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GEOPHYSICAL EVALUATION OF GRANULAR MATERIAL RESOURCES

Tuktoyaktuk Harbour, Northwest Territories

MARCH 1978

PREPARED BY

R.M. HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERS & PROFESSIONAL SERVICES
• GEOTECHNICAL DIVISION

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GEOPHYSICAL EVALUATION
OF
GRANULAR MATERIAL RESOURCES
TUKTOYAKTUK HARBOUR
NORTHWEST TERRITORIES

Prepared For

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

By

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CALGARY ALBERTA

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1.0 SUMMARY

This report outlines the results of a geophysical survey of Tuktoyaktuk Harbour, N.W.T., as requested by the Department of Indian Affairs and Northern Development (DIAND), and represents the second phase of a granular materials inventory conducted for the Tuktoyaktuk area. The first phase of the study encompassed an area within a 48 km (30 mile) radius of Tuktoyaktuk, and included an investigation of granular deposits on land, near shore and offshore.

The geophysical survey provided bathymetric data, and subbottom profiles of near surface stratigraphy representing lower and higher density materials. Maps of bathymetric contours and of low density material isopachs were prepared from the geophysical survey data. Based on a geologic assessment of the study area, it is assumed that the low density materials are silts and clays, while the higher density materials are sands and gravels.

To establish subbottom soil types and their quality, a limited field drilling program has been recom-

mended. Data from the drilling program can then be correlated with the geophysical survey, and extrapolated over the study area.

Preferred areas for dredging of harbour bottom granular material resources have been delineated, based on the geophysical survey data. The preliminary criteria employed in establishing these areas were that water depths should range between 3 m and 9 m (9.8 and 29.5 feet), and that the soft sediment thickness should be less than 2 m (6.6 feet).

The development and management of the granular material resources in terms of dredging techniques, equipment availability, overburden disposal, stockpiling of aggregate, and environmental considerations related to dredging and stockpiling have been considered in a preliminary overview. Detailed studies of these considerations will be required if the in-situ materials are proven to be desireable for development.

2.0 INTRODUCTION

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 study was to locate at least 10 million cubic yards of sand and gravel, with an emphasis on finding major deposits or stockpiling sites with year-round access from Tuktoyaktuk. The first 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 final report on the first phase of the study was completed in August 1977, (R. M. Hardy & Associates Ltd., 1977a). Based on the findings of this report, DIAND commissioned R. M. Hardy & Associates Ltd. to carry out a geophysical investigation of the granular material resources identified in the underwater sediments of Tuktoyaktuk Harbour (designated as Deposit 162).

Authorization for the geophysical field survey was received on September 20, 1977 from Supply and Services Canada, under Contract Serial Number 0SU77-00240. The contract was amended in March, 1978, to finalize the interpretation and evaluation of the geophysical field data.

The geophysical survey was performed in Tuktoyaktuk Harbour between September 29 and October 3, 1977. A preliminary report describing the field work was submitted in October 1977 (R. M. Hardy & Associates Ltd., 1977b).

This report describes the geophysical data acquisition, data interpretation and office studies, carried out in accordance with our terms of reference, as outlined under "Scope" in Section 3.0 of this report.

3.0 SCOPE

3.1 Geophysical Survey

The objectives of the geophysical survey were to obtain marine acoustic bottom and subbottom soundings in the study area, in order to -

(i) derive accurate bathymetric data,

(ii) profile the upper subbottom stratigraphy, and

(iii) delineate the thickness of the upper stratum of harbour bottom sediments.

These data were to be of sufficient detail to serve as baseline information for planning a limited field drilling program, to determine quantity and quality of the granular material resources in the study area. As well, the geophysical data would be used to delineate the most favourable development areas with respect to water depth and overburden thickness.

3.2 Office Studies

The objectives of the office studies were to -

(i) interpret the geophysical data,

(ii) outline the principle findings of the survey, including a clear statement of the assumptions made in interpreting the data,

(iii) prepare a series of maps, which were to include a location map showing the position of each survey line, a contoured bathymetric map of the study area and a map showing the major sand and gravel deposits as well as the sediment thickness,

(iv) propose a drilling program, which is required to fully determine the quantity and quality of material in the harbour, including a map showing proposed drill hole locations, and

(v) provide recommendations concerning the development and management of the harbour resources, including extraction techniques, equipment required, and possible stockpile sites.

4.0 PERSONNEL

Project management was carried out by Mr. T. J. Fujino, P.Eng., of R. M. Hardy & Associates Ltd. His responsibilities included the management of subcontractors and subconsultants, as well as administration and management of the project team.

Mr. N. Hernadi, P.Eng., of R. M. Hardy & Associates Ltd. acted as project engineer. His responsibilities included planning, administration and supervision of the geophysical survey, organization and coordination of specialist services and preparation of the final report.

Mr. J. D. Henderson, geophysicist, of R. M. Hardy & Associates Ltd. was responsible for the direct field supervision and management of the geophysical survey. Mr. Henderson also assumed responsibility for preparation of bathymetric and subbottom contour maps from the geophysical data.

Dr. V. N. Rampton, of Terrain Analysis and Mapping Services Ltd. acted as the geological subconsultant to R. M. Hardy & Associates Ltd. on this project. His responsibilities included delineation of the study area, and review of the study findings and recommendations.

Kenting Exploration Services Ltd., of Calgary, was subcontracted by R. M. Hardy & Associates Ltd., and was responsible for acquisition of geophysical field survey data. Kenting's survey team was comprised of a marine geophysicist and a navigation operator.

5.0 INVESTIGATIONAL PROCEDURE

5.1 General

Based on a geologic assessment of Tuktoyaktuk Harbour and vicinity, as well as the results of a previous investigation (E. W. Brooker & Associates Ltd., 1973), it was concluded that the underwater sediments in Tuktoyaktuk Harbour may, potentially, be a primary source of unfrozen granular materials. Therefore, the use of marine geophysics was recommended to:

(i) identify harbour bottom areas considered most favourable for further exploration by drilling,

(ii) provide subbottom soundings for interpolation of subbottom profiles with similar acoustic signatures, and

(iii) obtain accurate bathymetric data to assist in potential dredging operations.

5.2 Geophysical Data Acquisition

5.2.1 Logistics

The geophysical subcontractor, Kenting Exploration Services Ltd., shipped their equipment by air freight to Inuvik, N.W.T. on September 23, 1977. This equipment included all electronic instrumentation plus a 6.4 m (21 foot) inflatable Zodiac boat, propelled by twin 35 HP outboard engines. All equipment had arrived in Inuvik, N.W.T. by September 28, 1977. A fixed-wing charter was used to transport personnel and equipment from Inuvik, N.W.T. to Tuktoyaktuk on September 28, 1977. Accomodation for the field personnel in Tuktoyaktuk, N.W.T. was obtained at the CANMAR camp.

5.2.2 Survey Systems Utilized

The geophysical data acquired were marine acoustic subbottom soundings. Data were simultaneously obtained with three systems, operating independently at 7 kilohertz, 30 kilohertz, and 200 kilohertz. In marine acoustic soundings, frequency is a significant factor in determining depth of penetration in the subbottom sediments. Other factors involved in limiting depth of penetration are output power and dynamic range. The maximum penetration achieved on this survey was about 7 m (23 feet), in soft sediments with the 7 kilohertz system. The 200 kilohertz system does not penetrate subbottom sediments and serves as an accurate fathometer.

The systems used on the survey were:

(i) Raytheon RTT-1000A Profiling System - The RTT-1000A can be operated at frequencies of either 3.5 and 7 kilohertz. During this survey the 7 kilohertz frequency was used. The transceiver consists of a piezo-electric element mounted in a conical reflector, and was mounted approximately 0.3 m (1 foot) beyond the side of the boat. The reflections are recorded on a graphic recorder.

(ii) Kelvin Hughes MS26B Profiler - This system operates at a frequency of 30 kilohertz. It uses two identical piezo-electric transducers, one for transmitting, and one for receiving. Both elements are placed in housings on circular brass diaphragms, and are mounted on the base of one casting. The base of the casting is the reflector and the diaphragms are sound windows in that reflector. The reflections are recorded on a graphic recorder. The Kelvin Hughes system was mounted 0.3 m (1 foot) beyond the opposite side of the boat.

(iii) Furuno Fathometer - The Furuno Fathometer operates at a frequency of 200 kilohertz and yields accurate bathymetric data. It was mounted from the back of the boat behind the twin outboard engines. The data are displayed on a graphic recorder.

5.2.3 Positioning and Plotting of Survey Lines

A Mini-Ranger III positioning system was used to locate and determine the location of the survey lines over Tuktoyaktuk Harbour. The Mini-Ranger III is a line-of-sight positioning system operating in the frequency range from 5400 to 5600 MHz. The Mini-Ranger III operates on the principle of pulsed radar. It uses a mobile transmitter on the survey boat and two on-shore reference transmitters.

The exact location of the reference transmitters must be known. (These were surveyed in by using the Mini-Ranger III and initially locating two reference stations at known benchmarks on-shore).

The mobile transmitter sends out a pulsed radar signal to interrogate the on-shore reference transmitters. The elapsed time between the transmitted pulse and the reply pulse is recorded for each reference station. This range information together with the known locations of each reference station is trilaterated to provide a position fix of the mobile unit (survey boat). A mini-computer (Hewlett Packard Model 9825) was used to compute and display in real time the position of the survey boat. The real time record of the computer not only yields accurate position data, but also serves as a navigational system. The skipper of the boat uses the real time output of the computer to stay on the predetermined survey line. The probable range measurement accuracy is better than ±3 m (9.8 feet).

5.2.4 Geophysical Field Investigation

The field work was carried out between September 29th and October 3rd, 1977.

During the morning of September 29th, reference transmitters for the Mini-Ranger III were surveyed in. These transmitters were referenced to the Canadian Hydrographic Survey and Canadian Geodetic Survey benchmarks. Line surveys were not possible due to high winds and rough sea conditions during the afternoon. Lines 31 to 39, and a tie-in line, were surveyed during the morning of September 30th, until poor weather conditions precluded further survey for the remainder of September 30th, and all day October 1st.

Lines 15, 17, 19, 21, 23 and 25, two tie-in lines, and Aveltkok Inlet were surveyed on October 2nd. The remaining lines were surveyed during the morning of October 3rd. The survey was stopped during the afternoon, due to poor weather conditions, and budget limitations precluded continuing the survey on subsequent days. Accordingly, demobilization commenced during the afternoon of October 3rd, equipment and personnel were transported to Inuvik by fixed-wing charter on October 4th, and demobilization was completed in Calgary on October 5th.

5.2.5 Summary of Survey Data Obtained

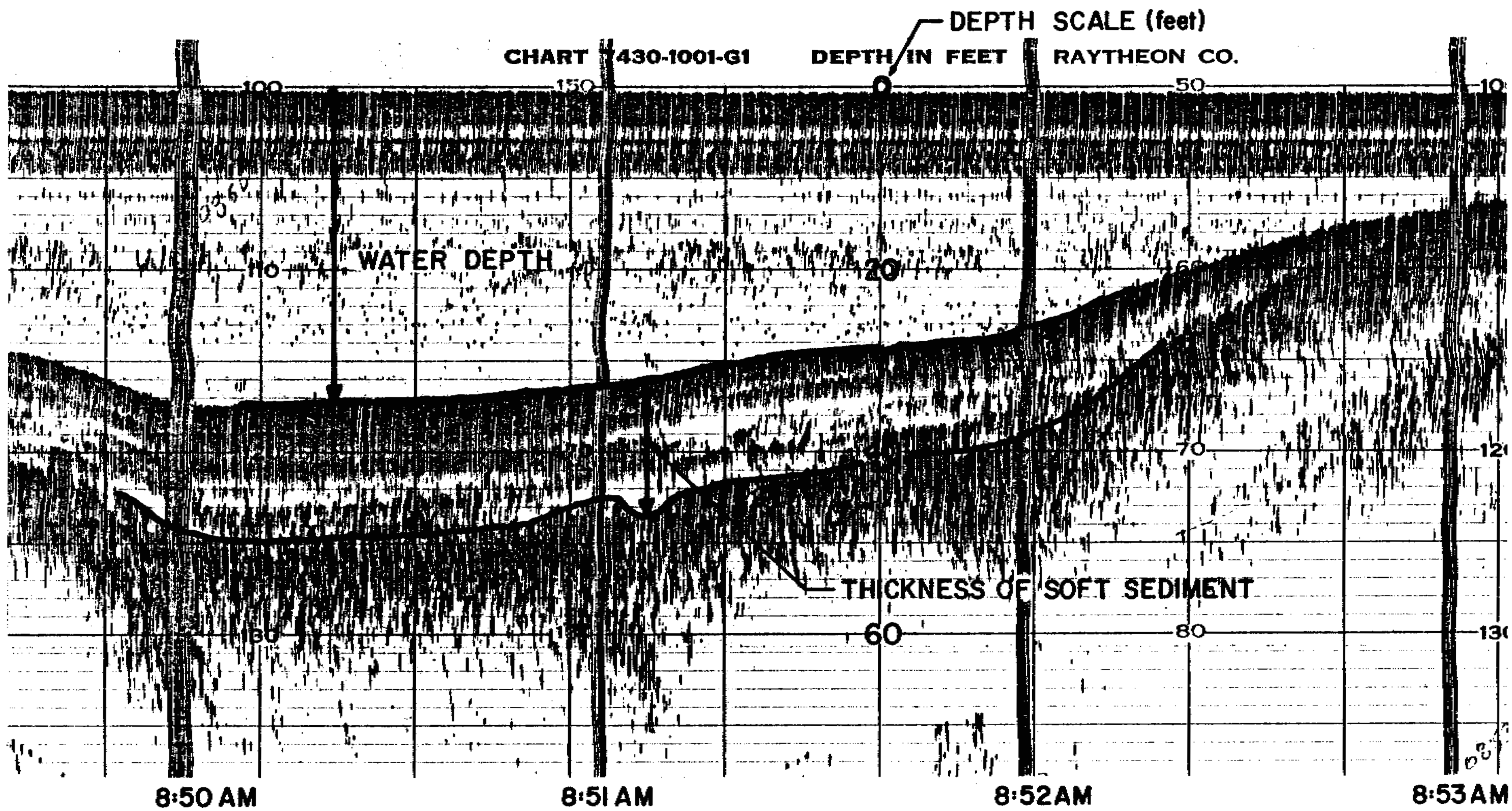
The survey data were delivered by Kenting Exploration Services Ltd. to R. M. Hardy & Associates Ltd. on October 7, 1977. The total amount of survey data collected was 45.1 line km (28.2 line miles). This coverage consisted of 29.3 line km (18.3 line miles) of parallel survey lines and 15.8 line km (9.9 line miles) of tie-in lines. All data were obtained at the three survey frequencies. Coverage of the study area, as well as data quality were considered adequate for plotting subbottom feature contour maps.

Kenting Exploration Services Co. Ltd. prepared a map of Tuktoyaktuk Harbour, at a scale of 1 to 5 000, superimposed on which is the accurate position of each survey line. This map has been reproduced at a scale of 1 to 10 000, and is included as Map 1 in Appendix A.

5.3 Geophysical Data Interpretation

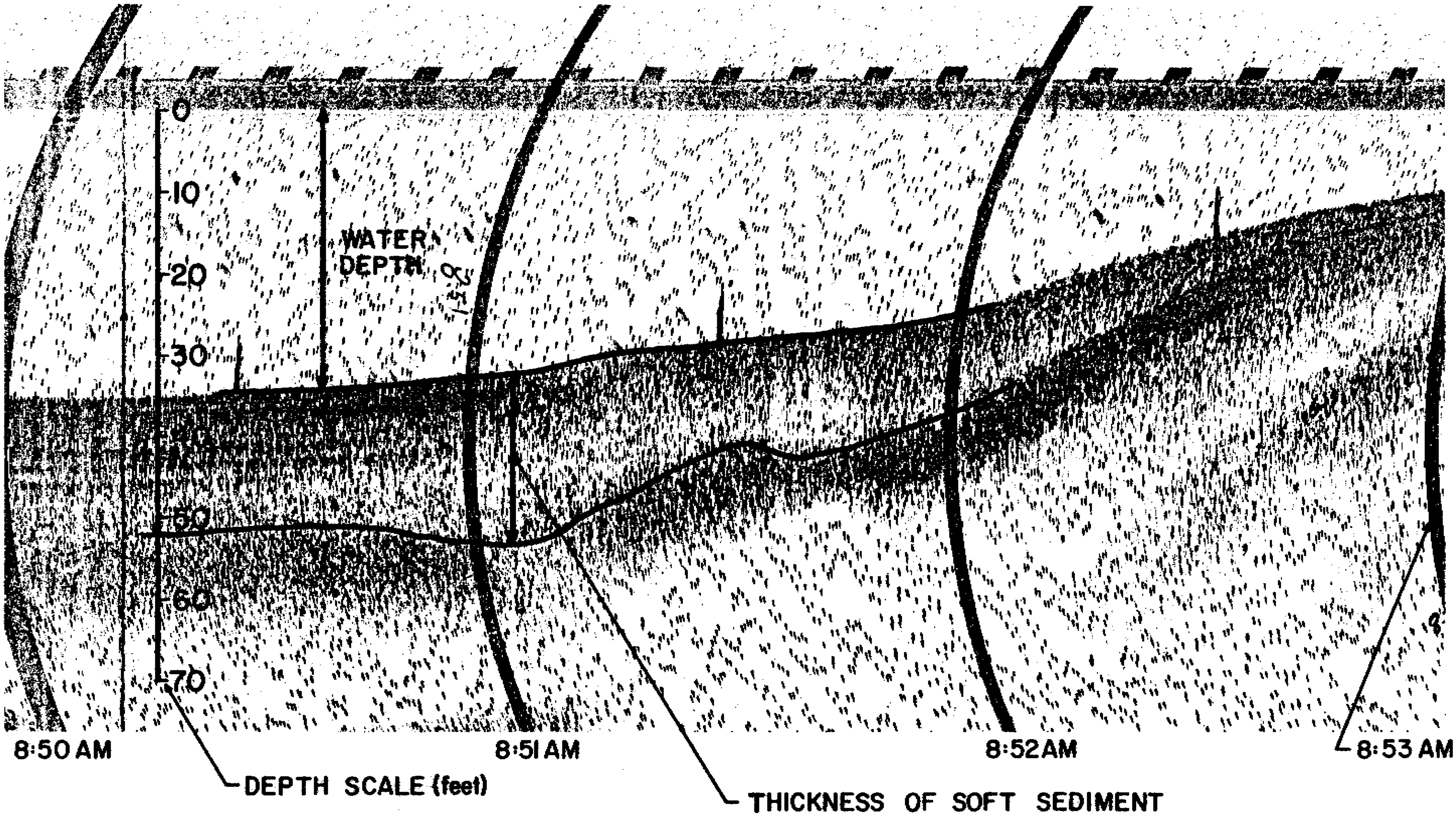
Typical examples of survey data at the three acoustic frequencies employed are shown on Figures 5.1 to 5.3. The times, manually recorded on the acoustic reflection records, correspond with the times shown on the survey line location map (Map 1, Appendix A). The sample records illustrate the penetration of acoustic waves at 7 and 30 kilohertz frequencies in the subbottom sediments, and the single reflection from the harbour bottom for the 200 kilohertz system. The depth to the reflectors is obtained by using scales on which the two-way travel time of acoustic waves has been converted to depths. The interpreter has to differentiate between real and multiple reflections. This differentiation is made by observing the consistency of certain reflections over distance, and by comparing the 7 and 30 kilohertz record.

The amplitude of a reflector at an interface depends on the change in density and acoustic velocities across an interface. A high density bottom, such as bedrock or sand and gravel, reflects the most acoustic energy and



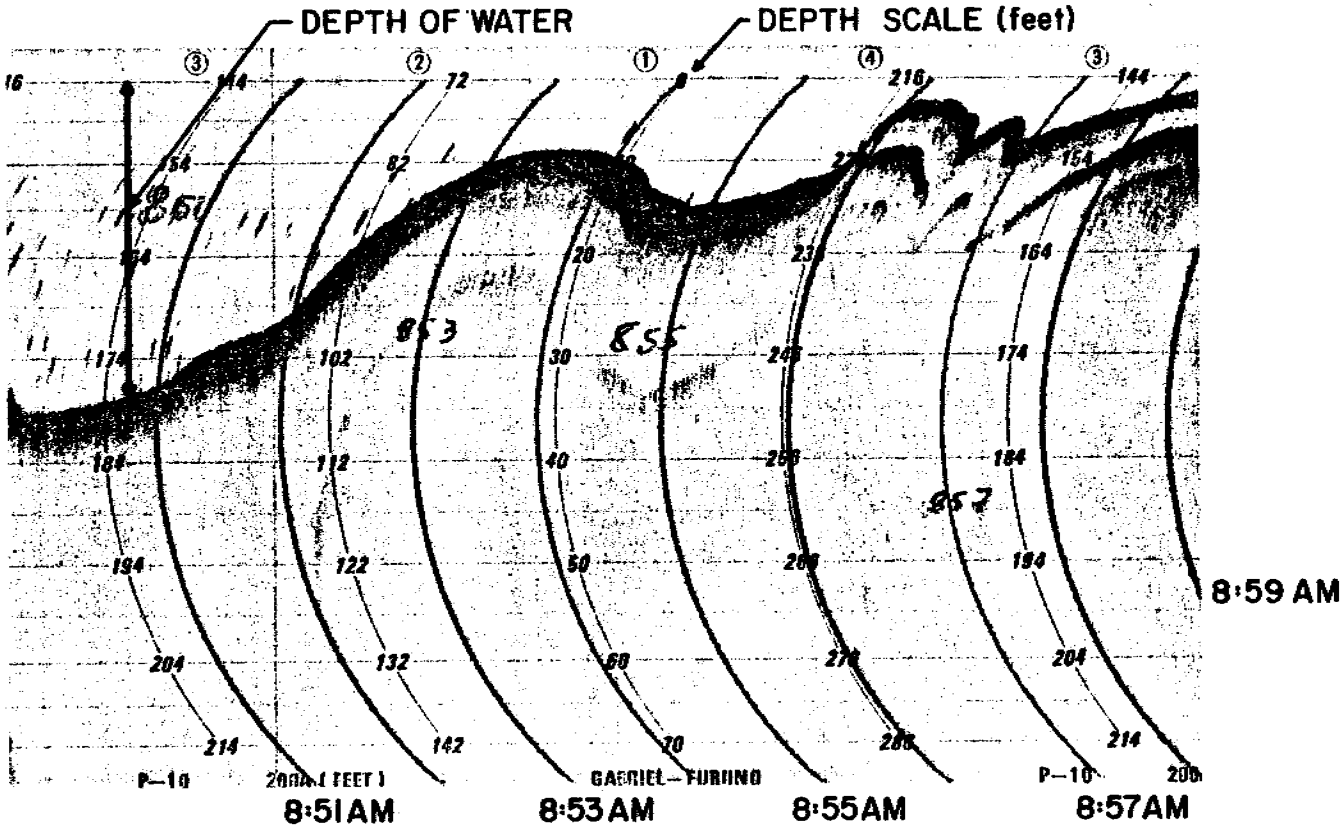
LINE 25, OCTOBER 2, 1977, 8:50 AM to 8:53AM

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TUKTOYAKTUK HARBOUR N.W.T. TYPICAL SURVEY DATA RAYTHEON RTT-1000 SYSTEM (7kHz) K4086 FIG. 5·1



LINE 25, OCTOBER 2, 1977, 8:50 AM to 8:53 AM

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TUKTOYAKTUK HARBOUR N.W.T. TYPICAL SURVEY DATA KELVIN HUGHES MS26B PROFILER(30 kHz) K4086 FIG. 5·2



LINE 25, OCTOBER 2, 1977, 8:50 AM to 8:59 AM

GOVERNMENT OF CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERS & PROFESSIONAL SERVICES • GEOTECHNICAL DIVISION	TUKTOYAKTUK HARBOUR N.W.T. TYPICAL SURVEY DATA FURUNO FATHOMETER (200 kHz) K4086 FIG. 5·3

very little energy penetrates into the subbottom sediments, so that no further stratification can be distinguished. On the other hand, a soft bottom will only reflect part of the energy (e.g., in the order of 50%). The remaining energy will penetrate and sufficient energy is reflected from subsequent layers to allow recognition.

The soft sediments are assumed to be low density silts and clays, while the harder bottom is expected to be higher density sand and gravel. This interpretation is supported by survey data near islands where the soft sediments become thinner, and where sand and gravel are seen exposed at the banks. Figures 5.1 to 5.3 are examples of sounding records on the approach to Fort Ross Islands, indicating the thinning of soft sediments near the islands.

The greatest probability of finding gravel, as opposed to sand and gravel, will be in areas of shallow sediments, where gravel is exposed along shorelines (i.e., near Conn Island and in the vicinity of the DEW Line Station).

6.0 FINDINGS OF THE INVESTIGATION

Map 2 (in Appendix A) is the bathymetric contour map of Tuktoyaktuk Harbour, within the survey area. The important features of this map were compared to the bathymetric data on the Canadian Hydrographic Service map of Tuktoyaktuk Harbour and Approaches (Map 7625, 1975) and an excellent correlation was observed. Map 3 in Appendix A is a contour map displaying the thickness of soft sediments over hard bottom. The thickness of soft sediments varies from a high of 10 m (32.8 feet) to a low of zero. Since the most likely interpretation is that the hard reflecting layer represents sand and gravel, the best prospects for dredging are in areas of shallow thickness of soft sediments. Substantial areas of thin, soft sediments are found in the north end of the harbour near Fort Ross Islands and Fort Hearne Island, as well as near shorelines and in Aveltkok Inlet. Smaller areas, favorable for dredging are found in the northwest approach to Tuktoyaktuk Harbour adjacent to Conn Island. Generally in the vicinity of the islands, shallow water and shallow thickness of sediments coincide, making these areas good prospects for dredging for granular materials.

For preliminary purposes, it has been assumed that a minimum 3 m (9.8 feet) of water depth is required for dredge operation, and that initial water depth should not exceed 9 m (29.5 feet) in the dredging area. Furthermore, it was assumed that soft sediment thickness (overburden) should not exceed 2 m (6.6 feet) in preferred development sites. Areas falling within these criteria are shown shaded on Map 3 in Appendix A. The geophysical data indicate that, generally, as water depth decreases, so does the thickness of soft sediments. Therefore, where a dredge can operate in waters shallower than 3 m (9.8 feet), thinner overburden depths may be encountered.

7.0 RECOMMENDED FIELD DRILLING PROGRAM

The geophysical survey provides information concerning water depth, and thickness of the upper soft sediment stratum. However, delineation of soil type and quality is based on correlating the geophysical data with observations along the shoreline, and with data obtained from bottom sampling. Accordingly, a limited field drilling program is recommended to fully determine the quality and extractable quantity of granular materials in the harbour bottom sediments.

A total of 33 test holes are recommended for the field drilling program, to be drilled at locations as shown on Map 3, in Appendix A. The majority of these test holes are located in the areas considered to be most favorable for development (i.e., water depths of 3 m to 9 m (9.8 to 29.5 feet), and soft sediment stratum thickness less than 2 m (6.6 feet)). A limited number of test holes are also recommended outside of these areas, in order to provide continuity of ground truthing data over the study area. The total depth of drilling (below the water level) should be a minimum 13 m (42.6 feet), resulting in a sediment penetration in the order of 4 m to 10 m (13.1 to 32.8 feet), depending on water depth. Representative sediment samples should be obtained from all test holes of all materials encountered. Sampling should be at depth intervals of 1.5 m to 2.0 m (4.9 to 6.5 feet).

Due to the high cost of rig mobilization, the drilling program should be carried out, if possible, with equipment based or operating in the Tuktoyaktuk area.

The drilling program could be carried out during summer or winter, depending on the type of equipment available. Drilling during the summer season could be considered if a barge fitted with a moon pool and equipped with a suitable drill rig were available. It should be noted that the attendant costs for a tug and barge for off the water drilling in the summer could be quite high. Conventional drill rigs operating in the winter from the ice surface would be preferred.

8.0 RESOURCE DEVELOPMENT AND MANAGEMENT

8.1 General

Recommendations concerning development and management of the harbour bottom granular material resources deal primarily with the technical aspects of extraction procedures, overburden removal and disposal, and stockpiling of extracted aggregate. Other aspects of development, including possible environmental concerns, are discussed briefly, in an overview basis and will require further in depth evaluation when this site is investigated in detail.

8.2 Extraction of Materials

8.2.1 Extraction Techniques

Extraction of harbour bottom aggregates could be accomplished by a number of dredging techniques, including -

(i) Clam dredging,

(ii) Suction dredging, and

(iii) Cutter suction dredging.

8.2.1.1 Clam Dredging

A clam dredge consists of a barge mounted crane, equipped with a clam bucket on cables. The clam bucket is dropped into the sediment, and the bucket load of sediment is dumped onto a barge, or dropped directly onto a stockpile. Some drainage of the dredged material generally occurs during handling, however provision for further drainage of the dredged material would be required in the stockpile area. The maximum depth of dredging by this method is limited only by the length of cable on the crane.

This method of dredging results in relatively small rates of production, and due to the considerable amount of material handling required (i.e., loading a barge, transport to stockpile and unloading), it may not be well suited for mining and stockpiling of aggregate from the harbour bottom. Also, stripping of overburden (such as a stratum of soft sediments above the sand and gravel) may be impractical with this method of dredging.

8.2.1.2 Suction Dredging

Suction dredging is accomplished by jetting a suction pipe to the desired depth into the sediment and pumping the loosened soil into a barge, or through a floating pipeline to the stockpile site. The dredged material is obtained from the cone shaped depression formed in the sediment above the tip of the suction pipe. When the sediment reaches a stable slope, the suction pipe must be lowered further into the sediment, or the dredge location must be changed.

Production rates of over 38 250 m^3/day (50,000 yd^3/day) may be achieved with large suction dredges, at operating depths to 45 m (148 feet) below sea level. Since the efficiency of suction dredging increases with increased penetration of the suction pipe into the sediment, overburden stripping is not practical with this method. However, fines will separate to some extent from the coarser aggregate by sedimentation in the slurry discharge area (stockpile). Dyking and drainage must be controlled in the stockpile area to suitably balance dredge production, and effluent discharge from the stockpile area.

8.2.1.3 Cutter Suction Dredging

This method of dredging 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 be operated at variable depths. As with a suction dredge, the discharge can be directed to a stockpile site through a floating pipeline. The area, depth and profile of dredging can be closely controlled with the ladder mounted dredging assembly.

Production rates for a typical cutter suction dredge are in the order of 15 300 m^3/day (20,000 yd^3/day) at operating depths ranging between 3 m to 15 m (10 to 50 feet).

Due to the control over depth of dredging that is possible with this method, cutter suction dredging is well suited for overburden stripping. A two stage dredging operation could be conducted with such a dredge, initially stripping the development area, then dredging the granular materials.

8.2.2 Equipment Availability

Since dredge mobilization costs are extremely high, the development of harbour bottom granular material resources should utilize, if possible, dredging equipment already operating in the Tuktoyaktuk area. Accordingly, a survey of dredging contractors was conducted for this study, to determine type and availability of equipment in the general area. It was learned that two dredging contractors have worked on artificial island construction in the Beaufort

Sea near Tuktoyaktuk, and both have dredging equipment in Tuktoyaktuk Harbour at the present time. A brief description of their equipment is outlined in the following paragraphs.

Beaver Dredging Company Limited of Toronto, operates the "Beaver Mackenzie" suction dredge out of Tuktoyaktuk, on long-term contract for artificial island building. This vessel is self-propelled and self-contained, requiring only a small tender tug to assist in anchor relocation. The "Beaver MacKenzie" is a large capacity suction dredge (0.85 m (2.8 feet) suction pipe bore) capable of dredging up to 76 500 m^3 (100,000 yd^3) of aggregate per day. It can operate to a depth of 45 m (148 feet), in minimum water depth of about 5 m (16 feet). If further commitments for artificial island construction are obtained for the "Beaver Mackenzie", it will remain at Tuktoyaktuk and may be available for harbour dredging immediately following break-up to approximately mid July. If long-term commitments are not obtained for this vessel, it will likely be removed from the Tuktoyaktuk area during summer 1978.

It should also be noted that Beaver Dredging Co. Ltd.'s European affiliates have developed a 20 ton pump for suction dredging, capable of operating from a barge. This unit will operate to depths in the order of 40 m (131 feet) with an aggregate production rates of up to 16 000 m^3/day (21,000 yd^3/day), through a 0.5 m (20 inch) pipeline. The mobilization costs for such a unit would be relatively small compared to other types of dredges, and it may, therefore, warrant further consideration in development of the harbour bottom granular material resources.

Northern Construction Company of Vancouver, B.C., operates an Ellicott Series 3000 "Super-Dragon" cutter suction dredge out of Tuktoyaktuk. This vessel is self-propelled, and is capable of dredging between depths of 3 m to 18 m (10 to 59 feet). This dredge has a 0.61 m (24 inch) suction pipe bore and produces aggregate at a rate of approximately 15 300 m^3/day (20,000 yd^3/day). Up to 1500 m (4920 feet) of discharge line (i.e., a floating pipeline) can be used without a booster pump. A small tender tug is required to support this dredge, to assist in anchor relocation, as well as for fuel supply and to ferry personnel. It is likely that present commitments will keep this dredge in the Tuktoyaktuk area through the 1979 summer season, and it may be available for harbour dredging during June, as well as after September until freeze-up.

In addition to the above operators, Arcnav Marine Limited of Calgary operates a clam bucket dredge in Tuktoyaktuk. This unit is capable of producing in the order of 3000 to 4000 m^3/day (3900 to 5200 yd^3/day), and can operate to depths in the order of 18 m (59 feet). Support equipment required for this operation would include barges to transport dredged material, and various pieces of equipment to off-load and handle the aggregate at the stockpile site.

Other dredging equipment that could be considered for use in Tuktoyaktuk Harbour are dredges operating on the Mackenzie River. However, the type and availability of these units have not been investigated at this time.

8.2.3 Overburden Disposal

As discussed earlier, the removal of overburden from the granular materials may only be practical by means of a cutter suction dredge. The other dredging techniques (i.e., clam dredging or suction dredging) are normally used to remove all materials indiscriminantly within the area being dredged.

Assuming that overburden stripping is carried out as a separate operation, a suitable disposal site will be required for this material. Two alternatives could be considered for overburden disposal operations, namely offshore disposal, and stockpiling on-shore. In either case, the overburden would be handled as a slurry and piped to the area in which it is to be placed.

As the first alternative, overburden could be pumped to an area of relatively deep water in the harbour, and allowed to settle as sediment. Such an area, with water depths ranging between 12 m to 34 m (39 to 112 feet) is outlined on Map 3 in Appendix A. Where the silt is deposited in deep areas within the harbour, a temporary increase in suspended sediment load would necessarily result. This increase in suspended sediment load, however, would not be substantially different than that associated with other dredging operations within the Southern Beaufort Sea area.

If the silt overburden were to be placed on land as a slurry, the construction of retaining dykes would be required. To facilitate consolidation of the placed material, provisions would have to be made for drainage. Some experience is available within the Mackenzie Delta area on the use of fine sand and silt as 'filler' within the interior of raised pads. The experience has been that a period of years is generally required before consolidation of the slurry placed materials occurs and the surface becomes trafficable.

On-shore overburden disposal has the disadvantage of utilizing stockpiling sites that could otherwise be utilized for aggregate. Furthermore, the costs associated with this method would be significantly more than offshore disposal.

8.2.4 Aggregate Stockpiling

Material dredged by suction or cutter suction dredging is piped as a slurry to a disposal or stockpiling site. Initially, a starter dyke must be present to limit the area of the slurry spread, and a 2 m (6.6 ft) dyke height is recommended for this purpose. Sorting of particles occurs within the stockpile area, with the coarser particles settling in the vicinity of the discharge pipe. The finer particles settle at the opposite end of the enclosed area, or may be removed with the water discharged from the stockpile area. As the stockpiled aggregate drains, this material can be utilized to heighten the perimeter dyke.

In preparation for the dredging operation, the prepared stockpile area should be capable of containing 3 to 4 days' aggregate production. It should also be noted that pumping of dredged material to heights greater than 4.6 m (15 feet) above the water level will significantly reduce dredge production rates, unless booster pumps are employed.

8.3 Stockpile Site Selection

8.3.1 Hydrologic and Thermal Considerations

Sand and gravel stockpile sites can be located either on land or in shallow water. As in the case of the silt overburden, the sand and gravel would be handled as a slurry and transported by pipeline from the dredge to the stockpile site. Where the sand and gravel are dredged and pumped as a slurry to a stockpile site located on land, the practical limit with respect to the height of placement above the water line is about 4.6 m (15 feet). Because of this practical limit, stockpiling operations on land will necessarily entail the rehandling of materials, or the use of booster pumps, to raise the slurry to higher elevations.

In the location of stockpile sites several factors as they relate to the hydrology and terrain conditions in the Tuktoyaktuk area must be considered. Firstly, those potential sites located in shallow water or on beaches are subject to wave action and fluctuations in water levels as a result of normal tides and storm surge activity on the Beaufort Sea. The impact of a storm surge can be greater than that associated with tidal fluctuations. Although the effects of storm surges will not be as severe in Tuktoyaktuk Harbour, increases in water levels in the order of 3 m (10 feet) have been documented along the southern coast of the Beaufort Sea (Henry, 1975). As storm surges are wind-generated events, wave action is potentially severe in exposed areas.

Where a stockpile site is located in shallow water or on land below the effect of wave action (i.e., during a storm surge event), provisions must be made to protect the stockpiled material. Two general approaches can be considered. Firstly, the exposed portions of the stockpile site can be protected against wave action by the use of rip rap. Where the sand and gravel are placed as a slurry, the slurried materials must be contained by a dyke or system of dykes. In this context, the exposed surface of the dyke must be protected from wave action. In the Tuktoyaktuk area, as is typical of much of the Mackenzie Delta area, suitable natural materials for rip rap are limited. Consequently this method of protection may be impractical.

The second alternative for reducing the impact of wave action would involve the use of energy dissipators. Sheet piling or timber piles can be used for this purpose, or as a further alternative the use of a 'sacrificial' berm could be considered, to protect the sand and gravel stockpile site in the event of a severe storm surge.

From the point of view of minimizing the effects of wave action, it would be preferable to locate stockpile sites above the high water level, and above the reach of waves, during a severe storm surge event. Several hydrologic and thermal problems must be considered if stockpile sites are located on high ground.

Firstly, many higher areas are "ice-cored", and as a consequence are susceptible to disturbance (i.e., thermal degradation and thermal erosion).

Secondly, because many of the potential sites in the Tuktoyaktuk area are located above an escarpment, the materials must be rehandled and transported by means of either a convenyor belt system or by truck from the beach area to the stockpile site. In the construction of haul roads, detailed consideration must be given to the handling of surface runoff and drainage through the active layer as well as minimizing thermal disturbance. The proper sizing, installation, and maintenance of culverts on roads in permafrost terrain has been a problem in the past.

8.3.2 Potential Stockpile Sites

Six potential aggregate stockpiling sites were identified in the vicinity of Tuktoyaktuk. Their locations are shown on Figure 8.1. Table 8.1 summarizes terrain conditions and other relevant data for these sites. These potential stockpiling sites were selected on the basis of airphoto interpretation, published data dealing with surficial geology of the area (Rampton and Bouchard, 1975) and the 1977 Granular Materials Inventory for Tuktoyaktuk (R. M. Hardy & Associates, 1977a).

Potential stockpile Sites 1 and 2 are closest to the townsite, but Site 1 is on an island that is accessible by road only in winter and is subject to active erosion by the sea. Site 2 is partly covered by intertidal flats and is fairly small. These sites are not as desireable as Site 3 which is located south of the townsite and the airstrip.

Site 3 is located on rolling moraine deposits. This area is not a potential source of granular materials and therefore has no subsurface information like Sites 4, 5,

LEGEND:

2 PROPOSED STOCKPILE SITE

SCALE: 0 1000 2000 3000 4000 5000 ft
0 500 1000 m

PROPOSED STOCKPILE SITES
TUKTOYAKTUK HARBOUR
NORTHWEST TERRITORIES

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

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FIGURE NO. 8·1

TABLE 8.1
POTENTIAL STOCKPILE SITES FOR TUKTOYAKTUK HARBOUR DREDGING

Potential Site Number	Location	Type of Landform	Material at Site	Topography & Relief	Approximate Size of Area	Distance*	Transportation from Site	Drainage	Possible Problems	Hydrologic and Thermal Considerations
1	Tuktoyaktuk Island	Glaciofluvial Terrace	Sand or gravel	Flat	21.2 acres (8.5 ha)	1.4 mi (2.2 km) in winter or summer	By barge in summer or over ice and road in winter	Good	May be too small, and susceptible to wave action	Site subject to active erosion and retreat of shoreline
2	Peninsula on Bay near SE part of town, S.W. of Ptarmigan Pt.	Glaciofluvial Terrace	Gravel over sand with patchy veneer of silt	Flat to hilly	2.6 acres (1.1 ha)	In winter 0.6 mi (1.0 km), in summer 2.3 mi (3.6 km)	By road in summer or over ice and road in winter	Good	Too small for all but small stockpile, also subject to being covered by water	Site partially covered by intertidal flats
3	Peninsula SE of airstrip and town, including Nallok Pt.	Rolling Moraine	Diamicton (till-like) 1.5 to 3 m thick	Flat to rolling	95.2 acres (38.1 ha)	3.2 mi (5.1 km) in winter or summer	By road in summer or winter	Good – some low areas	In airstrip approach area	Some thermal erosion may occur if land surface is disturbed and ice layers are present. Runoff will have to be controlled if this is the case
4	E shore of Eastern Entrance to Tuktoyaktuk Harbour	Glaciofluvial Terrace	Sand and gravel with patchy veneer of silt	Flat to hummocky, relief <15 m	39.7 acres (15.9 ha)	1.6 mi (2.5 km) in summer or winter	By barge in summer or over ice in winter	Well to moderately well drained upland area	Access over scarps	Some thermal erosion may occur if land surface is disturbed and ice layers are present. Runoff will have to be controlled if this is the case
5	E side of harbour, E side of Aveltkok Inlet	Glaciofluvial Terrace	Sand or gravel with patchy veneer of silt	Flat to hummocky, relief <15 m	21.2 acres (8.5 ha)	1.9 mi (3.1 km) direct line across harbour in summer or winter	By barge in summer or over ice in winter	Well to moderately well drained upland area	Access over scarps, some organic cover 1-4 m thick	Some thermal erosion may occur if land surface is disturbed and ice layers are present. Runoff will have to be controlled if this is the case
6	E side of harbour, N side of Mayogiak Inlet	Glaciofluvial Terrace	Sand, some gravel with patchy veneer of silt	Flat to hummocky, relief <15 m	31.7 acres (12.6 ha)	2.5 mi (3.9 km) in summer or winter	By barge in summer or over ice in winter	Well to moderately well drained upland area	Access from main harbour over scarps, but less of a problem from inlet	Some thermal erosion may occur if land surface is disturbed and ice layers are present. Runoff will have to be controlled if this is the case

*Distance measured to reference point in centre of town (see Figure 8.1) and 6 on the east side of the harbour (R. M. Hardy & Associates, 1977a). The moraine deposits are mapped as rolling moraine rather than moraine modified by thermokarst. They will contain some ice but the hilly areas may not be "ice-cored". Drilling would be necessary to obtain subsurface information on soils at this site. The site itself is fairly large and is accessible by road during summer and winter. Although this site falls within the airstrip approach area, the height of potential stockpiling will likely remain low and should not create a hazard for aircraft.

Sites 4 and 5 are on the west and east sides of Aveltkok Inlet on the east side of Tuktoyaktuk Harbour. Sites 4 and 5 are located on glaciofluvial material and have been described in the 1977 Granular Materials Inventory for Tuktoyaktuk as Deposit 159 (R. M. Hardy & Associates, 1977a).

These sites are flat to hummocky and are made up of sand with discontinuous gravel beds. In areas where gravel is near the surface, the active layer can be up to 2.4 m (8 feet) thick. Where organic deposits and fine grained soils are thicker the site is frozen fairly close to the surface (active layer of 0.6 m (2 feet) or less).

Disadvantages of Sites 4 and 5 include:

(i) Access by barge only during summer.

(ii) Scarps near the water may make development of the sites difficult.

(iii) The sites are part of a potentially developable granular materials deposit.

Site 6 is similar to Sites 4 and 5. It is located on the east side of the harbour on a glaciofluvial terrace. This site was identified as Deposit 160 in the 1977 Granular Materials Inventory for Tuktoyaktuk (R. M. Hardy & Associates, 1977a), and contains sand with irregular occurrences of gravel. The terrain is flat to hummocky and scarps are present on the harbour side of the proposed stockpile site. Better access is available along Mayogiak Inlet on the south side of Site 6. The active layer is up to 1.5 m (5 feet) thick where gravel is near the surface and is shallower

<0.3 m (1 foot) where fine grained material and peat are present. Site 6 has the same disadvantages as Sites 4 and 5, except the problem of scarps can be avoided if access by the inlet is used.

8.4 Environmental Considerations

8.4.1 Biological Harbour Population

Benthic invertebrates are relatively abundant and diverse on the silt and clay sediments which cover the bottom of Tuktoyaktuk Harbour. Common families of these organisms are oligochaetes, polychaetes, amphipods, and pelecypods (Slaney, 1973). In addition, phytoplankton are probably abundant due to proximity of the area to the mouth of the East Channel of the Mackenzie River which is a source of relatively warm, nutrient-rich waters (Aquatic Environments Ltd., 1977).

Benthic invertebrates are utilized as a food source by several fish species found in the Harbour. The most common of these include least cisco, humpback whitefish, fourhorn sculpin, boreal smelt, and inconnu (Slaney, 1973). Spawning by these species occurs in fall and, to be successful, requires a silt-free bottom in fresh water. Although these species probably do not spawn in the brackish waters of Tuktoyaktuk Harbour, they could spawn near the mouth of Freshwater Creek. Larvae of the species are common in shallow waters in most shoreline areas. Tuktoyaktuk Harbour is recognized as a nursery area for arctic cisco fry (DIAND, 1972). Pacific herring are also common but probably do not spawn in the Harbour (Slaney, 1973).

Several areas along the coast of the Harbour are traditional fishing areas utilized by native people of the Tuktoyaktuk area. These areas include the mouth of Freshwater Creek and the Western Entrance to the Harbour (Slaney, 1973). Whitefish and inconnu are among principal species caught.

Large numbers of white whales migrate to the Mackenzie River Estuary each summer, leaving again in August. Although they congregate in the vicinity of Hendrickson Island (Slaney, 1977) they generally do not enter Tuktoyaktuk

Harbour and are of little or no concern to proposed dredging in the Harbour. The endangered and protected Bowhead whale has recently been observed in outer Kugmallit Bay but no sightings have been recorded near Tuktoyaktuk Harbour (Slaney, 1977).

8.4.2 Effects of Dredging on Harbour Populations

Dredging in Tuktoyaktuk Harbour would alter bottom contours and increase turbidity of the waters, although natural turbidity levels are relatively high (Slaney, 1973). Inner areas of the Harbour would likely be the most sensitive since they would require the greatest time to flush and clear. Benthic invertebrates could withstand moderate increases in sedimentation rates due to increased turbidity (Slaney, 1973), however, they would likely be displaced by dredging. This effect would be temporary since populations would be reestablished after sedimentation rates returned to normal. Adult fishes would be little affected by increased turbidites (Slaney, 1973), although, on a short term basis, they may avoid turbid areas and thereby reduce the catch by native people. Fish larvae and fry, however, would likely be affected by dredging since benthic fauna available as food may be temporarily reduced.

8.4.3 Biological Description of the Shoreline

Vegetation on poorly drained flats and depressions is dominated by relatively extensive sedge-moss meadows. These are characterized by a closed cover of sedges, cotton-grass and mosses together with a few scattered shrubs (Corns, 1974). Active layers are thin (<0.6 m (2 feet)) and ground ice is often present as wedges and lenses. On moist slopes, the vegetation is predominantly a medium shrub-heath community characterized by a relatively dense cover of dwarf birch and scattered alder, Labrador tea, and willoc (Corns, 1974).

Well drained upper slopes and low hilltops support extensive low shrub-heath communities dominated by dwarf birch and low willows with an understory of heaths and herbs. Vegetation cover is incomplete and bare soil is often exposed.

Ponds and meadows in this area are important nesting and staging habitat for whistling swans (DIAND, 1972). Ducks are also numerous. Large flocks of snowgeese migrate through the area in fall, feeding in the wet sedge-moss meadows.

The area is not extensively used by ungulates due probably to the proximity of the Tuktoyaktuk settlement. However, the dry slopes and hilltops are habitat for arctic ground squirrels, arctic fox, and lemmings.

8.4.4 Effects of Stockpiling Dredged Materials

The proposed sites are located primarily in well to moderately well drained areas. Larger areas of organic deposits have been avoided.

Vegetation on the proposed stockpile sites is mostly dwarf shrub-heath tundra, and this would be destroyed, in areas utilized for stockpiling. No major impact on vegetation is expected adjacent to stockpile sites.

No significant impacts to mammals or birds are anticipated adjacent to stockpile areas. Some siltation of small ponds may occur but should be of little or no significance to nesting or migrating birds.

Rehabilitation of stockpile areas should include revegetation after the stockpiled material is removed, in order to stabilize the exposed surfaces.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The geophysical survey of Tuktoyaktuk Harbour provided data for preparation of a bathymetric contour map, as well as an isopach map of soft sediments over hard bottom. Based on a geologic assessment of the study area, the nature of the soft sediments are likely low density silts and clays, while the harder bottom is expected to be higher density sands and gravels. To establish subbottom soil types and their quality, sampling of these materials is required. Such bottom sampling data is then correlated with the geophysical survey data, and extrapolated over the study area. Accordingly, a limited field drilling program, comprised of 33 test holes, is recommended. The proposed test hole locations are shown on Map 3 in Appendix A.

If the drilling program proves granular materials of suitable quality for development, extraction of the resource should be by dredging. Based on the geophysical survey data, preferred development areas for dredging have been recommended, and are also shown on Map 3 in Appendix A. The preliminary criteria employed to delineate these areas were that water depths should range between 3 m and 9 m (9.8 and 29.5 feet), and that the soft sediment thickness should be less than 2 m (6.6 feet).

The development and management of the granular materials resources in terms of possible dredging techniques, equipment availability, overburden disposal, stockpiling of aggregate, and environmental considerations related to dredging and stockpiling have been considered in a preliminary overview. Detailed studies of these considerations are recommended if the in-situ materials are proven to be desireable for development.

Respectfully submitted,

R. M. HARDY & ASSOCIATES LTD.,

Per:

N. Hernadi, P.Eng.
Project Engineer

Per:

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

Calgary, Alberta.
March, 1978.
K4086

APPENDIX A

Maps

LEGEND

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

GOVERNMENT OF CANADA
DEPARTMENT OF INDIAN AND NORTHERN AFFAIRS

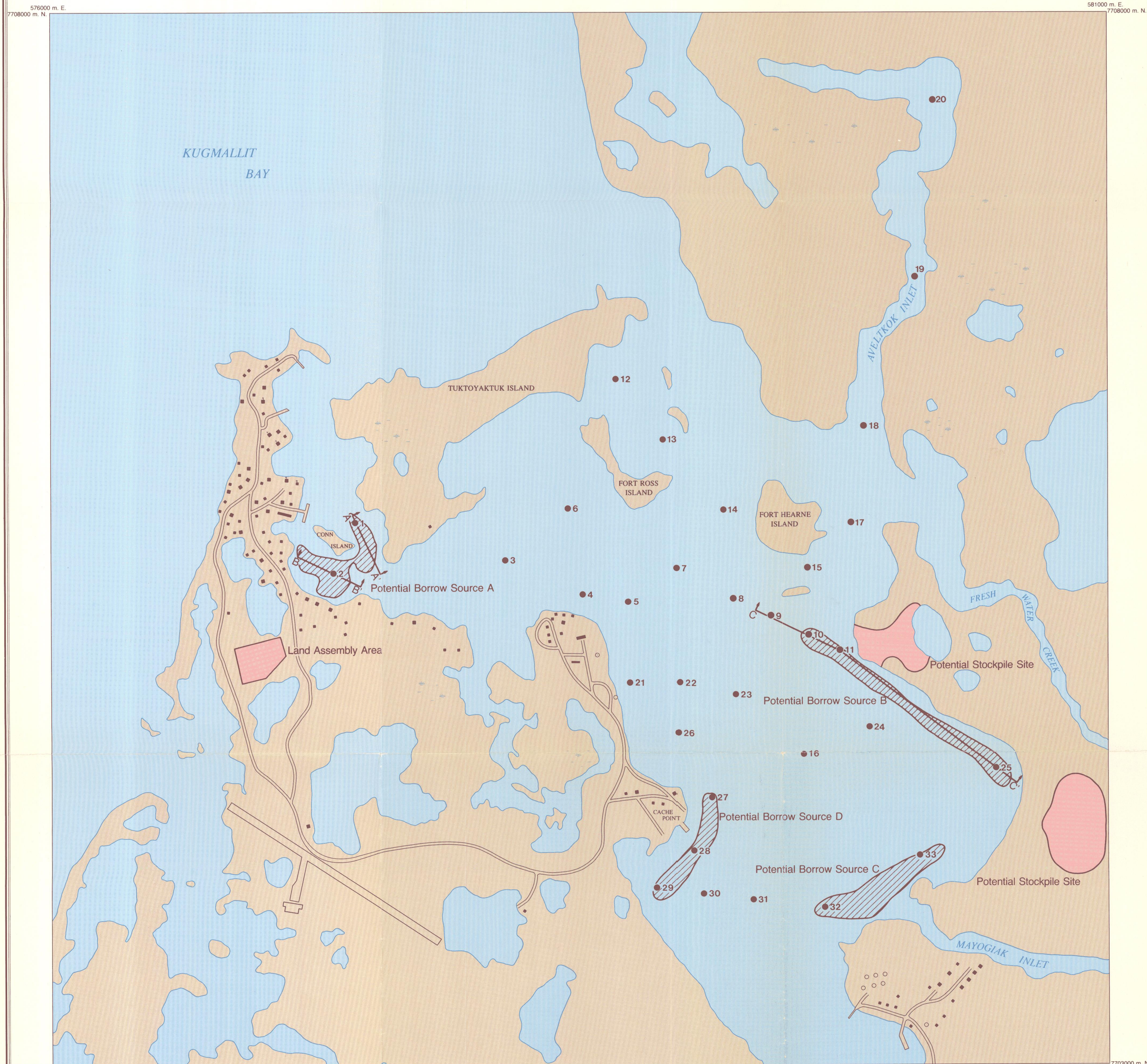
TUKTOYAKTUK HARBOUR, N. W. T.

POTENTIAL BORROW SOURCES

SCALE 1:10000

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

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



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

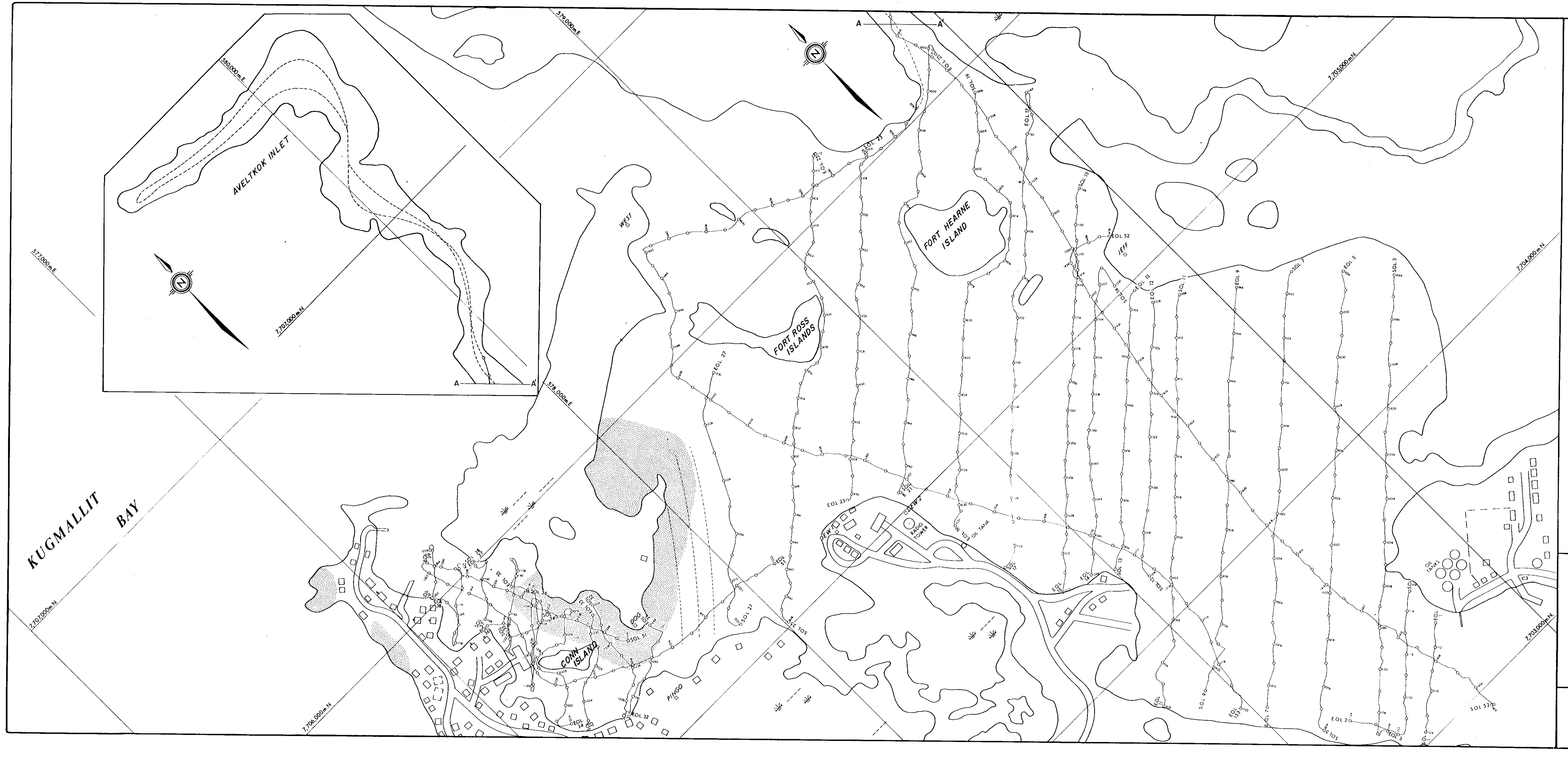
.1 0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Kilometers

N

HARDY ASSOCIATES (1978) LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES



LEGEND:

Position fix, 1300	S.O.L. 14	Survey Line
- - - - - - - -		Assumed Line Position (± 50 m)
JEFF		Shore Transponder Location

SCALE: 1:10 000

0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 Kilometres

0.1 0 0.1 0.2 0.3 0.4 0.5 Miles

Location map from Kenting Exploration Services Ltd., Calgary, Alberta
Field data from Kenting Exploration Services Ltd., Calgary, Alberta

SURVEY LINE LOCATION MAP

TUKTOYAKTUK HARBOUR

NORTHWEST TERRITORIES

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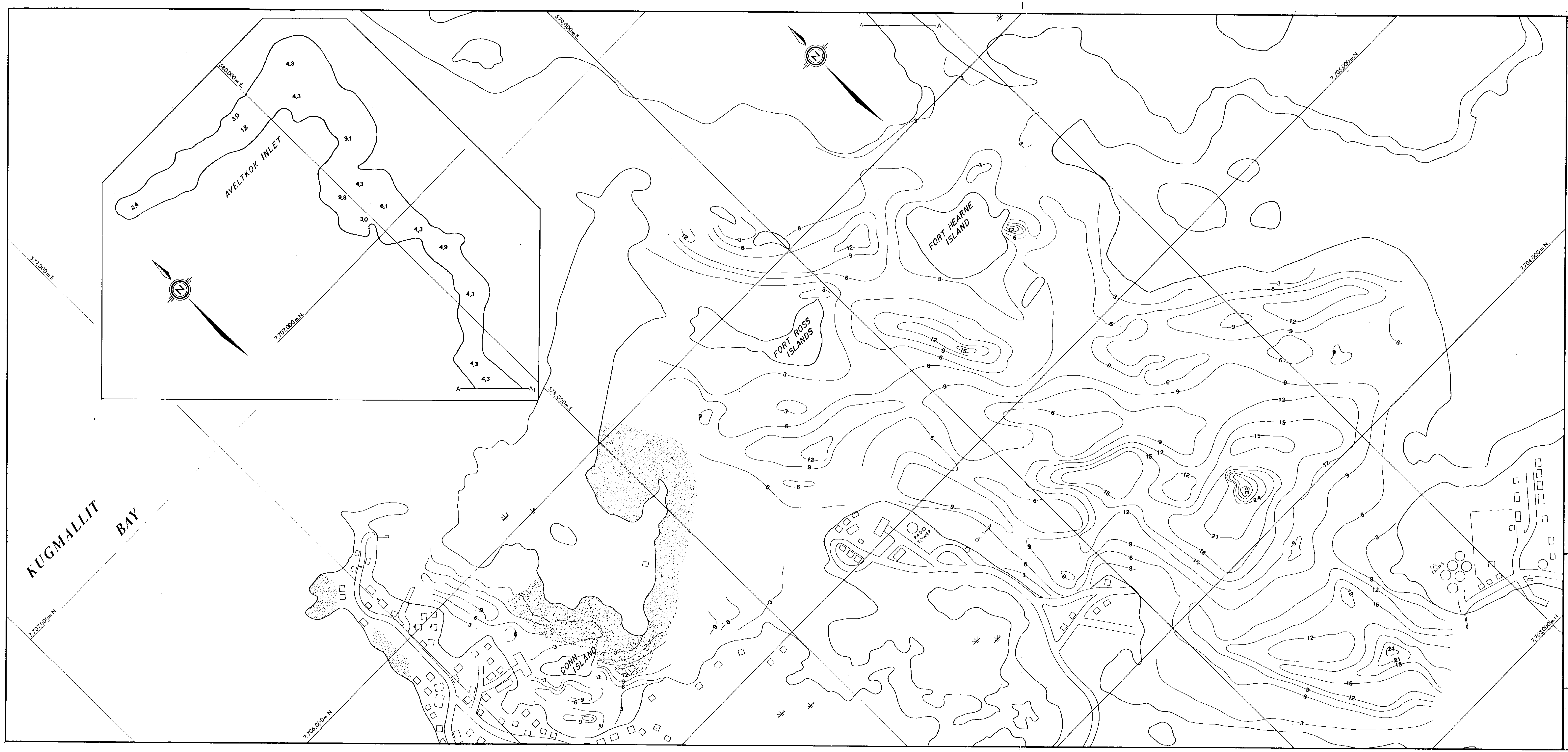
MAP 1



LEGEND:

Bathymetric Contours (3m contour interval)

4.3 Bathymetry Data in Metres

SCALE: 1:10 000

0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 Kilometres

0.1 0 0.1 0.2 0.3 0.4 0.5 Miles

Location map from Kenting Exploration Services Ltd., Calgary, Alberta

BATHYMETRIC CONTOURS MAP

TUKTOYAKTUK HARBOUR

NORTHWEST TERRITORIES

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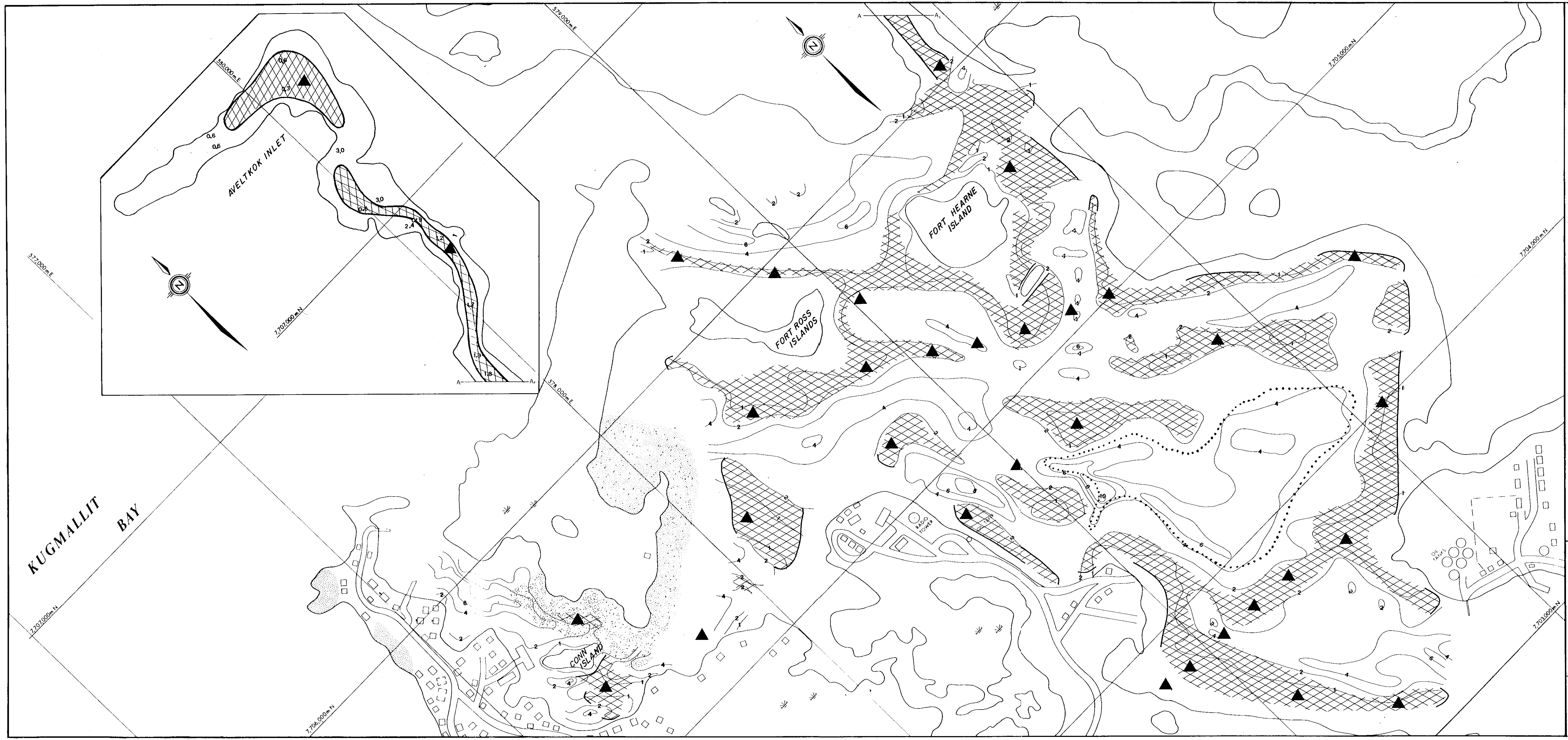
MAP 2



LEGEND:

Contours of equal overburden thickness (1 m intervals to 2 m isopach, then 2 m contour intervals)

0.6 Overburden thickness in metres

Most favorable development area, with water depths of 3 m to 9 m, and overburden less than 2 m (solid lines delineate geophysical survey limits)

Proposed test hole location

Potential overburden disposal area, with water depth greater than 12 m

SCALE: 1:10 000

0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 Kilometres

0.1 0 0.1 0.2 0.3 0.4 0.5 Miles

Location map from Kenting Exploration Services Ltd., Calgary, Alberta

OVERBURDEN ISOPACH MAP AND POTENTIAL GRANULAR MATERIAL SOURCES

TUKTOYAKTUK HARBOUR

NORTHWEST TERRITORIES

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MAP 3

APPENDIX B

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