Indian and Northern Affairs

Affaires indiennes et du Nord

GRANULAR MATERIALS INVENTORY

PHASE III

Tuktoyaktuk Harbour, Northwest Territories

APRIL 1979

PREPARED BY

HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERS & PROFESSIONAL SERVICES

GRANULAR MATERIALS INVENTORY

PHASE III

TUKTOYAKTUK HARBOUR,

NORTHWEST TERRITORIES

Prepared For

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

By

HARDY ASSOCIATES (1978) LTD.

CALGARY ALBERTA

April, 1979

K4553

HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

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April 11, 1979.

Mr. I. G. Petrie, Head,
Land Use Section,
Land Management Division,
Northern Water, Lands & Forests Branch,
Department of Indian Affairs &
Northern Development,
10 Wellington Street, 6th Floor,
HULL, P.Q.
K1A 0H4

Dear Sir:

Re: Phase III of the Granular Inventory
Tuktoyaktuk Harbour, N.W.T.
DSS File 01SU.C7111-8-0583

We are pleased to submit this report, in fifty (50) copies, which contains information on the sources of granular materials in Tuktoyaktuk Harbour.

We wish to acknowledge the cooperation received during this study from the members of the Tuktoyaktuk community, Department of Indian Affairs and Northern Development, Department of Fisheries of Environment Canada and Supply and Services Canada. We would be pleased, at your convenience, to meet with you, your staff or other government agencies to discuss any aspects of this study.

We appreciate this opportunity of being able to be of service to your analysis.

Yours truly,

HARDY ASSOCIATES (1978) LTD.,

Per:

T. J. Fujino, P.Eng.
Project Manager

TJF:vh
cc: Dr. L. G. Shaw

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1.0 SUMMARY

This report summarizes the results of a drilling program in Tuktoyaktuk Harbour, N.W.T. which was undertaken to identify and delineate sources of granular materials potentially available by dredging. This study represents the third phase of the granular materials inventory for Tuktoyaktuk initiated by the Department of Indian Affairs and Northern Development during 1977.

Four potential borrow sources were identified, containing a total of 630 000 m^3 (824,000 yd^3) unfrozen granular materials. All potential borrow sources contain fine to medium sands with variable gravel and silt content, and are suitable for general backfill, granular subbase and pads for light loading conditions.

Development of two potential borrow sources was considered by cutter suction dredging and by clam bucket dredging. The current range of costs for material placed in the Land Assembly area of Tuktoyaktuk, or other stockpile sites, was estimated at \$3.45 to \$6.90 per m^3 (\$2.67 to

$5.33 per yd^3) by cutter suction dredging, and $3.90 to $7.80 per m^3 ($3.00 to $6.00 per yd^3) by clam bucket dredging. These cost estimates were developed for dredging equipment presently operating in the Tuktoyaktuk area, and it was assumed that such equipment will still be available in the area for this project.

An environmental overview of the dredging operations indicates their impacts to be very limited, and a reclamation plan is proposed for disturbed areas after depletion of stockpiles.

2.0 INTRODUCTION

During 1977, the Government of Canada, through the office of the Department of Indian Affairs and Northern Development (DIAND), commissioned R. M. Hardy & Associates Ltd. of Calgary to carry out an assessment of granular material sources in the vicinity of Tuktoyaktuk, N.W.T. The principle objective of the initial phase of the study was to locate at least 7 600 000 m^3 (10,000,000 yd^3) of sand and gravel, with an emphasis on finding major deposits or stockpiling sites with year-round access from Tuktoyaktuk. This phase of the work encompassed a study area within a 48 km (30 mile) radius around Tuktoyaktuk, N.W.T., and included an investigation of granular deposits on land, near-shore and offshore. The report on the first phase of the study identified 22 potential sources of granular materials, and was completed in August 1977. This report identified the sediments in Tuktoyaktuk Harbour as a primary potential source of granular materials (Deposit 162), and further investigation was recommended to define quality and quantity of available materials.

As the initial stage to further investigate Deposit 162, DIAND authorized a geophysical survey of Tuktoyaktuk Harbour. The report covering the second phase of the granular inventory was submitted during March 1978. The geophysical survey provided bathymetric data and sub-bottom profiles of near surface stratigraphy representing lower density materials overlying higher density materials. Based on previous geologic assessment of the study area, it was concluded that the low density materials are silts and clays, while the higher density materials are sands and gravels. From the geophysical data, areas of minimum low density material thicknesses located in suitable water depths were identified as potentially preferred areas for dredging granular materials. A field drilling program was recommended to identify the quality of granular materials in these areas.

The results of the field drilling program in Tuktoyaktuk Harbour and the recommendations regarding the development of granular resources which were identified in the harbour bottom sediments are presented in this report.

Authorization to proceed with the Phase III study was received by Hardy Associates (1978) Ltd. on January 11, 1979 from Supply and Services Canada, under Contract Serial Number 0SU78-00304.

3.0 SCOPE

The principle objectives of this study were to:

a) provide limited ground truthing data of harbour bottom sediments previously delineated by the 1977 Geophysical Survey,

b) correlate bottom sampling data with the geophysical survey data, and extrapolate these data over the study area,

c) identify quality of granular materials within the harbour bottom sediments,

d) delineate areas potentially suitable for extraction of granular materials by dredging and define quantities available within the borrow areas identified,

e) provide recommendations concerning development of granular materials by dredging, and

f) assess environmental considerations related to dredging activities.

Following completion of field work, preliminary findings were discussed with DIAND representatives. Based on these discussions, directions were received to consider two potential areas for development by dredging. Firstly, dredging of approximately 76 500 m^3 (100,000 yd^3) of material suitable for the Land Assembly area in the Hamlet of Tuktoyaktuk, to be dredged from the vicinity of Conn Island. Secondly,

dredging and stockpiling of approximately 191 000 m^3 (250,000 yd^3) of material suitable for general fill, to be used over a five year period. The source of this material would be south of Fort Hearne Island along the east shore of Tuktoyaktuk Harbour, with stockpiling to be on the east shore.

4.0 PERSONNEL

Project management was carried out by Mr. T. J. Fujino, P.Eng., of Hardy Associates (1978) Ltd. His responsibilities included management of the project team, administration of the contract and cost control.

Mr. N. Hernadi, P.Eng., of Hardy Associates (1978) Ltd., as project engineer, was responsible for planning and supervising the field work, coordinating input from sub-contractors, subconsultants and specialists, and preparing the final report.

Mr. G. Daw, P.Eng., of Hardy Associates (1978) Ltd., was the party chief during survey of test hole locations and the field engineer during drilling operations.

Mr. A. Costin, of Hardy Associates (1978) Ltd., surveyed the test hole locations.

Dr. V. N. Rampton, of Terrain Analysis and Mapping Services Ltd., the geological subconsultant to Hardy Associates (1978) Ltd., provided geological input for delineation of

potential borrow sources and for identification of potential stockpile areas. He also reviewed the study findings and recommendations.

Dr. P. McCart, of Aquatic Environments Ltd., was retained as a subconsultant to assess the impacts of dredging activities on the aquatic environment.

5.0 INVESTIGATIONAL PROCEDURE

5.1 Field Work

5.1.1 Planning

Based on the previously obtained geophysical data, 33 test hole locations were selected for harbour bottom sampling from the ice surface. A tentative schedule for survey and field drilling was established for February 1979. This was followed by reviewing the proposed field work with the local residents. The meeting with the Hamlet of Tuktoyaktuk council, on February 5, 1979 was attended by Mr. C. J. Cuddy (DIAND, Inuvik), Mr. R. T. Barnes (Fisheries & Environment Canada, Inuvik) and Mr. N. Hernadi (Hardy Associates, Calgary). A brief presentation was made to the Council on the proposed investigation, and their acceptance of the proposed scope of the drilling program was obtained. The test hole locations were then finalized in consultation with Dr. V. N. Rampton, the geological subconsultant.

Approval to proceed with the field work was received on February 7, 1979 from Mr. A. E. Ganske (Regional Manager, Land Resources, DIAND, Yellowknife), and the schedule for field work was finalized for the period of February 12 to 23, 1979.

5.1.2 Survey of Test Hole Locations

Survey of test hole locations was carried out between February 12 and 17, 1979, by a two-man Hardy Associates survey crew, assisted by a local resident who acted as driver and helper. Surveying was by the traverse method using parallactic distance measurements, which resulted in an accuracy of ±10 m in locating test holes. The surveyed test hole locations are shown on the site map.

5.1.3 Field Drilling

The field drilling program was conducted between February 18 to 24, 1979. Drilling was carried out on a 24 hour basis utilizing two shifts per day. Each drill crew consisted of the Hardy Associates field engineer, a driller

and drill helper. The drill crew and equipment was contracted from SDS Drilling Ltd. of Calgary.

All 33 test hole locations were drilled successfully. The depth of drilling below ice surface ranged between 9.0 and 17.3 m, and sediment penetration averaged 6.0 m.

The drilling equipment utilized was a winterized Mayhew 500 Heli-drill equipped with mud pump for wet drilling. The drill rig consisted of two tent-enclosed sleighs. The larger sleigh housed the rig and mud pump. The smaller sleigh housed a Herman-Nelson heater and light plant, and also served as storage space. Water for circulation was obtained directly from the harbour after augering through the ice. The drill rig was towed by a Caterpillar 966C loader, which was also used to snow plow the ice surface to provide access to test hole locations.

The drill rig was mobilized from Inuvik, and drilling personnel were transported from Calgary.

The drilling procedure involved augering two 14 cm diameter holes approximately one metre apart through the ice. The first hole served as access for the mud pump suction hose, with the second ice hole being the drill hole. Test holes into the harbour bottom sediment were advanced by wet drilling, usually utilizing 12 cm insert bits. Casing and drilling mud were on hand if drilling conditions required their use. However, it was possible to keep all test holes open to a sufficient depth without setting casing.

Since undisturbed samples were not required and frozen soils were not encountered at any test hole location, samples were obtained predominantly by driving a 5.1 cm diameter split spoon sampler into the soil. This sampler is advanced by a standard driving energy of 475 Nm per blow and the number of blows required to advance the sampler provides an estimate of relative density (or consistency) of the soil strata encountered (ASTM D1586, Standard Penetration Test). This method of sampling was employed successfully in strata consisting predominantly of sands.

In strata of gravelly soils, some samples were obtained by rotating a 7.6 cm diameter thick-walled Shelby tube fitted with cutting teeth into the soil.

Thin walled 7.6 cm diameter Shelby tubes were pushed into the soil hydraulically to obtain samples of soft sediments. As well, bulk samples of soft materials, and occasionally of sand, were obtained by rotating an insert bit into the soil without circulation, thus allowing the lower portion of drill stem to become plugged.

Other sampling tools which were available included piston samplers, 10 cm diameter thick and thin walled Shelby tubes and an 8.9 cm diameter split spoon sampler.

All samples were logged, labelled and packaged, and were allowed to freeze prior to shipping at completion of the drilling program.

5.1.4 Logistics Support

All travel by Hardy Associates (1978) Ltd. personnel and SDS Drilling Ltd. personnel, as well as freight

shipments, were by PWA scheduled air service between Calgary and Inuvik. Personnel and freight transport between Inuvik and Tuktoyaktuk was over an ice road using a 4x4 crew cab truck rented in Inuvik. The drilling rig was trucked between Inuvik and Tuktoyaktuk.

E. Gruben's Transport, a local contractor, provided room and board for the field personnel, as well as diesel fuel and services for minor repairs to vehicles and equipment. Support equipment obtained locally included a bombadier during the survey phase and a Caterpillar 966C loader during the field drilling program. Gasoline was obtained directly from the Hamlet of Tuktoyaktuk.

The survey crew was mobilized to Tuktoyaktuk on February 11, 1979, and demobilized to Calgary on February 25, 1979, at the completion of drilling.

5.2 Laboratory Testing

The testing program on samples returned to our laboratory included the following tests:

a)	Mechanical grain size analysis	ASTM C-136
b)	Grain size analysis of fines by the hydrometer method	ASTM D-422
c)	Plastic limit of fines	ASTM D-424
d)	Liquid limit of fines	ASTM D-423

All tests were performed according to the applicable ASTM (American Society for Testing and Materials) test procedures published in the current Annual Book of ASTM Standards.

The results of the laboratory testing program are included in Appendix A.

6.0 ASSESSMENT OF DATA

Detailed soil profile logs for all test hole locations are included in Appendix A. An explanation of symbols and terminology used on the test hole logs is given in Appendix B.

6.1 Nature of Granular Materials and Overburden

At most test hole locations the upper stratum of harbour bottom sediments is comprised of a soft, low plastic, grey, clayey silt. The thickness of this stratum ranges from as little as 0.2 m (TH3) to the full depth of drilling into the sediment of 8.7 m (TH6). However, in most test holes, the thickness of the initial soft sediment stratum ranges between 0.2 to 3.0 m, averaging 1.6 m.

The materials encountered below the soft sediment are generally sands of various gradation, and variable silt and gravel content. At these locations the interface between soft silts and denser sands is frequently not well defined, but tends to be a transition zone, usually less than 1 m in thickness, of increasing density and sand content with depth.

At a few test hole locations (TH4, 7, 9 and 28), a distinct interface between the upper silt stratum and the underlying material is marked by a thin gravel stratum ranging between 0.3 and 1.5 m in thickness. These gravel strata are usually underlain by sand.

Frequently, a gradual change in texture of the sands was noted with depth. Where a textural change was encountered, the upper 1 to 4 m portion of the sand profile has a wider distribution of particle sizes, including gravel sized particles. The underlying sand is usually poorly graded, fine-grained and variable in silt content. This textural change is typical of the depositional sequence of surficial materials over much of the study area, which consists of glacial outwash overlying deltaic sands.

The angularity of the coarse sand and gravel sized particles is characterized predominantly as subrounded to subangular, with minor components of rounded as well as angular particles.

Grain size distribution determinations were carried out on samples returned to our laboratory. The results of these analyses are included in Appendix A.

6.2 Correlation with Geophysical Data

Data from the field drilling program were correlated with the previously obtained geophysical data for water depth and soft sediment thickness. Very good agreement was noted between the drilling and geophysical data, with an accuracy of ±1 metre, where test holes were located at or in close proximity to geophysical survey lines. Thus the geophysical data was used to extrapolate the test hole data over the study area. It should be noted that between geophysical survey lines and/or test hole locations the soil stratigraphy information has been inferred through interpolation.

6.3 Identification of Potential Borrow Sources

Four areas were identified and delineated within the northern portion of Tuktoyaktuk Harbour as potential borrow sources of unfrozen granular materials. These areas contain fine to medium sands with variable gravel and silt content, and are overlain by a thin stratum of clayey silt.

The granular materials within the delineated areas are rated as "fair" for construction usage, in accordance with the DIAND classification system (Table B1, page B-13, Appendix B).

The four areas identified have been designated as Potential Borrow Sources "A", "B", "C" and "D". These areas are outlined on the map included at the end of the report, and are discussed in the following sections.

6.3.1 Potential Borrow Source "A"

Potential Borrow Source "A" is located adjacent to Conn Island, and is the closest source identified to the Hamlet of Tuktoyaktuk. The outlined borrow source covers an area approximately 5.2 ha (13 acres). The water depth within the outlined area generally ranges from 2 to 10 m, with an overburden cover of soft clayey silt less than 2 m in depth. Two stratigraphic sections through this area are shown on Figures 6.1 and 6.2.

Test hole data in this area indicate that the better quality granular materials are generally found in the top 3 m of the soil profile, and dredging should be carried

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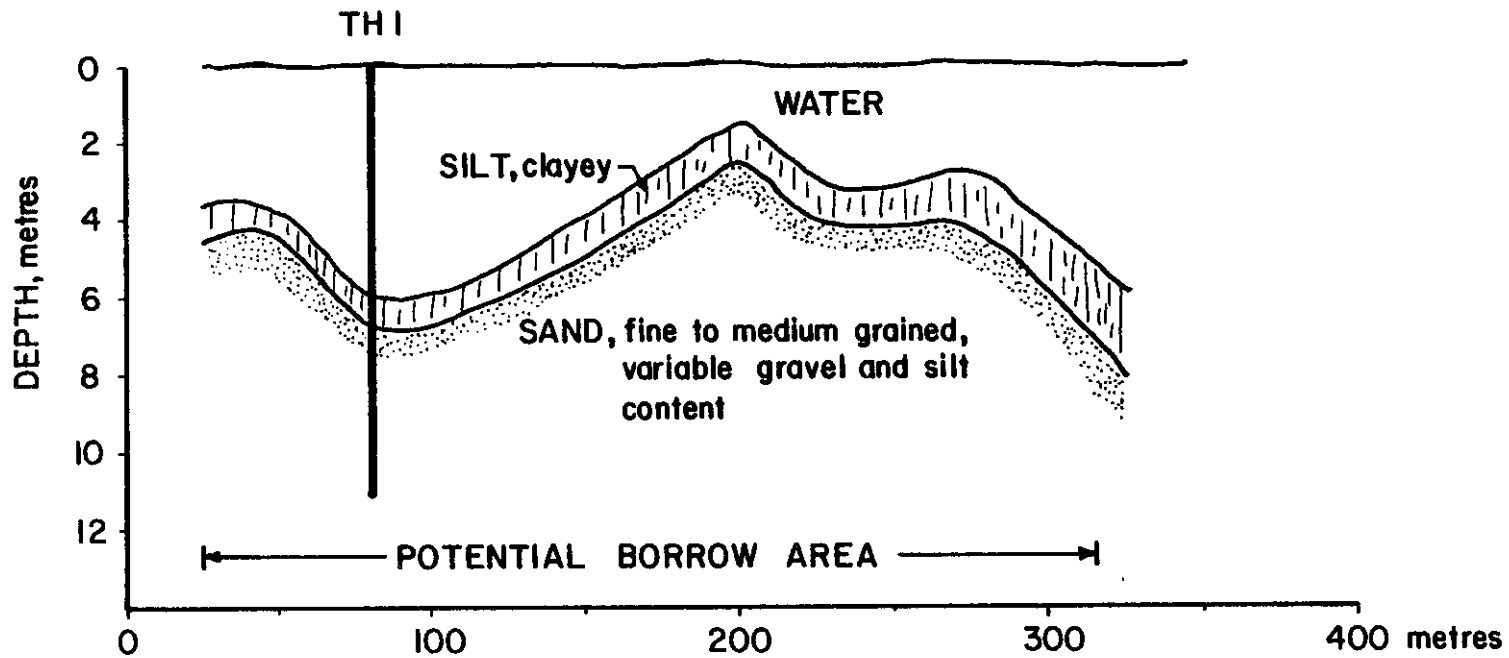
FIGURE 6-1

POTENTIAL BORROW SOURCE "A"

SECTION A-A'



NOTE: 1. Stratigraphy is inferred from geophysical soundings, except at testhole
2. Horizontal scale is 1:2500

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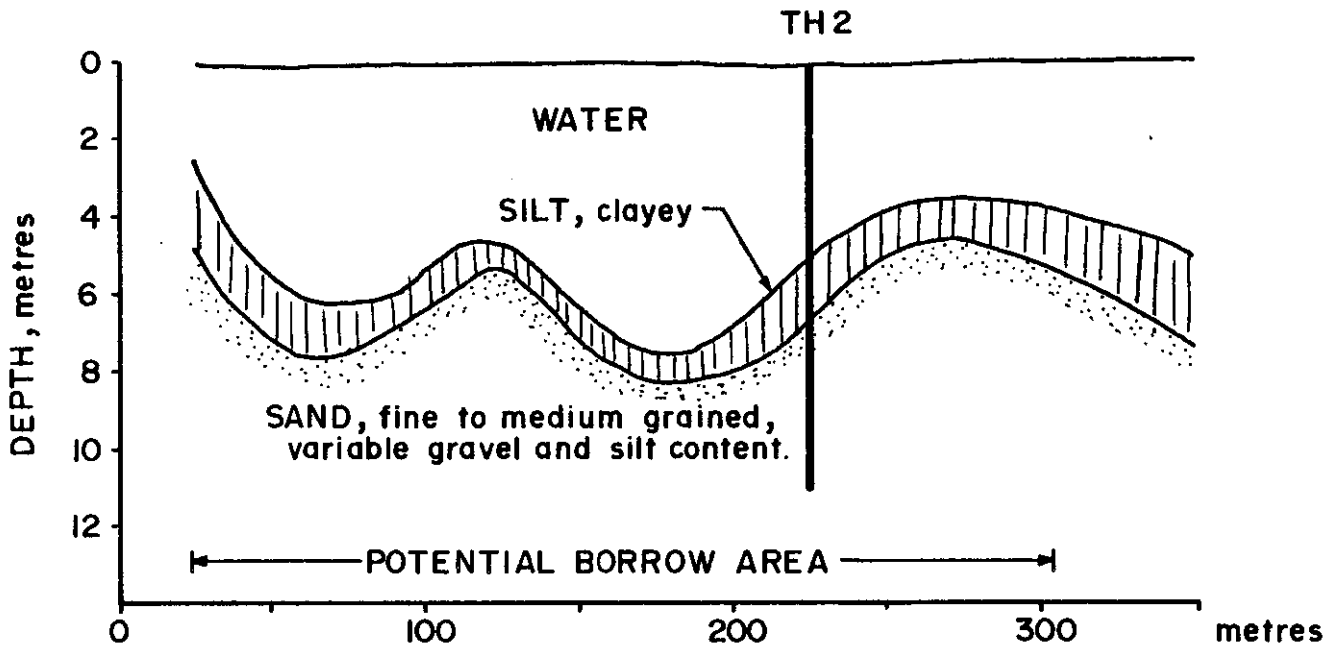
FIGURE 6·2

POTENTIAL BORROW SOURCE "A"

SECTION B - B'



NOTE : 1. Stratigraphy is inferred from geophysical soundings, except at test hole.

2. Horizontal scale is 1·2500

out in a manner that maximizes the recovery of these materials. The material obtained from this area will be poorly graded, fine to medium sands with a variable, but significant gravel content. Silt content will also vary. Test hole data indicate that gravel content in this potential borrow source could be highest among the four potential borrow sources identified.

The quantity of granular materials available in the top 3 m of sand within the outlined area is approximately 157 000 m^3 (205,000 yd^3). The average overburden thickness of 1 m will yield a net recovery of 75% granular materials, assuming an average dredging depth of 4 m.

6.3.2 Potential Borrow Source "B"

Potential Borrow Source "B" is located south of Fort Hearne Island and extends as a narrow strip adjacent to the east shore of Tuktoyaktuk Harbour. The outlined borrow

source covers an area of approximately 7.8 ha (19 acres). The existing water depth, within the outlined area, ranges from 3 to 9 m, with an overburden thickness averaging 1 m. A stratigraphic section through this area is shown in Figure 6.3.

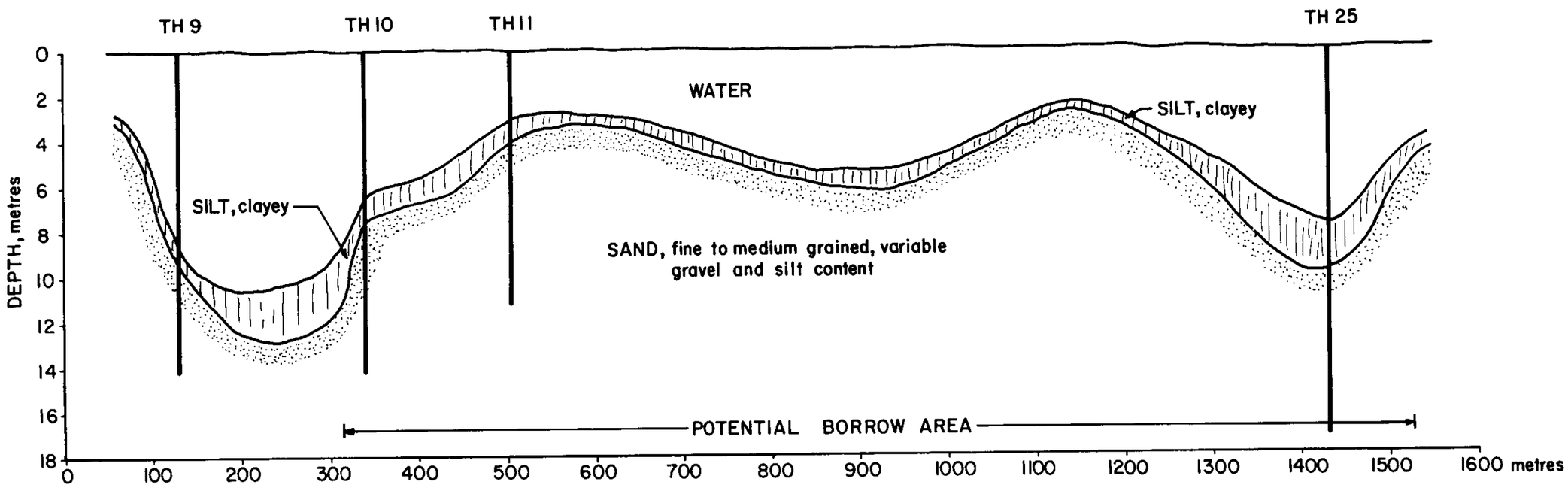
The better quality granular materials classified as "fair" quality sands, are generally found in the upper 2 to 3 m of the sand stratum. The quantity of granular materials within this zone of the outlined area is approximately 200 000 m^3 (262,000 yd^3). Where the average overburden thickness is 1 m, the net recovery of granular materials will be in the order of 70%, assuming an average dredging depth of 3.5 m.

6.3.3 Potential Borrow Sources "C" and "D"

Two areas designated as Potential Borrow Sources "C" and "D" have been delineated in the central portion of Tuktoyaktuk Harbour. Potential Borrow Source "C" is located

POTENTIAL BORROW SOURCE "B"

SECTION C-C'



NOTE: 1. Stratigraphy between testholes is inferred from geophysical soundings
2. Horizontal scale is 1:5000

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	FIGURE 6·3

along the east side of the harbour near the mouth of Mayogiak Inlet, and Potential Borrow Source "D" is near the west side, opposite Cache Point. The outlined areas cover approximately 5.6 ha (14 acres) and 3.5 ha (9 acres), respectively. Both areas are located in water depths ranging between 3 and 9 m, with average overburden covers of 1 m.

The better quality granular materials classified as "fair" quality sands, in both potential sources, are within the upper 2 to 3 m of the soil profiles. These zones will yield approximately 168 000 m^3 (220,000 yd^3) and 105 000 m^3 (137,000 yd^3) of granular materials from Potential Borrow Sources "C" and "D", respectively.

With an average overburden thickness of 1 m, the net recovery of granular materials will be in the order of 70%, assuming an average dredging depth of 3.5 m.

7.0 DEVELOPMENT OF HARBOUR BOTTOM GRANULAR RESOURCES

7.1 Potential Borrow Sources Considered for Development

Based on discussions with DIAND representatives following completion of field work, two potential borrow sources were to be considered for development. These include Potential Borrow Source "A" for 76 500 m^3 (100,000 yd^3) of material suitable for the Land Assembly site in Tuktoyaktuk, and Potential Borrow Source "B" for stockpiling 191 000 m^3 (250,000 yd^3) of material to be used as general fill over a five year period. The map at the end of the report shows the locations of these areas.

7.2 Engineering Considerations

7.2.1 Dredging Equipment Suitability

As discussed in Section 6.0, the better quality granular materials within all the identified potential borrow sources are generally located in the upper 3 m of the

soil profile, underlain by up to 2 m of clayey silt overburden. Consequently, to maximize recovery of the best quality materials, the dredging technique utilized should be capable of selectively and separately removing overburden, and be able to dredge within a soil profile of limited thickness.

The equipment best suited for this type of dredging operation is a cutter suction dredge. Such a dredge employs a cutter head to loosen the sediment and a suction pipe to remove the loosened material. The cutter suction assembly is mounted on a swinging ladder that can operate at variable depth. Thus the dredging depth can be closely controlled and separate overburden disposal can be accomplished. Discharge from the dredge is through a floating pipeline to shore. Onshore pipelines can carry the dredged material to stockpile or overburden disposal sites.

A barge mounted clam bucket dredge could also be considered for this work. In this method of dredging, the clam bucket is dropped into the sediment and each bucket

load of dredged material is dumped into a barge for transport, or directly to a stockpile site onshore. Overburden removal is feasible with this method of dredging by casting bucket loads of dredged material outside of the borrow area. Controlling overburden stripping, as well as the profile and depth of dredging within the borrow area is less precise with the clam bucket as compared to cutter suction dredging.

Suction dredging is accomplished by jetting a suction pipe into the sediment and obtaining material from the cone shaped depression crater formed above the tip of the suction pipe. This method of dredging is not well suited for selectively removing a thin overburden cover or dredging to a specific profile within limited depths. Therefore, suction dredging was not considered further in this study.

7.2.2 Development of Land Assembly Area

7.2.2.1 Dredging by Cutter Suction Method

This method of dredging produces large quantities of slurried material, and planning for dredging operations must include the following:

a) prebuilding of starter dykes to contain the dredged material,

b) maintaining of dykes and piling of dredged materials during dredging operations,

c) routing of the onshore slurry pipeline to minimize relief along pipeline route, and to accommodate road crossings, etc.,

d) provision for an onshore pipeline to dispose overburden material, if required, and

e) provision to drain a large volume of water from the fill site (i.e., up to 130,000 litres per minute).

During dredging, the slurry discharge should be monitored with respect to the quality of dredged materials. Thus, if excessive fines are observed in the discharge, the dredging pattern can be altered, or the discharge can be directed to the overburden disposal site. Since the dredged material is deposited as a slurry in the stockpile area, sorting of particles sizes will occur. The coarser particles will settle in the vicinity of the discharge pipe, while finer particles will remain in suspension longer. Consequently, some of the fines contained in the dredged material could be removed from the stockpile area along with the effluent draining from the site.

Dredged overburden and/or effluent draining from the land assembly area could be disposed in one of the nearby ponds. However, since large volumes of materials are involved, provisions to remove water from the pond will be required to preclude the possibility of flooding. Alternately, overburden disposal and/or effluent drainage could be direct into the Beaufort Sea to the west, or back to the harbour. The environmental impacts of these alternatives are discussed in a subsequent section.

7.2.2.2 Dredging by Clam Bucket Method

Dredging by the clam bucket method would be a much slower and less complex operation as compared to the cutter suction method. Materials dredged by the clam bucket could be stockpiled onshore directly by the dredge, when the dredge is located close to shore, or transport to shore would be by barge, when dredging further offshore. Movement of material onshore to the Land Assembly area would be by trucking which may necessitate an interim stockpiling requirement.

If the material is granular, sufficient drainage of the dredged material may occur during handling whereby trucking of the material may be possible without delay to the Land Assembly area. Where fine-grained material is encountered by the dredge, it can be cast aside by the clam bucket, or an alternate dredging location can be selected. Whereas the most efficient means of dredging by clam bucket involves excavation from a single area, thus forming a deep cone shaped depression crater within the sediment, the soil stratigraphy at the proposed borrow site is such that selective dredging from the upper 3 m of the sand will yield better quality materials. To achieve selective shallow dredging by the clam bucket, frequent repositioning of the dredging barge will be required.

7.2.3 Development of General Fill Stockpile

7.2.3.1 Dredging by Cutter Suction Method

Dredging by cutter suction from Potential Borrow Source "B" would be a similar operation to cutter suction dredging from Potential Borrow Source "A" for the Land

Assembly site. Consequently, the considerations discussed in the previous section will apply.

Two sites have been selected on the east shore of Tuktoyaktuk Harbour as potential stockpile sites for materials dredged by cutter suction, as indicated on the enclosed map. Both sites are low lying areas nearshore, but are beyond the limits of wave action and normal water level fluctions as a result of tides and storm surge activity. These sites have been selected to minimize pumping distance and pumping height for the dredged slurry. Both sites represent inset thermokarst basins within a flat sandy outwash bench capped with silt. Some peat is present in the lower lying areas.

The northerly potential stockpile site covers in the order of 5.2 ha (13 acres) and the southerly site is approximately twice that size. Either site could accommodate 191 000 m^3 (250,000 yd^3) of dredged material with the height of stockpile not exceeding 4 m.

Drainage of effluent associated with stockpiling at the northerly site could be accommodated in a pond immediately to the east of the stockpile area. Alternately, effluent drainage could be directed back into the harbour. There are no ponds adjacent to the southerly potential stockpile site, consequently effluent drainage from this area must be returned to the harbour. The dredged overburden could be disposed into a nearby pond through a separate pipeline regardless of the stockpiling location, or it could be returned into the harbour. If a pond is used for effluent drainage and/or overburden disposal, provisions to drain water from the pond will likely be required, to accommodate the large volumes of water and soil that will be deposited in the pond. The environmental impacts of effluent and overburden disposal are discussed in a subsequent section.

Drainage of the dredged granular material will be relatively rapid at the stockpile site. It is therefore anticipated that use of the stockpiled material can commence shortly after dredging operations are complete.

The stockpiled material will be difficult to rip when frozen. Therefore, removal of stockpiled material will probably be limited to a summer operation involving transport by barge, unless blasting of the stockpile is considered during winter.

7.2.3.2 Dredging by Clam Bucket Method

Dredging by the clam bucket method from Potential Borrow Source "B" will be a similar operation to that discussed in Section 7.2.2.2, and will require transport by barge to the stockpile site.

Since the production rate of a clam bucket dredge is relatively low compared to cutter suction dredging, clam bucket dredging from Potential Borrow Source "B" could be carried out as fill material is required on a yearly basis, as opposed to stockpiling a five year supply of material. Using this method of dredging from Potential Borrow Source "B", stockpiling should then be at a location accessible to the user site by overland road during summer. This will preclude barging the dredged material on two separate occasions.

7.3 Availability of Dredging Equipment

Northern Construction Company of Vancouver, B.C. currently operates an Ellicott Series 3000, "Super-Dragon", cutter suction dredge which is based out of Tuktoyaktuk. This vessel is self-propelled, with a dredging depth range of 1.5 m and 18 m. This dredge has a 0.61 m suction pipe bore, and is capable of dredging aggregate at a rate, in excess of, 15 300 m^3/day (20,000 yd^3/day). Up to 1500 m of discharge line can be used without a booster pump, if pumping above sea level does not exceed heights in the order of 5 m. A small tender tug is required as support to assist in anchor relocation, as well as for fuel supply and to ferry personnel. This dredge is under contract to Esso Resources Canada Limited for the 1979 summer season. However, it may be available for dredging in Tuktoyaktuk Harbour after break-up until approximately July 15, 1979, and after October 1, 1979 until freeze-up.

Northern Construction Company does not currently have committments for their cutter suction dredge in the Tuktoyaktuk area beyond the 1979 season. Consequently, this dredge may be moved out of the Tuktoyaktuk area during 1980.

However, the dredge may be available for harbour dredging during 1980, prior to its demobilization.

Arcnav Marine Limited of Calgary operates a barge mounted clam bucket dredge in the Tuktoyaktuk area. Current committments for this dredge indicate that this unit would likely be available for harbour dredging during 1979, as well as during 1980. The estimated daily production rate for this dredge is in the order of 1500 m^3 (2,000 yd^3).

7.4 Economic Considerations

The cost of dredging granular materials from Potential Borrow Source "A" for the Land Assembly site has been estimated by Northern Construction Company to be in the order of $2.60 to $5.20 per m^3 ($2.00 to $4.00 per yd^3) for dredging during 1980, using their cutter suction dredge presently operating in Tuktoyaktuk. This estimate includes the onshore work and represents the cost of the material in place at the Land Assembly site. Since the net dredge production may only be in the order of 75% due to the necessity for overburden removal from the borrow source, the

actual cost of dredged material in place at the Land Assembly site may rise to the order of $3.45 to $6.90 per m^3 ($2.67 to $5.33 per yd^3). This range of costs would also apply to granular material dredged from Potential Borrow Source "B" and stockpiled on the east shore of Tuktoyaktuk Harbour. It should be noted, however, that this cost estimate is only valid if Northern Construction Company's dredge is available in the Tuktoyaktuk area.

On the basis of their clam bucket dredge, presently operating in the Tuktoyaktuk area, Arcnav Marine Limited has estimated the current in place cost at the Land Assembly site for granular materials dredged from Potential Borrow Source "A" at $3.90 to $7.80 per m^3 ($3.00 to $6.00 per yd^3). Unit costs at the high end of the estimate apply when barging of dredged material is required. This cost estimate also applies for clam bucket dredging from Potential Borrow Source "B" and barging to a stockpile site.

Barging of stockpiled material across Tuktoyaktuk Harbour, including onshore handling costs, is currently estimated at $2.60 to $3.90 per m^3 ($2.00 to $3.00 per yd^3).

7.5 Environmental Considerations

7.5.1 Impacts of Dredging on Shoreline Erosion

Since the better quality granular materials are found in the upper portion of the soil stratigraphy, the recommended depth of dredging for both development areas, Potential Borrow Sources "A" and "B", is limited to approximately 4 to 5 m. This includes 1 to 2 m of overburden and 3 m of granular materials. Consequently, since the harbour bottom profile will not be altered significantly as a result of dredging, the existing current and wave patterns should not be affected, and the impacts of the proposed dredging on shoreline erosion should be negligible. As a precautionary measure for nearshore dredging operations, it is recommended that dredging to the full depth of 5 m below the existing harbour bottom be allowed only at distances greater than 30 m beyond the shoreline.

7.5.2 Impacts of Dredging and Stockpiling on the Aquatic Environment

There have been a number of studies describing communities of organisms found along the Beaufort Sea coast

of the Tuktoyaktuk Peninsula but few include sample data for stations within the harbour itself. None of which includes site-specific data for the precise areas within the harbour where dredging activity is planned. The following discussion is, therefore, general in nature.

7.5.2.1 Outline of Biological Information

Wacasey (1975) has divided the marine environment of the southern Beaufort Sea into four zones, on the basis of physical and biological parameters. Tuktoyaktuk Harbour and indeed the whole shoreline of the Tuktoyaktuk Peninsula lie within the area which he designates as the Estuarine Zone which extends out to depths of 10 to 15 m. Because of the influence of fresh water from the Mackenzie River, salinities within this zone are usually under 20‰ (parts per 1000) and may be as low as 0.1‰ in Kugmallit Bay. On July 20, 1973, for example, salinity within the harbour was 16.5‰ at a temperature of 4.6°C, while offshore in the bay, salinity was only 5.0‰ at a temperature of 10.0°C. This information, together with some biological data, suggests

that Tuktoyaktuk Harbour is a protected embayment, characterized by relatively stable environmental conditions. As such, it might be expected to be more productive biologically than Kugmallit Bay and the more exposed coastline of the Tuktoyaktuk Peninsula, particularly of those organisms which have difficulty adapting to wide fluctuations in temperature and salinity and to heavy sediment loads.

Among the major groups of animals which might be affected by dredging activity are:

1) The zooplankton. Grainger (1975) reports that protected inshore stations, including Tuktoyaktuk Harbour, supported much greater densities of zooplankton than did offshore stations but that the number of species taken was very small (i.e., a maximum of 3 in Tuktoyaktuk Harbour).

2) Zoobenthos. Wacasey (1975) summarized data concerning the diversity and biomass of zoobenthos in the southern Beaufort Sea (Table 7.1). Both the diversity and biomass of zoobenthos tend to be

TABLE 7.1

Summary of Data Describing Zones in Southern Beaufort Sea (from Wacasey, 1975)

Zone	Water Depth (m)	Salinity (‰)	Temperature (°C)	No. of Species per Station	Biomass	
					Range (g m^{-2})	Average (g m^{-2})
Estuarine	0-15	0.1-20	up to 16.6	1-32 usually <20	0.1-20	2
Transitional	15-30	20-30	7.0 to -1.58	20-40	1-20	5
Marine	30-200	30-33	-0.1 to -1.58	3-81	1-72	14
Continental Slope	200-900	34-35	-0.31 to 0.40	31-53	1-8	4

lowest in the Estuarine Zone. His figures indicate little difference in either parameter between samples taken in Tuktoyaktuk Harbour and offshore in Kugmallit Bay. He does note, however, that in Mason Bay, another protected embayment on nearby Richards Island, biomass values for the zoobenthos are higher than the average for the entire Estuarine Zone.

The zoobenthos, which in shallow nearshore environments in the Arctic live primarily in rather than on the bottom substrate, are the group most sensitive to the effects of dredging. They may be removed along with the excavated materials or smothered by accumulations of displaced sediments.

3) Fish. Galbraith and Fraser (1974) took 12 species of fish in Tuktoyaktuk Harbour in 1974. Of these, seven (*Coregonus autumnalis, C. sardinella, C. clupeaformis, C. nasus, Stenodus leucichthys, Lota lota,* and *Myoxocephalus quadricornis*) can be considered to be predominantly freshwater and/or

anadromous, and five (*Osmerus mordax, Eleginus gracilis, Liopsetta glacialis, Platichthys stellatus,* and *Acantholampenus mackayi*) can be considered to be predominantly marine. The whitefishes and ciscoes (*Coregonus* sp. and *Stenodus* sp.) are very important to domestic fisheries in the area. It is likely, however, that these species, which are able to utilize a diversity of foods and which spawn in fresh water well away from the harbour, are less sensitive to the effects of dredging than some of the marine species which are more dependent on the benthos for food (i.e., the flatfishes *Liopsetta* and *Platichthys*) and which are more likely to spawn within the harbour itself.

One species which was not taken in the harbour but which sometimes occurs in large numbers in the vicinity of Tuktoyaktuk is the herring (*Clupea harengers*). Hunter, as quoted in Galbraith and Fraser (1974), suggests that its appearance is associated with spawning.

Jones and Den Beste (1977) studied fish populations at Tuft Point on the Tuktoyaktuk Peninsula approximately 40 km northeast of the town of Tuktoyaktuk. The general conclusions of the study were that coastal waters in the vicinity of Tuft Point support a relatively abundant and diverse fish fauna (16 species). The region is of particular importance as a rearing area for the juveniles of anadromous species such as ciscoes, whitefish, and inconnu. The most important fish habitat zones are the nearshore shallows including bays and lagoons and the entrance areas of bays and lagoons. Fish are not nearly as abundant in offshore areas.

7.5.2.2 Potential Impacts and Mitigation

No site-specific biological work has been done in the area where dredging activities are proposed, and the following recommendations are necessarily general.

Dredging will result in the removal of substrate along with those organisms which live within and, to some extent, on it. It will also lead to a marked increase in suspended solids loads causing sedimentation of substrates and increased turbidity in the vicinity of the dredging activity. Phytoplankton production would be reduced within the turbid area surrounding the dredging activity as a result of reductions in light penetration. Among the animals, the zoobenthos which inhabit the substrate would be most affected by this activity both by their removal along with dredged materials and by smothering in nearby areas of sedimentation. Except for the possibility that spawning areas of some of the marine species might be destroyed, fish, which are highly mobile, would be least affected.

The impact of dredging activity can be reduced by:

a) minimizing the area of disturbance,

b) minimizing the time period over which disturbance occurs, and

c) using methods which minimize suspended solids loads and sedimentation of surrounding areas.

Overburden and dredging effluent disposal would probably be most damaging if it occurred within the harbour where sedimentation rates are likely to be lower than at offshore sites in the Beaufort Sea. If disposed of into the harbour, the existing substrates in the disposal areas should be similar to the sediments in the turbid water.

Disposal of turbid water in the Beaufort Sea would probably be less damaging than disposal in the harbour because offshore locations and the communities inhabiting them are already subject to greater environmental variability and greater sedimentation rates than those within the harbour. Disposal in this area would be best timed to coincide with early summer peaks in suspended sediment loads originating from the Mackenzie River.

Disposal on land would, of course, have the least effect on aquatic organisms. If a pond is used for disposal, it should be one which is relatively shallow and therefore fishless and has no direct connections to streams.

Overburden and effluent disposal from the stockpile sites should be placed so as to minimize impact on

Fresh Water Creek. Where necessary, berms and ditches should be provided to reduce drainage into natural waters.

7.5.3 Impacts of Dredging and Stockpiling on the Terrestrial Environment

A preliminary assessment of the terrestrial environment in the vicinity of the stockpile and Land Assembly sites was made on the basis of literature review, interpretation of aerial photographs and examination of some photos taken on the ground. Site-specific data have not been collected, therefore the following discussion is general in nature.

7.5.3.1 Description of the Environment

The vegetation of the stockpile and Land Assembly areas is characterized by sedge moss meadows. These meadows, typical of much of the coastal plain beside the Beaufort Sea, are made up of a closed cover of sedges, cottongrass and moss, together with some shrubs (Corns, 1974). Active

layers are thin (<0.6 m) and ground ice is present in the form of wedges and lenses. It is the ice wedges that give some of these areas the characteristic pattern of low centre polygons. The soils are poorly drained and high in organic matter content.

Regionally swans, ducks and geese use the extensive wet meadows and low centre polygon areas for nesting, feeding and staging (DIAND, 1972). Since the proposed sites are small and close to Tuktoyaktuk they may, at most, be used occasionally by nesting swans or ducks.

Caribou do not use these areas extensively probably because of the proximity to Tuktoyaktuk. Arctic ground squirrels, arctic fox and lemmings may utilize dry slopes and hilltops adjacent to the stockpile sites.

7.5.3.2 Potential Impacts

The vegetation of the proposed sites will be destroyed by stockpiling and some vegetation on small adjacent areas is likely to be killed by siltation. The

impacts of this development on the vegetation are quite small and localized because this plant community type is very common along the coastal plain. The Land Assembly area which will eventually be used for a housing development will be permanently altered. The biological productivity of the stockpile sites will be restored at least in part by the mitigative measures including revegetation outlined in the section on reclamation.

No significant impacts on birds or mammals are anticipated adjacent to the Land Assembly area or stockpile sites because of the low utilization and small areas involved. If a pond is used for overburden and effluent disposal, siltation and introduction of salt water will occur, and although the pond will remain intact it is likely to be shallower. The impacts of altering one or two small ponds in this manner should be of little or no significance regionally to nesting or migrating birds.

7.5.3.3 Reclamation

Since the Land Assembly area will be used for a housing development reclamation is not necessary. Stockpile

sites, silted areas where natural vegetation has been smothered, and the roadbed utilized for removal of stock-piled material will require reclamation. The recommended approach is to establish a seeded plant cover on these areas which will encourage the natural invasion of plant species native to the area.

As preparation for seeding, the site should be deeply ripped with a caterpillar mounted ripping tool. This will serve to mix some native soil high in organic content with the layer of coarse material remaining on the surface 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 10 to 15 cm 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 revegetation success for the first two years is recommended. Although the seed mix includes species that are winter hardy (Younkin, 1976) 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 CONCLUSIONS

The field drilling program in Tuktoyaktuk Harbour yielded data to identify the quality of granular materials in the harbour bottom sediments, and to delineate locations and quantities of unfrozen granular materials potentially recoverable by dredging. The study also provides data on engineering, economic and environmental considerations of developing two potential borrow sources by dredging.

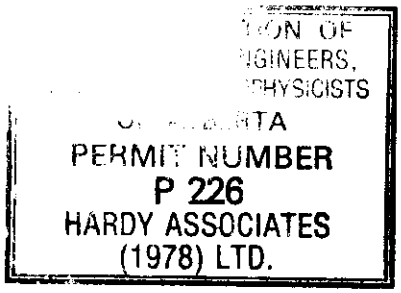
Large quantities of unfrozen, poorly graded fine, and fine to medium sands of variable silt content were located below a stratum of clayey silt in most portions of the study area. Using the DIAND criteria for classification of granular materials, these sands are rated as "poor" to "fair" for construction purposes. Concentrations of "fair" quality, poorly graded, fine to medium sands with variable gravel and silt content were identified in some locations, and discontinuous thin strata of poorly graded gravels were located in scattered areas.

Four potential borrow sources were delineated, containing a total of 630 000 m^3 (824,000 yd^3) unfrozen granular materials. All potential borrow sources contain fine to medium sands with variable gravel and silt content, and are suitable for general backfill, granular subbase and pads for light loading conditions.

Development of two potential borrow sources was considered by cutter suction dredging and by clam bucket dredging. The current range of costs for material placed in the Land Assembly area of Tuktoyaktuk, or other stockpile sites, was estimated at \$3.45 to \$6.90 per m^3 (\$2.67 to \$5.33 per yd^3) by cutter suction dredging, and \$3.90 to \$7.80 per m^3 (\$3.00 to \$6.00 per yd^3) by clam bucket dredging. These cost estimates were developed for dredging equipment presently operating in the Tuktoyaktuk area, and it was assumed that such equipment will still be available in the area for this project. The unit cost of dredging granular materials would certainly be increased if dredging equipment had to be mobilized to Tuktoyaktuk from southern bases.

An environmental overview of the dredging operations indicates their impacts to be very limited, and a reclamation plan is proposed for disturbed areas after depletion of stockpiles.

The volume of "fair" quality granular materials identified as recoverable by dredging falls short of the initial study objective of locating at least 7 600 000 m^3 (10,000,000 yd^3) of sand and gravel in the Tuktoyaktuk area. Based on current discussions, such large quantities of granular materials may not be required in the very near future. As the need for more granular material arises, the upland deposits of granular material which have been identified on the east shore of Tuktoyaktuk Harbour should be investigated in detail for future development.

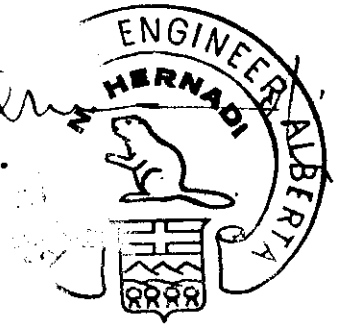


Respectfully submitted,

HARDY ASSOCIATES (1978) LTD.,

Per:

N. Hernadi, P.Eng.
Project Engineer



Calgary, Alberta.
April, 1979.
K4553

576000 m. E.
7708000 m. N.

581000 m. E.
7708000 m. N.

KUGMALLIT BAY

TUKTOYAKTUK ISLAND

FORT ROSS ISLAND

FORT HEARNE ISLAND

CONN ISLAND

CACHE POINT

AVELTIKOK INLET

FRESH WATER CREEK

MAYOGIAK INLET

Potential Borrow Source A

Land Assembly Area

Potential Borrow Source B

Potential Stockpile Site

Potential Borrow Source C

Potential Stockpile Site

Potential Borrow Source D

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

7703000 m. N.
576000 m. E.

7703000 m. N.
581000 m. E.

LEGEND

- Road
- Shoreline: sea
- lake
- river
- Swamp
- Building
- School
- Church
- Tank
- Radio tower
- Wharf or pier
- Airstrip
- Test hole ● 22

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TUKTOYAKTUK HARBOUR, N. W. T.

POTENTIAL BORROW SOURCES

SCALE 1:10000

.1 0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
Kilometers

N

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APPENDIX A

TEST HOLE LOGS

AND

LABORATORY TEST RESULTS

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7 WATER				
6	ML		6·1 SILT clayey, grey				
	SM		6·8 SAND fine grained, some gravel to 4 cm size, silty	C1		7·5 7·8	Grain size analysis
8			8·8 fine to medium grained, little fine gravel	D1		9·05 9·5	Some slough in sample Grain size analysis
10	SP		10·0 SAND fine grained				
12				D2		12·7 13·15	N=49 Grain size analysis
			Bottom of Hole at 13.15 m depth				
14							
16							

DATE: Feb. 23, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 1

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4			4·8				
	ML		SILT clayey, grey				
6			6·9				
	SM		SAND fine to coarse grained, some gravel, little silt				
			7·5 little gravel to 2 cm size				
8				D1		8·55 9·0	N=25 Grain size analysis
			9·5				
	SP		SAND fine to medium grained				
10				D2		10·0 10·5	slough sample Grain size analysis
			Bottom of Hole at 11.1 m depth Hole sloughing				
12							
14							
16							

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TEST HOLE NO. 2

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
			9·0				
	ML		SILT clayey, soft, grey with black organic	U1		9·0	Grain size analysis
			9·2 streaks			9·6	
10	SM		SAND fine to medium grained, trace gravel to 2 cm size, silt, occasional layers clayey silt, grey				
12							
14			Bottom of Hole at 14.1 m depth				
16							

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TEST HOLE NO. 3

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
			7·5				
8	ML		SILT soft, grey with black organic streaks	U1		7·5 7·8	
			9·3				
	GP		GRAVEL some sand, trace silt, rounded, to 6 cm size	C1		9·6 10·2	Grain size analysis
10			10·8				
	CL		CLAY silty, low plastic, grey				
12			Bottom of Hole at 11.7 m depth				
14							
16							

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TEST HOLE NO. 4

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
			10·0				
10	ML		SILT grey, soft				
			11·4				
	SM		SAND fine to medium grained, frequent soft silt layers, black, odorous	U1		11·4 11·7	
12							
14				D1		14·5 14·95	N=34
			Bottom of Hole at 14.95 m depth				
16							

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TEST HOLE NO. 5

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4			5·4				
6	ML		SILT clayey, little fine to medium grained sand, grey				
8							
10							
12							
14			Bottom of Hole at 14.1 m depth				
16							

DATE: Feb. 21, 1979 | LOGGED BY: G.D. | DRWN BY: PD/vh | CHKD BY: N.H.

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TEST HOLE NO. 6

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·5				
2			WATER				
4							
6							
			7·5			7·5	
8	ML		SILT clayey, soft, grey	U1		7·8	
			9·5				
	GP		9·8 GRAVEL				
10	SM		SAND fine to medium grained, silty, occasional pebbles				N=23 Grain size analysis
			11·2	D1		11·0	
	ML		SILT some fine sand, grey			11·45	
12			Bottom of Hole at 11.45 m depth				
14							
16							

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TEST HOLE NO. 7

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
			2·4				
	ML		SILT clayey, soft, grey				
4			4·5				
	SP		SAND fine to medium grained, trace gravel to 1.5 cm size				
6							
8				D1		8·4 8·7	Grain size analysis
10							
12							
14							
			Bottom of Hole at 15.3 m depth				
16							

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TEST HOLE NO.
8

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
		ICE				
		1·6				
2		WATER				
4						
6						
8						
		9·0				
	ML	9·3 SILT clayey, soft, grey				
	GP	GRAVEL	C1		9·3 9·6	
		10·0				
10	SM	SAND fine to medium grained, some silt, some gravel	D1		10·5 10·95	N=28 Grain size analysis
		12·0				
12	SP	SAND fine grained, poorly graded	D2		12·0 12·45	slough sample Grain size analysis
14						
		Bottom of Hole at 14.3 m depth				
16						

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TEST HOLE NO. 9

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6			6·3				
	ML		SILT clayey, grey				
			7·5				
8	SM		SAND fine to medium grained, some silt little gravel to 2 cm size	D1		8·3 8·75	N=11 Grain size analysis
10							
12							
14							
			Bottom of Hole at 14.3 m depth				
16							

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TEST HOLE NO. 10

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
			3·0				
	ML		SILT clayey, trace fine sand				
			4·0				
4	SP		SAND fine to medium grained, some gravel to 2 cm size				
				D1		5·0	N=22
						5·45	Grain size analysis
6							
8							
10							
			Bottom of Hole at 11.3 m depth				
12			Hole sloughing				
14							
16							

DATE: Feb. 23, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS
AND
NORTHERN DEVELOPMENT

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TEST HOLE NO. 11

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4			4·8				
	ML		SILT clayey, soft, grey, increasing stiffness with depth				
6							
8							
10							
			12·0				
12	SP		SAND fine grained				
14				D1		14·0 14·4	Grain size analysis slough sample
			Bottom of Hole at 14.4 m depth				
16							

DATE: Feb.23,24,1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 12

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·4				
2			WATER				
4							
			5·7			5·7	
6	ML		SILT clayey, soft, grey	B1			
			8·1			8·1	
8			some medium grained sand, occasional pebble, stiff				
10							
12							
				D1		13·15 / 13·6	N=14
14							
			Bottom of hole at 14.4 m depth				
16							

DATE: Feb. 23, 1979	LOGGED BY: N.H./G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 13

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
10							
			11·0				
	ML		SILT clayey, soft, grey	U1		11·0 11·3	
12							
14			Bottom of Hole at 14.0 m depth				
16							

DATE: Feb. 20, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 14

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·4				
2			WATER				
4							
6							
8							
			9·0				
10	ML		SILT clayey, soft, grey				
			12·0				
12	SM		SAND fine to medium grained, and silt, occasional pebble, grey				
14				D1		14·3 14·75	Grain size analysis N=14
			Bottom of Hole at 14.75 m depth				
16							

DATE: Feb. 21, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 15

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1.7				
2			WATER				
4							
6							
8							
10							
			11.7				
12	ML		SILT clayey, grey with black organic streaks				
14							
16			Bottom of Hole at 15.6 m depth				

DATE: Feb. 22, 1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 16

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·6				
2			WATER				
4							
6			6·3				
	ML		SILT clayey, trace fine sand				
8							
			9·0 --- some fine sand				
10			10·5				
	SP		SAND fine grained, trace silt				
12				D1		12·0 12·45	Grain size analysis N=10
			Bottom of Hole at 12.45 m depth				
14							
16							

DATE: Feb. 21, 1979 | LOGGED BY: N.H. | DRWN BY: PD/vh | CHKD BY: N.H.

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TEST HOLE NO. 17

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
			7·6				
8	ML		SILT clayey, trace fine sand, soft				
			10·0 some fine sand				
10							
12							
14			-- occasional pebble				
			Bottom of Hole at 14.8 m depth				
16							

DATE: Feb. 21, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 18

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6			6·6				
	ML		SILT clayey, trace fine sand, grey				
			7·3				
	SP		SAND medium to fine grained, and gravel to 3 cm size	D2		8·0	Grain size analysis
8						8·3	slough sample
				D1		8·75	N=23
							Grain size analysis
10			Bottom of Hole at 9.8 m depth Hole sloughing				
12							
14							
16							

DATE: Feb. 23, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 19

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·4				
2			WATER				
4							
6							
8							
10							
			11·0				
12	ML		SILT clayey, soft, dark grey				
			13·5				
14	CL		CLAY light grey, soft	U1		15·5 15·8	
16			Bottom of Hole at 15.8 m depth				

DATE: Feb. 21, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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NORTHERN DEVELOPMENT

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TEST HOLE NO. 20

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
			7·8				
8	SM		SAND fine to medium grained, silty, trace fine gravel to 0.6 cm size, tarry, black	U1		7·8 8·1	
			9·0				
	SP		SAND fine to medium grained, dark grey-brown				
10							
				D1		11·8 12·15	N=43
12			Bottom of Hole at 12.15 m depth				
14							
16							

DATE: Feb.19,20,1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 21

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
10							
			11·0				
	ML		SILT clayey, soft, grey with black organic inclusions				
			11·7				
12	SM		SAND fine to medium grained, little silt, grey				
14							
			15·3 little gravel to 3 cm size				
				D1		15·9	some slough in sample
16						16·1	
			Bottom of Hole at 16.1 m depth				

DATE: Feb. 23, 1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 22

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
10							
12							
			13·8				
14	ML		SILT clayey, trace fine sand, grey				
			14·4 increasing stiffness	U1		14·4 14·7	
			Bottom of Hole at 15.0 m depth				
16							

DATE: Feb. 20, 1979	LOGGED BY: N.H./G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 23

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
			5·4				
6	ML		SILT clayey, soft, grey				
			7·0				
	SP		SAND fine to medium grained				
8							
10				D1		11·3	
						11·4	
12			Bottom of Hole at 11.4 m depth				
14							
16							

DATE: Feb. 22, 1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 24

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·6				
2			WATER				
4							
6							
			8·0				
8	ML		SILT clayey, soft, grey				
			10·0				
10	SP		SAND fine to medium grained, little gravel				
				D1		11·3	N=38
12						11·75	Grain size analysis
			14·0				
14	SM		SAND some silt, some gravel	D2		14·3	N=37
						14·75	Grain size analysis
16							
			Bottom of Hole at 17.3 m depth				

DATE: Feb. 22, 1979 | LOGGED BY: N.H. | DRWN BY: PD/vh | CHKD BY: N.H.

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TEST HOLE NO. 25

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·5				
2			WATER				
4							
			5·5				
6	ML		SILT clayey, grey	U1		5·5 5·8	
			7·0				
	SP		SAND fine to medium grained	D1		7·6 7·7	slough sample
8							
10			--- fine grained, silty				
			Bottom of Hole at 10.0 m depth Bit plugging up				
12							
14							
16							

DATE: Feb. 19, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 26

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·6				
2			WATER				
4							
6							
			7·0				
	GP		GRAVEL little sand, trace silt	U1		7·0 7·1	Grain size analysis
			8·0				
8	SP		SAND fine to medium grained, trace silt	B1		8·0 8·1	Grain size analysis
				D1		9·0 9·45	N=9
10							
12				D2		12·8	N=69 Grain size analysis
			Bottom of Hole at 13.35 m depth				
14							
16							

DATE: Feb. 19, 1979 | LOGGED BY: G.D./N.H. | DRWN BY: PD/vh | CHKD BY: N.H.

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TEST HOLE NO. 27

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
		ICE				
		1·7				
2		WATER				
4						
6		6·3				
	ML	SILT clayey, soft, grey				
8		7·8 increasing stiffness				
		9·0				
	GP	GRAVEL to 5 cm size, rounded, trace sand,	C1		9·1 9·3	Grain size analysis
		9·8 trace silt				
10	SM	SAND medium to fine grained, some gravel,				
		10·8 little silt trace gravel	D1		10·8	slough sample Grain size analysis
12						
		Bottom of Hole at 12.9 m depth				
14						
16						

DATE: Feb. 23, 1979	LOGGED BY: G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

GOVERNMENT OF CANADA
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TEST HOLE NO. 28

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4			4·4				
	ML		SILT clayey, grey with black organic layers, occasional tarry layers, low plastic	D1		4·4	Grain size analysis and Atterberg Limits
			5·8			5·8	
6	SP		SAND medium grained, occasional silt layers to 6.0 m depth				
			6·6	C1		6·6 6·7	Grain size analysis
	SM		SAND fine to medium grained, some silt, gravel to 5 cm size from 6.6 to 7.0 m depth				
8							
			Bottom of Hole at 9.0 m depth Hole sloughing				
10							
12							
14							
16							

DATE: Feb. 22, 1979	LOGGED BY: N.H./G.D.	DRWN BY: PD/vh	CHKD BY: N.H.

GOVERNMENT OF CANADA
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TEST HOLE NO. 29

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4							
6							
8							
10							
12			12·0				
	ML		SILT clayey, trace fine sand, grey				
			13·5				
14	SM		SAND fine grained, some silt, occasional pebbles	D1		14·3 14·75	Grain size analysis N=12
			Bottom of Hole at 14.75 m depth				
16							

DATE: Feb. 22, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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NORTHERN DEVELOPMENT

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TEST HOLE NO.
30

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·55				
2			WATER				
4							
6							
8							
10							
			11·0				
12	ML		SILT clayey, trace fine sand, soft, grey				
			14·0				
14	SM		SAND fine grained, some silt, occasional pebbles, grey	D1		14·1 14·55	Grain size analysis N=16
			Bottom of Hole at 14.55 m depth				
16							

DATE: Feb. 18, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO. 31

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·6				
2			WATER				
4							
			5·8				
6	ML		SILT clayey, trace fine sand, grey				
8			8·3				
	SW		SAND medium to fine grained, some gravel to 4 cm size, occasional gravel layers up to 0.5 m thickness to a depth of 10.5 m	D1		9·7 10·2	N=36 Grain size analysis
10							
12			Bottom of Hole at 11.3 m depth Hole sloughing				
14							
16							

DATE: Feb. 22, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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TEST HOLE NO.
32

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1·7				
2			WATER				
4			4·8				
	ML		SILT clayey, soft, grey				
			6·0				
6	SP		SAND fine to medium grained, some gravel to 6.2 m depth, little silt, trace gravel to 2.5 cm size				
8				D1		8·0 / 8·45	N=33 Grain size analysis
10							
12							
14							
			Bottom of Hole at 14.3 m depth				
16							

DATE: Feb. 22, 1979	LOGGED BY: N.H.	DRWN BY: PD/vh	CHKD BY: N.H.

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HARDY ASSOCIATES (1978) LTD.
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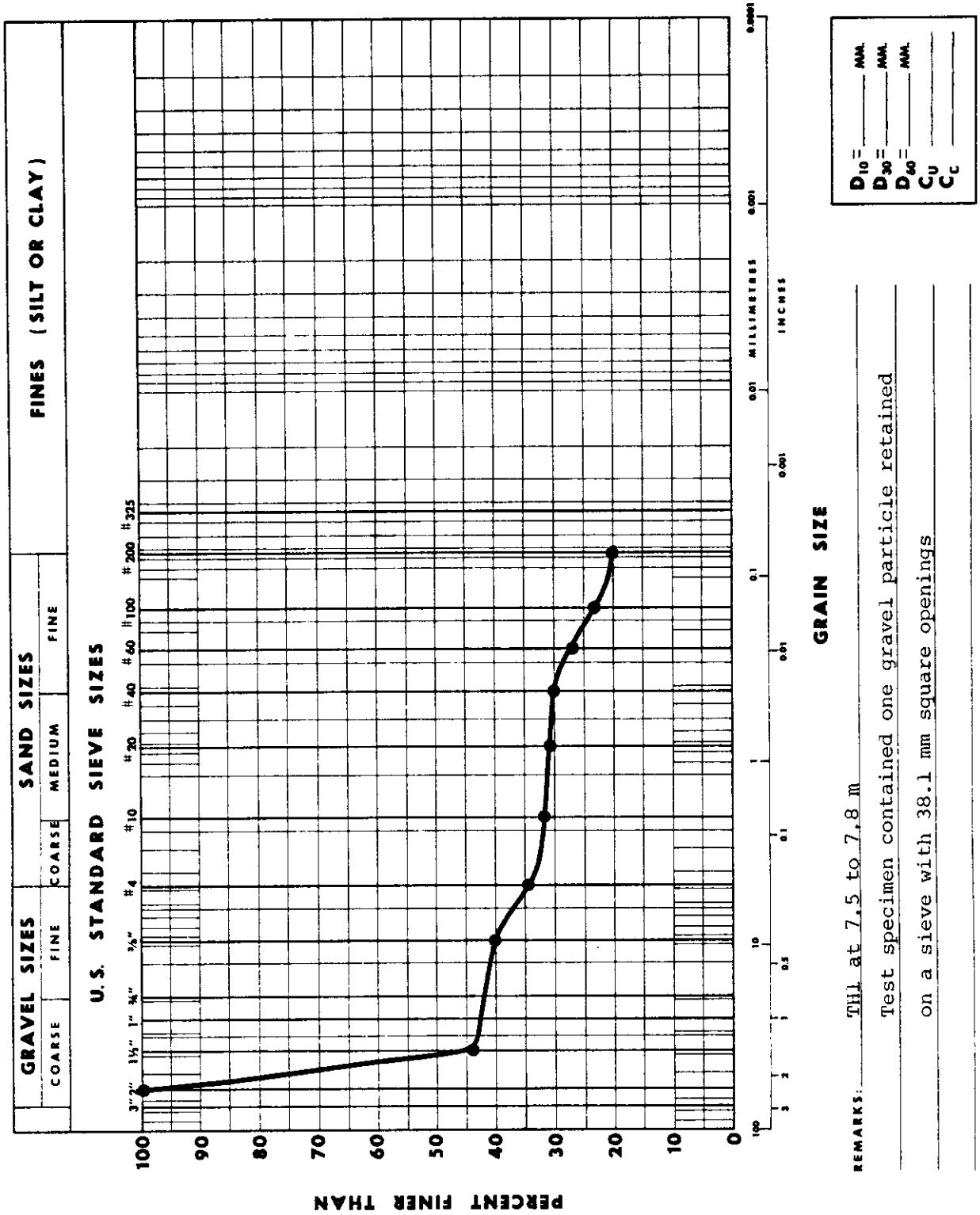
TEST HOLE NO. 33

GRAIN SIZE ANALYSIS



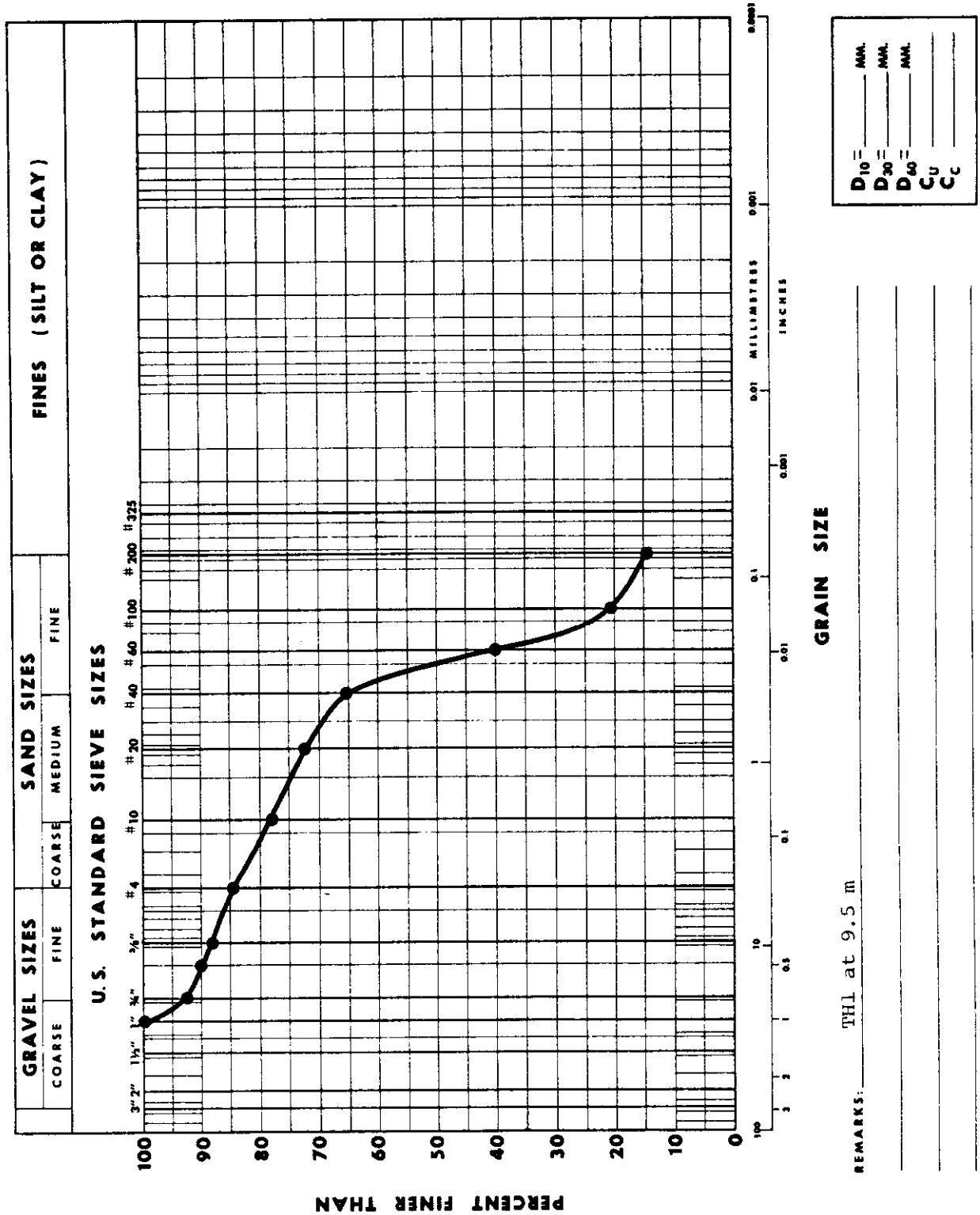
REMARKS: Till at 7.5 to 7.8 m

Test specimen contained one gravel particle retained on a sieve with 38.1 mm square openings

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 1

GRAIN SIZE ANALYSIS

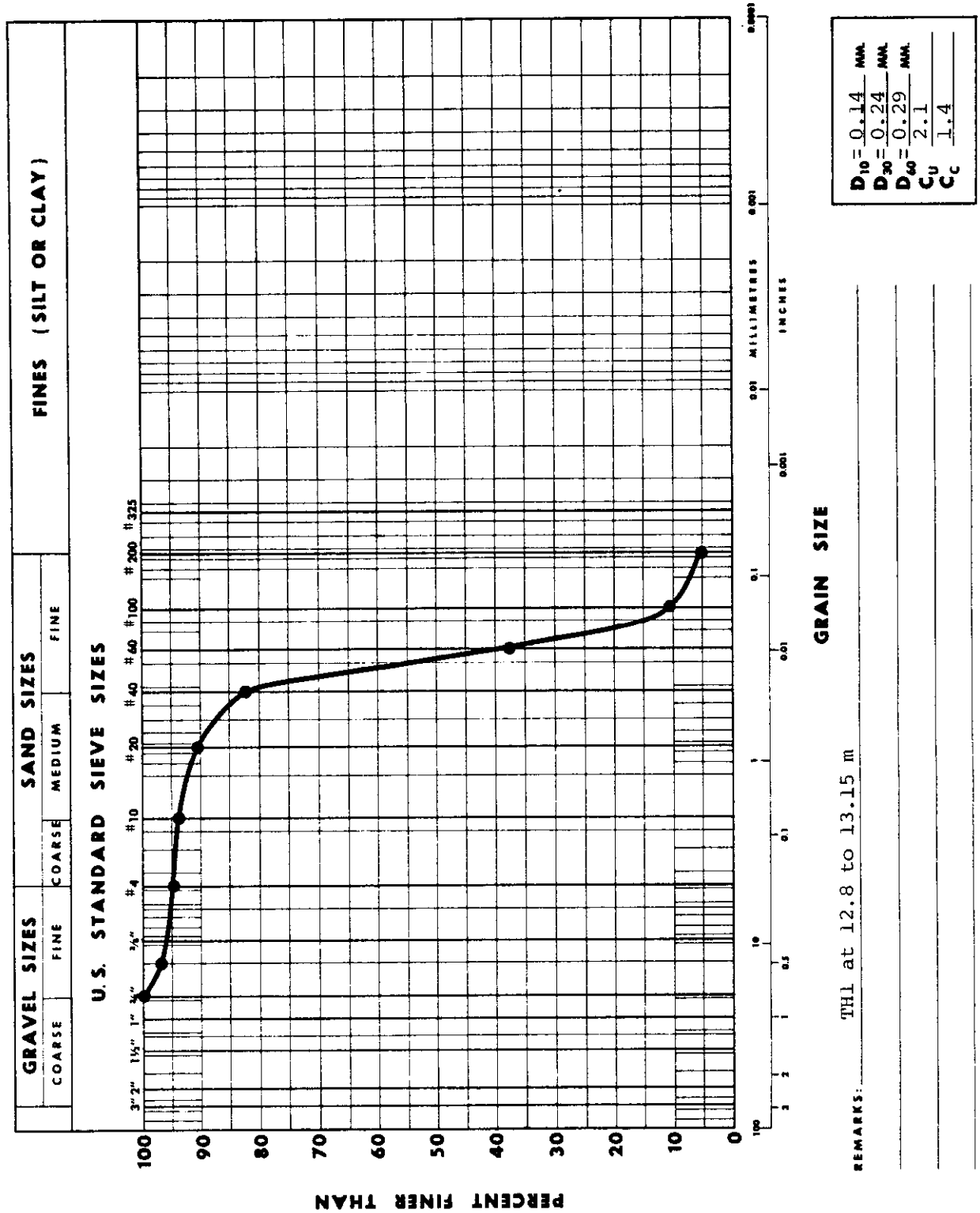


GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

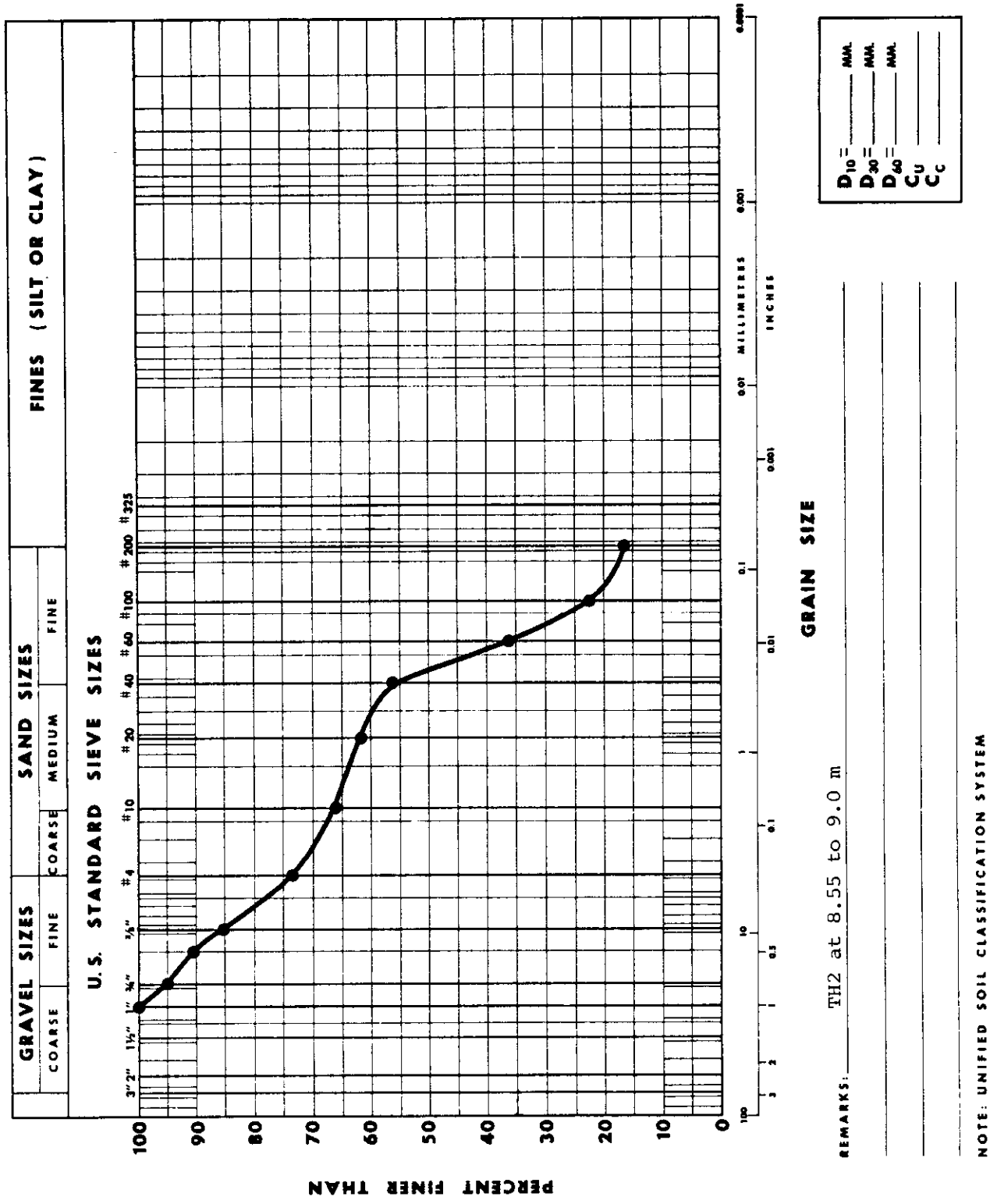
TEST HOLE NO.
1

GRAIN SIZE ANALYSIS



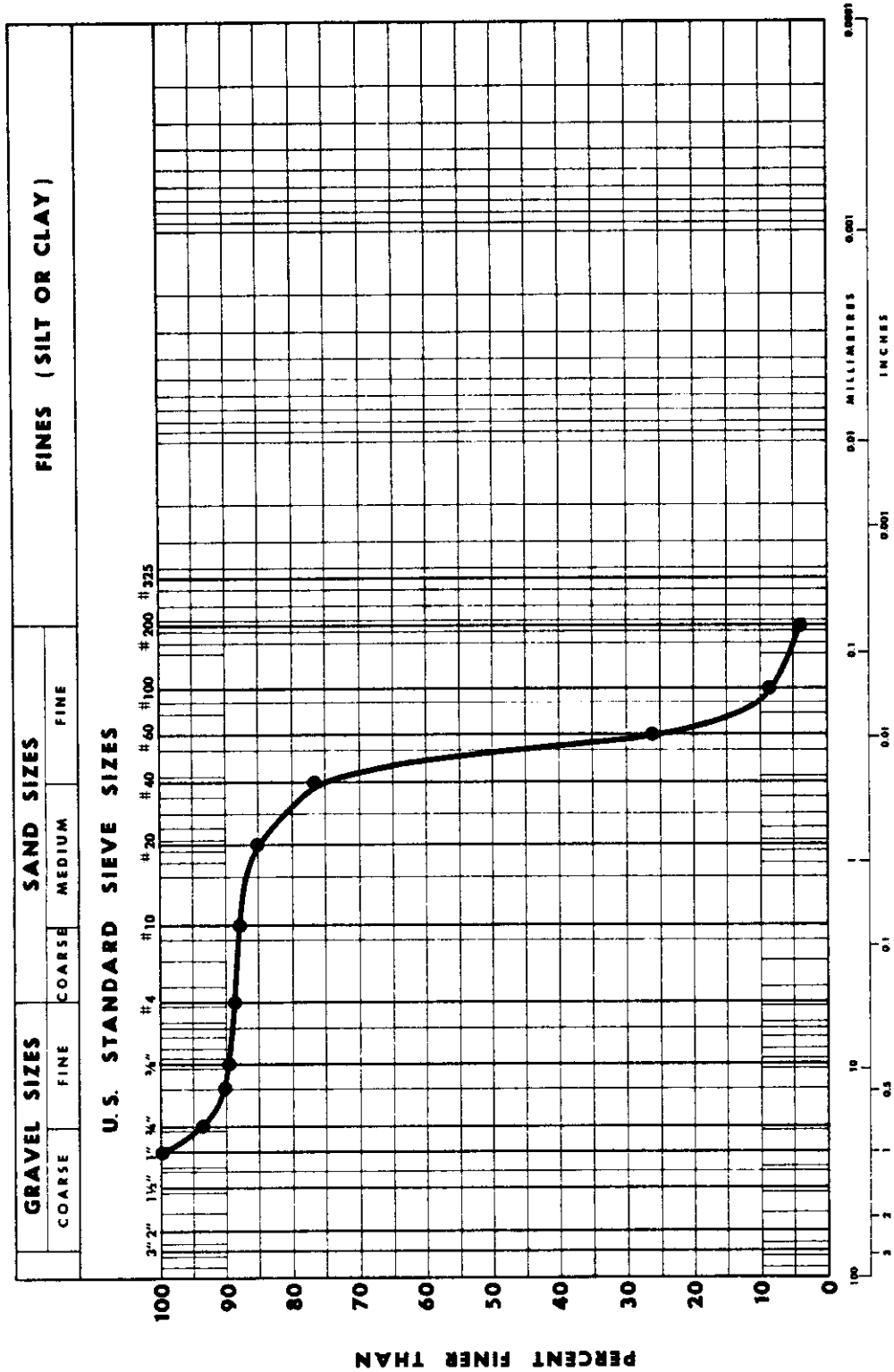
GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 1

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 2

GRAIN SIZE ANALYSIS



D_{10} = 0.15 MM.
D_{30} = 0.28 MM.
D_{60} = 0.30 MM.
C_u = 2.0
C_c = 1.74

REMARKS: TH2 at 11.1 to 11.2 m

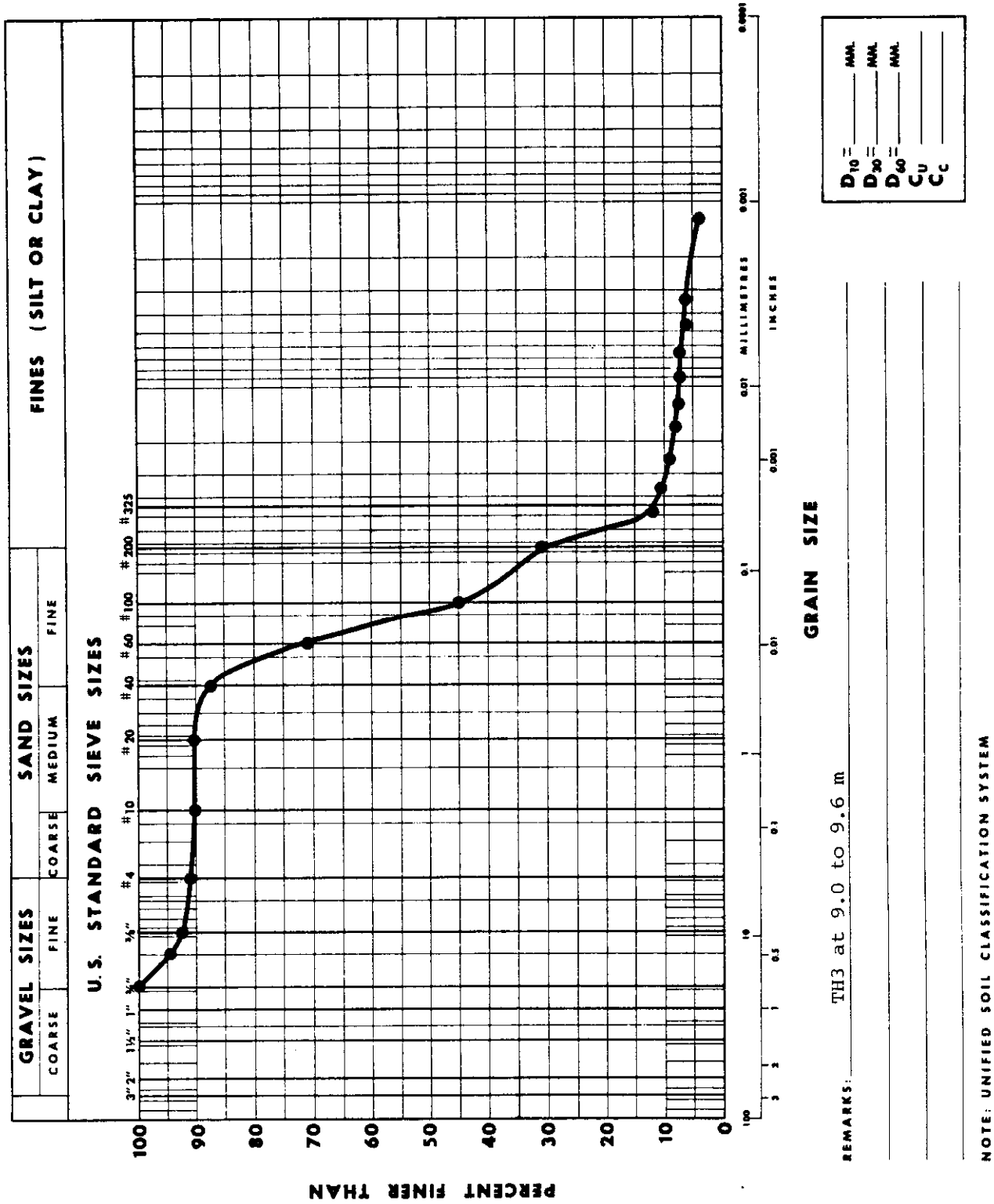
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

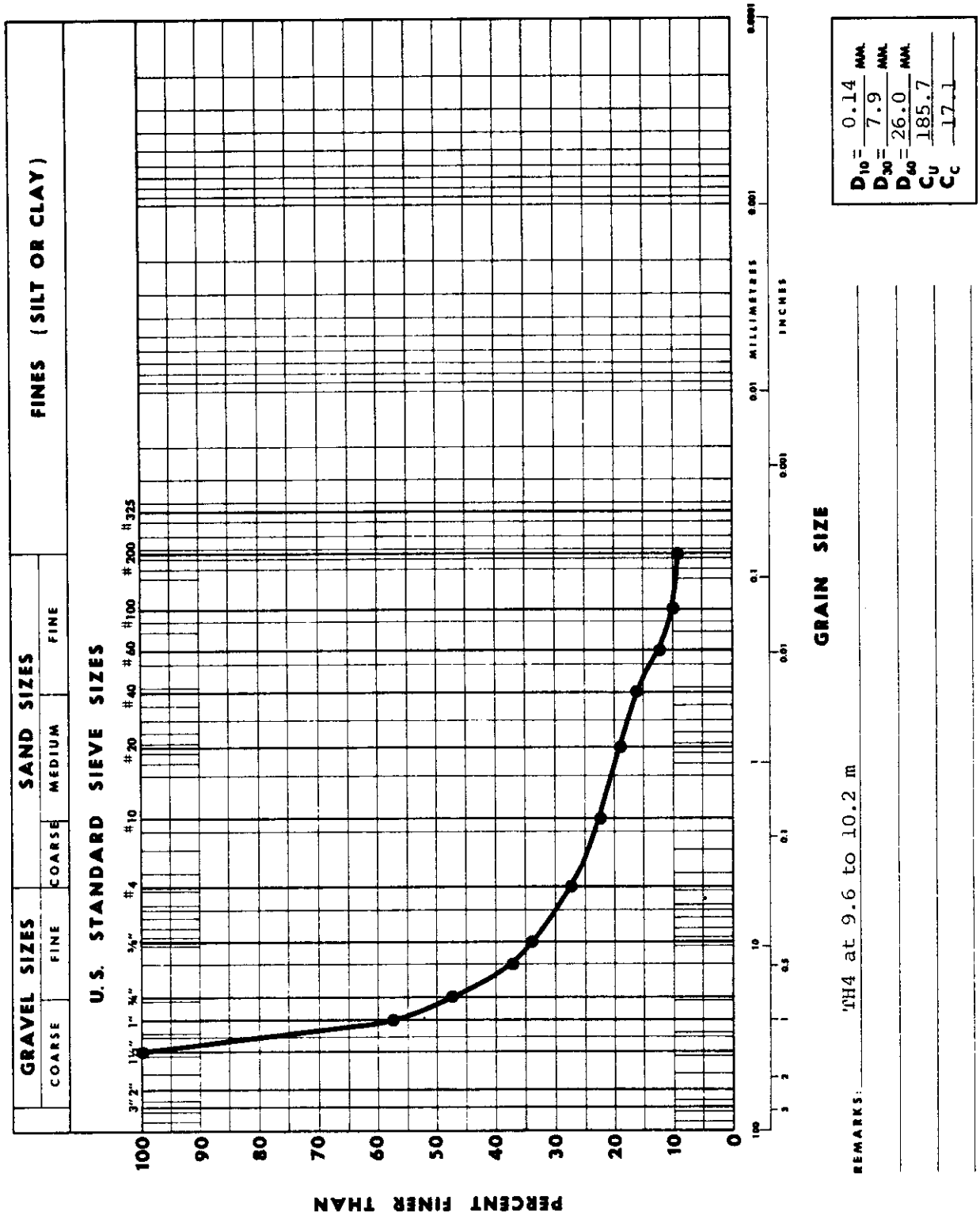
TEST HOLE NO.
2

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 3

GRAIN SIZE ANALYSIS



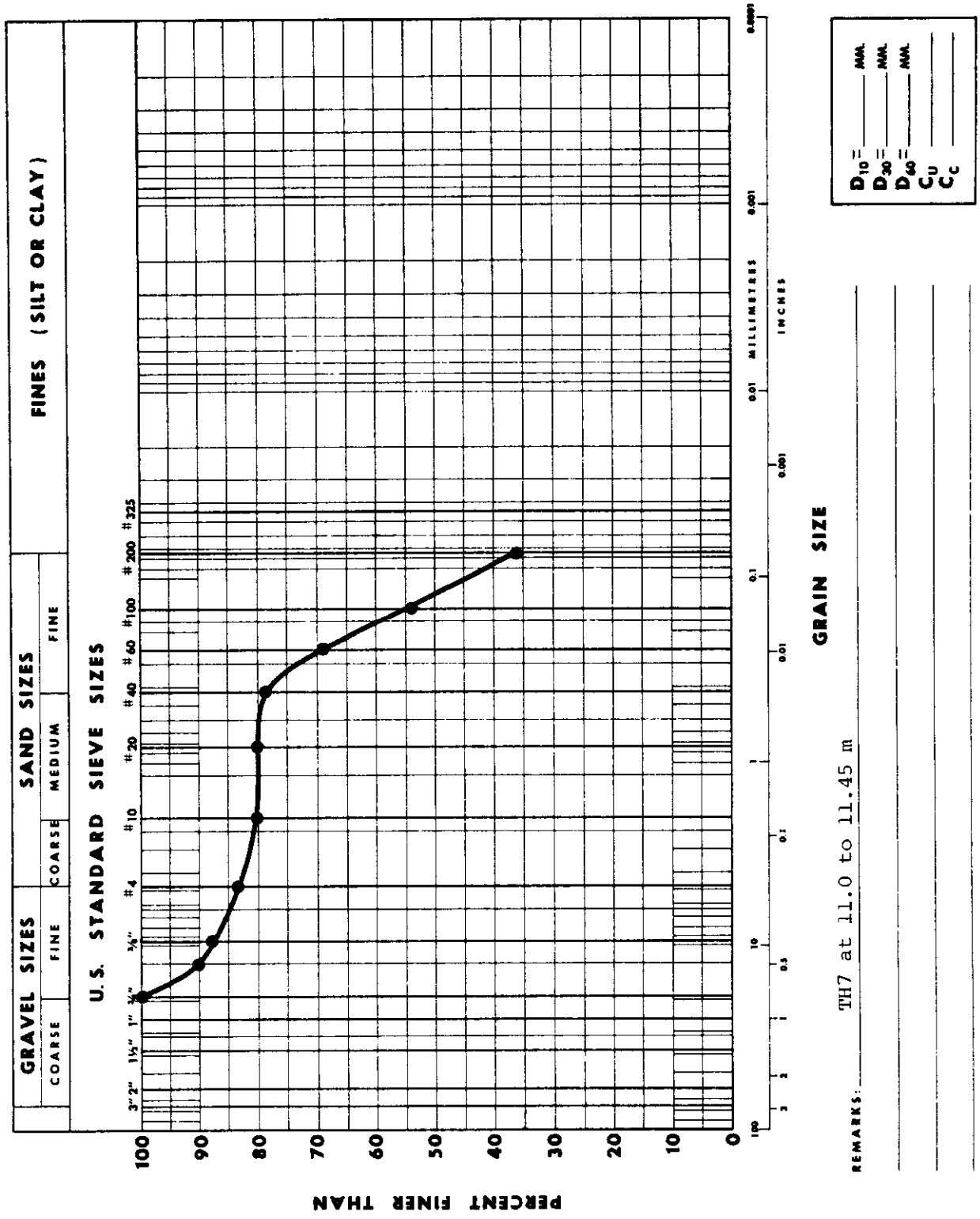
GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
4

GRAIN SIZE ANALYSIS

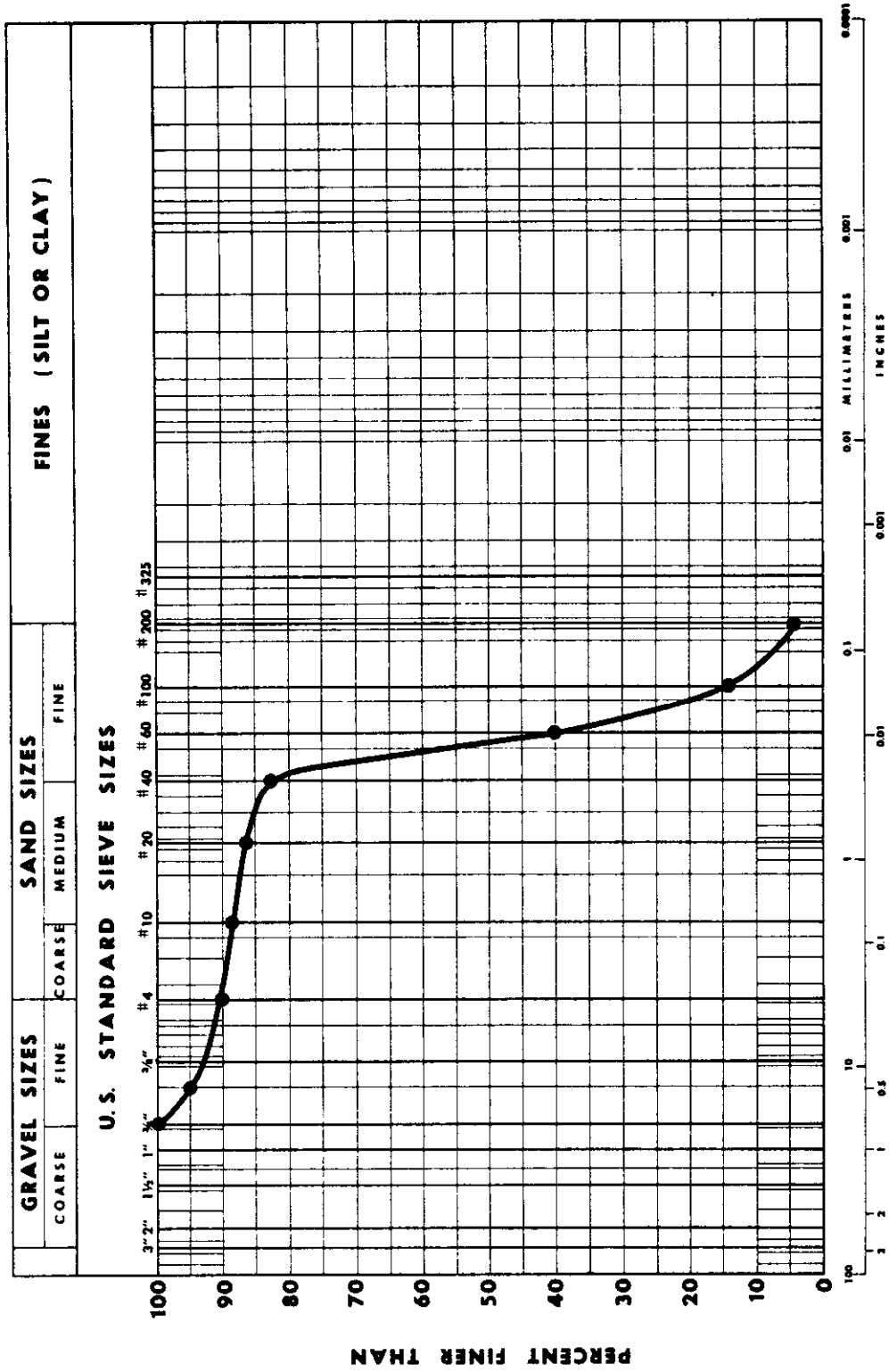


GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
7

GRAIN SIZE ANALYSIS



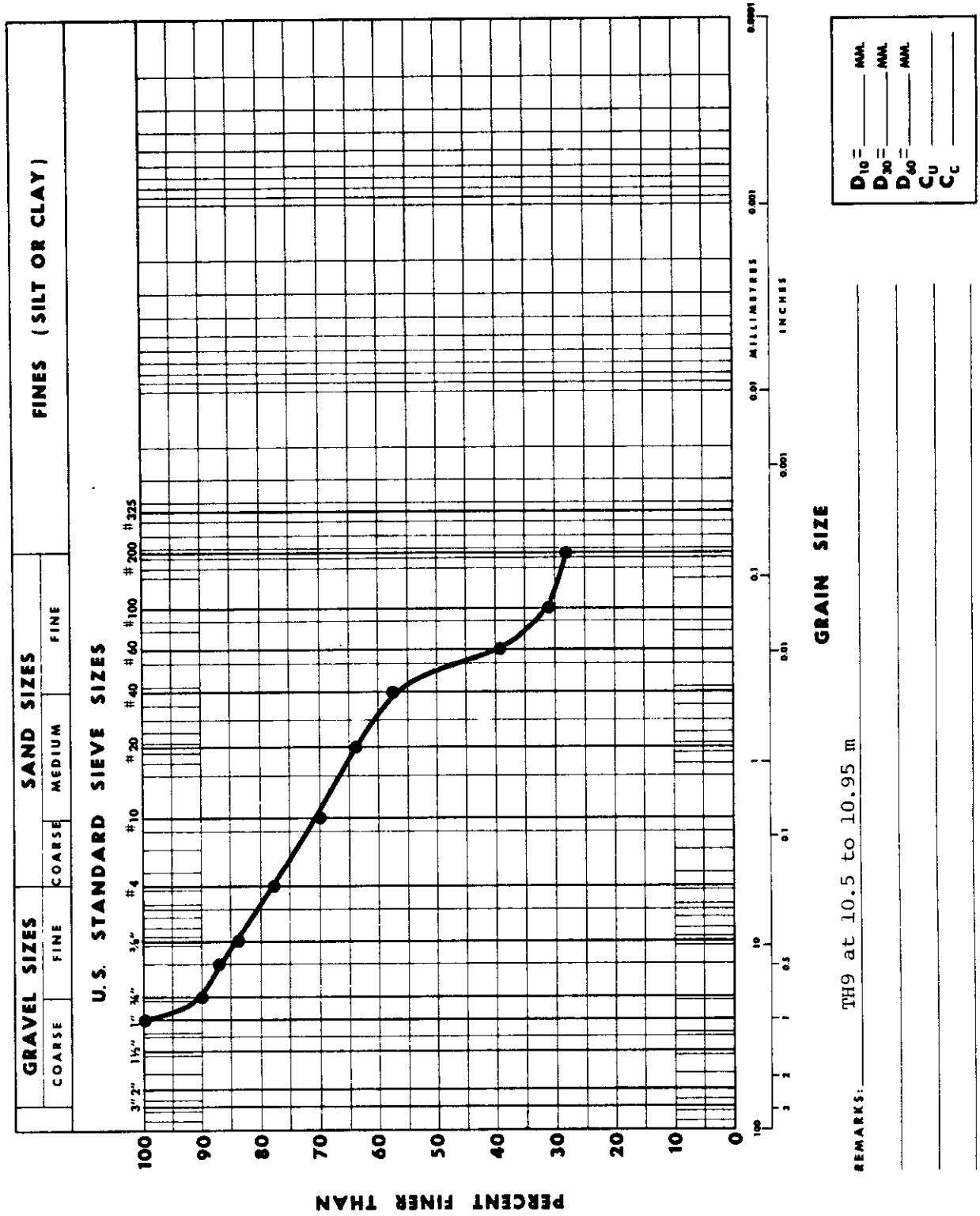
D_{10} = 0.11 mm.
D_{30} = 0.21 mm.
D_{60} = 0.30 mm.
C_U 2.7
C_C 1.34

REMARKS: TH8 at 8.4 to 8.7 m

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

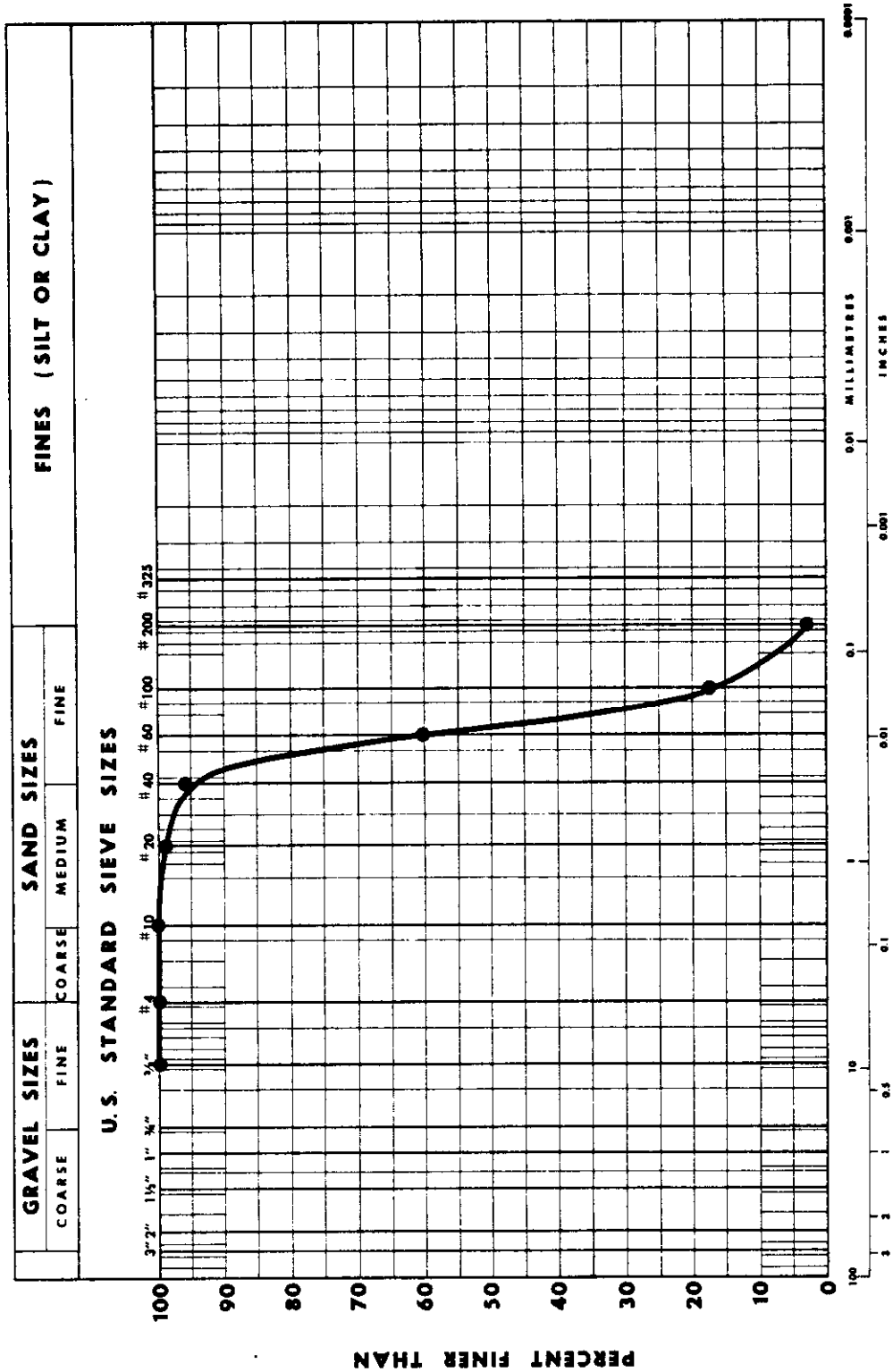
GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 8

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 9

GRAIN SIZE ANALYSIS



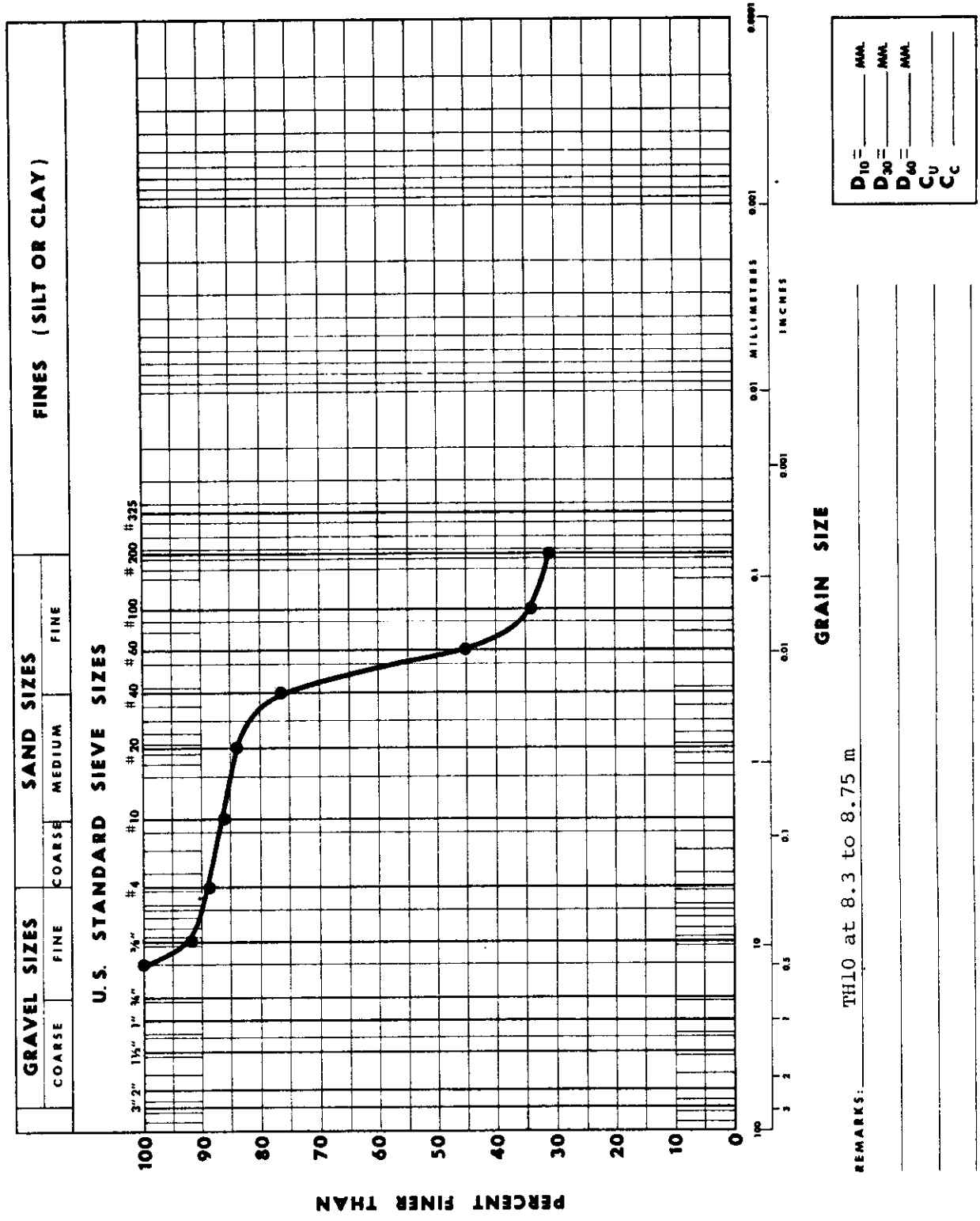
D_{10} = 0.12 mm.
D_{30} = 0.20 mm.
D_{60} = 0.25 mm.
C_u = 2.1
C_c = 1.33

REMARKS: TH9 at 12.0 to 12.45 m

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

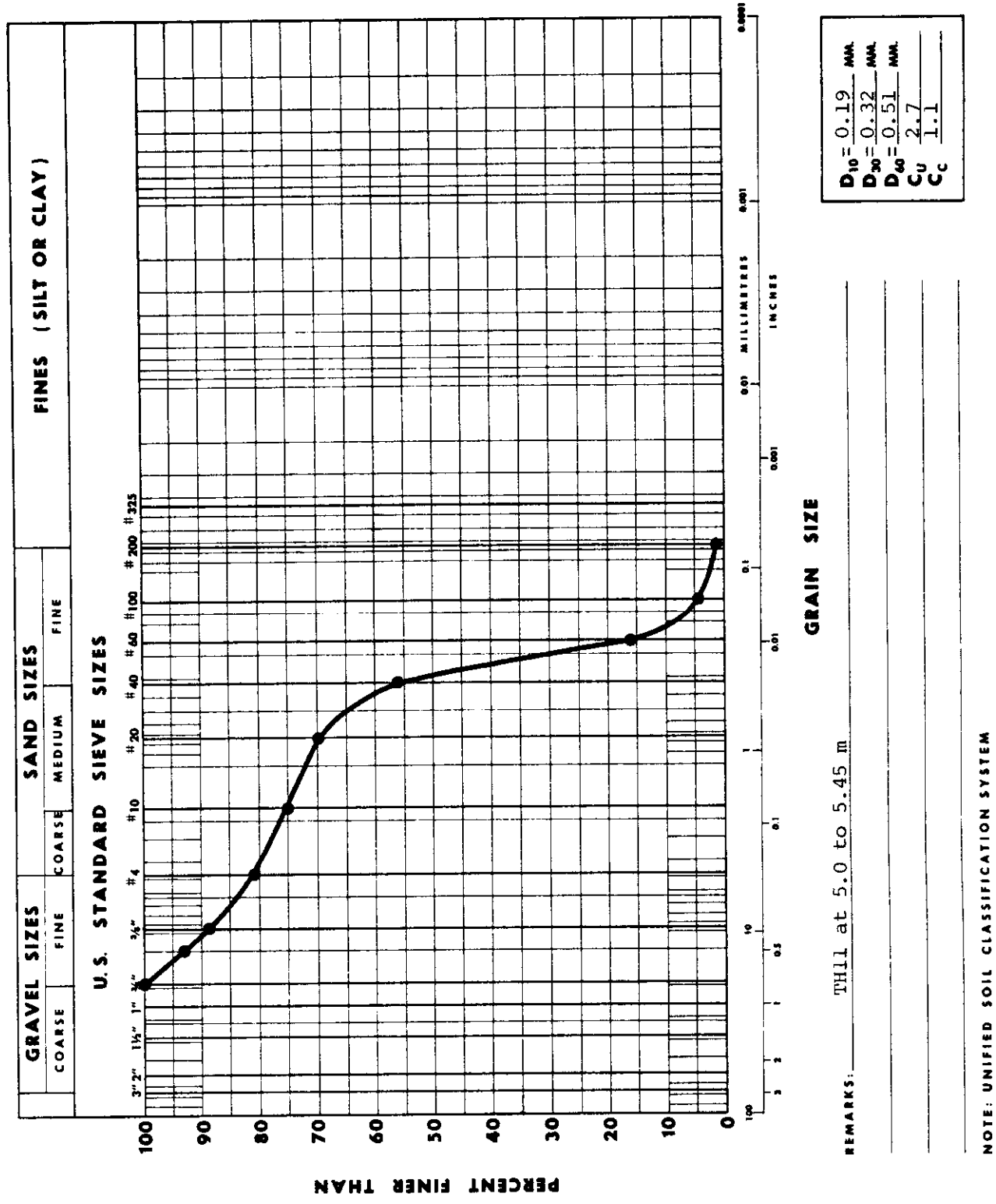
GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 9

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 10

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

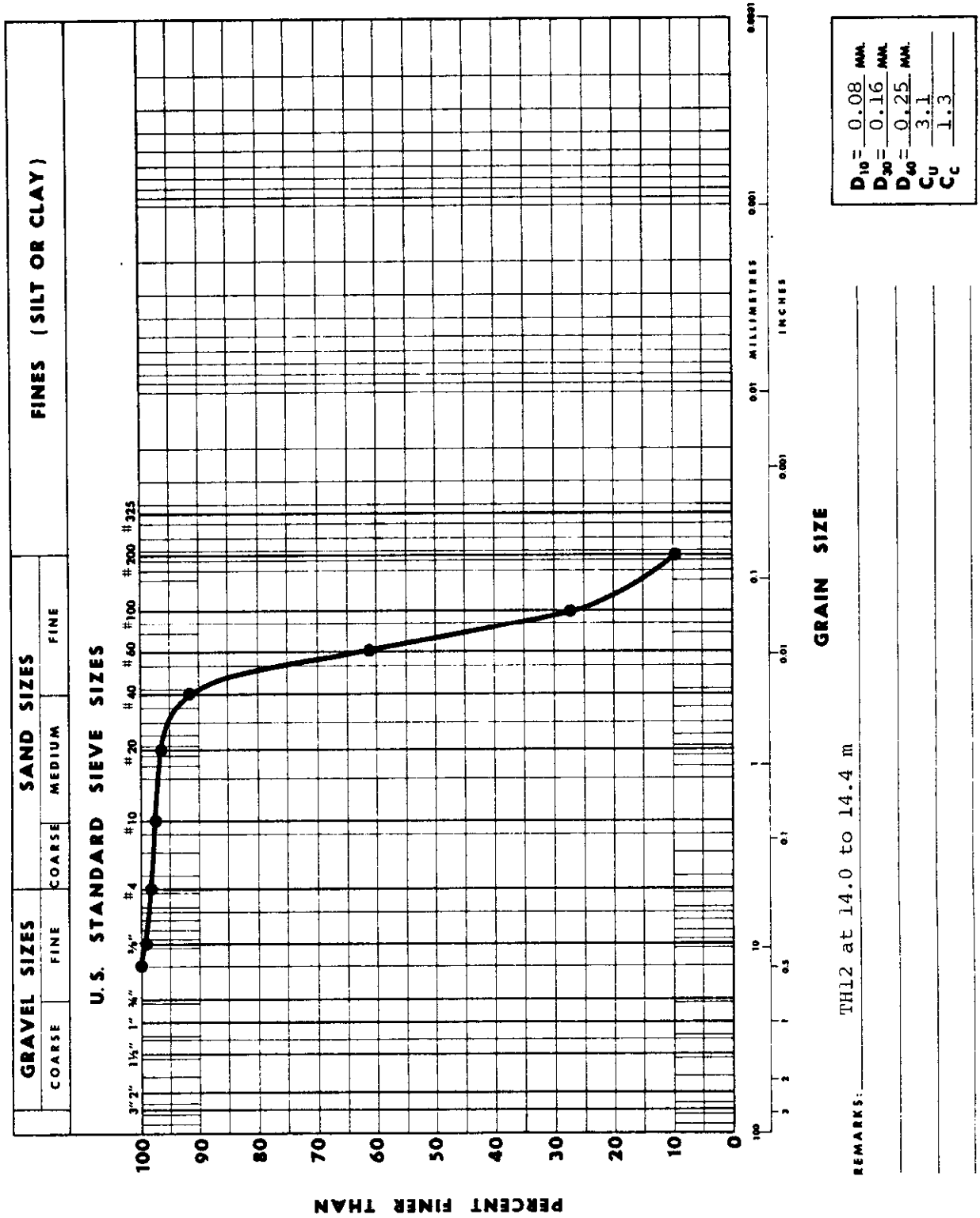
HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.

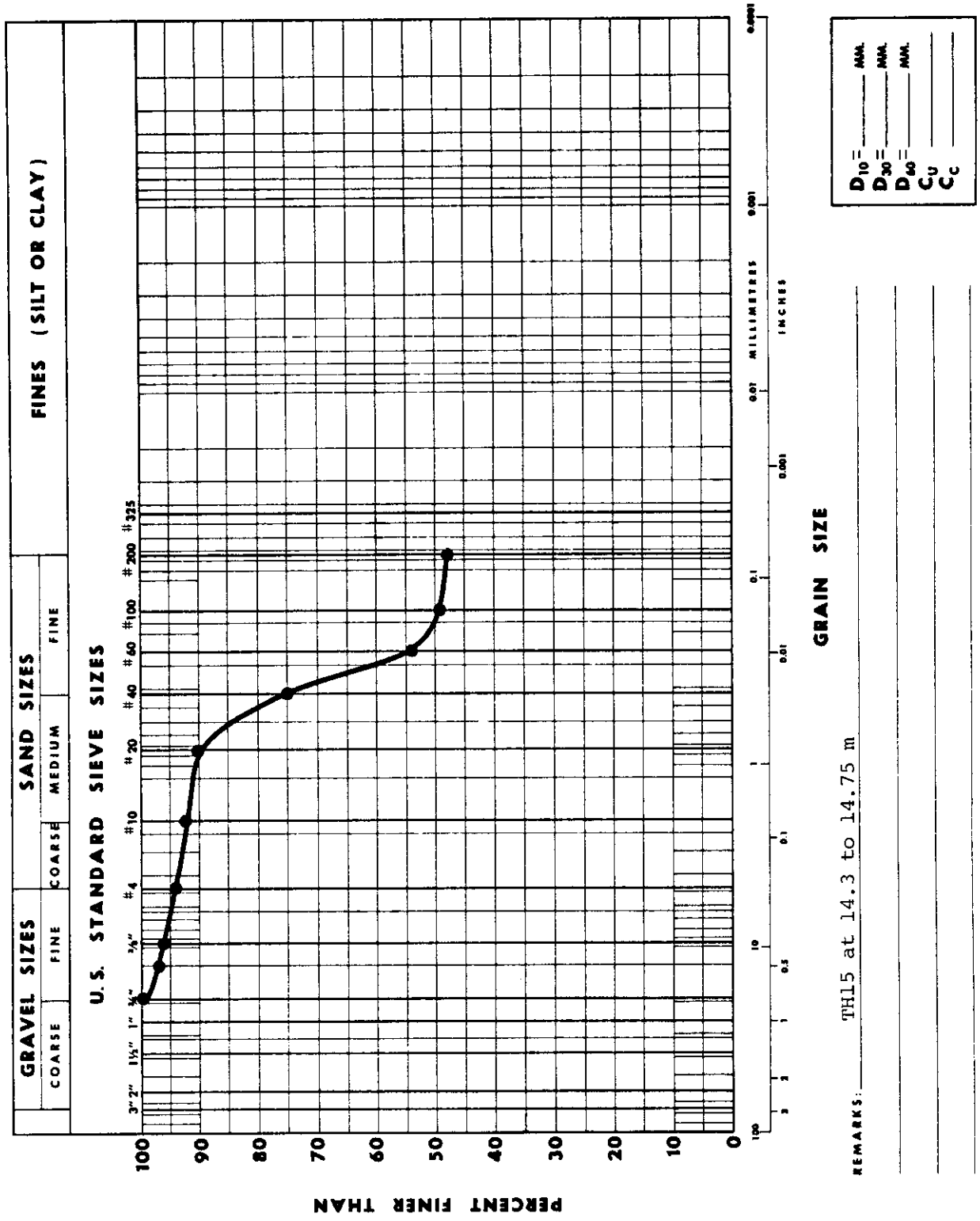
11

GRAIN SIZE ANALYSIS



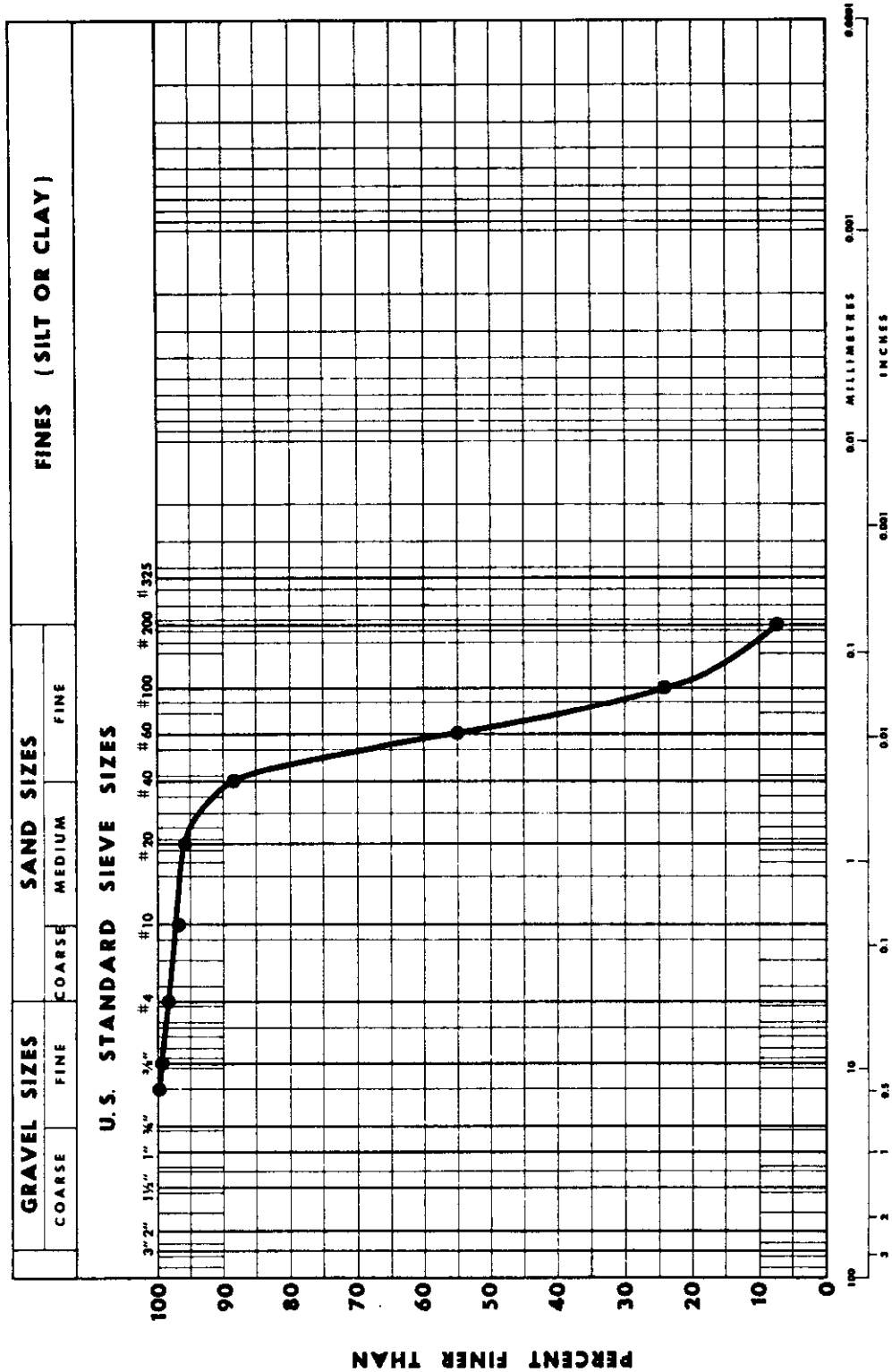
GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 12

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 15

GRAIN SIZE ANALYSIS



D_{10} = 0.09 mm.
D_{30} = 0.18 mm.
D_{60} = 0.23 mm.
C_U = 2.6
C_C = 1.6

REMARKS: TH17 at 12.0 to 12.45 m

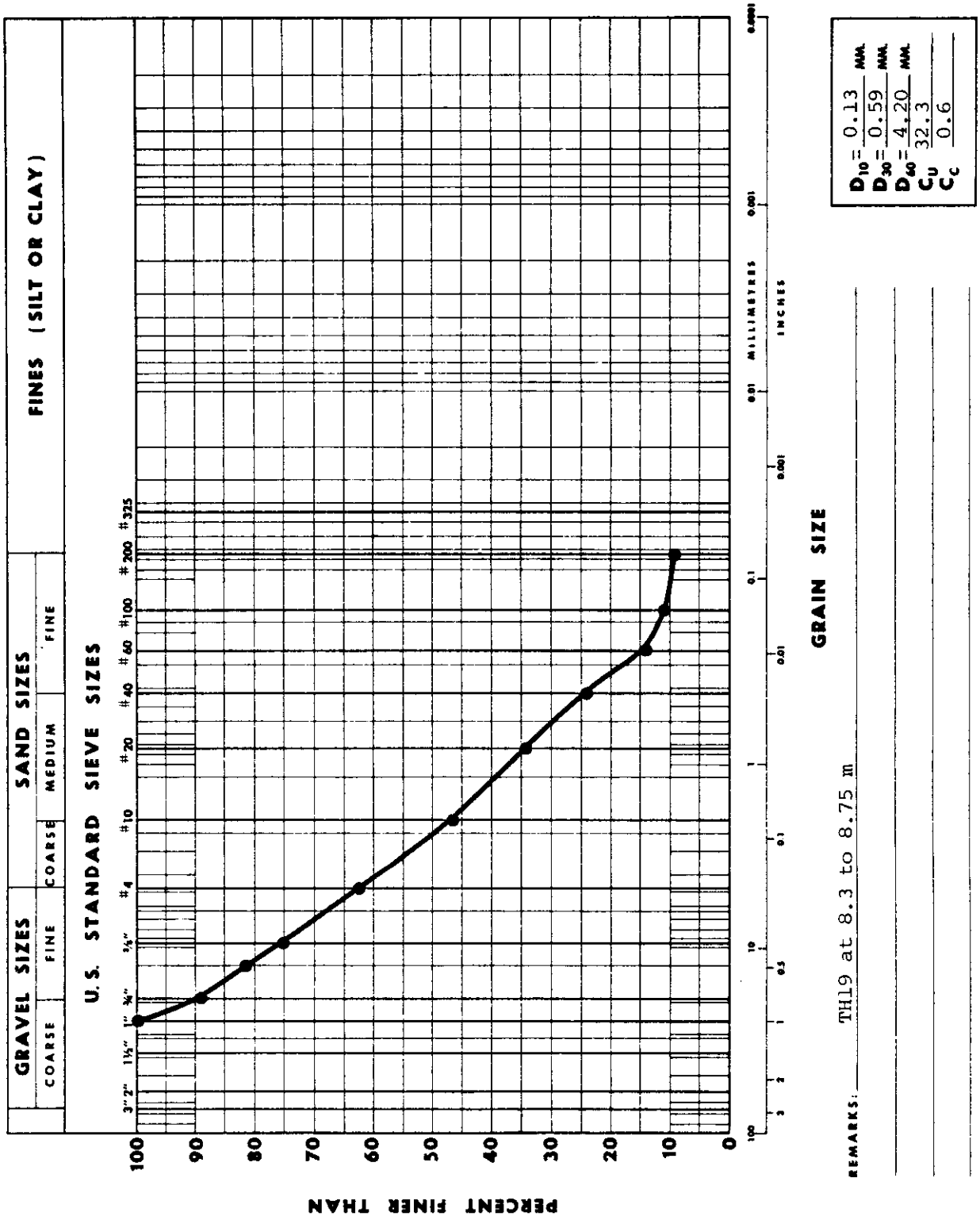
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
17

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

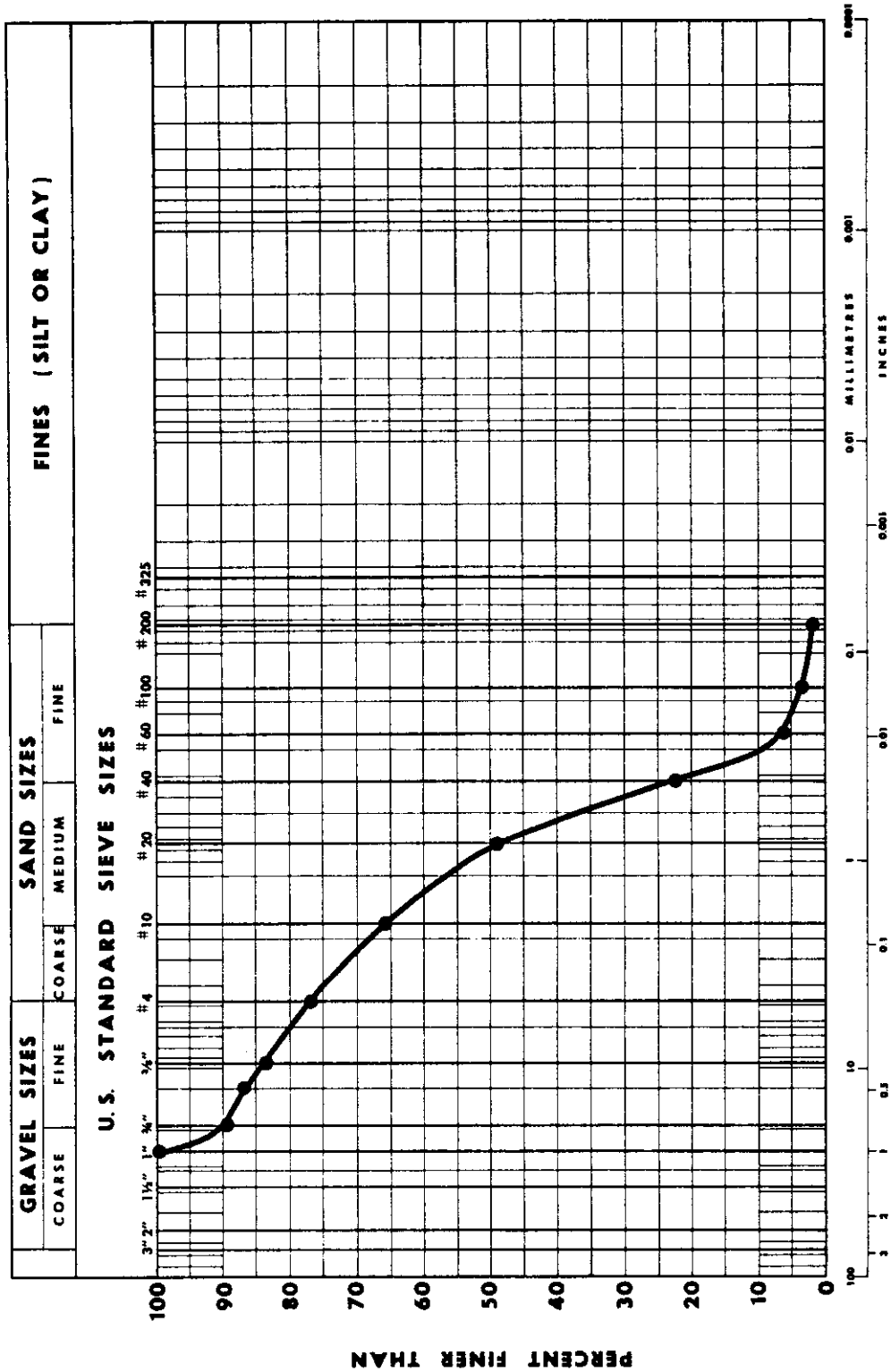
HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.

19

GRAIN SIZE ANALYSIS



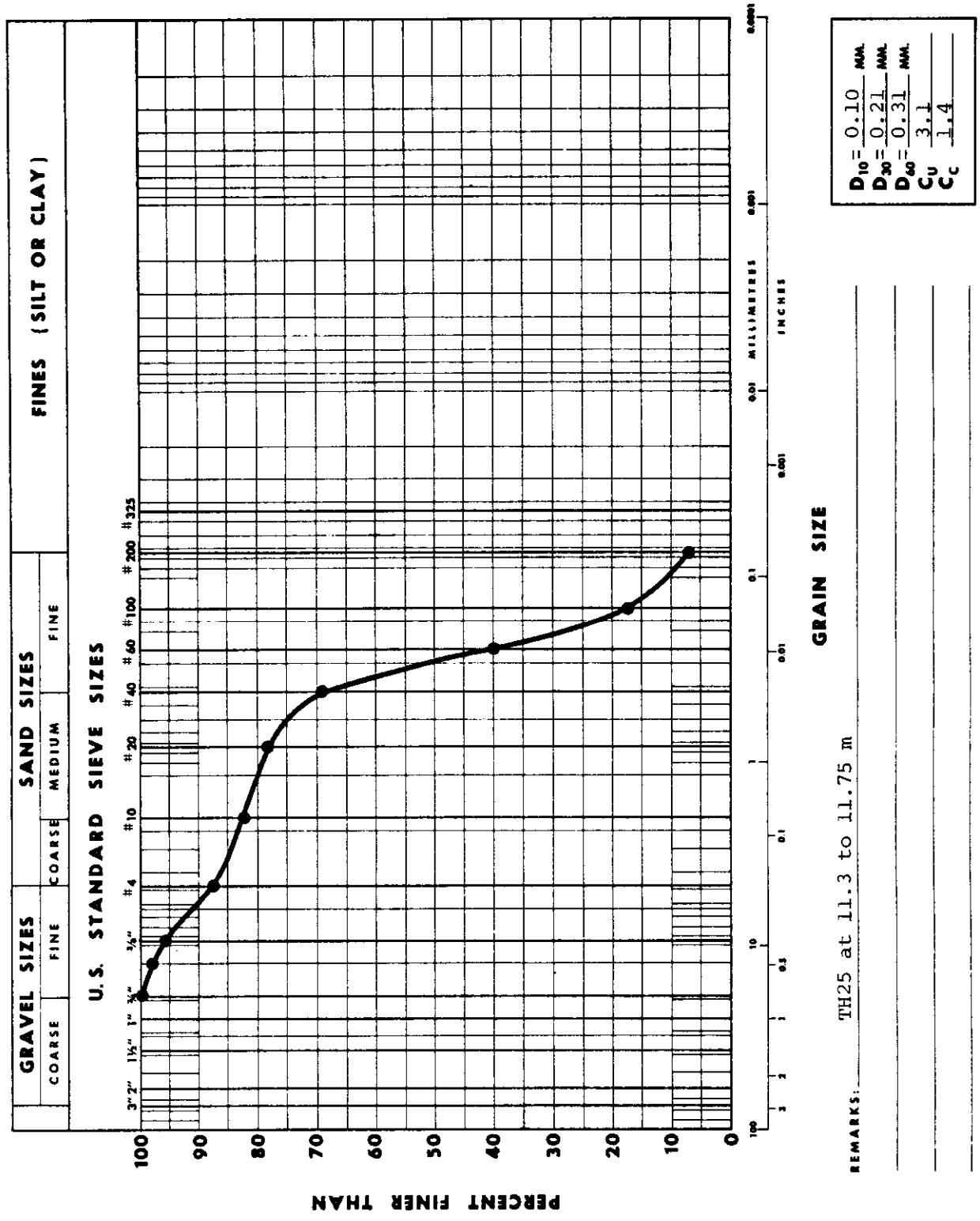
GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
19

GRAIN SIZE ANALYSIS

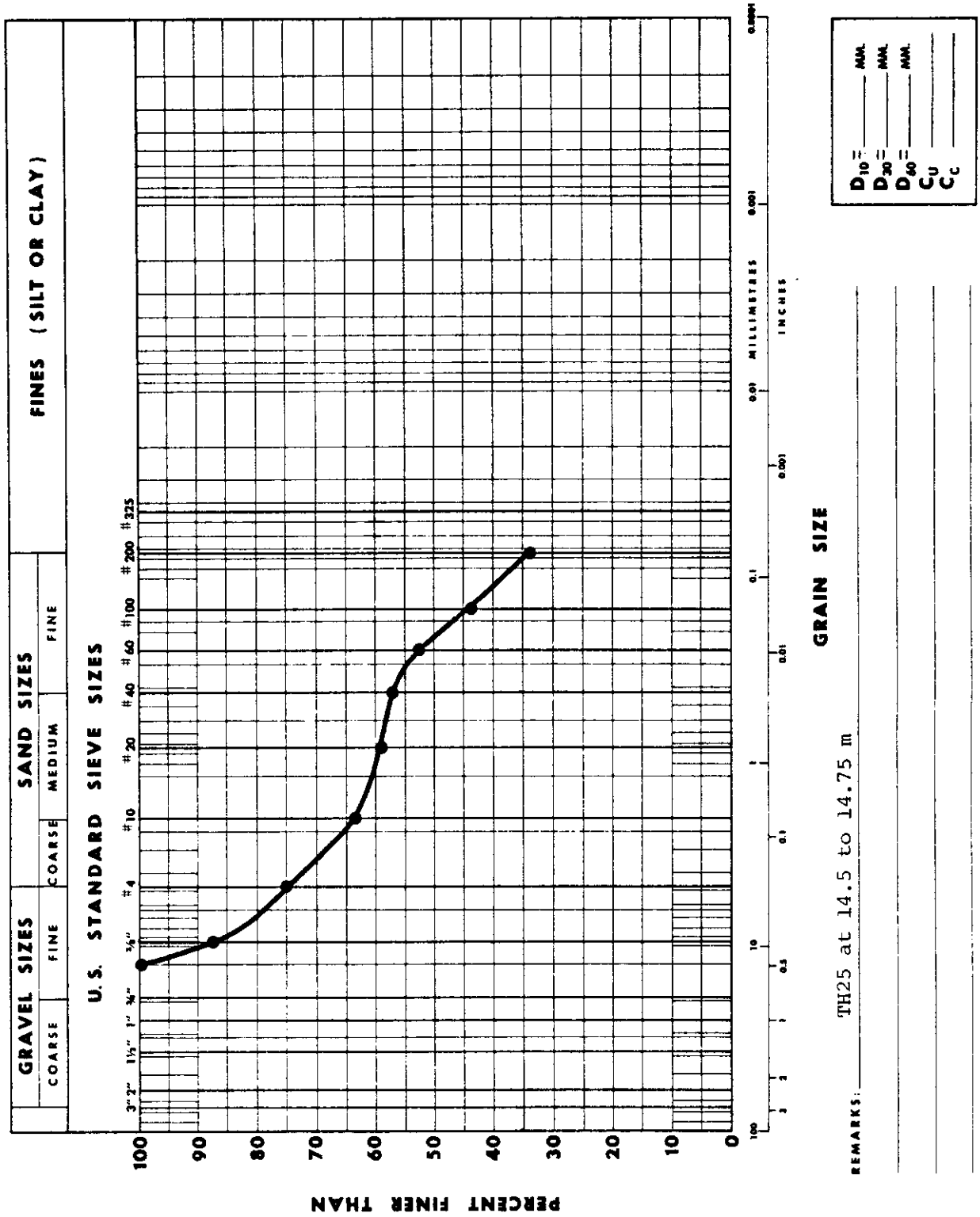


GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
25

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

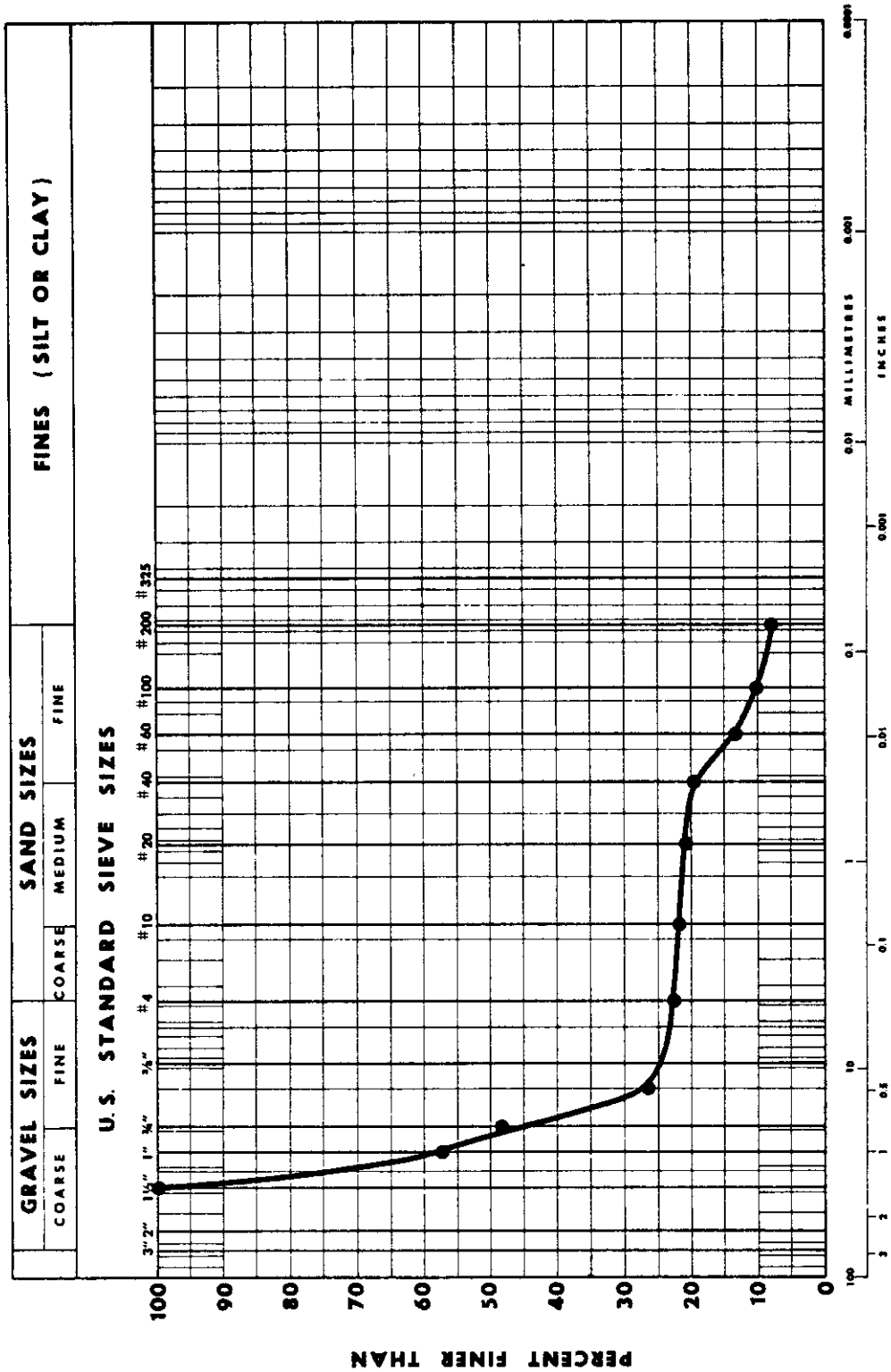
HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.

25

GRAIN SIZE ANALYSIS



D_{10} = 0.15 MM.
D_{30} = 14.0 MM.
D_{60} = 28.0 MM.
C_u = 186.7
C_c = 46.7

REMARKS: TH27 at 7 m

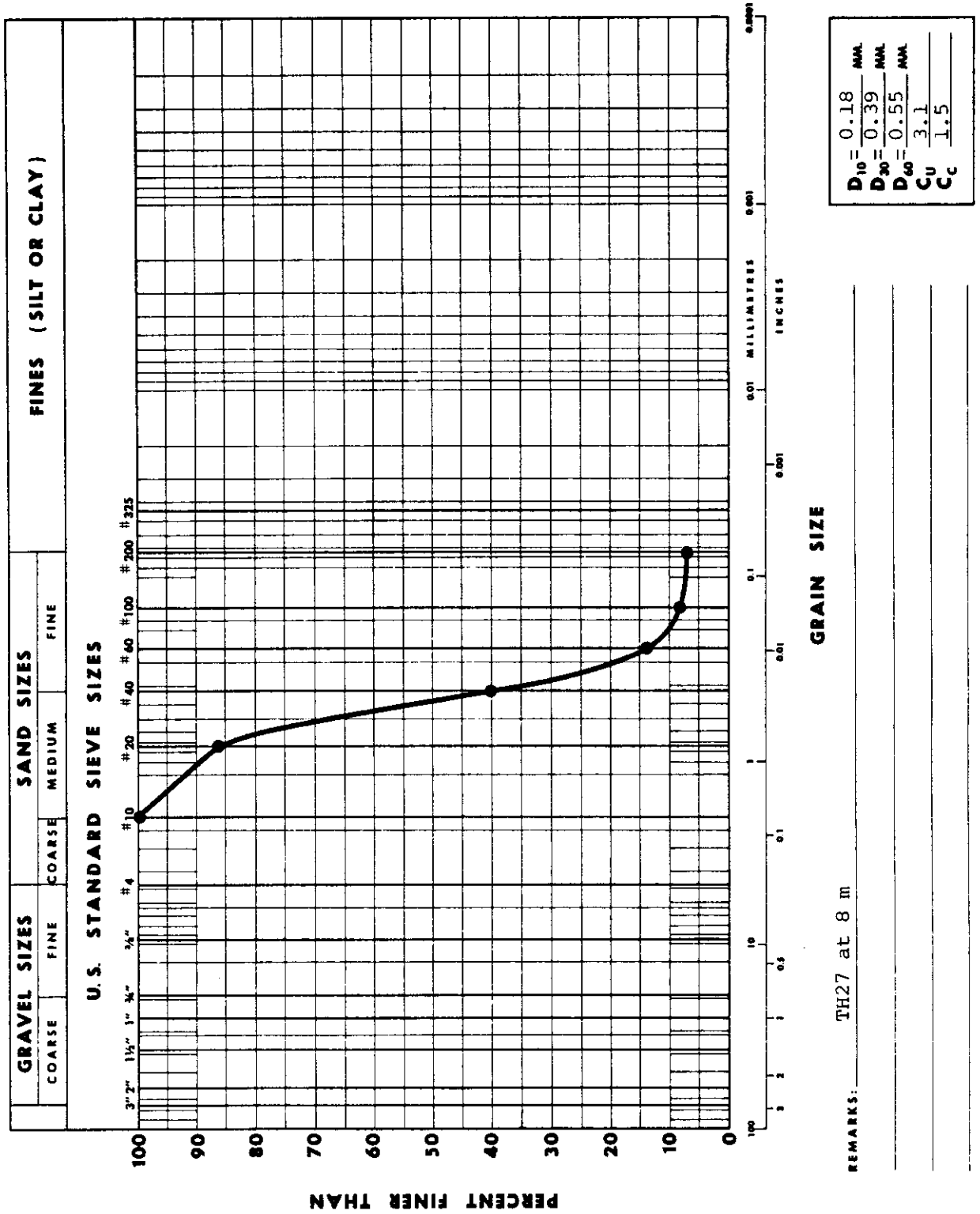
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

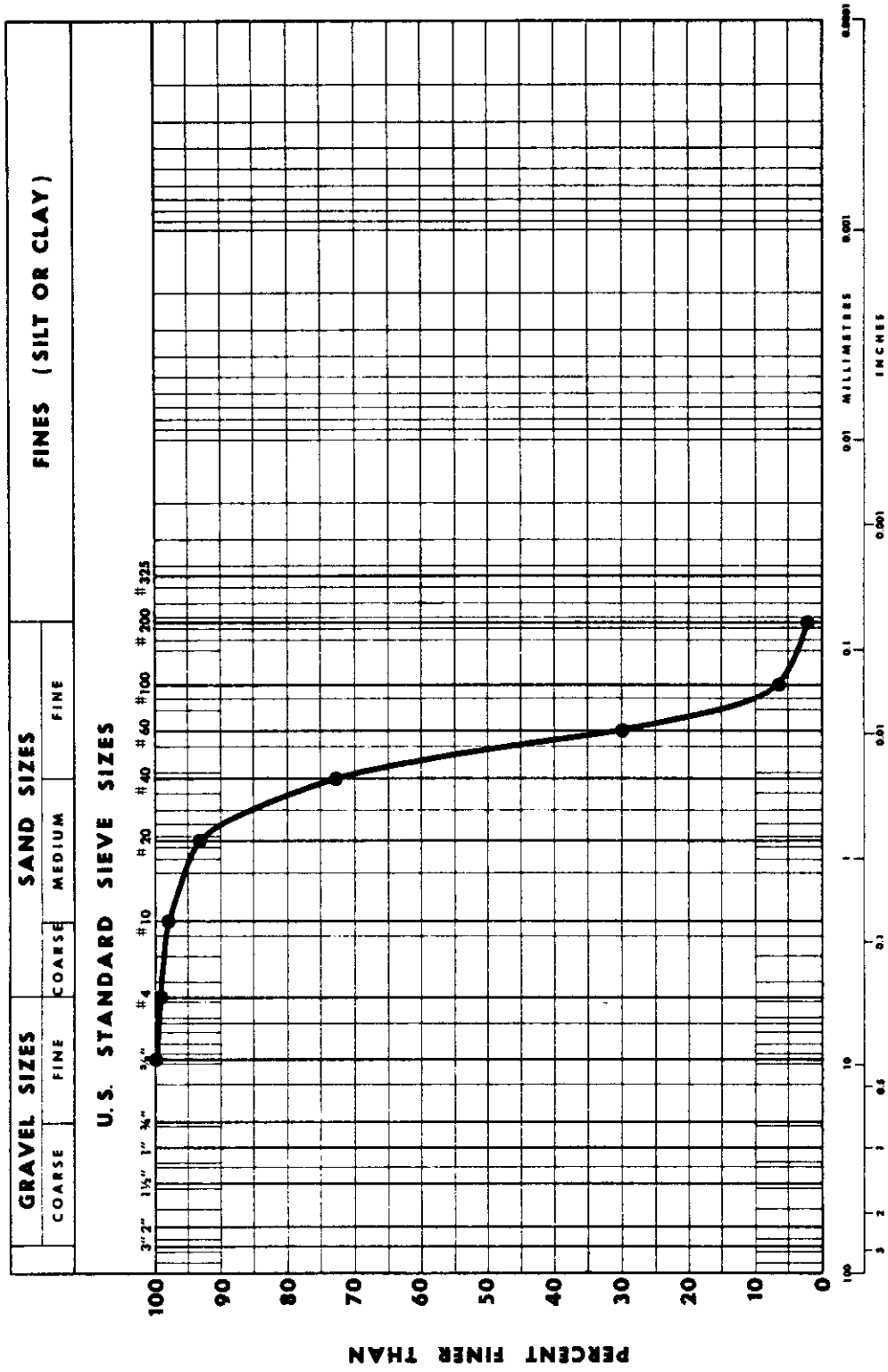
TEST HOLE NO.
27

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 27

GRAIN SIZE ANALYSIS



D_{10} = 0.16 mm.
D_{30} = 0.25 mm.
D_{60} = 0.38 mm.
C_u 2.4
C_c 1.0

REMARKS: TH27 at 12.8 to 13.25 m

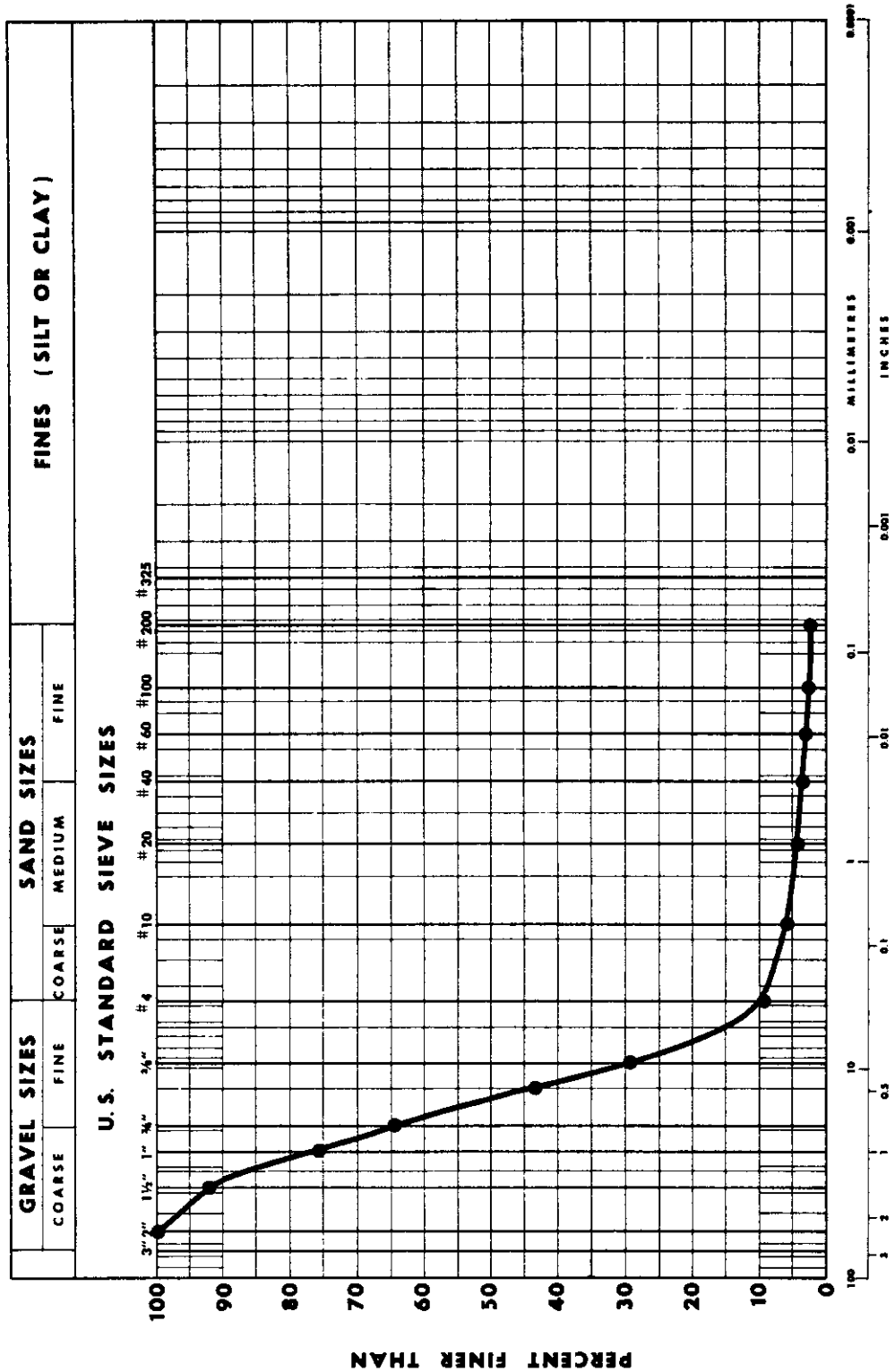
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
27

GRAIN SIZE ANALYSIS



D_{10} = 5.0 mm.
D_{30} = 10.0 mm.
D_{60} = 20.0 mm.
C_u = 4.0
C_c = 1.0

REMARKS: TH28 at 9.1 to 9.3 m

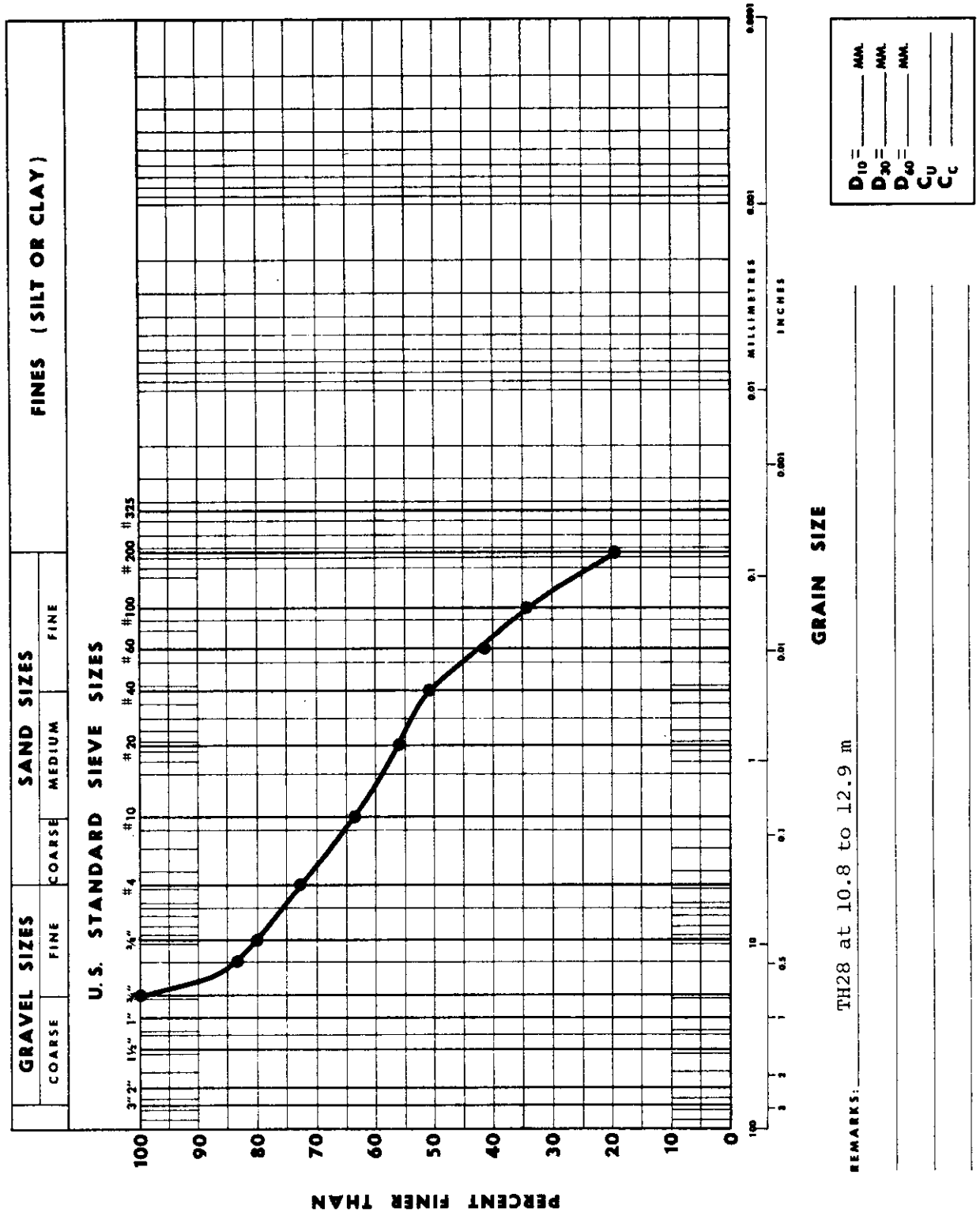
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
28

GRAIN SIZE ANALYSIS

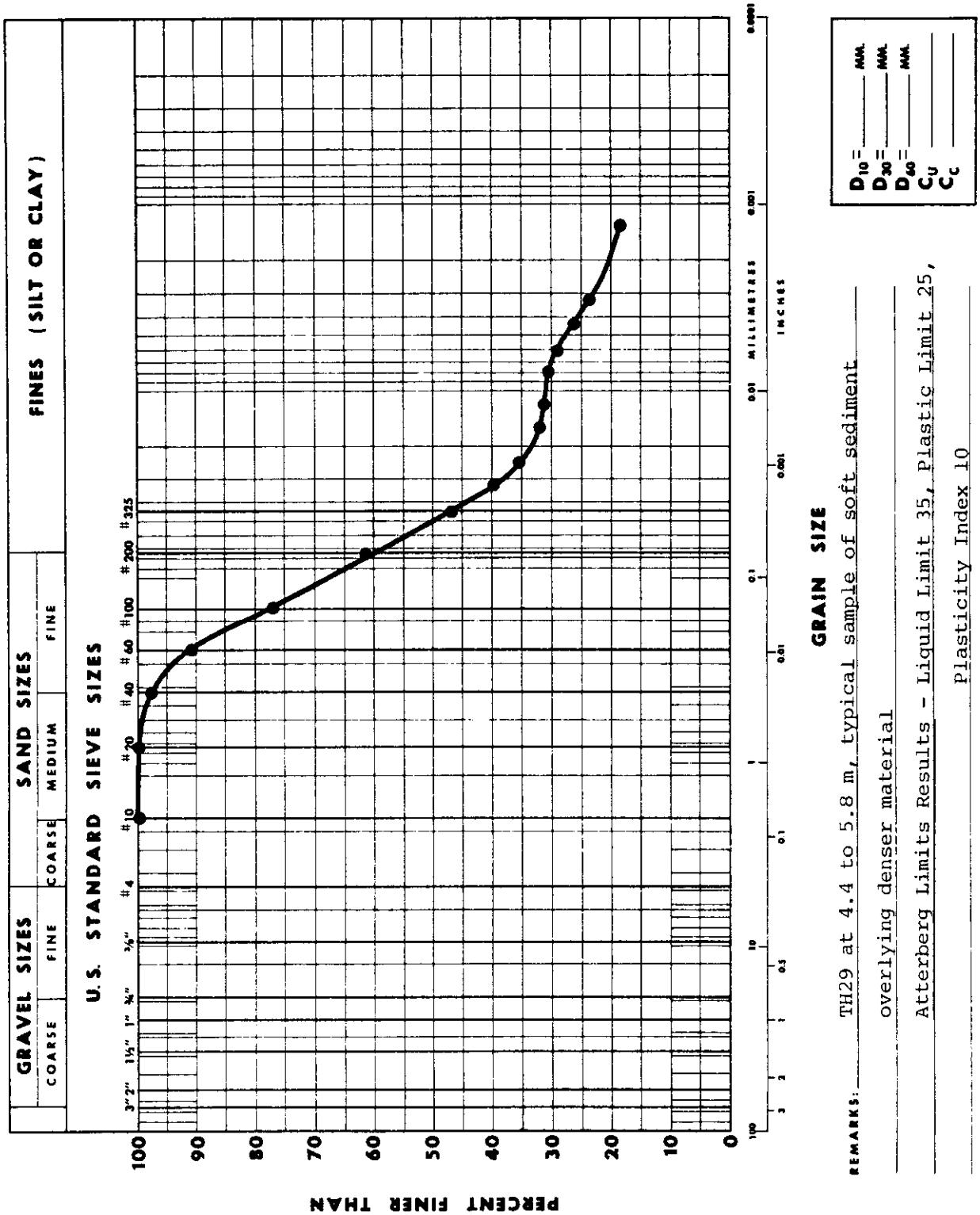


GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
28

GRAIN SIZE ANALYSIS



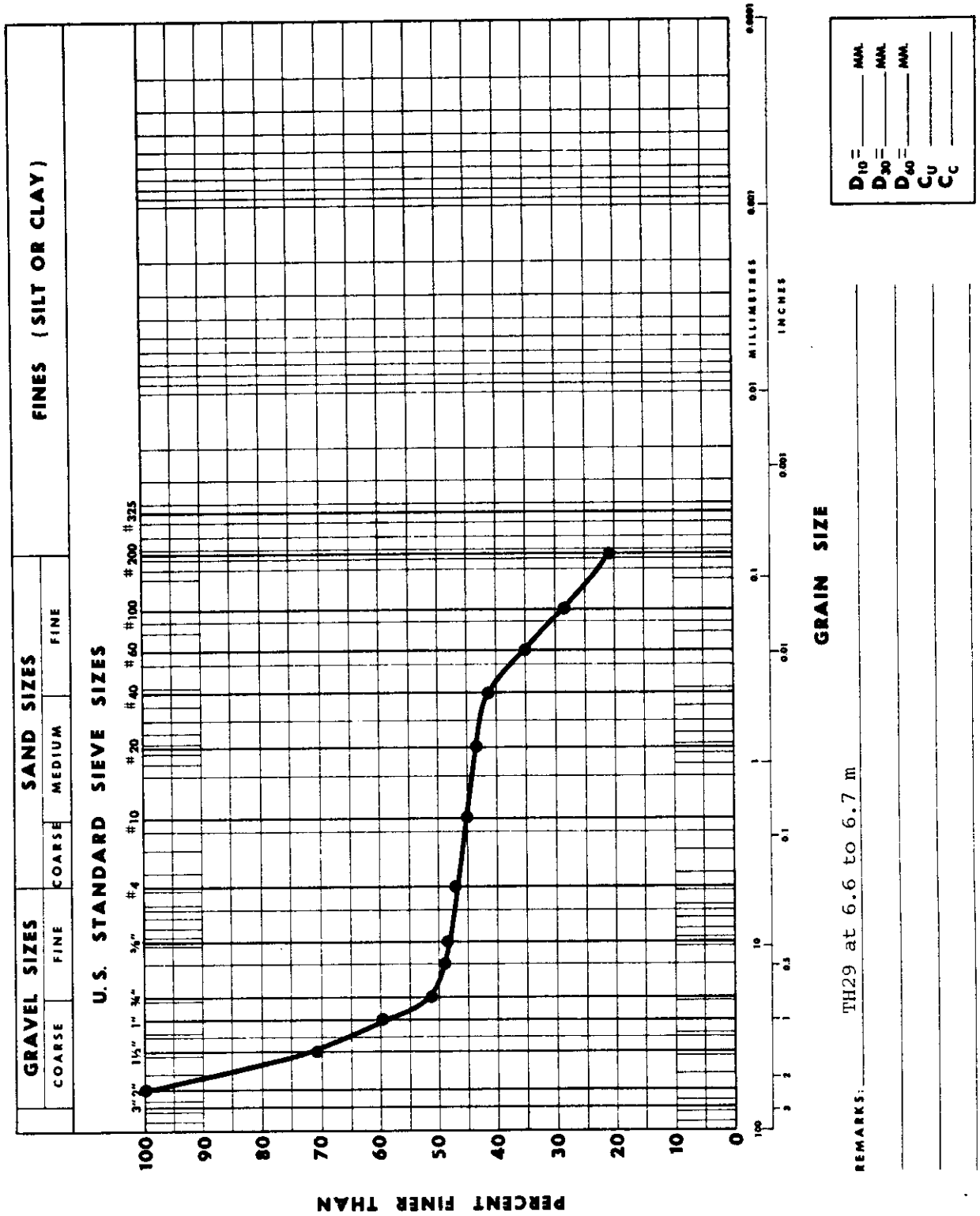
REMARKS: TH29 at 4.4 to 5.8 m, typical sample of soft sediment overlying denser material

Atterberg Limits Results - Liquid Limit 35, Plastic Limit 25, Plasticity Index 10

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

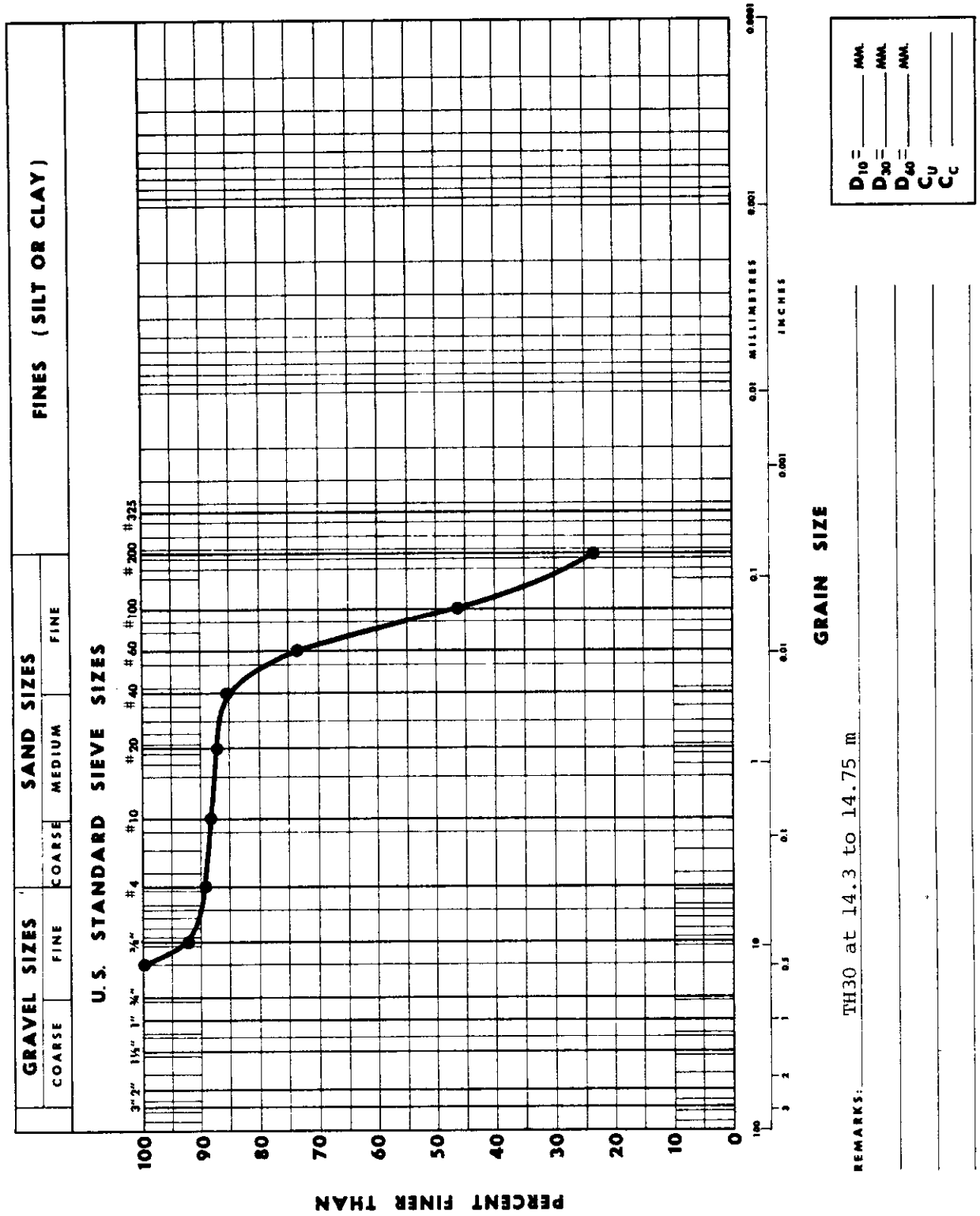
GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 29

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 29

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

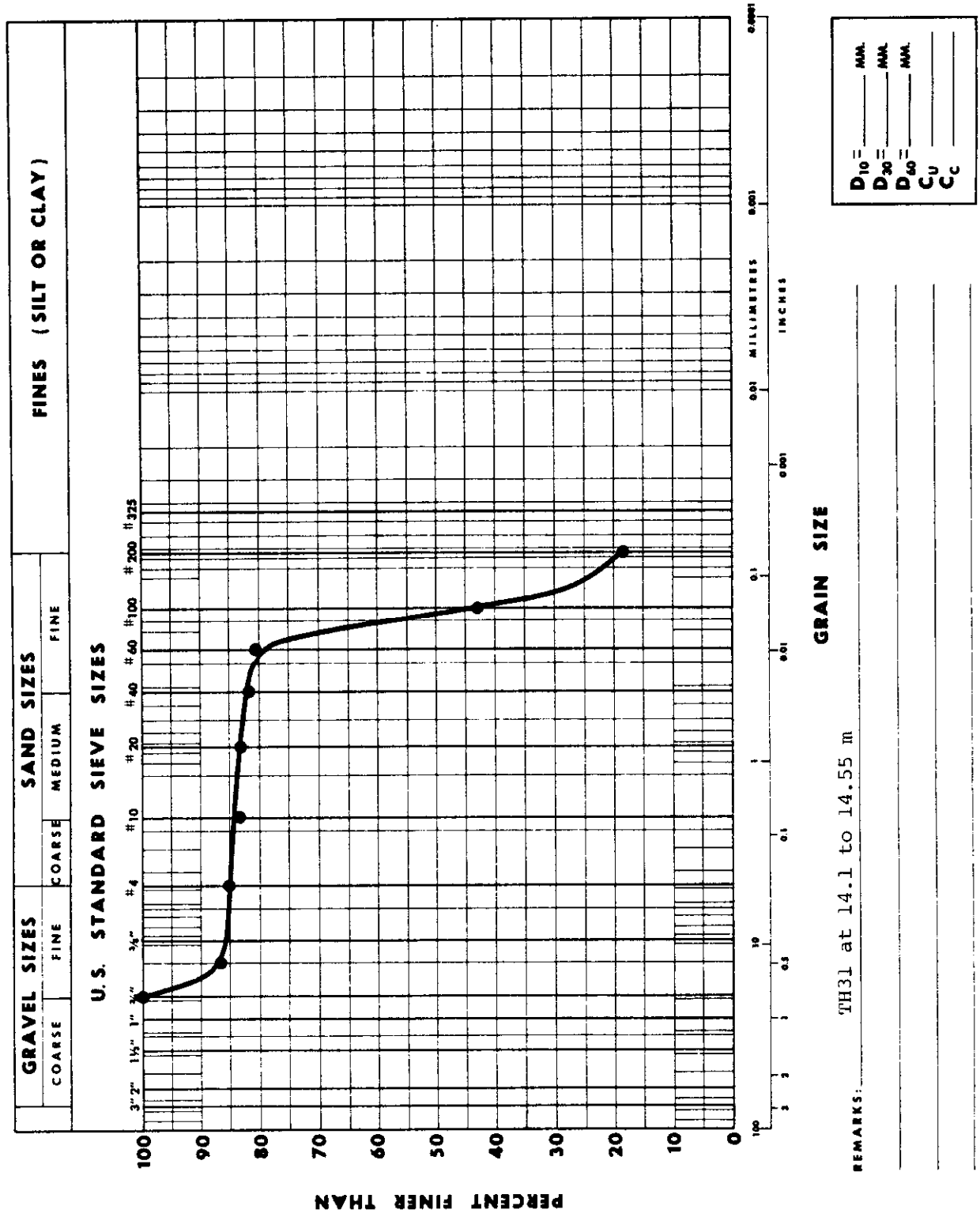
HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.

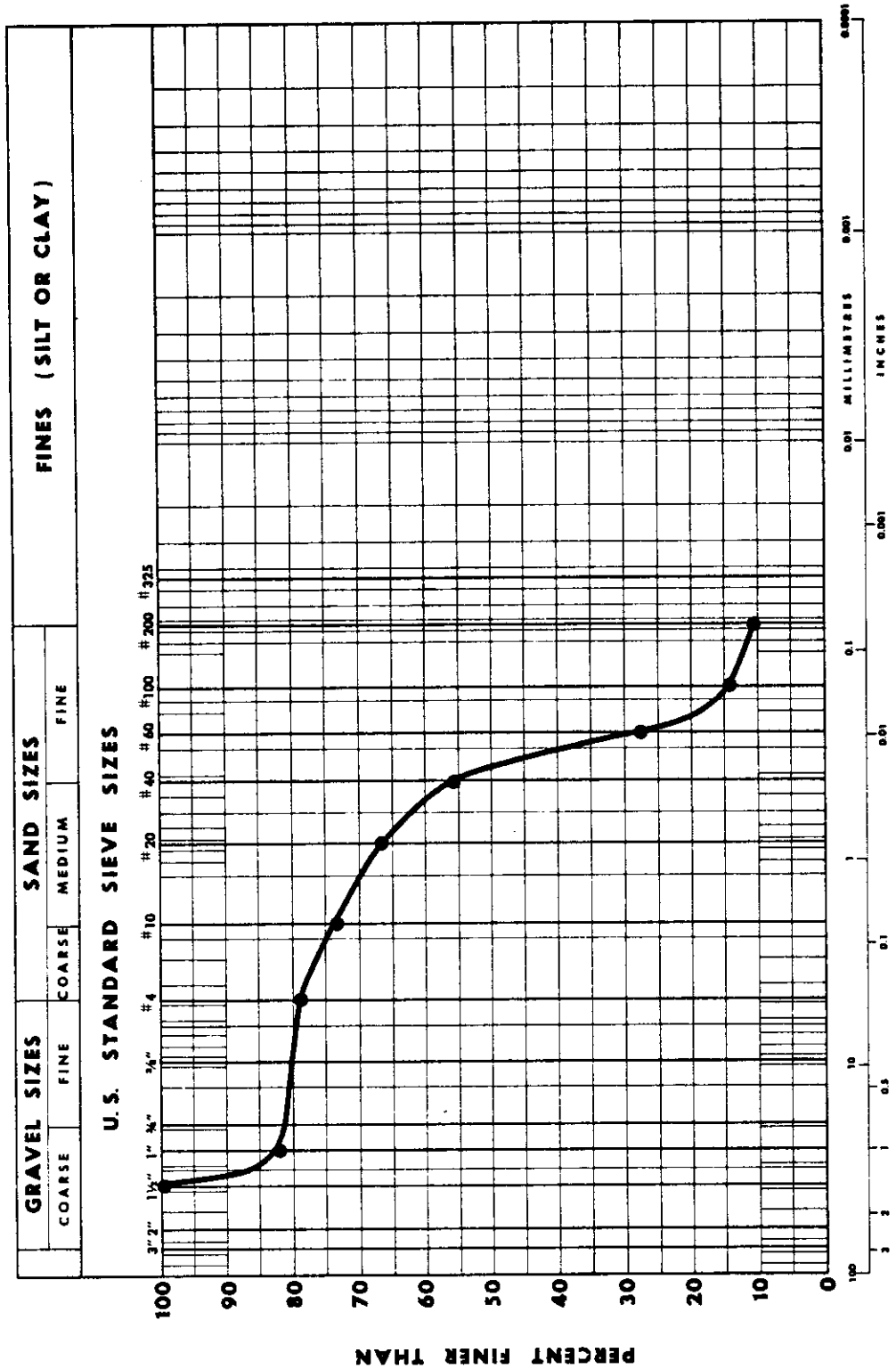
30

GRAIN SIZE ANALYSIS



GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 31

GRAIN SIZE ANALYSIS



D_{10} = 0.07 mm.
D_{30} = 0.28 mm.
D_{60} = 0.52 mm.
C_U = 7.4
C_C = 2.2

REMARKS: TH32 at 9.8 to 10.25 m

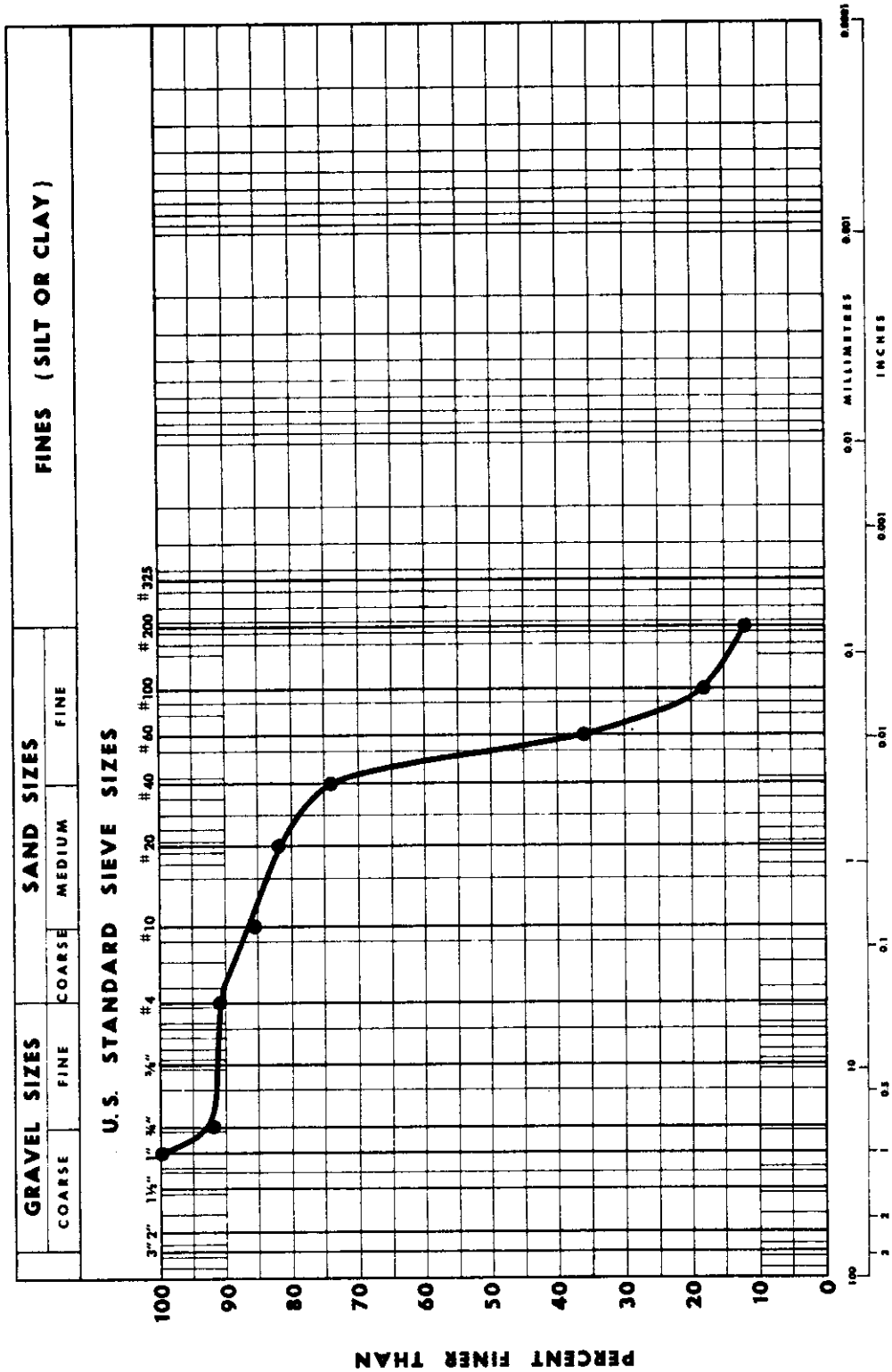
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TEST HOLE NO.
32

GRAIN SIZE ANALYSIS



D_{10} = 0.04 mm.
D_{30} = 0.21 mm.
D_{60} = 0.35 mm.
C_U = 8.8
C_C = 3.2

REMARKS: TH33 at 8.0 to 8.45 m

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES	TEST HOLE NO. 33

APPENDIX B

EXPLANATION OF TERMS AND SYMBOLS

APPENDIX B

EXPLANATION OF TERMS AND SYMBOLS

1.0 GENERAL

The terms and symbols used on the test hole logs to summarize the results of the field investigation and of subsequent laboratory testing are described in detail below and are illustrated on the appended exhibit test hole log (Figure 1).

General information, such as test hole number, date of drilling and inspector, is noted in the lower portion of the test hole log. Detailed subsurface information observed at each test hole location and laboratory test data are presented in columnar form on the test hole log. Each column used is described in detail below using the reference numbers shown on the appended blank test hole log (Figure 2).

It should be noted that the soil type, stratigraphic boundaries, and in situ conditions have been established only at the test hole location and that they are not necessarily representative of subsurface conditions elsewhere across the site.

Column 1: Depth: The depth of test hole below ice surface at time of drilling is shown in this column.

Column 2: Soil Group Symbol: A soil classification symbol in accordance with a modification of the Unified Soil Classification System[1] is noted in this column. A definition of each Group Symbol is given on Figure 3 "Modified Unified Classification System for Soils".

Column 3: Soil Graphic Log: Soil strata are depicted graphically in accordance with the Graphic Symbol shown on Figure 3.

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(1) References are listed on page B-14.

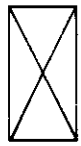
Column 4: Material Description: A detailed engineering description of each soil stratum encountered is noted in this column. This description is given in accordance with the criteria outlined in Section 2.1 "Soil Description". The interface between soil strata is shown noted as a single continuous line with the depth to the interface above the line. A short broken line indicates a change in soil type descriptors, the soil type remaining the same.

Column 5: Sample Type and Number: The type and reference number of each sample is recorded in this column at the appropriate depth. The type of sample is indicated by the following prefixes:

B	Bag Sample, usually from inside of plugged drill stem and bit
C	Core Sample
D	Split Spoon Standard Penetrometer Sample
U	Tube Sample

Column 6: Sample Condition: The condition of each sample, and whether it was recovered or lost, is recorded against depth in this column with the following symbols

undisturbed



disturbed

not recovered

Undisturbed samples refer to core or tube samples which have been recovered in a state relatively unchanged by sampling. As no attempt was made to prevent samples from freezing, no undisturbed samples were retained on this job. Disturbed samples are any other samples recovered from the hole. 'Not recovered' refers to samples lost down the hole.

Column 7: Depth: The depths of samples retained are noted in this column.

Column 8: Other Information: Test data and field observations not incorporated into the previous columns are presented here. Information for grain size analyses and Atterberg Limit determinations are included on separate forms following the test hole logs.

The number designated by N in this column refers to the number of blows of a 63.5 kg (140 lbs) hammer freely dropping 0.76 m (30 inches) to drive the 50.8 mm (2 inch) O.D. open-ended Standard Penetrometer 0.15 m (6 inches) to 0.45 m (18 inches) into the soil.

2.0 DESCRIPTION DETAILS

The various terms, symbols, and abbreviations are discussed in detail to facilitate interpretation and understanding of the data presented on the test hole logs.

2.1 Soil Description (Column 4)

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

2.1.1 Soil Description System

The following properties are described for a comprehensive soil classification system:

Grain size distribution or plasticity, colour, moisture, sensitivity, structure, foreign materials, and consistency or strength.

The soil in each stratum is described on the test hole logs using the Unified Soil Classification System modified slightly so that an inorganic clay of "medium plasticity" is recognized. Selected adjectives are used to define the actual or estimated percentage range by weight of the various components.

The identification of soil components and fractions is defined by the Modified Unified Soil Classification System which classifies soils into three major divisions:

Coarse-grained soils - gravel and sand
Fine-grained soils - silt and clay
Highly organic soils - peat

Classification of soils is based on the grain size distribution of that portion of the soil smaller than the 3-inch U.S. Standard sieve size.

Soils with 50 percent or more of the components coarser than the No. 200 U.S. Standard sieve size (0.074 mm) are described as COARSE-GRAINED (or granular) soils. Coarse-grained soils (gravel and sand) are classified by grain size distribution and are subdivided into coarse and fine gravel, and coarse, medium, and fine sand.

Soils with 50 percent or more of the components finer than the No. 200 sieve size are described as FINE-GRAINED soils. These may be cohesive or non-cohesive. Note

that for visual classification the No. 200 sieve size is about the smallest size of particle that can be distinguished individually by the unaided eye.

Fine-grained soils (silt and clay) are classified by behaviour on the basis of the liquid limit and plasticity index of the fraction finer than the No. 40 U.S. Standard sieve size. The boundaries defining the fine-grained soil groups are shown on the Plasticity Chart on Figure 3. The Plasticity Chart is also used to determine the behaviour of the fines content of coarse-grained soils.

Particle size and shape are usually described for coarse-grained soils, and plasticity is usually described for fine-grained soils. An exception to this rule applies when describing glacial till. Then plasticity, particle size, and shape are all included in the description.

The principal component of the fraction of the soil passing the 3-inch U.S. Standard sieve size is shown capitalized on the test hole logs.

The proportions by weight of the minor components are defined according to the following descriptors:

Descriptor	Proportion
"and"	50 to 35 percent
"some"	35 to 20 percent
"little"	20 to 10 percent
"trace"	10 to 1 percent

The descriptors used must not contradict the classification by the Modified Unified Soil Classification System.

The terms given above are used to define proportions by weight of granular components, but they may also be used to define the proportion of minor components of fine-grained material, according to the subdivisons of the Plasticity Chart shown on Figure 3. The adjectives are not used to subdivide a principal fine-grained component. The modifier "y" or "ey" (i.e., SILT - clayey) is used when the liquid limit and plasticity index plot close to the "A-line" on the Plasticity Chart.

The soil is described first by identifying the principal component, followed by the minor components in order of decreasing proportion by weight. This is followed by other significant identifying features such as plasticity, colour, moisture, structure, and strength.

2.1.2 Typical Example of a Complete Soil Description

"CLAY, silty, little medium sand, trace coarse gravel, medium plasticity, yellow-brown", describes a yellow-brown fine-grained silty clay soil containing 50 percent or more of components finer than the No. 200 U.S. Standard sieve size with minor components of sand and gravel. The fraction passing the No. 40 U.S. Standard sieve size plots above, and close the the "A-line" on the Plasticity Chart. The soil contains between 10 percent and 20 percent of sand particles generally in the size range No. 10 to No. 40 (i.e., finer than the No. 10 Standard sieve size and larger than the No. 40 Standard sieve size) and between 1 percent and 10 percent of gravel in the size range 3/4 inch to 3 inch. The identifying feature "medium plasticity"

indicates that the liquid limit plots between 30 and 50 on the Plasticity Chart. Such a soil is classified as CI by the Modified Unified Soil Classification System.

2.1.3 Typical Examples of the Use of Modifiers and Descriptors

(a) Coarse-grained soil with minor fine-grained component:

"GRAVEL fine, some silty clay", describes a coarse-grained soil with a minor component of fines, which has a liquid limit and plasticity index that plot above and close to the "A-line" on the Plasticity Chart. Such a soil is classified as GC by the Unified Soil Classification System.

"SAND some silt," is correct in that "silt" in this case is a minor component of non-plastic fines which plot below the A-line on the Plasticity Chart.

(b) Fine-grained soil with a minor coarse-grained component:

"CLAY silty, some fine sand", describes a fine-grained soil having a fines content in excess of 50 percent

(i.e., 50% of material finer than the No. 200 U.S. Standard sieve size), which plots above the "A-line" on the Plasticity Chart, with a liquid limit less than 50 on the Plasticity Chart, and has a minor component of fine sand.

"CLAY some silt, some fine sand", would not be used as the fines are classified by behaviour (plasticity) and not by particle size. Such a soil would be classified as CI or CL according to the Unified Soil Classification System.

2.2 Classification of Construction Materials

2.2.1 Granular Material

Table B-1 is a classification of materials based on the potential construction usage of the granular material. This classification system for Granular Materials was provided by DIAND.

TABLE B1

CLASSIFICATION OF GRANULAR MATERIALS

	Source Quality Description	General Description of Material	Minimum Technical Identification Parameters	Suggested Uses of Material
(1)	Excellent	Well graded sands and gravel suitable for use as aggregates with a minimum of processing	Petrographic Number - 160 max. Los Angeles Abrasion Loss - 35% max. Soundness Loss (Magnesium Sulphate) - 12% max. and meeting other requirements of CSA A23.1 - 1973	Portland cement concrete, asphaltic concrete, masonry sand, concrete block, surface treatment and roofing aggregate
(2)	Good	Graded sands and gravels with varying quantities of silt	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 structure
(3)	Fair	Poorly graded sands and gravels with or without substantial silt content	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	Nil	General non-structural fill

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TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
			ICE				
			1-6				
2			WATER				
4							
6							
			7-0				
	GP		GRAVEL little sand, trace silt	U1		7-0 7-1	Grain size analysis
			8-0				
8	SP		SAND fine to medium grained, trace silt	B1		8-0 8-1	Grain size analysis
				D1		9-0 9-45	N=9
10							
12							
				D2		12-8	N=69 Grain size analysis
14			Bottom of Hole at 13.35 m depth				
16							

DATE: Feb. 19, 1979 | LOGGED BY: G.D./N.H. | DRWN BY: PD/vh | CHKD BY: N.H.

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TEST HOLE NO. 35

FIGURE 1

TEST HOLE LOG

DEPTH (M)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE AND NUMBER	SAMPLE CONDITION	DEPTH (M)	OTHER INFORMATION
2							
4							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
6							
8							
10							
12							
14							
16							

DATE:	LOGGED BY:	DRWN BY:	CHKD BY:

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TEST HOLE NO.

FIGURE 2

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

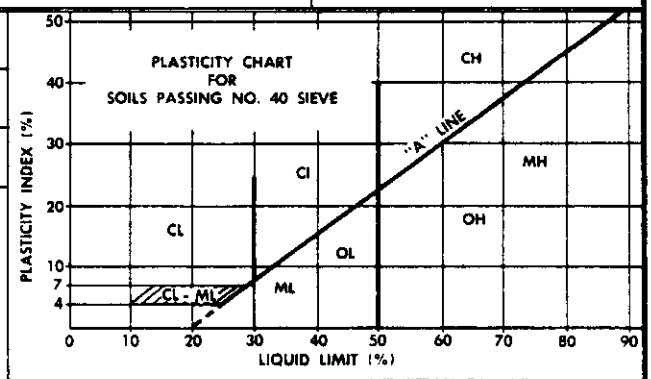
MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, 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		
		$W_L > 50\%$	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	

SOIL COMPONENTS

FRACTION	U S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL			50 - 35	and
coarse	3 inch	¾ inch		
fine	¾ inch	No 4		
SAND			35 - 20	some
coarse	No 4	No 10		
medium	No 10	No 40	20 - 10	little
fine	No 40	No 200		
SILT (non plastic) or CLAY (plastic)	No 200		10 - 1	trace

OVERSIZE MATERIAL

Rounded or subrounded COBBLES 3 inch to 8 inch BOULDERS > 8 inch	Not rounded ROCK FRAGMENTS > 3 inch ROCKS > 1 cubic yard 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%.

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FIGURE 3

APPENDIX C

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