Environmental Evaluation For A Marine Base At Mckinley Bay, Northwest Territories
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ENVIRONMENTAL EVALUATION FOR A MARINE BASE AT MCKINLEY BAY, NORTHWEST TERRITORIES

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ENVIRONMENTAL EVALUATION FOR A MARINE BASE AT MCKINLEY BAY, NORTHWEST TERRITORIES

PREPARED BY

DOME PETROLEUM LIMITED

AUGUST, 1979

EXECUTIVE SUMMARY

Dome/Canmar is proposing to dredge an access channel and a vessel mooring basin in McKinley Bay, Northwest Territories for the purpose of overwintering the company's drilling fleet and icebreaker.

In support of applications submitted to the Department of Environment for an Ocean Dumping Control Act Permit, and to the Ministry of Transport for approvals under the Navigable Waters Protection Act, and in accordance with the conditions embodied in an Approval-in-Principle given for the McKinley Bay project by the Assistance Deputy Minister, Department of Indian and Northern Affairs, an environmental evaluation for the proposed project has been prepared.

This report serves to describe the projected overwintering harbour and all activities associated with the construction and early operations of the proposed facility. It also provides the most detailed description of the existing environmental features of McKinley Bay and the surrounding area that is possible with existing information, and examines all of the potential environmental implications of the overwintering facility and associated activities.

Section 5.1 of the report summarizes the potential major and residual impacts associated with the proposed project. Not surprisingly, the major impact will be the alteration of the bathymetry of the sea floor as a result of the dredging of the access channel and mooring basin. Most impacts of the proposed dredging program upon the biota of the area will be limited in area and short term in duration. Immediate losses of benthic fauna are to be anticipated, followed by recolonization over a period of one to three years. Some fish may become entrained in the suction-dredge, particularly if dredging proceeds in the spring of 1980. However, substantial losses are not anticipated.

Impacts of the dredging program upon marine and terrestrial mammals and birds are expected to be limited to possible avoidance reactions in some instances, and to some species.

With respect to harbour activities and the overwintering of the drilling fleet, the possibility of an oil spill during fuel transfer or due to a shipping accident appears to offer the greatest concern. In this regard, an oil spill contingency plan has been developed to ensure adequate response and protection of the environment, should such an incident occur.

On the basis of the information contained in this report, it is our conclusion that the proposed project can proceed as currently envisaged without causing lasting, significant undesirable impacts upon the environment of the area.

ENVIRONMENTAL EVALUATION FOR A MARINE BASE
AT MCKINLEY BAY, N.W.T.

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1.0 INTRODUCTION

On June 25, 1979 Dome/Canmar approached the federal government to dredge an access channel and a vessel mooring basin in McKinley Bay located on the Tuktoyaktuk Peninsula (Figure 1.0-1).

The primary purpose of this facility will be to overwinter the Company's drilling fleet and the new AML-X4 icebreaker. The proposed site offers distinct logistical advantages over other sites due to its central location relative to future drilling activities and its close proximity to established support facilities at Tuktoyaktuk.

As a minimum requirement, Dome/Canmar is proposing to dredge an outer entrance channel 10 m deep and 9.8 km long, leading into an inner McKinley Bay mooring basin also 10 m deep. The Company plans to use at least four drill ships and the AML-X4 icebreaker in their exploration programs over the next few years. McKinley Bay could be used to harbour all these vessels over the winter months, November to May.

In support of this request, the Company submitted applications to the Department of Environment for an Ocean Dumping Control Act Permit, and to the Ministry of Transport for approvals under the Navigable Waters Protection Act.

On July 5, 1979 Company officials met with members of the Arctic Waters Advisory Committee, the Regional Ocean Dumping Advisory Committee, and the public, at both Tuktoyaktuk and Inuvik. The meetings served to clarify the Company's initial plans with respect to McKinley Bay and Tuktoyaktuk Harbour, to inform interested parties of steps being taken to address possible concerns, and to elicit cements viz a viz the project, shortcomings, and the concerns of the people.

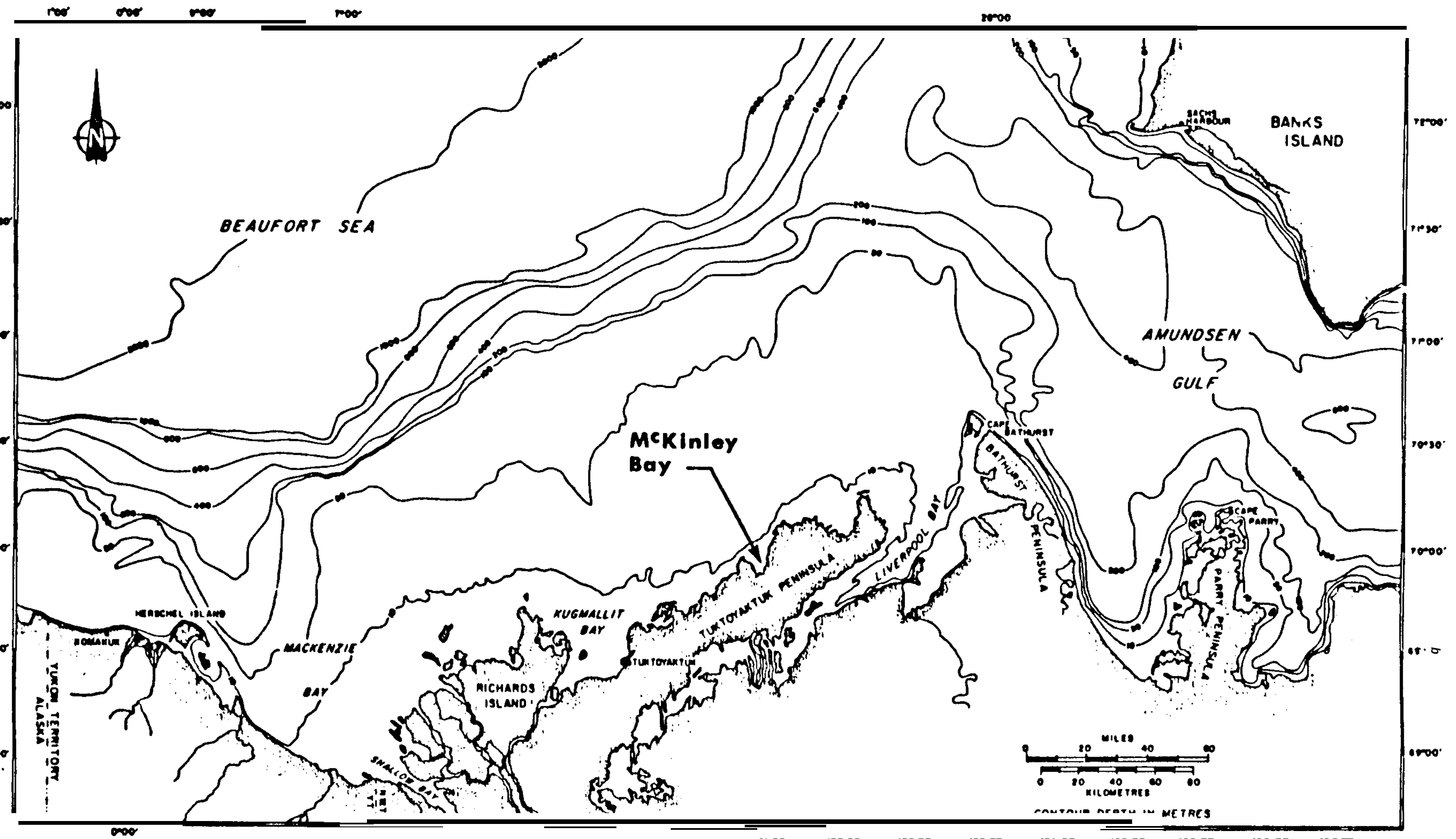


FIGURE 1.0-1 McKINLEY BAY

As a result of these actions and in accordance with the conditions embodied in an Approval-in-Principle given for the McKinley Bay project on July 13, 1979 by Mr. Ewan Cotterill, Assistant Deputy Minister, Department of Indian and Northern Affairs, an environmental evaluation for a proposed overwintering harbour in McKinley Bay has been prepared.

This report serves to describe the projected overwintering harbour and all activities associated with the construction and early operations of the proposed facility. It also provides the most detailed description of the existing environmental features of McKinley Bay and the surrounding area that is possible with existing information, and examines all of the potential environmental implications of the over-wintering facility and associated activities.

In its initial consideration of McKinley Bay, the Company anticipated the construction of shorebased fuel storage tanks to service icebreaker operations. Current plans do not require any shorebased facilities and therefore impacts of such facilities are not considered herein.

Experience in the construction and operation of the McKinley Bay anchorage will be a key factor in determining the merits of establishing shorebased facilities in support of exploration drilling. The role of McKinley Bay in future production activities depends upon the success of the current dredging program and the nature and location of the anticipated oil and gas discoveries.

The Company is currently preparing a long range overview of a possible production system. While this overview will be a forecast and not a definitive plan, it will be helpful in identifying potential future roles for the harbours and shore bases required during production activities.

2.0 PROJECT DESCRIPTION

Dome/Canmar is planning to develop a new deep water marine base at McKinley Bay, N.W.T. (Figure 2.0-1). The primary purpose of this base will be to overwinter the Company's drill ships including the new AML-X4 icebreaker. The proposed site offers distinct logistical advantages over other sites due to its central location relative to future drilling activities and its close proximity to established support facilities at Tuktoyaktuk.

As a minimum requirement, Dome/Canmar is proposing to dredge an outer entrance channel 10 m deep and 9.8 km long, leading into an inner McKinley Bay anchorage basin also 10 m deep. Canmar plans to use at least four drill ships and the AML-X4 icebreaker in their exploration programs over the next few years. McKinley Bay could be used to harbour all these vessels over the winter months, from November to May.

2.1 Project Need

One of the problems that has continued to face Canmar's Beaufort Sea operations since drilling activity began in 1975 has been the need to overwinter the drilling fleet in a suitable harbour. The basic requirements for such a harbour have always included:

a) sufficient water depth, in the harbour and its approaches, to accommodate the drilling fleet.

b) protection from winds and moving ice, and

c) adequate space to allow safe maneuverability of large vessels within the harbour.

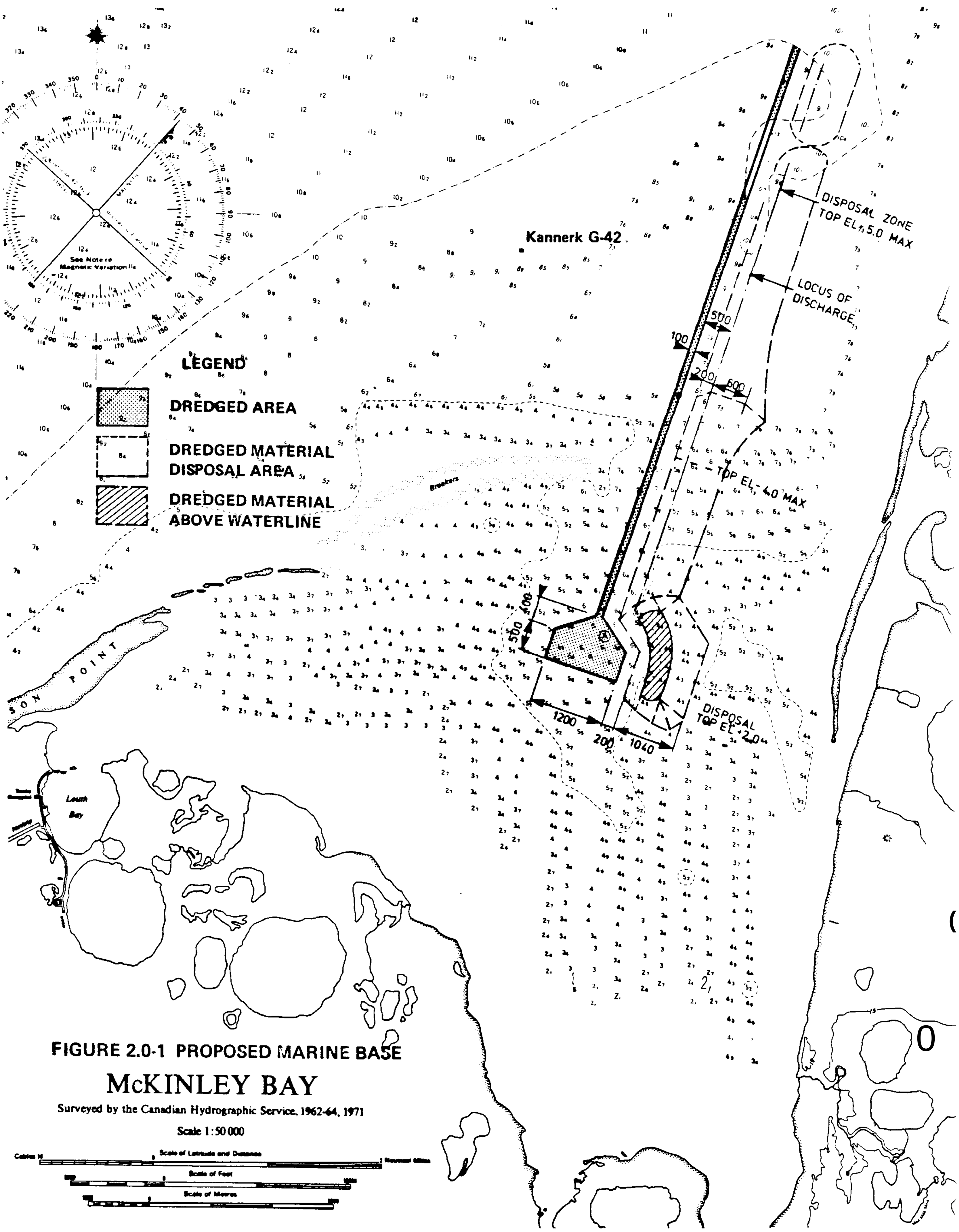


FIGURE 2.0-1 PROPOSED MARINE BASE

McKINLEY BAY

Surveyed by the Canadian Hydrographic Service, 1962-64, 1971

Scale 1:50 000

Early into the drilling program, Canmar conducted an investigation within the Beaufort Sea for a harbour for the drilling fleet. Harbour sites considered were: Summers Harbour, Booth Island; Pauline Cove, Herschel Island; Stokes Point; King Point; Atkinson Point West; Atkinson Point East; Tuktoyaktuk Harbour; Tuft Point; and Liverpool Bay.

Criteria used to assess the suitability of each harbour site included: harbour water depth; harbour approach water depth; need for dredging; protection from wind and moving ice; need for breakwater construction; suitability for building logistic infrastructure (airstrips, fuel tanks, building, etc.); space within the harbour to allow large vessel maneuverability; ability to accommodate deep draft icebreakers; distance to break through shorefast ice when breaking out of harbour; extent and severity of pressure ridges that are along breakout route from harbour entrance to open water; dates of harbour freeze-up and harbour ice break-up; and proximity to drillsites.

On the premise that major dredging programs had significant associated cost factors making them less attractive, sites such as McKinley Bay and Tuktoyaktuk Harbour, despite their other advantages, were bypassed in favour of locations with naturally adequate water depths, etc.

Initially, Pauline Cove at Herschel Island seemed to fulfill most of the necessary requirements and therefore, in the winter of 1976/77 Canmar's drill ships were harboured there. However, practical experiences obtained during that first winter's stay, and future plans for larger icebreakers, dictated that a more suitable harbour site was required. Dome/ Canmar's IEE for the Summers Harbour/Wise Bay area outlines the problems experienced at Pauline Cove. To overcome these problems, the fleet over-wintered at Summers Harbour near Cape Parry during the winter of 1977/78.

Two winters of experience at Summers Harbour have confirmed its suitability as an eastern Beaufort deep water overwintering area, especially for icebreakers, but has also identified certain disadvantages for the drilling fleet. In particular, the considerable distance of ice to be traversed by the drill ships in spring and fall have posed key problems.

During the winter of 1978/79 the search for a harbour suitable for installation of shore facilities in this area was extended to Wise Bay. Since the Wise Bay area offers several advantages over Summers Harbour including: even greater water depths; easier construction conditions and larger amounts of granular material; an existing airstriP as opposed to none; and probably better sources of fresh water, the Company has applied for permission to relocate their eastern "Port of Call" to Wise Bay.

However, the early breakout problems for drill ships, combined with the remoteness of the Cape Parry region relative to the current exploration program, has necessitated a re-evaluation of the need for medium draft overwintering facilities in a more central location, namely the Tuktoyaktuk Peninsula.

In this regard, it was recognized that any reconsideration of harbour facilities in the Tuk area necessitated dredging and associated cost factors. The two options which have been examined by our engineers were:

1. to dredge Tuktoyaktuk approach channel to 10 m to accommodate supply vessels and drill ships.

2. to dredge Tuktoyaktuk approach channel to 6 m to facilitate the movement of supply ships and to dredge a 10 m deep channel and mooring basin at McKinley Bay to accommodate drill ships and icebreakers.

Investigation of the availability, capability and cost of dredging equipment led to the adoption of the second option. By immediately mobilizing a large, self-propelled sea-going cutter-suction dredge, it was determined to be possible to meet the basic overwintering needs of drill ships and icebreakers at McKinley Bay, while improving the channel into Tuk Harbour for the supply vessels; all before the winter of 1980/81.

The first option was discounted largely on the basis that the greater volume of dredging required to deepen the approach channel at Tuktoyaktuk to 10 m (over 20 x $10^6 m^3$), and the much greater length of the required channel (nearly 40 km), would have made it very unlikely that the project, even though started in 1979, could have been completed by 1982. Other problems with this alternative were the anticipated increased susceptibility of a deeper, longer and more exposed dredged channel to silting, and the difficulties involved in disposing of the much greater volumes of dredged material which would be generated, especially at the harbour end of the channel.

2.2 Entrance Channel and Mooring Basin

Detailed engineering design considerations respecting the dredging of an entrance channel into, and a mooring basin inside McKinley Bay are addressed in the Engineering Report for Dredging Works prepared by Albery, Pulleritz, Dickson and Associates Limited. The most relevant information respecting the project has been extracted for presentation in this environmental report.

McKinley Bay - General Description of Site Conditions

McKinley Bay is an indentation in the coast of the Tuktoyaktuk Peninsula, about 100 km northeast of Tuktoyaktuk (Figure 2.0-1). The bay is unusual for the area because relatively sheltered water, six metres deep, is located only 10 km distance from the 10 m contour outside the bay. McKinley Bay covers about 150 km^2 and is roughly triangular in form, with the base 20 km wide at the mouth. A half submerged sand spit about 10 km long, extends halfway across the mouth of the bay from Atkinson Point on the west side and provides a degree of shelter from waves approaching from the northwest. Additional soundings have been taken for this project to confirm bathymetry given in published hydrographic chart 7622.

The coast at the mouth of the bay is bordered by an extensive sand beach which extends part way across the mouth forming part of the sand bar previously mentioned. It must be assumed that there is some littoral drift moving from Atkinson Point towards the east to the extremity of the spit. Further, since the spit is partly submerged, it must be presumed that it is slowly migrating landwards, into the bay, by continuous overwashing by tides and waves. This process probably accounts for shoreline recession observed in the area by C. P. Lewis (private communication).

On the more exposed east shore of the McKinley Bay, there is a sequence of spits or large bars which point into the bay, plainly indicating the presence and the southward direction of littoral drift under the action of northwesterly waves.

Bay Bottom Soils

An extensive series of boreholes were drilled in the area by Imperial Oil as part of a seismic exploration. They were logged by C. P. Lewis (private communication). Other holes were drilled for the same Company for geotechnical purposes (EBA, 1976). Most of the information from these sources show that fine to medium sand, with medium grain size of 200 to 300 micron, predominate. Two of the EBA boreholes indicated the presence of a layer of soft silty clay as much as 1.5 m thick to the south and east of the proposed mooring basin. Dome/Canmar's preliminary grab sampling results described herein suggest that the clay could extend into the dredged area, underlying the surface layer of soft mud. Subsequent core sampling has confirmed this fact.

Permafrost under sea covered areas is at a depth of many tens of metres and will not be encountered in this project. Detailed soil sample analysis is in progress, but results were not available at time of writing.

Bay-bottom Surficial Conditions

A program of grab sampling of surficial bottom sediment has been undertaken in connection with this project. The preliminary results indicate the presence of a layer of very soft, almost liquid mud, covering the bottom in deeper areas within, and in the approaches to McKinley Bay. Nearby shallower areas where wave energy or currents are stronger, the bed consists of hard packed sand. The edge of the mud covered area in places consists of thin mud patches lying on the sand. In others, there is a coherent layer of the very soft mud 0.2 m to 0.3 m thick overlying the sand. Elsewhere the mud is at least 0.6 m thick, possibly grading into a coherent layer of consolidated clay at greater depth (similar to that noted in the EBA borehole data).

The presence of soft, almost liquid mud implies active sedimentation and periodic or frequent mobilization of sediment under wave and current action. Also, the distribution of mud must correspond closely to areas of relatively low hydrodynamic energy. Mud does not remain in high energy areas such as on the nearby sand spit. The presence of a thin veneer of mud over the sand indicates the underlying sand is stable.

Detailed laboratory test results of grab samples were not available at time of writing.

General Design Considerations

A number of different design variants have been considered in the course of which general design criteria were evolved. The objective quite simply has been to provide a secure winter mooring for the drilling fleet and icebreaker support ships; a mooring which can be entered as late as possible in the fall and from which the vessels can be released at the earliest possible date the following spring.

An initial design contemplated the dredging of an elongated basin behind the spit and the reinforcement of the spit with the material dredged from the basin to form a protective beach-breakwater. In another design, an elongated basin was located in such a manner that part of the dredged material could be used to construct a causeway which connected the mooring basin to the land near the old Atkinson Point DEW Line Station.

Later it was concluded that neither wave protection nor land access were essential, and the final design consisted of a straight access channel connected to a mooring area of the largest possible dimensions, as close to the centre of the bay as possible. At first a circular basin, one nautical mile (1.85 km) in diameter, was suggested, but due to scheduling (cost) and dredge pipeline constraints, a smaller polygonal basin was adopted. The preferred arrangement best meets the prime objectives because the relatively large mooring area permits the use of an icebreaker to moor and release the vessels, while the central location maximizes the probability that ice can be pushed aside. The location of the mooring basin and the orientation of the access channel have also been chosen to minimize the volume of dredging required.

Project Description

The proposed facility is illustrated in Figure 2.01 of this report. For a more detailed description, the reader is referred to Drawing 660-1 of the Engineering Report.

Location and Dimensions

The origin of the channel-mooring basin is at Point "A", located where the channel centre line intersects the toe of the slope at the south side of the mooring basin. In the absence of known landmarks, Point "A" is provisionally identified by geographical coordinates; latitude 69° 57′ 32″ N and longitude 13° 11′ 13″ W. From Point "A" the axis of the dredged area (and the approach channel) runs 9.80 km on bearing 200° 00′ 00″ (measured inwards in accordance with navigation practice) to intersect the natural 10 m contour outside the mouth of McKinley Bay.

The mooring basin is in the form of a symmetrical (non-regular) pentagon, 1,200 m wide at the end, with parallel sides 500 m long and a 400 m tapered section connected to the access channel. The base width of the access channel will be 100 m.

Dredged Depth and Profiles

The mooring basin and access channel will be dredged for a clear-depth of 10.0 m below tidal (chart datum) to permit access by the largest icebreaker escorts. The channel will be dredged to a nominal width of 100 m as determined by the swing-width of the dredge. The average over-dredging is estimated at 0.375 m.

Where sand predominates, the side slopes will initially assume a typical angle of repose for sand, about 1:1.75, but will probably deteriorate subsequently to a gradient of 1:5 or less. In places where soft mud is dredged, the immediate side slope may be as steep as 1:3 or 1:4 but this will usually deteriorate quickly (within 2-3 years) to about 1:10 after which a slow creep flow will occur slowly over two or three decades to a final slope of 1:50 or flatter.

Proposed Harbour Use

With successful completion of the McKinley Bay dredging program, Dome/Canmar is planning to use the new harbour for overwintering of the drill ships and icebreaker between November and May. Three to four drill ships and the AML-X4 icebreaker could use the harbour. The ships would arrive late in the year (probably late October - early November) and be berthed for the winter. Diesel refueling may be necessary but would be accomplished by winter road from Tuktoyaktuk. Some treated sewage discharge would occur in McKinley Bay during the spring breakout activities. Breakout practice could involve piling of snow along the channels in winter to insulate the ice cover and spreading of coal dust on the ice in spring to enhance thawing. The need for ice blasting is not foreseen at this time. The icebreaker will probably start attempting ice break-up in the bay as early as May, so that the fleet can access the drill sites by early June. The primary corridors of movement for these ships to the drill sites in the next two years are anticipated as roughly straight lines 50 to 100 km north to northwest of McKinley Bay. Navigation aids similar to those used at Tuktoyaktuk Harbour in the form of marker buoys, chains and anchors will be employed along the outer dredged navigation channel. Some minimum maintenance dredging may be anticipated to remove materials slumped or settled into the channels over time.

2.3 Dredging Program

The total dredging program as proposed for McKinley Bay will require the removal and redeposition of approximately six million cubic metres of sands, silts and clays. The dredging project is anticipated to commence around the first of September, 1979 and will probably be completed by the summer of 1980.

Constraints on Selection of Dredging Equipment

The type and capacity of dredges considered exert dominant influences on projects of this type. The design, implementation procedures, schedules and costs are all interrelated with the choice of dredging equipment.

In the case of McKinley Bay, the remoteness of the site, the urgent need to commence in 1979, the shortness of the Arctic operating season, and the shallow existing depths of some areas to be dredged, left little choice as to the equipment to be used. Only sea-going self-propelled cutter-suction dredges could be seriously considered. No machines of this type were available in Canada and only two were found internationally, both Dutch owned. One was in the Persian Gulf and the other in Belgium.

The selection of a cutter-suction pipeline dredge in turn, placed practical limitation on the distance between dredging area and material disposal site while the need to maximize dredge efficiency further reduced the optimum distance to the disposal area to 500 m or less.

Dredging Equipment and Performance

The dredging will be implemented by the modern sea-going cutter-suction dredge "Aquarius", owned by Zanen Verstoep N.V. of The Hague, Netherlands (Figure 2.0-2).

Dredge Characteristics

Dimensions: length 107 m
breadth 19 m
draught 4.90 m (normal), 4.20 m (lightened) with spuds removed and minimum fuel and supplies aboard.

Cutter:	diameter	2.90 m
	minimum depth	6.0 m
	maximum depth	25.0 m

Spuds : 1 adjustable turning spud, 6 m travel
1 auxiliary anchor spud

Power:	Total three pumps	6 700 kW
	Cutter	2 000 kW
	Total two propellers	3 500 kW

Pipeline:	diameter	90 cm
	length land pipeline	2,000 m
	length floating pipeline	800 m
	discharge above water	
	steerable discharge scow	

Anticipated Performance

Pipeline velocity: 6 m/s
Pump discharge capacity: 3.8 m^3/s or 13,700 m^3/hour
Estimated solid pumping capacity (place measure) based on a preliminary assessment of local soil conditions: 3,500 m^3/hr. to 4,500m^3/hr.

Actual dredging rates will generally be lower than the estimated solid pumping capacities, because the rate of progress will often be limited by the maximum rate of forward advance of the dredge, rather than by the dredging capacity. This will be the case where the required depth of cut is generally less than the optimum depth of 2.3 m. Time is also lost for maintenance, adjustments to spuds, swing anchors and pipeline, and adverse weather conditions.

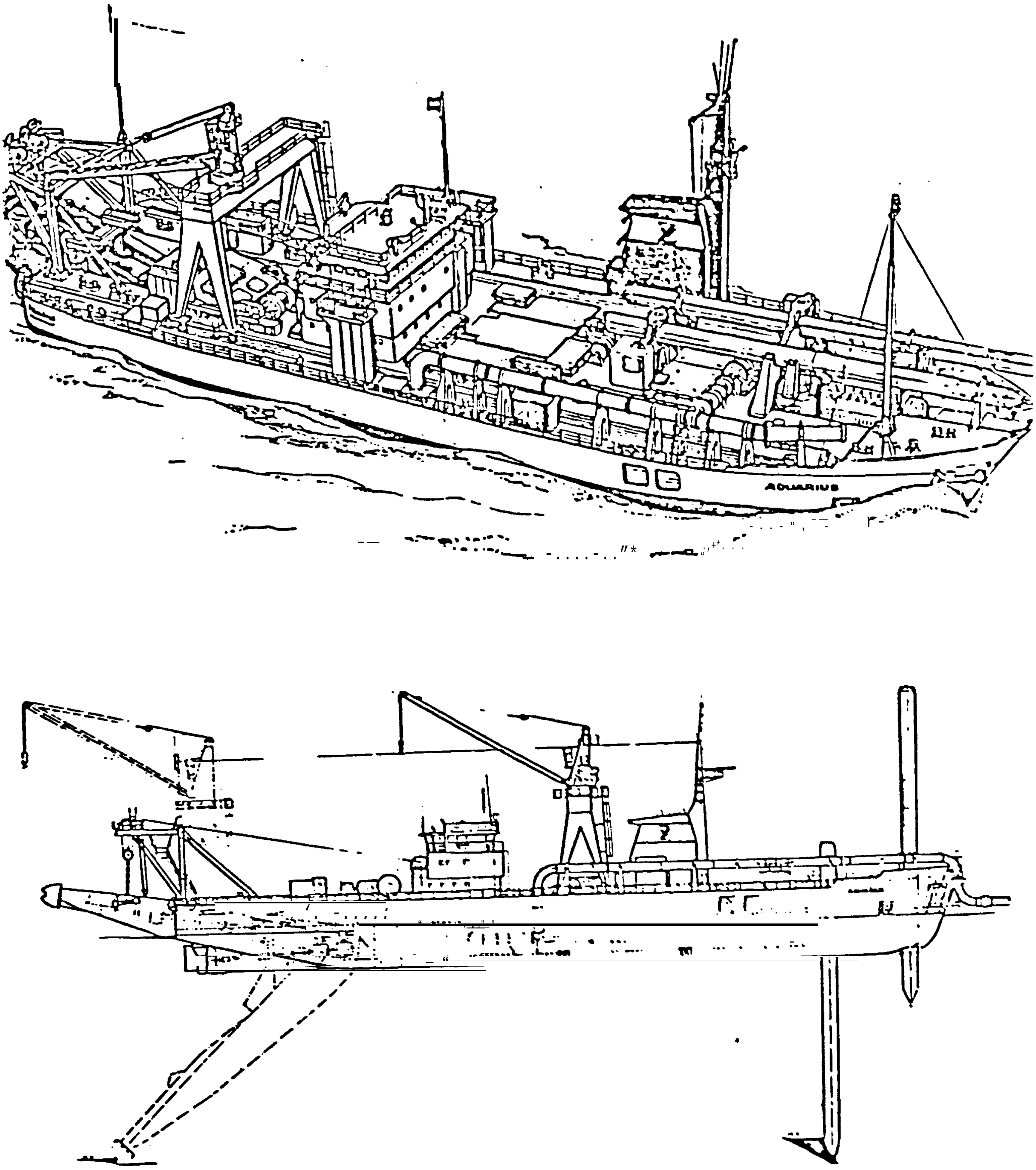


FIGURE 2.0-2 SEA GOING CUTTER SUCTION DREDGE
ZANEN VERSTOEP N.V.
"AQUARIUS"

Rate of Advance

The maximum possible advance speed is 20 m/hr. for a cut 100 m wide down to 2.3 m depth in suitable soils. About three minutes are required to complete each 100 m swing of the dredge and the dredge advances about one to two metres per swing.

It should be noted that the provision of an adjustable turning spud (one which can be used to push the dredge forward between swings) eliminates the elaborate and time-consuming "stepping ahead" procedures which are required with older cutter-suction dredges (Philpott, 1978).

The target rate of advance of the dredge is 2,000 m/week provided that; the depth of cut does not exceed 2.3 m, the pipeline does not exceed 500 m, and the soil does not exceed 0.2 kg/cm^2 shear strength or standard penetration test (STP) NG.

Dredged Material Disposal Plan

On the basis of available information on the directions of currents and waves in the area, it has been provisionally decided to locate all dredged material to the east of the dredging as shown in Figure 2.0-1.

For the access channel, the dredged material will be discharged from the floating discharge line along a line parallel to the channel at a centre to centre distance of about 500 m. The discharge point will be moved along progressively to keep pace with the dredge and to avoid excessive mounding of dredged material. It will also be directed away from the channel so that the slurry will tend to flow away from the dredged area to the extent possible. It is anticipated that the top elevation of the material redeposited to the east of the channel will be at -4 metres.

Disposal of dredged material from the mooring basin poses special problems because of the great width of the area and the limited length of floating discharge line. Another constraint is the decision to concentrate all of the dredged material on one side of the basin. This decision is based not only on consideration of wind and wave conditions, but also on the possible requirement of Canmar to facilitate future enlargement of the basin. The arrangement selected permits the basin to be extended both westwards and southwards, should the need arise.

Implementation of the dredge material disposal plan for the mooring area will require the use of both submerged pipeline and land pipeline. Dredging will start at the eastern edge of the mooring basin and in this case the mound of dredged material will be deliberately built up to a top elevation of 2.0 m above chart datum. Next, the exposed mound will be extended by means of land pipeline laid on the exposed surface of the mound of dredged material. Then as the area of dredging becomes more distant from the disposal area, it will be necessary to extend the land pipeline westwards along the southern margin of the basin area as a submerged discharge line to which the floating line will be connected. By means of this combination of floating, submerged and exposed land line, it will be possible to deposit all of the dredged material on the east side of the mooring basin.

The precise details of the foregoing dredging and disposal plan are still being worked out, and are subject to revision and refinement based on the results of soil investigations and studies still in progress.

The proposal to build-up an exposed mound of dredged material is based on the assumption that the material being dredged is a fairly clean sand such as shown in most of the EBA (1975) boreholes. Mud and soft clay or sand with a significant proportion of silt and clay would not stand on a stable slope sufficiently steep to form an exposed mound within 500 m or 600 m of the edge of the dredged cut. It may, therefore, be necessary to skim off the recently discovered layer of mud and soft clay before commencing the construction of the proposed mound.

On the basis of the design configuration illustrated in Figure 2.0-1, estimates were made of the total areas to be disturbed by dredging and redeposition of the spoil material in McKinley Bay and in the vicinity of the access channel. These estimates are presented in Table 5.3-1.

Ancillary Activities Associated with the Dredging Program

Accommodation for the dredging crew will be provided aboard the cutter-suction dredge "Aquarius". Treated sewage from the vessel will be discharged to the waters in the vicinity of the dredging operation. The ship's freshwater supply will be provided by on-board desalination equipment. All oily wastes and solid refuse will be held and disposed of in an approved manner.

A small portion of the foreshore near Louth Bay may be required for the purpose of temporary storage and staging for the dredge's pipeline equipment. Discussions are continuing with the Department of Indian and Northern Affairs to seek approvals as may be necessary, should this use of the foreshore be required.

3.0 ENVIRONMENTAL SETTING

The environmental setting provides the most detailed description of the existing environmental features of McKinley Bay and the surrounding area that is possible with existing information. Pertinent data related to climate and sea ice, oceanography, foreshore soils and terrain, vegetation, bioresources and resource utilization are identified and assessed. Discussion of bioresources includes both marine and terrestrial species that may be affected by the proposed development. The report focuses on McKinley Bay but also includes discussion of an offshore area north to northwest of McKinley Bay which will be used by the drill ships and icebreakers during travel to the drillsites.

The environmental setting was prepared largely by ESL Environmental Sciences Limited and LGL Limited. Other contributors included EBA Engineering Consultants Limited and R. M. Hardy & Associates Ltd.

The total study team was composed of the following:

ESL Environmental Sciences Limited

Wayne S. Duval	Planktonic Communities, Impact Assessment Project Director
John W. McDonald	Sea Ice and Oceanography Project Manager
Linda Martin	Oceanography, Impact Assessment
Tarek Jandali	Climate
Ron Fink	Drafting

LGL Limited

Aaron D. Sekerak	Impact Assessment
John A. Foster	Project Coordinator
John G. Ward	Marine and Terrestrial Mammals, Birds, Impact Assessment
William B. Griffiths	Invertebrates

LGL Limited (cent'd)

Peter C. Craig - Fisheries

Mark A. Fraker - Marine Mammals

Rolph A. Davis - Senior Review

EBA Engineering Consultants Ltd.

Neil MacLeod - Soils and Terrain

R. M. Hardy & Associates Ltd.

David E. Reid - Vegetation

Special acknowledgement is extended to Mr. Mike Lawrence of the Freshwater Institute, Winnipeg, for his fine cooperation and advice related to fisheries resources in the McKinley Bay area.

3.1 Climate and Sea Ice

The most comprehensive description of the climate of the Mackenzie Valley has been presented by Burns (1973 and 1974). This study is a broad overview of climatic factors measured in the Mackenzie Valley and Beaufort Sea area. Included are climatic controls, inversions> temperature, wind, precipitation, snow cover, ocean areas, ice, synoptic systems, cloud, visibility and icing. Burns characterizes the study area asa Marine Tundra climatic zone having long cold winters and cool short summers.

Reports prepared in connection with the Beaufort Sea Project also provide comprehensive documentation of ice conditions, climatic parameters and trends that are relevant to the exploration and potential production operations in the Beaufort Sea. In addition, many studies carried out by environmental consultants on behalf of industry and government provide valuable information relative to the physical environment in the study area.

Climatic stations operated by the Atmospheric Environment Service, Environment Canada (AES), in close proximity to the study area, are located at Tuktoyaktuk, Atkinson Point and Nicholson Peninsula. Other stations, at Cape Parry and Sachs Harbour are considerably further from McKinley Bay; however, they do provide valuable information on the prevailing climate along coastal areas.

Air Temperature

Temperature measurements were recorded at Atkinson Point during the period from 1959 to 1963. Monthly means and extreme observations are presented in Table 3.1-1.

Mean daily averages are above freezing for the months of June

TABL

MONTHLY MEANS AND EXT

AT ATKINSON POINT,

TEMPERATURE (^{o}C)	JAN	FEB	MAR	APR	MA
Mean Daily	-28.8	-29.3	-26.7		
Mean Daily Maximum	-24.6	-25.6	-22.9	-13.4	-
Mean Daily Minimum	-32.9	-32.9	-30.6	-22	
Extreme Observed Maximum	- 2.2	- 6.7	- 5.6	3.3	8
Extreme Observed Minimum	-46.7	-43.3	-46.7	-38.	

* Source: (Ministry of Transport, 1967)

through to September, whereas mean daily minimums are above freezing during July and August only. Extreme observed maximum and minimum temperatures are 27.8 and -46.7°C respectively.

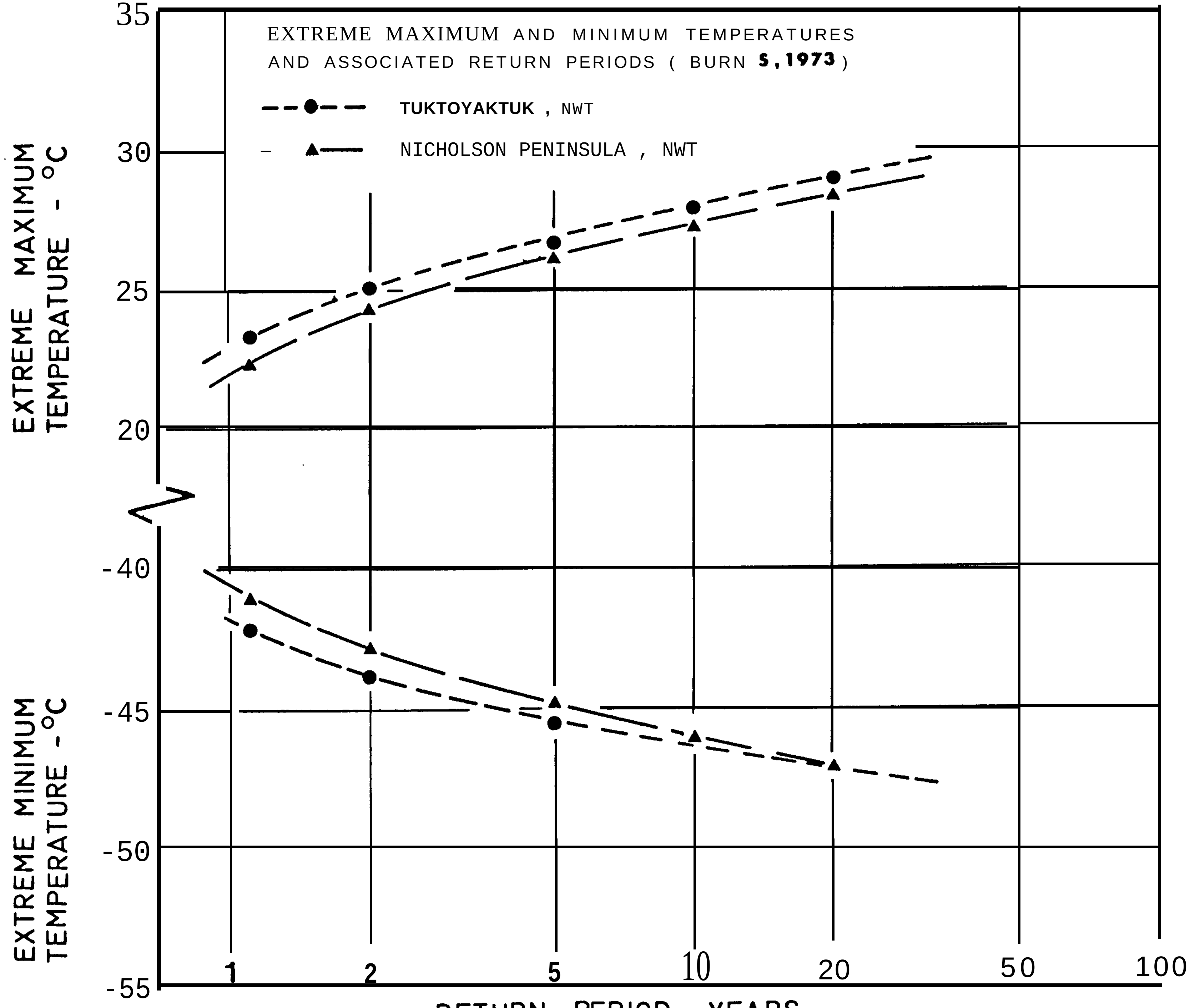
Average and extreme dates associated with first (Fall) and last (Spring) frost occurrences are important parameters in a cold environment such as that prevailing in McKinley Bay. Frost data for Tuktoyaktuk and Nicholson Peninsula are published by Hemmerick and Kendall (1972), and summarized in Table 3.1-2. The two stations exhibit similar trends relative to earliest (June 20) and latest (July 15) Spring frost dates. Spring frost dates at McKinley Bay will also be similar, although fall frost dates will be somewhat different. Tuktoyaktuk exhibits frost occurrences of one to three weeks later than those at Nicholson Peninsula. Since McKinley Bay is on the western edge of Tuktoyaktuk Peninsula Fall frost dates at McKinley Bay will be closer to those recorded at Tuktoyaktuk than at Nicholson Peninsula.

Extreme maximum and minimum temperatures and associated return periods (Burns, 1973) are presented in Figure 3.1-1 for Tuktoyaktuk and Nicholson Peninsula. For a return period of 20 years, the extreme maximum and minimum temperatures are 28°C amd -47°C respectively. These are comparable to extreme observed temperatures at Atkinson Point over a period of five years (Table 3.1-1).

Wind and Waves

Berry *et al* (1975) analyzed wind data from three coastal stations: Tuktoyaktuk, Cape Parry and Sachs Harbour. Wind data from each of these stations were extrapolated independently to arrive at estimates of prevailing conditions over the Beaufort Sea. Wind over the open water is the dictating paramater for estimating magnitudes of wave heights and storm surges.

FIGURE 3.1-1



EXTREME MAXIMUM AND MINIMUM TEMPERATURES
AND ASSOCIATED RETURN PERIODS (BURN S,1973)
TUKTOYAKTUK , NWT
NICHOLSON PENINSULA , NWT
EXTREME MAXIMUM TEMPERATURE - °C
EXTREME MINIMUM TEMPERATURE -°C
35
30
25
20
-40
-45
-50
-55
1
2
5
10
20
50
100
RETURN PERIOD - YEARS

TABLE 3.1-2

FIRST AND LAST FROST DATES
AT NICHOLSON PENINSULA AND
TUKTOYAKTUK, N.W.T. *

STATION	LAST FROST (SPRING)			FIRST FROST (FALL)			YEARS OF RECORD
	EARLIEST	AVERAGE	LATEST	EARLIEST	AVERAGE	LATEST	
Nicholson Peninsula	June 21	July 9	July 15	July 16	July 30	Sept. 7	14
Tuktoyaktuk	June 20	July 1	July 14	July 24	Aug. 26	Sept. 28	21

* Source: (Atmospheric Environment Service, 1972)

Statistical data relative to directional frequencies and mean monthly wind speeds during July, August and September are presented in Tables 3.1-3 and 3.1-4 respectively. Wind from the east is the most predominant in terms of frequency of occurrence, accounting for as much as 27% of all observations during the month of July. The second most frequent wind is from the west and northwest. These, however, are associated with the largest mean monthly wind speeds of 28 and 31 km/h, compared with only 26 km/h for wind from the east during September. Wind from the west and northwest will cause the most serious threat relative to wave action and storm surge occurrence due to relatively open exposure of the west coast of Tuktoyaktuk Peninsula.

Extreme wind speed predictions and the associated return periods are estimated for the Beaufort Sea (Berry *et al.*, 1975); these are presented in Figures 3.1-2 and 3.1-3 for winter (November to May) and summer (June to October) respectively. During summer when open water prevails, the extreme hourly mean wind speed, corresponding to a return period of 10 years, is in the range of 93 to 103 km/h.

Wave hindcasting in the Beaufort Sea has also been carried out using available meteorological data measured at coastal locations and extrapolated to open water. Both deep-water and shallow-water waves were predicted for a range of return periods (Berry *et al.*, 1975). Estimates of the significant wave heights for the Beaufort Sea during July to October are presented in Table 3.1-5 for several water depths. Unfortunately, the water depths for which waves were predicted only go down to the 10 metre depth. Most coastal locations are associated with a relatively large nearshore fetch having depths considerably less than 10 metres.

TABLE 3.1-3

DIRECTIONAL FREQUENCIES (%) OF
HOURLY WIND - BEAUFORT SEA*

WIND DIRECTION	MONTH		
	JULY	AUGUST	SEPTEMBER
N	8.1	7.9	8.5
NE	20.8	13.8	13.1
E	27.0	24.6	20.0
SE	7.8	9.2	9.2
S	3.0	4.8	5.2
SW	4.7	4.6	6.5
W	12.0	14.2	14.4
NW	10.5	15.7	18.3
CALM	6.3	5.2	4.9

* Source: Berry *et al.* (1975)

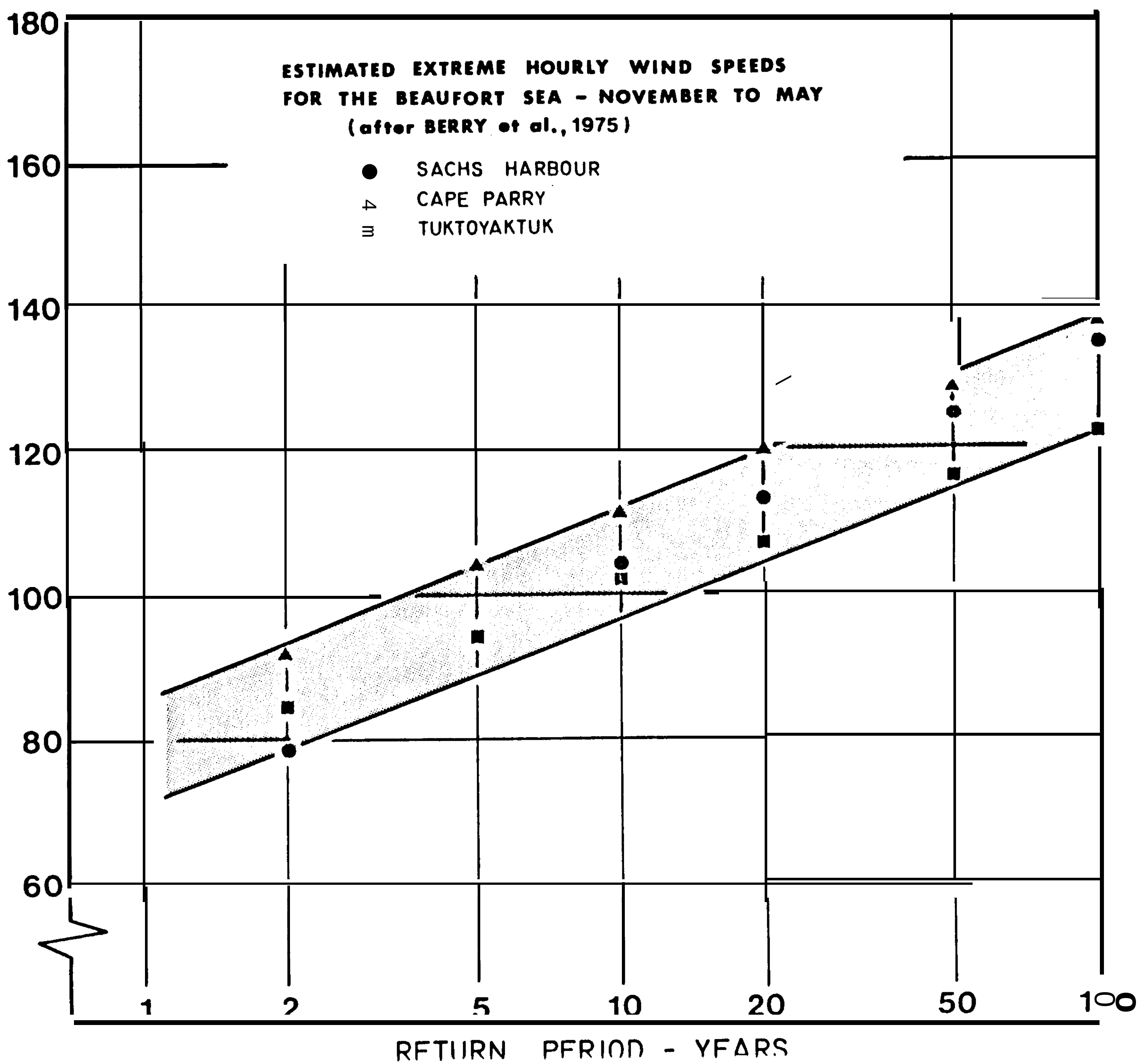
TABLE 3.1-4

MEAN MONTHLY WIND SPEEDS (km/h)
IN THE BEAUFORT SEA*

WIND DIRECTION	MONTH		
	JULY	AUGUST	SEPTEMBER
N	16	19	22
NE	21	21	23
E	23	24	26
SE	21	22	25
S	17	18	25
SW	20	20	26
W	22	24	28
NW	21	24	31

* Source: Berry *et al.* (1975)

FIGURE 3.1-2


ESTIMATED EXTREME HOURLY WIND SPEEDS
FOR THE BEAUFORT SEA - NOVEMBER TO MAY
(after BERRY et al., 1975)
SACHS HARBOUR
CAPE PARRY
TUKTOYAKTUK
4 m
EXTREME HOURLY WIND SPEED - KM/H
180
160
140
120
100
80
60
1
2
5
10
20
50
100
RETURN PERIOD - YEARS

FIGU E 3.1-3

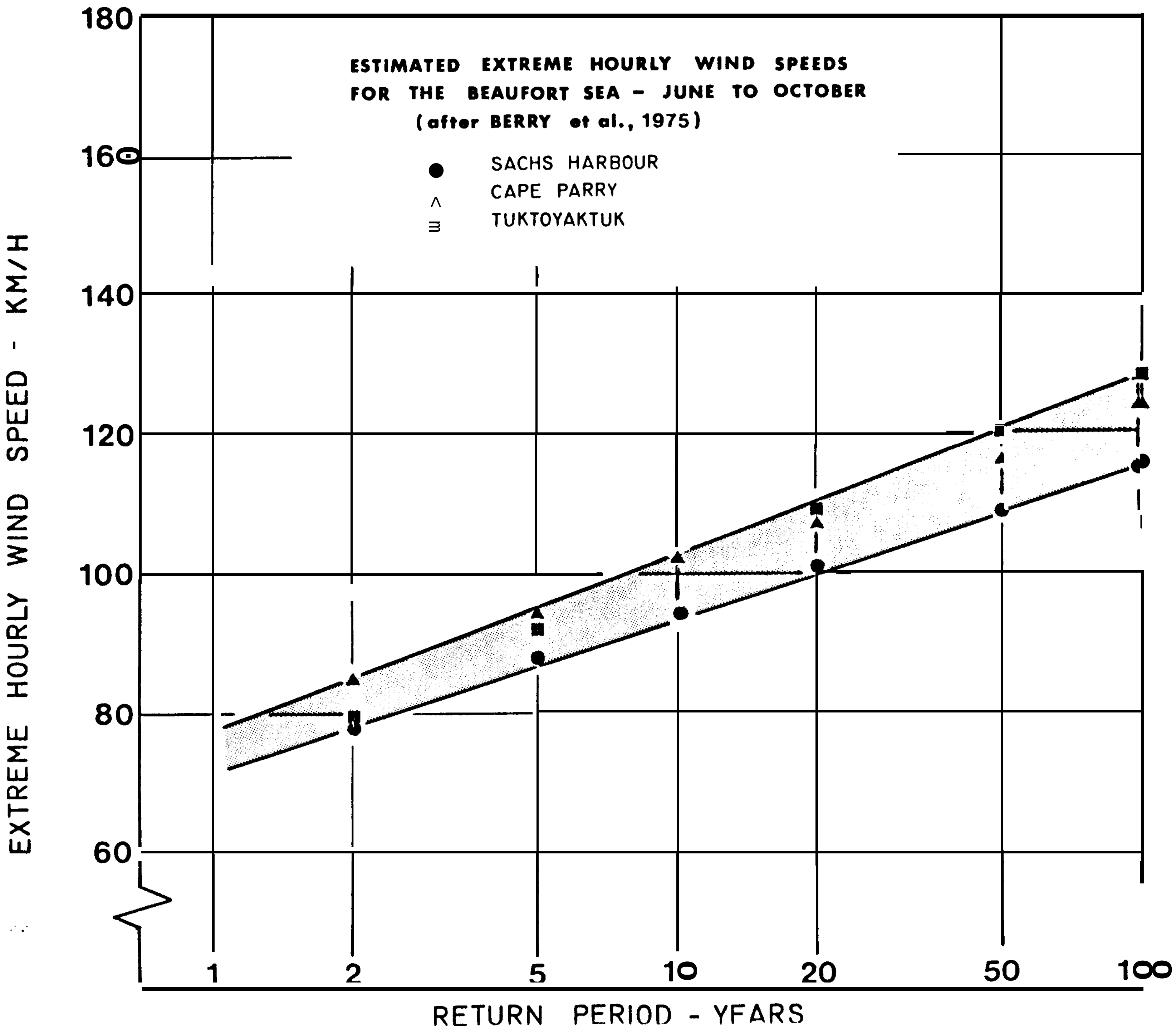

ESTIMATED EXTREME HOURLY WIND SPEEDS
FOR THE BEAUFORT SEA - JUNE TO OCTOBER
(after BERRY et al., 1975)
SACHS HARBOUR
CAPE PARRY
TUKTOYAKTUK
EXTREME HOURLY WIND SPEED - KM/H
180
160
140
120
100
80
60
1
2
5
10
20
50
100
RETURN PERIOD - YFARS

TABLE 3.1-5

ESTIMATED EXTREME WAVE HEIGHTS (metres)
FOR THE BEAUFORT SEA - JULY to OCTOBER*

RETURN PERIOD (YEARS)	WATER DEPTH (METRES)				
	75	50	35	20	10
2	3.2	3.1	2.5	2.1	2.0
5	4.3	4.2	2.9	2.6	2.6
10	5.2	5.2	3.3	2.9	3.1
20	6.3	6.3	3.6	3.2	3.7
50	8.0	8.2	4.1	3.8	4.6

* Source: Berry *et al.* (1975)

Storm Surges

Storm surges are a significant feature of the physical oceanography of the southern Beaufort Sea. Surges resulting in an increase in sea level of about one metre or more for several hours during the open water season are not uncommon. The strong west and northwest wind combined with a long fetch of shallow water provide ideal physical conditions for the formation of surges. Both positive (increase in sea level) and negative (decrease) surges can occur. These will have different impacts on development and operation in the study area. Winter surges can also occur. These are not large when compared with summer surges; however, even moderately high water levels in winter can result in large masses being pushed on shore.

A summary of historical records of storm surges is presented by Henry (1975). These include water level measurements recorded at various coastal locations. Henry (1975) also described a mathematical model for predicting storm surge levels in the Beaufort Sea utilizing meteorological data as input. The model was used to simulate documented surges to permit model calibration and verification.

One specific storm that occurred during September 1972, was documented at several locations including Atkinson Point. Water level rise at Atkinson Point peaked at about 1.2 metres on September 2, 1972. This surge was caused by a wind storm from the northwest with a maximum geostrophic speed of approximately 72 km/h.

Henry (1975) also presented water level records associated with a winter storm that occurred during January, 1974. Measurements at Tuktoyaktuk indicated that water levels peaked at about onemetre on January 6, 1974. This surge was also caused by a wind storm from the northwest with a maximum geostrophic speed of about 108 km/h.

Figure 3.1-4 depicts historical records of water level measurements at Tuktoyaktuk for the years 1962, 1963, 1964 and 1974. Both positive and negative surges are shown. However, only significant changes in water level are indicated (peaks greater than -0.5 m and less than 1 m are omitted). The years 1962 and 1963 were characterized by the presence of large open water areas conducive to storm surge occurrence during summer. However, 1964 and 1974 had summers with unusually persistent ice cover, hence, the lack of positive strong surge occurrences. Maximum positive observed surges approached 2metres during September 1962 and October 1963.

A statistical analysis of storm surge occurrences on the Mackenzie Delta was carried out by Slaney (1975). The study was based on a simple one-dimensional storm surge model combined with surface wind statistics compiled at Tuktoyaktuk. All factors contributing to rise in water level were superimposed, including maximum tide and influence of prevailing barometric pressure. Table 3.1-6 summarizes the results of the study which depicted maximum rises in water level at Kendall island and the associated return periods. Although Kendall Island is somewhat distant from McKinley Bay (approximately 190 km WSW), it none-the-less indicates trends in the relationship between surge height and return period. The Slaney study also made the following observations:

> "The observed distribution of maximum levels of driftwood is in the range of 2.4 to 3 metres above mean sea level. This implies that the predicted 30year flood level (present analysis) is approximately 0.6metres below minimum observed levels of driftwood. Since no recurrence interval can be associated with the location of driftwood and due to the lack of complete knowledge of the mechanism for its present distribution, no firm conclusions can be drawn from this comparison. It must be emphasized that the present analysis is based on a simplified one dimensional model and on meteorological data monitored at Tuktoyaktuk instead of the open water. Meteorologists at the Arctic Weather Central in Edmonton estimate that wind speeds on the open water are higher than those monitored on coastal areas by a factor ranging from 1.25 to 1.75. Furthermore, the predicted water level rise due to wind at the edge of the Mackenzie Delta is proportional to wind speed raised to the power 1.6

FIGUR

DAILY WATER L
AT **TUKTOYAKTU**
(**after** HENRY,

(- 0.5M < PEAKS < I

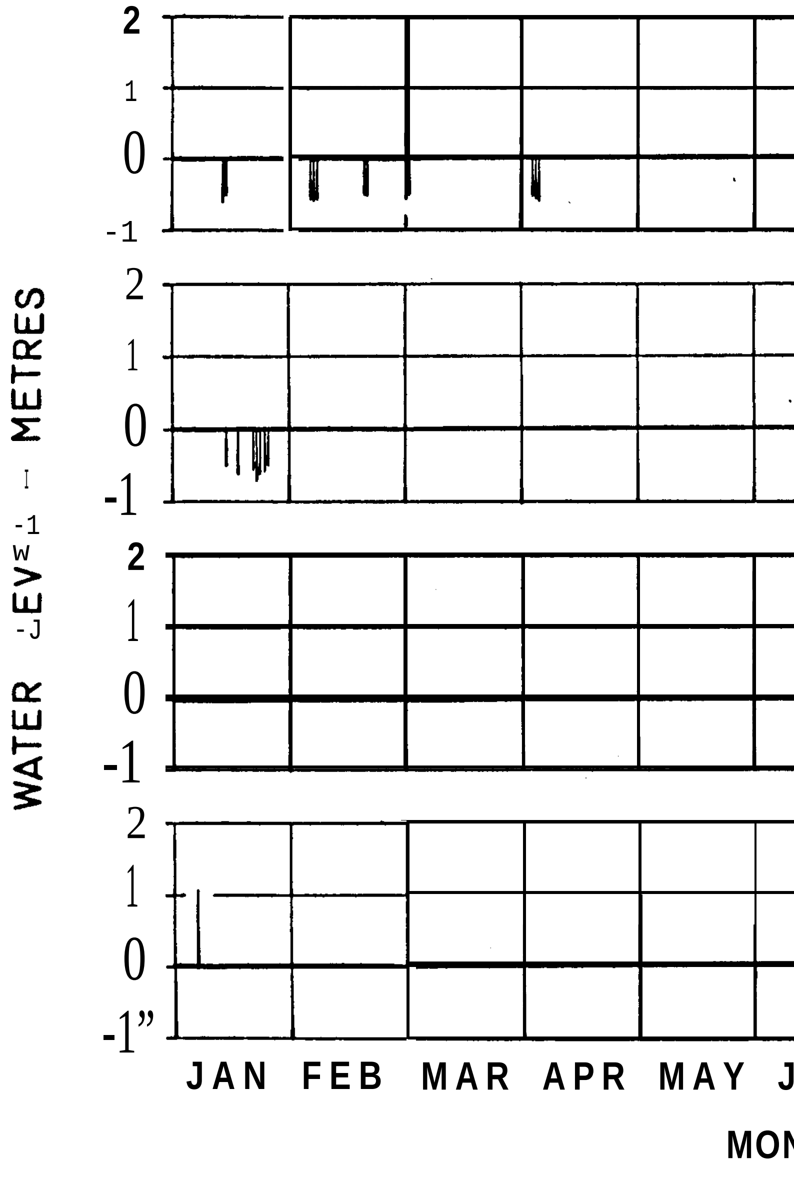


TABLE 3.1-6

FLOOD LEVEL RECURRENCE INTERVAL
AT KENDALL ISLAND, N.W.T.*

RETURN PERIOD (YEARS)	TOTAL WATER LEVEL RISE+ (METRES)
5	1.5
10	1.6
20	1.7
50	1.8
100	1.9

* Source: F. F. Slaney &Company Limited (1975)

\+ Total water level rise is comprised of storm surge superimposed on maximum tide (0.25 m) and water rise due to low pressure weather system (0.30 m) (approximately). For example, if a factor of 1.25 is used to relate wind speeds over the open water to those at Tuktoyaktuk, the predicted 50 year extreme flood level would be 2.4 metres above mean sea level instead of 1.8 metres."

Ice Cover

In the southeast Beaufort Sea three general types of ice cover occur (Kovacs and Mellor, 1974):

1. Landfast ice: a continuous sheet of typically smooth ice, stretching from the shore to anchoring points on grounded pressure ridges or ice island fragments. The outer edge generally coincides with the 18-20 m depth contour (isobath), and outer portions may be characterized by heavy ridging or rubble fields generated by early winter storms and subsequently "frozen in place". Detailed descriptions of this zone are given by Cooper (1 974) and Stringer (1974).

2. Transition (shear) zone: an irregular ice zone found from the seaward edge of the landfast ice which extends out to approximately the edge of the continental shelf. It is a zone of rapidly deforming, heavily ridged and highly irregular ice and acts as a boundary layer between the circulating ice of the Beaufort Gyre and the landfast ice. First-year ice predominates but some multi-year floes and ice island fragments are found.

3. Polar pack ice: an ice zone which extends outwards into the Arctic Basin and, in winter, is composed of multi-year floes with first-year ice growing and compressed between them. Its long-term average motion is a clockwise gyral circulation, but on a time scale of days the motion is very complex and irregular, governed largely by the wind stress field.

In the McKinley Bay area landfast ice prevails a minimum eight to nine months each year. During the brief summer open water period, this landfast ice disperses and an open water area may extend to beyond 500 km from the coast (Slaney, 1975). Yearly variations are extreme however, due to alterations in the prevailing wind structure. In 1974, a "bad" ice year, prevailing northerly winds kept multi-year ice floes within 50 km of the Tuktoyaktuk shoreline for most of the open water period.

In spring, SE winds are generally prevalent in the southeast Beaufort Sea and a polynya (large open water area) begins to form in the Cape Bathurst area, usually in March or April (Canadian Hydrographic Service, 1970). The Cape Bathurst polynya usually expands slowly in all directions after formation, with the Beaufort Sea gyre west of Cape Parry causing a net drift of ice away from the Cape Bathurst area.

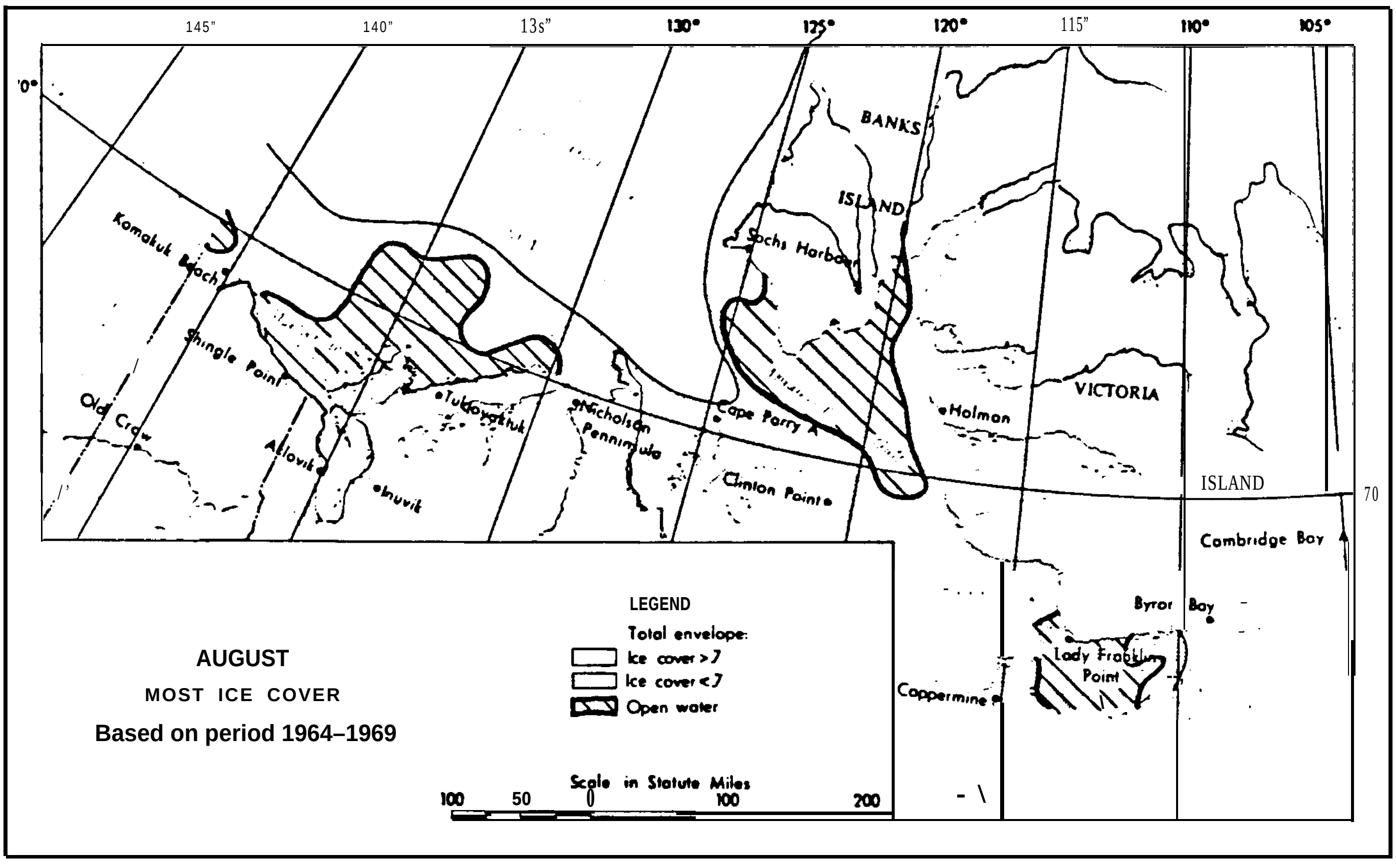
In salt water areas in the vicinity of Mackenzie Bay, clearing occurs near the end of June. By mid-July coastal areas contiguous to Amundsen Gulf are cleared, although in some years (such as 1978) areas east of Cape Bathurst have remained ice enclosed until late in the summer. Clearing elsewhere along the Arctic coast is usually delayed until late July (Burns, 1974). The average number of elapsed days from the mean date of first deterioration of ice to mean date of water clear of ice ranges from 30 to 50 days along the coast (Burns, 1974). Average date clear of ice for McKinley Bay is July 20 compared with June 30 in Kugmallit Bay; July 24 at the mouth of Liverpool Bay; and, July 23 at Cape Parry (Burns, 1974).

When southeasterly winds prevail through most of the summer, the pack ice can retreat as far as 73° to 74° North Latitude by August and September. However, during summers with frequent moderate to strong northwesterly winds, the pack ice is forced shorewards and can be kept within 50 Ian of shore until late August, such as the 1974 example.

Averaging the ice data provided from the many years of available observations enables plotting of "mean monthly" ice maps. These are provided in the "Arctic Atlas" produced by FENCO and Slaney (1978). Beaufort Sea maps indicate land-fast ice near McKinley Bay remains intact until early July. At this time an open water patch of about 20 km in width parallels the Tuktoyaktuk Peninsula which by August and September expands to greater than 150 km offshore. The Cape Parry/Franklin Bay area is subject to slightly more variable ice conditions in July (1/10 to 6/10 ice patches) but is usually kept open through August and September (with exceptions such as in 1978). In October, a mean concentration of about 7/10 and 9/10 new and first year ice is found throughout both areas.

It must be stressed that monthly ice concentrations are in reality extremely variable and seldom resemble the mean monthly mappings. A brief review of specific ice mappings for--the southeast Beaufort Sea between 1961-68 (Lindsay, 1975) and between 1974 and 1975 (McDonald and Martin, 1976) indicates there are extreme weekly and daily variations in ice cover in the summer months. The multi-year floe ice during summer can retreat as far as 500 km from shore or literally be forced up on the beach. A review of maps for August and September of most ice cover observed between 1964-69 (Burns, 1974) indicates waters east of Baillie Island including McKinley Bay always experience some nearshore open water but that to the west (including Cape Parry) continuous ice cover can occur to a concentration greater than 7/10 (Figure 3.1-5).

A review of 1973-1975 satellite imagery for the Tuktoyaktuk Peninsula area was made by Marko (1 975). He noted that there was "a great northward retreat" of the central ice pack boundary from the shoreline in the summers of 1973 and 1975. However, "the late and limited retreat of the 1974 pack led to a continued late-summer westward movement of ice out of Amundsen Gulf and away from the coast of Banks Island. The proximity of the pack to the coast confined the low-salinity silted waters from the Mackenzie River to an unusually small area leading to a thickening of the surface water layer reported elsewhere (Herlinveaux and de Lange Boom, 1976)".



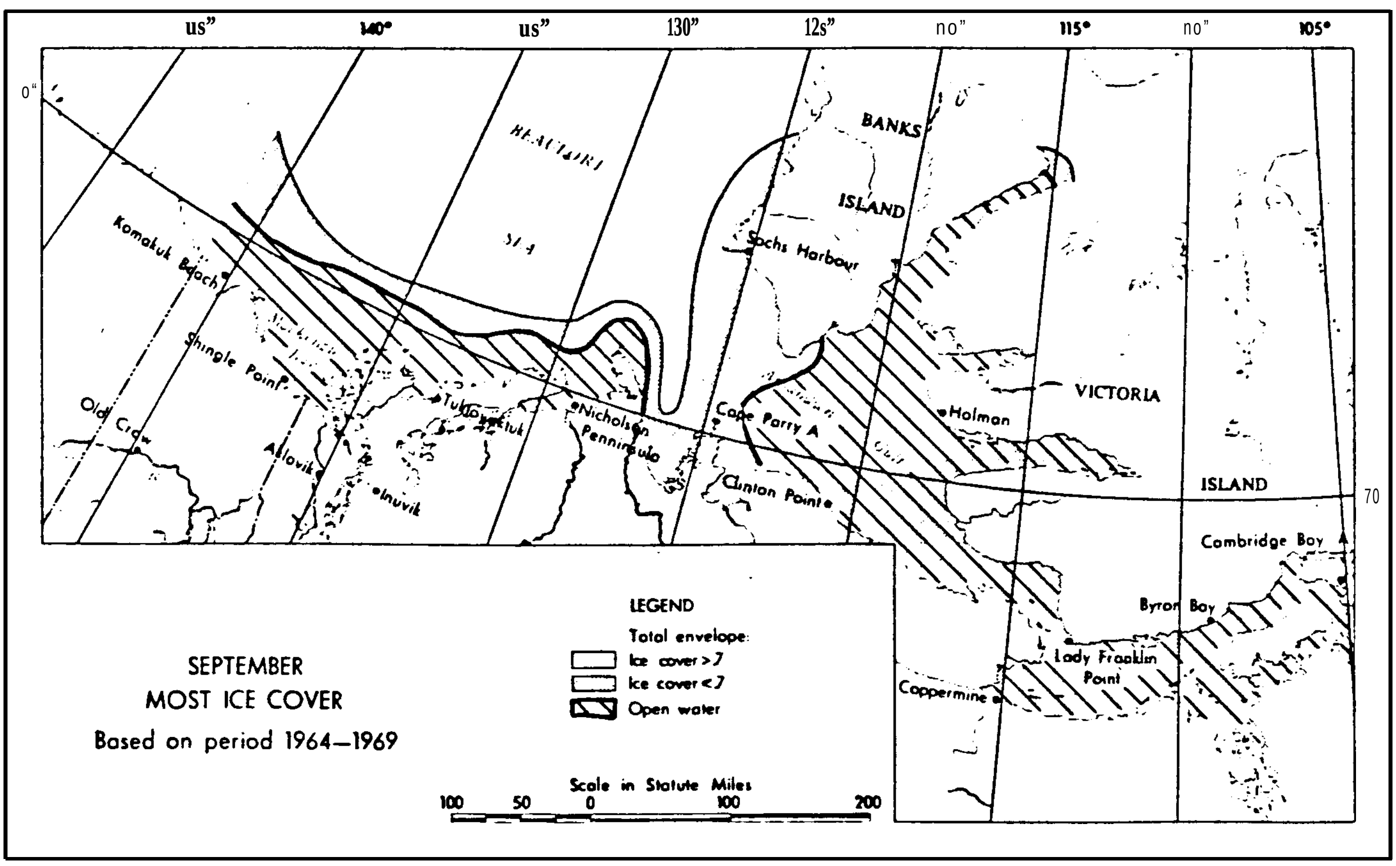


FIGURE 3.1-5

MOST ICE COVER OBSERVED (1 964-1 969)
(Redrawn from Burns, 1974)

Figures 3.1-6, 3.1-7 and 3.1-8 are satellite photographs from Marko (1975) which clearly show the variable ice conditions which occur from year to year and month to month in the McKinley Bay Area. In 1974, McKinley Bay was locked in fast-ice until late July while in 1973 it was completely open in early July with large leads and polynya extending offshore.

Freeze-up in the southeast Beaufort Sea occurs on average in the second week of October, but varies from late September in a congested season to early November if the pack has moved well offshore (Canadian Hydrographic Service, 1970). The Beaufort Sea anticyclone which usually dominates the weather picture in late September helps to move the polar pack shorewards which aids the rapid formation of ice.

The mean number of elapsed days from the mean date of the first occurrence of first year ice to mean date of complete freeze over is 20 to 25 days along the Arctic Coast (Burns, 1974). Mean dates of complete freeze over for the southeast Beaufort Sea range from October 21 at Shingle Point; October 15 at Tuktoyaktuk; October 31 at McKinley Bay; November 5 at Cape Bathurst; and, November 15 at Cape Parry. The Amundsen Gulf area is the last to completely freeze over because of the variable currents and polynya there.

During the winter a belt of land-fast ice extends seaward to about the 20m depth in the south Beaufort Sea as far east as Cape Bathurst. Its width varies from a few kilometers to as much as 50 km. Amundsen Gulf and areas immediately outside the land-fast ice are usually covered with first year ice which moves with the pack-ice and is difficult to distinguish from it. Maximum thickness of first year ice along the Tuktoyaktuk Peninsula (approximately 2 m) is usually reached sometime in May (Canadian Hydrographic Service, 1 970). The pack-ice is generally found 100 to 200 km seaward of the land-fast ice. The moving winter ice pack shears against the stationary land-fast ice producing extensive pressure ridges reaching several meters in height.

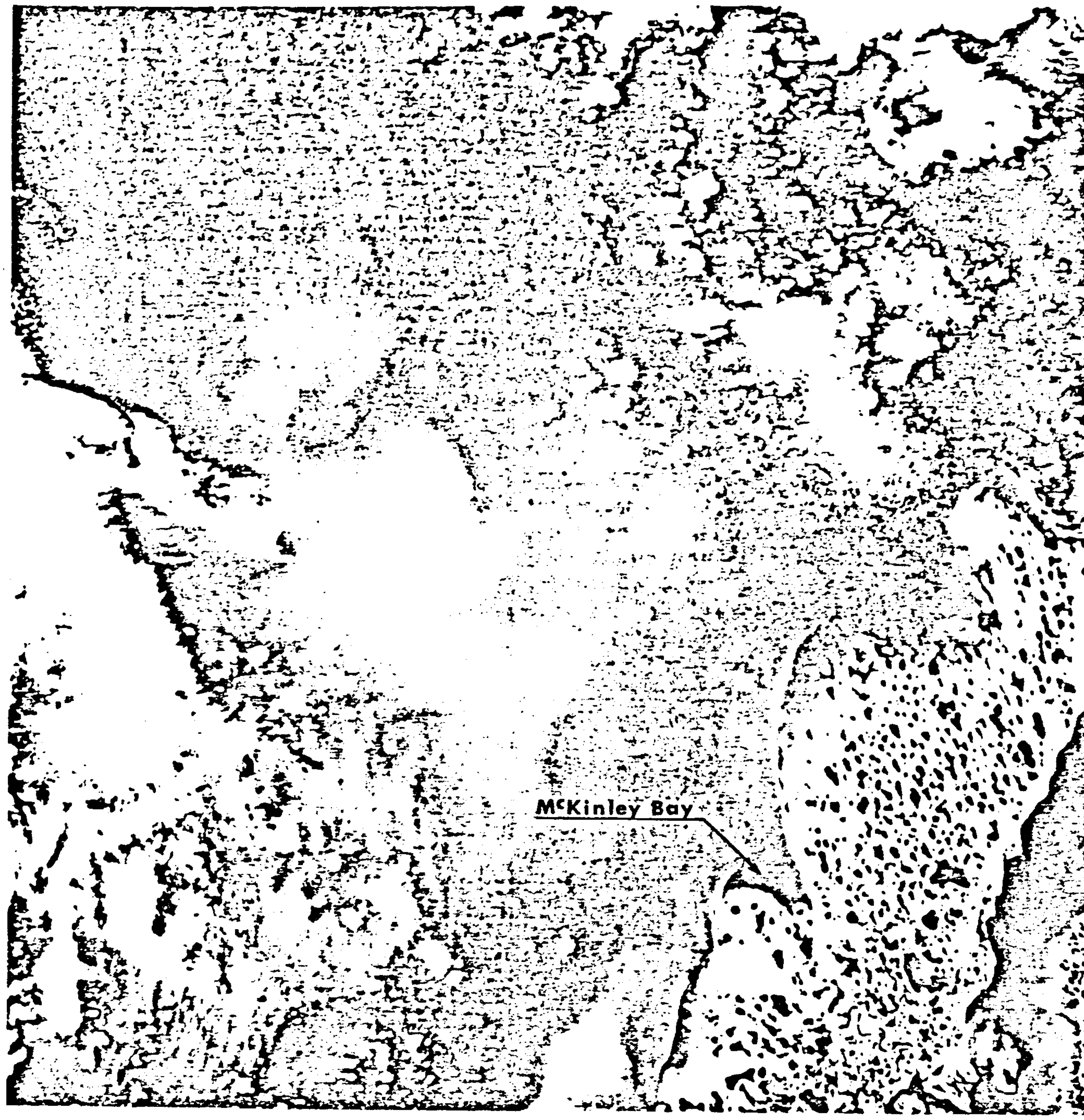


FIGURE 3.1 - 6

A JULY 7, 1973, ERTS SATELLITE IMAGE OF THE BEAUFORT SEA AND THE NORTHERN TUKTOYAKTUK PENINSULA. THE WHITE AREAS ALONG THE LEFT EDGE AND THE UPPER RIGHT CORNER OF THE IMAGE ARE CLOUD FORMATIONS. FLOES HAVING LINEAR DIMENSIONS UP TO SEVERAL KILOMETRES ARE SEEN TO BE SCATTERED IN A ROUGHLY COAST-PARALLELING BAND WITH A CONCENTRATION AREA NEAR POINT DALHOUSIE. (Redrafted from Marko, 1975)

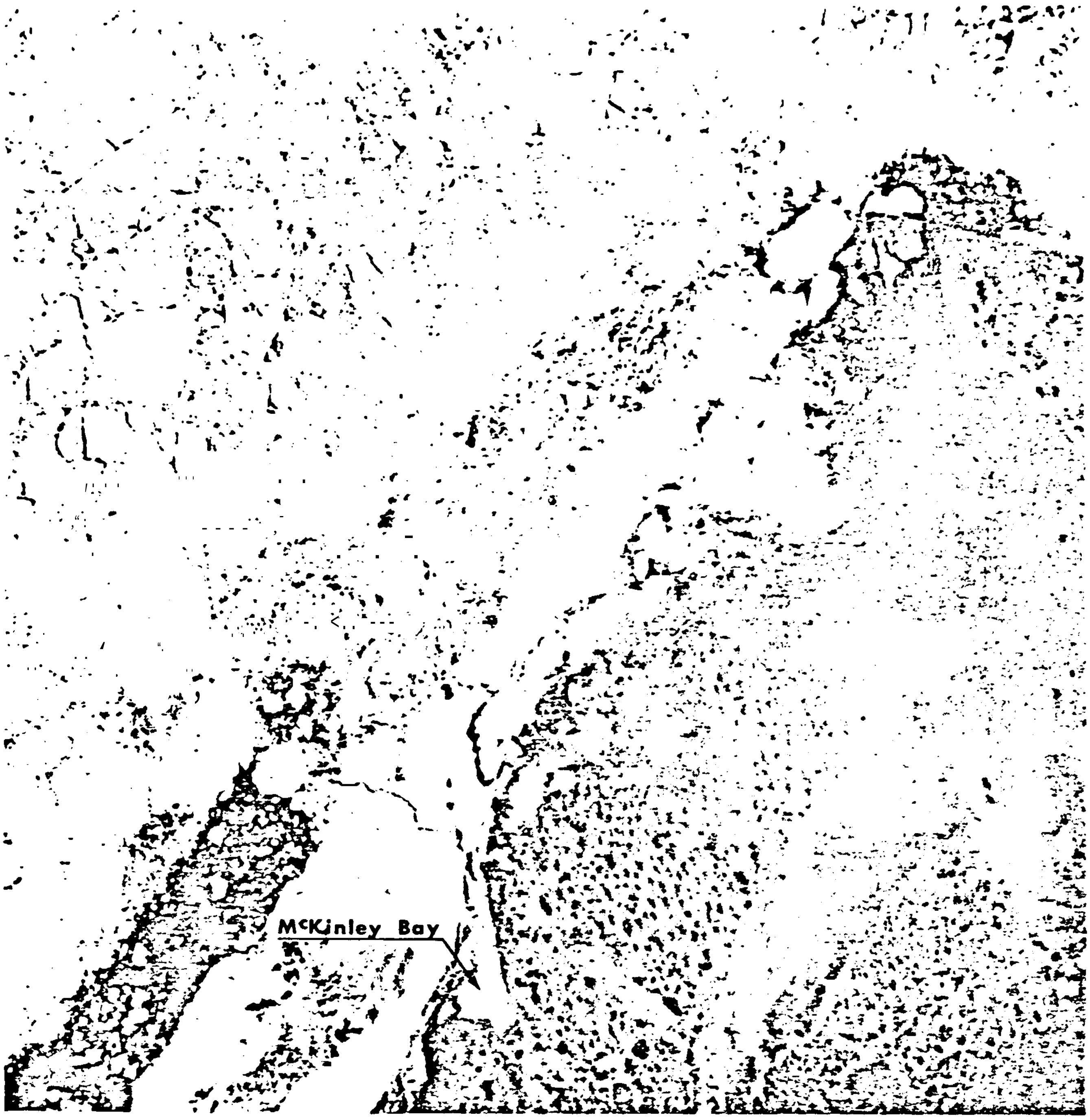


FIGURE 3.1 - 7

A JULY 19, 1974, ERTS SATELLITE IMAGE OF THE SAME AREA SHOWN IN FIGURE 3.1-6. A SMALL AREA OF OPEN WATER IS SEEN AT THE LOWER LEFT BETWEEN THE STILL INTACT LANDFAST- AND THE SEAWARD PACK-ICE. (Redrafted from Marko, 1975)

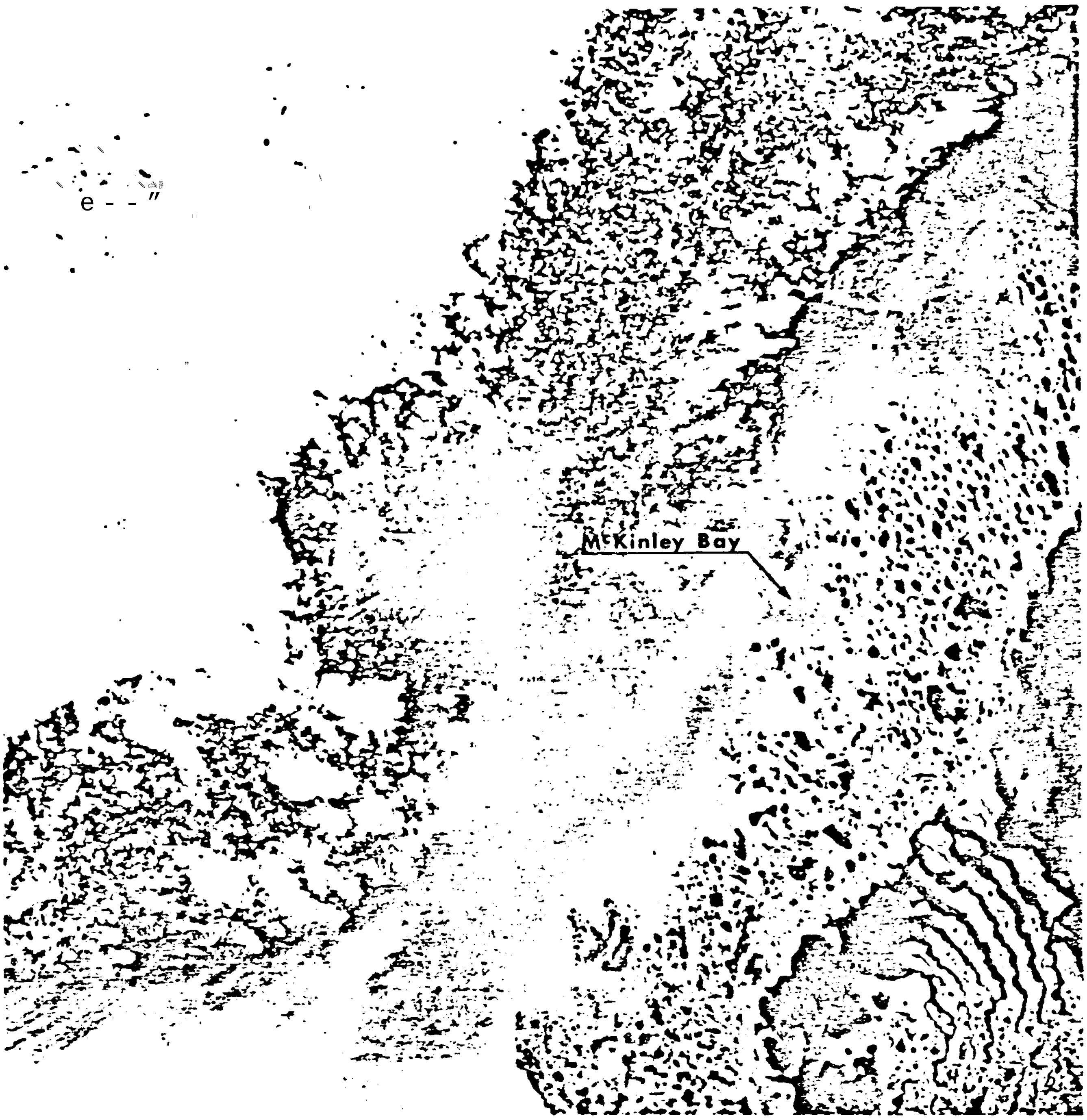


FIGURE 3.1 - 8

AN AUGUST 7, 1974, ERTS SATELLITE IMAGE OF THE AREA SHOWN IN FIGURE 3.1-6. A HEAVY CONCENTRATION OF FLOE ICE REMAINED IN-SHORE OF THE MAIN PACK. (Redrafted from Marko, 1975)

3.2 Oceanography

Circulation

The predominant current direction along the Tuktoyaktuk Peninsula is to the northeast chiefly as a result of periods of strong northwest winds and the Coriolis force on the Mackenzie River discharge (FENCO and Slaney, 1978). During less frequent strong easterly winds, currents reverse to the southwest off McKinley Bay. A sudden reduction in winds causes a relaxation of the current within about 24 hours (FENCO and Slaney, 1978). Highest currents along Tuktoyaktuk Peninsula are associated with storm force northwest winds. Longshore northeasterly currents can reach 1 to 2 knots during these summer open water occurrences, carrying heavy sediment loads (McDonald and Martin, 1976) but there have been no direct current measurements inside McKinley Bay. Tidesaresemi-diurnal with a range of 0.3-O.5m (McDonald and Cambers, 1977). Figure 2.0-1 shows the bathymetry as surveyed by the Canadian Hydrographic Service, 1962-64 amd 1971. It is anticipated that most tidal exchange probably occurs along the deeper northeast sides and that a slow gyral flow may be found along the western side and in the more protected waters near Louth Bay.

Mackenzie Plume Movements

The dominant marine feature of the nearshore south Beaufort Sea is the estuarine area resulting from the outflow of the Mackenzie River. Over the centuries, sediment deposition from this turbid outflow has generated a wide shallow coastal shelf extending north and east of the Mackenzie Delta.

The actual circulation pattern of the Mackenzie River water at any given time depends primarily on the previous prevailing winds and, to a lesser extent, the ice cover. The distribution of Mackenzie River water .

in open water conditions is generally northeasterly because the Coriolis force dominates wind effects for wind speeds less than about 3 m/see. Winds are typically less than 3m/sec in this region for at least 50% of the summer (Slaney, 1975).

Marko (1975) used satellite imagery to follow open water movements of silted brackish water from the Mackenzie River outflow. He observed the major contribution of sediments as a visual surface plume which extended seaward 55 to 70 km from Shallow Bay along the Mackenzie Canyon,and then veered easterly under the influence of the Coriolis force as a distinctive band 30 to 40 km wide,until dissipating off the Tuktoyaktuk Peninsula.

A similar sediment plume emerges from the eastern channel of the Mackenzie Delta,and merges with the plume from the western Mackenzie River in the western part of Kugmallit Bay. Some sediment also moves directly seaward along the Tuktoyaktuk Peninsula, particularly in the eastern portion where it may add to the edge of the continental shelf (Pelletier, 1975).

Marko (1975) noted:

> "A fairly consistent characteristic of the Mackenzie River plume is the presence of large existing eddies and intruding tongues of clear water along its perimeter. These are often seen to be directed to the south and southwest in line with the local flow direction of the neighboring Beaufort Sea gyre and may thus depict lines of contact between coastal and deep water flows. One of the most persistent and far--reaching of these eddies is found north-northwest of Richards Island. The existence of this eddy probably depends upon the Mackenzie River discharge into Kugmallit Bay."
>
> "Even in the absence of freshwater confinement by ice such as occurred in 1974, the turbid water can extend northward for hundreds of kilometres during the mid - to late summer months. An example of such flow near

the northern end of the Tuktoyaktuk Peninsula is seen in the July 15, 1975 image of Figure 99. The distinctive small eddies seen in this image have cores of clear, saline water which drift north-eastward with the prevailing late summer surface flow".

Figure 99 from Marko's report is displayed in this report as Figure 3.2-1. The surface waters of McKinley Bay are clearly influenced by the Mackenzie Plume in this photograph.

In heavy ice years such as 1974 the proximity of the summer pack-ice to the coast can effectively restrain offshore movements of the Mackenzie Plume to immediate nearshore areas. As a result the thickness of the low-salinity silted waters increases. In 1974 the offshore ice dam eventually broke out in the Cape Bathurst Area and led to an unusually high flow of silted water as far north as Sach's Harbour.

Offshore, the Mackenzie Delta river plume is typically two to fivem in thickness (McDonald and Martin, 1976) but can increase to 10m during heavy ice years such as in 1974. Proximate to McKinley Bay, plume thicknesses probably reach two to four meters during Mackenzie River water intrusions. The partially-mixed surface waters are usually more turbid, much less saline and considerably warmer than the denser oceanic waters beneath.

The extent of summer estuarine effects on waters inside McKinley Bay is anticipated to be highly variable but somewhat time-delayed compared to changes in Mackenzie River water which occur immediately offshore. During either low windspeeds (less than 3m/see) or westerly winds, the warm turbid low-salinity Mackenzie Plume is first transported eastward along the Tuktoyaktuk Peninsula and then slowly infiltrates the surface waters of enclosed bays such as McKinley Bay. During moderate to strong easterly winds this low salinity Mackenzie outflow is pushed northwesterly resulting in offshore replacement of Mackenzie waters by cold clear high salinity waters,

FIGURE 3.2 - 1

A JULY 15, 1975, ERTS SATELLITE IMAGE OF SILTED WATER EDDIES OFF-SHORE OF THE TUKTOYAKTUK PENINSULA. (Redrafted from Marko, 1975) upwel led or advected from the east. Curing such events the surface waters of McKinley Bay are probably slowly flushed of the fresher Mackenzie water, although wave action may keep the waters silted.

In November, the most rapid reduction in the Mackenzie River discharge occurs. By mid-month the volumetric discharge is only 15% that of midsummer flow (Milne and Smiley, 1976). Its silt load is also dramatically reduced. Formation of ice moves westward during the reduction in offshore influence of the warm Mackenzie outflow.

By December a more or less continuous ice cover up to one meter thick is found along the Tuktoyaktuk Peninsula. In Tuktoyaktuk Harbour, waters near the under-ice surface are gradually replaced through the winter with relatively clear fresh Mackenzie outflow, (Barber, 1968). It is not known if this occurs in McKinley Bay because there have been no winter oceanographic surveys conducted in the area. However, it's additional distance (approximately 100 km) from the East Channel outflow probably means McKinley Bay waters become very saline with little or no winter freshwater exchange from the Mackenzie. Marko (1975) also observed that there may be a reversal in the usual easterly current along the Tuktoyaktuk Peninsula in winter as the Arctic Gyre migrates southward. It is believed such currents may reach five km/day (Marko, 1975) and, if so would certainly block movement of fresh Mackenzie waters to McKinley Bay.

Salinity and Temperature

Large annual variations in salinity and temperature occur in the waters adjacement to the Tuktoyaktuk Peninsula due primarily to seasonal variations in Mackenzie River outflow, ice cover and wind climate. Numerous recent studies confirm wide horizontal and vertical variations in both these parameters for the waters in Kugmallit Bay and along the Tuktoyaktuk Peninsula (Cameron, 1953; Ince, 1962; Barber, 1968; Healey, 1971; Slaney, 1974; Herlinveaux and De Lange Boom, 1975; Slaney, 1975; McDonald and

Martin, 1976; McDonald and Cambers, 1977; and Slaney, 1977). Figure 3.2-2 shows locations of 1974 oceanographic sampling stations by Herlinveaux and de Lange Boom (1975).

As discussed in the section entitled "Mackenzie Plume Movements" the estuarine area resulting from the Mackenzie River outflow is the dominant feature of the physical marine environment in the southeast Beaufort Sea. Figure 3.2-3 (from Herlinveaux and de Lange Boom, 1975) shows a comparison of surface salinity distributions during easterly and westerly winds from measurements taken in 1952. During easterly winds when ice is absent, surface salinities can exceed 30‰ offshore off McKinley Bay as cold advected oceanic water (usually about 2 to 4° C) replaces the Mackenzie Plume along the Tuktoyaktuk Peninsula. During sustained westerly winds the ice pack generally moves closer to the shoreline and the Mackenzie Plume veers easterly along the Tuktoyaktuk Peninsula.

Inside McKinley Bay water salinities and temperatures have been measured at two stations near the head by the Freshwater Institute in 1978 (Figure 3.2-4). Water temperatures in the open water period ranged from 2 to 6° C and salinities from 9.3 to 33.1%, (Table 3.2-1) during their three visits. Continuation of their studies in summer 1979 should provide additional useful data.

Offshore of McKinley Bay surface water temperature measurements have ranged from 5 to 10°C and bottom temperatures at 15 to 35m depths from about -1.3 to +4°C in the summer months according to a few data presented by Herlinveaux and De Lange Boom (1975) and Grainger and Lovrity (1975). At stations 504 and 505 (Figure 3.2-4) on July 19, 1971 surface salinities were 17‰ and bottom salinities 31-32%. (Grainger and Lovrity, 1975). At shallower nearshore stations (stations 529 and 530, (Figure 3.2-4)) on July 22-23, 1973 surface salinities and temperatures were about 9‰ and 8°C and bottom salinities and temperatures about 10 to 13%., respectively. Both sets of measurements indicated residual effects of the fresh Mackenzie waters which can reduce salinities to less than 5‰ in this area (Herlinveaux and deLange Boom, 1975).

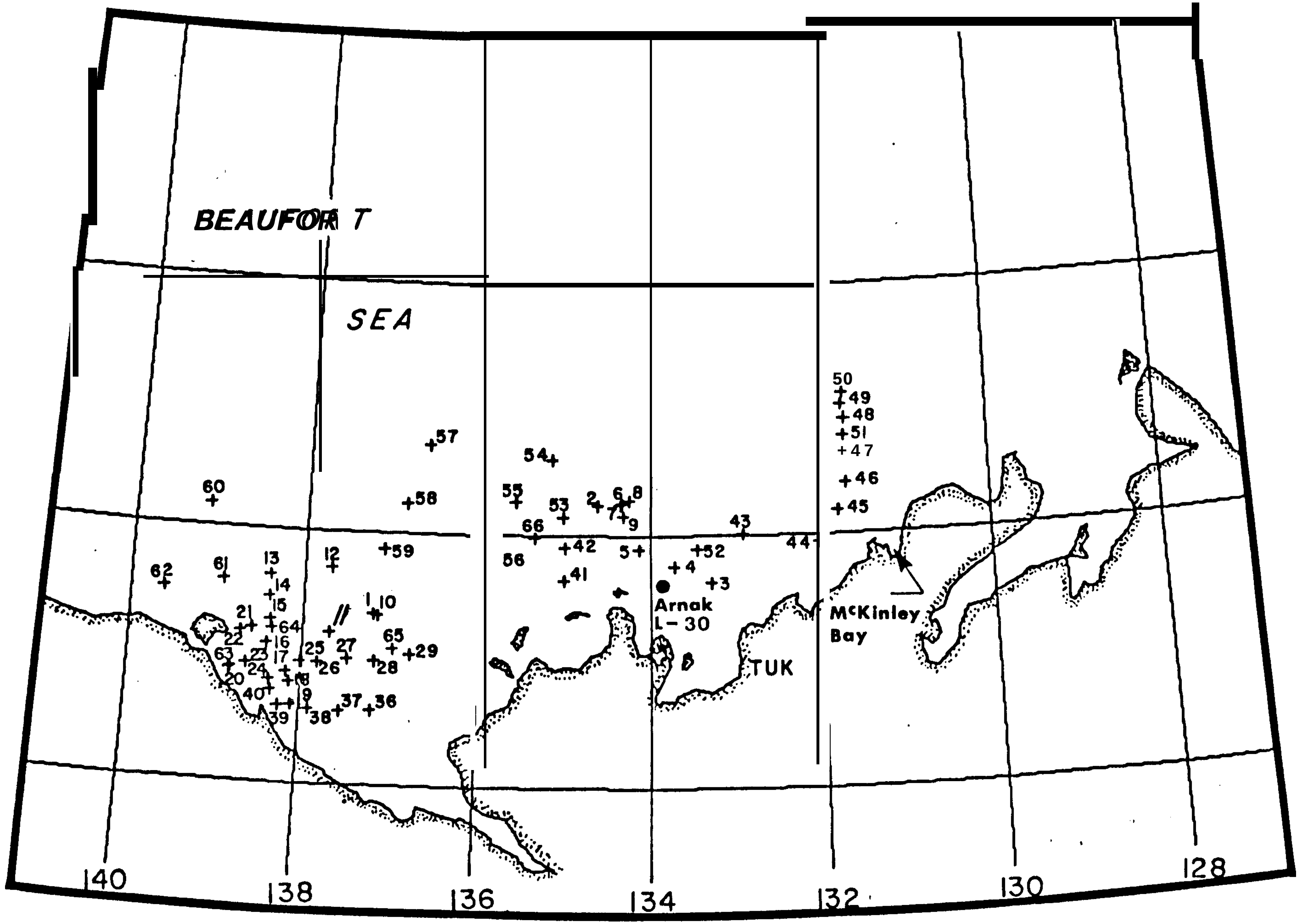
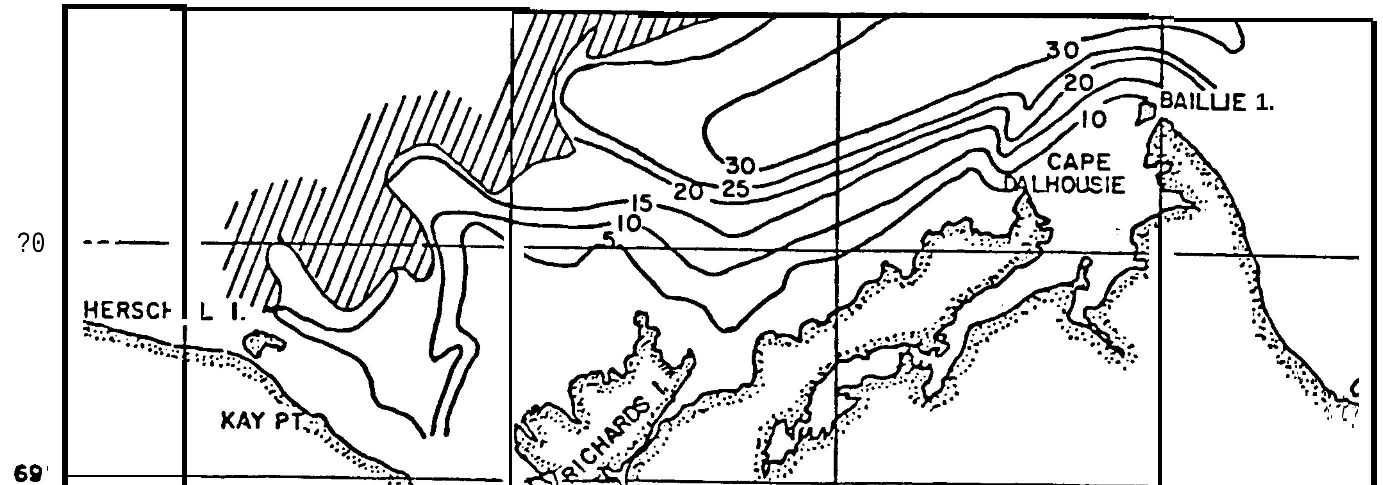


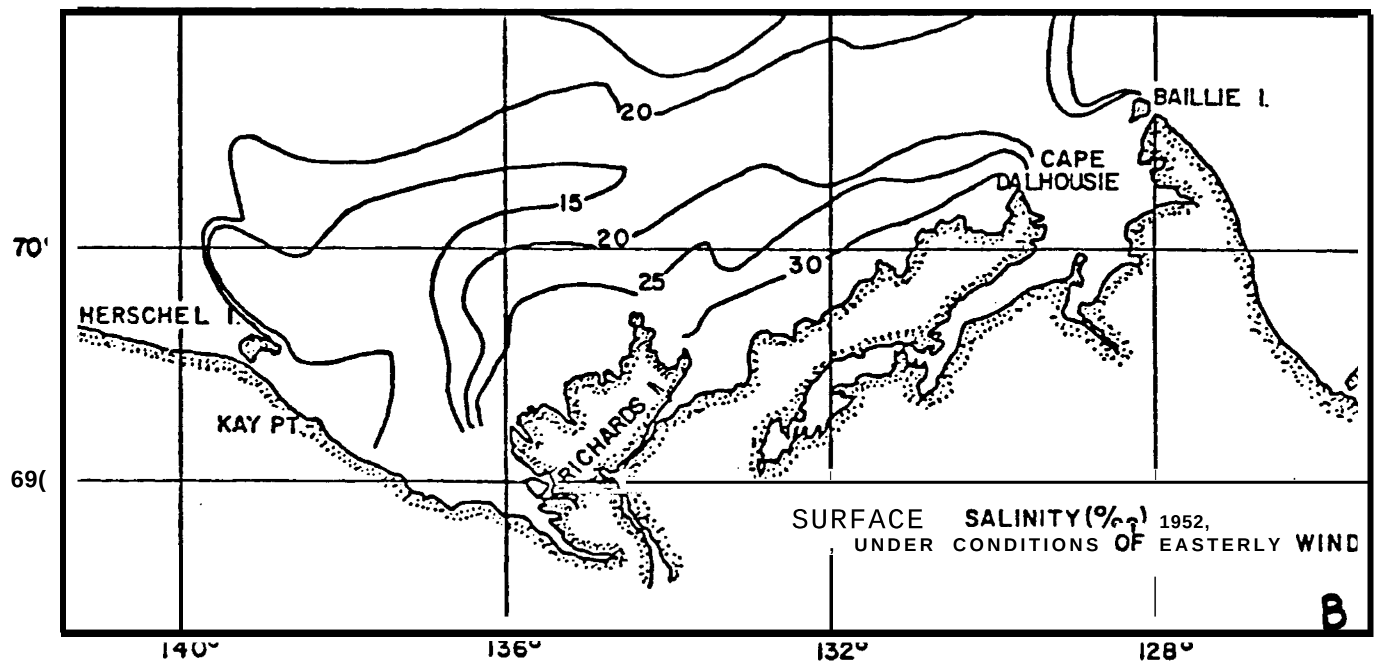
FIGURE 3.2-2

OCEANOGRAPHIC STATIONS, SUMMER 1974

(After Herlinveaux and de Lange Boom, 1975)



SURFACE SALINITY (‰), 1952,
UNDER CONDITIONS OF WESTERLY WIND



SURFACE SALINITY (‰) 1952,
UNDER CONDITIONS OF EASTERLY WIND

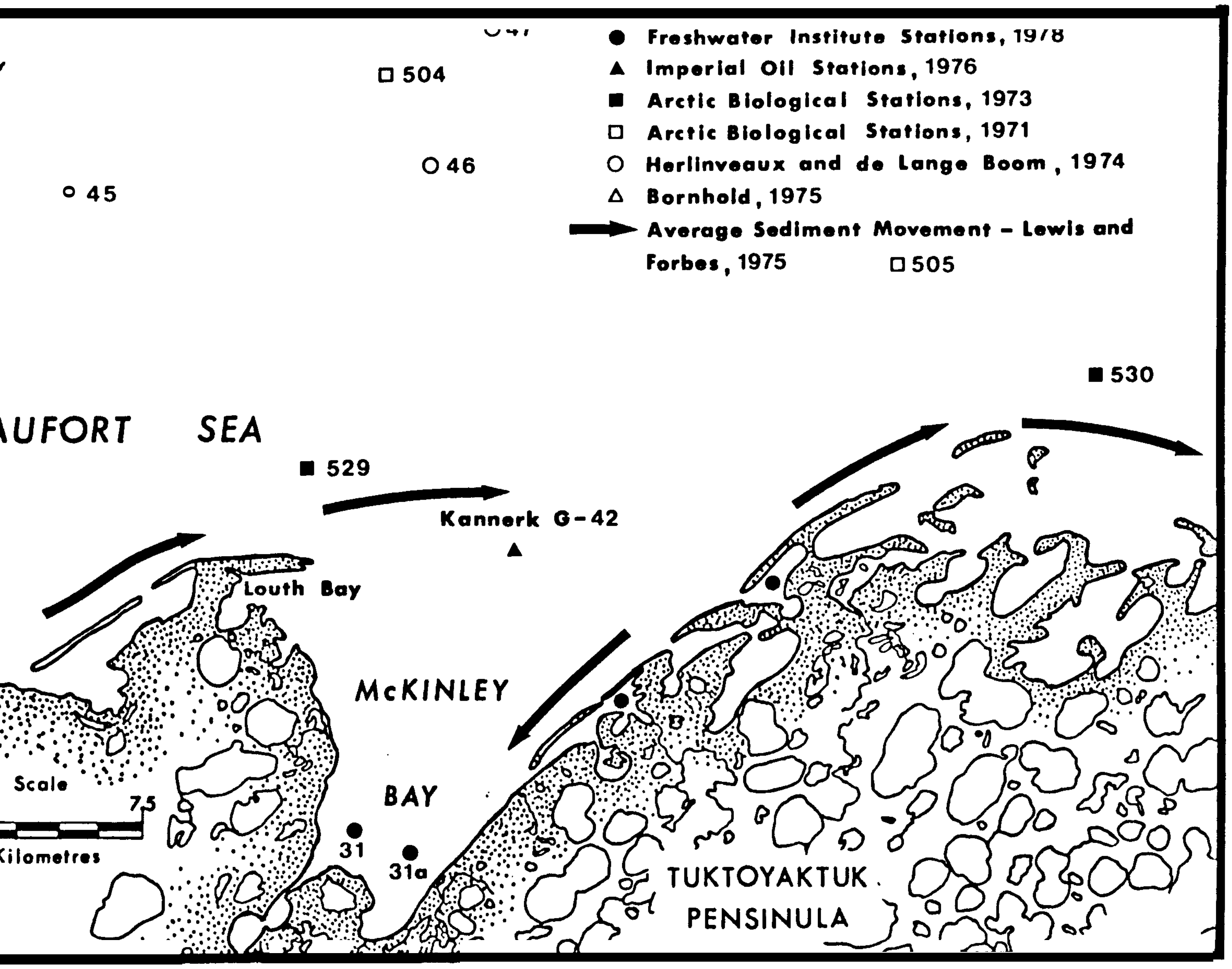


FIGURE 3.2-4
PHYSICAL/CHEMICAL OCEANOGRAPHIC
STATIONS NEAR McKINLEY BAY

TABLE 3.2-1

PHYSICAL-CHEMICAL DATA
COLLECTED IN McKINLEY BAY BY THE
FRESHWATER INSTITUTE, WINNIPEG IN 1978

Station	Date	Water Temperature (°C)	Conductivity (μmhos/cm)	Salinity (%)	pH	Total Hardness (mg/L)	Methyl Alkalinity (mg/L)	Suspended Carbon (μg/L)	Suspended Nitrogen (μg/L)	Total Suspended Solids (mg/L)
31	28/6/78	2.0	16,500	14.2	9.00	2,431	91	620	51	15.71
	3/8/78		30,500	10.3	8.10	5,200	60	470	51	15.71
	3/9/78	5.5	25,820	25.7	7.95	7,752	136	340	31	9.33
31A	28/6/78	6.0	11,800	9.3	9.00	1,615	84	1,035	128	10.50
	3/8/78		31,800	24.8	8.00	4,800	40	680	83	21.27
	3/9/78	2.1	29,440	33.1	7.85	8,160	153	225	35	18.13

Direct measurements by Slaney (1977) near Kannerk Artificial Island site on August 16, 1976 revealed a surface temperature of 5.0°C and conductivity of 38,100 µmhos. Bottom waters (11.3 m depth) were 4.0°C amd 40,600 µmhos conductivity. These high conductivities and associated salinities indicated the Mackenzie plume was not in the area at the time of these measurements.

During open water intrusions of Mackenzie Plume waters, the mixed surface freshwater layer can reach five meters thick off McKinley Bay, below which there is a marked thermocline and halocline (Herlinveaux and de Lange Boom, 1975). No data have been collected from inside McKinley Bay which would aid in describing its vertical stratification features.

During winter ice-covered conditions, the water temperature in McKinley Bay is probably near freezing and very saline (30‰) compared to waters further west such as in Tuktoyaktuk Harbour where the fresh Mackenzie outflow totally dominates the under-ice surface layer. However, winter measurements will be needed to confirm this conjecture for McKinley Bay.

Suspended Sediments, Turbidity and Water Quality Variations

The most pertinent and recent assessment of suspended sediments in the south Beaufort Sea was conducted by Bornhold (1975). He measured concentrations of suspended material at 23 offshore stations in the southeast Beaufort Sea from August 20 to September 9, 1975. Unfortunately his closest station to McKinley Bay (station 180) was about 40 km away [Figure 3.2-4). F.F. Slaney and Company Limited conducted nearshore sediment surveys in 1974, 1975 and 1976 for Imperial Oil Limited during numerous southeast Beaufort Sea. The most pertinent of their stations to McKinley Bay was a series of seven (45, 46, 47, 48, 49, 50, 51) running longitudinally offshore from the 20m to 40m depth contours (Figure 3.2-2). The following summary is based on statements from these reports.

The Mackenzie River contributes 15 x 10^6 tons of suspended matter annually, (Bornhold, 1975), although the annual variation in suspended sediment load is large. Peak sediment loads usually occur shortly after freshet in the upper reaches of the Mackenzie River. Suspended materials may not reach their maximum in the Mackenzie Estuary until as late as mid-August because of the long transit time from the upper tributaries to the Mackenzie mouth. Mackay (1963) estimated that the lower Mackenzie River can transport over 9.1 x 10^7 kg (100,000 tons) of sediment per day during freshet.

The major components of the suspended matter distributed by the Mackenzie River Plume through the southeast Beaufort Sea include fine inorganic particles, organic aggregates of plankton and inorganic particles, and phytoplankton themselves. Samples collected from Mackenzie Bay by Bornhold (1975) contained predominantly montmorillonite, kaolinite and some chlorite while inshore samples collected off Kugmallit Bay and along the Tuktoyaktuk Peninsula contained no kaolinite or montmorillonite and were abundant in chlorite.

Bornhold (1975) found that concentrations of suspended sediments were generally greatest in the waters off Kugmallit Bay where values typically exceeded 1.25 mg/ℓ. However, a station adjacent to the Tuktoyaktuk Peninsula yielded concentrations of 13.4 and 17.5 mg/ℓ at the surface and at 6 m, respectively; these were the highest values found influenced by the Mackenzie and Kugmal lit Bays. Slaney (1977) reported total suspended materials in nearshore portions of Mackenzie and Kugmallit Bays ranging from 19.8 to 966.3 mg/ℓ and from 5.9 to 348.4 mg/ℓ during 1974 and 1975 open water periods, respectively. These values are clearly one or two orders of magnitude higher than those observed in offshore waters by Bornhold (1975). In most cases, the suspended sediment levels were highest near the mouths of major Mackenzie River discharge channels.

Shallow waters of McKinley Bay are periodically exposed to high wave mixing and also the turbid Mackenzie Plume. As a result, short term high sediment loading can be expected there. The Freshwater Institute measured total suspended solids at the head of McKinley Bay ranging from 9.33 to 21.27 mg/ℓ during three specific visits in the 1978 open water period. Offshore suspended sediment data collected near the existing KANNERK G-42 artificial island site on August 16, 1976 revealed silted surface and bottom waters with total suspended solids of S7.3 and 60.0 ppm, respectively.

A longitudinal vertical profile of turbidities running offshore north of McKinley Bay (stations 45, 46, 47, 48, 49, 50) is displayed in Figure 3.2-5 (from Herlinveaux and de Lange Boom, 1975). The turbidity is presented as percent transmittance such that the lowest values correspond to the highest turbidities. The turbidity of surface waters was very high nearshore, under the influence of the Mackenzie plume, and decreased in magnitude and vertical extent offshore. A bottom turbidity maximum was also evident probably due to settling and migration offshore of uplifted sediments caused by wave activity and some Mackenzie Plume influence.

The only chemistry data presently available for the waters inside

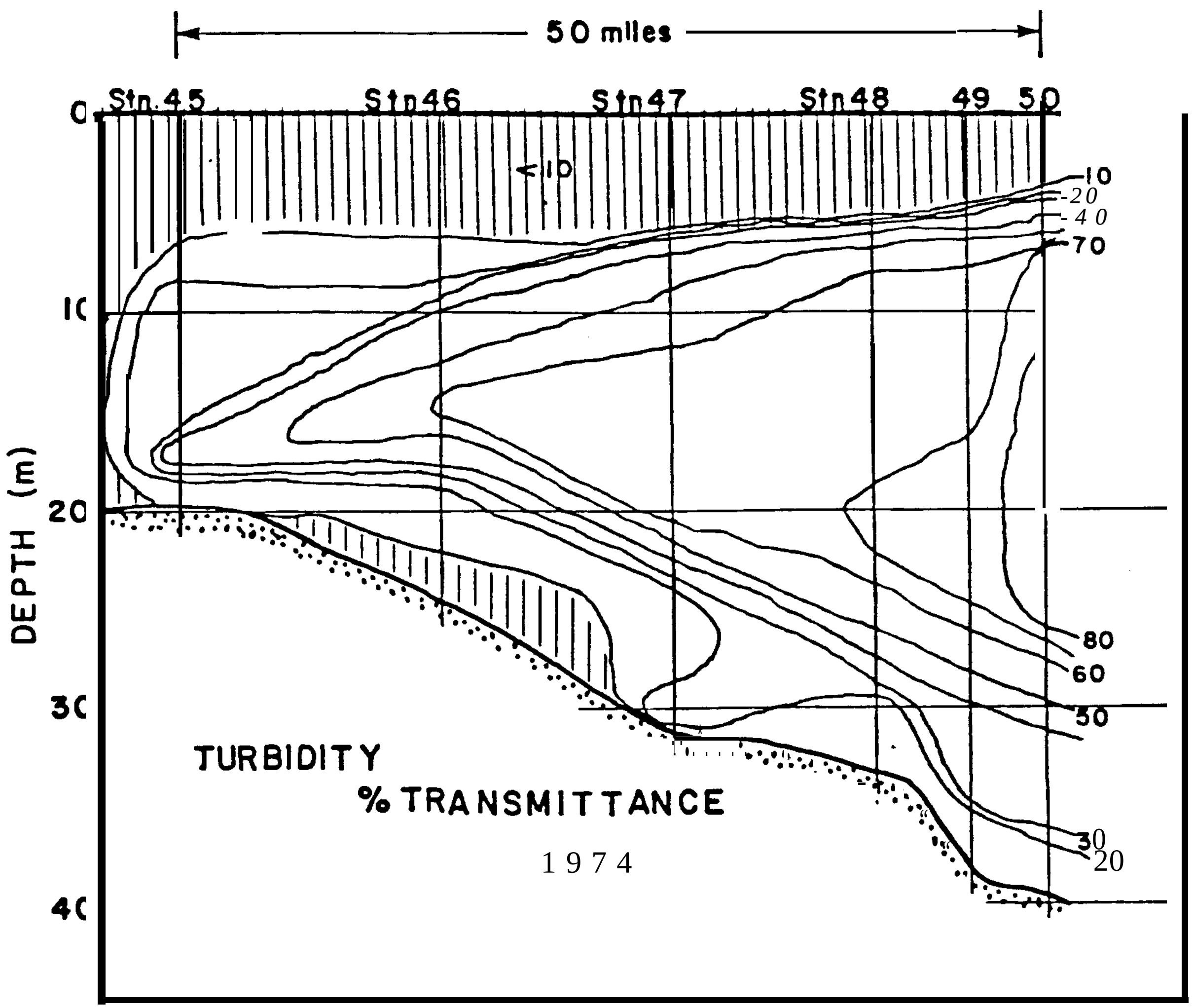


FIGURE 3.2-5

VERTICAL CROSS-SECTION OF TURBIDITY

for moving Mackenzie waters into the McKinley Bay area, thereby producing the low salinities. It is speculated that increased wave activity during these winds may have resuspended sediment-bound nitrogenous materials in the McKinley Bay waters. No further data on nutrients, trace metals and dissolved oxygen levels are available for McKinley Bay. Natural upwelling of bottom waters along the Tuktoyaktuk Peninsula during moderate to strong easterly winds probably elevates nutrient levels in the area periodically.

General water chemistry findings from offshore Beaufort Sea and industry studies are available. The closest once-sampled stations were numbers 529 and 530 in 1973 (Grainger and Lovrity, 1975). Slaney (1975) and McDonald and Martin (1976) found generally low levels of nutrients during open-water periods offshore of Mackenzie Bay as would be expected in the summer period of primary production. During the same period, surface DO saturation levels ranged between 61 and 127%. During easterly winds, intrusions of saline water into the usually fresh surface waters off Mackenzie Bay resulted in associated increased levels of alkalinity, hardness and pH (Slaney, 1974; 1975).

Dissolved trace metal concentrations measured at KANNERK G-42; shallow stations offshore Richards Island; and, Kugmallit Bay were frequently found to be below minimum detection limits of atomic absorption spectroscopy (Slaney, 1974; 1975; 1977).

Bottom Sediments and Coastal Processes

A summary of Pelletier's (1975) interpretation of 244 representative sediment samples from the south Beaufort Sea was provided to CANMAR, June, 1978 in an Assessment of "The Oil Sinking Ability of Mackenzie River Borne Sediments in the Beaufort Sea: A Literature Review" by Slaney (1978). The following pertinent information for the McKinley Bay area is provided from that summary. Dome is also conductingtheir own gee-technical investigations of bottom materials and coastal processes in the proposed areas of dredging to address specific engineering-related problems. Concurrently sediment chemistry information is being obtained in support of the Companies Ocean Dumping Control Act permit application.

Pelletier (1975) summarizes that except for the area northwest of Herschel Island which is thought to be receiving ice-rafted deposits, sediments of the floor of the Beaufort Sea are mainly fine-grained and consist predominantly of clay and silt in the western and central areas and somewhat coarser types in the eastern part. In the Mackenzie Delta area and its immediate offshore, this dispersal pattern is partly a result of the fine-grained sediment discharge from the Mackenzie River. Over the eastern portion of the shelf (along the Tuktoyaktuk Peninsula) the dispersal pattern is apparently due to sedimentation of fine particles over a relict surficial sand and partly due to the possibility that this sand is intermittently eroded by westward moving bottom currents. Thus the eastern shelf appears to serve alternately as a deposition and erosion site.

Interpretation of the Pelletier (1975) sediment maps indicates the bottom composition along the proposed McKinley Bay Harbour Entrance Channel will probably consist of: 40 to 60% silt; 20 to 40% clay; 10% sand; and, <1% gravel. Geochemical analyses for bottom sediments have been conducted during investigations of suction dredging and construction/ operation effects at artificial islands. The most relevant are presented in a study done at ARNAK L-30 (McDonald and Cambers, 1977).

Coastal processes and nearshore sediment transport along the Tuktoyaktuk Peninsula have been discussed in Lewis and Forbes (1975). In prepared direct testimony to the Mackenzie Pipeline Inquiry average current movements for sediments were presented for marine areas along the Tuktoyaktuk Peninsula. These movements are shown on Figure 3.2-4. The coast was discussed in separate segments consisting of sediment sinks toward which the sediment was believed to move, and source areas from which the sediments move from. McKinley Bay was described as a sediment sink for materials transported eastward along the Tuktoyaktuk Peninsula from Hutchinson Bay. Sink areas are typically very shallow and contain spits and lagoons that make them preferred locations for fish and shore bird populations (Lewis and Forbes, 1975).

The spits typically lie below the highest storm tide line. They are largest where offshore water depths are small (such as along the Tuktoyaktuk Peninsula) and/or where sediments supply is large (Lewis and Forbes, 1975). Their height and cross-sectional form are partially dependent on sediment size. The sandy-gravel spits west of Tuktoyaktuk tend to be higher and narrower than pure sand features east of Tuktoyaktuk. The sand spit at Atkinson Point reaches a maximum elevation of less than one meter (Lewis and Forbes, 1975). Storms and surges cause most of the erosion and longshore sediment movements along the Tuktoyaktuk Peninsula due to the heavy wave action.

Lewis and Forbes (1975) expand upon potential industry requirements that may cause changes in spits and bars:

> "Material supplied to the beaches, bars and spits is in continuous movement along the shore. Extracting gravel will tend to accelerate nearby shore erosion, particularly in the downdrift direction, and the effects of this must be determined. For example, if sand were taken from the beaches north of Tuktoyaktuk the supply to the beach which fronts the townsite would be interrupted and the coastal cliff there would retreat even more rapidly than it already is. A permanently dredged deep channel into Tuktoyaktuk Harbour would have the same effect unless the dredged material was pumped out downdrift from the channel."

> "The sources of material in the beaches is primarily local in nature. Little coarse sediment will move between the coastal segments I have identified. In some segments, the spits and bars may be relic in nature and material, once removed, will not be replaced. For example, Avadlek spit on Herschel Island was formed from sands and gravels supplied by deposits on the north and west sides of the island, deposits which no longer exist because of cliff retreat."

3.3 Foreshore Soils and Terrain

This section was prepared by EBA Engineering Consultants Limited. The preliminary terrain evaluation presented is based primarily on air photo analysis, supported by a limited literature review and a brief site visit conducted on June 23, 1979. That inspection was limited to the area on the west side of Louth Bay, where some abandoned facilities including buildings, roads, an airstrip and two storage tanks were examined.

Physiographic Description

The physiographic description provided by Mackay (1963) for the McKinley Bay area is as follows:

This area is generally less than 50 feet in altitude, with a narrow coastal strip lying below flood level. Large and small oriented lakes are numerous and both parabolic and blown-out parabolic dunes are common. Fixed longitudinal dunes are also present in the Point Atkinson region. There are numerous pingos but few visible signs of ground ice-sheets. From Hutchison Bay to McKinley Bay, three quarters of the surface is a flat, featureless tundra polygon plain. The transition from flat plains to the morainic hills in the south occurs abruptly at approximately 50 to 75 feet (elevation) .

Oriented lakes and parabolic dunes are abundant east of McKinley Bay and large tundra polygon flats are less frequent. The southern boundary occurs at 50 to 100 feet in altitude. The coast is indented, particularly east of McKinley Bay, where coastal recession of the oriented lake plain has caused an interfingering of land and water, resulting in bays that are remnants of the oriented lakes. Offshore waters are shoal, so that spits and bars are numerous. Offshore bars parallel the coast at distances up to several miles principally to the southwest of Point Atkinson, on the east side of McKinley Bay, and along the coast south from Cape Dalhousie. Some shoals lie 5 to 10 miles from shore.

Terrain Description

Figure 3.3-1 shows a terrain map prepared of the area to the west of McKinley Bay. A terrain classification legend to accompany Figure 3.3-1 is presented as Table 3.3-1. The region shown in the figure is low and very flat. The maximum elevation in the general area appears to be less than 10 metres and some of the coastal and northern parts of the area are less than 5 metres above sea level. Because of this low relief, the area is poorly drained and extensive, though probably thin, organic deposits have developed.

The soils observed in the Louth Bay area during the brief site visit consist predominately of fine-grained sand (often silty) with considerable organics mixed into the surface material, probably by frost action. This agrees with the description by Mackay (1963) of exposed soil on the east side of McKinley Bay of “stone-free sands and silts”.

Geologic Development

The principal terrain deposits consist of the Pleistocene Mackenzie River marine deltaic sands and silts. Other recent deposits have subsequently been derived from or been developed on these sandy sediments, including the bars and large spits that occur along the coastline. The erosion of the deltaic materials and coastal spits by wind supply the material that has been blown into sand dunes. On the surface of the deltaic sands, organic deposits have developed in the naturally low areas and depressions formed by low centre ice wedge polygons, while lakes have formed in the larger depressions. The reworking and subsequent deposition of the sand and silt with some organic deposits in a lake environment have produced lacustrine sediments that are very similar to the parent material except for differences in the structural characteristics and ground ice conditions. In addition, along the low coastal plain, storm surges and wave action have probably reworked the surface materials to produce localized areas of slightly cleaner and coarser material, as well as other areas where the finer sand and silt fractions are concentrated.

It appears unlikely that the maximum extent of late-Wisconsin glaciation reached as far as the McKinley Bay region. However, minor post-glacial marine submergence and some on-going submergence and coastal recession may have occurred.

Permafrost

The nature of the permafrost is the most significant geotechnical consideration at the subject site, which is located within the zone of continuous permafrost. Three obvious indicators of permafrost are visible on the air photos. They are summarized on Figure 3.3-1 and include the low pingos, extensive tundra polygons (low centre ice wedge polygons) and the steep, serrated lake shores that are indicative of thermokarst erosion. There are no apparent large ice slump features, similar to those that occur along the Eskimo Lakes and western part of the Tuktoyaktuk Peninsula, which are indicative of massive ground ice.

It is anticipated that this region will be characterized by relatively ice-rich surface soils, particularly within areas of extensive ice wedges and thermokarst shorelines, as well as extensive organic covered areas. However, some of the better drained areas do not appear to contain excessive ground ice.

The field reconnaissance trip noted some ice wedge thaw along the existing airstrip and roadways, although only relatively minor settlements had occurred. Where these facilities crossed the wetter, organic areas, more thaw settlement was evident, but major depressions had not formed.

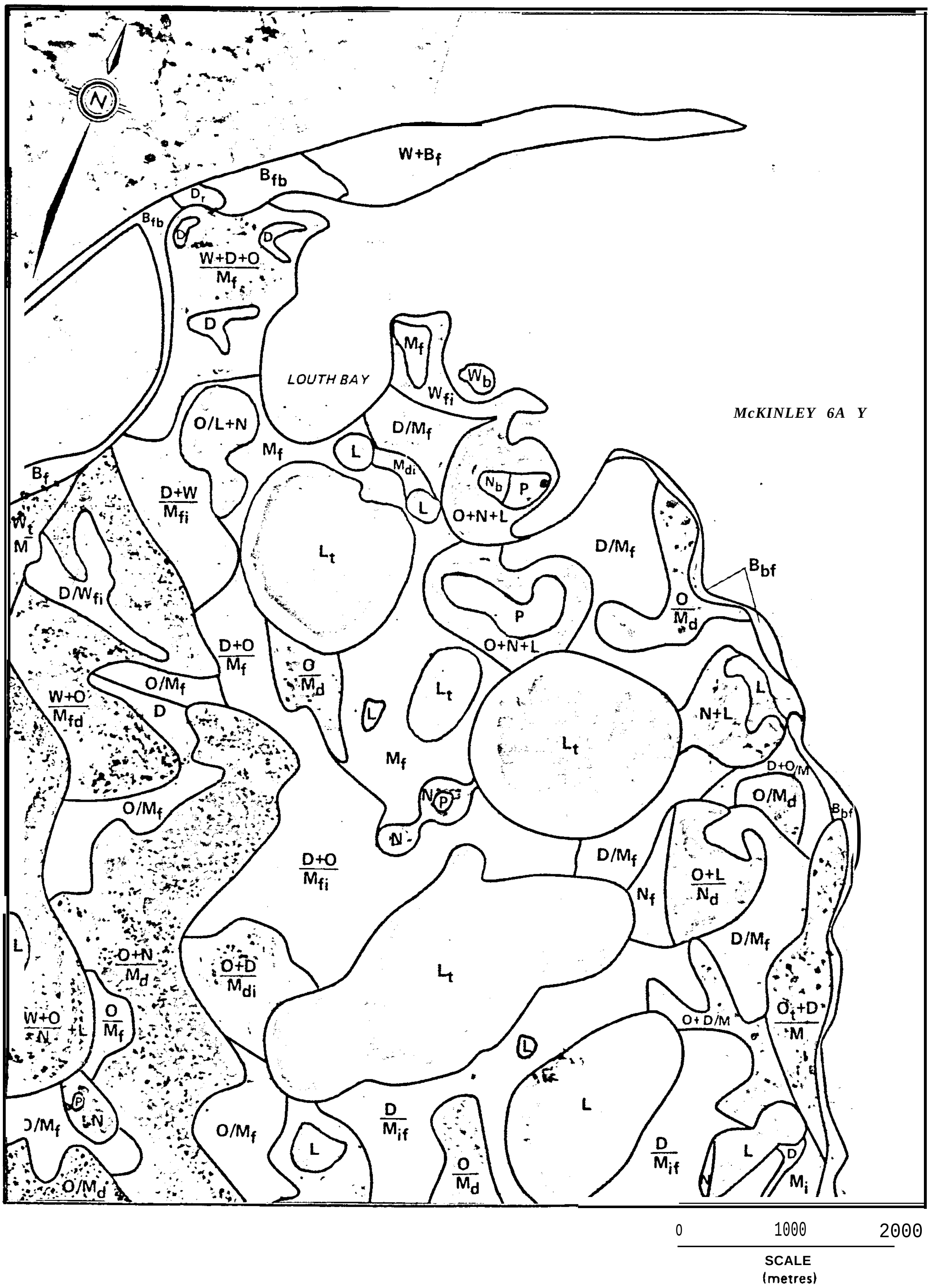


FIGURE 3.3-1 **TERRAIN MAP OF ATKINSON** POINT - McKINLEY BAY REGION

TABLE 3.3-1

TERRAIN CLASSIFICATION LEGEND

GENERAL FORMAT

'f where M is the landform, and
f is the topographic modifier

COMPOUND LANDFORMS

X/Y or	$\frac{X}{Y}$	thin or partial covering of Landform X overlying Landform Y
X +Y		approximately equal proportions of each landform

LANDFORMS

Marine:

S - spits and bars
B - beach
M - Pleistocene Mackenzie delta
W - coastal plain

Lacustrine:

L - lakes and ponds
N - lacustrine sediments

Organic:

o - peat

Eolian:

D - sanddunes

Permafrost:

P - pingo

TOPOGRAPHIC MODIFIER

f - flat lying
r - ridge
d - depressional

t - thermokarstic
b - bare or blown out
i - ice wedge (tundra) polygons

3.4 Foreshore Vegetation

This section was prepared by Hardy Associates (1978) Ltd. It provides a brief overview description of the vegetation of the McKinley Bay region with emphasis on the Atkinson Point area.

Approach

Vegetation studies of the McKinley Bay area are being conducted in two stages. The first stage is a preliminary assessment based on available literature and interpretation of aerial photography. The results of the first stage are presented in this report in the form of provisional descriptions and maps.

The map of the regional vegetation of McKinley Bay was prepared by transferring interpreted vegetation types from 1:50,000 aerial photography to the 1:50,000 NTS map of the area. The detailed map showing the vegetation of the Atkinson Point area was prepared by enlarging a portion of one of the previous air photos to 1:10,000 and transferring the interpreted vegetation types. Since air photo interpretation of arctic vegetation is difficult, and since little previous information is available for the area, the vegetation descriptions and maps in this report are subject to modification following the field reconnaissance.

The second stage of vegetation studies will include on-site investigation of the vegetation, and will serve to correct, if necessary, the provisional descriptions and maps. This stage will also provide more detailed data on major vegetation types and plant species of the study area. The results of the second stage will be combined with the first stage and presented as a final report.

Previous Studies

The vegetation of the McKinley Bay area is representative of the low arctic tundra which covers much of the coastal plain in northern Canada and Alaska. Vegetation studies in adjacent areas include the Tuktoyaktuk Peninsula (Mackay 1973, Cody 1965 and Hernandez 1973); the Mackenzie Delta (Gill 1973), Lambert 1972 and Reid 1977); the northern Yukon (Hettinger et al. 1973) ; and Alaska (Britton 1966).

The vegetation at Atkinson Point (the western tip of McKinley Bay) has been described by Corns (1974) as predominantly sedge communities. He included data which shows that small areas of low shrub heath and sedge heath communities also occur.

A map of the vegetation at a scale of 1:125,000 along the coast of the Beaufort Sea including McKinley Bay was prepared by the Forest Management Institute (FMI) (1975) . The most common vegetation types around the bay were shown to be low shrub wetlands, monocotyledonic wetlands, monocotyledonic meadows and tundra pond fields.

In this preliminary assessment of the vegetation, the 1:50,000 scale air photos have been interpreted in the context of the above descriptions by Corns (1974) and map

FMI (1977). These interpretations have been aided by comments and ground photographs from the staff of Dome Petroleum Limited and EBA Engineering Consultants Ltd. Additional aid was obtained by examining a variety of low level air photos (approximate scale 1:10,000) which were kindly loaned from Imperial Oil Limited in Edmonton.

The Vegetation of McKinley Bay

McKinley Bay area is covered by low tundra vegetation except for the exposed beaches, dunes and mud-flats along the coast, and the extensive ponds inland. Dry ridge and dune crests near the coast support a mixture of grasses and sedges, while the dryer tops, raised centre polygons and pingos are covered by dwarf shrubs, low herbaceous species, mosses and lichens.

Moist, flat to gently undulating plains are densely covered by a mixture of sedges, herbaceous species, low shrubs, mosses and lichens. Sedges, cottongrass and mosses characterize much of the wet, flat and depressional plains, and the margins of small ponds and lakes. The vegetation is generally less than 0.5 m tall, although medium sized shrubs (0.5 to 1.5 m tall) occur locally in wet areas along the base of slopes and along small streams.

Five provisional vegetation types are mapped and briefly described in the following sections. Figure 3.4-1 indicates the estimated dominant vegetation types surrounding McKinley Bay at a scale of 1:50,000. The vegetation in the vicinity of the candidate facility site at Atkinson Point is shown on Figure 3.4-2 at a scale of 1:10,000.

A brief description of the expected composition of the vegetation types is presented in the following sections.

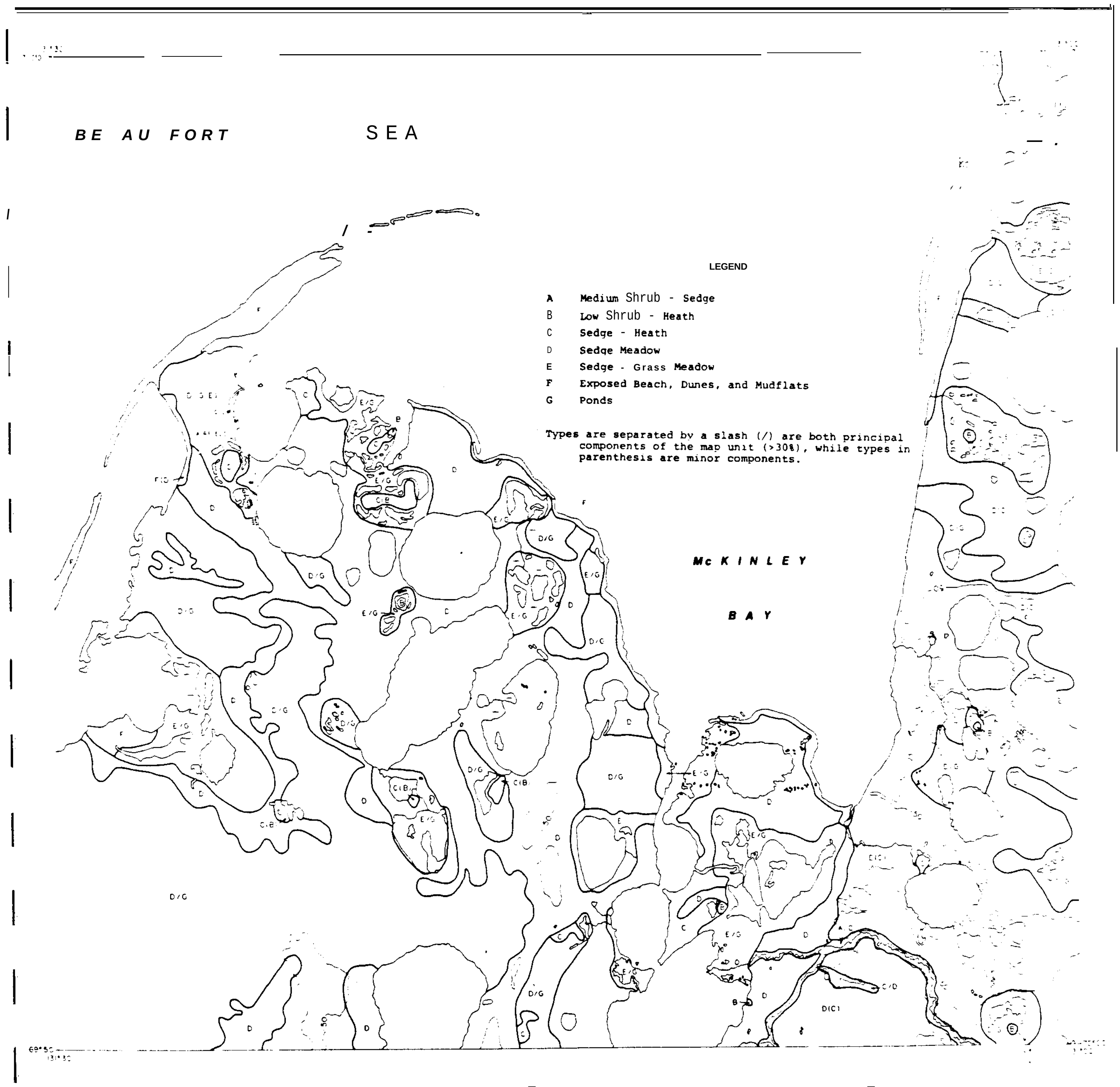


FIGURE 3.4-1

Vegetation{ OF THE MCKINLEY BAY AREA
NORTHWEST TERRITORIES

Medium Shrub-Sedge Type (A)

The medium shrub-sedge type occurs only very locally at the south end of the bay on wet habitats along small streams and the bases of slopes. Smaller stands may occur but they cannot be distinguished on the air photos and in total this type probably covers less than one percent of the study area.

Common shrubs (0.5 to 1.5 m tall) in this type are expected to be willows (Salix lanata and S. pulchra) although birch (Betula nana) and alder (Alnus crisps) may be present. The understory is likely made up of sedges, cottongrass, herbs, dwarf shrubs and mosses.

The Tall Shrub-Herb Type as described by Corns (1974) is probably similar although taller, and it occurs along stream channels of the western part of the Tuktoyaktuk Peninsula.

Low Shrub-Heath Type (B)

This type is likely limited to the dry crests and slopes of the numerous pingos which occur around McKinley Bay. Although some stands may be missed on the aerial photos, this type likely covers less than one percent of the study area.

Characteristic low shrubs of this type are likely to include crowberry (Empetrum nigrum) , Labrador tea (Ledum palustre) , bog cranberry (Vaccinium vitis-idaea) , and blueberry (V. uliginosum) . Other common species include arctic bearberry (Arctostaphylos rubra), wintergreen (Pyrola spp.) and arctic lupine (Lupinus arcticus) with a moss and lichen ground cover.

This type is likely similar to the low shrub-heath described by Corns (1974).

Sedge Heath (C)

The sedge heath occupies level to gently undulating terrain and the drier crests and slopes of raised centre polygons and probably covers up to five percent of the study area. This type often occurs in drained lake basins next to pingos and on slightly higher elevations on the south and east sides of McKinley Bay.

Although sedges and cottongrass are expected to dominate the vegetation, common shrubs are blueberry, bog rosemary (Andromeda polifolia) and leatherleaf (Chamadaphne calyculata), while the characteristic herbs are baked apple-berry (Rubus chamaemorus) and false asphodel (Tolfieldia pusilla). The wet depressions between polygons are characterized by similar species and a carpet of peat moss (Sphagnum spp.).

Corns (1974) described a sedge heath type which is likely very similar.

Sedge Meadow (D)

The sedge meadow type occurs on all soils that are wet throughout the growing season, on depressional to gently undulating terrain, low centre polygon areas, and wet perimeters of ponds and lakes. With a cover of 60 percent, these wet meadows are the dominant vegetation of the study area.

Sedges, cottongrass and mosses dominate this type. Broad leaved herbs and dwarf shrubs are probably present but minor components of the vegetation. Cover of mosses is high and may equal that of sedges and cottongrass.

Corns (1974) described a very similar community at Atkinson Point.

Sedge-Grass Meadow (E)

The sedge-grass meadow is a variant of the sedge meadow and is likely found near the coast where periodic inundation by salt water occurs. Often these wet areas appear to be drained lake basins and they cover approximately five percent of the study area.

Although sedges and cottongrass are present, the dominants shift to alkali grass (*Puccinella* spp.), *Carex subspathacea*, *Stellaria humifusa* and *Chrysanthium arcticum*, with very few heath and willow shrubs.

This type is likely similar to the herb type described by Corns (1974).

The Vegetation of Atkinson Point

The area around Atkinson Point, except for the existing disturbances (airstrip, tank storage and buildings), is entirely vegetated. The grass-herb meadow occurs along the coastline and in some drained lake basins, however, the sedge meadow type is dominant over most of the flat wet terrain. Small areas of sedge heath and low shrub heath occur on drier raised centre polygons and pingos.

3.5 Aquatic Bioresources

3.5.1 Planktonic Communities

The planktonic communities of the southern Beaufort Sea have been the subject of considerable investigation since the onset of offshore hydrocarbon exploration and subsequent initiation of industry and government sponsored environmental baseline programs. However, determination of the species composition, diversity, standing stock and productivity of McKinley Bay phytoplankton and zooplankton communities have not been included in these investigations. Since there are documented similarities in the structure of planktonic communities in areas of the Beaufort Sea with common physical-chemical oceanographic characteristics, data collected from areas adjacent to McKinley Bay are briefly summarized in this section.

Phytoplankton

Grainger (1974) described phytoplankton communities of nearshore areas of the Beaufort Sea, and reported that the majority of the algal community was comprised of extremely small nannoplankton,(2-20μ) and that both species composition and abundance varied substantially with season and depth. He also noted that a large proportion of the nearshore phytoplankton community was of fresh water origin and included *Rhodomonas minuta* and *Chroulina* Spp. Hsiao (1976) and Hsiao *et al.* (1977) subsequently examined and described nearshore and offshore Beaufort Sea phytoplankton communities in further detail. In general, diatoms dominated nearshore phytoplankton communities, whereas flagellates were more abundant in offshore waters outside the influence of the highly turbid Mackenzie River plume. Hsiao (1976) suggested that higher temperatures, higher nutrient concentrations and lower light intensities favour the growth of diatoms in nearshore waters, while the greater abundance of flagellates in offshore waters is a reflection of poor growth conditions for other algal groups, and a tolerance of flagellates to high light intensities and low nutrient levels. In most areas within the southern Beaufort Sea, there was a general increase in the proportion of flagellates from late August to early September with diatoms predominating during June and July (Hsiao, 1976; Duval, 1977). Most investigations have also shown that the number of algal taxa present in phytoplankton communities was highest in offshore waters unaffected by the turbid Mackenzie River discharge.

In most nearshore portions of the Beaufort Sea, the most abundant phytoplankters have been centric diatoms of the genus *Chaetoceros* (Hsiao, 1976; Hsiao *et aZ.*, 1977). Available data also suggest that phytoplankton abundance may be highest during mid-August, although regional differences in the timing of blooms appear to be closely related to the local oceanographic conditions, particularly light and nutrient availability. Hsiao *et aZ.* (1977) suggested that the productivity of nearshore phytoplankton communities was limited by light availability, while nitrate was the limiting factor to the production of offshore phytoplankton communities. These authors demonstrated that rates of primary production in the Beaufort Sea were 2 to 8 times higher in nearshore areas, probably as a result of the influence of the nutrient-rich Mackenzie River discharge. However, it should be emphasized that the spatial extent of these low salinity, relatively high nutrient content waters varies with prevailing winds (Section 3.1) and the general circulation pattern during the open-water season (Section 3.2). During extended periods with predominant westerly winds, the Mackenzie plume extends along the Tuktoyaktuk Peninsula up to and beyond McKinley Bay. This phenomenon, in conjunction with an upwelling of nutrient-rich waters, may stimulate nearshore productivity along the Tuktoyaktuk Peninsula throughout much of the open-water season.

Phytoplankton communities have been examined in three areas adjacent to McKinley Bay. During late July 1973, phytoplankton samples were collected from several depths at Beaufort Sea Project Stations No. 529 and 530 (Figure 3.2-4). At this time, salinities through the water column ranged from 8.8 to 11.2 °/oo, indicating a strong freshwater influence from the Mackenzie River. *Thalassiosira* spp. and *Euglena* spp. were the most abundant phytoplankton genera recorded from Station 529 and 530, although *Goniaulax catenata* was also relatively abundant at Station 530 (Hsiao, 1976). The standing stock and taxonomonic composition of phytoplankton collected from different depths during this study are summarized in Table 3.5 -1.

TABLE 3.5-1

STANDING STOCK AND TAXONOMIC COMPOSITION OF PHYTOPLANKTON COLLECTED FROM BEAUFORT SEA PROJECT STATIONS 529 AND 530, JULY 22-23, 1973 (after Hsiao, 1976)

Parameter	Station 529				Station 530		
	0 m	3 m	5m	10m	0 m	3 m	5 m
Standing Stock cells x 1000/ℓ	61	67	169	139	154	70	50
No. Diatom genera/% crop	8 85.3	5 71.6	7 69.8	6 95.7	11 52.0	4 77.1	3 34.0
No. Flagellate genera/% crop	1 13.1	1 23.9	1 21.9	1 2.9	1 28.6	1 11.4	1 26.0
No. Dinoflagellate genera/% crop	1 1.6	1 4.5	1 8.3	1 1.4	1 18.3	1 11.4	1 38.0
No. blue-green genera/% crop	0	0	0	0	1 0.7	0	1 2.0

During this period, diatoms were generally the most abundant algal group, both in terms of standing stock and number of recorded algal taxa (Hsiao, 1976; Hsiao *et aZ.,* 1977). These trends are characteristic of nearshore Beaufort Sea waters under the influence of the Mackenzie plume, but may not be representative of the situation in McKinley Bay when easterly winds force the turbid fresh water away from the Tuktoyaktuk Peninsula and more saline waters are found in McKinley Bay and adjacent waters. Marked differences in the vertical distribution of phytoplankton were also observed during these studies; standing stock was highest at the surface at Station 530, and highest at a depth of 5m at Station 529. The possible reasons for this difference were not examined by Hsiao *et aZ.* (1977), but may be related to localized differences in light penetration, increasing the depth of the euphotic zone at the station nearest to McKinley Bay (Station 529).

Planktonic communities were also examined at a proposed artificial island site approximately 3 km north of McKinley Bay (Slaney, 1977). Only surface phytoplankton communities were described during this baseline program completed on August 16, 1976. The standing stock of surface phytoplankton (4.54 x 10^5 cells/litre) was approximately 2-3 times higher than those observed by Hsiao (1976) in the same area but in late July. As indicated in Table 3.5-2 , the phytoplankton community was dominated by centric diatoms of the genus *Chaetoceros*, in contrast to the *Thalassiosira* and *Euglena* observed earlier in the season by Hsiao (1976). Virtually 100% of the surface phytoplankton community was comprised of diatoms (Bacillariophyceae) in contrast to the greater proportion of flagellates and dinoflagellates reported in the earlier study.

Zooplankton

Zooplankton communities north of McKinley Bay were also examined during the Beaufort Sea Project cruises and other investigations related to potential artificial island construction. Grainger and Grohe (1975) described the species composition and abundance of zooplankton communities collected from approximately 100 offshore and nearshore stations in the southern Beaufort Sea. These stations included Station No. 529 located approximately 5 km north of Atkinson Point, and Station No. 530 located to the northeast of McKinley Bay.

TABLE 3.5-2

SPECIES COMPOSITION AND STANDING STOCK OF SURFACE PHYTOPLANKTON OBSERVED AT KANNERK G-42 Artificial ISLAND SITE, AUGUST 16, 1976 (after Slaney, 1977)

Taxonomic Group	Genus/species or Group	Standing Stock (cells/k)
Chrysophyte - Bacillariophyceae	*Chaetoceros* spp.	3.59×10^5
Chrysophyte - Bacillariophyceae	*Thalassiosira nordenskoldii*	4.76×10^4
Chrysophyte - Bacillariophyceae	*Nitzschia* spp.	1 .60x104
Chrysophyte - Bacillariophyceae	*Navicula* spp.	1.58×10^4
Chrysophyte - Bacillariophyceae	*Fragilaria* spp.	6.80×10^3
Chrysophyte - Bacillariophyceae	*Cyclotella* spp.	4.00×10^3
Chrysophyte - Bacillariophyceae	*Melosira islandica*	2.40×10^3
Chrysophyte - Bacillariophyceae	*Thalassiosira baltica*	1.60×10^3
Chrysophyte - Chrysophyceae	*Ebria tripartite*	4.02×10^2
Chrysophyte - Bacillariophyceae	*Amphora ovalis*	4.00×10^2
Chrysophyte - Chrysophyceae	*Chrysococcus rufescens*	4
Chrysophyte - Bacillariophyceae	*Asterionella formosa*	2
Protista - Cileatea	Tintinnids	2
Protista - Rhizopodea	Foraminiferida	2

Copepods and rotifers were the most abundant components of zooplankton communities examined throughout much of the southern Beaufort Sea. However, although rotifers were numerically the most abundant group in some years, they contributed little to the total biomass of zooplankton communities (Duval, 1977). As in the case of phytoplankton, fresh water forms were often abundant in brackish areas affected by the discharge of the Mackenzie River (Grainger and Grohe, 1975; Grainger, 1975). The most abundant zooplankter found in nearshore surface waters of the Beaufort Sea was the calanoid copepod *Limnocalanus macrurus*, while in offshore areas outside the influence of the Mackenzie River plume, the dominant zooplankter was generally *Oithona helgolandicus*. Grainger (1975) reported that the abundance of zooplankton in the Beaufort Sea was greatest in Mason Bay and Tuktoyaktuk harbour, and relatively high in nearshore waters along most of the Tuktoyaktuk Peninsula. In general, he observed that the abundance of zooplankton decreased with increased distance from shore while species diversity increased. Grainger (1975) also found that species diversity increased with depth. The standing stock of Beaufort Sea zooplankton was generally highest from August to mid-September, with the maximum standing stock occurring during mid-August in most years (Duval, 1977).

The species composition and abundance of zooplankton communities collected north of McKinley Bay from July 22-23, 1973 were described by Grainger and Grohe (1975). Zooplankton were collected in vertical hauls from depths of 10 and 8m, respectively at Stations 529 and 530, and standing stock expressed as total number of zooplankters per m^2 water surface. The species composition and standing stock of zooplankters collected during this oceanographic cruise are shown in Table 3.5- 3 . Calanoid copepods dominated the zooplankton community at both Beaufort Sea Project stations during mid-July, although the species composition and abundance of juvenile (nauplii) stages were substantially different. Fresh water cyclopoid copepods (either *Cyclops* sp. or *Cyclopina* sp.) found at these stations confirm the periodic transport of low salinity waters along the Tuktoyaktuk Peninsula.

TABLE 3.5-3

THE SPECIES COMPOSITION AND STANDING STOCK OF ZOOPLANKTON COMMUNITIES COLLECTED AT BEAUFORT SEA PROJECT STATIONS 529 AND 530, 22-23/07/73. (after Grainger and Grohe, 1975)

Taxa	Station 529 Standing Stock/m^2	Station 530 Standing Stock/m^2
HYDROZOA		
Halitholus cirratus		2
ANNELIDA (POLYCHAETA)		
Unknown larvae		4
ARTHROPODA (CRUSTACEA)		
Copepoda		
Acartia clausi	1	4
Acartia sp.	1	
Limnocalanus macrurus	140	117
Pseudocalanus minutus	6	10
Eurytemora herdmani	27	155
Cyclops Sp.	10	
Cyclopina sp.		4
nauplii	79	963

Slaney (1977) subsequently described zooplankton communities collected approximately 3 km north of McKinley Bay at a proposed artificial island site (Kannerk G-42). Samples were predominantly unidentified naupliar and copepodite stages of a calanoid copepod, most likely *Limnocalanus macrurus*, and standing stock (2400 zooplankters/m^2 in 11.4 m vertical haul) was at least an order of magnitude higher than observed by Grainger and Grohe (1975) one month earlier in the open water season.

3.5.2 Infaunal and Epibenthic Invertebrates

Information on distribution and abundance of infaunal and epibenthic invertebrates (infaunal organisms live in bottom substrates, whereas epibenthic organisms live on or near the bottom) in the Beaufort Sea region is far from complete; however, knowledge has slowly been accumulating over the past 30 and particularly during the last 10 years.

Prior to oil and gas development in the coastal regions of the Beaufort Sea, most studies of arctic invertebrates were qualitative in nature. MacGinitie (1955) conducted extensive survey work at Point Barrow, Alaska from 1948 to 1950 and documented the species composition of the invertebrate community. Several taxonomic studies have been reported for a variety of arctic infaunal and epibenthic organisms: sponges (De Laubenfels, 1953), polychaetes (Pettibone, 1954), amphipods (Shoemaker, 1955), molluscs (MacGinitie, 1959), mysids (Holmquist, 1963), and cumaceans (Given, 1965). A review of existing literature and unpublished data on the distributions, abundances and life histories of benthic organisms, with emphasis on the Alaskan arctic coast, has been compiled by Carey (1977). In addition, Feder *et al.* (1976) have published an annotated literature review of benthic invertebrates of arctic regions in Canada and Alaska.

With the discovery and development of oil and gas in or near both the Canadian and Alaskan parts of the Beaufort Sea, several quantitative studies of infaunal and epibenthic invertebrates have been undertaken that enable us to characterize communities in different regions. Wacasey (1975) has described four zone types (both physically and biologically) in the Beaufort Sea: estuarine or nearshore zone, transition zone, marine zone, and continental slope zone (Table 3.5-4). Wacasey (1975) found that each zone supported a somewhat different community and that generally biomass increased with depth at least to a depth of 200 m. Carey *et al.* (1974) and Carey (1977, 1978) sampled across the Alaskan Beaufort Sea continental shelf in depths ranging from 20 to 2000 m and

TABLE 3.

ZONE TYPE AND PHYSICAL AND BI

lone Type	Water Depth m	Salinity ‰	Temperature °C	No. of Species Station	Biomass Range (gm^{-2})	Biomass Mean (gm^{-2})
Estuarine or Nearshore	0-15	0.1-20	up to 16.6	to 32	0.1-20 usually 20	2
Transitional	15-30	'0-30	7.0 to 1.58	0-	1-?0	5
Marine	30-200	IO-33	0.1 to 1.58	3-81	1-72	14
Continental	200-900	14-35	0.31 to 0.40	1-35	1-8	4

*Adapted from Wacasey 1575).

found that species composition (particularly gammarid amphipods) was influenced by depth and that biomass typically increased with depth and distance from shore from the 20 m depth contour to the edge of the continental she-if (200 m).

Only the estuarine zone (nearshore 0-15 m depth) will be further considered since the proposed site of development (McKinley Bay) falls within this area. In waters less than two meters deep, Beaufort Sea infauna (mainly polychaete worms and bivalve molluscs) is sparse and unevenly distributed; this is attributed to an annual depopulation caused by the scouring action of the bottom-fast ice (MacGinitie, 1955; Griffiths, *et al.*, 1975, 1977; Wacasey, 1975; Carey, 1977, 1978; Broad, 1978, 1979; Griffiths and Craig, 1978; Griffiths and Dill inger, 1979). However, resident populations of oligochaete worms and chironomid larvae have been found at these shallow depths indicating that at least some organisms withstand being frozen during the winter (Broad, 1978, 1979). Typically, in nearshore (O-2 m depth) areas the invertebrate community is dominated by motile epibenthic crustaceans (principally gammarid amphipods, mysid shrimp and marine isopods (Slaney, 1974, 1975, 1976; Griffiths *et al.*, 1975, 1977; Wacasey, 1975; Carey, 1978; Griffiths and Dill inger, 1979). These organisms are important to the higher trophic levels. Numerous feeding ecology studies have shown that these invertebrates comprise major components of the diet of fish, birds, and marine mammals (Griffiths et *al* ., 1975, 1977; Kendel *et al.*, 1975; Stirling *et al.*, 1975b; Bendock, 1977; Bradstreet, 1977; Fraker *et* aZ., 1977; Bain and Sekerak, 1978; Craig and Griffiths, 1978; Johnson, 1978, 1979). Epibenthic invertebrates appear to migrate into the nearshore waters each spring, where they grow rapidly during the ice-free season, and emigrate out in late summer and fall although some remain at least until early winter (November) (Broad, 1979; Griffiths and Dillinger, 1979). First year individuals are the dominant life cycle stage collected in nearshore waters (Carey, 1978; Griffiths *et al.*, 1979). Whether these are nursery areas for epibenthic invertebrates or if the absence of older and larger members of the populations is due to differential predation is not known at this time. The results of several studies suggest that deeper waters (2 to 15 m deep), are a winter refuge for epibenthic invertebrates and that the nearshore ice-stressed areas are repopulated each spring (Feder and Schamel, 1976; Feder *et al.*, 1976; Broad, 1979; Griffiths and Dillinger, 1979).

In Beaufort Sea (from Point Barrow Alaska to Cape Dalhousie NWT) nearshore waters (2 to 15 m in depth) the infaunal community is composed primarily of polychaete and oligochaete worms and bivalve molluscs (Wacasey, 1975; Carey, 1977, 1978; Jones and Den Beste, 1977; Broad, 1978, 1979). Infaunal biomass is generally low (average 2g m^{-2}). However, in Mason Bay (depth 4-6 m), a protected embayment of the Mackenzie Delta, biomasses of 8-20g m^{-2} (average 5g m^{-2}) have been recorded (Wacasey, 1975). He postulated that these high standing crops reflected the more stable conditions and enhanced nutrient supplies that can occur in some protected embayments. Similarly high biomasses (5-7g m^{-2}), due primarily to epibenthic invertebrates, have been reported in Simpson Lagoon (depth 2-3 m), a barrier-island lagoon system on the Alaskan Beaufort Sea coast (Griffiths and Craig, 1978; Griffiths and Dillinger, 1979). It 'bus appears that some protected areas along the Beaufort Sea coast maintain higher invertebrate standing crops than unprotected nearshore areas.

No site specific information on invertebrates is available for McKinley Bay. Jones and Den Beste (1977) and Slaney (1977) examined the species composition and distribution of the invertebrate community at Tuft Point, located approximately 50 km southwest of McKinley Bay. Both studies showed the infaunal community was dominated by polychaete and oligochaete worms and bivalve molluscs, while motile crustaceans (i.e. gammarid amphipods, mysids and marine isopods) were the most abundant epibenthic fauna. This community structure is typical of that found at other locations along the Beaufort Sea coast from Point Barrow to Cape Dalhousie (Griffiths *et al.*, 1975, 1977; Slaney, 1974, 1975, 1976, 1977a, 1977b; Broad, 1978, 1979; Carey, 1977, 1978; Griffiths and Craig, 1978;

Griffiths and Dillinger, 1979). It can probably be assumed with some certainty that McKinley Bay supports a similar infaunal and epibenthic community. Samples taken off the mouth of the Bay in 1973 and 1976 contained polychaetes and oligochaetes as the dominant infaunal organisms (Slaney, 1977a). No epibenthic samples were collected.

During the ice-free season the continuous discharge of warm freshwater from the numerous rivers along the Beaufort Sea coast creates a brackish environment in the nearsnore waters (section 3.2). In winter, due to salt exclusion during the freezing processes and reduced freshwater inflow, some nearshore waters (2-3 m deep) can become hypersaline(50‰ circulation is restricted (Griffiths and Dillinger, 1979; Truett, 1979). Consequently, organisms living in such nearshore environments (<3 m depth) must survive drastic variations in temperature (-2.5 to 16.0°C) and salinity (O to 50‰) (Griffiths and Craig, 1978; Broad, 1979; Griffiths and Dillinger, 1979). Broad (1979) using selected epibenthic organisms (amphipods, mysi ds and isopods) , showed that they were capable of surviving acute salinity changes from 5 to 70‰ and gradual salinity changes from 0.25 to 65‰, as compared to their normal salinity of about 32‰. A year round sampling program conducted in Simpson Lagoon, Alaska showed that infaunal bivalves and several species of epibenthic invertebrates (amphipods and mysids) survived a wide range of temperatures (-2.5 to 12.0°C) and salinities (2.0 to 40.0°/00) with no apparent ill effects (i.e. they produced young) (Griffiths and Dillinger, 1979; LGL unpublished data).

Nearshore waters in the Beaufort Sea are often turbid due to wind and wave action and freshwater input (section 3.2). Maximum turbidities generally occur after periods of high winds and in areas affected by the Mackenzie Plume. Infaunal and epibenthic invertebrates survive short and long periods of high sediment loading in shallow enclosed areas like Simpson Lagoon, Alaska, in the Mackenzie Delta, N.W.T. and near Tuft Point, N.W.T. (Slaney, 1975, 1976; Jones and Den Beste, 1977; Griffiths and Craig, 1978; Griffiths and Dillinger, 1979). However, there have been no detailed studies on the community structure of invertebrate communities in the area in relation to sediment loads and their effects.

Numerous arctic epibenthic invertebrates, excluding continuous breeders (e.g. the isopod *Mesidoteca entonon*), breed in late fall or early winter after ice-cover and brood their young until the following spring (Griffiths and Dillinger, 1979). For this reason the winter months are of particular importance to these species. Studies conducted in early spring (May-June) in high arctic locations have shown that several species of amphipods (particularly the newly released young) are associated with and feed on phytoplankton which live on the undersurface of the ice (Buchanan, *et al.*, 1977; Thomson *et al.*, 1978).

In summary, the nearshore (0-15 m) region of the Beaufort Sea (from Pt. Barrow to Cape Dalhousie) is typified by an infauna dominated by polychaete and oligochaete worms and bivalve molluscs and an epifauna comprised of motile crustaceans (amphipods, mysids and isopods). During the annual cycle these organisms survive dramatic fluctuations in temperature, salinity and turbidity. Arctic epibenthic invertebrates commonly breed and carry their young during the winter months (October through May).

3.5.3 Fish

During the past decade, numerous fisheries studies have been conducted along the Beaufort Sea coastline. In one recent review, Craig and Haldorson (1979) note that nearshore environments along the Beaufort Sea coastline provide essential habitat for several arctic fishes, particularly the anadromous species harvested by man. During the short arctic summer, large numbers of fish enter coastal waters and feed extensively on nearshore food resources. These fish must accumulate food reserves to support them through the long winter and adult fish must attain a critical level of food reserves or they will not spawn (Bolotova, 1976). During winter months, several species of marine fish use nearshore waters for feeding and spawning.

The importance of nearshore waters to fish populations is now recognized and a general pattern of fish utilization of these waters has been documented. Craig and McCart (1976) summarized much of the work prior to 1976; more recent studies include Jones and DenBeste (1977), Olmsted (1977) , Poulin (1977) and Craig and Haldorson (1979). Portions of the present description of nearshore fishes have been abstracted from the latter references.

Despite the general pattern which has emerged, caution is necessary when applying this information to the McKinley Bay study area because few data are available for either this site or even most of the Tuktoyaktuk Peninsula. The data base for McKinley Bay consists of several unpublished surveys which were conducted by the Arctic Biological Station, Ste. Anne de Bellevue (J. Hunter, pers. comm.) and the Department of Fisheries and Oceans, Inland Waters, Winnipeg (M. Lawrence, pers. comm.). The National Museums Canada, Ottawa, also has a collection of fish caught in McKinley Bay in August 1977 (D. McAllister, pers. comm.). Further surveys along the Tuktoyaktuk Peninsula are scheduled this summer

(M. Lawrence, pers. comm.). A useful but brief sampling effort for fish was conducted at Tuft Point, 50 km to the southwest of the present study area (Jones and DenBeste, 1978). These data and more general fisheries information from the Tuktoyaktuk - Mackenzie Delta region (Abrahamson, 1963; Hunter, 1975; Bray, 1975; Percy, 1975; Galbraith and Fraser, 1974; Mann, 1974 and 1975; Poulin, 1977; Olmsted, 1977; Freeman, 1976; Brakel, 1977; de Graaf and Machniak, 1977; Fenco and Slaney, 1978) provide a limited basis for describing possible fish use of the McKinley Bay study area. Many of the species recorded in the present study area have been studied elsewhere along the Yukon and Alaskan Beaufort Sea coastlines and it is likely that aspects of these studies will apply to the populations in McKinley Bay.

Fish Populations in the Study Area

The species of fish found in McKinley Bay and near the Tuktoyaktuk Peninsula (Table 3.5-5) are those which are common along much of the Beaufort Sea coastline (Craig and McCart, 1976). At least eighteen species are recorded in the Bay itself (M. Lawrence, J. Hunter, and D. McAllister, pers. comm.). These include six anadromous fishes and twelve marine species.

In general, whitefish species are not common in the study area. While these fish are abundant closer to the Mackenzie River, few have been taken along the Tuktoyaktuk Peninsula as far away as McKinley Bay (M. Lawrence, pers. comm.).

Sculpin of the genus *Icelus* have also been caught off the mouth of McKinley Bay (J. Hunter, pers. comm.); other marine species (*Boregadus sp., Gymnocanthus tricuspis, Aspidophoroides olrikii, Liparis sp.*) have been collected about 35 km north of McKinley Bay in offshore waters (D. McAllister, pers. comm.).

A listing of fish species is also available for the nearby Tuft Point-Warren Point area located 50 km southwest of McKinley Bay. Here Jones and DenBeste (1978) and Bray (1957) collected 17 species in nearshore waters (Table 3.5-5). The most abundant species caught during mid and late summer periods at this location were arctic cisco, least cisco and fourhorn sculpin; herring are also occasionally abundant along the Tuktoyaktuk Peninsula (Hunter, 1975; Olmsted, 1977). Fenco and Slaney (1978) list an additional three species that have been taken along the peninsula (Table 3.5-5).

Information regarding fish abundance in the study area is sparse. A few data have been collected along the Tuktoyaktuk Peninsula (Galbraith and Fraser, 1974; Bray, 1975; Olmsted, 1977; Jones and DenBeste, 1978) and additional information will become available when a report in the Beaufort

Table 3.5-5 Fish species recorded in McKinley Bay and surrounding areas.

	McKinley Bay[1]	Tuft Point[2]	Tuktoyaktuk Peninsula[3]
<u>dromous Species</u>			
rctic cisco *(Coregonus autumnalis)*	X	X	X
east cisco *(C. sardinella)*	X	X	X
umpback whitefish *(C. pidschian)*	X	X	X
oreal smelt *(Osmerus eperlanus)*	X	X	X
road whitefish (C. *nasus)*	X	X	X
inespine sticklebacks *(Pungitius pungitius)*	X	X	X
[nconnu *(Stenodus lencichthys)*		X	X
<u>ine Species</u>			
ourhorn sculpin *(Myoxocephalus quadricornis)*	X	X	X
acific herring *(Clupea harengus)*	X	X	X
affron cod *(Eliginus navaga)*	X	X	X
rctic flounder *(Liopsetta glacilis)*	X	X	X
tarry flounder *(Platichthys stellatus)*	X	X	X
ibbed sculpin *(Triglops pengli)*	X		
nailfish *(Liparis)*	X		
rctic cod *(Boreogadus saida)*	X	X	X
Stout eelblenny *(Lumpenus medius)*		X	X
Slender eelblenny *(Lumpenus fabricii)*	X	X	X
Arctic staghorn sculpin *(Gymnocanthus tricuspis)*	X	X	X
Pacific sandlance *(Ammodytes hexapterus)*		X	
Arctic lamprey *(Lampetra japonica)*			X
Pa?e eelpout *(Lycodes diapterus)*			X
Eelpout *(L. jugoricus)*	X		
Hamecon *(Artedielus scabor)*	X		

Table 3.5-5 Continued . . .

Table 3.5-5 Fish species recorded in McKinley Bay and surrounding areas. (Continued)

	McKinley Bay[1]	Tuft Point[2]	Tuktoyaktuk Peninsula[3]
Freshwater Species			
Burbot *(Lota Zeta)*			x

1 M. Lawrence, Oceans & Fisheries, Inland Waters, pers. comm.; J. Hunter, Arctic Biological Station, pers. comm.; and D. McAllister, National Museums Canada, pers. comm.

2 Jones and DenBeste (1978) ; Bray 1975

3 Fenco and Slaney (1978)

Sea Project series is completed (Galbraith and Hunter, in prep.). Some information on the relative abundance of fish in McKinley Bay is available (Table 3.5-6). Three marine species (arctic and starry flounder, fourhorn sculpin) were numerous, followed by arctic cisco and saffron cod. The average catch per unit effort at two sites in the lower bay was 10.4 fish/hr during two sampling periods.

The most useful of the published data are the relative abundances of fish caught by gill net at Tuft Point (Table 3.5-6). Jones and DenBeste (1978) report that the average catch per unit effort for fish at Tuft Point (13 fish/hr) was intermediate between those recorded at Kaktovik Lagoon, Barter Island (3 fish/hr; Griffiths *et al.*, 1975) and along the Yukon coast (46 fish/hr; Kendel et *al.*, 1975).

Based on these limited lines of evidence, it appears that Tuktoyaktuk Peninsula in the McKinley Bay region supports fish populations which, in terms of species and relative abundances, are generally similar to those populations occurring at other coastal locations along the Beaufort Sea coastline which have received scientific study. In general, more flounders have been caught in McKinley Bay than in other areas but additional data are necessary to determine the importance of the study area to these fishes.

Distribution and Habitat Utilization

McKinley Bay is a large and shallow body of water on the north side of Tuktoyaktuk Peninsula. It measures approximately 4-12 kmwide, 10 km long and 3-4 m deep in its centre. Within the study area there are three general types of aquatic habitat used by fish: (1) the freshwater input to the bay, (2) the brackish bay and nearshore waters, and (3) the offshore marine waters.

(A) Freshwater Habitats

Many of the fish found in McKinley Bay and along the Tuktoyaktuk Peninsula during summer months are anadromous (Table 3.5-5). These fish

Table 3.5-6 Catch per unit effort (CPUE) for fishes caught by gillnets in (a) lower McKinley Bay, 25 July - 5 August and 30 August - 5 September 1978 (M. Lawrence, pers. comm.), and (b) the Tuft Point area, 15-25 July and 26 August - 3 September 1977 (from Jones and denBeste 1978).

	CPUE (gillnet/hour)			
	McKinley Bay		Tuft Point	
	July	Aug/Sept	July	Aug/Sept
Arctic flounder	11.5	0.4	0.4	0.4
Starry flounder	5.3	0.5	0.1	0
Fourhorn sculpin	1.3	1.9	1.1	7.7
Arctic cisco	0.3	1.5	3.4	13.7
Saffron cod	1.0	0.1	0.4	0.5
Pacific herring	0.3	0.1	0.1	0.9
Least cisco	0	0.2	1.2	3.6
Broad whitefish	0	0	0.6	1.1
Humpback whitefish	0	0	0.3	0
Inconnu	0	0	0.6	0.2
Boreal smelt	0	0	0	0.6
Arctic cod	0	0	0	0.1
TOTALS	19.7	4.7	8.2	28.8
Hours fished	7.2	11.8	43.5	13.5

probably originate from the Mackenzie River or larger streams on the peninsula (Olmsted, 1977; Fenco and Slaney, 1978; Jones and DenBeste, 1978). The Anderson River which flows into Liverpool Bay may be another source of the cisco and whitefish that migrate through the study area (J. Hunter, pers. comm.).

While it appears that most anadromous fish originate outside the study area, there are several small stream and lake systems which flow directly into McKinley Bay. No data are available on these watercourses but they may also be a source of some anadromous fish. The largest of these will be surveyed this summer (M. Lawrence, pers. comm.).

(B) Nearshore Habitats (< 2 m deep and enclosed or protected coastal waters)

During the open-water season, anadromous and marine fish utilize brackish, nearshore habitats extensively for feeding and migrating. Although fish use of specific habitats in McKinley Bay remains to be investigated, it is likely that some generalizations regarding fish use of nearshore habitats along the Beaufort Sea will apply to the study area.

Recent studies have shown that fish are not distributed evenly in coastal waters (J. Hunter, pers. comm.; Craig and Haldorson, 1979). Two prominent trends in the spatial distribution of fish, particularly the anadromous species, are:

1) Most anadromous fish are found in nearshore rather than in offshore waters. In the Mackenzie Delta area, Hunter (pers. comm.) found that, in general, few anadromous fish are caught seaward of the 4.3 m contour line where water temperatures and salinity often change from brackish to marine conditions.

2) Within the nearshore environment, fish numbers are highest along mainland and island shorelines as opposed to lagoon centers or other areas distant from any shoreline.

Reasons for this habitat preference are not known although shoreline waters tend to be slightly warmer and less saline than other areas.

Many fish travel parallel to the shoreline along a surprisingly narrow corridor. Craig and Haldorson (1979) found that the abundance of anadromous fish declined steadily with increasing distance from shore out to about 80 or 90 m. Abundance was relatively uniform from about 80 to 120 m offshore (Figure 3.5-l). Note, however, that numbers of fourhorn sculpin, a marine species, were uniform across the same distance. This shoreline affinity occurred when the water was not exceptionally rough aue to storms and the sampling location was at or near prominent land projections into the lagoon.

The abundance and distribution of the fish species using nearshore habitats change dramatically during the period of ice cover. These changes are marked by the disappearance of most of the dominant anadromous species (cisco, whitefish) that are common during the brief summer. In winter, some marine species use nearshore habitats for feeding and spawning.

(C) Offshore Habitats (generally > 2 m depth or marine waters)

The scant information available to describe fish resources in offshore waters suggests that (1) fish densities are lower in the offshore zone compared to the nearshore zone, and (2) marine fishes rather than anadromous fishes account for most of the species in offshore waters (McAllister, 1962; Bray, 1975; Griffiths *et al.*, 1975 and 1977; Jones and DenBeste, 1978: Craig and Haldorson, 1979). It is reasonable to expect that these two trends also apply to the McKinley 3ay study area. The deeper

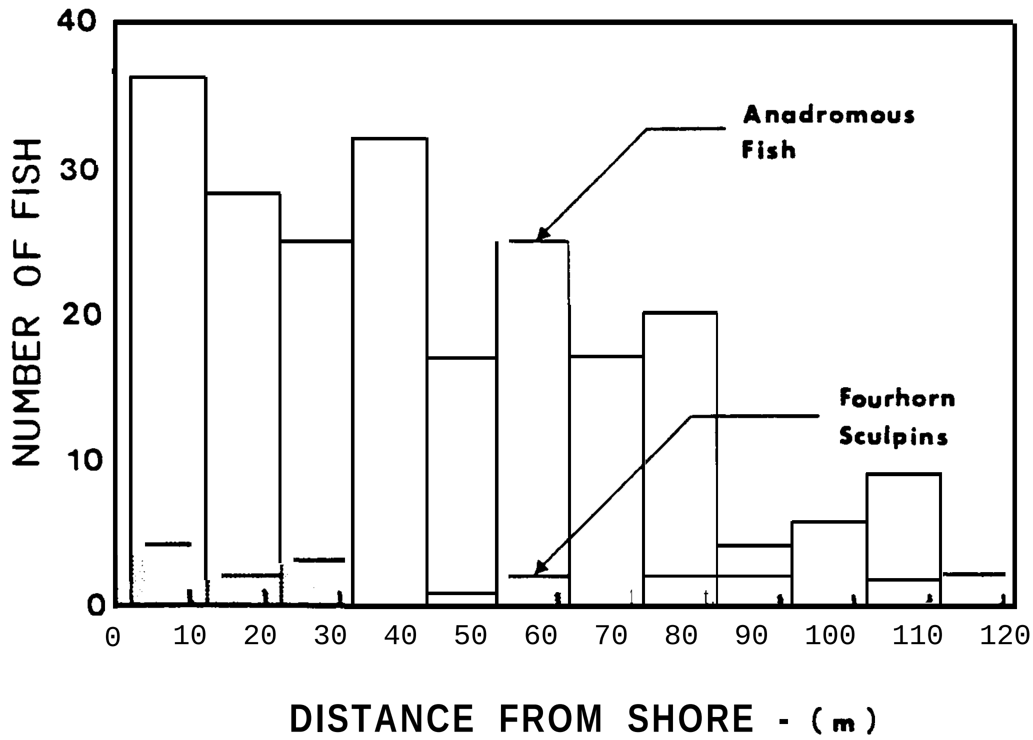


FIGURE 3.5-1

ABUNDANCE OF ANADROMOUS FISH AND FOURHORN SCULPIN AS A FUNCTION OF DISTANCE FROM SHORE*

(Source: Craig and Halderson, 1979)

* Data from gillnet sets off points of land at Simpson Lagoon, Alaska during seven calm days in 1978. No gillnet was set between 0-2 m.

central portion of McKinley Bay and marine waters offshore from the bay presumably support populations of marine fish, but relatively few ciscoes and whitefish. Offshore areas in Kugmallit and Mackenzie bays, for example, contained few concentrations of fish other than boreal smelt and fourhorn sculpin (Percy, 1975).

Movements and Migrations

Most researchers who have studied fish movements in Beaufort Sea waters have found that fish are highly mobile and evaluations of their local abundance are complicated by day-to-day pulses of movement and larger scale movements over several weeks (e.g. Percy, .1975; Craig and Haldorson, 1979). Although the timing of fish movements in McKinley Bay has not been documented, it is probable that anadromous fish are present and migrating through the area from break-up to freeze-up and marine species are present year round. Ciscoes and whitefish may swim through McKinley Bay on their migrations to and from the Mackenzie River or other natal streams during the open-water period. Marine species probably reside in the deeper central waters of McKinley Bay and offshore marine waters; some of these fish probably migrate into the nearshore waters by mid or late summer and retreat from these areas as surface ice increases in thickness during winter months.

Food Sources

Fish use shallow habitats along the Beaufort Sea coast for one over-riding purpose, namely to feed on the abundant food supply. Each spring as the ice melts, anadromous and marine fishes invade nearshore waters and feed extensively on epibenthic invertebrates (organisms living on or near bottom substrates) and zooplankton. McKinley Bay is thought to be a good summer feeding area for fish (J. Hunter, pers. comm.) as is probably most of the entire coastline in this region.

The food habits of the major species of fish are surprisingly similar. Feeding studies conducted from Prudhoe Bay, Alaska. to Tuft Point, N.W.T. and in the High Arctic all show that the diets of nearshore fishes consist mainly of epibenthic amphipods, mysids, isopods and planktonic copepods (e.g., Kendel *et al.*, 1975; Griffiths *et al.*, 1975, 1977; Sekerak, 1976; Craig and Griffiths, 1978; Jones and DenBeste, 1978). The significance of the epibenthic feeding pattern is that the fish do not generally rely on infaunal invertebrates (organisms living within bottom substrates) which would be disrupted by dredging operations in McKinley Bay.

Epibenthic invertebrates are abundant and widely distributed in shallow coastal waters although their numbers are typically underestimated because conventional sampling gear used to collect infaunal invertebrates does not capture many of the mobile epibenthic organisms (Griffiths and Dill inger, 1979).

Life-histories

Extensive life-history and distribution data have been compiled for the fishes common to the Beaufort Sea coastline (earlier papers are summarized in Craig and McCart, 1976; also, Poulin, 1977; Olmsted, 1977; Jones and DenBeste, 1978; Craig and Griffiths, 1978). Much of this work pertains to fishes west of the McKinley Bay study area; however, the data gathered by M. Lawrence (pers. comm.) for fish along the Tuktoyaktuk Peninsula and by Jones and DenBeste (1978) for fish at Tuft Point suggest that the overall life-history characteristics of populations along the Tuktoyaktuk Peninsula are similar to those of populations elsewhere. Table 3.5-7 shows age and size ranges for the Tuft Point collections. Mature, immature and young-of-the-year fish of most species were present. It is suspected that young-of-the-year arctic cisco and whitefish migrate into brackish coastal waters from the Mackenzie River or other streams supporting these species. On the other hand, the young-of-the-year of the marine species were probably spawned in nearby coastal waters during winter. J. Hunter (pers. tom.) found that larval Pacific herring were relatively abundant in McKinley Bay in previous summers.

Table 3.5-7 Occurrence of young-of-the-year (Y-O-Y) and size and age ranges of subsamples of fish caught at Tuft Point, Tuktoyaktuk Peninsula (from Jones and DenBeste 1978)

Species	No. Y-O-Y	Older Fish n	Size range (mm)	Age range
Arctic cisco	4	221	57 - 488	1 - 13
Least cisco	0	88	66 - 336	1 - 12
Fourhorn sculpin	126	105	43 - 295	1 - 10
Broad whitefish	*	38	89 - 541	1 - 15
Humpback whitefish	*	14	182- 418	4 - 12
Inconnu	0	26	140 - 710	2 - 14
Arctic flounder	1	22	59 - 323	1 - 11
Saffron cod	1	22	300 - 420	5 - 10
Boreal smelt	81	8	190 - 283	5 - 10
Pacific herring	5	15	240 - 310	9 - 13
Starry flounder	0	6	218- 355	8 - 15
Sand lance	15	0		
Arctic cod	0	1	177	2

* 4 unidentified whitefish fry were caught

3.504 **Mammals**

Marine Mammals

The most numerous species of marine mammals in the eastern Beaufort Sea region, which includes the McKinley Bay area, are white whale *Delphinapterus leucas)*, bowhead whale *(Balaena mysticetus)*, polar bear *(Ursus maritimus)*, bearded seal *(Erignathus barbatus)*, and ringed seal *(Phoca hispida)*. All except the bowhead whale have been studied in some detail in this region.

Seven other species of marine mammals have also been recorded for the eastern Beaufort Sea. Walrus *(Odobenus rosmarus)* and harbour seal *(Phoca vitulina)* are rare but regular visitors to the area (Harington, 1966; Barry, 1967; Stirling, 1974; Stirling et aZ., 1975b, 1977). Killer whales *(Orcinus orca)* have been reported for the eastern Beaufort Sea (Barry, 1967), but this species is apparently an irregular visitor. Also, extralimital records of narwhal *(Monodon monoceros)*, northern fur seal *(Callorhinus ursinus)*, hooded seal *(Cystophora cristata)*, and harp seal *(Phoca groenlandica)* have been reported for the eastern Beaufort Sea area (Banfield, 1974; Stirling *et aZ.*, 1975b, 1977; Smith, 1977). These seven species are uncommon in the eastern Beaufort Sea region and are not considered further in this report.

The following three sections on marine mamma'ls describe the abundance and distribution of white and bowhead whales, polar bears, and bearded and ringed seals in the eastern Beaufort Sea generally and, as far as is possible with available information, in the vicinity of McKinley Bay specifically.

Bowhead and White Whales

Bowhead whales are large (up to 18 m in length) baleen whales that were formerly circumpolar in distribution and are now confined to arctic and sub-arctic regions in the Sea of Okhotsk and from Davis Strait west to Wrangel Island (M. Fraker, LGL Limited, pers. comm.). The species is now considered rare and endangered. The western Arctic stock (population), which uses the Beaufort Sea during the open-water period, was hunted intensively during the 60 years from 1850 to 1910 (Fraker and Bockstoce, in prep.). In 1978 this stock was estimated to number between 1700 and 2400 animals (Braham *et al.* , 1979). The bowheads of the western Arctic apparently comprise most of the total world population.

During the period from late April to early June, bowhead whales migrate from their wintering grounds in the Bering Sea to their summering area in the eastern Beaufort Sea region (Fraker, in press). In spring, large expanses of open water are usually present only in the eastern Beaufort Sea and western Amundsen Gulf, and it is to these areas that the whales migrate first. To reach these areas, they apparently use a broad area of leads that lies far offshore from the Tuktoyaktuk Peninsula (Fraker, in press). Bowhead whales have been. recorded in Amundsen Gulf by early May (Fraker, unpubl.) and-apparently many are present there by mid-June (Figure 3.5-2).

The distribution of bowhead whales in the eastern Beaufort Sea region from July to September is poorly known. Observations recorded by whalers operating in the eastern Beaufort Sea near the turn of the century have been plotted by Fraker and Bockstoce (in prep.) and provide some information on the probable summer distribution of bowheads. The results (Figure 3.5-3) indicate that the Bathurst zone, which includes the McKinley Bay area, was used extensively by bowhead whales seaward to about the 50-m depth contour. Systematic survey data on the present summer distribution of bowhead whales are lacking but recent incidental sightings in the vicinity of McKinley Bay indicate that bowhead whales still use this zone in July and August (Fraker *et al.*, 1978; Fraker and Bockstoce , in prep.).

During the summer there is an apparent gradual westward shift in the bowhead population (Figure 3.5-3). None of the whalers' observations after late August were made east of Cape Bathurst, and recent sightings made north of Kugmallit Bay indicate that bowhead whales move into that area around the beginning of August (Fraker and Bockstoce, in prep.). The latest of recent sightings in the area north of Kugmallit Bay have been made in mid-September, and many whales have recently been observed westof the Mackenzie Delta in the . latter half of September (Fraker *et al.*, 1978; Fraker and Bockstoce, in prep.).'

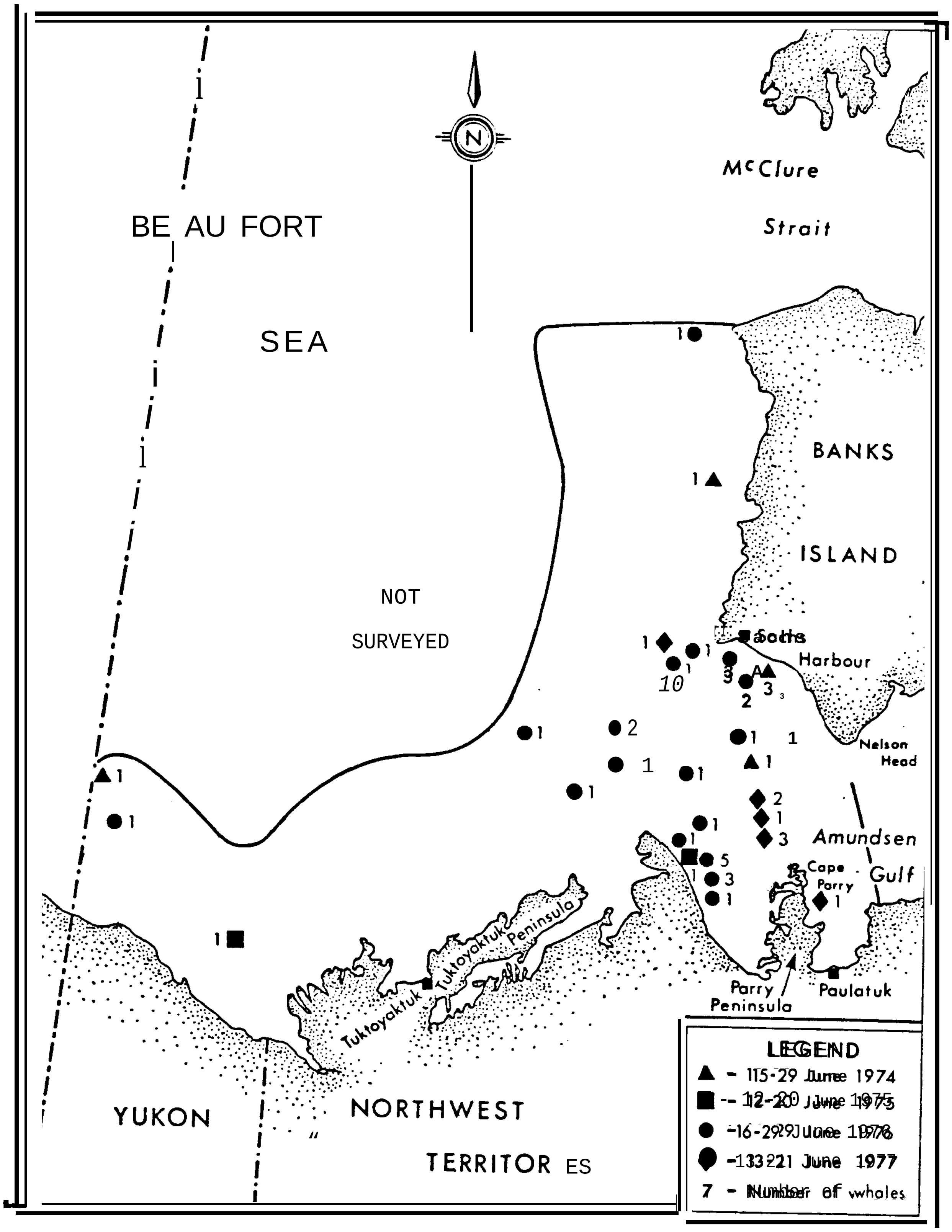


FIGURE 3. 5-2

SIGHTINGS OF BOWHEAD WHALES RECORDED DURING CANADIAN WILDLIFE SERVICE SEAL SURVEYS

(Adapted from Fraker, in press)

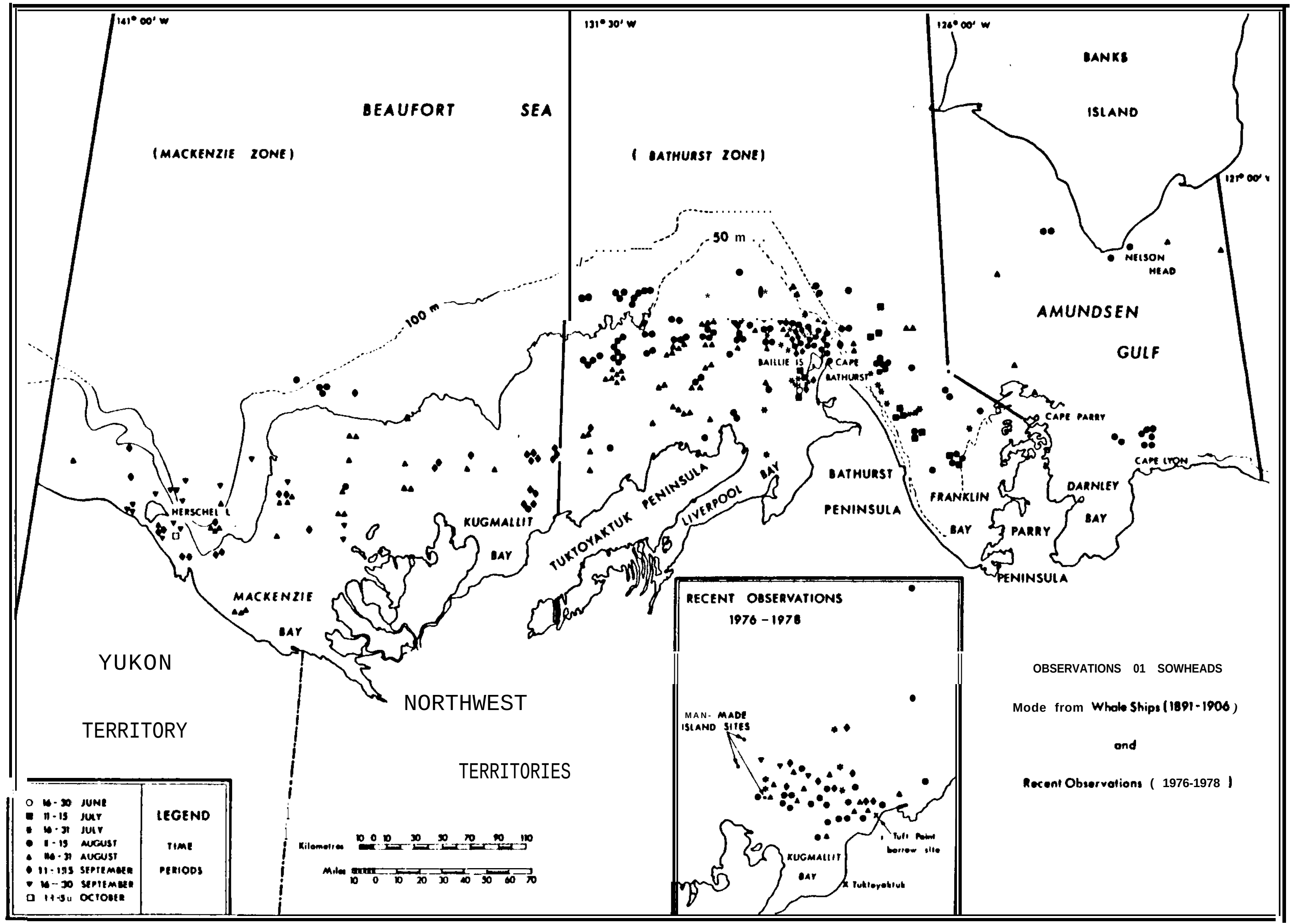


FIGURE 3.5-3

LOCATIONS OF BOWHEAD WHALE OBSERVATIONS

Each symbol represents an observation of one or more whales.

(After Fraker and Bockstoce, in prep.)

Thus it appears that most bowhead whales have left Amundsen Gulf by the end of August, and the Bathurst zone by mid-September.

White whales are small (up to 5 m in length) toothed whales that have a circumpolar distribution (Banfield, 1974). During the period from late April to early June, white whales, like bowhead whales, migrate from wintering grounds in the Bering Sea to the Amundsen Gulf region, using a broad area of leads located far offshore (Fraker, in press). White whales have been recorded in the western Amundsen Gulf by mid-May, and by mid-June large numbers (over 3000 in some years) are present there.

In late June and early July, most white whales leave the Amundsen Gulf area and travel westward along the Tuktoyaktuk Peninsula to the Mackenzie River estuary where they gather in large concentrations in the southwest part of Kugmallit Bay, in Niakunak Bay, and in the vicinity of Kendall Island (Fraker *et aZ.* , 1978). Total numbers in these areas have been estimated to be as large as 6000 (Fraker *et aZ.*, 1978). While in the estuary, the whales are hunted by Inuit from the settlements of Aklavik, Inuvik, and Tuktoyaktuk. Approximately 140 are landed each year, and an estimated 70 are lost after being wounded or killed (Fraker, 1979). This hunt plays a very important role in the local culture and economy of the Mackenzie Delta region.

Large numbers of white whales occupy the estuary for about one month. Newborn young are present at this time, and some may be born there. In late July or early August, the number of whales present drops dramatically (Fraker *et* aZ., 1978). Where the white whales go after leaving the estuary is not known, because there has been little survey effort in the Beaufort Sea region during the latter part of the summer. White whales have been observed east of the Mackenzie River estuary in the Beaufort Sea and Amundsen Gulf in July, Very little is known about the timing or route of the fall migration from the Beaufort Sea. The latest sighting of white whales in Amundsen Gulf was made before mid-September, and this is probably the last part of the movement out of the eastern Beaufort Sea region (Fraker *et al.*, 1978).

Bearded and Ringed Seals

Bearded seals are very large, measuring up to 2.85 m in length and possibly 397 kg in weight, whereas ringed seals, with maximum measurements of 1.62 m and 101 kg, are the smallest of the pinnipeds (i.e., seals, sea lions and walrus); both species are holarctic in distribution (Banfield, 1974). In the southeastern Beaufort Sea region, ringed seals outnumber bearded seals by an-approximate factor of 16 (Stirling *et al.*, 1977).

Populations of bearded and ringed seals in the southeastern Beaufort Sea have been surveyed annually from 1974 to 1979 (Stirling *et aZ.*, 1975b, 1977, 1979). These surveys, which preceded ice break-up in the southeastern Beaufort Sea, have been conducted around mid-June when seals are moulting and the greatest numbers haul-out on the ice to bask. For these surveys, the southeastern Beaufort Sea region was divided into four strata, and the same set of transects in each stratum have been surveyed annually. The locations of these strata, and of the transects which extended offshore to a distance of 160 km, are shown in Figure 3.5-4.

Densities of seals observed on the transects were extrapolated to the entire study area in order to obtain estimates of numbers of seals (Table 3.5-8). It should be kept in mind that these are minimum population estimates. There is no known way of relating the numbers observed hauled-out on the ice to total populations present in the area (Stirling *et al.*, *1979).* In addition, the numbers of seals on the ice surface varies with time of day and weather conditions, and seal surveys cannot be conducted entirely under optimum conditions. Stirling *et aZ.* (1979) provide corrected population estimates, but these are considered to be very preliminary in nature (I. Stirling, Canadian Wildlife Service, pers. comm.), and have not been included in this report.

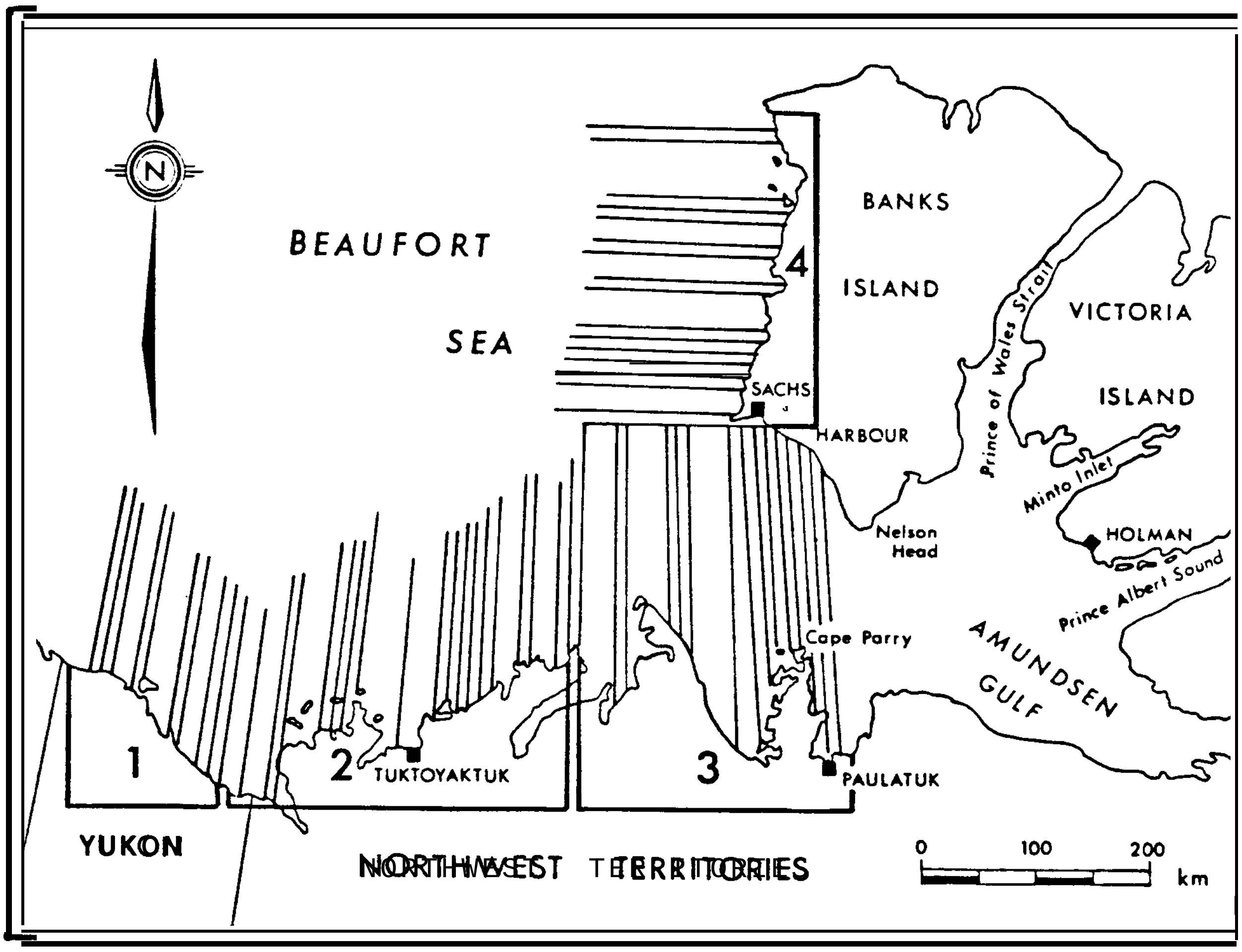


FIGURE 3.5-4

STRATA AND TRANSECT LINES SURVEYED DURING CANADIAN WILDLIFE SERVICE SEAL SURVEYS

(From Stirling *et al.*, 1977)

Table 3.5-8. Uncorrected Estimates of Beaufort Sea Seal Populations, 1974 to 1978 (From Stirling *et aZ.,* 1979).

Year	Ringed Seal	Bearded Seal
1974	41,983	2,759
1975	21,661	1,197
1976	22,420	1,350
1977	19 780	1,329
1978	51,538	2,893

The uncorrected estimates of ringed and bearded seal numbers shown in Table 3.5-8 provide an index of trends in seal populations in the southeastern Beaufort Sea region. During the period between 1974 and 1978, populations of both species underwent a large and rapid decrease followed by a large and equally rapid increase in numbers. The decrease observed between 1974 and 1975 may have started between 1973 and 1974 (Smith and Stirling, 1978; Stirling *et al.*, 1979). The decrease in ringed seal populations between 1974 and 1975, and possibly that of bearded seals also, is thought to have been the combined result of a 90% reduction in reproduction, a probable increase in mortality, and large-scale movements out of the eastern Beaufort Sea by a significant proportion of the population; the extent to which each of these factors contributed to the decrease is unknown (Stirling *et al.*, 1977, 1979). The rapid increase in numbers of both ringed and bearded seals between 1977 and 1978 was in part or whole apparently due to large scale immigration. The major changes that have occurred in seal populations in the Beaufort Sea apparently occurred as a result of natural stimuli that are at best poorly known. Stirling *et al.* (1977) speculated that the decrease in numbers between 1974 and 1975 was caused by the heavy ice conditions that prevailed throughout that period. Environmental conditions associated with the increase between 1977 and 1978 have not yet been assessed (Stirling *et al.*, 1979).

Specific data on the numbers, distribution, and activities of ringed and bearded seals in the marine areas adjacent to McKinley Bay throughout the year are lacking or have not been analyzed. However, more general information collected on ringed and bearded seals in the Beaufort Sea does permit some discussion of these aspects in relation to the McKinley Bay area.

The numbers of bearded and ringed seals recorded in stratum 2, which includes the marine areas adjacent to McKinley Bay, have generally followed the same trends described above for the total Beaufort Sea populations. In 1978, the uncorrected population estimates of ringed and bearded seals in stratum 2 were 12,400 and 2,000 respectively (Stirling *et aZ.*, 1979). In 1975, a year of low numbers, this area contained an uncorrected estimate of 3,600 ringed and

440 bearded seals; and in 1974, a previous year of relatively high numbers, it contained an uncorrected estimate of 16,300 and 1,400, respectively (Stirling *et al.*, 1975b, 1977).

The distribution and movements of ringed and bearded seals between break-up in early July and freeze-up in late October are poorly known. In late summer there is a movement of seals out of the Amundsen Gulf area (Smith and Stirling, 1978). A large majority of these animals are young-of-the-year and apparently they are leaving the breeding areas prior to freeze-up. Large numbers of these animals pass Cape Bathurst and also Herschel Island. T.G. Smith, Arctic Biological Station, (pers. comm.) has speculated that between these two points the seals move offshore in order to avoid the turbid Mackenzie River waters.

During winter most seals that occur in fast-ice areas adjacent to McKinley Bay are ringed seals, which maintain breathing holes by scraping the ice with claws on the foreflippers. Bearded seals occur largely in areas of moving ice flows which, in the McKinley Bay area, occur approximately 20 km offshore, depending on ice conditions. This species can occur in fast-ice areas and probably does so to some extent in the McKinley Bay area.

The pupping areas of ringed seals in the western Arctic are widely scattered through the fast-ice areas, mainly in the large bays of Amundsen Gulf and to a lesser extent in the land-fast ice of nearshore areas of the Tuktoyaktuk Peninsula and Banks Island (Stirling *et al.*, 1975). Ringed seal pups are born in lairs beneath the snow that accumulates around ice hummocks and pressure ridges. Pupping occurs from late March through early April but pups are not weaned for two months. Densities of birth lairs in the Beaufort Sea region are poorly known and difficult to determine, but they can vary substantially from year to year. Smith and Stirling (1975) reported that densities of birth lairs in the Amundsen Gulf in 1974 decreased by a factor of 10 from those in 1973.

Bearded seal pupping appears to be concentrated in the offshore moving lead systems north of the Tuktoyaktuk Peninsula and west of Banks Island. Some pupping also occurs in shore-fast ice as well (Stirling and Smith, 1975). Pupping occurs approximately in late April. Pups are born on the ice and are able to enter the water soon after birth (Chapskii, 1938 in Stirling *et aZ.,* 1975; Burns, 1967 in Stirling *et al.*, 1975).

Polar Bears

Polar bears are circumpolar in distribution (Banfield, 1974). At one time it was theorized that the entire species population was a single unit, and that the bears lived a nomadic existence and wandered over their entire range. However, recent studies in Canada, Norway and the United States have shown that there are many relatively discrete populations of polar bears that are fairly localized in their movements (Lentfer, 1974 in Stirling, 1978; Stirling *et aZ.,* 1975a). For example, the rate of exchange between western (Alaskan) and eastern Beaufort Sea populations is estimated to be in the order of only five to 10 percent (Stirling, 1978).

During the winters of 1972-73 and 1973-74 the eastern Beaufort Sea population of polar bears was estimated to be about 1800, but during the winter of 1974-75 the estimated population was only 1200 (Stirling, 1978). The estimated population apparently increased to approximately 1500 during the 1975-76 winter but was again at 1200 during the 1976-77 winter. The major decline in polar bear numbers was apparently caused by a major decrease between June 1974 and June 1975 in numbers and availability of ringed and bearded seals, the major food of polar bears (Stirling *et aZ.,* 1975a, b; Stirling, 1978).

With the exception of females that come ashore to den, polar bears in the eastern Beaufort Sea spend most of their time on sea-ice. During the open-water period (June to October) polar bears move offshore and remain with the polar pack-ice where they are able to continue to hunt seals. Only occasionally do any polar bears remain on either the mainland or islands during this period (Stirling *et al.*, 1975a).

From freeze-up (approximately late October) until when break-up begins (approximately late May) polar bears are present throughout the southeastern

Beaufort Sea-Amundsen Gulf region. Their distribution during this period, however, is not uniform. Stirling *et al.* (1975a) reported that polar bears were present in largest numbers in active-ice zones (Figure 3.5-5), where wind and currents cause much movement of ice, creating open leads, pressure ridges and other ice formations in which seals are relatively accessible to polar bears. Stable nearshore ice with suitable habitat for ringed seal birth lairs is preferred by adult females with cubs of the year, possibly because of the general absence in this habitat of adult males, which may prey on cubs.

Pregnant females den from about early November to late March or early April; young are born between late November and January (Stirling *et al.*, 1975a). Dens are dug in drifted snow. In the eastern Beaufort Sea region; most dens appear to occur along the west coast of Banks Island (Figure 3.5-6) although a few have been reported along the mainland coast, including one immediately to the eastof McKinley Bay. Some denning may also occur on the pack-ice (Lentfer, 1975).

Figures 3.5-7, 3.5-8, and 3.5-9 show locations where polar bears have been killed or tagged in the eastern Beaufort Sea. Although the most important areas for polar bears apparently occur off Banks Island, the area off the Tuktoyaktuk Peninsula and off McKinley Bay, specifically, is apparently heavily used by polar bears during the winter months. It is important to note that the locations of bear kills and locations where bears were tagged may present a somewhat biased picture of distribution and relative abundance because hunting and tagging efforts have not been evenly distributed throughout the region. Notwithstanding the possible biases, the McKinley Bay area appears to be important to polar bears (and presumably seals, also).

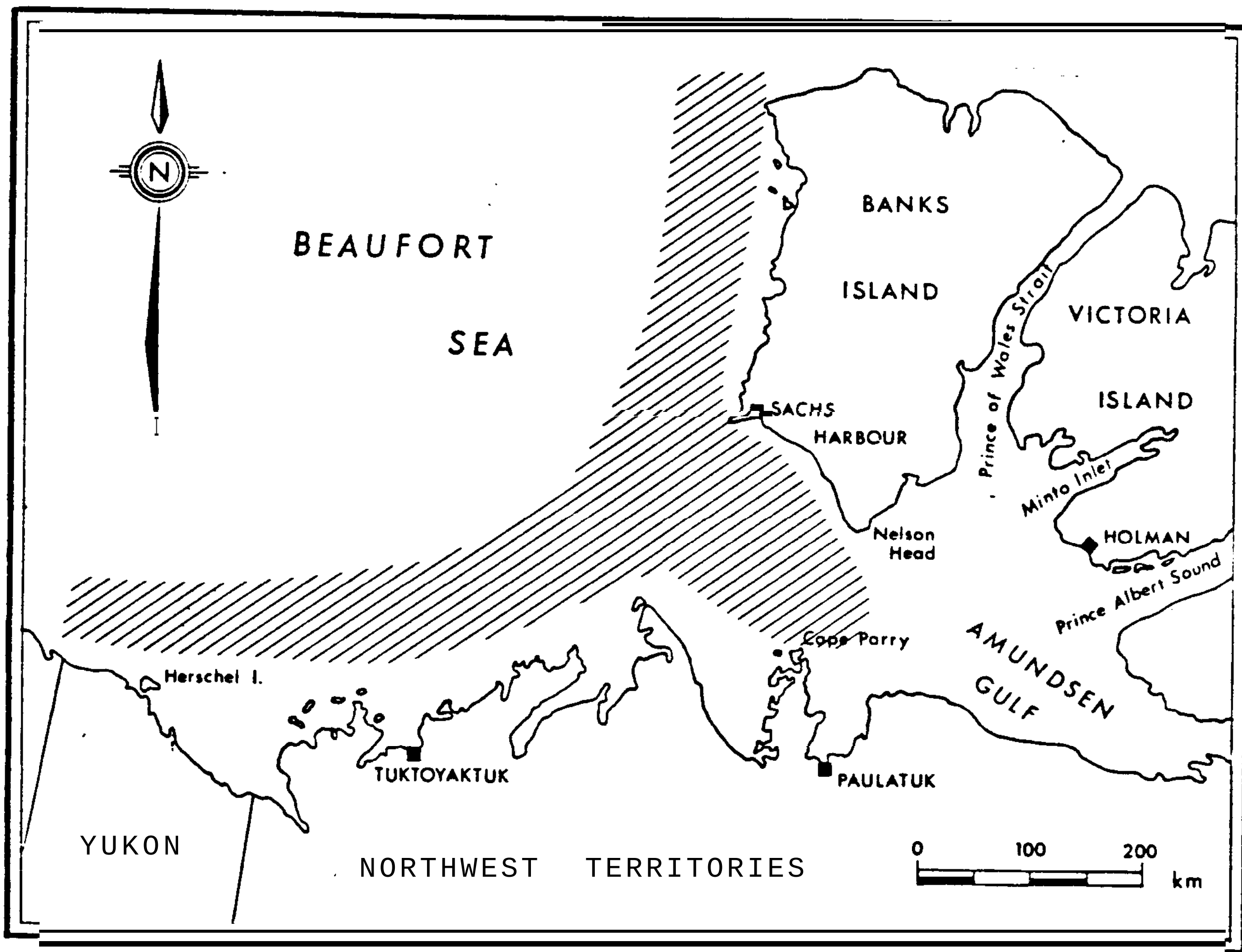


FIGURE 3.5-5

DISTRIBUTION OF POLAR BEAR SEA ICE HABITAT WHICH IS HIGHLY IMPORTANT DURING THE PERIOD BETWEEN FREEZE-UP AND BREAK-UP (APPROX. OCTOBER-JUNE).

The hatched area represents areas of moving ice where seals, the polar bear's main prey, are readily available and abundant. Landfast ice, south of the hatched area, is. ringed seal pupping habitat.

(After Stir-l ing *et al.* , 1975a)

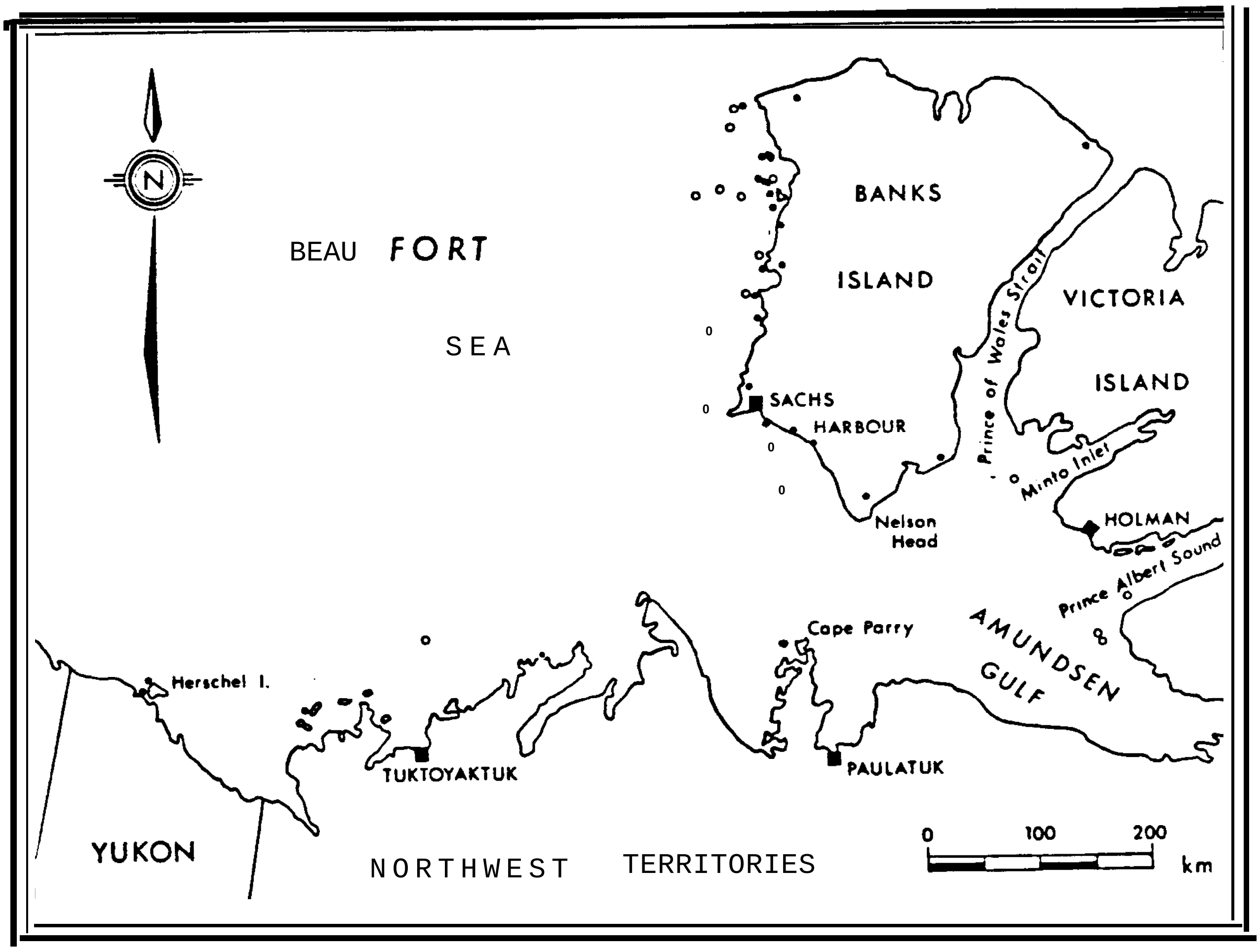


FIGURE 3 .5-6

LOCATIONS OF DENS AND EARLY SPRING SIGHTINGS OF FEMALE POLAR BEARS WITH NEWBORN CUBS.

Dots represent dens; open circles represent sightings.

(After Stirling *et al.*, 1975a)

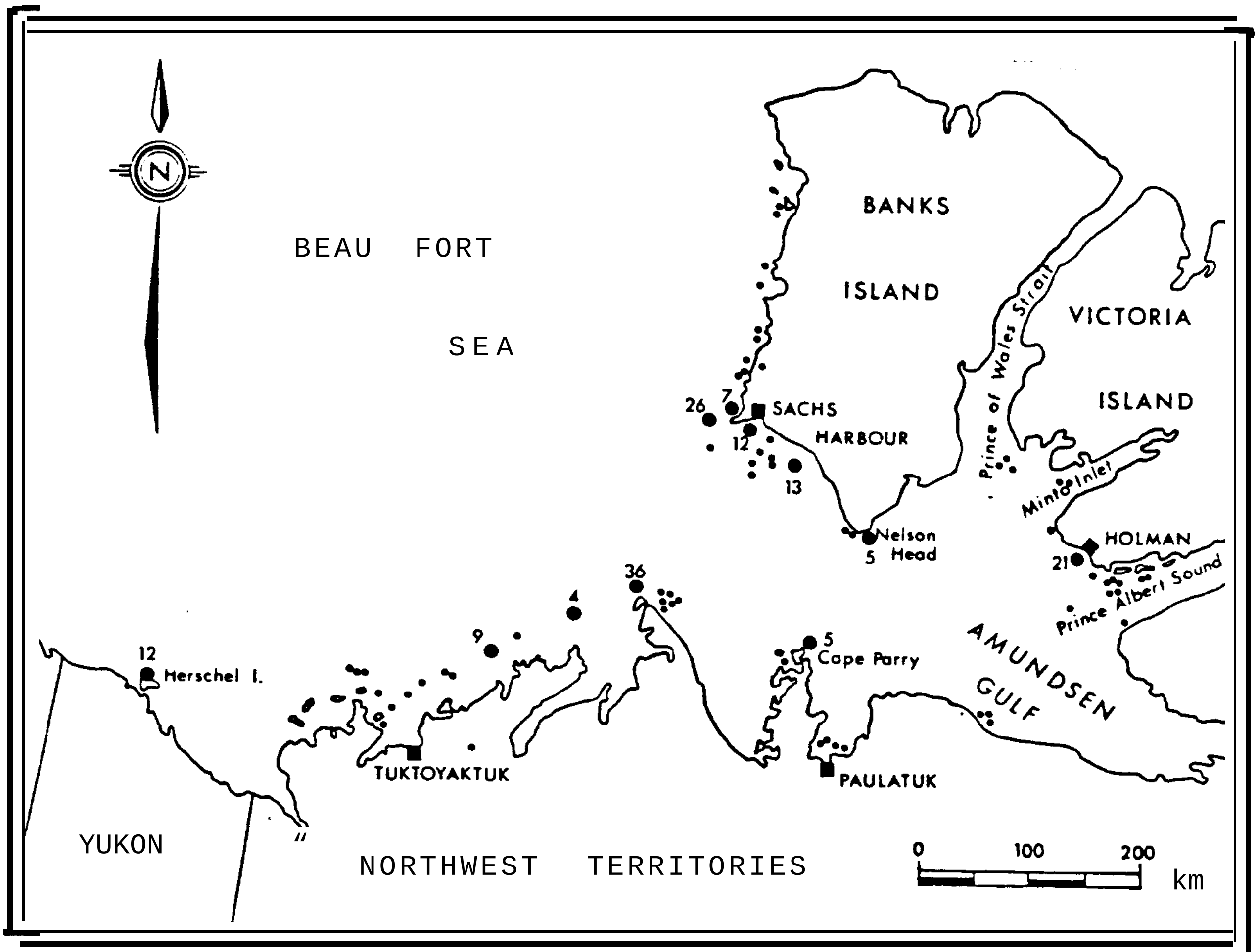


FIGURE 3.5-7

LOCATIONS OF 226 KILLS OF POLAR BEARS BY INUIT HUNTERS, 1969-70 to 1974-75.

Small dots represent single kills; larger dots with a number indicate the number of bears killed at that locale.

(After Stirling *et al.*, 1975a)

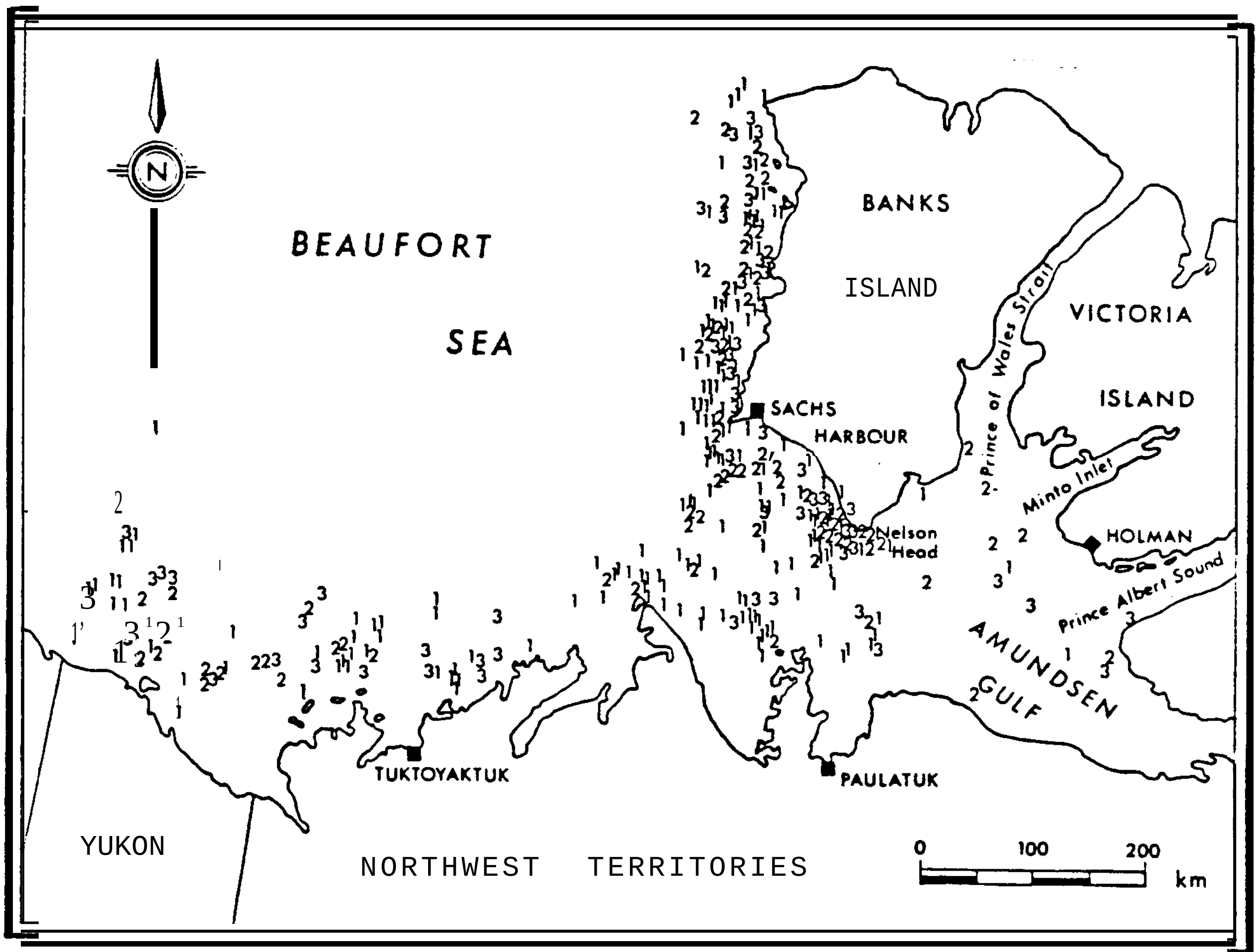


FIGURE 3.5-8

LOCATIONS WHERE POLAR BEARS WERE TAGGED IN THE WESTERN ARCTIC FROM OCTOBER 1970 TO JULY 1975.

Males are represented by ?'s, females by 2's, and family groups by 3's.

(After Stirling *et aZ.* , 1975a)

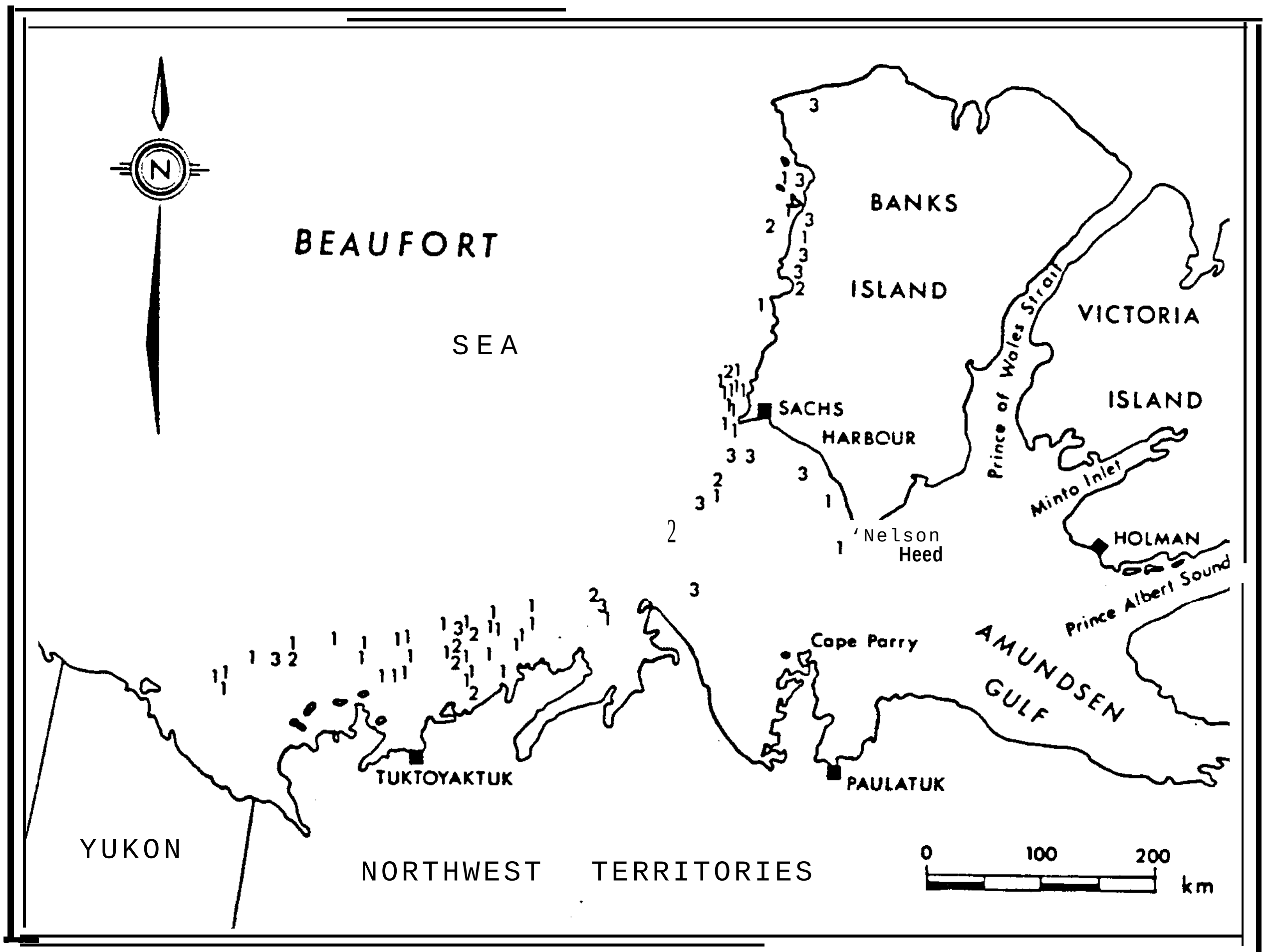


FIGURE 3.5-9

LOCATIONS WHERE POLAR BEARS WERE TAGGED IN THE WESTERN ARCTIC IN 1976 AND 1977.

Males are represented by l's, females by 2's, and family groups by 3's.

(After Stirling, 1978)

Terrestrial Mammals

Nineteen species of terrestrial mammals have ranges that may include all or part of the Tuktoyaktuk Peninsula (Table 3.5-9). In the case of shrews, which are small insect-eating animals, the peninsula lies on the edge of their range and they are not expected to be abundant in the McKinley Bay area.

Small Herbivores

Nine species of small herbivores may occur in the McKinley Bay area (Table 3.5-9), but most will probably be rare. Only lemmings and ground squirrels are expected to be relatively common. Arctic ground squirrels are present in the McKinley Bay area (LGL Limited, unpubl. data) and Abrahamson (1963) reported that they were numerous in sandy banks along coasts in the Tuktoyaktuk-Cape Parry area. Little is known about the abundance of lemmings on the Tuktoyaktuk Peninsula, but because the peninsula is well within their range (Banfield, 1974), one or both species are expected to be common in the McKinley Bay area. Lemmings are not of direct economic importance but they are an important food source for several groups of birds (e.g., owls, jaegers) and for carnivorous mammals (e.g., arctic fox, ermine) in arctic regions (Pitelka *et al.*, 1955; McPherson, 1969; Banfield, 1974; Simms, 1978). Their numbers are known to be cyclic and this has been reported to cause cycles in populations of predatory species (e.g., arctic fox, snowy owl) that are heavily dependent on them as a food source (Pitelka *et al.*, 1955; McPherson, 1969).

Muskrats are an important furbearer in the upper Mackenzie Delta area (Brakel, 1977) and apparently some animals may be trapped from lakes on the western half of the Tuktoyaktuk Peninsula, including lakes south of McKinley Bay (Freeman, 1976 b). However, in general , the 1 akes around McKinley Bay are not considered to be good muskrat habitat (Nolan *et al.*, 1973), and therefore it is probable that they will contain only a few, if any, muskrats.

Table 3.5-9 Terrestrial Mammals Whose Distribution Ranqes Include the Tuktoyaktuk Peninsula.[1]

Species [2]	Scientific Name [2]	Cements
Insectivores		
Masked shrew	*Sorex cinereus*	at northern limit of range[3]
Dusky shrew	*Sorex obscurus*	at northern limit of range
Arctic shrew	*Sorex arcticus*	at northern limit of range
Small Herbivores		
Snowshoe hare	*Lepus americanus*	at northern limit of range
Arctic hare	*Lepus arcticus*	at southern limit of range
Arctic ground squirrel	*Spermophilus parryii*	at northern limit of range
Northern red-backed vole	*Clethrionomys rutilus*	at northern limit of range
Brown lemming	*Lemmus sibiricus*	
Collared lemming	*Dicrostonyx torquatus*	
Muskrat	*Ondatra zibethicus*	at northern limit of range
Meadow vole	*Microtus pennsylvanicus*	at northern limit of range
Tundra vole	*Microtus oeconomus*	at northern limit of range
Larqe Herbivores		
Barren-ground caribou	*Rangifer tarandus (groenlandicus)*	on edge of range[4]
European reindeer	*Rangifer tarandus (tarandus)*	domesticated
Carnivores		
Tundra wolf	*Canus lupus (mackenzii)*	
Arctic fox	*Alopex lagopus*	
Red fox	*Vulpes vulpes*	
Grizzly bear	*Ursus arctos*	
Ermine	*Mustela ermines*	
Wolverine	*Gulo gulo*	

[1] Based on information from Banfield (1974).

[2] Based on Banfield (1974).

[3] Tuktoyaktuk Peninsula lies on the northern or southern limits of the species' range.

[4] See Figure 3.5-10.

Large Herbivores

Barren-ground caribou of the Bluenose herd may occasionally wander onto the Tuktoyaktuk Peninsula in fall, winter or spring when Liverpool Bay and Eskimo Lakes are frozen, but in general the peninsula lies north and west of major areas used by this herd (Figure 3.5-10). The most common large herbivores on the Tuktoyaktuk Peninsula are reindeer that are part of the reindeer herding operation carried out in the northern part of the Reindeer Grazing Reserve. European reindeer were introduced to the reserve in 1935 (Abrahamson, 1963) and have been herded in this area with varying success since that time. The present reindeer operation, which is largely confined to the Tuktoyaktuk Peninsula, is described in the Resource Utilization section.

Carnivores

(a) Tundra Wolf

No information is available on the numbers or frequency of occurrence of wolves on the Tuktoyaktuk Peninsula. The fact that wolves are hunted in areas of the peninsula located south and west of McKinley Bay (Freeman, 1976b) indicate that they do occur there. In general, wolves depend heavily on caribou as a food source except during the summer denning period (Kelsall, 1968; Kuyt, 1972). Few caribou occur on the peninsula but the presence of the domestic reindeer herd in the area possibly attracts some wolves in winter. It is also probable that wolves that occurred in the area would be heavily hunted because of their potential depredations on the domestic reindeer herd.

Wolf denning areas are not known to be present on the Tuktoyaktuk Peninsula. Denning areas are generally found where there is both a wide diversity of food sources (i.e., waterfowl, upland birds, small mammals, and fish) and good denning habitat (Kelsall, 1968). Kelsall (1968) reported that denning areas for tundra wolves appear to be most common near coastlines having a diversified terrain, and in and near the valleys of major lakes and rivers.

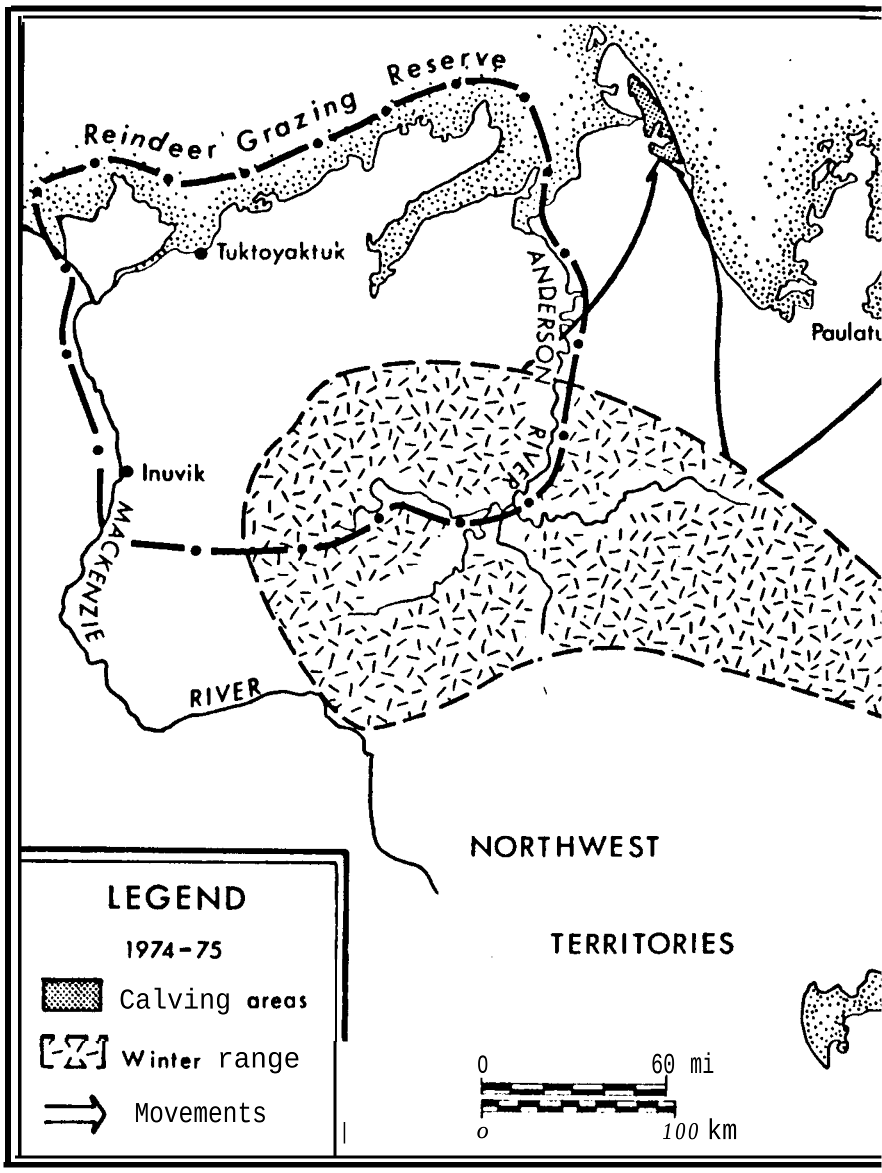


FIGURE 3.

APPROXIMATE WINTER RANGE AND CALVING
AND LOCATION OF THE REINI

(Adapted from Hawley *et a*

(b) Arctic Fox

The arctic fox is the most economically important of the terrestrial mammal species that occur in the southeastern Beaufort Sea region (Brakel, 1977), but relatively little information exists on population levels in this region. Arctic fox populations generally are reported to fluctuate widely, possibly in response to the cyclic abundance of lemmings, a major food source of this species (Chesemore, 1968b; McPherson, 1969; Banfield, 1974). In the southeastern Beaufort Sea region, trapping returns provide an indication of population levels (e.g., Table 3.5-10) but the facts that trapping returns represent minimum population levels and that trapping effort varies from year to year depending on fur prices and fox abundance must be kept in mind. During the period from 1957 to 1974, for example, the numbers of arctic fox furs exported from all of the coastal communities in the southeastern Beaufort Sea region varied from a low of about 1000 in the winter of 1959-60 to a high of about 13,000 in 1973-74 (Table 3.5-10). The proportion of the total arctic fox population that these returns represent is unknown.

Winter movements and distribution of arctic foxes in the southeastern Beaufort Sea region are poorly understood. Present evidence suggests that in fall after freeze-up, large numbers of foxes move off the land and on to the sea-ice, where they scavenge on the remains of seals killed by polar bears (Chesemore, 1968a; Stirling and Smith, 1976; Usher, 1976). In spring, these foxes can also be a significant predator of ringed seal pups present in subnivean birth lairs in fast-ice areas (Smith, 1976). The abundance of lemmings apparently also has a major effect on the winter movements and distribution of foxes. In years when lemmings are abundant, the seasonal fox movements may fail to develop and in a year following a major decline in lemming numbers, there may be a major fall movement of foxes into coastal areas (Chesemore, 1968a; Usher, 1976). In late winter prior to break-up, foxes return inland to occupy summer den sites.

The timing of the breeding cycle of arctic foxes in the southeastern Beaufort Sea area has not been studied but information reported by Banfield (1974) should generally apply to this area. Mating takes place during the

Table 3.5-10 Numbers of Arctic Fox Furs Exporte
(Adapted from Brakel 1977)

	Aklavik	Inuvik	Tuktoy-aktuk
1957-58	370	*	420
1958-59	235	*	757
1959-60	9	*	104
1960-61	8	2	267
1961-62	55	144	848
1962-63	3	10	577
1963-64	26	428	905
1964-65	22	16	1 3
1965-66		75	260
1966-67	10	1845	249
1967-68	38	101	420
1968-69	12	502	539
1969-70	18	227	"351
1970-71	93	1098	476
1971-72	56	491	2067
1972-73	85	173	852
1973-74	87	1405	574

* Data missing

period between late February and late April. Den sites are dug out as early as late March. Young are born between mid-May and mid-June and are weaned approximately 2-4 weeks later, which is about the same time that they start to emerge from the den. The adults abandon the young approximately in mid-August, after which time the young gradually disperse.

Arctic fox den sites are particularly important for several reasons. Den sites are traditional and are used intermittently over periods of many years, possibly even centuries in some cases (McPherson, 1969). In years when lemmings are abundant, an average of 9.6 young foxes (range: 4-14) are weaned at a den site, while in years when lemmings are scarce, no young may be produced or den sites may not even be occupied (Macpherson, 1969). Den sites are most common in sandy, well-vegetated areas of gentle slope, but in arctic Canada they are not very abundant anywhere. In 1961-63 in the central District of Keewatin where McPherson (1969) studied arctic foxes, occupied den sites were a minimum of 1.6 km and an average of 5.0 km apart; an average of 70 km^2 was available for the support of each occupied den.

Little specific information is available on the use of the McKinley Bay area by arctic foxes. These animals are probably present in the area in winter, but nothing has been reported on their relative abundance at this time. Nolan *et al.* (1972) classified the Tuktoyaktuk Peninsula as an important area for arctic foxes and reported that, in 1972, several den sites were found in sand dune areas along the eastern portion of the seaward coastline of the Tuktoyaktuk Peninsula, which includes the McKinley Bay area. Slaney (1975) reported that trappers considered Atkinson Point an important arctic fox denning area. Arctic foxes were sighted in the Atkinson Point area on three occasions in late July 1977 (LGL Limited, unpubl. data) but their breeding status was unknown.

(c) Red Fox

Red fox includes the colour phases known to the fur trade as black, cross, silver and red. The cross and red colour phases are the most common in the fur exports from coastal communities in the southeastern Beaufort Sea region (Brakel, 1977).

As with the arctic fox, trapping returns provide the only information on the abundance of red foxes in the Tuktoyaktuk Peninsula area. In some years significant numbers of red fox furs have been exported from the Tuktoyaktuk area. For example, in 1972-73, 237 red fox furs were exported from Tuktoyaktuk and in 1976-77, 414 were exported. This compares with 852 arctic fox furs exported in 1972-73 and 1725 in 1976-77 (Zoltai *et aZ.,* 1979). The proportion of the total population of red foxes trapped each year is unknown and probably varies depending on the overall abundance of red foxes and on fur prices. Freeman (1976a) indicated that the best trapping areas for red foxes are in the vicinities of the upper part of the Eskimo Lakes and possibly of the Smoke and Anderson rivers.

Red fox denning has been reported for Richards Island (Slaney, 1974). This species dens in the same types of areas as arctic foxes, and therefore could den in low numbers on the Tuktoyaktuk Peninsula.

(d) Grizzly Bear

Grizzly bears are wide-ranging and occur over all of the Tuktoyaktuk Peninsula during the period from late April-early May, when they emerge from their dens, to late October-early November, when they again enter dens (Nolan et *al.*, 1973b; Pearson and Nagy, 1976). Most of the northern half of the Tuktoyaktuk Peninsula, including the McKinley Bay area, is poorly drained with numerous lakes and extensive wet areas and is considered to be only occasionally used by grizzly bears because of a general lack of suitable denning habitat (Nolan *et aZ.*, 1973 b). RRCS (1972) reported that a pingo 10 km south of McKinley Bay contained approximately five dens. The extent to which use of this denning site is traditional is unknown. Pearson and Nagy (1976) reported that grizzly bears that denned in the area between Tuktoyaktuk and Inuvik did not use the same den sites in 1975 that they used in 1974. However, in that region potential denning habitat is abundant, whereas in the McKinley Bay area and in areas further to the northeast along the Tuktoyaktuk Peninsula, denning habitat. is limited (Nolan *et al.*, 1973b). Densities of grizzly bears on the northern end of the peninsula have not been reported, but in the area between Tuktoyaktuk and Inuvik, which is reported to be a common use area for grizzly bears (Nolan *et al.*, 1973b), a density of one bear/200 km^2 has been reported (Pearson and Nagy, 1976). By comparison, Pearson and Goski (1974) reported a density of one bear/65 km^2 on the arctic coastal plateau of the Yukon Territory, an area classed by Nolan *et al.* (1973b) as a high use area for grizzly bears.

(e) Ermine and Wolverine

The ranges of ermine and wolverine, as reported by Banfield (1974), include the Tuktoyaktuk Peninsula, but their distribution and abundance in this area is not known. Barry (1967) reported that, in 1963 when lemmings were abundant, ermine were commonly seen around his camp in the Anderson River Delta. In the period 1964-67, relatively large numbers of weasels (probably mainly ermine) were exported from Tuktoyaktuk, but since that time few have been exported (Zoltai *et al.*, 1979). The locations where these animals were trapped and the reasons for the decline in the export of such furs are unknown.

Wolverine are typically widely dispersed and solitary, even in prime habitat (van Zyll de Jong, 1975). Barry (1967) reported that wolverine were scarce in the Anderson River Delta area. Few wolverine furs have been exported from Tuktoyaktuk possibly because they are scarce, are difficult to trap, and/or are used domestically (Zoltai *et al.*, 1979).

3.5.5 Birds

Table 3.5-11 lists 71 species of birds that are common in-the area or whose breeding ranges include the Tuktoyaktuk Peninsula. Of these, 18 are terrestrial and 53 are aquatic species.

Terrestrial Birds

Terrestrial birds tend to be widely distributed during both migration and nesting, and thus, site specific developments affect only small fractions of populations. However, several species of cliff-nesting raptors are particularly vulnerable to disturbance (Fyfe and Olendorff, 1976), and some species populations are relatively low. In the McKinley Bay area there are no cliffs, and therefore cliff-nesting raptors are not of concern. Both snowy owls and short-eared owls, which are ground-nesting raptors, may nest in the McKinley Bay area, but their abundance and distribution is unreported and probably varies from year to year depending on the abundance of lemmings (Pitelka *et al.*, 1955).

Aquatic Birds

Aquatic birds are of concern because of their tendencies to concentrate in large numbers during certain periods of the year. During migration, many species often concentrate in large numbers in traditional staging areas; during nesting, some areas have very high densities of birds (in some cases because nesting habitats are limited in extent); and during the moulting period these species often concentrate in traditionally-used areas.

(a) Loons and Grebes

Four species of loons have been recorded in or near the McKinley Bay area (Table 3.5-11). Of these, the common loon is the least numerous (Johnson *et al.*, 1975). Only small numbers of transient common loons have been recorded along the southeastern Beaufort Sea coast (Searing *et al.*, 1975), "'

Table 3.5-11 BirdSpecies That Potentially Nest on the Tuktoyaktuk Peninsula[1] or That are Common Transients in the Area.

Species[2]	Scientific Name [2]	Comments
eons and Grebes		
Common loon	*Gavia immer*	transients
Yellow-billed loon	*Gavia adamsii*	transient
Arctic loon	*Gavia arctica*	
Red-throated loon	*Gavia stellata*	
Horned grebe	*Podiceps auritus*	
;wans and Geese		
Whistling swan	*Olor columbianus*	
Canada goose	*Branta canadensis*	
Black brant	*Branta bernicla*	
White-fronted goose	*Anser albifrons*	
Snow goose	*Chen caerulescens*	transient
)ucks		
Mal 1 ard	*Anas platyrhynchos*	
Pintail	*Anas acuta*	
Green-winged teal	*Arias carolinensis*	
American wigeon	*Anas americanus*	
Northern shoveler	*Anas clypeata*	edge of range[4]
Canvasbacks	*Aythya valisineria*	edge of range
Greater scaup	*Aythya marila*	
Lesser scaup	*Aythya affinis*	edge of range
Oldsquaw	*Clangula hyemalis*	
Common eider	*Somateria mollissima*	
King eider	*Somateria spectabilis*	
White-winged scoter	*Melanitta deglandi*	
Surf scoter	*Melanitta perspicillata*	transient
Red-breasted merganser	*Mergus serrator*	

Table 3.! 1 Continued . .

Table 3.5-11 Continued

Species[z]	Scientific Name[2]	Comments
Raptors		
Rough-legged hawk	*Buteo lagopus*	
Gyrfalcon	*Falco rusticolus*	
Snowy owl	*Nyctea scandiaca*	
Short-eared owl	*Asio flammeus*	
Ptarmigan		
Willow ptarmigan	*Lagopus lagopus*	
Rock ptarmigan	*Lagopus mutus*	
Shorebirds		
Semipalmated plover	*Charadrius semipalmatus*	
American golden plover	*Pluvialis dominica*	
Black-bellied plover	*Pluvialis squatarola*	edge of range
Ruddy turnstone	*Arenaria interpres*	transient
Common snipe	*Capella gallinago*	
Whimbrel	*Numenius phaeopus*	
Lesser yellowlegs	*Totanus flavipes*	
Pectoral sandpiper	*Calidris melanotus*	
White-rumped sandpiper	*Calidris fuscicallis*	
Baird's sandpiper	*Calidris bairdii*	
Least sandpiper	*Calidris minutilla*	
Dunlin	*Calidris alpina*	
Semipalmated sandpiper	*Calidris pusilla*	
Sanderling	*Calidris alba*	edge of range

Table 3.5-11 Continued . . .

Species [2]	Scientific Name [2]	Comments
Shorebirds		
Long-billed dowitcher	*Limnodromus scolopaceus*	edge of range
Stilt sandpiper	*Micropalama himantopus*	
Buff-breasted sandpiper	*Tryngites subruficollis*	
Hudsonian godwit	*Limosa haemastica*	edge of range
Red phalarope	*Phalaropus fulicarius*	
Northern phalarope	*Lobipes lobatus*	
Jaegers, Gulls and Terns		
Pomarine jaeger	*Stercorarius pomarinus*	edge of range
Parasitic jaeger	*Stercorarius parasiticus*	
Long-tailed jaeger	*Stercorarius longicaudus*	
Glaucous gull	*Larus hyperboreus*	
Herring gull	*Larus argentatus*	edge of range
Mew gull	*Larus canus*	edge of range
Bonaparte's gull	*Larus Philadelphia*	
Sabine's gull	*Xema sabini*	
Arctic tern	*Sterna paradisaea*	
Passerine		
Horned lark	*Eremophila alpestris*	
Common raven	*Corvus corax*	
American robin	*Turdus migratorius*	
Water pipit	*Anthus spinoletta*	
Yellow warbler	*Dendroica petechia*	edge of range

Table 3.5-11 Continued . . .

Table 3.5-11 Continued

Species [2]	Scientific Name [2]	Comments
Passerine		
Hoary redpoll	*Carduelis hornemanni*	
Common redpoll	*Carduelis flammea*	
Savannah sparrow	*Passerculus sandwichensis*	
Tree sparrow	*Spizella arborea*	
Lapland longspur	*Calcarius lapponicus*	
Smith's longspur	*Calcarius pictus*	
Snow bunting	*Plectrophenax nivalis*	

[1] From Godfrey (1966).

[2] According to AOU (1957, 1973, 1976).

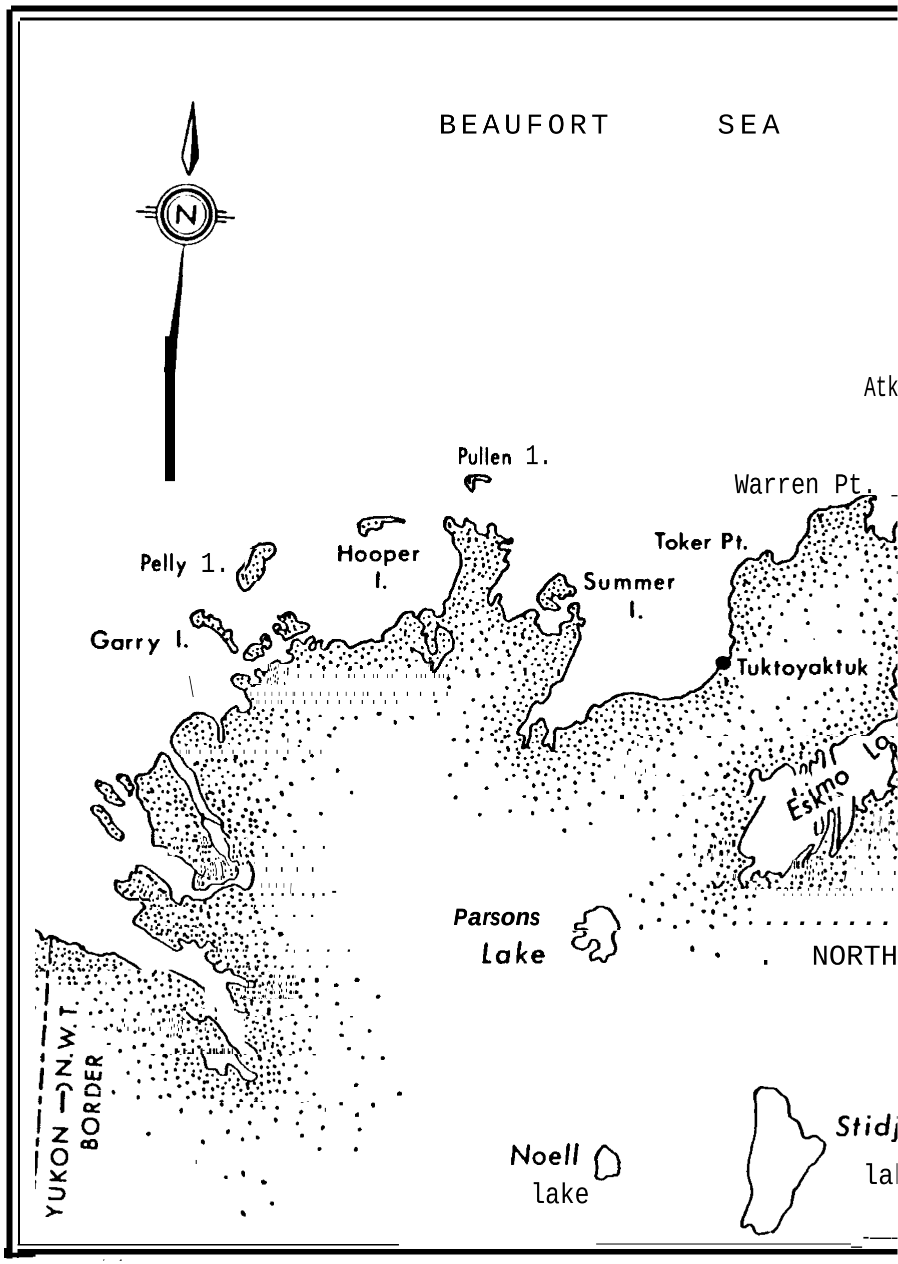
[3] These species do not nest on the peninsula but they are common during migration anti/or during the summer moulting period of waterfowl (Searing *et al.,* 1975; Barry, 1976).

[4] The Tuktoyaktuk Peninsula lies on the edge of the breeding range for these species (Godfrey, 1966).

and although this species nests as far north as the Mackenzie Delta, it apparently does not nest on the Tuktoyaktuk Peninsula (Godfrey, 1966; Johnson *et al.*, 1975).

The other three species--yellow-billed, arctic and red-throated loon --are common along the seaward side of the Tuktoyaktuk Peninsula during their spring and fall migration, which occurs in late May-early June and in late August-early September, respectively, in the southeastern Beaufort Sea (Johnson *et aZ.,* 1975; Searing *et aZ.,* 1975). For example, Barry (1976) estimated that between 29 May and 16 June 1972, 4500 yellow-billed loons, 9000 arctic loons, 200 red-throated loons, and 24,150 unidentified loons migrated eastward past Cape. Dalhousie on the northeast end of the Tuktoyaktuk Peninsula (location on Figure 3.5-11). Also, between 22 August and 13 September 1972, a comparatively large movement of red-throated loons was recorded at Toker Point, 70 km south-east of McKinley Bay (Searing *et* aZ., 1975). Despite the large movements of loons along the seaward side of the Tuktoyaktuk Peninsula, migrating loons apparently do not concentrate in this area or in any other coastal or offshore areas in the southwestern Beaufort Sea (Searing *et aZ.,* 1975).

Yellow-billed loons apparently do not nest on the Tuktoyaktuk Peninsula (Godfrey, 1966), but both arctic and red-throated loons are common nesters on lakes in this area (Searing *et* aZ., 1975). During the June-August period, arctic loons are widely distributed in small numbers on lakes and along coasts of the Tuktoyaktuk Peninsula. Red-throated loons are also widely distributed on the Tuktoyaktuk Peninsula during this period, but they apparently fly to the nearby coastal areas in order to feed; and often they concentrate in moderate numbers in these areas. In 1974, for example, Searing *et al.* (1975) reported a count of approximately 40 red-throated loons at the head of McKinley Bay in early July and similar counts in a barrier island lagoon 20 km southwest of Atkinson Point in both early and late July. In general, however, large concentrations of loons have not been recorded on the Tuktoyaktuk Peninsula during the nesting season.



FIGURE

Geographic NAMES ON AND N

One species of grebe may occur in the McKinley Bay area. Godfrey (1 966) included the Tuktoyaktuk Peninsula within the breeding range of the horned grebe. However, this species is relatively uncommon in the -southeastern Beaufort Sea region (Johnson *et aZ.,* 1975) and no grebes were recorded in 1974 during surveys of the lakes and coastal areas of the Tuktoyaktuk Pen"insul a (Searing *et* aZ. , 1975).

(b) Swans and Geese

Each spring, large numbers of whistling swans, Canada geese, brant, snow geese and white-fronted geese migrate into the southeastern Beaufort Sea region. With the exception of brant, the Mackenzie River valley is the major migration corridor for these species both during their northward migration in spring and during their southward migration in fall. Brant, which winter along the Pacific coast, migrate to and from the southeastern Beaufort Sea region via coastal routes around Alaska, although in spring many travel overland between the Yukon-Kuskokwim Delta, Alaska, and coastal areas west of the Mackenzie Delta (Johnson *et al.*, *1975).*

During the spring migration period (approximately mid-May to mid-June) whistling swans, Canada geese, brant, snow geese and white-fronted geese migrate along the seaward coastline of the Tuktoyaktuk Peninsula (Searing *et* aZ., 1975; Barry, 1976). Barry (1976) estimated that, between 29 May and 16 June 1972, 21,900 brant, 9400 Canada geese, and 1100 white-fronted geese migrated eastward past Cape Dalhousie. Small numbers of migrating whistling swans and snow geese were also observed during the study at Cape Dalhousie. During this spring migration period, most coastal areas of the southeastern Beaufort Sea, including the McKinley Bay area, are still largely ice-covered and therefore would not be important spring concentration areas.

With the exception of snow geese, all of the above species are reported to nest on the Tuktoyaktuk Peninsula, but apparently only brant and white-fronted geese nest in significant numbers in the McKinley Bay area. Nesting in the Beaufort Sea area by snow geese is restricted to colonies on

Banks Island, in the Anderson River Delta, and in the Kendall Island area (Barry, 1967, 1976). Canada geese nest in the Husky Lakes-Liverpool Bay area (RRCS, 1972), but they apparently are not abundant nesters anywhere in coastal areas of the Beaufort Sea (Searing *et al.*, 1975). Whistling swans are common nesters on the Tuktoyaktuk Peninsula but nesting birds are apparently widely distributed (Searing *et al.*, 1975). Barry (1976) listed McKinley Bay as a critical whistling swan nesting area.

Barry (1976) lists the coastal area from Warren Point to Atkinson Point as a critical nesting area for both brant and white-fronted geese. RRCS (1972) reported that this area was used for nesting by 250 pairs of brant and an unknown number of pairs of white-fronted geese.

During the approximate period from mid-July to mid-August, swans, geese and ducks undergo a moult of their flight feathers. During this moult they are flightless (and relatively vulnerable) and often they concentrate in large numbers in traditionally-used areas. The head of McKinley Bay is considered a critical moulting area for both swans and geese (Barry, 1976). RRCS (1972) reported that this area was used by 1500 white-fronted geese, 700 brant and 250 whistling swans. In 1974, approximately 100 whistling swans, 150 white-fronted geese and 80 brant were recorded there in late-July and early-August (from original data reported by Searing *et al.*, 1975).

During fall migration, brant and snow geese migrate westward along the Tuktoyaktuk Peninsula, but only brant stage in this area. In late August, 1974, approximately 3000 brant were recorded in the coastal areas between Warren Point and Atkinson Point and approximately 600 in McKinley Bay (Searing *et al.*, 1975). Most brant have left the southeastern Beaufort Sea area by the end of the first week in September (Searing *et al.*, 1975). The Mackenzie Delta and Yukon North Slope are the major fall-staging areas for snow geese, white-fronted geese, Canada geese and whistling swans (Koski, 1977).

(C) Ducks

Table 3.5-11 lists 14 species of ducks that may occur in the McKinley Bay area. The first five are dabbling ducks and the remaining nine are diving ducks .

Dabbling ducks generally occur in low numbers in the southeastern Beaufort Sea area and most nesting apparently occurs in the Mackenzie Delta (Searing *et al.* , 1975). Mallard, green-winged teal and northern shoveler are uncommon in the Beaufort Sea area. Pintail and American wigeon are common moulters in the area during late July and early August but their numbers at most locations are apparently small (Searing *et* aZ., 1975).

Of the nine diving duck species that occur in the southeastern Beaufort Sea region, common eiders, king eiders and oldsquaws are the most numerous in the McKinley Bay area. During the spring migration period, large numbers of these species migrate eastward through the eastern Beaufort Sea area, utilizing offshore leads as feeding and resting areas (Johnson *et al.* , 1975). For example, Barry (1976) estimated that, between 29 May and 16 June 1972, ? ,130,000 oldsquaws, 549,000 common eiders and 695,000 king eiders migrated eastward past Cape Dalhousie. After the spring migration period, only small numbers of eiders are present in the Tuktoyaktuk Peninsula area (Searing *et* aZ. , 1975). Oldsquaws nest on lakes on the Tuktoyaktuk Peninsula and gather in large numbers in this area during the moulting period in late July-early August. In 1974, approximately 2000 moulting oldsquaws were observed in coastal areas between Warren Point and Atkinson Point in late July and early August. Few were recorded in McKinley Bay in that year. However, in 1977 approximately 3500 oldsquaws were recorded near Atkinson Point in McKinley Bay in late July and early August (Sharp, 1978). Fall migration of oldsquaws in the southeastern Beaufort Sea region occurs largely in late August and in September (Searing *et al.*, 1975).

Scoters are not as numerous as eiders and oldsquaws, but they occur abundantly at specific locations (Searing *et* aZ., 1975). During the moulting period, both white-winged and surf scoters occasionally occur in large numbers along the coastline of the Tuktoyaktuk Peninsula, particularly in Liverpool Bay, but large concentrations have not been reported for the McKinley Bay area (Searing *et aZ.* , 1975). In summer and fall 1974, scaup (mainly greater scaup) were common on lakes and in coastal areas of the Tuktoyaktuk Peninsula; largest numbers were recorded in a bay near Toker Point (Searing *et* al., 1975). Other species of diving ducks listed in Table 3.5-11 occur in the area in relatively small numbers.

(d) Shorebirds

Relatively little is known about shorebirds in the McKinley Bay area. Table 3.5-11 lists 20 species that may nest in the McKinley Bay area (Godfrey, 1966) but no data are available on their abundance there. Shorebirds migrate into the southeastern Beaufort Sea region in late May and June and most have left the area by early September (Searing *et al.*, 1975). Although large numbers of shorebirds are present in the region, no major concentration areas for shorebirds were recorded on the Tuktoyaktuk Peninsula during aerial surveys of coastal areas in July and August, 1974 (Searing *et aZ.,* 1975).

(e) Jaegers, Gulls and Terns

All three species of jaegers (Table 3.5-11) occur in the Beaufort Sea area. In late May and early June, large numbers of jaegers migrate into the eastern Beaufort Sea region from Alaska following coastal routes (Johnson *et* aZ., 1975; Richardson *et al.*, 1976). Jaegers nest on the arctic coastal plain and use both tundra and ocean habitats during July. Jaegers begin their return migration to wintering areas as soon as the young are fledged but immature and non-breeding birds may begin their return migration by mid-June (Searing *et aZ.,* 1975). Between 29 May and 16 June, 1972 approximately 6000 birds of each species migrated eastward past Cape Dalhousie (Barry, 1976). In 1974 during coastal surveys in July and August, few jaegers of any of the three species were recorded in the Tuktoyaktuk Peninsula area.

Five species of gulls and one species of tern may occur in the McKinley Bay area but only the glaucous gull is numerous. In 1972, Barry estimated that 35,400 glaucous gulls passed Cape Dalhousie between 29 May and 16 June. This species is also a common nester along the coastline of the Tuktoyaktuk Peninsula and in the McKinley Bay area. The largest colonies of this species in the southeastern Beaufort Sea area occur in the Eskimo Lakes and Cape Dalhousie areas (Searing *et* aZ., 1975), but the glaucous gull is also an important nester along the coastline between Warren Point and Atkinson Point (Barry, 1976). Sabine's gulls and arctic terns are occasional nesters at Cape Dalhousie (Barry, 1976) but, in general, they apparently occur in small numbers in the eastern Beaufort Sea region (Searing *et* aZ., 1975).

3.6 Resource Utilization

Reindeer Herding

The reindeer herding operation is operated out of Tuktoyaktuk by William Nasogaluak and utilizes all of the Tuktoyaktuk Peninsula between the Parsons Lake area and Cape Dalhousie. Reindeer are wintered in the Parsons Lake area until late March when herders start to move animals toward the eastern end of the peninsula. Calving occurs between early April and early May in areas of the peninsula south of Tuktoyaktuk. By early June the animals are on the eastern half of the peninsula. They remain in this area until late October, at which time herders round the animals up and begin moving them west towards the Parsons Lake wintering area (W. Nasogaluak, pers. tom.).

Each year during the period from 15-30 June, the reindeer are rounded up and moved to corrals at Atkinson Point where animals are tagged, antlers are removed, and animals are selected for slaughter. In June 1979, approximately 10,000 animals were moved through the corrals at Atkinson Point and in recent years up to 2000 animals have been slaughtered for meat. The operation has increased in size in recent years. In 1972, the herd numbered approximately 4000 animals and about 200 animals were slaughtered (Nowosad, 1972).

After the animals are tagged and de-antlered at the corrals on Atkinson Point, they are released to disperse on the eastern portions of the Tuktoyaktuk Peninsula. The reindeer remain in the eastern portions of the peninsula without being attended by herders, but regular checks of the area by aircraft are made by the owner, Mr. Nasogaluak. In winter, herders keep close check on the reindeer in order to prevent wide dispersal of the animals.

The current economic value of the herding operation was not obtained during this study. The operation provides employment for four herders during the period from late October to late May and for about 30 people during the June roundup period.

Hunting, Trapping and Fishing

Hunting, trapping and fishing on the Tuktoyaktuk Peninsula are carried out by people from Tuktoyaktuk (Freeman, 1976a). These activities apparently provide approximately 10 percent of the jobs in Tuktoyaktuk, but the mixture of life-styles obscures labour force and employment statistics (Brakel, 1977).

In general, these activities are an important source of food and are the major or sole source of income for a significant number of people. For many of the people these activities also have important cultural values.

Hunting

Residents of Tuktoyaktuk hunt polar bears, seals, white whales, caribou and birds, but of these, only the hunting of polar bears and seals (and probably ptarmigan on an opportunistic basis) occurs in the McKinley Bay area (Freeman, 1976b).

Polar bear is economically the most important mammal hunted in the McKinley Bay area. The hunting season extends from 1 December to 31 May. The numbers of polar bear hides exported from Tuktoyaktuk between 1964 and 1977 are shown in Table 3.6-l . In 1978-79, the regular quota of 22 polar bears was taken by Tuktoyaktuk residents but a special quota of four additional bears was not filled (D. Vincent, N.W.T. Wildlife Service, pers. comm.). The value of polar bear hunting has increased in recent years. In 1973-74, polar bear hides sold for an average of $1073; 11 bears yielded $11,800 of cash income to Tuktoyaktuk residents (Brakel, 1977). In 1978-79, polar bear hides were selling for approximately $250 per foot of hide (W. Spencer, N.W.T. Wildlife Service, pers. comm.). An eight-foot hide, for example, would sell for $2000 dollars and the 22 taken by Tuktoyaktuk residents would yield approximately $44,000.

Stirling *et al.* (1975a) show the locations of polar bear kills made during the period 1969-70 to 1974-75 (see Section 3.5.4). Of the 79 polar bear kills recorded between Herschel Island and Cape Bathurst, nine were

TABLE 3.6-1

FUR EXPORT RETURNS FOR TUKTOYAKTUK FOR 1964-1977[1] (From Zoltai *et al.*, 1979)

	1964-65	65-66	66-67	68-69	69-70	70-71	71-72	72-73	73-74	74-75	75-76	76-77
Beaver		1							6		1	
Muskrat	210	14	8	104	713	984	2123	2797	1162	403	580	3954
Arctic Fox[2]	138	266	249	539	353	476	2070	856	580	1066	910	1725
Red Fox[3]	8	88	69	136	143	56	66	237	127	69	120	414
wolf						3	6	1	4		11	18
Bear, unspecified			2	3	1		1	3	11	2	1	6
Polar Bear	22	25	32	17	5	4	12	21	11	21	13	15
Marten	493	386	266	21	494	344	162	250	146	40	111	73
Weasel	158	277	234	1	49	12		24	6			
Mink	25	28	9		6	6	6	14	57	2	6	20
Wolverine		1			4	1		1	4		1	2
Otter						1		1				
Lynx	1	6		9				4	20	1		4
Seals[5]							53	26	37	1	4	18

[1] Returns from 1967-68 are not available.

[2] Reported as "Blue Fox" and "White Fox".

[3] Reported as "Black Fox", "Cross Fox", "Red Fox", and "Silver Fox".

[4] May include grizzly and black bear.

[5] Seal records kept only from 1971 onward. Does not include seals taken for food.

located offshore from McKinley Bay. The most important bear hunting area for Tuktoyaktuk residents is at Cape Bathurst (see Section 3.5.4; Freeman, 1976a).

Between 1971 and 1974, an annual average of 39 seal skins were exported from Tuktoyaktuk, and they provided an average income of $677 (Brakel, 1977). Recent sales of seal skins have apparently diminished (Table 3.6-1) presumably because of the low prices paid for skins. Formerly seals were hunted for dog food, but this activity has also declined because of the greatly reduced numbers of dogs (Freeman, 1976a).

In the cases of seals and also of many of the furbearers, the data on numbers of furs exported do not accurately reflect the total number of animals actually taken or killed (Berger, 1977; Smith and Taylor, 1977). Many seals may be killed and sink before they can be recovered. The furs and meat of animals may be used domestically and therefore they are not recorded. For example, Berger (1977) reported that four times as many wolverine are taken as are exported.

White whale hunting is a major activity for residents of Tuktoyaktuk but this activity is restricted to the Mackenzie Delta area. Each year an average of about 140 white whales are landed. No whale hunting occurs in the McKinley Bay area.

Caribou hunting is prohibited in the Reindeer Grazing Reserve, which includes all of the Tuktoyaktuk Peninsula. Caribou hunting by Tuktoyaktuk residents is carried out in areas south of the Tuktoyaktuk Peninsula between the Anderson and Kugaluk rivers, and on Cape Bathurst (Freeman, 1976a).

Waterfowl hunting by Tuktoyaktuk residents occurs along the coast of the Tuktoyaktuk Peninsula from the Mackenzie Delta to Warren Point (F

Trapping

The numbers of furs of terrestrial mammals exported from Tuktoyaktuk are shown in Table 3.6-1 .

Arctic foxes were previously trapped during the period from 1 November to 30 April, but regulations have been changed, and in 1979-80 the trapping season will extend from 1 October to 15 April (D. Vincent, pers. comm.). Most arctic foxes taken by Tuktoyaktuk trappers are taken in coastal areas between Hooper Island and Cape Bathurst (Freeman, 1976a). Arctic fox traplines are numerous along the coast of the Tuktoyaktuk Peninsula and include the McKinley Bay area. The numbers of arctic foxes taken in this area are unknown. In general, arctic fox numbers are cyclic and in 1978-79, the population was apparently at a low and few animals were taken (D. Vincent, pers. tom.).

The numbers of red foxes trapped in recent years has apparently increased (Table 3.6-1)and in 1978-79 apparently many foxes of this species were taken by Tuktoyaktuk trappers (D. Vincent, pers. comm.). Red fox furs were being sold for an average price of approximately $150 and cross fox furs about $250 (Edmonton Fur Auction Sales (1972) Ltd. , pers. comm.). Most red fox trapping is carried out in the Eskimo Lakes area and in the Smoke and Anderson rivers area (Freeman, 1976a).

Wolves and wolverine may be taken in the McKinley Bay area, but most of these and the other furbearers are probably taken in areas to the south and west of the Tuktoyaktuk Peninsula.

Fishing

Freeman (1976 in Fenco and Slaney, 1978) recorded that some fishing occurred in Hutchison and McKinley Bays, but data on catches are not available. The species that were taken in McKinley Bay were probably ciscoes and whitefish.

Although there is historical evidence of fishing in McKinley Bay, the bay does not appear to have been fished by residents from surrounding areas for the past 4 to 5years (Richard Barnes, Federal Fisheries Officer, Inuvik, pers. comm.).

4.0 INVENTORY OF PAST DREDGING PROJECTS AND DOCUMENTED IMPACTS IN THE SOUTH BEAUFORT SEA

This report section addresses the sources and types of previous dredging impact studies that have been completed in the southern Beaufort Sea. Summaries are presented of each type of environmental impact noted in the reports cited.

Descriptions/Sources of Recent Pertinent Dredging Studies

All pertinent dredging impact studies in the south Beaufort Sea have been conducted in connection with artificial island construction and hydrocarbon exploration during the last eight years in waters offshore of the Mackenzie Delta (Appendix 4.0-1). Most studies have been industry sponsored and at the request of government regulatory agencies. In particular, ESSO Resources Ltd. (Imperial Oil Limited) have sponsored many of the dredging-related programs. Some of these reports are available to the public while others are proprietary information of the sponsor oil company.

Since 1972, over twenty artificial islands have been or are being constructed as platforms for exploration drilling operations. As a result, several oceanographic inventory and monitoring programs have been conducted, and some of these have assessed the direct or indirect effects of the dredging-related activities on physical/biological processes. Artificial islands were constructed with materials from three primary sources; these included: bottom granular and silt materials dredged in summer from marine areas immediately adjacent to island sites; granular materials dredged in summer from marine areas considerably removed from island sites and transported by tug and barge; and, sands and gravels mined in winter from borrow pits on shore and transported to the island sites by truck on winter ice. Most island construction materials, however, were taken from the marine sources using clamshell and suction-type dredges, and these activities were the focus of several studies.

In 1976 ARNAK L-30 artificial island in Kugmallit Bay was constructed by Imperial Oil Limited using the "Beaver Mackenzie" (Figure 3.2-2), the largest suction dredge utilized to date in the southern Beaufort Sea. The island was built in 35 days with approximately 1.5 million cubic yards of granular materials dredged from marine areas surrounding the island and transported to the island site by a floating pipeline. An intensive biophysical program of aquatic studies at the ARNAK L-30 site to examine the effects of environmental perturbations associated with uncontained hydraulic fill activities was carried out for Imperial Oil Ltd. by F.F. Slaney & Company Limited (1977). During July and August 1977, Imperial constructed ISSERK F-27 artificial island and concurrently sponsored an environmental baseline and monitoring study of the hydraulic dredging and barging activities (Envirocon, 1977). These two studies provide the most detailed recent impact assessments of dredging in the southern Beaufort Sea.

A recent study on the proposed Mackenzie River Dredging Project (Renewable Resources, 1978) provides some additional information regarding possible mitigative measures in Mackenzie River waters. Inventory studies of Tuktoyaktuk Harbour granular material resources by Hardy (1977 and 1978) also address the potential environmental impacts associated with dredge removal of gravel and disposal of the overburden at marine or terrestrial sites.

Identified Environmental Impacts

Dredging-related activities in the south Beaufort Sea have been identified to have certain impacts on the physical, chemical and biological environments. The following summary of observed or anticipated dredging-related impacts to physical/chemical features and import bioresources of Mackenzie and Kugmallit Bay has been based on a review of available and pertinent information.

Physical and Chemical Oceanography

The most immediate impact of dredging on the physical environment is an alteration in bottom bathymetry. In dredged shallow marine areas (depths <2 m) where winter ice usually freezes to the bottom, a thicker winter ice cover can often result. This may cause localized and short term delays and changes in break-up patterns during the spring. Large scale deep excavations in nearshore waters can also result in changes in wave refraction processes, such that the pattern of wave energy reaching the coastline is modified. Localized shoreline erosion and/or deposition effects can also result under these circumstances. Changes to sediment composition due to dredging and deposition of the dredged materials have been shown to increase the percent composition of silts and clays in bottom materials within approximately a 1-km radius of suction dredge outlets (Envirocon, 1977; McDonald and Cambers, 1977).

Dredging and broadcast of marine sediments has been observed to cause significant increases in suspended materials, turbidity and sedimentation rates downstream of the dredge (McDonald and Cambers, 1977). These effects are most pronounced during freeze-up when background turbidities are typically lower. Inside the Mackenzie plume the effects of dredging are not easily distinguished from background turbidity levels during much of the open water season.

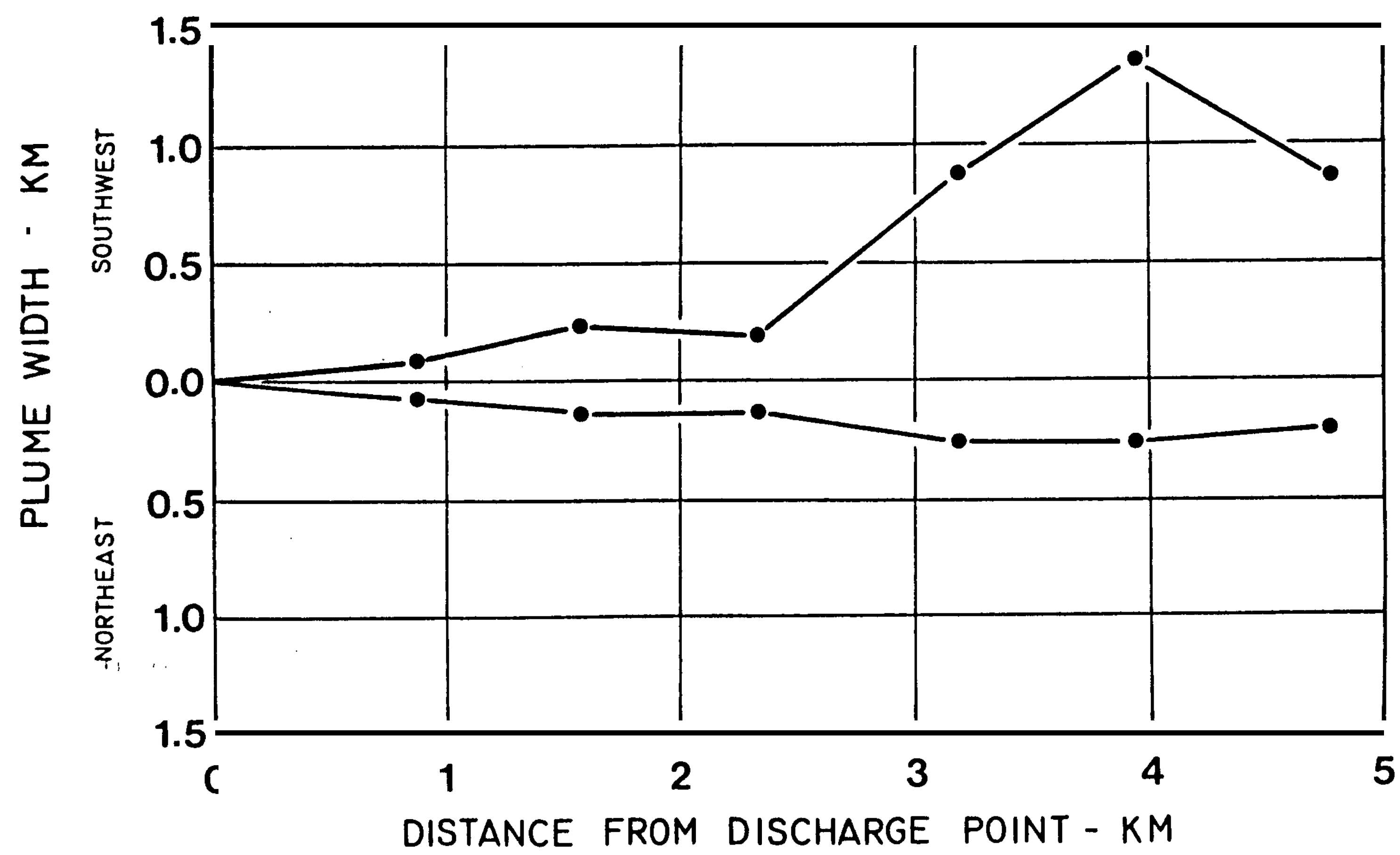
A detailed investigation of the surface transmittance inside and outside the dredge-created plume at ARNAK L-30 was conducted for Imperial Oil Limited by McDonald and Cambers (1 977). The results of this survey indicated that the dredging operation resulted in reduced transmissibility over an operating radius of between 1 and 5 km for the artificial island site (Figure 4.0-1). Horizontal cross-sections of transmissibility were measured downstream within the plume and ranged from 82% to 40% at its outer edges to 0% at the core of the plume (Figure 4.0-2). Background transmittance levels in areas not affected by the plume were variable (maximum of 82%) and depended on the presence or absence of Mackenzie River water at the dredge site.

FIGURE 4.0-1

HORIZONTAL EXTENT OF MEASURABLE TURBIDITY PLUME CHARACTERISTICS

Downstream Arnak L-30, Az = 149°

July 31, 1976



Source: McDonald and Cambers, 1977

FIGURE 4.0-2 **Page** One

DOWNSTREAM EFFECTS OF DREDGING
ON SURFACE LIGHT TRANSMISSIBILITY
Downstream **Arnak** 1-30, Az = **149°**

(Source : McDonald and Cambers, 1977)

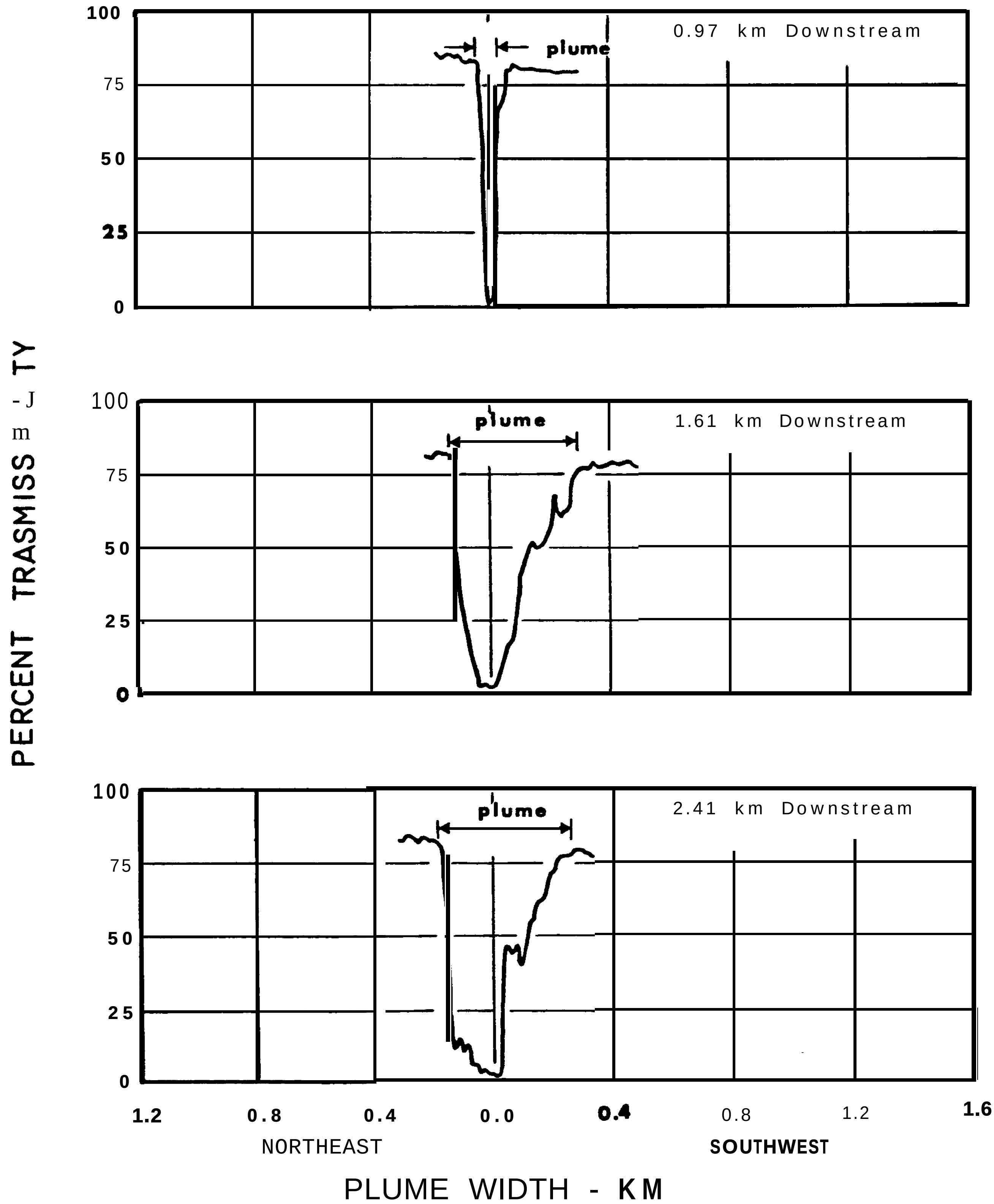


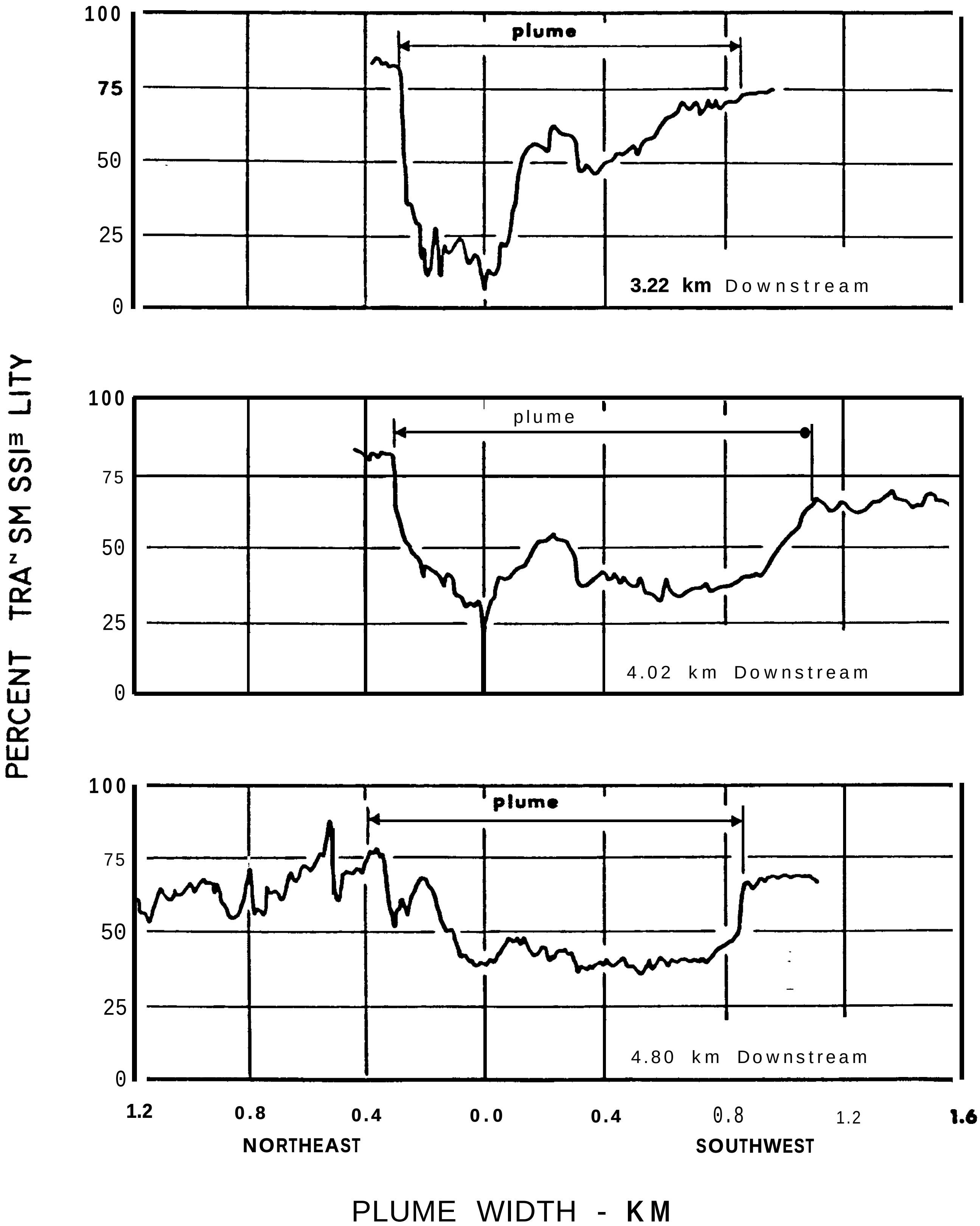
FIGURE 4.0-2 Page Two

DOWNSTREAM EFFECTS OF DREDGING

ON SURFACE LIGHT TRANSMISSIBILITY

Downstream **Arnak** L-30, **Az = 149°**

(Source: McDonald and Cambers , 1977)



Vertical cross-sections of transmissibility inside and outside the influence of the plume are shown in Figure 4,0-3. The plume-affected station shows that about 2/3 of the vertical water column had been influenced by sediment from the plume at the time of measurement.

Levels of suspended solids measured outside and inside the visible dredge plume at ARNAK L-30 artificial island during 1976 ranged from 8.8 to 66.0 ppm and from 25.3 to 333.0 ppm, respectively (McDonald and Cambers, 1977). However, summer storms elevated natural suspended solid levels in nearshore areas to as high or higher than waters disturbed by dredges (McDonald and Martin, 1976), and concentrations of turbidity, settleabl e materials and suspended solids returned to pre-dredging levels shortly after the dredging operation had ceased (McDonald and Cambers, 1977).

Very localized, short term reductions (l-2 mg/ℓ) in dissolved oxygen concentrations have been observed in turbidity plumes created by dredging, although lower short term bottom dissolved oxygen concentrations (4 and 6 mg/ℓ) have been measured near artificial islands after storm events (McDonald and Cambers, 1977; McDonald and Martin, 1976). Breaking waves are probably the cause of these low DO concentrations due to their uplifting of organic bottom materials with a higher biochemical oxygen demand.

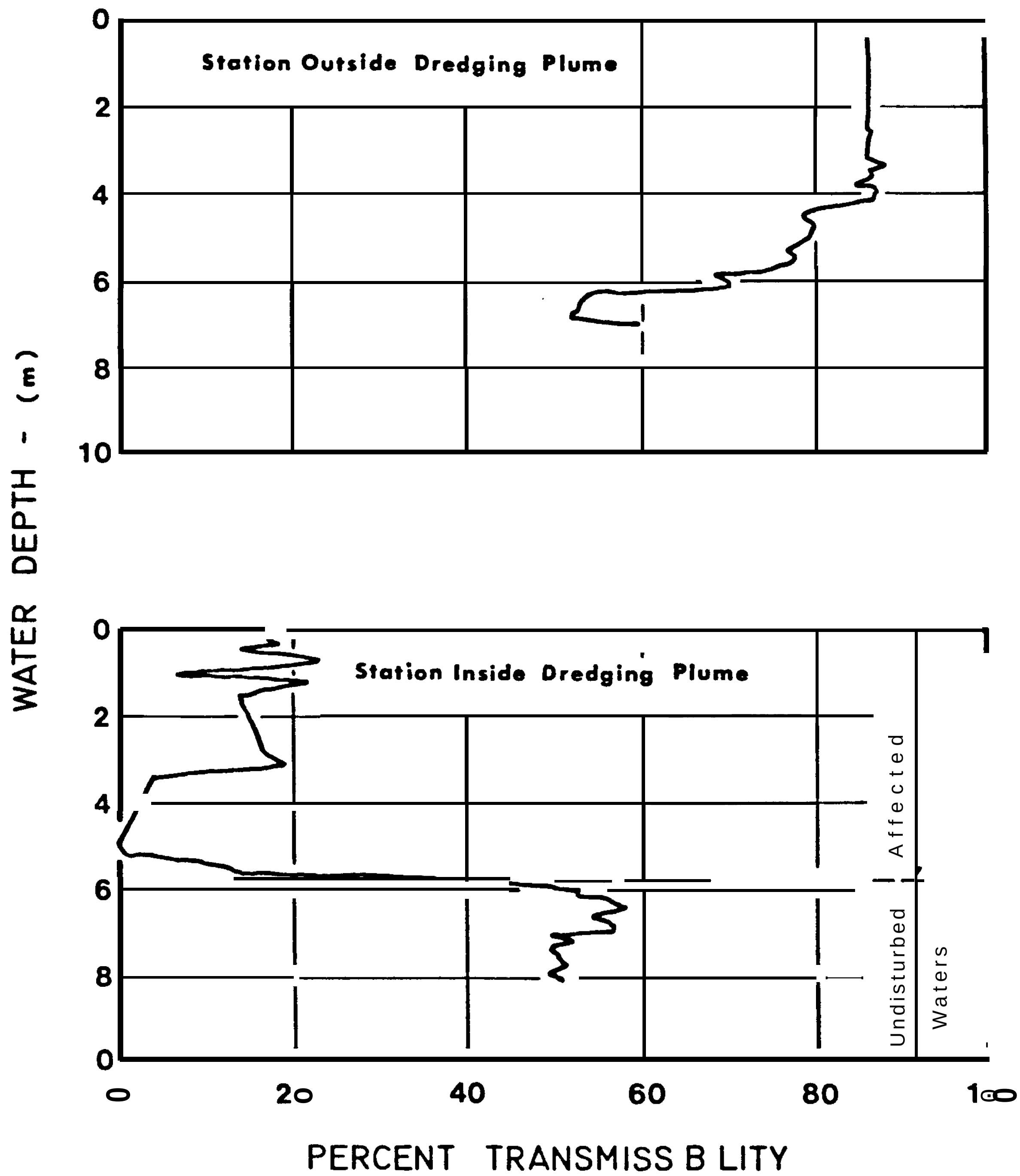
Short term dredging-related variations in vertical temperature and salinity stratification have also been documented. During July 1976, a strong halocline and thermocline were measured outside the dredging-created plume at ARNAK L-30. Monitoring within the ARNAK plume indicated that hydraulic dredging had caused localized mixing of warmer and less saline surface water with cooler saline waters from greater depths, resulting in a homogeneous vertical profile within the plume (McDonald and Cambers, 1977). However at ISSERK during August 1977, there was little apparent background stratification and therefore any subsequent changes resulting from mixing within the dredging plume were not detected (Envirocon, 1977).

FIGURE 4.0-3

TRANSMISSIBILITY WITH DEPTH

July 31, 1976

(Source: McDonald and Cambers, 1977)



Whales and Marine Mammals

The most significant potential impact of dredging activities on marine mammals appears to be associated with logistics traffic which has been reported to disturb whales in some instances, and also to block or impede their movement (Fraker *et al.*, 1977). Ford (1977) examined sounds produced by operating dredges and suggested that they were audible to whales within a radius of 2,900 m, and may result in avoidance responses within this distance. It has also been suggested that cumulative disturbances to whales during their residence in the Mackenzie Estuary may affect their reproductive success; however, insufficient data is available to substantiate or quantify this possible impact.

The possibility of adverse effects to the whale hunt may occur if dredging occurs in or near traditional native hunting areas during the whaling season. However, monitoring of the whale hunt in the Mackenzie Estuary since 1972 has not identified any reduced success in whale hunting due to industrial activities in the area (Fraker *et aZ.*, 1977). Conflicts with whalers have been avoided by conducting concurrent whale monitoring programs, and when necessary, rescheduling specific logistics and development activities (Fraker, 1976).

Fish

The most common fisheries concerns related to suction dredging activities at artificial island sites are localized losses of supportive food sources (zooplankton and epibenthic invertebrates), alterations in migration patterns due to local increases in the suspended silt load and turbidity, and alterations of loss of fish habitat because of dredging disturbances and the has resulted in low levels of concern for arctic fish near dredging-related activities at artificial island sites. Fish populations utilizing Mackenzie Bay during summer do not use the area for spawning; consequently, no physical interference with spawning has been suggested during open water dredging activities (Poulin, 1976). Although herring may spawn during the late spring, they likely do not utilize silt and sand substrates where dredging operations tend to be centered.

Plankton

Hydraulic suction dredging in the shallow waters of the turbid Mackenzie Estuary has to date had no significant adverse phytoplankton species composition or diversity (Duval, 1977; Jones and Den Beste, 1977). In some surface samples, an increase in chlorophyll a concentration suggested that reduced rates of primary production will likely occur in deeper (1 to 5 m) waters due to light attenuation beneath the turbid plume (Duval, 1977).

Hydraulic suction dredging in deeper waters outside the influence of the Mackenzie River plume which results in marked reductions in light intensity could lead to short term, localized decreases in photosynthetic rates, changes in phytoplankton species composition and diversity, and reductions in phytoplankton standing crop (Duval, 1977). Some studies have demonstrated marked increases in zooplankton grazing rates in surface turbidity plumes created by hydraulic dredges, although differential ingestion of larger phytoplankton cells may have contributed to the increased grazing rates within turbidity plumes (Duval , 1977). Duval (1977) also reported that the abundance and individual size of zooplankton collected from within the ARNAK L-30 plume were also significantly higher than in adjacent waters outside the influence of the dredging operation.

Benthos and Epibenthos

The most significant direct impacts of dredging operations to infaunal invertebrates are their physical burial and removal during excavation and redeposition of spoil (Bengeyfield, 1976; Envirocon, 1977). However post-construction sampling adjacent to some artificial islands has shown that infaunal recolonization of totally disturbed areas may commence rapidly (within one year) after termination of dredging (Bengeyfield, 1976) . Larger epifaunal benthos are generally mobile enough to avoid areas of high sediment deposition, although site specific alterations in benthic productivity may result if dredging affects nutrient recycling and primary production.

Another possible short term impact of dredging to filter-feeding infaunal species may be a reduction in their filtering efficiency as a result of increased siltation and larger size particles suspended in the water column (Olmsted, 1977); however, there have been no actual observations of this form of sublethal effect.

In general, monitoring of dredging activities in turbid nearshore waters has confirmed only short term and site-specific effects on benthic and epibenthic communities (Jones and Den Beste, 1977; Bengeyfield, 1976; Envirocon, 1977; Olmsted, 1977).

5.0 ENVIRONMENTAL IMPACTS AND MITIGATION

5.1 Summary of Potential Major and Residual Impacts

This section was prepared largely by ESL Environmental Sciences Ltd. and LGL Limited in consultation with Dome/Canmar. It serves to summarize potential major and/or residual impacts of the proposed dredging program, related activities, and use of the McKinley Bay harbour for overwintering of drill ships and icebreakers. Impacts are summarized on a discipline basis in point form.

Climate and Sea Ice

Changes in ice breakup conditions in McKinley Bay can be expected as a result of proposed breaking-out programs in the spring. Icebreaker movements and reductions in ice cover caused by coal dusting and snow-insulating may cause an advance in breakup by as much as one month.

Oceanography

(a) Major short and long term effects of proposed dredging activities on bottom sediments and bathymetries can be anticipated. The spatial extent of disturbance within and outside McKinley Bay are estimated at 5.85 km^2 and 18.77 km^2, respectively, including the dredged channel, moorage basin and spoil areas. The percent of the bottom surface of McKinley Bay that will be either directly covered by heavier spoils and dispersed fines or excavated is estimated at 5.85%.

(b) A turbidity plume of suspended fines may extend for several kilometres beyond the dredging site. Based on previous studies conducted during construction of an artificial island, deposition of heavier fines (silts) will probably occur within 0.5 km of spoil sites to average depths of approximately 16 cm.

(c) Major short term increases in suspended sediment levels and turbidity can be anticipated throughout the duration of the program.

(d) Short term changes in water quality and long term alterations in sediment chemistry can be expected in the event of a major oil spill within or outside McKinley Bay.

Planktonic Communities

(a) Short term changes in the productivity and abundance of phytoplankton and zooplankton communities may result from alterations in nutrient levels and light transmissibility associated with dredge-created turbidity plumes. These changes could Persist throughout the duration of the dredging program. Surface productivity may be increased, although production in deeper waters and on an aerial basis could be significantly reduced. Potential reductions in primary production, if they occurred early in the growing season, could have implications to other marine bioresources because of the high degree of trophic interdependence within arctic marine ecosystems. However, adverse impacts of dredging on planktonic communities would be restricted to the region continuously or intermittently affected by the turbidity plume.

(b) A large oil spill could have major short term adverse impacts (acute lethal and sublethal) to phytoplankton and zooplankton communities.

Infaunal and Epibenthic Invertebrates

(a) The proposed dredging program could result in the direct loss (by burial and smothering) of approximately 49 x 10^3 kg of benthic infauna and epifauna over an estimated area of 24.7 bn^2 within and outside McKinley Bay. Recolonization of affected areas by infauna would probably begin within a year of the disturbance but could require several years to reach pre-disturbance status. Recruitment of mobile epifauna to disturbed areas would be relatively rapid, and probably reach normal abundance levels within a few months.

(b) Maintenance dredging, if required, would delay re-establishment of infaunal and epibenthic invertebrates in dredged channels, basins and spoil deposition areas.

(c) Any diesel oil reaching the sediments following a large oil spill could have long term effects on the abundance and diversity of hersthic invertebrates, particularly infauna.

Fish

(a) The majority of the potential impacts of the proposed dredging program to fish will be short term and minor.

(b) Entrainment of young-of-the-year, small fish, and planktonic stages into the cutter-suction dredge will result in direct but relatively minor losses; demersal species will be the most vulnerable to entrainment.

(c) Although most anadromous fish follow and remain in close proximity to shorelines during migration, individuals found further offshore in areas where the dredge is operating or in areas affected by the turbidity plume may have migration patterns altered or delayed.

(d) If turbidity plumes extend into shoreline environments, some loss or disturbance of spawning habitat and nursery areas could occur as a result of siltation. This area of concern would be greatest during the 1980 spring-summer dredging program and during any spring maintenance dredging since marine species (other than herring) spawn during winter with eggs hatching in late winter or early spring. It is thought that herring spawn in the spring. However, most marine species are not selective spawners and would probably move into adjacent undisturbed areas.

(e) Dredging will result in some temporary alteration of habitat for demersal species as well as short term reductions in food supplies due to mortality of benthic invertebrates in disturbed areas. Both effects will be relatively short term except in areas where maintenance dredging retards or prevents recolonization by benthic food organisms.

(f) A large fuel spill could have major short term effects to fishery resources of McKinley Bay and adjacent areas. The severity of such effects would depend on the location and size of the spill, fish abundance, stage of development and the type of habitat affected.

Marine Mammals

(a) The assessment of impacts of the proposed dredging program and subsequent activities on marine mammals is limited by the level of information regarding the use of McKinley Bay by both seals and whales.

(b) White whales occur in and near McKinley Bay during the summer, and dredging activities during this period could affect the entrY of whales into the bay while dredging is in progress.

(c) Ice-breaking activities in the spring could result in some mortality of ringed seal pups.

(d) A major oil spill could result in some mortality of marine mammals (primarily seals) if individuals came into direct contact with the surface slick.

Terrestrial Mammals

(a) The proposed dredging operations and overwintering activities associated with the drilling fleet are not expected to impact upon terrestrial mammals.

(b) Foxes, grizzly bears and wolves may be attracted to the over-wintering area, but proper garbage disposal will minimize this potential problem.

Birds

(a) The proposed dredging operations and overwintering activities associated with the drilling fleet are not expected to have a significant impact upon the bird resources of the McKinley Bay area.

(b) A fuel spill in McKinley Bay could result in mortality to birds and fouling of shoreline habitat. The potential magnitude of these effects would depend on the size and timing of the spill, and on the effectiveness of containment and cleanup procedures.

Resource Utilization

The fox trapping season in 1979-80 will begin on October lst. Fall icebreaking activity in fast-ice areas in McKinley Bay may temporarily impede movement by trappers along the coast, depending on when they begin to travel on the ice along the coast.

5.2 Discussion of Potential Environmental Impacts

This section was prepared largely by ESL Environmental Sciences Limited and LGL Limited in consultation with Dome/Canmar. It serves to identify and discuss potential environmental impacts associated with the proposed dredging and harbour related activities leading to the development of recommended mitigation measures and, where appropriate, monitoring programs.

Climate and Sea Ice Impacts

The generation of a small artificial island of dredged material inside McKinley Bay adjacent to the mooring basin may have minor influences on ice cover formation in parts of McKinley Bay. Freeze-up in the immediate vicinity of the island may be slightly advanced due to possible reductions in thermal mixing and reduced circulation.

Proposed break-out operations in the spring will affect ice breakup conditions in McKinley Bay and the access channel leading to open water.

It is anticipated by Dome that the icebreaker could start "milling around" in McKinley Bay as early as May, testing the strength of winter ice cover along the entrance channels and basins. It is also hoped that coal dusting and thermal snow packing along the channels will not only reduce the thickness of ice cover but also enhance thermal decay. The result may be an advance of breakup in McKinley Bay of as much or more than a month ahead of that which would have occurred naturally for the bay.

Offshore, the icebreaker will attempt to cut a swath probably in May-June through the land-fast ice from McKinley Bay north to the drill sites. This could cause some weaknesses in the land-fast ice and may result in some additional localized movement and advancement in breakup along the route, especially near the shear zone (edge of moving pack ice and land-fast ice). However, if the icebreak route is single and straight, the extent of the disturbed and weakened ice will probably be small in comparison to the large area of anchored land-fast ice in the area.

Oceanography Impacts

Dredging and Related Activities

(a) Bottom sediments and coastal processes

The dredging program and associated spoiling of dredged materials will alter the bathymetry of the area. Table 5.3-1 provides general estimates of the total physical areas which may be directly disturbed within and outside McKinley Bay. On the basis of the calculations, a total of 24.62 km^2 (5.85 + 18.77) may be physically impacted by dredging or deposition of heavy and/or fine spoils fractions. Of this total, approximately 5.85 km^2 or 5.85% of the estimated area of McKinley Bay may be influenced by one or another of the components.

A general physical assumption is made related to fines dispersal adjacent to spoil sites. During the marine broadcast of dredged materials, the heavier spoils (sands and gravels) should settle out direct"ly but the fines (silts and clays) will take longer to settle and, dependent on currents, will spread over larger distances. No current measurements are available for inside McKinley Bay, however it is expected

TABLE 5.3-1

APPROXIMATE ESTIMATES OF AREAS TO BE DISTURBED DURING THE PROPOSED DREDGING OF THE ACCESS CHANNEL AND MOORING BASIN

Total Area of McKinley Bay: 100 km^2 (from grid estimates)

Area of Proposed Mooring Basin:

1.2 km x 0.8 kmwide = 0.96 km^2

Area of Proposed Spoil Material Dumping Adjacent to Mooring Basin:

2.4 km long x 1.04 kmwide = 2.49 km^2

2.4 km long x 2.04 kmwide = 4.89 km^2 (Heavier spoils plus dispersed fines $\pm$ 0.5 km outside heavier fines)

Total area of possible disturbance created by dredging and spoiling of material from mooring basin in McKinley Bay (including heavier spoils, fines and dredged basin):

(0.96 + 4.89) = 5.85 km^2

Percent of area within McKinley Bay that may be either directly covered by heavy spoils or dredged out during the proposed project:

$$\frac{(0.96 + 2.49) \times 100}{100} = 3.45\%$$

Percent of area within McKinley Bay that may be either directly covered by heavier spoils and dispersed fines or dredged out during the proposed project:

$$\frac{(5.85) \times 100}{100} = 5.85\%$$

Area of Proposed Access Channel to be Dredged (outside McKinley Bay):

9.8 km long x 0.115 kmwide (30° slope) = 1.13 km^2

Area of Proposed Spoil Materials Dumping from Access Channel:

9.8 km long x 0.8 kmwide = 7.84 km^2

(9.8 km long x 1.8 km wide) = 17.64 km^2 (Heavier spoils plus dispersed fines $\pm$ 0.5 km outside heavier fines)"

Total area of possible disturbance created by dredging and spoiling of material from access channel leading into McKinley Bay (including heavier spoils, fines and dredged channel): (1.13 + 17.64) = 18.77 km^2

that undermost operating conditions the currents will be light (20 cm/see) and variable because of the small tides and wide entrance. A conservative assumption is therefore made that most significant fines deposition (silts) will occur within about 0.5 km of the deposition site, although the actual turbidity plume may extend several kilometres beyond. The settled fines may in some bottom areas reach thicknesses of several centimetres but depths are expected to be highly variable dependent on currents and duration/ volume of spoils discharge. If 25% of the dredged materials were evenly distributed as slowly settleable fines within a 0.5 km perimeter of the heavier spoils piles, an average layer of sediments approximately 16 cm thick would settle out over the existing substrate. This settling may also cause an increase of the silt/clays percentage composition in the effected bottom materials but probably no geochemistry changes (see Section 4.2). However, it must be stressed that these estimates are extremely hypothetical at this stage. In-situ monitoring near the actual spoil dispersal sites would be required to obtain more specific, quantitative estimates for spoiled sediments dispersal.

A possibility of long term minor effects on sediment transport processes may occur as a result of the design configurations for dumping of spoil materials. The results of on-going coastal processes examinations in the McKinley Bay area by Dome will certainly be necessary to determine the final locations for dredged channels and spoil sites.

(b) Circulation and Mackenzie plume movements

Since no alteration to the shore zone features are contemplated and since the small “artificial island” to be created will be located well inside McKinley Bay, no significant changes in circulation and of Mackenzie plume movement would be anticipated. Moreover, the "artificial island" created is expected to erode below the water line within a couple of years, thereby further reducing the possibilities of significant effects upon circulation occurring.

(c) Salinity and temperature

The colder, more dense, water and bottom sediments discharged at the surface during dredging will generate considerable mixing, possibly breaking down local vertical stratification to some degree. However, such localized stratification effects are expected to be small and should last only as long as the dredge is operating.

A possibility exists also that McKinley Bay may become slightly more saline in summer due to the newly dredged deeper channels allowing more saline bottom waters into the bay which can easily be mixed to the surface during moderate to high wind/wave activity.

(d) Suspended sediments, turbidity and water quality variations

Major short term increases can be expected in suspended sediments and turbidity loading with resultant reductions in light transmissibility through the water column in part of McKinley Bay during the actual dredging process. As described in Section 4.0, elevated levels of suspended sediments and turbidities from cutter-suction dredging activities atARNAK L-30 were traced for up to 5 km from the deposition site. In calculating deposition areas for settleable fines, it is assumed that currents would most probably be small and variable during operating conditions and that most settleable fines would be deposited within about 0.5 km of the spoil sites. Depending on in-situ wind conditions and tidal circulation within the bay at the time, a turbid plume could extend much further, clouding the water column for several kilometres downstream of the site. At ARNAK L-30, with similar sediments conditions, turbidity and suspended solids levels were significantly increased inside the dredging plume (McDonald and Cambers, 1977). Upper ranges of turbidities increased from about 20 ppm SiO_2 before dredging to as high as 118 ppm SiO_2 during dredging. Also, during dredging, the mean surface turbidity outside the turbidity plume when the Mackenzie plume was present was 40.6 ppm and inside the plume was 63.8 ppm SiO_2. Increased turbidities were experienced to some degree in all directions for at least 1.5 km.

Although the turbid Mackenzie plume does not frequent McKinley Bay as often as it does at ARNAK L-30, natural wave action along the shallow McKinley Bay shoreline would be expected to elevate turbidities and suspended solids frequently. The major difference being a higher salinity of the turbid water present naturally in McKinley Bay. Open water effects of dredging plumes on sediments loading in McKinley Bay would thus be most pronounced during calm periods, but since these are usually occasions when the Mackenzie plume is expected to frequent the area, the visual effects will probably be somewhat modified. McDonald and Cambers (1977) experienced difficulty in visually discerning the dredging-induced turbidity plume from the Mackenzie plume during periods of their overlap, although differences in turbidities and suspended sediments of 20 to 40% were measurable by instruments.

A short-term minor effect on dissolved oxygen levels may also occur during dredging in McKinley Bay and just offshore. Because of the dredging spoils plume, a slight (1 to 20 mg/l) lowering of dissolved oxygen may occur inside the plume but would soon be replenished by the high natural saturation levels of oxygen in these waters (McDonald and Cambers, 1977). Nutrient levels are not expected to be altered to any great extent unless the sediment overburden is rich in organic detritus resulting from sinking of planktonic organisms and decomposition of benthic invertebrates.

Proposed Harbour Use - Oceanography Impacts

(a) Bottom sediments and coastal processes

Minor but potentially long term changes to bottom sediments and bathymetry may occur as a result of break-out processes in the spring. When the icebreaker tries to break open McKinley Bay and entrance for the drill ships to escape in May-June, large rafts of ice may be moved around the open portions of the shallow bay waters. Some scouring of bottom sediments may result with redeposition of both heavier and fine sediments. Propellor turbulence during maneuvering may also elevate large amounts of fines at this time when under-ice sediments loading and turbidity is probably at an annual low. A two to four day period for most of the fines to settle to the bottom will probably be required after all ships' activities stop. Sediment spread outside immediately disturbed areas will probably be small, although no information on under-ice currents in McKinley Bay is available.

(b) Circulation and Mackenzie plume movements

The general circulation and interaction of McKinley Bay waters with Mackenzie plume should not be affected by proposed harbour use.

(c) Salinity and temperature

No anticipated long term effects are expected.

(d) Suspended sediments, turbidity and water quality variations

Under normal harbour use there will be only minor short-term effects on water quality. Long term effects could occur in the event of a major oil spill.

During spring break-out exercises the movement of ice and bottom materials by icebreakers maneuvering in McKinley Bay may cause localized but potentially large increase in turbidity and suspended solids. It will also occur at a time of year when natural sediment loading is lower and will probably last until at least 2 to 4 days after operations cease.

Other minor water chemistry impacts may result from the settling of coal dust into the water column after the breaking-out process, the discharge of treated sewage from the ships and the possibility of small chronic spills of hydrocarbons. Sewage discharges will cause localized increases in nutrients but only during the spring break-out exercises. During winter, Dome's plans are that there will be no crew on board and hence no sewage discharge from the ships. Small chronic spills of diesel oil on ice may also occur during re-fuelling by haul trucks from Tuktoyaktuk in the winter but no major impacts are expected. Ambient air temperatures would be near or below the average pour point of diesel fuels (-20° C). Any toxic constituent?

of spilled fuel (primarily volatile aromatic hydrocarbons) would dissipate to the atmosphere, before spring, further reducing the volumes of oil that could reach the water colum.

A large oil spill in the Bay could cause long term effects on water chemistry and bottom sediments. Most oil would probably remain inside the Bay deposited on shorelines and mixed with bottom sediments because it has been noted as a "sediment sink". Assuming normal conditions, a major spill due to a shipping accident outside McKinley Bay would probably be transported along the Tuktoyaktuk Peninsula towards Amundsen Gulf, potentially soiling a considerable area of coastline. Surface oil, oil/water emulsions and oil mixed with sediments may be transported under the ice and along open water areas. The Dome contingency plan emphasizes containment of all oil inside McKinley Bay. Pertinent recent studies describing technical oil/ice/sediments interactions in Arctic waters include Walker (1975), NORCOR (1975), Wong et al. (1976), and Slaney (1978).

Impacts to Planktonic Communities

Dredging and Related Activities - P-lankton Impacts

(a) Phytoplankton Impacts

The three major environmental factors affecting the species composition, growth and primary productivity of phytoplankton communities are temperature, nutrient availability and light intensity. In nearshore areas of the southern Beaufort Sea suchas McKinley Bay, the phytoplankton community is dominated by centric diatoms (Bacillariophyceae, centrales) adapted to relatively low light intensities and higher nutrient concentrations associated with the suspended sediment plume of the Mackenzie River (Hsiao, 1976). In the less turbid offshore waters outside the periodic influence of the Mackenzie River, the phytoplankton community is predominately flagellates (Chrysophyceae) and dinoflagellates (Dinophyceae) adapted to highlight intensities and low nutrient levels. Primary productivity and phytoplankton abundance is typically highest in the nearshore areas (Hsiao, 1976; Hsiao *et al.*, 1977).

Any potential impacts of dredging activities on McKinley Bay phytoplankton communities will be localized and a direct function of changes in physical and chemical oceanographic conditions within the bay. Potential changes in the oceanographic character of McKinley Bay which could affect primary producers during and shortly after the dredging program include: redistribution of bottom sediments, increased suspended sediment loads in the form of a turbidity plume, disruption of normal temperature and salinity stratification, and a general increase in average salinities.

Redistribution of bottom sediments and deposition of spoil materials may have a short term positive impact on phytoplankton communities since nutrients associated with these sediments and any organic overburden will likely be simultaneously re-distributed throughout the water column. There are no available data describing nitrate, phosphate and silicate levels in the sediments of McKinley Bay, although the fact that the bay is norms"lly a sink for suspended sediments carried by the Mackenzie River (Section 3.2) reinforces the possibility that nutrients carried by this watercourse also accumulate in the bay. Grainger (1975) reports that the Mackenzie River is rich in nitrate and silicate but not phosphate, and that offshore phytoplankton communities are limited by nitrate availability. Release of nitrate and silicate from sediments and overburden as a result of dredging activities could result in spatially restricted and short term increases in the growth and production of nutrient-limited phytoplankton species. These species would likely include dinoflagellates and flagellates, although growth of diatoms could also be stimulated by higher ambient silicate concentrations. It should be emphasized, however, that this type of positive impact would occur only if nutrients and not light is the major factor limiting photosynthetic production by McKinley Bay phytoplankton communities.

As indicated earlier, dredging activities within McKinley Bay will create a turbidity plume which could extend several kilometres from the sites of sediment removal and deposition. Increased turbidity will decrease light intensities throughout the water column and also result in a slight shift in the quality of light towards the red end of the visible spectrum. Changes in light quality will not likely cause any significant effect on phytoplankton communities since the presence of accessory pigments generally facilitates absorption of a wide range of light wavelengths. On the other hand, decreased light penetration could reduce primary production if phytoplankton are adapted to relatively high light levels. However, given the normally high background turbidity levels within nearshore portions of the southern Beaufort Sea, and the fact that "shade-tolerant" phytoplankton species (particularly centric diatoms) predominate in these waters, potential reductions in photosynthetic production are likely to be restricted to only the deepest portions of the water column.

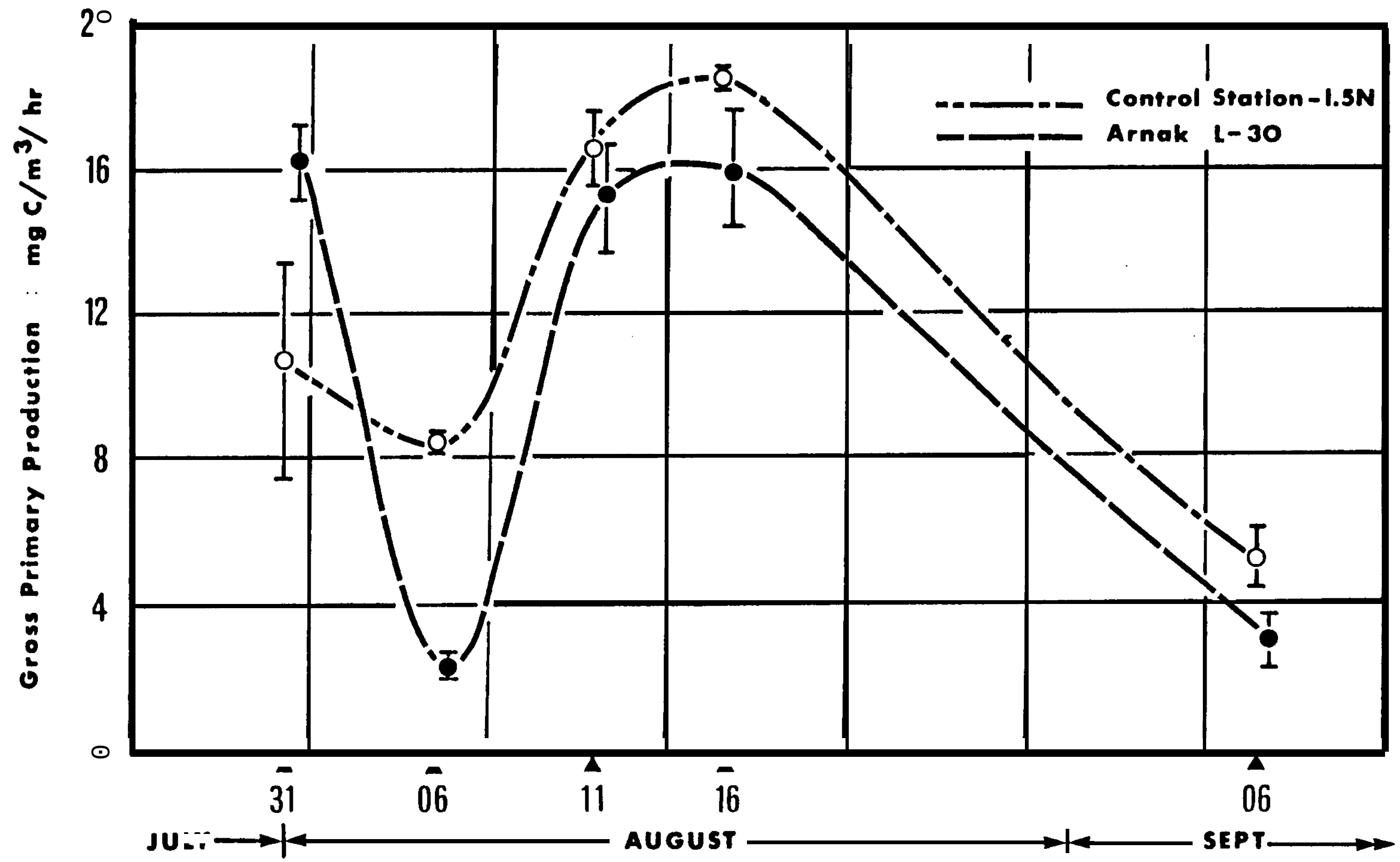
Possible disruption of the normal temperature and salinity profile within the dredge-created turbidity plume could alter sinking rates and the overall vertical distribution of phytoplankton. However, such effects are considered relatively insignificant since they would have no sustained positive or negative impacts. On the other hand, greater exchange with offshore waters could potentially alter the species composition and diversity of the phytoplankton community. Although the lack of data describing the present species composition of the McKinley Bay phytoplankton community limits accurate delineation of probable changes, these could include a reduction in the relative abundance of Chlorophytes (eg. Euglena spp.) and an increase in the proportion of flagellates (Chrysophyceae) more typical of saline offshore waters.

The effects of physical and chemical perturbations associated with dredging activities were examined during the construction of ARNAK L-30 artificial island in the Beaufort Sea (Duval, 1977). The species composition, diversity, standing stock and productivity of surface phytoplankton communities within and outside the dredge-created turbidity plume were examined at several times during and following the construction program. In general, there were no major differences in the species composition of phytoplankton communities collected from control and turbid waters. The diversityof surface phytoplankton communities was also unaffected by the construction activities. Surface chlorophyll a concentrations were increased by the dredging activities, suggesting that nutrients contained in the overburden stimulated primary production within the upper few centimeters of the water column. However, measurement of rates of gross primary production did not reinforce this potential positive impact. Although rates of GPP were approximately 60% higher within the turbidity plume immediately following initiation of dredging activities (Figure 5.2-1), production was neither significantly increased nor decreased. Duval (1977) suggested that at greater depths in the water column the potential stimulator effect of nutrient enrichment could be overridden by light limitation resulting from the dredge-created turbidity plume.

FIGURE 5.2-1

RATES OF GROSS PRIMARY PRODUCTION ASURED URIN CONSTRUCTION OF ARNAK L-3○ RT CI SLAND

(Source: Duval 1977)



(b) Zooplankton Impacts

Zooplankton communities within McKinley Bay could be directly and indirectly affected by the proposed dredging program. The indirect effects would depend on the concurrent effects of dredging on phytoplankton communities since rates of secondary production lie within limits determined to a large extent by primary productivity. Since feeding rates of herbivorous zooplankton are linearly related to phytoplankton abundance (Burns, 1969; Mullin, 1963), changes in zooplankton feeding and secondary production could follow decreases or increases in primary production. Duval (1977) measured feeding rates of zooplankton communities within and outside the turbidity plume created during construction of ARNAK L-30 artificial island. The feeding rate of herbivorous zooplankton (Primarily *Limnocalanus macrurus*) within the plume was 2.7 times higher than control values outside the plume, and zooplankton standing stock was also 3.1 times greater. Although these results were only observed near the surface and considered preliminary in nature (Duval, 1977), the study suggested that possible increases of surface primary production' and phytoplankton standing stock may contribute to short term and localized increases in feeding rates and greater zooplankton abundance. This potentially positive impact of dredging activities was supported by data which demonstrated significantly larger zooplankton within the dredge-created turbidity plume (Figure 5.2-2), although Duval (1977) suggested other natural causes which could have resulted in the observed trends.

As indicated in the phytoplankton section, changes in the species composition of phytoplankton communities could follow a potential increase in the salinity within McKinley Bay. This could have an additional indirect effect on zooplankton communities. An increase in the relative abundance of small flagellates (Chrysophyceae) which cannot be efficiently filtered by zooplankton, or an increase in the proportion of phytoplankton genera which are of low nutritional value may decrease feeding rates and ultimately secondary production. In the monitoring program at ARNAK L-30, Duval (1977) noted that zooplankton within the turbidity plume only ingested phytoplankton cells larger than 6µ, and probably highly unstable. On the other hand in upper Chesapeake Bay, the abundance and species diversity of the infaunal community appeared similar to the predredging community after one and a half years of recolonization in spoil areas; however, this was not the case in dredged channels (Flemer *et aZ.*, 1967; Pfitzenmeyer, 1970). The infaunal community in dredged areas of a Swedish estuary (Byfjord) required about one and a half years to partially restore its species diversity, and larval recruitment was extremely slow immediately after the dredging project (Rosenberg, 1977).

The latter effect was thought to be a result of increased turbidity. Such detailed and long-term studies of recolonization have not been performed in arctic regions, and until this type of research is conducted, it is only possible to speculate on what indirect effects are associated with dredging and how long arctic infauna and epibenthos will require to regain their natural abundance and diversity. Re-establishnent of the infaunal community in spoils areas, dredged channels and basins to predisturbance status will take considerably longer. Dispersal of some arctic infaunal organisms is believed to be slow (Ellis, 1960). In addition, many arctic infaunal invertebrates (especially bivalves) are long lived (i.e. 10 or 15 years) and have slow growth rates; consequently, these communities will likely require decades to return to predisturbance status with respect to species, age structure and biomass. However, it has been documented that recolonization begins within one year after dredging in the shallow waters of the Beaufort Sea (Section 4.0).

Re-establishnent of epibenthos after the dredging program should be rapid, probably within months. This is due to their highly mobile nature, relatively short life spans (2 or 3 years), and the fact that they naturally repopulate shallow water regions annually after ice break-up (Section 3.5.2).

It should be noted that a common concern associated with dredging operations in southern regions is the release of pollutants (heavy metals, pesticides, oils, etc.) from contaminated sediments. Such materials have been shown to be absent or in extremely low concentrations in Beaufort Sea sediments (McDonald and Cambers, 1977) and are not concerns in relation to the present study.

In summary, certain long term impacts are anticipated for infauna of McKinley Bay and of the channel, spoil areas and regions in close proximity to dredging operations outside the bay. Short term impacts are expected on epibenthos in the dredged channels and basins, and in spoil areas both within and outside of the bay. Impacts to epibenthos are likely to be much more spatially limited than potential impacts on infauna.

Proposed Harbour Use - Invertebrate Impacts

Potential impacts of using McKinley Bay as a harbour on infaunal and epibenthic communities include early clearance of ice as a result of coal treatment and breaking out in the spring, introduction of sewage from overwintering ships, accidental spillage of diesel fuel during refueling and transfer operations, and the introduction of sediments and chemical contaminants into McKinley Bay from adjacent land based facilities. The area of greatest concern is in relation to the potential for major oil spills during the open water season. Adequate mitigative measures (Section 5.4) will reduce these areas of potential concern.

Some maintenance dredging may be required prior to breaking out of vessels in the spring. Impacts associated with maintenance dredging will be similar to those described for initial dredging activities, although the duration of disturbance will be short, and quantities of spoil relatively small. The cumulative effect of maintenance dredging will be to further delay re-establishnent of a typical infaunal and epibenthic community in channels, basins, spoil areas, and in regions heavily affected by the turbidity plume. The infaunal community within such areas will likely have a lower species diversity and be composed primarily of species that are early colonizers of disturbed sites. These species typically have rather fast growth rates and short life spans. The abundance of epibenthic invertebrates in dredge disturbed regions would also be reduced, but the areas would probably be quickly recolonized with epibenthos from unaffected areas.

Impacts to Fish

Dredging and Related Activities - Fish Impacts

The proposed dredging program in McKinley Bay may have direct and indirect impacts to resident and anadromous fishery resources. Direct impacts may include entrainment of some fish and disruption of migration patterns, while indirect impacts may result from loss of bottom habitat, reduced food supply and decreased feeding efficiency. Each of these potential impacts is discussed in this section.

One of the direct effects of the proposed dredging program on fish communities could be entrainment of small individuals into the intake of the cutter-suction dredge. Young-of-the-year with limited swimming ability and benthic dwelling species would be most affected by entrainment. However, it is not possible to quantify the direct mortality of fish resulting from entrainment since the distribution and abundance of susceptible species within McKinley Bay is unknown. The prediction of possible impacts is further complicated by the lack of information regarding possible avoidance responses of fish under high ambient suspended sediment concentrations. Anadromous species found within the region (Section 3.5.3) probably would be unaffected by entrainment since juvenile stages are normally reared in fresh water environments. On the other hand, potentially vulnerable species would include those with demersal young (eg. some sculpins, eel blennies, eel pouts) which could be drawn into the cutter-suction dredge. Other species with planktonic juvenile stages such as arctic cod, saffron cod, and Pacific herring, may not be as vulnerable to entrainment as the demersal species, although some mortality could result when large quantities of water containing plankton are taken into the intake of the dredge. Due to the limited spatial extent of dredging activities, direct losses associated with entrainment will likely be minor and will only occur during actual operation of the dredge. Since there have been no documented reports of dense congregations of young-of-the-year or small juveniles in the Beaufort Sea, they likely disperse naturally over large areas, further reducing the potential for elimination of substantial numbers of fish through entrainment.

The second potential direct effect of dredging on fishery resources is disruption of the migration patterns of anadromous species and general movements of marine species. As indicated in Section 3.5.3, anadromous fish known or expected to utilize McKinley Bay during some phase of their life history include: arctic cisco, least cisco, broad whitefish, humpback whitefish, and inconnu. Anadromous species are probably present and migrating through the region throughout the open-water period, although the precise timing of fish movements in McKinley Bay has not been documented. However, since anadromous fish are generally most abundant in waters proximate to shorelines, dredging activities within the central portion of McKinley Bay (generally at least 1-2 km from the shoreline) are likely to affect only a small proportion of the migrating fish. It should also be emphasized that fish within the Beaufort Sea normally experience relatively high suspended sediment levels, particularly during storm surges, and there are no documented cases when migration patterns have been disrupted. Anadromous species migrating in close proximity to the cutter-suction dredge or the dredge-created turbidity plume could, however, be adversely affected if migration was interrupted.

Dredging activities may also result in direct loss of suitable spawning habitat and the siltation of eggs and nursery areas. Fish species thought to spawn in nearshore marine waters include pacific herring, arctic flounder, fourhorn sculpin, saffron cod and arctic cod. Particular spawning and nursery areas utilized by these species in the southern Beaufort Sea have not been located. However, Percy (1975) suggested that Pacific herring could spawn in coastal areas along the Tuktoyaktuk Peninsula, and Hunter (pers. comm.) reported that larval herring were abundant in McKinley Bay. Herring spawn in spring under ice while other marine species spawn during winter with eggs hatching in late winter or early spring. Consequently, the proposed summer dredging program would not cause direct interference with spawning fish or unhatched eggs. Nursery areas are typically along sheltered shorelines, and since dredging will generally be restricted to deeper waters, only site-specific and short term disturbance of shoreline nursery areas is anticipated.

An indirect effect of dredging on fish will result from the loss of habitat during the dredging operation and during redeposition of the sediments and overburden. As previously discussed, sampling programs in other coastal areas of the Beaufort Sea have indicated that many fish, especially anadromous species, are most abundant in close proximity to shorelines, while dredging in McKinley Bay will primarily be in areas where anadromous fish are normally least abundant. Spoil deposition will alter the existing habitat utilized by fish in the region. Some new shoreline habitat will be created when spoil is deposited along the breaker line. A comparison of gillnet catch results between artificial island sites where dredging activities were on-going and completed artificial islands (Poulin, 1976), showed little difference between numbers of fish utilizing the two areas. The low catch data obtained in both disturbed and undisturbed waters were considered typical of abundance levels found throughout the nearshore waters of the southern Beaufort Sea (Poulin, 1976). The results of this investigation also indicated rapid immigration of fish to newly created shoreline habitat.

Associated with habitat loss will be the potential reduction of food supplies due to mortality of epibenthic invertebrates. However, it is generally believed that anadromous fish are limited by the availability of fresh water habitats and not by the marine environment which provides an extremely abundant food supply for fishes. Anadromous and marine fish species are also highly mobile and would likely move to areas with more abundant food resources. Resident fish populations would be most affected by possible food shortages due to dredging, although benthic invertebrates drawn into the cutter-suction dredge and deposited with the spoil would increase food availability in certain areas. It is not known if McKinley Bay supports resident fish populations, although J. Hunter (pers. comm.) suggested that flounders and other bottom-dwelling species (sculpins, eel pouts, eel blennies) might utilize the Bay for extended periods. However, since recolonization by benthic food organisms will begin shortly after the end of dredging activities and since the total affected benthic habitat in the bay will only be approximately 7.8%, impacts to fish due to loss of food organisms will be short term and relatively localized.

Another indirect impact due to dredging activity may be a slight reduction in feeding efficiency of opportunistic feeders such as arctic flounder, saffron cod and herring. Increased bottom turbidities and disturbance of epifauna may hamper the ability of these species to locate benthic food organisms. However, the mobility of these species and the probable abundance of food organisms in adjacent areas makes the possibility of reduced feeding efficiency a minor concern.

Proposed Harbour Use - Fish Impacts

Use of McKinley Bayas an over-wintering area for drill ships and the AML-X4 icebreaker may result in direct and indirect impacts to some fish species utilizing the Bay. Concerns related to fish center around the introduction of coal dust (which may be utilized to enhance ice melt), fuel oil and suspended sediments into the water column, as well as probable changes in break-up dates. The following section discusses these potential concerns, as well as potential impacts associated with maintenance dredging required to keep the channels and mooring basins navigable.

The spreading of coal dust along the entrance channels to increase ice melt will introduce coal fines into the water column at a time when the water is relatively free of suspended sediments. Since quantities of coal dust are expected to be small, only minor impacts are expected. The potential effects of these fines to fish could include minor respiratory irritations and possible effects on the digestive system.

Increased suspended sediment loading caused when the ships break out, and at a time when concentrations of suspended sediments are generally low, are a minor concern. Effects would be restricted to deep water areas and would be of short duration.

Introduction of fuel oil and sewage into McKinley Bay may also affect McKinley Bay fishery resources. Minor chronic spillage of diesel oil during winter fuelling of vessels should not affect fish since air temperatures would be near or below the pour point of diesel fuel and hydrocarbons will remain on the ice surface. Toxic volatile fractions would evaporate before they could enter the water column during spring break-up further reducing the concern for effects to fish. Some primary treated sewage may be discharged into the Bay during the spring breaking-out process; however, the quantity is expected to be very small and restricted to small areas and effects on fish are not expected.

Most concerns for fish during maintenance dredging would be similar in nature but smaller in magnitude to those previously described. Periodic dredging would likely interfere with the establishment of bottom-dwelling marine fishes in channels, basins and spoil areas.

Fishing by personnel could, if unrestricted, potentially reduce resident fish populations within the bay.
However, fishing restrictions imposed on company personnel should minimize this concern. A major oil spill could seriously affect fishery resources and supportive food webs. Site-specific and detailed contingency plans will minimize the risk and adverse impacts of such spills.

Impacts to Marine Mammals

Dredging and Related Activities - Marine Mammal Impacts

There is little available information describing the abundance and distribution of marine mammals in and near McKinley Bay during the open-water period. As a result, assessment of the potential impacts of dredging operations on marine mammals must be considered preliminary. However, some information has been collected from areas adjacent to McKinley Bay which can be used to delineate some potential effects of the proposed project.

Underwater sounds are apparently the major stimulus for avoidance responses by white whales to dredging activities and ship traffic (Ford, 1977; Fraker *et al.*, 1978). However, it is not known whether the responses occur because the white whales are alarmed by the sounds or because the sounds obscure portions of their vocalizations, which are used for social communication and echo-location (Ford, 1977). White whales have been observed to avoid operating dredges by as much as 4 km and by as little as 0.4 km (Fraker, 1977, 1978). A similar variable response by white whales to boat and barge traffic has also been reported (Slaney, 1975; Fraker *et al.*, 1978). Sound and frequency levels will be a major factor in determining the distances by which white whales avoid dredges and ships but other influencing factors probably include water depth, nearness of obstacles such as shallow water or land, boat speed, traffic intensity, activities of whales (e.g., feeding), and recent experiences of whales (Fraker, 1978).

Responses of bowhead whales to ship traffic and dredging activity have not been recorded, but as a minimum, reactions of a similar magnitude to those recorded for white whales could be expected. Responses of seals to ship and dredging activities in the Beaufort Sea area are also unknown, but probably are no more extreme than those of white whales and could be less. Terhune *et al.* (1979) reported that, in the Gulf of St. Lawrence, underwater noise from ships was sufficient to mask harp seal vocalizations within 2 km of the ship and that it caused a reduction in seal vocalizations. The change

Seals could be impacted by dredging activities in two ways. First, underwater noises from the dredging operation could cause seals, like white whales, to avoid the immediate vicinity of the dredges where noise levels would be highest. Second, dredging activities could interfere with the food resources or feeding activity of seals. Bearded seals feed on benthic organisms (Burns, 1967) which could be temporarily reduced or eliminated from dredged-out and spoil deposition areas, representing up to 7.8% of the total area of McKinley Bay. The sediment plume created during dredging may reduce the ability of ringed seals to feed in affected areas. Ringed seals are opportunistic feeders, preferring pelagic organisms such as fish, zooplankton and crustaceans (McLaren, 1958).

Potential impacts to seals from dredging in McKinley Bay will probably be relatively minor. However, lack of information on the numbers of seals that use the McKinley Bay area during the open water period, and on the reaction of seals to dredging and ship activity makes the assessment of potential impacts to seals speculative at this time.

Proposed Harbour Use - Marine Mammal Impacts

McKinley Bay will be used as a wintering site for the drill ships and icebreaker. In late spring the ships will leave the harbour and in late fall the ships will again return for the winter. Most aircraft activity would probably occur during the ship-wintering period and be concentrated in spring when the ships are being prepared for the drilling season and in fall when they are being shut-down for the winter. Both helicopters and fixed-wing air-craft (on skis) will probably be used. Ship refueling may be carried out in winter with fuel being trucked to the ships over a winter road from Tuktoyaktuk.

In fall, some ice-breaking activity will probably be required in order that ships can enter the harbour. Ringed seals and occasional bearded seals will probably be present in the fast-ice areas through which the ice-breaker will pass. The reaction of adult seals to the passage of icebreakers is unknown. However, the facts that both bearded and ringed seals can main-in the ice. McKinley Bay is some distance from the Mackenzie Delta and the paths of icebreakers from this bay will be at right angles to the routes used by white whales to reach the delta area. The potential for adverse effects on migrating white whales because of ice-breaking activities in spring is suspected to be low, but a monitoring program would be required to substantiate this hypothesis.

Aircraft activity in the McKinley Bay area, if sufficiently intense, may have a minor disturbing effect on any polar bears that occur in the immediate vicinity of the bay and may cause them to avoid the immediate area. However, most polar bears tend to occur farther offshore in active-ice zones and would not be affected by the aircraft activity. Whales are not present in the area during the winter. Seals are under the ice and only those animals (if any) in the immediate vicinity of the ships would possibly be disturbed by the aircraft. The effect on seals would be minor.

Impacts to Terrestrial Mammals

Dredging activities are not expected to affect any of the terrestrial mammal species since dredging activities are scheduled during summer open-water periods when terrestrial mammals are confined to on-shore habitats. In winter, when ships are present in the harbour, arctic foxes may be attracted to the area if personnel feed the animals or if improper garbage disposal is practiced. However, if these activities are prevented, no significant impacts due to winter harbour use are anticipated with respect to terrestrial mammals. In the event the Company pursues the use of a small foreshore area near Louth Bay for the temporary storage and staging of dredging pipe, terrestrial mammals may avoid the immediate area during periods of activity.

Impacts to Birds

Dredging and Related Activities - Bird Impacts

The proposed 1979 dredging program would start approximately 1 September and would begin at the seaward end of the proposed channel, located 7-10 km from the mouth of McKinley Bay and approximately 4 km away from the nearest shore. During fall migration, large numbers of brant, oldsquaw and glaucous gulls potentially use shoreline areas in and adjacent to McKinley Bay, but 1979 dredging activities should have little or no effect on this use. The dredging activity will be confined to a relatively small area at any particular point in time and the distance between the dredging activity and shore would be sufficiently great to eliminate the potential for any major and probably all or most minor disturbing effects. Most brant will have left the area by the end of the first week in September, and most oldsquaw and glaucous gulls by late September (Searing *et aZ.*, 1975).

If the dredging program is not completed by freeze-up in 1979, it will be completed in the early spring of 1980. Subsequent maintenance dredging, if required in succeeding years, will probably take place during the summer and will be concentrated in the access channel outside McKinley Bay.

Moulting by waterfowl in the Beaufort Sea area occurs from approximately mid-July to mid-August. In the McKinley Bay area, concentrations of moulting oldsquaw have been reported along the Louth Bay barrier islands (Sharp, 1978) as well as in coastal areas 20 km west of Atkinson Point (Searing *et al.*, 1975). In addition, swans, brant and white-fronted geese are reported to moult in the inlet at the head of McKinley Bay; this inlet is located approximately 10 Ian from the nearest area to be dredged. Spencer and Barry (1976) studied the effects that the noise and the general activity associated with a drilling operation in the Mackenzie Delta had on moulting swans and geese. Unless noise levels from the dredging operation are greater than those from the drilling operation they studied, the results of their studies suggest that the noise and boat activity associated with dredging operations conducted during the moulting period will not adversely affect the use of the important area at the head of McKinley Bay or the coastal areas west of Atkinson Point.

Since all dredging (both initial and maintenance) will be carried out during the open water period, the spring migration (April-June) of aquatic birds along the Tuktoyaktuk Peninsula will probably not be affected. The possible use of a small portion of the foreshore near Louth Bay after September 1st is not anticipated to have a significant impact on the few remaining birds.

Proposed Harbour Use - Bird Impacts

The use of McKinley Bay only as a wintering site for drillships and icebreakers is not expected to have any effects on use of the area by birds. In fall, birds will have left the area by the time ships return to the harbour. In spring, birds do not use the McKinley Bay area as a major staging area. Nesting birds that are present in the area by late May-early June would not be affected by the spring ice-breaking activities. Helicopter flights to and from the ships may cause a minor disturbance of birds, but they are not expected to affect the use of the area by nesting birds. Minor fuel spills may occur during winter refueling operations, but as long as they are properly cleaned up prior to spring melt, no impacts to birds would result. In the event the Company pursues the use of a small foreshore area near Louth Bay for the temporary storage and staging of dredging pipe, the impacts on birds will be limited because most will have left the area by the latter part of August.

Impacts to Resource Utilization

Reindeer Herdina

Potential impacts to the reindeer herding operation could occur during June when the corrals and buildings in the Atkinson Point area are used to tag reindeer, remove antlers and slaughter selected animals. Aircraft activity will be the major source of potential impact on herding. An unexpected, low-level helicopter or fixed-wing aircraft flight over the area at a critical time could disturb reindeer that were being herded into the corrals. Such aircraft flights could occur during the course of servicing ships in McKinley Bay prior to their spring departure. During June, it will be particularly important that close liaison be maintained with people directing the reindeer herding operation, in order to avoid this potential impact.

Unauthorized low-level flights (of a sight-seeing nature) to view reindeer that are present on the eastern Tuktoyaktuk Peninsula during the May-October period could cause unnecessary disturbance to reindeer. Such flights are unlikely to occur but should be specifically prohibited as part of a general policy to ensure that potential sources of impacts to the herding operation are minimized.

Hunting, Trapping and Fishing

Dredging operations in McKinley Bay will not coincide with hunting and trapping activities in the area and fishing has not been conducted in McKinley Bay for several years.

The use of harbour facilities at McKinley Bay to overwinter ships may affect hunting and trapping activities in the area. In the fall, icebreaker activity in fast-ice areas in the McKinley Bay area late in the drilling season may temporarily impede ice travel along the coast by trappers. Ship paths through fast-ice areas should refreeze relatively rapidly and the potential impact would not occur after the ice-breakers ceased operations. The significance of this potential impact will depend on the timing of trapping operations. Polar bear hunting would not be affected since the season does not begin until 1 December. In spring, fox trapping will have been completed and polar bears will probably have moved offshore before ice-breaking activities begin outside of McKinley Bay.

5.3 RECOMMENDED IMPACT MITIGATION MEASURES

On the basis of the information reviewed for the purposes of this environmental assessment report, a number of mitigative measures specific to the proposed dredging program in McKinley Bay can be recommended, and still others are encompassed in the design and timing of proposed Dome/Canmar development. Recommended and project design-related (noted with an asterisk*) mitigative measures are summarized in the following section for each phase of the McKinley Bay project.

Dredging and Related Activities

(a) The sand spits and barrier islands at the north end of McKinley Bay should be avoided as much as possible during the dredging operation. Deposition of spoil material onto the spit and associated islands should be avoided unless demonstrated to be necessary for protection of the harbour or other purposes. Deposition of spoil material to form additional low islands in McKinley Bay could increase the amount of habitat available for nesting and/or moulting water birds, particularly brant, old-squaws, eiders and gulls.

(b) In areas where the depth of the water column permits and where deemed appropriate, spoil materials could be discharged beneath the water surface rather than surface broadcast to decrease the size of the resultant turbidity plume and to minimize the aerial extent of benthic habitat totally covered or inundated with spoil materials.

(c) Whale movements within the area should be monitored prior to and during all dredging activities, particularly in waters outside McKinley Bay during the period of whale presence.

*(d) Proposed dredging during fall will reduce potential impacts to planktonic communities and primary productivity, since growth cycles peak during late July and August, and phytoplankton and zooplankton standing stock will be relatively low after about mid-September.

*(e) The suction-cutter dredge will create rectangular channels which will naturally slump to produce channel walls with a slope of approximately 30°. This may increase the opportunity for recolonization of excavated channels by benthic invertebrates since the collapse of vertical walls will introduce infauna to disturbed areas.

*(f) The fall timing of dredging activities will minimize adverse impacts to sensitive life history stages and habitat of marine fish, since most species spawn in late winter or early spring. In a similar manner, the most sensitive stages of anadromous species, particularly young-of-the-year will not be present in McKinley Bay during most of the dredging program.

(g) In order to minimize the frequency of maintenance dredging and therefore, repeated disturbance of benthic habitat, the channel and basin should be excavated to the greatest practical depth. However, this depth should also consider the probable area over which spoil must be distributed.

Proposed Harbour Use

(a) Maintenance dredging, if required, should be timed or located, if possible, to minimize disturbance of birds utilizing sand spits and Louth Bay during the spring and summer, and to avoid young-of-the-year of anadromous fish species which could be present in the bay during the spring and early summer.

(b) Any activities which could disturb moulting oldsquaw, and migrating oldsquaw and brant in Louth Bay and at Atkinson Point should be minimized during the period from Mid-July to the end of August.

(c) Disturbance to Atkinson Point reindeer herds should be avoided by minimizing aircraft flights within 3 km of this area during June, and routing all flights into McKinley Bay from the northeast. Unauthorized low-level flights to view reindeer herds on the Tuktoyaktuk Peninsula should be prohibited.

(d) All fuel spills should be contained and treated as per the contingency plan developed for McKinley Bay.

(e) All garbage should be disposed of in an acceptable manner to avoid attraction of polar bears and arctic foxes.

(f) Activities of all personnel associated with the proposed project should be supervised to avoid disturbance of sensitive wildlife and moulting, nesting and/or staging birds.

(g) All fishing by project personnel should comply with existing Northwest Territorial Fish and Game regulations. :

5.4 OIL SPILL CONTINGENCY PLAN

The most significant environmental impact associated with operating conditions at McKinley Bay would result from an accidental spill of fuel oil into the water or on ice during transfer thereof, or due to a shipping accident. Fuel oil could also be spilled on land due to a vehicular accident or chronic leakage from a tank truck during winter, when the winter road may be in use.

Canmar has prepared an Oil Spill Contingency Plan which specifically addresses the Company's proposed 1979/80 operations at McKinley Bay. This plan follows the general practices outlined in detail in the Canmar Oil Spill Contingency Plan - 1978.

This plan is divided into five main phases, each delineating a sequence of actions and/or responses.

Phase I:

a) Discovery
b) Reporting
c) Assessment
d) Alerting
e) Monitoring and Tracking

Phase II: Countermeasures

Phase III: Shoreline Cleanup

Phase IV: Disposal

Phase V: Post Operational Analysis

The degree of response to an oil spill in each of the aforementioned phases will depend upon the degree of severity of the oil spill. It must also be recognized that the elements of any one of the aforementioned phases may take place concurrently with one or more of the other phases.

This "plan" is prepared as a site specific plan for 1979/80 operations at McKinley Bay. As such, the general geographic area of application of the plan falls within the perimeter of the area shown in Figure 5.4-1.

The possible oil spills that would have to be considered would be of a minor or intermediate nature (as defined in Chapter 1 of the "Canmar Oil Spill Contingency Plan - 1978") and would in all probability originate from a shipping accident or spillage during transfer of fuel.

Phase I

Following the discovery of an oil spill, the procedures with respect to reporting, assessment, alerting and monitoring and tracking as delineated in "Canmar's Oil Spill Contingency Plan - 1978" - Chapter 2 (pages 2.1 to 2.20) will apply for this Oil Spill Contingency Plan.

Phase II: Countermeasures

This part of the Contingency Plan deals with the various countermeasures and cleanup techniques that are presently available to Canmar. Specifically, the following types of spills are considered:

a) Oil spills within the confines of the harbour - open water

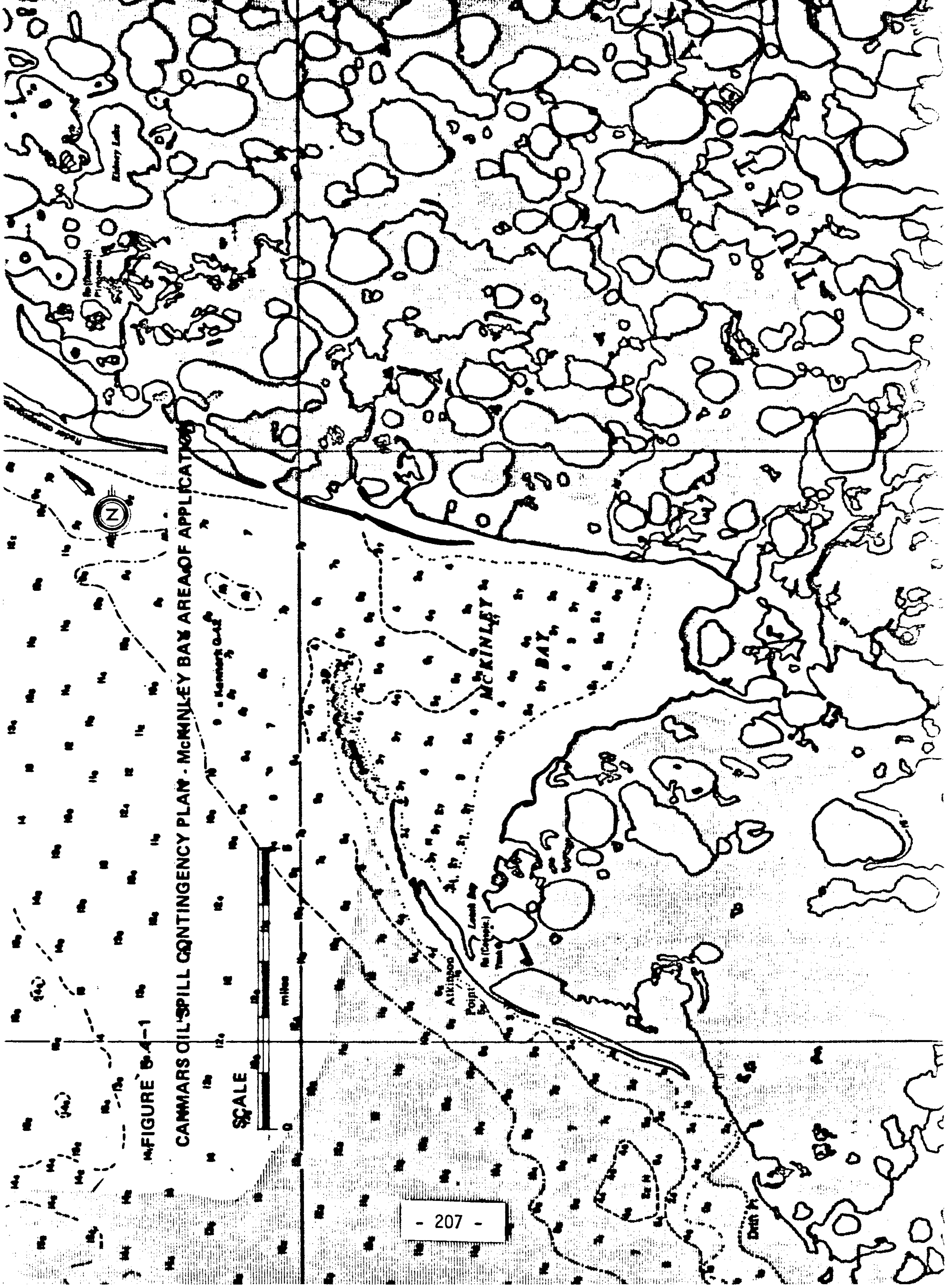


FIGURE 5.4-1

CAMMARS OIL SPILL CONTINGENCY PLAN - McKINLEY BAY AREA OF APPLICATION

TABLE 5.4-1

CANMAR OIL SPILL EQUIPMENT TO BE AVAILABLE FOR MCKINLEY BAY

- 5,000 feet of 18″ inshore boom
- one Morris 3-square skimmer
- 400 feet of 2″ oil resistant hose with support fittings
- one 3″ Komline Sanderson pump with 2″ Camlock adaptors
- 10 bundles 3M - #151 sorbent pads
- 10 rolls #M - #126 sorbent sweeps
- 300 feet of sorbent booms
- 100 bags of “floor dry” Eagle Picher sorbent
- one oil spill workboat
- 3 x 10,000 gallon oil storage bladders
- miscellaneous small equipment - pitchforks, shovels, empty sorbent wringers, etc.

A final "polishing" (if necessary) of the remaining oil films left on the water's surface may be carried out with sorbent pads and/or sweeps.

It is anticipated that most oil, if spilled into the waters of McKinley Bay, would tend to remain there, because of oceanographic conditions and documentation which would suggest that McKinley Bay is considered to be a sediment sink. In this regard and recognizing the particular biological significance of certain coastal regions, booms would be deployed if necessary, or as a precautionary measure, in areas illustrated in Figure 5.4-2. In this manner the most significant aquatic habitats should be protected.

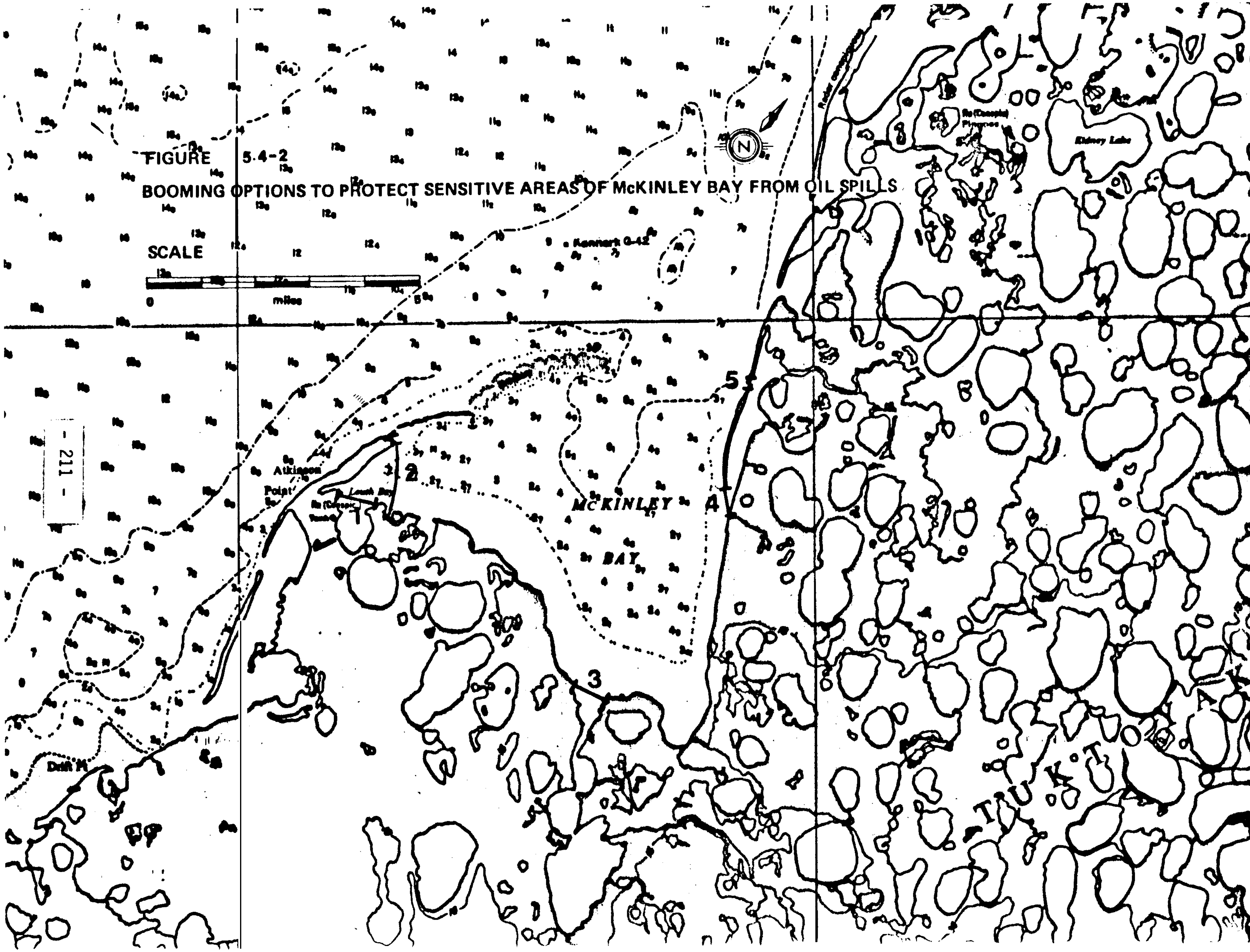
b) Oil Spills Within the Confines of the Harbour - Ice Conditions

All oil spills occurring in the harbour during periods of partial and complete ice cover would be dealt with by manual and/or mechanical methods.

Depending on the severity of the ice and water conditions at the time of the spill, skimmers, pumps, and sorbents may be used to recover the spilled oil. Manual and mechanical means may be used to collect the contaminated ice and snow for temporary storage, until such time that the oil can be removed from the ice and snow in induced or natural melting. However, it is anticipated that the major portion of the clean-up operation would take place in the spring time when the oil would surface through the ice, in the brine channels, to accumulate on the surface of melt pools where it could be

FIGURE 5.4-2

BOOMING OPTIONS TO PROTECT SENSITIVE AREAS OF McKINLEY BAY FROM OIL SPILLS



recovered manually (sorbents) and/or mechanically (skimmers and pumps).

c) Land Spills

In all probability oil spilled on land would be contained within the immediate area. However, some oil may escape this area by accident or design. In this case the spill would be dealt with by Canmar as follows:

a. Steps would be taken immediately to prevent the spill oil from entering the water. (Dykes, drainage ditches, etc. may be constructed.)

b. Any flowing liquid product would be pumped directly into empty oil drums and/or storage bladders for disposal.

c. 'Floor Dry' sorbent and/or sorbent pads would be spread on top of the spill (if possible) to absorb any remaining oil.

d. The saturated sorbents along with the contaminated soil would be shovelled into empty oil drums for disposal.

Phase III: Shoreline Cleanup

Oil spills at the harbour site which result in contamination of the shoreline area will activate the procedures described in Chapter 4 of the "Canmar Oil Spill Contingency Plan - 1978".

Depending upon the severity of the shoreline contamination, all or a portion of the cleanup techniques cited in Chapter 5 will be used.

Phase IV: Disposal

Chapter 5 of the "Canmar Oil Spill Contingency Plan - 1978" lists the methods available to Canmar, in the Beaufort Sea area, to dispose of oil, water-in-oil emulsions and oil contaminated debris.

All recovered product that cannot be reused will be transported to Canmar's Tuktoyaktuk base camp, where it will be disposed of through incineration.

Phase V: Post Operational Analysis

Following completion of an oil spill cleanup, Canmar would do a post operational analysis of the incident. A final report would be prepared which could be used to update the "Canmar Oil Spill Contingency Plan - 1978", if necessary. A final report on the incident would be submitted to the appropriate government agencies.

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