GEOTECHNICAL INVESTIGATION OF POTENTIAL SAND AND GRAVEL RESERVES
INUVIALUIT SETTLEMENT REGION
DEPOSIT 467 (WILLOW RIVER)
AKLAVIK, N.W.T.

Hardy BBT Limited

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

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Prepared for:

Indian and Northern Affairs Canada

Prepared by:

Hardy BBT Limited

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EXECUTIVE SUMMARY

Indian and Northern Affairs Canada is carrying out detailed assessments of selected granular resource deposits in the Inuvialuit Settlement Region. As a part of this assessment, the present report describes the findings of the 1989 geotechnical investigation at the 467 Site on the Willow River, which had previously been identified as a potential source of granular material for the community of Aklavik.

A field drilling program was carried out to delineate areas containing potentially extractable granular materials. Laboratory and office studies followed the drilling program to establish the suitability of the borrow for different uses, to quantify potentially extractable volumes, and to discuss development considerations.

A proven volume of 346 000 m^3 of Classes 2 to 4 granular materials was delineated during this investigation, with corresponding estimates of 5 785 000 m^3 and 10 440 000 m^3 for probable and prospective reserves. These volumes incorporated findings from the previous R.M. Hardy (1976) and Klohn Leonoff (1988) studies. The component volumes of proven reserves of Class 2, 3 and 4 materials now total 186 000 m^3, 144 000 m^3 and 16 000 m^3, respectively.

The total volumes of proven reserves for Classes 2 and 4 are well in excess of the expected requirements for these materials for the Aklavik region, up until at least the year 2006 (EBA, 1987). For Class 3, the proven reserves (144 000 m^3) represent some 90% of anticipated demand. The short fall should be readily met from those reserves classified as probable or from lower quality Class 2 materials. Although no Class 1 material was identified in this deposit, it is suggested that with further processing of Class 2 reserves, it will be feasible to meet the limited demand (300 m^3) for Class 1 material.

Development should proceed in a regular manner starting from the southern edge of the East Area deposit and progressing northward along the edge of the escarpment in a series of benches. It is assumed that development would take place during the winter with access along a winter road from Aklavik.

Typically, the uppermost 2.5 to 3 m of these deposits are not strongly ice bonded, and ripping operations should be feasible, although slow progress may be encountered in some areas. In order to ensure drainage control, it is recommended that the benches be maintained above the active permafrost layer and preferably developed along the scarps bordering the site.

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1.0 INTRODUCTION

1.1 GENERAL

Hardy BBT Limited (HBT) of Calgary, Alberta, were contracted by Supply and Services Canada (SSC) to carry out a geotechnical investigation of potential sand and gravel reserves for the 467 (Willow River) deposit near Aklavik, in the Inuvialuit Settlement Region. The Scientific Authority for the project was Mr. R.J. Gowan, Geotechnical Advisor, Land Management Division, Indian and Northern Affairs Canada (INAC).

The study which was partially funded by the Inuvialuit Final Agreement (IFA) Implementation Program, Task 7 - "Sands and Gravel Inventory" was authorized under Contract No. A-7134-8-0053/01ST, dated March 8, 1989.

The Inuvialuit Final Agreement provided that the Federal Government grant to the Inuvialuit people title to some 90 650 square kilometres (35 000 square miles) in the Western Arctic. These lands are subdivided into two categories, with and without subsurface rights, referred to as 7 (1)(a) and 7 (1)(b), respectively. The location of these lands is shown on Figure 1. Granular materials are considered part of the surface estate, consequently they are owned by the Inuvialuit on both 7 (1)(a) and 7 (1)(b) lands.

The study included the preparation of a multi-year, geotechnical investigation plan for the detailed assessment of granular resources in the Inuvialuit Settlement Region, specifically near the communities of Inuvik, Aklavik, Tuktoyaktuk, Sachs Harbour, Paulatuk and Holman. In March, 1989, HBT submitted a proposed program, and as a first phase of this plan, three sites were investigated in the late winter of 1989; the 467 Site near Aklavik, the I407 Site near Inuvik and the 155 South Site near Tuktoyaktuk.

The following report discusses the investigation of the 467 or Willow River Site, which is located approximately 20 km to the west of Aklavik as shown on Figure 2. A Glossary of Terms is provided at the conclusion of the text.

1.2 PREVIOUS WORK

The initial identification of the 467 (Willow River) deposit area by airphoto interpretation and limited geotechnical investigation, including one test pit, three exposure logs and four grain size analyses, was carried out by R.M. Hardy & Associates Ltd. in 1976. This study provided a preliminary estimate of some 20 000 000 cubic yards of granular material at this site. The initial assessment was that the deposit contained fair to good quality granular material, that it should be easily extractable, and that there was good winter access from Aklavik.

In April, 1987, the Northwest Territories Public Works and Highways Department undertook a limited program of test pitting and small scale extraction at the 467 deposit. The materials identified contained a large proportion of cobble sized material, unsuitable for roadworks and other aggregate uses, without further processing (crushing and/or screening).

The 1988 Klohn Leonoff (KL88) study "Western Beaufort Region Concrete Aggregate Study" for INAC examined the 467 deposit as one of six potential sites along the western side of the McKenzie Delta and the Yukon Coast which might provide materials suitable for use in manufactured shore protection elements for offshore hydrocarbon protection structures. The study included bulk sampling of natural exposures and of an existing excavation and involved a full suite of concrete aggregate suitability tests on both fine and coarse aggregates. It was concluded that the materials from this site were not suitable for production of concrete aggregates.

Previous reports by EBA (1987) and Hardy BBT (1988), noted that the majority of the granular requirements for the community of Aklavik, for the next 20 years, particularly of Class 3 and 4 materials, could be expected to be met from the 467 (Willow River) deposit. This would represent some 78% of projected total requirements for Aklavik.

The reference section of this report lists five previous studies relevant to this site.

1.3 SCOPE OF WORK

The scope of work for the present investigation was defined in the contract document as follows:

1) Briefly review available information for those sources on Inuvialuit and adjacent lands that have been recommended for further investigation.

2) Prepare a phased, multi-year site investigation plan for review and acceptance by representatives of the Inuvialuit Land Administration (ILA), the Government of the Northwest Territories (GNWT) and INAC.

3) Organize and conduct a winter field program to complete the site investigation work approved for the fiscal year 1988/89.

4) Conduct laboratory testing of samples obtained during the field investigation and analyze the field and laboratory data.

5) Prepare a comprehensive granular source evaluation report describing the site investigation work undertaken and the results of the laboratory testing and data analysis.

Tasks 1 and 2 above were completed and presented in the HBT interim report entitled: "Proposed Geotechnical Investigation Plan, Potential Sand and Gravel Reserves, Inuvialuit Settlement Region", March, 1989. This proposed investigation plan report was finalized in May, 1990.

Specifically, it is the scope of the following report to describe the field and laboratory geotechnical investigations carried out during March through May of 1989, for the 467 (Willow River) deposit, and to integrate the results of this study with the findings of previous work in order to delineate and characterize the potential sand and gravel reserves available.

2.0 INVESTIGATION METHODOLOGY

2.1 PRELIMINARY WORK

Prior to carrying out any field work, published reports and maps for the region were reviewed and the INAC computerized granular resources borehole and test pit log data base was also consulted.

Following this review of existing information, a proposed, phased, multi-year program of geotechnical site investigations was presented to INAC and the ILA at a meeting in Inuvik on March 7, 1989. In this program, sites requiring more precise definition of granular reserves were identified.

2.2 FIELD INVESTIGATION

A drilling program was carried out from March 13 to March 21, 1989, using a Nodwell-mounted CME 750 auger drill rig operated by Midnight Sun Drilling Ltd., of Whitehorse, Yukon. The field work was under the full-time supervision of members of the HBT geotechnical staff.

Site personnel on each shift included a driller, a driller's helper, a bear monitor and a geologist or engineer. A drill supervisor for Midnight Sun Drilling Ltd. was responsible for scouting access routes and moving equipment between sites. Crew changes from the base of field operations in Inuvik were normally made by 206B helicopter. A detailed summary of the field operations is included in Appendix B.

Drilling or moving was maintained 24 hours per day in two 12-hour shifts. Five boreholes were drilled using 150 or 200 mm diameter solid-stem flight augers. Photo 4 (Appendix D) shows the drilling rig in operation. Auger cuttings were visually logged on site.

Samples of representative materials were taken at regular intervals from the auger returns. These were sealed in labelled plastic bags and transported to the HBT Yellowknife soil testing laboratory.

The primary area of concern for this investigation was the East Area, shown in Figure 3, in which four boreholes were extended to depths of between 2.5 and 7.3 m. One additional hole was attempted in a further potential source area to the west. However, this hole (467B004) was terminated at a shallow depth due to the presence of boulders.

The borehole logs and explanatory sheets are presented in Appendix A, with their locations shown on Figure 3. In addition, Table 1 presents a summary of the field work undertaken in terms of distribution of boreholes, depths and numbers of samples.

Borehole elevations were obtained by hand level methods and, accordingly, are relative elevations only with a maximum error of up to 2 m (i.e. ± 1 m). Relative distances between boreholes were chained and are considered to have a maximum error of 0.5 m. Boreholes within the deposit were located with respect to identified landmarks on airphotos and photomosaics. UTM grids were superimposed on the site plan from a 1:50 000 scale photomosaic. UTM grid references for boreholes are considered to have an absolute error in the range of 100 m.

2.3 LABORATORY TESTING

Conventional laboratory testing for classification purposes was carried out on selected samples in the HBT Yellowknife soils laboratory. This testing, as listed in Table 2, included: grain size analyses, moisture content determinations, and petrographic analyses. The results are presented in Appendix C. Concrete aggregate suitability testing was not performed on samples from this site since index testing and petrographic analyses suggested that these materials may be unsuitable. In addition, the comprehensive set of tests conducted by Klohn Leonoff (1988) led to the conclusion that "the aggregate from this source should be rejected for use in high quality concrete".

TABLE 1

SUMMARY OF 1989 FIELD WORK

467 (WILLOW RIVER)

Area	Hole Number	Depth of Hole (m)	Number of Samples	
			Grab	Core
EAST	467B001	7.1	3	
	467B002	7.3	2	–
	467B003	2.5	1	
	467B005	4.5	2	
WEST	467B004	0.6	1	–

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TABLE 2

TEST SPECIFICATIONS AND PURPOSE

	Test Designation	Method	Number Done	Rationale For Test
Geotech-nical	Soil Moisture Content	ASTM D 2216	4	Basic material property; can indicate thaw pond potential and material workability
	Particle-Size Distribution	ASTM D 422 with sample preparation by ASTM D 421	4	Indicator of whether deposit meets gradation criteria for various uses (i.e. concrete); determines frost susceptibility
Lithology	Petrographic Analysis	ASTM C 295 CSA Can 3-A23.1, Clause 5.5	*1	Identifies particle types; specifically, determines any deleterious materials
Concrete Aggregate Suitability Analysis	Bulk Specific Gravity and Absorption	ASTM C 127 - C 128	*1 *1	Minimum specific gravity required for some uses (eg. concrete, riprap); absorption results indicate susceptibility to freeze - thaw degradation
	Los Angeles Abrasion	CSA A23.2-M77-16A and 17A	*1	Determines resistance to physical wear
	Sulphate Soundness	CSA A23.2-M77-9A	*1	Evaluates resistance to weathering
	Alkali-Aggregate Reactivity	ASTM C 289	*1	Determines potential for adverse reactions between cement and aggregate

* Test done by Klohn Leonoff (1988)

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3.0 SITE DESCRIPTION

The 467 (Willow River) deposit area is located approximately 20 km to the west of the community of Aklavik, on the northeastern edge of the Richardson Mountains. The deposit comprises two separate areas, an east and a west area. Both areas are located on a broad terrace between 60 and 120 m above sea level. To the west of the deposit, the ground rises steeply to the Richardson Mountains, and to the south, the site is bounded by an 80 m high relatively steep slope down to the Willow River floodplain.

The surface of the eastern area has a relatively thin cover of surficial overburden. Adjacent to the southern slope, the surface is well drained, however, the northern part of the landform is believed to be less well drained. The western area may have a thicker cover of peat and organic clays and silts. The surface of this area is likely to be moderately to well drained. The active layer is estimated to be in excess of 2 m below exposed gravels, and 1 m or less where surficial peats are present.

This landform has been interpretated as a kame terrace/delta, believed to have been formed by streams flowing out of the Richardson Mountains along the edge of a sheet glacier covering the MacKenzie Delta and adjacent terraces.

To the east of the 467 deposit, the terrain is formed of gently sloping morainal deposits leading down to the MacKenzie Delta. Colluvial deposits are present in the slopes west of the site, and a poorly drained lake basin area lies to the north.

Appendix D includes a selection of photographs illustrating the site topography (Photos 1 to 3 and 5).

4.0 DESCRIPTION OF MATERIALS

4.1 GENERAL

The following section provides detailed descriptions for each of the principal material types identified at the 467 (Willow River) Site, which include the following:

- Surficial Materials
- Gravels
- Sands

Two schematic geological cross-sections (A-A' and B-B') summarizing the findings of the present investigation are presented in Figures 4 and 5. Additional laboratory test information from an R.M. Hardy and Associates Ltd. 1976 report and from a Klohn Leonoff Limited 1988 report are also included in Appendix E.

4.2 SURFICIAL MATERIALS

Layers of peat or organic silts and clays, less than 0.2 m thick, were encountered in Boreholes 467B001, 467B002, and 467B003. Borehole 467B005 in the central portion of the East area, revealed 0.6 m of sandy silt overlying the granular materials. Figure 3 presents a plan of the thickness of surficial deposits at the borehole locations.

The one hole (467B004) attempted in the West area encountered boulders and cobbles in a frozen organic matrix at ground surface.

4.3 GRAVELS

Figure 6 presents a composite grading curve for four samples from the present investigation, along with five other gradings from previous studies. It is noted that these gradings are restricted to material of less than 76 mm diameter due to the constraints of taking sufficiently large samples to be representative of the very coarse fraction (cobbles and boulders).

In most of the boreholes, cobbles and boulders of up to 250 mm diameter were confirmed in a layer of sandy gravel, which ranged in Unified Soil Classification between GP, GF, GM, and GC, that is, poorly graded clean gravels as well as silty and clayey sandy gravels. These gradings are grouped in the upper (finer) part of the composite plot (Figure 6).

Natural exposures on the southern edge of the site, as well as test pits examined in the previous studies, recorded well graded gravels (GW) with boulders of up to 500 mm diameter. The gradings of the bulk samples from these locations form a narrow band in the lower (coarser) portion of the composite gradation plot (Figure 6).

While it is expected that there will be considerable variability in both the fines content and the proportions of cobbles and boulders over the site, it is not certain that these two groupings represent distinctly different material types, or that they represent the full range of variation. Consequently, Figure 6 does not show an envelope enclosing the gradations. Further, it is suggested that differences in sampling methods may contribute to the differences in the gradations. If this is so, the gradings of the bulk samples recovered from natural exposures and test pits are probably more representative of the granular material at the site.

Table 3 presents a summary of the relative proportions of different size components within this deposit, along with the results of moisture content determinations and petrographic number (PN) evaluations, 148 and 166 for the present survey, 250 for a sample from the 1988 Klohn Leonoff study, and 121 for a sample from the 1976, R.M. Hardy survey.

Upon initial examination, the considerable range of PN values, from 121 to 250, reported by the three studies suggests that there may be an equally wide range of materials present in the 467 deposit. Upon closer study, however, it is apparent that test results from the three studies are not strictly comparable in that substantially different size fractions were examined by each study. The initial R.M. Hardy (1976) results were apparently based upon a petrographic analysis of material less than 75 mm (3 inch), although this cannot be confirmed on the data summary sheet (Appendix E). The analysis for this present study was based upon 38 mm (1.5 inch) minus material, while the Klohn Leonoff (1988) work was carried out on the

TABLE 3

COMPONENT PERCENTAGES OF
GRANULAR DEPOSITS
SOURCE 467 (WILLOW RIVER)

BOREHOLE NUMBER 1989 SURVEY	SAMPLE NUMBER PREVIOUS SURVEYS	SAMPLE INTERVAL (m)	COMPONENT PERCENTAGE			MOISTURE CONTENT (%)	PETROGRAPHIC NUMBER
			GRAVEL %	SAND %	FINES %		
467B001		5.0 – 5.5	56	28	16	7	148
467B002		4.5 – 5.5	56	30	14	7	–
467B005		1.2 – 1.8	45	29	26	10	166
467B005		3.0 – 3.6	48	35	17	8	–
	467–A(e)*	0.5 – 0.8	70	27	3	–	121
	467–B*	0.4 – 1.9	67	29	4	–	–
	467–C(e)*	1.5 – 4.0	72	25	3	–	–
	467–D(e)*	0.6 – 3.7	72	24	4	–	–
	6**	–	71	25	4	–	250

* R.M. Hardy (1976)
** Klohn Leonoff (1988)

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12.7 mm (0.5 inch) minus fraction. Since the poorer quality and deleterious materials, such as chert, claystone and ironstone, tend to be concentrated in the finer size fractions, with better quality materials in the coarser size fractions, it follows that higher PN values should be expected for the finer fractions analyzed by Klohn Leonoff (1988), with the lowest PN values from the initial R.M. Hardy (1976) work.

Reference should be made to the Klohn Leonoff (1988) report for details regarding the suitability of 467 deposit materials for the production of concrete aggregate. Their general conclusion, however, was that "aggregate from the Willow River source should be rejected for use in high quality concrete" (Klohn Leonoff, 1988, p.58).

Proven thicknesses of gravel were 7.1 m, 7.3 m, 0.8 m, and 4.5 m, in Boreholes 467B001, 467B002, 467B003, and 467B005, respectively. Figure 3 presents the quality and thickness of granular materials at each borehole location.

4.4 SANDS

Material classified as sand with considerable fines (sf) was encountered only in one borehole, 467B003, to a depth of 2.5 m at the base of the hole. No particle size distribution analysis was carried out on this deposit.

5.0 CLASSIFICATION OF GRANULAR MATERIALS

The quality of granular materials encountered during the field program has been evaluated primarily according to gradation. Each sample subjected to a grain size analysis has been categorized according to the modified Unified

Soil Classification (U.S.C.) scheme. This has then been related to a classification scheme developed by INAC for regional granular resource evaluations. The INAC scheme has been developed to reflect the general requirements of the AASHTO specifications for soils and soil aggregate mixtures for highway construction purposes, i.e. embankments, subgrades, sub-base, base and surface courses. A summary of the adapted classification scheme used in this study is presented in Table 4. In addition to the gradation of the granular materials, attention has also been given to other factors such as moisture and ice content, and petrography.

The four classes of granular material are described as follows:

<u>Class 1 Granular Material</u>

Class 1 material is well-graded with a low fines content, and comprises hard and durable particles, which meet the following criteria; a maximum petrographic number (PN) of 160, a maximum L.A. Abrasion loss of 35%, and maximum sulphate soundness loss of 12%. Consequently, it is suitable for use as concrete or asphalt aggregate after minimal processing. There are no known sources of this quality of material in the Aklavik area.

<u>Class 2 Granular Material</u>

Class 2 material is similar to Class 1 except that it is of lower quality due to somewhat poorer grading, a higher fines content and less durable particles, which meet the following criteria; a maximum PN of 200 and a maximum L.A. Abrasion loss of 60%. With processing, it may be upgraded to concrete aggregate quality. Class 2 materials may be used in highway construction as

TABLE 4

Quality Classification of Granular Materials

Granular Material Class	General Description of Material	Minimum Technical Indentification Parameters	Suggested Uses of Material
(1) Excellent	Well graded gravels and sands suitable for use as aggregates with a minimum of processing. <5% fines.	Petrographic Number - 160 max. Los Angeles Abrasion Loss - 35% max. Soundness Loss (Magnesium Sulphate) - 12% max. and meeting other requirements other requirements of CSA A23.1 - 1973.	Portland Cement Concrete, Asphaltic Concrete, Masonry Sand, Concrete Block, Surface Treatment and Roofing Aggregate.
(2) Good	Well graded sands and gravels with varying quantities of silt. <10% fines	Petrographic Number - 200 max. Los Angeles Abrasion Loss - 60% max. Fines greater than 10% passing the 200 sieve can be removed with minimum of processing.	Granular base and sub-base. Winter sand backfill for trenches and slabs. Pads for structures.
(3) Fair	Poorly graded sands and gravels with or without substantial silt content. <20% fines	Petrographic Number - 250 max. Can be processed to meet local frost susceptibility criteria.	Granular sub-base. General backfill material, pads for equipment.
(4) Poor	Poorly graded granular soils of high silt content, possibly containing very weak particles and deleterious materials. >20% fines.	Nil	General non-structural fill.

NOTE: Based on classification developed by INAC

Moisture content ideally <10%; if moisture content 10 - 20%, requires drying before use.

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granular base and sub-base material, but may be more prudently reserved as a source of lower quality aggregate or structural fill.

Class 3 Granular Material

Class 3 material generally comprises poorly graded sands and gravels with fines content of up to 20%, and with particles meeting the durability criterion of a maximum PN of 250. It can be processed to meet local frost susceptibility criteria. The presence of moderate amounts of fines makes it ideal as a surface course material, which requires the presence of a binding component. In addition, this material may be used as general fill for embankment construction.

Class 4 Granular Material

Class 4 material comprises poorly graded granular soils with a substantial fines content of more than 20%. There are no durability criteria for this class of granular material. Class 4 material is generally acceptable only for use as non-structural fill.

6.0 GRANULAR BORROW QUANTITIES

Table 5 presents quantities of material, by quality class, for both the East and West area deposits, based on both the present investigation and also on R.M. Hardy & Associates Ltd's earlier work in 1976. These confidence levels of reserves are presented and defined in Table 5, including proven, probable and prospective. These confidence levels represent increasing certainty moving from prospective to proven.

A total volume of Classes 2 to 4 materials in the range of 4 440 000 m^3 is estimated to occur within the 467 Site (East Area). Proven quantities of granular borrow are calculated to be about 173 000 m^3 of which over 80% is estimated as Class 3, with the remaining material evenly divided between Classes 2 and 4. Probable and prospective material quantities are assessed as comprising similar proportions of Classes 2 to 4 material, with a total probable volume of about 2 285 000 m^3 and a total prospective volume of about 4 440 000 m^3.

For the 467 Site (West Area), only Class 2 material was identified, with proven, probable and prospective volumes of 173 000, 3 500 000 and 6 000 000 m^3 respectively.

The anticipated total required volumes of granular materials for the Aklavik region excluding speculative projects, up until the year 2006, are as follows (from EBA 1987):

Class 1	300 m^3
Class 2	4 900 m^3
Class 3	162 500 m^3
Class 4	10 500 m^3

The volumes of proven reserves delineated in the present report for Classes 2, 3 and 4 were 186 000 m^3, 144 00 m^3 and 16 000 m^3 respectively. For Classes 2 and 4, therefore, proven resources should be capable of meeting the projected demand. For Class 3 the proven resources represent some 90% of the projected demands. The shortfall of some 24 000 m^3 could be met by using the available reserves of Class 2 material beyond that required, or be most likely met from those reserves identified as Class 3 probable.

TABLE 5

SOURCE 467: SUMMARY OF GRANULAR RESERVES

AREA	GRANULAR MATERIAL CLASS	AVERAGE THICKNESS (m)	RESERVES (m^3)		
			PROVEN (1)	PROBABLE (2)	PROSPECTIVE (3)
EAST	2		13 000	140 000	140 000
	3	4.6	144 000	1 930 000	3 870 000
	4	0.5	16 000	215 000	430 000
WEST	2		173 000	3 500 000	6 000 000
TOTAL	2 – 4		346 000	5 785 000	10 440 000

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DEFINITIONS OF RESERVE SUBCLASSES

[1] Material in each class whose occurrence, distribution, thickness and quality is supported with a high degree of confidence by ground truth information such as geotechnical drilling, test pitting, and/or exposed stratigraphic sections. The thickness of material encountered in a borehole is usually extrapolated to a radius not exceeding 50 metres around the hole, with adjustments applied by assessing landform type and anticipated or known deposit homogeneity.

[2] Material in each class whose existence and extent is inferred on the basis of several types of direct and indirect evidence, including topography, landform characteristics, airphoto interpretation, extrapolation of stratigraphy, geophysical data and/or limited sampling. Additional investigation is needed to determine a reliable material volume. The volume is estimated by projecting known parameters (typically those of proven resources) over the entire deposit, with adjustments for landform type, anticipated homogeneity and other site characteristics such as ice content and drainage.

[3] Material in each class whose existence is merely speculated on the basis of limited indirect evidence, such as airphoto interpretation and/or general geological considerations. The volume is typically estimated from the maximum areal extent of the deposit and the estimated relief of the geomorphic feature, with adjustments for anticipated site and deposit characteristics.

By convention, the quantities in each confidence level are cumulative; i.e. PROBABLE includes PROVEN, PROSPECTIVE includes PROBABLE and PROVEN quantities.

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Although no Class 1 material was encountered in this deposit, confirming the earlier assessment by Klohn Leonoff (1988), it is suggested that further processing of Class 2 reserves should be feasible to meet the limited anticipated demand (300 m^3) for Class 1 material.

7.0 DEVELOPMENT CONSIDERATIONS

7.1 GENERAL DEVELOPMENT STRATEGY

The terrace remnant morphology and relatively coarse-grained nature of the 467 site has resulted in a well-drained deposit amenable to standard gravel extraction development.

Granular material should be excavated so that good surface drainage is maintained. Excavations on the upper surface of the feature, especially if they were to be extended to below the base of the permafrost active layer, should be avoided since these could flood. Instead, the site should be developed from benches along the scarps bordering the site. These benches would blend into the surrounding terrain with little grading upon abandonment.

No high quality (Class 1) granular materials requiring special or separate development have been identified in the 467 deposit. Accordingly, the available quantities can best be developed in a regular manner starting from the southern edge of the terrace and progressing northward and along the edge of the escarpment in a series of benches.

Access to Aklavik is along gentle slopes to the east and northeast that lead down to the surface of the MacKenzie Delta. An existing access route through the Willow River gorge is somewhat rough, but still manageable. Ice roads and seismic lines provide winter access from an existing borrow source at the mouth of the gorge back to Aklavik.

7.2 DEVELOPMENT METHODOLOGY

It is assumed that development would take place during the winter with access along an ice road from Aklavik. A winter operation would involve ripping the overburden where encountered, pushing the overburden to the edges of the area to be developed, ripping the granular material, pushing the ripped material into temporary stockpiles, loading and trucking the granular material to stockpile sites at the community, and upon completion of extraction, spreading the stockpiled overburden on the slopes of the completed excavation and/or other disturbed areas such as access roads. The stockpiled frozen granular material would then be available for community use during the following summer as thawing of the stockpile progressed.

The major potential problem anticipated with a winter operation would be the rippability of the materials encountered. In this regard, however, the subsurface conditions identified comprise a relatively high component of poorly bonded, friable, granular materials devoid of overburden that should be easily rippable. A thin organic cover above granular materials should not present major ripping problems.

7.3 ABANDONMENT AND RECLAMATION

In preparation for abandonment, the area should be cleaned of all debris, and topographic irregularities associated with pit operations, such as ridges and mounds, should be removed. No significant terrestrial disturbances are anticipated during winter operations for areas outside the pit limits.

Disturbed areas should be contoured and smoothly graded, so as to blend into the surrounding terrain. In this regard, the anticipated benched method of gravel extraction should require only minor contouring and slope flattening to provide an acceptable surface for restoration. Previously stockpiled overburden should be mixed into the abandoned surfaces in preparation for establishing a seeded plant cover.

Prior to seeding, the site should be deeply ripped with a caterpillar mounted ripping tool. This will serve to mix some native topsoil high in organic content with the compacted layer of coarse material remaining on the pit floor after cleanup, thereby, improving fertility and moisture holding capacity of the surface materials. This operation would be most successful when done in late fall after frost has penetrated 100 to 150 mm into the surface but before the entire active layer is frozen. Clods of soil generated by ripping at this time would provide a roughened surface that would reduce the potential of wind erosion and provide protected microsites for the establishment of seeded and native species.

Seed and fertilizer should be applied by broadcast in late fall, immediately following ripping. The recommended seed mixture includes Boreal creeping red fescue, Nugget Kentucky bluegrass, Fairway crested wheatgrass and Engmo timothy in a 2:2:1:1 ratio, by weight, applied at 56 kg/ha (50 lb/ac). Fertilization should be with a 14-28-14 mix of N, P_2O_5 and K_2O, applied at 440 kg/ha (400 lb/ac) at the time of seeding, and again at the beginning of the second growing season. Annual monitoring of re-vegetation success for the first two years is recommended. Although, the seed mix includes species that are winter hardy and species with moderate tolerance to saline soil conditions, harsh climatic and site conditions may require that portions of the site be reseeded or that fertilization be continued for more than two years.

8.0 CLOSURE

A field drilling program was carried out at the Site 467 on the Willow River to delineate areas containing potentially extractable granular materials. Laboratory and office studies followed the drilling program to establish suitability of granular materials for various uses, to quantify potentially extractable volumes and to discuss development considerations.

A total volume of 10 440 000 m^3 of Class 2 to 4 granular material was estimated for the three confidence levels for the 467 Site - (East and West Areas). The assessment for the West Area was based on previous investigations. A large majority of material, more than 80%, in the East Area was of Class 3, with the remaining material being Classes 2 and 4. Only Class 2 material was identified in the West Area.

It is considered that through additional processing of Class 2 material, to provide some Class 1 quality material, the proven and probable deposits identified in this study should be capable of meeting the projected demand for each class, up until the year 2006.

Development should proceed in a regular manner starting from the southern edge of the East Area deposit and progressing northward along the edge of the escarpment in a series of benches. It is assumed that development would take place during the winter with access along a winter road from Aklavik.

Typically, the upper 2.5 to 3 m of these deposits are not strongly ice bonded, and ripping operations should be feasible, although slow progress may be encountered in some areas. In order to ensure drainage control, it is recommended that the bench excavations be maintained above the active permafrost layer and preferably developed along the scarps bordering the site.

Respectfully submitted,
Hardy BBT Limited

PERMIT TO PRACTICE
HARDY BBT LIMITED
Signature ______
Date May 30, 1990
PERMIT NUMBER: P 4546
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Paul Glen, P.Eng.
Senior Project Engineer

Reviewed by:

Vince Jobling, P.Eng.
Engineering Geologist

PG/sc
CG10346R.PG3

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Hardy BBT Limited, 1989. Proposed Geotechnical Investigation Plan Potential Sand and Gravel Reserves Inuvialuit Settlement Region. Report prepared for INAC.

Klohn Leonoff Consulting Engineers, 1988. Western Beaufort Region Concrete Aggregate Study. Report prepared for INAC.

R.M. Hardy and Associates Ltd., and T.A.M.S.L., 1976. Granular Materials Inventory - Yukon Coastal Plain and Adjacent Areas. Report prepared for DIAND (IGRANCAT Study No. 176 H-GYMS).

GLOSSARY OF TERMS

Absorption

The moisture contained in saturated and surface-dry aggregate, as a percentage of the dry weight.

AASHTO Specifications

A set of specifications for the testing of soil and soil aggregate mixtures for highway construction purposes, as formulated by the American Association of State Highway and Transportation Officials.

Active Layer

In permafrost regions, the active layer is that surface layer of ground which thaws annually. The active layer may be up to several metres in thickness. Granular material in the active layer which is ice-bonded during the winter may become loose and workable after thawing.

Aggregate

An assemblage of different sized particles of natural granular material or crushed rock used in the manufacture of concrete, mortar and asphalt. These materials are also used with or without additional processing for road construction, drainage works and construction fills.

Alkali

In the context of concrete aggregate testing, alkali refers to trace amounts of alkali metals, such as sodium and potassium, that may occur in cement. When cement and aggregate are mixed to produce concrete adverse reactions may occur between certain aggregates and the alkali component of the cement (see "Alkali-Aggregate Reactivity").

Alkali-Aggregate Reactivity
The potential of an aggregate to adversely react with the alkali component of cement, so leading to problems such as swelling and slaking of the concrete.

Alluvial Fan
A low, outspread, relatively flat to gently sloping mass of detritus, shaped like an open fan or a segment of a cone, deposited by a stream where it issues from a narrow mountain valley upon a plain or broad valley.

ASTM Standards
Test specifications of the American Society for Testing Materials, in this report referring to testing of soil and concrete aggregate.

Borrow
Any natural material, such as clay, silt, sand, gravel or bedrock, which is extracted from its original location for engineering construction purposes elsewhere (see "Fill").

Chert
A micro-crystalline form of silica which may be of organic or inorganic origin. While normally a physically sound component in aggregates, chert is considered deleterious because of its high degree of potential reactivity with the alkali content of cement. (see "Alkali-Aggregate Reactivity").

Colluvial
Pertaining to any loose, heterogeneous and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.

Concrete Aggregate Suitability Testing

A set of tests, the results of which when taken together are used to determine the suitability of gravel deposits for concrete production. Individual tests include petrographic analysis, the Los Angeles abrasion test, sulphate soundness analysis, alkali reactivity determination, specific gravity determination and water absorption testing.

Conglomerate

A coarse-grained clastic sedimentary rock, composed of rounded to subangular fragments larger than 2 mm in diameter cemented in a fine-grained matrix of sand, silt or clay.

CRREL Coring

This is a method of obtaining cores of frozen soil or ice as developed by the Cold Regions Research and Engineering Laboratory. A specifically designed coring bit is used in conjunction with a hollow-stem auger barrel, so that the latter acts as the core barrel. Following drilling, the cores are extruded horizontally by a piston into suitable containers.

CSA Standards

Test specifications of the Canadian Standards Association, in this report referring to testing of soil and concrete aggregate.

Drowned Meltwater Channel

A meltwater channel is a drainage course specifically formed by erosion due to glacial meltwater flow. When such a channel is subsequently occupied by a branch of either a lake or the sea, it is referred to as a drowned meltwater channel.

Fault Controlled Escarpment

An escarpment is a long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the continuity of the land by separating two level or gently sloping surfaces. An escarpment may have been formed by differential vertical movement along a fault line, in which case it is said to be "fault controlled".

Fill

Artificially placed deposits of natural earth materials (soil or rock) and/or waste materials (see "Borrow").

Fines

All material passing the #200 U.S. Standard sieve size, including both silt and clay, having grain sizes of less than 75 microns.

Flood Plain

The surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is formed by alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current.

Frost Susceptible Soil

Soil in which significant ice-segregation will occur, resulting in frost heave, or heaving pressures, when the requisite moisture and freezing conditions exist. Silts or soils with appreciable fines content are considered to be frost susceptible.

<u>Geotechnical</u>
Pertaining to the application of scientific methods and engineering principles to the acquisition, interpretation and use of knowledge of materials of the earth's crust for the solution of engineering problems.

<u>Glaciofluvial Terraces</u>
Terraces formed by the deposition of material carried by meltwater streams flowing from wasting glacier ice.

<u>Grab Sample</u>
A disturbed sample of soil collected from drill cuttings, as from the flights of an auger drill.

<u>Grading Curve</u>
A plot showing the results of a grain size analysis. For each size tested, the proportion by weight of the total sample which is less than that size is plotted. The grading curve is formed by joining successive points.

<u>Grading Envelope</u>
A plot describing the range of gradings of any composite set of soils. The envelope includes two separate grading curves marking the upper and lower size limits of the material described.

<u>Grain Size Analysis</u>
A test for determining the distribution of particles of defined size fractions of a given soil or aggregate sample.

<u>Granular Material</u>
Any material not passing the #200 U.S. Standard sieve size, including sand, gravel and cobble sizes. Boulder sized material, in excess of 1000 mm diameter, would not normally be included as granular material.

<u>Hollow-Stem Auger</u>
A borehole drilling technique in which the rotation of spiral shaped flanges, or flights, serve to raise soil material to ground surface, having firstly been loosened or broken up by a cutting bit at the base of the auger. The central stem of the auger is hollow to enable sampling and testing of undisturbed soil at the base of the hole.

<u>Indurated</u>
Pertaining to a rock or soil hardened or consolidated by pressure, cementation, or heat.

<u>Interstitial</u>
Pertaining to the voids within a host rock or soil assemblage, geologically the term is specifically applied to a mineral deposit filling such voids, in this case it is used specifically with reference to ice-filled voids.

<u>Isopach</u>
A line on a map drawn through points of equal thickness of a designated stratigraphic unit, or group of units.

<u>Kame Terrace</u>
A terrace consisting of stratified sand and gravel formed as a glaciofluvial deposit between a melting glacier or a stagnant ice lobe and a higher valley wall or lateral moraine, and left standing after the disappearance of the ice.

Lacustrine
Pertaining to, produced by, or formed in a lake or lakes.

Lithology
The mineralogical composition and physical characteristics of a rock.

Los Angeles Abrasion Test
This is a laboratory test of the durability of aggregate particles. It uses standardized equipment to test the resistance to wear of gravel particles. A weighed amount of sieved gravel is loaded into the test instrument with a set of grinding spheres, and is then subjected to a set number of rotations (e.g. 500). The grinding spheres are then removed and the gravel and sand content separated and weighed. The percentage decrease in the amount of gravel is a measure of the durability of the aggregate.

Moisture Content
The amount of water in a given soil mass expressed as a percentage of the weight of the soil after it has been dried to constant weight at 105° to 110°C.

Morainal
Pertaining to accumulations of unsorted, unstratified glacial drift, predominantly till.

Mudstone
A blocky or massive, nonfissile, fine-grained sedimentary rock in which the proportions of clay and silt are approximately equal.

Normal Portland Cement

This is the cement which is normally supplied by a manufacturer unless another type is specifically called for. Having a medium rate of hardening, it is suitable for most kinds of concrete construction.

Overburden

Unconsolidated natural soil or fill material overlying either bedrock or an unconsolidated borrow deposit.

Oversized Material

Any granular material with a diameter in excess of 76 mm. In normal granular resource processing such material must be wasted. However, it may be of use as rip-rap material in erosion control.

Permafrost

Any soil, subsoil, or other surficial deposit, including bedrock, in which a temperature below 0°C has existed continuously for more than two years.

Petrographic Analysis

The determination of the percentage content of different rock type groupings in a sample of aggregate. This analysis is carried out in order to determine the overall quality of a sample, in terms of its Petrographic Number (PN).

Petrographic Number, PN

This number is the measure of the overall quality of a gravel sample. It reflects the amount of physically unsound or potentially chemically reactive particles in a sample. Rock and mineral constituent types are rated between 1 and 20, for excellent to very deleterious respectively. The total weight percentage for each rock type is then multiplied by its soundness rating, and the resulting values are summed to give the overall PN for the sample. Poorer quality aggregates thus would have higher PN values.

Poorly Graded

A soil assemblage is said to be poorly graded when all of the constituent particles are of about the same size, or when a continuous distribution of particle sizes from the coarsest to the finest is lacking.

Quartzitic Sandstone

A medium-grained clastic sedimentary rock composed of sand sized quartz grains, set in a silica cement.

Sheet Glacier

A glacier of considerable thickness and areal extent, forming a continuous cover of ice and snow over a land surface, spreading outward in all directions, and not confined by the underlying topography.

Solid-Stem Auger

As for hollow-stem auger, but the auger stem is solid, not allowing for undisturbed sampling and testing with the auger in place in the hole.

Specific Gravity

The ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at a temperature of 4°C.

Sulphate Soundness Test

This test is used to estimate the ability of a sample of aggregate to resist excessive changes in volume as a result of changes in physical conditions, that is, its ability to resist physical weathering. The sample is subjected alternately to immersion in a saturated solution of sodium or magnesium sulphate and drying in an oven. The formation of salt crystals in the pores of the aggregate tends to disrupt the particles, similarly to the action of ice. The reduction in size of the particles, as shown by a sieve analysis, after a number of cycles of exposure, denotes the degree of unsoundness.

Surficial Deposits

Unconsolidated and residual, alluvial, or glacial deposits lying on bedrock or occurring on or near the earth's surface; they are generally unstratified and represent the most recent of geologic deposits.

Terrace Remnant

A terrace is any long, narrow, relatively level or gently inclined surface, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope. Where a relatively small section of terrace formation is separated by erosion from the remainder of the original feature, then, it is referred to as a "terrace remnant".

Tertiary

The first period of the Cenozoic era, following the Cretaceous period of the Mesozoic era and preceding the Quaternary. The Tertiary is believed to have covered the span of time between 65 and 2 million years ago.

Thaw Pond Potential

The probability of ponds forming within a granular borrow area as the active layer thaws.

Thermokarst

Karstlike topographic features produced in a permafrost region by the local melting of ground ice and the subsequent settling of the ground. The irregular karst topography is normally associated with the dissolution of limestone by groundwater, rather than with thawing of permafrost terrain.

Tundra

A treeless, level or gently undulating plain characteristic of arctic or subarctic regions. It usually has a marshy surface, which supports a growth of mosses, lichens and low shrubs and is underlain by permafrost.

Unified Soil Classification (U.S.C.)

A standard soil classification system developed by the U.S. Bureau of Reclamation and the Corps of Engineers in 1952, and is intended for use in all engineering problems involving soils. A more recent, modified version of the U.S.C. is presented following the borehole logs in Appendix A of this report.

Universal Transverse Mercator (UTM) Co-ordinates

A geographical reference system for determining locations. It is based on the division of a sphere into UTM zones, each six degrees of longitude wide and numbered consecutively in each Hemisphere (East or West) from the International Dateline (180th Meridian); and each with an overlying metric grid, centered parallel to the Central Meridian of the zone and the Equator, such that North America is largely within Zones 2W to 22W, and the grid co-ordinates 500,000 m E; 0,000,000 m N represent the intersection of the zones Central Meridian and the Equator.

Water Absorption Test

A test to estimate the capacity of an aggregate sample to absorb water into pore spaces. The procedure consists of soaking the sample in distilled water for 24 hours, surface-drying and weighing in air, and then oven-drying and weighing in air again. The water absorption is obtained by expressing the difference between the weights of the saturated and the oven-dried sample in air, as a percentage of the latter.

Well Graded

A soil assemblage is said to be well graded when there is a continuous distribution of particle sizes from the coarsest to the finest, in such proportions that the successively smaller particles almost completely fill the spaces between the larger particles.

PG/rb
CG10346.GLS
Eng_Geo

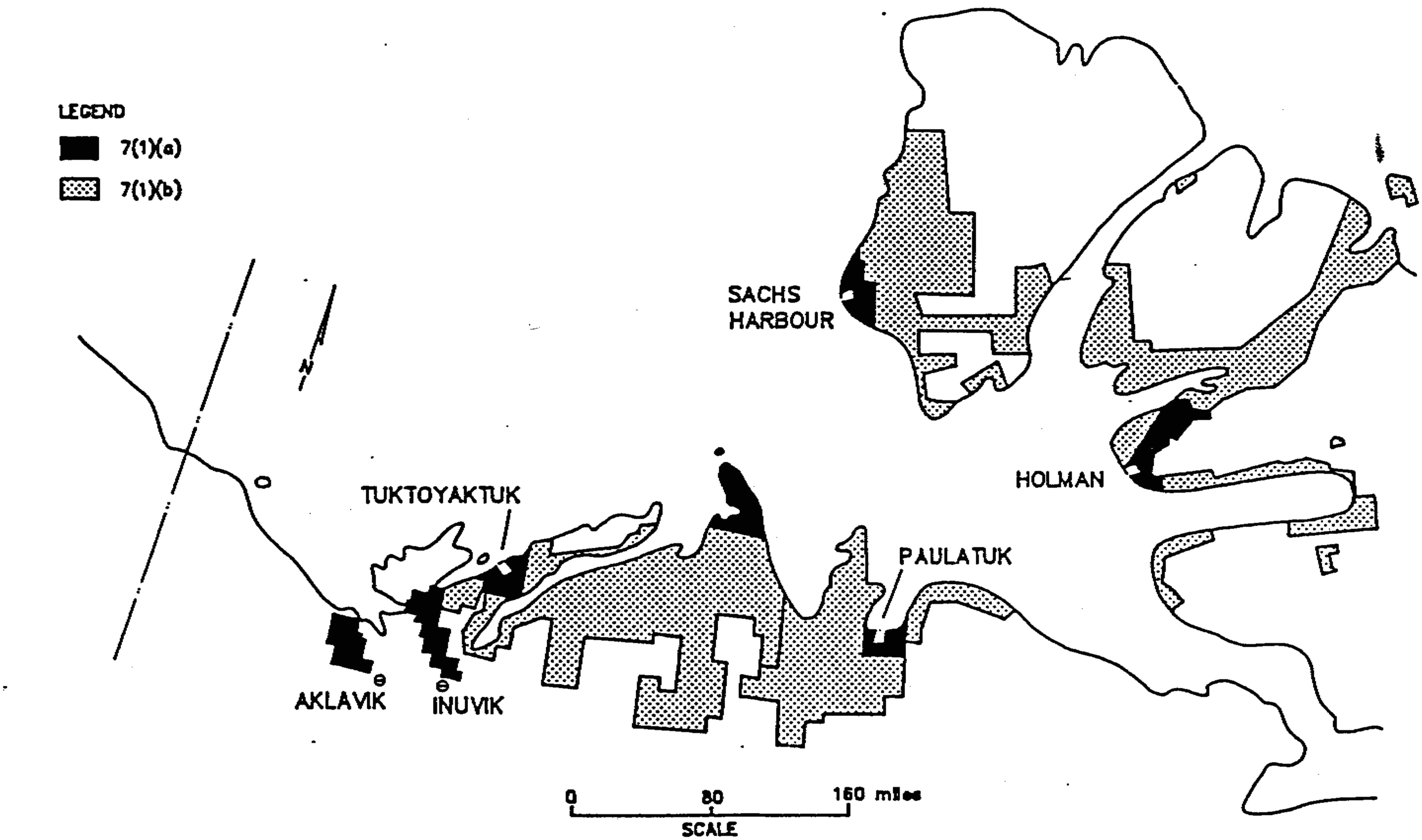

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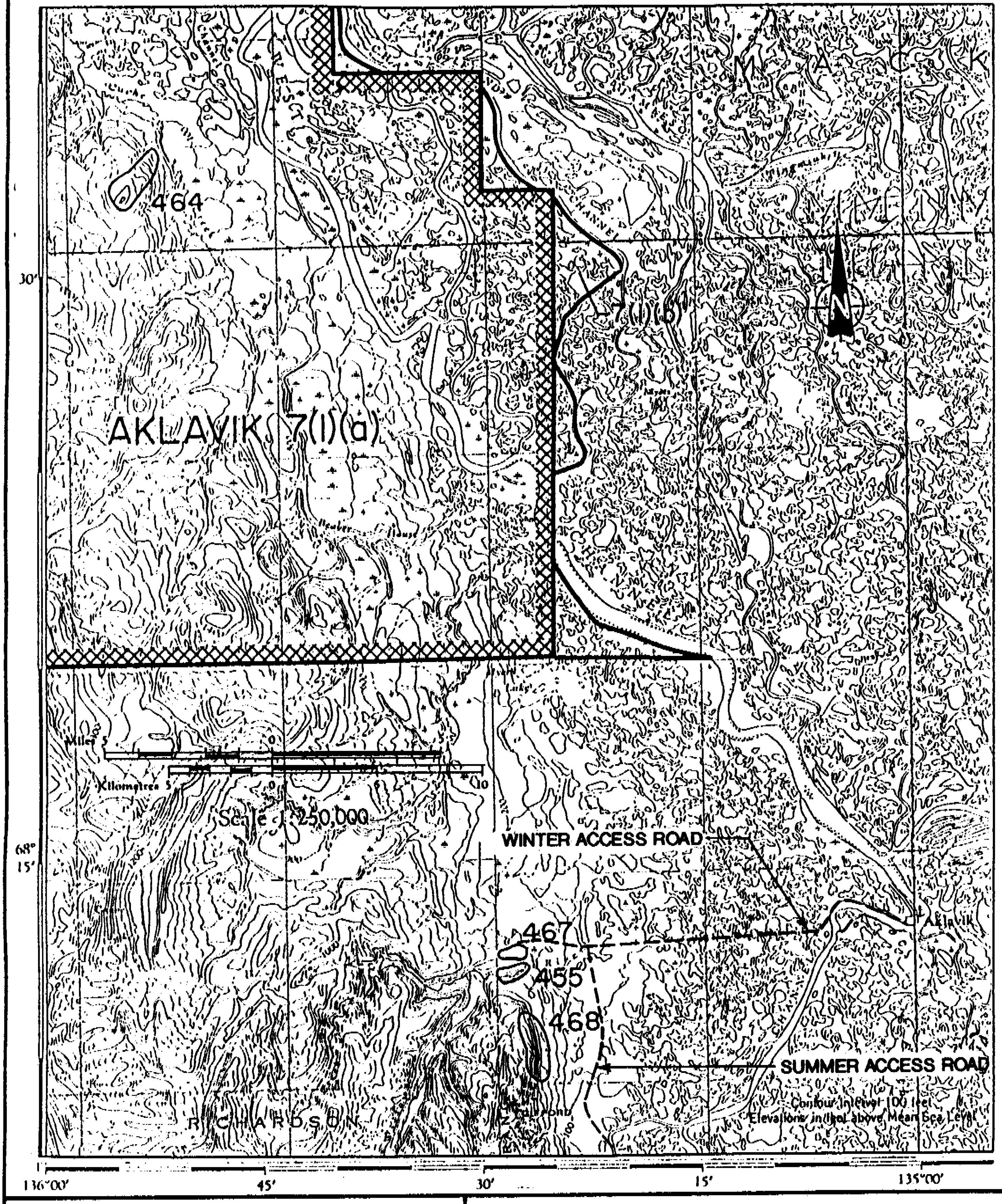
FIGURE 1. INUVIALUIT LANDS LOCATION PLAN

CG10346

HBLT 15 - 87/05



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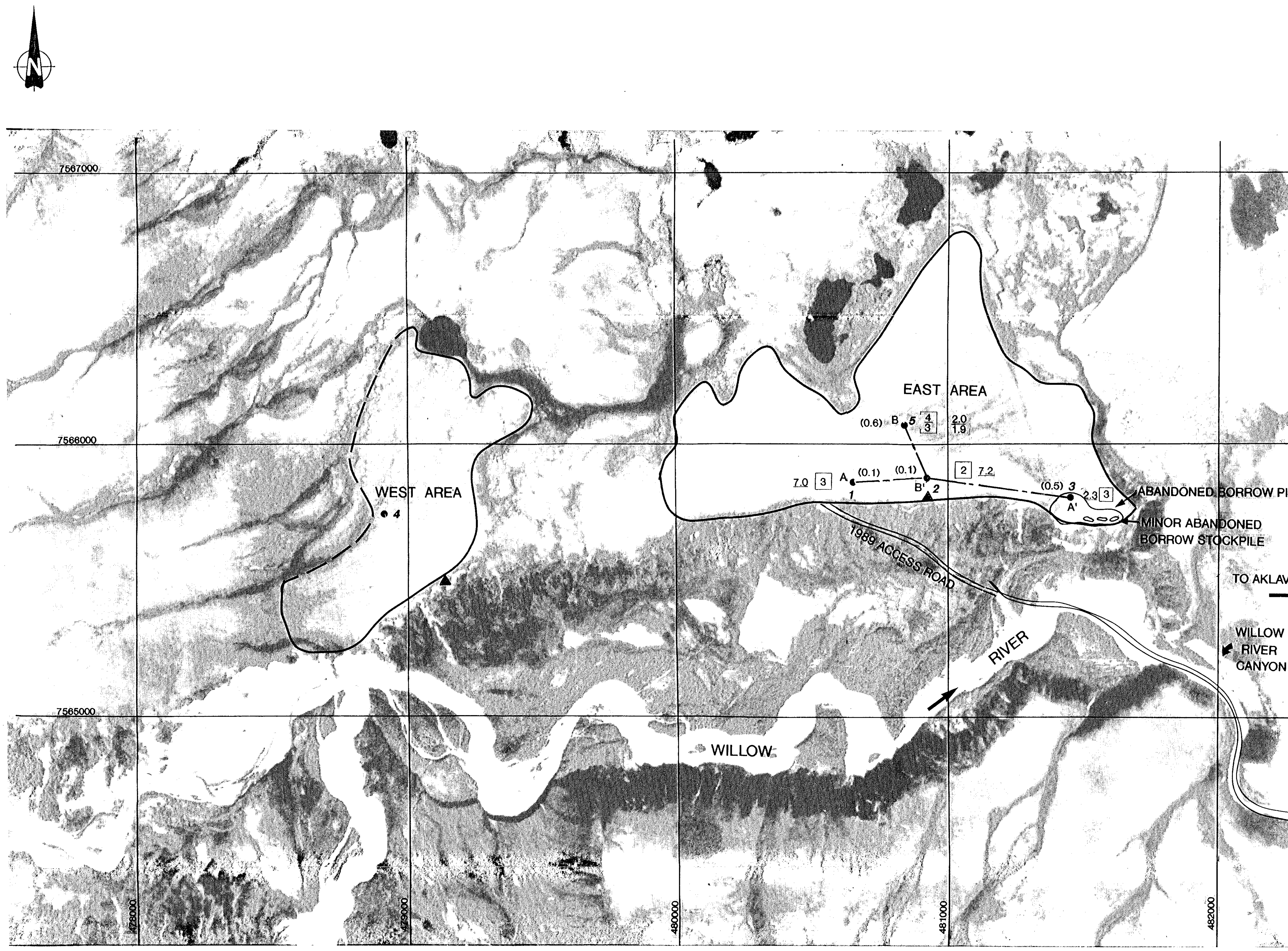
467 (WILLOW RIVER) DEPOSIT, AKLAVIK

SITE LOCATION PLAN

Figure 2

CG10346

HBLT 14 - 87/05



LEGEND

Thickness at Borehole (in metres)

1.2 / 0.9 = Thickness of Overlying Material / Thickness of Underlying Material

[1] / [2] = Quality of Overlying Material / Quality of Underlying Material

Source Quality Classes

- [1] Excellent
- [2] Good
- [3] Fair
- [4] Poor

(0.5) Overburden Thickness at Borehole (in metres)

A —— A' Cross Section

*2 ● Borehole Locations

Deposits Drilled During 1989 Program

▲ R.M.Hardy & Associates Ltd. 1976 Study (Logged Exposure)

NOTE: Geodetic control based on 107 B/4 Provisional Map U.T.M. Grid Zone 8

* Abbreviated borehole numbers eg. 1= 467B001

100 0 100 200 300 400

SCALE (m)

REFERENCES

Hardy BBT Limited

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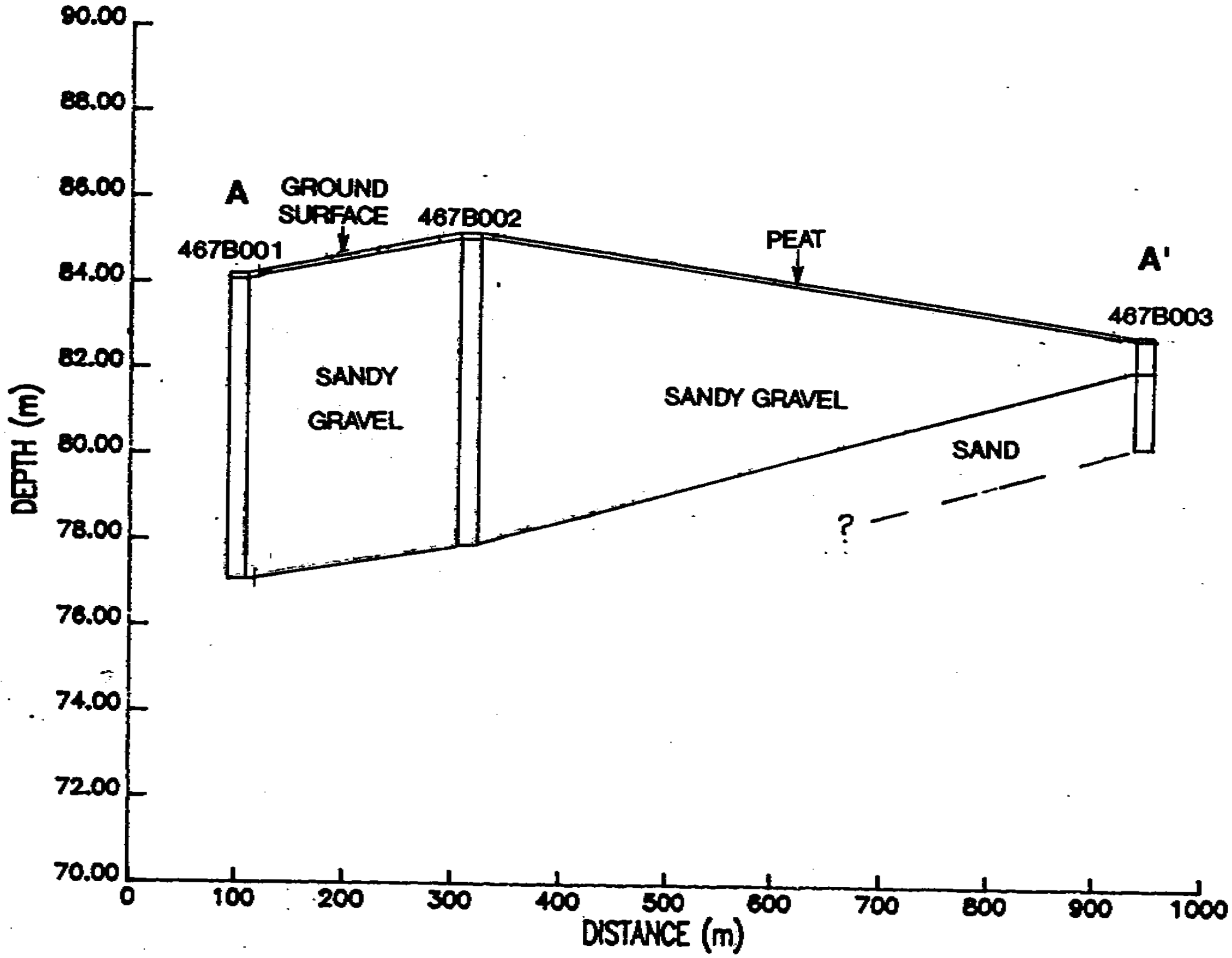
INUVIALUIT SETTLEMENT REGION
GRANULAR RESOURCES EVALUATION
WILLOW RIVER 467 DEPOSIT

MATERIAL THICKNESS AND QUALITY
TEST HOLE AND CROSS SECTION LOCATION PLAN

SCALE AS NOTED DATE 05/03/90 MADE TE CHKD YK APPD PKG

JOB No. CG10346 FIGURE 3 REV.

HBLT 51A-87/11



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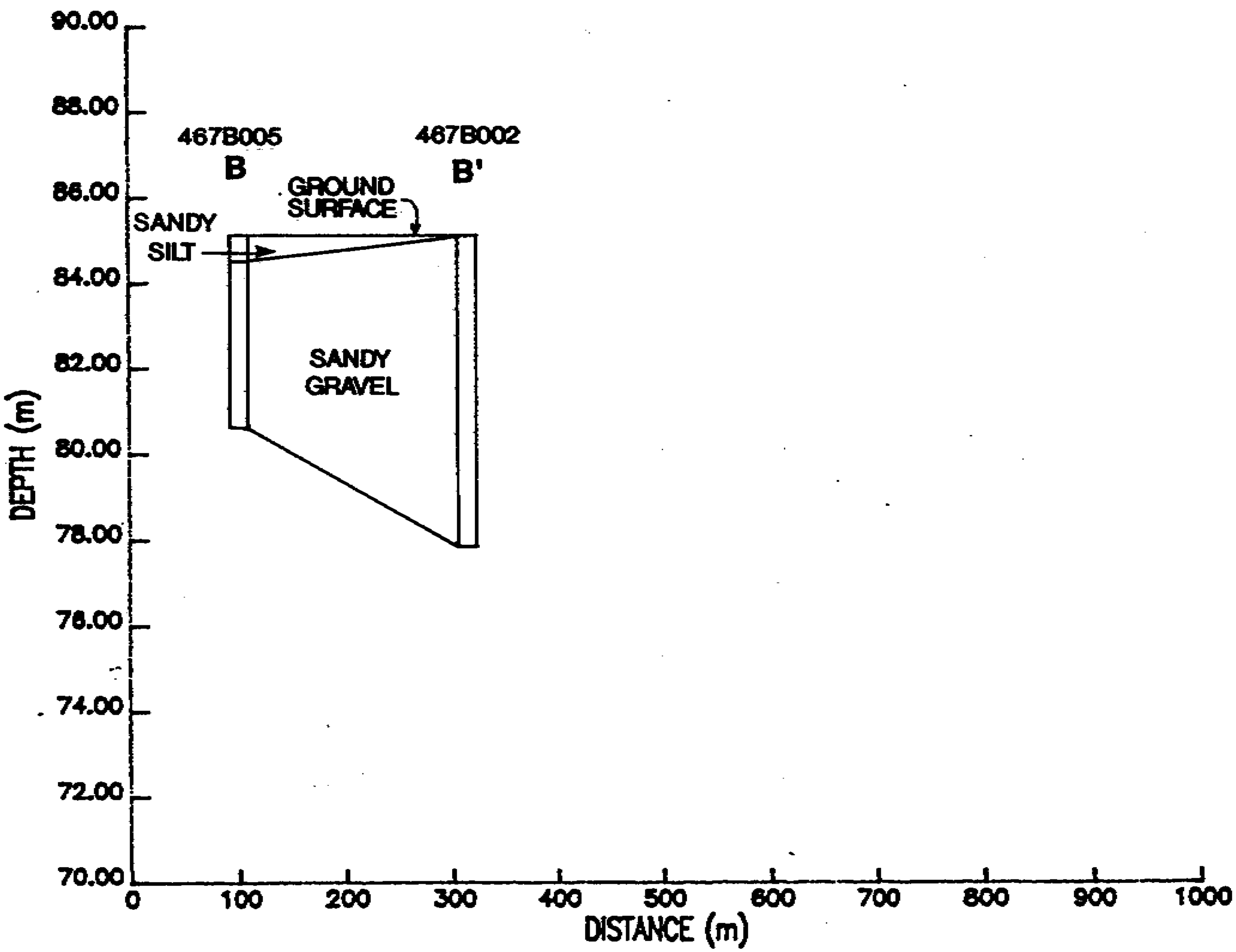
WILLOW RIVER (467)
CROSS-SECTIONAL PLOT A – A'

Figure 4

HBLT 15 87/05



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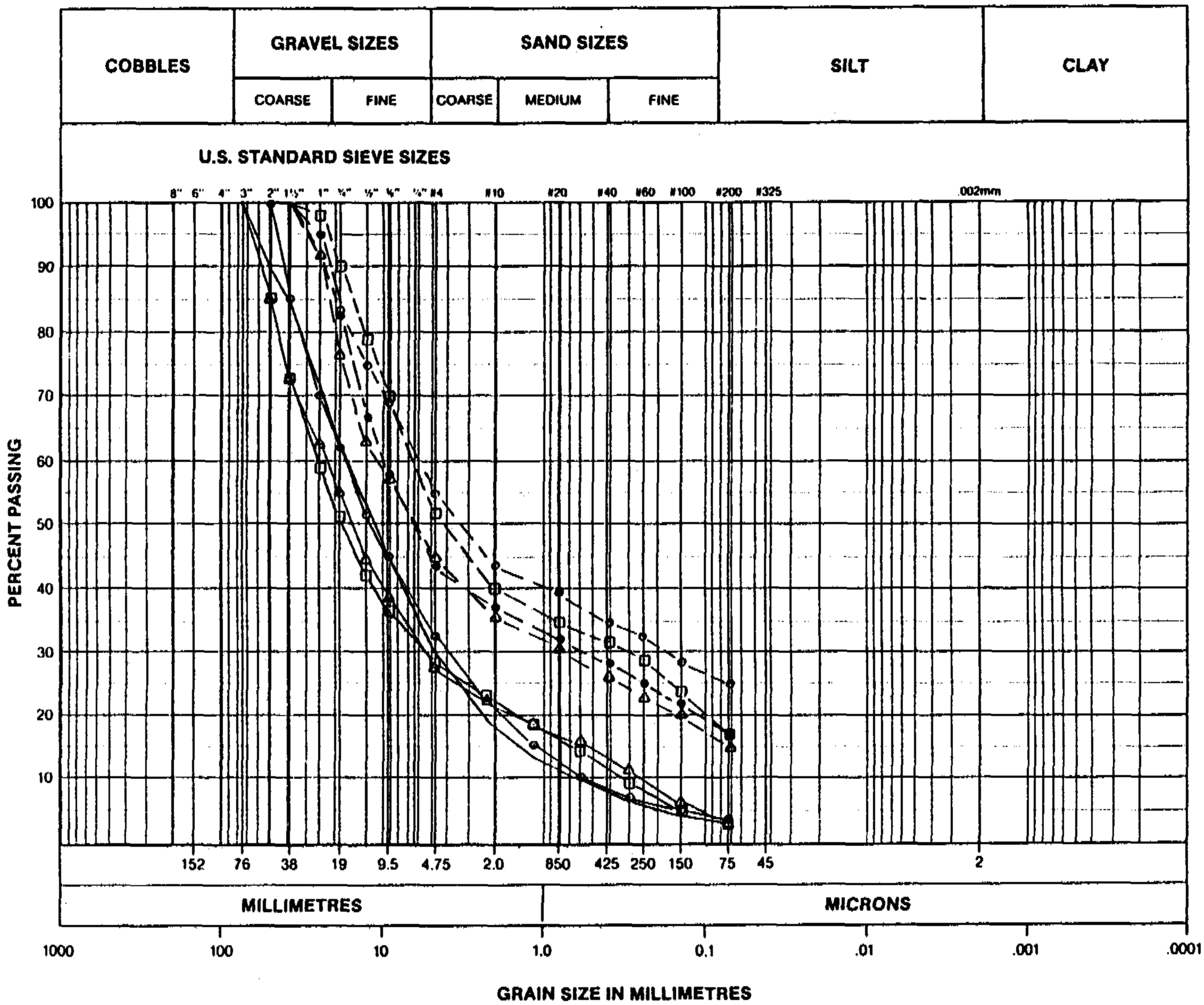
WILLOW RIVER (467)
CROSS-SECTIONAL PLOT B – B'

Figure 5

HBLT 15 87/05



REMARKS:

——————— 1976 Survey Samples

– – – – – – 1989 Survey Samples

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

SUMMARY

D_{10} = ________ mm	GRAVEL ________ %
D_{30} = ________ mm	SAND ________ %
D_{60} = ________ mm	SILT ________ %
C_U = ________ mm	CLAY ________ %
C_C = ________ mm	

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467 (Willow River) Deposit

Composite Grading Curve

Test Hole No. .... Sample .... Depth ....

GRAIN SIZE DISTRIBUTION

JOB NO. CG10346

Figure 6

APPENDIX A

Boreholes Logs and Explanatory Sheets

GROUND ICE CLASSIFICATIONS

CATEGORY	GROUP SYMBOL	SUBGROUP SYMBOL	DESCRIPTION
		F	UNDIFFERENTIATED
NON-VISIBLE ICE	N	Nf	POORLY BONDED OR FRIABLE FROZEN SOIL
		Nbn	WELL BONDED FROZEN SOIL WITH NO EXCESS ICE
		Nbe	WELL BONDED FROZEN SOIL WITH EXCESS ICE. FREE WATER PRESENT WHEN SAMPLE THAWED.
VISIBLE ICE LESS THAN 25mm THICK	V	Vx	INDIVIDUAL ICE CRYSTALS OR INCLUSIONS
		Vc	ICE COATINGS ON PARTICLES
		Vr	RANDOM OR IRREGULARLY ORIENTED ICE FORMATIONS
		Vs	STRATIFIED OR DISTINCTLY ORIENTED ICE FORMATIONS
VISIBLE ICE GREATER THAN 25mm THICK	ICE	ICE+ Soil Type	ICE GREATER THAN 25mm THICK WITH SOIL INCLUSIONS
		ICE	ICE GREATER THAN 25mm THICK WITHOUT SOIL INCLUSIONS

NOTE: 1. UF signifies unfrozen ground.

2. F? or UF? indicates likely thermal condition not obvious during drilling.

ADAPTED FROM NRC 7576

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EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of field investigation and subsequent laboratory testing are described in these pages.

It should be noted that materials, boundaries and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

TEST DATA

Data obtained during the field investigation and from laboratory testing are shown at the appropriate depth interval.

Abbreviations, graphic symbols, and relevant test method designations are as follows:

*C	Consolidation test	*ST	Swelling test
D_R	Relative density (formerly specific gravity)	TV	Torvane shear strength
Fines	Percentage by weight smaller than #200 sieve	VS	Vane shear strength (undisturbed-remolded)
k	Permeability coefficient	w	Natural moisture content (ASTM D 2216)
*MA	Mechanical grain size analysis and hydrometer test	w_l	Liquid limit (ASTM D 423)
		w_p	Plastic limit (ASTM D 424)
N	Standard penetration test (CSA A119.1-60)	ε_f	Unit strain at failure
N_d	Dynamic cone penetration test	γ	Unit weight of soil or rock
NP	Non plastic soil	γ_d	Dry unit weight of soil or rock
pp	Pocket penetrometer strength	ρ	Density of soil or rock
*q	Triaxial compression test	ρ_d	Dry density of soil or rock
q_u	Unconfined compressive strength		
*SB	Shearbox test	→	seepage
SO_4	Concentration of water-soluble sulphate	▼	observed water level

**The results of these tests usually are reported separately*

SOIL CLASSIFICATION AND DESCRIPTION

Soils are classified and described according to their engineering properties and behaviour.

The soil of each stratum is described using the Unified Soil Classification System[1] modified slightly so that an inorganic clay of "medium plasticity" is recognized.

The use of modifying adjectives may be employed to define the actual or estimated percentage range by weight of minor components. This is similar to a system developed by D.M. Burmister.[2]

The soil classification system is shown in greater detail on page 2.

SAMPLE TYPE — The type of sample is shown at the appropriate depth interval using the following abbreviations:

- A auger sample
- B block sample
- C rock core, or frozen soil core
- D drive sample
- P pitcher tube sample
- U tube sample (usually thin-walled)
- W wash or air return sample
- O other (see report text)
- ⧅ indicates no sample recovery

1. "Unified Soil Classification System", Technical Memorandum 3-357 prepared for Office, Chief of Engineering, by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S. Army, Vol 1, March 1953.
2. American Society for Testing and Materials. Procedures for Testing Soils, "Suggested Methods of Testing for Identification of Soils", 4th Ed; pp 221-233, Dec. 1964.

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	

SPECIAL SYMBOLS

BEDROCK (Undifferentiated)

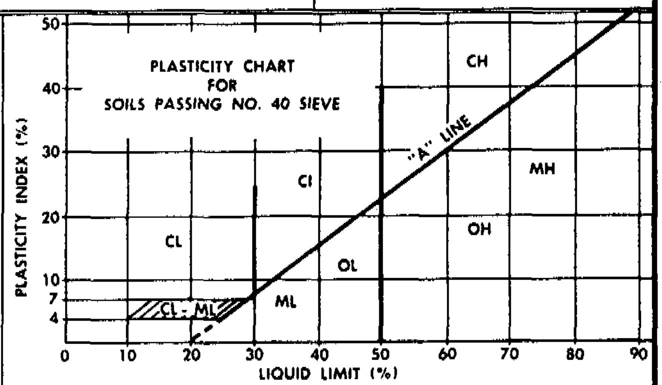
VOLCANIC ASH

SOIL COMPONENTS

FRACTION	U S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL coarse	76 mm	19 mm	50 - 35	and
GRAVEL fine	19 mm	No 4		
SAND coarse	4.75 mm	2.00 mm	35 - 20	some
SAND medium	2.00 mm	425 μm	20 - 10	little
SAND fine	425 m	75 μm	10 - 1	trace
SILT (non plastic) or CLAY (plastic)	75 μm			

OVERSIZE MATERIAL

Rounded or subrounded	Not rounded
COBBLES 76 mm to 203 mm	ROCK FRAGMENTS > 76 mm
BOULDERS > 203 mm	ROCKS > 0.76 cubic metre in volume



1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.

Hardy BBT Limited

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GRANULAR MATERIALS CLASSES (GMC)[1]

Class 1 Granular Material

Class 1 material is well-graded with a low fines content, and comprises hard and durable particles, which meet the following criteria, a maximum petrographic number (PM) of 160, a maximum L.A. Abrasion loss of 35%, and maximum magnesium sulphate soundness loss of 12%. Consequently, it is suitable for use as concrete or asphalt aggregate after minimal processing. Sources of Class 1 material are relatively scarce in the Inuvik region and are considered to be of too high quality for use in highway construction, and should be reserved specifically as a source of high quality aggregate. A PN of 160 is somewhat higher than might be expected for excellent aggregates, particualarly for concrete aggregates. Specifically, chert components of these aggregates may cause acceptable reactions with the alkali in Normal Portlan cements. An alkali-aggregate reactivity test should also be performed and evaluated before using these materials as concrete aggregates.

Class 2 Granular Material

Class 2 material is similar to Class 1 except that it is of lower quality due to somewhat poorer grading, a higher fines content and less durable particles, which meet the following criteria; a maximum PM of 200 and a maximum L.A. Abrasion loss of 60%. With processing, it may be upgraded to concrete aggregate quality. Class 2 materials may be used in highway construction as granular base and sub-base material, but may be more prudently reserved as a source of lower quality aggregate or structural fill.

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[1] Refer to GMC column on borehole logs.

Class 3 Granular Material

Class 3 material generally comprises poorly graded sands and gravels with low to high fines content of up to 20%, and with particles meeting the durability criterion of a maximum of PN of 250. It can be processed to meet local frost susceptibility criteria. The presence of moderate amounts of fines makes it ideal as a surface course material, which requires the presence of a binding component. In addition, this material may be used as general fill for embankment construction.

Class 4 Granular Material

Class 4 material comprises of poorly grade granular soils with a substantial fines content of more than 20%. There is generally durability criteria for this class of granular material. Class 4 material is generally acceptable only for use as non-structural fill.

Class 5

Class 5 material comprise fair to excellent quality bedrock, felsenmeer, talus or similar extremely coarse granular material, suitable for quarrying and processing to produce potentially excellent construction materials ranging from general fill, to concrete aggregate, building stone, and erosion control materials such as rip rap or armour stone.

Class 7 - Organic

I - Ice

U - Unusable Materials

ILA GRANULAR RESOURCES INVENTORY	467 (WILLOW RIVER)	BOREHOLE No. 467B001
UTM ZONE: 8 N7566040.00 E480670.00	MIDNIGHT SUN DRILLING – SOLID STEM AUGER	Project No: CG10346
INAC – INUVIALUIT SETTLEMENT LANDS	NODWELL MOUNTED CME 750	ELEVATION 84.20 (m)

SAMPLE TYPE: GRAB SAMPLE; CRREL CORE

DEPTH (m)	PLASTIC – M.C. – LIQUID (20 40 60 80)	GMC	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	NRC ICE TYPE / GRAIN SIZE	DEPTH (m)
0.0		6	TOPSOIL – silty, non-plastic, medium brown, rootlets, frozen			Nbn	0.0
			GRAVEL(GF) – medium to coarse grained, frequent cobbles/boulders to 250mm, subrounded to rounded, well sorted, red-brown to brown, medium to coarse sand,				
1.0			grab sample – 1.2 to 1.8m	Grab			1.0
			trace silt				
2.0			... increase in silt and clay, moist, sandy			Nbn	2.0
3.0		3					3.0
4.0							4.0
5.0	•		grab sample – 5.0 to 5.5m	Grab		(5.0–5.5m) 56% gravel, 27% sand, 17% fines	5.0
6.0			grab sample – 5.8 to 6.0m	Grab		Nbn	6.0
7.0			END OF HOLE @ 7.1m				7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0

Hardy BBT Limited Calgary, Alberta	COMPLETION DEPTH 7.1 m	COMPLETE 14/03/89
	LOGGED BY GB	DWG NO. Page 1 of 1

GRANULAR RESOURCES INVENTORY	467 (WILLOW RIVER)	BOREHOLE No. 467B002
UTM ZONE: 8 N7566050.00 E480950.00	MIDNIGHT SUN DRILLING – SOLID STEM AUGER	Project No: CG10346
INAC – INUVIALUIT SETTLEMENT LANDS	NODWELL MOUNTED CME 750	ELEVATION 85.20 (m)

SAMPLE TYPE: GRAB SAMPLE; CRREL CORE

DEPTH (m)	PLASTIC – M.C. – LIQUID (20 40 60 80)	GMC	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	NRC ICE TYPE / GRAIN SIZE
0.0		6	TOPSOIL – gravelly, medium to coarse grained, trace clay, sand, silt, non-plastic, medium brown, frozen, rootlets			Nbn
0.6			GRAVEL(gf) – medium to fine grained, well rounded, cobbles to 100mm, medium brown, trace sand, trace silt and clay grab sample – 2.1 to 2.5m	Grab (2.1–2.5)		Nbn (3.1)
4.5	• (5.0)	3	GRAVEL(GF) – sandy, moist, silt, clay – medium plastic grab sample – 4.5 to 5.5m	Grab (4.5–5.5)		(4.5–5.5m) 56% gravel, 30% sand, 14% fines Nbn
7.3			END OF HOLE @ 7.3m			

Hardy BBT Limited Calgary, Alberta	COMPLETION DEPTH 7.3 m	COMPLETE 14/03/89
	LOGGED BY GB	DWG NO.

ILA GRANULAR RESOURCES INVENTORY	467 (WILLOW RIVER)	BOREHOLE No. 467B003
UTM ZONE: 8 N7565960.00 E481480.00	MIDNIGHT SUN DRILLING – SOLID STEM AUGER	Project No: CG10346
INAC – INUVIALUIT SETTLEMENT LANDS	NODWELL MOUNTED CME 750	ELEVATION 82.90 (m)

SAMPLE TYPE ■ GRAB SAMPLE ◪ ☒ ▤ ◫ ◫ CRREL CORE

DEPTH (m)	PLASTIC M.C. LIQUID (20 40 60 80)	GMC	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	NRC ICE TYPE GRAIN SIZE	DEPTH (m)
0.0		6	TOPSOIL– clayey, frozen, highly plastic, trace silt, pebbly, brown–black				0.0
		3	GRAVEL(gf) – well graded, brown, little sand, silt and clay			Nbn	
						Nbe/Vc	
1.0			SAND(sf) – pebbles, dense, black–brown				1.0
		3	grab sample – 1.5 to 2.0m	■			
2.0						Vx/Vc	2.0
			END OF HOLE @ 2.5m				
3.0							3.0
4.0							4.0
5.0							5.0
6.0							6.0
7.0							7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0

Hardy BBT Limited Calgary, Alberta	COMPLETION DEPTH 2.5 m	COMPLETE 14/03/89
	LOGGED BY GB	DWG NO. / Page 1 of 1

ILA GRANULAR RESOURCES INVENTORY	467 (WILLOW RIVER)	BOREHOLE No. 467B004
UTM ZONE: 8 N7565930.00 E478930.00	MIDNIGHT SUN DRILLING – SOLID STEM AUGER	Project No: CG10346
INAC – INUVIALUIT SETTLEMENT LANDS	NODWELL MOUNTED CME 750	ELEVATION 121.00 (m)

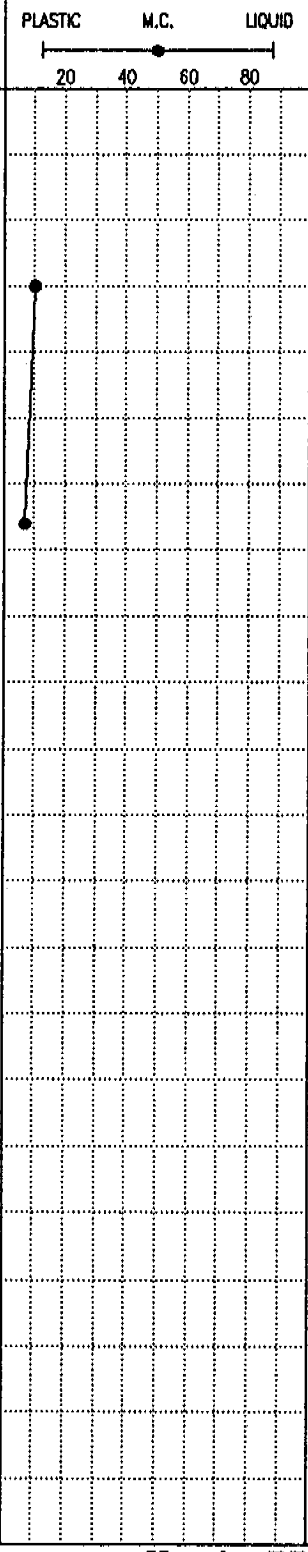
SAMPLE TYPE ■ GRAB SAMPLE ◩ ⊠ ▤ ◫ ◫ CRREL CORE

DEPTH (m)	PLASTIC M.C. LIQUID 20 40 60 80	GMC	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	NRC ICE TYPE GRAIN SIZE	DEPTH (m)
0.0			GRAVEL(gw) – well graded, boulders and cobbles to 300mm, brown-black, frozen			Vx	0.0
		I	ICE AND ORGANICS(Pt) – frozen, black-brown grab sample – 0.4 to 0.5m	■		ICE	
1.0			END OF HOLE @ 0.6m				1.0
2.0							2.0
3.0							3.0
4.0							4.0
5.0							5.0
6.0							6.0
7.0							7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0

Hardy BBT Limited Calgary, Alberta	COMPLETION DEPTH 0.6 m	COMPLETE 14/03/89
	LOGGED BY GB	DWG NO. Page 1 of 1

ILA GRANULAR RESOURCES INVENTORY	467 (WILLOW RIVER)	BOREHOLE No. 467B005
UTM ZONE: 8 N7566240.00 E480870.00	MIDNIGHT SUN DRILLING – SOLID STEM AUGER	Project No: CG10346
INAC – INUVIALUIT SETTLEMENT LANDS	NODWELL MOUNTED CME 750	ELEVATION 85.20 (m)

SAMPLE TYPE: GRAB SAMPLE; CRREL CORE



DEPTH (m)	GMC	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	NRC ICE TYPE / GRAIN SIZE
0.0	5	SILT(ml) – sandy, trace fine gravel, non-plastic, brown, frozen			
1.0	4	GRAVEL (GF) – fine to coarse grained, poorly graded, subrounded to subangular, some sand, some fines, medium brown, frozen grab sample – 1.2 to 1.8m	Grab		Nbn (1.2–1.8m) 45% gravel, 29% sand, 26% fines
3.0	3	grab sample – 3.0 to 3.6	Grab		Nbn (3.0–3.6m) 48% gravel, 35% sand, 17% fines
4.5		END OF HOLE @ 4.5m			

Depth scale: 0.0 to 11.0 m

Hardy BBT Limited Calgary, Alberta	COMPLETION DEPTH.4.5 m	COMPLETE 14/03/89
	LOGGED BY GB	DWG NO.

APPENDIX B

Summary of Field Operations

Operational Calendar - INAC INUVIALUIT
Granular Resource Investigation

March 10 to 12, 1989

Midnight Sun Drilling Ltd. mobilized from Whitehorse. All drilling and accessory equipment in Inuvik by the morning of March 13, 1989. The field program was carried out in two 12 hour shifts per day.

March 12, 1989

HBT staff mobilized from Calgary.

March 13, 1989

Site investigation program begins. Midnight Sun Drilling Ltd. personnel fly to I-407 site to check access route conditions.

Move equipment on-site and open access to the I-407 primary drilling site.

March 14, 1989

00:00 - 11:00	Continue to move equipment to-site.
11:00 - 12:00	Drill and sample Borehole I407B001 to a completed depth of 6.7 m.
12:00 - 13:45	Drill and sample Borehole I407B002 to a completed depth of 7.9 m.
13:45 - 15:30	Drill and sample Borehole I407B003 to a completed depth of 7.9 m.
15:30 - 17:00	Drill and sample Borehole I407B004 to a completed depth of 7.1 m.
17:00 - 16:30	Drill and sample Borehole I407B005 to a completed depth of 7.0 m.

March 14, 1989

16:30 - 18:00	Drill and sample Borehole I407B006 to a completed depth of 3.3 m.
18:00 - 19:30	Drill and sample Borehole I407B007 to a completed depth of 5.8 m.
19:30 - 21:30	Drill and sample Borehole I407B008 to a completed depth of 6.3 m.
21:30 - 23:00	Drill and sample Borehole I407B009 to a completed depth of 5.3 m.
23:00 - 24:00	Commenced drilling and sampling of Borehole I407B010.

March 15, 1989

00:00 - 02:00	Continue Borehole I407B010 to a completed depth of 5.6 m.
02:00 - 04:30	Drill and sample Borehole I407B011 to a completed depth of 6.0 m.
04:30 - 07:00	Drill and sample Borehole I407B012 to a completed depth of 6.0 m.
07:00 - 10:30	Drill down. Canadian Helicopter crew fails to show up at the in-town helipad. Change of shift has to be accomplished by truck.
10:30 - 15:00	Re-drill Borehole I407B003 and take CRREL ice core samples. Complete borehole at a depth of 8.2 m.
15;00 - 19:00	Re-drill Borehole I407B011 and take CRREL ice core samples. Complete borehole at a depth of 9.8 m.
19:00 - 20:00	Drill and sample Borehole I407B013 to a completed

	depth of 5.2 m.
20:00 - 21:00	Re-drill Borehole I407B013 and take CRREL ice core samples. Complete borehole at a depth of 5.2 m.
21:00 - 24:00	Drill and sample Borehole I407B014 to a completed depth of 4.0 m. Cat employed to back-blade a trail to secondary drilling area on tip of the Caribou Hills escarpment.

<u>March 16, 1989</u>

00:00 - 03:00	Drill and sample Borehole I407B015 to a completed depth of 3.9 m. Cat continues to back-blade a trail.
03:00 - 08:30	Move rig to site of Borehole I407B016, prepare to drill
08:30 - 14:00	Drill Borehole I407B016 and take CRREL ice core samples. Complete borehole at a depth of 8.8 m.
14:00 - 24:00	Move drill and accessory equipment to the 155 South site at Kittigazuit Creek. The Cat begins ploughing out access route at approximately 18:00 hours.

<u>March 17, 1989</u>

00:00 - 09:30	Continue move to Kittigazuit Creek. Access trail ploughed out as far as the stockpiles at 155 South, located at 155SB018 in area H. One bulk sample collected from stockpiles.
09:30 - 10:30	Drill and sample Borehole 155SB023 to a completed depth of 3.8 m. A one-half hour site reconnaissance made by helicopter to determine access routes to the various drilling locations and photograph the drilling operation. The Cat kept busy ploughing out access trails to the various drilling locations.
10:30 - 11:30	Drill and sample Borehole 155SB024 to a completed depth of 3.8 m. The Cat continues ploughing out

	access trails.
11:30 - 14:00	Drill and sample Borehole 155SB025 to a completed depth of 7.0 m.
14:00 - 19:00	Take CRREL ice core samples in Borehole 155SB023. Complete borehole at depth of 4.2 m.
19:00 - 20:30	Move rig to location 155SB026.
20:30 - 24:00	Drill and sample Borehole 155SB026 to a completed depth of 5.0 m.

March 18, 1989

00:00 - 03:00	Drill and sample Borehole 155SB027 to a completed depth of 4.0 m.
03:00 - 08:00	Drill and sample Borehole 155SB028 to a completed depth of 9.5 m.
08:00 - 13:00	Drill and sample Borehole 155SB029 to a completed depth of 10.0 m.
13:00 - 14:00	Move rig to location 155SB030.
14:00 - 16:00	Drill and sample Borehole 155SB030 to a completed depth of 4.0 m.
16:00 - 16:50	Move rig to location 155SB031.
16:50 - 19:00	Drill and sample Borehole 155SB031 to a completed depth of 5.0 m.
19:00 - 20:00	Move rig to location 155SB032.
20:00 - 23:00	Drill and sample Borehole 155SB032 to a completed depth of 3.0 m.
23:00 - 24:00	Commence drilling and sampling Borehole 155SB033.

March 19, 1989

00:00 - 02:00	Continue Borehole 155SB033 to a completed depth of 5.0 m.
02:00 - 04:00	Drill and sample Borehole 155SB034 to a completed depth of 2.6 m.
04:00 - 08:00	Rig down, prepare to move.
08:00 - 24:00	Move equipment to Willow River (467 Site). Cat begins ploughing out the access route at approximately 17:00 hours.

March 20, 1989

00:00 - 04:30	Continue move to Site 467.
04:30 - 06:00	The Cat pulls the rig up the hill slope and the rig is set-up.
06:00 - 11:30	Drill and sample Borehole 467B001 to a completed depth of 7.1 m.
11:30 - 12:30	Move rig to Borehole 467B002 site.
12:30 - 16:00	Drill and sample Borehole 467B002 to a completed depth of 7.3 m.
16:00 - 17:45	Drill and sample Borehole 467B003 to a completed depth of 2.5 m.
17:45 - 19:00	Move rig to Borehole 467B004 site.
19:00 - 19:30	Drill and sample Borehole 467B004 to a completed depth of 0.6 m.
19:30 - 21:00	Move rig to Borehole 467B005 site.

21:00 - 23:30	Drill and sample Borehole 467B005 to a completed depth of 4.5 m.
23:00 - 24:00	Move equipment back to Inuvik.

March 21, 1989

00:00 - 19:00	Continue move to Inuvik.

March 22 to 23, 1989

Ship out samples, deliver ice core samples to the Geological Survey of Canada, meet with INAC officials, and de-mobilize operations, including Midnight Sun Drilling Ltd.

ENG_GEO\CG10346T.D1

APPENDIX C

Laboratory Test Results

PROJECT: INAC INUVIALUIT GRANULAR STUDY PROJECT NO.: CG10346
LOCATION: WILLOW RIVER (467 DEPOSIT)

BOREHOLE #:	SAMPLE INTERVAL	%GRAVEL:	%SAND:	%FINES	D50	MOISTURE CONTENT %:	PETROGRAPHIC NUMBER (PN)	USC
467B001	5.0 – 5.5	56	27	17	5.8	7	148	GF
467B002	4.5 – 5.5	56	30	14	5.5	7	–	GF
467B003	–	–	–	–	–	–	–	–
467B004	No sample	Sent	(Ice Only)	–	–	–	–	–
467B005	1.2 – 1.8	45	29	26	3.4	10	166	GF
467B005	3.0 – 3.6	48	35	17	4.2	8	–	GF

467T4

FILE: CG10346
CLIENT: INAC

PREPARED BY: BF
DATE: May 11, 1989

SAMPLE: 467B001
5.0 – 5.5 m

LITHOLOGIC/MINEROLOGIC DESCRIPTION	Chemical Quality	Physical Quality	PN MULT.	WEIGHTED PERCENT IN EACH FRACTION							Total Weighed Composition %	PN # Contribution
				1 1/2"	1"	3/4"	5/8"	1/2"	3/8"	#4		
Sandstone, very strong	Good	Good	1	4.3	5.5	12.7	8.8	10.8	9.2	14.3	65.6	65.6
Metamorphic/Volcanic	Good	Good	1			0.6	0.7	1.7	2.5	2.9	8.4	8.4
Crystalline	Good	Good	1						0.1		0.1	0.1
Carbonate	Good	Good	1						0.1	0.2	0.3	0.3
Sandstone, moderately strong	Good	Moderately Good	1.5		1.4	2.4	1.1	1.1	2.2	1.5	9.7	14.6
Sandstone, weathered		Fair	3			0.6	0.7	0.9	1.2	1.5	4.9	14.7
Chert	Fair		3					0.7	0.4	0.4	1.5	4.5
Shale/Mudstone		Fair	3				2.2	0.9	0.6	1.5	5.2	15.6
Carbonate		Fair	3							0.4	0.4	1.2
Sandstone, highly weathered		Poor	6						0.3	0.9	1.2	7.2
Shale/Mudstone, weathered		Poor	6		1.4			0.4	0.3	0.6	2.7	16.2
Totals				4.3	8.3	16.3	13.5	16.5	16.9	24.2	100.0	148.4

PETROGRAPHIC NUMBER: 148

SUMMARY OF PETROGRAPHIC EXAMINATION

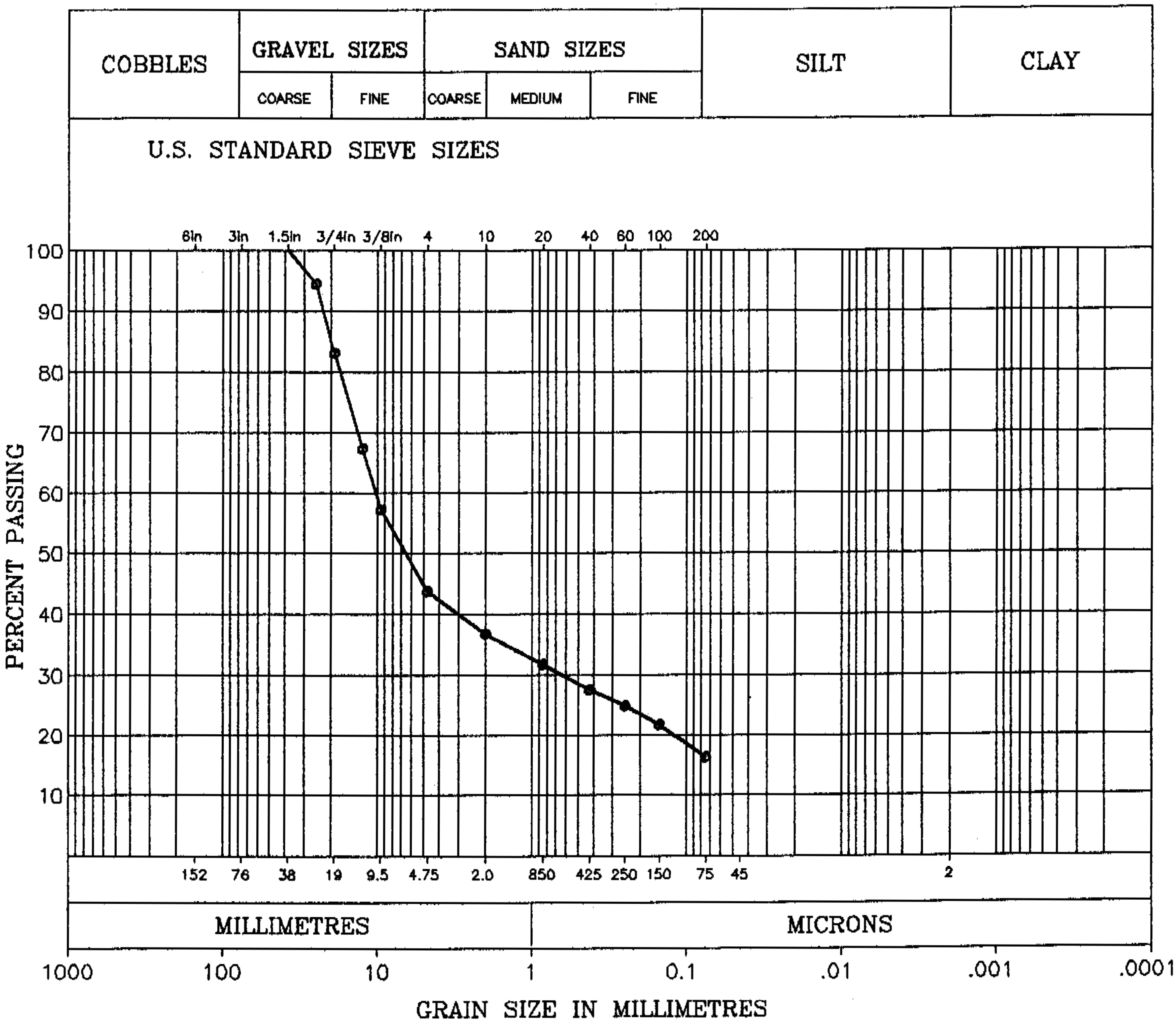
INAC148

FILE: CG10346 PREPARED BY: BF SAMPLE: 467B005
CLIENT: INAC DATE: June 1, 1989 1.2 – 1.8 m

LITHOLOGIC/MINEROLOGIC DESCRIPTION	Chemical Quality	Physical Quality	PN MULT.	WEIGHTED PERCENT IN EACH FRACTION							Total Weighed Composition %	PN # Contribution
				1 1/2"	1"	3/4"	5/8"	1/2"	3/8"	#4		
Sandstone, very strong	Good	Good	1	7.2	20.1	16.0	7.0	11.4	5.1	6.1	72.9	72.9
Crystalline	Good	Good	1		1.5	0.5		0.2		0.1	2.3	2.3
Metamorphic/Volcanic	Good	Good	1			2.0	0.3	0.2	1.0	0.7	4.2	4.2
Sandstone, moderately strong	Good	Moderately Good	1.5			0.5	1.1	0.9	1.7	1.2	5.4	8.1
Sandstone, weathered		Fair	3			1.0	0.3	0.4	1.0	1.2	3.9	11.7
Mudstone		Fair	3			0.5		0.2	1.0	1.5	3.2	9.6
Chert	Fair		3					0.4	0.5	0.9	1.8	5.4
Sandstone, highly weathered		Poor	6					0.4	0.4	0.9	1.7	10.2
Mudstone, weathered		Poor	6				0.3	0.5	0.1	0.3	1.2	7.2
Ironstone	Deleterious		10					0.5	0.7	1.0	2.2	22.0
Mudstone concretions	Deleterious		10			0.5		0.2	0.2	0.3	1.2	12.0
Totals				7.2	21.6	21.0	9.0	15.3	11.7	14.2	100.0	165.6

PETROGRAPHIC NUMBER: 166

SUMMARY OF PETROGRAPHIC EXAMINATION



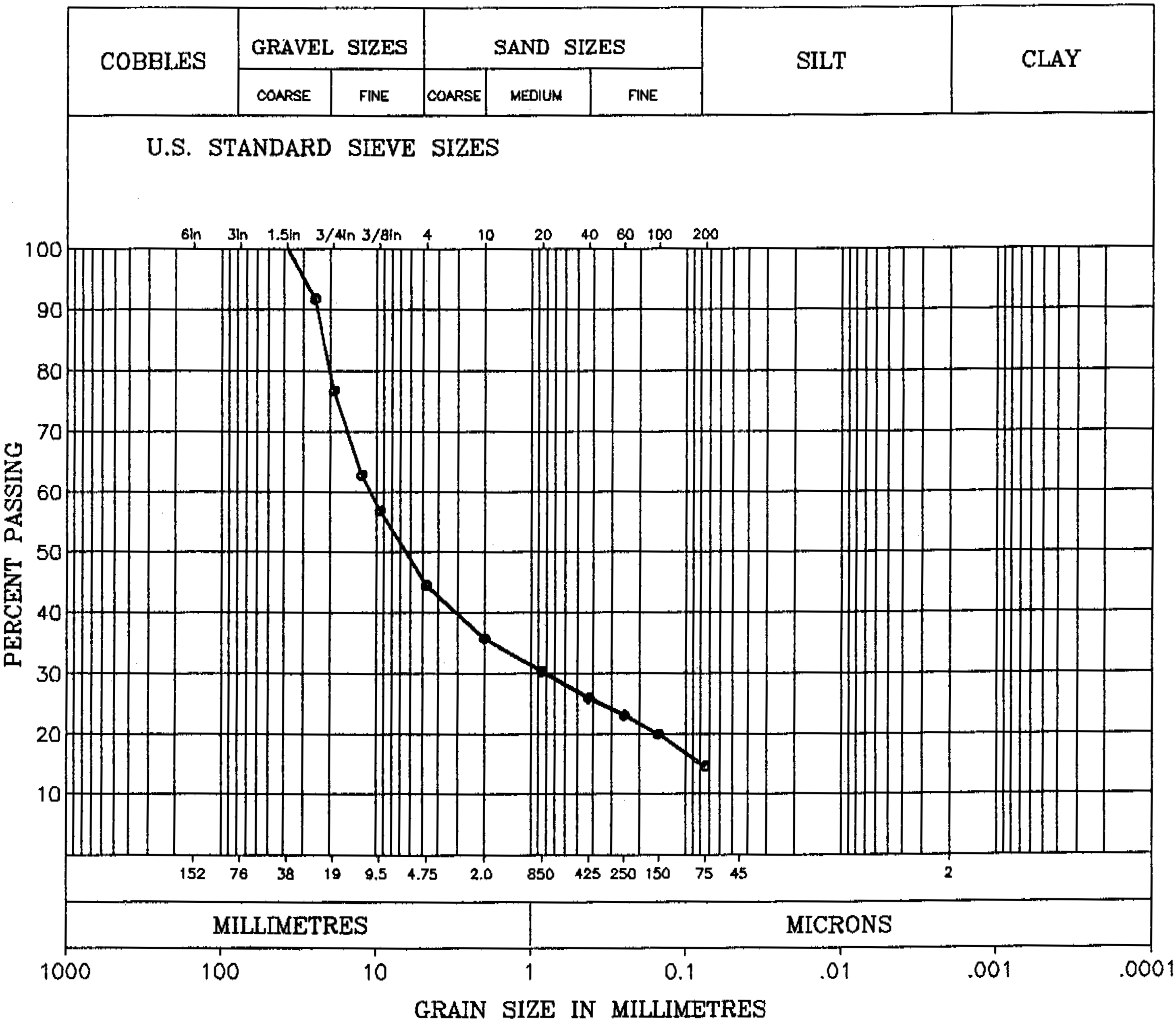
REMARKS:

SUMMARY			
D_{10} =	mm	GRAVEL	56. %
D_{30} = 0.68	mm	SAND	27. %
D_{60} = 10.	mm	FINES	17. %
C_U =			
C_C =			

Hardy BBT Limited

GRAIN SIZE DISTRIBUTION

PROJECT No: CG10346
LOCATION: 467
HOLE: B001
SAMPLE:
DEPTH: 5.0 –5.5 m
TECHNICIAN: JB
DATE: 89.04.25



REMARKS:

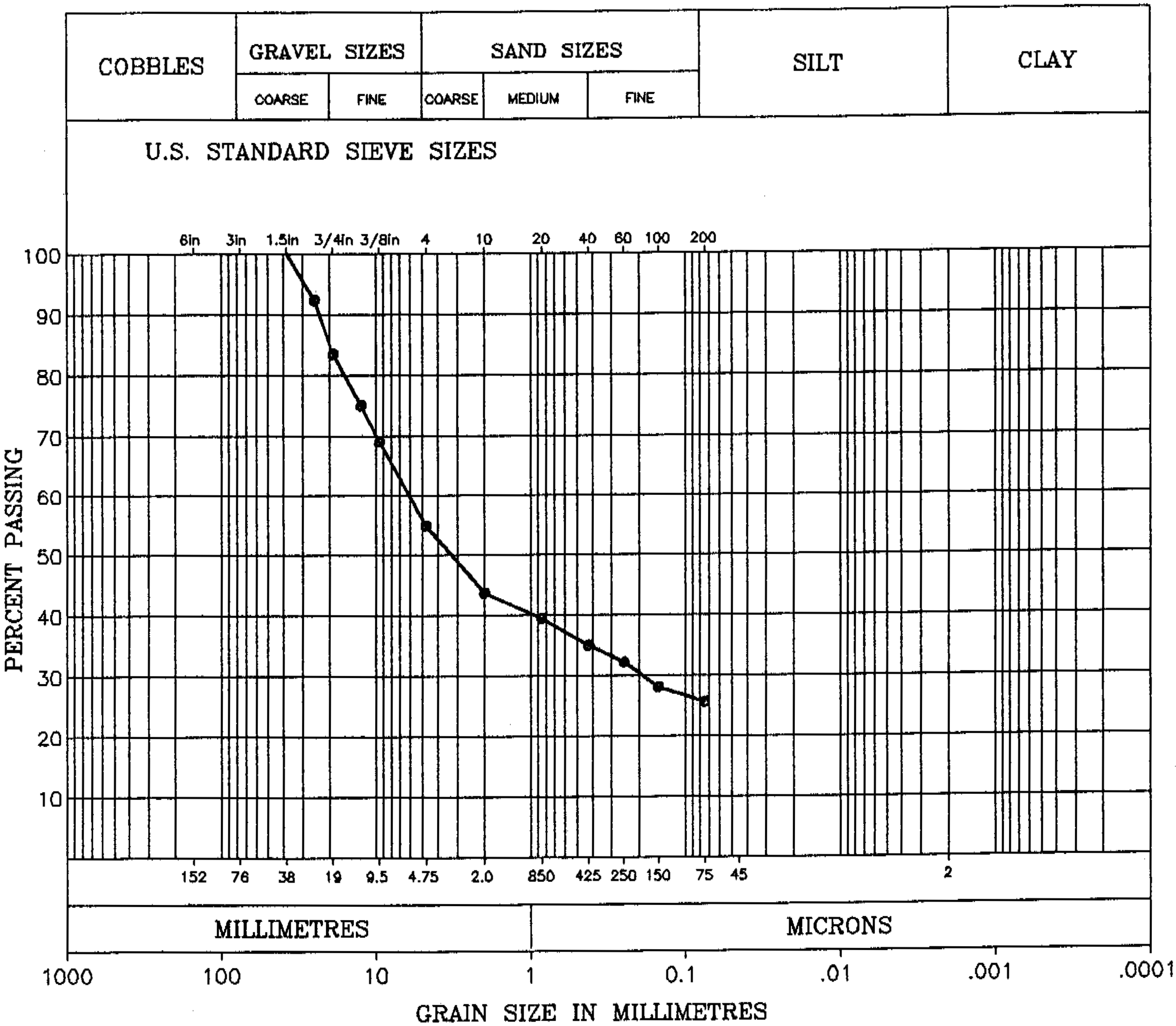
SUMMARY

D_{10} =	mm	GRAVEL	56. %
D_{30} = 0.82	mm	SAND	30. %
D_{60} = 11.	mm	FINES	14. %
C_U =			
C_C =			

Hardy BBT Limited

GRAIN SIZE DISTRIBUTION

PROJECT No: CG10346
LOCATION: 467
HOLE: B002 SAMPLE:
DEPTH: 4.5 – 5.5 m
TECHNICIAN: JB DATE: 89.04.25



REMARKS:

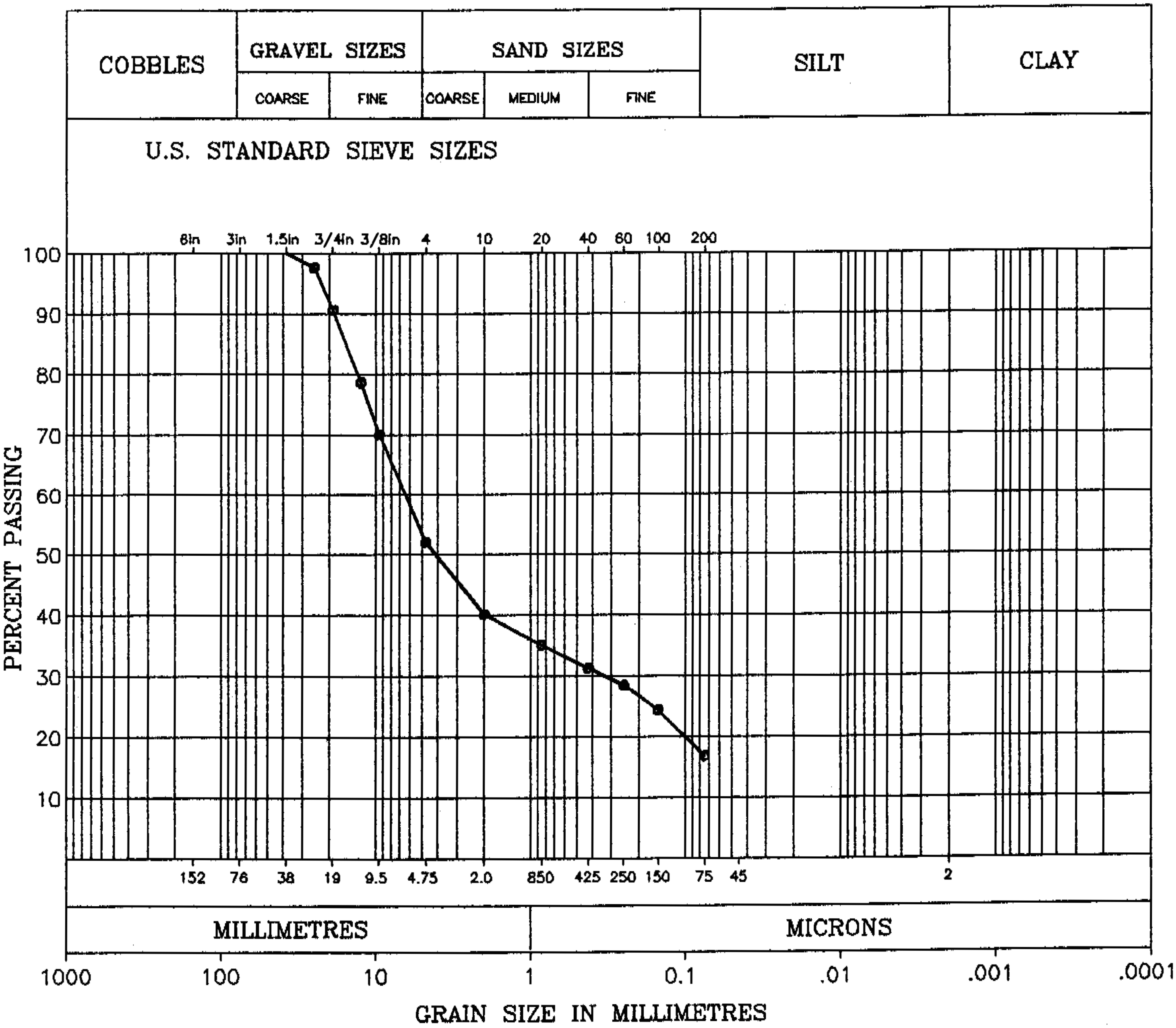
SUMMARY

D_{10} =	mm	GRAVEL	45. %
D_{30} = 0.20	mm	SAND	29. %
D_{60} = 6.5	mm	FINES	26. %
C_U =			
C_C =			

Hardy BBT Limited

GRAIN SIZE DISTRIBUTION

PROJECT No: CG10346
LOCATION: 467
HOLE: B005
SAMPLE:
DEPTH: 1.2 – 1.8 m
TECHNICIAN: JB
DATE: 89.04.25



REMARKS:

SUMMARY

D_{10} =	mm	GRAVEL	48. %
D_{30} = 0.35	mm	SAND	35. %
D_{60} = 6.9	mm	FINES	17. %
C_U =			
C_C =			

Hardy BBT Limited

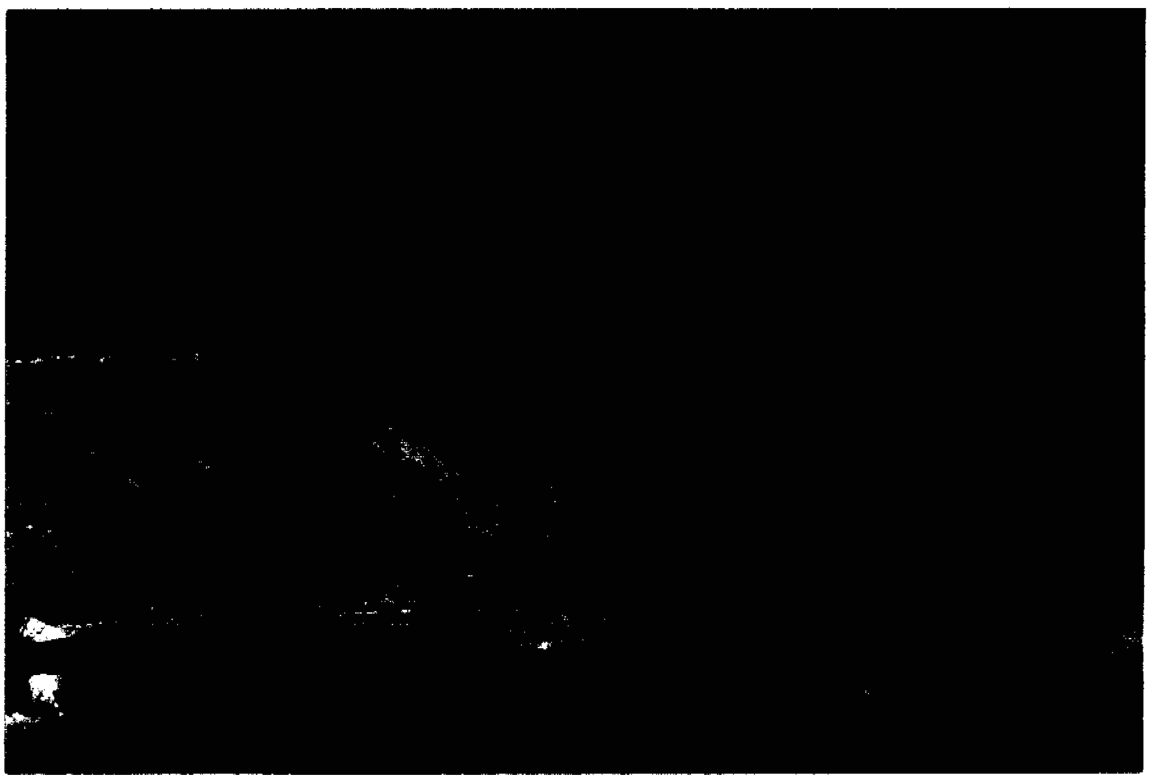
GRAIN SIZE DISTRIBUTION

PROJECT No: CG10346
LOCATION: 467
HOLE: B005 **SAMPLE:**
DEPTH: 3.0 – 3.6 m
TECHNICIAN: FP **DATE:** 89.04.25

APPENDIX D

Photographs

1. Access route from the Willow River floodplain onto the 467 deposit.



2. View east through the Willow River Gorge. Access through this gorge is poor in winter or summer.

3. Current source of gravel for Aklavik is obtained from the Willow River stream – bed, 1 km east of the Willow River Gorge.

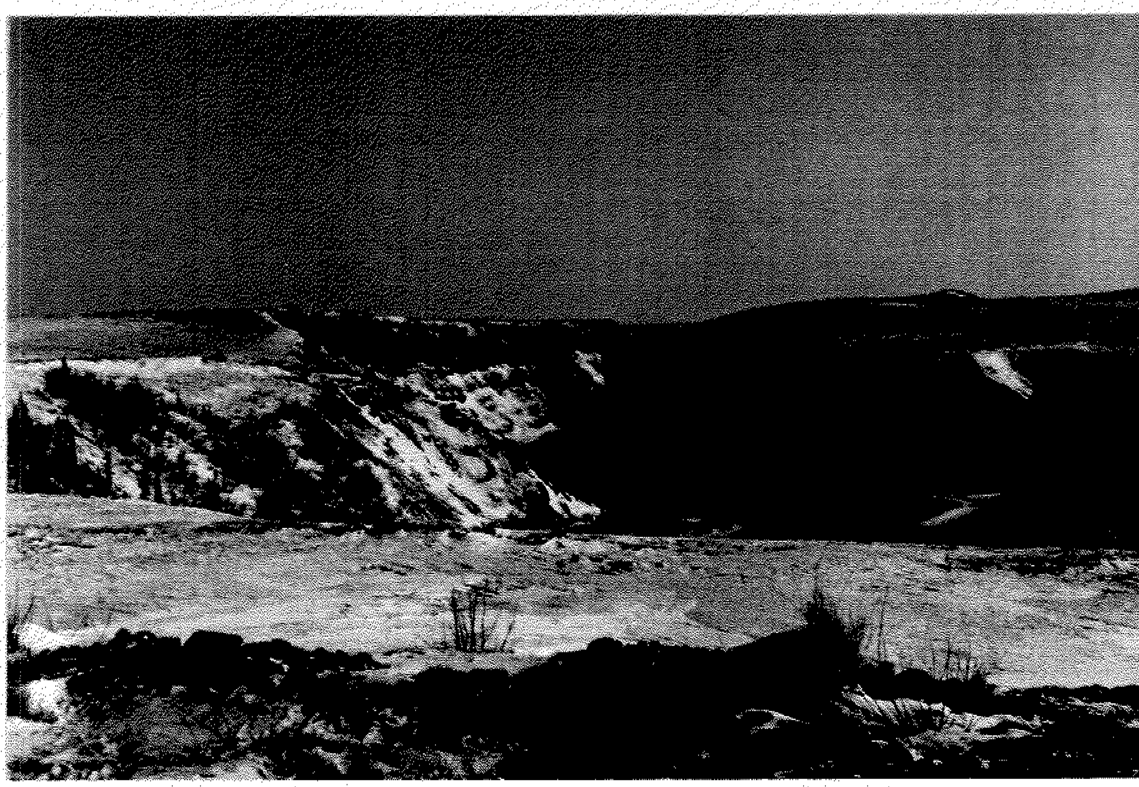
4. Winter drilling at Site 467.

5. Disused gravel pile at east end of deposit. The granular material is coarse and contains high amounts of fines.

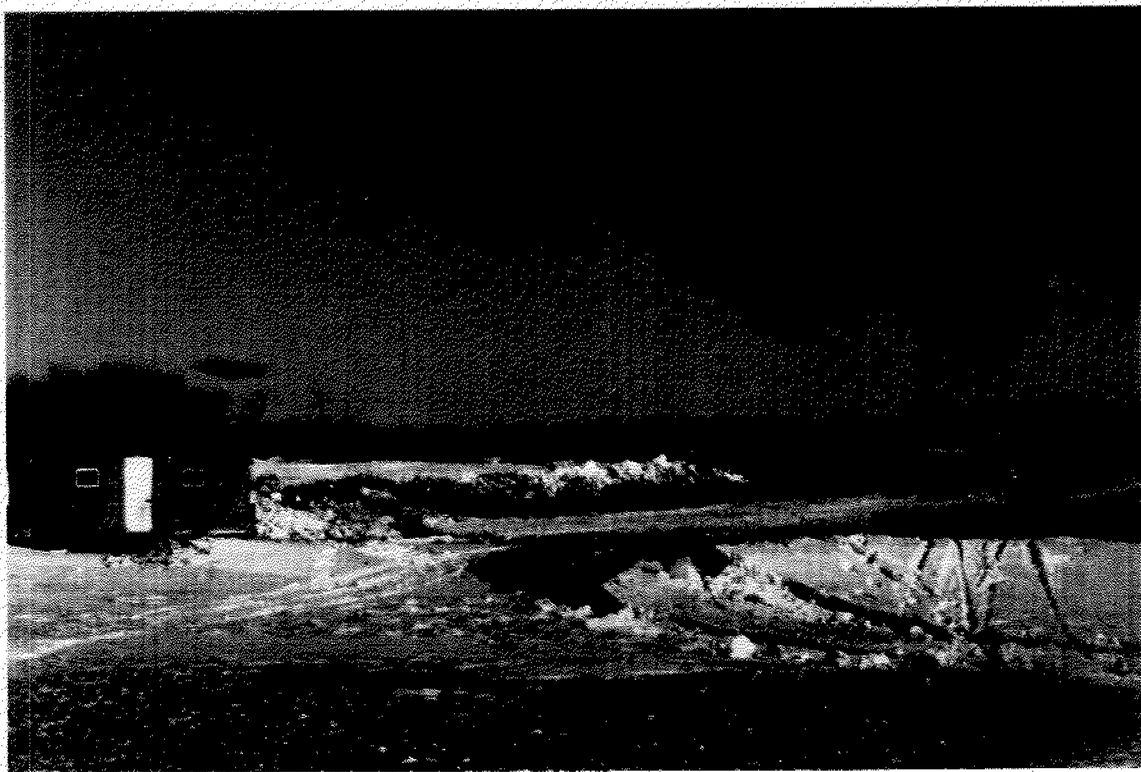
APPENDIX D

Photographs

1. Access route from the Willow River floodplain onto the 467 deposit.

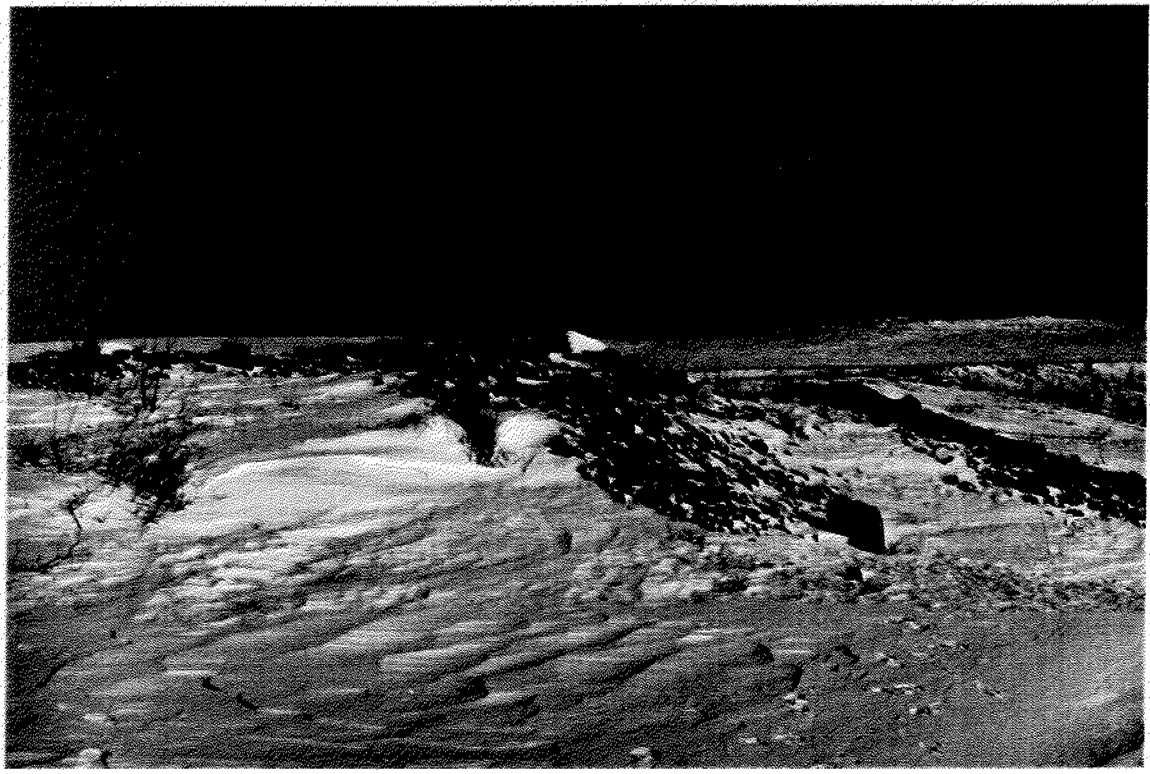


2. View east through the Willow River Gorge. Access through this gorge is poor in winter or summer.



3. Current source of gravel for Aklavik is obtained from the Willow River stream – bed, 1 km east of the Willow River Gorge.

4. Winter drilling at Site 467.



5. Disused gravel pile at east end of deposit. The granular material is coarse and contains high amounts of fines.

APPENDIX E

Data From
Previous Studies

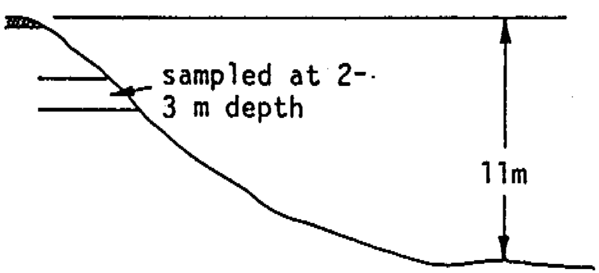
DATA FROM

KLOHN LEONOFF CONSULTING ENGINEERS (1988)

TEST HOLE LOG

SAMPLE DATA				SYMBOL	ELEV COLLAR	UNCONFINED COMPRESSION kPa
WEIGHT HAMMER 63.5 Kg					ELEV GROUND	100 200 300 400 ● FIELD VANE △ LAB VANE ■ UNCONF
HEIGHT DROP 0.76 m					CO-ORD LOCATION	PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
DEPTH / ELEV	O.D / I.D	BLOWS / .15m	NO.		DESCRIPTION OF MATERIAL	x — — o — — x 10 30 50 70 90 %

DEPTH	NO.	DESCRIPTION OF MATERIAL
		0.3m Peat and Organics -silty
1		Gravel and Sand
2	☒ (2–3 m)	- well graded to 20cm - thin silt layers - sub angular to sub rounded - brown, dry
3		NOTE: Sample taken between 2 and 3m depth.
4		
10		
11		11.0m



Klohn Leonoff Consultants Ltd.
CIVIL & GEOTECHNICAL ENGINEERS

JOB No	PA 2291.01.01
PROJECT	CONCRETE AGGREGATE STUDY
LOCATION	WILLOW RIVER
HOLE No.	EXPOSURE No. 1
DATE	Sept. 27/86 PLATE

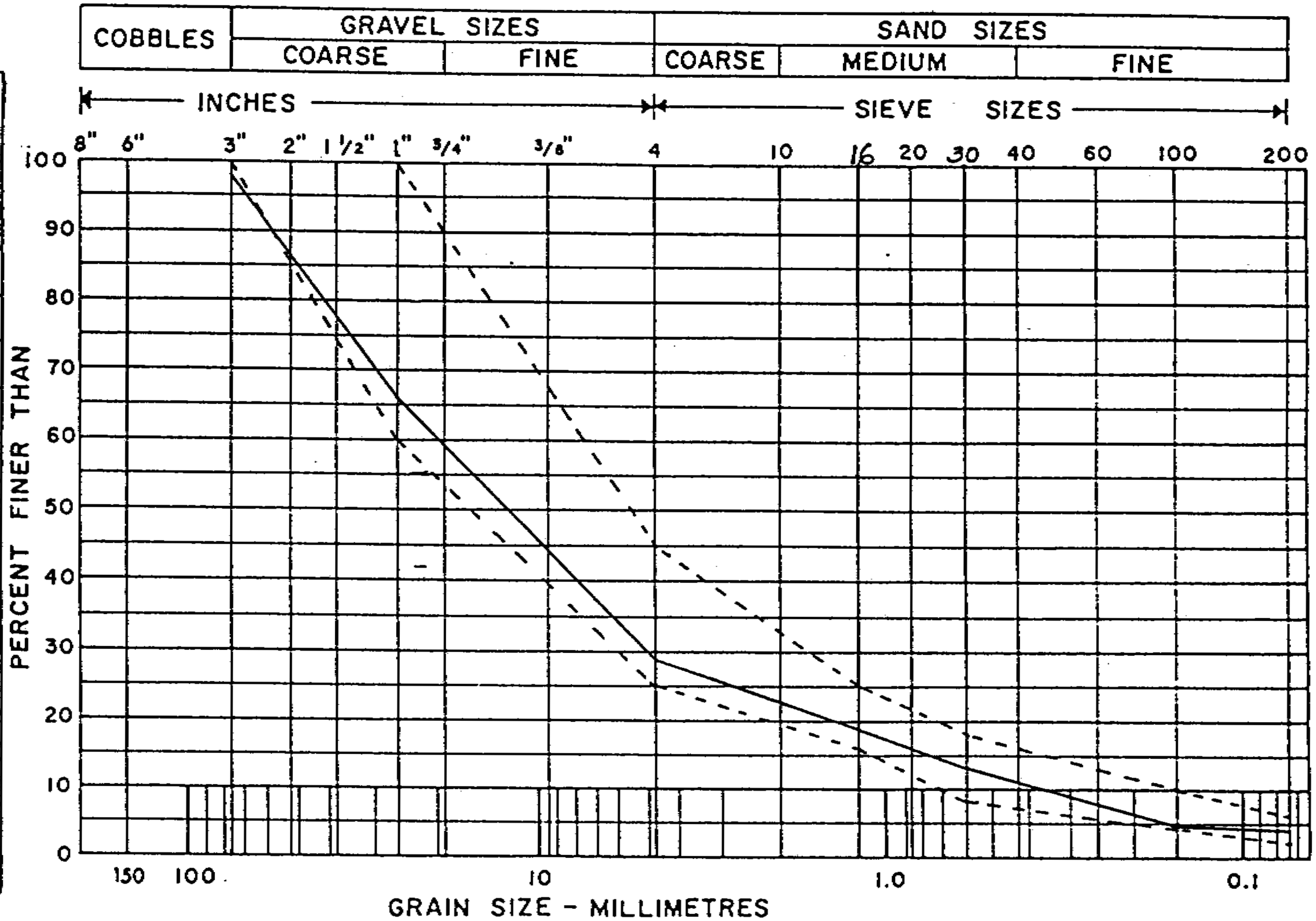
K L C METRIC

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No.
PROJECT
LOCATION
SAMPLE TYPE No. 6 Willow River
DATE

GRAIN SIZE ANALYSIS
GRANULAR SOILS

SIEVE SIZES		% PASSING
U.S.	METRIC	
6"	150 000	
3"	80 000	
2"	50 000	
1.5"	40 000	
1"	25 000	
.75"	20 000	
.5"	12 500	
.375"	10 000	
No. 4	5 000	
No. 8	2 500	
16	1 250	
30	630	
40	400	
50	315	
100	160	
200	80	



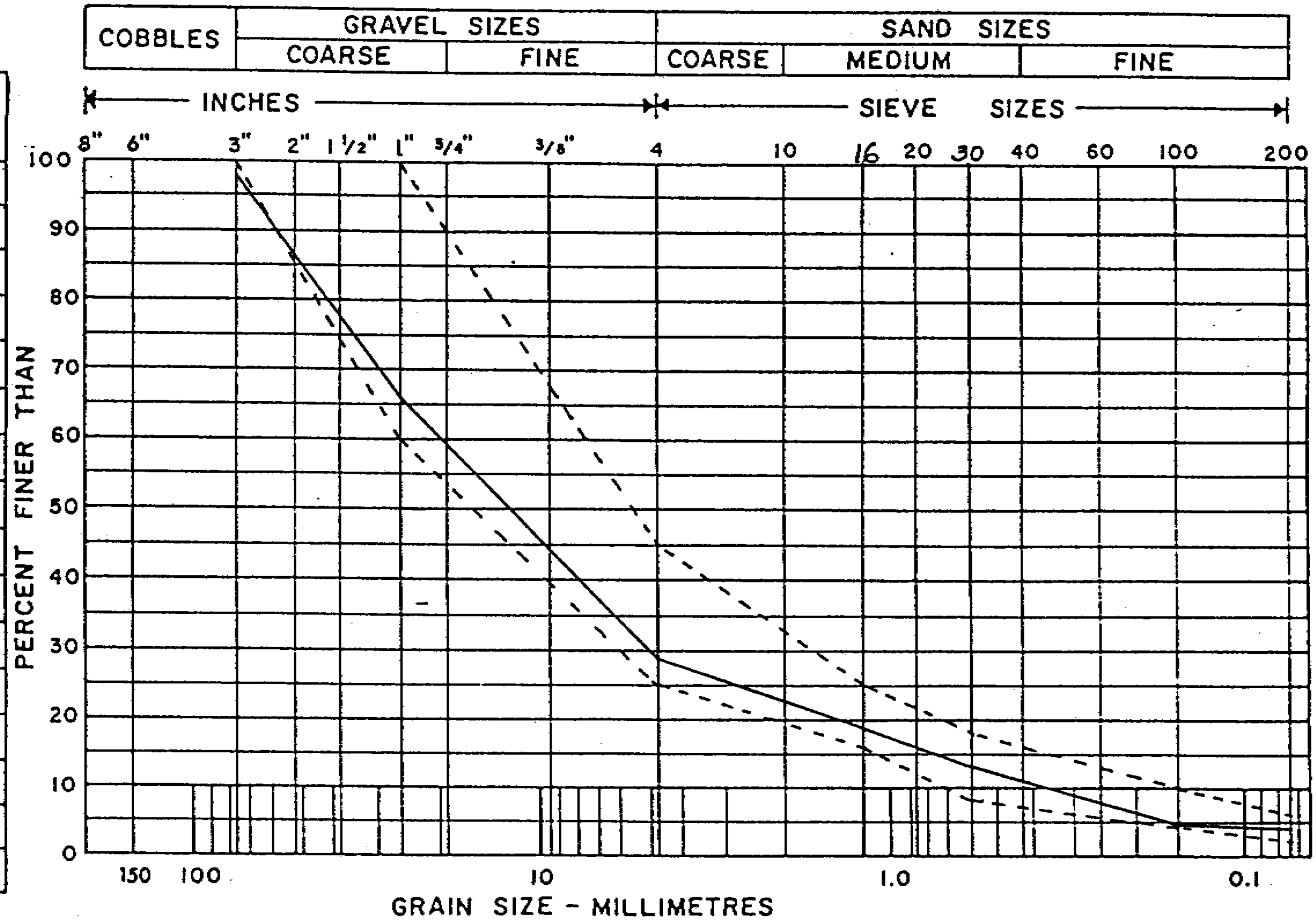
REMARKS: ____________________

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No.
PROJECT
LOCATION
SAMPLE TYPE No. 6 Willow River
DATE

GRAIN SIZE ANALYSIS
GRANULAR SOILS

SIEVE SIZES U.S.	SIEVE SIZES METRIC	% PASSING
6"	150 000	
3"	80 000	
2"	50 000	
1.5"	40 000	
1"	25 000	
.75"	20 000	
.5"	12 500	
.375"	10 000	
No. 4	5 000	
No. 8	2 500	
16	1 250	
30	630	
40	400	
50	315	
100	160	
200	80	



REMARKS:

SIEVE ANALYSIS

DATE SAMPLED: ____________________ DATE TESTED: ____________________

COARSE AGGREGATE

SIEVE SIZE	PERCENT PASSING
100mm (4")	
75mm (3")	
50mm (2")	
38.1mm (1-1/2")	
25.0mm (1")	
19.0mm (3/4")	
12.5mm (1/2")	
9.5mm (3/8")	
4.75mm (#4)	
2.36mm (#8)	
1.18mm (#16)	

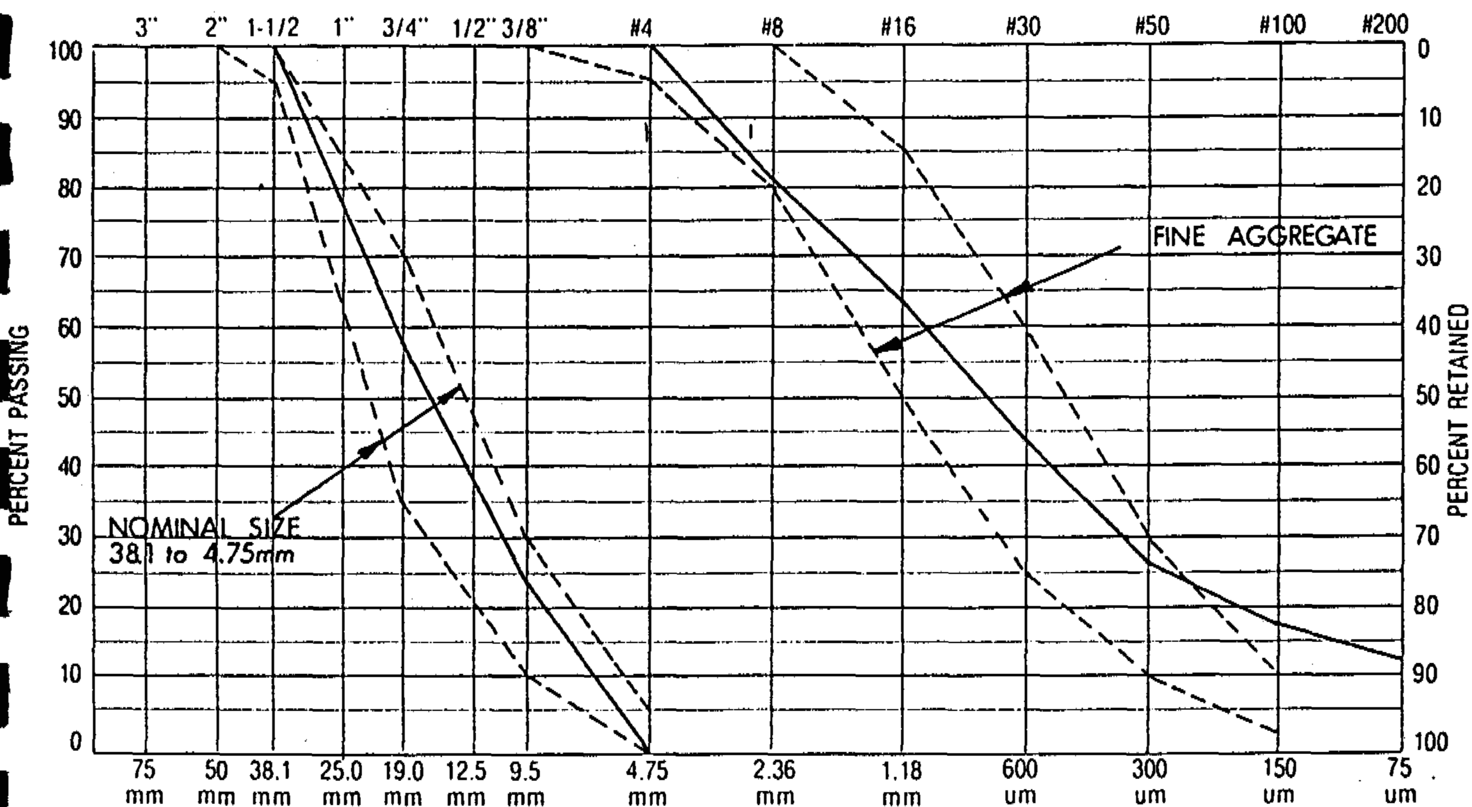
% FINER THAN 75um (#200) SIEVE =

FINE AGGREGATE

SIEVE SIZE	PERCENT PASSING
9.5mm (3/8")	
4.75mm (#4)	
2.36mm (#8)	
1.18mm (#16)	
600um (#30)	
300um (#50)	
150um (#100)	
75um (#200)	

FINENESS MODULUS =
% FINER THAN 75um (#200) SIEVE =

ASTM C33 GRADING LIMITS



KLOHN LEONOFF CONSULTANTS LTD.
CIVIL • GEOTECHNICAL • HYDRAULIC

JOB NO.	
PROJECT	
LOCATION	
TYPE OF SAMPLE No. 6 Willow River	
DATE	PLATE NO. A-

SIEVE ANALYSIS

DATE SAMPLED: ____________________ DATE TESTED: ____________________

COARSE AGGREGATE

SIEVE SIZE	PERCENT PASSING
100mm (4")	
75mm (3")	
50mm (2")	
38.1mm (1-1/2")	
25.0mm (1")	
19.0mm (3/4")	
12.5mm (1/2")	
9.5mm (3/8")	
4.75mm (#4)	
2.36mm (#8)	
1.18mm (#16)	

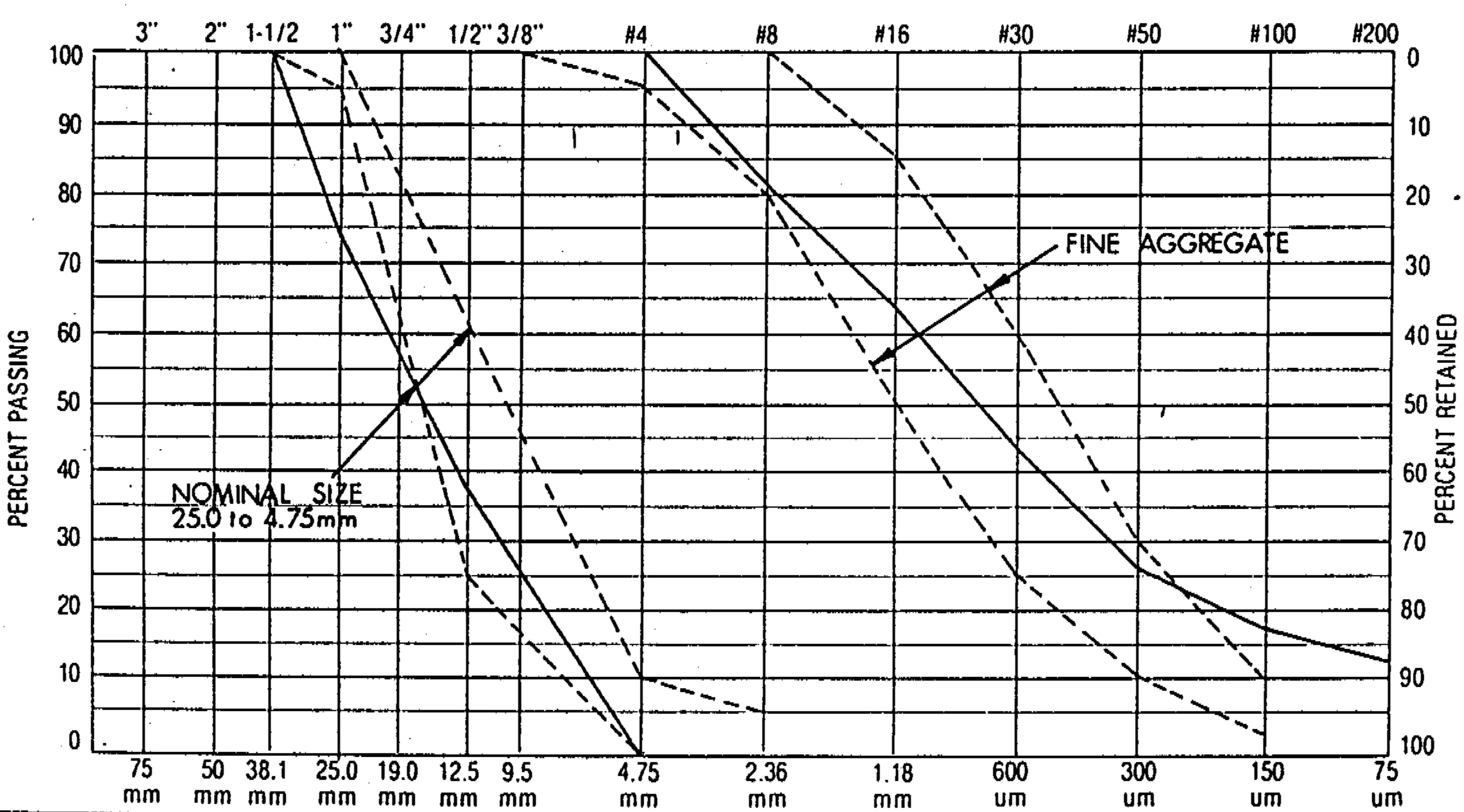
% FINER THAN 75um (#200) SIEVE =

FINE AGGREGATE

SIEVE SIZE	PERCENT PASSING
9.5mm (3/8")	
4.75mm (#4)	
2.36mm (#8)	
1.18mm (#16)	
600um (#30)	
300um (#50)	
150um (#100)	
75um (#200)	

FINENESS MODULUS =
% FINER THAN 75um (#200) SIEVE =

ASTM C33 GRADING LIMITS



KLOHN LEONOFF CONSULTANTS LTD.
CIVIL • GEOTECHNICAL • HYDRAULIC

JOB NO.	
PROJECT	
LOCATION	
TYPE OF SAMPLE No. 6 Willow River	
DATE	PLATE NO. A-

PETROGRAPHIC ANALYSIS OF AGGREGATES

PROJECT NO.: PA 2291.01.03

SOURCE: No. 6, WILLOW RIVER

CONSTITUENTS	REMARKS	COMPOSITION OF FRACTIONS RETAINED ON SIEVES (%)					PHYSICAL QUALITY	WEIGHTED COMPOSITION OF SAMPLE % BY WEIGHT	PETRO. FACTOR	PN
		1"	3/4"	½"	3/8"	#4				
QUARTZITE	*			79.3	66.8	47.6	Good	63.4	1	63.4
	**			28.0	15.4	19.8				
CHERT	*			6.0	14.5	25.1	Fair	15.8	3	47.4
	**			2.1	3.3	10.4				
SANDSTONE	*			8.6	4.2	7.4	Fair	7.3	3	21.9
	**			3.0	1.0	3.1				
SILTSTONE	*			1.0	1.1	1.5	Poor	1.1	6	6.6
	**			0.3	0.2	0.6				
CLAY IRONSTONE	*			5.1	13.4	18.4	Deleterions	12.5	10	125.0
	**			1.8	3.1	7.6				
NOTE: Approximately 1-2% of particals can be classified as flat or flan and elongated										

* on each sieve size ** weighted composition of sample

BASIC PETROGRAPHIC NUMBER = 264.3
CORRECTION FOR CONCRETE USE = 14.6
PN = 249.7
≃ 250

DATA FROM

R.M. HARDY AND ASSOCIATES (1976)

TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NCR ICE TYPE VISUAL ICE %	DEPTH (FT)	OTHER INFORMATION
	Pt	0.2	PEAT - organic cover.		UF		
1	CL	1.6	CLAY - little gravel, silty, brown, damp.				
2, 3, 4, 5, 6, 7	GW	7.5	GRAVEL - well graded to 8" cobbles, little fine to coarse sand, trace fines, occasional boulder to 20" size, subrounded to rounded, loose, brown, damp.				
8			Bottom of Pit				Sample from 1.6'-2.5'

DATE: Oct. 10, 1976	LOGGED BY: CPM	DRWN BY: MB/vh	CHKD BY: GCD/TJF

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TEST PIT NO. 467-A(e) SHEET 1 OF 1

TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NCR ICE TYPE VISUAL ICE %	DEPTH (FT)	OTHER INFORMATION
	Pt	0.3	PEAT		UF		Organic Color: #5+ Coal Removed: #2+
1	ML	1.3	SILT - little gravel, little sand, trace organics, brown, damp.				Lightweight Pieces - Fine Aggregate: 0.05%
2–6	GW	4.2 6.2	GRAVEL - well graded to 13" boulders, some fine to coarse sand, sub-angular to rounded, brown, damp. — becoming cleaner.				
7			Bottom of Pit				Sample from 1.3'-6.2'

DATE: Oct. 11, 1976	LOGGED BY: CPM	DRWN BY: MB/vh	CHKD BY: GCD/TJF

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TEST PIT NO. 467-B SHEET 1 OF 1

TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NCR ICE TYPE VISUAL ICE %	DEPTH (FT)	OTHER INFORMATION
0–5.0	Pt		PEAT - fibrous, silty, brown, moist.		UF		Lightweight Pieces - Fine Aggregate: 0.20%
5.0–85.0	GW		GRAVEL - well graded to 7" cobbles, little fine to coarse sand, trace silty fines, subangular to subrounded, brown moist.				Exposure not logged in detail below 14' because of steepness of bank.
65.0			increasing in cobble and boulder sizes.				
85.0			Bottom of Pit				Sample from 5.0'-13.0'

DATE: Oct. 10, 1976	LOGGED BY: SA	DRWN BY: MB/vh	CHKD BY: GCD/TJF

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TEST PIT NO. 467-C(e) SHEET 1 OF 1

TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	ICE GRAPHIC LOG	NCR ICE TYPE VISUAL ICE %	DEPTH (FT)	OTHER INFORMATION
0–1.2	Pt		PEAT - fibrous, silty, brown, moist.		UF		Lightweight Pieces - Fine Aggregate: 11.23%
1.2–12.5	GW		GRAVEL - well graded, some fine to coarse sand, frequent cobbles to 6" size, subrounded, medium dense, brown, moist, rootlets to 3.5' depth.				Gravel continues to estimated depth of 65'.
12.5			Bottom of Pit				Sample from 2.0'-12.0'

DATE: Oct. 11, 1976 | LOGGED BY: SA | DRWN BY: MB/vh | CHKD BY: GCD/TJF

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

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TEST PIT NO. 467-D(e)
SHEET 1 OF 1

GRAIN SIZE ANALYSIS

SAMPLE 4Y67-A(e) DEPTH 1.6'-2.5'

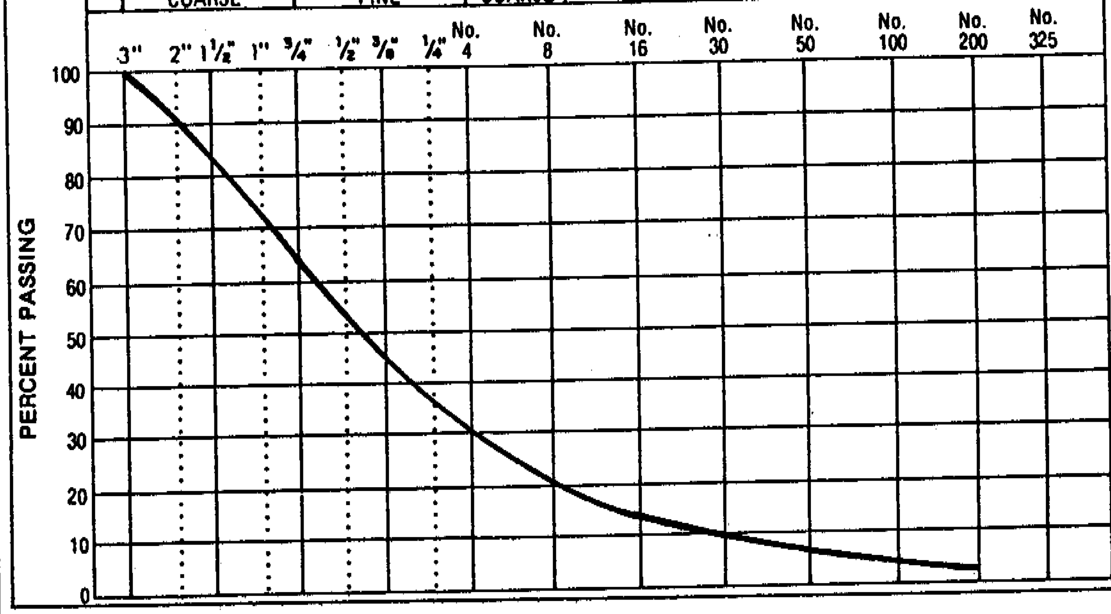
DATE SAMPLED Oct. 10, 1976 SAMPLED BY CPM

LAB TEST NUMBER 119HA

GRAVEL SIZES		SAND SIZES			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	
36.6 %	33.3 %	11.6 %	10.5 %	4.6 %	3.4 %

MAX. SIZE	% > 3"
9"	33.2

SIEVE SIZE	PERCENT PASSING
3"	100.0
2"	89.8
1 1/2"	85.3
1"	71.9
3/4"	63.4
1/2"	53.4
3/8"	45.1
1/4"	
No. 4	30.1
No. 8	19.0
No. 16	13.3
No. 30	9.7
No. 50	6.6
No. 100	4.6
No. 200	3.4



SAMPLE 467-B DEPTH 1.3'-6.2'

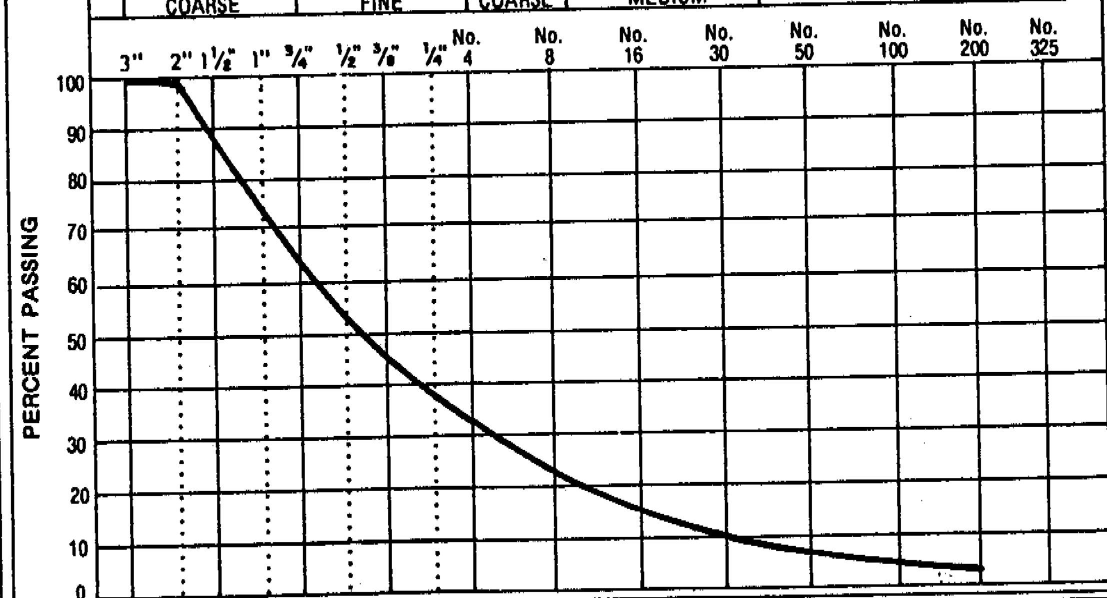
DATE SAMPLED Oct. 11, 1976 SAMPLED BY CPM

LAB TEST NUMBER 120HA

GRAVEL SIZES		SAND SIZES			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	
37.8 %	29.6 %	11.6 %	12.5 %	4.9 %	3.6 %

MAX. SIZE	% > 3"
4"	17.0

SIEVE SIZE	PERCENT PASSING
3"	100.0
2"	100.0
1 1/2"	84.7
1"	70.3
3/4"	62.2
1/2"	51.9
3/8"	45.5
1/4"	
No. 4	32.6
No. 8	22.3
No. 16	15.5
No. 30	10.6
No. 50	7.0
No. 100	5.0
No. 200	3.6



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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERS & PROFESSIONAL SERVICES
• GEOTECHNICAL DIVISION

DEPOSIT No. 467

GRAIN SIZE ANALYSIS

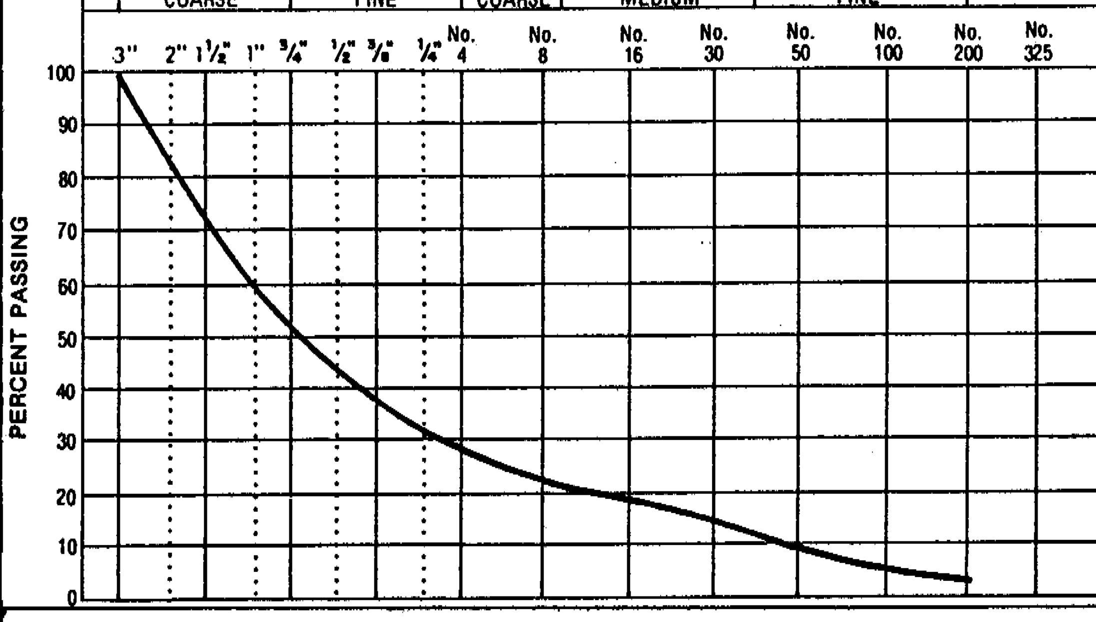
SAMPLE 467-C(e) DEPTH 5.0'-13.0'

DATE SAMPLED Oct. 10, 1976 SAMPLED BY SA

LAB TEST NUMBER 122HA

GRAVEL SIZES		SAND SIZES			FINES
48.8 %	23.0 %	6.2 %	10.0 %	8.9 %	3.1 %
COARSE	FINE	COARSE	MEDIUM	FINE	

MAX. SIZE	% > 3"
5"	3.3



SIEVE SIZE	PERCENT PASSING
3"	100.0
2"	85.4
1 1/2"	72.3
1"	58.8
3/4"	51.2
1/2"	42.3
3/8"	37.2
1/4"	
No. 4	28.2
No. 8	23.2
No. 16	19.0
No. 30	14.6
No. 50	9.0
No. 100	5.0
No. 200	3.1

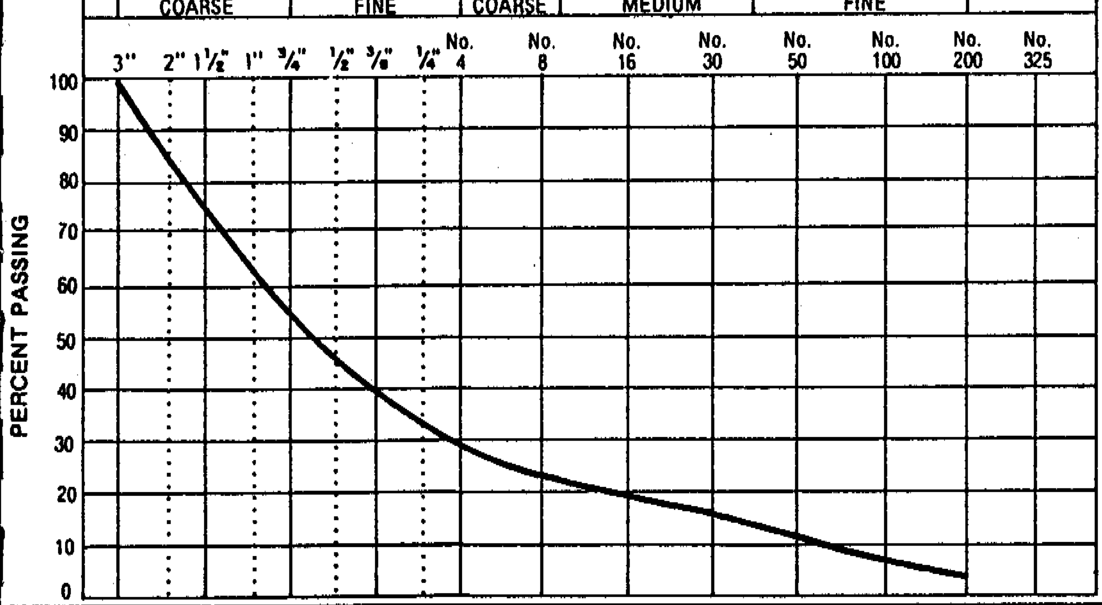
SAMPLE 467-D(e) DEPTH 2.0'-12.0'

DATE SAMPLED Oct. 11, 1976 SAMPLED BY SA

LAB TEST NUMBER 122HA-B

GRAVEL SIZES		SAND SIZES			FINES
45.1 %	27.2 %	5.2 %	9.5 %	9.5 %	3.5 %
COARSE	FINE	COARSE	MEDIUM	FINE	

MAX. SIZE	% > 3"
4"	10.2



SIEVE SIZE	PERCENT PASSING
3"	100.0
2"	85.7
1 1/2"	72.6
1"	62.3
3/4"	54.9
1/2"	44.9
3/8"	38.2
1/4"	
No. 4	27.7
No. 8	22.6
No. 16	19.2
No. 30	16.2
No. 50	11.4
No. 100	6.0
No. 200	3.5

GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERS & PROFESSIONAL SERVICES
• GEOTECHNICAL DIVISION

DEPOSIT No. 467

SUMMARY OF LABORATORY TEST DATA FOR SUITABILITY OF AGGREGATES IN CONCRETE

PETROGRAPHIC ANALYSIS

COARSE AGGREGATE

ROCK TYPE	CLASSIFICATION	TOTAL WEIGHTED COMPONENT %
Quartzite	Strong to very strong, Good	33.7
Quartzitic Sandstone		1.9
Sandstone		59.9
Granite		0.3
Chert	Potentially reactive, Fair	0.1
Ironstone	Friable, Poor	4.0
Clay lumps	Deleterious	0.1
PN:= 121	INTERPRETATION: Good quality for aggregate	100.0

SOUNDNESS OF AGGREGATE - SULPHATE TEST

COARSE AGGREGATE: LOSS= 4.37

FINE AGGREGATE: LOSS= 14.39

OTHER TESTS

LIGHTWEIGHT PIECES IN AGGREGATE: 0.21%

SPECIFIC GRAVITY: FINE: 2.59, COARSE: 25.8

WATER ABSORPTION: FINE: 2.54%, COARSE: 2.11%

ORGANIC IMPURITIES TEST

NUMBER : 4

COAL REMOVED : 2

COAL & ROOTLETS REMOVED :

COAL CONTENT : 0.21%

COMMENTS: Sulphate Test was performed for 5 cycles in Magnesium Sulphate solution.
Specific Gravity Test was performed at 20°C.
Lightweight Pieces were determined by floating on Zinc Chloride solution with a Specific Gravity of 2.0.

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TEST PIT NO. 467-A(e)