 1.00m cobbles
	C		2				ICE+ (40mm layer)
	C		3		Nbn Vs		CLAY AND SILT - some gravel - little coarse to fine sand - low to medium plasticity - organic inclusions
2					Vx		2.00m
	C		4		Nbe		- gravel mostly comprised of siltstone - brown with rusty specks - ice lenses 1/4mm-6mm spaced @ 3/4mm-8mm
	C		5		Vr		
3	C		6		Vs		
	C		7				
4							SHALE - SILTSTONE - low plasticity - laminated - weathered in upper 3.0m - calcareous inclusions below 5.0m - grey - ice lenses 1/2mm-8mm spaced @ 2mm-20mm
	C		8				
	C		9				
5							
	C		10				
6							
	C		11				
	C		12				6.45m
7							END OF HOLE

Notes:

1. Hole located on a broad plain sloping 2% easterly.
2. Vegetation mainly consists of grasses & low shrubs with occasional conifer to 4m tall.
3. Peat tussocks cover the surface.
4. Poorly drained.
5. Hole augered to 0.3m, then cored to 6.45m.

COHESION - Kg./Sq. cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
x - - - - - 0 - - - - - x
10 30 50 70 90%



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-184
DATE	Aug. 13/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15cm.	No.
	B		
	B		1
1	C		2
2	C		3
3	C		4
4			
5	C		5
6			
7			

SYMBOL

PERMAFROST

LOCATION

ELEVATION

N.R.C. CLASS	N.F. or F.
	NF
Nbe Vx Vs Vr	
ICE	
Nbe	
ICE+	
ICE	

DESCRIPTION OF MATERIAL

0.10m ORGANIC COVER
0.35m PEAT - dark brown

CLAY AND SILT
- little fine to coarse sand
- trace fine gravel
- low to medium plasticity
- organic pockets
- grey with rusty zones
- ice lenses 1mm-7mm spaced @ 2mm-15mm

2.90m

ICE

4.50m

4.60m SAND
- some gravel
- little silt
- brown

4.80m ICE + SILT & CLAY

ICE

6.00m

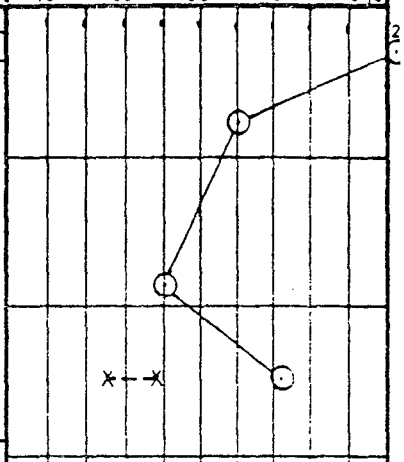
END OF HOLE

Notes:

1. Hole located on a rounded area with a north draining valley located 100m east and another valley 100m west of the site.
2. Surface slopes gently towards north, east and west from the site.
3. Vegetation consists of occasional conifer to 4m tall.
4. Good drainage.
5. Hole augered to 0.35m, then cored to 6.0m.

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF.

PLASTIC LIMIT | WATER CONTENT | LIQUID LIMIT
10 30 50 70 90%



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-183
DATE Aug.13/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW 15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	C		18				As above
					ICE+		10.75m
11	C		19		Vx Vr		GRAVEL - some sand, coarse to fine - little silt and clay - grey - ice lenses 2mm-4mm spaced @ 10mm-20mm
							11.50m
12					ICE+		ICE & SILT & CLAY
13							
							13.80m
14	C		20		Vr		14.00m SILT AND CLAY - little sand - fine - slight to low plasticity - coal specks - grey - ice lenses 1/4mm-3mm spaced @ 3mm-15mm
15							END OF HOLE

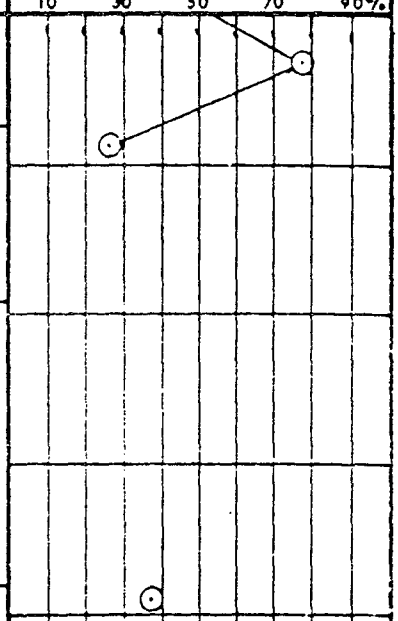
Notes:

1. Hole located on crest of S.W. sloping hillside, at head of landslide.
2. Surface at site slopes 2% S.W. while hillside to the S.W. ascends 30%.
3. Vegetation mainly consists of grasses with low bushes and conifers to 2m tall.
4. Moderate to fair drainage.
5. Surface is undulating with local relief of 0.5m.
6. Hole augered to 0.5m, then cored to 14.0m.
7. Thermistors installed to depths of 0.2, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 5.0 and 8.0m.

LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF.

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%



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CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-182
DATE	Aug. 12/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

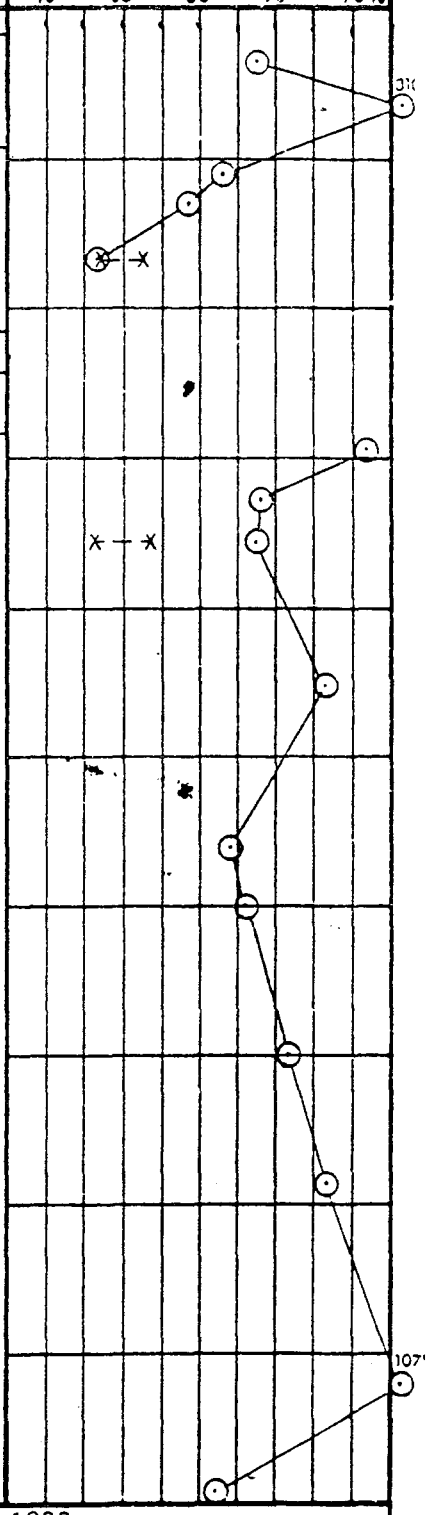
DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	N.R.C. CLASS	N.F. or F.	DESCRIPTION OF MATERIAL
	B					NF	0.20m ORGANIC COVER
	B		1			0.5M	ORGANIC SILT & CLAY - trace fine sand - slight to low plasticity - dark brown
	C		2		ICE+		0.80m
1							
	C		3		Vs		CLAY AND SILT - little to some sand - trace gravel - low to medium plasticity - brownish grey - ice lenses 1/4mm-6mm spaced @ 1mm-10mm
	C		4		Vx		
	C		5		Nbe		1.80m
2							
	C		6		ICE		2.30m ICE
	C		7		ICE+		ICE & SILT & CLAY
3							2.80m
	C		8				ICE+ (30mm layer)
	C		9		Vx		CLAY AND SILT - trace sand - fine to coarse - trace gravel - low to medium plasticity - grey - ice lenses 1mm-12mm spaced @ 1mm-15mm
	C		10		Vr		
4					Nbe		
	C		11				
5							
6	C		12				
	C		13				
7							
	C		14				
8	C		15				
9					ICE+		
	C		16		Vx		
					Vr		
10	C		17		Nbe		

(Cont'd.)

PERMAFROST
LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF.

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
10 30 50 70 90%



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-182
DATE	Aug. 12/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B					NF	0.05m ORGANIC COVER
	B		1				
	B		2			0.7M	
1	C		3		Nbe		ICE+(40mm thick)
	C		4		Vs		CLAY AND SILT - some gravel - little sand - trace sand & gravel below 3.0m - low to medium plasticity - greyish brown with rusty zones - ice lenses 1/4mm-2mm spaced @ 1mm-20mm - longitudinal ice lenses 7mm-12mm thick from 3.7 to 4.7m
	C		5		Vr		
2	C		6		Vx		
3	C		7				peat layer
	C		8				
4	C		9				
	C		10		ICE+ Nbe		organic inclusions
5	C		11		Vr Vs		ice lens 20mm spaced @ 20mm 5.00m
6							END OF HOLE

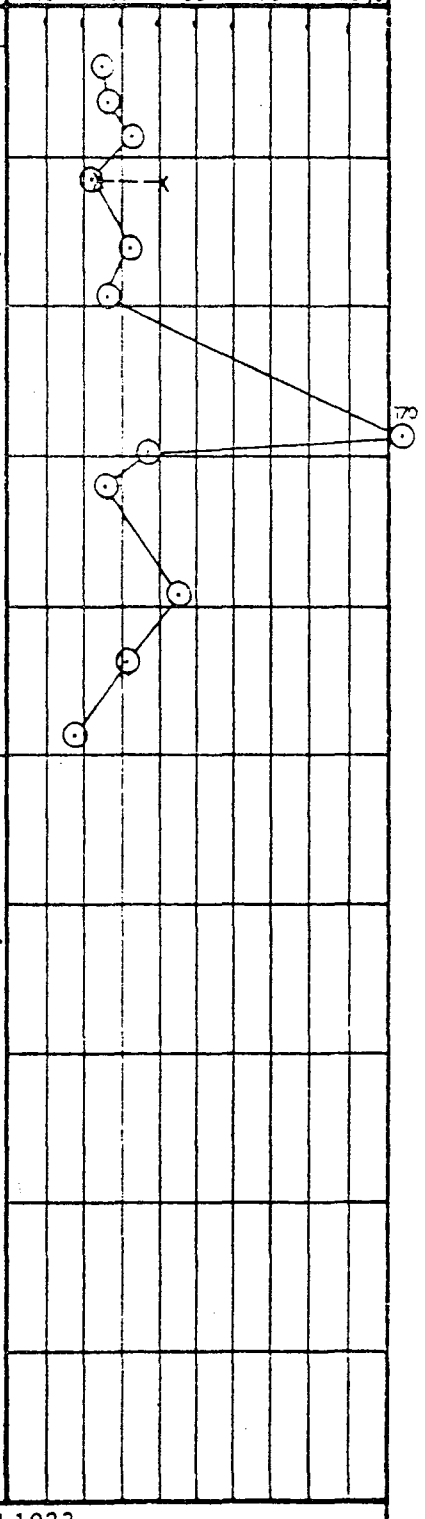
Notes:

1. Hole located on a broad plain sloping 3-5% easterly.
2. Dempster Highway located approx. 250m east.
3. Vegetation mainly consists of grasses with occasional low bushes and conifers.
4. Ground surface irregular with small frost mounds to 1m high.
5. Drainage is poor.
6. Hole augered to 0.7m, then cored to 5.0m.

LOCATION
ELEVATION

COHESION - Kg./Sq. cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%



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CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-181
DATE Aug. 12/78 PLATE

K.L.C. - METRIC

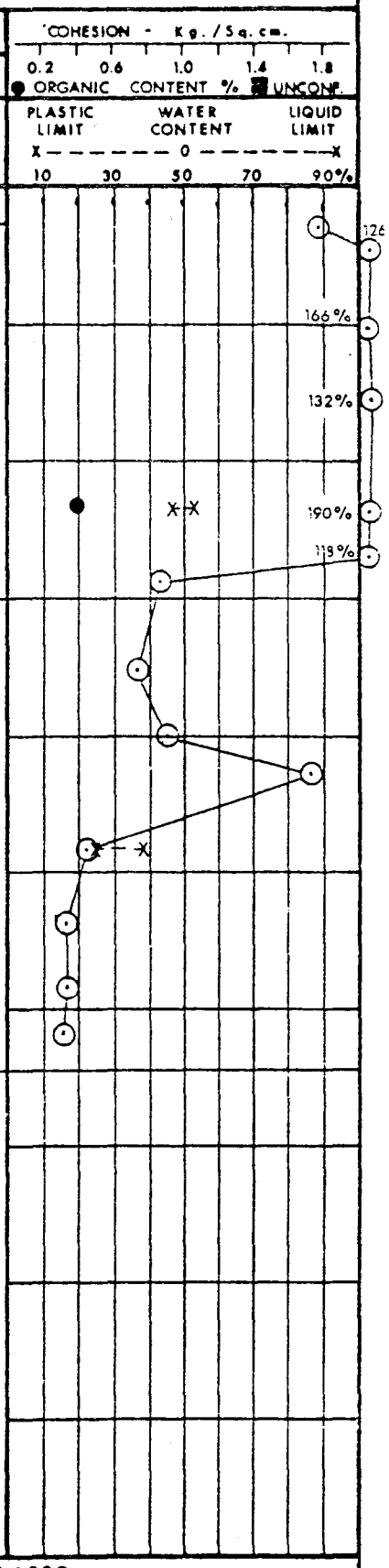
TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B					NF	0.25m ORGANIC COVER
	B		1				
	C		2		Vr		ORGANIC SILT
					Vs		- trace fine sand
1					Vx		- slight plasticity
	C		3				- peat layers
					Vr		- brownish grey
	C		4		Vs		- ice lenses 1/4mm-14mm spaced @ 1mm-15mm
2							
	C		5				
	C		6				
3							3.00m
					Nbe		CLAY AND SILT
	C		7		Vr		- little gravel
					Vs		- little fine to coarse sand
4	C		8				- trace cobbles & boulders
	C		9				- low to medium plasticity
							- laminated
5	C		10				- grey with rusty zones
							- ice lenses 1/2mm-8mm spaced @ 3mm-20mm
	C		11				gravel layer mostly comprised of siltstone
							peat layer
6	C		12				wood chips
	C		13				
							6.45m
7							END OF HOLE

Notes:

1. Hole located on an undulating ground surface sloping 2% westerly.
2. Vegetation consists of grasses with occasional stunted conifer to 5m tall.
3. Surface covered with peat tussocks.
4. Moderate to poor drainage.
5. Augered to 0.3m, then cored to 6.45m.



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CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-180
DATE	Aug. 11/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
11	C		17		Vs Vr Nbe		SILT AND CLAY - trace to little sand - slight to low plasticity - laminated - organic inclusions - grey - ice layers 20mm-30mm spaced @ 100mm-150mm from 8.5mm-11.0m - ice layers 50mm thick from 11.0-11.3m - sample not recovered from 11.5 to 14.7m
12	C		18				
13	B		19				
14							
15	SPT	42 65 67	20		Vr Vs		14.70m SILT-organic laminations - ice lenses 1mm-3mm 15.15m END OF HOLE
16							

LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● ORGANIC CONTENT % ■ UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X – – – – – 0 – – – – – X
10 30 50 70 90%

Notes:

1. Hole located in centre of a broad east-west trending flat bottomed valley.
2. Dempster Highway located approx. 150m east of site.
3. Vegetation consists exclusively of grasses.
4. Poor surface drainage.
5. Hole augered to 0.25m, then cored to 11.5m and then drilled with air to 15.15m.

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-179
DATE	Aug.11/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B		1			NF	0.25m PEAT - dark brown
	B		2				
	C		3		Nbe		ORGANIC SILT AND CLAY
	C		4				- trace fine sand
1	C		5		Vr		- trace fine gravel
					Vx		- low plasticity
							- peat layers
					Vs		- ice lenses 1/4mm-3mm spaced @ 1mm-15mm
2	C		6				- ice crystals 2mm-8mm spaced @ 3mm-15mm
							2.00m
					Nbe		SILT
							- some sand - fine to medium
					Vs		- slight plasticity
3	C		7				- organic & peat laminations
					Vr		- greyish brown
	C		8				- ice lenses 1/2mm-2mm spaced @ 3mm-8mm
							3.60m
4					Nbe		4.00m GRAVEL
	C		9				- some sand - coarse to fine
					Nbe		- little silt
	C		10		Vs		- rusty greyish brown
5							ORGANIC SILT AND PEAT & SAND
							5.20m
	C		11		Nbn		- stratified
6					Vs		- greyish brown with rusty zones
					Vx		- ice lenses 1/4mm-1mm spaced @ 1mm-15mm
	C		12		Vr		SILT AND CLAY
7	C		13				- trace fine sand
							- slight to low plasticity
							- rusty laminations
							- organic inclusions
							- grey
							- ice lenses 1mm-8mm spaced @ 10mm
							7.25m
	C		14		Nbe		7.50m
8							PEAT
							- dark brown
					Vs		
	C		15		Vr		SILT & CLAY
					Nbe		- laminated
							- grey
9	C		16				←ICE+ (60mm layer)
							←ICE+ (40mm layer)
	C		17				
10							10.00m (Cont'd.)

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
ORGANIC CONTENT % UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X — — — — — — 0 — — — — — — X
10 30 50 70 90%

464%
180%
151%
138%
303

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-179
DATE	Aug.11/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
LOCATION
ELEVATION
PERMAFROST
SYMBOL
COHESION - Kg./Sq. cm. (0.2 0.6 1.0 1.4 1.8)
ORGANIC CONTENT % UNCONF.

SAMPLE DATA				N.R.C. CLASS	N.F. or F.	DESCRIPTION OF MATERIAL	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 30 50 70 90%)
DEPTH	TYPE	BLOW/15 cm.	No.				
21				ICE+		As above	
22	B		23				
23	B		24			23.00m	
24	B		25	N		BEDROCK - hard drill action	
25						25.00m	
26						END OF HOLE	

Notes:

1. Hole located on a broad plain. Ground sloping (1-2%) south-easterly.
2. Vegetation is exclusively grasses.
3. Moderately well drained.
4. Peat tussocks cover land surface.
5. Hole augered to 0.4m, then cored to 3.1m and then drilled with air to 25m.
6. Sample No. 25 not recovered.

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JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-178
DATE Aug. 11/78 PLATE

K.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.
11	B		15
12	B		16
13	B		17
14	B		18
15	B		19
16	B		20
17			
18	B		21
19	B		22
20			

SYMBOL

PERMAFROST

LOCATION

ELEVATION

N.R.C. CLASS: ICE+

N.F. or F.

DESCRIPTION OF MATERIAL

As above

(Cont'd.)

COHESION - Kg./Sq. cm.
0.2 0.6 1.0 1.4 1.8
ORGANIC CONTENT % UNCONF.

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-178
DATE Aug. 11/78 PLATE

R.L.C. - METRIC

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15 cm.	No.
1	B		1
	B		
	C		2
2	C		3
	C		4
3	B		5
	C		6
4	B		7
5	B		8
	B		9
6	B		10
7	B		11
8	B		12
9	B		13
10	B		14

SYMBOL

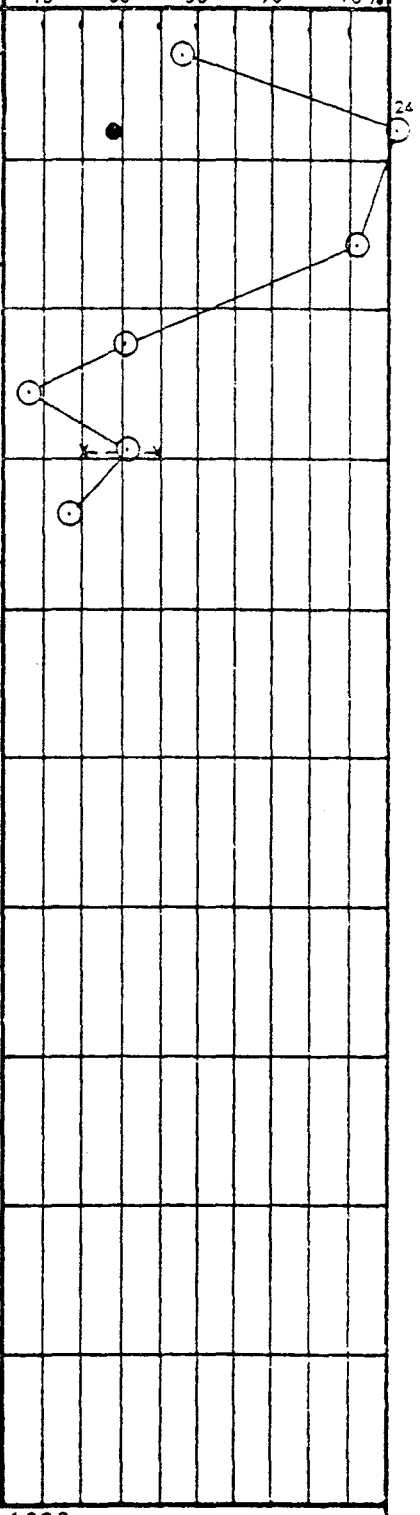
PERMAFROST

N.R.C. CLASS	N.F. or F.	DESCRIPTION OF MATERIAL
	NF	0.35m PEAT - dark brown
Vr Vs		ORGANIC SILT AND CLAY - little to some sand - trace gravel - low plasticity - peat inclusions - greyish brown
ICE +		
Nbe Vr		
ICE +		1.70m
Vx Vs Nbe		CLAY AND SILT - little sand, coarse to fine - little gravel - medium plasticity - organic pockets - greyish brown - ice crystals 1mm-3mm spaced @ 3mm-7mm
ICE +		
Nbe Vx		← cobbles
		3.10m
ICE+		ICE + SILT & CLAY - trace cobbles below 14.0m

LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● ORGANIC CONTENT % ■ UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
X — — — — — 0 — — — — — X
10 30 50 70 90%



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Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-178
DATE Aug.11/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.

SAMPLE DATA				SYMBOL	PERMAFROST		LOCATION	COHESION - Kg./Sq.cm. 0.2 0.6 1.0 1.4 1.8 ● FIELD VANE △ LAB VANE ■ UNCONF.
DEPTH	TYPE	BLOW/15cm.	No.		N.R.C. CLASS	N.F. or F.	ELEVATION	PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT; x — 0 — x; 10 30 50 70 90%
							DESCRIPTION OF MATERIAL	
1	B					NF	0.10m ORGANIC COVER	
	B		1				CLAY & SILT - some sand - little gravel - low to medium plasticity - dark grey	
						0.7M		
					Nbe Vr		gravel, some sand - ice lenses 1/2mm-3mm spaced @ 3mm-12mm	
2	C		2				1.70m	
					Vx Vr Nbe			
3	B		3					
	B		4					
4	B		5				SILTSTONE - sandstone interbeds - fractured - brown	
5	B		6					
	B		7				5.50m	
6							END OF HOLE	
7							Notes:	

1. Hole located on a sloping hillside. Terrain slopes 5% easterly.
2. Dempster Highway located approx. 200m east of site.
3. Vegetation consists of grasses with occasional clump of bushes.
4. Drainage is good.
5. Hole augered to 0.7m, then cored to 2.0m and then drilled with air to 5.5m.
6. Thermistors installed to depths of 0.2, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m.

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-177
DATE	Aug.10/78 PLATE

TEST HOLE LOG

HAMMER WT. 63.5Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW/15cm.	No.
	B		
	B		
	C		2
	C		3
	C		
2			
	C		5
	B		6
	B		7
	B		8
5	B		9
	B		10

SYMBOL

PERMAFROST

N.R.C. CLASS	N.F. or F.
	NF
Vx	0.35M
Nf, Vx	
ICE+	
Nbe	
ICE+	
Vr	
Vs	
Nbn	

LOCATION

ELEVATION

DESCRIPTION OF MATERIAL

0.10m ORGANIC COVER

SILT AND CLAY
- little coarse to fine sand
- little gravel
- low plasticity
- organic & peat inc'usions
- greyish brown with rusty laminations
- ice crystal 1/2mm-3mm spaced @ 3mm-8mm

1.15m
1.40m
1.60m

GRAVEL
- some coarse to fine sand
- little silt and clay
- brown
- gravel comprised of oxidized siltstone

2.30m
2.50m

ICE + SILT & CLAY

GRAVEL
- little sand-coarse to fine
- little silt and clay
- brown
- gravel comprised mostly of oxidized siltstone

ICE + SILT & CLAY

SHALE - SILTSTONE
- low to medium plasticity
- fractured
- grey

6.50m

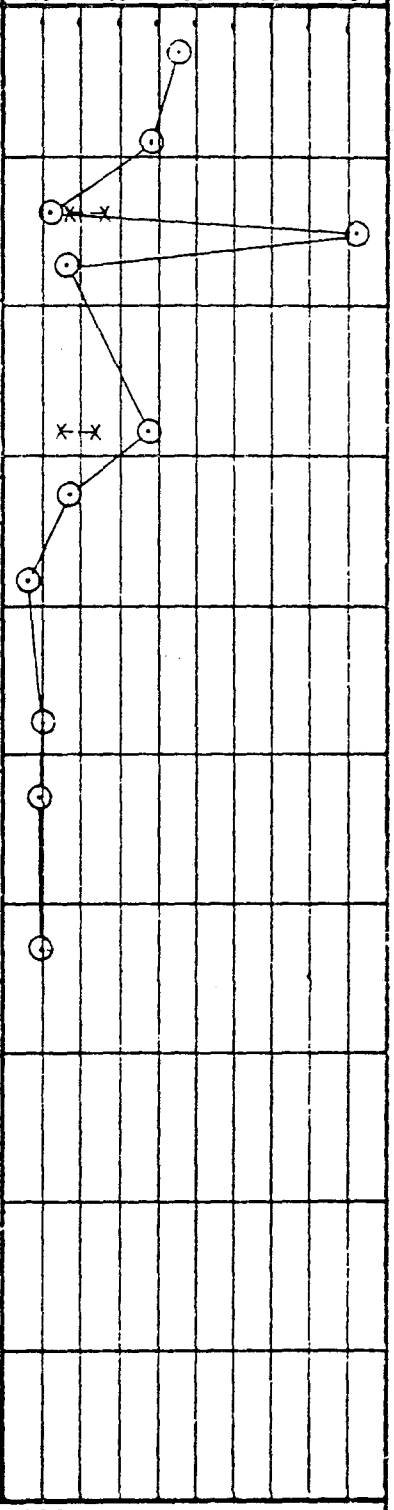
END OF HOLE

Notes:

1. Hole iocated on toe of a broad pediment slope. Terrain slopes 2% easterly.
2. Vegetation is exclusively grass.
3. Peat tussocks cover land surface
4. Hole augered to 0.35m, then cored to 3.3m and then drilled with air to 6.5m.

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● FIELD VANE △ LAB VANE ■ UNCONF

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
10 30 50 70 90%



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No.	AL1023
PROJECT	Dempster Lateral
LOCATION	
HOLE No.	78-176
DATE	Aug.10/78 PLATE

METRIC

TEST HOLE LOG

HAMMER WT. 63.5 Kg.
HT. DROP 76 cm.
SAMPLE DATA

DEPTH	TYPE	BLOW 15 cm.	No.	SYMBOL	PERMAFROST N.R.C. CLASS	PERMAFROST N.F. or F.	DESCRIPTION OF MATERIAL
	B					NF	0.05m ORGANIC COVER
	B		1			0.3M	
					Vs		ORGANIC SILT
	C		2		ICE+		- trace fine sand
1					Vs		- trace gravel-greenish brown
					Nbe		- ice lenses 1mm-6mm spaced @ 3mm-8mm
	C		3		ICE+		
	C		4		Vr		1.50m some sand
2					Ice +		
					Vr		
	C		5		Vs		GRAVEL
	B		6		Vx		- little to some sand
3					Vc		- sand, fine to coarse
							- little silt
							- gravel mostly comprised of quartzite and sandstone
	B		7				- brown
4							
5	B		8				5.00m
							END OF HOLE
6							

Notes:

1. Hole located on a broad rounded saddle between two mountains.
2. Dempster Highway is located approx. 100m east of the site.
3. Vegetation is exclusively grasses.
4. Land surface is moderately well drained.
5. Peat tussocks cover the surface.
6. Hole augered to 0.3m, then cored to 5.0m.
7. Thermistors installed to depths of 0.2, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0m.

LOCATION
ELEVATION

COHESION - Kg./Sq.cm.
0.2 0.6 1.0 1.4 1.8
● ORGANIC CONTENT % ■ UNCONF

PLASTIC LIMIT | WATER CONTENT | LIQUID LIMIT
X - - - - - - 0 - - - - - - X
10 30 50 70 90%

N.P

Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No. AL1023
PROJECT Dempster Lateral
LOCATION
HOLE No. 78-174
DATE Aug. 9/78 PLATE

K.L.C. - METRIC

APPENDIX III

GEOCON INC.

GEOTECHNICAL REPORT

GENERAL CONDITIONS AND LIMITATIONS

A. USE OF THE REPORT

A.1 The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation or if the project is not initiated within eighteen months of the date of the report Geocon should be given an opportunity to confirm that the recommendations are still valid.

A.2 The comments given in this report are intended only for the guidance of the design engineer. The number of test holes to determine all the relevant underground conditions which may affect construction costs, techniques and equipment choice, scheduling and sequence of operations would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual test hole data, as to how subsurface conditions may affect their work.

B. FOLLOW-UP

B.1 All details of the design and proposed construction may not be known at the time of submission of Geocon's report. It is recommended that Geocon be retained during the final design stage to review the design drawings and specifications related to foundations, earthworks, retaining systems and drainage, to determine that they are consistent with the intent of Geocon's report.

B.2 Retention of Geocon during construction is recommended to confirm and document that the subsurface conditions throughout the site do not materially differ from those given in Geocon's report and to confirm and document that construction activities did not adversely affect the design intent of Geocon's recommendations.

C. SOIL AND ROCK CONDITIONS

C.1 Soils and rock descriptions in this report are based on commonly accepted methods of classification and identification employed in professional geotechnical practice. Classification and identification of soil and rock involves judgment and Geocon does not guarantee descriptions as exact, but infers accuracy only to the extent that is common in current geotechnical practice.

C.2 The soils and rock conditions described in this report are those observed at the time of the study. Unless otherwise noted, those conditions form the basis of the recommendations in the report. The condition of the soil and rock may be significantly altered by construction activities (traffic, excavation, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil and rock must be protected from these changes or disturbances during construction.

D. LOGS OF TEST HOLES AND SUBSURFACE INTERPRETATIONS

D.1 Soil and rock formations are variable to a greater or lesser extent. The test hole logs indicate the approximate subsurface conditions only at the locations of the test holes. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of boring, the frequency of sampling, the method of sampling and the uniformity of subsurface conditions. The spacing of test holes, frequency of sampling and type of boring also reflect budget and schedule considerations.

D.2 Subsurface conditions between test holes are inferred and may vary significantly from conditions encountered at the test holes.

D.3 Groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities on the site or adjacent sites.

E. CHANGED CONDITIONS

Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the use or reliance by the client of this report that Geocon is notified of the changes and provided with an opportunity to review the recommendations of this report. Recognition of changed soil and rock conditions requires experience and it is recommended that an experienced geotechnical engineer be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

F. DRAINAGE

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage can have serious consequences. Geocon can take no responsibility for the effects of drainage unless Geocon is specifically involved in the detailed design and follow-up site services during construction of the system.