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Oil Spill Scenario for the Labrador Sea

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OIL SPILL SCENARIO FOR THE LABRADOR SEA

by

B.R. LeDrew
K.A. Gustajtis
Centre for Cold Ocean Resources Engineering
Memorial University of Nefoundland
St. John's, Newfoundland
Canada A1B 3X5

for the

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
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ABSTRACT

This study develops a scenario following a large oil spill from a blowout of an exploratory well in the Labrador Sea. Scenario development leads to the delineation of gaps in pertinent baseline information and serves to identify the applicability and inadequacies of available countermeasure techniques.

The Standard Labrador Sea blowout event occurs on Nain Bank, where the water depth is 200 metres. It starts on November 1 and lasts nine months. Twenty-four hundred cubic metres of light, sweet crude and 360,000 cubic metres of gas are released daily.

Twelve study topics are presented as input to the scenario narrative. These are categorized as follows: the physical environment (emphasis on ice); resource utilization practices (potential, immediate and direct impact); factors peculiar to the area and that influence blowout probability; the behaviour of oil as it rises from the seabed and as it interacts with ice; the environmental prediction and logistics capability of the Labrador area to support a major countermeasures effort; and finally, an appraisal of the Canadian state of response preparedness.

The hypothetical spill releases a total of 490,000 cubic metres of oil, one-half of which is dispersed as small droplets in the water column. Of the remaining oil, which surfaces as a slick, 14 percent is handled by countermeasures efforts: nine percent is burned; four percent is recovered; and one percent is chemically dispersed. The ice cover distributes the oil in low concentrations of the order of 0.1 percent over an area of 10,000 square kilometres along the northeast coasts of Newfoundland and Labrador.

Seven percent of the oil comes ashore. Immediate and major impacts are felt by seabirds, spawning capelin, whelping and breeding harp seals, and offshore fishing.

Recommendations are made of approaches to achieve the objectives of the Arctic Marine Oilspill Program (AMOP) insofar as it applies to the Labrador Sea.

RÉSUMÉ

Pour cette étude, on a simulé une éruption d'hydrocarbures, analogue à celles qui pourraient jaillir des puits d'exploration de la mer du Labrador. Cette tactique a permis d'identifier les lacunes concernant les données fondamentales et de déterminer l'applicabilité et les insuffisances des techniques de lutte déjà existantes.

La poussée se produit sur le banc de Nain, où l'eau atteint une profondeur de 200 mètres. Elle débute le 1er novembre et dure neuf mois. Chaque jour, 2 400 m^3 de pétrole brut, léger et non sulfuré, ainsi que 360 000 m^3 de gaz sont rejetés.

La simulation se fonde sur 12 critères, regroupés comme suit: l'environnement physique, où l'accent est mis sur les glaces; les modes d'exploitation des ressources et leurs conséquences éventuelles, immédiates et directes; les caractéristiques de la région, dont dépend la probabilité d'une éruption; le comportement des hydrocarbures, au moment où ils quittent le fond marin jusqu'à ce qu'ils entrent en contact avec les glaces; les moyens de prévision et d'organisation que possèdent les organismes mésologiques du Labrador pour mettre en oeuvre une opération massive de nettoyage et finalement l'évaluation de l'aptitude du Canada à réagir à toute éventualité.

Au cours du déversement simulé, 490 000 m^3 de pétrole sont rejetés et la moitié est dispersée dans la mer sous forme de petites gouttelettes. L'autre moitié forme une nappe à la surface de l'eau: 14 p. 100 sont neutralisés par les mesures de lutte, 9 p. 100 sont brûlés, 4 p. 100 sont récupérés et 1 p. 100 est dispersé au moyen de procédés chimiques. La plaque de glace répartit les hydrocarbures à faible concentration (0,1 p. 100) sur une étendue de 10 000 km^2, le long des côtes du nord-est de Terre-Neuve et du Labrador.

La proportion de pétrole atteignant le rivage est de 7 p. 100. Les effets, immédiats et considérables, se répercutent sur les oiseaux de mer, sur le capelan pendant le frai et sur le phoque du Groenland en période de reproduction. La pêche hauturière en subit également les contrecoups.

Les recommandation portent sur les façons d'atteindre, dans la mer du Labrador, les objectifs du Programme sur les déversements d'hydrocarbures en milieu marin arctique.

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1 INTRODUCTION

The Arctic Marine Oilspill Program (AMOP) was developed by the Environmental Emergency Branch of the federal Environmental Protection Service in response to the observation that, "few proven or probable countermeasures (are) available to deal with an oil well blowout or any large oil spill in ice covered or ice-infested waters" (Ross, 1977).

The general objective of the program is to develop oil spill countermeasures for use in Arctic offshore waters. The product of the program is the development and acquisition of skills and equipment to deal successfully with a major Arctic oil spill. These will be used by operational agencies such as the Canadian Coast Guard and oil company cooperatives.

Foregoing the immense task of studying the entire Arctic in detail, certain "high risk" regions were selected for study, as follows:

- Southern Beaufort Sea;
- Sverdrup Basin;
- Baffin Bay, including Lancaster Sound;
- Davis Strait, including Home Bay and Cumberland Sound; and
- Labrador Sea.

The Labrador Sea (Figure 1.1), although not geographically part of "Arctic Waters", was included as a special study area under AMOP.

The present study was commissioned as a "scene setting" exercise for the Labrador Sea. As such, it is seen as a prerequisite to the more specific countermeasures development part of the program. Hence, the objectives of the present study were to:

(1) define the magnitude of the cleanup task presented by a major oil spill in the Labrador Sea; and
(2) identify research directions to solve operational and design problems.

It was felt that these objectives could best be met by carrying out a scenario building exercise that represented a reasonable projection of the most serious disaster situation likely to be faced by those charged with planning and carrying out oil spill countermeasures.

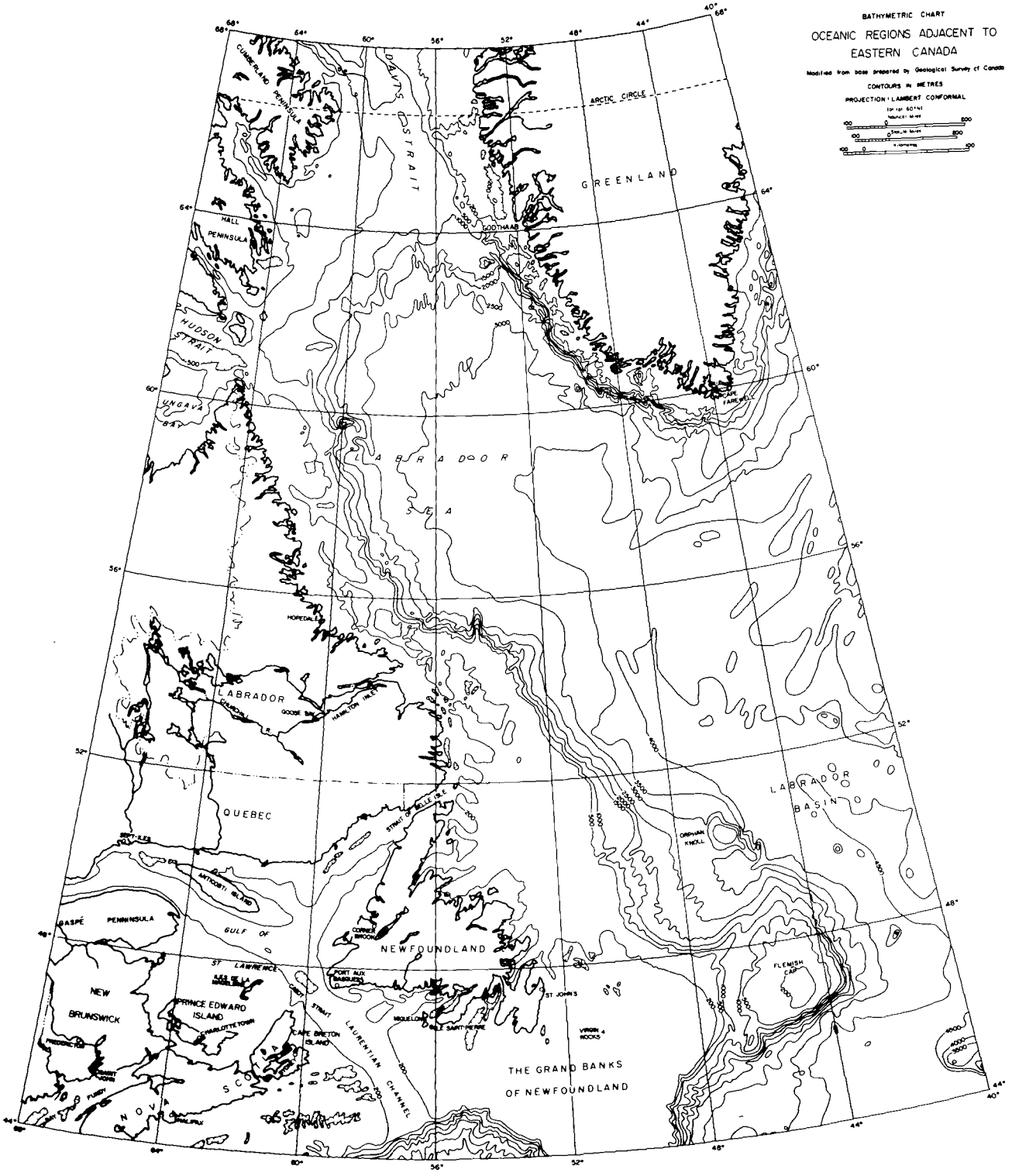

FIGURE 1.1 THE LABRADOR SEA

1.1 Scope

The study was planned to be practical and mission oriented. Information was considered and presented with reference to the needs of contingency planners. The presumption was made that, where possible, attempts would be made to remove spilled oil from the marine environment.

The scope of the study is defined as follows:

- The study was limited to addressing spill "macro movement" until such time as the spill is unavailable to cleanup efforts. The ultimate fate of the oil is only considered generally.

  It is important to note that no spill movement modelling was scheduled for this study since this had been undertaken as part of a recent study by NORDCO (1977). As with all present models, no computer prediction could be made during the period of ice cover; consequently, such an exercise is of very limited use to a winter situation until such time as ice (and oil-in-ice) movements can be predicted.
- The study identifies and considers a single, specific spill event related to exploration activities, rather than to production or transportation, since an adequate year-round technology for these latter two has not been developed for the Labrador Sea. To identify the catastrophic event, a "Standard Labrador Sea Blowout" analogous to the "Standard Beaufort Sea Blowout" is developed.
- Information on the physical environment is presented and assessed in relation to the various countermeasures functions.
- Existing Canadian contingency materials, procedures and personnel are identified, assessed, and applied to the spill response.
- The scenario is constructed on the assumption that present technology (drilling, spill countermeasures, transportation) would be applied and operated to recent past standards.
- Efforts to mitigate damage (e.g. cleaning of fouled fishing gear) are not examined in any detail; however, the likelihood of such damage and the nature of occurrence is part of the narrative.
- Long term or cumulative effects of oil in the marine environment are not considered. Consideration of impacts is limited to those marine resources which are exploited by man, and any interference with these resource utilization activities.

Several candidate areas are not addressed either because of constraints of time and money, or because they recently have been, or are now being addressed elsewhere. Examples of the latter include a detailed consideration of biological impacts (addressed in a recent report to the Provincial Mines and Energy Department St. John's, Newfoundland, by Northlands Associates, 1977); and a review of remote sensing technology for tracking oil and oil in ice. This is the subject of a major AMOP study contracted to the Canada Centre for Remote Sensing.

1.2 Study Organization

In carrying out this study, C-CORE utilized the skills and experience of many of its researchers in areas in which it possesses technical competence. As well, subcontractors representing sources of competence in other disciplines and having additional on-site experience were called upon to contribute as follows: ShawMont Engineering, logistics; Northlands Associates, living renewable resources; and Atlantic Progress Limited, risk. Also, the scientific authority, Dr. D. Thornton, contributed the section on plume behaviour.

The individual chapters are presented as separate studies with each listing its own table of contents, list of references and authors. To ensure that consistency and completeness were achieved in each contribution, the project manager and staff researcher composed the scenario and acted as editors.

The approach taken was to first amass available relevant information, and then to develop a plausible sequence of events by identifying the spill event and hypothetically applying existing Canadian countermesaures capabilities and equipment to the situation. Thus, the scenario, while presented here first, was the last section to be written.

Twelve study topics were selected to provide input to the scenario. These fall into the following categories: the physical environment (particularly ice); resource utilization practices (in terms of potential, immediate and direct impact); factors peculiar to the area and influencing blowout probability; the behaviour of oil as it rises to the surface and as it interacts with ice; the environmental prediction and logistics capability of the Labrador area to support a major countermeasures effort; and finally, an appraisal of the Canadian state of response preparedness.

While amassing available information on assigned topics, each study drew heavily on sources already in the literature; however, where possible original data is presented. This pertains particularly to Chapters 5, 6 and 7, which deal with ice.

During initiation of the study, the Ocean Engineering Information Centre (OEIC) at Memorial University carried out a series of literature searches using the following computer data bases:

- Biological Abstracts
- Engineering Index
- Environment (Environment Canada)
- Enviroline
- Geo-ref (Geological Reference File)
- Meteorological and Geoastrophysical Abstracts
- NTIS(National Technical Information Service)
- Oceanic Abstracts
- Pollution Abstracts
- RESORS IV (Canada Centre for Remote Sensing)
- Tulsa (Petroleum Abstracts).

Geographic terms applicable to Labrador and the Labrador Sea were first searched on all the computer data bases. This generated a total of 1213 citations covering the following subject areas:

- Ice (pack ice, icebergs, sea ice)
- Oceanography (hydrography)
- Meteorology
- Geology
- Shoreline features
- Logistics
- Biology (sea mammals, sea birds, plankton, fisheries)
- Human activities (fishing, sealing, transportation).

The computer data bases were subsequently searched for citations that would be relevant to the topics under study. These included the following subject areas:

- Remote sensing (oil, ice)
- Oil in ice (impact, effect and fate)
- Oil spill countermeasures
- Oil movement and simulation of oil spills
- Plume behaviour
- Environmental hazard monitoring and prediction

- Biological aspects of oil pollution
- Environmental impact assessment.

The computer searches generated a large number of citations. Pertinent material was selected from the large volume of computer printouts and these references were retained for further examination. The references are available in either paper copy or microfilm through the Ocean Engineering Information Centre.

Many pertinent references are cited in individual chapters of the study; however, anyone wishing to pursue a subject area in more detail should contact the OEIC. The Centre will make the printouts available for use at Memorial University. Alternatively, copies can be supplied for the cost of photocopying and mailing.

The address is:

Ocean Engineering Information Centre
Engineering Building
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5
Telephone: (709) 753-1200 Ext. 3891/92

1.3 The Labrador Sea

The Labrador Sea is described under the AMOP Program as not in "Arctic Waters" but a special case for inclusion. While the region is not geographically in the Arctic, it combines features of both the arctic and the temperate marine environment: it is physically harsh but biologically rich (LeDrew, 1977).

The major feature that it has in common with the Arctic is the presence of ice. However, this ice is different from that which is generally encountered in more northern latitudes. It is relatively warm and while sometimes quite thick, generally weak. Most of it is formed in the Labrador area under turbulent conditions. These turbulent conditions create ice fields which move rapidly and have highly irregular and unreliable surface profiles.

The turbulent water conditions of the region create a condition atypical of Arctic marine systems - extremely high biological productivity. The high production levels found in what are essentially Arctic waters are impressive. This production is being utilized by a large offshore fleet, which to date is mostly foreign. The offshore Labrador is not isolated, and when biological factors are considered, a large area including regions to the north (Davis Strait) and south (Northern Newfoundland) must be included.

The rapid currents and wind conditions act to disperse any pollutant, and to spread its effect large distances to the south and east. Consequently, the entire northeast coast of the island of Newfoundland must be included in any countermeasures scheme.

The Labrador Coast has a low population density, even for Canada. Six thousand people are spread along 2000 km of coastline from the Strait of Belle Isle to Nain. However, this is a relatively high population density in comparison to other arctic regions.

Living renewable marine resources along the coast are heavily utilized in this area. The effects of pollution could be disastrous to some populations of species which are already under heavy stress as a result of hunting or fishing. However, any direct cause/effect relationship would probably be impossible to clearly establish.

The physical area contained by the Labrador Sea is shown in Figure 1.2, which compares the area with the Canadian Beaufort Sea and the North Sea. In addition, Figure 1.1 illustrates how the region is exposed to the Arctic as well as to the open seas of the Atlantic.

1.4 A Perspective

During the early stages of this exercise an attempt was made to discern the relative size of the spill to be described in the scenario. Taking the 1500 bbl/day flow rate over the 270-day duration results in a total spill of 607,000 m^3 (4.05 million barrels). This is four times the amount released by the TORREY CANYON (151,000 m^3), and it is equivalent to thirty ARROW spills (@20,000 m^3). The event seems extreme in relation to these other ecological catastrophies, even given that our scenario deals with a long-term, relatively low-volume release versus the short-term, high-volume release typified by a tanker disaster. Additionally, the release site is well offshore.

The point is often made that the probability of any blowout is low; one offshore is lower; and one offshore and containing oil, lower still. Yet within the period during which this study was undertaken, two events occurred which serve to reinforce the need to plan against the unlikely and the unexpected. Astonishingly, three gas blowouts occurred simultaneously in the Pembina field in Alberta. Given the low frequency of such events, one wonders what, if any, probability would have been given to such an occurrence.

An unenviable record was established by the AMOCO CADIZ, a 233,690 dwt Liberian registered supertanker, as it broke up on the rocks off Porsal, France. The vessel released more oil than the TORREY CANYON did, as a full cargo of 302,260 m^3 (63

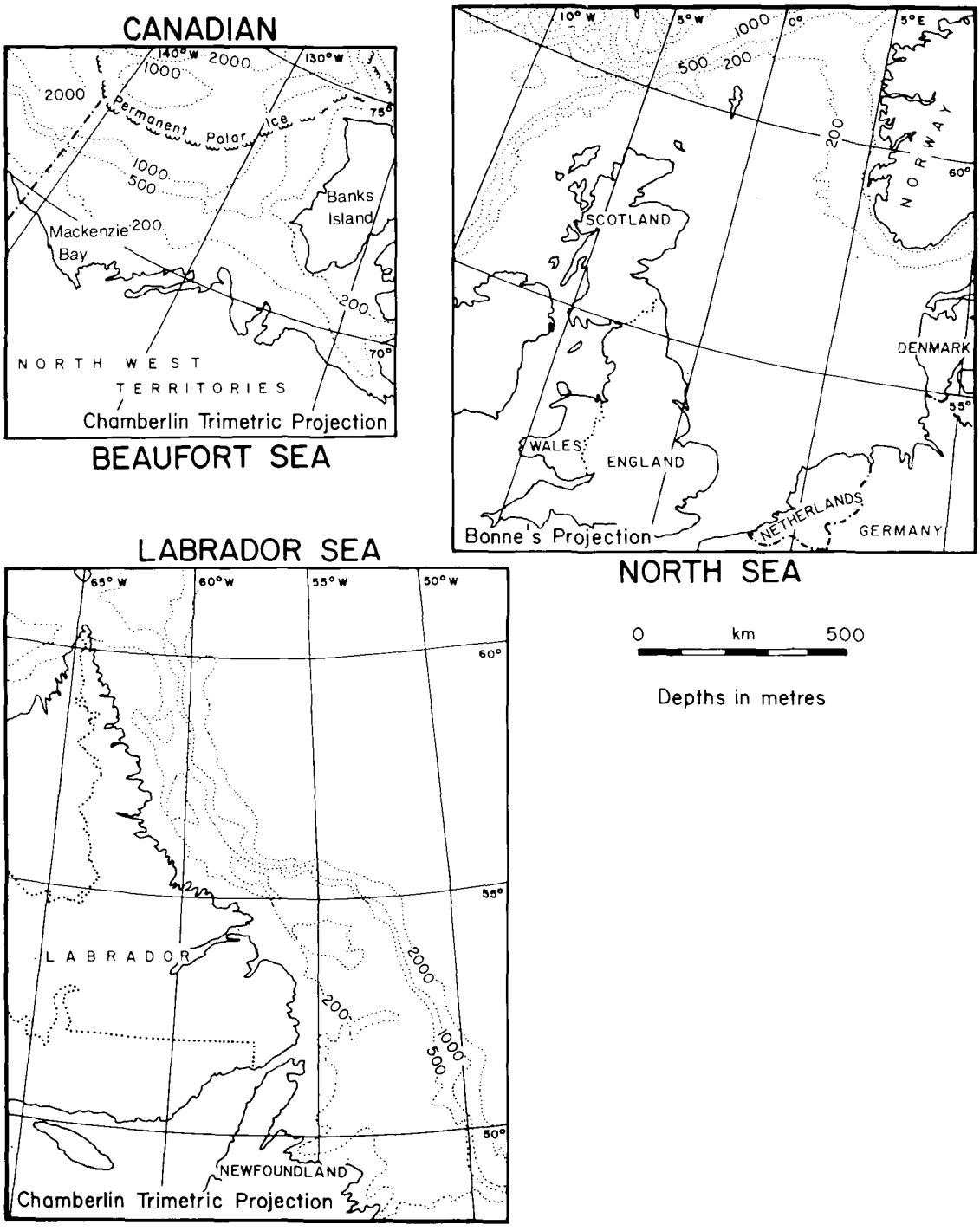

FIGURE 1.2 COMPARISON OF THREE OFFSHORE AREAS

million Imperial Gallons) escaped from the wreck. It has been eleven years since the TORREY CANYON disaster. Technology's failure to prevent and helplessness to respond to another man-induced disaster is illustrated once again.

During December 1977, an example was provided of an extreme event of nature. The "one hundred year sea state" brought waves far into shore along the exposed east coast of the Avalon Peninsula (Walsh, 1977). The Marine Sciences Research Laboratory of Memorial University, located in a picturesque setting on the cliffs of LogyBay, came precariously close to being washed away. Fortunately, offshore winds kept conditions from worsening and while the facility was damaged, the structure was not lost. It is very conceivable that an environmental disaster which is orders of magnitude greater than the AMOCO CADIZ spill can occur in our offshore waters.

It can be argued convincingly that an oil spill event identical to the one described in this article will never occur. Such a coincidence would indeed be incredible. Clearly, however, as offshore hydrocarbon exploration and development proceeds, accidents will occur. Every reasonable step should be taken to ensure against their occurrence; but, at the same time, preparations must be made to develop an adequate response capability.

The exercise of scenario development is useful in assisting to achieve the objectives identified since it serves to forcefully delineate gaps in pertinent baseline information and to illustrate the inadequacies of available countermeasure techniques. There is a danger, however, that by identifying and describing in detail an unlikely but damaging event, its probability will be seen as more likely, simply because of increased awareness of it. The intent of this exercise is precisely the opposite. By exposing responsible personnel to the potential problems and, wherever possible, candidate solutions, a general improvement in spill response preparedness should be realized. Potentially, not only the probability of the event can be reduced by improving prevention measures, but the consequences can be minimized by development of better countermeasures.

1.5 Acknowledgements

Many people contributed to this document. While many of the chapters include acknowledgements, specific credit to people whose contributions were significant to the total effort are as follows:

- David Thornton, Larry Coady and Colin Duerden: Liaison Committee.
- Mike Taylor: layout and illustration reproduction.

- Gill Campbell drafted most Figures.
- Mike Fleming: organization of the flow of literature.
- Sherilyn Beaton: accounts; Carol Hunt: coordination of office support.
- Direction, guidance, sound advice and review of the final product: Harold Snyder.

As well, the cooperation and encouragement received from the large number of people contacted during the course of this project is acknowledged.

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CHAPTER 2
SCENARIO OF AN OIL BLOWOUT IN THE LABRADOR SEA

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2 INTRODUCTION

This chapter presents the hypothetical blowout situation and a description of ensuing countermeasures-related events. It draws heavily on the information contained in all of the contributing studies. This input is applied and the presentation made in narrative form rather than as a scientific report, i.e., references are lacking.

Much of the scenario description is necessarily highly speculative, but it does represent a best effort at producing a realistic projection.

As a final section, recommendations are made on research needs relevant to achieving the objectives of the AMOP program as applied to the Labrador offshore.

The blowout described is intended to be a reasonable projection of the extreme event. Some comment is in order regarding how reasonable it is. Clearly, the flow rate cited (15000 bbl/day) is much greater than that described as the standard Beaufort Sea Blowout (Milne and Smiley, 1976), where a flow rate of 2500 bbl/day declining to 1500 bbl/day after one month is hypothesized. During discussions with government officials, as well as in conversations with industry representatives, it was emphasized that this volume was probably of the right order of magnitude. For comparison, the Ekofisk Bravo Blowout released 18000 bbl/day during its seven and one-half day duration (Vanderkooy, 1977). The gas flow envisaged for our case is probably quite conservative since it was suggested that a gas to oil ratio of 500:1 was reasonable. This compares with the 150:1 ratio used.

The duration of release was established at nine months. Should a blowout occur in late fall, it is probable that a relief drilling vessel could not enter the area until mid-June of the following season. Given all the problems encountered during normal drilling in the area and combining these with the precision needed in relief well drilling, it would seem reasonable to expect the operation to take six weeks to complete. Hence, it is assumed that the blowout is contained and the flow halted by the end of July.

Within this timeframe, the spill response scenario is constructed. The scenario itself, however, contains no detailed consideration of actual relief well drilling and other efforts to stop the release.

2.1 The Blowout

The well is located 80 km offshore on the Nain Bank where the water depth is 200 m. It is approximately 250 km NW of Eastcan et al Bjarni H-81 (drilled in 1973) and 320 km SSE of Eastcan et al Karlsefni H-13 (drilled in 1975).

This is the second exploration well in the Nain area of the Labrador Sea. The main objectives were the lower Cretaceous Sandstone (Bjarni Sandstone) that bears gas in Bjarni H-81 and the Palaeocene Sandstone (Cartier Sandstone) that was very porous and thick but aquiferous at Gudrid H-55. Stratigraphic traps in the Tertiary were possible.

The well, forecasted to 3,800 metres (12,500 ft), was intended to obtain stratigraphic information adjacent to a major abrupt pinchout against basement or buttress, which was well developed in the Nain and Saglek areas.

The well was spudded on August 25 and drilling was completed on October 31, at 3170 m (10,400 ft) (Figure 2.1). The Bjarni Sandstone, which contained hydrocarbon shows and yielded gas, mud filtrate and oil, had been intersected at 3030 m (9950 ft) two days before the disconnect was made. Preparations were begun to test the well; however, the operation was suspended because of the presence of an iceberg. The iceberg, estimated at 5,000,000 tonnes, was approaching from the north.

Attempts to tow the iceberg were futile because of high winds. Speculation was made that the iceberg might have a draught sufficient to threaten seabed emplacements. Its sail height was 50 m, which indicated a keel depth in the order of 200 m. Therefore, the decision was made to suspend the well and remove the Blowout Preventor (BOP). Operations to run a cement plug were initiated; however, heavy seas necessitated waiting on weather, and this operation could not be completed. The rig had to move off the hole, leaving the BOP in place.

The iceberg subsquently approached the site and destroyed the BOP, apparently by bottom gouging. A large and violent oil flow with gas appeared around the iceberg. The total flow was estimated to be 15,000 barrels/day of light sweet crude. Gas flows could not be measured, but were estimated at 0.36 million m^3/day of gas with strong H_2S odor. The blowout and the released fluids are described in Table 2.1.

After four days of slow movement, the iceberg rolled and appeared to come free of the seabed. It then drifted off relatively quickly.

2.2 Monthly Events Following Blowout

It is assumed that a blowout occuring late in the drilling season would not be brought under control until the following summer. The consequences of an uncontrolled flow of oil for this nine-month period are outlined in the following narrative.

2.2.1 November. Following a brief period of discussion among officials of the Department of Energy Mines and Resources, the Operator, and the Canadian Coast Guard,

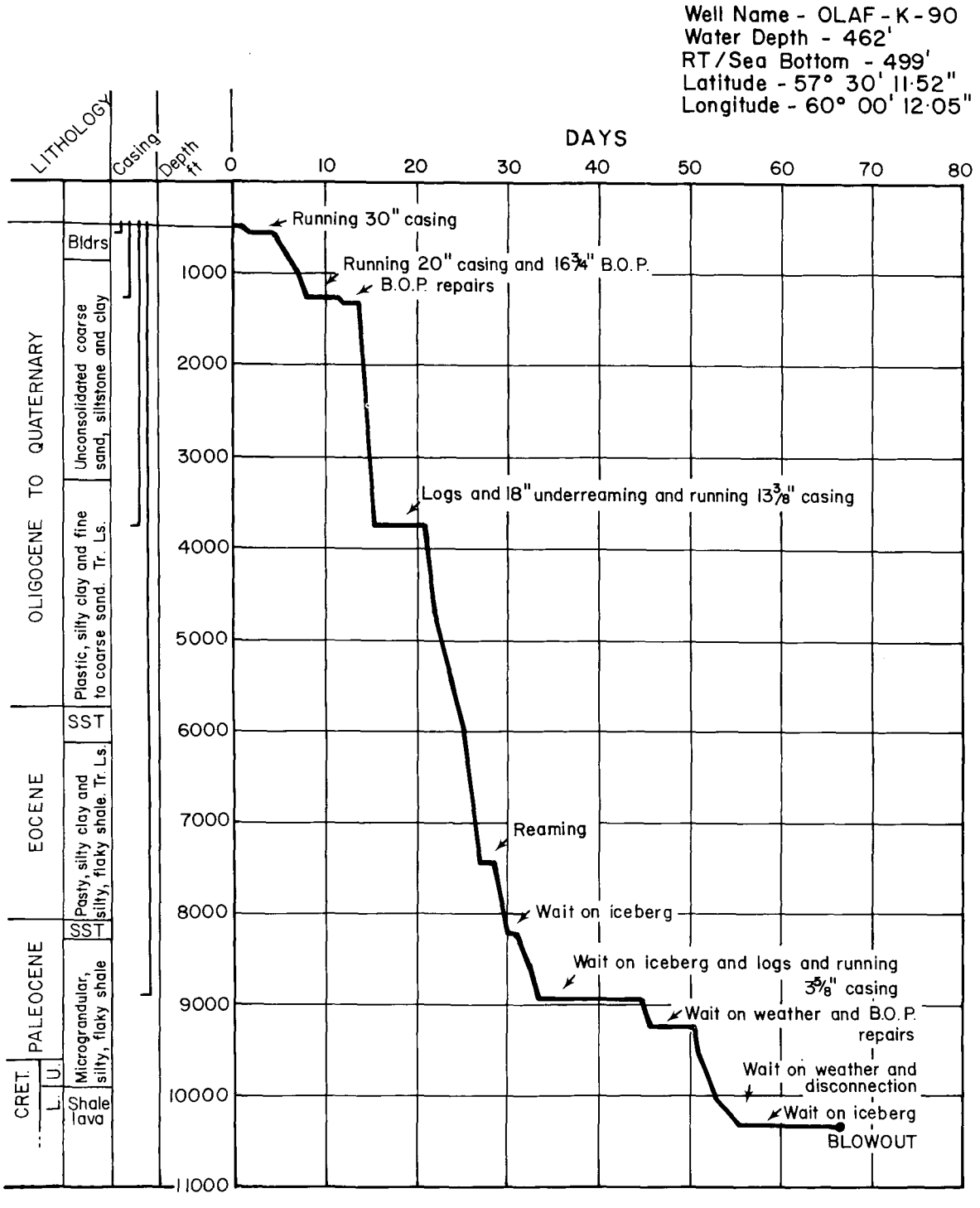

FIGURE 2.1 HYPOTHETICAL BLOWOUT PROGRESSION CURVE

TABLE 2.1 LABRADOR SEA BLOWOUT

Place: Labrador Sea: $57^{o}30'$N, $60^{o}00'$W

Water Depth: 180 m

Oil Type: light, sweet crude oil

Oil Density: 0.8251 gcm^{-3} (40°API)

Oil Flow Rate: 2.4×10^{3} m^{3}/day = 1.7 m^{3}/min = 2.8×10^{-2} m^{3} s^{-1}
(15,000 bbl/day)

Gas Type: natural gas

Gas Flow Rate: 3.6×10^{5} m^{3}/day = 250 m^{3}/min = 4.2 m^{3} s^{-1}
(13 MMcfd) normalized to atmospheric pressure

Oil to Gas Ratio: 1:150

Blowout Period: November 1 to August 1 (273 days)

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it is agreed that the Coast Guard will immediately take over control of countermeasures operations. The Regional Marine Emergency Officer (RMEO) at St. John's is appointed as on-scene commander. He moves to Goose Bay, where an operations centre is established within three days.

A total of 50 personnel, including staff from the Canadian Coast Guard (CCG), Environmental Protection Service (EPS), Fisheries and Marine Service (FMS), Canadian Wildlife Service (CWS), Department of National Defence (DND), Atmospheric Environment Service (AES), Department of Energy Mines and Resources (DEMR), the provincial government, and the Operator are assigned to the Centre. As well, observers are appointed from Denmark and the U.S. Coast Guard.

The ice-capable, offshore supply vessel stationed at Botwood for Search and Rescue operations is deployed immediately to the blowout site. The vessel is equipped with a Framo ACW 400 skimmer and two Vikoma sea packs. The Canadian Armed Forces make two Hercules aircraft from Trenton AFB available for airlift of equipment to Goose Bay. Charter aircraft and vessels that the Operator has on site are made available to assist in cleanup operations.

Field operations are established at the site and at Hopedale.

The Canada Centre for Remote Sensing and the Ice Forecasting Central of Atmospheric Environment Service make aircraft available for remote sensing and tracking of the oil slick. Tracker aircraft of fisheries surveillance, as well as International Ice Patrol Hercules aircraft, are placed on standby to provide further back-up support.

Sea ice is present inshore along the northern portion of the Labrador coast, south to Nain. The blowout site, however, is ice free. Predominant winds are from the western sector, with 20 percent of the wind due west.

High sea states are common. Waves greater than 10 metres occur 30 percent of the time. Air temperatures approach 0° C and result in a serious freezing spray problem.

Storm conditions prevail for five days and winds exceeds Beaufort Wind Scale 4 for more than 35 percent of the time. Total cloud cover predominates during half of the month, and visibilities are equal to or less than 5.0 nautical miles for one out of every four days. Fog, rain and snow occur equally, cumulatively accounting for 30 percent of the poor weather conditions during the month.

Labrador current velocities would be expected to peak in early fall, and a conservative estimate of their velocity is 40 cm/s. Local surface velocities increase significantly during storm conditions. The surface water temperature at the blowout site ranges from 0 to 1° C.

Oil movement is predominantly offshore with a general south-eastward component; it drifts approximately 24 to 48 km daily. As a result of the predominant wind direction from the western sector and the frequent storm conditions, the oil rapidly moves into the Labrador Sea proper.

With the exception of deployment of dispersants available on site, no counter-measures are attempted during the first week. The limited supply of available dispersants accounts for recovery of less than 50 barrels of oil. An oceanographic vessel from the Bedford Institute of Oceanography is directed to the site to monitor the effects of the oil spill.

By mid-November, five offshore supply vessels (four Operators, one Coast Guard) are available and working in the area. Attempts are made to contain and recover some of the oil. Sea state and freezing spray hamper operations and make containment by booms ineffective. The Framo skimmer, operating close to the wave ring, manages to recover some oil from uncontained slicks. Officials optimistically estimate that 25,000 barrels of fluid are recovered, of which about one-half would be oil. Pumping and storage becomes a probelm as the storage capacity of the supply vessels is approximately 5,000 barrels each.

One-half of the oil released does not form a surface slick but is dispersed in the water column as it rises from the seabed. The remaining crude oil surfaces with the

gas in a violent boil area. The oil tends to be contained within a wave ring 180 m in diameter; however, wind, currents, and waves rapidly spread slicks, and emulsions form readily. One-half of the surface oil evaporates in the first few weeks. Degradation proceeds rapidly in the open ocean.

As a result of the currents and wind patterns, no oil reaches shore. Scattered reports of oil seabirds are received, however, and three fishing vessels operating in the area report sighting oil that interfered with their fishing activity. By the end of the month, environmental impacts are relatively minor.

In order to reduce the hazard of noxious gas to work crews, and when it becomes clear that the blowout will not be curtailed before the ice moves into the area, the decision to flare the gas is made. Ignition is made from one of two helicopters operating from Hopedale.

2.2.2 December. Weather conditions are similar to those evident during November, with the exception of the presence of 1/10 to 4/10 ice cover at the blowout site, which results in a reduced sea state and lessens the freezing spray problem. Shorefast ice is common as far south as Hamilton Inlet. Total cloud cover, which makes satellite monitoring with visible and infrared sensors difficult, occurs for 18 of the 31 days. Visibilities are marginally improved over November.

The winds shift slightly to the north, which results in a net southward increase in both ice and oil movement. Poorly consolidated ice cakes and grease are common at the blowout site. Icebreaker support is required to keep Goose Bay open.

The first deliveries of recovered oil are transferred to the underground storage tanks at Goose Bay. Some delays are encountered in transferring recovered fluid from dockside to storage tanks; however, a temporary piping arrangement is set up, and with heating, fluid is sucessfully pumped from the vessels.

At sea, attempts at containment are curtailed because of the presence of ice. Although sea state and storm conditions have moderated, the presence of ice and colder temperatures significantly reduce recovery capability. Less than 5,000 barrels of oil are recovered.

Attempts to keep the gas ignited continue, and the presence of ice permits some burning of oil (an estimated 10,000 bbl) confined between ice floes.

Approximately 55,000 barrels (25 percent) of the surface released oil are contained under or in the ice, where evaporation and degradation are negligible. The remaining 160,000 barrels of surface oil slowly drifts into the Labrador Sea proper, where rapid degradation and evaporation occur.

The presence of drift ice as far south as the Straits of Belle Isle adds protection for the coastal areas from direct contamination by oil. There is no offshore fishing activity in the sea during December. Scattered reports of oiled seabirds are the only direct evidence of environmental damage.

All requested countermeasures equipment is at Goose Bay and ready for deployment by mid-December.

2.2.3 January. Air temperature averages -5° C. Predominant wind direction is from the north and northwest sectors. Approximately 35 percent of the time wind speeds are greater than 22 knots, and windchill becomes a serious problem with regard to outside activity. Cloud cover is similar to that which was evident during December, but visibility improves somewhat.

The blowout site is 5/10 to 7/10 ice covered; and although surface currents are reduced (15 to 25 cm/s), the parallelled nature of the predominant winds increases the ice drift rate to 39 km daily. The ice edge is approximately 10 to 25 km from the blowout site and much of the oil reaching the surface is contained in or under the sea ice.

Flaring of the gas continues with the support of helicopters operating from Hopedale. An optimistic estimate that 10 percent of the surface oil is burned at the blowout site is made. Of the remaining 200,000 barrels, 50 to 70 percent are under the ice and preserved from rapid degradation. By the end of the month, approximately 2,400 km^2 of ice have been at least partially contaminated by oil.

Use of the Framo skimmer is attempted; but due to the cold temperatures, it has little success and only 500 bbl are recovered.

Goose Bay has to be closed as operations headquarters and icebreaker support curtailed since there are no large-scale operations that require the expensive effort of keeping Lake Melville open. Gander and St. Anthony are established as observation headquarters. One oceanographic vessel remains at the site for scientific investigation and the remaining vessels are released.

Flaring of the gas continues.

The normal offshore fishing activity is disrupted for two of the 14 vessels operating in the area. They report the presence of oil and oil/ice in the area and they move on to avoid oil contamination of their gear. Scattered reports of oiled pelagic birds continue to be received.

The oil and oil/ice mixture has reached approximately 1,200 km south of the blowout site by the end of January.

2.2.4 February. Weather conditions are essentially the same as January's, with the exception of an increase in winds from the south and southwest at the cost of the northeastern component. Surface currents remain the same: 15 to 25 cm/s. The net drift of ice and associated oil is, however, reduced because of the counteracting winds. The drift rate of ice at the blowout site is 35 km daily, a slight reduction from that experienced in January. Localized storm conditions sporadically increase the rate of movement to as much as 100 km/day.

Ice concentration at the blowout site is 8/10 to 10/10; the ice edge is 25 km to the east. Sea ice is present along the entire Labrador-northeast Newfoundland coast to Conception Bay. Ninety percent of the surface released oil is contained under or in the individual floes, and an area of ice covering 5,000 km^2 is affected by this oil.

Countermeasures for February are reduced to continued flaring of the gas and attempts to burn some of the surface oil. The flaring operation is less sucessful because of the abundance of ice. Because the flame was frequently smothered by the ice cover, daily helicopter overflights are made from Hopedale, weather permitting. AES and Canada Centre for Remote Sensing (CCRS) aircraft, with operations based at Gander and St. Anthony, attempt to track the oil and ice. All surface vessel operations in the pack are curtailed by mid-month, due to their immobility when the sea ice is in compression.

The sixty fishing vessels normally operating near the ice edge abandon operation because of the reported presence of oil and oil-soiled ice.

Scattered reports of oiled pelagic seabirds continue to be received. The northward migration of seals at the end of the month does not appear to be seriously hampered; however, some abnormal behaviour patterns are reported.

Oil and oil-soiled ice appear in Conception Bay by the end of February.

2.2.5 March. The climate begins to moderate, and winds shift towards the west and southwest. Beaufort Wind Scale 4 winds occur less than 30 percent of the time. Air temperatures hover close to 0° C. Surface water currents are still relatively low (15 to 25 cm/s).

Ice concentrations at the blowout site are 5/10 to 7/10. The ice field extends almost to St. John's. The combination of surface currents and winds parallels the situation that existed in February, and produces an average daily drift of 36 km.

The majority of the oil is still contained either under or in the individual ice floes.

Countermeasures are restricted to burning attempts. Burning operations at the wave ring are somewhat more successful as a result of the confining influence of the pack ice. Flaring of the gas continues.

The floe movement monitoring operation adopted during the previous month is still active. An ice-reinforced, fishery research vessel is assigned to the site to replace the oceanographic vessel and to continue environmental studies.

All offshore Labrador fishing activity continues to be curtailed.

Reports of oiled pelagic seabirds are more common over a much larger area. A significant portion of the "front area" is obviously contaminated by oil. Although the overall concentration of oil is low, scattered pools between and under floes interfere with the whelping of harp seals. Their white coats appear to have a reduced fat content. One of the two causes is evident: oil covering the adults discourages nursing. Additionally, the nursing adults are not as well nourished as they are normally. Apparently their pursuit of food is hampered by the presence of oil. A high infant mortality is suspected. Concerned Fisheries officials reduce the offshore quota on harp seals by 50 percent.

Almost 8,000 km^2 of ice are contaminated by oil by the end of March.

2.2.6 April. Air temperatures regularly rise above 0° C, and contribute to degradation of the ice cover. Weather conditions, including visibility and cloud cover, are similar to conditions that existed during March. However, the wind direction has a stronger north-northwest component, and mean speeds are reduced. Wind velocities of 40 km/h or greater occur less than 25 percent of the time. The ice cover effectively dampens the wave height.

Coastal runoff is still relatively low, and surface water current speeds remain at 15 to 25 cm/s. At the blowout site, the 5/10 to 7/10 ice cover moves at an average rate of 38 km/day as a net result of currents and winds.

The surface water temperatures at the ice edge are -1 to 0° C, and some melting of the sea ice occurs. The oil trapped in this surface ice becomes available to evaporation and degradation. Additionally, 50 percent of the oil released from the blowout during the month is on open water and rapidly dissipates.

The oil released by the melting ice forms into slicks that are too thin and/or scattered for recovery techniques. Attempts to ignite the localized oil layers found in the melt pools at the surface of cakes proves to be impractical.

Field operations from Hopedale, St. Anthony, and Gander continue; but because of ice conditions, countermeasures activities are limited to monitoring and

tracking oil/ice movement and attempts at air-deployed ignition. The airborne operation to flare the gas and ignite the oil contributes to the burning of approximately 10 percent of the oil at the blowout site.

Because of the presence of oil-contaminated ice off the Avalon Peninsula, an operational headquarters is set-up at St. John's.

The formation of leads and the increasing number of seabirds (especially the family Alcidae: murres, quillemots and puffins) results in a greatly increased number of reports of oiled pelagic birds as far south as the Avalon Peninsula. At the front, harp seal breeding, which normally follows whelping, appears to be disrupted. The seal pups appear less healthy.

Offshore fishing vessels remain clear of the area because of the oil.

The oil release during April contributes to a total area of contamination of approximately 10,000 km^2. In addition to the amount released at the blowout site during the month, the rapid melting at the ice edge releases an estimated 50,000 barrels of oil.

2.2.7 **May.** The air temperature is generally above freezing. The wind speed has moderated substantially; calm conditions prevail for as much as five percent of the time. The winds are shifting towards the west and south and this slows the southward drift of the pack ice. Offshore winds contribute to a loose pack ice cover, which is continually being blown into the warm Labrador Sea water. Surface water current speeds remain at 15 to 25 cm/s, and ice drift velocity averages 20 km/day.

At the blowout site, ice concentrations are 4/10 to 5/10. The southern boundary of sea ice extends to Cape Freels. Landfast ice starts to melt out of Lake Melville and the Coast Guard re-establishes Goose Bay as operations centre with icebreaker support.

Five ice-capable supply vessels and one small, coil-heated tanker are deployed to the blowout site. Surface water temperatures at the site are above the freezing point of seawater (0° C) and loose open ice is encountered. Two Framo skimmers are successful in recovering oil in the leads. Other recovery devices such as the Oil Mop and the Bennett system, operating from tender vessels, are only marginally successful. Transfer of recovered oil was a major problem and the use of these devices is curtailed. Boom deployment is hampered by ice.

As a result of containment by the slow drifting ice and the relatively calm conditions, burning consumes a significant proportion of the surface oil. Attempts to ignite oil that is melting out at the ice edge or covering melt pools still prove impractical, and these efforts are discontinued.

Because of the danger that surface oil slicks at the ice edge present to seabirds, the use of chemical dispersants is authorized. Two offshore vessels equipped for dispersant application operate along the ice edge. By this time, the available Canadian supply of concentrates has been transported to the area. These permit 10 to 15 hours of continuous use. Supplies from outside Canada, plus stepped-up manufacturing, serve to increase this quantity considerably. Operation from Goose Bay continues to be supplemented with support from Gander (aircraft), St. Anthony (aircraft and ships), and Hopedale (helicopters).

The large flocks of murres that are normally seen at the ice edge in May are seriously affected by oil pollution. Oiled seabirds, including sea ducks, are reported along the southern Labrador and northeast Newfoundland coasts. Oiled adult birds either abandon the nests or produce less viable eggs. Land-based hunters along the Labrador and northeast Newfoundland coast report reduced seal numbers.

The Labrador offshore fishing activity remains curtailed because of the oil.

May is the most successful month to date for countermeasures operations: it is estimated that 20 percent of the surface oil is burned at the blowout site, seven percent recovered, and one percent chemically dispersed. Fifty percent of the remaining oil is lost either by dispersion or by evaporation.

2.2.8 June. Climatic conditions improve considerably and temperatures are well above freezing. Visibility of five nautical miles or more occurs 70 percent of the time. Prevailing winds are blowing from the south-southwest, with a substantially reduced northern component. Coastal runoff contributes to an increase in surface currents, which are in the range of 25 to 35 cm/s. At the blowout site, ice cover is reduced to 1/10 to 4/10, with the ice edge less than 15 km away. The ice velocity averages 25 km/day. The southern ice limit has retreated to Hamilton Inlet.

The rapidly melting sea ice releases a large volume of essentially unweathered oil in an area extending from the blowout site south along the entire northeast section of Newfoundland. Because of the prevailing wind direction, the oil generally moves offshore; however, currents and physiography in local areas (e.g., White Bay) serve to bring substantial amounts of this oil ashore.

At the blowout site, countermeasures activities increase; however, while flaring of the gas is uninterrupted, efforts to encourage burning of the oil are less successful because of the reduced containment provided by the ice cover.

Containment with booms becomes marginally successful when weather conditions and sea state permit. There is little recovery of oil that is not contained within the booms. Oil that either covers individual ice cakes or that which is released from the melting ice is too thin to recover or to ignite. Dispersant use is increased, however these chemicals are less effective on the weathered oil.

Oil starts to become evident along coastal areas of southern Labrador and northeast Newfoundland. Shoreline clean-up operations are initiated adjacent to settled areas; however, except for some localized areas, most of the oil washed ashore is extremely thin.

The major impact of this thin oil coating is on the capelin spawning. Although the oil concentrations are low, the capelin eggs, which are laid on the beach, react unfavourably to the oil. Unsuccessful incubation of eggs and a reduction in larval survival results. Scientists indicate that this reduced survival would probably not have a long-term effect on capelin populations. There was concern, however, that heavily oiled beaches might be ruined for many years to spawning and that this could permanently reduce capelin populations if the fish refuse to move to other spawning sites. Herring spawning in the shallow waters of Notre Dame Bay is also detrimentally affected by the oil that comes ashore.

Inshore fishermen along the southern Labrador coast complain about fouled cod traps and gill nets. There is a general reluctance to put gear in the water because of the risk of fouling with oil.

Seabird populations along the coast are normally quite large by this time. Gulls and shearwaters come close inshore along southern Labrador and northeast Newfoundland during the capelin spawning period, and many of these birds become oiled. There are also signs of oiling among breeding and migrating sea ducks, which are concentrated along the Labrador coast. Adult seals and other sea mammals found inshore along the coast display no ill effects.

The offshore fleet continues to avoid the area off southern Labrador.

During June, the net fate of oil is as follows: 15 percent is burned at the blowout site; 10 percent is recovered from containment booms; and less than one percent is chemically dispersed. In addition to the amount released at the blowout site during the month, an additional 600,000 barrels are released from the melting sea ice. A relatively small proportion (nevertheless, a substantial amount of oil) reaches the beaches as a weathered crude residue.

Relief well drilling is initiated by mid-June.

2.2.9 **July.** Weather conditions are generally warmer and milder. Sea states of less than 0.75 m are experienced 50 percent of the time. The wind is predominantly from the southern sector. Surface currents are in the order of 35 to 40 cm/s, and the entire coast is ice free, with the exception of scattered ice along the northwestern sector of Labrador.

Oil released at the blowout site drifts at a rate of 30 cm/s (25 km/day).

At the blowout site, the gas continues flaring. Containment of the oil within the wave ring is attempted by deployment of a fire-resistant boom. While much of the oil escapes beneath the boom skirt, an estimated 20 percent of the released oil is burned.

Several Vikoma boom systems are deployed and used, along with three Framo ACW 400 skimmers operating from supply vessels. This operation is successful in recovering 20 percent of the surface oil.

On-site storage of oil is supplied by small tankers and Dracones. More permanent storge is supplied by the underground tanks at Goose Bay.

Reports of large numbers of oiled seabirds continue.

The offshore fishing fleet continues to avoid the area. Inshore char fishermen in the Nain area do not deploy their gill nets after one fisherman reports fouling of his gear. Inshore fishermen in northeast Newfoundland and southern Labrador report fouled gear and reduced catches.

Oiled shorelines are reported at scattered locations in Notre Dame Bay and White Bay, Newfoundland. On the coast of Labrador, oil comes ashore near Cape Harrison and among the offshore islands in the Nain area. An estimated eight km of beach is lightly to moderately oiled.

An attempt is made to utilize Armed Forces personnel and equipment to clean some beach areas in Labrador. A major operation is undertaken in Byron Bay, near Cape Harrison, where a 50-man camp is established. Heavy equipment for transfer to shore is brought to the area using ship transport and heavy helicopters.

Difficulties are experienced in locating disposal areas in the backshore. The bedrock has little overburden and the soils are very porous. Nevertheless, several sites are eventually located well away from the beach. Operations are initiated to remove the oiled sand and gravel using front-end loaders and tracked-transport vehicles. After two weeks, three km of shoreline have been cleaned of oiled debris.

A shift in winds, however, then threatens to bring oil ashore again. Hand-operated snow blowers are used to spread peat moss along the shoreline in an effort to

reduce the amount of oil that would reach the beach. However, only 1.5 km of beach is protected in this manner before the oil comes ashore. After four weeks' work involving a 50-man crew, a total of only 1.5 km of beach have been cleaned, and the decision is made to discontinue shoreline cleanup attempts in isolated areas.

Monitoring studies on capelin larval survival provide inconclusive evidence of the effects of oil damage. Surveys of seabird colonies in the affected area are undertaken by Canadian Wildlife Service scientists. Early results indicate a major disruption of breeding and hatching success in some colonies.

By the end of July, the blowout is brought under control by successful completion of a relief well. The Operations Centre at Goose Bay is maintained for a further six-week period to continue coordination of shoreline cleanup efforts, monitoring and scientific surveys, as well as to carry out decommissioning.

2.3 Net Fate and Impacts

Table 2.2 summarizes the fate of the oil cumulatively, by month, for the duration of the blowout. Of the total amount released, only one-half appears as a slick at the surface. The rest is dispersed in the water column and does not form a slick; hence, it is unavailable to cleanup efforts. Of the remaining proportion, 14 percent (seven percent of the total released) is accounted for by the various countermeasures methods employed. Even this low figure is probably highly optimistic. Seven percent of the remaining oil reaches the shoreline in dispersed patches from Nain to Conception Bay.

Of the oil handled by various countermeasures, burning is the most successful, accounting for 63 percent of the oil removed by human efforts. It seems reasonable to accept that a major effort would be made to burn the oil along with flaring the gas. Given the operational problems of getting vessels and aircraft to the site, even assuming effective ignition and wicking systems were available, the proportion of oil burned in comparison to the amount surfacing at the blowout site would probably not greatly exceed the nine percent postulated.

The impacts described in the scenario are summarized in Table 2.3. These are highly speculative and include only the following: (a) major and immediate effects on species that are harvested by man; and (b) interruptions of that harvesting activity.

2.4 Recommendations

As a result of this exercise, the following items were identified as relevant to achieving the objectives of the AMOP program insofar as it applies to the Labrador Sea.

TABLE 2.2 FATE OF OIL BY MONTH

Month	Total Released	Total Surfacing	Evapo-ration	Recov-ered	Chemically Dispersed	Burned	Oil in Ice	Oil Released from Ice	Oil Ashore
November	450,000	225,000	106,000	12,500	50	--	--	--	--
December	465,000	232,500	80,000	5,000	--	10,000	55,000	--	--
(Cumulative)	915,000	457,500	186,000	17,500	50	10,000	--	--	--
January	465,000	232,500	28,000	500	--	23,250	153,000	--	--
(Cumulative)	1,380,000	690,000	214,000	18,000	50	33,250	208,500	--	--
February	420,000	210,000	10,500	--	--	--	189,000	--	--
(Cumulative)	1,800,000	900,000	224,500	18,000	50	33,250	397,500	--	--
March	465,000	232,500	10,500	--	--	5,000	206,500	--	--
(Cumulative)	2,265,000	1,132,500	235,000	18,000	--	38,250	604,000	--	--
April	450,000	225,000	75,625	--	--	22,500	101,250	50,000	--
(Cumulative)	2,715,000	1,357,500	310,625	18,000	--	60,750	655,250	50,000	--
May	465,000	232,500	71,500	13,000	800	46,500	30,000	80,000	--
(Cumulative)	3,180,000	1,590,000	382,125	31,000	850	107,250	605,250	130,000	--
June	450,000	225,000	378,400	22,500	16,875	33,750	--	605,000	75,000
(Cumulative)	3,630,000	1,815,000	760,525	53,500	17,725	141,000	--	735,000	75,000
July	465,000	232,500	74,400	37,200	1,400	46,500	--	--	50,000
(Cumulative)	4,095,000	2,047,500	834,925	90,700	19,125	187,500	--	--	125,000

N.B. All values are in bbl. One bbl = 0.1193 m^3 = 35 Imp. Gal.

TABLE 2.3 MONTHLY SUMMARY OF IMMEDIATE AND MAJOR IMPACTS

Month	Impact
November	Scattered, oiled seabirds Offshore Labrador fishing - three vessels curtail efforts
December	Scattered, oiled seabirds Offshore Labrador fishing - three vessels curtail efforts
January	Scattered, oiled seabirds Offshore Labrador fishing - two vessels curtail efforts
February	Scattered, oiled seabirds Offshore Labrador fishing - 60 vessels curtail efforts and depart the area.
March	Scattered, oiled seabirds Offshore Labrador fishing - vessels stay clear of area (61 were present in 1977) Seals - Harp Seal whelping area ("The Front") contaminated (20 percent) by oil ice. Infant mortality and reduced viability evidenced in 20 percent of pups. Offshore harp seal quota cut by 50 percent.
April	Large numbers of oiled seabirds, especially murres and puffins. Reduced breeding success in harp seals. Offshore Labrador fishery - vessels stay clear of area (20 vessels were present in 1977).
May	Large numbers of oiled murres. Scattered reports of other oiled seabirds from Labrador coast and northeast Newfoundland. Presence of oil near colonies interferes with seabird nursing and hatching. Offshore Labrador fishery - vessels stay clear of area (17 vessels present in 1977).
June	Oil comes ashore in scattered locations on the northeast coast of Newfoundland. Beach spawning by capelin hampered in beaches scattered along coast; beach material (spawning habitat) altered. Herring spawning in shallow water of Notre Dame Bay affected as eggs come in contact with oil. A few inshore fishermen along southern Labrador coast have gear fouled. Many fishermen express reluctance to put gear in the water. Many reports of oiled seabirds are received. Nursing and hatching appears to be affected in some colonies. Offshore Labrador fishery - vessels stay clear of area (30 vessels were present in 1977).

TABLE 2.3 MONTHLY SUMMARY OF IMMEDIATE AND MAJOR IMPACTS (Continued)

July	Oiled seabirds occur in large numbers. Oil comes ashore near Cape Harrison and along the islands near Nain. The shoreline along the northeast coast of Newfoundland continues to receive a light to moderate oiling at scattered locations. Inshore fishermen throughout northeastern Newfoundland and Labrador report fouled gear and reduced catches. Char fishermen in Nain area refuse to deploy fishing gear after reports are received of one set of char gear being fouled. Offshore Labrador fishery - vessels remain clear of the area (24 vessels in 1977).

2.4.1 Contingency Planning. Given the limited support facilities available in Labrador, prior planning is essential for any major operation. An exercise such as that which produced the Beaufort Sea Contingency Plan is recommended as a prerequisite to further offshore drilling.

2.4.2 Oil Recovery Systems. High-volume, integrated recovery devices should be developed. Such devices must be mounted on, or adapted to work from, seaworthy and ice-capable platforms which may be utilized in the open sea as well as in heavy pack ice.

2.4.3 Disposal. Given the problems of storage, transport, and transfer of recovered fluids, a system for efficient on-site incineration of recovered oil would prove invaluable.

2.4.4 Dispersants. The present approval system appears to act as a major impediment to the development of an adequate state of preparedness for use of this option. The federal approval procedure should be re-examined to enable contingency planners to include adequate supplies of acceptable products.

2.4.5 Shoreline Countermeasures. Sensitivity mapping should include information on the entire area of the northeast coast of Newfoundland, as well as Labrador. One important item to include is the time and location of capelin beach spawning.

It appears highly unlikely that a cleanup technique can be developed that is both efficient and effective in handling large quantities of oil-contaminated beach material; consequently, research efforts should concentrate on shoreline protection measures.

2.4.6 Environmental Hazard Prediction. Weather and sea state prediction capabilities are limited by the lack of offshore data. Methods of remote data collection should be developed further to provide improved localized forecasts.

The wave climate of the shelf region needs to be more accurately described.

2.4.7 Ice Characterization. The formation, structure and dynamics of the Labrador ice pack needs to be better understood. This can be achieved by carrying out further field studies throughout the full period of pack-ice presence.

Movement and divergence of individual floes needs to be documented in order to predict the fate of oil transported by ice.

2.4.8 Test Spills. A satisfactory understanding of the behaviour of oil in the Labrador offshore can best be achieved through conducting a series of controlled spills.

2.4.9 Field Studies. In the Labrador offshore, the physical conditions are different from true Arctic regions. Therefore, field tests directed to this specific area are needed to answer many of the questions posed.

2.4.10 Technology. Two major recommendations are perhaps outside the scope of this study, but they should be presented, nevertheless. Because of the particularly rigorous operating conditions in the Labrador offshore, the human element requires a systems support capability not yet achieved elsewhere. Technology must be developed that reduces the likelihood of accidents due to human error. Further, technology must be developed so that should a blowout occur, immediate and effective action could be taken to curtail the discharge. Eventually, this means developing a year-round capability to operate in the Labrador offshore.

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CHAPTER 3
GEOLOGY AND HYDROCARBON POTENTIAL OF THE LABRADOR CONTINENTAL MARGIN

by

K.A. Gustajtis

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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3 INTRODUCTION

This chapter gives an overview of the physiography, geology and geological history of the offshore Labrador, and the reported petroleum potential of the region. Included as well is a summary of exploration history to date. For convenience, a geological time scale is included in the Appendix to this chapter (Table A.3.1).

The Labrador continental shelf is generally delineated by the 500-metre isobath and encompasses an area of approximately 20.0 x 10^4 km^2 (50.0 x 10^6 acres) (Figure 3.1). Its northern and southern boundaries are just north of 60^oN parallel and 52^oN parallel, respectively. The adjacent land mass is the eastern extremity of the Canadian Precambrian Shield, and forms part of the Labrador-Ungava Peninsula. The granitic and metamorphic rocks of coastal Labrador give no clue to the existence of deep offshore sedimentary basins. The crystalline rocks of the Precambrian Shield slope seaward, and are overlain by a wedge of sediments ranging in age from Jurassic or older to late Tertiary.

These coastal plain sediments are believed to have been deposited under extension tectonics as a result of seafloor spreading between Canada and Greenland that commenced in the early Jurassic. The shelf is typical of many in high latitudes in that it is separated from the mainland by a discontinuous marginal channel. The marginal channel is believed to be the surficial contact between Precambrian crystalline rocks to the west and a seaward thickening prism of Mesozoic/Tertiary coastal plain strata to the east. Reworked glacial drift, predominately morainic debris in the order of tens to several hundreds of metres thick, is the main surficial deposit on the shelf.

3.1 Labrador-Ungava Peninsula.

3.1.1 Geology. The mainland physiography and geology is generally summarized by Bostock (1970) and Greene (1974). Precambrian quartzo-feldspathic gneisses of the amphibolite facies comprise much of the bedrock of Labrador. To the extreme north, gneisses of granulite-facies dominate. Granite rocks are widely distributed throughout Labrador, and anorthonites and associated basic and ultrabasic intrusives occur in a relatively large area around Nain and southern Labrador. The Labrador-Ungava Peninsula is essentially devoid of any sedimentary cover except for a small portion in the extreme southeast, where Paleozoic strata of the St. Lawrence Lowlands are found.

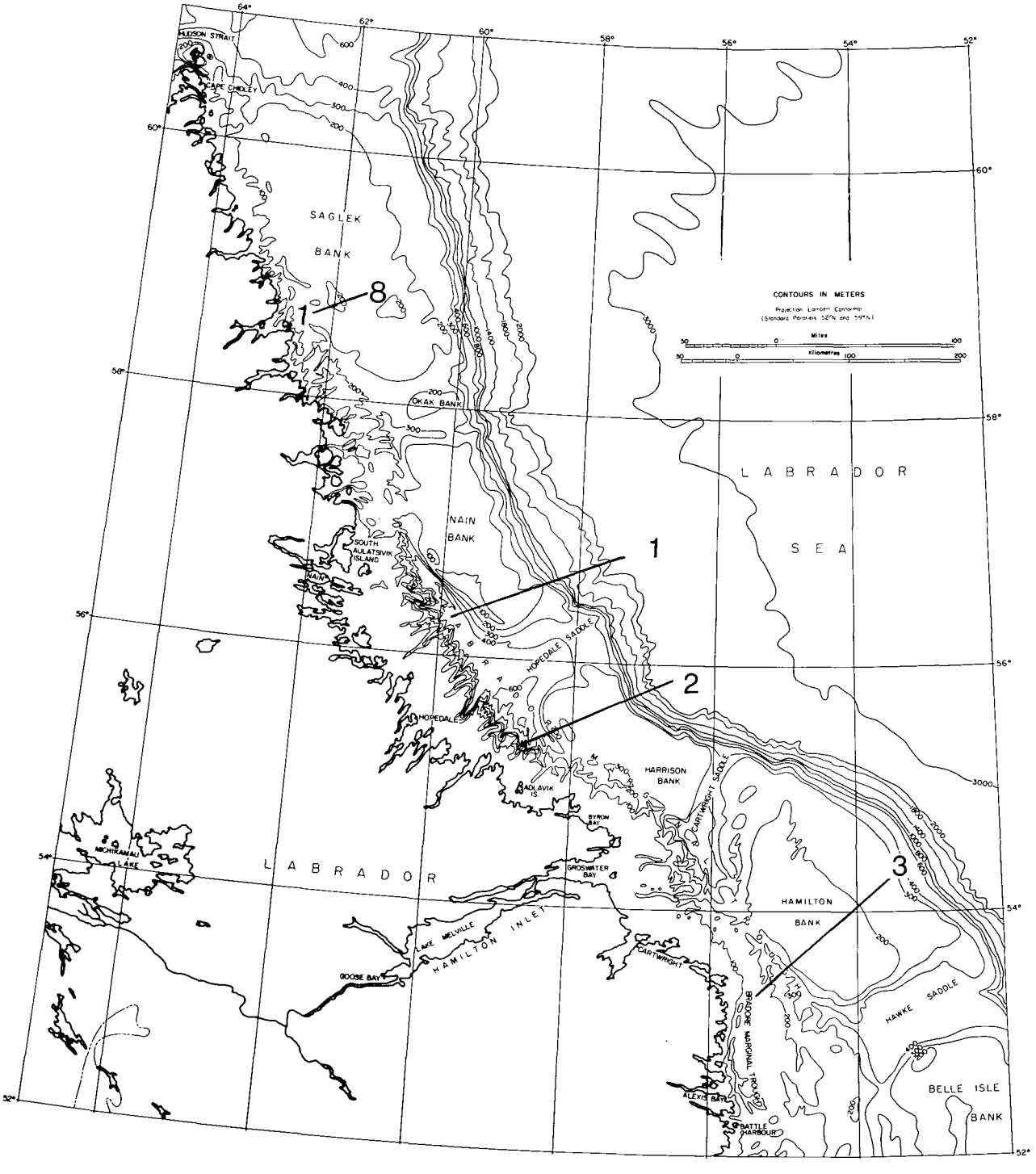


FIGURE 3.1 LABRADOR CONTINENTAL MARGIN
(N.B. Line 1-8 on Saglek Bank refers to Figure 4.15; Lines 1, 2 and 3 refer to Figure 3.9)

3.1.2 Physiography. An outstanding general characteristic of this landmass is the extreme flatness which is evidence of long and continued erosion. North from approximately 57°N, the coast forms the eastern boundary of a Tertiary erosional surface which, after a regional late Tertiary uplift, is now tilted westward; it has been fragmented by subsequent erosion. This old fragmented surface rises abruptly from the sea in northern Labrador as the Torngat Mountains. South of latitude 57°N, the same peneplain is present but at a much lower level, mostly about 600 m above the sea bed (McMillan, 1972).

Despite the general uniformity of the terrain, the mainland of Labrador is divisible physiographically into a series of fairly distinct regions (Figure 3.2). These regions are in part a reflection of the differences in the underlying geological structure; also, they are due to regional variations in the Cenozoic development of the peninsula, especially the differences in uplift, dissection, and glacial history.

The majority of the surface of Labrador is a peneplain which ranges in height from 300 to 700 metres above sea level, which Greene (1974) designated by the term plateau. Areas of low relief at elevations less than 300 metres are termed lowlands, and are confined to two small regions surrounding the Lake Melville Basin and the Strait of Belle Isle near Blanc Sablon. Areas of moderate relief at elevations not exceeding 1000 metres are termed the uplands, and are represented by the Kaniapiskau and Hope ranges, which are carved out of igneous and metamorphic bedrock. The former, forms the core of the Labrador-Ungava peninsula, and the latter forms a discontinuous series of hills. There are two areas in Labrador that can be described as mountains: the rugged northern coastal region referred to as the Labrador Highlands, which is made up of three different mountain groups - Torngats, Kaumajets and Kiglapait; and the Mealy Mountains south of Lake Melville.

3.1.3 Pleistocene Glaciation. The old peneplain, unevenly uplifted late in the Tertiary period, has been further altered during Pleistocene glaciation as evidenced by the extensive cover of glacial till. The Labrador-Ungava peninsula acted as a major ice centre for at least two of the Pleistocene glacial phases, although definite correlations between these glaciations and the four "classical" periods of the North American continent have not yet been established. Glacial flow features over Labrador peninsula generally show a fairly simple if not entirely decipherable pattern. The indicators of glacial movement, principally striations and drumlins, suggest that central Labrador-Ungava was an ice-remnant area, among one of the last to be deglaciated (Kirby, 1966).

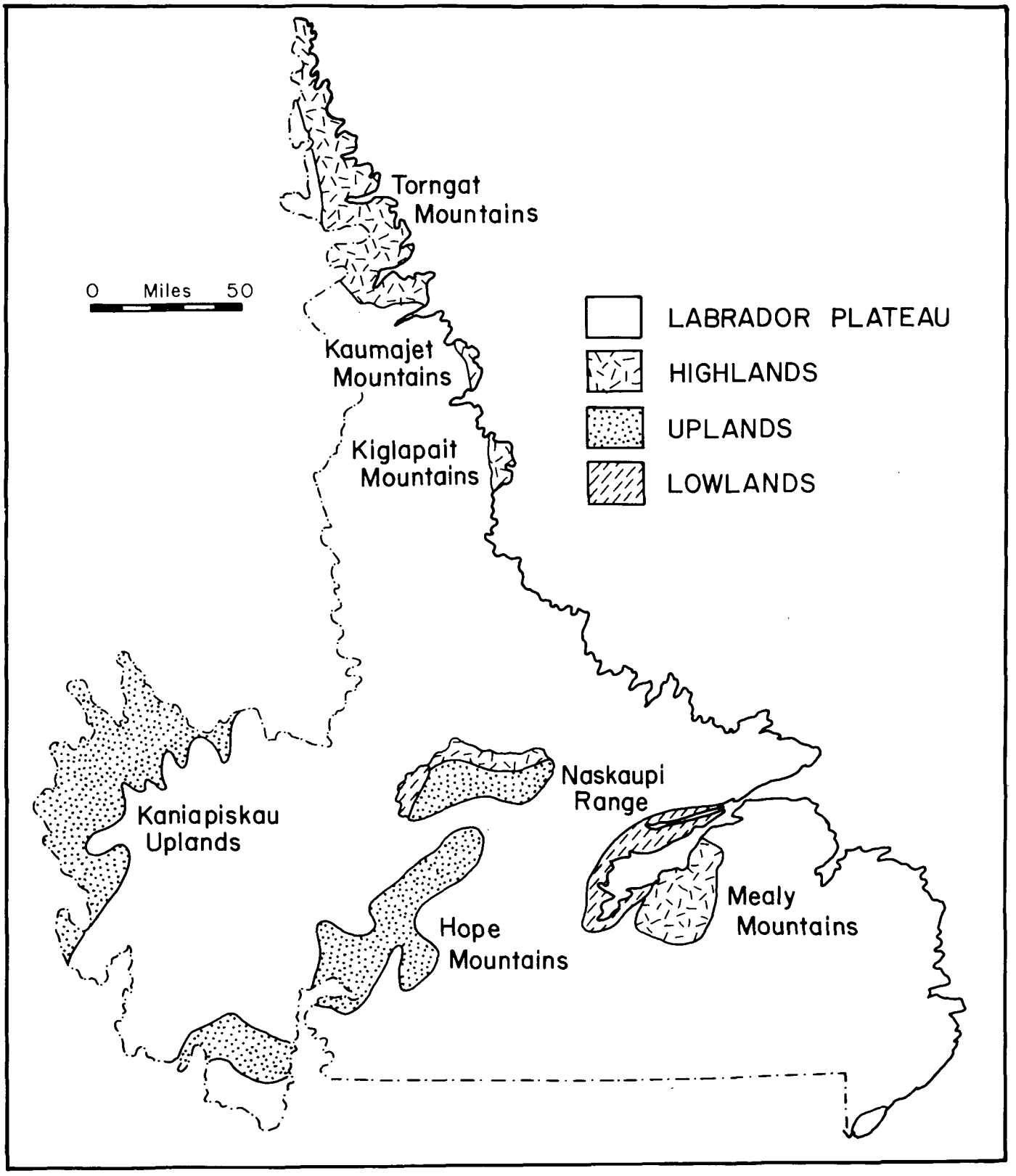


FIGURE 3.2 PHYSIOGRAPHIC SUBDIVISIONS OF LABRADOR
(modified from Greene, 1974)

The ice dispersal from the area is inferred from the radial pattern of the glacial flow features.

The Laurentide ice sheet may have originated on the high ground of Baffin Island to the north or within the Labrador-Ungava peninsula, either in valley glaciers in the highlands of the northeast or along the Laurentian Scarp in the south. Wherever the original site, the plateau of Labrador-Ungava was covered at maximum thickness by an ice sheet several hundred metres thick. The factors controlling movement of ice within the ice sheet were the ground relief and the ice thickness.

The extent of the classical Wisconsin glaciation in the eastern Arctic is uncertain. Work in Baffin Island indicates that both mountain tops and low lying areas along the northeast coast remained ice free throughout the Wisconsin, and it is possible that the situation may have been very similar in northeastern Labrador-Ungava (Lϕken, 1966). Investigations suggest that a late Wisconsin ice sheet, known as the "Cockburn Glacial Phase", was centered over Foxe Basin and Hudson Bay about 8,300 B.C., and may be correlated with the Cochrane re-advance in Ontario. Radiocarbon dates from marine shells indicate that the Arctic mainland coast became ice free about 10,000 years ago, and that there was rapid disintegration of the Cockburn ice over Hudson Bay and Foxe Basin between 8,000 and 7,000 years ago. The central part of the Lake Plateau of Labrador-Ungava was finally deglaciated about 6,000 years ago.

In northern Labrador, the late glacial and post-glacial emergence was not a continuous process (Lϕken, 1966). By the time the edge of the Wisconsin ice sheet had withdrawn to the present coastline, a network of valley glaciers originating on the Ungava Bay side of the mountains filled the valleys and fjords along the Atlantic coast. During the period that followed, when the ice front retreated westwards towards the drainage divide, several halts and re-advances occurred as shown by a number of end and lateral moraines.

3.1.4 Coastal Morphology. The coastal morphology along Labrador is the result of the interaction between isostatic recovery following the melting of the ice sheets, post-glacial eustatic rising of sea level, and the variations in their speeds. The post-glacial sea level movements along the Newfoundland and Labrador coasts indicate that the coast is apparently emerging due to isostatic rebound, as seen by the raised beaches (Figure 3.3).

The coastal region is typical of northern coastlines that have undergone recent inundation. It is characterized by an extensively indented coastline with long fjords; additionally, it is shielded by thousands of small rocky islands (skjaergaard), which give an

FIGURE 3.3 RAISED BEACHES AS A RESULT OF ISOSTATIC RECOVERY OF COASTAL LABRADOR (DEUS CAPE)

estimated total coastline of over 10,000 km. For the last 4000 years, the maritime provinces have been submerging three to five times faster than eustatic rise in sea level. The recent rise in sea level at the rate of about 15 cm per century in this area has produced a drowned shoreline. A detailed coastal classification for Labrador is not yet available. The Eastcoast Petroleum Operators Association (EPOA) funded a study to examine the coastal environment of Nova Scotia, Newfoundland and Labrador, using aerial photographs and 1:250,000 topographic maps (Scarlett et al, 1977). A first-order approximation of the coastal types along Labrador is provided in this study, and was used extensively in compiling the following section.

3.2 Coastal Environments and In-Shore Zone Dynamics.

The character of the shore zone of Labrador ranges from sheltered, low energy beaches, composed of poorly sorted glacial drift with sand cobble and boulder beaches, to resistant rock cliffs directly exposed to the Labrador Sea.

The combination of inherent factors, (such as bedrock, surficial sediments and relief) with meteorological and oceanographic conditions gives this area a great variety of coastal environments.

The shoreline was classified into two major sub-divisions:

- *Beach:* defined in the broadest sense as regions with some form or aggregate regardless of particle size; and
- *Non-Beach:* areas with exposed bedrock lacking the presence of any aggregate.

These two groupings were further subdivided into two groups: (i) steep slopes and (ii) intermediate to low slopes (Figures 3.4, 3.5, 3.6 and 3.7). The presence or absence of aggregate depends both on the sediment availability and the marine energy regime; furthermore, it reflects the vulnerability or susceptibility of a shoreline to an oil spill impact, which in turn is related primarily to the longevity of the oil in the environment.

Areas sheltered from direct wave approach have low energy beach environment; they are usually characterized by a thin layer of poorly sorted mud, sand and pebbles. By contrast, exposed coasts with intense wave action have resulted in a coastline simplified by erosion to headlands and deposition across embayments.

A detailed discussion of the coastal vulnerability to oil spill impacts is beyond the scope of this paper. However, a first-order approximation of susceptibility of the Labrador offshore is provided in Figure 3.8, which indicates that approximately 50 percent of the Labrador coastline consists of areas of low energy that have some form of beach or aggregate present. See the appendix to this chapter (Table A.3.2).

Coastal environments have received extensive studies with reference to oil spill vulnerability in various regions of the world (e.g., Gundlach and Hayes, 1978; Owens et al, 1977).

Exposed rocky headlands and wave cut platforms are generally least affected by an oil spill. Wave action is usually high and the natural cleansing of the shoreline occurs rapidly, generally within weeks. The rate of oil removal is a function of the wave climate; the greater the wave energy, the more rapidly oil will be removed. Approximately 18 percent of the total Labrador coastal region is represented by this type of coastline.

The coastal environments most adversely affected by an oil spill are those composed of sheltered regions. The numerous coves, protected embayments, and offshore islands along the central Labrador shores are representative of this type of coastal environment. The predominance of beach (Figure 3.8) similarly testifies to a sheltered,

FIGURE 3.4 LOW SLOPE AND BEACH (PAMIULIK BAY)

FIGURE 3.5 STEEP SLOPE AND BEACH (SNYDER BAY)

FIGURE 3.6 LOW SLOPE AND NO BEACH (NEAR MAKKOVIK BAY)

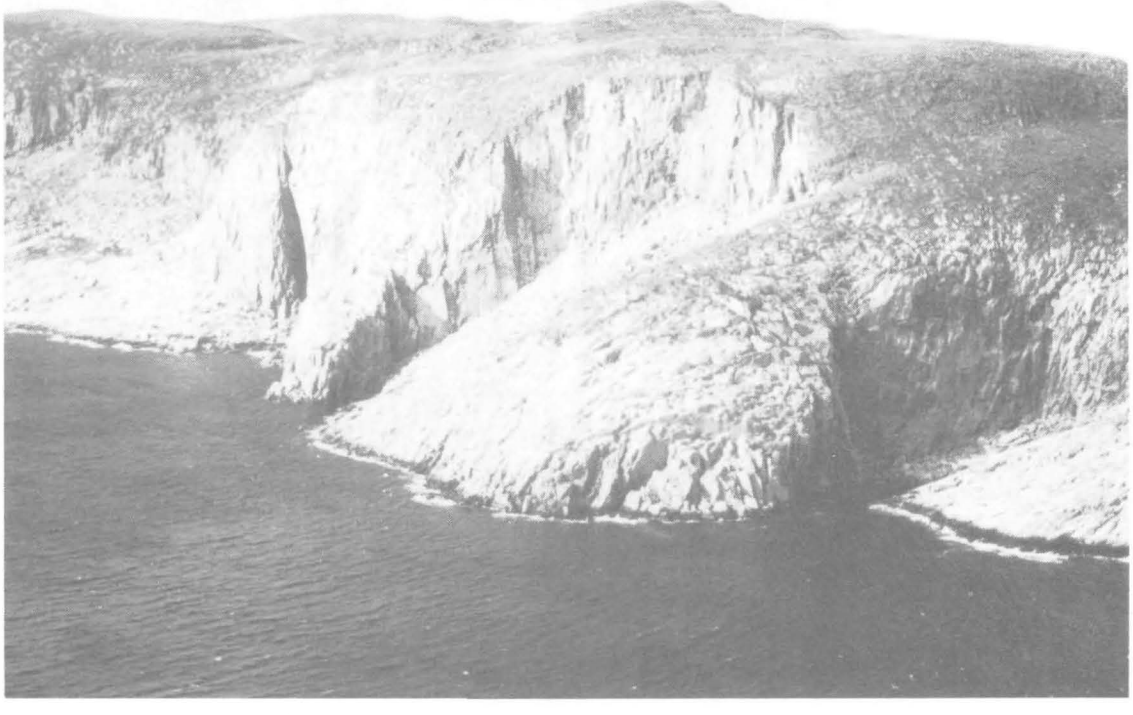


FIGURE 3.7 STEEP SLOPE AND NO BEACH (CAPE HARRISON)

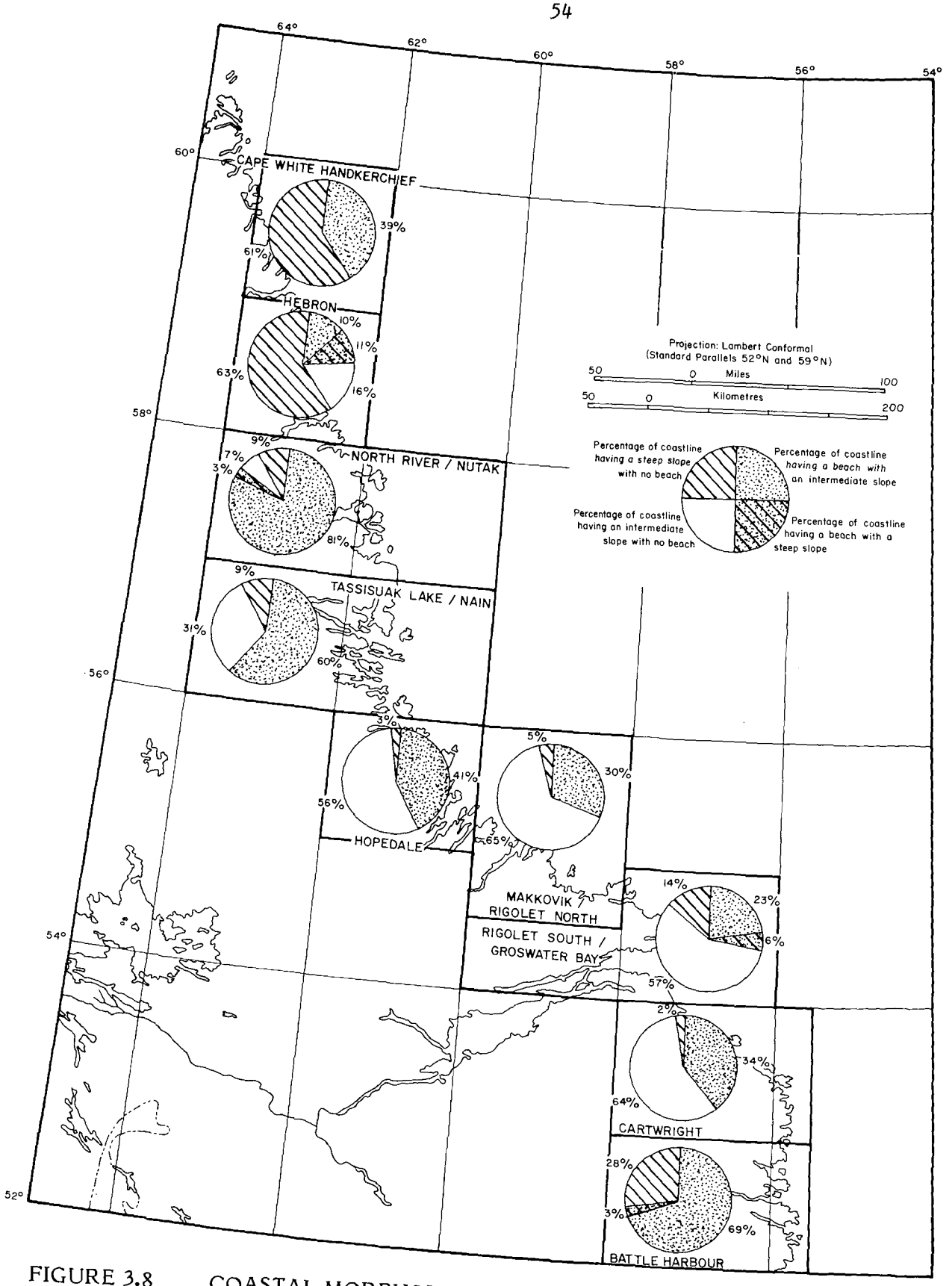


FIGURE 3.8 COASTAL MORPHOLOGY OF LABRADOR

low energy region. The residence period of oil in this type of coastal region would be expected to be very long, in the order of several years.

An intermediate coastal grouping in terms of oil spill vulnerability would be the coarse-grained sandy and gravel beaches, where the oil would penetrate rapidly and to considerable depth. In such an environment, burial may be rapid, possibly within a few days. Because of the associated high energy environment along the coast, the beach agreggate would generally be expected to be coarse grained sand and gravel. This category, as already mentioned, accounts for approximately 50 percent of the entire Labrador Coast.

3.3 Labrador Continental Shelf

The rugged surface of the Precambrian Shield off Labrador slopes seaward into a discontinuous trench known as the marginal channel, which is as much as 600 m deep. This marginal channel is a fundamental structural feature common to many shelves in high latitudes (Holtedahl, 1950) (Figure 3.1 and 3.9).

Various origins have been suggested for the marginal channel, including fault tectonics and/or a glacial origin. McMillan (1972) suggested that these channels, mark "the boundary between thick, soft rocks on the east and hard, mainly crystalline rocks on the west, and are the westernmost parts of a system of tectonic hinge lines". This system of hinge lines has its fundamental origin at the initiation of continental drift or rifting. Grant (1972) suggests that the marginal channel resulted from the eastward-flowing glaciers preferentially eroding the softer sedimentary strata. The conclusion seems to be that faulting ultimately did control the western limit of the coastal plain sediments, and the presence or absence of these soft sediments regulated the presence or absence of the glacially formed marginal channel.

Northeast of this channel, the seafloor rises to an outer shelf with a smooth surface, except where trenched by gullies and deep channels. Most of the outer shelf is composed of six relatively shallow (200 m) banks separated by transverse channel that are generally no more than 500 m deep (Figure 3.1). The shelf edge is delineated at 500 m, in contrast to the 200 m depth taken to be the shelf break along the coast of western North Atlantic, south from Newfoundland. The outer Labrador Shelf is floored with glacial drift, possibly as a result of the glacier excavation along the marginal channel.

The transverse troughs are also probably the result of glacier erosion. Løken and Hodgson (1971) illustrate that the transverse troughs off Western Greenland and Baffin Island lie off major fjords, implying that glacier erosion may have followed pre-existing fluvial systems.

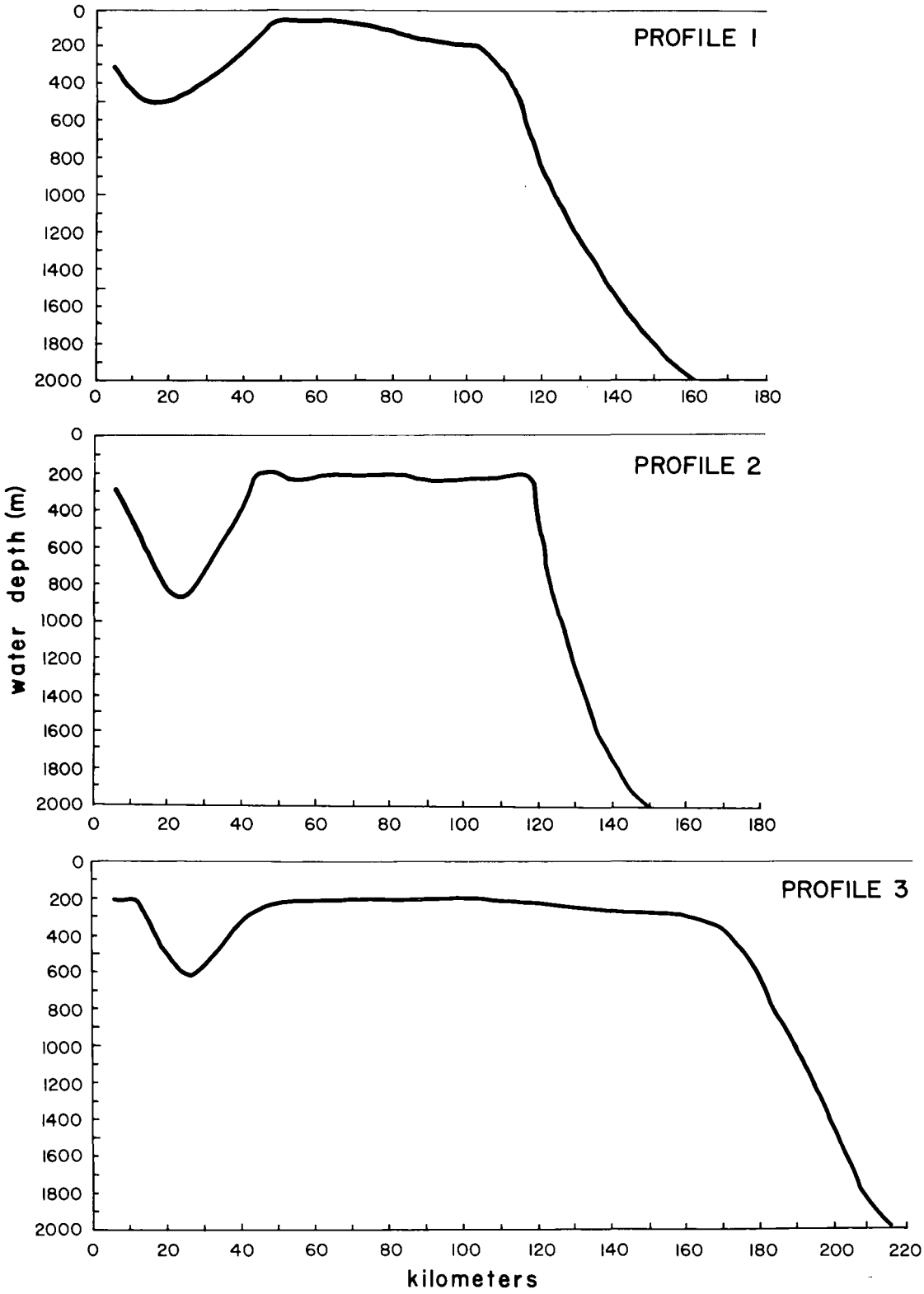


FIGURE 3.9 THREE PROFILES ACROSS THE LABRADOR SHELF AS INDICATED IN FIGURE 3.1

The effects of the Pleistocene glaciations on the continental margin and specifically on the shelf evolution are much more pronounced in the Labrador Sea than at lower latitudes on the Atlantic seaboard. On the shelf, the widespread occurrence of a glacial drift cover (in places more than several hundred metres thick), the presence of an ice-enhanced margin channel, and the incidence of ice movement and scouring together provide substantial evidence of glacial and peri-glacial influence on the continental margins. From Deep Sea Drilling Project (DSDP) cores in the Labrador Sea and North Atlantic, two major glaciation events have been identified in the late Cenozoic: one about 1.5 million years ago (m.y.), and a second at 0.4 to 0.5 m.y. It is possible that this second major glacial period corresponds to the early Illinoian.

Hamilton Bank and periphery, an area of 50,000 km^2, has been covered in a reconnaissance survey (Van der Linden et al, 1976). Results indicate that the bank is covered with relict glacial sediments that have been reworked through repeated cycles of erosion and deposition by ice and water. An ubiquitous cover of poorly sorted glacial drift is overlain by a thin veneer of sand on the bank and with mud in the saddles.

3.3.1 Boulder Beds. The most serious geological problem yet confronted by the exploration companies drilling on the Labrador Shelf is the presence of extensive boulder beds. The thicknesses of boulder beds encountered to date are highly variable and are included in the stratigraphic interpretation presented in Figure 3.15. The boulder beds vary both in their horizontal distribution as well as total thickness. The problem presented to exploratory drilling is compounded by the fact that these beds cannot be adequately detected with conventional seismic techniques. Spudding problems result because of their unconsolidated nature. As a result, the specific well-site locations are determined by trial and error. The most severe conditions encountered were in the Tenneco et al, Leif E-38. Seven separate holes were attempted before a successful spudding was completed, for a total time loss of 24 days.

3.3.2 Iceberg Scouring. The yearly passage of icebergs southward over the Labrador continental shelf is well documented (Gustajtis and Buckley, 1977). However, there are no data available on the frequency with which icebergs impinge on the sea floor either as a function of water depth or geographical distribution. The size and configuration of furrow marks are influenced by the size and shape of the scouring icebergs, the strength of the currents, and the nature of the substrate. The preservation of the scour depends on the bottom currents and the sedimentation rate. Very little is presently known about any of these factors.

Smaller icebergs with shallow draught tend to be most numerous. Consequently, topographic "highs" tend to be more subjected to the impacts of icebergs than topographic "lows". Depressions are partly but not completely protected from the incursions of icebergs by the barrier effect of the adjacent higher ground. Icebergs are known to capsize frequently, and this can result in an increase in draught. This phenomenon enables icebergs to run aground in all but the deepest topographic depressions on the shelf (Harris and Jollymore; 1974; Harris, 1974).

Available side scan sonar coverage of the Labrador Shelf indicates that scours are common everywhere. Their average width is approximately 30 m; total length is in the order of one km or more. Depth of scouring appears to be limited to about 6 m, although substrate characteristic would be very important in determining their maximum penetration.

3.4 Geological History of the Continental Shelf.

Before discussing the petroleum potential for the Labrador region, it is necessary to examine the geological history or evolutionary sequence of events that gave rise to the region.

The tectonic history of the present day Labrador Shelf may be divided into two periods: before and after seafloor spreading between Canada and Greenland. The latter period is by far the more important, because of the opening up of the basin, which allowed sediment accumulation that ultimately could produce hydrocarbons (McMillan, 1972).

Initiation of rifting on an emerging ridge system, (the mid-Labrador Ridge) began about 200 m.y. and a new seafloor may have been fairly widespread by mid-Jurassic time (160 m.y.). At the same time, the marginal basins were pushed up, a process that may have contributed to further folding of the Mesozoic sediments. This event heralded a period of erosion for the margin, during which time several hundred metres of Jurassic sediments were removed. Towards the Late Cretaecous, when the formation of the central Labrador Sea was largely completed, a new phase of deposition began, with the whole region subsiding to its final isostatic level. The Labrador Sea may be compared to the Red Sea rift and its attendant Jordan Valley transform fault during the Late Triassic and mid-Jurassic time. From seismic evidence and the recent drilling information, the accumulation of these coastal plain sediments since the Late Cretaceous appears to have been largely uninterrupted until the onset of Quanternary glaciation.

Direct information on the composition of offshore sediments is limited to the released well-site reports and the few interpretive papers published on this data.

Magnetometer, gravity metre, and seismic data show that the sediments are thick throughout the whole area. The approximate western limit of coastal plain sediments and their thickness off Labrador are determined from the position of the marginal channel (Figure 3.10).

The Labrador Shelf is estimated to contain more than 15.0×10^4 km^3 of prospective sedimentary rocks, a figure that does not include the extreme southeast portion off the Strait of Belle Isle, where igneous intrusions are common and structural development may be poor.

The broad Cartwright Arch is present at the physiographic promontory at Domino Point on the southern Labrador coast, at $53^{\circ}30'$N latitude. Coastal plain sediments strike approximately NNW south of the arch and along the northeastern shelf of Newfoundland. To the north of the arch, the sediments strike NW to WNW. In addition, magnetic basement rocks approach the surface on the crest of this arch. The continuous cover of coastal plain sediments, does not occur close to shore in the south. North of the Cartwright Arch, the coastal plain sediments, in most places, abruptly thicken seaward. Facies changes and pinchouts are believed to be common.

To date, the exploratory targets have been the block faults at the initial stages of seafloor spreading between Labrador and Greenland (Figure 3.11). The faults encountered on the Grand Banks and Scotian Shelf appear to be rather small compared with those anticipated off Labrador.

3.4.1 Organic Maturation. The maturation or organic diagenesis is a significant parameter in assessing the hydrocarbon capacity of sediments. The maturation history is controlled by several factors including temperature, pressure, time and exchange capacity with the mineral matrix. A detailed investigation is presently underway at the Bedford Institute of Oceanography (Personal Communication, L.P. Purcell, 1978).

The present and past geothermal gradients in various hydrocarbon bearing basins appear to have had an influence on the relative magnitude of hydrocarbon recovery. Considerable evidence suggests that high geothermal gradients in basins of high heat flow enhance the efficiency of petroleum generation and entrapment, provided that the essential geological conditions are present. A good appraisal of either the type or amount of hydrocarbon that can be found in the Labrador area cannot be made at present because of the lack of information. Subaerial outcrops of potential hydrocarbon source rocks are lacking in either the Labrador Sea or Baffin Bay oceanway. One exception is a relatively small, localized outcrop sequence of Cretaceous - Tertiary marine sandstones and shales

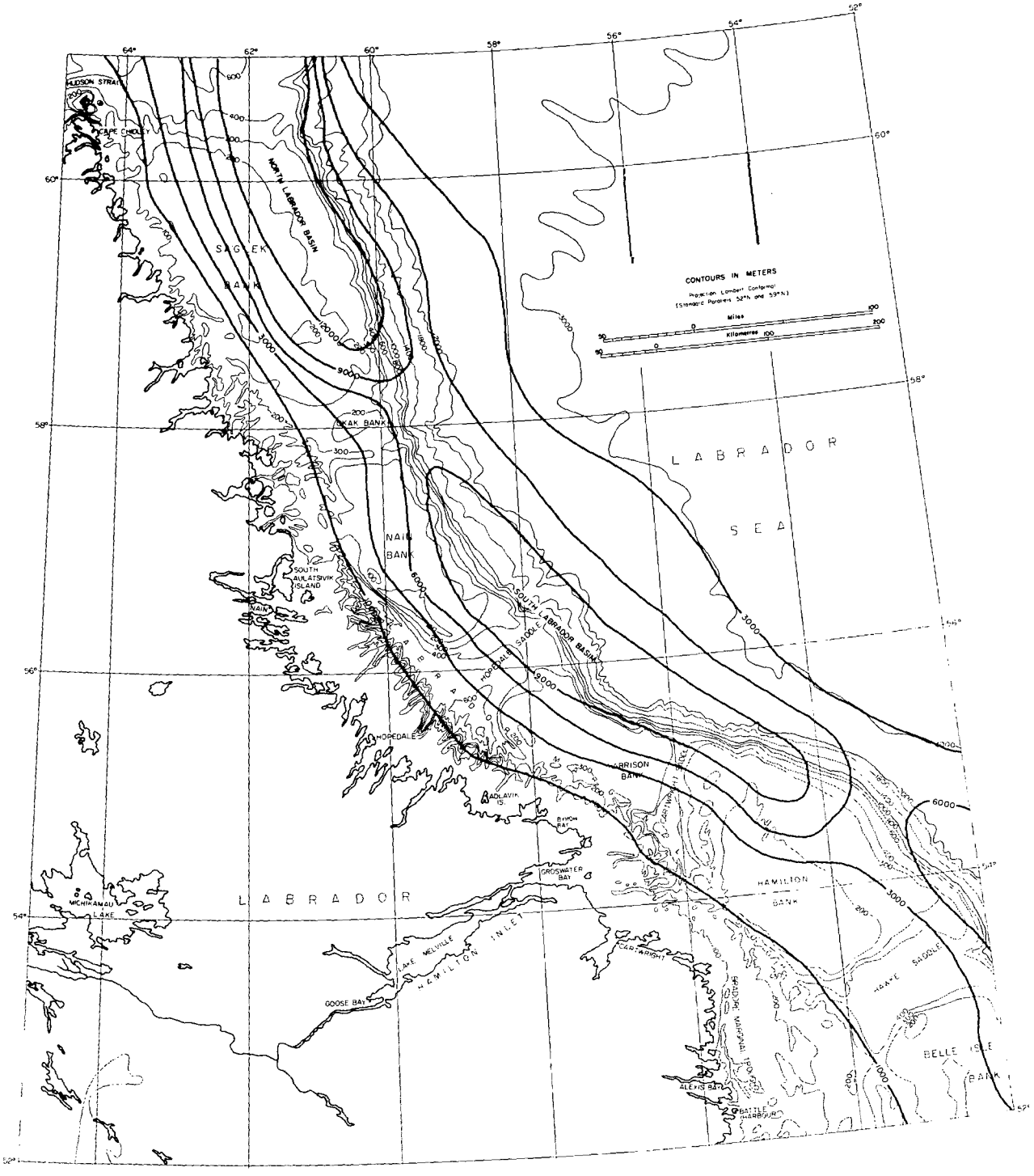


FIGURE 3.10 ISOPACHS ALONG LABRADOR CONTINENTAL MARGIN
(Adapted from Oilweek, February 17, 1975)

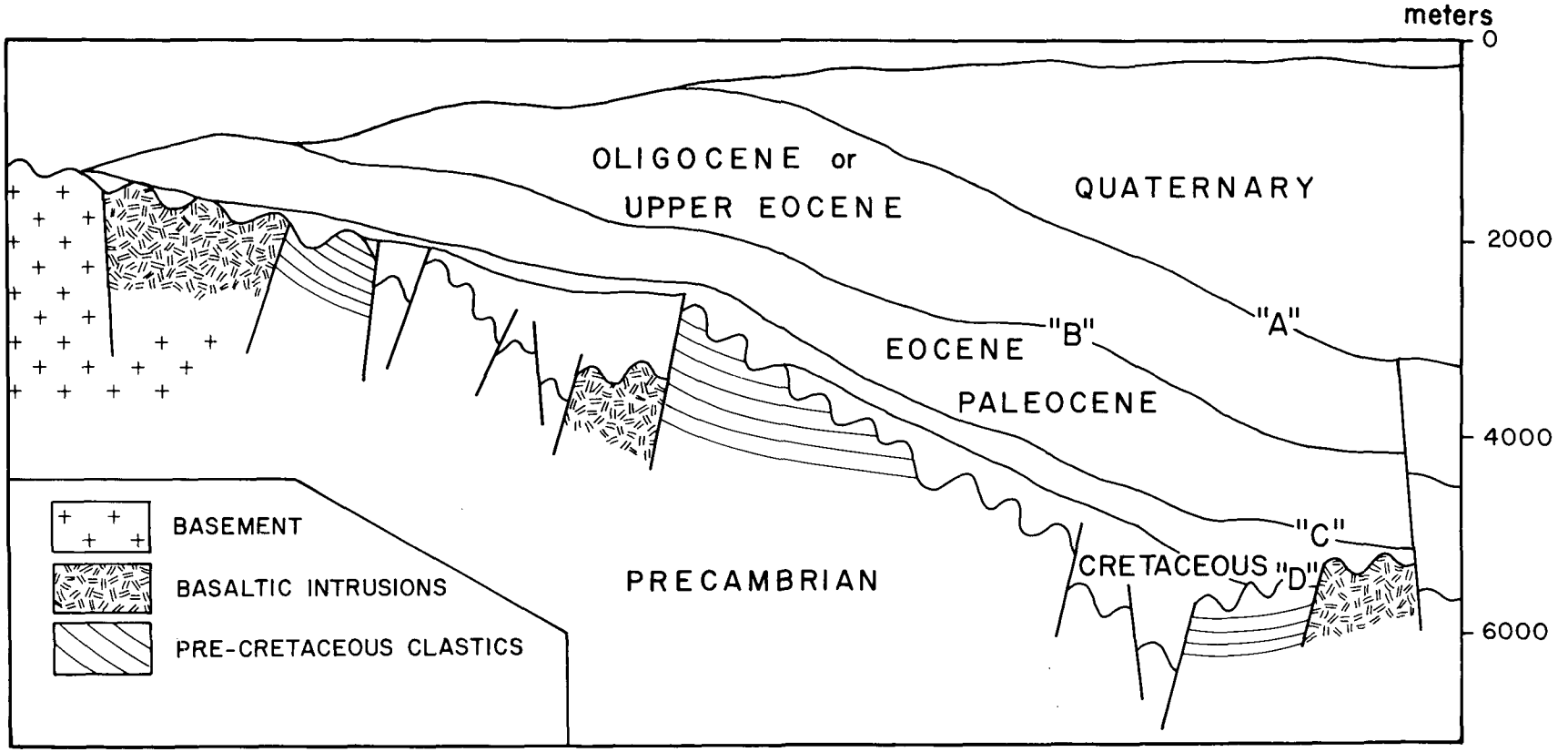


FIGURE 3.11 CROSS-SECTION: LABRADOR CONTINENTAL SHELF
(Source: Launais et al, 1977)

approximately 1500 m thick; it is situated in western Greenland on the Mugssuaq Peninsula, north of Disko Island. This outcrop contains abundant bituminous material. A recent oil seep has also been discovered off Scott Inlet in Eastern Baffin Island (Loncarevic and Falconer, 1977).

Studies of kerogen (organic matter) type and coloration in residues from well cuttings, as well as palynological studies, seem to indicate that the rocks encountered on the Grand Banks and Scotian shelf are thermally immature and have a poor potential for generating hydrocarbons. The younger sediments in these wells contain mostly immature amorphous kerogen of marine origin, the type most favourable for generation of oil. Deeper in the wells, where temperatures might have been high enough to generate oil from the amorphous material, kerogen of terrestrial origin, mostly herbaceous and woody materials, occurs. This material requires much higher temperatures to generate oil and gas.

In the Labrador Shelf rocks, organic coloration studies indicate that herbaceous and woody material near the bottom of some of the wells approached maturity and therefore formed gas.

3.4.2 Petroleum Type. Petroleum is a collective term which describes the whole range of solid, liquid and gaseous compounds of carbon and hydrogen. The chemical composition of petroleum is not fixed. It includes variable amounts of the different molecules from the heaviest solid hydrocarbons up to ethane and methane C_2H_6 and CH_4, both of which are gases (at STP), and propane (C_3H_8), the lightest, which occurs as a liquid. The most usual compositions found are those with the molecular arrangements C_nH_{2n+2} (the paraffins); C_nH_{2n} (the olefines); and C_nH_{2n-6}(the benzenes or aromatics). Crude oils are roughly classified according to the preponderant series and are referred to as being "paraffinic" (or having a paraffin base) when the paraffin series forms a major proportion of the mixture. These are the lighter, generally greenish coloured and more fluid crudes.

The specific gravity of crude petroleum ranges from 0.7 for very light crude oils, up to more than 1 for some solid bitumens. The normal range however is between 0.75 to 0.95 g/m^3, with most crudes being in the range of 0.82 to 0.87. It is British practice to refer to the specific gravity and of course this quantity is required in any calculations of volume and weights. American practice is to use a second scale known as the API gravity, read in degrees. This avoids the use of a wholly decimal figure and indicates lighter crudes by a higher number. Therefore, it reads opposite to the specific

gravity. The conversion from specific gravity to API gravity can be calculated from the formula:

$$^{o}API = \frac{141.5}{S.G.} - 131.5$$

10° API is equivalent to a specific gravity of 1.

It is likely that during the early stages of drifting and the beginning of seafloor spreading, the coastline was heated as occured along the Red Sea: the high thermal gradients, which may have existed in the embryo shelf area during the Late Triassic and Early Jurassic, may have persisted later, thereby providing the thermal gradients suitable for hydrocarbon formation. Higher temperatures generally result in a gas-rich area. In the younger sediments, the amorphous material is often in the immature-mature transitional stage; and if areas on this shelf are found with mature amorphous material, oil might be expected. Present discoveries indicate that the Labrador offshore is a gas-rich area. Table 3.1 lists the three gas wells and the tested flow rates.

TABLE 3.1 MEASURED GAS FLOW RATES FROM THREE WELLS TESTED ON THE LABRADOR SHELF

Test Well	Flow Rate m^3/day
Bjarni	370,000
Gudrid	700,000
Snorri	280,000

Source: Launais et al, 1977.

In summary, if sizable oil deposits are discovered, both the geochemistry and geothermal evidence indicate that it may be a light oil, low in sulphur.

A type example for use in this scenario could be a sweet crude, 40° API, as suggested by the Newfoundland Department of Mines and Energy (NORDCO, 1977). Industry officials agree that this is a reasonable assumption (P. Buemi, personal communication, 1978).

The Snorri drill site contained samples of oil:

- fluid recovered at surface

water - 7.650 cc
gas - 300 litres
oil - 200 cc (which shrunk to 100 cc after transport)

- reservoir temperature 70°C (158°F)
- some discrepancy in the composition of the oil may be due to questionable preservation of sample
- a mean molecular weight ≈ 230
- a boiling point between 290 and 320°
- API gravity value between 28 and 40°

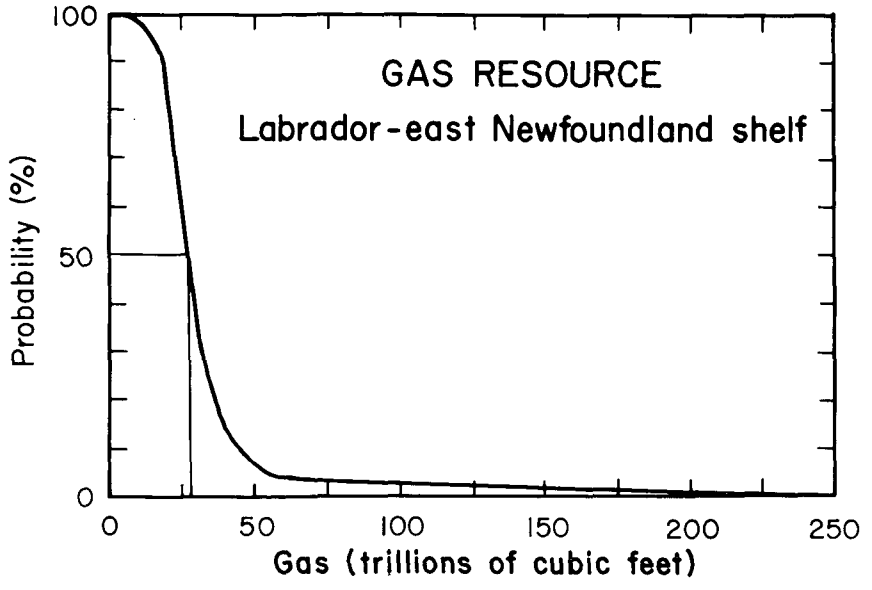
3.4.3 Geo-Pressure. Abnormal formation pressures are encountered worldwide, and vary in depth from a few hundred metres to over 7000 metres. High formation pressures are essentially closed systems, restricting or preventing fluid movement. High pressure has not been considered a problem in the Labrador area; but BP Canada, in their well-site report for Indian Harbour, report abnormal pressures at shallow depths which they state are a concern which obviously requires future monitoring (BP Canada, 1975).

Prior to spudding a well, geophysical data may be utilized to study not only the structural configuration, but also possible engineering factors in drilling. Properly interpreted, the data may predict the top of over-pressured zones to within 150 metres, and pore pressure to within one pound per gallon mud weight.

3.4.4 Hydrocarbon Potential. The 1976 estimates of the federal Department of Energy, Mines and Resources for the potential oil and gas resources of the Labrador-East Newfoundland Shelf region are presented in Figure 3.12. The probability curves presented indicate significant potential for oil and gas. "These curves are highly skewed, with the maximum values several times larger than the mean, indicating the possibility of large gas and oil resource potential at low probabilities" (Energy, Mines and Resources, 1977b).

3.5 Drilling History.

In 1968, Eastcan Exploration Ltd., the completely owned subsidiary of the French company, Compagnie Francaise de Petroles (CFP), and Amerada each acquired 33 1/3 percent stakes in the granted 28 million acre (120,000 km^2) permit area off the Labrador coast held by the U.S. Tenneco Group. The acreage consists of 431 permits issued by the federal government from 1966 onward, for a primary term of twelve years. The area stretches over 1,500 km along the coast and extends over 300 km in width; it is as large as the whole British section of the North Sea. In 1972, Tenneco decided to



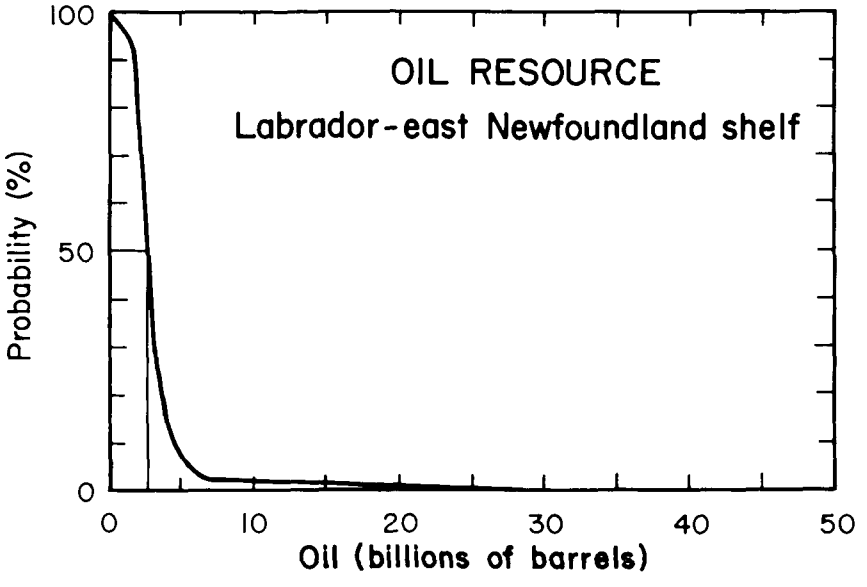


FIGURE 3.12 ESTIMATES OF OIL AND GAS RESOURCES FOR LABRADOR-EAST NEWFOUNDLAND SHELF
(Source: EMR, 1977)

withdraw from this inhospitable region, following an unsuccessful attempt in the previous year to drill the first well in the region.

Tenneco participation was replaced by three new companies: Aquitaine, Agip and Sunoco; Eastcan farmed out part of its holding to the CFP subsidiary Total Leonard, and Amerada surrendered half of its stake to Gulf Exploration and Gulf Oil Ltd. The participation within the "Labrador Group" is shown in Table 3.2.

The area off Labrador represents possibly the most difficult operating conditions under which oil exploration has ever taken place. Deep water, heavy pack ice, icebergs and fierce storms make drilling difficult and production impossible with current methods and equipment.

All areas having any petroleum potential are in water depths greater than 180 m and many of the best areas are in water more than 300 m deep. At present, there are few drilling rigs in existence that can drill in such deep waters.

The Labrador Group, with Eastcan as operator, holds title over approximately half of the shelf, including almost the entire area of the banks at water depth less than 200 m, as shown in Figure 3.13. The oil company permit holdings are listed in Table 3.2.

A total of 12 exploratory wells have been drilled with varying degrees of success in the Labrador offshore, as summarized in Table 3.3. The locations of these exploratory wells are illustrated in Figure 3.14. Ten of these wells have been drilled by the Eastcan Labrador Group, whereas Leif E-38 and Indian Harbour M-52 involved Tenneco et al and B.P. Columbia et al, respectively. Both Indian Harbour M-52 and Verrazano L-77 were officially listed as plugged and suspended (Energy Mines and Resources, 1977a), implying intent to resuming drilling at some future time. Cabot G-91, the most northerly location, was never successfully spudded because of extensive glacier boulder beds and was abandoned after 29 days at a total depth of 1608 feet. Similarily, Leif E-38 unexpectedly terminated in 1971 at only 3,557 feet total depth as a result of a violent storm and an approaching iceberg. Of the remaining eight successfully completed wells, three have produced significant gas discoveries, as summarized in Table 3.1.

The following section summarizes the drilling history in the Labrador offshore, and outlines the geological results released. Under the Canada Oil and Gas Regulations, an operator is required to submit comprehensive reports on every program undertaken within the permittee's offshore acreage. These reports, together with associated items such as cores, cuttings, and paleontological materials derived from drilling operations, are held strictly confidential for a specified time period before being made available for public examination.

TABLE 3.2 KEY FOR PERMIT HOLDERS SHOWN IN FIGURE 3.13

No.	Permittee	Ownership (Percent)	Holdings (Acres)
1	Total Eastcan Exploration Ltd.	28.33	25,477,541
	Amerida Minerals Co. of Canada Ltd.	16.67	
	Gulf Oil Canada Ltd.	16.67	
	Aquitaine Co. of Canada Ltd.	13.33	
	AGIP Canada Ltd.	10.00	
	Total Petroleum (N.A.) Ltd.	5.00	
	Sun Oil Co. Ltd.	10.00	
2	Imperial Oil Enterprises Ltd.	100	1,894,948
3	BP Exploration Canada Ltd.	50	5,004,140
	Supertest Investment Petroleum Ltd.	50	
4	Hudsons Bay Oil & Gas Co. Ltd.	100	827,144
5	Aquitaine Co. of Canada Ltd.	100	778,693
6	Paddon Hughes Development Co. Ltd.	100	753,693
7	West Coast Petroleum Ltd.	75	36,333
	Ulster Petroleums Ltd.	25	
8	Lochiel Exploration Ltd.	100	550,576
9	Pacific Petroleum Ltd.	50	188,428
	Phillips Petroleums Canada Ltd.	50	
10	Texaco Exploration Canada Ltd.	100	178,483
11	Mobil Oil Canada Ltd.	50	36,488
	Solar Energy Resources Ltd.	25	
	Michigan Wisconsin Pipeline Co.	12.50	
	American Natural Gas Production Co.	12.50	
12	Tricentrol Canada Ltd.	69	35,228
	Oakwood Petroleums Ltd.	31	

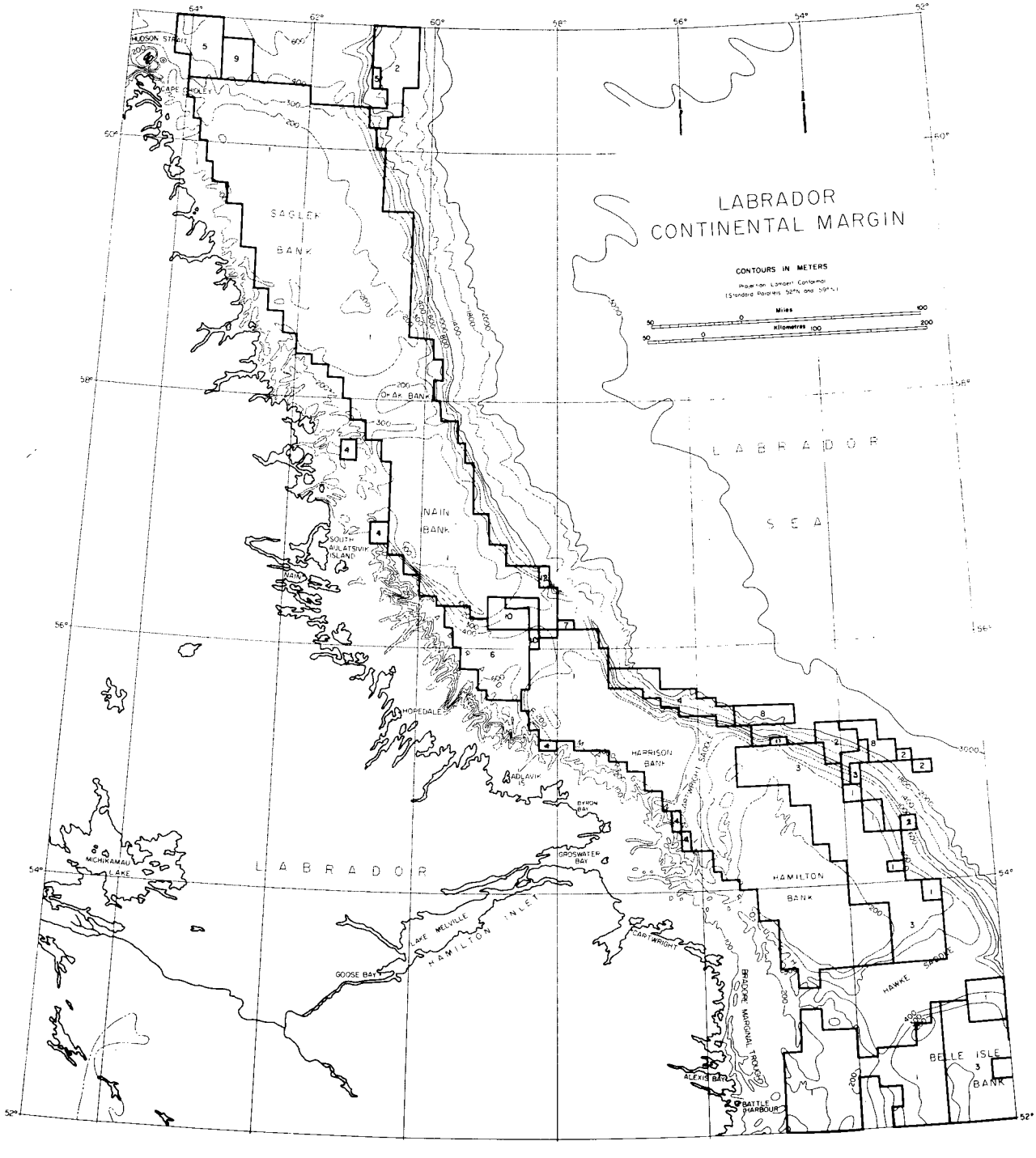


FIGURE 3.13 FEDERAL OIL AND GAS EXPLORATORY PERMITS: OCTOBER 1, 1977

TABLE 3.3 EXPLORATORY WELLS: LABRADOR OFFSHORE

Spud Date	Well Name	Location	Water Depth (ft)	Total Depth (ft)	Status
25/7/71	Tenneco et al Leif E-38	54°17'30"N 55°05'52"W	550	3,557	Plugged and abandoned; no show
1/8/73	Eastcan et al Leif M-48	54°17'46"N 55°07'20"W	545	6,165	Plugged and abandoned; no show
20/8/73	Eastcan et al Bjarni H-38	55°30'30"N 57°42'06"W	456	8,251	Plugged and abandoned; gas find
14/7/74	Eastcan et al Gudrid H-55	54°54'30"N 55°52'32"W	992	9,311	Plugged and abandoned; gas find
5/8/75	Eastcan et al Freydis B-87	53°56'13"N 54°42'40"W	586	7,592	Plugged and abandoned; no show
15/8/75*	BP Columbia et al Indian Harbour M-52 Project #8613-B3-1-2	54°21'51"N 54°23'49"W	649	12,986	Plugged and suspended; no show
18/9/75*	Eastcan et al Karlsefni H-13	58°52'15"N 61°46'42"W	573	13,612	Plugged and suspended
27/9/75	Eastcan et al Cartier D-70 Project #8613-E2-1-7	54°38'51"N 55°41'30"W	1,058	6,322	Plugged and abandoned; no show
30/9/75	Eastcan et al Snorri J-90 Project #8613-E2-2-1	57°19'45"N 59°57'44"W	462	10,531	Suspended gas well and oil
31/7/76	Eastcan et al Cabot G-91	59°50'20"N 61°43'55"W	587	1,608	Never successfully spudded; plugged and abandoned
27/8/76	Eastcan et al Herjolf M-92	55°31'53"N 57°44'53"W	476	13,406	Plugged and abandoned
1/9/76	Eastcan et al Verrazano L-77	52°26'37"N 54°11'53"W	599	1,509	Plugged and abandoned

* Re-entered in 1976

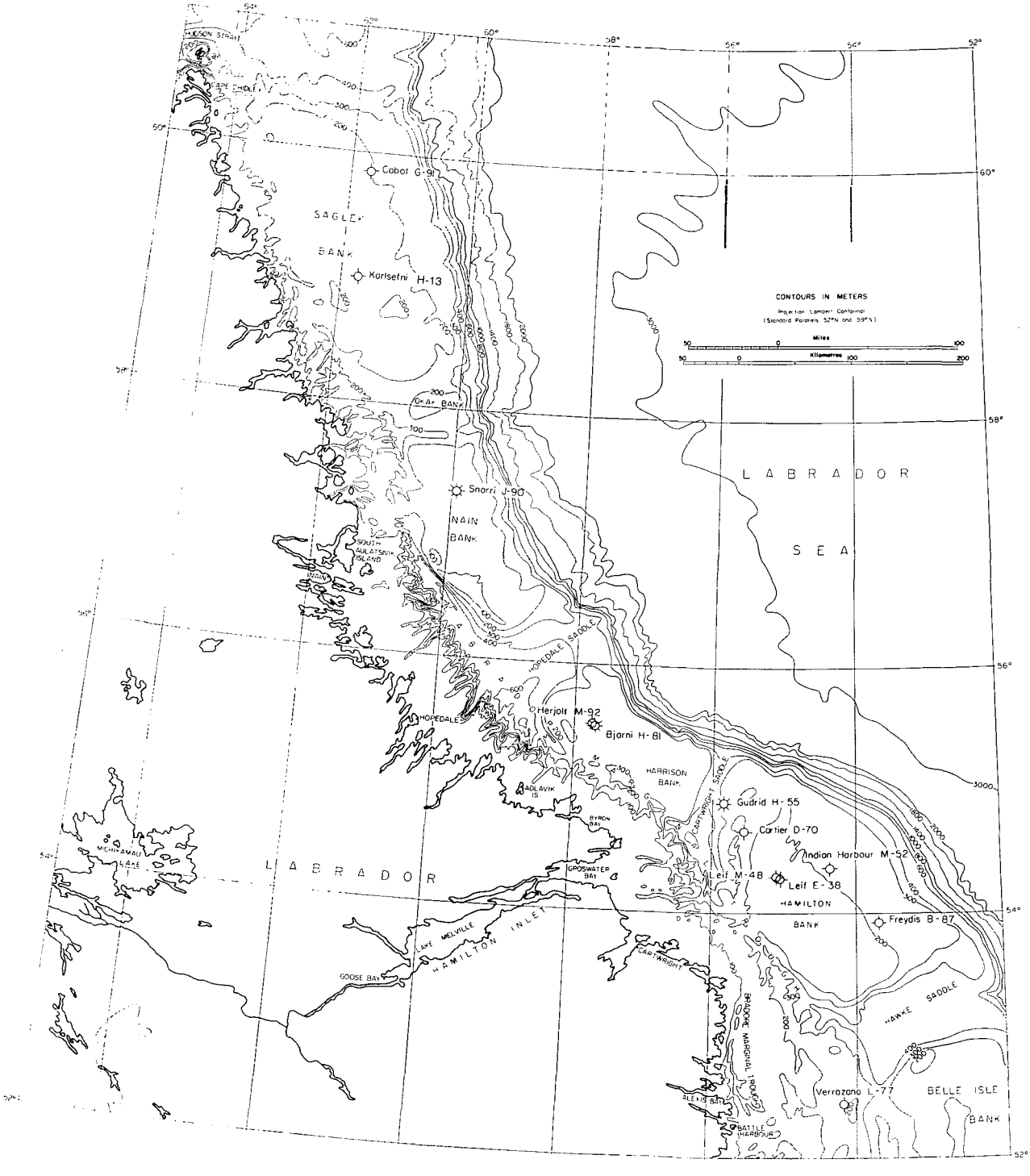


FIGURE 3.14 DRILLING ACTIVITY: LABRADOR CONTINENTAL MARGIN

Information submitted by a company can only become available prior to its release from confidential status with the written consent of the company. Certain general data may be released at any time. Well history reports, well logs and associated materials from an exploratory well may be released two years after the rig release date. It is on the basis of these well-site reports, as indicated in Table 3.3, that the stratigraphic interpretations were made (Figure 3.15).

3.5.1 **1971.** The first well drilled in the Labrador offshore was Tenneco et al Leif E-38. It was drilled in 1971 using a conventional drilling rig, the *Typhoon.* Twenty-four days (McWhae and Michel, 1975) were lost in simply attempting to drill through shallow glacial boulder beds, which involved seven successive locations (Duval et al, 1975). The well had to be abandoned on September 26 at only 1083 m (3567 ft) in Tertiary sediments because of a combination of a violent storm and an approaching iceberg. The well was improperly abandoned with the BOP remaining on the seafloor. In 1973, the well was re-entered and plugged according to regulations and the BOP was retrieved.

3.5.2 **1973.** Eastcan Exploration Limited, now the principal operator in the Labrador offshore, resumed drilling by means of the dynamically positioned drillship *Pelican.* Eastcan et al Leif M-48 was drilled slightly more than 1.75 km (one mile) northwest of Tenneco et al Leif E-38, to a total depth of 1880 m (6165 ft), terminating in lower Cretaceous volcanic rocks. The well was plugged and abandoned as dry; however, a well-developed, fine grain sandstone reservoir layer was encountered from 1258 to 1300 m (4124 to 4270 ft) and termed the Main Leif Sandstone. It was well sorted, with permeability (horizontal) ranging from 65 to 22 mD (millidarcy) and a porosity ranging from 28 to 32 percent.

The second well drilled in 1973 was Eastcan et al Bjarni H-81, some 135 miles northwest on Harrison Bank. The well was spudded on August 29 and suspended on October 12 at 2321 m, (8252 ft) in a weathered basaltic flow dated by potassium-argon isotope determination at 122 $\pm$ 6 m.y. As a result of deteriorating weather, the well was plugged and suspended. In 1974, gas discovered in the lower Cretaceous continental arkosic to argillaceous sandstone overlying the basic volcanics was tested. An open drill stem test was used and yielded 13 MMCFPD of 0.675 specific gravity gas and a small amount of 55° API condensate (through a 1 1/4 in choke). The permeability and porosity of this gas-rich zone varied from less than 1.0 to 207.0 mD and 12.7 to 25 percent, respectively.

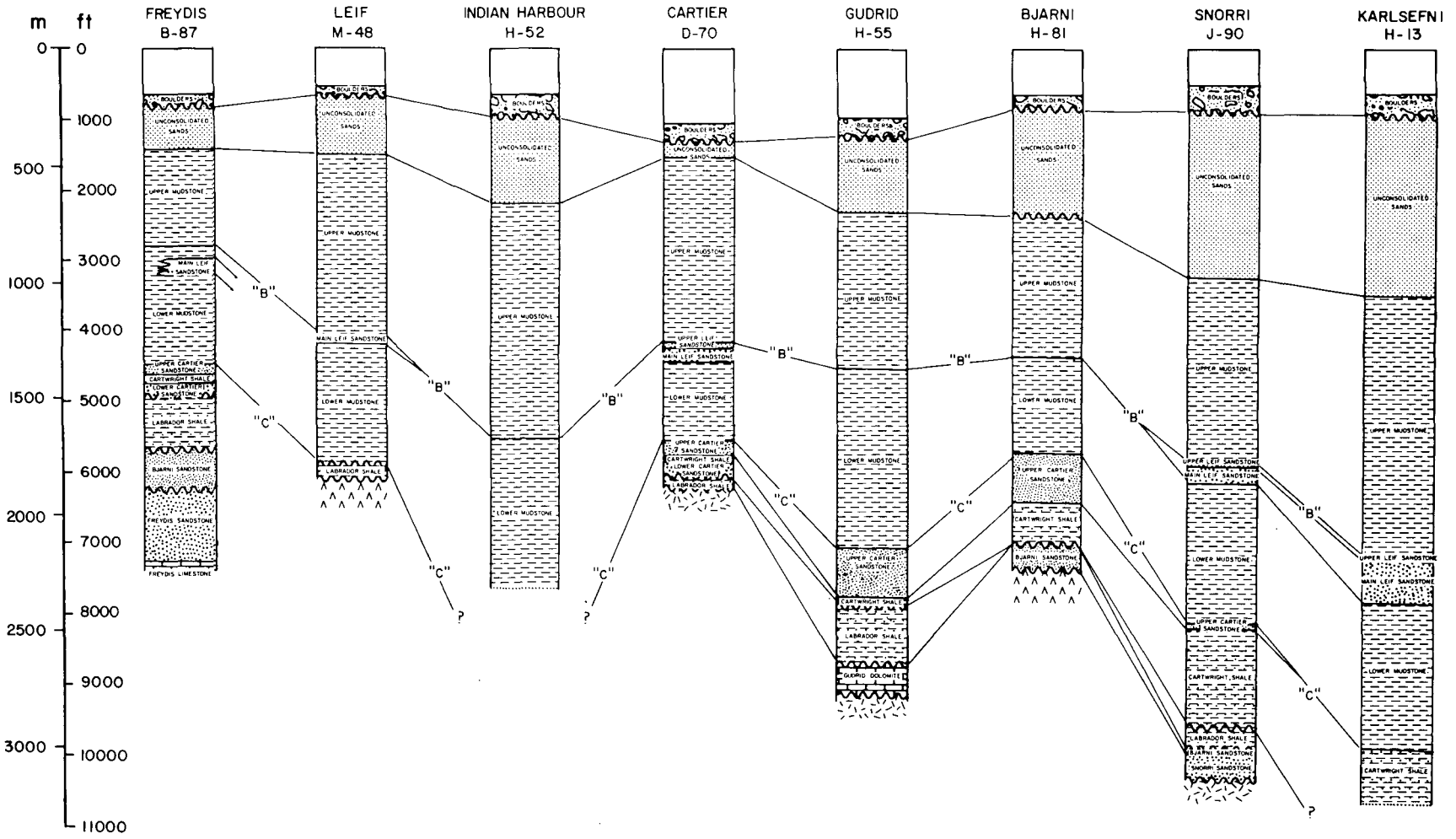


FIGURE 3.15 LITHOSTRATIGRAPHY OF THE UPPER MESOZOIC-CENOZOIC SECTION PENETRATED BY THE EXPLORATORY WELLS, LABRADOR SHELF, NEWFOUNDLAND

3.5.3 **1974.** *Pelican* drilled and tested Eastcan Gudrid H-55, approximately 87 km (50 miles) northwest of Leif M-48 and 136 km (85 miles) SW of Bjarni H-81. The well was spudded on July 12 and abandoned on October 3 after testing gas (at a maximum rate of 20 MMCFPD and some condensate but no water) which was discovered in the dolomite layer encountered 2662 m (8736 ft) overlying Precambrian basement. This Carboniferous dolomite reservoir was 85 m (280 ft) thick, with average porosities approximately 9.15 percent and permeabilities of 1.81 to 245 mD (weighted average 33.05 mD).

3.5.4 **1975.** Exploration activity was stepped up considerably as Eastcan took on the *Sedco 445*, also a dynamically positioned drillship, to help the *Pelican*. The first well spudded using the *Pelican* was Freydis B-87 on July 2; it was abandoned at 2314 m (7592 ft) on August 8 in Middle Ordovician Limestone. Seven hundred and forty-two feet of good sandy reservoir was penetrated (Leif Sandstone, Cartier Sandstone, and Bjarni Sandstone) but all three reservoirs were aquiferous; the latter two had permeabilities in the range 40.6 mD and 47.1 to 51.8 mD, at porosities 29.5 to 32.5 percent and 22.0 to 27.2 percent, respectively.

The *Pelican* then proceeded to Karlsefni H-13, the first test well on Saglek Bank, where the Tertiary-Cretaceous section, on the basis of seismic interpretation, was believed to be extremely thick. The well spudded on August 12, 1975 after two moves that required approximately 48 hours, due to the presence of extensive boulder beds. The well was suspended on September 25, 1975 at 3284 m (10,774 ft) in Paleoscene shales following logging and running of the 9-5/8 in casing as previously planned. This well was deepened in the summer of 1976. The well report for that phase of the program is still confidential, although no hydrocarbon bearing reservoir had been reported.

Sedco 445 drilled the first test well in the Nain area of the Labrador Sea, approximately 250 km N.W. of Eastcan et al Bjarni H-81. Snorri J-90 was located on a structure that persisted from the basement to the "C" seismic marker. The main objectives were the lower Cretaceous Sandstones (Bjarni Sandstone) that bear gas in Bjarni H-81, and the Paleocene Sandstone (Cartier Sandstone) that was very thick but aquiferous at Gudrid H-55. The well was spudded on July 26; because of worsening weather conditions, it was suspended on October 21 at 3210 m (10,531 ft) in Metamorphic Precambrian basements. Significant hydrocarbon shows were encountered in the upper Cartier Sandstone. A porosity of 22.3 to 28.4 percent and a permeability of 60.7 to 70.0 mD provided a flow rate of 280,000m^3/day. Other aquiferous reservoirs were encountered in the Ecocene (Leif Sandstone). Hydrocarbon shows were also noticed in the

lower Cretaceous (Bjarni and Snorri Formations) but these formations contain only thin and poor reservoir potentials, without commercial interest.

The final test well drilled by Eastcan using the *Pelican* was Cartier D-70, approximately 31 km (19 miles) south-southeast of Eastcan et al Gudrid H-55, and 53 km (33 miles) northwest of Eastcan et al Leif M-48. Cartier D-70 was the fifth test well in the Harrison-Domino area of the Labrador Sea, and its objective was to test a large tilted fault block, the next structure to the south of the Gudrid H-55 gas discovery well. The well was spudded on September 27, 1975, and was abandoned at 1927 m (6322 ft) on October 29 in Precambrian (Granodiorite) basement. Five hundred and seventy feet of sandstone reservoirs were penetrated but all reservoirs were aquiferous. The Leif Sandstone had a porosity of 34.3 percent and a permeability of 192.5 mD; and the Cartier Sandstone had a porosity of 31.5 percent and a permeability of 192.5 mD.

The third dynamically positioned drillship, *Havdrill*, drilled a test well for BP Canada on Hamilton Bank, 52 km (32 miles) east of Eastcan et al Leif M-48. Considerable spudding problems were encountered as a result of an extremely hard boulderous seabed, resulting in four separate holes, and a loss of approximately seven days. The fourth hole was successfully spudded on August 21, 1975. Because of deteriorating weather conditions, the well was suspended on October 15, at 2363 m (7753 ft), before encountering any reservoir beds. The hole has not been re-entered.

3.5.5 **1976.** The remaining three wells were drilled by Eastcan in 1976; however, well site reports are still unreleased. The most northerly location, Cabot G-91, was reported never successfully spudded because of the problem with glacial boulder beds. Verrozono L-77 was plugged and suspended in September 29, 1976 at a depth of 459 m (1,507 ft), twenty days after spud date. Both of the above-mentioned test wells were drilled using the dynamically positioned drillship *Petrel*. The *Zapata Ugland*, a semi-submersible quick-release rig, drilled and completed Herjolf M-92, located less than two miles from the Bjarni H-81 location. Because of the confidential status of the well-site reports, little else can be said about the results of the 1976 drilling program.

3.5.6 **1977.** No active drilling took part in the Labrador offshore during 1977.

TABLE 3.4 RESERVOIR CHARACTERISTICS ENCOUNTERED IN THE EXPLORATORY WELLS: LABRADOR OFFSHORE

Well	Reservoir	Lithology	Thickness Total	Thickness Effective (meters)	Porosity (percent)	Permeability (millidarcys)
Freydis B-87	Main Leif Sandstone	Very fine to silty sand and argillaceous sandstone	93	79		
	Cartier Sandstone	Coarse, arkosic glauconite sandstone	52	48	31	40.6
	Bjarni Sandstone	Medium to coarse arkosic glauconite sandstone	120	99	24.0	49.5
Leif M-48	Leif Sandstone	Very fine to silty and argillaceous sandstone	43		28.1 - 32.0	65.0 to 223.0
Cartier D-70	Leif Sandstone	Fine to silty and argillaceous sandstone		63	34.3	95
	Cartier S. Sandstone	Argillaceous, arkosic glauconite sandstone	124	110	31.5	192.5
Gudrid H-55	Cartier Sandstone	Feldspathic, glauconite sandstone and pyrite	213		27.5 - 28.7	23.8 to 33.4
	Gudrid Dolomite			85	9.15	1.81 to 2.45; weighted average 33.05
Bjarni H-81	Cartier Sandstone					
	Bjarni Sandstone	Arkosic, argillaceous sandstone, parallic (deltaic)	119	46	12.7 - 25.1	1.0 to 207.0
Snorri J-90	Leif Sandstone	Fine to very fine porous, argillaceous sandstone	98	50	34.3	65.3
	Upper Cartier Sandstone	Fine, porous sandstone; sometimes calcareous	17	17	22.3 - 28.4	60.7 to 70.0
	Bjarni and Snori Formations	Immature sandstone and greywacke interbedded with shale and lava	191	141	33.6	101
	Sand in lower Mudstone	Very fine, silty sandstone	15	12	29.3	5.3

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CHAPTER 4
OCEANOGRAPHY AND CLIMATOLOGY OF THE LABRADOR SEA

by

K.A. Gustajtis

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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4 INTRODUCTION

An understanding of the environmental conditions that a region can experience is important for providing both reasonable day to day operational support, as well as input to the necessary design criteria for the extreme situation. In planning logistical support, it is necessary to know in advance the type of environmental conditions that the operation may encounter.

The main objective of this chapter is to provide the planner with a more substantial, factual data base upon which to plan logistical support programs. Temperature, precipitation, duration of daylight, wind speed, and visibility, either individually or in combination, strongly influence and frequently determine the type of activity that can be undertaken. The particular activity itself will dictate the minimum requirements that are necessary for its safe and successful operation. An example is the limit of visibility and ceiling height that is required for aircraft landing.

Examination of historical data provides, in hindsight, expected mean conditions that could be encountered. This information would be useful in the decision-making process to determine what would be feasible and/or reasonable to expect in terms of an operational activity.

Oceanographic or climatic conditions in themselves are not necessarily dogmatic. It is the urgency of a given operation that often determines the limitations. For example, for a supply boat engaged in the transport of non-essential commodities, it would be at the discretion of a captain to hold for weather, if it proved to be either inconvenient or impractical to proceed. There are, however, upper limits at which safe and reliable operation ceases to be reasonable or expected. The design criteria are meant to accommodate these extreme conditions.

This document summarizes the available physical oceanographic and meteorological information for the Labrador Continental Margin and thereby identifies the environmental limitations imposed both in terms of the normal operating periods as well as the extreme conditions that can be expected.

4.1 Physical Oceanography

The coastal waters off Labrador are predominantly under the influence of the Labrador Current, which flows south over the Labrador continental margin to the Newfoundland Grand Banks, and represents the southernmost extension of waters of Arctic origin. Dunbar (1951) illustrates that the Labrador Current is part of the "Eastern

Arctic Waters", which he defined as being bounded on the north by the Lincoln Sea, on the south by the Strait of Belle Isle, on the east by Cape Farewell, and on the west by the western shore of Hudson Bay (Figure 1.1).

It is the southern transport of this cold Arctic water mass down the Labrador coast that influences the climatic conditions for much of eastern Canada. For nearly six months of the year, the Labrador Current contributes to the formation and southward transport of pack ice, which blocks the entire coast and extends south to the Newfoundland shores in March and April.

Despite the importance that the Labrador Current has on the climate of the region and its role in the very extensive fishery on the eastern coast, very little detailed information is available. Studies of the water dynamics have been few, and usually they have been incidental to other work such as iceberg flow and distribution. This section provides a synoptic review of both the historical and the most recent information available on the oceanographic conditions along the Labrador Continental Margin. A discussion is presented on the water masses: their sources, characteristics and speed of transport.

4.1.1 Historical Background. Dunbar (1951), in his extensive coverage of the physical oceanography of the eastern arctic areas, summarized historical information sources for the Labrador Sea. The most important of these were the *Marion* and *General Greene* expeditions of the early 1930's, on which a large part of our present knowledge of the Labrador current proper is still based.

In 1948, a Canadian naval expedition carried out a series of hydrographic stations every hundred miles along the Labrador coast. During the summers of 1949 to 1951 inclusive, the research vessel *Blue Dolphin* carried out oceanographic survey operations in the Labrador coastal waters, including several major fjords (in particular, the Hamilton Inlet and Hebron Fjord).

Additional work has taken place under ICNAF agreements in the Labrador Sea, with minor activity on the continental shelf. A survey line that has been run repeatedly under this program starts at Seal Island and runs across the southern portion of Hamilton Bank to beyond the 200-metre contour.

The United States Coast Guard has carried out extensive oceanographic observations along the southern portion of the Labrador Shelf between Hamilton Inlet and the Strait of Belle Isle (Andersen, 1968).

Memorial University ran several S.T.D. lines as well as a series of current metre deployments on the southern portion of Saglek Bank (Allen, 1972). At the present

time, the Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Darmouth, N.S., is actively involved in a series of ocean circulation studies both on and off the Labrador continental margins (Lazier, 1966; Allen and Huntley, 1977).

Since 1976, Imperial Oil Canada has carried out a series of year-round oceanographic cruises in the northern Labrador Sea - Davis Strait region. Generally, other previous investigations in this region have been during the ice-free season from mid-summer to late fall. One other exception was a series of oceanographic stations carried out from the *MV Arctic Explorer* in February, 1977, while drifting with the pack ice (Culshaw and LeDrew, 1977).

Despite these references, the serious lack of data in the winter and spring precludes any extensive discussion of the seasonal variability of the Labrador current.

Additional local information on surface currents and weather conditions in the Labrador Sea can be found in the "Sailing Directions - Labrador and Hudson Bay" (Environment Canada, 1974).

4.1.2 General Circulation in the Labrador Sea. The main feature involved in the ocean circulation in the Labrador Sea and Baffin Bay is the northward flow of the West Greenland Current along the West Greenland Slope, and its southward movement along the Canadian coast of Baffin Island and Labrador. The West Greenland current is composed of the East Greenland Current, and the Irminger Current, which becomes re-energized on rounding Cape Farewell. The Labrador Current is the combination of the flows of the Baffin Island and West Greenland Currents, with added energy from the waters moving outwards from Hudson Bay and Foxe Channel through Hudson Strait (Figure 4.1).

4.1.2.1 The West Greenland Current. The water of the West Greenland Current is a mixture of waters of widely different origins and characteristics. The oceanographic conditions along the West Coast of Greenland at any given time are dependent upon the relative strength of the contributing currents.

Off the southeast coast of Greenland, the East Greenland Current is mainly restricted to the shelf area, and the characteristics of the water are those of Polar origin. Off the shelf, and in part underneath the flow of the East Greenland Current, is the comparatively warm Irminger Current, which is a branch of the North Altantic Current.

The East Greenland Current and the western branch of the Irminger Current round Cape Farewell to flow along the west coast of Greenland as the West Greenland Current. The mixing of these two water masses, and the northward flow of this mixture

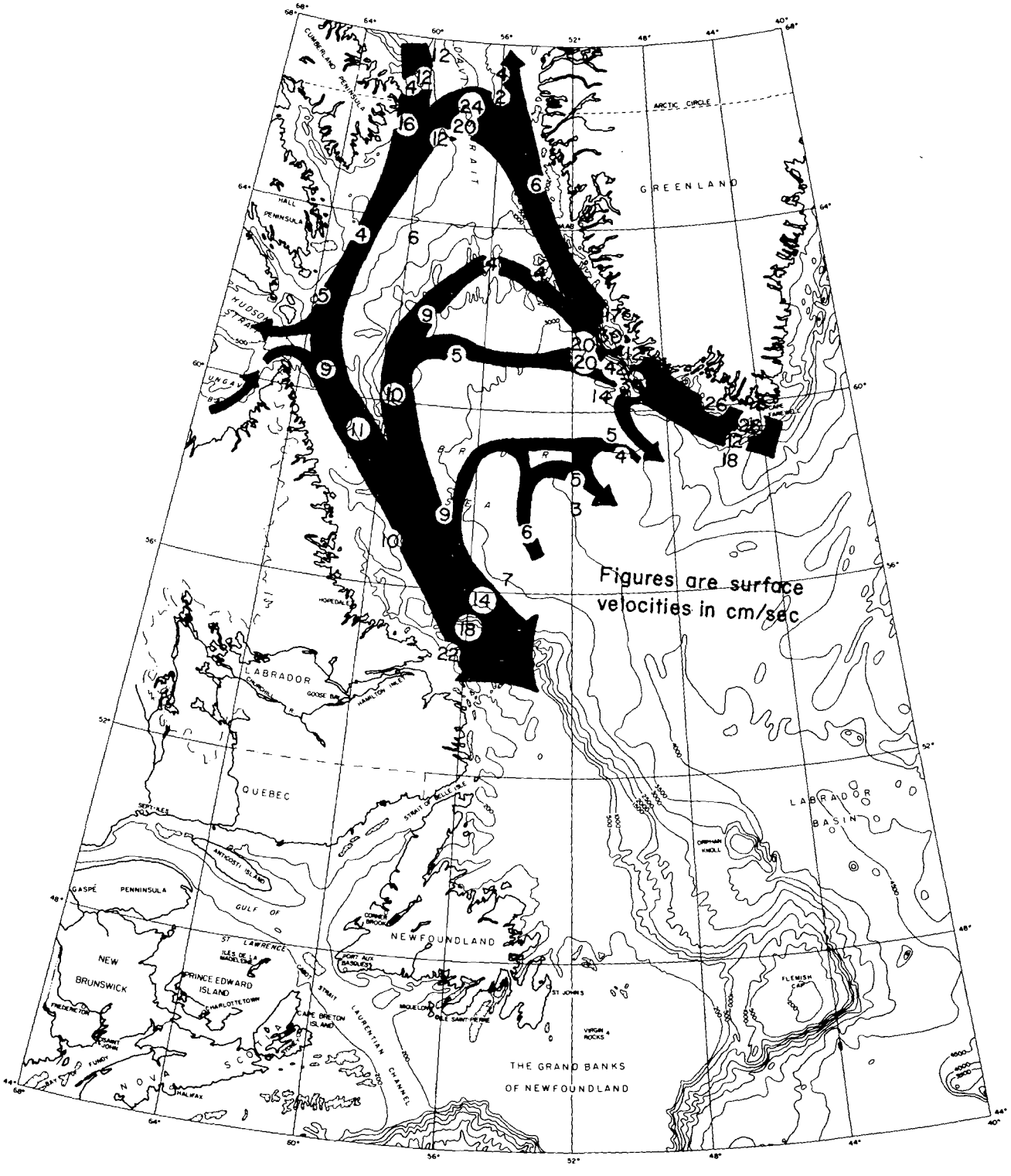


FIGURE 4.1 SURFACE CURRENTS FOR THE LABRADOR SEA
August - September (from Dunbar, 1951)

as the West Greenland Current, are responsible for the very pronounced differences in the water characteristics of east and west Greenland.

While the East Greenland current carries great masses of heavy polar ice which blocks the Greenland coast for the greater part of the year, the West Greenland Current appears in most years as relatively mild and nearly ice-free as far north as Latitude 67°N. The Labrador Current that flows southward on the Canadian Eastern Continental Shelf is a cold water stream of comparatively low salinity, and corresponds in its characteristics to the waters of the East Greenland Current. As the West Greenland Current flows northward, part of it branches off westward, and its northward transport rapidly decreases beyond Latitude 65°N (Nielsen et al, 1977).

4.1.2.2 The Canadian Current and Arctic Waters. The Canadian Current consists of arctic waters largely derived from Smith, Jones, and Lancaster Sounds. It travels south along the coast of eastern Baffin Island down to Hudson Strait. One arm enters the Strait, flows west and then turns across the Strait to join the outflowing current along the south shore. The other arm flows directly south across Hudson Strait to ultimately merge south of Cape Chidley, forming the Labrador Current proper.

Arctic water also enters Foxe Basin through Fury and Hecla Straits. Part of this water flows out into Hudson Strait. The remainder enters Hudson Bay, which has a slow cyclonic circulation in which large quantities of warm, fresh river waters intermingle with the arctic water. Water leaves Hudson Bay around Mansel Island and flows out into the Labrador Sea along the south shore of Hudson Strait.

4.1.2.3 The Labrador Current. The Labrador Current receives its energy from the Canadian Current and West Greenland Currents, supplemented by the flow of the Hudson Bay and Foxe Basin through Hudson Strait. It is divided into inshore and offshore streams.

The inshore stream is confined to the continental shelf and contains the greater volume of the cold polar water. It has a low salinity and is usually associated with floating and disintegrating ice; hence, its physical properties are continually being renewed and it retains them for considerably longer distances than would otherwise be expected.

Much of the cold (<1°C), fresher (<33°/oo) Baffin Island or Canadian Current finds its way into the Hudson Strait. Most of this flow appears to pass through the constricted channel of the Gabriel Strait between Resolution Island and the south shore of Baffin Island, where a strong surface current is observed.

Water entering Hudson Strait reaches about 250 km into the strait to Big Island, where it recurves and exits along the south side of the strait. The water leaving Hudson Strait has characteristics of polar basin water, fresh and cold, and appears to form the shelf current with the Baffin Island Current, which it rejoins in the vicinity of Saglek Bank.

Little is known of the net flow through Hudson Strait. Geostrophic calculations are difficult to make because of the strong tidal currents. From an incomplete cross-section (Smith et al, 1937) reported by Matthews (1976), an estimated net outflow is given of about 0.5 Sverdrups (SV), which appears to be consistent with the volume of the shelf current. The tidal currents in Hudson Strait near Cape Chidley are reported to reach 300 cm/s and the maximum tidal transports have been measured in the order of 12 SV (Easton, 1972; Matthews, 1976).

Overall average transport is in the ratio of 1:3 for shelf to slope currents (Smith et al, 1937; reported by Dunbar, 1951); thus, about 75 percent of the flow is of West Greenland origin. The total overall southward current is about 5 SV (Matthews et al, 1976).

The annual inflow and outflow to and from the Labrador Sea were calculated by Backey (1961) as follows:

INFLOW

	km^3
West Greenland Current	157,000
Outflow from Canadian Archipelago	45,500
	202,500

OUTFLOW

West Greenland Current to Baffin Bay	31,000
Labrador Current	145,000
	176,000

The calculations are based on an observation in the upper 500 fathoms, and the discrepancy of 26,500 km^3 per year is believed to represent the water that sinks and moves out of the Labrador Sea into the Atlantic at greater depths (Backey, 1961; Lazier, 1973).

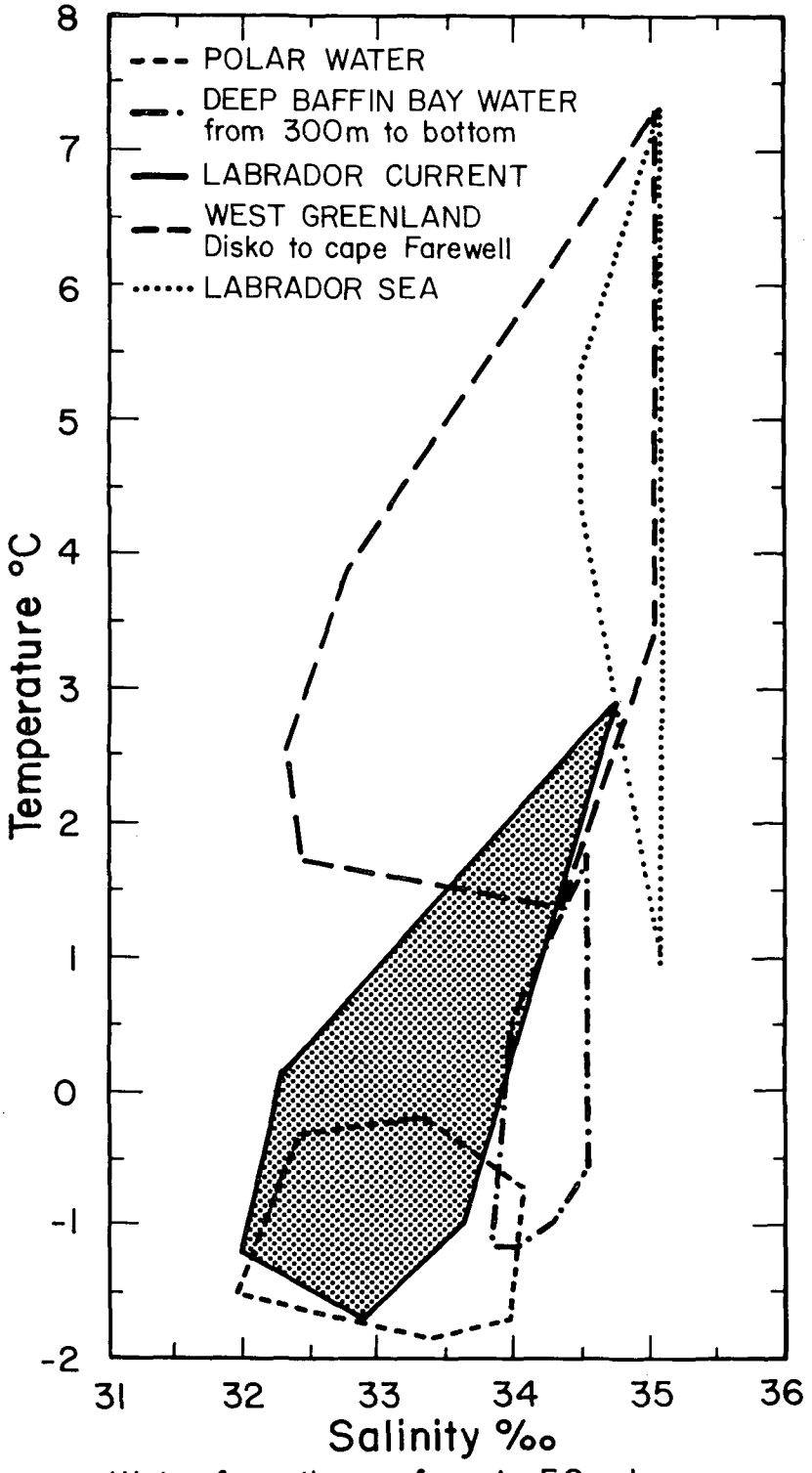
4.1.2.4 Water Masses of the Eastern Arctic. Water masses can be classified on the basis of their temperature and salinity characteristics. For the study of water masses, it is convenient to make use of temperature-salinity diagrams, with a particular water mass being expressed by a polygon whose sides enclose its specific range of temperature and salinity. Surface data needs to be omitted, because annual variations and local modifications may lead to discrepancies. Dunbar (1951) illustrates that the water types found in the Eatern Arctic of North America can be separated into five principal types, as shown in Figure 4.2.

As noted, the waters which form the Labrador Current are the West Greenland Current waters and the polar waters from the Canadian Arctic Current in Baffin Bay. Thus, the polygon representing Labrador current water overlaps both the West Greenland waters and the polar waters. The polygon extends a little further into the dilution range than does the polygon for the polar water, due to the continuation of the terrestrial drainage dilution as well as solar warming, to which the water is subjected en route.

4.1.3 Surface Temperature and Salinity. A series of six monthly horizontal temperature and salinity distributions for the Labrador Continental Margin is included in Figures 4.3 to 4.14. The Marine Environmental Data Service of Environment Canada was used to compile these distributions, which are in turn the result of various expeditions in the region from the 1920's to approximately 1976. The figures are thus composite presentations of the probable conditions during a particular month. Variations from these mean conditions must be expected, especially at the surface, where local seasonal effects are most important. Lack of ship traffic in the region during periods of ice-cover precludes presentation of data for six months of the year.

4.1.3.1 Temperature. The distribution of surface temperatures clearly shows the warm offshore Labrador Sea water, even in May, when the isotherms are incomplete because of ice conditions along the coast. As the ice dissolution proceeds northward, the surface temperatures rises. The characteristic, uniform cold temperature of the inshore portion of the Labrador current lends itself to a very stable water mass that resists the penetration of solar heating by convective mixing.

In Figure 4.15, an S.T.D. profile perpendicular to the coast across the southern portion of the Saglek Bank in August shows that except for a very thin surface layer, the water mass distribution is essentially unchanged from the winter. The stable, relatively warm surface layer in the late summer and fall would indicate that surface pollution would undergo relatively little mixing at depth.



Water from the surface to 50m is omitted (from Dunbar, 1951)

FIGURE 4.2 WATER MASSES OF THE EASTERN ARCTIC

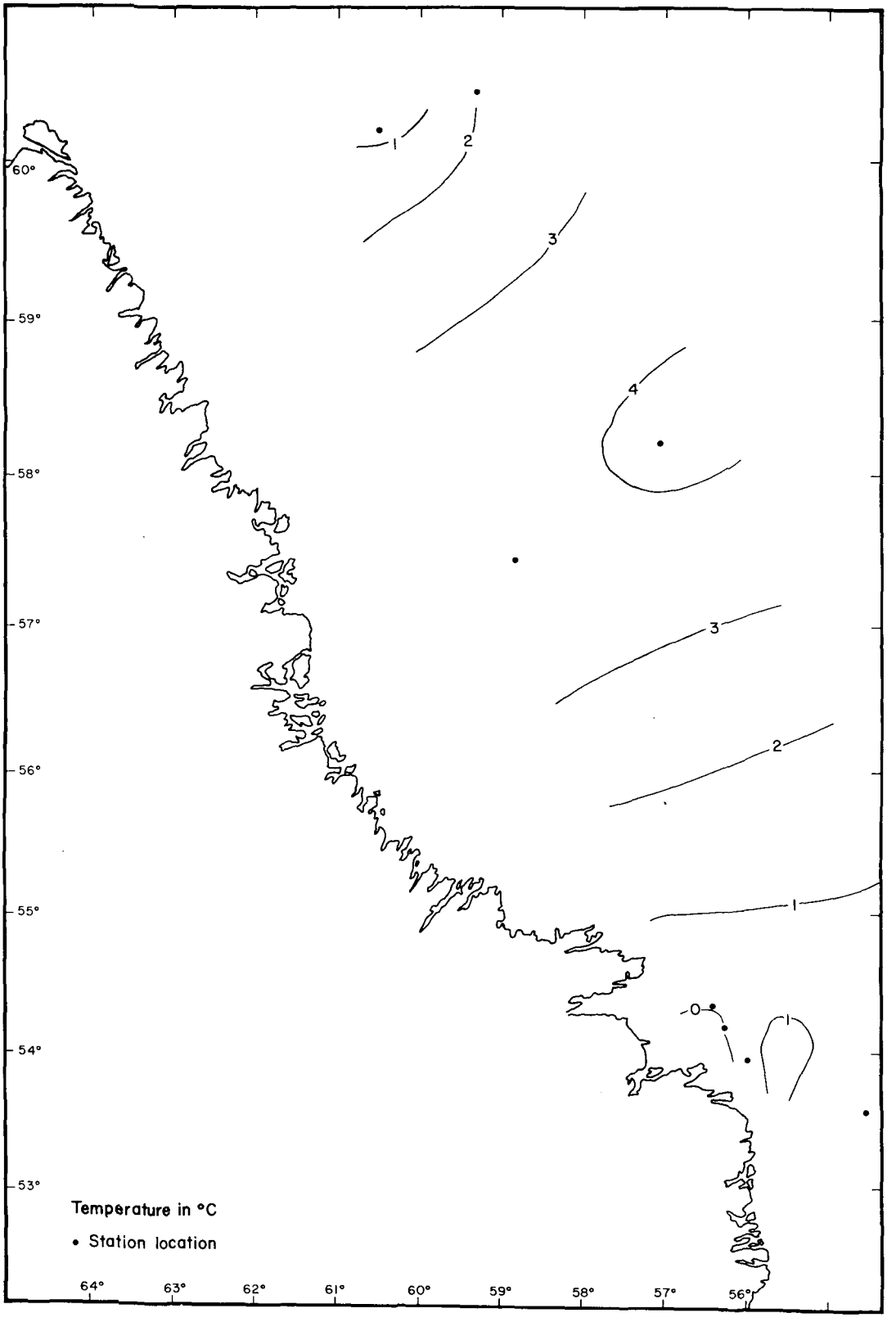


FIGURE 4.3 SURFACE TEMPERATURE: MAY

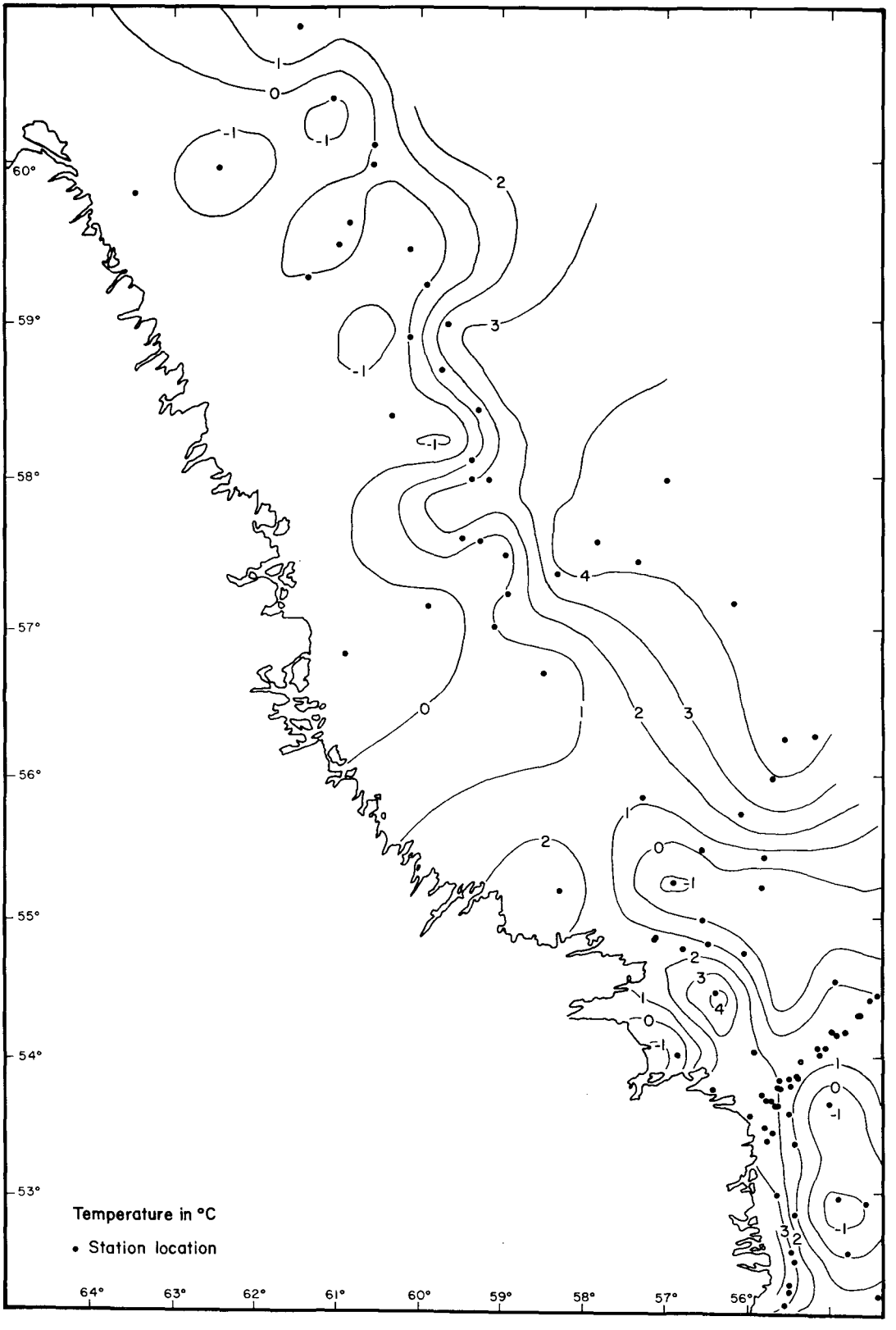


FIGURE 4.4 SURFACE TEMPERATURE: JUNE

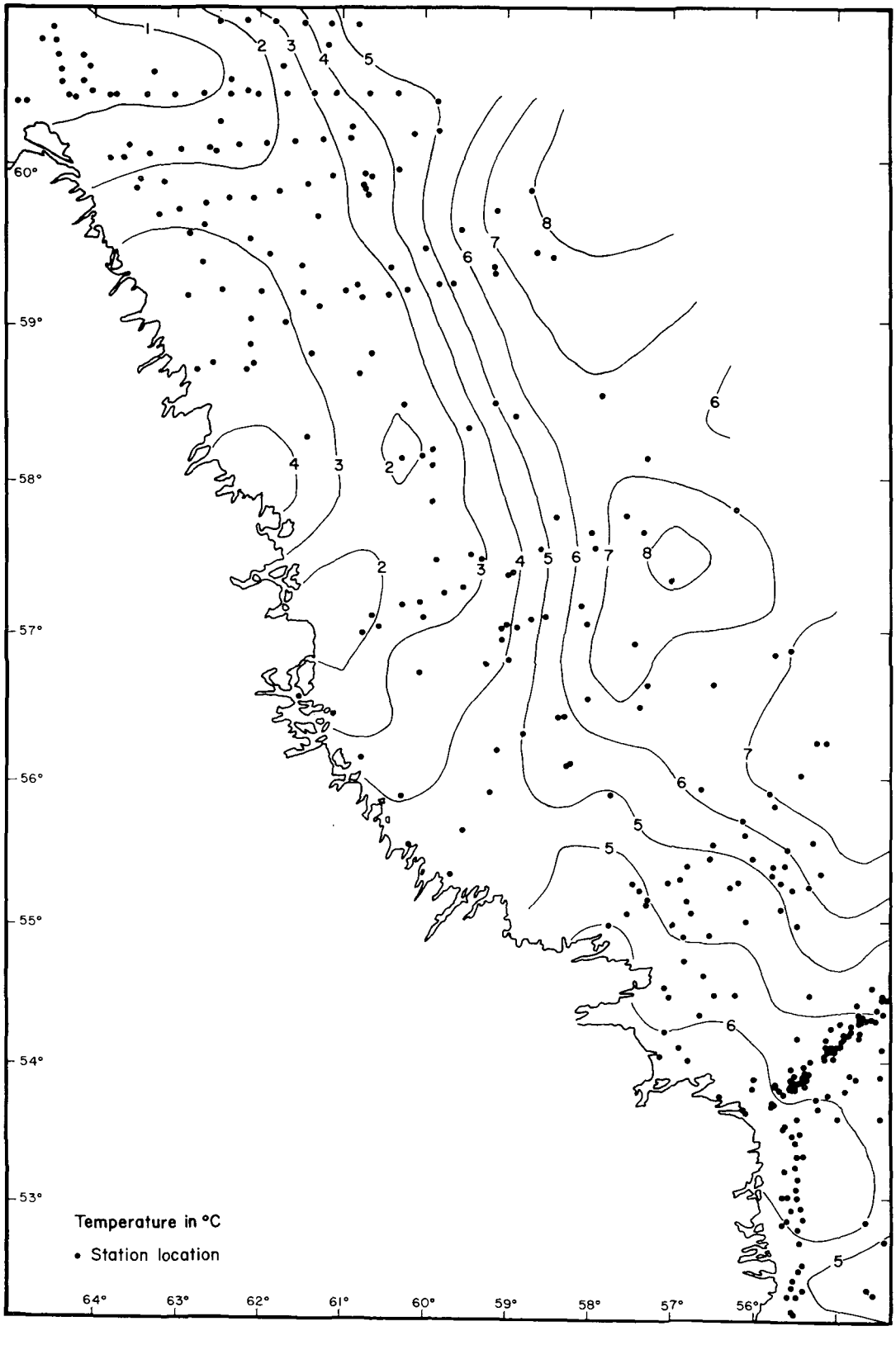


FIGURE 4.5 SURFACE TEMPERATURE: JULY

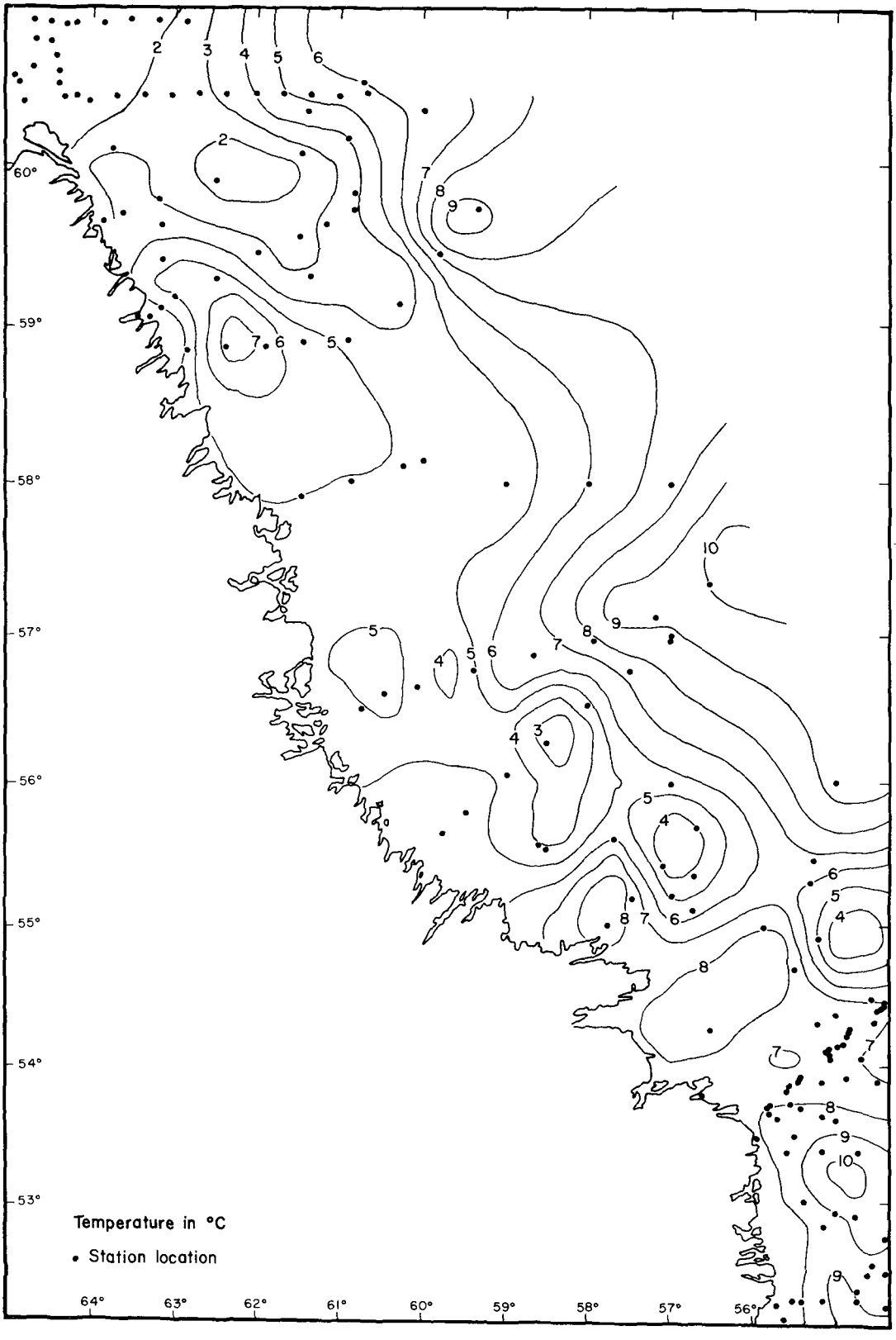


FIGURE 4.6 SURFACE TEMPERATURE: AUGUST

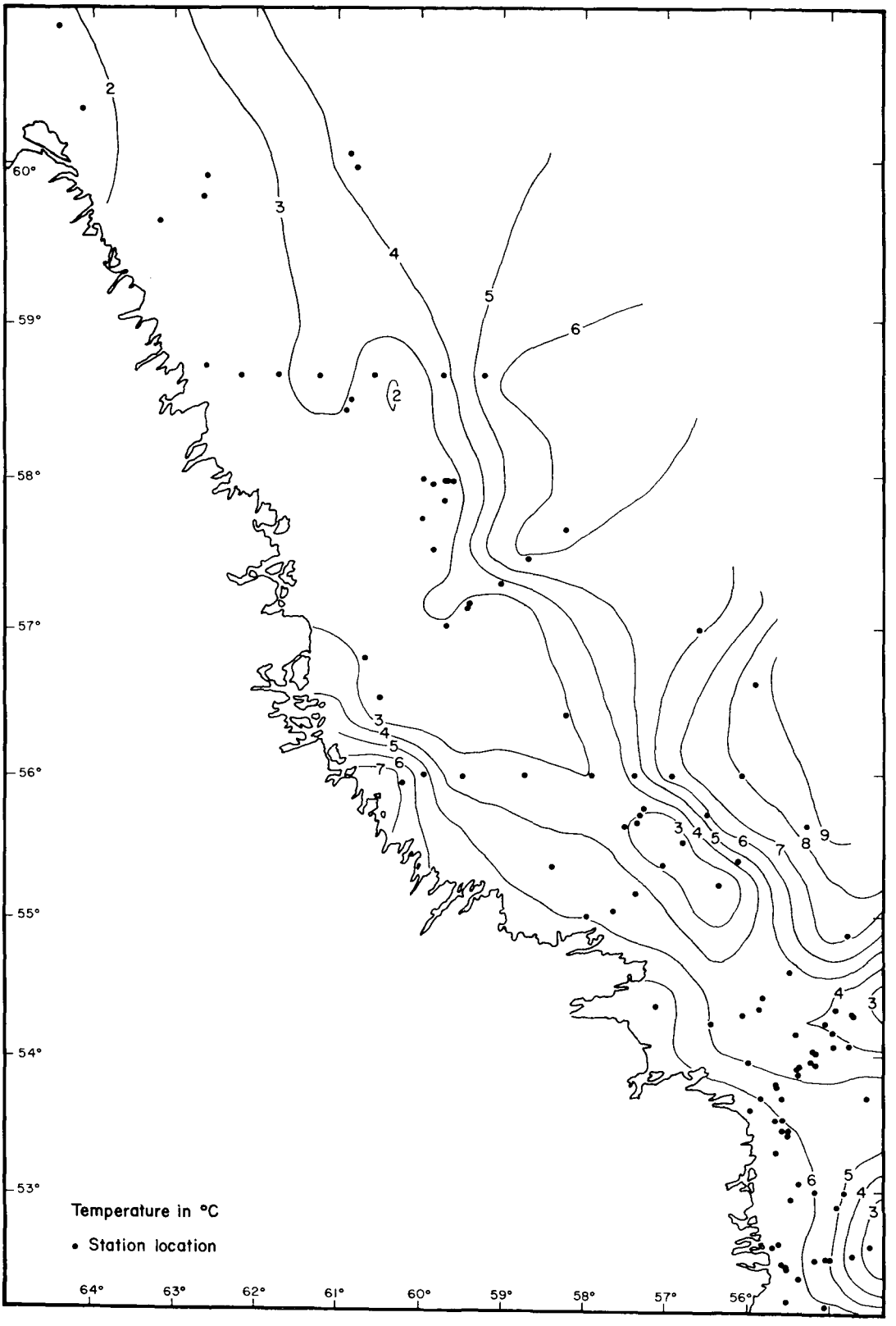


FIGURE 4.7 SURFACE TEMPERATURE: SEPTEMBER

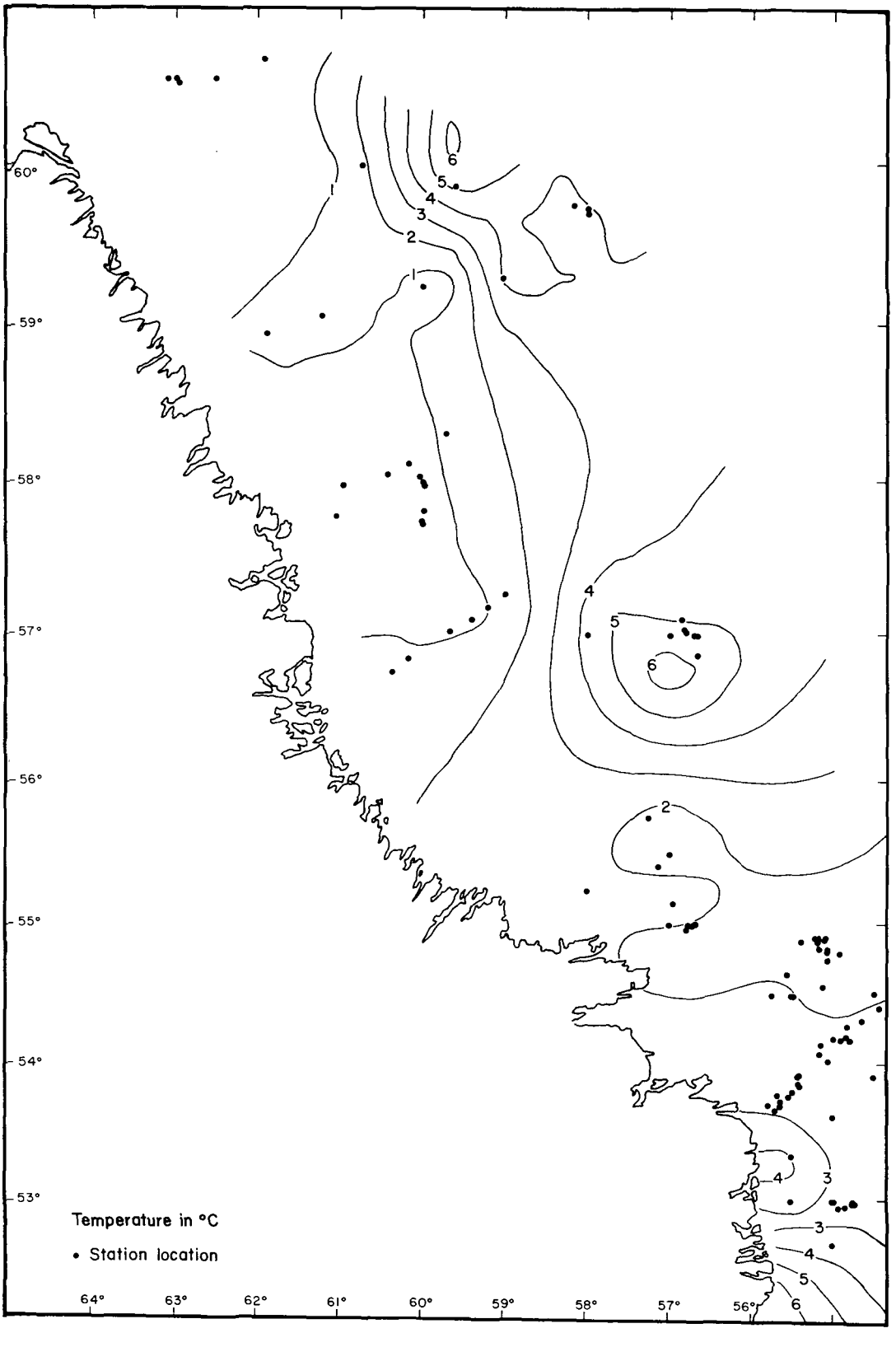


FIGURE 4.8 SURFACE TEMPERATURE: OCTOBER

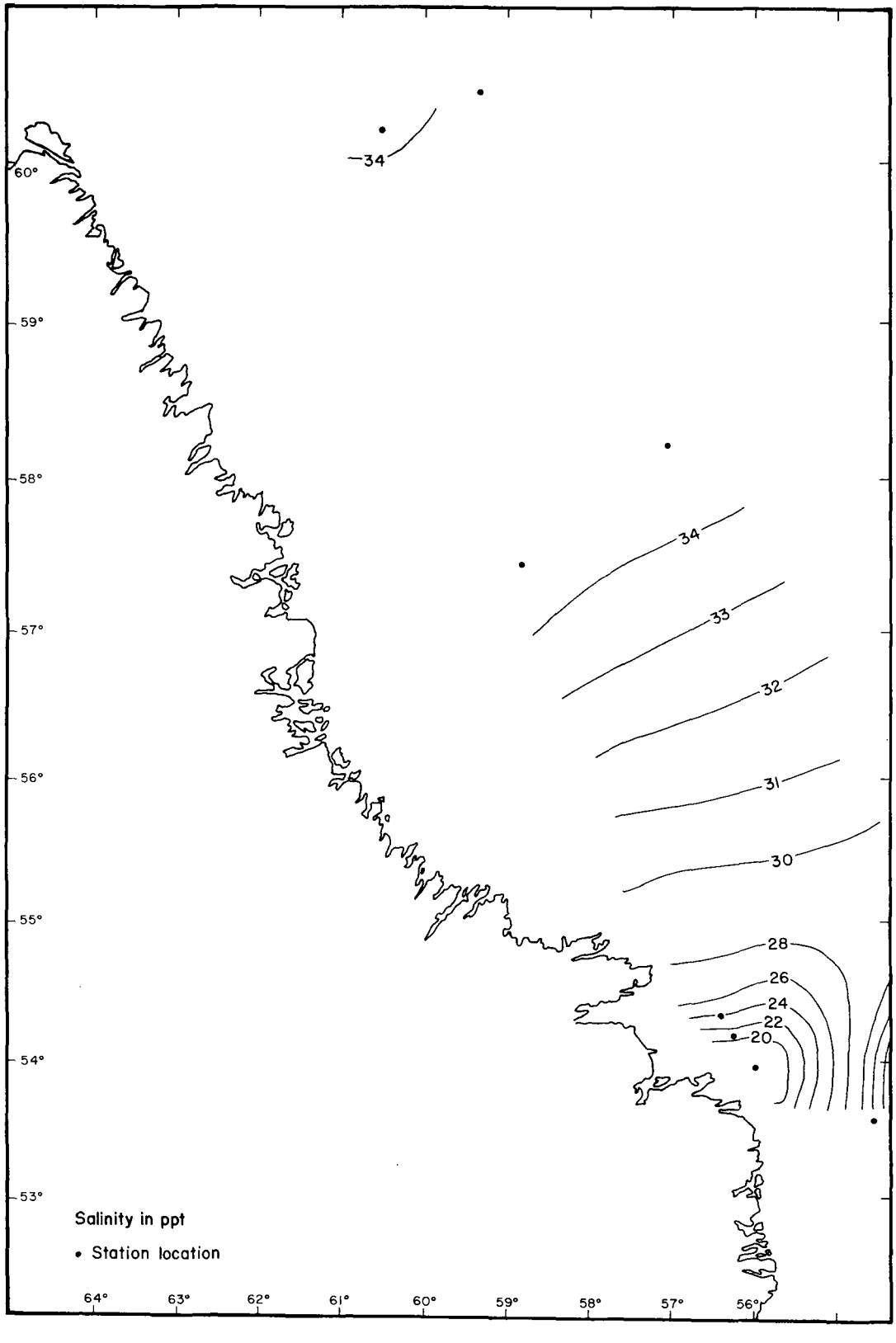


FIGURE 4.9 SURFACE SALINITY: MAY

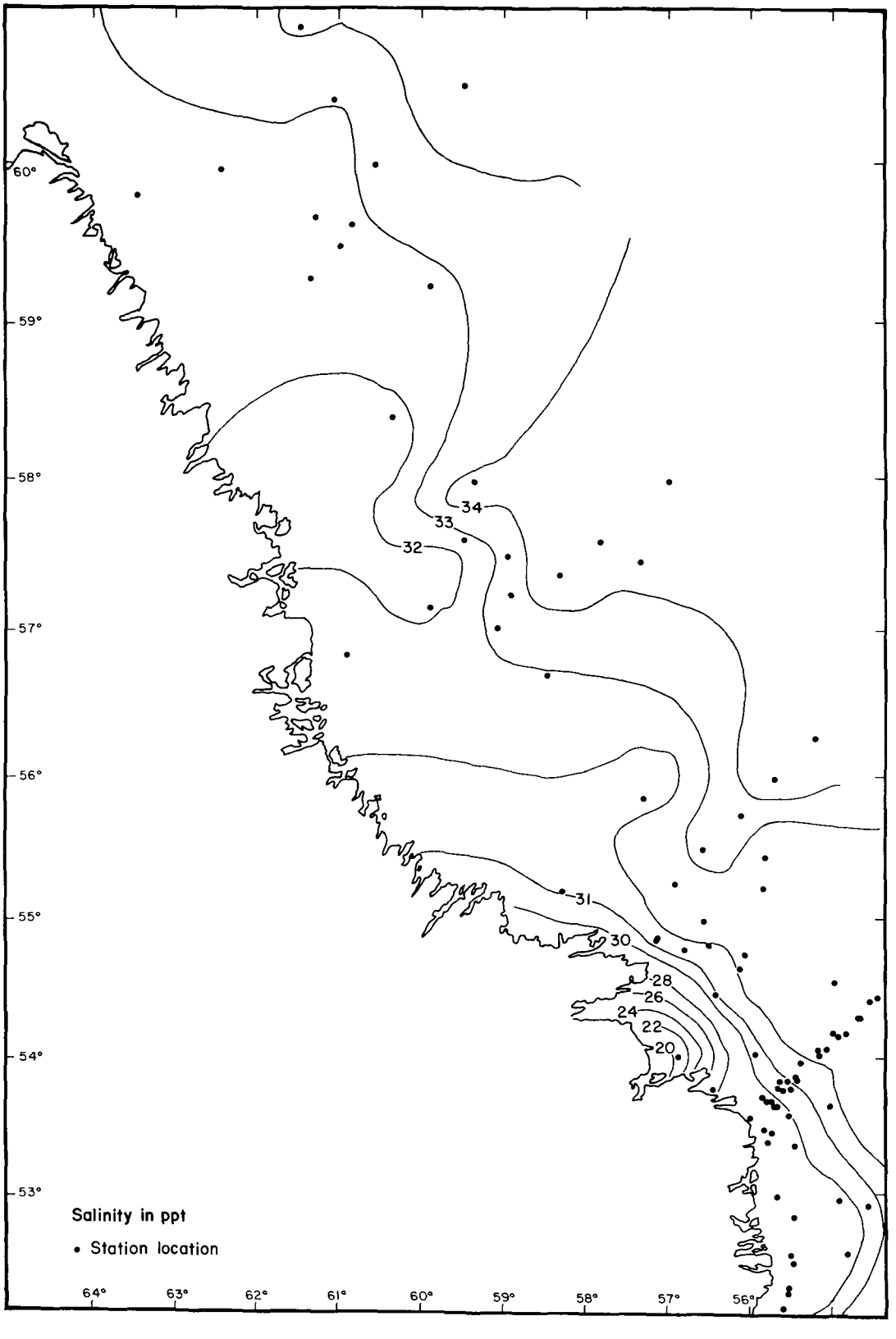


FIGURE 4.10 SURFACE SALINITY: JUNE

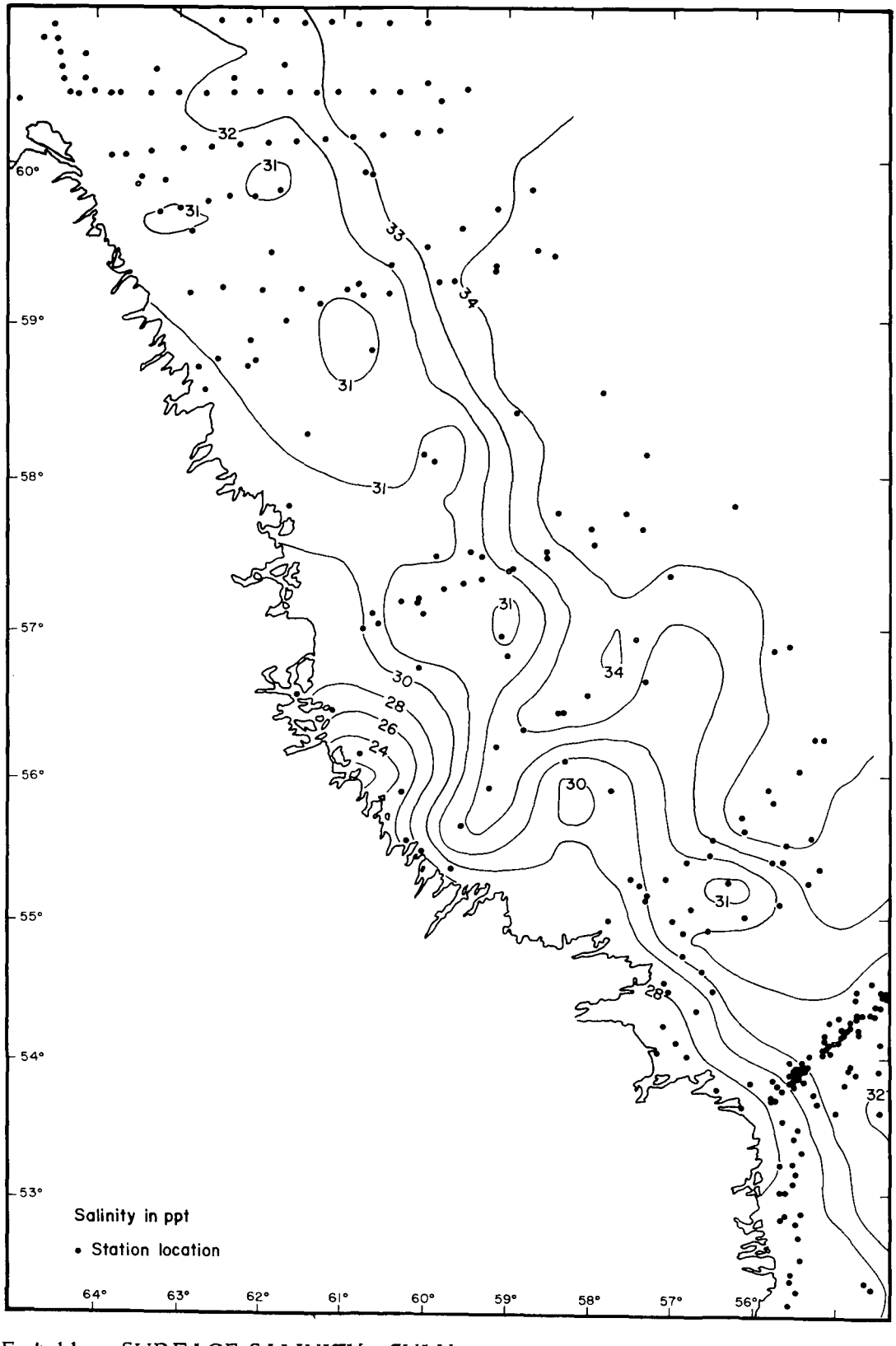


FIGURE 4.11 SURFACE SALINITY: JULY

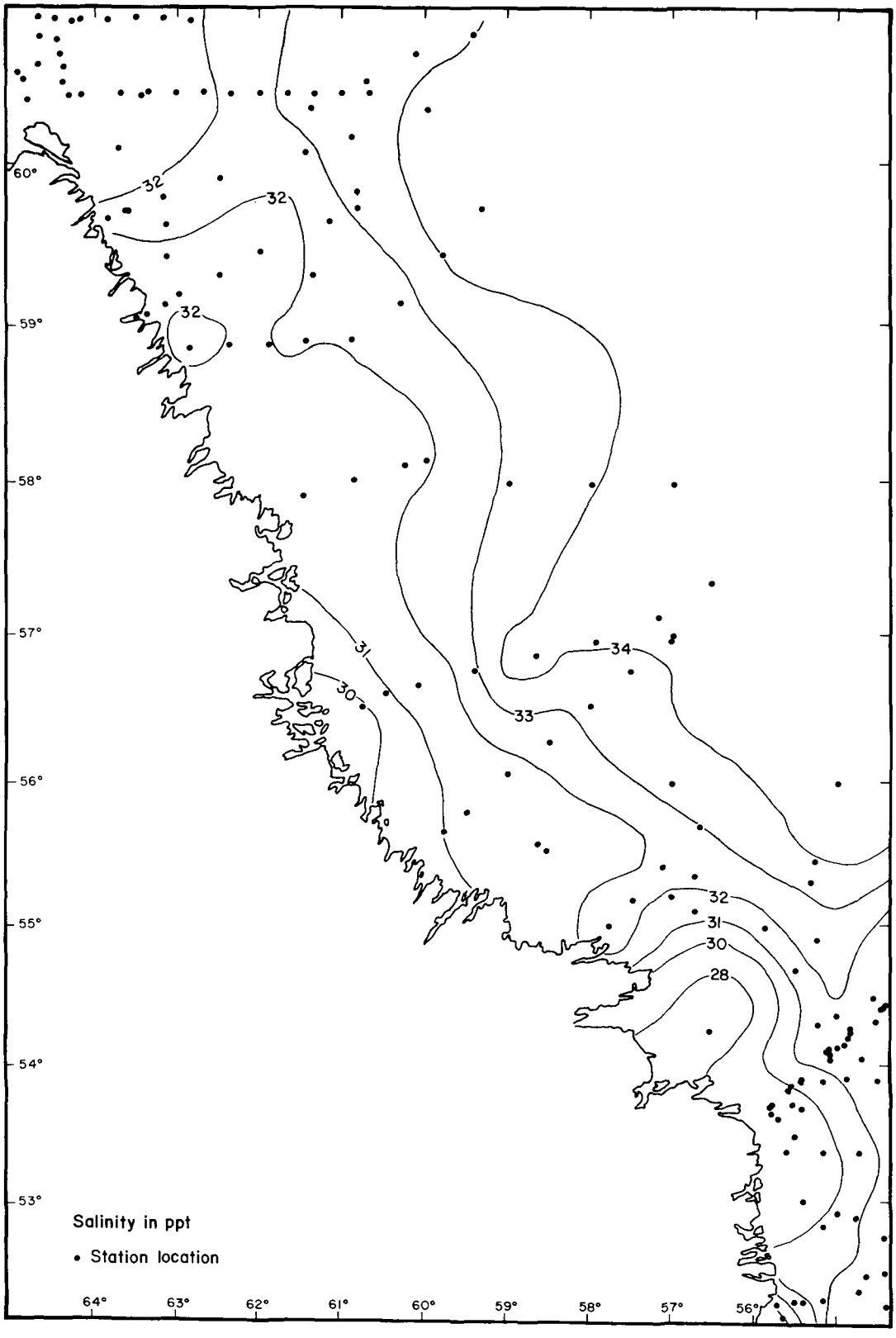


FIGURE 4.12 SURFACE SALINITY: AUGUST

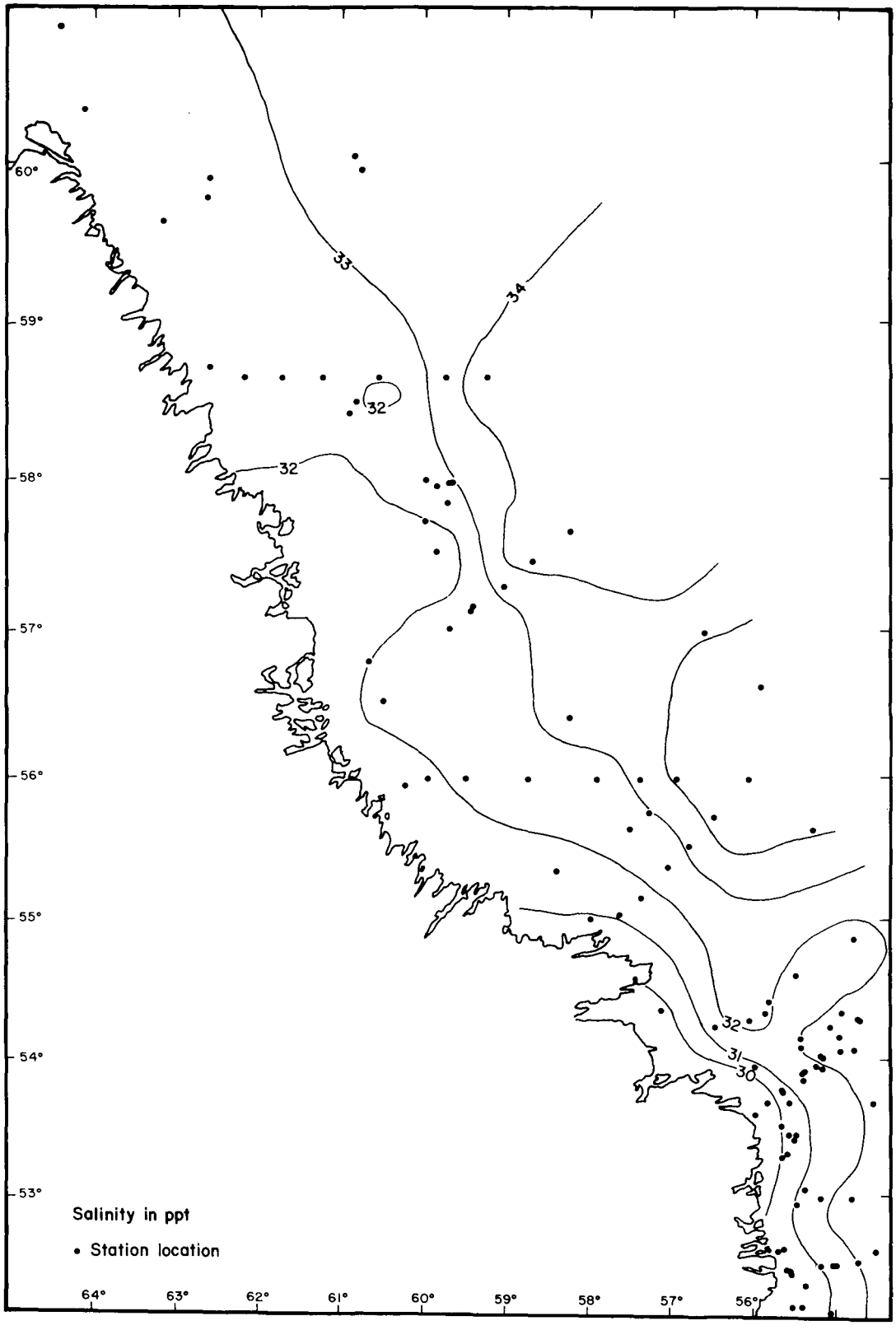


FIGURE 4.13 SURFACE SALINITY: SEPTEMBER

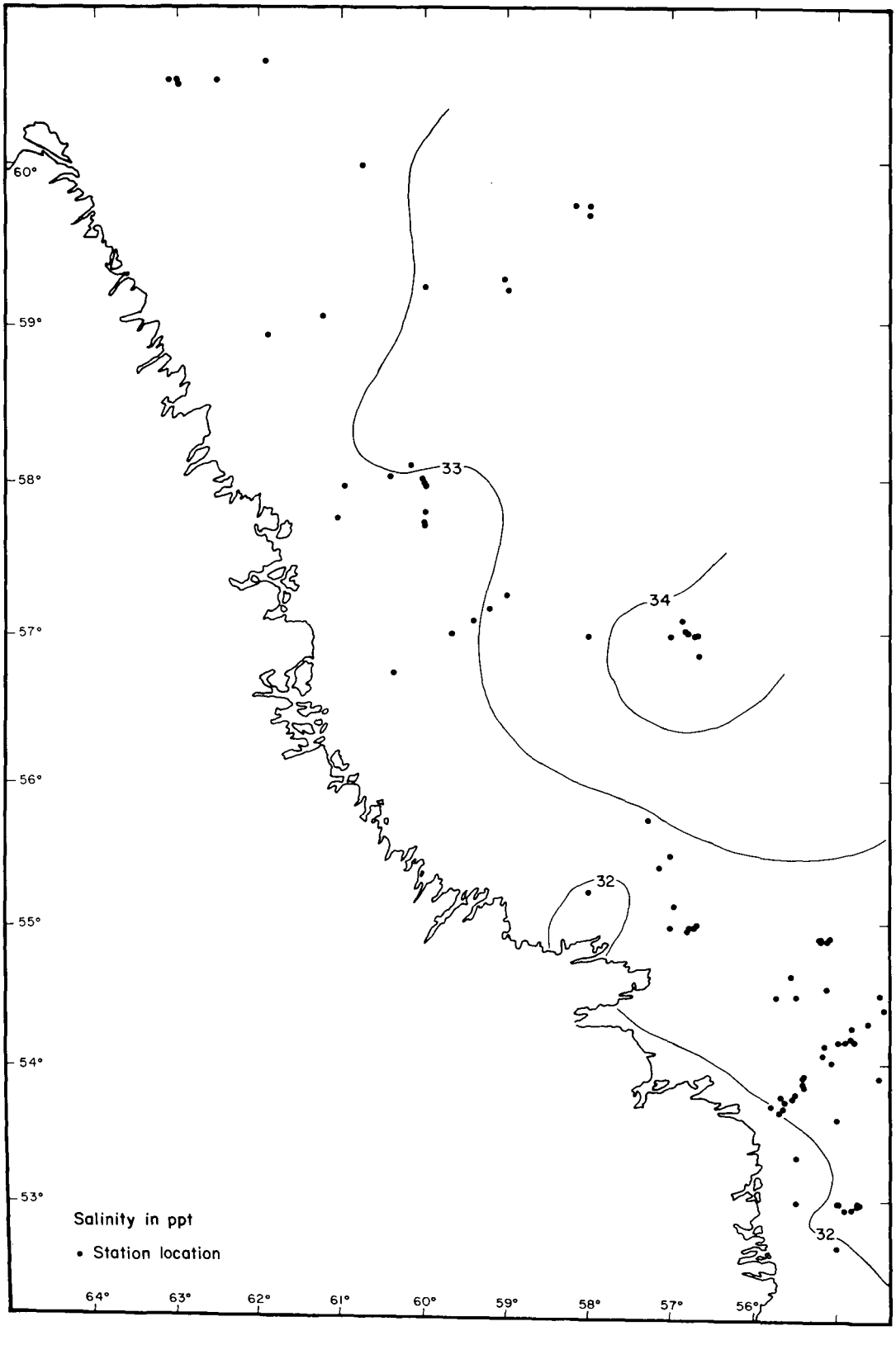


FIGURE 4.14 SURFACE SALINITY: OCTOBER

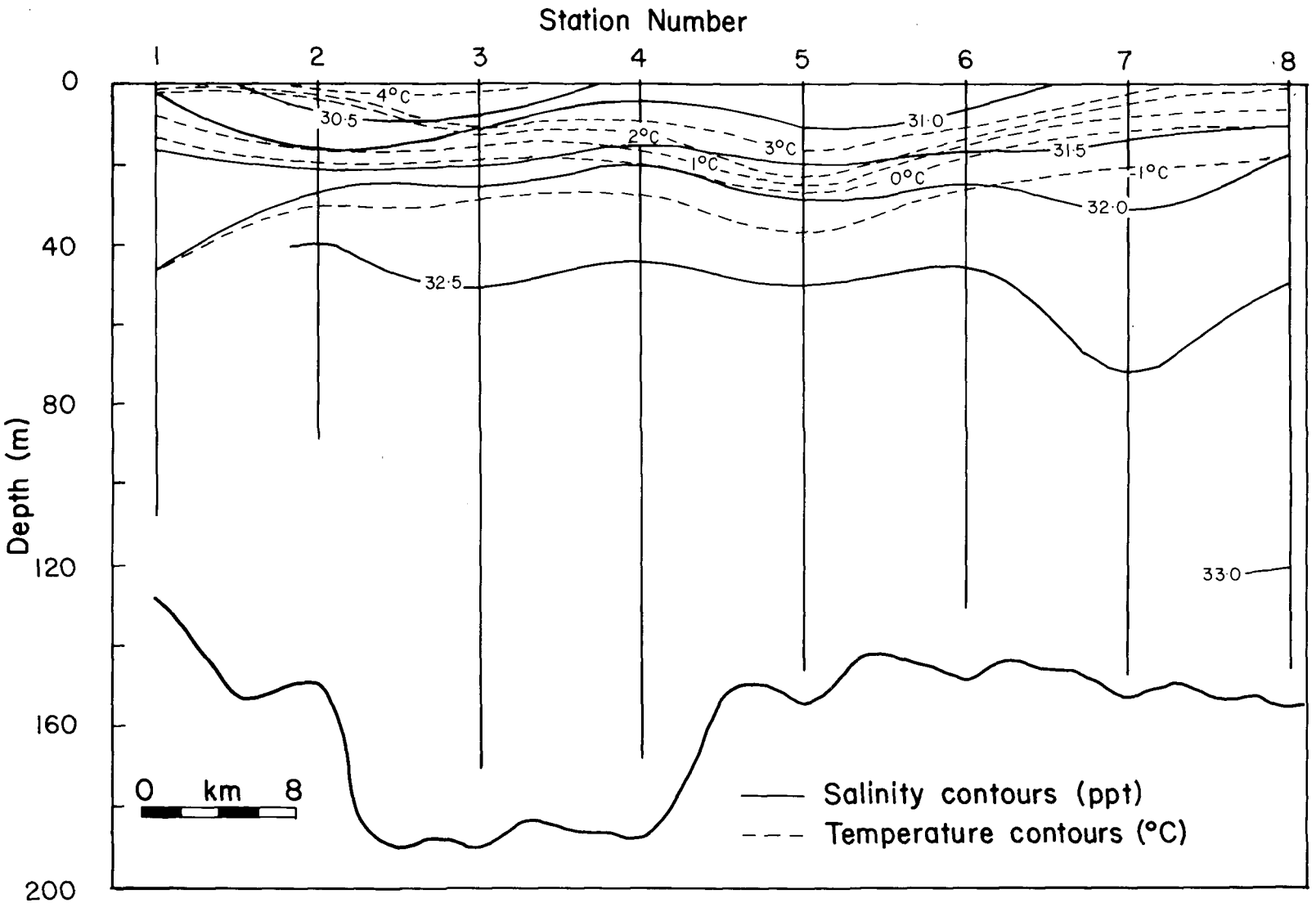


FIGURE 4.15 S.T.D. MEASUREMENT ACROSS THE SAGLEK BANK: AUGUST 11 AUGUST 11 TO 13, 1972
(see Figure 3.1 for location of stations, from Allen, 1972)

4.1.3.2 Salinity. Surface salinities are compiled from the same sources as the temperature figures mentioned previously. The more saline West Greenland Current is clearly seen offshore. One striking feature is the importance of land drainage. This is particularly evident in the early summer as run-off contributes to a large fresh water input. The other feature is the northward progression of this coastal run-off as the season proceeds.

The fact that the isotherms run at right angles to the isohalines in summer and fall indicates that solar heating in-situ is of greater significance in heating the surface layer than the influx of relatively warm land-drainage water.

Very few of the watershed areas along the Labrador coast have any measured discharge rates available. The Labrador Drainage Basin represents an area of 272,000 km^2/; the principal river is the Churchill, with a drainage area of 130,500 km^2. This river has been regulated since 1971, and includes 13,700 km^2 of the Naskaupi and Kanairktok Rivers, diverted since 1972. The other major watersheds for which discharge rates are available, the Eagle River, has a drainage area of 10,100 km^2. Monthly discharge rates in cubic feet per second are included in Figure 4.16. Mathews (1976), quoting a private communication from Jordon, estimates that the run-off from Ungava Bay and Hudson Bay has a much greater effect on the coastal component of Labrador than the local run-off.

Vandall (Personal Communication, 1978) states that the Labrador Current may represent six to ten times as much fresh water content as the Gulf of St. Lawrence, making it the largest single source of freshwater input into the world oceans. The freshwater run-off would be expected to impart seasonal changes in the Labrador Current, with the Hudson Bay peak run-off overriding all other sources (Matthews et al, 1976). A detailed discussion of the freshwater input in the Labrador Current is the subject of a paper in preparation at the Bedford Institute of Oceanography (Vandall, Personal Communication, 1978).

4.1.4 Current Velocities. Very little recent, direct current metre work has been done in the Labrador offshore. Those current metre records which have been done show fluctuations on a wide range of time scales. The most consistent is the semi-diurnal tidal period oscillation component (12.42 h), and an inertial (14.4 h) rotation, which is largely produced by the passage of storm systems.

The work by Memorial University on the Saglek Bank spanned most of August, with three current metre arrays (Allen, 1972). A low-pressure system moved through the area at the end of the month and resulted in an intense storm. Current velocities at the

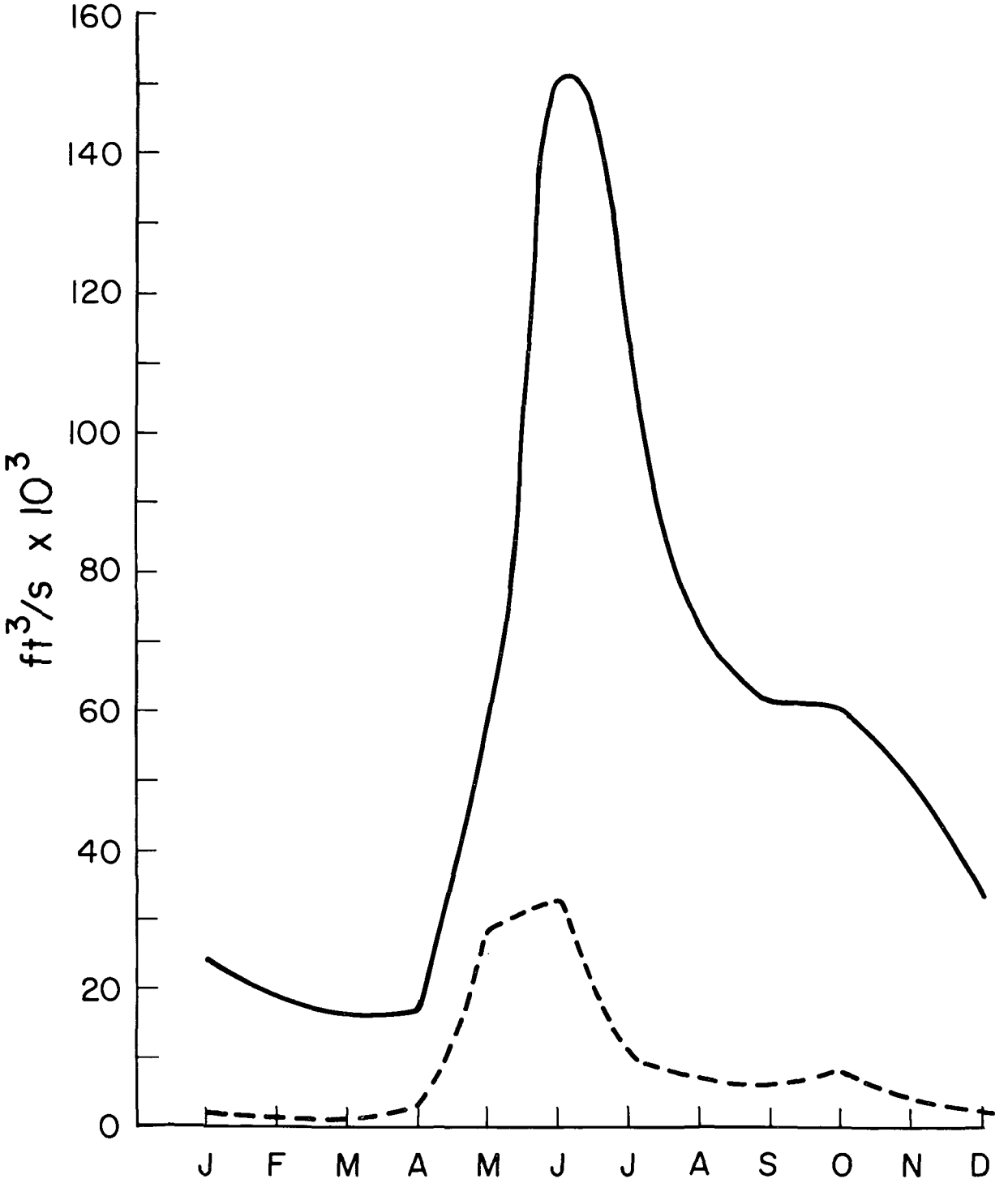


FIGURE 4.16 MONTHLY DISCHARGE RATES: CHURCHILL AND EAGLE RIVERS
Churchill River (———)
Eagle River (-----)

surface (13-metre depth) increased from 20 to 45 to 50 cm/s during the time preceding the storm, and reached a high of 75 cm/s as a result of the storm.

Current velocity at a depth of >155 m was approximately 15 cm/s and remained unaffected by the storm. At intermediate depths from 120 to 140 m, velocities averaged slightly higher (15 to 20 cm/s) and reached a peak velocity of about 35 cm/s as a result of the storm. A schematic representation of this data is provided in Figure 4.17.

Beyond these few measurements on current velocities, the only other source of available information is the surface currents reported by Dunbar (1951) and Smith et al (1937). Figure 4.1 is based on the former, while Figure 4.18 is taken from the latter (Matthews et al, 1976).

The *Marion* and *General Greene* expeditions in the early 1930's encountered small northward countercurrents along the outer margin of the Labrador current. These were reconfirmed by recent work (Allen and Huntley, 1977). Dunbar (1951), quoting Smith et al (1937), gives the following account of the water transport of the Labrador current in a southeasterly direction:

off Nachvak Fjord	1.9×10^6 m^3/s
off Cape Harrison	5.3×10^6 m^3/s
off Hamilton Inlet	4.7×10^6 m^3/s
off Domino Island	5.0×10^6 m^3/s
off Strait of Belle Isle	3.5×10^6 m^3/s

Lack of winter data prevents any detailed discussion of velocities during the period of ice cover. Dunbar (1951), however, argues that with the onset of winter, the current velocities would decrease as a result of reduced land drainage: "And as land drainage increases during the summer, the volume of coastal water grows. The dynamic height of currents, especially close to the shore, rises and the velocity of the currents consequently increases".

A seasonal variation in the surface current velocities of the Labrador current are discussed by NORDCO (1977). These results are directly reproduced from their report, (Figures 4.19 to 4.22), and are based on information (personal communication) from Dobson et al, 1977. Since no further information is available, it is difficult to comment on the quantity or quality of this data. A peak current velocity in the fall supports the argument of Dunbar (1951) and Matthews et al (1976) (presented previously) on the importance of terrestrial drainage.

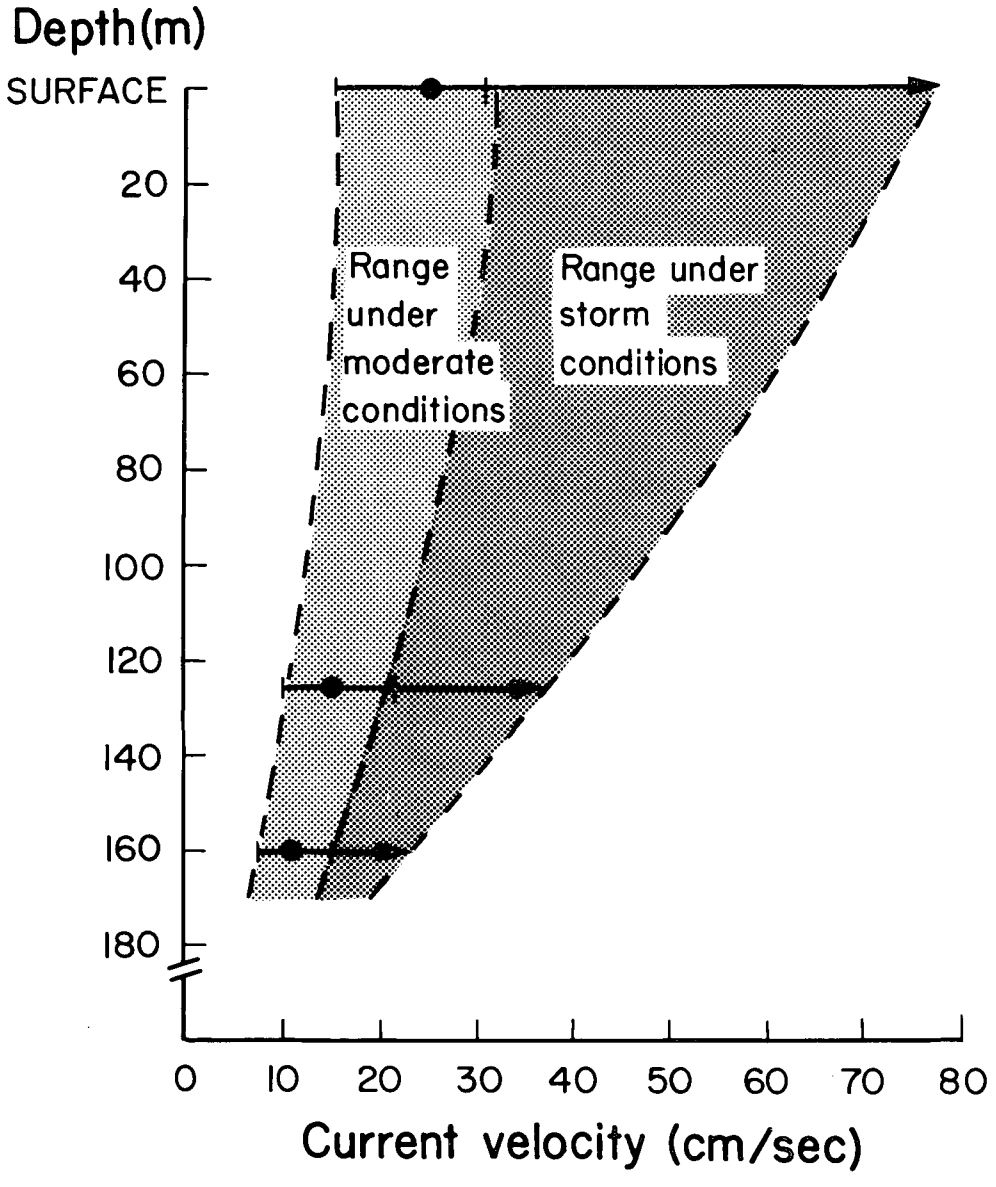


FIGURE 4.17 CURRENT PROFILE ON SAGLEK BANK, LABRADOR: AUGUST, 1972
(Based on work reported by Holden, 1973)

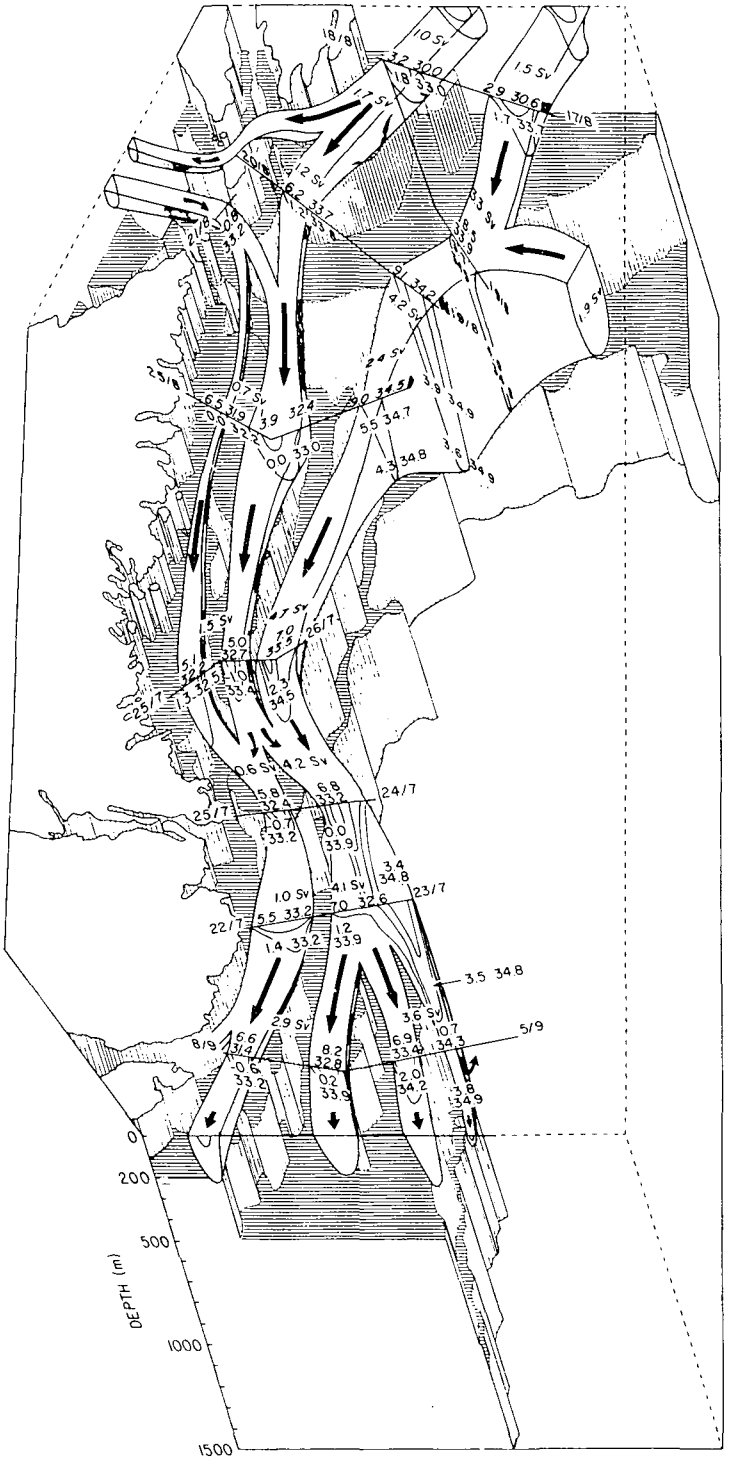


FIGURE 4.18 THE LABRADOR CURRENT IN PERSPECTIVE
(Source: Matthews et al, 1976)

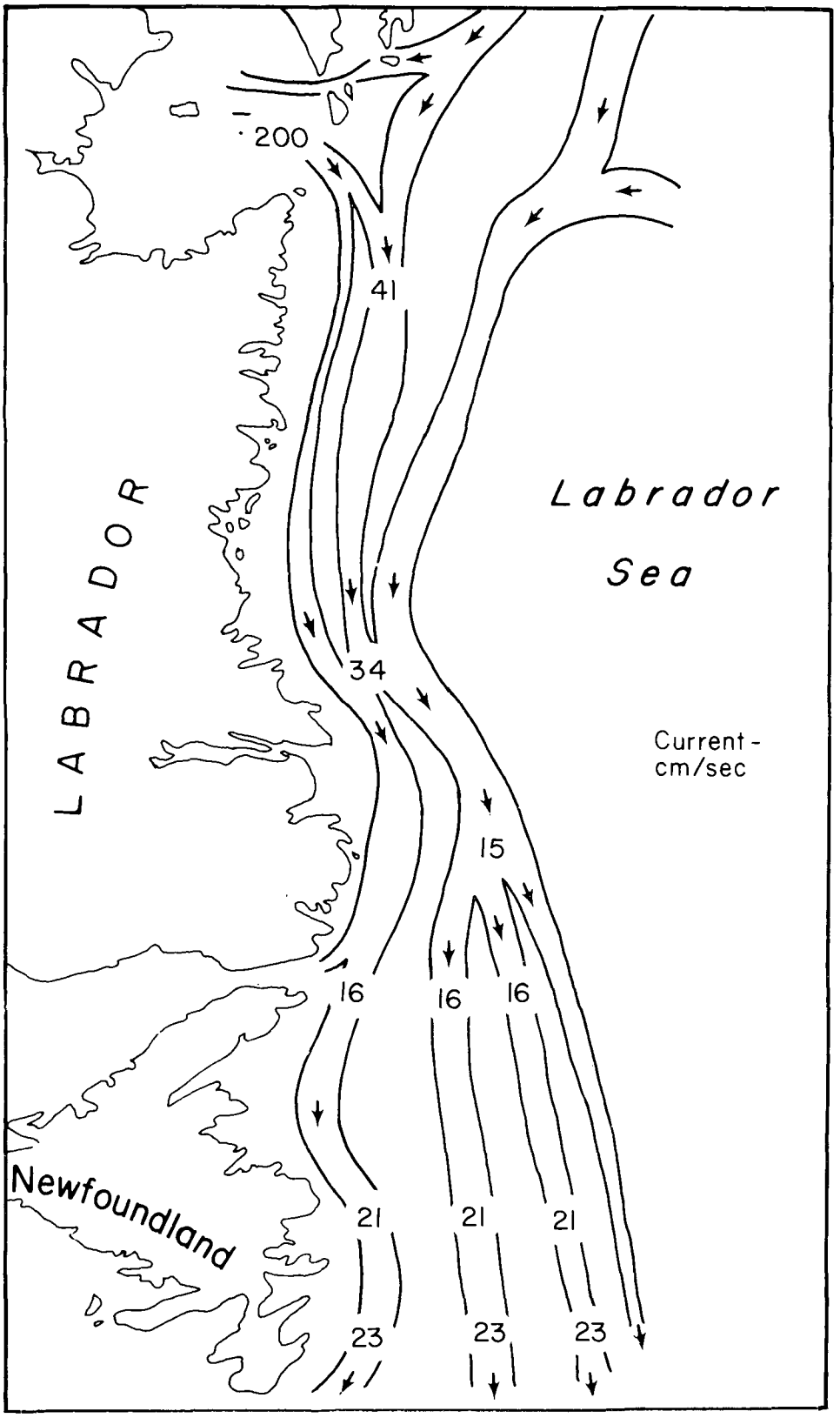


FIGURE 4.19 SPRING SURFACE CURRENT VELOCITIES: LABRADOR CURRENT (from NORDCO, 1977)

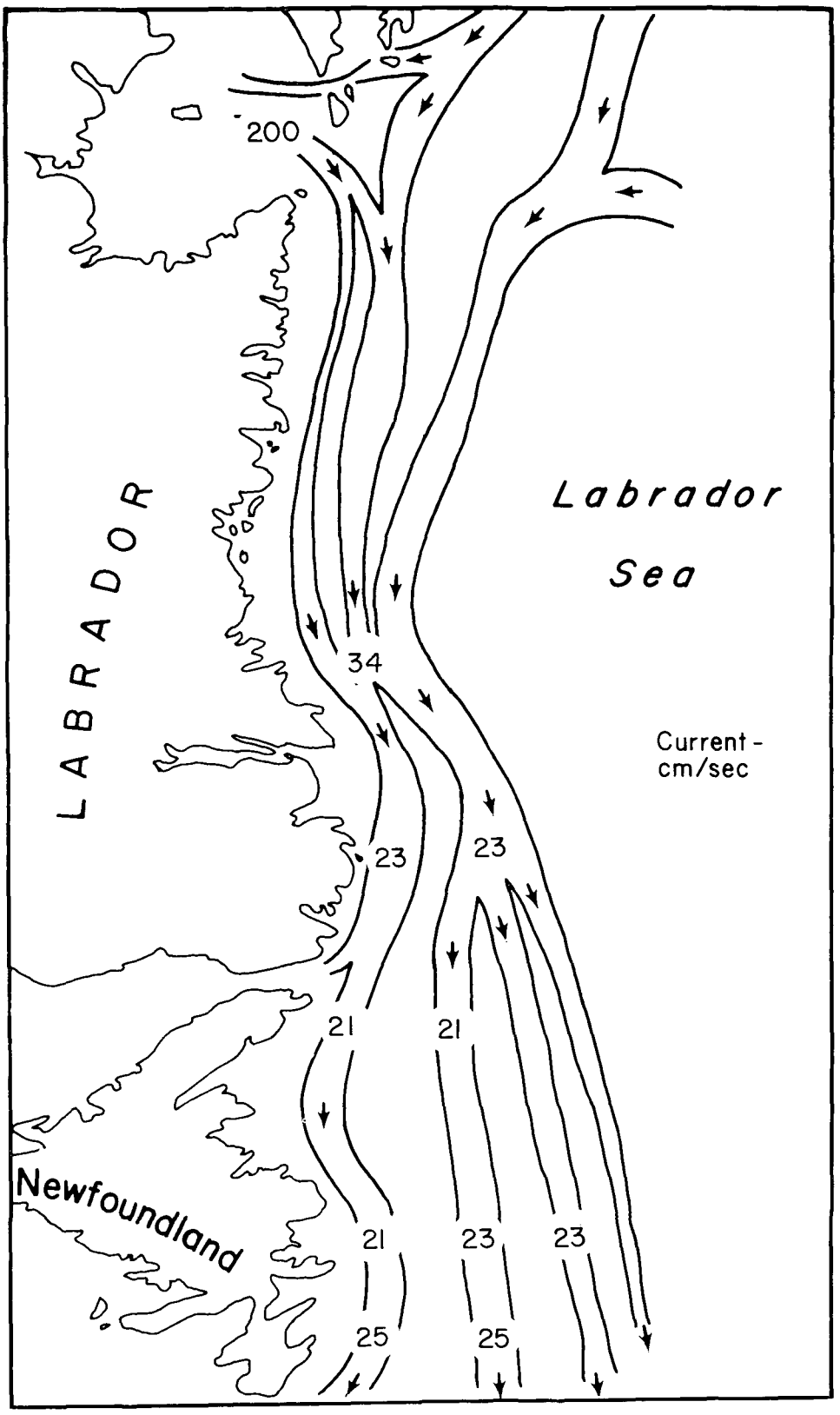


FIGURE 4.20 SUMMER SURFACE CURRENT VELOCITIES: LABRADOR CURRENT (from NORDCO, 1977)

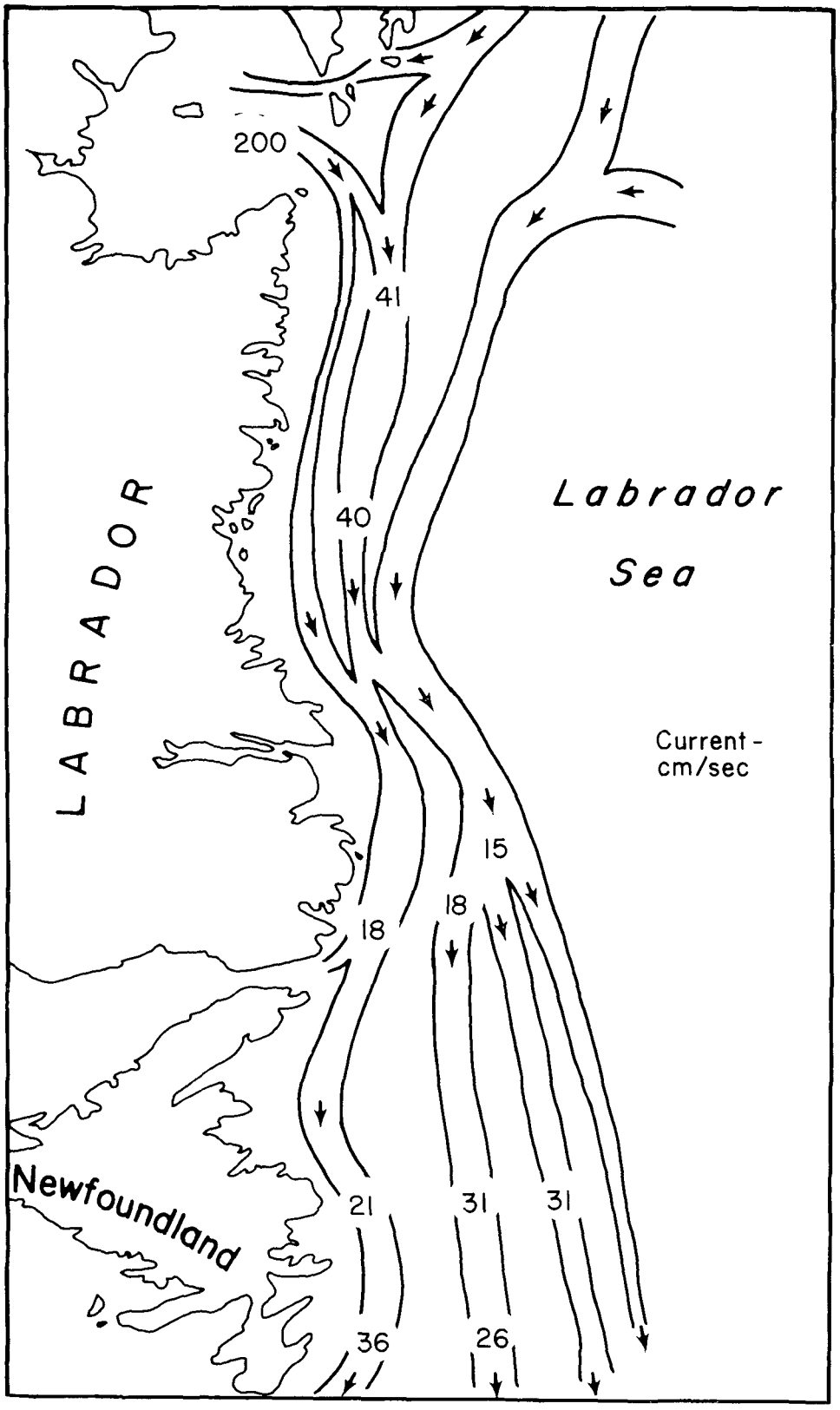


FIGURE 4.21 FALL SURFACE CURRENT VELOCITIES: LABRADOR CURRENT (from NORDCO, 1977)

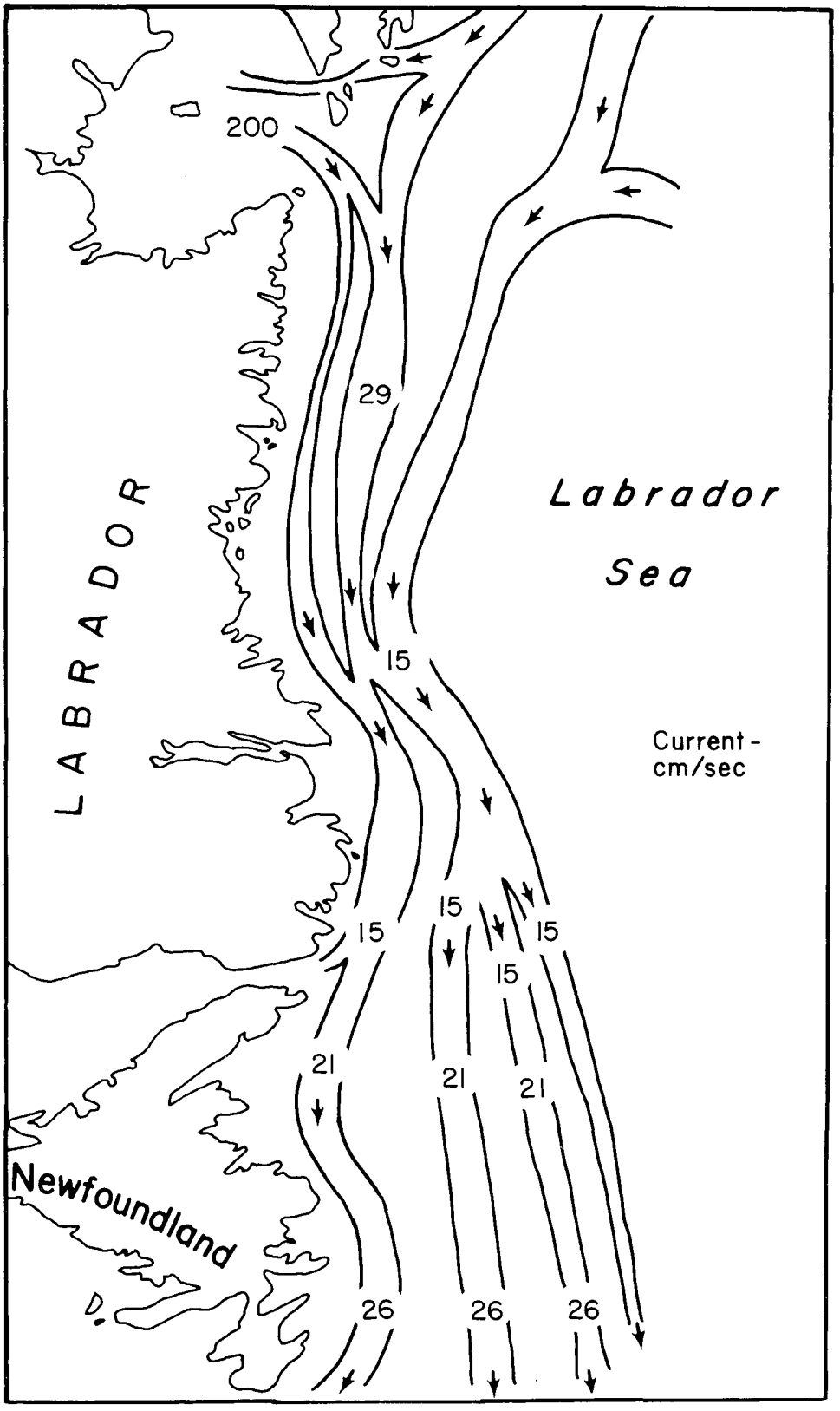


FIGURE 4.22 WINTER SURFACE CURRENT VELOCITIES: LABRADOR CURRENT (from NORDCO, 1977)

4.1.5 Sea State. Similarly, synoptic wave climatological data for the Labrador coast is very sparse. The most comprehensive studies to date have been the reports by Neu (1972, 1976), which deal with the wave climate of the Canadian Atlantic Coast and Continental Shelf. The studies involved the analysis of visual, ship-reported wave height information for the year 1970, compiled by the Canadian Armed Forces, Meteorology and Oceanography (METOC) Centre, Halifax, Nova Scotia. A more recent project was begun by the Atmospheric Environment Service of Environment Canada, and the preliminary analysis of five years' data (May 1972 to April 1977) has been completed (Anonymous, 1977). This data base also relies on ship reports.

Both studies address themselves to the entire Canadian Atlantic Coast, on a scale which makes any detailed discussion of their results for the Labrador continental margin difficult. Also, both studies avoid the continental margin directly, and this is the area of immediate interest.

The only direct survey with wave gauges in the Labrador offshore is the Wave Rider Buoy Program, carried out from the drillships operating in the region. Table 4.1 lists the locations and time of year during which these readings are available. Results from the Wave Rider Buoy Program are available from the Marine Environmental Data Service Branch (MEDS) of Environment Canada. This information, although sparse, represents actual wave characteristics measured during the operating season in the area of interest.

One of the more important contingency-planning requirements is a knowledge of the sea state. The planning of the operation, as well as the choice and design of countermeasure techniques, all require reliable wave characterization information. Therefore, a complete picture of the wave climate should be a top priority in the collection of oceanographic data for the Labrador Sea. The effectiveness of oil containment and recovery equipment falls off rapidly as wind and wave action approaches Beaufort Wind Scale 4 (Table 4.2).

Examination of these various data sources clearly indicates that sea state varies greatly with season, as a result of the seasonal variations of wind speed, direction and duration. From an applied scientific or engineering point of view, the physical characteristics of more immediate use are the wave parameters of height and period, and duration of propagation. Design criteria also require seasonal occurrence and distribution of extreme wave height information, as well as the probability of occurrence of a specified maximum wave during a specified time interval.

TABLE 4.1 WAVE RIDER BUOY DATA: LABRADOR CONTINENTAL SHELF

Date	Location	
	Lat.(N)	Long.(W)
1973		
July 31 to October 25	55°30'	57°42'
1974		
July 6 to August 10	54°54'	54°52'
July 9 to October 3	49°08'	51°14'
August 10 to August 17	55°30'	57°42'
August 18 to September 29	57°20'	59°58'
September 30 to October 29	55°30'	54°45'
1975		
July 6 to August 1	53°56'	54°43'
August 1 to October 9	53°56'	54°42'
August 19 to October 17	58°52'	61°46'
July 9 to October 21	54°21'	54°23'
1976		
September 27 to October 12	54°31'	54°24'
August 30 to November 20	55°31'	57°45'
August 1 to August 28	59°50'	61°45'
September 3 to September 22	52°26'	54°12'
August 29 to September 7	57°20'	59°58'
September 13 to October 23	58°52'	61°47'

For the purpose of this report, we can consider all waves to be wind generated as a result of energy transfer from the moving air mass to the sea surface. The height and period of wind-generated waves are a function of three factors: (1) the wind velocity; (2) the duration or time that the wind blows; and (3) the fetch or distance of water over which the wind blows.

Wave height and wavelength will generally increase to a definite maximum with increasing wind velocity and duration. The fetch is important in determining the wavelength. The effects of different wind speeds and their effects on the sea surface can be qualitively described in what is called the Beaufort Wind Scale (Table 4.2).

When considering water gravity waves, it is important to distinguish between Deep Water Waves, whose properties differ substantially from Shallow Water Waves. The generally accepted criterion for differentiating between these two classes is occurrence of water depth greater than half the predominant wave length for the deep water waves.

As deep water waves enter shallow water, the wavelength becomes shortened and the height increases. The depth over the Labrador continental shelf is generally between 150 and 250 m, and wave propagation is as Deep Water Waves, whose motion is unaffected by the bottom topography.

The wave properties obtained by visual observations are equivalent for practical purposes to those defined as "significant waves"; the height is the mean height of the highest third of all the waves in the wave train. The maximum wave height (H max) is related to the significant wave height in a Rayleigh relationship. According to various sources quoted by Neu (1976), the ratio between the extreme wave height and the significant wave height is between 1:1.7 and 1:2.0

Neu's (1976) results demonstrate that the sea state along the Labrador coast is highly non-uniform with respect to time and space. During the late fall and early winter, the monthly energy level was approximately five times greater than that during the summer. Energy concentration on the Labrador coast was three to four times that over the Scotian Shelf.

In the winter, the strong northwest winds are parallel to the eastern seaboard of Labrador and would generate large seas. The encroachment of the pack ice in the area acts as an effective damping agent, reducing sea state significantly, even over short distances into the ice edge.

For any type of operation in the ocean, it is important to forecast the period of time that interruption from waves would result. In oil exploration, the motion of platforms becomes critical when waves are larger than 3 m, and drilling is usually stopped when the significant wave height exceeds 7 or 8 m.

The percentage exceedance distributions for the two areas indicated in Figure 4.23 are summarized in Table 4.3; these are based on the results of the AES Wave Climatology Study (May, 1972 to April 1977, Anonymous, 1977). The largest wave height

TABLE 4.2 BEAUFORT WIND SCALE

Beaufort Number	General Wind Description	Sea Conditions	Wind Speed (miles/hour)	Wind Speed (kilometres/hour)	Wave Height (feet)	Wave Height (metres)
0	Calm	Smooth as mirror	Less than 1	Less than 1	0	0
1	Light air	Small, wavelet-like scales; no foam crests	1-3	2-5	0.5	0.15
2	Light breeze	Waves short; crests begin to break	4-7	6-11	1	0.3
3	Gentle breeze	Foam has glassy apperance; not yet white	8-12	12-20	2	0.6
4	Moderate breeze	Waves now longer; many white areas	13-18	21-29	5	1.6
5	Fresh breeze	Waves pronounced and long; white foam crests	19-24	30-39	10	3.1
6	Strong breeze	Larger waves form; white foam crests all over	25-31	40-50	15	4.7
7	Moderate gale	Sea heaps up; wind blows foam in streaks	32-38	51-61	20	6.2
8	Fresh gale	Height of waves and crests increasing	39-46	62-74	25	7.8
9	Strong gale	Foam is blown in dense streaks	47-54	75-87	30	9.3
10	Storm	High waves with long overhanging crests; large foam patches	55-63	88-101	35	10.8
11	Violent storm	Exceptionally high waves	64-75	102-120	--	--
12	Hurricane	Sea completely covered with streaky foam; air filled with spray and foam	Above 75	Above 120	--	--

Source: D.A. Ross, (1974) Introduction to Oceanography, Prentice Hall, Inc., Englewood Cliffs, N.J. 07632

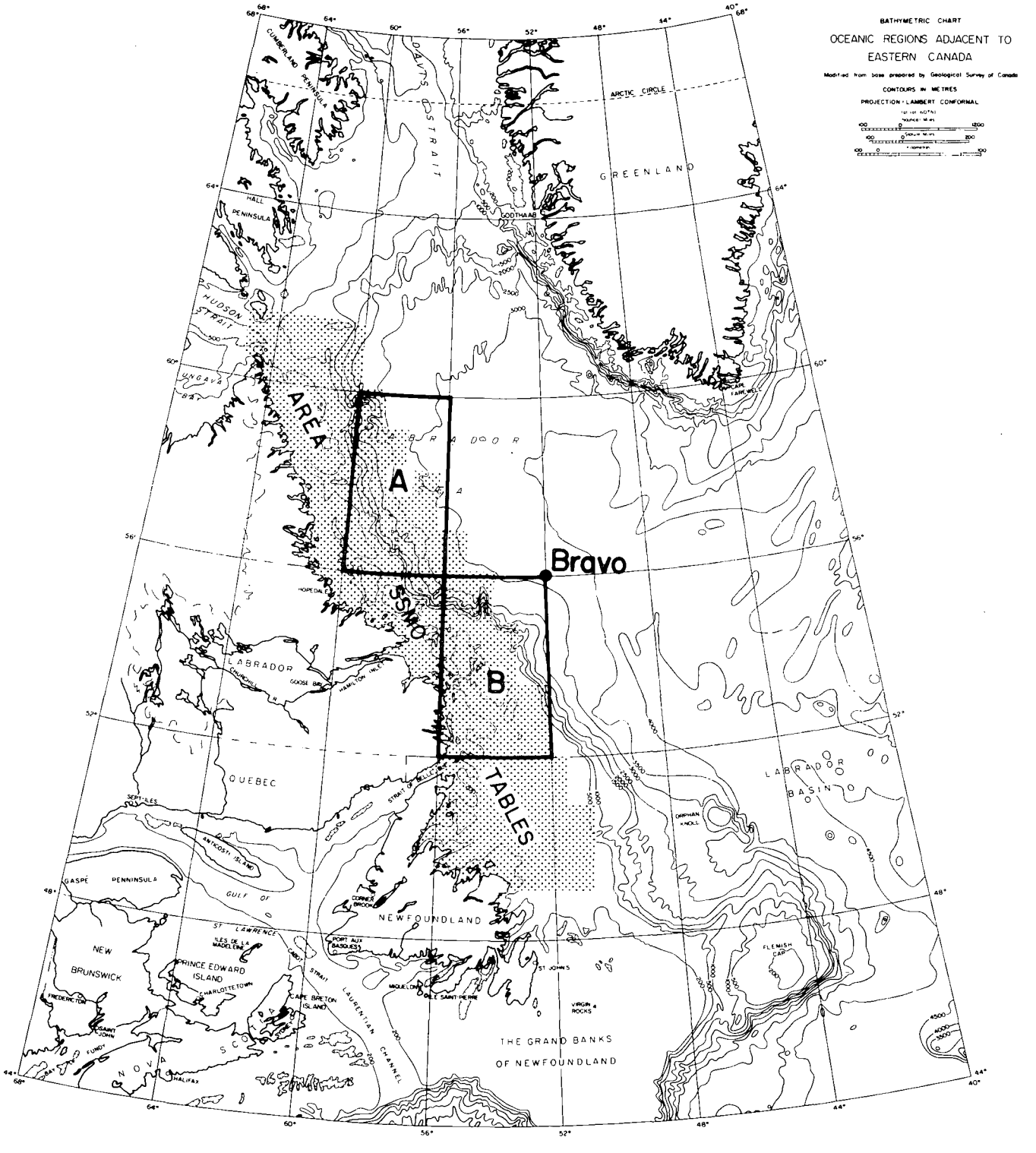


FIGURE 4.23 AREAS OF THE LABRADOR SEA DISCUSSED IN THE TEXT

TABLE 4.3 WAVE HEIGHT AND PERIOD PERCENTAGE EXCEEDANCE PER MONTH FOR AREAS A AND B SHOWN IN FIGURE 4.23

	MONTH	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	AREA	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Prob. of 75% Ice cover	.132	.023	.270	.574	.152	.403	.027	.013	.171	.055	.013	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.035	.000
Probability of Significant Wave Heights	≥ 0.5 m	.865	.977	.727	.426	.848	.597	.067	.987	.797	.929	.933	1.000	.929	.990	.981	.994	1.000	1.000	1.000	1.000	.997	1.000	.964	1.000
	≥ 1.5 m	.752	.955	.603	.397	.739	.574	.723	.840	.365	.574	.370	.953	.397	.474	.532	.690	.766	.896	.871	.465	.850	.980	.832	.968
	≥ 3.5 m	.284	.532	.160	.213	.226	.239	.160	.187	.019	.116	.027	.383	.016	.048	.045	.074	.107	.157	.274	.403	.350	.480	.366	.558
	≥ 5.5 m	.077	.184	.028	.028	.052	.042	.013	.010	.003	.000	.000	.120	.000	.003	.000	.010	.010	.023	.052	.161	.127	.167	.123	.181
	≥ 7.5 m	.013	.045	.007	.011	.013	.010	.000	.000	.000	.000	.000	.023	.000	.000	.000	.003	.000	.000	.006	.052	.023	.030	.032	.045
	≥ 10.5 m	.000	.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000
	< 0.5 m	.003	.000	.004	.000	.000	.000	.007	.000	.032	.016	.053	.000	.071	.010	.019	.006	.000	.000	.000	.000	.003	.000	.000	.000
	< 1.5 m	.116	.023	.128	.028	.110	.023	.250	.147	.465	.371	.617	.047	.603	.526	.468	.310	.234	.104	.129	.035	.150	.020	.133	.032
	< 3.5 m	.584	.445	.571	.213	.623	.358	.813	.800	.810	.829	.960	.617	.984	.952	.955	.926	.893	.843	.726	.597	.650	.520	.599	.442
	< 5.5 m	.790	.794	.702	.397	.797	.555	.960	.977	.826	.945	.987	.880	1.000	.997	1.000	.990	.990	.977	.948	.839	.873	.833	.841	.819
	< 7.5 m	.855	.932	.723	.415	.835	.587	.973	.987	.829	.945	.987	.977	1.000	1.000	1.000	.997	1.000	1.000	.994	.998	.977	.970	.932	.955
	< 10.5 m	.868	.974	.730	.426	.848	.597	.973	.987	.829	.945	.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.997	1.000	1.000	.964	1.000
Probability of Significant Wave Periods	≥ 5 sec.	.777	.945	.631	.394	.771	.561	.830	.970	.592	.727	.639	.983	.746	.822	.729	.864	.920	.960	.913	.961	.909	.973	.851	.968
	≥ 8 sec.	.287	.474	.131	.191	.239	.252	.207	.240	.087	.175	.040	.450	.081	.162	.152	.239	.214	.368	.410	.500	.326	.483	.327	.519
	≥ 10 sec.	.045	.119	.007	.028	.042	.087	.050	.023	.000	.006	.007	.094	.007	.026	.023	.055	.027	.087	.090	.181	.117	.143	.117	.155
	≥ 12 sec.	.066	.019	.000	.007	.003	.019	.003	.008	.000	.000	.000	.010	.003	.003	.003	.010	.000	.017	.010	.052	.020	.030	.006	.035
	< 5 sec.	.090	.032	.099	.032	.077	.035	.143	.080	.236	.218	.348	.017	.254	.178	.271	.136	.080	.040	.087	.039	.091	.027	.113	.032
	< 8 sec.	.581	.581	.599	.234	.610	.345	.767	.747	.741	.946	.946	.542	.919	.838	.848	.761	.786	.632	.590	.500	.674	.517	.638	.481
	< 10 sec.	.823	.858	.723	.297	.806	.510	.923	.963	.828	.938	.980	.906	.993	.974	.977	.945	.973	.913	.910	.819	.883	.857	.848	.845
	< 12 sec.	.861	.861	.730	.418	.845	.577	.970	.980	.828	.945	.987	.990	.997	.997	.997	.990	1.000	.983	.990	.948	.980	.970	.958	.965

Largest Wave Height and Period Observed in Five Years (May 1972 - April 1977)

Area	Highest Wave in Meters (Period in Seconds)	Month/Year	Highest Wave in Meters (Period in Seconds)	Month/Year
A	10(11)SE	Mar./74	14(6)NW	Dec./72
B	12(12)NW	Feb./73	17(11)S	Oct./73

and period observed during observation time from May 1972 to April 1977 are also included at the base of Table 4.3. Neu (1976) estimates that the 10 and 100 year recurring wave heights for the Labrador region are 20 and 26 m, respectively.

The results of the wave rider program carried out from the drillships operating in the Labrador offshore are summarized in Table 4.4. As can be seen, the proportion of time during which wave height is less than 0.75 m decreases from a high in mid-summer

TABLE 4.4 WAVE RIDER RESULTS: LABRADOR SHELF

MEDS* Station Number	Year	Month	Wave height less than .75 m (% of total time)	Wave height greater than 3 m (% of total time)
17	1973	August	28.5	27.5
17		September	14.0	30.0
17		October	0	22.6
94	1974	July	12.5	22.1
94		August	6.7	23.6
94		September	6.7	27.8
17	1975	July	37.0	22.9
17		August	10.0	20.6
17		September	7.5	26.6
17		October	0	26.6
18	1975	August	4.6	30.0
18		September	2.9	30.0
94	1976	July	43.4	21.8
94		August	4.10	23.4
94		September	5.20	28.9
94		October	0	17.6
17	1976	September	1	22.4
17		October	3.6	21.8
24	1976	September	2.10	28.9
24		October	1.12	29.9
24		November	0.9	18.7
23	1976	August	47.2	21.89
23		September	0	18.3

* Marine Environment Data Service, Environment Canada

(over 45.0 percent of the time in July, 1975) to nil in the late fall. During this same time period, the occurrence of wave heights greater than three m increases by October to November. During late December and January, the formation of sea ice effectively damps out the energy peak in the Labrador Sea proper.

Figure 4.24 illustrates that weather (primarily sea state) has proven to be the most significant factor causing down time during the exploration drilling program.

4.2 Climate

The most extensive study of the climatology of the Labrador region is provided by Hare (1951) in his thesis on the climate of the "Eastern Canadian Arctic and Sub-Arctic". A condensed version dealing specifically with Quebec and Labrador was subsequently published (Hare et al, 1953). Hare, and more recently Barry (1959), have both provided comprehensive summaries of the physical and dynamic climatology of the Labrador-Ungava Peninsula. The sparsity of data that hampered these earlier works has changed little in the intervening 20 years, and has even intensified as a result of the discontinuance of several weather stations in the northern half of the coast.

The problems of sparsity of data are even further compounded offshore. The major source of weather information for the Labrador region is from the shore-based stations, although ship reports in the area are collected and processed. With the advance of seasonal pack ice and the closing of coastal harbours to navigation, ship movements and hence ship reports decline.

A detailed discussion of the source and format of systematically collected environmental data for the Labrador region is provided in Chapter 13.

At present, no long-term meteorological information over the Labrador ice pack exists, and the extrapolation of land-based information across the Labrador Sea is tenuous. An opportunity to investigate the inadequacies of this type of data interpretation was provided in February 1977, when a reseach vessel drifting south in the Labrador pack ice (LeDrew and Culshaw, 1977) carried out meteorological measurements. A hindcast comparison with shore-based stations at Hopedale and Cartwright on the Labrador coast indicated a serious discrepancy in the resulting interpretation. A low located over Hudson Bay on February 9 moved east into the Labrador Sea. The Atmospheric Environment Service interpreted it as dissipating upon leaving Hudson Strait; however, shipboard measurements indicated the low actually intensified upon entering the Labrador Sea (Newell, 1977).

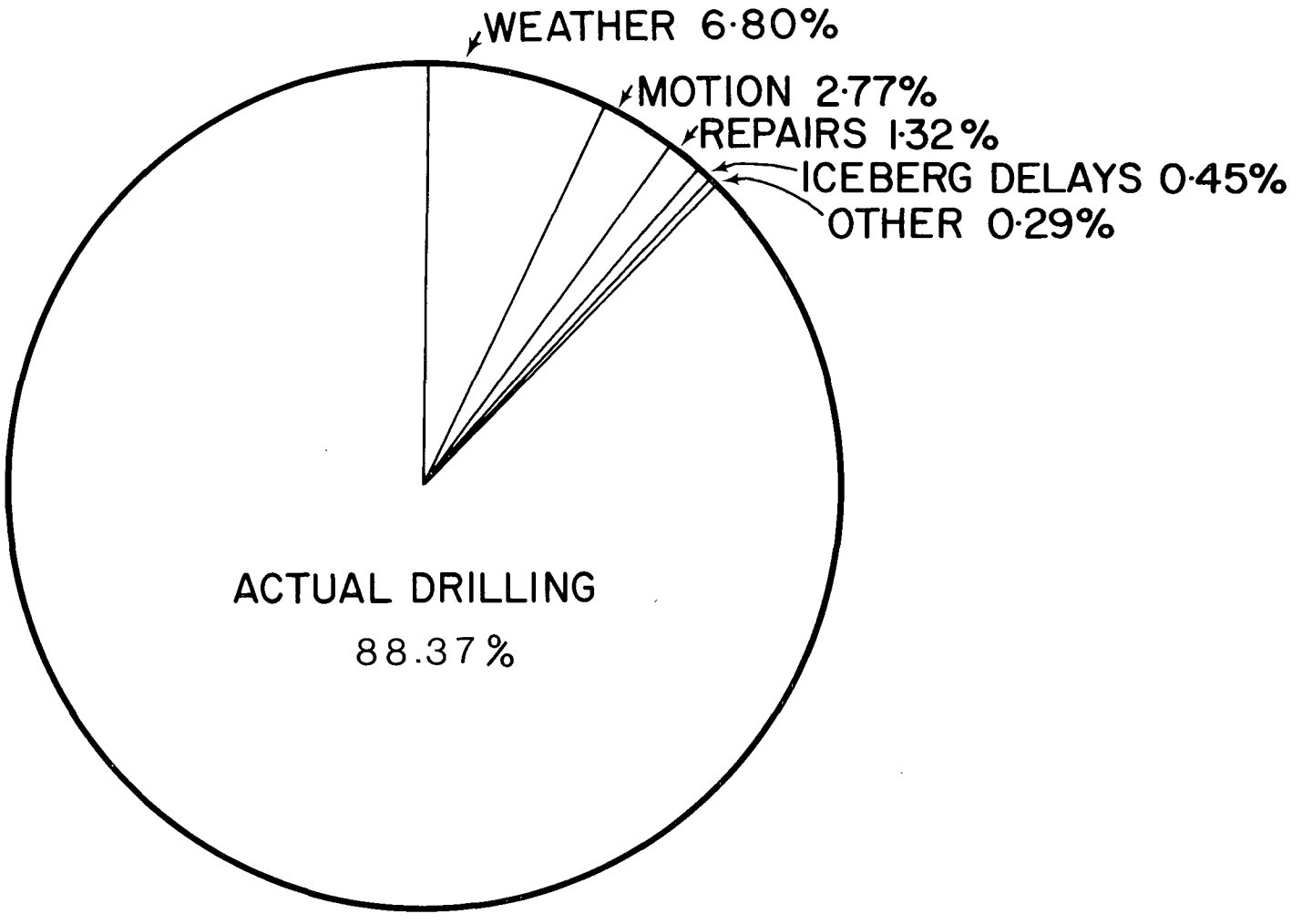


FIGURE 4.24 TOTAL TIME INVOLVED IN OFFSHORE LABRADOR DRILLING PROGRAM: 1973-1975 INCLUSIVE

A brief synoptic coverage of the climate of the Labrador Sea has recently been published by Bursey et al (1977). Two additional reports should be mentioned: (1) an unpubished manuscript by Banfield (1973), summarizing the climate of Labrador; and (2) a report by Peach (1975), which discusses the climate of both Newfoundland and Labrador and its effect in tourism and outdoor recreation.

Except for Bursey et al (1977), the above-mentioned reports deal almost exclusively with land-based interpretations.

A major source of data for this chapter has been the Summary of Synoptic Meteorological Observations (SSMO), provided by the National Oceanic and Atmospheric Administration, National Climatic Centre, Ashville, N.C. The information was summarized in 21 tables, which are listed in the Appendix to this chapter. The data relies on observations obtained from ship logs, ship weather reporting forms, published ship observations, automatic observing buoys, teletype reports, and on cards purchased from several foreign meteorological services. It covers the period from 1879 to 1971. The data coverage area is shown in Figure 4.23; and unless otherwise stated in the text, this is the region that is discussed in this chapter.

4.2.1 Factors Influencing Climate

4.2.1.1 Temperature. Mean, maximum and minimum air temperature for the Labrador Sea are shown in Figure 4.25. The Labrador Sea is considerably colder for most of the year than the worldwide norm for this latitude. This temperature anomaly can be clearly seen in Figure 4.26, which illustrates the difference between the recorded temperature atpoints across Canada and the mean for that latitude. Although during the summer (July) the area is considerably colder than similar latitude zones, the winter period (January) is relatively mild.

This seasonal variability results from the location of Labrador in terms of (a) the surrounding disposition of the continental and ocean areas; and (b) the prevailing physical characteristics of the adjacent ocean water masses, especially temperature, as discussed previously.

The Labrador-Ungava Peninsula is subject to a continental climate, mitigated only at the coast as a result of marine influence. As Hare (1951) explains, the eastern Arctic and sub-Arctic of Canada is an area within which there are large sea surfaces in free communication with the Arctic Ocean and the Atlantic. The presence of this vast water surface gives the region a climate in which continental and marine influences intermingle.

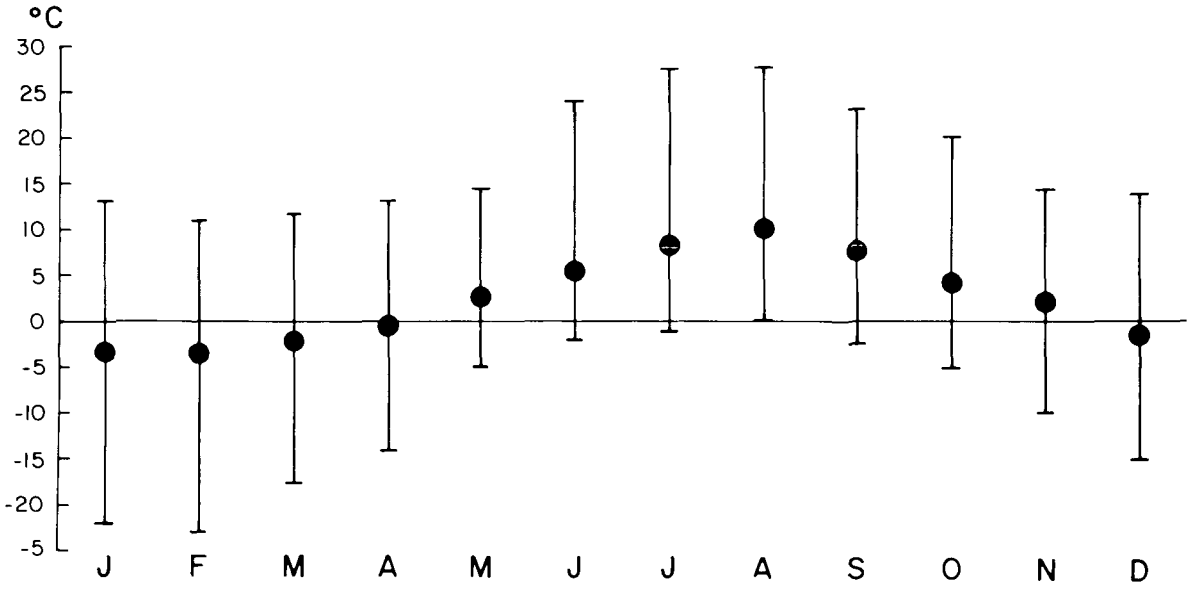


FIGURE 4.25 MAXIMUM, MEAN AND MINIMUM AIR TEMPERATURE BY MONTH FOR THE LABRADOR CONTINENTAL SHELF

In August and September, while sea surface temperature reaches 9 to 10°C in the central areas of the Labrador Sea, the colder water of the central and northern coast may remain below 4°C. This cool water would be expected to have a considerable influence on coastal temperatures in the summer; however, the winds are predominantly offshore during this period, and this effect is very limited.

Ice in the Labrador coast and offshore region is discussed in detail in the following chapter. Fast ice develops along the shore in northern Labrador during late October or early November; it develops during December in the inlets further south. Far more important is the pack ice, which moves south with the Labrador current, and normally reaches northern Labrador by mid-December; it reaches the Belle Isle Strait by mid-January. The maximum advance and width are reached in April, by which time the pack extends along most of the northeast coast of Newfoundland. The pack persists until June, when melt rapidly occurs.

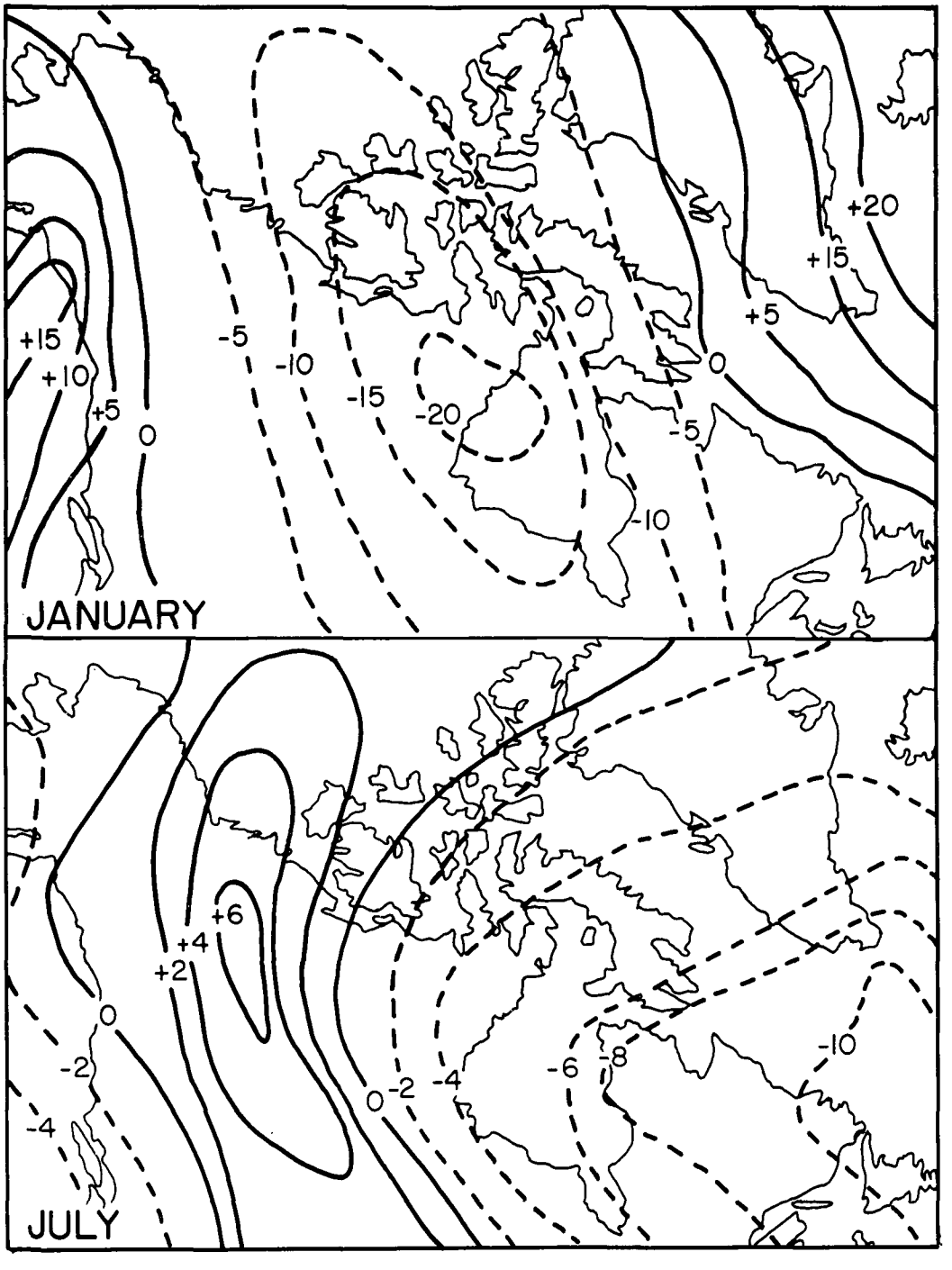


FIGURE 4.26 CANADIAN TEMPERATURE ANOMALIES
(i.e., the difference between recorded temperature (°F) and mean for that latitude. Solid lines indicate positive; and dashed, negative anomalies)

The Labrador pack ice has little effect on the climate of the coast as a result of the predominantly offshore winds during the winter; but even with easterly winds, the fetch over sea ice imposes a negligible modification upon air mass characteristics.

4.2.1.2 Mean Annual Surface Pressures. The whole of Labrador is located within the sphere of influence of the portion of the atmosphere circulation known as the "westerlies" or the "west wind", so named after the direction of origin of the majority of the weather systems through this belt. At the surface, the mean pressure patterns are controlled by the Icelandic flow.

As shown in Figure 4.27, the seasonal pattern of mean pressures changes dramatically. In the winter, there is a strong northwesterly gradient over most of eastern Canada. The January pressure distribution is typical of the average mid-winter pattern; during the months of November to March inclusive, the situation would only vary slightly from that shown. The whole of Labrador lies within the area covered by the wind circulation around the low pressure centre located between southern Greenland and Iceland (known as the Icelandic Low). The long-term mean pressure of this low is less than 100 kPa (Bursey et al, 1977). Areas of low pressure are generally associated with stormy, unsettled weather; consequently, such conditions can be expected to be a common feature of the winter climate of much of Labrador.

In the Northern Hemisphere, there is counterclockwise air circulation around centres of low pressure systems; prevailing wind direction is therefore northwesterly over all of Labrador for the mid-winter. Thus, the region draws much of its air from the eastern Canadian Arctic Archipelago.

Between late winter and summer, the Icelandic Low transfers westward to southern Baffin Island and weakens (Figure 4.27). Consequently, the circulation around this July low is relatively weak. The degree and frequency of storms is reduced as compared with the winter situation, and the prevailing wind direction is now westerly.

During the fall months, the weak low pressure centre from southern Baffin Island re-intensifies and gradually migrates eastward towards the winter position off Iceland.

The monthly wind direction distribution shown in Figure 4.28 for offshore Labrador illustrates this shift from a predominately northwest direction in the winter to a south and southwesterly pattern in the summer. The other feature evident in these illustrations is the increased percentage of calm periods during the summer. Table 4.5 summarizes the mean wind speed by direction for this same area.

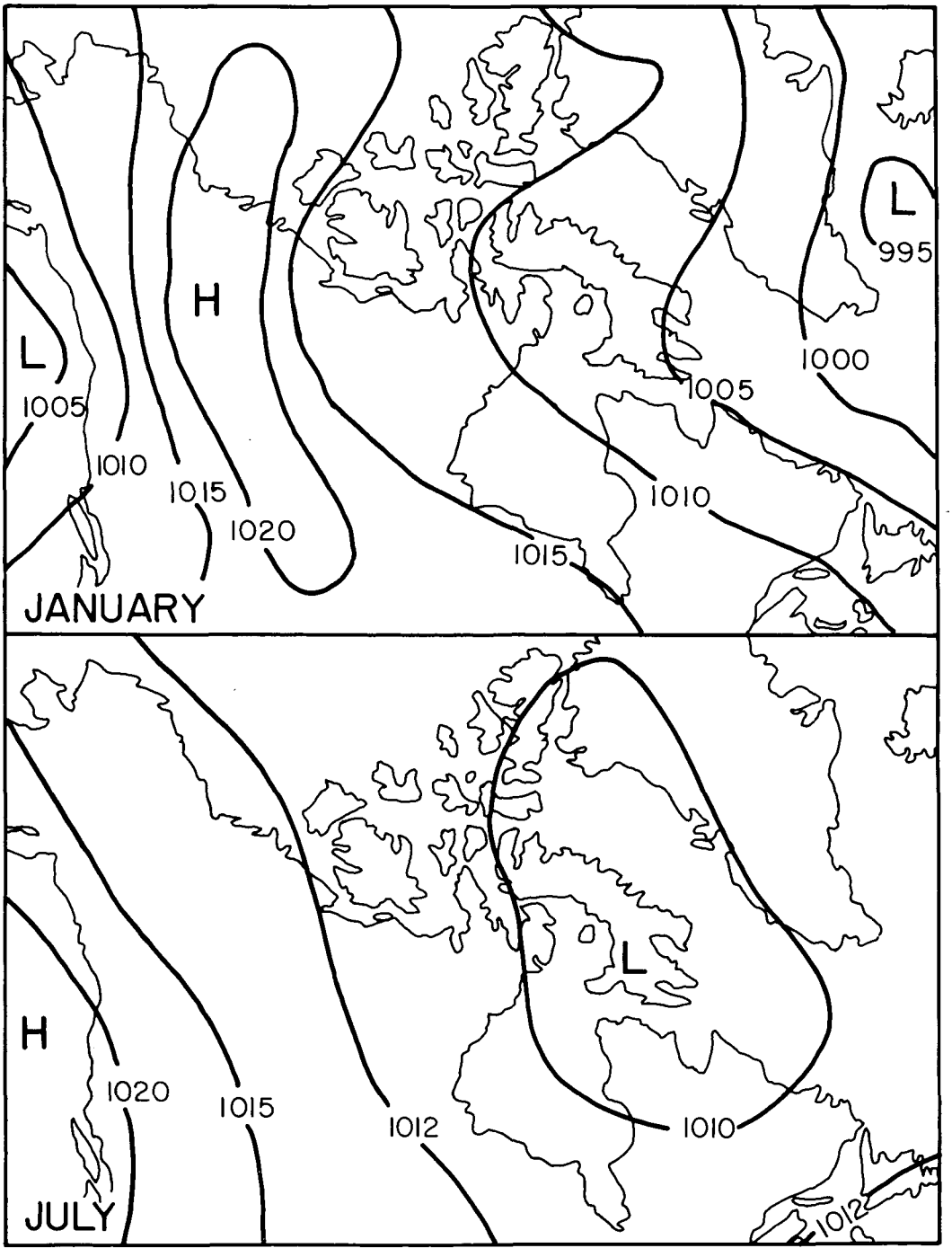


FIGURE 4.27 MEAN SURFACE PRESSURE DISTRIBUTION (mb)

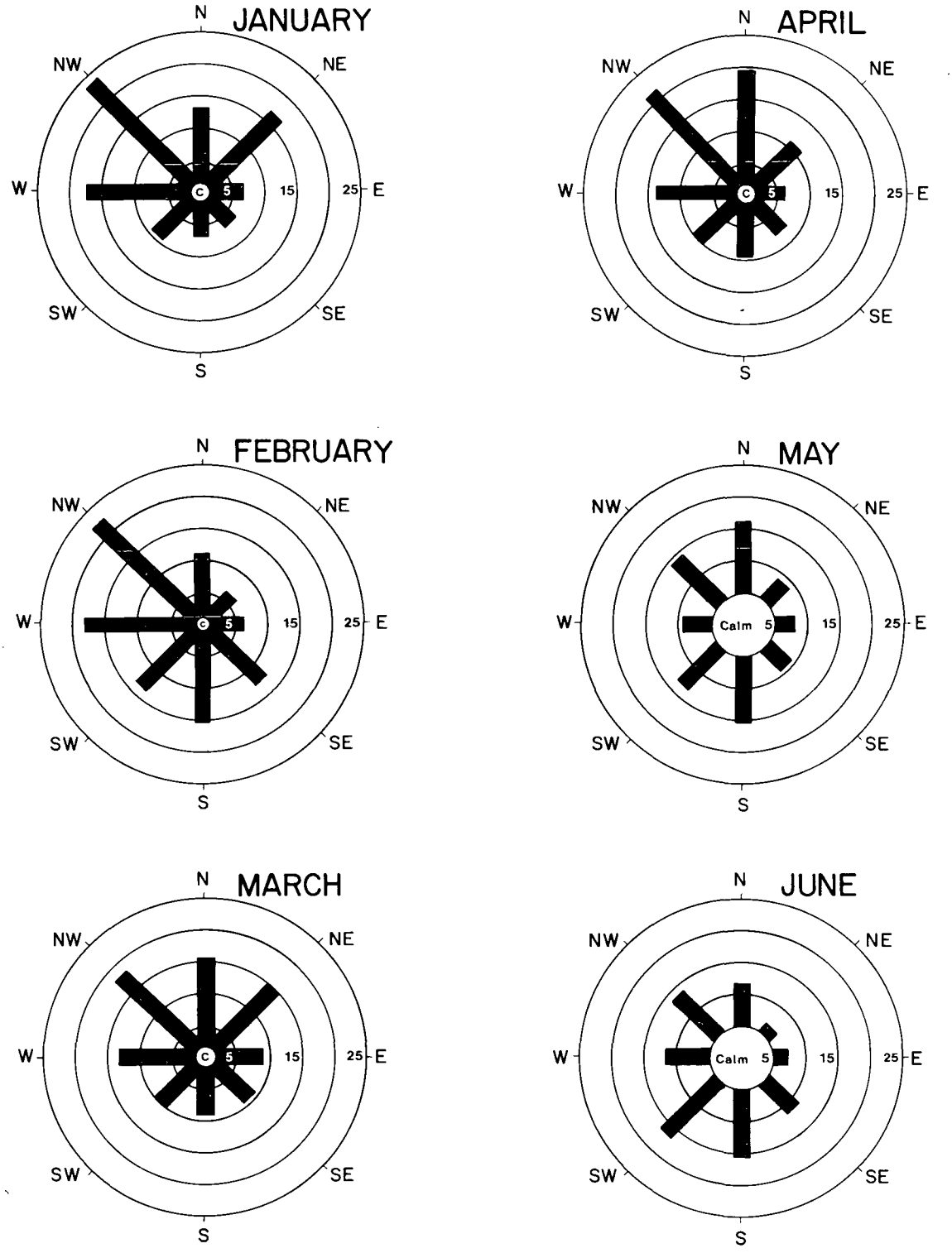


FIGURE 4.28 MONTHLY CHANGE IN WIND DIRECTION: LABRADOR OFFSHORE AREA

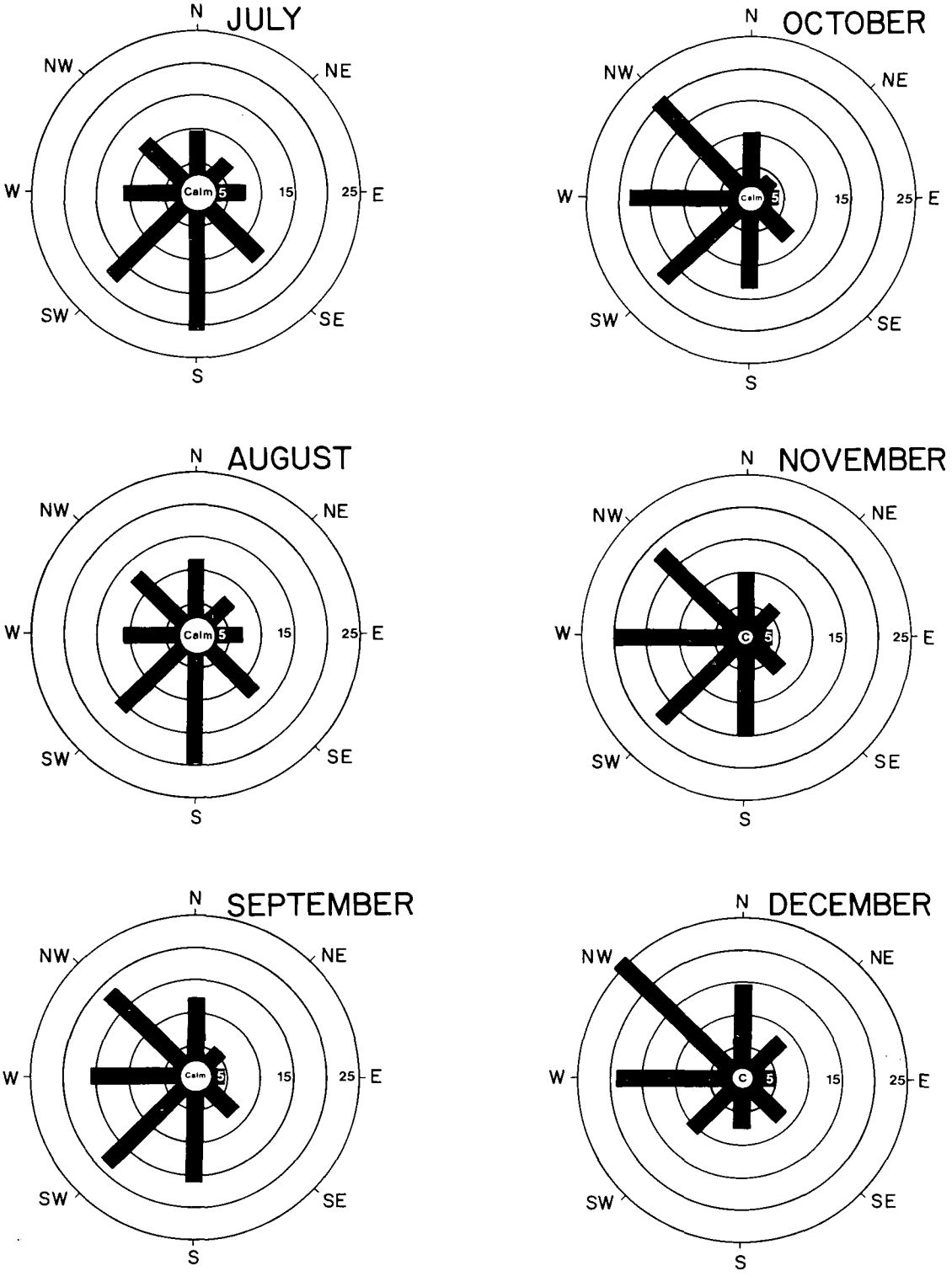


FIGURE 4.28 MONTHLY CHANGE IN WIND DIRECTION: LABRADOR OFFSHORE AREA (Continued)

TABLE 4.5 MEAN WIND SPEED (KNOTS) BY DIRECTION FOR THE SSMO AREA SHOWN IN FIGURE 4.23

	N	NE	E	SE	S	SW	W	NW
January	18.6	19.6	18.8	17.2	16.8	16.8	19.1	20.6
February	20.4	16.0	15.3	17.7	16.9	16.5	18.6	20.9
March	18.8	17.7	14.9	15.9	16.6	14.8	17.5	19.3
April	19.4	16.8	14.3	13.0	12.7	13.6	15.8	16.3
May	13.4	11.2	12.5	10.9	12.2	11.8	13.2	14.4
June	13.2	10.8	11.1	12.0	12.7	12.7	13.3	15.8
July	11.9	10.2	10.7	12.0	12.5	12.4	12.9	14.0
August	13.0	11.8	11.3	11.9	12.7	12.1	13.3	14.1
September	15.9	13.3	13.2	13.4	14.3	14.4	14.8	17.0
October	16.6	16.2	14.8	17.8	16.1	16.0	17.5	19.5
November	17.7	17.7	17.1	18.3	18.9	17.5	18.8	21.2
December	20.3	21.4	17.0	18.4	18.7	19.8	19.4	20.2

In order to gain some idea of the winds that may be expected in the Labrador offshore, Figure 4.29 summarizes the percentage of the time winds greater than 40.7 km/h (i.e., Beaufort Wind Scale 5) would be experienced, and would generate waves approximately 3 m high, depending on the fetch conditions available.

The strongest winds are encountered in the winter months. Extrapolating from Archibald (1969), it can be estimated that maximum gust speed for the Labrador offshore is approximately 210 km/h. Archibald (1969) reports a sustained hourly wind speed in excess of 129 km/h for Cape Race, Newfoundland. Although this location is south of our area of interest, this figure gives an order of magnitude idea of the winter wind conditions that can be experienced in the Labrador offshore.

In cold climates, the combination of temperature and wind produces the greatest heat loss and discomfort. The term *wind chill* is normally used to define an excessive heat loss or rate of cooling produced by a combination of low temperature and strong winds. Wind chill is obviously very significant for exposed operations, as it can cause not only serious discomfort but also frostbite or even death.

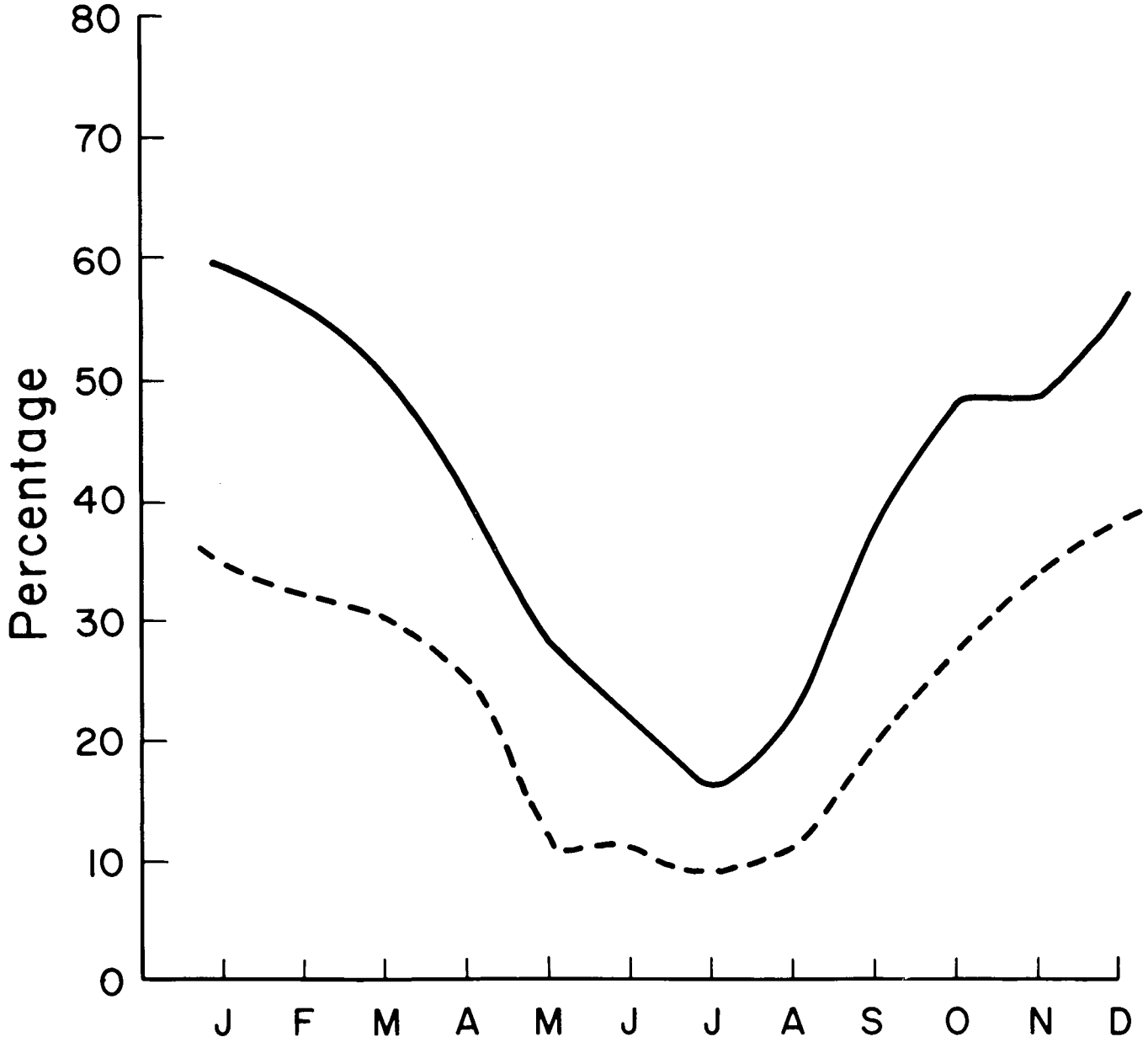


FIGURE 4.29 PERCENTAGE OF OBSERVATION TIME WHEN WINDS ARE EQUAL TO OR GREATER THAN BEAUFORT WIND SCALE 5

——— Weather Ship Bravo; ------- SSMO Area.
Source: Bursey et al, 1977

Calculations of heat loss experienced by a person in the open were made by Siple and Passel (1945). Results are expressed in units of kilocalories per square metre per hour (Kcal/m^2/h). The value of 1400 Kcal/m^2/h is considered the threshold above which exposed human flesh begins to freeze. Values for the Labrador coast during January range from 1300 south of Groswater Bay to 1500 at Cape Childey.

A mean wind-chill pattern for the month of January is provided in Figure 4.30. Extrapolations to the offshore are inexact due to the lack of detailed wind information, although one would expect a northward dip of the isopleths because of the moderating influence of the marine temperature regime.

A method was developed for the U.S. Army by Westbrook (1961) to predict the frequency of occurrence of certain wind-chill values from the means of temperature and wind speed. Based on his nomogram, the percentage of time during which the wind chill can be expected to reach or exceed 1400 Kcal/m^2/h (frostbite threshold) in the Labrador offshore was calculated (Table 4.6).

TABLE 4.6 FROSTBITE THRESHOLD: LABRADOR OFFSHORE

Month	Wind Chill Greater than or Equal to Frostbite Threshold (percentage of time)
December	4
January	8
February	7
March	3
April	2

This frostbite threshold is reached less than 10 percent of the time for the Labrador offshore, in comparison to 33 percent over the interior of Labrador for the same time period (Peach, 1975).

4.2.1.3 Storm Tracks. Certain areas of the globe are sources for frequent formation and passage of low pressure storm systems. Such regions are referred to as *frontogenetic*, meaning origin of fronts. The term *front* is used to note fairly distinct zones that separate two extensive and dissimilar air masses. Such frontal zones are not stationary but migrate in a fairly regular seasonal pattern and also irregularly on a short-term basis.

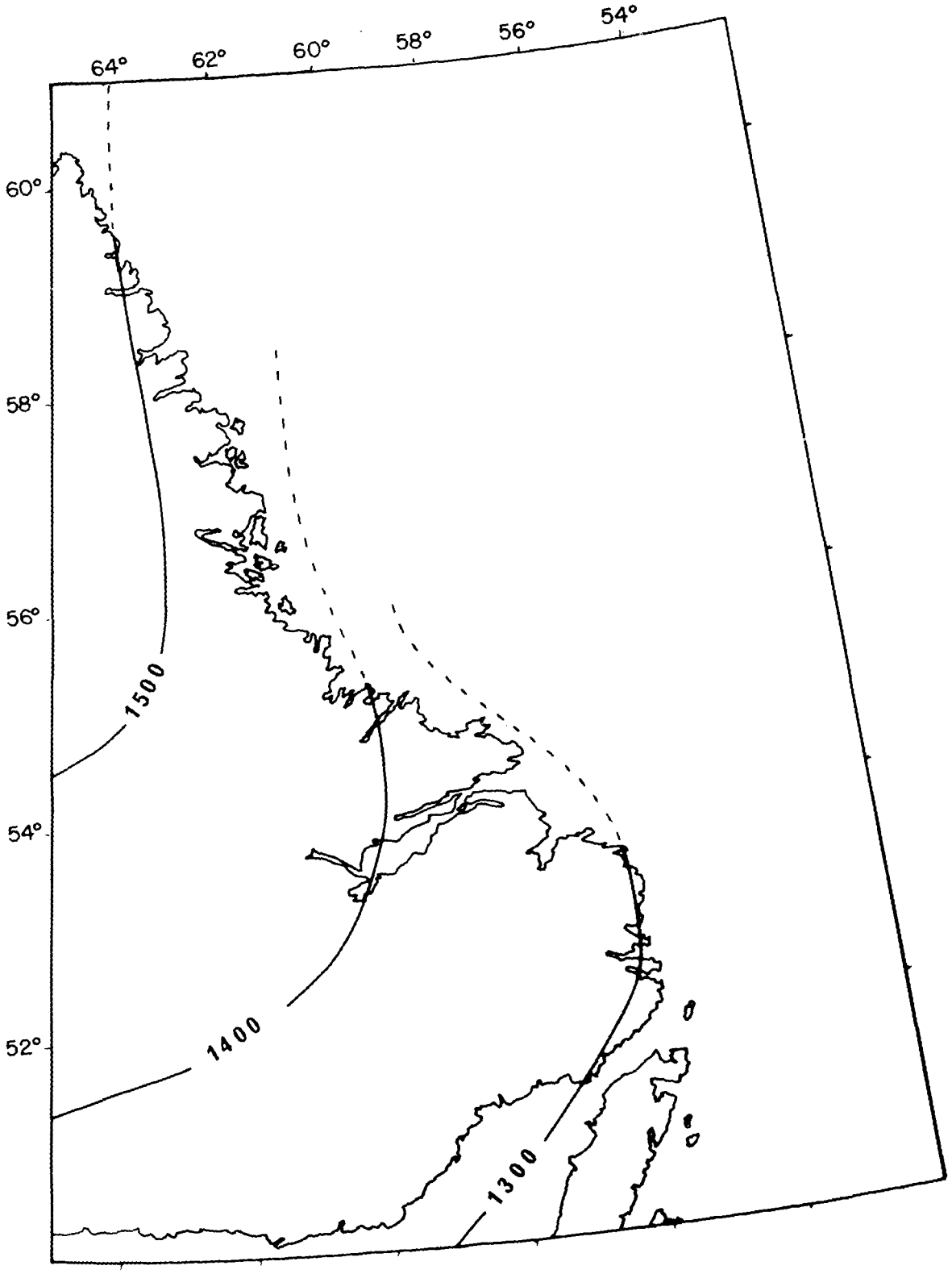


FIGURE 4.30 MEAN WIND CHILL: JANUARY
(units kilogram calories per square meter per hour)

Two such frontal zones determine the routes of low pressure storm systems that cross the Labrador Continental Margin (Figure 4.31):

(1) The *American Arctic Front Zone* (AAFZ) delineates a boundary between the cold air masses over the Arctic Ocean or northern Canada, and the much warmer, moist air of the Pacific Ocean. Although located over western Canada during both winter and summer, this zone is responsible for the creation of the numerous storm centers that track eastward towards and across the eastern Canadian sub-Arctic. In the winter, the AAFZ tracks across central and southern Labrador. During the summer, its position is just north of our immediate area of interest.

(2) The *Atlantic Polar Front Zone* (APFZ) separates the cold or cool and dry air of the Arctic or sub-Arctic region from warm moist air of sub-tropical origin. The APFZ is responsible for creating many of the more intense, low-pressure storms that penetrate Labrador from the southwest. Such storms can be especially intense during the winter, when they are responsible for heavy snowfalls, especially over southern and southeastern Labrador. During the winter, the APFZ lies in the vicinity of the eastern seaboard of the United States.

In January, about 35 percent of all observation time is taken up with frontal activity centered over southern Labrador and towards the Gulf of the St. Lawrence, with a steady decrease to less than 25 percent over extreme northern Labrador.

By mid-summer, the APFZ has migrated over the Great Lakes area, and the relatively weak storms generated travel in a northeasterly direction. Such storm tracks are more likely to affect the northern half of Labrador during this season. During the summer, in northern and southwestern Labrador, frontal weather conditions take up about 40 to 50 percent of all observation time, whereas southern Labrador is similar to the winter, experiencing 20 to 40 percent of observation time.

A low, sometimes called a depression, is synonymous with cyclones and represents an area of low pressure, referring to a minimum of atmospheric pressure in two dimensions on a constant height chart. Cyclones affecting the region are better illustrated by depression-frequency figures rather than by the behaviour of semi-permanent centers of action.

Such data are not available for the Labrador Sea; however, percentage frequencies of cyclone crossing the meridian 55° west between 5°N latitude intervals are given in Table 4.7 and they illustrate typical seasonal relationships. The percentages are derived from Perry and Wilson (1953) as reported by Hare (1951); they are based on data

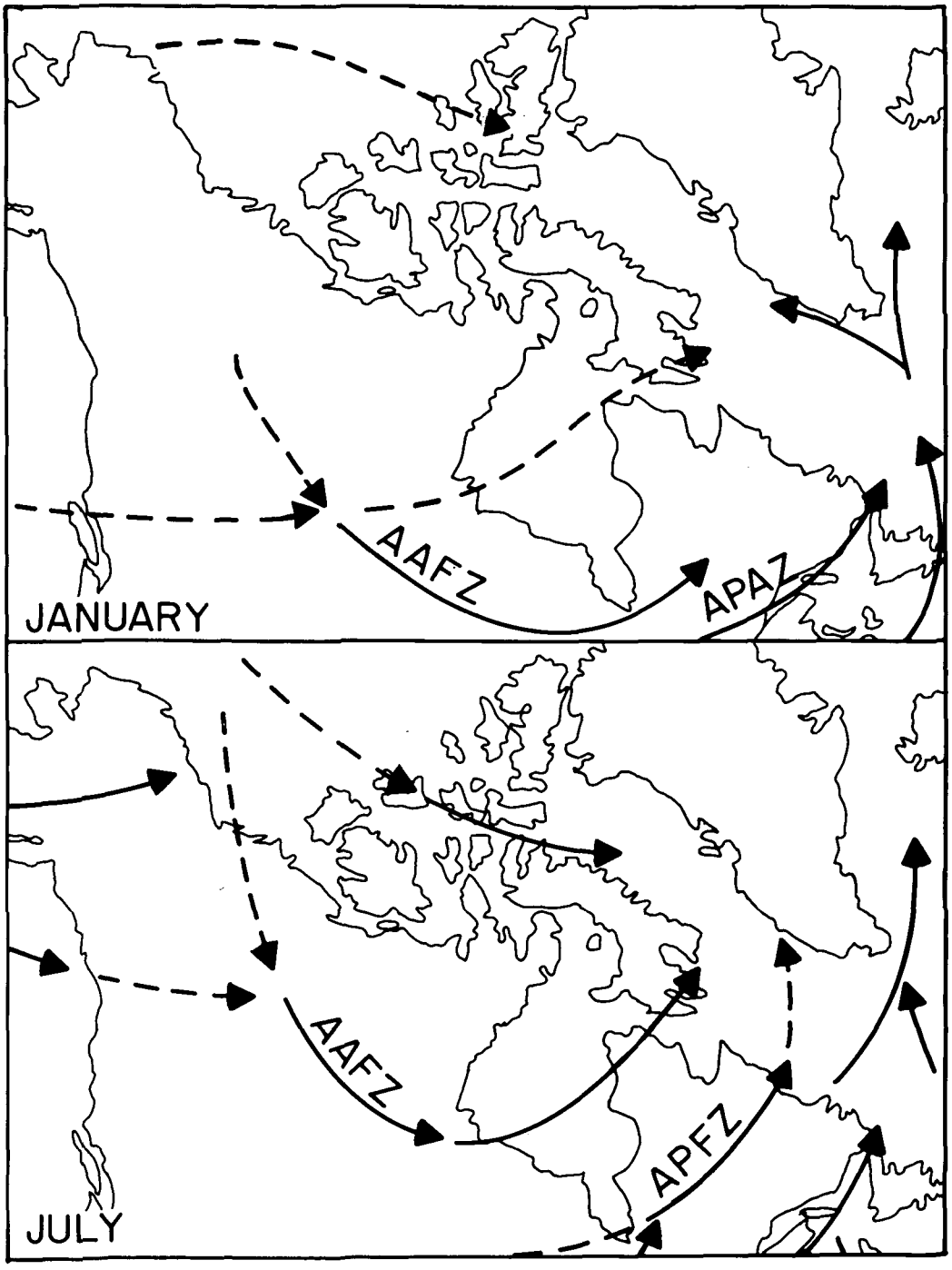


FIGURE 4.31 PRINCIPAL TRACKS OF CYCLONES
——— primary tracks; ------- secondary tracks

covering a two-year period. The data demonstrates the northward movement of cyclone activity related to the Atlantic Polar Frontal Zone in the summer and winter.

4.2.2 Precipitation and Icing. Mean annual precipitation decreases from about 950 mm over southern coastal Labrador to nearly 310 mm at Cape Childey (Bursey et al, 1977). The highest annual precipitation normally occurs over the upland areas of southern Labrador. Precipitation offshore could be expected to closely parallel coastal patterns.

The forms of precipitation are summarized in Figure 4.32. Snow accounts for about 43 percent of the annual precipitation over southern coastal Labrador and 50 percent at Resolution Island (Bursey et al, 1977). The period of maximum monthly snowfall is October through March, when it is roughly three times the mean. Maximum monthly rainfall occurs from May through October, when it is approximately 2.5 times the monthly mean. The rainiest three-month period is usually July through September, when 40 to 50 percent of the annual rain accumulates in the southern part of the coastal Labrador; 73 percent accumulates at the northern tip.

TABLE 4.7 PERCENTAGE FREQUENCIES OF CYCLONES CROSSING 55°W IN LATITUDE INTERVALS OF 5°.

Latitude °N	Winter (percent)	55°W Spring (percent)	Summer (percent)	Autumn (percent)
70 - 75	10	7	9	9
65 - 70	10	10	12	12
60 - 65	13	11	13	16
55 - 60	13	17	20	17
50 - 55	16	18	21	16
45 - 50	15	13	12	11
40 - 50	14	14	9	11
35 - 40	8	8	6	9

One of the more damaging and dangerous forms of cold weather is freezing precipitation. In the open sea, this is compounded by freezing spray. This condition is produced when rain or drizzle originating from an altitude whose temperature is above freezing falls upon a surface whose temperature is below freezing, and thus forms an ice

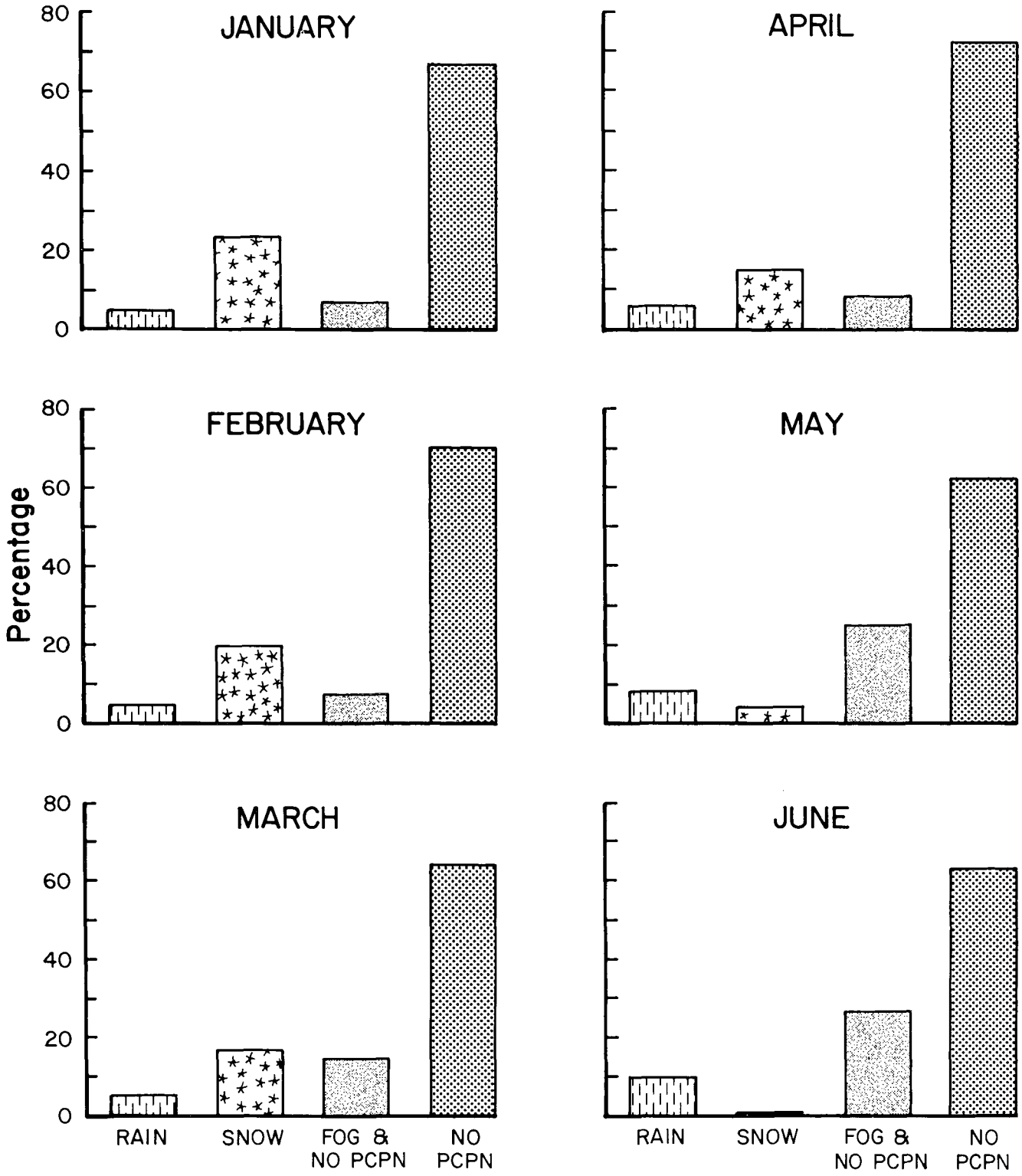


FIGURE 4.32 MONTHLY PRECIPITATION PATTERNS: LABRADOR OFFSHORE AREA

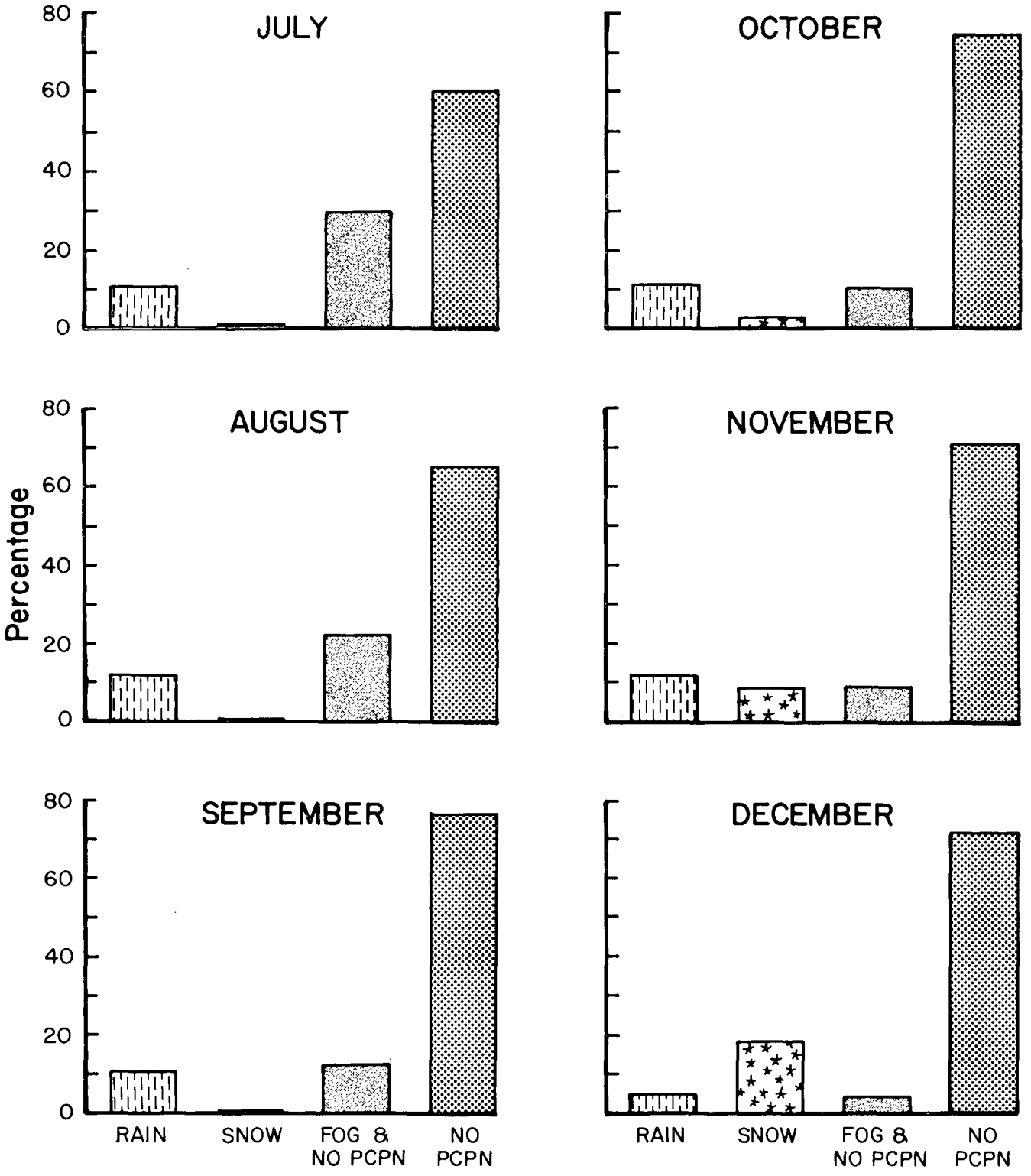


FIGURE 4.32 MONTHLY PRECIPITATION PATTERNS: LABRADOR OFFSHORE AREA (Continued)

coating. The amount of ice accumulation will vary according to intensity of the precipitation and wind velocity.

Freezing precipitation occurs most often in association with the advance and passage of a cyclonic low pressure storm centre. If such cyclonic storms have originated well to the south of Labrador (especially during early and late winter), it is quite likely that they will contain air of tropical origin whose temperature remains above freezing during passage across Labrador. The relatively warm air of tropical origin is contained within the "warm sector" of the "low" between the warm front and the following cold front. Consequently, freezing precipitation may result at the surface either: (a) just ahead of the warm front, as rain from the advancing front encounters below-freezing air near ground level; or (b) from clouds within the warm sector, as rain from the relatively warm (above freezing) air of this sector strikes a surface whose temperature is below freezing.

In the open sea, with air temperatures at or below freezing, ocean spray becomes a serious concern. Ice buildup of sufficient thickness is capable of causing extensive damage and superstructure icing can be sufficient to capsize vessels. Security can be gained in the pack ice, where sea state is significantly reduced.

MacKay and Thompson (1969) present data on the annual number of hours of freezing precipitation. The east coast of Newfoundland experiences the greatest duration of freezing precipitation in Canada. Freezing precipitation is primarily associated with easterly airflow patterns.

There have been no studies of the monthly variability in frequency of freezing precipitation relating specifically to Labrador. The cold winter climate would result in very little freezing precipitation throughout much of the winter, with a tendency for more frequent occurrences near the beginning and end of the winter period. Duval et al (1975) state that by late November freezing spray and icing problems are particularly severe in the Labrador offshore.

4.2.3 Cloud Cover and Visibility. Analysis of the annual variation in the amount of cloud cover for the Labrador offshore is presented in Figure 4.33, which indicates the degree of cloudiness for each month (expressed as oktas). There are only four months (July, August, September and October) when the region is not totally obscured for more than 50 percent of the time. September is the most cloud-free month, having two oktas or less cloud coverage approximately 25 percent of the time. This extensive cloud coverage is the result of relatively cold, dry arctic air masses encountering moisture from the much warmer North Atlantic air flow.

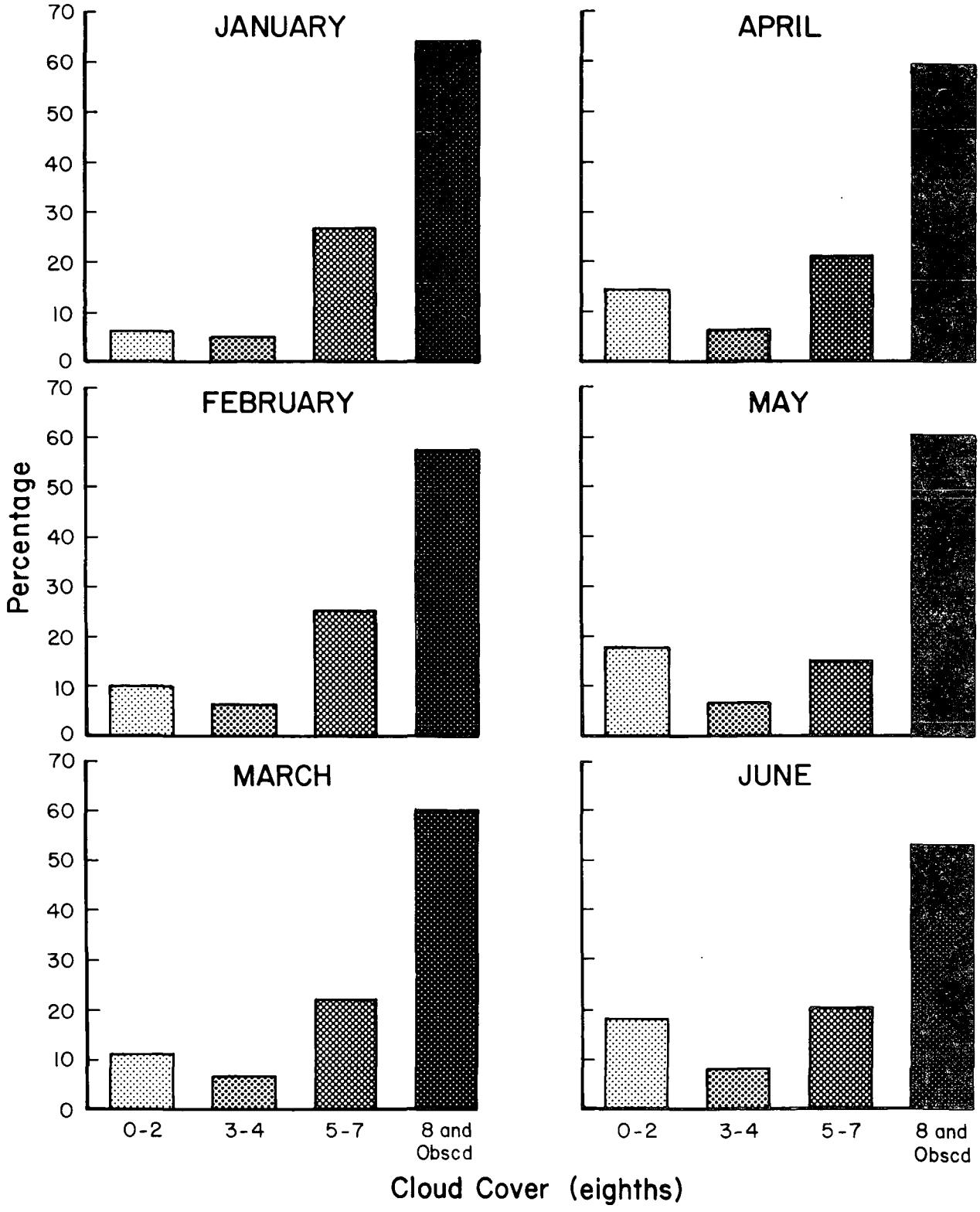


FIGURE 4.33 MONTHLY CLOUD COVER: LABRADOR OFFSHORE AREA

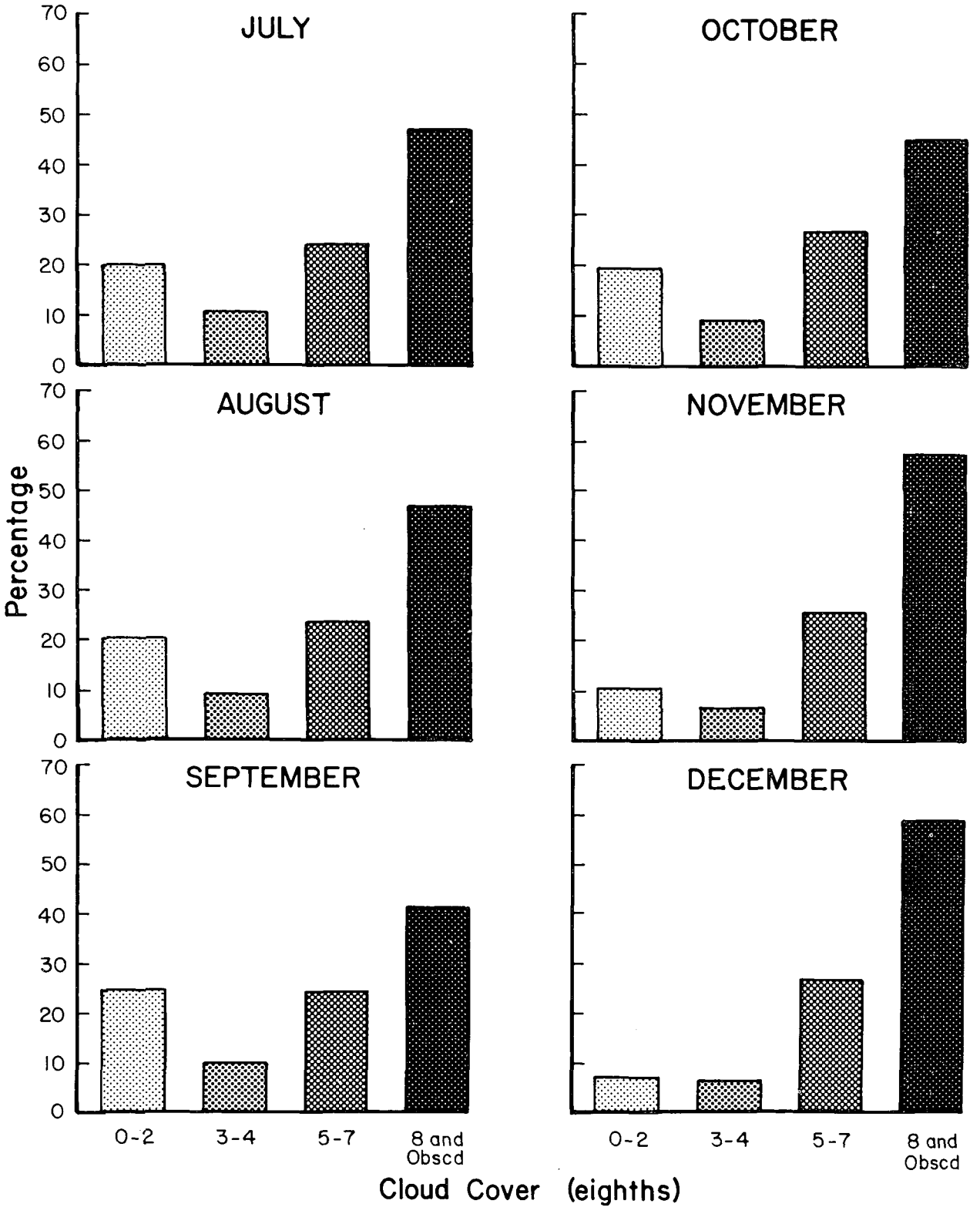


FIGURE 4.33 MONTHLY CLOUD COVER: LABRADOR OFFSHORE AREA (Continued)

Figure 4.34 presents average monthly visibility ranges. Fog represents a visibility of less than 0.5 nautical miles, and is most persistent in May and June. September is, again, the best month, with visibility of five nautical miles or greater 85 percent of the time.

Late spring is characterized by a persistent fog and low cloud cover. This is caused by advection of relatively warm and moist air over the melting ice and cold water. Offshore winds during the summer are relatively dry and, as a rule, fog does not occur under these conditions.

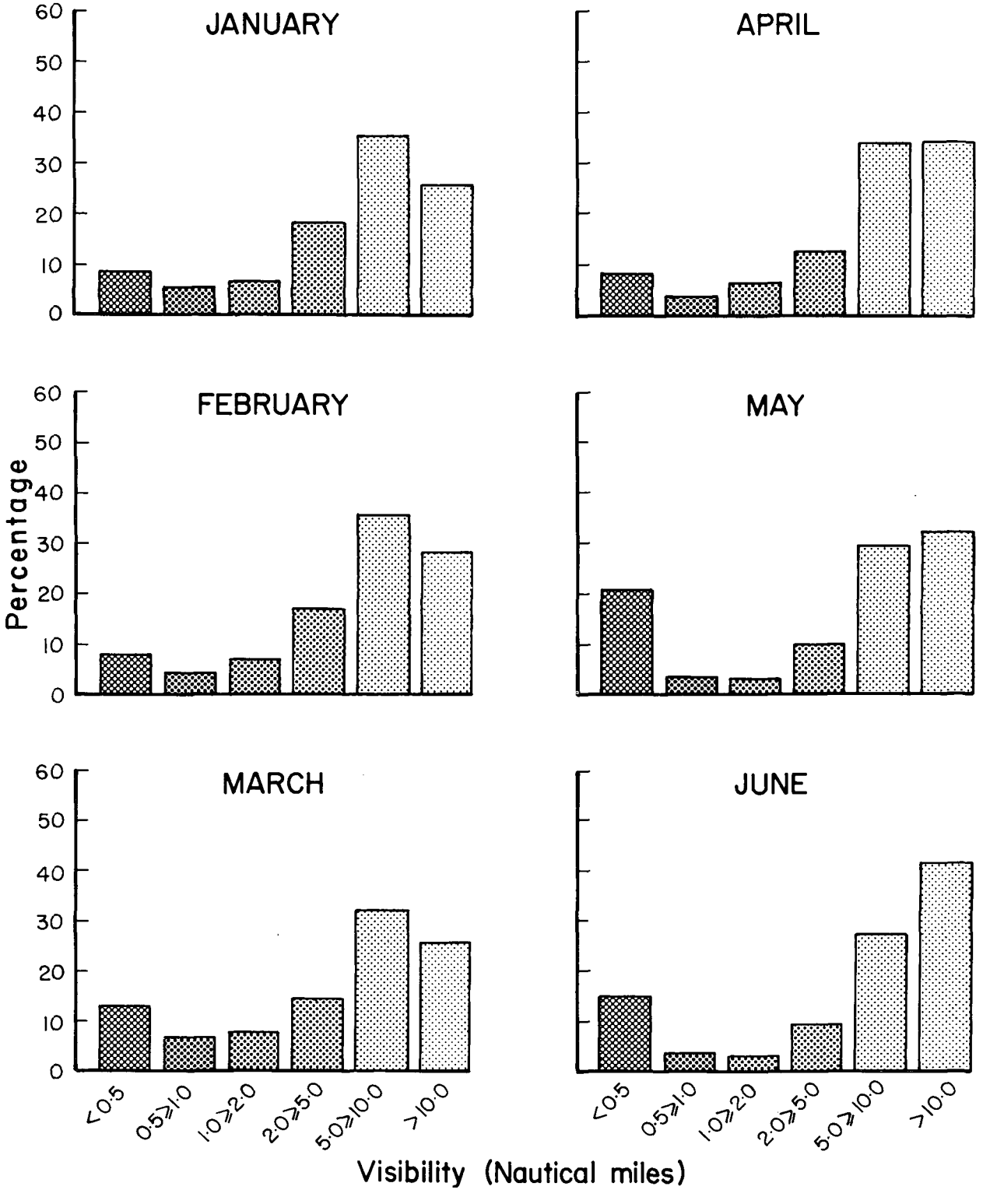


FIGURE 4.34 MONTHLY VISIBILITY RANGES: LABRADOR OFFSHORE AREA

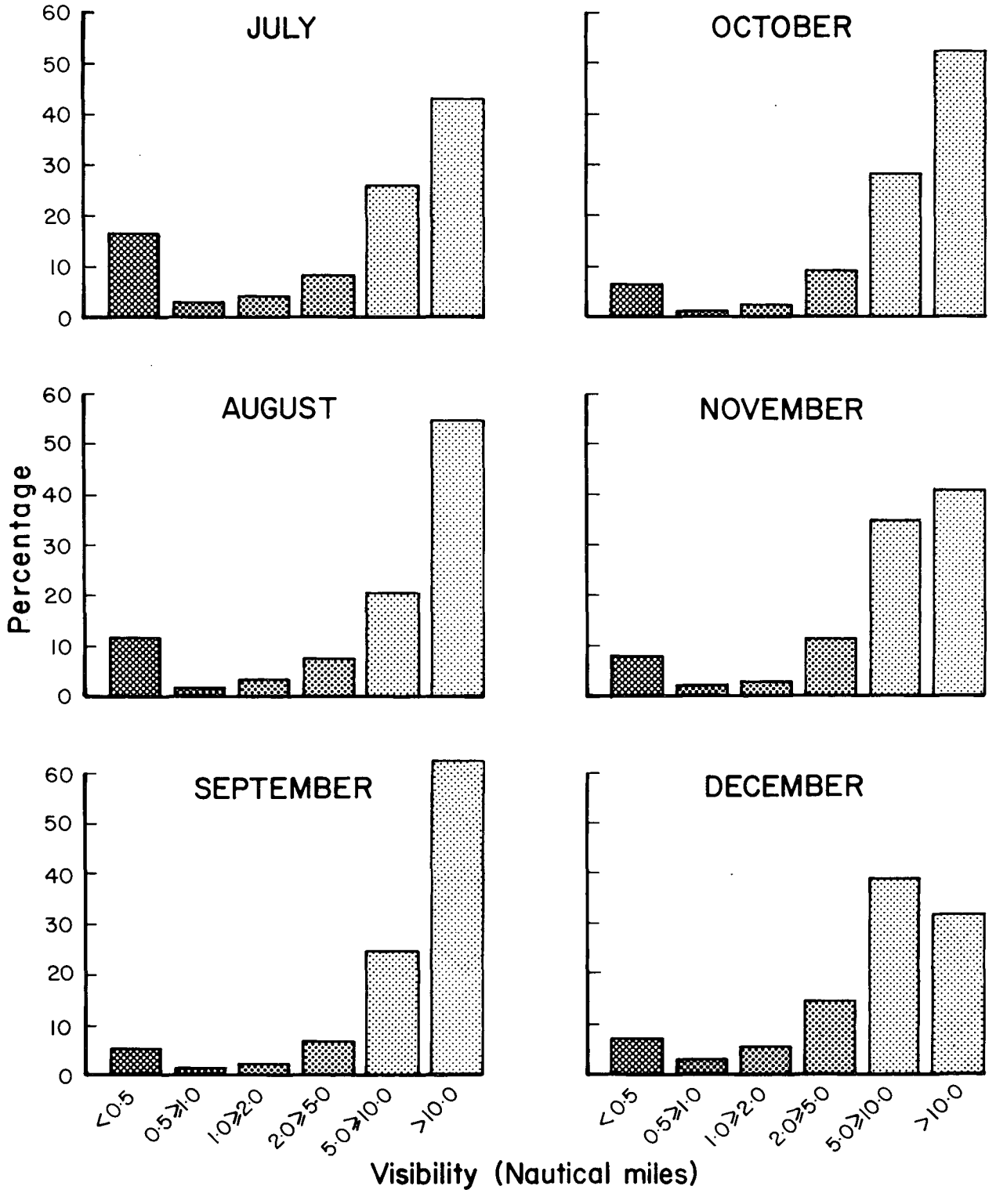


FIGURE 4.34 MONTHLY VISIBILITY RANGES: LABRADOR OFFSHORE AREA (Continued)

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CHAPTER 5
LABRADOR SEA
SYNOPTIC ICE DESCRIPTION

by
J.M. Skidmore

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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5 INTRODUCTION

The conditions along the coast of Labrador vary annually, from being totally ice bound from January through May, to having open water during August to November. Principal factors which affect the ice season and determine its severity are air temperature, wind, sea state and water currents (Markham, 1973). An attempt is made in this chapter to outline the influence that these factors have in the Labrador Sea on the physical characteristics of ice, its distribution, and its annual variation. Physical characteristics of the ice per se are considered only briefly here since a more extensive coverage is given in Chapter 6.

5.1 Formation and Growth

Ice found in the Labrador offshore may be ice formed locally both as shorefast ice and open sea ice; ice that has drifted from the Arctic; and southward drifting icebergs. Icebergs are discussed in Chapter 7.

Ice crystals form in the sea when the surface temperature is about -1.67^{o}C (29°F). The exact freezing point varies with the salinity of the water, which in turn varies with freshwater input; and to a much lesser extent it varies as a result of evaporation which is related to the water and air temperature. Salinity in Arctic waters is generally 31°/oo or less, (Sater et al, 1971). The ice will form first in colder areas and in areas near the coastline, especially shallow and sheltered waters, where the salinity is the lowest.

The crystal structure of sea ice is independent of the inorganic salts in sea water. Due to the action of the sea surface during freezing, some salt is trapped in the new ice. The salinity content is usually 4 to 6°/oo (Sater et al, 1971). The amount of salts trapped in what are termed brine pockets directly relates to the strength of the ice (Lewis, 1971). There is a constant draining of these pockets as the ice sheet grows, so that ice increases in strength with age.

The ice crystals form a layer which appears oily or opaque on the sea surface while freezing continues. Ice is termed grease ice when the crystals have coagulated to form a soupy layer on the surface, giving the sea a matt appearance (World Met. Org., 1970). The ice is usually a grey colour at 10 to 15 cm thickness and is called grey ice. The ice whitens as it thickens and white ice is usually 30 to 70 cm thick. The thick soupy layer can reach one metre in thickness before becoming solid.

In areas where the sea surface is relatively calm, a thin, elastic ice crust termed nilas may form. The ice crystals are oriented in vertical bundles and such ice cracks easily (Canadian Hydrographic Service, 1970). Dark nilas is less than five cm thick and light nilas is five to ten cm thick. Nilas often forms between ice floes within the pack. This thin ice is easily rafted or crushed with wind or wave action. The thickened layer of ice is broken by wave action into pancakes (Figure 5.1): pieces of ice about 0.2 to 4.0 m in diameter that have rounded, raised rims due to abrasion from wave action (Weeks and Lee, 1958).

The ice damps wave action; and in calm periods, the pancakes will be refrozen together into a large, single sheet. Subsequent wave action will cause the sheet to break. Pancakes with diameters of 3 to 21 m have been measured in the south Labrador Sea. Measurements of floes off Saglek indicated that diameters range from 1.5 to 140 m, with a mean diameter of approximately 12 m (Chapter 6). Ice accumulated by winds and currents can make up a floe from 20 m to 10 km in diameter (World Met. Org., 1970).

The normal maximum thickness for the Labrador sea pack ice appears to be about two m. Ridges formed as a result of compression between floes can increase the height of the ice to over two m (Bursey et al, 1977). The ratio of height to depth for ridges is about 1:4 (Lewis 1971); but because of the activity of the pack, hydrostatic equilibrium is seldom reached. Ice thickness is seldom homogeneous due to fracture, refreezing, ridging and various stages of ice development.

It is evident that continuous movement in the pack causes the ice to be broken and rejoined many times so that an individual floe can consist of many pieces of ice of various sizes. Figure 5.2 shows a floe containing single pancakes that very in size between 2 and 20 m (Windsor 1978). The range in size of the pieces suggests a variation in thickness as well, which would result in a highly variable subsurface profile. This characteristic is discussed more extensively in the following chapter.

Pack ice thickness measurements south of Cartwright on the Labrador Coast (in 1972) averaged 1.52 m, with some floes measuring 2.59 m (Bradford, 1973). These measurements suggest subsurface depth differences of up to 60 cm.

5.2 Shorefast ice

Generally, in the Canadian Arctic, fast ice formation is associated with shallow water, presence of offshore islands and an absence of strong currents and tidal phenomena. It usually reaches thickness of one to two m. The first freeze-ups are often broken by storms. Air temperature is largely responsible for the rapid growth in

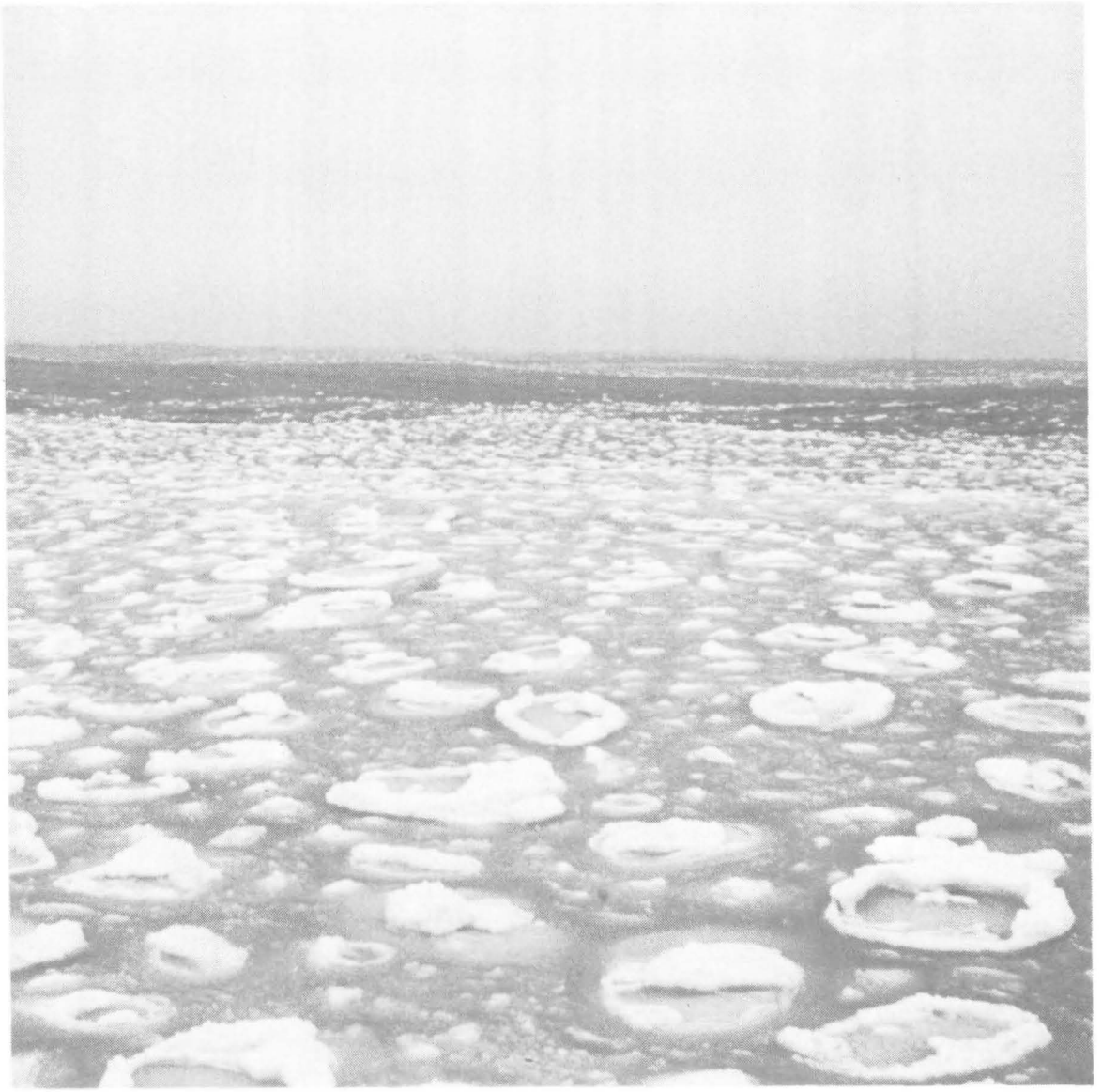


FIGURE 5.1 PANCAKE ICE AT THE EDGE OF THE LABRADOR ICE FIELD: FEBRUARY
(Pancakes in the foreground are about one metre in diameter.)

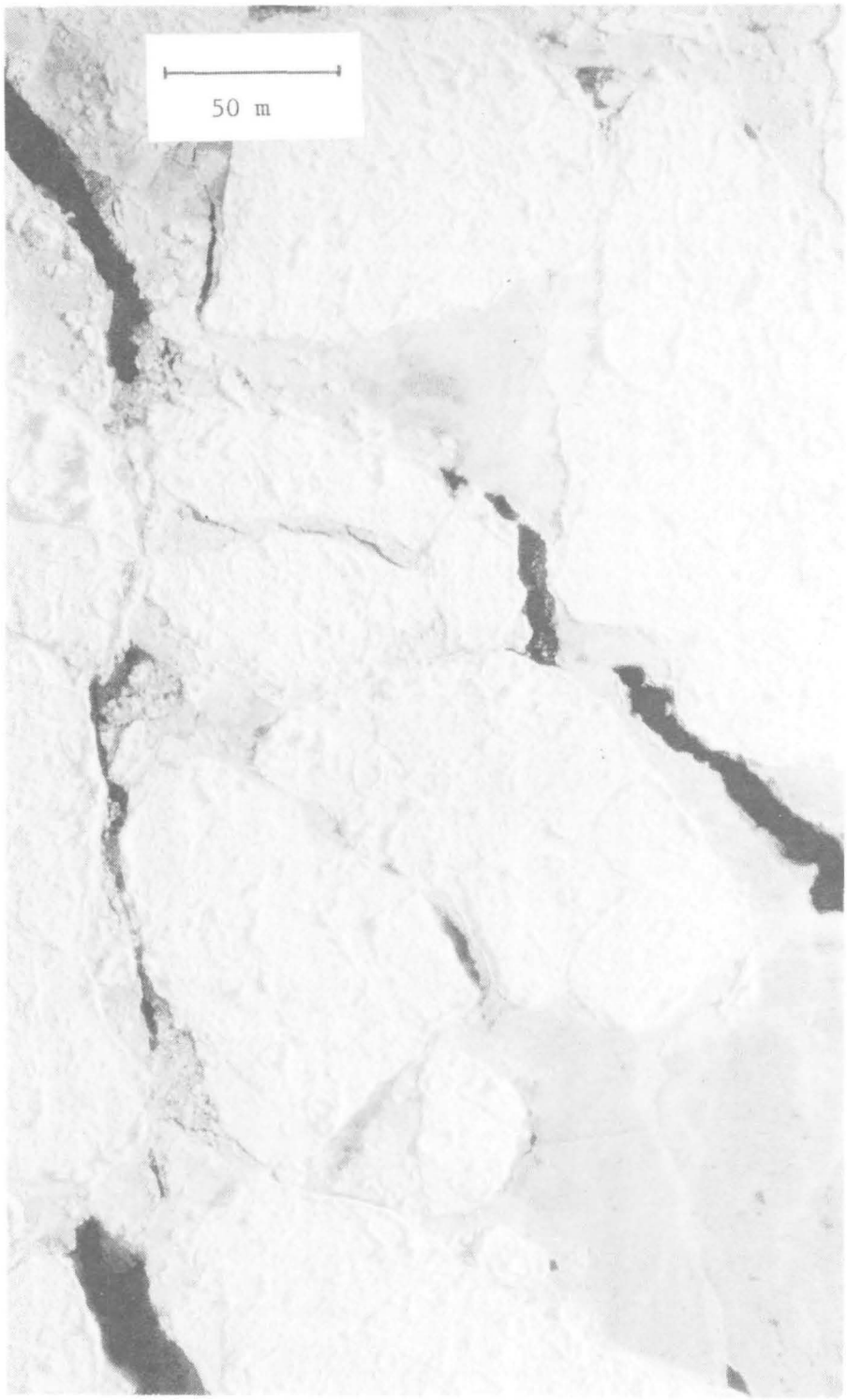


FIGURE 5.2 ICE FLOES AND NEWLY FORMED WHITE ICE BETWEEN ICE FLOES

thickness, which occurs usually in late November or early December (Table 5.1). The break up and ablation is related to air temperature but is retarded by insulative snow cover.

TABLE 5.1 SHOREFAST ICE FORMATION AT THREE COASTAL AREAS OF LABRADOR

		Complete Freeze Over	Water Clear of Ice
Hopedale Harbour	1965	Dec. 14	June 07 1966
	1966	Dec. 15	June 07 1967
	1967	Dec. 28	June 05 1968
	1968		June 09 1969
	1969	Dec. 27	June 28 1970
	1970		1971
	1971	Dec. 9	after June 23 1972
	1973	Dec. 26	after May 31 1974
	1975	Dec. 8	June 19 1976
	1835		August 2 1836*
Cartwright Harbour	1966	Dec. 23	May 20 1967
	1967	Dec. 30	May 13 1968
	1968	Dec. 30	May 25 1969
	1969		May 15 1970
	1971		June 3 - June 8 1972
	1973		June 8 1974
	1975	Dec. 4	May 20 1976
Cape Harrison	1942		June 15 1943
	1943		June 26 1944
	1946		June 16 1947
	1947		May 31 1948

Ice Thickness Data for Canadian Selected Stations, Environment Canada.

* Wilson (1976)

The melting of the surface produces a drainage system for the ice so that a low density, fresh-water layer forms between the ice and sea water. Storms and wave action break off large floes from the edge of the fast ice. Due to the relative calm of the area, solar heating is particularly intense and final break-up occurs quickly (Jacobs et al, 1975).

Along the northern Labrador Coast, the bays and inlets are frozen by early November but initial formation is controlled more by distance from the open sea than by latitude. Lake Melville usually freezes during the first half of December; and at the same time, fast ice forms at the head of Groswater Bay. While Hopedale can freeze in early December, Cartwright often does not freeze up until late December.

Fast ice is particularly extensive from Cape Harrison to north of Nain (latitude 57°N), an area characterized by extensive offshore inlets. Ice thickness here reaches about 0.9 m (Canadian Hydrographic Service, 1974). Bursey et al (1977) describe fast ice as occurring in the bays and inlets south of Hamilton Inlet extensively from Cape Harrison to Saglek, then northward in a rather narrow band to Cape Chidley.

5.3 Seasonal Distribution

The maps in Figure 5.3, from the U.S. Naval Oceanographic Office (1968), show the average ice cover extent along the Labrador coast. (N.B. Two separate ice atlases are now being compiled. Seaward limits of each atlas should correspond with Figure 5.3; however, the breakdown of concentration of coverage may vary.)

An examination of satellite imagery for a seven-year period (1970 to 1977 inclusive) shows that by December 1 the southern ice boundary is just north of 60°N latitude; however, in 1974, the ice limits reached 56-55°N latitude by this time. (P. Scholefield, Personal Communication, 1978).

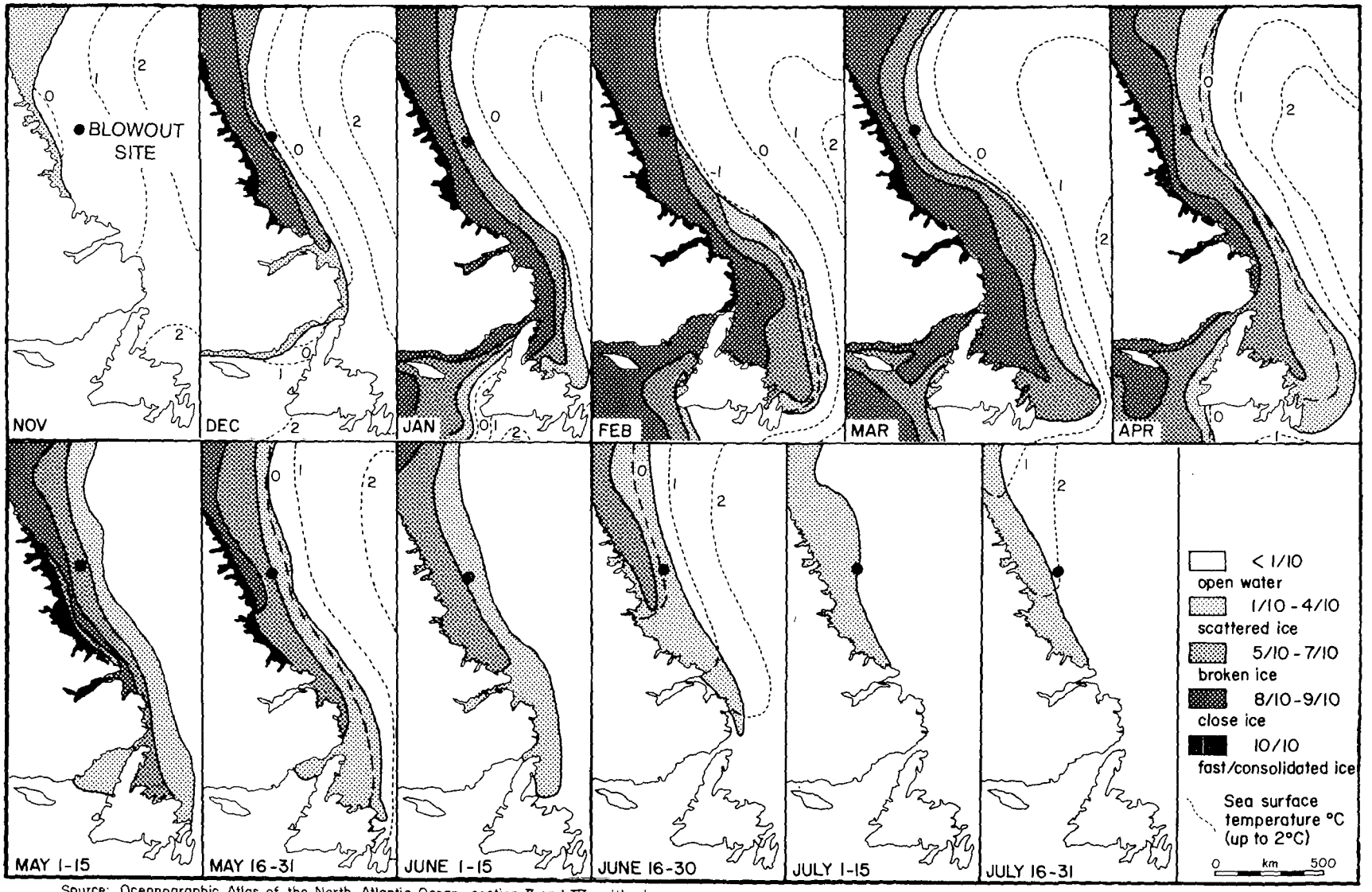
The ice field comprises both ice formed locally as well as drift ice, which is formed in the Arctic areas of Hudson Strait and the Davis Strait, and is then transported south by currents into the Labrador Sea.

Mean ice conditions are described by Markham (1973), from a 13-year period ending in 1971. Figure 5.4 shows the ice cover probability for the most severe months of January, February and March. Ice always reaches the Strait of Belle Isle by January, even in the mildest years.

A summary of average air temperatures for the winter period at two coastal locations are included in Table 5.2. The effect of two cold winters of 1972 and 1973 should not affect this mean value; however, during those years, the ice limit south of latitude 49° extended further eastward than normal during March.

5.4 Factors Influencing Distribution

5.4.1 Weather. Data presented in the Ice summary and Analysis for Eastern Canada Seaboard 1968-71, indicate that wind and temperature are the two major determinants of



Source: Oceanographic Atlas of the North Atlantic Ocean, section II and III, with changes

FIGURE 5.3 MEAN LIMITS OF SEA ICE: LABRADOR COAST

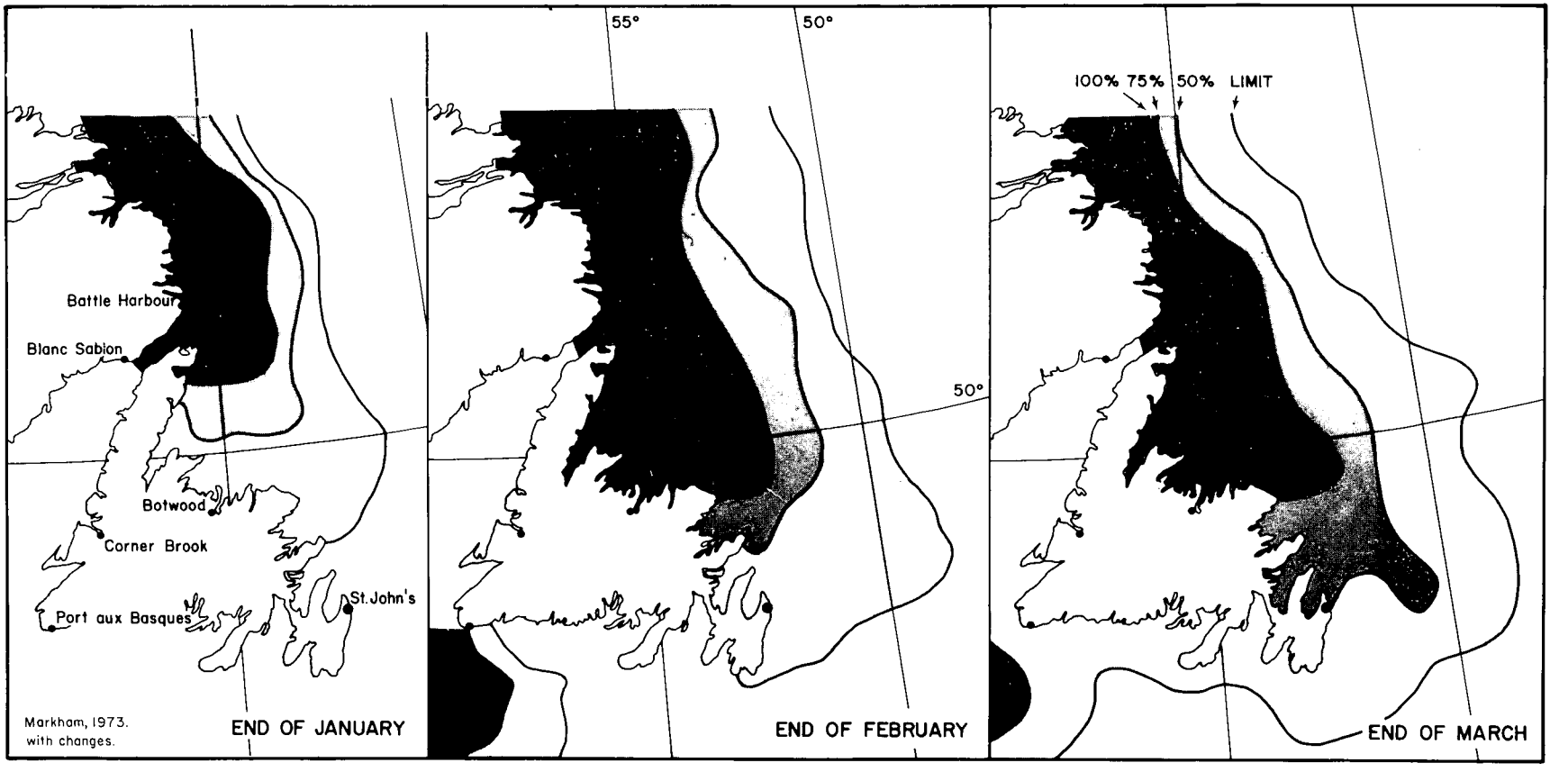


FIGURE 5.4 MEAN ICE PROBABILITY LIMITS (1958 - 1971)

TABLE 5.2 AVERAGE AIR TEMPERATURES FOR HOPEDALE AND BATTLE HARBOUR, LABRADOR (^{o}C)

Ice Summary and Analysis, Eastern Canadian Seaboard 1970-71; Met. Branch, Department of Transport, Ottawa.

	November	December	January	February	March	April
Hopedale	-4.17	-11.2	-17.1	-15.9	-10.6	-4.8
Battle Harbour	-1.17	-6.6	-9.3	-10.2	-5.8	-2.8
(converted to SI)						

seasonal ice distribution. These conditions are a result of various pressure patterns passing over the Labrador Sea.

Low pressure centres affecting the Labrador Sea usually move eastward or northward across or near the area. About eight lows per month, on the average, affect the area (Bursey et al, 1977). A detailed discussion of atmospheric conditions is presented in Chapter 4.

Migratory lows remaining just south of the Labrador Sea produce relatively mild temperatures and onshore winds. Prolonged easterly winds on the Labrador coast may compress the pack to a narrow band of about 80 km (Canadian Hydrographic Service, 1974). The milder temperatures retard formation of the ice, although the pack may be thicker due to ridging and rafting.

Storm systems moving north or northeastward and toward south or western Greenland often produce a cold, strong westerly or northwesterly circulation. The effect is a broad, dispersed pack with cold air temperatures leading to rapid ice growth. These lows can be relatively deep and long lasting, affecting the South Greenland area from January through to April, thereby resulting in a broad band of ice extending southward.

If these low pressure systems track into the Davis Strait and stall, cold westerlies are circulated across the Labrador Sea; the band of pack ice, while quite wide, is not accelerated in its southward drift. Long-lasting lows over the Davis Strait spread the ice seaward for a distance in excess of 300 km (Canadian Hydrographic Service, 1974).

Low pressure systems moving through the centre of the region may persist for long periods. Winds can blow onshore over the northern part of the coast and offshore over the southern part at the same time. These winds create divergence and compression

in different areas of the pack simultaneously. As such systems move seaward, northwest winds may develop over the whole area and all of the pack broadens along the entire coast. High pressure systems following the lows and containing cold air cause freezing in open areas, which solidifies the pack. Such systems usually weaken and dissipate once the air is warmed as it passes over the open water.

Environment Canada provides a summary of ice conditions south of 55°N for the period from 1964 to 1971 inclusive. A brief summary follows to illustrate the variability of Labrador ice conditions.

During the spring of 1965, the band of coastal Labrador pack ice was narrower than usual due to strong onshore winds from February to April. These winds also retarded southward movement of the pack. In May and June, prevailing westerly winds dispersed the pack seaward into warmer water, where melting occurred. During the 1967 ice season, unusually strong offshore winds cleared the drifting pack ice during May, before the fast ice broke out in the first week of June. Normally, however, the pack ice is the controlling factor in determining shipping routes. In every other year since records began in 1953, the fast ice broke before the coastal pack ice had cleared.

On the coast of Labrador during 1968, warmer than average temperatures suggested a light ice season and early clearing of ice; however, a strong north-northwest wind in late May brought colder temperatures and caused the ice to linger much later than usual. Again, in the 1969 to 1970 ice season, temperatures as much as 5.6°C above average were responsible for light ice conditions that spring. From April to July, however, temperatures dropped to below normal as low pressure systems brought northerly winds down the coast. As a consequence, ice was late in clearing the coast.

During the 1970 to 1971 season, the Labrador Sea had a cover of close pack ice by mid-December. In January, a short period of warm east-southeast wind disintegrated much of the coastal ice. Northwesterly winds in mid-January brought lower temperatures (1.8 °C below normal) and ice grew rapidly, spreading seaward. This growth continued until the end of February, when warmer temperatures and southwest winds caused a northward retreat of the pack-ice boundary. A brief exception occurred with a period of easterly winds in late April, when ice closed in the Strait of Belle Isle region, remaining there until it melted in the fourth week of May.

Markham (1973) describes the 1972-1973 winter as the coldest in approximately 30 years. The mean low centered east of Cape Farewell and contributed a colder than average air source from western Foxe Basin, Hudson Bay. A definite offshore trend

between latitude 45° and 50°N extended the pack ice cover almost as far as longitude 45°W.

Historical data indicates that ice conditions have been much more severe than records from the last 20 to 30 years would indicate. Reports from the 1800's (Wilson, 1976) tell of ships finding 400 miles of ice off the Labrador coast in July 1826. In 1816, the Labrador coast apparently was blocked with ice for the entire year. On July 14, 1817, floes of 15 to 18 m thick, and 91 m in diameter were reported 96 to 128 km south of Hopedale. Descriptions of the ice suggest it was second year or multiyear ice. It was not possible to enter Hopedale Harbour until August 9 of that year.

In 1853, ice blocked Hopedale Harbour on August 5. In 1880, the drift ice bordered the Labrador Coast for about 65 km during the second and third week in July. It is unfortunate that records are not available for at least 100 years in order to provide a better appreciation of mean conditions and long-term trends.

5.4.2 Drift Rates. Ice off the Labrador coast moves in a general southward direction, following the Labrador current. The current, as it leaves the Davis Strait, moves at about .51 to 1.02 m/s; along the Labrador coast (112 km seaward), it moves at a rate of 0.19 to 0.37 m/s (Canadian Hydrographic Service, 1974). A more detailed discussion is provided in Chapter 4.

Satellite tracking of ice floes in 1973 gave an average speed of 0.24 m/s during stable weather conditions (McClain, and DeRycke, 1974). This figure is consistent with observation from vessels in the Labrador area.

Wright (1896) reports the travel of a group stranded on the ice for 197 days in 1873; they drifted from latitude 78°N in the Smith Sound area to 53°35'N, where they were rescued by a sealing ship. This southerly drift averaged 0.26 m/s from Hudson Strait to a point off Hamilton Inlet, where their daily average decreased to about 0.15 m/s (Iselin, 1927). Iselin suggests their drift was probably accelerated by prevailing northwest winds.

Calculations of drift rates during 1977 (Winsor, 1978) off Saglek averaged 0.27 m/s; in storm conditions off Cape Harrison, they averaged 0.92 m/s. Mapping of the drift of individual floes indicates some northward movement attributable to high winds (LeDrew and Culshaw, 1977).

5.4.3 Dissolution. The progression of the pack ice eastward and southward generally reaches the maximum limit in April, although ice is carried into the Grand Banks area

until June or July. The band of ice varies in width from about 150 to 260 km (Bursey et al, 1977).

Factors such as ice thickness, sea surface temperature, air temperature, and ice concentration all affect the rate of ice dissolution. As well, sea state can act to disperse the ice and thereby encourage melting. Sea surface temperatures show a warming trend after April (Chapter 4).

The Strait of Belle Isle is essentially open water by mid-June; Hamilton Inlet by the end of the same month; Nain by mid-July; and Resolution Island by the first of August. During late June and July, the ice that is present occurs as discontinuous patches in concentrations of four to six-tenths coverage (Bursey et al, 1977).

Drift ice which reaches latitude 43°N regardless of the season is quickly melted by the relatively warm water. The winds during April and May are generally westerly and tend to push the ice to deeper, warmer water, where rapid melting occurs. Ice has completely cleared from the Labrador coast by the third or fourth week in July (Dinsmore, 1972).

Sea surface isotherms indicate the melt region of the pack ice at approximately 0°C, as shown in Figure 5.3. Because of its much lower thermal conductivity, the air is less important than the water in promoting melting. Air temperature can be important, however, in the formation of melt pools on the surface of the ice.

5.4.4 Wave Action. The swell and wave action during ice formation acts to fracture thickening ice sheets. A heavy swell will crack the ice perpendicular to the direction of wave propagation (Squire and Allan, 1977). The resulting cakes of ice, about two to nine metres in diameter (Winsor, 1978) become rounded with continual abrasion, and their edges become raised as a result of this interaction. These cakes can be reconsolidated by wind and current action or refrozen in calm, cold conditions, as shown in Figure 5.2. The new ice sheet would be subject to further wave action, cracking and new cake formation, in a repeated pattern. "In the Labrador Sea where floes are a short-lived phenomenon, any sizeable floe will be reduced to 10 m ice cakes after a few hours of wave activity" (Squire and Allan, 1977).

Wave conditions in the Labrador Sea are quite severe and are discussed in Chapter 4. Peak wave energy occurs in December or January, with a reported maximum of 18 m (Neu, 1970). The maximum wave height for 1970 in the Labrador Sea was 16 to 17 m (Neu, 1972). Wave energy decreases in February and March but a secondary peak can occur in April (Neu, 1970). While the calculation of this wave energy is based upon

measurements outside of the ice zone, it is this wave energy transfer through the ice that is the primary cause of ice break-up (Squire and Allan, 1977).

5.5 Second and Multi-Year ice

Some of the ice in the Labrador Sea is transported by the water currents from the Arctic, specifically from the Davis Strait and the Foxe Channel via Hudson Strait. The floes from these areas, comprising mainly first-year ice, generally reach Cape Chidley early in November (Dickson and Lamb, 1972).

The Canadian Hydrographic Service (1974) indicates that ice in the Labrador Sea before January is of local formation, since drifted ice from Loks Land and Cumberland Sound can only reach latitude 59°N by the beginning of January. Ice from Davis Strait (with thicknesses of 1.2 to 1.5 m) may reach Groswater Bay in February (Canadian Hydrographic Service, 1974).

Since it does not survive the summer, ice formed in the Labrador Sea is always less than one year old. However, there have been reports of second year or multiyear ice in the area; therefore, it must be assumed that any such ice has drifted south from the Arctic.

Floes of second year or multiyear ice are thicker and substantially stronger than first-year ice, and therefore present a hazard to navigation. The reason for this greater strength is that ice that survives one winter season is subject to warming temperatures in summer, which expel much of the entrapped brine. The ice becomes harder, less dense and stands higher in the water. The melting and refreezing of the surface gives the ice a bluish-green hue. Ice which survives more than two summers is termed multiyear ice. It is almost salt free, quite smooth and blue coloured throughout when the surface is visible (World Met. Org., 1970). Multiyear ice in the Arctic grows to an average thickness of three to four metres (Walker and Penny, 1973).

Hudson Strait and Davis Strait are mainly ice free during the summer. Ice may survive the summer in the Foxe Basin (Dinsmore, 1972). Dunbar (1971) points out that since the 1950's, there has been a trend of increasingly severe climate, with more ice surviving the summer in Baffin Bay.

Reports of multiyear ice in the Labrador Sea are indicated by Bursey et al (1977), and Sailing Directions (Canadian Hydrographic Service, 1974). The AES Ice Analysis and Summaries (1964 to 1971) do not indicate multiyear floes. One report of a piece of multiyear ice in the Southern Labrador Sea described the floe as having horizontal dimensions of 9.14 by 24.38 m (Nolte and Trethart, 1971).

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CHAPTER 6
ICE FEATURE CHARACTERIZATION LABRADOR OFFSHORE

by
W.D. Winsor
and
B.R. LeDrew

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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6 INTRODUCTION

In February 1977, a pilot study was carried out as a joint undertaking between C-CORE and Newfoundland Oceans Research and Development Corporation (NORDCO) Limited. The Ship-in-the-Ice Project was aimed at studying the Labrador pack ice: its formation, movement and the forces generated by and acting on it (Culshaw and LeDrew, 1977).

Except for a few limited or proprietary studies (e.g., Nolte and Trethart, 1971, reviewed by Skidmore for this study) there is almost no information on the physical forces in the Labrador pack ice. Consequently, this report is based mainly on the observations and measurements of ice features that were discerned during the Ship-in-the-Ice Project. General comments and speculation on the processes of ice formation are included, along with a critique of the limitations of sampling methodology available to collect field data on pack ice.

6.1 Ship-in-the-Ice Pilot Study

A small (Norske Verital 1A1), ice-classed vessel, M/V Arctic Explorer, was chartered for the month of February to provide a research platform and base of operations. As originally planned, the vessel was to proceed north from St. John's, enter the pack ice at about 56°N, "dock" into a large floe (with a major dimension of 1 to 2 km), and drift south with it for a two-week study period. During this time, a remote sensing synthetic aperture radar (SAR) overflight was scheduled to take place (Worsfold, Strong and Wedler, 1977). The vessel would serve as a reference point and data gathered was to be used in the analysis of SAR images.

By the third week of February, the vessel would break free of the pack and return to St. John's, to terminate charter by the end of February. The brief study period would serve to establish the feasibility of using a vessel as a research platform in the Labrador pack. Further, attention would be focused on the winter research needs in the offshore Labrador.

The work plan was never realized, as no large floe was located. The largest floes accessible were of comparable size to the ship itself (50 m). It was only possible to position the ship in a recently agglomerated breccia of ice cakes. The ice went through a continuous cycle of compaction and divergence so that the ship's movement relative to the ice was almost a daily occurrence. Consequently, of 18 days in the study area, only six were spent "frozen in"; 10 days were spent moving or trying to move; and two days

were lost due to storm conditions. Nevertheless, a unique opportunity was afforded to observe ice movement and formation processes on a continuous basis.

On-ice work was conducted in two general locations: off Saglek, from February 7 to 16; and off Hopedale-Cape Harrison, from February 18 to 25 (Figure 6.1). The SAR overflight took place on February 25.

Field methods are described and raw data archived in the Ship-in-the-Ice Field Data Record (LeDrew and Culshaw, 1977).

6.1.1 Summary: Ship-in-the-Ice Pilot Study. The Labrador ice field is a very dynamic region with a continual cycling: from forming, through break-up, to reconsolidation. Major types of ice conditions represent identified stages of this cycling and include:

(a) the extensive floes of consolidated cakes (breccia) separated by a network of leads and fracture zones;

(b) the succeeding stage when floes are completely fragmented and break up into individual cakes, which are loosely agglomerated; and

(c) a third stage, characterized by a solid cover resulting from lateral compression of the cakes.

The compressed field (c) can be distinguished from the consolidated field (a) by the fact that it would not break-up under swell conditions. The compressed plate would be expected to act as pseudo-plastic material under the influence of flexural stress imposed by swell trains propagating through the ice.

A series of ice thicknesses and surface feature descriptions are examined. The information is portrayed in a series of vertical profiles that serve to illustrate the gross features and dimensions of ice present in the field.

The results of the salinity and density measurements are inconclusive. The variability of the results indicates that the methodology employed limits the accuracy of the salinity values to about one part per thousand, and there appears to be a systematic error in the density values. Neither the salinity nor the density information could be used to examine spatial variations in the ice cover. Salinity values obtained were normal for first-year ice, indicating that the high turnover (breaking and refreezing) in much of the ice had not impeded brine rejection.

The determination of the internal crystal structure of the ice provides valuable information on the formation processes of the ice cover. The fact that most of the ice encountered was fine grained confirms that this material undergoes considerable

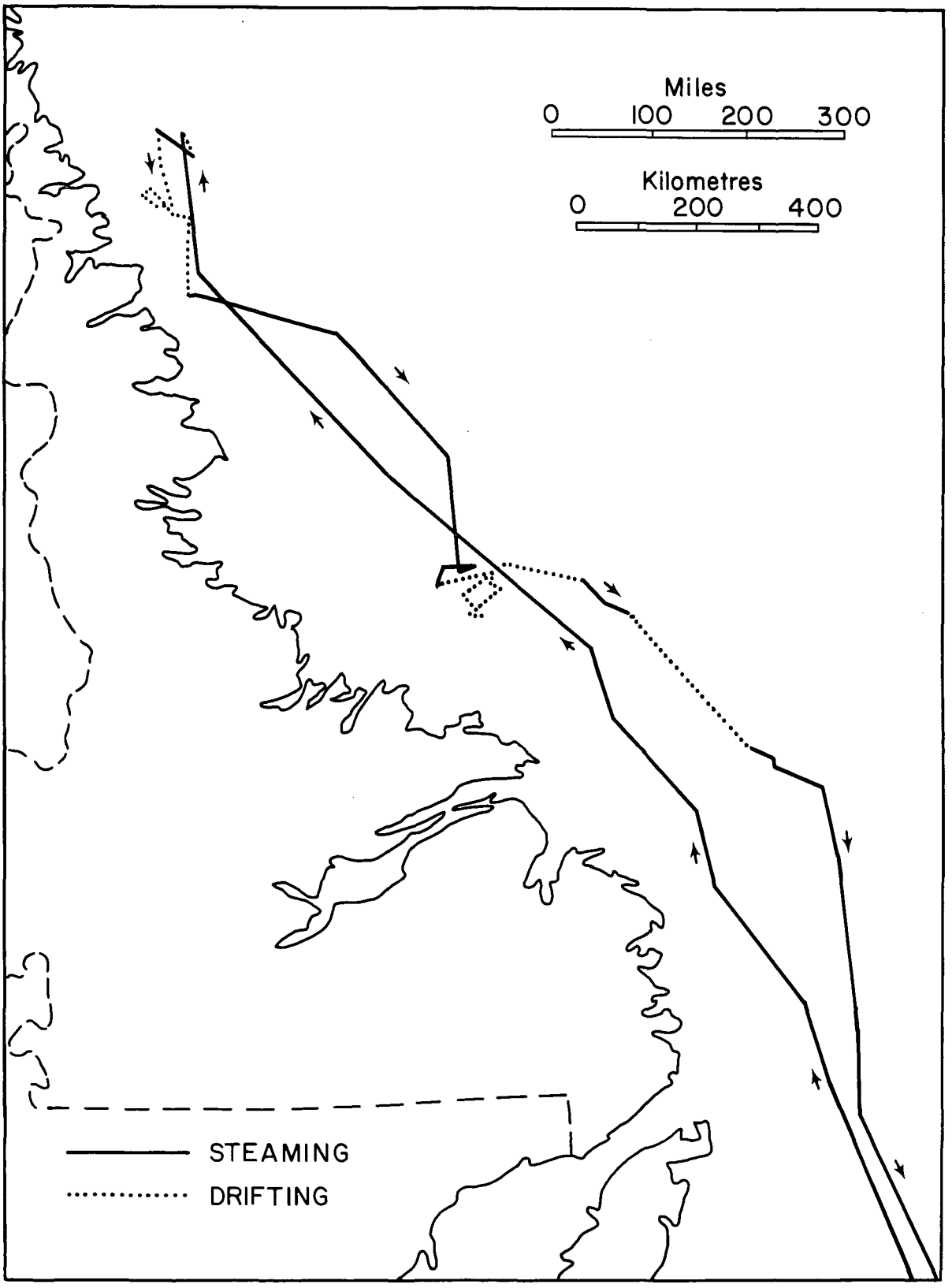


FIGURE 6.1 TRACK CHART OF THE ARCTIC EXPLORER

mixing before it attains its final structure. Ice which does not undergo turbulent formation has an ordered and columnar structure (e.g., ice which formed in the refrozen leads); such ice was uncommon, and occurred only in relatively thin portions of core samples from defined cakes.

The type of disordered structure found is in marked contrast to the very ordered crystal structure of Arctic sea ice samples examined.

Results suggest strongly that the ice conditions encountered are unique to the geographic region, so that extrapolations from work done in other, more northerly locations are probably inappropriate. In order to obtain better knowledge of ice conditions, ice forces and dynamic movement of the sea ice, further field studies are recommended.

6.2 Vertical Sections and Photo-Records

A Hasselblad 500 EL (70 mm format) camera with an 80 mm lens was mounted on a support bracket that was bolted to the footrest located on the front passenger (left) seat of a Bell Jet Ranger helicopter. Two sequences of photographs were obtained over the ice in the Saglek region: one landward to seaward for 80 km, and another over several icebergs to illustrate iceberg/pack ice interaction. Low cloud cover and unsuitable flying weather prevented similar aerial photo work over the ice in the Hopedale - Cape Harrison region.

Figure 6.2(a), line 1-0, is a 100 m vertical section. The line is traced on the accompanying photograph, Figure 6.3. This line was taken across what can be termed floe-agglomerated ice. This type of ice has been identified by other workers (Weeks and Lee, 1958; 1962) in the initial layer in shorefast ice, where thicknesses of up to 300 mm are reached. In the cited cases, the ice continued to thicken as a homogeneous sheet. In the pack ice, breaking and re-agglomeration appears to be a continual process and the extensive floes are periodically formed by the refreezing of small cakes and brash which result from each break-up sequence.

At the sample time, this local floe adjacent to the ship had a maximum dimension of about 500 m, free from any fracture boundary. The right end of the thickness profile is incomplete due to limited time at the station.

Line 2-0, Figure 6.2(b), is a vertical section across a small floe. The ice debris dam at its edge indicates that it is a defined floe rather than a fragment of agglomerated cakes such as that which was described for line 1-0. Figure 6.4 is an aerial photograph of similarly sized floes. Such floes are defined by distinct edges adjacent to small thin

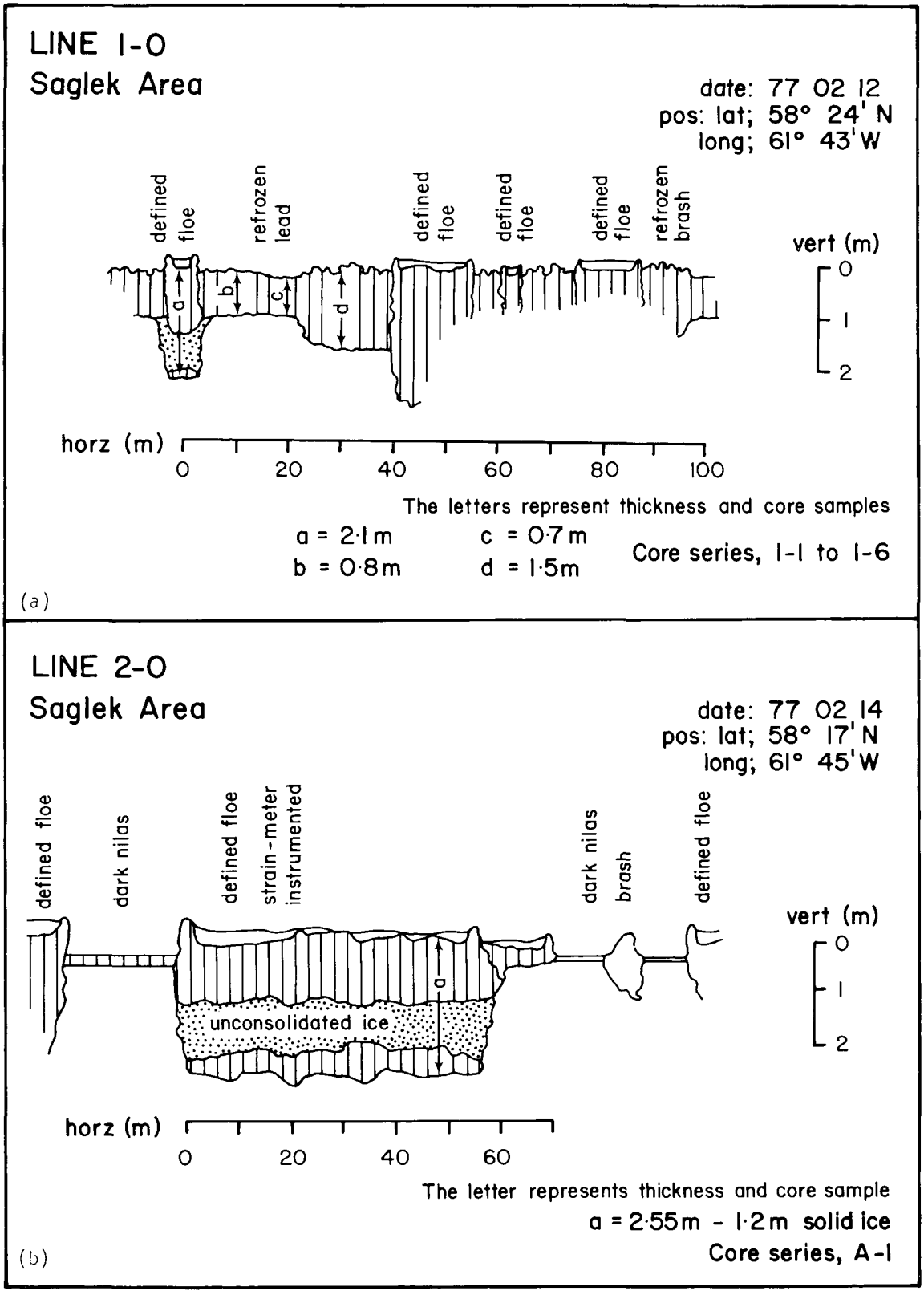


FIGURE 6.2 ICE FEATURE CHARACTERIZATION LINES (a) AND (b)

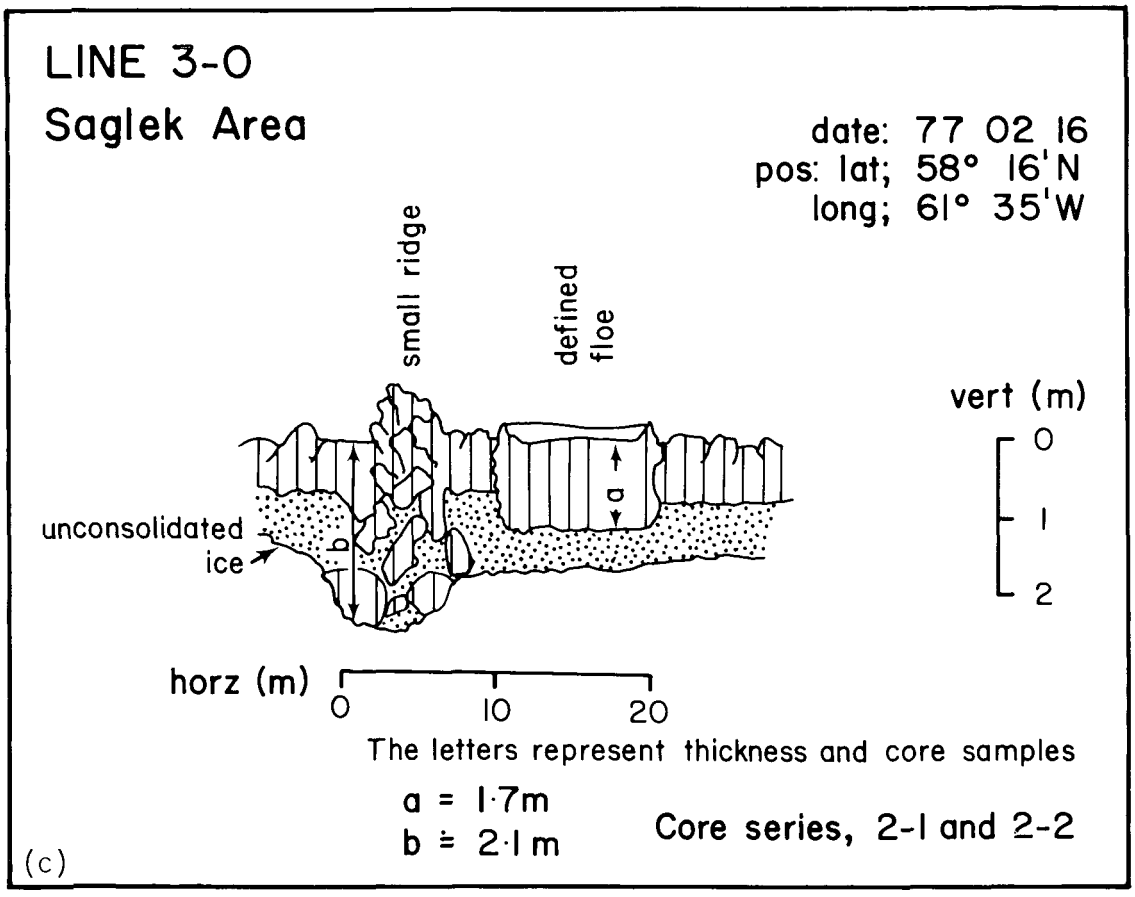
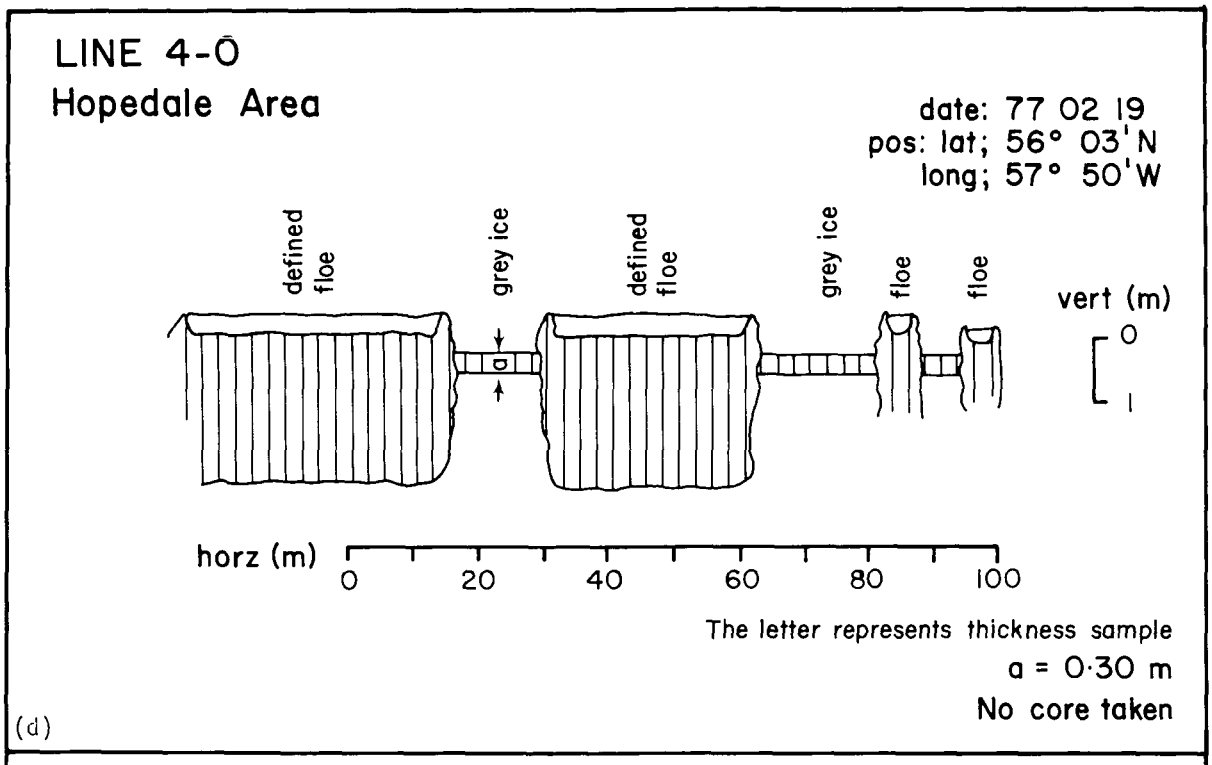


FIGURE 6.2 ICE FEATURE CHARACTERIZATION LINE (c)



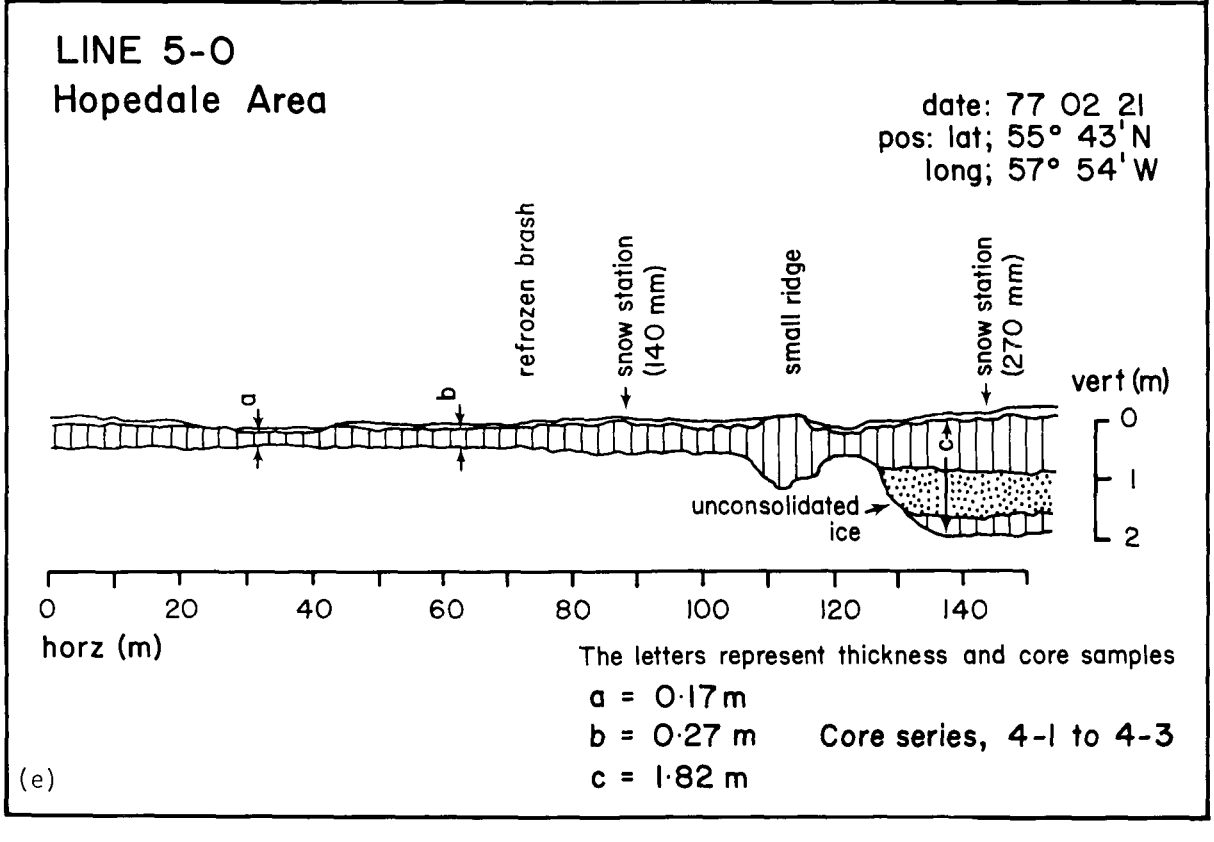


FIGURE 6.2 ICE FEATURE CHARACTERIZATION LINES (d) AND (e)

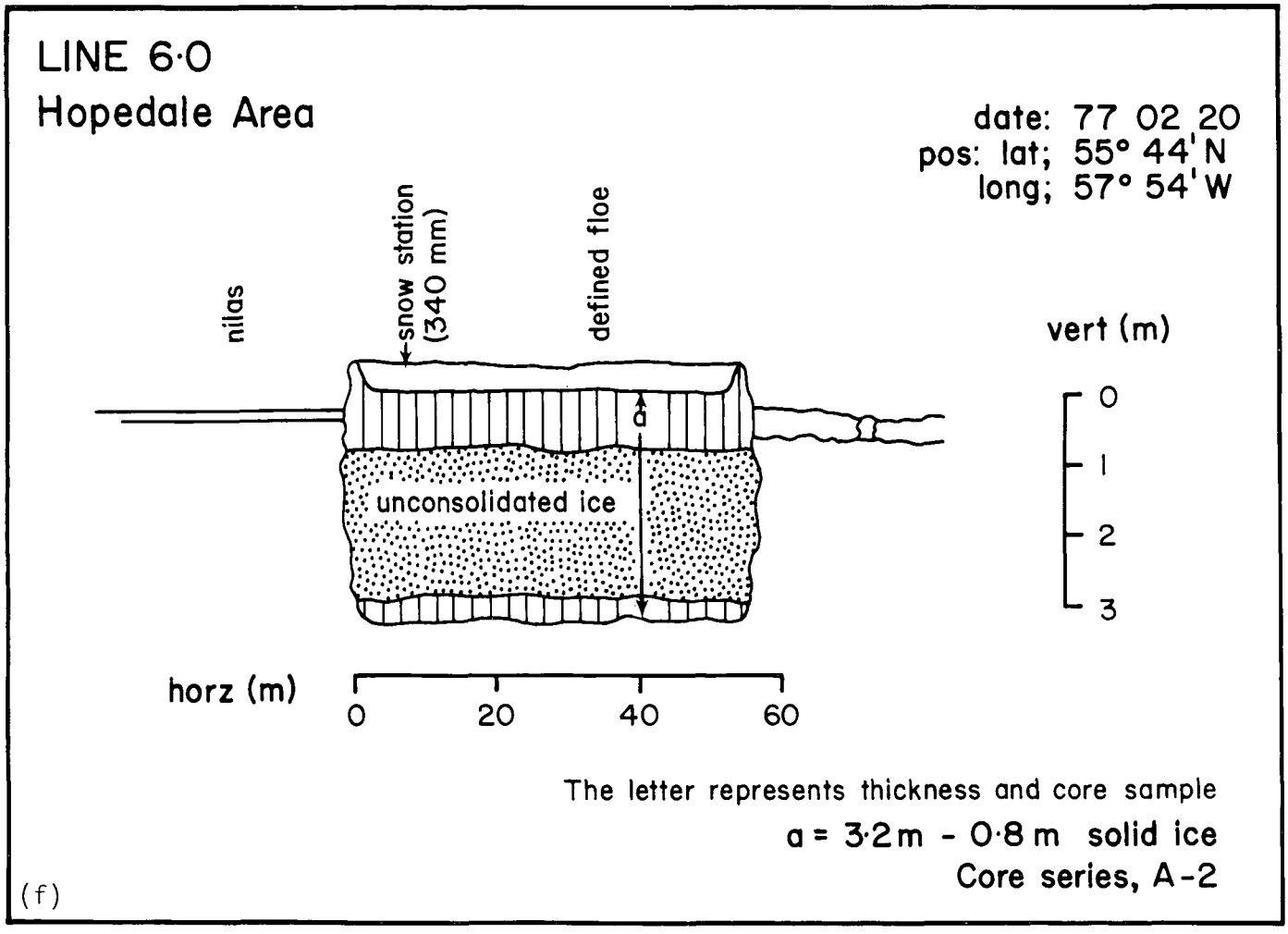
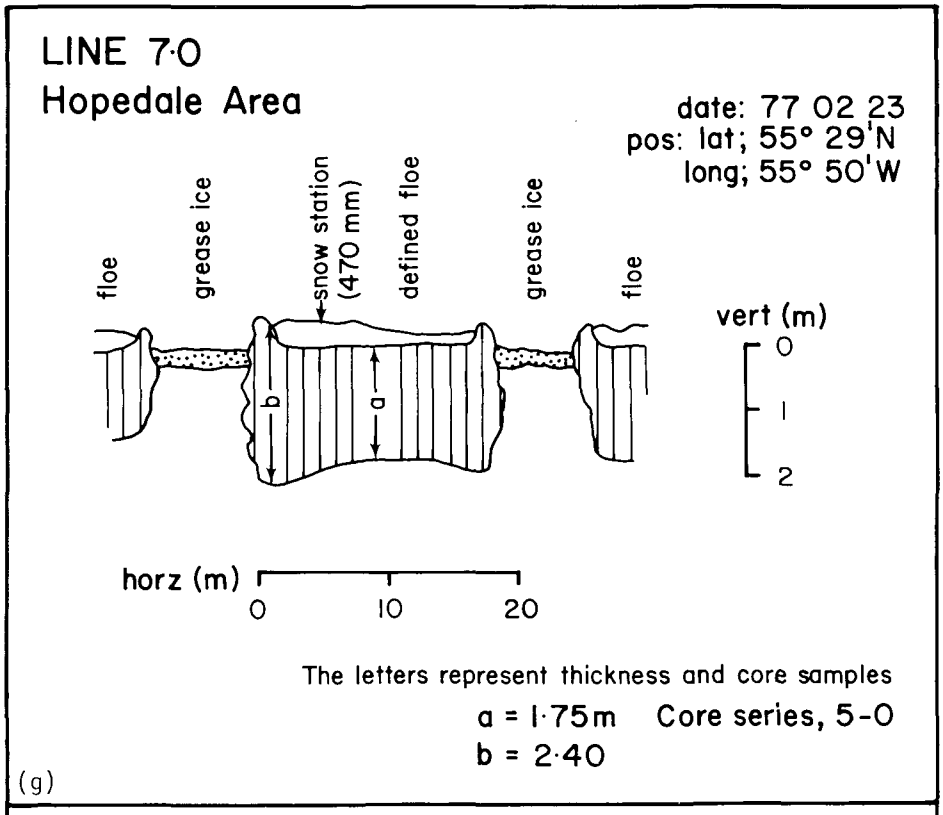


FIGURE 6.2 ICE FEATURE CHARACTERIZATION LINE (f)



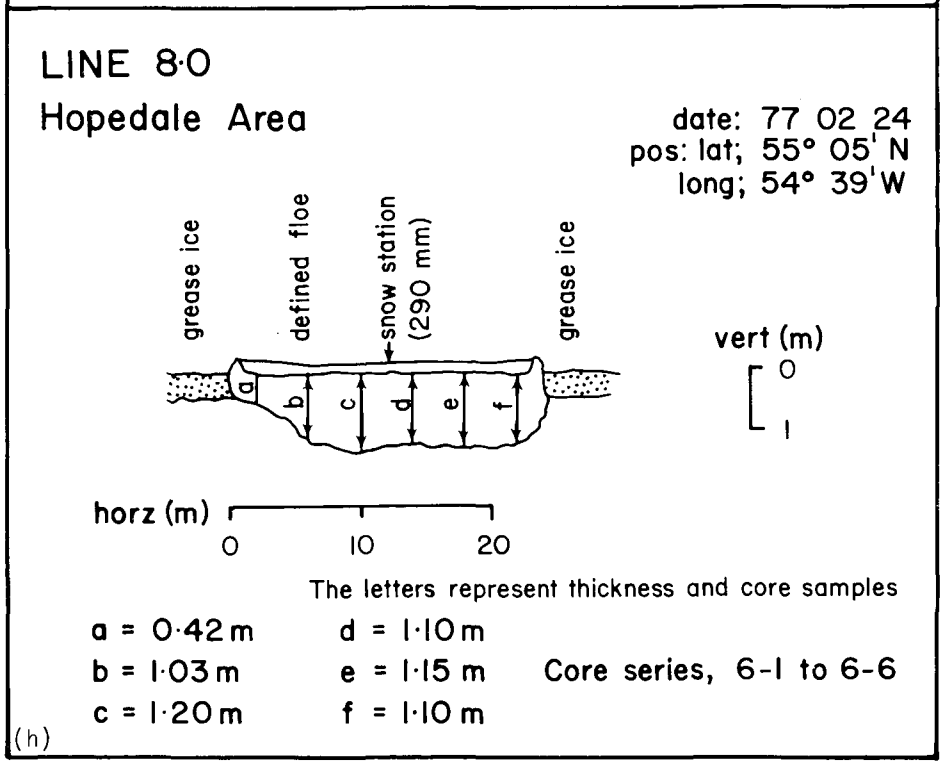


FIGURE 6.2 ICE FEATURE CHARACTERIZATION LINES (g) AND (h)

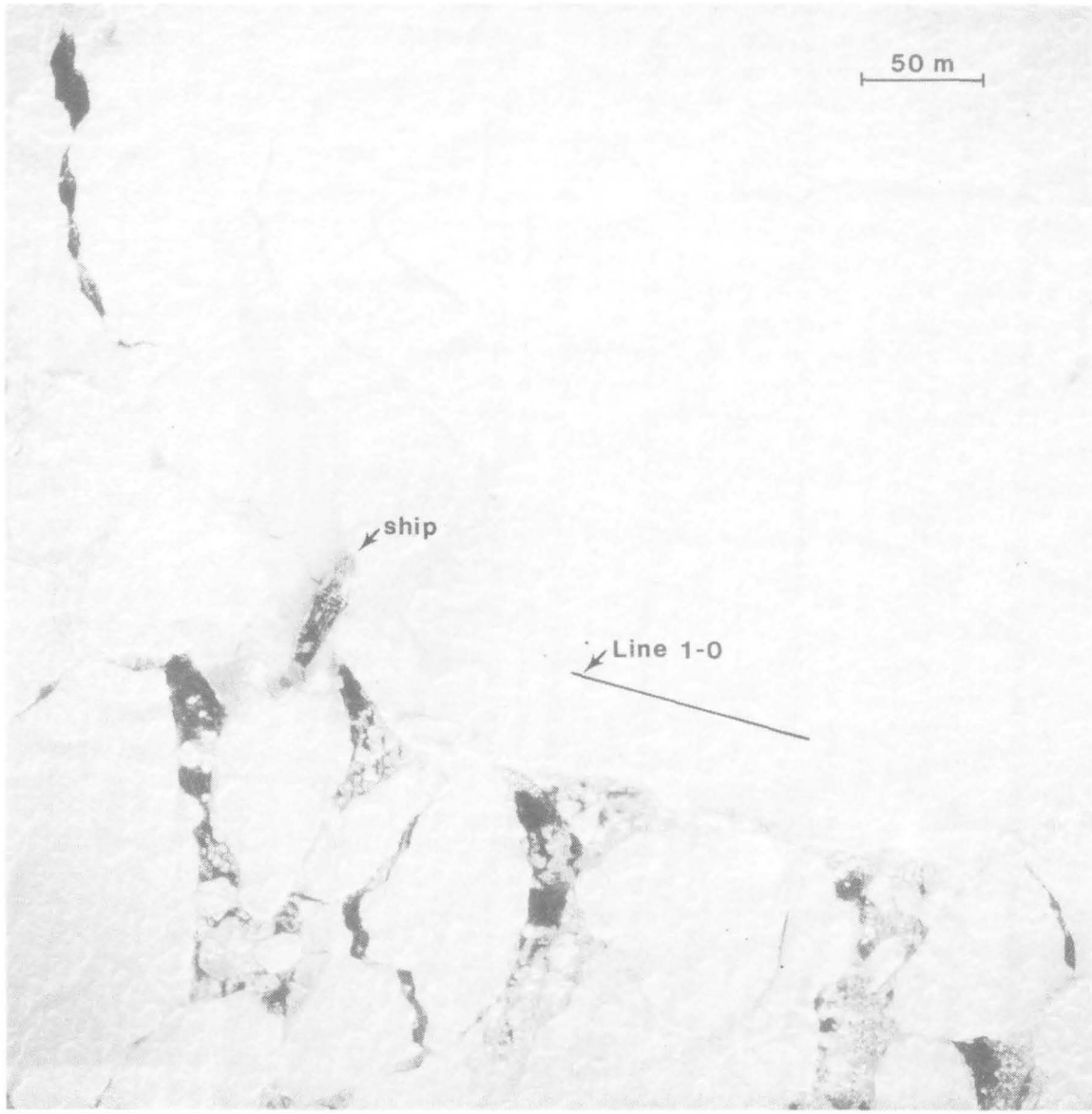


FIGURE 6.3 INDIVIDUAL CAKES AND ICE DEBRIS REFROZEN INTO A RELATIVELY LARGE FLOW (top right)

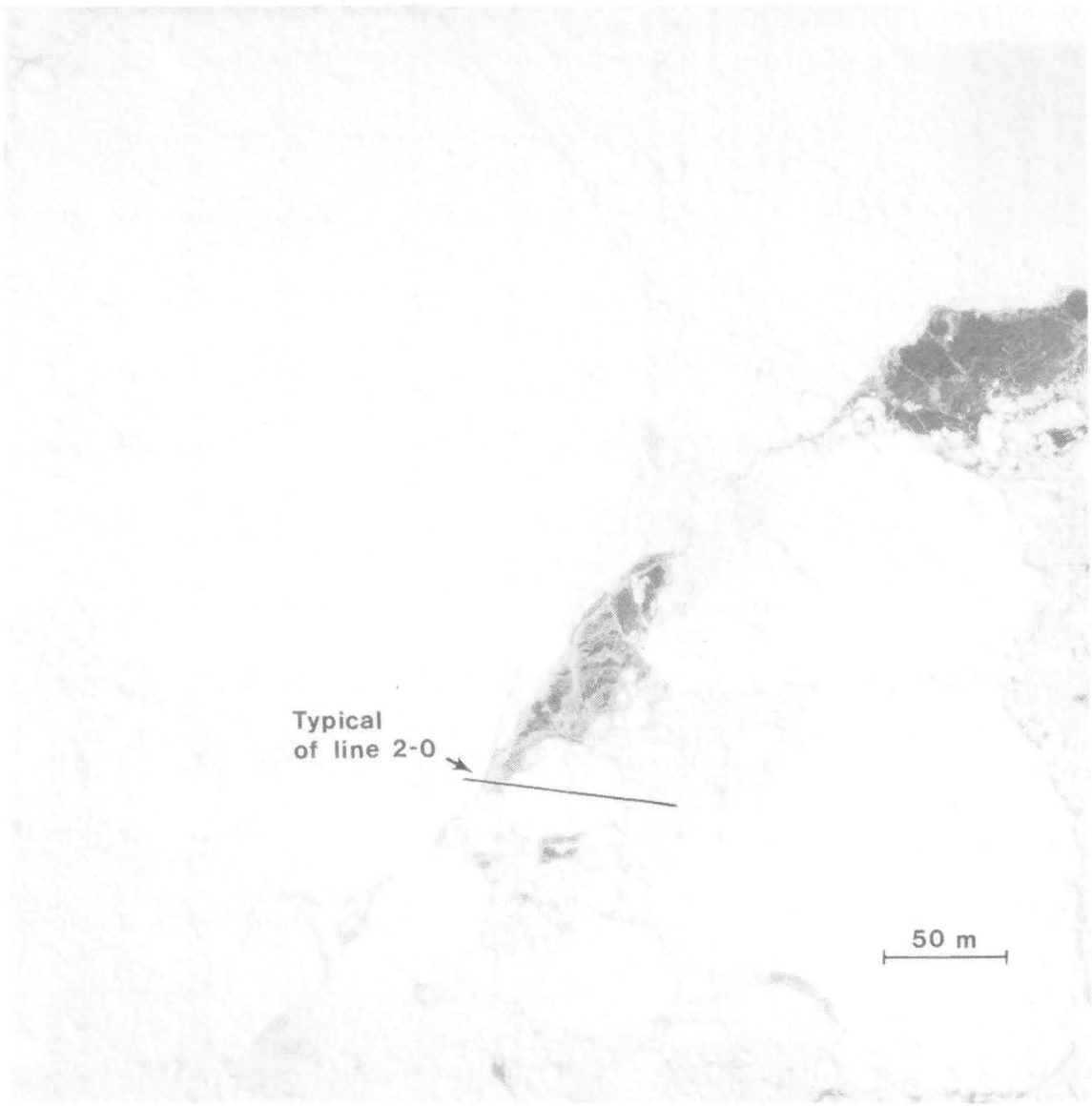


FIGURE 6.4 A FEW SMALL DEFINED FLOES (50 m) WITHIN PACK ICE

narrow layers of newly formed ice. The continual movement and abrasion of these floes can be heard when standing on the ice.

Survey line 3-0 in Figure 6.2(c) was completed while the ship was underway but unable to make any headway through the ice. The plan view of the ice is presented in Figure 6.5. This section is particularly interesting because it suggests that there is a continuous thick layer of frazil ice underlying the solid ice cover. This contrasts with lines 1-0 and 2-0, where the layer of frazil ice was discontinuous and appeared to underlie identifiable ice cakes and agglomerated floes. Unlike line 1-0, where the cover is a relatively continuous refrozen sheet, the cover at line 3-0 is composed of ice cakes and brash that are not well cemented together; rather, they are pushed together by the lateral compression of the pack. When walking along the ice surface, this condition was quite evident, as the continual relative movement within the ice could be sensed.

The distinct sub-surface layer of frazil ice is not a major obstacle to a ship's progress in its own right (since it is a fluid mixture), however, it appears to be a manifestation that the local ice field is under lateral compression. A second indication of lateral compression is a network of small ridges within the field. Figure 6.6 shows the surface view of such a ridged network. The fact that these ridges can run perpendicular to leads demonstrates that the stress field within the ice can be uni-directional rather an equi-axial.

It is relatively easy to predict how this ice condition can evolve to the one observed at line 1-0. The stress field releases and the frazil ice flows up to and surrounds the small ice debris while it remains trapped beneath defined cakes and floes. In the event of calm, cold weather, the ice freezes together into a continuous sheet. The sheet breaks again under wave and storm conditions, and the cycle is repeated. Figure 6.7 contains histograms of size distribution of cakes measured from aerial photographs taken over some specific surface areas in the Saglek region. Measurements were taken of discrete cakes within agglomerated floes, as evidenced by their raised boundary. The lower limit is reached when the smaller-sized pieces are no longer plane stable, and hence roll to their stable buoyancy configuration. Under dynamic conditions, plane stable cakes will become the dominant size feature. They are small enough to resist fracture by plate bending, yet large enough to resist crushing by lateral compression.

A second set of vertical profiles was taken in the Hopedale region after the ship had moved 220 km south of the initial station. Here, the ice conditions were very different. The total volume of ice per unit area was less, but the defined floes were as

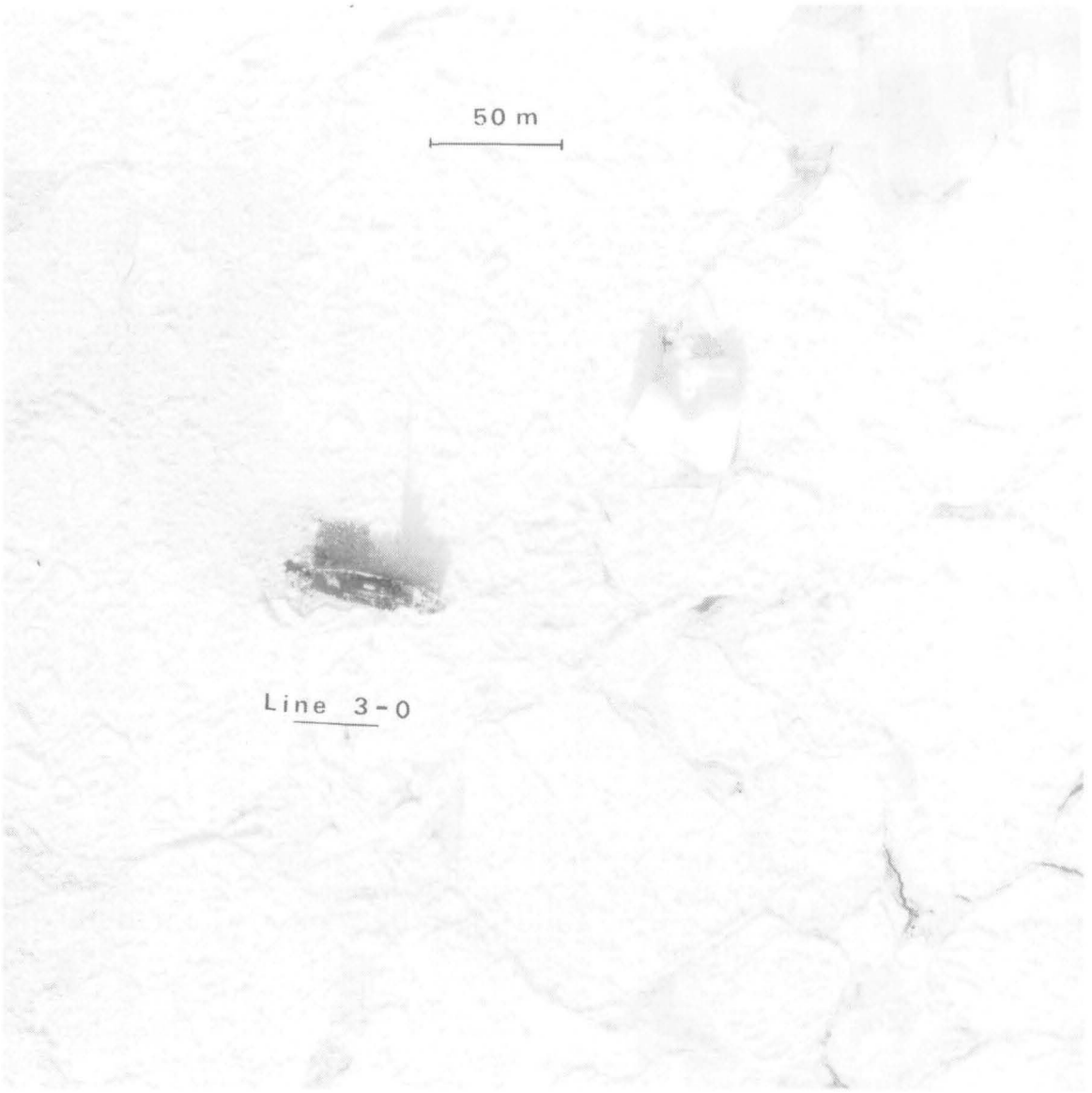


FIGURE 6.5 SHIP BESET IN ICE UNDER LATERAL COMPRESSION

FIGURE 6.6 NETWORK OF RIDGES INDICATING PACK ICE IN LATERAL COMPRESSION

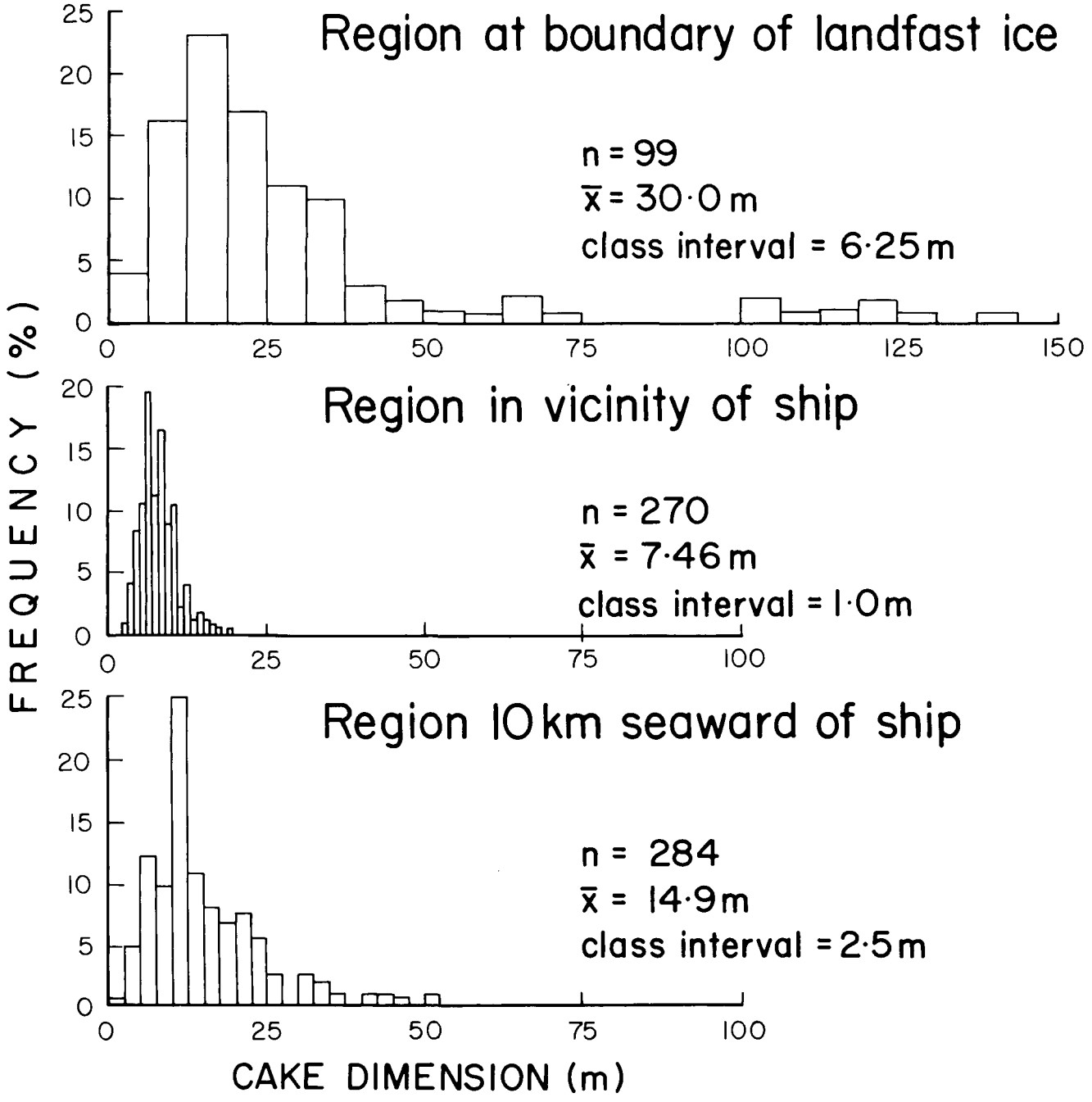


FIGURE 6.7 CAKE SIZE DISTRIBUTION

thick as or thicker than those in the Saglek region. In general, the area was characterized by more open water and thin new ice. Line 4-0 of Figure 6.2(d) was surface profiled, but broke apart before it was possible to take any core samples. The young grey ice layer that served to cement the larger cakes together fractured under swell conditions of such a long period and low amplitude that they were undetectable to human senses.

The ice at line 5-0, Figure 6.2(c), consisted of thin grey ice to grey-white ice, which cemented small cakes and brash to make a continuous sheet. While there was evidence of frazil ice trapped beneath the older features, there was none beneath the new ice at this location.

The floe, profiled by line 6-0 and shown in Figure 6.8, was selected as a site to make strain measurements. It served as a stable platform but it represented an uncommon feature in the surrounding ice field.

The ice cake illustrated in Figure 6.2 (g) was sampled during a period of heavy swell and loose conditions of about 8/10 cover. The area between cakes was full of loose, fluid frazil ice which could not bear any weight. This condition is illustrated in Figure 6.9.

Survey line 8-0, Figure 6.2(h), was completed after a snowstorm with high wind (speeds to 56 km/h and wind direction from 90° to 250^{0}) had completely broken the ice into cakes. The floe with the strainmeter (Figure 6.8) was fractured in half.

The ice cover at the time of the remote sensing overflight (February 25) can be described as follows: 40 to 50 percent ice cakes and the interstitial area filled with a thick layer (0.5 to 1. 0 m) of frazil ice. Figure 6.10 (a and b) shows oblique photographs of the ice condition. The surface crack in the frazil indicates the presence of a thick layer, with the ice above freeboard draining and cracking. The accumulation of this fluid ice-water mixture seemed to result from abrasion between cakes. This condition was the result of offshore or parallel to shore winds. There was no lateral compression of the pack ice and hence no ice-water fluid on the underside of the floe sampled in line 8-0. At the time there was a heavy swell running in the ice (wave height from 2.5 to 3 m, with a period of 10 to 12 seconds). The non-compressed pack appeared to have much less affect on wave attenuation than did ice in lateral compression.

6.3 Ice Property Measurements. Ice cores were taken to serve as sample material for the ice property measurements. Each core was sectioned into 100 mm lengths with a handsaw. For each section, the top 50 mm was placed in a plastic sample bag, labelled and stored in the freezer to return to the laboratory for macro-structural analysis. The

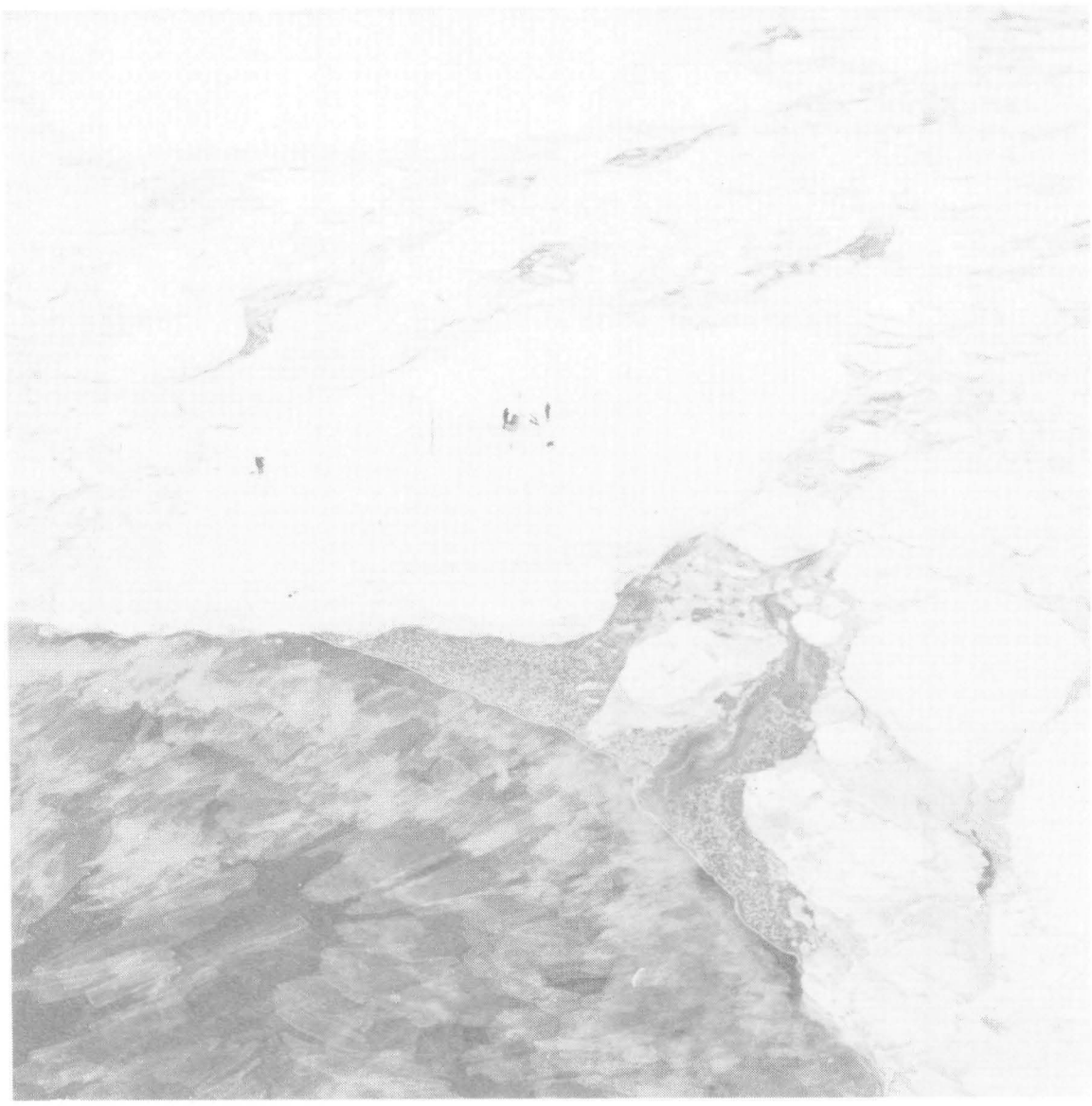


FIGURE 6.8 VIEW OF FLOW INSTRUMENTED WITH ICE STRAINMETERS

FIGURE 6.9 LOOSE ICE OFF HOPEDALE
(Note "ice pulp" between cakes.)

FIGURE 6.10 ICE CONDITION FOLLOWING A SNOW STORM ACCOMPANIED BY HIGH WINDS
(Not Onshore Winds)

bottom 50 mm was divided; half was used for salinity determination, and the remainder was used for the density measurement.

6.3.1 Salinity. The procedure followed for the salinity measurement was to place the ice samples in 200 ml polystyrene cups. Each batch of samples were placed in a cardboard container, covered with a plastic sheet to minimize evaporation, and placed in a cupboard in the shipboard laboratory. When the ice had melted and the water had reached ambient temperature, the salinity was measured with a YSI Salinity-Conductivity-Temperature (SCT) meter. In cases where the sample volume was insufficient to immerse the probe, the sample was diluted with an equal volume of distilled water. The measurement was adjusted to account for the dilution.

The salinity determinations from the core samples are subdivided into the Saglek region and the Hopedale region; they are plotted Figures 6.11 and 6.12. Each data point represents one salinity determination from a 100 mm core segment. A total of seven cores are reported in Figure 6.11; six in Figure 6.12. The salinities for the six cores collected from a single cake on the day preceding the SAR overflight are presented in Figure 6.13. The individual profiles show considerable scatter of the points with depth; yet when the plots are collected on a single graph, this scatter is similar to that reported by other investigators for floe-agglomerated sea ice (Weeks and Lee, 1962), i.e., in the order of one part per thousand. When the profiles are normalized for thickness and replotted (Figure 6.14), the typical inverted "S" resulted.

After determining salinities onboard the vessel, a series of samples from one of the cored profiles was sealed in sample bottles, refrozen to minimize any evaporation or change of salinity, and returned with the ship. This was done to have a reference calibration of a profile using chemical titration for salinity.

As illustrated in Figure 6.15, the field measurements, with the SCT meter, show both a systematic bias to lower values of salinity and a random scatter from the trend of the inverted "S", which is well defined in the reference profile. This scatter of measured values indicates that the field instrument has a salinity resolution of less than one part per thousand. Lacking a relatively large number of samples, which would permit statistical treatment of the data, it is not possible to comment on vertical or horizontal variations in salinity of the ice.

The reference profile, however, confirms that there is a salinity variational trend with depth.

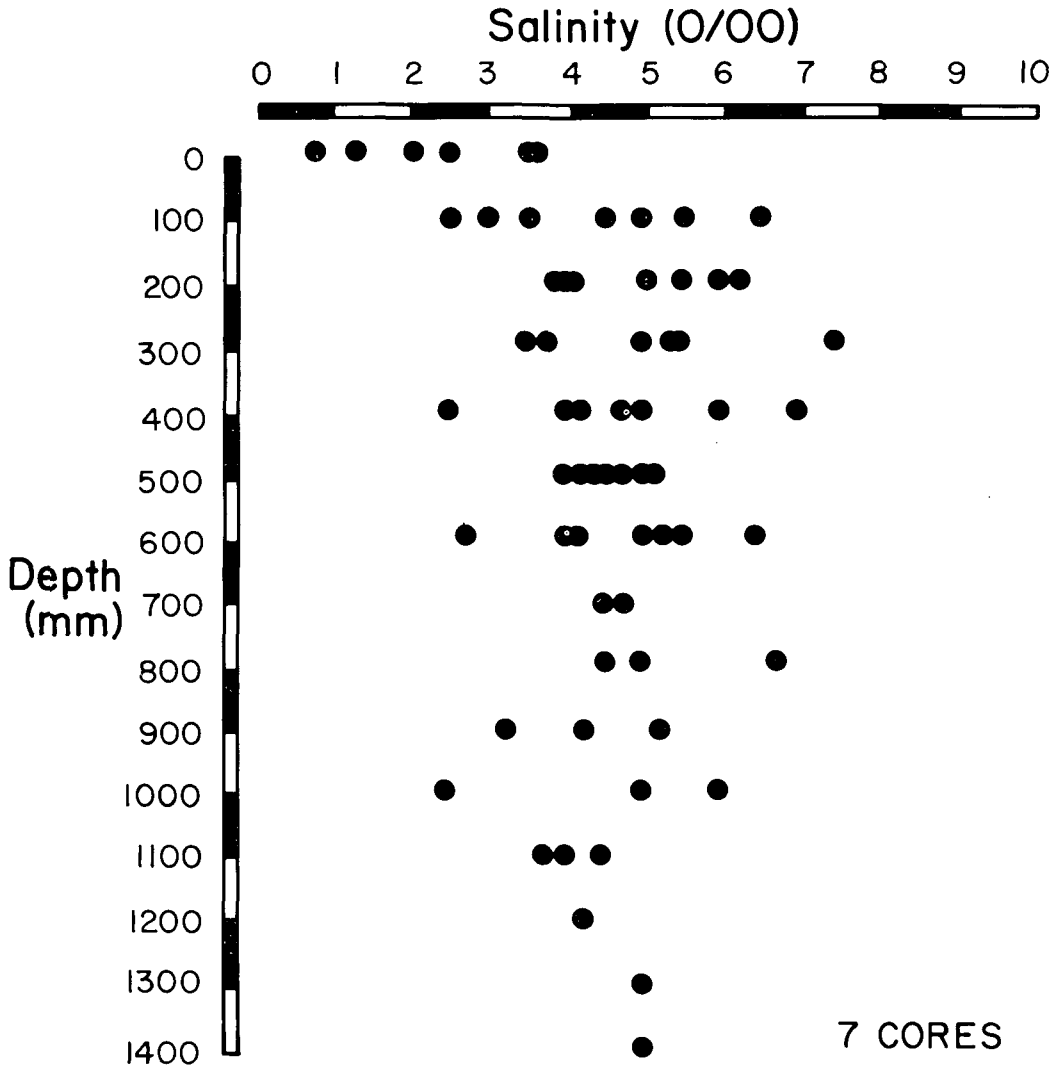


FIGURE 6.11 SALINITY PROFILE OF PACK ICE CORES: SAGLEK AREA

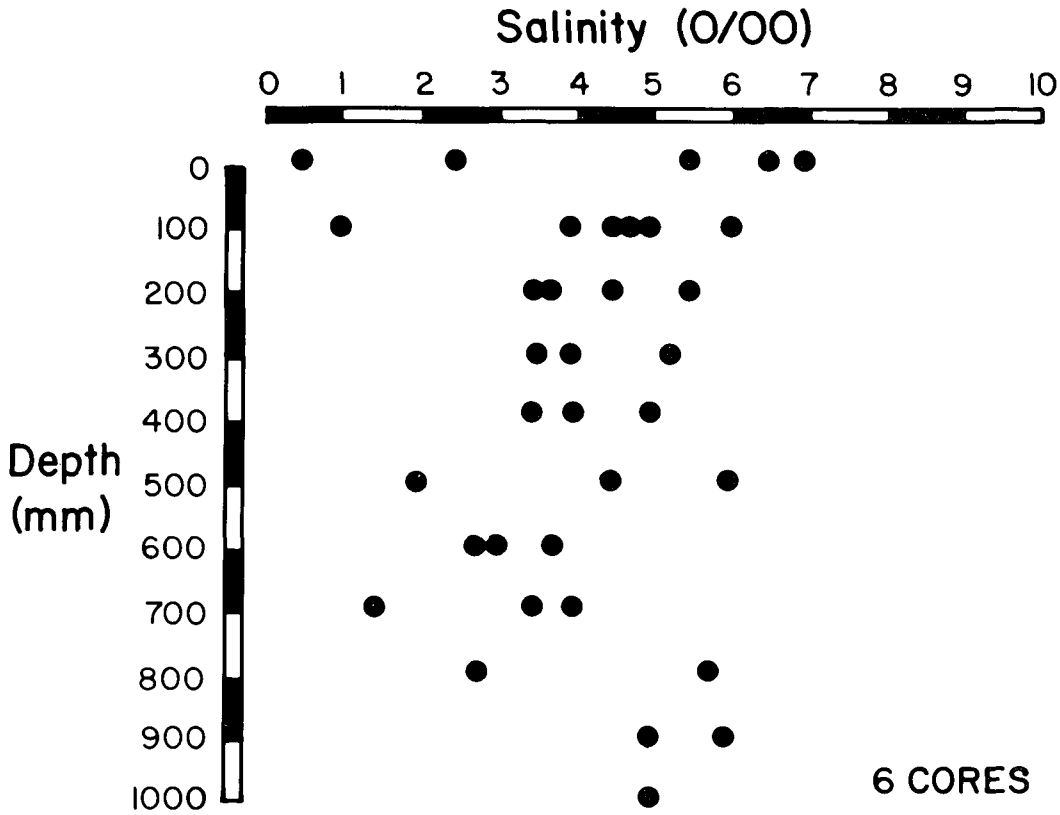
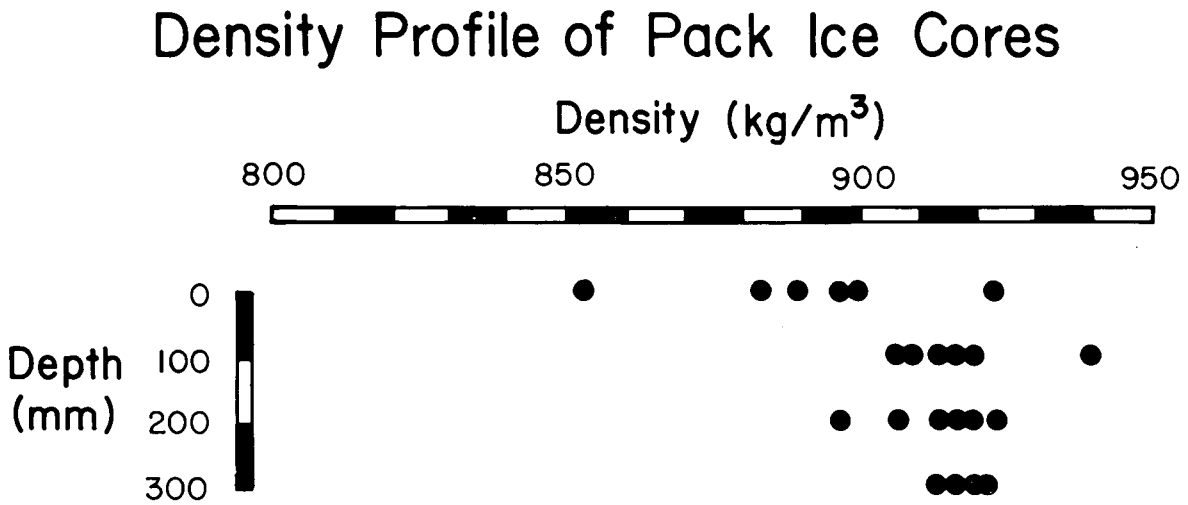


FIGURE 6.12 SALINITY PROFILES OF PACK ICE CORES: HOPEDALE AREA



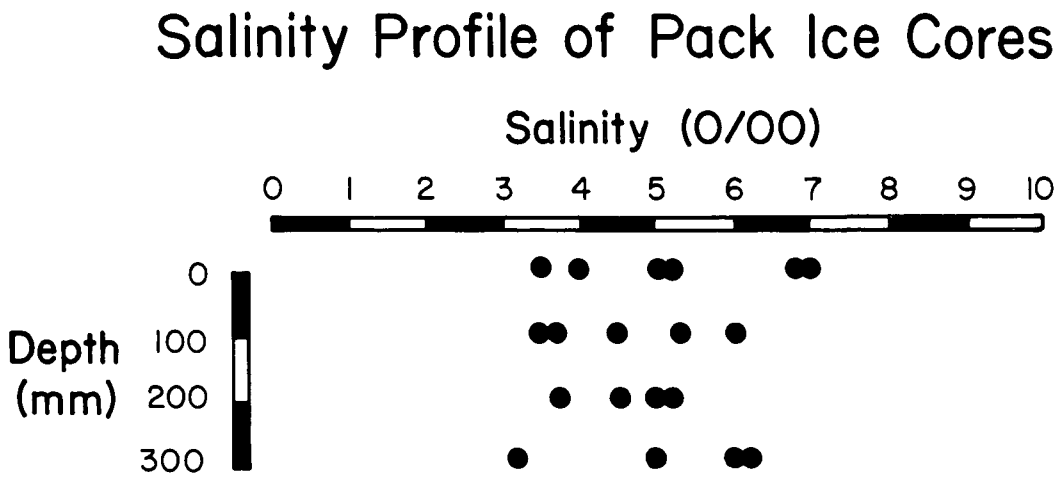


FIGURE 6.13 DENSITY AND SALINITY PROFILES OF PACK ICE CORES: SERIES OF CORE SAMPLES TAKEN FOR SAR OVERFLIGHT

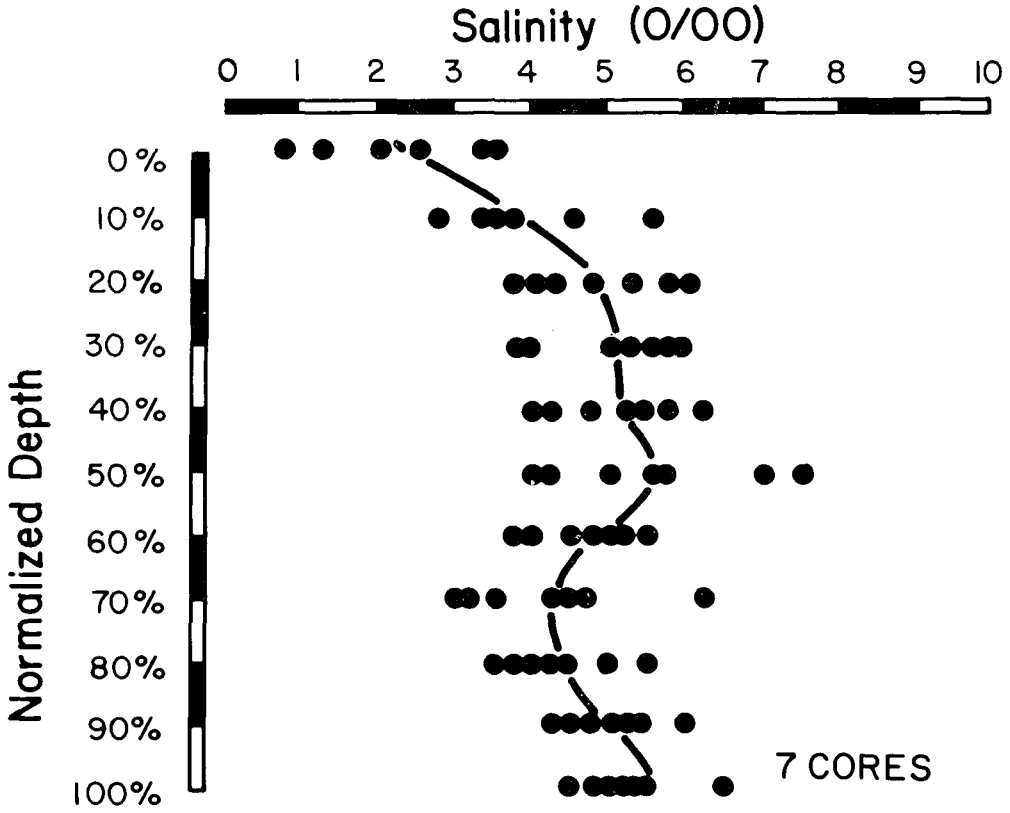


FIGURE 6.14 NORMALIZED SALINITY PROFILES OF PACK ICE CORES: SAGLEK AREA

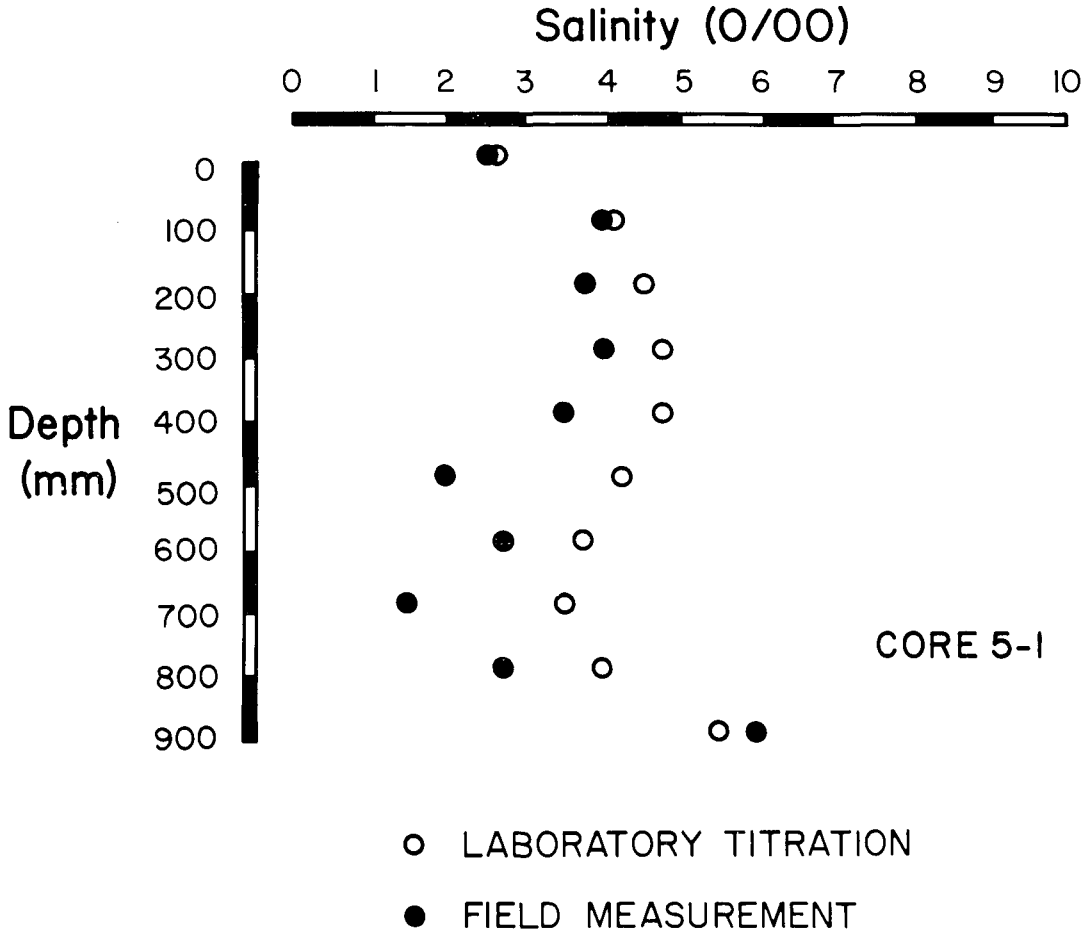


FIGURE 6.15 COMPARISON OF FIELD MEASUREMENT WITH LABORATORY TITRATION; SALINITY PROFILE OF PACK ICE CORES

6.3.2 Density. It is necessary to preface presentation of the results of the density profiles with some remarks on ice type, the technique of sample collection, and density determination.

The ice of the cakes appeared to be very porous. This feature was displayed by the fact that the ice readily shattered when impacted by cutting tools. As well, auger holes which penetrated below freeboard filled quickly (about 30 s) with water. All the ice core samples appeared to have approximately the same porosity, and any fluid in the pore channels drained from the cores when they were removed from the ice.

The ice density determination was by a suspension method. The ice was first suspended in kerosene to determine the weight of kerosene displaced, and then the weight of the ice resting at the bottom of the kerosene filled beaker was measured. This method relates the density of ice to the kerosene and the estimate of the absolute density is calculated based on the density of the kerosene.

Porosity of the ice would not affect the subsequent density measurements if the channels could be maintained to allow the inflow and outflow of the immersion fluid (kerosene). The wide scatter of the density values as presented in Figures 6.16(a) and (b) indicates that the original structure of the ice was not maintained. The exposure of the core to the colder air would, no doubt, cause water to freeze and dam some internal channels. Such structural changes would produce an error in density values and may well explain the scatter of points evident in the results.

The measurements tend to an upper limit of 930 to 940 kg/m^3, whereas the variance shows a negatively skewed distribution away from the maximum.

This type of measurement cannot be used to show if there is any variation of density in the ice because the scatter is greater than any spatially observed trend.

The density profiles for the top 400 mm of the ice cake sampled on the day preceding the SAR overflight are plotted in Figure 6.13, as well as the associated salinity profile.

6.3.3 Crystal Structure. The internal structure of the ice was also determined from the cored samples. As noted, half of each 100 mm section of the core was packaged and stored in a freezer, and returned with the ship to St. John's. Thin sections, which reveal the internal structure of the ice, were prepared in the cold room laboratories of the Engineering Department, Memorial University, Newfoundland.

The thin section preparation technique, detailed by Lau (1977a) involves thinning sections of each ice sample until it is possible to resolve the structure of a single

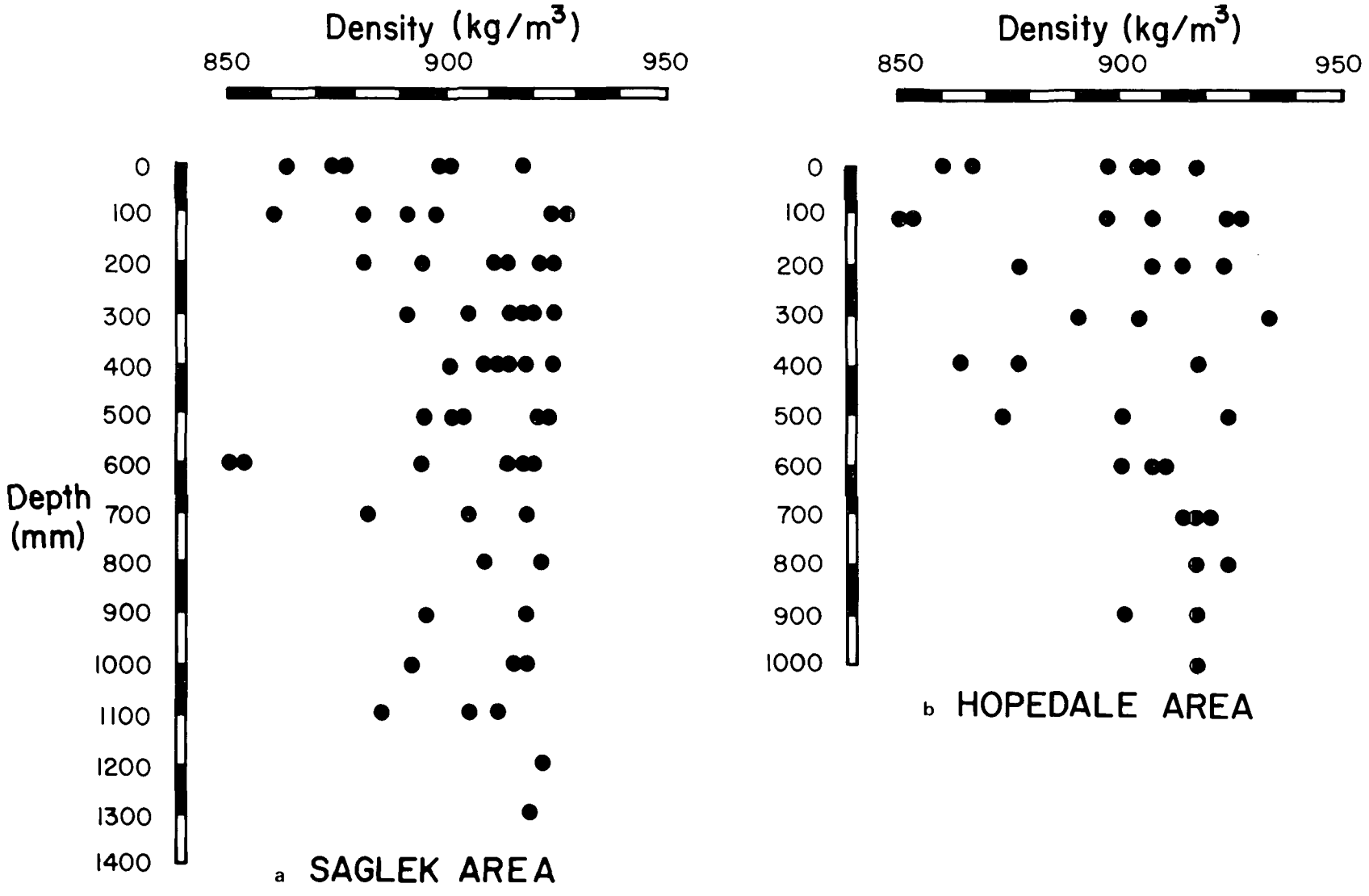


FIGURE 6.16 DENSITY PROFILES OF PACK ICE CORES
(a) Saglek Area; (b) Hopedale Area

layer of crystal grains. The internal composition of the ice is contrasted by a set of polaroid sheets, which are used to polarize incident light. Black and white negative, and colour transparency photographs of each specimen were taken. The results are presented in summary form in Figure 6.17(a) and (b).

The classification method used is detailed by Lau (1977b) and is summarized in Table 6.1. It is an adaptation of the method developed by Michael and Ramseier (1971) for river and lake ice.

The first classification character identifies the period of ice formation and growth: primary (P) for the initial surface cover; secondary (S) for the vertical growth; and tertiary (T) for any superimposed ice accumulation at the upper surface.

The second classification character describes the degree of order in the internal structure. This, in turn, relates to the type of formation process which the material has experienced. High disorder, isotropic grain orientation suggests that there was turbulence at the solidification interface which prevented columnar grain growth by fracture of the frazil ice. Hence, the grains at the freezing front were mechanically stirred to produce a random oriented structure. The structures shown in Figure 6.18(a) and (b) are of this type of ice-equiaxial, regular-sized grains (the scale is given by the 10 by 10 mm grid). In contrast, ordered columnar ice with anisotropic grain orientation forms under still conditions, where the advancing interface is undisturbed by wave or current action. A plane and vertical section of typical columnar ice is illustrated in Figure 6.19(a) and (b). The interlocking and irregular grain boundaries are typical of sea ice.

The third classification character denotes the grain size. Like the degree of order, the grain size is dependent on the hydrological environment and the thermal gradient present during the formation process. A large temperature gradient can reduce the grain size because it increases the probability of nucleation of new crystals.

Structural examination of the thin sections reveals that fine grain (less than 5 mm) structure is the predominant ice type encountered. This ice appears to have isotropic internal properties, with a random distribution of the c-axis direction. This is in contrast with the ice sampled in the Arctic (Weeks and Assur, 1967), in which the normal internal structure is columnar ice. Evidence to date suggests that coastal landfast ice from lower latitudes (50°N) is more than 95 percent fine grained (Lau and Rossiter, 1978). There is a much greater variation of ice types in the offshore pack ice. The ice cores from the Saglek region can be sub-divided into two groups: the defined cake or floe, and

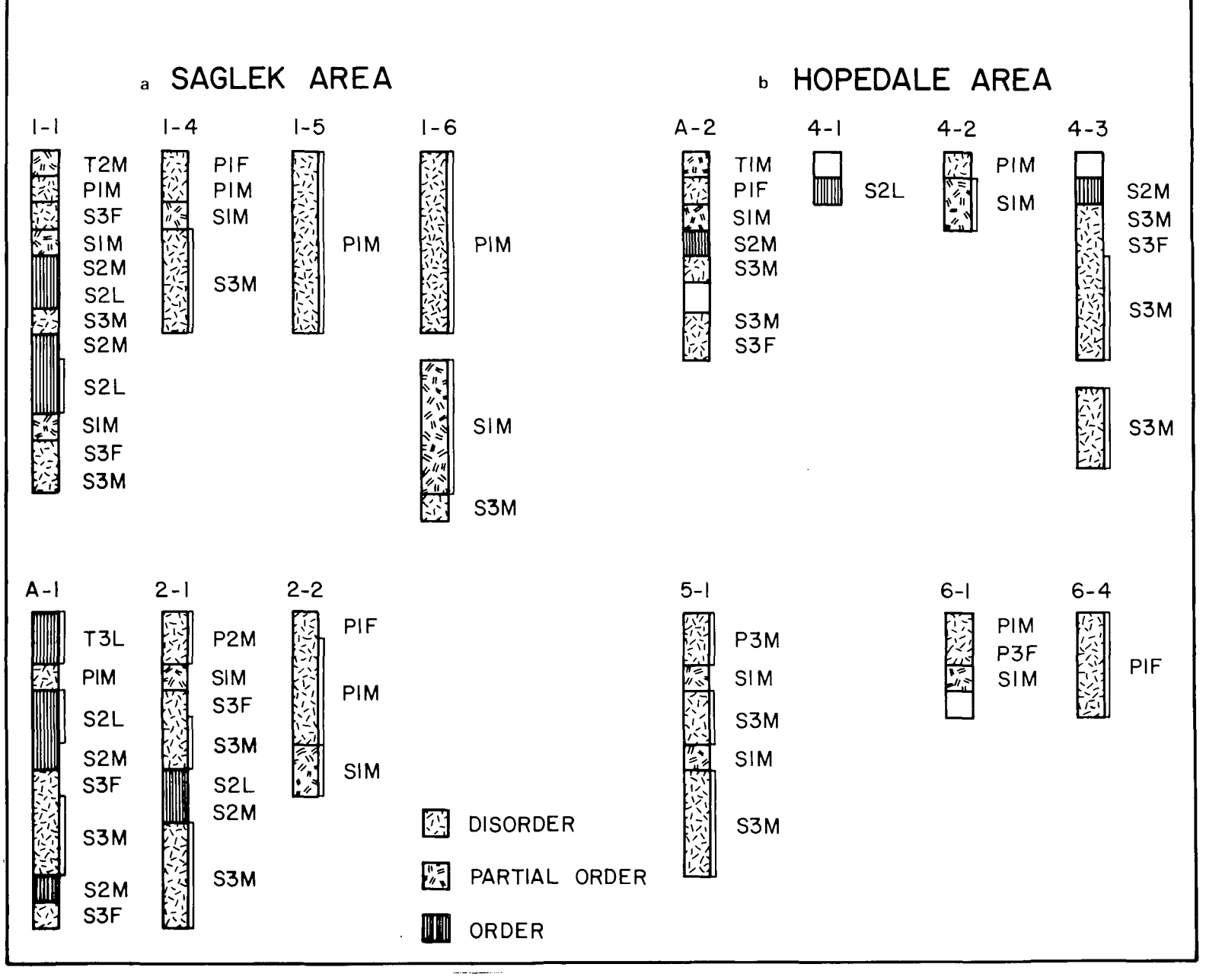


FIGURE 6.17 CRYSTALLOGRAPHY PROFILE OF SEA ICE CORES
(a) Saglek Area; (b) Hopedale Area

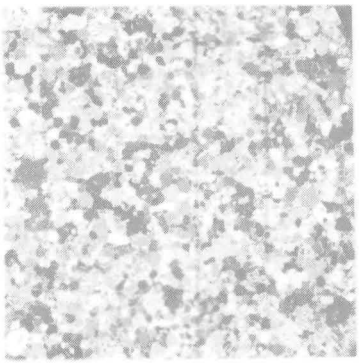
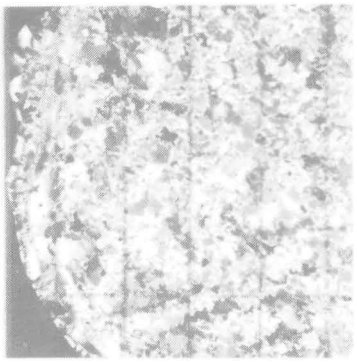
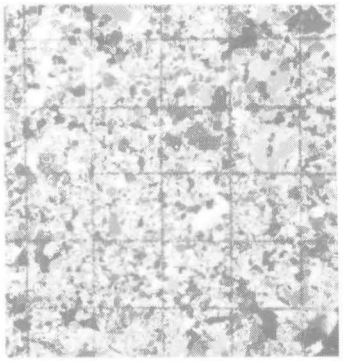
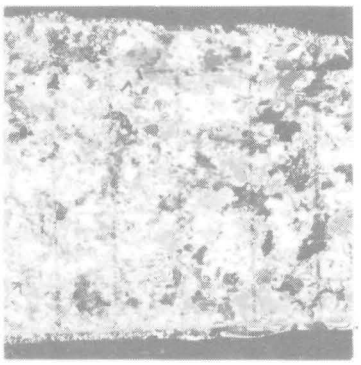
HORIZONTAL SECTION			
VERTICAL SECTION			
FINE less than 1 mm	P1F	P2F	P3F
MEDIUM 1 to 5 mm	P1M	P2M	P3M
LARGE 5 to 20 mm	P1L	P2L	

TABLE 6.1(a) PRIMARY ICE

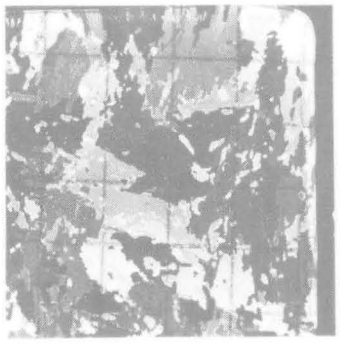
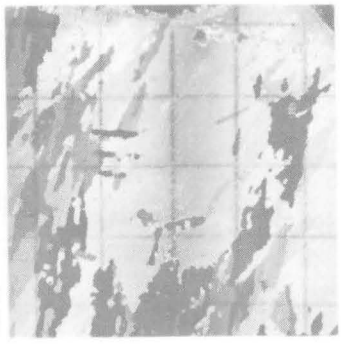
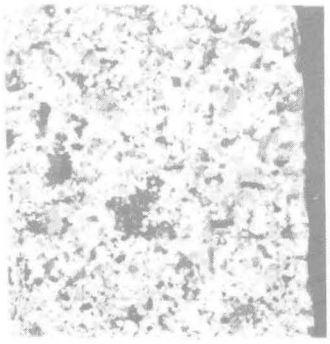
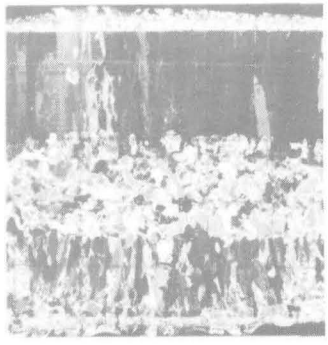
HORIZONTAL SECTION			
VERTICAL SECTION			
FINE less than 1 mm	S1F	S2F	S3F
MEDIUM 1 to 5 mm	S1M	S2M	S3M
LARGE 5 to 20 mm	S1L	S2L	S3L
EXTRA LARGE 20 to 100 mm	S1XL	S2XL	
GIANT		S2G	

TABLE 6.1(b) SECONDARY ICE

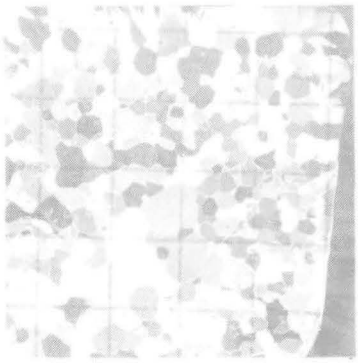
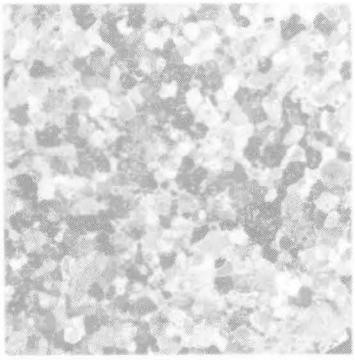
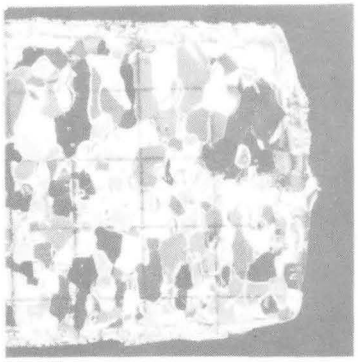
HORIZONTAL SECTION			
VERTICAL SECTION			
FINE less than 1 mm	T1F	T2F	T3F
MEDIUM 1 to 5 mm	T1M	T2M	T3M
LARGE 5 to 20 mm	T1L	T2L	

TABLE 6.1(c) SUPERIMPOSED ICE

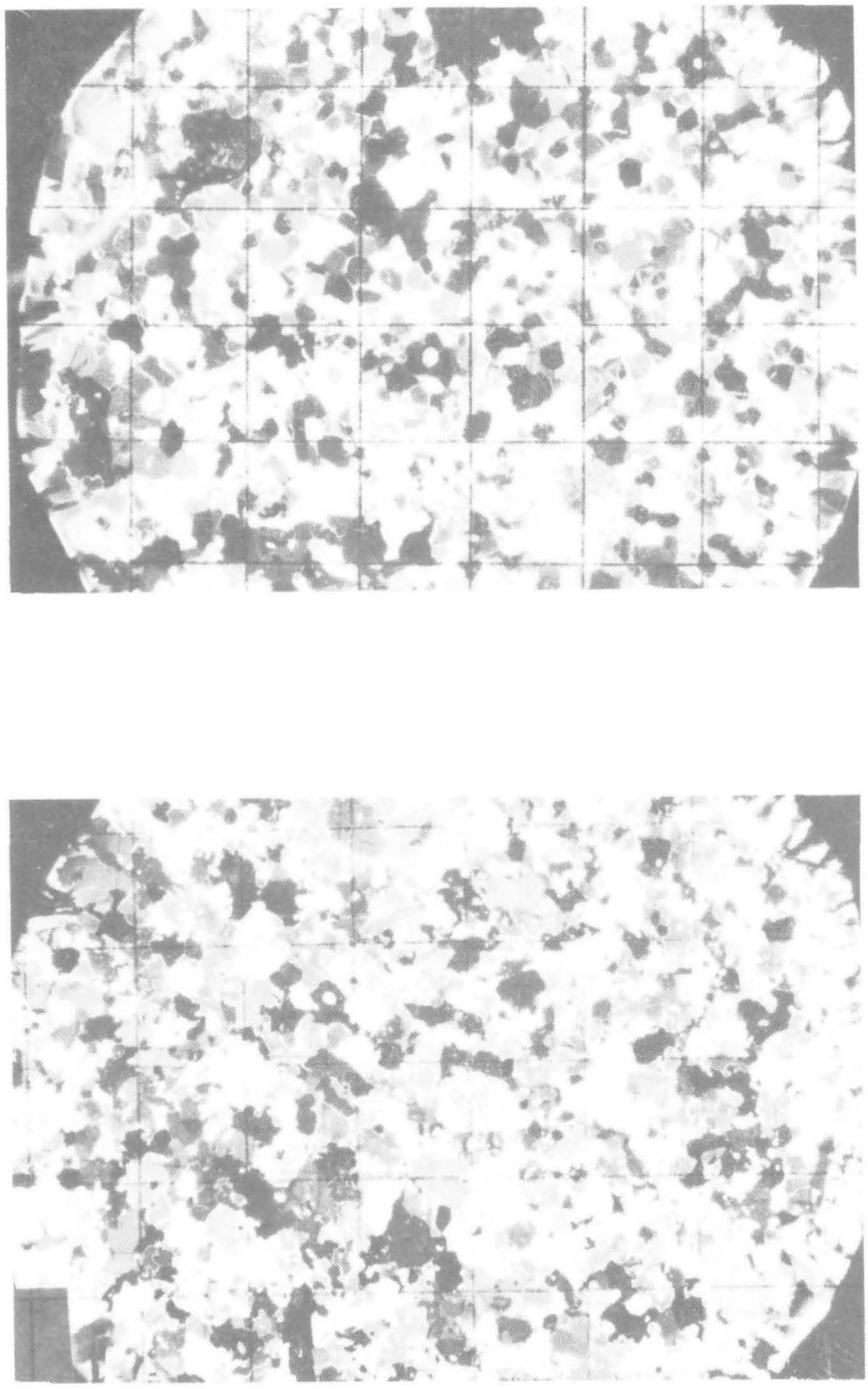
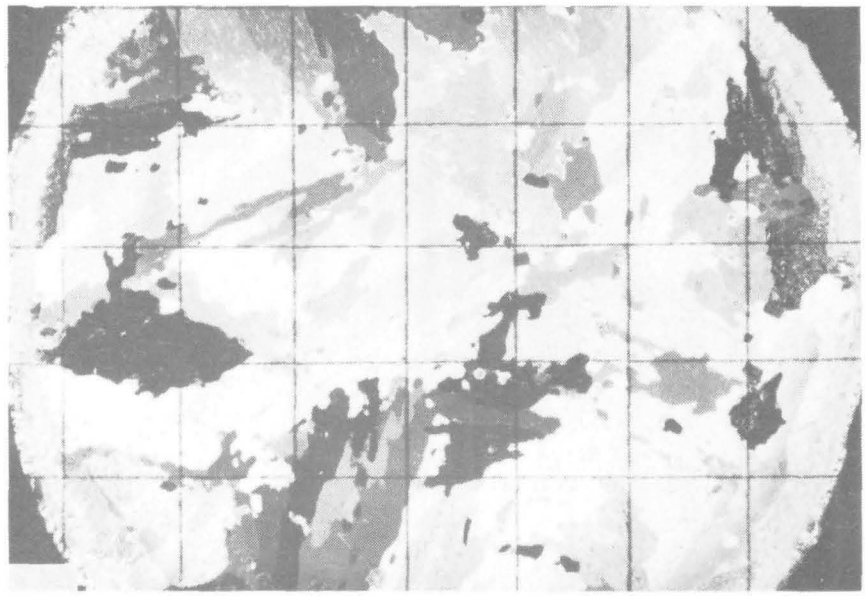


FIGURE 6.18 EXAMPLES OF MACRO-STRUCTURE OF SEA ICE FORMED UNDER TURBULENT HYDROLOGICAL CONDITIONS



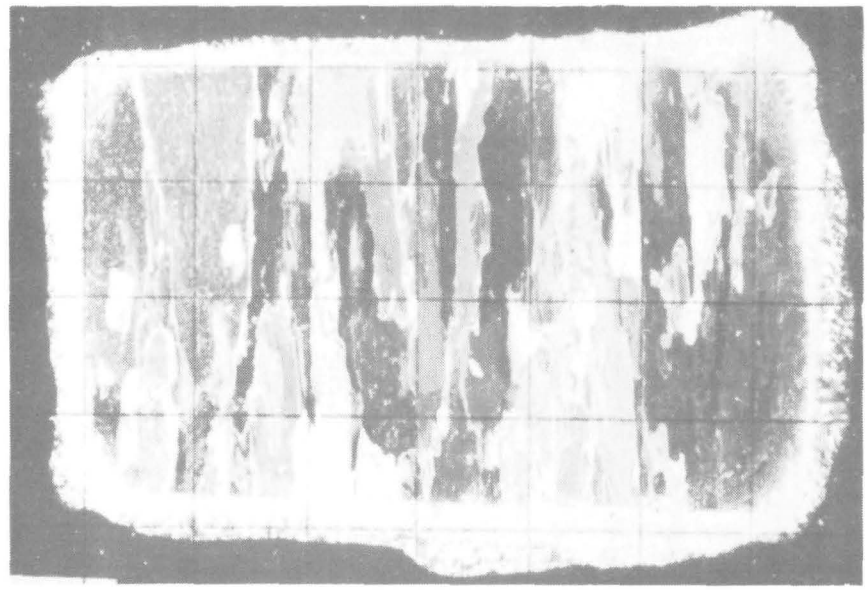


FIGURE 6.19 MACRO-STRUCTURE OF COLUMNAR ICE

the refrozen brash. In every case, the defined cake or floe contains some columnar ice. For example, profiles 1-1 and A-1 in Figure 6.17(a) contain about 50 percent columnar ice (i.e., showing order). This feature is not as well defined for the Hopedale region, Figure 6.17(b), but profile A-2 shows a thin level of columnar ice, type S2M. This large proportion of fine-grained ice suggests that there is continual water agitation at the solidification interface, causing the crystal dendrites to fracture and re-orient before they are incorporated into the thickening sheet.

The ice type which forms is dependent on both the water turbulence at the boundary as well as the rate of growth. In the lower latitudes 50°-60°N, vertical thickening is slow compared to the arctic; hence, there is more time for the water to circulate and fracture the frazil ice at the interface. This slower ice formation process would tend to result in a large fraction of fine-grained ice.

Columnar ice growth occurs when the frazil ice at the interface can advance undisturbed by water movement. There are two possible explanations for the occurrence of columnar ice in the cakes and floes. The first is that there are periods when conditions are quiet enough for columnar growth to proceed and thicken the defined cakes. The second, proposed by Lau (1977c), suggests that the perimeter dam build-up, which is evident on the top side of the floe, also occurs on the underwater side (Figure 6.3g). Such a dam could create a quiet boundary layer of water adjacent to the solidification interface.

In addition to these two distinct thermal gradient solidification processes, there appears to be a third important type of ice accumulation in the drifting sea ice. This is a type of second generation ice. The field is very dynamic, so that open water is continuously exposed by divergence of parts of the field. As soon as open water appears, it freezes, and the new ice thickens quickly. The ice structure in Figure 6.20 is a thin section of ice from a refrozen lead. This section, with indistinct grain boundaries, is typical of young sea ice; however, within the pack, this type of ice appears to be short-lived since it was found only in the one sample.

The aerial photography in Figure 6.21 illustrates how this lead ice is fractured and rafted in still weather. Hence, most of this new ice, which has heretofore been described as frazil or grease ice, would be crushed or abraded to an "ice pulp" in rough weather.

In the absence of any adequate expression, the term "ice pulp" is introduced here to define a semi-fluid ice/water mixture when the ice particles comprise frazil plus abraded, older ice.

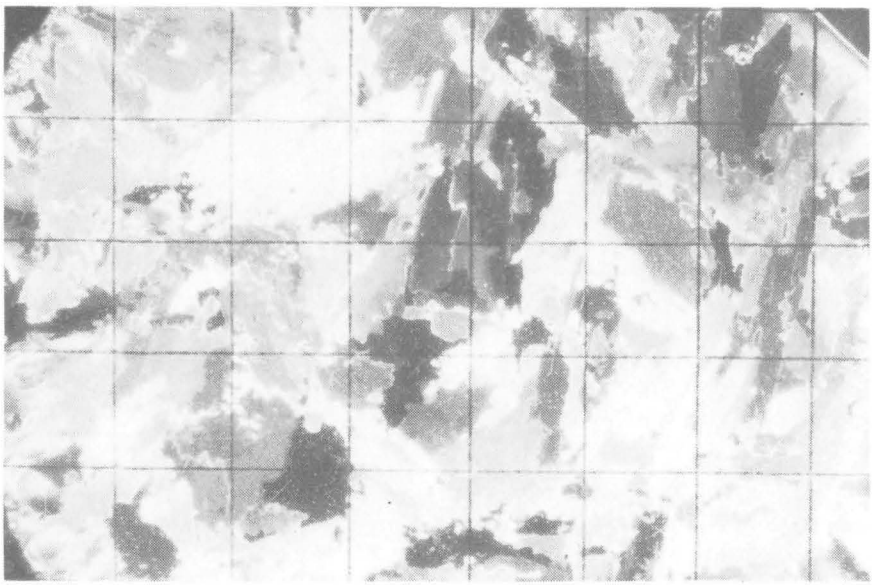


FIGURE 6.20 TYPICAL MACRO-STRUCTURE OF YOUNG GREY SEA ICE

The grinding at the edges of individual cakes contributes to this pulp. At the end of the turbulent period, the ice pulp fills the interstitial gaps between the defined cakes. Since much of this material (70 to 90 percent) is already ice, the pulp can reconsolidate to a solid cover with much less heat removal than is necessary to freeze water. Since the ice field does not have the equivalent self-insulating quality of fast ice, the presence of ice pulp can explain the occurrence of very thick ice in the pack. It can also explain why the internal structure of pack ice is mainly fine grained. Refrozen ice, which cements the defined cakes into continuous floes, is comprised almost exclusively of frozen ice pulp. This is illustrated by cores 1-4, 1-5, 1-6 and 2-2 in Figure 6.17(a).

It is interesting to note that this second generation ice (refrozen ice pulp) does not possess high salinities. In fact, in cases where the ice was maintained above free board, salinities are below normal. These observations indicate that in the relatively high air temperatures (-10 to $0^{o}C$) of the offshore region, the normal brine rejection mechanism of sea ice formation is rapid compared to the advance of the solidification interface.

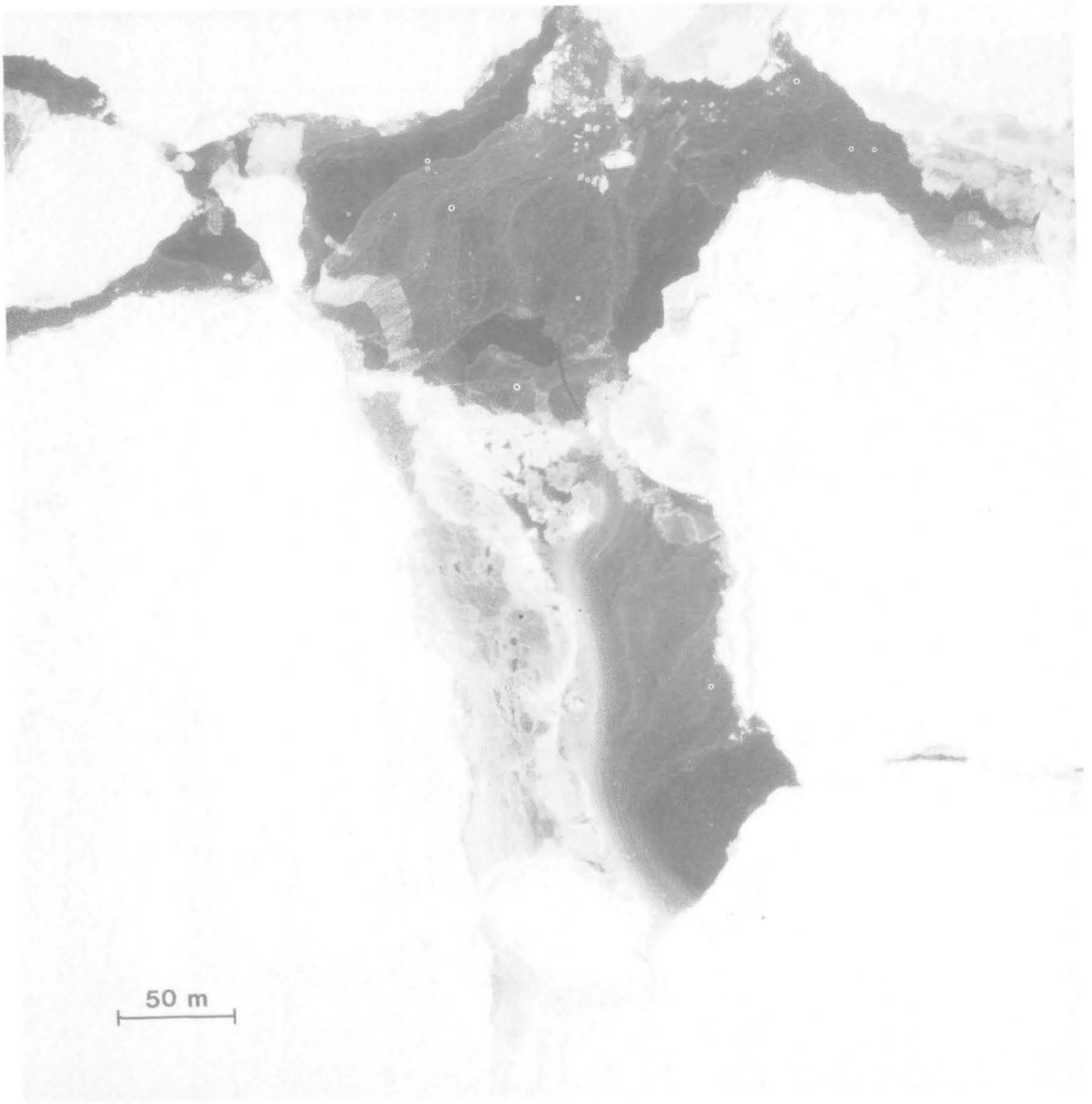


FIGURE 6.21 YOUNG SEA ICE FORMS CONTINUALLY ON LEAD WATER WITHIN THE PACK ICE

6.4 Snow Features of the Sea Ice Cover

Using the Geotest F40 snow characterization kit, six stations were completed at various locations on the sea ice cover in the area referred to as the Hopedale region. This work was undertaken to provide ground truth information for the SAR remote sensing overflight. Sampling was carried out from February 20, 1977, after the ship had travelled into the prospective image area, until February 25, when the overflight occurred.

The objective was to provide a sampling of the types and amounts of snow cover overlying the ice. The results illustrate the spatial distribution of the snow cover within the local ice field. There was no opportunity to resample any one site to evaluate how much snow accumulated from a snowfall in relation to the actual precipitation. The density, hardness and temperature measurements along with the documentation of snow features followed the format suggested in the manual accompanying the kit (Geotest, 1962).

Results are presented in summary form in Tables 6.2 and 6.3. The snow depth varied between 140 and 470 mm for the different sites tested. There was a snowfall which dropped 194 mm on Goose Bay and 205 mm on Hopedale overnight on February 21-22, 1977. The snow was accompanied by winds of 15 to 35 km/h, so that most of this snow probably accumulated with ice pulp filling the gaps between the defined floes.

Based on this information, one would suspect that the extent of the snow cover on the ice is dependent on the age of the particular floe. New floes appear to be generated continually within the pack. The surface features of floes also change so that the catchment basin of individual floes varies over time. Defined floes are normally ringed by a dam of crushed ice debris, which leaves the top surface of the floe like a shallow dish which fills up with snow. Above this dam or ridge, there is little to hold wind-blown snow on a floe. Further accumulations of snow are likely to be deposited in the lower regions between distinct floes and transformed to slush by contact with the water.

At the time of the remote sensing overflight, there was a thick snow overburden that covered the floes. Those pans with a ridge on them were so weighted down with snow that water was visible on the ice surface at the centre. The cake on which the final snow station was done (station 5) was atypical, and appeared to be a thin piece of refrozen lead. It lacked a perimeter ridge of ice debris, so there was less snow accumulated on it than on most of the surrounding floes.

TABLE 6.2 SNOW STATION DESCRIPTION

Station Number	Date (Feb. 1977)	Time (NST)	Location	Description
1	20	1530	55°44'N 57°53'W	Medium floe (50 x 60 m). Ice characterization line 6-0. In tightly packed ice cover. Strainmeter instrumented floe A-2.
2-1	21	0925	55°43'N 57°53'W	Newly refrozen rubble, about 250 mm thick. Ice characterization line 5-0 at 95 m point.
2-2	21	1020	55°43'N 57°53'W	On a distinct pan (7 x 6 m) refrozen in the continuous cover. Ice characterization line 5-0 at 152.5 m point.
3	23	1555	55°29'N 55°50'W	On a loose floe 1.75 m thick at centre; 2.40 at edge. Floe size range 5 to 25 m. Ice characterization line 7-0.
4	24	1305	55°05'N 54°39'W	Loose floe 24 x 11 m. Average snow thickness for floe 220 mm (n = 24). Ice characterization line 8-0.
5	25	1305	54°27'N 54°01'W	Loose floe; floe size range 5 to 15 m.

TABLE 6.3 SUMMARY OF SNOW STATION DATA

Station No.	Surface Feature	Snow Thickness (mm)	Crystal Layer (T=Top)	Classification Description	Density (kg/m^3)	Hardness (g/cm^2)	Depth (mm)	Temperature Profile (°C)	Temperature Air (°C)
1	Rippled	340					10	-12	-12
			T-190	Plates	340	250	50	-9	
							150	-8	
			190-340	Plates	280	150	250	-6	
2-1	Smooth	140	T-100	Columns	120	1	~ 50	-9	-10
			100-140	Plates			~100	-8	
2-2	Smooth	270							-10
							10	-9	
			T-90	Cry. fine	180	5	40	-12	
			90-270	Cry. fine	280	50	130	-10	
							210	-5.5	
3	Smooth	470							-17
					140		T	-17	
					210		100	-14.5	
			T-340	Powder	190	25	200	-12	
							300	-10	
			340-470	Asym. Cry.	200	25	450	-4	
4	Smooth	290							-5
			T-30	Crust	168	120	T	-4	
							~ 50	-8	
			30-100	Light fine Cry.	160	15	~100	-8	
							~150	-8.5	
			100-260	Dense fine Cry.	256	130	~200	-8	
							~250	-6.5	
			260-290	Large Cry.	208	6	290	-5	
5	Smooth	200							-0.6
			T-70	Dense New (Wet)			T	0	
							50	-1.5	
							100	-3	
			70-200	Dense Cry.			150	-3	
							200	-3	

In addition to carrying out snow stations, six snow samples from various surface locations were melted down and salinity determined. All values were quite low, generally below the range detectable on the YSI SCT meter in use ($\leq 1^{o}/oo$).

6.5 General Observations on Ice Formation

The Labrador ice field is a massive ice cover omitting its southern extension off the coast of Newfoundland (approximately 150,000 km^2 adjacent to the coast, omitting its southern extension off the coast of Newfoundland) which moves generally southward under the combined influence of wind and ocean currents. The landward boundary is defined by the extent of the landfast ice which normally stretches from headland to headland, or between islands. The seaward boundary varies from 100 to 200 km offshore. The evidence presented in this study indicates that most of this ice has formed in the open ocean.

In the early stages of formation, ice develops as small pancakes, a feature which is evident in the irregular top surface of the ice encountered. Pancake ice continues to form throughout the winter at the ice edge. In the presence of sea surface motion, once the ice is substantial enough to develop rigidity, there is continual abrasion between cakes. This grinds away at the edges to produce a thick layer of ice pulp that occupies the interstital area between the cakes. Frazil ice formed in the water column probably also contributes to the ice pulp.

The accumulating ice cakes tend to attenuate ocean swell; so within the field, the combination of low temperature and a still surface will allow the cakes to consolidate into relatively large floes of continuous coverage. The surface of these floes is extremely rough, making it difficult and hazardous to operate any existing type of surface transport vehicle.

During relatively quiet conditions, the water current (and possibly wind stress) causes the floes to break and diverge. The relative movement creates open areas of water within the ice. At low air temperatures, this open water freezes, producing short-lived areas of new ice, which are rafted and crushed by movement of the thicker floes (Figure 6.22). In the Arctic, leads often produce ridge material (Parmerter and Coon, 1972); however, in the Labrador offshore, new lead ice does not usually contribute material for ridge formation.

The floes, comprised of loosely cemented cakes, are weak in the bending mode and break readily under the influence of swell. During extended periods of incoming ocean swell, the ice breaks into fragments (this mechanism has been documented by

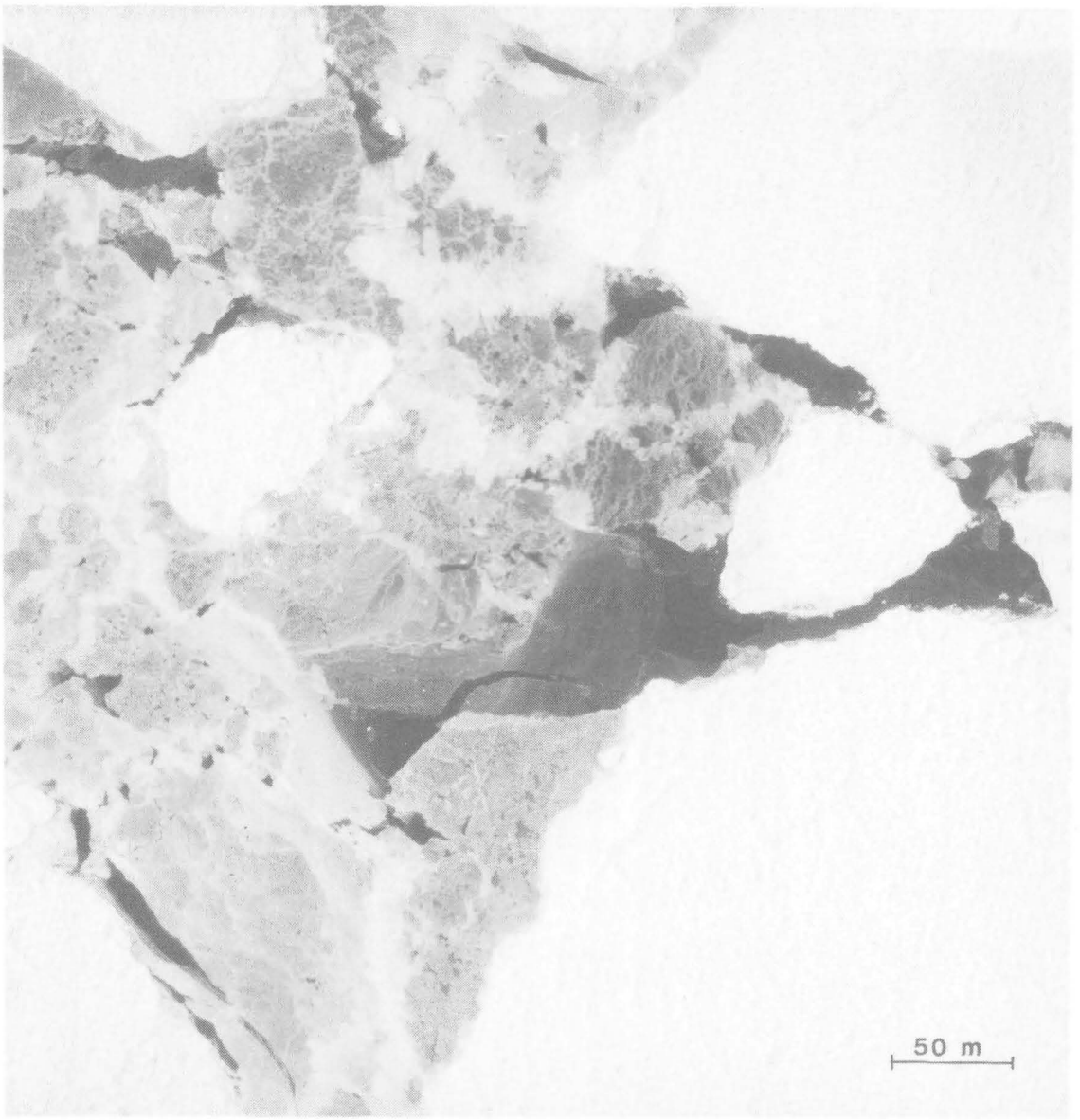


FIGURE 6.22 AERIAL PHOTOGRAPH ILLUSTRATING NEW ICE FORMATION AND RELATIVE MOVEMENT WITHIN THE ICE FIELD

Squire and Allan, 1977) or cakes of diameter 5 to 15 metres. The extent of the break-up will depend on factors such as floe thickness and size; degree of cementing; wind velocity and direction; and swell direction, period and amplitude.

After the ice has diverged, relative movement between the fragments will cause the edges to abrade again, producing ice pulp. Such a mixture can accumulate to considerable thickness as a consequence of a one or two-day storm.

After the ice fragments, and if the ice movement is limited at a boundary, the pack can again be compressed. The sound of the particles of ice moving relative to one another can be heard at the ice level, confirming that the ice is forced together rather than frozen. Any ice pulp present will be pushed down to underlie the solid cover. The forces within this type of compression field can be directional; hence, it is a stress rather than a pressure.

Areas under lateral compression are marked by the formation of small pressure ridges. Such ridges are most likely to consist of fragmented ice created by the break-up process rather than the thinner lead ice. It is difficult to navigate a ship in such areas. Even though the ice is already broken, the ship possesses no means by which to clear the ice from the bow region. When forward progress of the vessel is halted by ice, the boat backs up to ram. However, as the vessel moves astern, ice pushes in again to fill any open water; hence, little or no forward progress is achieved.

While pack ice under lateral stress is somewhat unstable, no doubt it could freeze into a solid cover if the temperature were to remain low and conditions stabilize for a long enough time period. The ice features of the continuous pack ice cover observed suggest that this condition is created when compression abates (e.g., the wind changes from a particular bearing). When this occurs, the ice mixture (cakes, floes, ice pulp) re-orients and the ice pulp surfaces, where it acts to grout and cement the floes into a continuous cover.

The rough ice surface and the internal crystal structure of the ice itself are evidence that the breaking/reforming process described above is continual throughout the winter season. The cycle time is probably in the order of five to ten days, as this is the frequency with which storm tracks pass through the region during the winter. Not all phases need to occur in a given cycle; further, conditions such as lateral compression can be very localized to areas in which dimensions are in the order of a few kilometres.

Clearly, the pack ice has a (growth) history which is quite different from that of fast ice. This is illustrated by the thicker accumulation of first year pack ice;

thicknesses of up to four metres were measured. Such thickness cannot be achieved by a continuous sheet growing parallel to the thermal gradient across the interface. For example, assuming about 1500 deg. days of frost by mid-February, the predicted thickness would be in the order of 1.4 m.

ACKNOWLEDGEMENTS

The authors make grateful acknowledgement to: the participants in the Ship-in-the-Ice Program, a joint study carried out by the NORDCO and C-CORE research groups; D. Dunbar, of NORDCO, who must receive credit for the photographs comprising Figures 6 and 9 of this chapter; G. Lau, for the preparation of the layout of the photographic work; and A. King and G. Lau, for the preparation of the ice thin sections of the field samples.

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CHAPTER 7
ICEBERG HAZARD

by
K.A. Gustajtis

Centre for Cold Ocean and Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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7 INTRODUCTION

Icebergs have always been a significant hazard to shipping and navigation in the northwest Atlantic, especially in the winter and spring when they increase in number. Further north along the Labrador coast, icebergs are present throughout the year, with a seasonal peak in late spring and early summer.

With the advent of offshore exploration in the Labrador region, the need for an oil rig to move out of the way of an approaching iceberg was clearly evidenced by the near disaster of the *Typhoon* (Chapter 9) which in 1971 drilled the first exploratory well in the area. At the present time, the use of dynamically positioned drillships has facilitated the ability to move off site quickly if an approaching iceberg cannot safely be towed away.

Icebergs reported during the drilling season in the Labrador region ranged in size from 100,000 tons to as much as 20 million tons. A 10-million ton iceberg has a sail height of 50 to 75 m and a keel depth of 200 to 300 m. Such an iceberg is comparable to a 100-storey office building.

7.1 Seasonal Variability

The most reliable source of iceberg data along the Labrador coast is the International Ice Patrol, which is operated under the auspices of the U.S. Coast Guard. Seasonal iceberg density distributions for the Labrador region have been discussed in a recent paper (Gustajtis and Buckley, 1977), from which Figures 7.1 to 7.4 have been obtained.

During the winter, the total number of icebergs along the Labrador coast is relatively low, with the southern extent reaching 55-57°N latitude, coinciding approximately with the sea ice boundary. By the spring, the iceberg distribution covers the entire Labrador offshore, with iceberg numbers peaking in a central core along the outer continental shelf, and dropping off rapidly both landward and seaward. With the dissolution of sea ice and the presence of warmer surface temperatures, iceberg deterioration commences at a rate indicated by Table 7.1 (Murray, 1969). By late fall, iceberg concentrations along the coast have usually dwindled to a few isolated individual icebergs.

Both the total number as well as the relative size of individual icebergs decreases southward from 60°N latitude. Table 7.2, based on historical iceberg records from the International Ice Patrol (1963 to 1977 inclusive), illustrates the size distribution

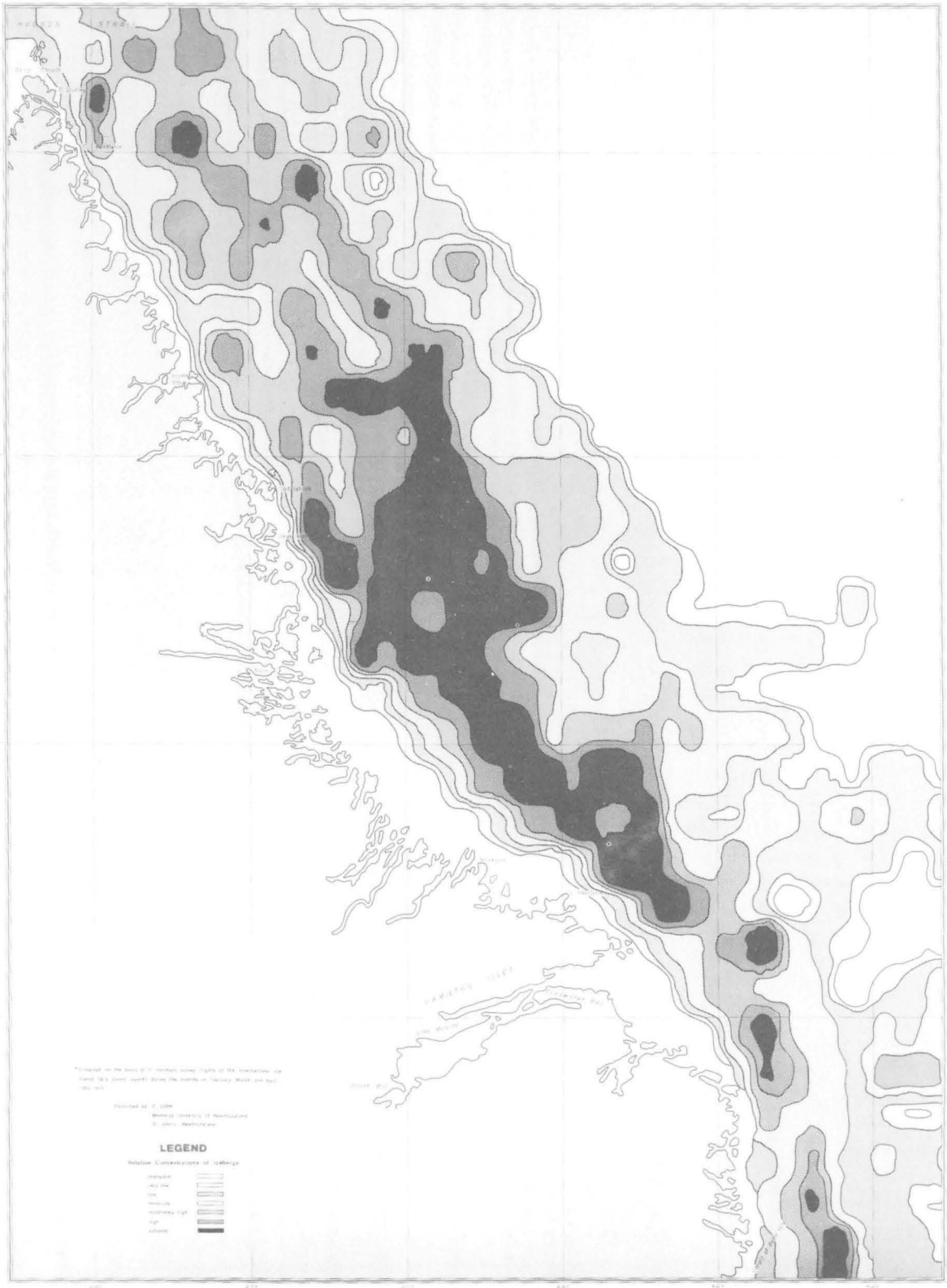

FIGURE 7.1 AN AVERAGE SPRING* ICEBERG DENSITY DISTRIBUTION ALONG THE LABRADOR COAST (Source: Gustajtis and Buckley, 1977)

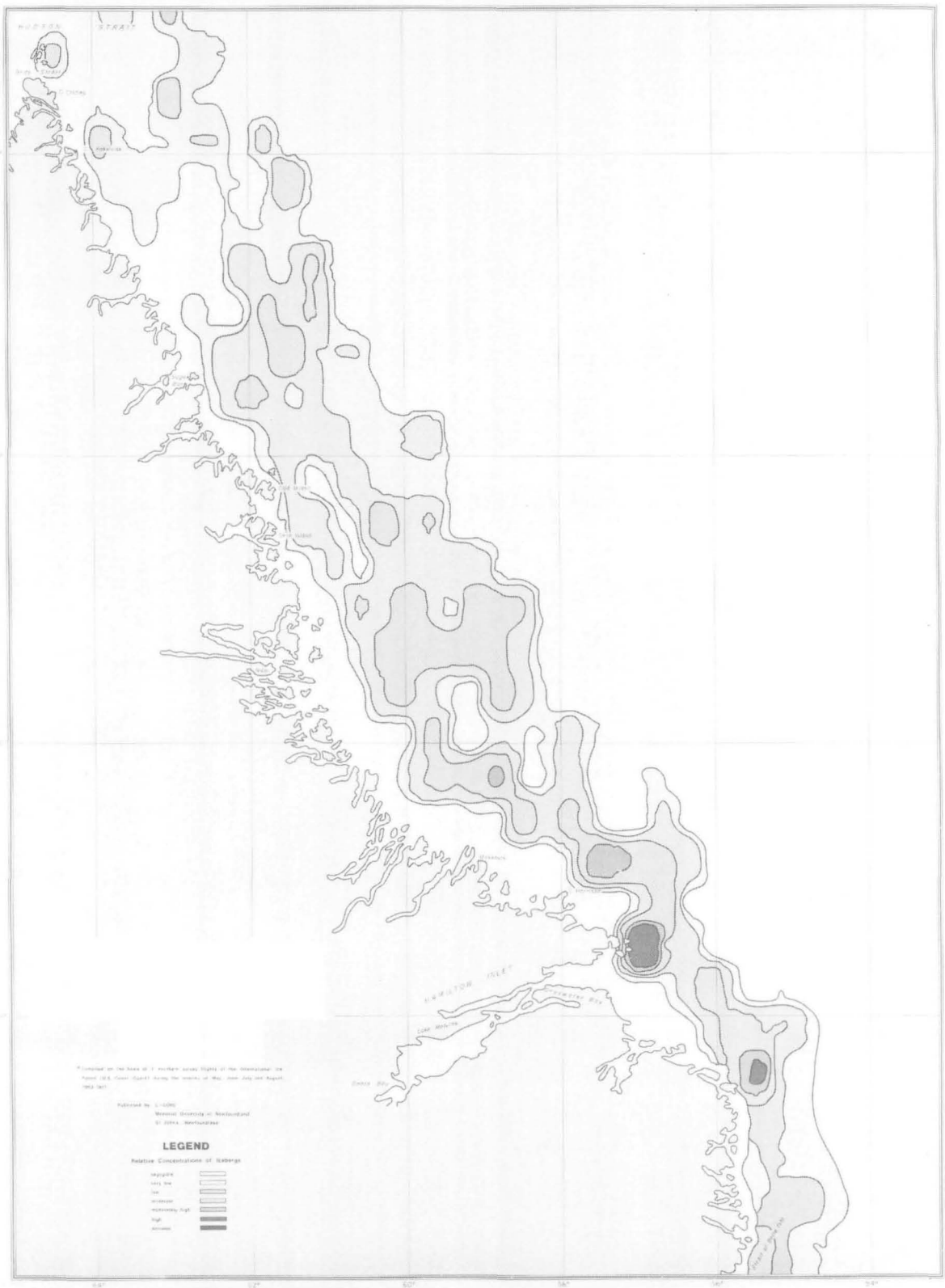

FIGURE 7.2 AN AVERAGE SUMMER* ICEBERG DENSITY DISTRIBUTION ALONG THE LABRADOR COAST (Source: Gustajtis and Buckley, 1977)

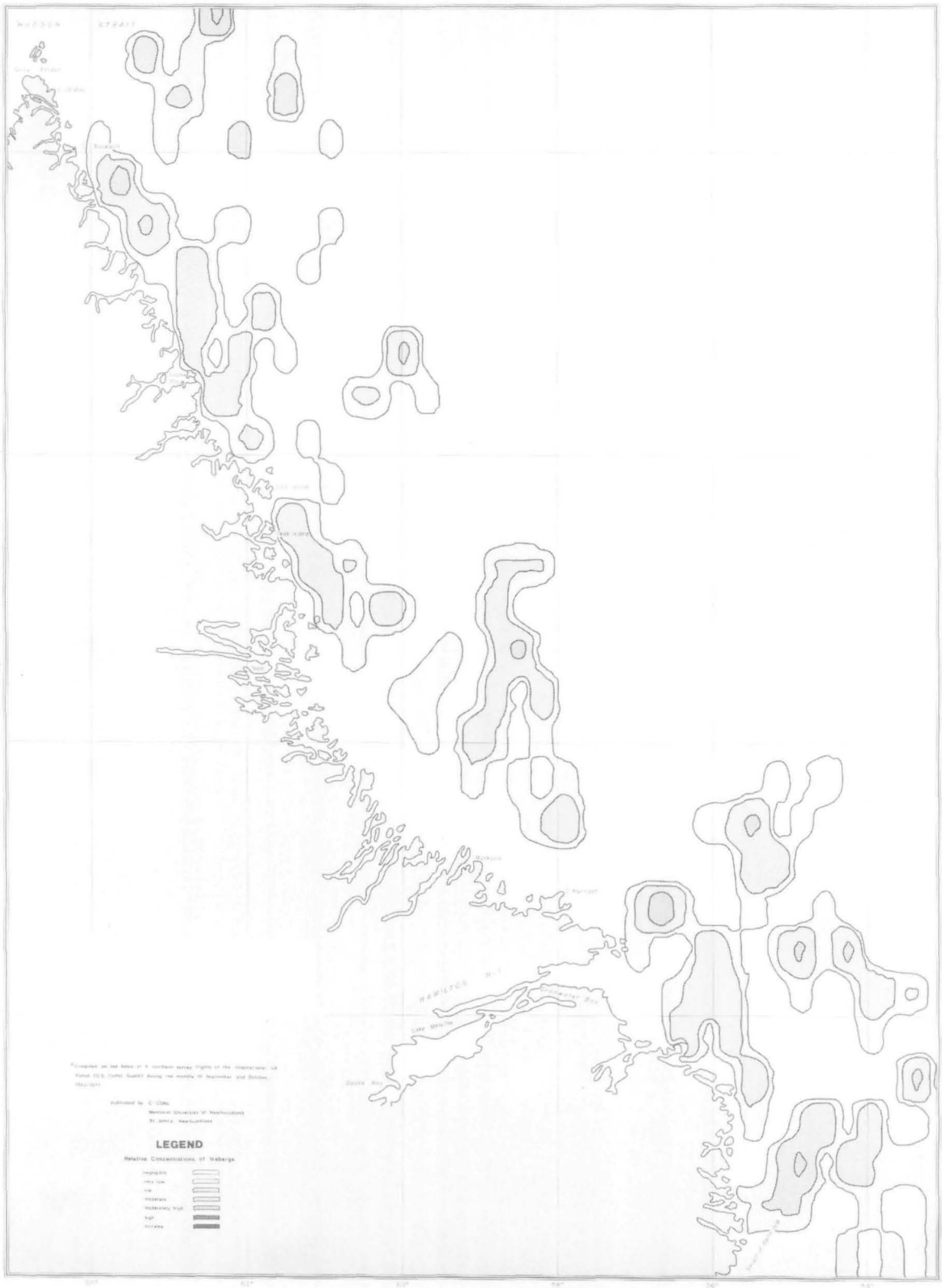

FIGURE 7.3 AN AVERAGE FALL* ICEBERG DENSITY DISTRIBUTION ALONG THE LABRADOR COAST (Source: Gustajtis and Buckley, 1977)

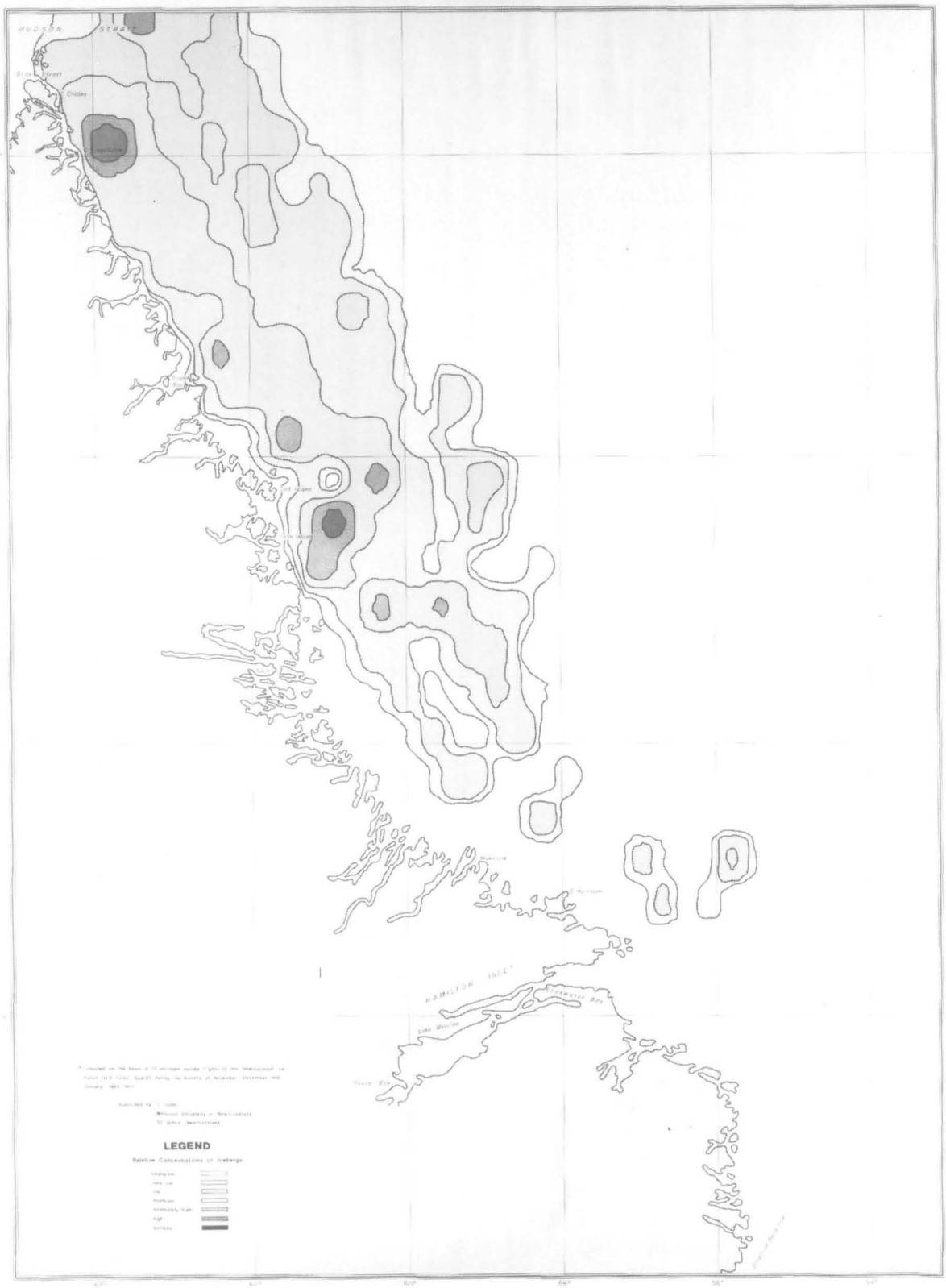

FIGURE 7.4 AN AVERAGE WINTER* ICEBERG DENSITY DISTRIBUTION ALONG THE LABRADOR COAST (Source: Gustajtis and Buckley, 1977)

TABLE 7.1 DETERIORATION TIME IN DAYS FOR ICEBERGS
(Source: Murray, 1969)

Type of Iceberg	Seawater Temperature (°C) 2	4
Small (20 m high and 50 m long)	8 days	5 days
Medium (35 m high and 100 m long)	16 days	10 days
Large (> 40 m high and > 100 m long)	24 days	15 days

TABLE 7.2 SIZE DISTRIBUTION OF ICEBERGS REPORTED BY THE INTERNATIONAL ICE PATROL (1963-1977) PER DEGREE LATITUDE
(Percent Distribution)

°N	Growlers	Small	Medium	Large
60	6.4	43.3	33.5	16.8
59	4.2	49.9	29.4	15.5
58	4.2	48.0	36.6	11.2
57	4.3	41.9	42.2	11.7
56	5.1	51.6	34.1	9.3
55	3.9	61.4	27.8	7.0
54	16.6	52.3	24.5	6.7
53	10.2	52.4	26.5	10.9
52	16.7	52.2	24.6	6.5

found for the Labrador region. Large icebergs, defined as those greater than 100 m across, decrease in relative number from approximately 15 percent in northern Labrador to approximately 6 percent at 52°N, whereas growlers increase by approximately the same proportion. The data base for this table is derived from flights made during the winter and early spring. In the summer and fall, a similar distribution would be expected; however, the total proportion of larger icebergs would be reduced.

7.2 Iceberg Impact Effects

The development of radar has facilitated the detection of icebergs, particularly under poor visibility conditions. However, the small iceberg fragments or "growlers" (approximately the size of a piano and of the order of less than 1,000 tons) continue to present a serious threat. Under calm conditions, growlers can be detected by radar at distances of three to four km with reasonable reliance; however, during moderate and rough sea conditions, when sea clutter extends beyond three km on the radar scope, growlers large enough to cause serious damage to ships may pass undetected.

A plot of maximum range of detection of icebergs as a function of the cross-sectional area, taken from Dinsmore (1972), is shown in Figure 7.5. It can be seen that for icebergs having a broad cross-section, the expected range is between 15 and 20 km (10 to 15 nautical miles). However, for sea ice floes and growlers having an exposed cross-section of 10 and 100 ft^2, the maximum range of detection is two and four nautical miles, respectively.

Iceberg ice has a reflection coefficient of approximately 0.33 and reflects radar waves 60 times less effectively than a ship of equivalent physical cross-sectional area. The prime concern therefore would be that these poorly visible, low lying ice masses may hit a vessel, causing substantial damage.

Additionally, it should be noted that the drillships such as the *Pelican*, which have operated in recent years in the Labrador sea, are ice reinforced only forward, and are essentially conventional vessels for the greater part of their length. As such, these vessels should not be considered ice strengthened while in the drilling mode. Figure 7.6 presents the results of a study commissioned by the Eastcoast Petroleum Operators Association (Chapter 14) which illustrates that even a relatively small iceberg fragment can produce substantial damage if it is travelling at speeds of the order of 50 cm/s (one knot).

The average rate of iceberg drift has been estimated at about 2.5 percent of the wind velocity, and in the Labrador region to be at approximately 30° to the right of

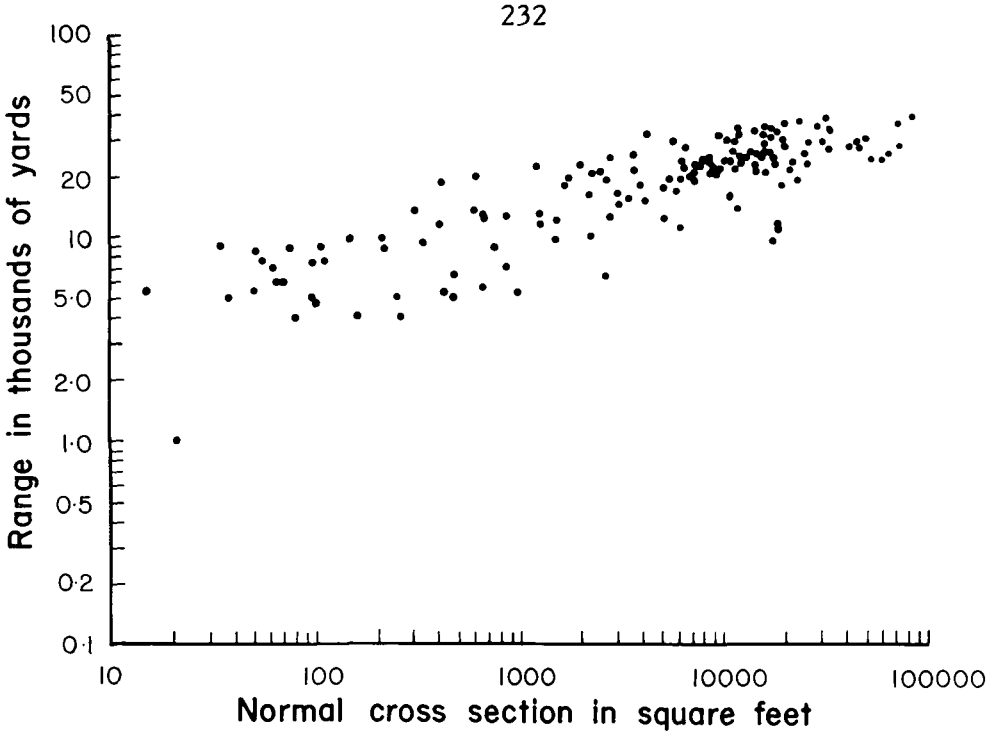

FIGURE 7.5 RELATION BETWEEN RADAR MAXIMUM RANGE OF DETECTION AND ICEBERG PHYSICAL CROSS-SECTIONAL AREA ILLUMINATED AT THE MAXIMUM RANGE
(Source: Dinsmore, 1972)

the wind direction. However, accurate iceberg drift predictions are still highly speculative and in an early experimental stage.

7.3 Probability of Impact

This section considers the monthly probability of an iceberg 100 m across at the waterline striking a drilling platform 150 m in diameter. The calculations made are based on the simplistic assumption that icebergs travel in a straight line.

Anderson's (1971) monthly flux numbers were used, as shown in Table 7.3. Calculations of distribution along lines of latitude were based on the information portrayed in Figure 7.7 for the years 1963 to 1967 (Murray, 1969). The flux numbers of icebergs across each degree of latitude were calculated per one degree longitude from shore, as summarized in tabular form in the Appendix to this chapter.

The probability of contact designated P (θ) between an iceberg with an approach angle θ and a platform size s in a rectangle size E x S where E is the distance of one degree latitude and S the distance of one degree longitude for the geographical area under study can be expressed as follows (Blenkarn and Knapp, 1969):

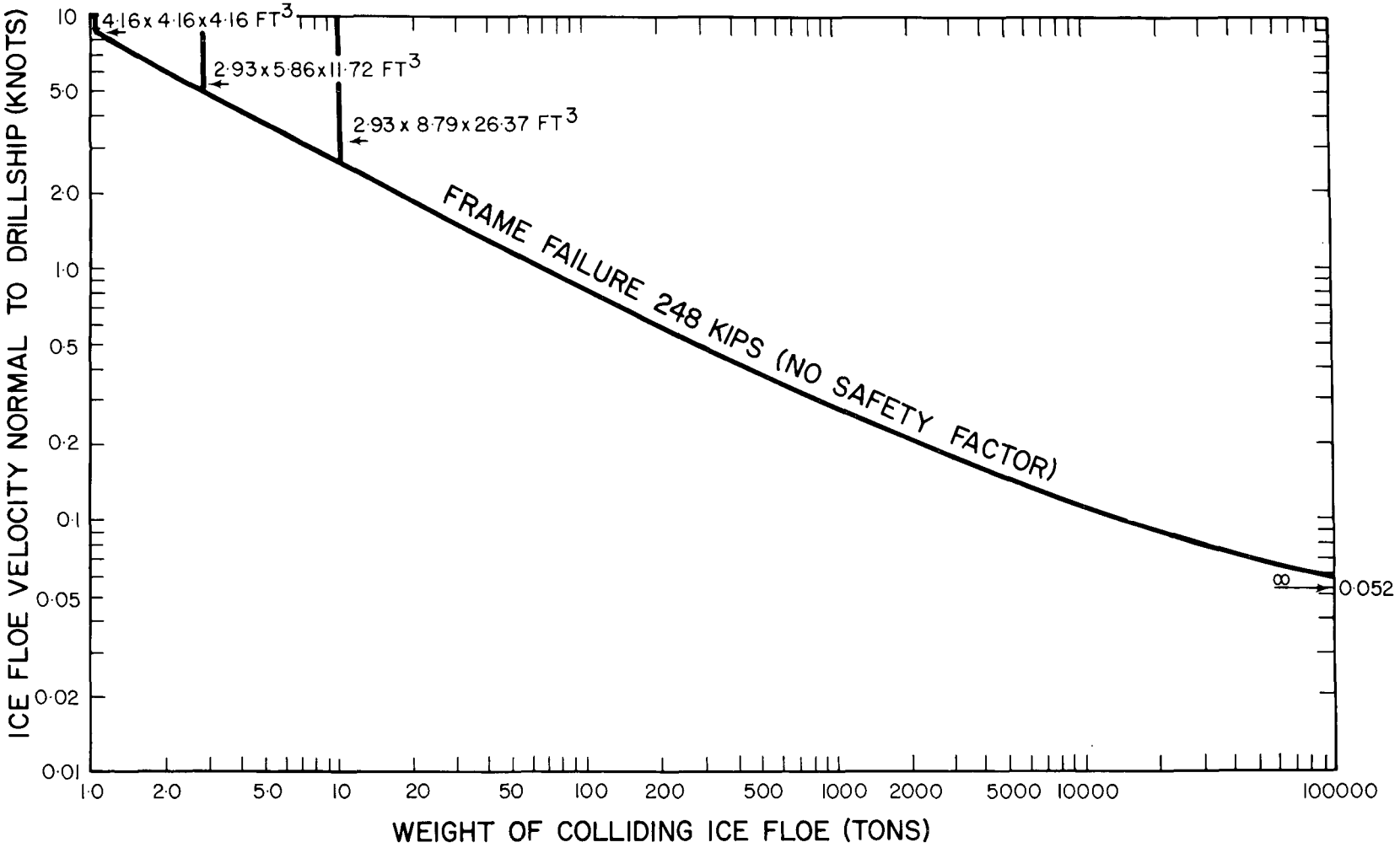

FIGURE 7.6 ICEBERG IMPACT EFFECTS AS A FUNCTION OF SIZE AND SHAPE
(Source: Total-Eastcan Exploration Ltd., 1972)

TABLE 7.3 MONTHLY AVERAGE FLUXES OF ICEBERGS ACROSS EACH DEGREE OF LATITUDE

Flux Across	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
61°N	106	95	134	135	145	138	122	86	60	49	49	87	1206
60°N	103	95	128	131	144	142	124	87	51	40	40	74	1159
59°N	97	94	122	130	142	141	129	90	53	26	36	59	1119
58°N	87	92	115	129	139	140	135	95	62	21	26	43	1084
57°N	73	88	112	128	132	137	127	99	56	20	16	31	1019
56°N	49	77	112	112	133	134	122	106	68	28	10	19	966
55°N	31	59	99	105	126	130	120	118	75	35	11	10	909
54°N	17	39	82	98	116	118	91	81	49	32	15	6	744
53°N	12	30	73	93	111	107	64	54	33	23	11	2	613
52°N	9	23	62	89	106	102	42	34	22	14	9	0	512
51°N	4	14	40	76	86	67	37	11	2	5	5	0	347
50°N	3	8	35	66	75	32	22	5	1	2	3	0	263

Source: Anderson, 1971

$$P(\theta) = \frac{W + s}{W}$$

where W is the width of the rectangle normal to the iceberg path. From geometry,

$$W = \frac{1}{E\cos\theta + S\sin\theta}$$

If it is assumed that all approach angles are equally likely, P(A), the probability averaged over all possible values of θ can be expressed as:

$$P(A) = \frac{2}{\pi}\int_0^{\frac{\pi}{2}} \frac{(w + s)\, d\theta}{E\cos\theta + S\sin\theta}$$

performing the integration:

$$P(A) = \frac{1.149\,(W + s)}{E^2 + S^2}$$

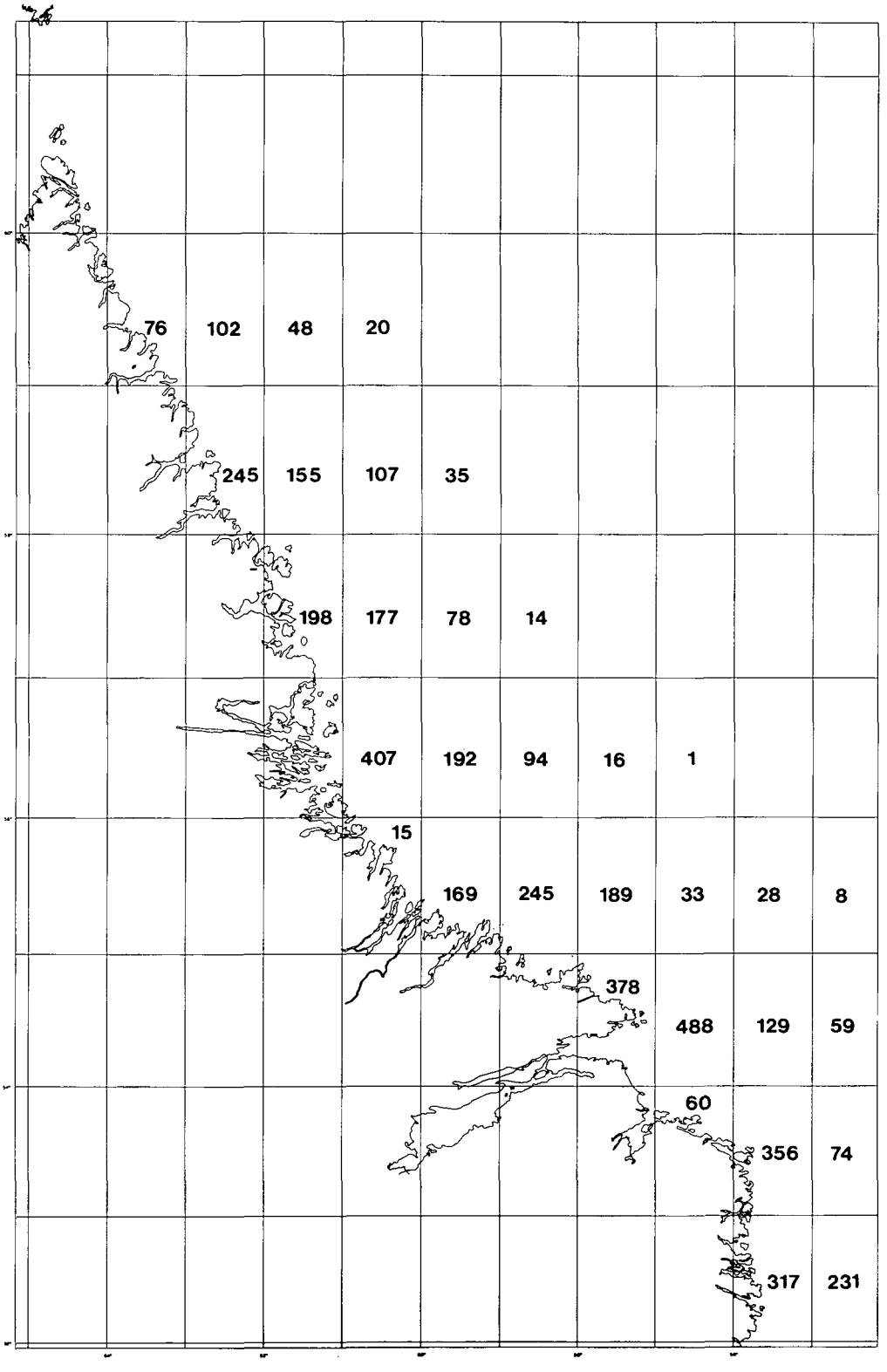

FIGURE 7.7 NUMBER OF ICEBERGS SIGHTED BY THE INTERNATIONAL ICE PATROL PER DEGREE SQUARE (1963 to 1967) (Source: Murray, 1969)

The probability of one iceberg impact per degree latitude was then multiplied by the given number of icebergs crossing that degree per month. The results of these monthly probability calculations are presented in tabular form in the Appendix to this chapter.

Table 7.4 summarizes the annual probability for the entire Labrador region and shows that the probability of an iceberg collision increases to the north. The average annual probability of impact between an iceberg and a drilling rig on the Grand Banks south of St. John's, Newfoundland, has been estimated to be in the order of 0.05 (Amoco Canada Petroleum Company Ltd., 1971). Duval et al (1975) of Total-Eastcan Exploration Ltd., estimated that the probability of an impact with a drilling ship is less than 0.10 for a summer operation. This figure appears to be quite conservative.

TABLE 7.4 ANNUAL PROBABILITY OF ICEBERG IMPACT P(A) FOR THE LABRADOR OFFSHORE
(Distance from Shore 1° Longitude)

	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	347	.81	486	1.13	231	.54	93	.22						
59°N	504	1.1	325	.75	224	.52	67	.16						
58°N	455	1.04	412	.94	184	.42	33	.08						
57°N	580	1.32	275	.63	132	.30	31	.07						
56°N	29	.07	240	.54	346	.78	250	.57	48	.11	38	.09	10	.02
55°N	318	.72	418	.94	109	.25	55	.12	9	.02				
54°N	60	.13	357	.80	74	.17	97	.22	156	.35				
53°N	190	.43	141	.32	74	.17	80	.18	86	.19	43	.10		
52°N	271	.60	123	.27	61	.14	15	.03	26	0.06	10	.02		

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CHAPTER 8
RESOURCE UTILIZATION AND POTENTIAL IMPACT

by

Northland Associates Limited
P.O. Box 1734
St. John's, Newfoundland A1C 5P5

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8 INTRODUCTION

The continental shelf off Labrador is one of the most productive fisheries areas of the world. At least 15 nations send boats into the offshore zone. In 1975, these vessels took 286,000 metric tonnes of fin fish from ICNAF Area 2 (International Commission for the Northwest Atlantic Fisheries - Annual Report, 1976) (N.B. ICNAF AREA 2 covers the Labrador offshore north of 52°14'N. Figure A.8.1 in the Appendix to this chapter indicates the location of ICNAF Statistical Areas). Canada's share of this total was 5,000 metric tons. Newfoundland-based boats took practically all of the Canadian catch.

Seventeen species of marine mammals and 55 species of seabirds occur in the waters off the coast of Labrador. Considering these 72 species of birds and mammals in the aggregate, millions of individuals are involved, either breeding in the area or passing through it at particular periods of the years. Each spring, approximately 200,000 seals of various species are harvested in these waters.

Commercial fishing and harvesting of marine mammals and seabirds takes place throughout much of the offshore area in which petroleum exploration is taking place. These renewable resource utilization activities are diverse with respect to the species harvested, the method employed, and the season of operation.

It has not been possible to consider all aspects of resource utilization in Labrador coastal waters. Because of constraints of time and money, only a general characterization is given. The principal objective has been to determine what species are harvested, where, when, in what numbers, and by whom. This information is conveyed mainly in graphical and tabular form.

In many instances, a judgment had to be made regarding how the data could be most effectively presented. For example, there were 391 pages of computer printouts for commercial fisheries' harvest by Newfoundland vessels alone. These data are synthesized into a few tables and maps showing locations and average annual harvests. There was insufficient time to do even this much analysis of the international effort. The latter is limited to boat numbers and species totals.

One of the difficulties encountered during this study related to the scarcity of material describing resource utilization at the community level. The Licensing Branch of Federal Fisheries was able to provide data on numbers of fishermen per community. However, no current information was available on the amount of fixed fishing gear

operated per community. Fishermen are not required to provide such information when applying for a license. Similarly, catch data available from the Economics and Intelligence Branch of Federal Fisheries do not accurately locate the catch of inshore fishermen. This is particularly true for groundfish, as fish buyers report the catch from a number of fishermen as an aggregate.

Similar data gaps on harvest at the community and local level exist for marine mammals. Data are presented for seal harvests at particular communities along the coast. However, these data represent the point at which the seal pelts were sold, not the point at which they were taken. Nonetheless, such data are useful in calculating total value of the marine resource to the coastal residents.

Very little information of any kind exists for the seabirds harvest along the coast. Since seabirds are seldom sold, these are no value figures for this resource. No attempt is made to place a value on the seabirds consumed by local residents. Numbers of birds and eggs harvested are suggested; these numbers are conservative.

The Labrador Inuit Association's report on the social, economic and legal problems of hunting in northern Labrador contains a chapter on migratory birds. Some data from that chapter are used in this report.

Sources for the information used in compiling the fisheries section of the report are the Economics and Intelligence Branch, the Licensing Branch, and the Surveillance Branch of federal Fisheries. Discussions with individuals from Federal Fisheries generated much useful information.

Published literature on resource utilization generated only a limited amount of data, with two exceptions. The Royal Commission Report on Labrador provided considerable general insight into resource utilization on the coast. Also, Fisheries Service reports on Arctic char and salmon contained much data on the harvest of these species in northern Labrador.

A short meeting with four members of the Labrador Resources Advisory Council generated some information of a general nature and served to clarify a number of specific points.

Since 1976, Northland Associates personnel have been involved in a number of resource baseline inventory and impact studies along the coast. Consequently, personal knowledge and experience in the area proved to be of some value, particularly with respect to utilization of marine mammals and seabirds. It is clear, however, that a field study is required to adequately characterize resource utilization at the community level.

Labrador Coast Marine Environment

Labrador lies at about the same latitude as Great Britain; however, cold air masses and a cold current combine to create both an Arctic and sub-Arctic environment over the land and the sea. In addition, the sea ice which is present for half the year along most of the coast has a strong influence on the pattern of resource utilization. Ice may form as early as October or November in northern Labrador and it is not until May or June that the Labrador Sea is free of ice.

Theoretically, a seven-month harvest of marine resources is possible. In reality, climate reduces the fishing season to approximately five months in southern Labrador and three to four months in northern coastal areas (Royal Commission Report, 1974). Landfast ice, present from December to May or June, is the major influene on the inshore fishermen; Arctic drift ice from Davis Strait, present in coastal waters from January to May, is a major constraint to both the foreign fleets offshore and to the inshore fishermen.

8.1 Commercial Fisheries

The 6,000 residents of coastal Labrador harvest the fisheries resources inshore only. There are 13 permanent communities on the coast; however, an additional 17 (sometimes more) temporary fishing stations are occupied during summer. Figure 8.1 shows the population density along the coast. These figures are from the 1971 census, the most recent for which complete information is available.

Considering the coast as a whole, licensed fishermen comprise 13 percent of the total population: in northern Labrador (north of Hamilton Inlet), six percent; in southern Labrador (Hamilton Inlet to Cape St. Charles), 19 percent; and in the Straits of Bell Isle region, 20 percent.

The greater involvement with fisheries in the more southerly sections of the coast reflects the longer ice-free season, type and number of shore facilities, and the greater variety of species available to the fishermen.

Table 8.1 shows the percentage of fishermen by fishing station and the type of shore facilities available in each station. Data on registered fishermen is for the 1975 season, the most recent year for which information was readily accessible. The licensing section of Federal Fisheries indicated that this is a good 'base year' around which to discuss resource utilization.

Fishing vessels based in insular Newfoundland pursue the fish stocks in Labrador waters (inshore and offshore), particularly southern Labrador, with considerable

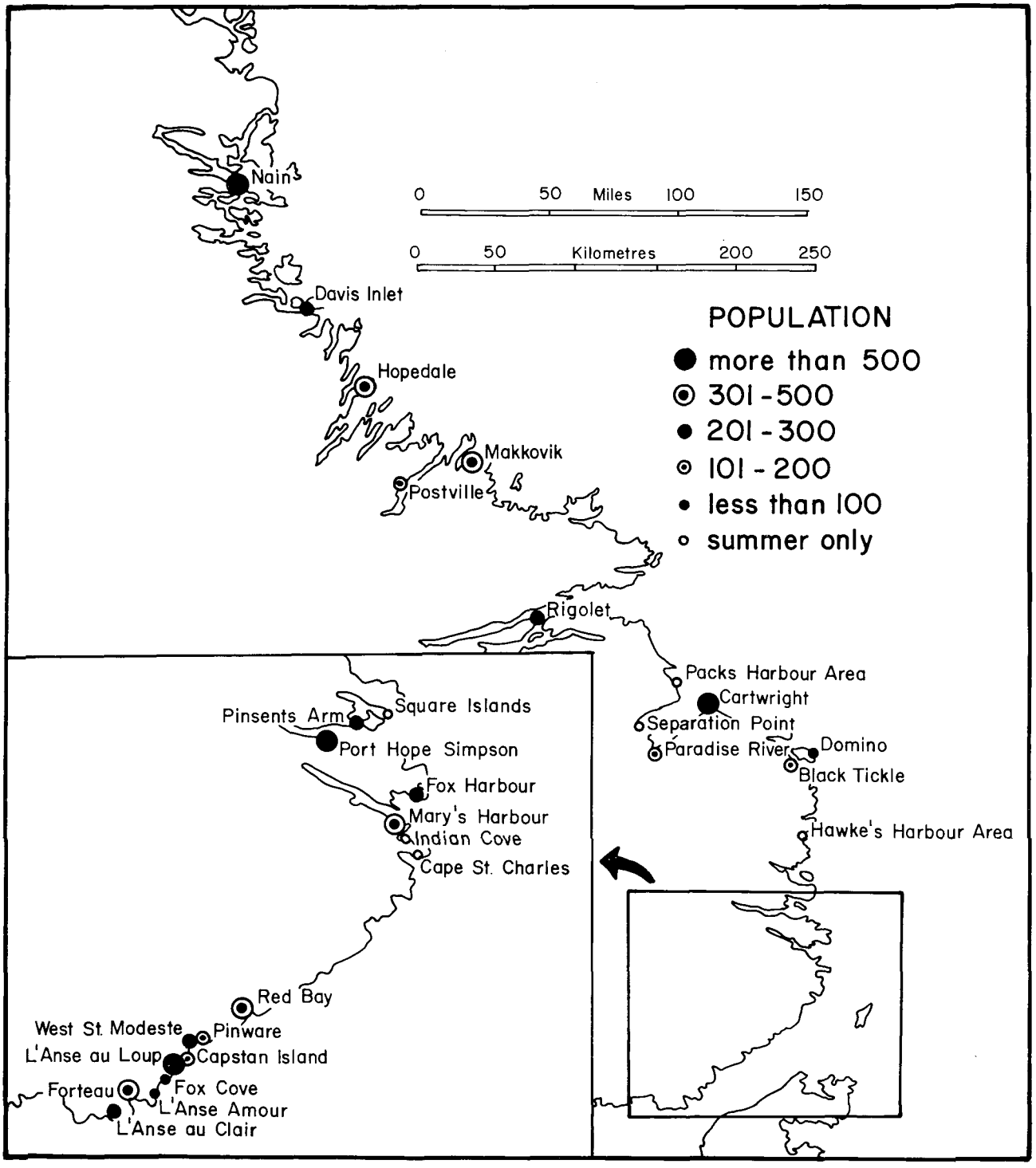

FIGURE 8.1 COASTAL LABRADOR COMMUNITIES

TABLE 8.1 POPULATION CENSUS[1] FISHERMEN[2] BOATS[2] AND SHORE FACILITIES[2] FOR COASTAL LABRADOR FISHING LOCATIONS

Fishing Location[3]	Population	Number of Licensed Fishermen	No. of Boats	Shore Facilities
L'Anse au Clair	249	27	8	WR, CS, SP
Forteau	465	57	30	CS, BD, WR, SF
L'Anse Amour	95	8	2	
Fox Cove	16	-	2	
L'Anse au Loup	536	71	28	CS, SP, WR
Capstan Island	117	9	5	CS, WR, SF
West St. Modeste	277	29	13	CS, BD
Pinware	167	17	7	CS, SF, WR
Red Bay	301	55	52	SP
Cape St. Charles	Summer	33	23	
Indian Cove	Summer	13	5	
Mary's Harbour	366	43	30	
Fox Harbour	268	40	40	CS, SP
Port Hope Simpson	548	40	25	SP, CS, WR
Pinsents Arm	213	60	8	
Square Islands	Summer	21	12	
Hawkes Harbour area	Summer	56	10	SR, SP
Black Tickle	194	20	14	SP
Domino	13	3	2	
South Head area	Summer	10	4	SP
Cartwright	675	36	42	
Separation Point	Summer	3	4	
Packs Harbour area	Summer	23	14	SP
Rigolet	238	35	13	
Paradise River	112	13	8	
Makkovik	307	13	9	SP
Postville	164	14	3	
Hopedale	447	11	7	SP
Davis Inlet	274	3	1	
Nain	512	56	37	

SP = Slipway (Provincial)
SF = Slipway (Federal)
WR = Wharf
CS = Community Stage
BD = Bait Depot
1 1976 Census
2 1975 data from Fisheries and Marine Service
3 Fishing Locations as shown in Figure 8.4

intensity in some years and at some seasons. North of Cape Rouge (in the vicinity of Hamilton Inlet), the northern Labrador salmon and char fishing regulations restrict the fishery for these species to residents. These regulations were gazetted in 1975 under the Newfoundland Fisheries Regulations, pursuant to Section 34 of the Canada Fisheries Act. Island-based fishermen can take salmon and char south of Cape Rouge.

The area of potential petroleum development off the Labrador Coast provides a livelihood for commercial fishermen from Canada (primarily Newfoundland) and from 15 or more foreign nations. The total volume of fin fish taken from Labrador offshore waters during 1974 and 1975 averaged 270,500 metric tonnes annually. The catch was composed mainly of cod, herring, redfish and capelin. Of this volume, some 4,000 tonnes (1.5 percent) was taken by Canadian vessels, primarily by vessels from insular Newfoundland. In terms of the total catch of all species, therefore, it is the international fleet which takes by far the greatest harvest from Labrador.

Cod, salmon, Arctic char, and trout are the major species taken by inshore Labrador fishermen. During the period 1974-76, an average catch of 783 tonnes was recorded for the last three species. Cod landings for the coast averaged 4,698 tonnes over this same period, over 99 percent of this from southern Labrador (south of Hamilton Inlet).

At this point, a brief inventory of the resource is in order. For further background information, the appendix to this chapter illustrates distributions and catch records for the various species discussed.

8.1.1 The Fisheries Resource

8.1.1.1 Groundfish. *Cod (Gadus morhua).* Cod is the single most important species in Newfoundland-Labrador in terms of landed weight and landed value. In terms of employment, the inshore groundfish fishery, which relies heavily on cod as its most important species, will involve approximately 15,000 fisheries in 1978 (Riche, Personal Communication, 1978).

There are six stocks of cod in the Newfoundland-Labrador area. The largest stock is the Labrador-East Newfoundland stock complex. Two separate management portions of this stock are relevant to this study:

1. Northern Labrador management portion (ICNAF Division 2G and 2H).

From 1958 to 1964, the average catch in this area was 5,000 tonnes for all nations. The Canadian average catch during this period, 1,100 tonnes, was taken entirely by inshore fishermen.

2. Southern Labrador-East Newfoundland management portion (ICNAF Divisions 2J, 3K, and 3L).

While the fishery of this stock has been ongoing for many years, a sharp increase in total (offshore and inshore) annual landings began in 1959. This increase was due largely to the development of a winter-spring offshore fishery in Labrador by European trawlers. This fishery was aimed at the prespawning, spawning, and post-spawning concentrations of cod (Pinhorn, 1976).

A major characteristic of this complex is a shoreward feeding migration in early summer and an offshore movement in late summer and fall in response to cooling water temperatures. Spawning occurs as early as February or March in the northern part of the area and progressively later in the south. In some areas (e.g., Hamilton Inlet Bank), large numbers of prespawning, spawning and postspawning cod are concentrated during April and May at depths of 225 to 300 m.

During this same period of increasing offshore foreign catches, the Canadian (mostly inshore Newfoundland) catch showed a decline. Fluctuations in landings are due to changes in stock abundance, and to the variations in fishing effort caused by ice conditions. Severe ice conditions frequently prevent the fleets from operating in the area for the full fishing season.

Quotas for this management portion will probably fluctuate around 550,000 tonnes annually, Canadian and international.

The fishery in general consists of otter trawling in winter, when the fish are in deep water and forming prespawning concentrations. In spring, the spawning concentrations are fished. A summer inshore capelin feeding migration permits the fish to be taken by long-lining and cod-traps. In the fall, the cod begin to form concentrations related to overwintering and spawning on the southwest slopes of the Hamilton Inlet Bank and the north slope of Hawke Channel. Cod may also concentrate near icebergs (ICNAF, 1964).

The traditional floater fishery for cod on the Labrador coast is essentially a thing of the past. The present day "floater" fleet consists of island-based longliners, which move into southern Labrador waters if catches are poor off the northeast coast of the island. In 1977, 29 longliners were active from Battle Harbour to Frenchmans Island until med-September or October. In the three years preceding 1977, from 20 to 50 longliners operated along this section of coast each year; the number depended on the state of the fishery on the northeast coast. Crews live on board the vessels.

Most of the catch is sold fresh to collection stations in the area. In addition, several thousand quintals of salt cod is produced by these longliners during their stay on the Labrador coast.

Redfish (Sebastes mentella). Presently, this resource is being harvested only in deep water (200-640 m) at the edges of the continental shelf. Because of heavy exploitation, no further virgin stocks of redfish remain on the continental shelf off Newfoundland-Labrador. However, a large pelagic oceanic stock occurs throughout the Labrador Sea, extending from the banks of Labrador and northern Newfoundland to West Greenland (Pinhorn, 1976).

The stocks of redfish in the Newfoundland-Labrador area have been divided into six subdivisions for management purposes. One of these, Labrador-Northeast Newfoundland (ICNAF Subarea 2 and Division 3K), is relevant to our discussion.

The first redfish fishery began in this area in 1958. From a high of 187,000 tonnes in 1959, the harvest declined to 20,000 tonnes by 1968. Today, the stock is still in a depressed state (Pinhorn, 1976).

Canadian landings of redfish from this management area have been negligible.

Flatfish. Flatfish have been increasingly important to the Newfoundland fishing industry since the 1960's. From the 1940's to the 1960's, harvesting was almost entirely by otter trawlers in the offshore areas. In recent years flatfish have also become important to inshore longline and gill net fishermen (Pinhorn, 1976).

On the basis of quantities landed, American plaice (Hippoglossoides platessoides) is the most important flatfish to the Newfoundland fishery. However, very small landings (10 tonnes) are recorded annually for Labrador. Some other flatfish taken in small quantities in Labrador waters are Greenland halibut (Reinhardtius hippoglossoides), witch (Glyptocephalus cynoglossus), and winter flounder (Pseudopleuronectes americanus). Landings are usually less than 10 tonnes annually.

8.1.1.2 Pelagic Fish. *Atlantic herring (Clupea harengus harengus).* An extensive herring fishery has not developed in Labrador because of their failure to appear reliably year after year on coastal fishing grounds. Harvests in the 1960's averaged less than 100 tonnes annually. In 1972, over 2,400 tonnes were landed. Sustainable yields for coastal Labrador are probably about 5,000 tonnes annually (Pinhorn, 1976).

Capelin (Mallotus villosus). The capelin is one of the most important fish species in Newfoundland waters. It is the major single food item for cod and a number of

other commercial species and is a key food for several species of seals, whales, and seabirds.

Capelin are circumpolar in distribution. They are abundant in southern and central Labrador, and almost certainly occur in northern Labrador as well. Deeper water spawning appears to be the rule in Labrador waters, and while some beach spawning does occur during mid-July or later, concentrations of fish appear to be smaller than those on the island. Inshore spawning is suspected from Hamilton Inlet south, where suitable beaches exist (Northland Associates, 1977). Preferred beaches generally have pebbles of 0.5 to 2.5 m in size. Capelin have also been observed near Nain and on beaches in Makkovik Bay.

In the offshore, large concentrations of adult and immature capelin have been located on Hamilton Inlet Bank from August to November (Pinhorn, 1976). There is no information on whether capelin in the region are represented by one or more discrete populations.

While some numbers are presently taken offshore, there would appear to be considerable potential for expanded offshore and inshore harvest of this species. This would seem particularly true of the offshore areas, where limited exploratory fishing has proven very successful.

8.1.1.3 Anadromous Species. *Atlantic salmon (Salmo salar).* Templeman (1968) suggests that some salmon live year-round in the Labrador Sea at depths greater than 1,800 metres. May (1973) states that the greatest spring concentration occurs about 180 km east of the Strait of Belle Isle. From this area of spring concentration, salmon move to the coast of Newfoundland and Labrador in late spring and early summer. There is also a fall migration of salmon from Maritime rivers into northern Labrador; however, these fish do not account for a high proportion of the salmon taken in the area.

Based on scale readings of samples from commercial catches in southern and northern Labrador over several years, it has been shown that the vast majority of salmon taken in the inshore waters of Labrador originate from Labrador rivers (L. Coady, Personal Communication, 1978). The greater runs of salmon are to rivers south of Davis Inlet.

Arctic char (Salvelinus alpinus). The sea-run Arctic char occurs all along the coast of Labrador but is the dominant salmonid in the vicinity of Nain and to the north. This species is anadromous; but it does not undergo extensive seaward migrations as does the Atlantic salmon and, in fact, its movements appear to be localized in the bays and

inlets at the mouths of the parent rivers (Coady, 1974). Char move from fresh water to these marine locations when rivers break up in the spring, and return to the rivers starting in July.

8.1.2 Resource Utilization: Inshore. The inshore and near-shore marine environment contains a substantial fisheries resource base (Figure 8.2). Despite the presence of a variety of species, only five (cod, salmon, Arctic char, trout, herring) are being harvested in substantial volumes. At present, there is inadequate knowledge of the other species, and inadequate gear to harvest them; however, a recent program of experimental fishing for non-traditional species along the coast seems to have promise.

Sea ice restricts the shore-based fishery to a short, three to five-month season for most of the coast. However, the coastal residents living in dispersed and isolated communities have adapted to this condition and can make a living from the sea. Nevertheless, greatly improved shore facilities are needed.

The northern Labrador fishery is in an even more precarious position. It is based on overreliance on two species, salmon and Arctic char. The long-term future of this fishery depends on the return of the once abundant cod, and the limited potential of some nontraditional species.

8.1.2.1 Northern Labrador (Cape Childey to Hamilton Inlet). *Cod.* Until recent years, cod had been the major species providing income to residents of this northern coast. This fishery was conducted in 10 to 20 fathoms (20 to 40 m) of water using cod traps and hand lines. Shore facilities for cod were confined to individual fishing stages. Salt cod was the product in the earlier days: close to 1000 tonnes were produced during some years in the 1960's. In 1977, however, only about 51 tonnes were taken on this section of coast.

At the present time, no northern Labrador residents own longliners with which to pursue the fall cod fishery in deeper waters, or search out other species such as turbot or flounder. In fact, the short fishing season might well make it impractical for northern residents to own these relatively large and expensive vessels.

Salmon. In recent years, the salmon has become the most important commercial species in the section of coast from Cape Harrison to Hopedale (Coady, 1974). In this area, Arctic char are fished only to provide supplementary income in late spring before salmon become available. The same fishermen exploit both species.

The annual production of salmon in this area has averaged 111 tonnes in recent years (Table 8.2). This was approximately 15 percent of the total production for the entire Labrador coast for the same period. Fishermen in the Makkovik and Hopedale

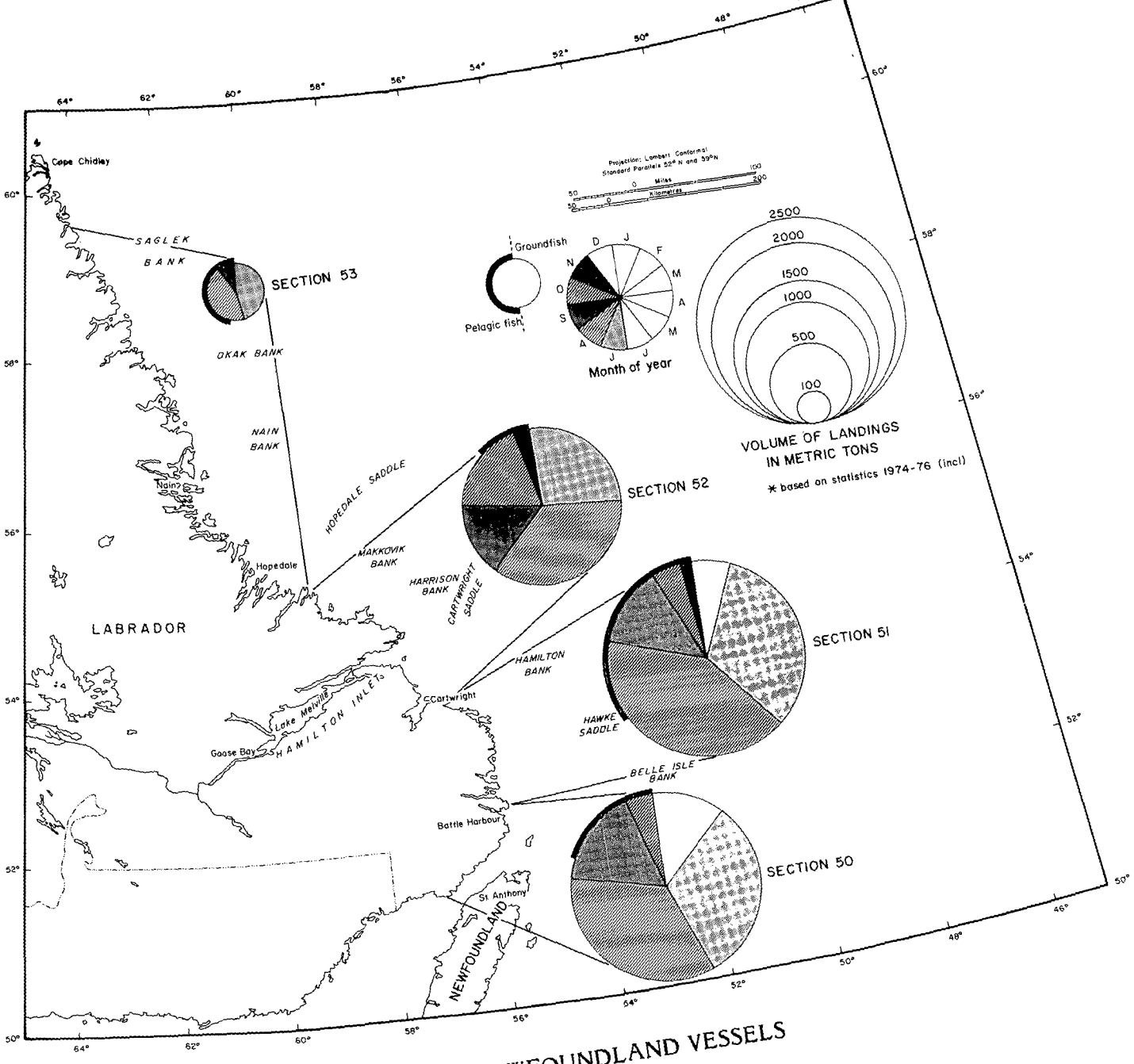

FIGURE 8.2 AVERAGE ANNUAL LANDINGS: NEWFOUNDLAND VESSELS

areas were the major beneficiaries of the salmon harvest. However, in recent years increasing numbers of salmon have also been taken in the vicinity of Nain.

Salmon fishermen are licensed and carefully regulated. It is probable that the northern Labrador salmon fishery could not absorb many more fishermen and still provide adequate return per unit effort. While the total catch could not be safely increased, improvements in handling and marketing would, no doubt, raise the value of salmon taken.

Flower's River, just south of Davis Inlet, is the northernmost river containing a run of salmon adequate to sustain any commercial exploitation. Most of the salmon caught in the vicinity of Nain are taken among the outer islands of Voisey, Nain, and Okak Bays. The salmon fishery is conducted mainly by surface gill nets set out from shore on the outer islands and headlands. July and August are the most productive months.

Arctic char. Nain is the centre of Labrador's Arctic char fishery. The fishing effort is, however, dispersed some distance north and south of this community (Figure 8.3). Practically all rivers from Nain to Cape Childley contain char as the dominant species.

Some 100 Nain fishermen pursue the char fishery, the majority establishing summer fishing camps along the coast. There may be as many as 40 separate camps and these can be relocated during the season since the fishery spreads progressively north as the coastal ice recedes.

The peak fishery is from late July to early or mid-August. This is the period when the fish begin the return run up-river from the bays and inlets where they spent the spring and summer.

Gill nets are set on points or headlands. The surface set nets are aligned in fleets perpendicular to the shore, with an L-shaped leg placed on the seaward end (Coady and Best, 1976). Later in the season, nets are moved farther into the bays as the char move toward the mouths of parent rivers. Char are taken commercially only in the bays up to the river mouth, never in the rivers.

The nets are checked once or twice daily, weather permitting. Each fisherman uses from one to five nylon gill nets; each net is from 20 to 40 fathoms (40 to 80 m) in length. Total weekly landings in excess of 10,000 kg are not unusual during July and August. Individual fishermen can take 225 kg in a good day. During this period, the Nain plant operates 24 h/day and employs 45 people.

Serious Arctic char fishing began after the decline of the northern Labrador inshore cod fishery in the late 1960's. Initially, the char were salted. With the

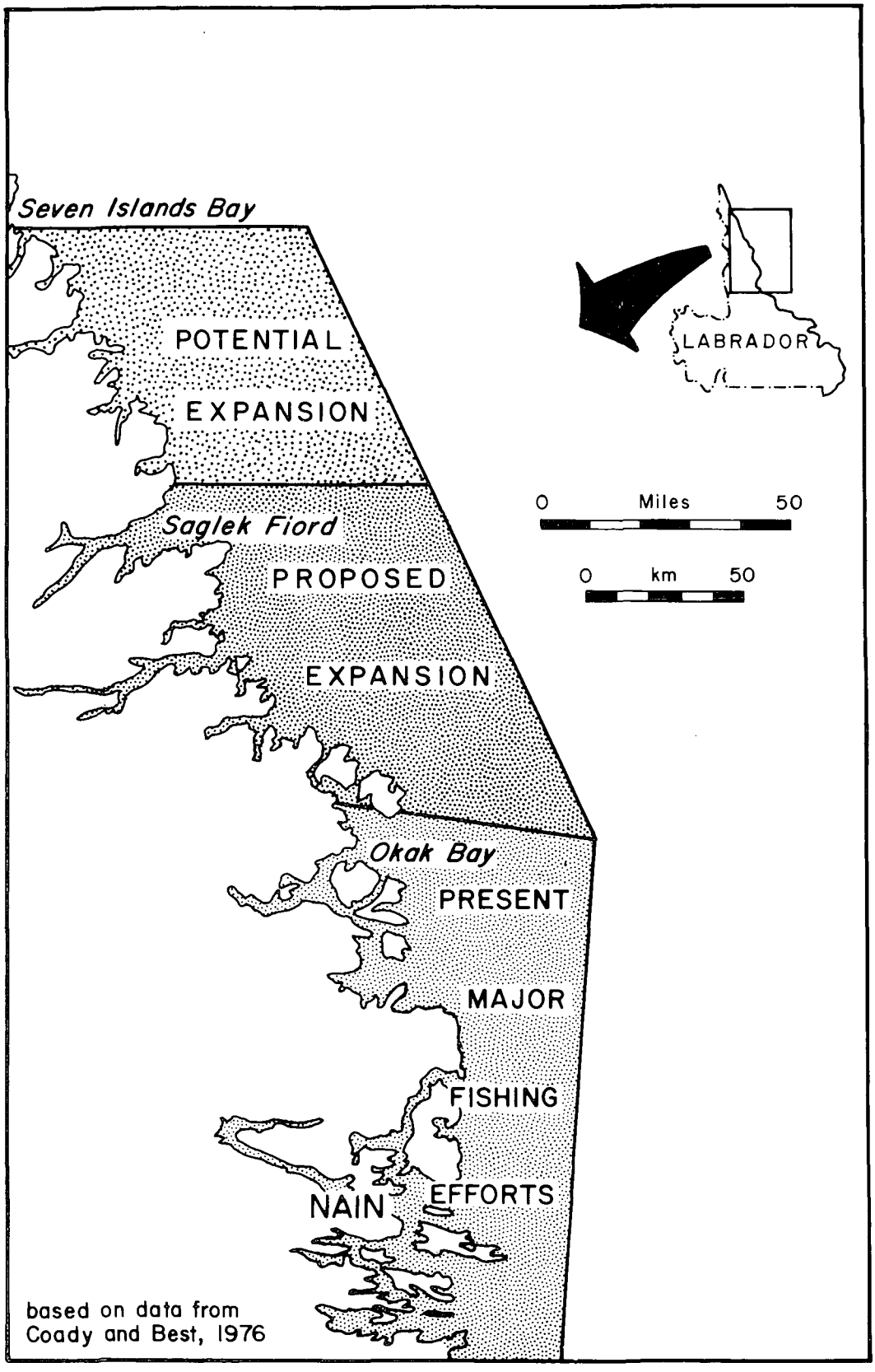

FIGURE 8.3 CURRENT, PROPOSED AND POTENTIAL ARCTIC CHAR FISHING AREAS

introduction of large freezing facilities at Nain in 1970, fishermen wished to avail themselves of higher prices for fresh char. Consequently, they began to abandon the fishery farther north and concentrated closer to the community.

Since 1970, the average size of char landed at Nain, and the catch success per unit effort, have both declined (Coady and Best, 1976). Should the current fishing trends continue, there is danger that stocks in the vicinity of Nain will collapse. The Arctic char is not a highly productive resource, and depletion will be followed by a slow recovery.

The fishery north of Okak Bay is virtually untapped (Figure 8.3) and it is to this area that fishery managers are trying to divert effort. This effort met with limited success in 1977, when some fishermen did move further north. The move was voluntary, since neither legislation nor quotas have yet been enacted to force such a move (B. Dempson, Personal Communication, 1978).

Potential species. Results of an experimental Icelandic scallop (Chlamys islandicus) fishing project conducted near Nain (Brothers, 1976a) indicated that commercial beds exist in the area. The report indicated that local fishing boats could be rigged to harvest the resource.

Greenland halibut or Greenland turbot (Reinhardtius hippoglossoides) have been taken in the Makkovik-Postville area, and good catches of this species were also made in the Hopedale Deep in 1960 (Templeman, 1973). More recently, Brothers (1976b) reports some Greenland halibut taken in the Hopedale Deep in 1975. The best potential for this species would appear to be in the deep water beyond 200 fathoms (400 m) in the Makkovik area. It would be a limited gill net or longline fishery.

Fish Processing. Land-based processing is an important segment of the fishing industry. Coastal Labrador has very limited processing capability at present (Figure 8.4). In northern Labrador, there are two processing facilities and five collection stations. The processing plants are at Nain and Makkovik. The Nain plant receives fish from the Nain-Davis Inlet area and north along the coast, while all of the catch from Davis Inlet south to Hamilton Inlet is taken to the Makkovik plant. These two plants are open from June until November; the peak operating period is from July to September.

One of the five collection stations, Smokey, is a summer-active operation only. Most of the stations have a basic freezer unit. Smokey is somewhat unique; it is a floating barge fitted with freezing facilities and carries a complete range of fishing supplies from salt to fuel. In 1977, it was base of operations for 15 longliners using gill nets on the nearby shoals. The barge was also a production base for frozen salmon.

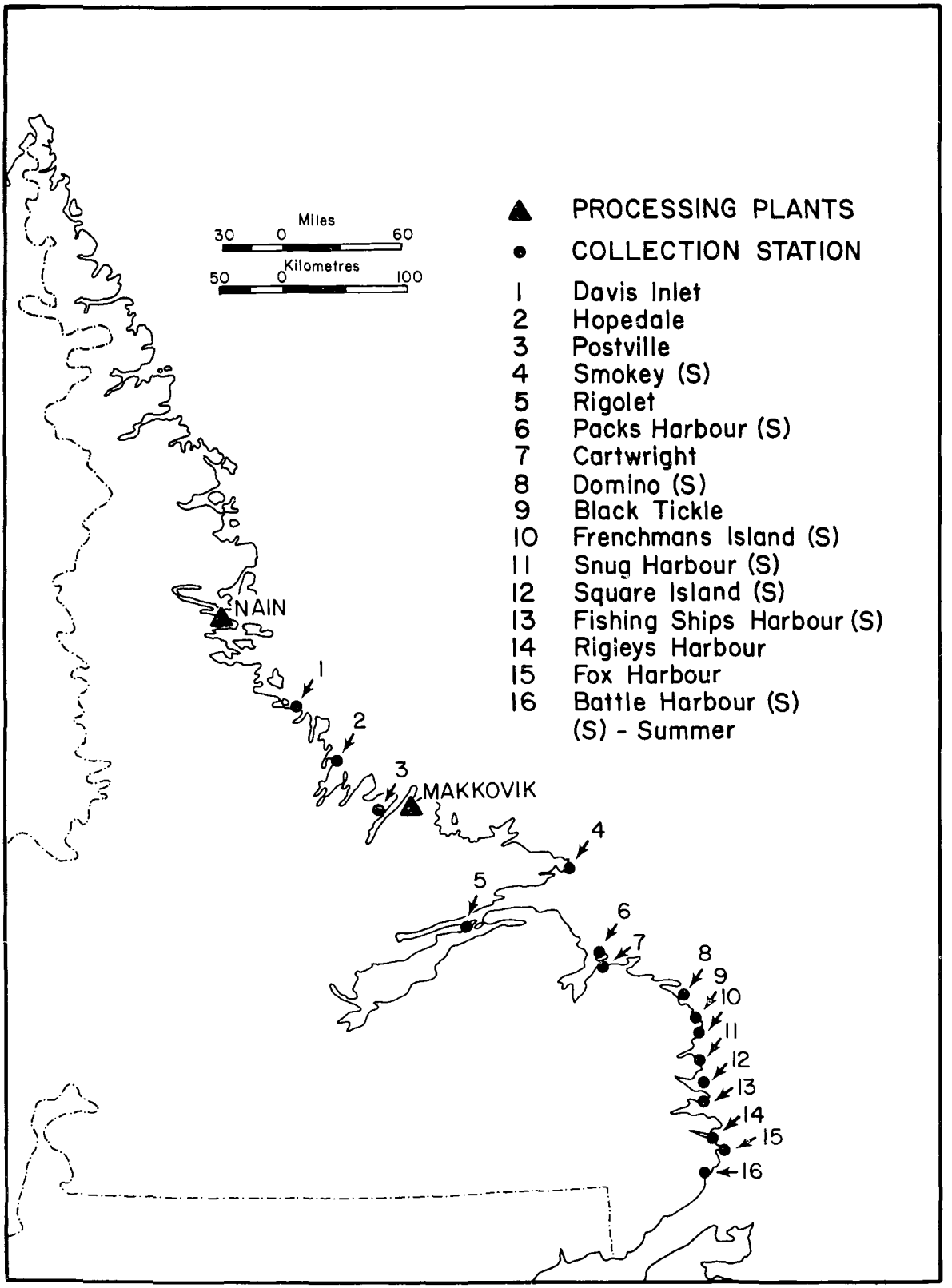

FIGURE 8.4 PROCESSING PLANTS AND COLLECTION STATIONS IN LABRADOR

Table 8.2 shows the landings at the collection stations and at the processing plants in 1975. Figures for landings at Nain and Makkovik are the actual landings by fishermen operating out of these communities and do not represent fish processed.

Sports fishery. The Provincial Department of Tourism supplied the locations of commercial sport fishing camps on the coast. There are five such camps in northern Labrador (Figure 8.5). These camps are on the coast or close to the coast at the river mouth. Atlantic salmon, Arctic char and possibly sea-run brook trout would be the species of interest.

TABLE 8.2 1975 LANDINGS AT FISH PLANTS AND COLLECTION STATIONS IN LABRADOR

	Salmon (t)	Char (t)	Trout (t)	Cod (t)
Nain	77.1	22.7		
Makkovik	39.0	4.1		
Davis Inlet	2.7	7.9		
Hopedale	12.7	.9		
Postville	8.2	1.6		
Smokey	4.5			304.8
Rigolet	62.1			
Pack Harbour	72.6			
Cartwright	17.5		3.6	
Domino	6.8			
Black Tickle	27.2			177.8
Frechmans Island	49.9			50.8
Snug Harbour	10.0			
Square Island	49.9			
Fishing Ships Harbour	54.4			
Rigleys Harbour	24.9			
Fox Harbour	54.4			101.6
Battle Harbour	49.9			
Totals	623.8	32.2	3.6	635.0

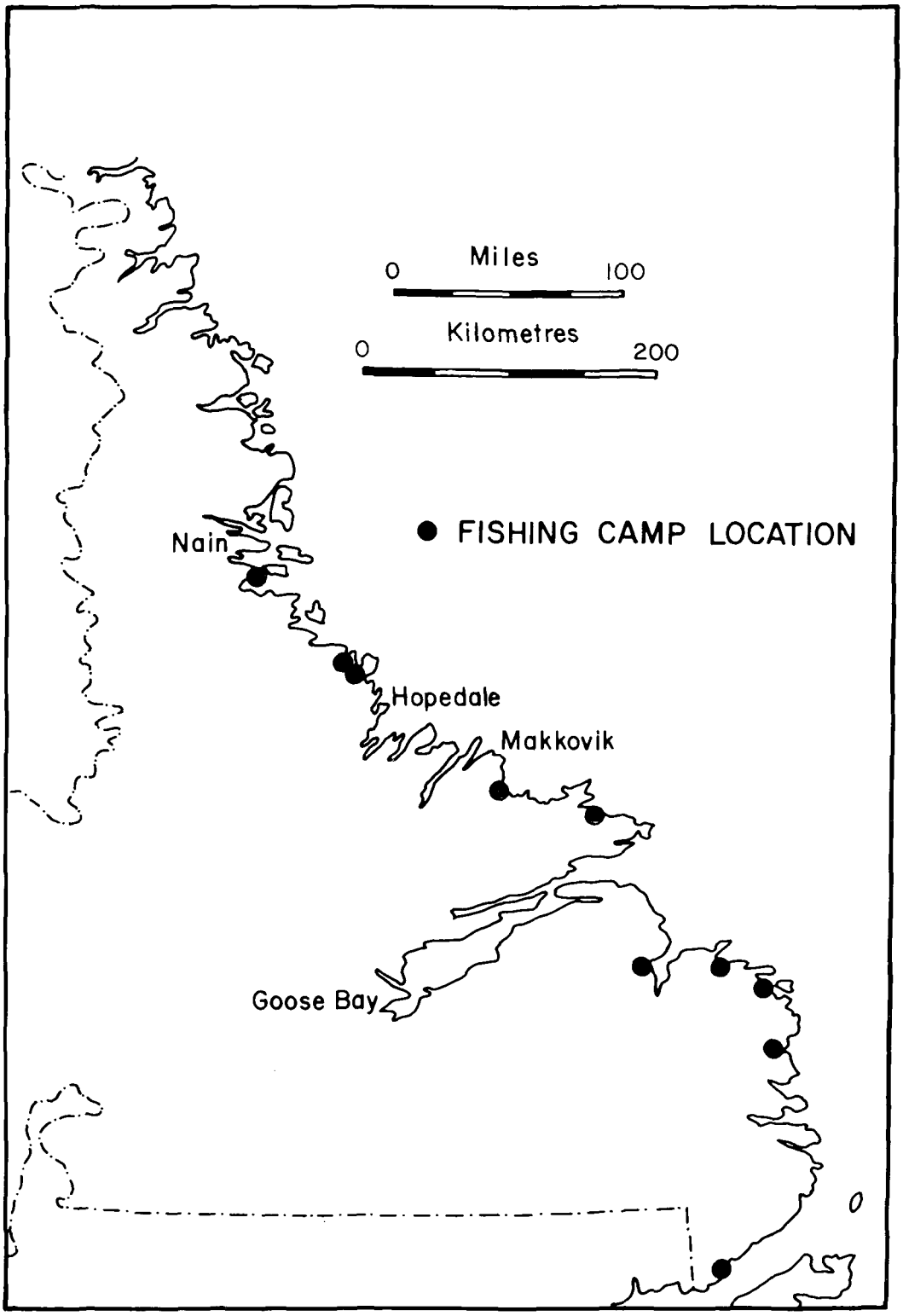

FIGURE 8.5 COMMERCIAL SPORT FISHING CAMPS ON THE LABRADOR COAST

8.1.2.2 Southern Labrador (Hamilton Inlet to Cape St. Charles). *Cod.* Cod stocks have declined in southern Labrador as they have in the north. Landings from the cod trap fishery in recent years are much reduced when compared to former times. For the most part, in this area of the coast, as in the north, residents lack the proper gear to pursue the fall cod fishery in deeper waters. To some extent, salmon, and more recently herring, have partially offset the drop in cod landings.

This section of southern Labrador is frequented in summer and fall by longliner fishermen from insular Newfoundland. Each longliner may fish 40 to 50 gill nets. They take a considerable volume of cod, which the coastal resident, with his inadequate gear, cannot reach. However, at present there are 12 to 15 longliners in southern Labrador (including the Straits area). As this fleet grows, local vessels will be in a position to compete with island boats for cod.

The increased offshore winter and spring fishery for cod on the Labrador Banks after 1950 was a major factor in the reduction of cod stocks in inshore waters. The cod caught inshore were old, mature cod. They were taken in traps set in shallow waters in harbours and channels along the coast. The European trawler fleet increased its catches off Labrador (ICNAF Subarea 2) until the late 1960's. This international fishery reduced the ages and sizes of cod so that the older, mature cod that had formerly come inshore in summer and fall were no longer abundant. In recent years, as much as 90 percent of the total Labrador catch has been taken by the offshore fleet.

In ICANF Division 2J, the small-boat trap and hook-and-line fisheries are the predominant harvest methods. They operate from June to September. In recent years, a small longliner and modest gill net fishery carried out by vessels from Newfoundland has operated in this section from June to December; July to December are the months of peak catch.

Salmon. Approximately 70 percent of the Atlantic salmon landings along the coast are from southern Labrador. For the period from 1974 to 1976 inclusive, this amounted to average annual landings of about 500 tonnes.

The home river salmon stocks along this section of coast were considerably higher 50 years ago (Labrador Royal Commission Report, 1974). There were no effective controls to the fishery at that time, and as a result, overfishing reduced the stocks. However, an apparently recent shift in migration patterns has made salmon from southern rivers more available to fishermen in this region, thereby partly offsetting any decline in local stocks.

There are two potential dangers to the salmon stocks along the coast. First, the decline of inshore cod stocks has caused Newfoundland longliners to concentrate on salmon. Second, the large proportion of two sea-year salmon taken in the Greenland fishery (Peet and Pratt, 1972) represents a continuing drain on Labrador fish. It will take a concerted effort to maintain Atlantic salmon populations at their present level.

The peak months of the salmon fishery in this area are June, July and August.

Trout. The sea-run brook trout migrates into the salt water but stays relatively close to its parent river. This species is most abundant in southern Labrador, but it is present in the north. A commercial fishery for this species has been in existence only since the early 1970's.

Trout are taken from June until September. Approximately 20 tonnes have been landed annually in southern Labrador during the period from 1974 to 1976 inclusive.

Atlantic herring. Scattergood and Tibbo (1959) report that herring occur at various points along the coast of Labrador as far north as Cape Harrison. These fish are part of a stock that extends from the northern part of the Gulf of St. Lawrence to Cape Harrison and offshore towards Davis Strait.

A small commercial herring fishery exists in southern Labrador utilizing the older age classes of fish. Most of the fish are caught close to shore during the summer. The fishery is uncertain because of the unpredictable movements of the herring concentrations. While sustainable yields from this area are probably less than 5,000 tonnes (Winters, 1976), during the period from 1974 to 1976 inclusive an average annual catch of only 421 tonnes was recorded for southern Labrador.

While it has been reported in the Labrador Royal Commission Report, 1974, that spawning concentrations of herring occur under the ice in some southern Labrador bays, these locations are not precisely known.

Capelin. A few tonnes of capelin are harvested each year from inshore waters. There are primarily for domestic use.

Potential species. Results of exploratory fishing indicate that a good potential shrimp fishery could be developed in areas of the Hawke Channel, where depths range from 200 to 225 fathoms (400 to 450 m) (Brothers, 1976b). As well, turbot are being taken by longliners in the deeper waters of Hawke Channel.

Fish processing. While no processing plants are found in southern Labrador, ten collection stations are located along the coast, (Figure 8.4). Seven of these stations are summer settlements only. Most of the collection stations along this section of coast

are equipped with freezing units owned by processing plants in insular Newfoundland. The catch from each station goes to the island, most of it to St. Anthony. Table 8.1 indicates the type and location of shore facilities along the coast.

Table 8.2 shows the landings at these stations in 1975. Some of the collection stations are more elaborate than the others and have potential for expanding activities:

Cartwright: In addition to salmon in 1975, this station also received 8,000 pounds of gill-netted brook trout taken in the Cartwright-Sandwich Bay area.

Black Tickle: Black Tickle is designated as a native community. A multipurpose fish plant is now under construction. This plant will be capable of doing every type of processing except canning.

Square Island: This summer operation is well-equipped and is most developed to the point of being classified as a processing plant.

Rigleys Harbour: The government community stage here is close to the level where it can be registered as a processing facility.

Fox Harbour: This excellent government facility has a herring machine, ice machine and other extras that almost bring it into the processing plant category.

Sport fishery. Four commercial fishing camps are located on or near salt water in southern Labrador (Figure 8.5). Altantic salmon and sea-run brook trout are the attractions at these camps.

8.1.2.3 Strait of Belle Isle. The Labrador Royal Commission Report (1974) suggests that fishermen in this area "appear to be more innovative, sophisticated in fishing techniques, and generally better-equipped than those on the rest of the coast". Some longlining is done here since there is a bait-holding depot at West St. Modeste. There are five community stages in the Straits (Red Bay, West St. Modeste, l'Anse-au-Loup, Fortune, l'Anse-au-Clair). The major effort is the production of salted cod and a pickled fish product line. Cod, salmon, herring, and capelin are the major species taken by the Straits fishery.

Potential. This area shows great promise because nearby fishing ground offer the potential for a fishery in mackerel, redfish, shrimp, and scallops. The Straits also enjoy a longer fishing season than elsewhere on the coast.

Sports fishery. There is one commercial fishing camp on the coast in the Straits. It is at the mouth of the Forteau River, where Atlantic salmon is the major attraction.

8.1.3 Resource Utilization: Offshore. There is no major Canadian effort to fish in offshore Labrador. Of the 586 vessels present in ICNAF Area 2 in 1977, only 22 (3.9 percent) were Canadian (Figure 8.6). They were primarily Newfoundland stern trawlers from plants at Fortune, Grant Bank, Burin, Marystown, Trepassey, St. John's and Catalina. The few Canadian vessels that were present operated primarily in the southern portions of Division 2. Figure 8.7 shows the average annual catch for Newfoundland vessels by species and by ICNAF Division. Except for salmon, Arctic char, trout, and a small volume of cod, these are essentially offshore catch figures.

To encourage Canadian boats to pursue traditional species in new waters (e.g. the winter cod fishery in ICNAF Division 2), a special incentive program is being established. The program will cover additional costs for vessels fishing in these areas, and will assure a minimum catch value for the trip. It is the federal government's intention to encourage Canadian vessels to take the entire Canadian quota annually. This same incentive program offers financial encouragement for Canadian vessels to fish for non-traditional species (e.g., silver hake, grenadier).

At present, offshore Labrador waters are dominated by foreign fleets. Each foreign vessel must submit a weekly report to St. John's or Halifax indicating its catch and supplying other requested information such as precise location, ice conditions, etc.

The following is a seasonal overview of offshore trawler activity.

8.1.3.1 Winter (January, February, March). In ICNAF Division 2G and 2H, a limited number of forgein trawlers (16 in 1977) pursue a winter fishery for cod during January and February. This fishery is greatly influenced by ice conditions. Frequently ice will force the fleet to move farther south. The boats can request an amendment to their licence so that the harvest may be continued in Area 2J.

Beginning towards the end of January and continuing through February and into March, there is a concentration of forgein vessels off the Hamilton Banks (Division 2J). Most of the foreign nations have allocations for cod and other species in this area. During these months, from 60 to 90 vessels may be concentrated in a radius of 35 to 40 km in the vicinity of the banks.

Ice conditions, again, greatly influence the positioning and directly govern the fishing activity. The boats can steam through almost any drift ice condition. However, trawls can be operated in a limited number of ice conditions only, since blocks of ice may either get under the trawl thereby lifting it off the bottom, or ice may enter the trawl. When ice conditions interfere with bottom trawl operation, the ships leave the area.

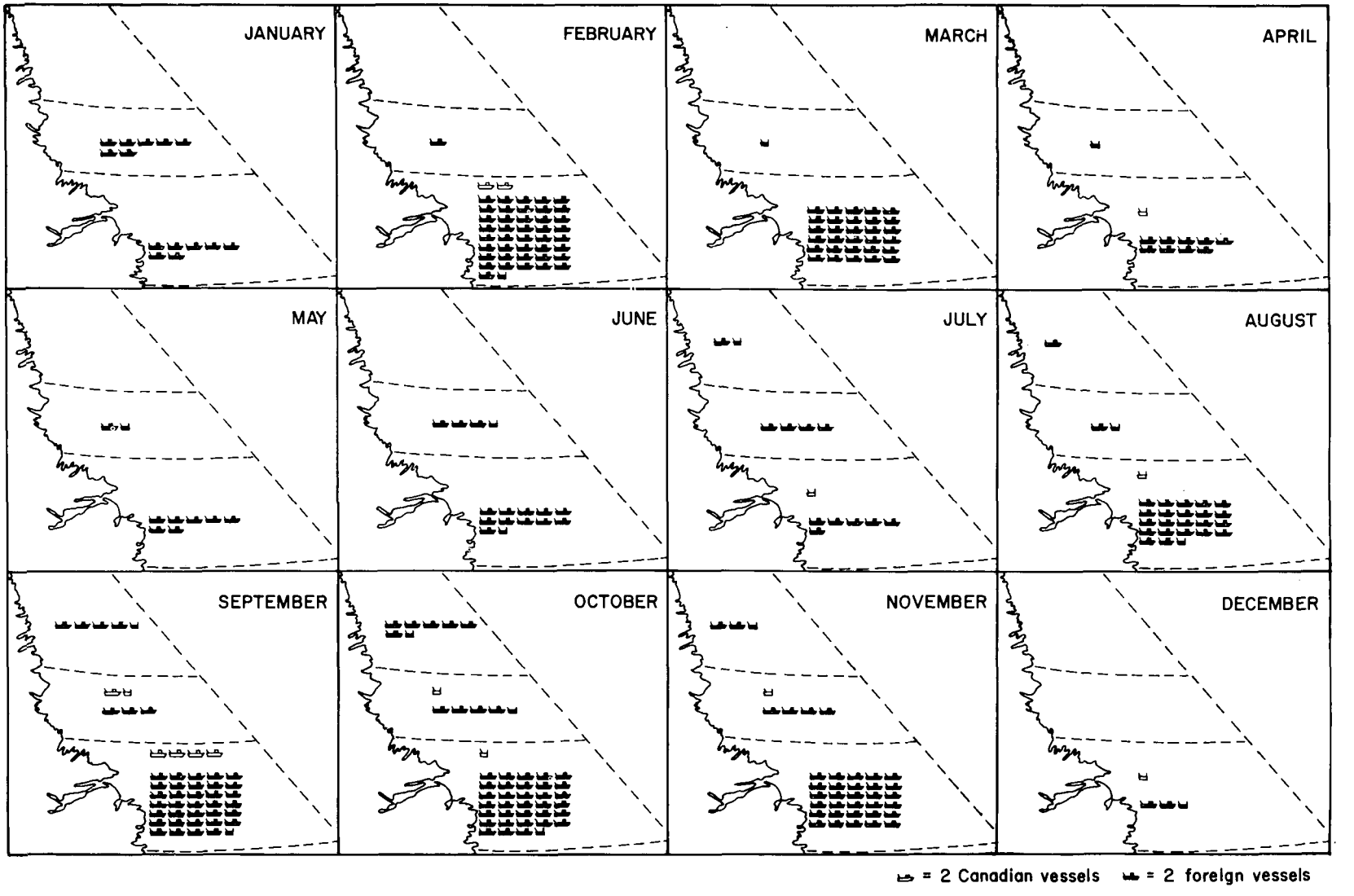

FIGURE 8.6 CANADIAN AND FOREIGN FISHING VESSEL OPERATION OFF LABRADOR DURING 1977

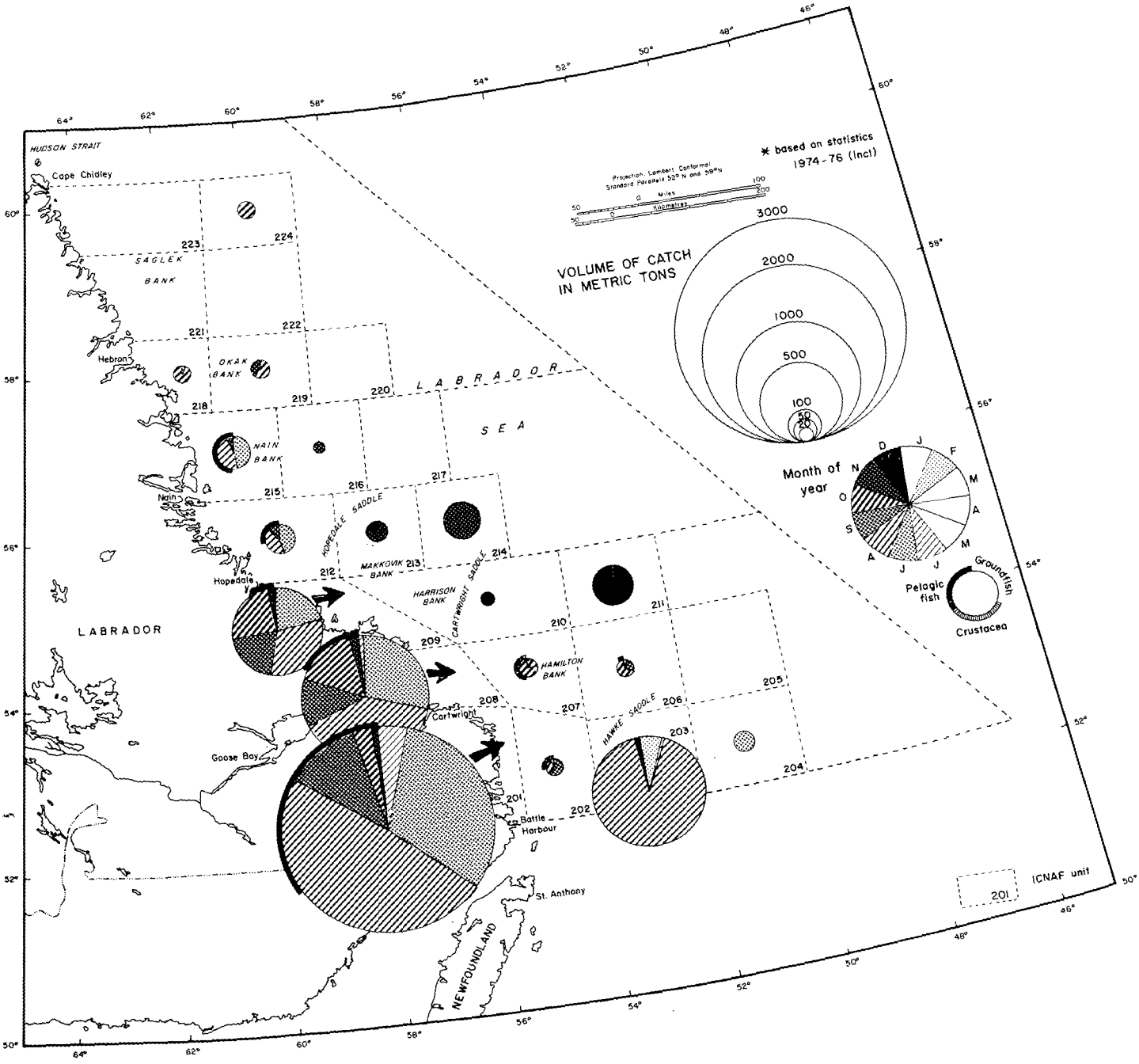

FIGURE 8.7 AVERAGE ANNUAL CATCH: NEWFOUNDLAND VESSELS

Ninety-nine percent of the boats operated by the foreign fleets are stern trawlers, since side trawlers cannot work well in ice.

8.1.3.2 Spring - Mid-Summer (April-July). In April, the concentration of vessels on the Hamilton Banks breaks up. Some boats go home, while others go back farther north to complete their allocations for species possibly missed because of winter ice conditions. Generally, there is a minimum of activity during this period.

8.1.3.3 Fall and early winter (August-December). In late August/mid-September to mid-November, another concentration of boats takes place, this time for capelin off Spotted Islands (Division 2J). Fifty vessels or more may concentrate in a 10 km^2 area. They huddle, break up, and huddle again in a continuing search for the capelin stocks that are also breaking up.

In fishing for capelin, the trawl is raised off the bottom. This permits vessels to concentrate more than in fishing for groundfish. In the latter, the bottom position of the trawl requires a fishing technique which prevents close crowding.

There may also be a small number of vessels fishing for cod and other species in Divisions 2G and 2H in the fall. The catch rate is usually lower in the fall in these areas than it is in the winter.

8.2 Marine Birds

Newfoundland-Labrador coastal waters are the centre of abundance for many species of seabirds occurring in the Northwest Atlantic (Northland Associates, 1977). Two million seabirds nest in this general region (Nettleship, 1976). Substantially more than that number occupy the area following hatching and during migration.

Waterfowl and shore birds are also abundant in Labrador inshore waters, since a leg of the Atlantic Flyway passes down the coast. Inder and Gillespie (1974) have shown the probable migration routes for four of the major species harvested in Labrador (Figure 8.8). In addition, important estuarine and coastal-wetland habitat occurs along the coast.

Little or no harvest data ara available on these species. This is largely because much of the kill is illegal and therefore not sampled in harvest estimates. Even the legal kill is poorly known because of poor harvest sampling response and even poorer or no harvest sampling in some cases (sea ducks and murres). Because of these data restrictions, much of the information contained in this report is derived from personal experience while living and working in northern Labrador and northern Newfoundland (the latter probably being not too dissimilar from southern Labrador).

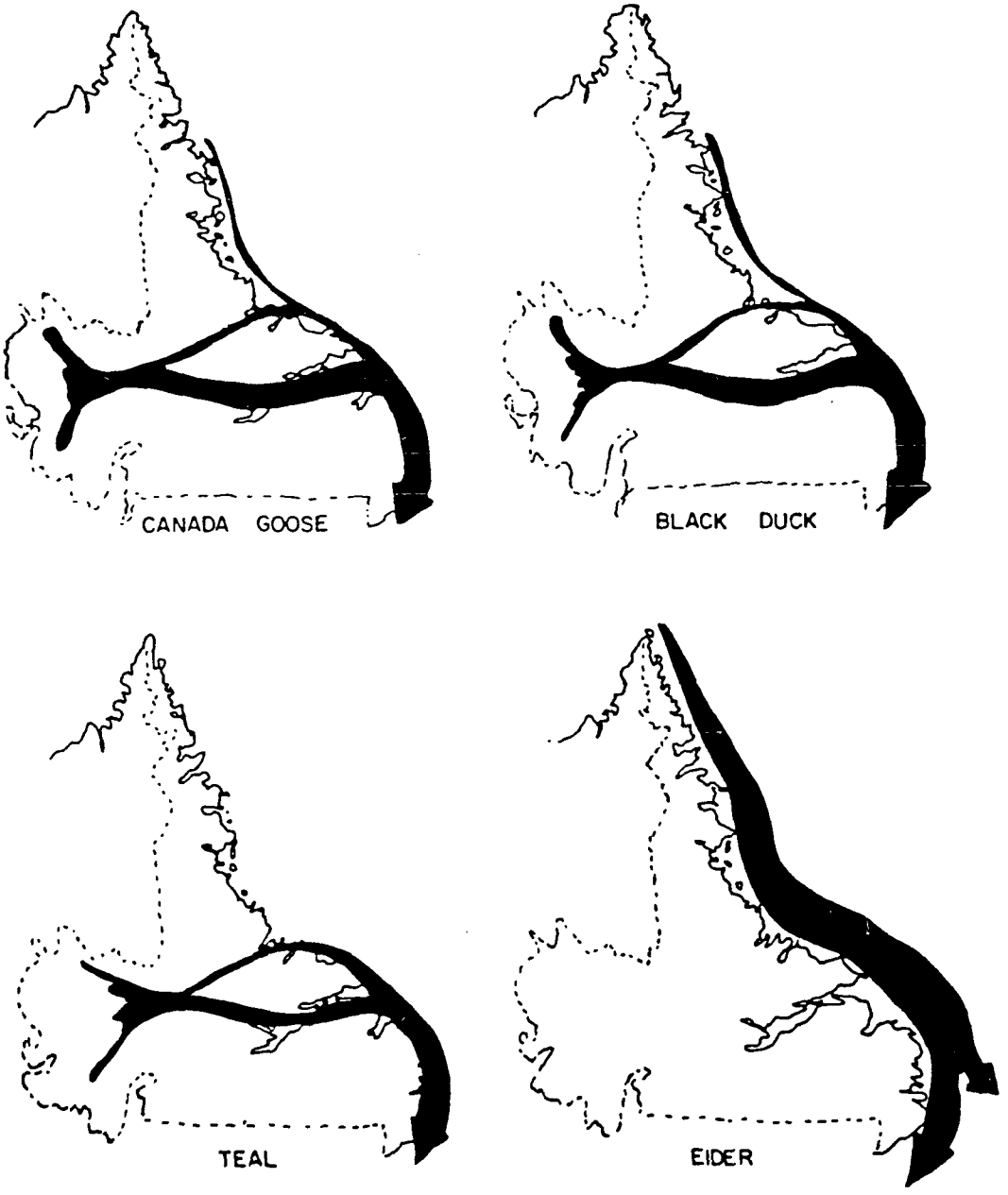

FIGURE 8.8 SUGGESTED MAJOR MIGRATION ROUTES: LABRADOR
(Source: Inder and Gillespie, 1974)

It should also be pointed out that even though much of the harvest is illegal, the illegality must be put into its proper context. It is illegal because many of the international laws making it so did not consider the traditional way of life in Labrador or even the population dynamics of the species that are covered by these laws. As a result, much of the illegal harvest is of little consequence to the species concerned and of great consequence to the upkeeping of a traditional coastal lifestyle which is in danger of being gradually eroded.

Ames (1977) states that the hunting of migratory birds and the collection of their eggs has always been a means of support for the people of Labrador. Coastal people traditionally depend on these birds and their eggs as the only source of fresh meat and protein during the break-up period in the spring, when other sources of wild meat are unavailable and when the supply of frozen meat in the stores is either exhausted or unpalatable.

Migratory birds arrive on the coast about the middle of May and congregate in the open water areas within the ice. As the ice disperses, the birds occupy increasingly greater areas of open water. Hunting is first directed against the early concentrations. Later, as the ice disperses, boats are used to reach the islands and offshore open water areas where the birds have now gathered. Nesting begins some time in June.

One point of interest arose from a meeting held with four members of the Labrador Resources Advisory Council (February 1978). It was the contention of the Council that the traditional seabird hunting activities had always been self-regulating, but that this had now changed. When Newfoundland became a province in 1949, it was obliged to accept the regulations of the Migratory Birds Convention Act, since Canada was a member state of that convention. This resulted in enforcement by the Canadian Wildlife Service and by the RCMP. Traditional hunting patterns altered considerably. Licences, seasons, bag limits, and restrictions on the use of particular firearms and fire power were implemented. Abuse of these apparently unreasonable regulations was inevitable and this in turn may have destroyed the previous traditional self-regulation, without replacing it with an effective alternative.

Harvesting of marine birds on the coast is largely dependent on weather and the availability of birds rather than set seasons and bag limits. The harvest is also probably closely related to fishing activity: shooting and egging (removal of eggs from nesting colonies) usually begins in the spring with break-up but decreases in June and July when fishing starts. Shooring, increases again in the fall and continues until freeze-up.

Fall is the peak shooting period. Winter shooting probably occurs only in southern Labrador.

In Labrador, the harvesting of marine birds is now probably in large part a recreational activity, possibly with subsistence overtones. Although there are no reliable data available on numbers of birds taken, it is probable that the harvest fluctuates considerably from year to year. It is not known what percentage of each species is removed annually by shooting and egging. With the exception of the terns (common and Arctic), which are declining, present status of major colonial breeding seabirds in Labrador is stable or on the increase (Nettleship, 1976). However, numbers of some species (e.g., Common Murre) were formerly much larger that at present; the reduction has occurred because of egging and shooting at breeding sites.

8.2.1 Habitat. Part of the success of the total marine bird population along the coast has been due to the fact that there are many isolated and unpopulated offshore islands and sections of coastline where breeding colonies can be established. A number of large estuarine zones along the coast provide excellent inshore feeding and resting areas. Extensive areas of lowland wetland habitat also serve to concentrate particular species.

Areas of known, heavy shorebird harvest are shown in Figure 8.9. Brown et al (1975) show the areas off the Labrador coast where seabirds are concentrated near the shore at different times of the year (Figures 8.10 and 8.11). These inshore and shoreline concentrations are, of course, the source of most of the harvest.

8.2.2 Resource Utilization. *Loon Family.* Two species of this inshore bird, the Common Loon (Gavia immer) and the Red-throated Loon (G. stellata) are common in Labrador. Both are commonly shot. Young birds are favoured for eating. This is an illegal, traditional harvest. Loons are inshore birds.

Shearwater and Petrel Family (Procellariidae). Three species of this family are commonly killed for food, primarily during the summer months. The three include Northern Fulmar (Fulmarus glacialis), Greater Shearwater (Puffinus gravis) and Sooty Shearwater (P. griseus). The latter two are especially prized food items. These birds are inhabitants of the offshore zone; however, they come inshore during foggy weather.

Swan, Goose and Duck Family (Anatidae). Sixteen members of this family are commonly taken in coastal Labrador, (Table 8.3). All are basically inshore birds. The first four inhabiting saltwater marshes and the intertidal zone; the rest inhabit somewhat deeper inshore waters. Members of this family arrive in southern Labrador in April and arrive in the north in May. By December, most birds are out of the north and by January they are usually gone from Labrador south (Figure 8.9).

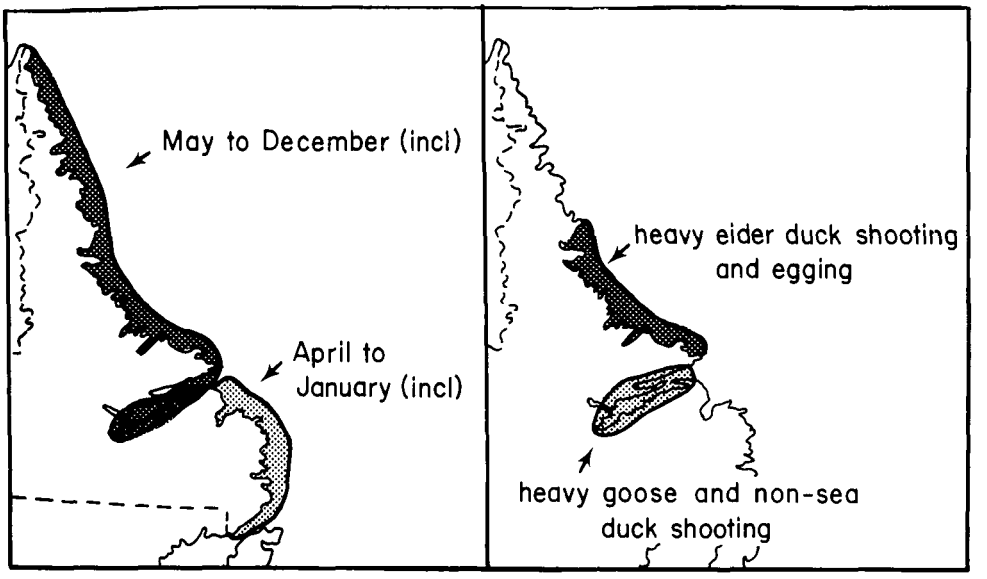

FIGURE 8.9 PERIOD OF PRESENCE OF DUCKS AND GEESE IN COASTAL LABRADOR; KNOWN AREAS OF HEAVY WATER FOWL UTILIZATION IN LABRADOR

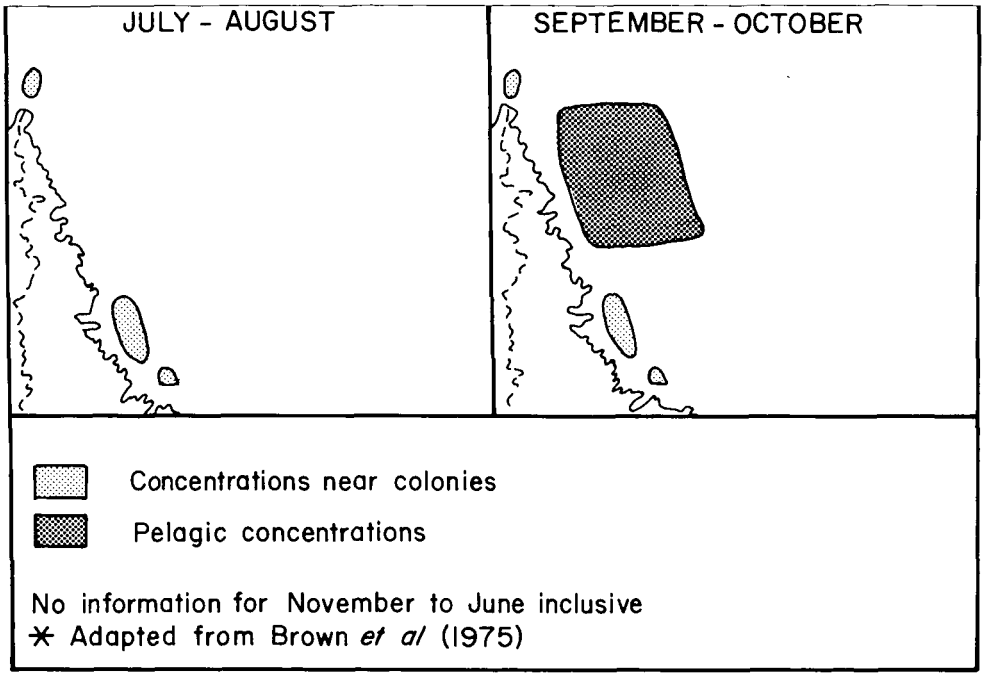

FIGURE 8.10 PELAGIC BIRD CONCENTRATIONS OFF NORTHERN LABRADOR

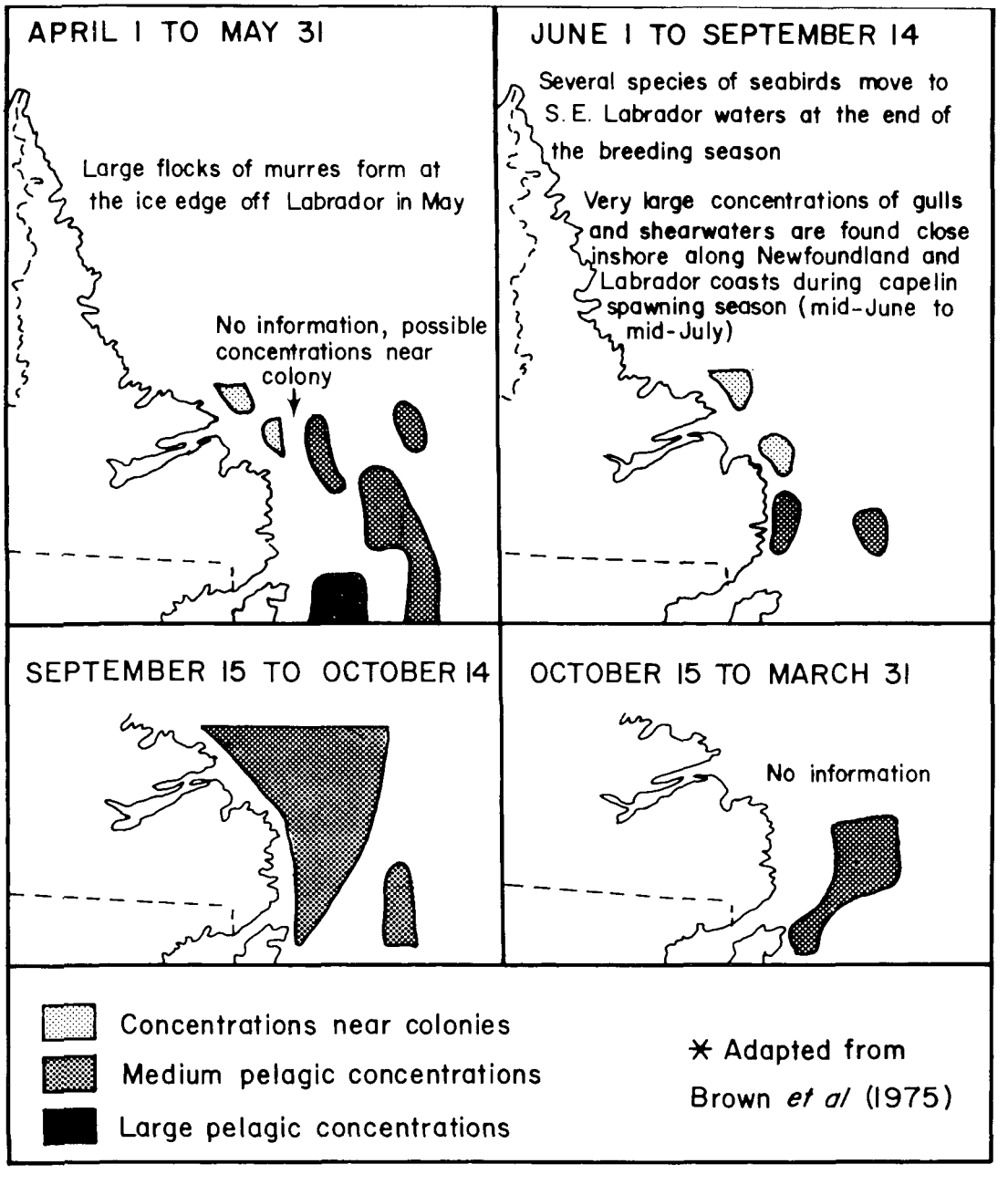

FIGURE 8.11 PELAGIC BIRD CONCENTRATIONS OFF SOUTHERN LABRADOR

TABLE 8.3 ANATIDAE PRESENT IN COASTAL LABRADOR: AVERAGE KILL ESTIMATES, 1972-1975

Common Name	Species	Kill Estimates[1]
Canada Goose	(Branta canadensis)	3049
Black Duck	(Anas rubriques)	3562
Pintail	(A. acuta)	573
Green-winged Teal	(A. carolinensis)	2321
Greater Scaup	(Aythya marila)	340
Common Goldeneye	(Bucephala clangula)	2693
Barrows Goldeneye	(B. islandica	
Oldsquaw	(Clangula hyemalis)	NIA
Harlequin Duck	(Histronicus histronicus)	NIA
Common Eider	(Somateria mollissima)	NIA
King Eider	(S. spectabilis)	NIA
White-winged Scoter	(Melanitta deglandi)	NIA
Surf Scoter	(M. perspicillata)	NIA
Common Scoter	(Oidemia nigra)	NIA
Common Merganser	(Mergus merganser)	368
Red-breasted Merganser	(M. serrator)	1654

1 NIA - No Information Available

Reliable kill estimates for these birds are only available for eight species. The estimates apply only to the legal season (September 1 to November 30) and are for the whole of Labrador; no breakdown is available for the coastal portion of the harvest. The kill figures were obtained by averaging the kill estimates for the years from 1972 to 1975 inclusive from Cooch and Newell (1977).

The illegal spring kill of the birds is unknown, although it is probably less than the fall kill for the following reasons: (1) law enforcement is present in some communities; and (2) many people participate only in the early part of the spring hunt, believing that after this time the birds should be left alone to breed.

Reliable figures for seaduck kills are non-existent. We do know, however, that this kill is very substantial and that eider ducks make up the larger proportion of it. Inder and Gillepsie (1974) report a mean annual harvest during the period from 1959 to 1965 of 1640 eiders, which is undoubtedly low.

Illegal spring shooting of seaducks is common, as is egging on the offshore islands for eider duck eggs. The kill during the set season is also substantial. Authorities have made a token concession to traditional hunting practices: scoter ducks and their eggs may be taken, without restriction, by Inuit and Indians.

Inder and Gillepsie (1974) and Northland Associates' observations show that areas in which a large portion of the waterfowl kill are known to occur include: (1) Nain to Makkovik: heavy eider ducks shooting and egging; and (2) the north shore of Lake Melville and Groswater Bay: heavy goose and non-seaduck shooting (Figure 8.9). Undoubtedly, there are areas in which large kills are made.

Plover, Surfbird and Turnstone Family (Charadriidae). Woodchuck, Snipe and Sandpiper Family (Scolopacidae). Phalarope Family (Phalaropodidae). These three families are collectively known as the shorebirds. Fourteen species of these families inhabit marine-influenced areas on the Labador coast (Table 8.4).

TABLE 8.4 SHORE BIRDS PRESENT IN COASTAL LABRADOR

Semipalmated Plover	(Charadrius semipalmatus)
American Golden Plover	(Pluvialis dominica)
Black-bellied Plover	(Squatarola squatarola)
Ruddy Turnstone	(Arenaria interpres)
Common Snipe	(Capella gallinago)
Spotted Sandpiper	(Actitis macularia)
Greater Yellowlegs	(Totanus melanoleucus)
Purple Sandpiper	(Erolia maritima)
White-rumped Sandpiper	(E. fuscicollis)
Least Sandpiper	(E. minutilla)
Semipalmated Sandpiper	(Ereunetes pusillus)
Sanderling	(Crocethia alba)
Red Phalarope	(Phalaropus fulicarius)
Northern Phalarope	(Lobipes lobatus)

The taking of these birds, with the exception of snipe, is illegal; it occurs primarily as the first kill by youngsters and of other people shooting them only when a

flock shot presents itself. Flock shooting is necessary because the small size of these birds makes it uneconomical to shoot at individual birds. The legal fall kill of snipe in Labrador (averaged for the years from 1973 to 1975 inclusive) is reported at 1231 by Cooch (1976). This figure gives no estimate of the coastal portion of the total. The estimate is probably also very inaccurate since many hunters lump several kinds of shorebirds into the snipe category in their returns.

While the return in meat from the shorebird kill is probably negligible, the pursuit of these birds is a traditional part of growing up for children on the coast. For older hunters, the shooting of these birds is usually an offshoot of other activity. Most members of this family arrive in May and June and have departed by November.

Jaeger and Skua Family (Stercorariidae). Gull and Tern Family (Laridae). Members of both these families of birds are completely protected, but 13 species are nevertheless utilized on the coast. Of the Jaeger and Skua Family, these include Pomarine Jaeger (Stercorarius pomarinus), Parasitic Jaeger (S. parasiticus), Long-tailed Jaeger (S. longicaudus) and Skua (Catharacta skua). In the Gull and Tern Family, the species include Glaucous Gull (Larus hyperboreus), Iceland Gull (L. glaucoides) Great Black-backed Gull (L. marinus), Herring Gull (L. argentatus), Ring-billed Gull (L. delawarensis), Ivory Gull (Pagophila eburnea), Black-legged Kittiwake (Rissa tridactyla), Common Tern (Sterna hirundo) and Arctic Tern (S. paradisaea).

With the exception of the terns, all of the above-mentioned 13 species are commonly shot as food items. In addition, the terns, Glaucous Gull, Great Black-backed Gull and Herring Gulls are commonly egged. Ring-billed Gulls are possibly egged in the Lake Melville area also. No estimate of the shooting and egging take is available but it certainly is a very substantial, traditional one.

Birds of this family arrive in April and May and may stay until January in southern Labrador. The Ivory Gull and Glaucous Gull, which are popular winter food species often are present all winter in the Labrador offshore (Bursey and LeDrew, 1977).

Auk, Murre and Puffin Family (Alcidae). These birds are extensively hunted on the coast. Six species are involved; and, with the exception of the Dovekie (Plautus alle), all are readily killed. Dovekies, because of their small size, are usually killed by hunters who are afforded a flock shot. The other members of this family are Razorbill (Alca torda), Common Murre (Uria aalge), Thick-billed Murre (U. lomvia), Black Guillemot (Cepphus grylle) and Common Puffin (Fractercula arctica).

These birds usually arrive in April in southern Labrador and progress north as ice conditions allow (Figures 8.10 and 8.11). Ice probably forces them out of the southern Labrador in January.

The only estimate of kill available is one of 3000 murres for the Labrador coast in 1960 (Inder and Gillepsie, 1974). The present-day kill is probably higher. For Inuit and Indians, the take of members of this family and their eggs is unrestricted. For other people, only murres may be taken; the season is from September 1 to March 31. Very large numbers of all six species are taken annually on the coast. The take is traditional and partly legal, and as well partly illegal.

Eggs of Black Guillemots are prized but few are taken because they are hard to find. It is not known whether any of the seabird colonies on the coast are egged. However, the egging potential is certainly great since in total at least 117,590 pairs of murres, puffins and razorbills nest on the coast between Nain and Cartwright (Brown et al 1975).

8.3 Marine Mammals

Eight species of whales occur regularly in Newfoundland-Labrador waters and several others are occasional visitors. The early history of whaling in the province "is one of wide fluctuations in effort and catches related to economic factors, war, and changes in whale abundance" (Pinhorn, 1976). In 1972, the Government of Canada banned commercial whaling on the Atlantic coast of Canada. Operations out of Dildo, Williamsport, Hawkes Harbour and a few other locations in the province phased down or had essentially ended prior to 1972. The only whale harvest in Newfoundland today is the very occasional shooting of a northern pilot whale (Globicephala melaena) for meat.

Six species of dolphins and porpoises visit waters off Newfounland-Labrador. Two of these are harvested in relatively small numbers, primarily by fishermen.

Six species of seals commonly occur in Newfoundland-Labrador waters, two species (harp and hood) are harvested intensively in a well-regulated fishery. The other species are taken in much smaller numbers in a basically unregulated harvest. This section of the report deals primarily with seal harvest. These are the only marine mammals readily taken by shore-based Labrador residents.

8.3.1 Resource Utilization

8.3.1.1 Delphinidae (dolphins and porpoises). The Atlantic white-sided dolphin (Lagenorhynchus acutus) and the Harbour porpoise (Phocoena phocoena) are common in

the inshore waters of Newfoundland and Labrador. While these species are not usually subjected to direct fishing, they are frequently captured in gill nets and cod traps. The meat is very palatable; and when the animals are removed from the nets, they are usually saved for food. They are, along with the white-beaked dolphin (Lagenorhynchus albirostris), occasionally shot for food.

No estimate of population size in Newfoundland-Labrador waters are available for these or the other species of Delphonidae occurring here. It has been suggested that capture in fishing nets may contribute significantly to the mortality of some species (Pinhorn, 1976).

It is considered unlikely that a commercial fishery for these species will be developed in the province.

8.3.1.2 Pinnipedia (seals, walrus). Walrus are extremely rare in these waters and are not considered further in this report.

The harvest of seals has considerable economic and cultural value to Newfoundland and Labrador. The harp seal is taken in greatest numbers, primarily by island residents who pursue the species both inshore and offshore in an extremely well-regulated harvest.

In Labrador, the harvest of seals has a different character. Landings are much smaller, and although a small number of other species of seals are taken each year, the utilization of the resource in Labrador may be generally described as an opportunistic and unregulated harvest of ringed and harp seals by landsmen.

Ice conditions permitting, seals may be taken in most months, particularly in southern Labrador (Figures 8.12 to 8.16). However, the bulk of the harvest occurs in April, May and June. Beginning in 1978, an April 20 to November 30 season was imposed for ringed seals in Lake Melville; however, this season does not pertain to the coast.

Seal species harvested in Newfoundland and Labrador are:

Bearded seal (Erignathus barbatus). This large seal frequents the broken ice of offshore Labrador and northern Newfoundland. A small harvest of 25 to 50 seals is made each year during the period of ice cover (records of Labrador Services Division, Provincial Department of Rural Development). These numbers are undoubtedly conservative since only animals offered for sale are reported. These show the major part of this small harvest to occur between Makkovik and Nain (Figure 8.12). Almost certainly, small numbers are also taken farther north and south.

Harbour seal (Phoca vitulina). Scattered populations of this species occur in Labrador waters. Dense aggregations have been recorded in some estuaries north of Nain.

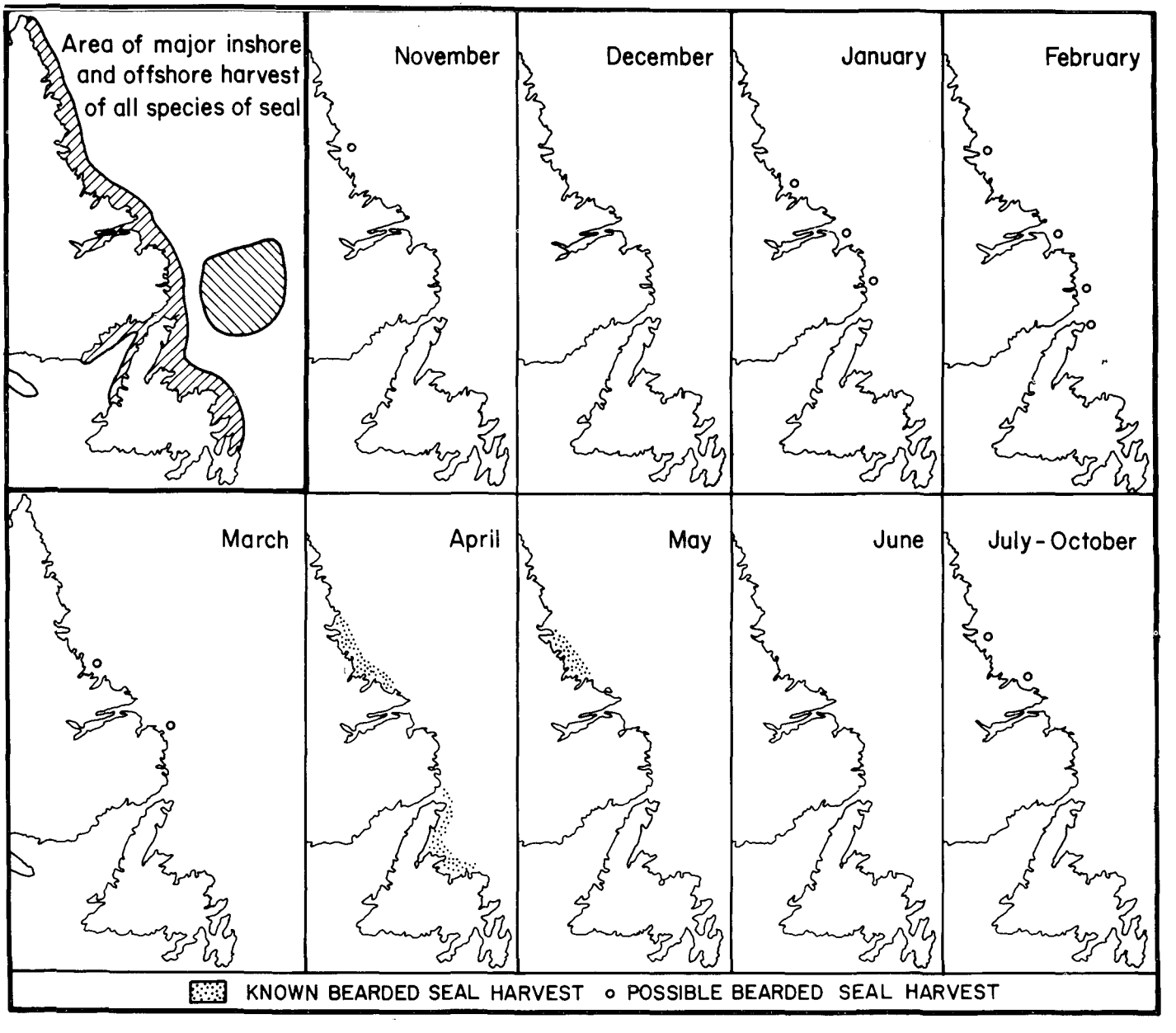

FIGURE 8.12 BEARDED SEAL HARVEST

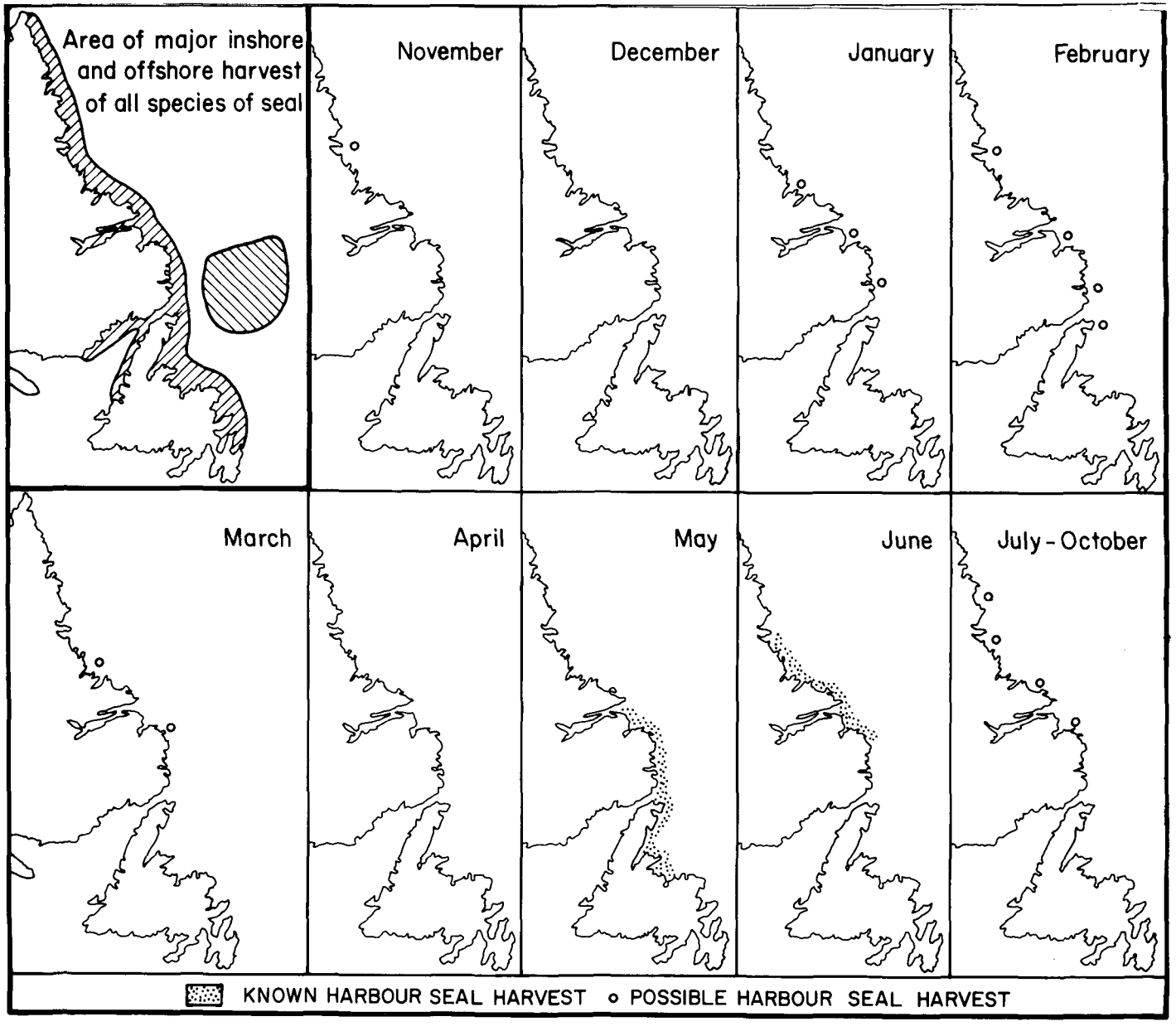

FIGURE 8.13 HARBOUR SEAL HARVEST

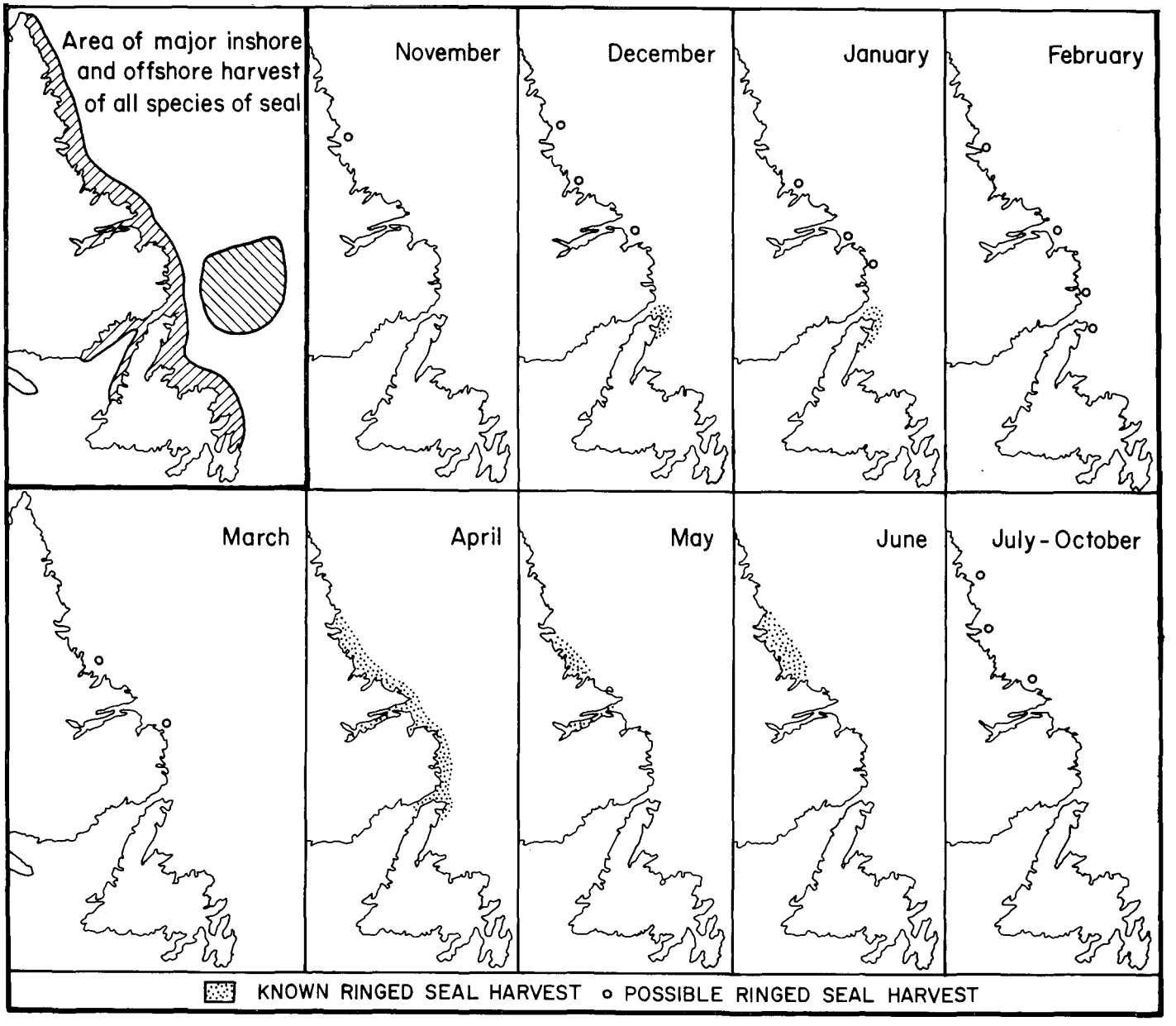

FIGURE 8.14 RINGED SEAL HARVEST

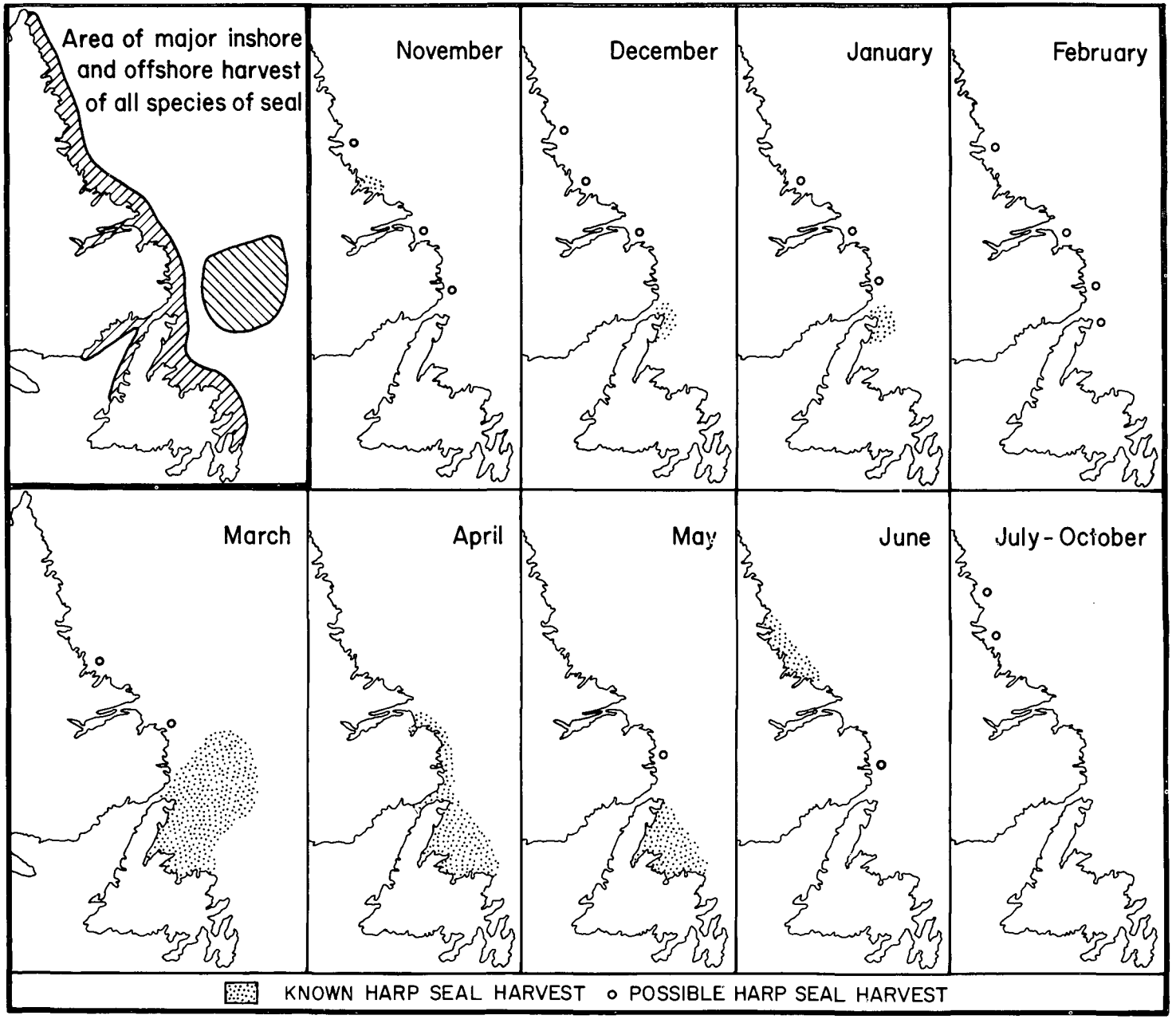

FIGURE 8.15 HARP SEAL HARVEST

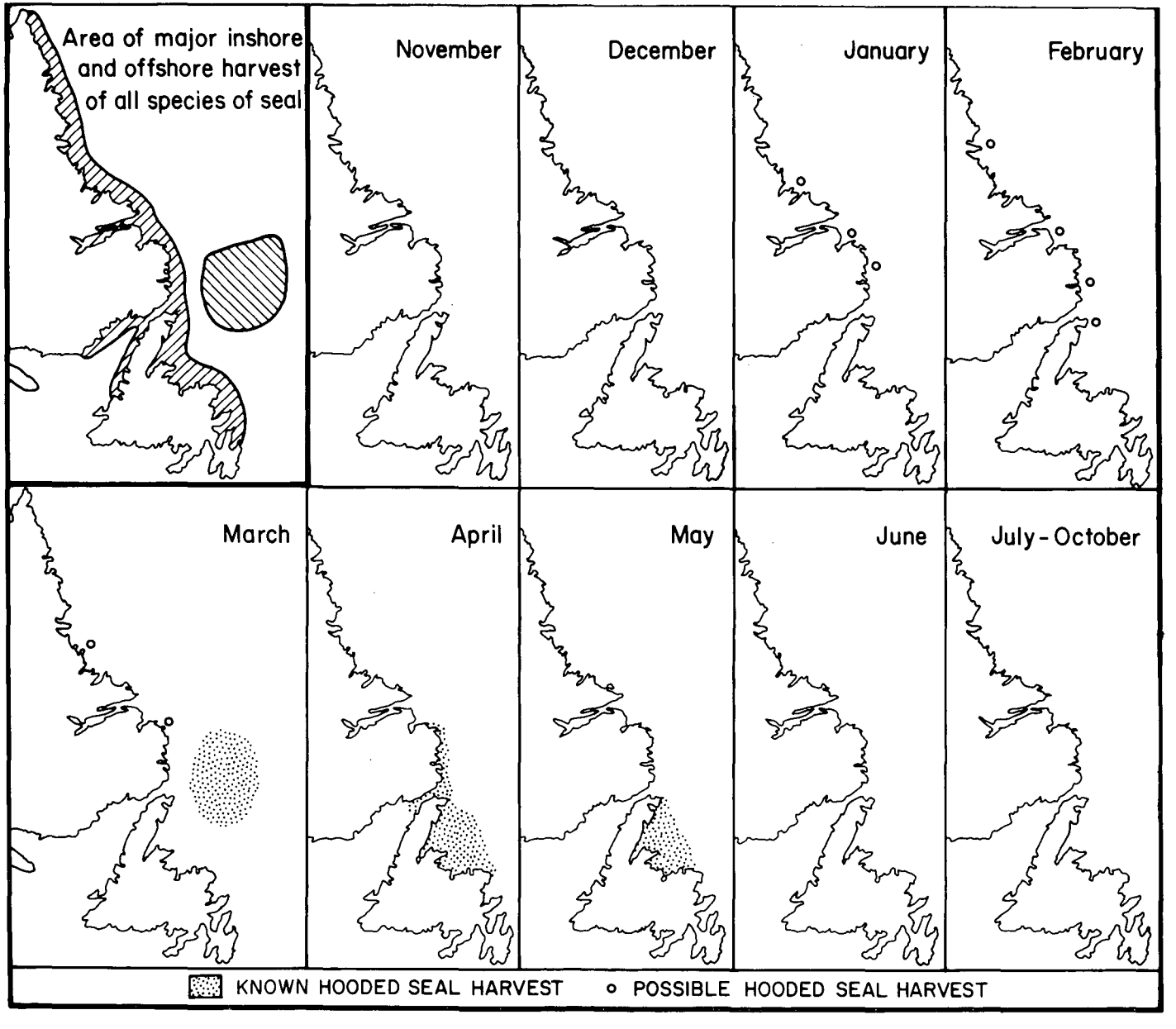

FIGURE 8.16 HOODED SEAL HARVEST

Small harvests (less than 300 seals) are made annually in Labrador (Figure 8.13). These figures are based on Labrador Services Division records, which do not reflect possible harvests south of Makkovik.

Ringed seal (Pusa hispida). This seal occurs in substantial numbers in the fast ice along the Labrador coast from Groswater Bay to Cape Chidley. There is also a population (probably resident) in Lake Melville (Figure 8.14). This is the species most commonly harvested in Labrador. From 1972 to 1976, Fisheries and Marine Service records show that 10,265 ringed seals were harvested. This figure is undoubtedly conservative since it reflects only pelts offered for sale.

Harp seal (Pagophilus groenlandicus). Approximately 1.5 million harp seals occupy Newfoundland-Labrador waters between November and June each year (G. Winters, Personal Communication, 1977). Adult harps migrate south along the coast of Labrador in November and December. Whelping takes place during mid-March in the Gulf of St. Lawrence and at the Front off northern Newfoundland. After whelping, the adults breed and then undertake a northward offshore migration in late April and early May.

Most harp taken in Labrador are captured by land-based residents during the southward and northward migration. It is only in the Straits area that Labrador residents occasionally have an opportunity to take harps at the Front. It is during the southward migration (in Labrador) and after whelping (Newfoundland and southern Labrador) that the greatest harvest of harps takes place (Figure 8.15).

The seal hunt, primarily for harp seals, was an integral part of the social and economic fabric of Newfoundland from the early 1700's to the 1930's. In some years during this period, it was not uncommon for 400 vessels (ranging from 70 to 200 tonnes) and 13,000 men to be engaged in the hunt and to land over 500,000 seals. Since the 1930's, the offshore hunt has declined. For the last few years, only four or five large Newfoundland-based vessels have prosecuted the hunt. Landings now are less than 100,000 pelts.

Prior to 1971, the hunt was largely unregulated. Following the imposition of quotas in 1971, the harvest increased annually until 1977, when unfavourable weather and publicity caused a reduction in catch. The harp seals are now being managed for an annual increase, and this strategy appears to be working. Federal Fisheries scientists have indicated that the size of the annual herd increment in 1977 permitted an increase in the quota for 1978.

Residents of Labrador share a small harp quota of 10,000 with Greenland and other sections of the Canadian Arctic. In most years, fewer than 1,000 harp seals are

taken in Labrador (Labrador Services records). Again, these records are conservative. In the Straits (Forteau, Red Bay area) landsmen undoubtedly harvest significant numbers of harps. For example, Carino Co. Ltd. of Dildo, Newfoundland, sent a ship to the Quebec North Shore and Southern Labrador to pick up 6,000 seals taken up to January 15, 1978.

Hooded Seal (Cystophora cristata). While catch records since 1972 indicate that the hooded seal is not taken in Labrador, there may be occasional kills, especially south of Hamilton Inlet (Figure 8.16).

The "hood" is however, economically important to the island. It is taken in conjunction with the harp seal harvest at the Front and is also harvested in lesser numbers landsmen in northeast Newfoundland.

A quota (15,000 for 1978) is placed on the hood harvest. Canadian vessels are be permitted approximately half of this number.

8.3.1.3 Structure of the seal fishery. "Seal resources are exploited by several types of technology with variations depending upon geographic conditions" (Dunn, 1977). Animals are taken with nets, rifles, shotguns or clubs.

There are two distinct facets to the hunt:

- Inshore: landsmen pursuing the hunt either of foot or in vessels up to 150 tons gross weight.
- Offshore: harvest by vessels over 150 tons tross weight concentrating primarily on whelping and moulting sea herds. Canada and Norway share this quota.

Operations are seasonal. Weather conditions considerably influence the success of the hunt. The hunting season extends from early winter to late spring, depending on geographic location and method of harvest.

The sealing industry provides employment and earnings during the lowest point in Newfoundland's (and Atlantic Canada's) highly seasonal economy. In the past five years, some 4,000 Newfoundland-Labrador landsmen and 100 to 200 men operating from large vessels at the Front harvested an average of 65,273 seals annually, valued at $1,112,945.

Inshore Hunt. In recent years, the longliner has proved to be an excellent sealing vessel. Its use has changed the concept of the traditional inshore harvest from one of men on foot or in very small boats to an activity which now harvests a greater number of seals than the Newfoundland-based large offshore vessels. However, large numbers of landsmen (3,000 to 4,000) still pursue the harvest in the traditional way.

Harps form the major portion of the inshore catch. Beaters (one to three month-old harps) constitute approximately 60 percent of the inshore harvest; bedlamers

(one to five year-old harps) make up another 25 percent. The whitecoat (newborn harp) is relatively unimportant to the sealers who hunt near the land.

Hoods and other seals (excluding harps) contribute from six to eight percent of the inshore harvest.

The inshore hunt takes place along the entire coast of Labrador and northern and northeastern Newfoundland island (Figure 8.12). The largest landings are in the island section of the area.

No fixed quota is set for the inshore hunt; rather, a Canadian target allotment of 30,000 is established for harps and 7,500 for hooded seals. While this inshore allotment for harps is exceeded in most years, reduced offshore catches usually assure that the overall inshore-offshore quota is not exceeded.

Table 8.5 details the total catch and pelt value for the Newfoundland inshore seal harvest for the period from 1972 to 1977.

TABLE 8.5 SEALS: NEWFOUNDLAND AND LABRADOR TOTAL ANNUAL CATCH ALL SPECIES

	Landsmen and Longliners		Offshore Harvest	
Year*	Number	Values ($)	Number	Values ($)
1972	20,657	254,780	21,086	179,911
1974	23,277	392,148	25,507	292,573
1975	45,348	1,114,986	32,779	515,355
1976	62,496	975,257	32,121	521,577
1977	59,882	1,291,831	28,819	464,577

* 1973 Figures Not Available

Approximately eight to ten percent of the numbers in Table 8.5 are taken in Labrador. The average total value of the landsmen's harvest along the Labrador coast is $95,000. Tables in the appendix to this chapter contain a more detailed breakdown of the inshore harvest for Labrador.

Earnings for the 3,000 to 4,000 people who pursue the inshore harvest vary considerably. A weekend hunter may earn just a few dollars, whereas crewmen of successful longliners can realize $5,000 to $6,000 each for a few weeks' work.

Offshore Hunt. The offshore harvest primarily benefits the residents of insular Newfoundland because of the geographic location of the whelping grounds. It is based primarily on the harp seal. This species forms 90 to 95 percent of the harvest. Whitecoats contribute 80 to 90 percent of this. Hooded seals make up nearly all of the remainder of the offshore catch. Curtailment of the whitecoat harvest would effectively terminate the offshore effort.

The annual quota is fixed each year for the offshore harvest. In 1971, a total (inshore and offshore) quota of 245,000 harps was set by the federal government for the Northwest Atlantic hunt. Canada and Norway share these quotas. In 1972, the total quota was 150,000 and it remained at that level until 1977, when it was raised to 170,000. The total quota for 1978 is 180,000 harps.

Of the total 1978 quota, Canadian ship-based offshore hunters will be permitted to take 62,000 harps at the Front. This figure increases from 52,000 in 1977. Norwegian ships can take 35,000 harps at the Front.

The 1978 quota for hooded seals is 15,000, half of which will be taken by Canadian ships.

Earnings to the sealer in the offshore harvest are usually high. Unless the hunt is a failure, an individual will earn between $2,000 and $3,000 for the four to five week period.

The total catch and pelt value for the Newfoundland-Labrador offshore harvest for the period 1972 to 1977 is also shown in Table 8.5.

8.3.1.4 Value of the seal harvest. In 1976, the seal harvest returned $5.9 million to Atlantic Canada and part of Quebec. Over half of this ($3.8 million) came from the sale of pelts; the remainder came from sale of meat, oil, and from employment generated by the processing of pelts and seal carcasses. Earnings from the 1976 hunt benefitted 18,000 people in Atlantic Canada.

Of the 6,000 licenced sealers in the 1976 harvest, 86 percent (5,160) were based in Newfoundland and Labrador.

8.3.1.5 Future of the sealing industry. Dunn's 1977 study warns that the sealing industry must carefully plan management strategies if it is to improve its economic position. He states that the industry is over-capitalized at present, and market conditions are uncertain. Thus, while seal populations (particularly harps) are well managed and on the increase, the industry faces an uncertain future in the offshore hunt.

The inshore harvest, particularly the traditional landsmen hunt of northern Newfoundland and Labrador, would probably continue in spite of market conditions and the general unhealthy state of the industry.

8.4 Potential Impact

In a Woods Hole Oceanographic Institute study (1976) of the effects of petroleum development on the commercial fishery off the northeastern United States, it was pointed out that the development "involves the intrusion of a new aggressive industry into a region which values its traditional ways". This statement is particularly applicable to the petroleum and gas exploration and development activities taking place and planned to take place off the coast of Labrador.

In this chapter we address the immediate and direct impacts which a major oilspill event from offshore petroleum exploration activities can have on the inshore and offshore harvesting of fish, seabirds, and marine mammals.

Impacts on oil exploration and production activities such as loss of fishing space, surface obstructions and debris, and inshore and offshore interactions are not dealt with here. Similarly, this chapter does not deal with the biological interaction between oil and organisms (i.e., long-term and cumulative effects). A recently completed study (Northland Associates, 1977) offers a preliminary discussion of this.

Of special concern to the Newfoundland-Labrador area is the fishing industry. Many of the problems which might be anticipated between the petroleum and fishing industries are practical and operational ones. Figure 8.17 shows the relationship between boundaries of the oil lease areas and the productive fishing grounds. There is clearly a potential for conflict. The fishing "industry", and the harvest of seabirds and marine mammals in Labrador waters is not an industry in the same sense that the oil industry is. As the Woods Hole study recognized, the fishing industry is a diffuse collection of individual operators; impacts are felt at very local and personal levels. Adjustments that might be required in the future are also at the local and personal level.

Reporting on the biological resources is complicated by the fact that these resources are never constant. Size of populations, distribution, recruitment, natural mortality, and harvest mortality are continously varying. It is therefore not possible to quantify precisely what the potential impact could be.

Catch and landing statistics are similarly sometimes difficult to interpret. Landings data deal with volumes and values landed at specific ports without reference to where the fish are caught. ICNAF statistics report catches within divisions or sub-

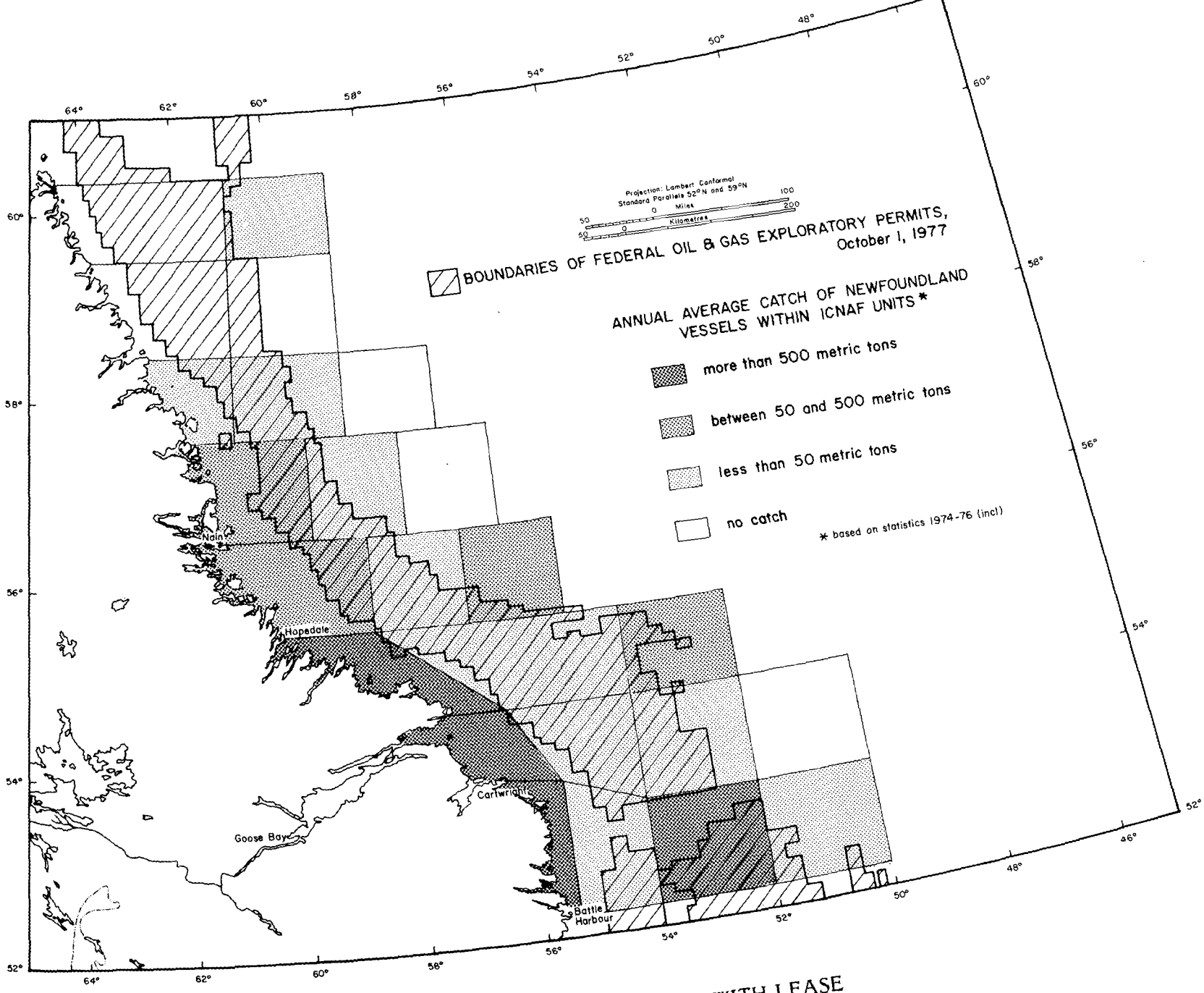

FIGURE 8.17 COMPARISON OF PRODUCTIVITY OF FISHING WITH LEASE BOUNDARY

divisions, but in a manner which frequently makes it difficult to separate coastal and offshore fisheries. For the most part, however, we feel we have worked our way through the available data reasonably completely and have presented it in a meaningful form.

Details of type and value of gear owned and operated have not been obtained since 1973 from all Labrador fishermen. In that year, there were 843 inshore fishermen. Eight hundred were listed as casual (less than 21 weeks' fishing) and 43 were listed as part-time (22 to 28 weeks' fishing). A review of these Tables in the appendix to this chapter will show that more fishermen fish for shorter periods as one proceeds north.

Using the same 1973 data but doubling the value to bring it in line with 1978 prices, the types and value of the gear are also shown in the Appendix Tables. Gear with an approximate value of $2,000,000 is presently being used on the coast.

Statistics from the Licensing Branch of Federal Fisheries show that in 1975 there were 819 registered fishermen along the coast. This is similar to the 1973 data. It suggests that the amount of fishing gear operated today is also similar to that operated five years ago.

In 1976, Labrador inshore fishermen landed 8,059.9 tonnes of fish valued at $2,772,000. Principal species that year were cod ($1,364,000), salmon ($1,190,000), herring ($119,000), and Arctic char ($69,000).

In 1976, landsmen harvested 5,146 seal pelts for a value of $133,000. No values are available for the seabird harvest. It should also be recognized that the values given for fish and marine mammals represent that portion of the harvest which is sold. The part consumed at home is not recorded here.

Labrador offshore waters are fished by some 15 nations. Major offshore effort is in ICNAF Divisions 2H and 2J. Fewer vessels fish the northern ICNAF Division 2G. Combining catch statistics from Divisions 2GHJ for the period 1974 to 1976 inclusive, the following average annual catches are taken in Labrador offshore waters: Foreign fleet - 177,737 tonnes; Canadian vessels - 286 tonnes; Newfoundland vessels - 1,523 tonnes. Figure 8.18 shows a breakdown by ICNAF Division.

The total value (marketed plus consumed at home) of the marine resource to the people of the Labrador coast is probably at least $3,000,000, and possibly closer to $4,000,000 annually. This computes to $500 to $700 per individual for the 6,000 people on the coast.

By national standards, the economy of the Labrador coast would be considered to be subsistence. Income levels, and the seasonality of resource use coupled with the

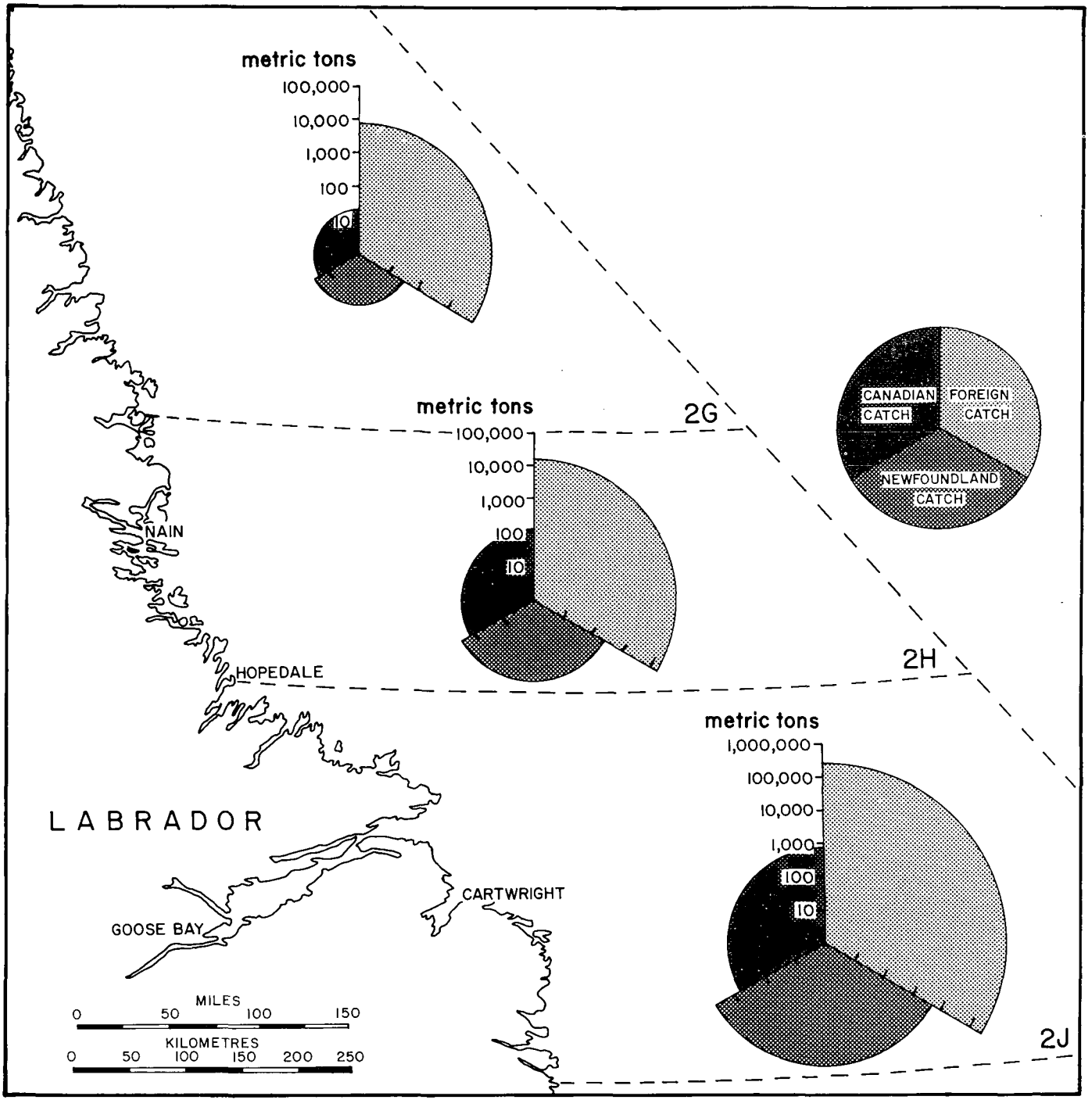

FIGURE 8.18 NEWFOUNDLAND, CANADIAN AND FOREIGN AVERAGE ANNUAL CATCH FOR ALL SPECIES 1974-1976

high degree of under-employment supports such a view. However, a careful observer of material comforts and life styles will see a contradiction to the standard concepts of poverty.

There is a considerable amount of real income not reflected in cash flow. At least half of the protein requirements are met by harvesting from the land and from the sea, most of it from the sea. Seasonality of resource use is offset by the fact that economic activity occurs throughout the year as various resources (land and sea) are harvested.

8.4.1 The Blowout. While there have been some studies dealing with the effect of an oil spill on marine life, there have been no definitive studies on the effects of an oil spill on the fishing industry and renewable resource utilization. It is difficult to separate all the variables. A decline in fish catches or seabird harvest may be due to oil, a decline in harvest effort, natural fluctuations in animal numbers, or from a variety of other natural and man-made causes.

The evidence does suggest, however, that the effects of chronic pollution are not too damaging except in a very localized situation. The following section briefly summarizes potential impacts of oil from the hypothetical blowout.

8.4.1.1 November to December. It is assumed that the slick will drift offshore initially.

Fisheries. The blowout site is 80 km off the Labrador coast. It falls in ICNAF Division 2H, near the boundary of units 215 and 216. Based on past movement patterns, few Canadian vessels will be in the vicinity at the time of the blowout. Four to five Canadian and Newfoundland vessels have averaged approximately 16 tonnes of groundfish and pelagic species annually from units 215 and 216 combined (Figure 8.7).

It is unlikely that a November 1 blowout would interfere significantly with Canadian-Newfoundland fishing activity during the first two months of the spill.

Some 38 vessels of the foreign fleet will be in the blowout area in late fall - early winter. While only eight were in ICNAF area 2H during November, 1977, 30 were to the south in area 2J (Appendix Tables). Some vessels of the foreign fleet could be expected to come into contact with a southward moving slick during the first two months.

Seabirds. There are insufficient data to determine if seabird concentrations occur offshore during the period from November to January. Even if there were, local residents would not harvest birds so far offshore.

Marine Mammals. An offshore drift of oil in November and December would not interfere with any marine mammal harvest activity by Labrador residents.

8.4.1.2 January to April. It is assumed that the pack ice will distribute the oil generally southward.

Fisheries. Canadian and Newfoundland offshore fishing activity in the January-May pathway of the slick is minimal or absent. There could be a few (four to five) vessels on Hamilton Banks in February. Inshore fishing activity along the Labrador coast at this time is non-existent.

The concentration of foreign vessels on the Hamilton Banks from late January, through February, and possibly to early March will be in or adjacent to the trajectory of the slick. As many as 90 vessels may be concentrated in a radius of 35 to 40 km in the vicinity of the Banks. The target species is cod. The boats are stern trawlers which operate in all except the most severe ice conditions. Oil-infested ice could essentially curtail that year's winter fishing effort on the Hamilton Banks.

Seabirds. There are no known concentrations of seabirds in the January to April path of the oil slick.

Marine Mammals. During this period, the slick would contact ringed, bearded, and harbour seals from Makkovik to southern Labrador. There is very limited inshore harvest activity at this time.

Of more concern is the possibility that the slick would contact young harp seals on their southward inshore migration during January and contaminate the Front whelping grounds in February and March. Contamination of the Front would cause either a dispersal of harps or oiling of adults and secondary oiling of young. In either case, the presence of a massive volume of oil at the Front during whelping would possibly curtail the harvest for that year.

8.4.1.3 May to July. Given the duration of the blowout, it is likely that some oil will find its way to shore during late spring and early summer.

Fisheries. A direct inshore (westerly) drift of oil would approach the complex of outer islands, bays, and river mouths in the Nain region. The Arctic char and salmon fishery in the area could be adversely affected. In 1977, this fishery value was $318,925.

The peak fishery is in July and August. Should oil find its way into the bays and inlets at this time, it would disrupt the fishery completely and possibly promote the demise of stocks in rivers close to Nain. As previously noted, these stocks have been overfished and are close to collapse.

July and August are also the most productive months for the salmon fishery in the vicinity of Nain. Salmon are taken in surface gill nets set primarily among the outer

islands of Voisey, Nain, and Okak Bays. Salmon in these northern waters appear to be predominately from home rivers.

Loss of the salmon fishery for a few years would cause economic hardship to fishermen of the region. However, a reduced fishing effort would aid in rehabitation of stocks. Currently, the summer season is a period of self employment for nearly all adult males in the Nain area; in the winter, some 75 percent receive unemployment insurance or social assistance.

Fouling of Arctic char and salmon fixed gear would be expected if oil came ashore. The fact that this is an island-filled estuarial situation compounds and prolongs the problem. The oil will be present for a longer period. Surface gill nets for salmon and char would be vulnerable to fouling by weathered oil. Fouled gear would have to be cleaned or replaced. However, most of the nets are nylon, which would have good potential for successful cleaning.

Approximately 100 fishermen operate in the Nain area from June to August. From 300 to 500 gill nets, valued from $75,000 to in excess of $100,000, would be in the water. Loss of one or more summer's fishery plus the expense of replacing fouled gear if required, would probably result in the entire population in the Nain area receiving social assistance. These people could not, without help, generate the necessary capital to replace gear.

Capelin are both deep water and beach spawners along the Labrador Coast. They spawn during mid-July or later, using beaches with pebbles in the 0.5 to 2.5 cm size range. These fish are subject to a very high mortality during spawning. When concentrated on the beaches, they are suceptible to any stress.

Capelin eggs are laid to incubate in the interstitial areas of beach material. Because of this, probably no other pelagic fish species is as susceptible to inshore pollution. Weathered oil would be toxic to spawning adults and could be expected to smother eggs lying on beach material. As well, the beach spawning habitat could be destroyed for years in locations where weathered oil acted to alter permeability and other characteristics of beach material. In terms of identifying sensitive shorelines it is therefore essential to document the inshore spawning locations of capelin along the Labrador Coast.

If oil reached shore in the Nain area, it could cause significant immediate damage to the commercial beds of scallops that occur there. Should the oil become incorporated into the bottom sediments, the damage would be prolonged for years. The potential scallop fishery might not materialize.

A small turbot fishery has been initiated in Nain. It was valued at $1,915 in 1977. Its potential for growth would be set back by an oil spill.

The Nain fish processing plant depends on raw material (Arctic char and salmon) from a limited area. If Voisey, Nain and Okak Bays were contaminated by oil this plant would have to close. Forty-five plant workers would be without jobs.

The Nain plant utilizes fresh water from the town water supply. Plant operation would therefore not need to be curtailed because of oil-contaminated sea water around the plant.

While there are few wharves and stages in the Nain area, the government facility is relatively extensive and oiling could be a problem for this facility. Boats would be somewhat fouled from passing through oiled water and from being pulled up on oiled beaches. The effect of oil-contaminated cooling water circulating through marine engines is not known, but could result in some minor damage.

Seabirds. During May and June, there are large breeding and migrating concentrations of sea ducks inshore in the vicinity of Nain. Eiders are particularly abundant and heavily harvested by local residents, even in the spring when it is illegal. A much larger harvest occurs from Nain to Makkovik during the legal season.

In addition to eiders, there would be spring concentrations of auks farther offhsore. At the heads of bays, large concentrations of loons, geese, black ducks, goldeneye, and mergansers would be expected.

An oil spill arriving inshore during the spring would disperse these birds, possibly beyond reach of local hunters. On the other hand, some birds are attracted to oiled areas and may be killed by the oil.

The dependence of local residents on a spring bird harvest has already been discussed.

Perhaps, the direct mortality of some birds and the possible destruction of feeding areas for the year would be more serious. Parent birds are tied to the nesting locations in the spring. They use traditional feeding areas and if these are oiled, abandonment of eggs or young could occur. Also, viability and hatching success of birds eggs is much reduced by an oil coating.

Seabirds are very susceptible to oil pollution. Species that congregate are the most susceptible of all. Auks, murres, and puffins (harvested by the thousands along the coast) could be considerably reduced in numbers immediately, with the potential for long-term population reduction. Such birds have a long life span and are slow breeders.

Mortality is highest where temperatures are low and food is not readily accessible, i.e., conditions which are characteristic in Labrador in the spring.

Consequently, the inshore drift of a large volume of oil may have the immediate effect of denying local residents of particular sections of coast a needed spring and summer harvest of seabirds. The immediate seabird mortality and oiling of feeding areas, will result in much reduced hatching success for the season and a consequent future reduction of numbers.

Marine Mammals. Oil from the hypothetical blowout moving inshore in the spring will enter an area occupied by resident ringed seals, bearbed seals, and harbour seals. It is also possible that adult and sub-adult harp seals returning north in June will contact the oil near shore.

Most of the seals taken in Labrador are harvested in spring and fall. In 1976, in the Nain area, this harvest consisted of 1632 ringed seals, 182 harp seals, seven bearded seals, and nine harbour seals, cumulatively valued at from $40,000 to $60,000.

Oil coming inshore at this time would disperse the seals, possibly making them inaccessible to local residents. No large population reductions would be expected because of the oil. No case of extensive marine mammal mortality attributable to oil has been reported in the literature. However, the presence of such large numbers of harp seals in the Labrador Sea has to be of concern; nowhere else is there such potential for extensive damage to such large numbers of harps.

8.4.2 General Considerations Of Oil Pollution and Resource Utilization. If the oil spill were to occur at another time or endured longer than as envisioned in the scenario, the impact could be much greater. For example, the major Canadian, Newfoundland, and foreign offshore fishing effort is conducted in the Labrador Offshore during the late summer/fall period.

Similarly, seabird (particularly murre) concentrations would occur in the path of the oil off southern Labrador during late spring and early summer. The northward migration of adult harp seals during May and June would also be intercepted.

8.4.2.1 Offshore. Clearly, a large spill on the fishing grounds would interfere with fishing activity for a period immediately after the spill and during clean-up. Fishermen would avoid the total area. The spill would eventually fragment. Depending on the density of these residues, fouling of fishing gear might occur. the magnitude of the problem to fishermen depends on type of oil, frequency and size of spills, time taken to complete clean-up, and sea state. It is conceivable that part of a season may be lost,

particularly where a major effect is concentrated in a small area over a short period of time. Over the long term, the impact from a single spill on a particular ground would probably be small.

Gear used offshore is not the fixed kind. Deep water gear is less likely to be fouled because of the depth. Also, the vessel can elect not to set the gear in an area where oil is visible.

Marine mammals appear simply to avoid an oiled section of water. Except for possible contamination at the Front, oil would not appear to have a major effect on this resource.

Seabirds do get into considerable difficulty with oil on water. A large offshore spill, particularly in spring and fall off southern Labrador, could cause reduction of numbers for the following year's harvest by local residents.

8.4.2.2 Inshore. It is generally accepted that oil moving inshore and onto the beaches is the worst possible kind of situation. Discussion on the ecological implications of this are given in a previous study (Northland Associates, 1977) as well as in numerous other literature.

The seasonal pattern of inshore resource utilization on the Labrador coast will serve as a starting point for a brief discussion of worst cases and critical areas:

- Summer: primarily fishing, some birding
- Fall: birding, fishing, some sealing
- Winter: slight sealing, some birding in southern Labrador and the Strait
- Spring: birding, sealing, fishing.

Fishing (Arctic char and salmon in northern Labrador; cod, salmon, herring in southern Labrador and the Straits) is the major resource. All inshore fishing is carried out using mainly fixed gear during ice-free periods of the year. This coincides with the period of most intensive petroleum exploration activity. It is also the time when blowout oil could, depending on wind and current, move inshore without the protective ice barrier.

Potential or existing shellfish fisheries would be very vulnerable to oil, particularly if oil became incorporated into the sediments. Tainting is a common problem at such times. It could take years before such shellfish beds are opened again.

Estuarial fisheries are extremely vulnerable to oil pollution. As already mentioned, oiling of the Arctic char and salmon bays near Nain essentially would eliminate the basic resource in northern Labrador for one or more seasons. This overdependence on two species is a cause for concern.

Estuarine pollution, and inshore oil generally, may affect migration routes of the Atlantic salmon. This would in turn reduce stocks of sports fish for the commercial camp operator. More seriously, it would also probably reduce the net catches by commercial fishermen.

The greatest variety of fixed gear and shore facilities for the fishery occurs in southern Labrador and the Strait area. Here, a greater variety of species are available to the fishermen. Also, some of the gear used is not fixed gear. Capelin and herring seines, for example, would not be deployed if waters were visibly oiled. Consequently, the southern Labrador-Straits fishery, with its broader base of target species and techniques, would possibly not be as seriously disrupted by oil pollution of inshore areas as would the more narrow based fishery of northern Labrador.

Both the Nain and Makkovik coastal fish processing plants utilize fresh water from the town system. This permits operation if oil reaches shore in the vicinity of the plant, provided of course that the raw material is not contaminated. The collection stations which have running water utilize fresh water. Presumably, in the event of oil contaminating sections of shoreline in northern Labrador, the fishing industry could continue if fishing grounds were not contaminated.

Collecting plants in southern Labrador send their fish to insular Newfoundland for processing. This might be considered an advantage when considering inshore oil pollution in southern Labrador.

Estuaries and sheltered bays are numerous along the Labrador coast. Salmon, char and other fish; shellfish; waterfowl; aquatic mammals such as otter and muskrat; and some seals abound in estuaries and coastal marshes and are part of the reason why inshore Labrador waters are so productive. The numerous estuaries are also locations for much commercial fishing (char, salmon, trout), trapping, birding, and for recreational pursuits such as sports fishing and boating.

Estuaries are, for the most part, balanced systems. If oil moves into an estuary, the balance could well be destroyed.

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CHAPTER 9
PROBABILITY OF AN OIL BLOWOUT AND THE CONCEPT OF RISK

by
T. Kierans
Atlantic Progress Limited
37 MacKenzie Street
St. John's, Newfoundland
A1A 2V4

and

B. LeDrew
Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial Univeristy of Newfoundland
St. John's, Newfoundland
A1B 3X5

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9 INTRODUCTION

In the last ten years, twelve exploration wells have been drilled into offshore Labrador's sea floor (Mines and Energy, 1977). Three of these wells have resulted in encouraging gas discoveries. Oil industry spokesmen estimate that the oil potential of the general area is between three and twenty-six billion barrels. At $15/barrel, this oil estimate alone indicates a resource value between $45 billion and $390 billion.

If the good ratio of success in exploration drilling is maintained, i.e., one success in four against one in 18.4 in Western Canada, (Loutfi, 1973); and if the appropriate extraction technology is developed along with the continued demand for oil and gas, the oil companies involved and the province of Newfoundland and Labrador should anticipate economic benefits similar to those experienced in other hydrocarbon rich areas of the world.

For this reason, it is proper that the exploration of this important potential resource should be pursued. However, there should be prudent regard for all the possible consequences to the existing social and economic structure of the province.

In the last ten years, Canada and the province of Newfoundland and Labrador have strived for and finally achieved a comprehensive 200-mile management jurisdiction over offshore fishing grounds. These fisheries are located directly above the indicated hydrocarbon deposits. In addition, the strong Labrador Current which follows the coastline southward above the Labrador offshore oil and gas exploration areas is recognized for its influence on the productivity of other fisheries adjacent to the island of Newfoundland. Thus, any massive spills originating off Labrador could be expected to influence fisheries much further south.

Taken together, the Labrador shelf, the Grand Banks of Newfoundland and the coastal waters connecting the two areas comprise one of the most productive of the world's renewable marine food resources. The area is capable of yielding annually, on a well-managed renewable basis, hundreds of thousands of tons of protein harvest.

In addition to the deepsea offshore fishing, the small boat coastal fishery has been the traditional social and economic foundation for the Province of Newfoundland and Labrador. With the continuing demand for food resources, its future, if undamaged, could be at least as promising as the hydrocarbon potential. Furthermore, its social significance will be permanent.

The confluence, in both time and place, of the above two developments for the province and for Canada has resulted in a third sobering and significant realization. This

is simply that, notwithstanding advances in offshore oil well drilling technology, serious oil blowouts from both exploration and production wells continue to occur, under even the best of dry land conditions. For example, Ocean Industry (1977) lists sixteen major and two minor blowouts on offshore drill rigs between 1955 and 1974.

The main purpose of this document is to identify, albeit in relative terms, the likelihood of such an event occurring as a result of exploration drilling in the Labrador offshore.

9.1 Drillships and Drilling Systems used in the Labrador Sea

The first attempt at drilling off Labrador was made in 1971 by a conventional drillship, the *Typhoon*. This operation proved to be both hazardous and unsuccessful. In addition to encountering problems with spudding in on a seabed strewn with boulder particles, the drillship with its anchored positioning system could not stay on the hole during the weather conditions it encountered. On September 26, the combination of a violent storm and an approaching iceberg on a collision course forced the vessel to abandon the site, leaving the 12 m tall Blowout Preventor on the seabed (Duval, Corgnet and Duval, 1975).

With the exception of one well drilled in 1976, all subsequent operations have been carried out by dynamically positioned drillships: the *Havdrill*, the *Pelican*, the *Petrel* and the *Sedco 445*. The one exception was the self-propelled semisubmersible *Zapata Ugland*, which was equipped with a quick release anchoring system (Kobus, Meyers and Haines, 1977). The perennial threat of icebergs has necessitated this ability to quickly disconnect and leave a specific drilling location.

Because drillships are subject to vertical motion as a result of severe sea states, adequate heave compensators have to be placed on top of the marine riser. Except for these features, essentially conventional drilling systems are used. The Appendix to this chapter contains a description of the systems on the Pelican (Ferrero and Ple, 1976).

Drilling procedure, logistics and deployment methods in use are generally the same as those of conventional drilling technology elsewhere. Here again, the exception relates to the iceberg threat. Special iceberg towing vessels accompany each operation. These ice-class vessels have towing equipment on board to divert icebergs (up to a certain size) from a safety region around the drilling operation. The development of this procedure is described by Ainslie and Duval (1975).

The drillship system illustrated in Figure 9.1 is capable of drilling in water depth up to 350 m, with wells as deep as 8,000 m.

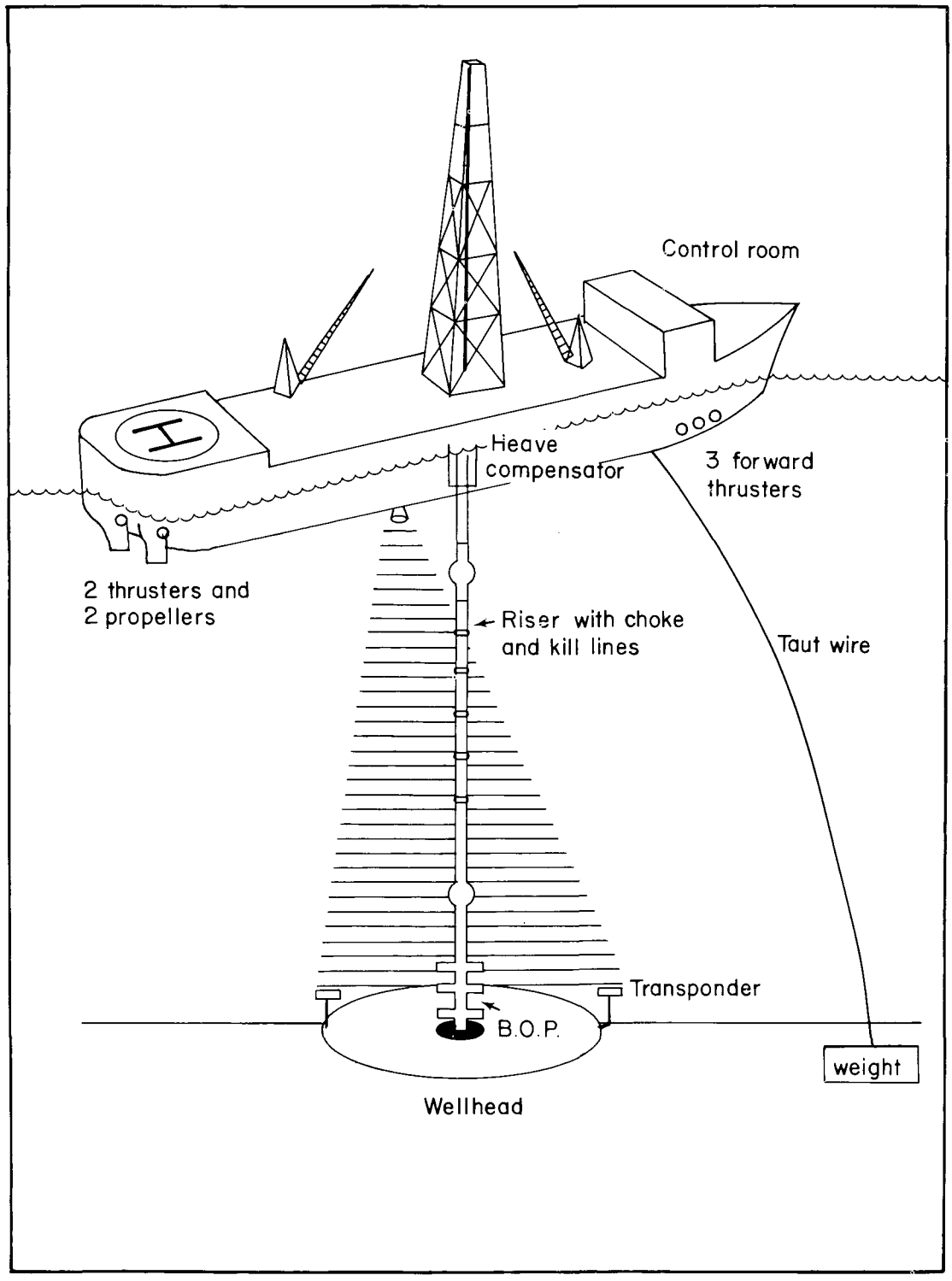

FIGURE 9.1 DYNAMIC POSITIONING OF DRILLSHIP OFFSHORE LABRADOR

9.2 What is a Blowout?

During drilling operations, the drilling mud circulation system serves to maintain a dynamic pressure balance between the hole and the formation. Should formation pressure rapidly build up and counterbalance the mud weight, a "kick" occurs. By adjusting the mud weight, the "kick" is usually brought under control; however, should this fail, the Blowout Preventor (BOP) valves may have to be activated and the pressure contained through the kill and choke lines.

Should the BOP valves not be activated or fail to operate properly, a blowout occurs. Fluid may also escape up the hole between the formation and the casing. Depending on the nature of the material contained in the high pressure formation, the blowout fluid may or may not contain oil or gas.

Offshore blowouts can occur during either exploration or production operations. Blowout orifices may be above the water surface as in the case of the Ekofisk Bravo incident (Vanderkooy, 1977), or underwater, either in the riser pipe or at the sea floor itself.

The term 'cratered blowout' is used when the fluid comes out of the ground on the outside of the casing pipe lining the well. The cratered underwater blowout is perhaps the most difficult situation to contend with. This was the case at the Santa Barbara blowout in 1969, where an estimated 13,000 tonnes of oil were lost nto the sea over a 100-day period. This was a relatively low rate of flow.

Potential flow rates in the North Sea have been estimated at 15,000 tonnes/day over a "worst case" life of 500 days (Westergaard, 1977). Actual experience to date, however, has not demonstrated this worst case projection.

Methods of dealing with blowouts include capping the well by replacing damaged wellheads and closing the well.

Should control of the original hole prove impossible, blowouts usually can be contained by drilling a relief well. This involves directional drilling of a separate hole to intersect the high pressure formation near the original hole.

As illustrated in Figure 9.2 heavy drilling mud is then pumped into the formation to block off the flow. This procedure is both difficult and time consuming. For example, Lewis et al (1977) describe a blowout in the shallow waters (15 m) of the Gulf of Mexico. Under relatively ideal operating conditions, it took 48 days to successfully drill a relief well and curtail the blowout.

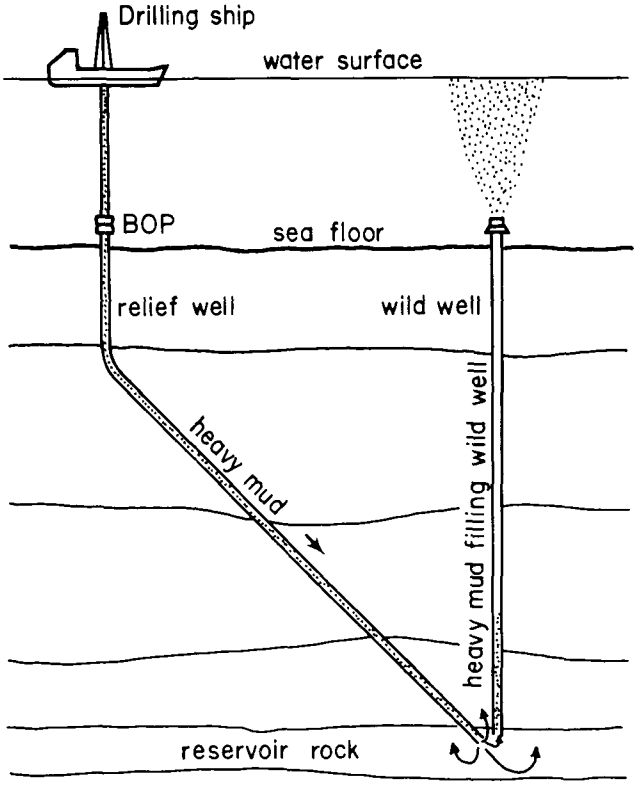

FIGURE 9.2 RELIEF WELL DRILLING

9.3 The Probability of a Blowout

Probability is defined as the number of times something will occur over the range of possible occurrences, expressed as a ratio. It is generally acknowledged that the probability of a blowout from any one well is very low; the probability of such a blowout containing oil is even smaller.

Historical statistical data is very limited, amounting to little more than accident counts for blowouts from production operations. Bercha (1978) has reviewed the historical data on blowouts and presented a summary of available figures, along with his own projections in tabular form. The results of Bercha's work for the Beaufort Sea, as well as his summary of other studies are presented in Tables 9.1 and 9.2 respectively.

There are insufficient data available to provide statistical information on blowout probabilities in the subject area. Therefore, common sense and general analytical

TABLE 9.1 SUMMARY OF BEST ESTIMATES OF BLOWOUT PROBABILITIES: BEAUFORT SEA

Type of Blowout Event	Probability of Event			
	System and Condition			
	Island Summer	Island Winter	Drillship Summer	Weighted Average
(1) Blowout (Any kind)	0.577×10^{-3}	0.652×10^{-3}	2.41×10^{-3}	1.51×10^{-3}
(2) Blowout (Q ~ 50 bbl./day)	0.721×10^{-4}	0.814×10^{-4}	3.02×10^{-4}	1.89×10^{-4}
(3) Blowout (Q ~ 500 bbl./day)	1.76×10^{-5}	1.99×10^{-5}	7.36×10^{-5}	4.62×10^{-5}
(4) Blowout (Q ~ 5K bbl./day)	0.880×10^{-6}	0.994×10^{-6}	3.68×10^{-6}	2.31×10^{-6}

Best estimates for the blowout probabilities obtained through this work are summarized in Table 9.1 for the various systems and conditions averaged for both the normal and diapir areas. Averages range from a maximum probability of approximately 3×10^{-3} per well for a blowout which will almost certainly be gas, to a minimum of approximately 1×10^{-6} per well for the probability of a major oil spill caused by a blowout. Within the statistical 90 percent confidence interval, these values may vary from 20 to 200 percent. Approximate probabilities for groups of wells and well-start rates can be obtained on the basis of the values given in Table 9.1, on the basis of linear proportioning.
(Source: Bercha, F.G. EPS 3-EC-78-12: Table 7.1)

information must be relied upon, which naturally allows a wide range of interpretation. Before doing so, it is worthwhile to review Bercha's work briefly as a pertinent example of detailed analytical work on blowout probabilities.

Bercha compared probabilities between artificial island and drillship systems using the "fault tree" technique. It was applied to a 12-month drilling period (three wells) for an artificial island drilling system located in shallow water (zero to ten m). This was compared with a four-month summer (also three wells) offshore drilling system using three drillships, one of which was dynamically positioned, in 170 m of water.

TABLE 9.2 STATISTICAL DATA ON BLOWOUTS

	Probability of Event/Well			
Item	Blowout on Land	Blowout Offshore	Oil Blowout Offshore	Remarks
Kash (28)	0.38×10^{-3}	2.3×10^{-3}	3.0×10^{-4}	Production wells mostly. Offshore are all fixed platforms.
Goodwin (23)	0.40×10^{-3}	2.3×10^{-3}	2.7×10^{-4}	World production and exploration; mobile rigs.
Goodwin (23)	-	5.2×10^{-3}	6.2×10^{-4}	North Sea - Production & Exploration.
Greene (24)	-	6.0×10^{-3}	-	Exploratory
Mackay (31)	-	2.5×10^{-3}	-	Exploratory.
Milne (38)	-	1.0×10^{-3}	1.0×10^{-4}	Milne (38) quotes probability of oil or oil plus gas blowout within range shown.
Snider (62)	-	4.7×10^{-3}	3.7×10^{-4}	All blowouts occurred for self-elevating or semi-submersible units. None for drillships which constituted 12% of population. Mostly production drilling. One-twelfth blowouts have oil.
Average	0.39×10^{-3}	3.4×10^{-3}	3.3×10^{-4}	Note that oil blowout means blowout with which oil is associated; hence, generally small oil blowout.
Reduce by 20% for Exp.	0.31×10^{-3}	2.7×10^{-3}	2.6×10^{-4}	
Comparable Values from this Work	$.46 \times 10^{-3}$	2.4×10^{-3}	3.0×10^{-4}	Information averaged from Table 6.2 (EPS 3-EC-78-12)

Source: Bercha, F.G. 1978 (EPS 3-EC-78-12: Table 6.11)

It was established that under Beaufort Sea conditions, drillships had approximately four to five times the probability of a blowout over the artificial island system.

These probability analyses are admittedly based on limited time and data. They do indicate, however, that the probability of exploration oil well blowouts is considerably higher for Beaufort Sea drillships over artificial island drill systems in the same general area.

It can also be stated that the Beaufort Sea's artificial island probability is somewhat higher than that for a conventional dry land oil well blowout, for instance, in Alberta, where three serious gas blowouts occurred in late 1977.

In considering the results of his fault tree analysis, Bercha examined the sensitivity of the total system to order of magnitude variations of five factors or input probability groups. These are generally defined as:

HUM	-	human error
ENV	-	environmental severity factor
GEOL	-	geological data: refers only to kick-causing conditions of pressure, porosity, and productivity.
EQPT	-	equipment failure related to kick detection, well control and platform failure.
ENG	-	engineering errors

Based on an extensive examination of all possible combinations of factor groups and variations, several conclusions were drawn (Figure 9.3). In all cases, the geological factors dominate. Since an increase in kick frequency will directly lead to more uncontrolled kicks, this conclusion is reasonable.

Environmental severity and human error are next in significance. These two factors are related clearly since a major influence of the environmental severity factor is its amplification of human error rates. Equipment and engineering failures are clearly of a secondary nature.

In comparison with the island system, it was concluded that the drillship system was more sensitive to human and environmental efforts, presumably because of the active and mobile nature of drillships.

9.3.1 Probability Influencing Factors for the Labrador Sea. To examine the record of drilling to date, all the Labrador Sea well reports that have been released were reviewed.

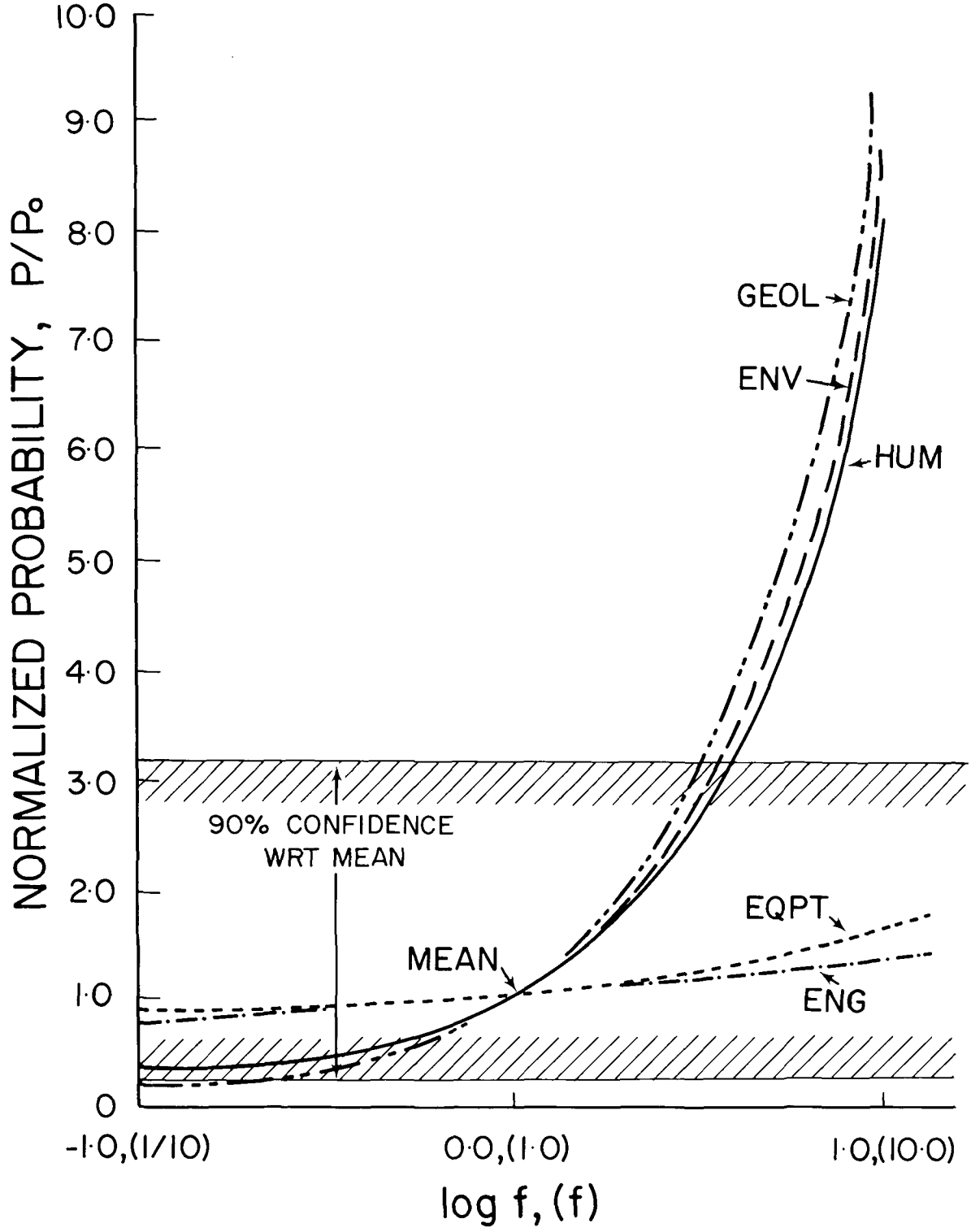

FIGURE 9.3 SENSITIVITY OF DRILLSHIP IN SUMMER TO FACTOR VARIATION
(Source: Bercha, F.G. (1978) (EPS 3-EC-78-12: Table 6-6)

These are:

- Corgnet and McWhae (1973) - Eastcan et al Lief M-48
- Corgnet and McWhae (1973a) - Eastcan et al Bjarni H-81
- B.P. Exploration Canada Ltd. (1975) - BP Columbia et al Indian Harbour M-52
- Corgnet and McWhae (1975) - Eastcan et al Gudrid H-55
- Ferrero, McWhae and Ple (1975) - Eastcan et al Karlsefni H-13
- McWhae, Ferrero and Ple (1975) - Eastcan et al Snorri J-90
- Ple and Ferrero (1976) - Eastcan et al Freydis B-87
- Ferrero and Ple (1976) - Eastcan et al Cartier D-70

These reports were used extensively in considering the relative importance of the various probability influencing factors.

GEOL

The geological information combined in these reports is discussed in Chapter 3. There are no reports of kick situations; however, the BP report (1975) makes the following observation:

> "The Labrador Coast is proving to be a much more difficult drilling area than the Grand and Sable Banks. Abnormal pressures have been encountered at much shallower depths and must be closely monitored. Pressure reversals, severe mud ringing and boulders are other problems."

However, Eastcan, with their more extensive experience, do not report any delays due to well kicks.

The formations that have been encountered appear to be quite large and porous. Of eight holes drilled by Eastcan, three have resulted in significant hydrocarbon (gas) shows (Launais, Corgnet and Verdier, 1977). This would appear to indicate generally that if a blowout were to occur it would be of a high volume, albeit mainly gas.

ENV

The well reports also detail some of the environmental problems encountered. Because of the presence of shallow boulder beds, spudding has proven to be difficult; an average of two attempts have had to be made for each hole started. Figure 9.4 presents the extreme case of Indian Harbour M-52, where four attempts were made to spud in the well. The delays incurred by spudding in the wells, waiting on weather, and ice and

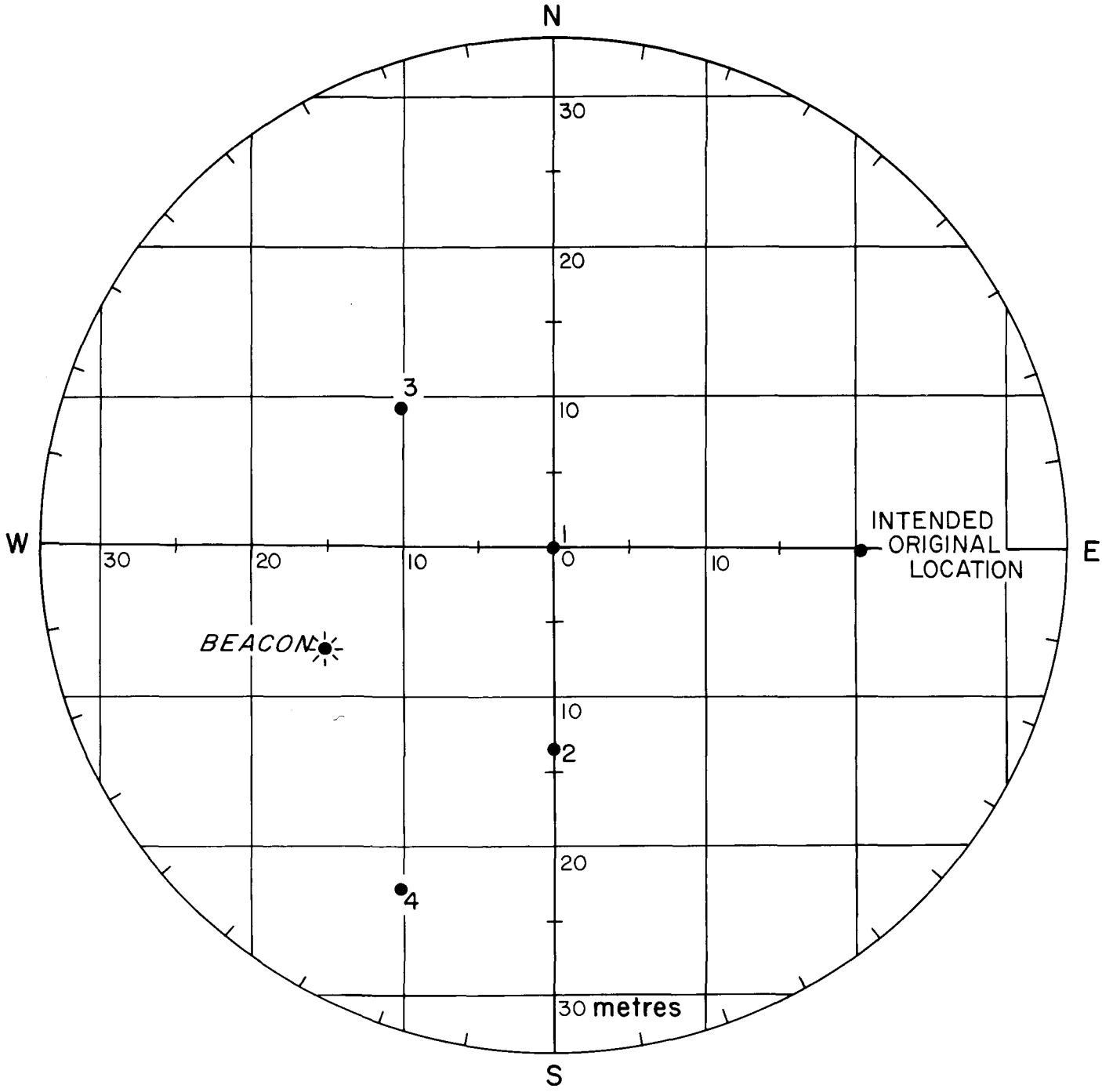

FIGURE 9.4 LOCATION OF TOUR SPUDDING ATTEMPTS ON BC COLUMBIA ET AL INDIAN HARBOUR M-52

icebergs, combined with the depths at which reservoirs have been found (2400 to 3400 m), have meant that of the three gas wells discovered to date, two were completed late in the season and had to be suspended for testing during the following season.

Icebergs are described as the most critical factor associated with oil exploration off the coast of Labrador (Duval, Corgnet and Duval, 1975). Besides threatening the drilling rig, bottom scours of up to six metres deep could destroy the wellhead. This was dramatically illustrated during the Typhoon experience. As mentioned, the combination of a storm and approaching iceberg forced the rig to abandon the hole leaving the BOP on the seabed.

A subsequent wellsite survey carried out by submersible (Verlet and Duval, 1972) revealed what was believed to be a recent iceberg scour. It was described as a 6 m (20 ft) deep "crater" located 18 m (60 ft) SSW of the wellhead. The BOP had remained on the seabed from September 1971 until the summer of 1973. Perhaps ironically, 1972 had the largest number of icebergs ever recorded for the Labrador offshore.

Ainslie and Duval (1975) describe the system used to track and avoid icebergs in what is termed "Iceberg Alley". Given the forces influencing iceberg drift: wind, pack ice, and currents, it is clear that a casual observer cannot accurately predict iceberg drift (Figure 9.5a). A prediction formula has been developed which gives good agreement for predicted speed but is less reliable for direction (Figure 9.5b), mainly because the water current profile at the iceberg is not available.

Three ice observers are stationed permanently on board each of the drillships. They continuously monitor ice and iceberg movements using the ships' radar. Iceberg positions are plotted every hour and predictions are made on their path. (N.B. Tracking icebergs on radar can present practical problems, especially during heavy sea states (Chapter 7).)

If an iceberg approaches too close to the rig, attempts may be made to tow it. This technique was developed by engineers at Memorial University (Bruneau and Dempster, 1972) and the operation is reportedly generally successful for icebergs smaller than 1×10^6 tons.

If a iceberg cannot be diverted and continues to approach the rig, operations to secure the well are initiated. First, the drill pipe is suspended in the hangoff tool. Icebergs drift at a speed of between 0.5 and one knot. When they are between 0.5 and one nautical mile (i.e., one hour) away, and it is reasonably certain their path will intercept the drilling location, the riser pipe is disconnected.

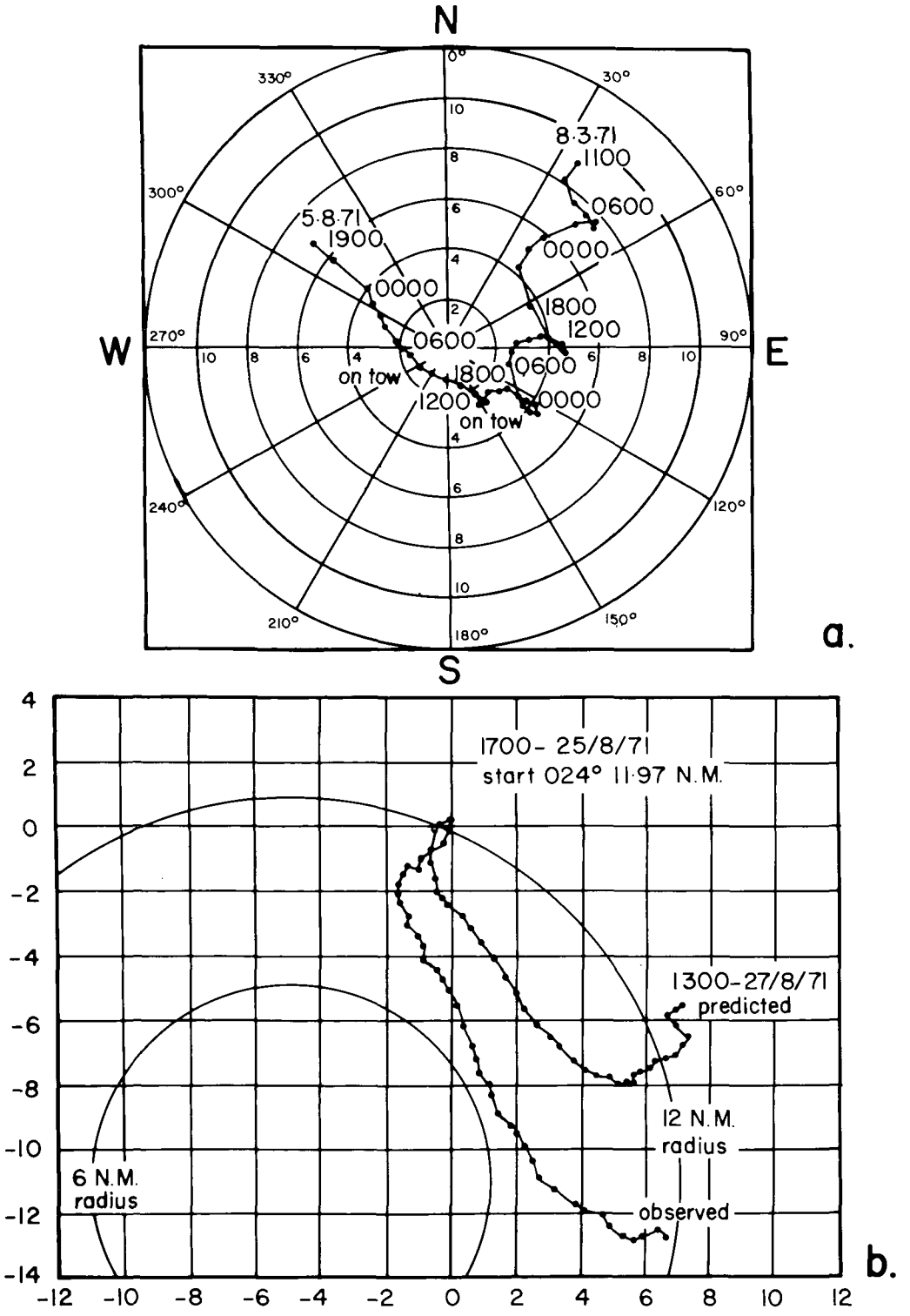

FIGURE 9.5

(a) RADAR PLOT, ICEBERG TRACKS
(b) COMPARISON OF OBSERVED AND PREDICTED TRACKS

(Source: Ainslie and Duval, 1975)

If the draught of the iceberg is such that it could hit the BOP, disconnection must be done below the BOP stack. In this case, the well must be suspended with cement plugs and cement retainers run before disconnecting. Such a situation has already occurred in 1973. Despite the critical importance of knowing iceberg draught (it can only be grossly approximated from measuring sail height), no rapid, reliable and accurate measurement method has yet been developed.

In addition to the items discussed above (boulder beds, icebergs), other environmental problems peculiar to Labrador have been described by Launais, Corgnet and Verdier (1977). These include water depths of 140 to 300 m; low water temperature, -1 to 2°C; currents up to two knots at the surface; and strong seas.

Low water temperatures can present problems for hydraulic lines. Perhaps because of this, the Pelican is equipped with an emergency back-up acoustic system that controls four functions in the BOP, plus a multiplex system that operates all functions. These are in addition to two hydraulic and one electro-hydraulic systems (Appendix to this chapter).

Strong seas, especially late in the season, create motion problems for drillships, although less so for semi-submersibles. Substantial waiting-on-weather time is reported for drillship operation during September and October, especially if testing operations are planned during this time period.

There are other considerations related to environmental factors, e.g., weather, and environmental hazard prediction reliability and accuracy; however, these are considered in greater detail elsewhere in this document.

HUM

Human error is invariably cited as the major source of failure in oil spill events. As pointed out by Cairns (1970) "Human error is the single element most consistently present in any event in which human beings are directly engaged".

The human error factor is difficult to quantify or discuss without on-site exposure; however, as pointed out by Bercha (1978) environmental severity amplifies human error rates. It has not been possible in this study to examine, for example, the probability of errors and sequences of errors being committed by ice observers which could contribute to a catastrophe. These error rates would relate to training, experience, fatigue, complexity of tasks, decision points, etc. Without such an examination, one is limited to the observation that the probability of this factor will increase with environmental severity.

EQPT and ENG

The statistics for the probability of a blowout from production and exploration in the North Sea (Table 9.2) indicate a rate approximately twice that of the world rate. Bercha (1978) speculates that this may be attributable to the combination of harsh conditions and initial operator problems.

During the early days of drilling in the North Sea, four rigs were lost through some major mishap (Hutcheson and Hogg, 1975). It seems likely that these failures could be attributable to equipment selection rather than environmental severity since early operations in the North Sea were merely extrapolations of Gulf of Mexico drilling technology.

It could perhaps, be argued that the use of the Typhoon in the Labrador Sea is another example of inadequate equipment selection.

9.3.2 Relative Probability of an Oil Blowout in the Labrador Sea. Based partly on the foregoing discussion, an attempt will be made to establish the relative probability of an oil blowout from exploratory operations in the Labrador Sea. To do this, Table 9.3 lists blowout probability influencing factors and compares their relative severity with the North Sea and the Beaufort Sea. Each factor is described as greater, lesser, or of equal severity, compared to the region noted.

Without weighing individual items (excepting for geopressures: obviously the most important item under GEOL), it can be concluded that existing drilling operations in the Labrador Sea are somewhat more hazardous than for the North Sea, and in terms of the important Environmental and Human factors, much more hazardous than the Beaufort Sea.

Accepting at face value the figure presented for an oil blowout probability for the North Sea (Table 9.2), we can now comment that the relative probability of an oil blowout from exploratory drilling in the Labrador Sea would be greater than that for the Beaufort Sea.

9.4 The Concept of Risk

"La recherche petroliere au Labrador est donc une grande aventure, passionnante et pleine de risques; c'est aussi une aventure tres onereuse, mais les serieux encouragements obtenus des forages autorisent a penser que les espoirs de mettre en valeur un nouveau et vaste bassin petrolier sont a la mesure des risques encourus." (Launais, Corgnet and Verdier, 1977).

TABLE 9.3 COMPARISON BETWEEN THE LABRADOR SEA AND THE NORTH AND BEAUFORT SEAS

	Labrador Sea Compared to	
Blowout Probability Influencing Factors	North Sea	Beaufort Sea
GEOL		
Area of Sediments	less	greater
Depth of Sediments	greater	greater
Geo Pressures	LESS	MUCH LESS
Shallow Gas and Oil Layers	less	equal (?)
Strength of Cap Rock	?	?
Size of Gas and Oil-Bearing Formations	less	greater
Productivity of Gas and Oil-bearing Formations	less	greater
Total GEOL	LESS SEVERE	LESS SEVERE
ENV		
Meteorological		
Air Temperature	more severe	less severe
Precipitation and Fog	more frequent	more frequent
Wind	less	greater
Prediction Accuracy	more inaccurate	more inaccurate
Sea Surface		
Pack Ice	much greater	less severe
Icebergs	much greater	much greater
Sea State	slightly less	much greater
Water Column		
Currents	much greater	much greater
Water Temperature	more severe	equal
Depth	greater	greater

Blowout Probability Influencing Factors	Labrador Sea Compared to North Sea	Labrador Sea Compared to Beaufort Sea
Seabed		
Scour	much greater	greater
Relief	greater	much greater
Boulder Beds	much greater	very much greater
Total ENV	MORE SEVERE	MORE SEVERE
HUM		
Operator Capabilities (environmental severity related to factors only)	?	equal (?)
Regulatory Control	more stringent	less stringent
Total HUM	?	GREATER PROBLEM(?)
EQPT		
Drillship	equal	equal
Mud System	equal	equal
Heave Compensator	?	greater problem
Marine Riser	?	?
BOP	?	?
BOP Connections	?	equal
Casing	more sustantial	equal
Total EQPT	EQUAL	EQUAL
ENG		
Rig Selection	equal	equal
Equipment Design	equal	?
Material Selection	equal	equal
Total ENg	EQUAL	EQUAL(?)

Risk is commonly defined as the product of the probability of a failure occurrence, expressed as a ratio, multiplied by the total cost of the tangible and intangible consequences of the failure, expressed in monetary terms.

Risk is by far the most significant of all calculations associated with oil well blowouts because it forms the foundation of the cost calculations of insurance to compensate all other interests who may be damaged by a blowout. Additionally, risk is the number that the oil industry must compute in order to determine the total costs of a venture. Without this risk number, cost calculations can not be presumed to include serious consideration of the consequences of and compensation for damages caused by a blowout.

Detailed consideration of the consequence of a major oil blowout are beyond the scope of this study. It should be pointed out that in terms of annual primary productivity, the area is 10 to 40 times that of the Beaufort Sea (Milne and Smiley, 1976). On the other hand, the Labrador Sea and the more southerly adjacent regions are high energy systems that might be expected to quickly reduce the toxicity of pollutants.

The full economic, social, and environmental consequences of a large loss of oil into the Labrador Sea is highly contentious. There are those who claim that it would almost certainly be catastrophic for the fishing industry of the whole province, involving ultimately the loss of hundreds of thousands of tons of high protein food, and the associated loss of several thousands of jobs. There are others who would disagree with these claims. Such contentious but vital probability, consequences and risk levels should be the object of early, intensive and comprehensive studies.

Whatever the result of the consequences calculations, the resulting monetary number should be multiplied by the probability of the blowout, which is expressed as the ratio of number of probable blowouts over the number of probable exploration holes to be drilled. This risk value should subsequently form the basis for calculating the cost of ensuring the adequate compensation of third-party interests for damages caused by a blowout in the Labrador Sea. The actual collection of such compensation payments and the method of compensating those actually damaged by blowouts should also be determined.

9.5 Conclusions and Recommendations

Clearly, all recommendations should have as their goal the reduction of risk for owners, employees, contractors and third parties. This can be accomplished by continuing the current efforts of industry to reduce both the probability and consequences of a blowout.

With regard to recommendations on the basic philosophy of exploratory well drilling, it should be emphasized that long industrial experience has shown that the final assessment of the merit of a design of a drilling system or any other vital piece of equipment or procedure should be that full compensation for third-party damages caused by an accident or malfunction of the equipment or process is available.

Furthermore, its availability should be guaranteed, for example, by insurance. This philosophy is no different than the everyday experience in regard to Workmen's Compensation regulations or the issuance of owners' licences to drive vehicles.

In the case of exploratory oil drilling, because of the long-term nature of the consequences of potential oil blowouts to the future of the region's fishing industry, this compensation ability should be based on payment for both short-term and long-term damages, including social damage to the province as well as to individuals. The compensation required would appear, because of the value of the fishing industry, to be very large. Any other assumption would be imprudent at this time, and until proved.

Industrial experience has demonstrated that when such damages compensation is legally required, the economics involved in the industry quickly motivate and bring to bear protective measures which substantially reduce failure probabilities and consequences and thereby risk. Moreover, the protective measures required are tied to real industrial justice and responsibility. The actions required from those in governmental authority, where there are large compensation requirements for failure or accident, result in more meaningful response than any other measure.

ACKNOWLEDGEMENT

Because of the frequent reference in this report to the F.G. Bercha and Associates Limited, final report to Environment Canada, on "Probabilities of Blowouts in Canadian Arctic Waters" special acknowledgement is made of this excellent study and its influence on this report.

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CHAPTER 10
FLOW STRUCTURE OF AN UNDERWATER BLOWOUT

by

D. Thornton

Environmental Emergency Branch
Environmental Protection Service
Environment Canada
Edmonton, Alberta

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10 INTRODUCTION

In order to discuss the fate of the oil from a subsea oilwell blowout, and hence to appreciate the likely oil distribution facing cleanup crews, it is necessary to understand the behaviour of the blowout fluids as they emerge from the sea floor and rise through the water column.

The blowout is defined in Chapter 2 (Table 2.1). To summarize for convenience: the water depth in this area is approximately 200 m; light, sweet crude oil (40° API gravity) is assumed to flow at a rate of 2400 m^3/day (15,000 bbl/day) accompanied by natural gas at a rate, normalized to atmospheric pressure, of 360,000 m^3/day (13 MMcfd). This oil to gas ratio of 1 to 150 is the same value that is frequently used in similar analyses of oilwell blowouts for the Beaufort Sea.

The blowout fluids are assumed to issue freely from a circular opening at the sea floor (the pipe exit) of diameter 15 cm. This is not an unreasonable assumption, as long as the fluids do not escape outside the well casing and crater the surrounding earth, since any obstruction in the well bore would soon be cut away by sand and grit entrained with the fluids.

The flow resulting from a subsea blowout may be roughly divided into two main parts based on the driving forces; a jet region where the initial momentum of the emergent fluids dominates, and a plume region where the buoyancy of the escaping gas is the driving mechanism. It is also convenient to consider separately the upper portion of the buoyant plume where the flow impinges on the water surface.

10.1 The Jet Region

A schematic representation of the flow resulting from a subsea blowout, taken from Mundheim and Fannelop (1976), is shown in Figure 10.1. The flow near the point of release has the character of a jet, which as it spreads, entrains water and loses its initial velocity.

The only applicable analysis of submerged jets with large, turbulent flows seems to be that of Abramovich (1963). His work indicates that the velocity decay of an essentially gaseous jet emerging from a pipe will be very rapid (roughly inversely proportional to the square of the distance from the pipe exit).

In this subject case, the velocities should be only a few metres per second at a vertical distance less than 10 m from the pipe exit. The rapid decay is a consequence of the significant difference in densities between the bulk of the jet fluid (by volume, seven parts gas and one part oil at 200 m depth) and the water.

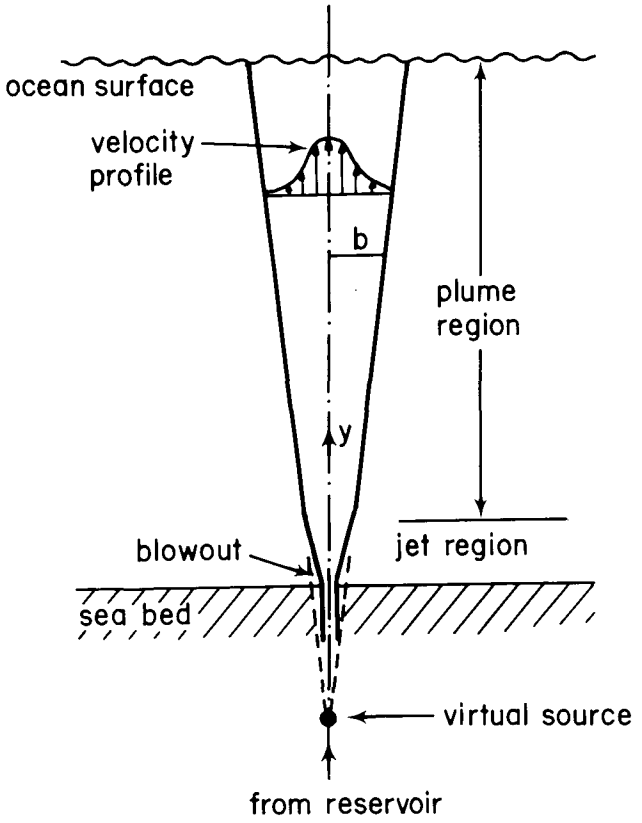


FIGURE 10.1 SCHEMATIC REPRESENTATION OF UNDERWATER STRUCTURE, JET AND PLUME (from Mundheim and Fannelop, 1976)

Since buoyancy forces become dominant within the order of 10 m from the sea floor, little accuracy is lost from the point of view of an observer on the surface by neglecting the initial momentum of the blowout fluids for depths greater than about 100 m. For most purposes, it suffices to consider only the buoyant plume solution corresponding to a buoyant point source located at, or close to (Figure 10.1), the sea floor.

The jet solution is of interest, however, in establishing forces on objects intended to intercept or block the flow, and in calculating inflow velocites along the bottom to evaluate the possibility of sea bed erosion or danger to divers. According to Mundheim and Fannelop (1976), using a method by Taylor (1958), water velocities of the order of one m/s or more occur only in the immediate lateral vicinity of the jet (within two to three m, depending on flow rate). Velocities of less than 0.25 m/s can be expected at distances exceeding 10 m laterally from the jet axis.

However, another reason for interest in the region near the pipe exit is that to a significant extent the break-up of the blowout fluids as they enter the water column may determine the eventual fate of the oil. For example, the energy dissipation near the

sea floor conceivably could cause the formation of stable emulsions. To examine this possibility, Topham (1975) injected mixtures of oil and gas under water through a common pipe exit.

Topham used two crude oils: Norman Wells crude, which was known not to form stable emulsions; and Swan Hills crude, which was thought likely to form stable water-in-oil emulsions. In the experiments, two gas superficial velocities, 1.9 and 14 m/s, were used. (The superficial velocity is that which the fluid would have if it occupied the pipe alone.) The oil superficial velocity of 0.25 m/s was based on expected flow rates from a hypothetical blowout in the Beaufort Sea. With this oil velocity, the two gas flow rates used by Topham were expected to result in two different flow regimes within the pipe. "Slug" flow was predicted for the low gas velocity (with alternate sections of oil and gas emerging) and "annular" flow was expected for the higher gas velocity (with oil flowing up the sides of the pipe and gas up the centre). If the two expected flow regimes did stabilize in the experiments, the difference in flow obviously did not cause a variation in the fate of the emergent oil.

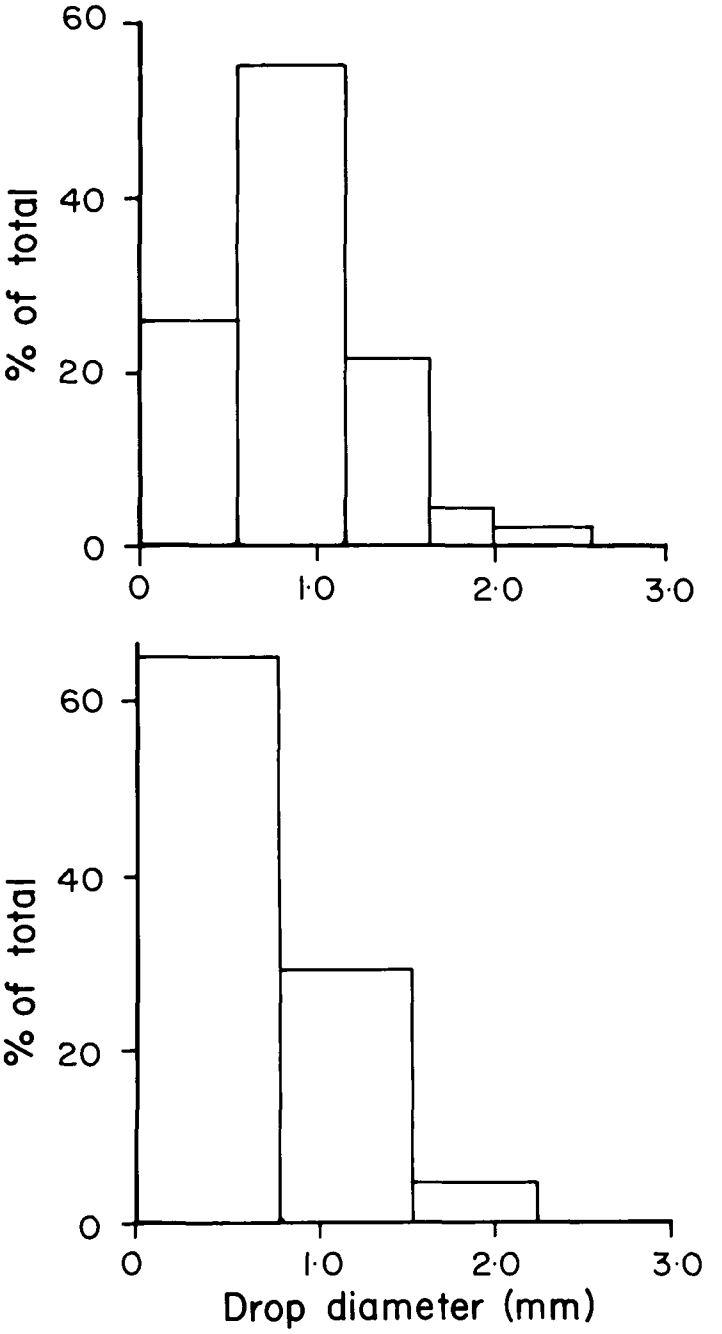
The bursting action of oil-covered gas bubbles near the pipe exit broke the oil into fine droplets. In general, the higher gas flow velocity produced smaller oil droplet sizes, as did larger pipe diameters (Topham used 0.64, 2.2, 7.6 and 14.7 cm). The decreasing oil droplet size was associated with the increasing violence of the bubble release from the pipe, as might be expected. The major portion of the oil was contained in droplets with diameters in a range of 0.05 to 1 mm. Two droplet size distributions obtained by Topham are reproduced in Figure 10.2.

Stable emulsions did not form with either crude oil.

For the subject hypothetical blowout, the superficial gas and oil velocities are about 18 and 2.4 m/s, respectively. Despite the order of magnitude increase in the oil superficial velocities compared to Topham's experiments, the flows within the pipe are predicted to be of the annular type with, perhaps, some small oil droplets entrained within the central core of gas.

There is little reason to suspect that the average oil droplet size will be very different from the 0.5 to 1 mm range noted previously (Topham, Private Communication). Oil droplets of this size have terminal velocities between five and seven cm/s; and if they escape from the main plume of bubbles and entrained water, they will rise to the surface within 40 to 60 min.

Topham's work indicated that a small proportion, in the order of one percent of the oil was shattered into small drops of less than 50 micrometres in diameter. The



Injection of Norman Wells crude into seawater, 22 mm diameter pipe, gas exit velocity of 14 m/sec

FIGURE 10.2 OIL DROPLET SIZE DISTRIBUTIONS (from Topham, 1976)

terminal velocity in this case is 0.5 mm/s or less. If these droplets escaped from the main plume, it would be days and many kilometres from the blowout site before they approached the surface, if at all.

10.2 The Plume Region

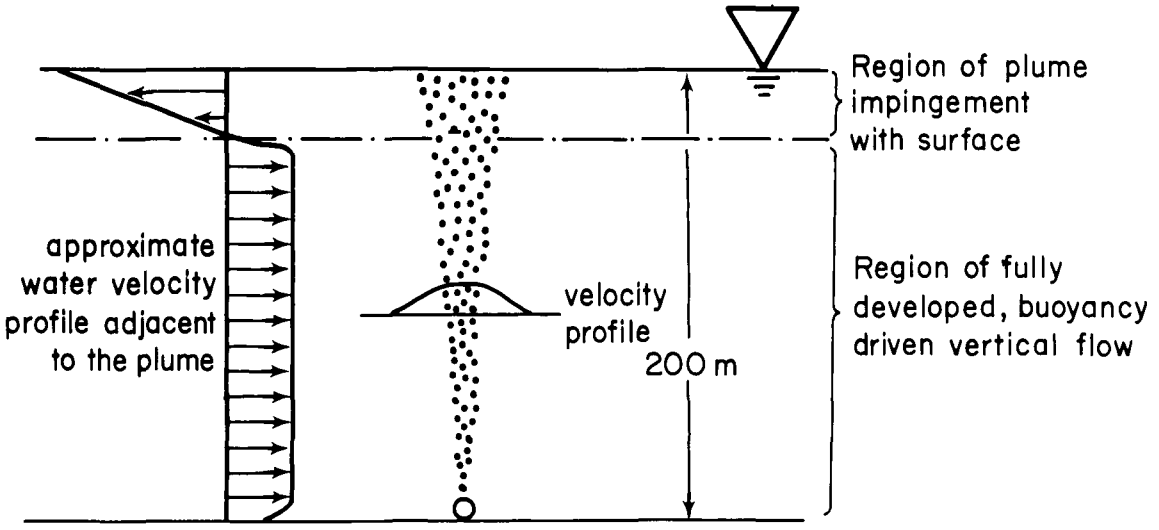
10.2.1 Theoretical Considerations. The plume region is the part of the vertical flow structure between approximately 10 to 20 m from the sea bed and the sea surface. In this region, buoyancy is the driving mechanism as gas bubbles formed at the pipe exit expand, slowly at first, and then much more rapidly as they approach the surface. The gas bubbles rising through the water column entrain water and create an upward current or water plume, which in turn entrains the more slowly rising oil droplets.

Beyond a certain limiting size, large, expanding gas bubbles break up. Observations from bubble curtains (line sources) (Mudheim and Fannelop, 1976); point sources (Topham, 1975); and theoretical considerations (Levich, 1962) indicate that the maximum diameter is in the range of one to three cm. (Single bubbles in this size range would have terminal velocities of 0.3 to 0.6 m/s; and if separated from the plume they would rise the 200 m to the surface in about five to ten minutes).

Morton, Taylor and Turner (1956) provide a method for the analysis of buoyant plumes based on an analogy with heat-driven plumes. Ditmars and Cederwall (1974) have modified this approach to include the effect of increasing buoyancy with height caused by gas expansion (which they take to be isothermal). The modified theory also takes into account the natural rise velocity of the gas bubbles relative to the induced plume velocity.

A schematic representation of the bubble plume model, taken from Ditmars and Cederwall, is included in Figure 10.3. In an analogy with single phase buoyant plume theory (e.g., thermally driven plumes), the lateral distributions of vertical velocity and density difference are taken to be similar at all heights (gaussian), and the rate of water entrainment is characterized by an entrainment constant. The entrainment constant must be determined empirically.

Using the expressions of Ditmars and Cederwall, NORDCO (1977) calculated the predicted plume width and average vertical water velocity with height for the subject blowout. These are reproduced in Figure 10.4. In this figure, the plume radius is defined to be $\sqrt{2}$ times the standard deviation of the lateral distribution of the vertical velocity. As may be noted from Figure 10.4, an essentially conical plume is predicted, which is usual for buoyant plume theories.



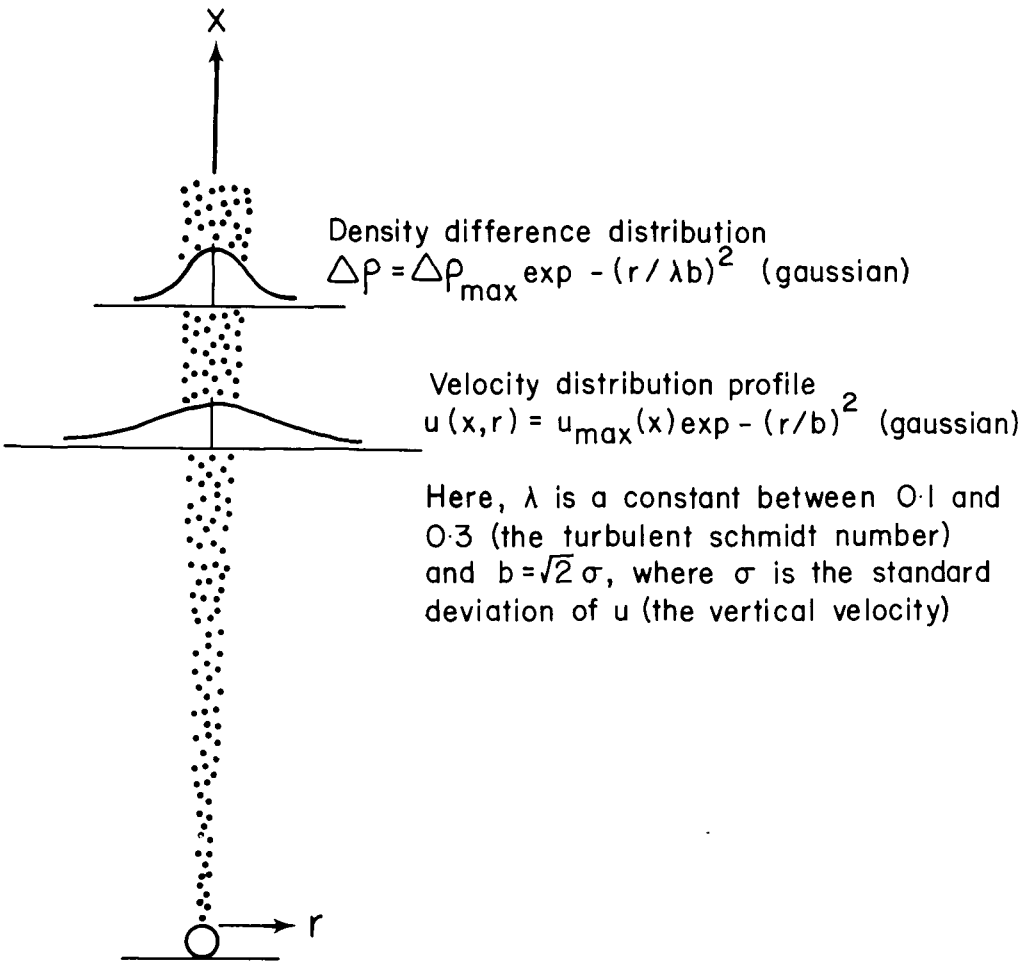


FIGURE 10.3 SCHEMATIC REPRESENTATIONS OF BUBBLE PLUMES (after Ditmars and Cederwall, 1974)

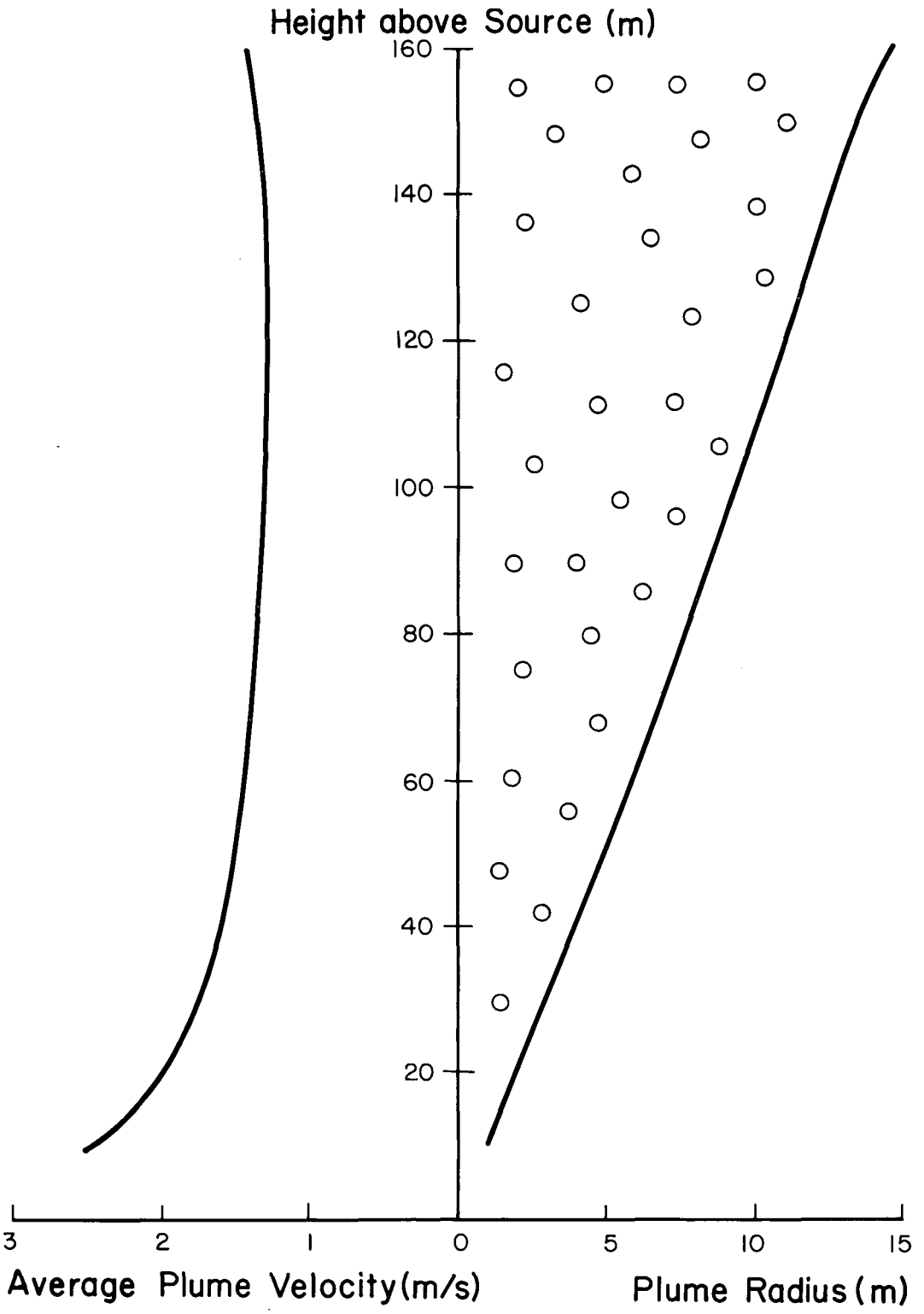


FIGURE 10.4 AVERAGE PLUME VELOCITY AND PLUME PROFILE (from NORDCO, 1977)

The theory, therefore, predicts an average plume velocity over most of the water column of just over one m/s; so oil droplets entrained in the flow would surface in about three minutes. Moreover, at about 40 m depth, just below the region where the flow deflects from the water surface, the approximate width of the essentially conical plume is predicted to be 30 m.

10.2.2 Experimental Evidence. Although the agreement between the theory derived from an analogy with thermal plumes and small-scale bubble plume experiments is satisfactory, experimental work with large-scale air bubble plumes in water depths of 23 and 60 m by Topham (1975) has indicated some discrepancies from simple theoretical predictions. In his experiments, the rising gas bubbles entrained the surrounding water to form a rising plume which was initially conical in shape, but became cylindrical above a certain height. Specifically, the plumes in 60 m of water became cylindrical about 23 m vertically from the source. In these experiments, gas flows of 3.7 to 40 m^3/min were used, which should be compared to a rate of 250 m^3/min (and depth of 200 m) for the hypothetical Labrador Sea blowout.

Measured radial profiles of vertical velocity were not similar along the cylindrical portion of the plumes and thereby violated one of the assumptions embodied in the usual plume theories. According to Topham (1978), the feature of air-bubble plumes may be caused by the local turbulence created by the bubbles themselves modifying the eddies, which are generated by the large-scale shear associated with the plume as a whole.

In terms of the final disposition of the oil, the formation of a cylindrical plume over part of the water column is not of great significance for the current water depth; although, of course, in deeper waters it would have considerable ramification for the size of the plume near the surface. For the subject case, the width of the bubble plume near the surface will be taken to be 30 m, as estimated by NORDCO. This may slightly high, based on Topham's experimental work; but this possibility does not radically alter the overall scenario.

10.3 The Near-Surface Region

In Topham's experiment, the general pattern of the interaction of the plume with the water surface was consistent, although the overall scale increased with increasing airflow rate and with source depth. The main features of the interaction were a central boil area on the surface where the bubbles left the water, surrounded by an outwardly directed radial surface current.

A ring of waves concentric with the plume centre marked a change in direction of the radial surface currents. The near-surface flow inside the wave ring took the form of radially expanding torroidal vortices which came to a halt at the wave-ring radius, where the flow turned downwards in a complex mixing region. This downward mixing entrained the inward-directed flows outside the wave ring.

For the moment, we will consider the data obtained by Topham in 60 m of water using a gas flowrate of 26 m^3/min. The vertical velocity profiles at a variety of radial positons are shown in Figure 10.5.

Oil drops one mm in diameter have a natural rise velocity of the order of five cm/s; and if they were swept outwards from the plume at a depth of three m (approximately the maximum outward radial current depth in Topham's experiments), they would rise to the surface at a radial distance of about 20 m, i.e., within the wave ring (of radius 32 m in Topham's experiment).

The oil would be swept out to the wave ring by the ~0.5 m/s surface current and tend to collect there because of the containing effect of the inwardly directed current of about 0.2 m/s outside the wave ring. However, once the oil thickness exceeded about one to two cm, the potential head associated with the oil would overcome the velocity head of the containing current and oil would begin to escape. Moreover, even before this situation could be attained, local surface currents, if greater than about 0.2 m/s, would cause leakage from the "downstream" side of the wave ring. In the Labrador Sea, surface currents are typically in the range of 0.3 to 0.4 m/s. Of course, wave action and winds would also tend to cause leakage from the wave ring.

Smaller oil drops, with lower natural rise velocities, could well reach the wave ring before surfacing and become entrained in the downward mixing current below the wave ring and eventually surface outside. Some might be carried back towards the wave ring by the inward radial currents; but, more likely, the movement of the majority of the oil surfacing outside the wave ring would be dominated by residual surface currents and winds.

The proportion of oil which might surface quickly is dependent upon the distribution of oil droplet sizes near the surface and the detailed nature of the turbulent currents in the region. Despite the simple discussion above for the rise of one mm diameter oil droplet to the surface, the turbulence associated with the expanding toroidal vortices may be sufficient to carry even droplets of this size out to the wave-ring radius, where down-mixing currents extended 10 to 15 m downwards in Topham's experiments and

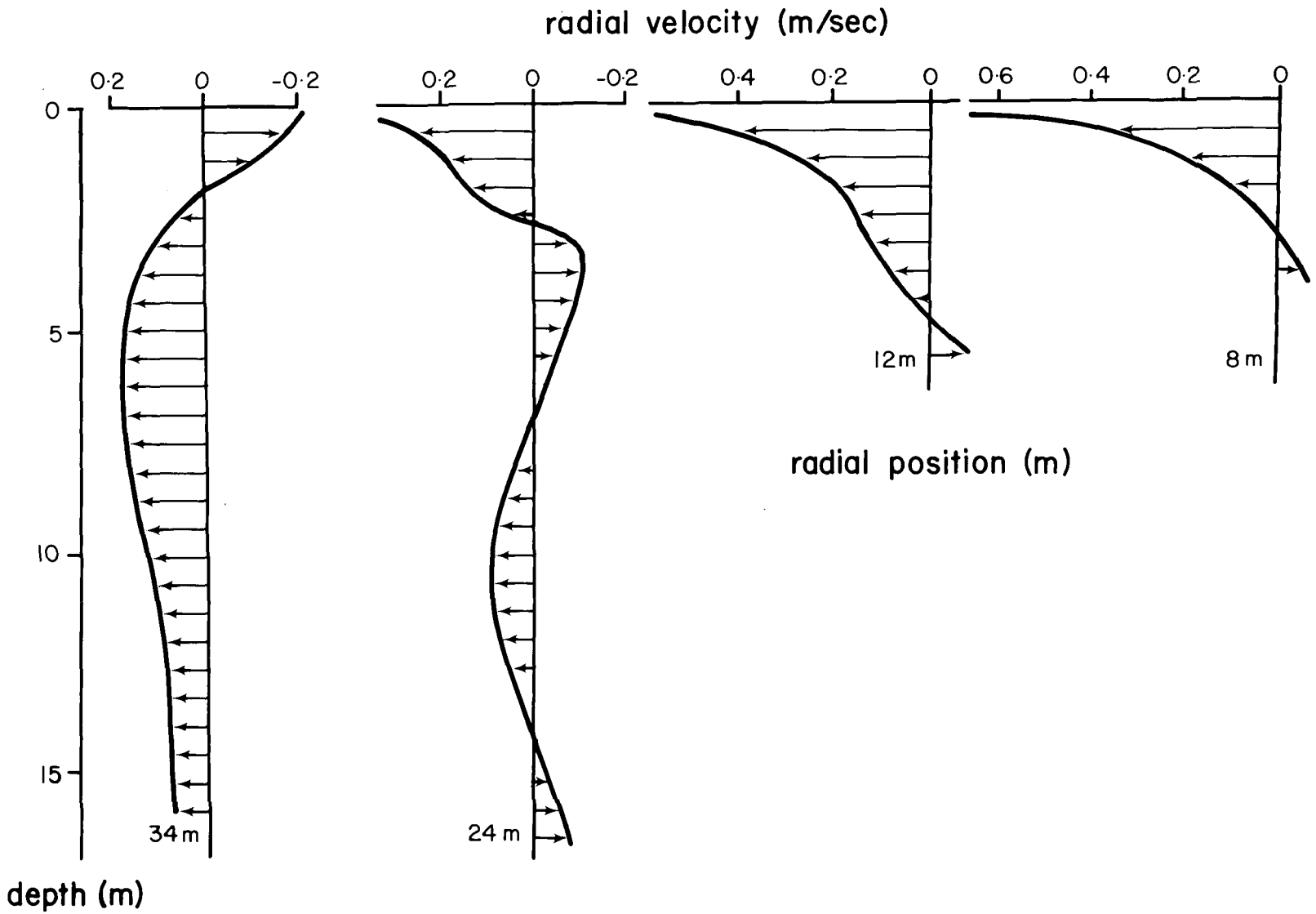


FIGURE 10.5 RADIAL VELOCITY PROFILES OF INDUCED CURRENTS
SOURCE DEPTH 60m, AIRFLOW RATE 25.1 m^3/min
(from Topham, 1973)

were of the same order of magnitude as the natural rise velocity of the droplet. If so, even the larger oil droplets may escape the immediate vicinity of the plume before surfacing.

Moreover, the spatial and size distribution of oil droplets in the boil area itself is uncertain. It is possible , for instance, that the "scrubbing" action of gas bubbles during their ascent in the plume (two to three min in 180 m depth) could cause their coalescence with many of the slower-moving oil droplets. If so, from simple interfacial considerations, it is likely that most of the gas bubbles might have an oily skin. The thickness of the skin is uncertain. For illustration, although this extreme is unlikely, if all the oil were associated with bubbles of diameter about one cm, the oil skin on each bubble would average about 10 micrometres in thickness. The water flow around the bubbles could distort the bulk of the skin into a pendular oil droplet beneath the bubble, or even strip some of the oil away.

The detailed behaviour of an oily gas bubble breaking the water surface in the boil area of the plume is unknown. It seems probable that some oil would tend to flash over the water surface to form a surface slick; but it also seems likely that oil droplets, probably considerably smaller in diameter than one mm, would be thrust down a few metres into the water column as the gas bubble breaks the surface.

It is difficult, then, even based on Topham's experimental scale, to assess the fraction of oil droplets which would likely surface within the wave ring and quickly form a fairly coherent slick; or, equivalently to estimate the proportion which could escape under the influence of near-surface currents and probably become more quickly dispersed. This difficulty is compounded further in the case of the hypothetical Labrador Sea blowout, where the blowout fluid volumes are increased by a factor of ten.

Topham developed an empirical relationship for the wave ring radius as a function of gas flow rate and water depth. Although it is strictly valid only for the range of parameters in his experiment, he extrapolated to water depths of 180 m by assuming a virtual origin at a depth of 60 m. This procedure was adopted since the relative bubble volume increase is very rapid above this point and near-surface currents are mainly dictated by the upper part of the plume column.

NORDCO (1977) utilized the same approach, despite the order of magnitude increase in gas-flow rate, and estimated a wave ring radius of approximately 90 m for the hypothetical Snorri blowout. Whether or not the other features of the near-surface flow (e.g., currents, etc.) would scale in the same ratio of approximately 1:3 (32 m:90 m) is unknown.

Whatever the detailed nature of the near-surface region, it seems likely that a signigicant proportion of the oil will be entrained by currents and carried outside the wave ring.

Oil droplets with diameters between 0.1 and one mm have natural rise velocities in the range of about 0.1 to five cm/s. If these droplets were carried beyond the wave ring at depths of about 10 to 20 m, they would surface 200 m to five km "downstream" from the blowout plume in a residual current of about 0.3 m/s.

By the time (0.2 to five hours) these particles surfaced, if at all, considerable lateral spreading could have occurred. The magnitude of the areal spreading is uncertain due to the lack of data regarding turbulent diffusion under moving pack ice. However, based on an empirical relationship for the spreading of dyes in open water (Okubo, 1971), the suspension of finely divided oil droplets escaping from the plume would spread laterally from the diameter of the wave ring (180 m) to about 500 m in about five hours.

10.4 Other Considerations

1. The above discussion assumes a uniform ambient water column with no cross-currents or waves present. Consideration of these factors leads to a considerable increase in complexity. Furthermore, the paucity of experimental data means that the value of such an extended analysis is dubious. The following points, however, are noted:

   a) The effect of stratification may be significant, especially for greater depths. Cederwall (1975) provides the equations for a stably stratified fluid, but these are for incompressible fluids and require numerical solution. McDougall (1975) has confirmed that in a stably stratified environment, fluid may shed from the sides of the plume as it rises. This means that oil droplets may be released from the plume to be carried by deep water currents over considerable distances before surfacing.

   b) Shuto (1971) has analyzed the effect of cross streams and waves on plume dilution. The studies may not be directly applicable to the gaseous plumes considered above; however, the general results are probably valid here. It is found that since the length of the plume is longer and its cross-sectional shape is altered by the cross current, the rate of entrainment of water and thus the dilution are increased.

   For the hypothetical Labrador Sea blowout, with an average cross current of about 0.3 m/s, the upper portion of the plume could be displaced perhaps 40 m

laterally from the source below. This corresponds to a plume leaning at approximately 10° to the vertical.

2. Topham (1977) has recently confirmed the formation of gas hydrates during a discharge of simulated natural gas in water depths of 325 to 650 m. These solids are compounds of gaseous hydrocarbons and water, which are thermodynamically stable at high pressures and low temperatures. Since hydrates have a specific gravity close to one (0.92 - 0.96), if the gas from an underwater blowout is converted into this solid form, the buoyancy forces will be effectively eliminated and a water plume will not form. Topham concluded from his underwater discharges that the minimum water depth for hydrate formation in $7^{o}C$ water appeared to be about 300 m. This is close to the temperature and pressure expected from thermodynamical laboratory work. A reduction of water temperature would decrease the minimum water depth for hydrate formation. However, it is likely that hydrate formation would play little or no role at the subject depth of 200 m.
3. Since the bubble velocities are of the order of one to two m/sec, and the diameter of the boil area is expected to be about 30 m, the volume occupied by gas in the near surface portion of the plume is only about one percent. Hence, the danger to surface vessels from loss of buoyancy, or stability, is negligible. However, the fire danger associated with the emergent gas would be considerable.

10.5 Conclusions

In view of the uncertainty concerning the detailed behaviour of oil in the near-surface region, a somewhat arbitrary decision will be made regarding the ultimate disposition of the oil. For discussion purposes related to the interaction of the oil and the ice, it is assumed that 50 percent of the oil (comprising the droplets with the large diameters) would surface within a wave ring of radius 90 m and would evenly "paint" the surface in this region. At an oil flowrate from the well of 1.7 m^3/min, and an ice velocity of 0.3 m/s, the oil would be distributed under the ice inside the wave ring at an <u>average</u> thickness of about 0.25 mm.

The remaining 50 percent of the oil, in the form of a finely divided suspension of small droplets less than one mm in diameter, would be carried beyond the wave ring by near-surface currents. Based on simple arguments related to their natural rise velocities, these would surface in the order of a kilometre away "donwstream" from the blowout. When this oil surfaces, if at all, it would be unlikely to collect in (averge) thicknesses much over a micrometre because of areal diffusion and the random component of the velocity of the ice sheet.

10.6 Tabular Summary

Water Depth

190-200 m *(Jet Region)*

- emergent fluids seven parts gas and one part oil with velocities >one m/s;
- bursting gas bubbles near the exit;
- oil shattered into small drops about one mm and less in diameter.

190- ~20m - *(Plume Region)*

- buoyancy (gas bubble) driven water plume rising at about one m/s;
- gas bubbles expanding and breaking into bubbles of maximum size, about one cm;
- oil drops of size about one mm and less in diameter entrained in the vertical water plume;
- an unknown fraction of the oil coating the surface of the gas bubbles.

~20m-Surface *(Near Surface Region)*

- gas escapes in a boil area about 30 m in diameter;
- radially outward surface currents averaging about 0.5 m/s extend to a radius of approximately 90 m (wave ring radius);
- radially inward surface currents beyond the wave ring radius;
- 50 percent of the oil (0.9 m^3/s) surfaces within the wave ring, which would "paint" a band of oil 180 m wide, 0.25 mm average thickness under ice moving at a velocity of 0.3 m/s;
- 50 percent of the oil escapes beyond the wave ring and surfaces 200 m to 5 km "downstream" of the blowout site over an area up to 0.5 km wide.

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CHAPTER 11
PREDICTED OIL-ICE INTERACTION FOR A HYPOTHETICAL BLOWOUT IN THE LABRADOR SEA

by
James R. Rossiter

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial Univeristy of Newfoundland
St. John's, Newfoundland A1B 3X5

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11 INTRODUCTION

This chapter focuses on the most probable ways in which oil from a blowout, rising to the surface, might interact with the types of ice to be expected in the Labrador Sea. Separate chapters contain information on the typical oil-gas plume behaviour, a synoptic summary of ice conditions in the Labrador Sea, and a discussion of ice observations in this area. These four studies are naturally closely interrelated.

Since ice covers large parts of the Labrador Sea for much of the year, any practical countermeasures planned for a blowout must consider the way in which the oil might behave in ice-infested waters. The discussion in this section assumes that all of the oil comes from the hypothetical sub-surface blowout, the characteristics of which are summarized in Chapter 2 (Table 2.1).

Although these characteristics are probably reasonable assumptions, it must be kept in mind that any given blowout could deviate considerably from this one. Moreover, spills from other sources (e.g., from tankers) would be expected to behave very differently. This report is also based on the unique character of ice in the Labrador Sea, and the predictions are therefore different from those made for other areas, such as the Beaufort Sea.

Further, the predictions made here are based on rather scanty experimental data, and therefore must be viewed sceptically. Where possible, estimates of a probable range of behaviour have been given. Areas that appear fruitful for further study are also indicated.

11.1 Physical Setting

11.1.1 Plume-Surface Interaction. The hydrodynamics of the rising plume for the hypothetical blowout are controlled by the large volume of gas which escapes with the oil. This situation has been examined experimentally by Topham (1975) for water depths to 60 m, and the main features have been summarized and extrapolated to our hypothetical study case in Chapter 10.

The plume reaches the surface within a radius of 15 m - the boil area. Surface currents are induced by the rising gas: outward radial currents from the boil area to the wave ring; inward radial currents, toward the wave ring, at larger distances. These currents have speeds of 0.2 to 0.5 m/s at the surface, decreasing with depth, but they are present to five to ten m below the surface. At the wave ring, predicted to be about 90 m in radius for our case, the outward and inward currents meet. Below the wave ring, there is a downward flow of water 10 to 20 m deep.

This description is the expected behaviour under calm conditions with no currents. In the Labrador Sea, the surface currents are in the order of 0.3 m/s. (Chapter 4), and there are significant currents even at depth. No measurements have been made of large-scale plumes with cross-currents, but it might be surmised that the major effect of the cross-current would be to laterally displace the top of the plume from its origin by 15 to 40 m (for our case). However, it is also possible that the up-current side of the wave ring would be considerably closer to the boil area, and the downstream side commensurately further away.

There are also no data on the effect of wind and waves. Since high sea states are common in the Labrador Sea, this is an important consideration.

Considerable mixing of the surface currents might be expected due to wind and wave action, and material rising to the surface will tend to be carried downwind and downstream (Topham, 1975).

For discussion purposes, Thornton, in Chapter 10, has divided the oil rising in the plume into two equal portions: the larger droplets (greater than about one mm diameter), which surface within the wave ring; and the smaller droplets. The latter have rise speeds similar to that of the downward currents at the wave ring, and are therefore expected to be carried down to about 10 or 20 m, and to surface one km or more downstream. These two divisions of the total oil will be examined separately in this report. The characteristics of the hypothetical plume behaviour near the surface are summarized in Section 10.6 of Chapter 10.

11.1.2 Ice Conditions. Ice conditions in the Labrador Sea have been described in Chapter 5 by Skidmore and in Chapter 6 by Winsor and LeDrew. The ice is primarily first year pack ice, which does not form a continuous rigid sheet, but is made up of many individual cakes. These cakes adhere as floes that are usually five to 50 m in diameter, about two m thick, highly mobile, and change constantly with varying weather conditions.

The predominant features of the region are its warm temperature (usually above -10 and often above -5°C), and the frequent storms (every four days, on average), with the resulting winds and waves. Becauses of these climatic conditions, the ice is poorly consolidated, very porous, and accompanied by large amounts of "ice pulp", particularly beneath the floes. Although this unconsolidated ice freezes during periods of low temperature, the normal condition is for much of the ice cover to have very little shear strength.

Ice can be expected at the blowout site from December to July, with cover varying from 1/10 to 9/10. During storm activity, it is possible for the ice to be under

compression, giving the illusion of being a rigid sheet. However, this is a temporary condition, and with a change in wind velocity, particularly if waves are present, the ice will once again break into individual floes.

11.2 Oil/Ice Interaction

11.2.1 Within the Wave Ring

11.2.1.1 Calm Conditions. The surface currents generated by the blowout act as a natural mechanism for clearing the area inside the wave ring of surface material (Topham, 195). Hence, it is likely that under calm conditions both ice and oil will be moved from the boil area toward the wave ring. At the wave ring considerable mixing would be expected, with both unconsolidated ice and oil most likely carried to a depth of 10 to 20 m by the downward currents.

The effect of lateral currents would be to carry ice away from the downstream side of the wave ring, while ice reaching the wave ring from the upstream side would flow around the wave ring to the downstream end. Since the Labrador current is not significantly slower than the expected plume-induced currents, it is likely that this flow around the wave ring would be a loosely-controlled process.

To demonstrate that it is unlikely for individual floes to enter the wave ring under the conditions set out above, we will examine the effect of the radial surface current inside the wave ring on an individual floe. This situation is depicted in Figure 11.1. At time t = o, the floe is at the edge of the wave ring, and has velocity $+\mu_1$. Its motion is henceforth determined by the current inside the wave ring, which has velocity μ_2, which is of course negative in direction.

A similar problem has been treated by Sodhi and Dempster (1975) for icebergs. The equation of motion is:

$$M \frac{d\bar{v}}{dt} = \frac{1}{2} \rho_w C_w A |\bar{u} - \bar{v}| (\bar{u} - \bar{v}) \qquad (1)$$

where M is the mass of the floe,

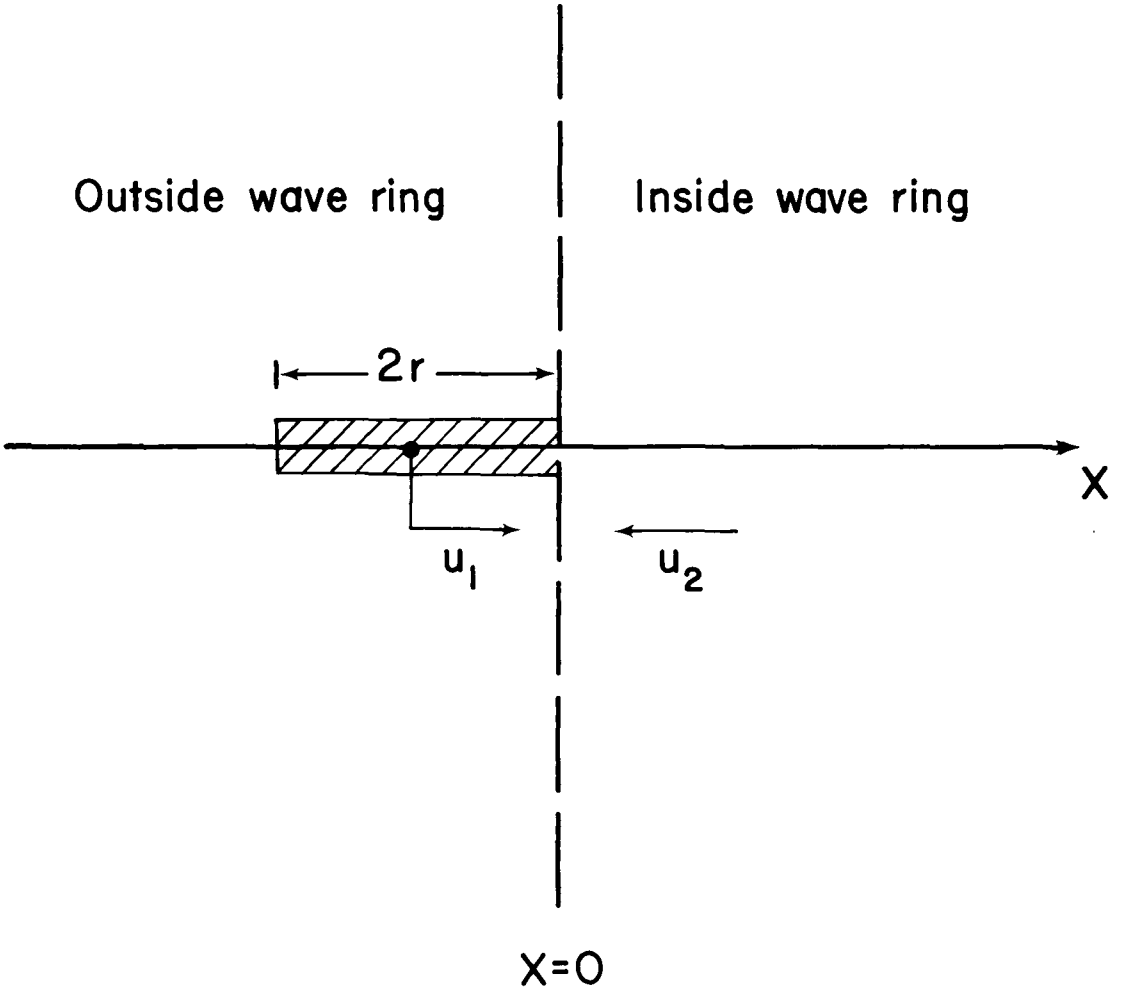
$\bar{v}$ is the velocity of the floe,

ρ_w is the density of the surrounding water,

C_w is the water form-drag coefficient,

A is the frontal area of the floe in the water,

and $\bar{u}$ is the velocity of the new current.



Ice floe (hatched), radius r, about to enter the wave ring at time t = 0 and position x = 0, with initial velocity u_1. Inside the wave ring the floe will encounter opposing current with velocity $-u_2$.

FIGURE 11.1 ICE FLOE MOVEMENT

Equation (1) has the solution (Sodhi and Dempster, 1975):

$$\frac{u_2 - v}{u_2 - u_1} = \frac{1}{1 + \frac{t}{\tau}} \tag{2}$$

where v is the speed of the floe at time t, and

$$\tau = \frac{M}{\frac{1}{2} \rho_w C_w A \, |u_2 - u_1|} \tag{3}$$

a characteristic time corresponding to the properties of the floe and the difference in initial velocities.

We are interested in determining the total distance x traversed by the floe into the wave ring, i.e., the solution of the differential equation:

$$\frac{dx}{dt} = u_2 - \frac{u_2 - u_1}{1 + \frac{t}{\tau}} \tag{4}$$

which is

$$x = u_2 t - (u_2 - u_1) \, \tau \, \ln(1 + \frac{t}{\tau}) \tag{5}$$

To calculate a specific example, assume that the floe is a cylindrical plate with radius r (where r is usually five to 50 m), thickness two m, and density 900 kg/m^3. The form-drag coefficient is not likely to differ greatly from one and the water density is approximately 1020 kg/m^3. As an extreme case, let the initial speed of the floe be 1.5 m/s, a value of five to 15 times greater than usually observed under calm conditions. The current within the wave ring is assumed to be -0.5 m/s, based on experimental work by Topham (1975).

Then, substituting into equation (3),

$$\tau \simeq 1.5 \, r \text{ s.} \tag{6}$$

The floe will reserve direction, i.e., start to return to the wave ring, when v = 0. Using equation (2), this will be at time t - 3τ. Substituting into equation (5), the penetration into the wave ring is given by

$$x \simeq 2r \text{ m.} \tag{7}$$

Hence, under calm conditions a floe is expected to penetrate into the wave ring to its diameter, and only the larger floes will reach the boil area.

This analysis ignores water surface drag on the floe, which may be significant because of the highly irregular underwater shape of sea ice, and would help keep floes outside the wave ring. On the other hand, the effect of even slight winds, which would tend to keep the floe moving in its initial direction, has also been ignored.

The effect of a large volume of pack ice would be expected to exhibit much more complex behaviour; but under calm conditions, assuming that the floes are reasonably independent and that the currents induced by the plume are near 0.5 m/s, there seems no reason to believe that a large number of floes will cross the wave ring area.

The nature of oil/ice mixing at the wave ring can only be surmised. It is expected that some of the oil would coat floes as they cross the wave ring, and some oil would be entrained with unconsolidated ice by the turbulent currents at the wave ring. Whatever the mixing mechanism, it is worth examining the total volume of ice that might intersect the wave ring.

Assuming a very conservative rate of 0.1 m/s (less than nine km/day), and an average ice thickness of one m, approximately 1.6×10^6 m^3 of ice would intersect the 180 m diameter wave ring per day. Since only 1.2×10^3 m^3 of oil surfaces within the wave ring per day, the total oil to ice ration is less than 0.1 percent. Although it is not clear that the oil would mix uniformly with the ice, these are the volumes of ice that would have to be contended with in order to recover the oil.

It might be conceptually possible to attempt clean-up operations within the wave ring. Although this is a possible alternative under calm conditions from a physical point of view, the danger of explosion from the rising gas would be, at the least, extreme. Novel methods of ignition without hazard to personnel would need to be considered.

11.2.1.2 Turbulent Conditions. During any type of storm conditions, which are frequent in the Labrador Sea, the simple model described above is unrealistic. At these times, the pack ice is driven at high speeds (1 m/s is common) (Section 11.2.3) by the wind; wave action is likely to be severe; and the ice can be under compression, with individual floes forced together by pressure.

Under these conditions, it is likely that the wave ring area will be covered by ice which is probably moving relatively quickly. The large forces involved with the emerging gas are likely to maintain the boil area in a state of high turbulence as the gas escapes (Topham, 1977). The wave ring itself will probably not be visible, although the

induced surface currents will probably be maintained under the ice cover. Under these conditions, the majority of the oil will become trapped in the sub-surface structure of the ice. The mean thickness of the oil covering the bottom of the ice can be determined to be 0.1 to 1.0 mm for ice moving at 0.1 to 1 m/s.

The underside of a floe in the Labrador Sea is not usually smooth, but a rough, highly irregular water-ice mixture. This material has a density near that of ice (900 kg/m^3); and the oil, with a density over 800 kg/m^3, will mix easily with unconsolidated ice in turbulence, as observed in laboratory experiments by Martin (1976).

Oil rising in leads between floes would be expected to accumulate at the surface of slush ice when floes are forced together. During periods of turbulence, the unconsolidated ice is forced up between the floes, so that the ice would accumulate oil that does not surface directly beneath cakes.

It is likely that some of the oil will rise quickly within the consolidated ice through the brine channels. Ice in the Labrador Sea is highly porous, and water flows into the brine structure easily (Lau and Rossiter, 1978), usually within minutes. Sea ice can entrain small amounts of oil (about one percent) within its matrix (Wolf and Hoult, 1974), particularily if the ice is near freezing. Consequently, it could be expected that most or all of the oil that thinly coats the undersides of floes (i.e., 0.1 to one mm) might become entrained within the floe and not come quickly to the surface.

It is also possible that the oil will not spread uniformly, but that some floes will acquire a greater thickness of oil adhering to their undersides. Thicknesses of oil of the order of a centimetre (the sessile drop thickness) are probable (MacKay et al, 1976). In this case, enough oil would be available to rise to the ice surface, particularly during melting conditions (Section 11.2.3).

11.2.1.3 Fate of oil rising inside the wave ring. It appears that oil surfacing within the wave ring will mix with the ice through one of the following mechanisms: (1) turbulence at the wave ring where two opposing currents meet; (2) wave action due to storms, which forces unconsolidated ice up between floes; or (3) gravity forcing oil to rise within brine channels into more consolidated ice.

Once the oil becomes mixed within ice, it is likely to remain with the ice until it melts. Hence, the oil will travel a considerable distance, as discussed in Section 11.2.3.

11.2.2 Outside the Wave Ring. It has been assumed that 50 percent of the oil will surface within the wave ring. The other 50 percent, made up of droplets smaller than about one mm, will not reach the surface within the wave ring because of the slower rise

speeds. Since it is likely that a rather broad distribution of droplet sizes will be formed, having a broad range of rise times, these smaller droplets will most likely spread over a large area before reaching the water surface or ice undersurface.

Assuming that these small droplets are forces to a depth of 20 m at the wave ring, and will have rise speeds of 5×10^{-2} m/s (one mm droplet) to 5×10^{-4} m/s (50 micron droplet) (Topham, 1975), they will use in 0.1 to 10 hours.

With a prevailing current speed of 0.3 m/s, they will surface to 120 m to 12 km downstream. Moreover, turbulent spreading would help to spread these droplets laterally on the order of 500 m (Chapter 10). Turbulence due to wave action might keep these droplets in suspension for even longer times (Greene, 1977). Hence, the area covered by this fraction of the oil as it reaches the surface is likely to be substantial, on the order of at least 10^7 m^2.

The oil is expected to be very finely disseminated when it reaches either open leads or the bottom of floes. In either case, as explained in Section 11.2.1, the oil would soon become bound with unconsolidated ice, and be carried with it downstream, thus covering a much larger area over a period of time. It is highly unlikely that this portion of the oil would be available for any kind of recovery.

11.2.3 Ice Movement. If the oil from a blowout does indeed become entrained rather completely with ice in the Labrador Sea, it is of interest to know how the ice moves. There appear to be two distinct movements: a steady flow of the ice generally south and east with the Labrador current at about 0.3 m/s; plus a larger, more random component during storms, during which speeds can be greater than 1.5 m/s. At this rate, some oil would reach the ice edge within the winter season, but the majority would be in transit during the winter, and melt out during the spring. Hence, a swath of ice from the blowout site through to the Grand Banks could be affected by oil, although the amounts in any given place likely would be rather small.

As the area becomes warmer in the spring, it is likely that more oil would rise through the brine channels and other intersticies to the ice surface where it could mix with snow on the surface. If a particular floe had accumulated a significant portion of oil, it is possible that recoverable amounts might from on the surface of that floe.

This oil would probably have been protected from some weathering, particularly evaporation. However, the typical thickness of oil needed for burning is in the order of 10^{-2}m, and this is approximately two orders of magnitude thicker than the average expected.

It is interesting to consider whether or not the floes would diverge significantly from each other during their movement. There are very few data available, but four radar reflectors were followed during a portion of February 1977 (LeDrew and Culshaw, 1977), and the results indicate that the floes did not diverge greatly. In Figure 11.2, the movement of the reflectors during a period of three days is shown. The Δ shows the accumulated drift of the ship between intervals, and the speed indicated (m/s) is an average net speed. (Actual mean speed could have been greater since the path taken was not necessarily direct.) The r_a is the average distance of the reflectors from the ship at each point. The reflectors did not diverge greatly, although one reflector was lost to the tracking system.

Hence, it is possible that if a particular area of ice contained a large amount of oil, it would prevent the oil from spreading greatly; and if the ice could be tracked, some oil might be recovered as the ice melted naturally. Studies in the Arctic have shown that 90 percent of oil entrapped within first-year ice does surface after spring thaw (Greene, 1977).

11.3 Conclusions

There are large gaps in our knowledge of the conditions in the Labrador Sea; and when one extrapolates a set of poorly known conditions onto a hypothetical situation, the best-guess outcome is not necessarily very reliable. However, several points seems to stand out with respect to oil-ice behaviour in this region:

(1) The area is a very high energy region, with frequent storms, high sea states, and high temperatures compared to other ice-covered regions. There are several mechanisms for mixing the oil and ice, but few mechanisms that will tend to concentrate oil.

(2) Much of the ice in the region is poorly consolidated, porous and has low strength. It is likely that the oil will mix easily with this ice under turbulent conditions, and that the rising gas will readily escape to the atmosphere.

(3) The pack is generally in motion, with a net average movement ± 10 km/day, which indicates that the oil will become entrained with a large volume of ice. The volume of ice passing over the blowout site is about three orders of magnitude greater than the rising oil volume.

(4) The ice will probably decrease turbulent spreading of the oil by entraining oil within the ice. There are indications that a group of floes may not diverge significantly from each other, even though they move a considerable distance.

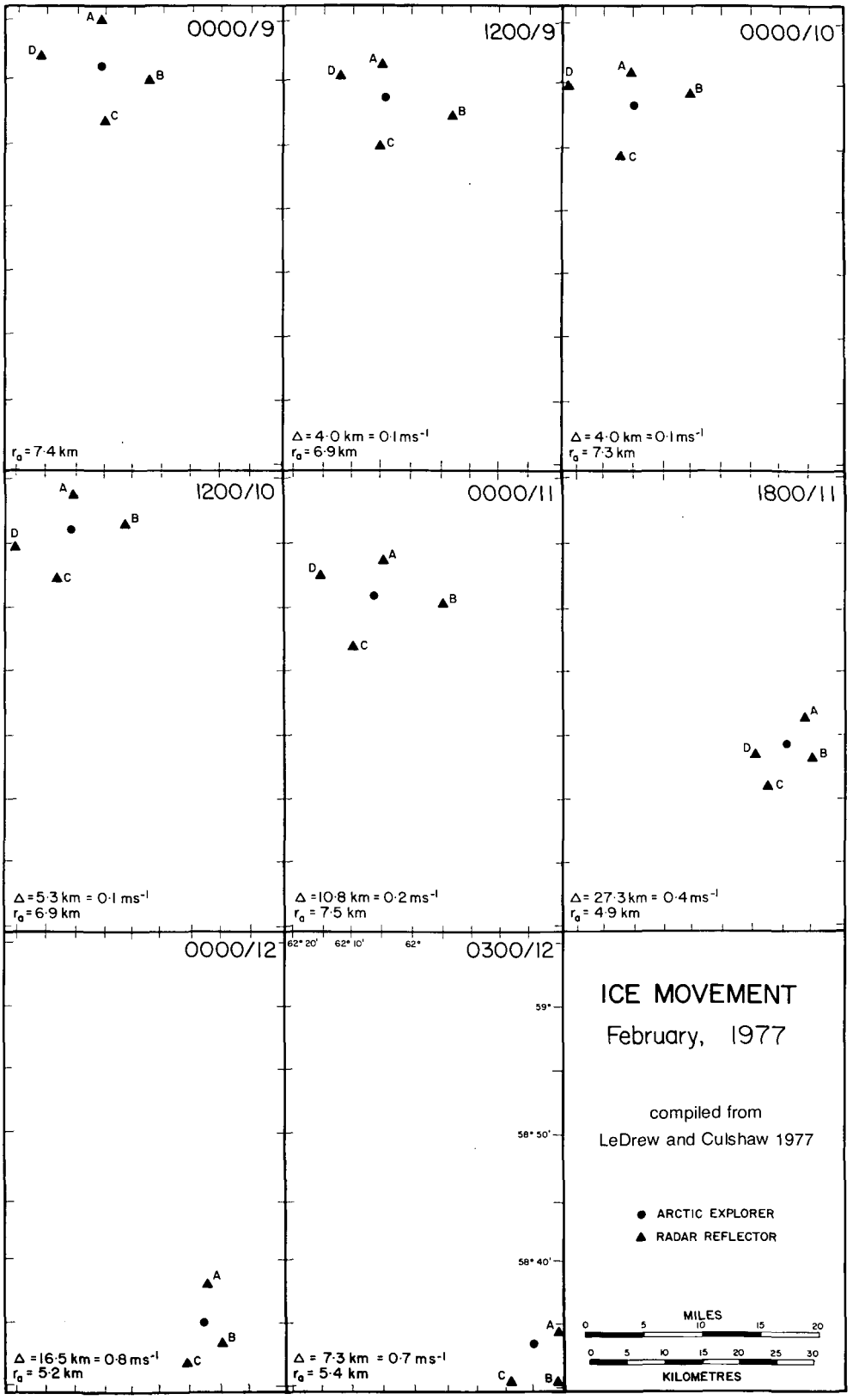


FIGURE 11.2 DIVERGENCE AND MOVEMENT OF LABRADOR PACK ICE

11.3.1 **Future Research.** Areas for future research include the following:

(1) In order to assess any particular clean-up procedure, considerably more needs to be known about the mechanism of oil-ice mixing in the Labrador Sea, and the ways in which oil would eventually separate from the ice. Very little is known about any of the physical properties of warm sea ice.

(2) Although the general picture of ice movement in the Labrador Sea is established, details of the movement and the ultimate fate of ice through the season is not well known. This knowledge will undoubtedly be gained from newer satellite data. These results should indicate more about the driving mechanism of the ice (especially the relative effects of wind and current), and the stresses that are developed within the Labrador pack.

(3) It will also be necessary to understand better the plume-surface interaction in ice-covered water. Even the nature of the plume in the presence of 0.1 to 0.3 m/s corss currents needs to be delineated.

The major conclusion to come from this introductory study is that the volume of ice passing over a given region of the Labrador Sea is significantly greater than the expected volume of oil from a blowout. The tremendous mobility of the Labrador pack ice is the prime consideration of any attempted clean-up.

ACKNOWLEDGEMENTS

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CHAPTER 12
LOGISTICS CAPABILITY: LABRADOR

Prepared by

ShawMont Newfoundland Limited
P.O. Box 9600
St. John's, Newfoundland
A1A 3C1

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12 INTRODUCTION

In general, this chapter describes the logistics capability and support services of the Labrador area with reference to the supporting needs of countermeasures activities.

The following will be documented:

(a) Communications: systems in use; availability, reliability and capability.

(b) Navigation: (marine and air) navigation aids, their location and seasonal duration; traffic management systems; navigation systems (Loran A, Loran C), accuracy and reliability.

(c) Transportation: (air, land and sea) location of landing strips, physical dimensions, support facilities, (hangars and warehouses); fuel and maintenance facilities;
- harbours and ports: pilotage, turning basin anchorage; bathymetry; wharf description (draft) and condition; storage and warehousing; operational season.
- vehicles: aircraft and ships stationed in the area.

(d) Services centres: food; fuel; lodging areas capable of providing life-support requirements.

The location and actual condition of facilities and materials (and their capacity to support increased demand) will be included.

In keeping with the above requirements, the study attempts to construct a realistic picture of the problems that can be expected to be encountered in attempting to respond to an emergency situation off the coast.

Information is presented in narrative form, tables and figures. Standard base maps have been used for illustration purposes.

The report includes a bibliography.

SUMMARY

In general, the facilities that are available locally to support any type of major oil spill countermeasures operation off the Labrador coast are very few and in most cases completely inadequate. While communications and navigational aids in some areas have been greatly improved in recent years, in many cases they are still subject to seasonal fluctuation in atmospheric conditions, and can provide only intermittent services at best.

Airport facilities, with the exception of those at Goose Bay and St. Anthony, are practically non-existent, being confined to a number of small (usually unpaved) landing strips, and several sea plane anchorages with few, if any, navigation and landing aids.

While there are a number of excellent harbours along the coast, these usually lack any type of major docking facility, and all are subject to complete shutdown for five to seven months during the winter season due to heavy ice conditions.

Support facilities such as warehouses, accommodations, medical facilities, services centres, etc., are only available in the larger communities of Goose Bay and St. Anthony. Elsewhere, the supply of these services is very limited and sufficient only to meet the requirements of the local populace, with little capacity to support any increased demand that might be caused by a major countermeasures operation.

It is evident that such an operation would have to be virtually self-supporting under the most hazardous of conditions, and therefore some prior consideration should be given to the procedures to be followed should such a catastrophe occur.

12.1 Communications

Until recently, coastal Labrador was largely dependent on two tropospheric scatterwave radio systems, which formed the basis of the telecommunication network linking Labrador to Newfoundland and mainland Canada, and on a variety of private, commercial and government-owned microwave, HF and VHF systems. At best, these facilities were unreliable due to variations in atmospheric conditions.

Recently, however, the situation has been vastly improved with the completion of a new heavy route microwave system by the Newfoundland Telephone Company Limited. This system, along with the implementation of Fringe Radio and smaller microwave systems, has virtually eliminated the HF radio network; and while the reliability is still not that of highly developed areas, there has been a marked improvement in coastal land-based communications.

The following sections will attempt to describe generally the communications systems that are now available to an emergency logistics support operation.

12.1.1 Microwave Systems. The new microwave system, recently installed by the Newfoundland Telephone Company Limited, links Goose Bay to all the major communities on the Labrador coast. The system has a capacity of 120 circuits and has been designed to meet the needs of the area, at the expected growth rate, to 1995. Most of the coastal communities south of Nain that could possibly become operations centres in the event of an oil spill emergency now possess fairly reliable service. Communities not possessing this service can be tied into the system quickly. The main obstacle to be overcome is a reduction in the reliability of the system during the winter due to maintenance and transportation problems at remote sites.

Microwave is an instrument for conquering distance by establishing modern communications networks through high quality telephone circuits. The method is usually dependable and offers ample capacity. The system utilizes signals that travel by line-of-sight. The signals are relayed by towers stationed about every 50 km. The Newfoundland Telephone Company System servicing coastal Labrador south of Goose Bay is a six GHz system and follows the route:

- Mt. St. Margaret (owned and operated by CNT, Northern Peninsula)
- L'Anse au Loup
- Woody (Relay tower)
- Mary's Harbour

- White Hill (Relay tower)
- Sand Hill (Relay tower)
- Cartwright
- Steele Creek (Relay tower)
- Moliak (Relay tower)
- Double Mer (Relay tower)
- Mulligan (Relay tower)
- Goose Bay.

The area north of Goose Bay is serviced by a 900 MHz system which follows the route:

- Goose Bay
- Northwest River
- Double Mer (Relay tower)
- Monkey Hill (Relay tower)
- Hopedale
- Flowers (Relay tower)
- Zoar (Relay tower)
- Nain.

An outline of the new mircowave system indicating the system capacities and the communities directly serviced is shown in Figure 12.1. Most of the coastal communities are now tied into this system, which provides them with very dependable telephone service. The larger communities are serviced directly as indicated in Figure 12.1, while most of the smaller communities are linked indirectly into the system via very high-frequency Fringe Radio.

There are still a number of small summer fishing settlements on the outer islands and headlands, which depend on single radio-telephone circuits for communications; however, the residents usually move back into the larger, more sheltered and better serviced communities for the winter.

The new system would enable an emergency, land-based communications network to be established with a minimum of delay. This system would provide good, dependable service from any major community south of Nain.

All areas to the north of Nain, including Saglek, which has an excellent airstrip and is strategically located, are not serviced by this system and have to be tied in by

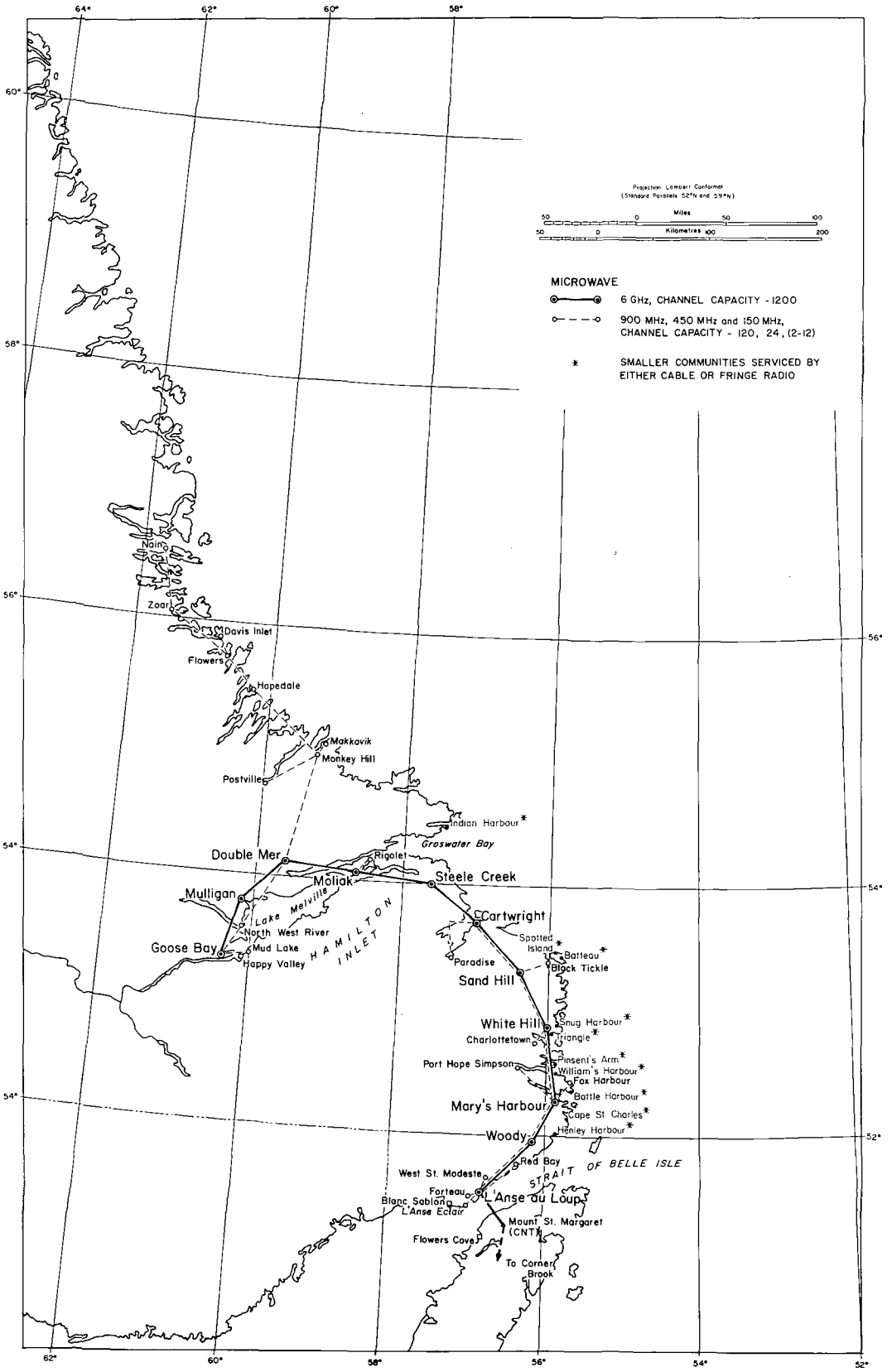


FIGURE 12.1 COMMUNICATION SYSTEMS: LABRADOR COAST

alternative means. It may well be worthwhile to consider the establishment of a direct emergency line from Saglek to Nain as part of any ongoing countermeasures plan.

12.1.2 Fringe Radio. The Fringe Radio system allows a number of communities to share a high-quality toll circuit which is available on a 24 h/day basis. The system requires a central receiving station which accepts a VHF signal from a number of different communities within a given range. For example, the station at White Hill on the Labrador coast receives signals from two separate systems, each of which services three communities.

Whenever a community on system number one makes a call, the only other community that could place a call at the same time would be one of the three communities on system number two. The two remaining communities on each system will receive a busy signal until such time as the call on that particular system is completed. This form of communication, while sometimes slow, is more than adequate for the communities it services, since they are usually very small and in many cases temporary. The VHF signal used is stronger and more dependable than the scheduled HF radio, which was available to most of these smaller communities in the past.

The Newfoundland Telephone Company Limited presently have two Fringe Radio systems operating in Labrador. The central receiving stations for these systems are located at White Hills and at Mary's Harbour. The outlines of the two systems and the communities they service are indicated in Figure 12.2.

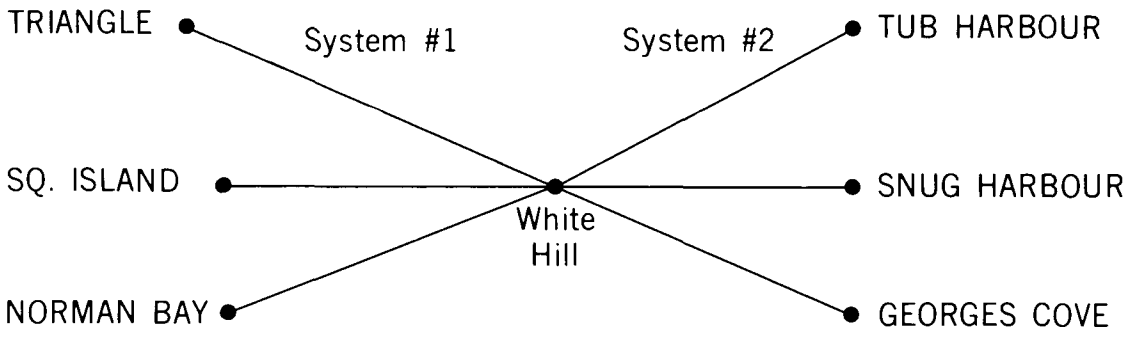
The temporary "summer communities" have their telephone facilities removed during the winter. These services can be restored on very short notice in the spring when families start moving back into the area, or in the case of extended emergency situation.

From White Hill and Mary's Harbour, calls can be patched directly into the new microwave system, allowing local residents to enjoy communication as modern as that which exists anywhere within the province.

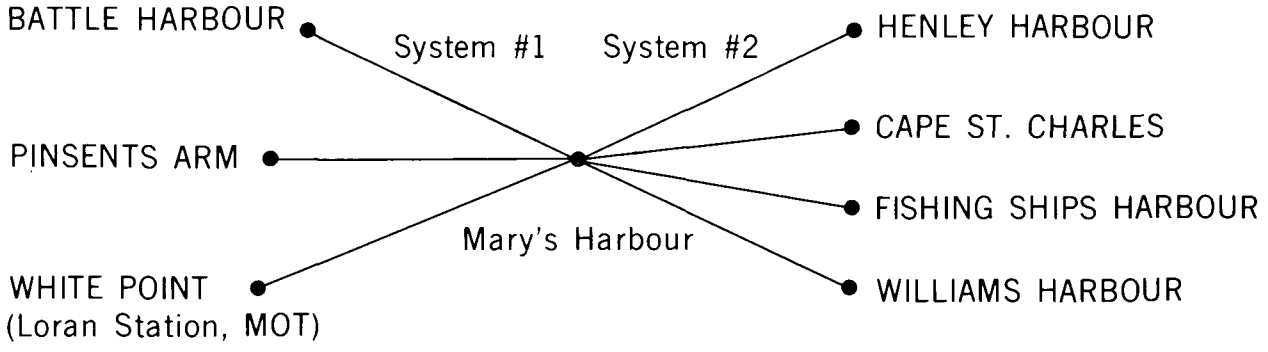
While it is not likely that any of the smaller communities serviced by Fringe Radio would be utilized as a major operations centre in the event of a spill, communications with these communities could prove valuable in directing the operations of task forces engaged in such activities as beach clean-up and spill containment in localized areas. The biggest problem to be overcome with this type of system is the build-up of ice on the signal towers during the winter.

12.1.3 HF Radio. In recent years, the dependance of Labrador residents on the HF Radio network has been lessened considerably by the development of Fringe Radio and

WHITE HILL FRINGE RADIO (150 MHz)



MARY'S HARBOUR FRINGE RADIO (150 MHz)



NOTES:

(1) Most of the communities serviced are temporary summer communities from which the radio facilities are moved during winter.

(2) A call on either System 1 or 2 sends a 'busy' signal to the remaining communities on that particular system.

FIGURE 12.2 FRINGE RADIO NETWORKS

Microwave. However, HF Radio is likely to remain the most economical medium of telephone service in the smaller and more remote communities.

The Newfoundland Telephone Company Limited has often set up "summer HF systems" to service temporary fishing camps and the military. These systems are usually monitored by an operator based at Goose Bay who provides scheduled attention only. From Goose Bay, the HF call can be relayed via microwave to anywhere in Canada. Unfortunately, due to the scheduling of the operator, calls can only be made during certain specified times of the day or week.

This system, although not usually used during the winter, can be set up to operate year-round. HF equipment is usually available at a moment's notice; however, arrangements of billing and servicing often have to be implemented beforehand in order to get the system into operation, and to have an operator stationed at Goose Bay. These details can be handled with very little delay and should present no problems in an emergency situation.

The use of the microwave system has eliminated most of the HF radio stations that formerly had been in existence, with the result that congestion on the air waves has been greatly reduced. This has caused an improvement in service for those parties still using the system, which according to the Ministry of Transport statistics, had a reliability under the formerly congested conditions of about 60 to 80 percent.

However, this does not solve the problems caused by atmospheric interference. Unlike the VHF and UHF signals used with Fringe Radio systems, which are virtually unaffected by atmospheric interference, HF Radio is extremely vulnerable to changes in the atmosphere. Arctic storms and solar activity may cause radio blackouts for weeks at a time. Minor sources of interference often reduce the signal to a thin whisper, or distort it into a clanging metallic noise of which only a fraction is intelligible.

Problems with HF radio communication are further compounded by man-made limitations such as scheduling. As well, the whole field of HF communications must be very efficiently supervised and the assignment of frequencies must be highly refined if interference between neighbouring users is to be avoided.

Some flexibility of operation can be gained by operating on two or more channels and switching to the one which offers the best reception. The HF transmitter at Goose Bay can operate on four frequencies; however, the radio operators man only the most efficient one or two at any particular time.

12.1.4 Private Radio. In the past, many of the private radio systems on the Labrador coast made use of double-side band equipment which inefficiently used the available HF frequencies. This resulted in a large amount of interference in areas where there was a proliferation of HF radio equipment. The double-side band set offers much less privacy than the single-side band radio, which operates on a narrower wave length and cannot be monitored as easily by normal transistor radios and other receivers. As a result of these factors, most of the older systems have been converted to use single-side band equipment.

While the private networks are not licensed for general public traffic, they sometimes offer emergency communications when local telephone systems are out of order.

Since these networks operate on HF signals, they are often rendered useless by major atmospheric disturbances.

A list indicating the more important private and Government HF Radio Stations on the Labrador coast is given in Table 12.1.

12.1.5 Ministry of Transport Radio (Ship-to-Shore). There are only two manned marine radio stations in Labrador. These are located at Cartwright and Goose Bay, with a remote facility located at Hopedale. Communications from these stations are unpredictable; blackouts occur frequently and last for periods ranging from two hours to several days. The blackouts are caused by atmospheric conditions in the coastal Labrador area and in some cases by the limitation on the number of frequencies allocated.

These factors make ship-to-shore communications very unreliable. However, with the proper frequency allocations and sufficient diversity, it should be possible to maintain a communications link with any ship possessing standard marine radio equipment and located at the edge of the continental shelf.

Hopedale has a remote marine facility operating on a channel 5-9 duplex system out of Goose Bay. This is a two-way communication system that does not require relays and operates on a HF frequency of 2182 KHz. Although Cartwright has a manned radio station which monitors marine activity, communications have to be relayed through Goose Bay, thereby reducing the effectiveness.

Both the Cartwright and Hopedale operations are shut down during the winter when shipping activity off the coast is nil; however, these facilities could be operated year-round in the event of an offshore emergency.

The range of these facilities during ideal conditions is 150 to 200 miles during the day and in excess of 400 miles at night. Communications with shipping beyond the

TABLE 12.1 GOVERNMENT AND PRIVATE HF RADIOS ON THE LABRADOR COAST

Nain	I.G.A.	Labrador Airways; R.C.M.P.; L.S.D.
Davis Inlet	I.G.A.	L.S.D.
Hopedale	I.G.A.	L.S.D.; R.C.M.P.; Labrador Airways; M.O.T.
Postville	I.G.A.	L.S.D.
Makkovik	I.G.A.	L.S.D.; Labrador Airways; Forestry
Rigolet	L.S.D.	
Goose Bay	M.O.T.	Labrador Airways; Forestry
Happy Valley	I.G.A.	R.C.M.P.
Northwest River	I.G.A.	L.S.D.
Cartwright	I.G.A.	R.C.M.P.; Labrador Airways; Forestry; M.O.T.
Spotted Island	M.O.T. **	
Black Tickle	I.G.A.	M.O.T.*
Batteau	M.O.T. **	
Frenchman's Island	M.O.T. *	
George's Cove	M.O.T. **	
Port Hope Simpson	M.O.T. *	
Mary's Harbour	I.G.A.	R.C.M.P.; Labrador Airways; M.O.T. *
White Point	M.O.T.	
Henley Harbour	M.O.T. **	
Forteau	I.G.A.	R.C.M.P.; Labrador Airways
St. Anthony***	I.G.A.	Labrador Airways

KEY:

I.G.A.	International Grenfell Association
R.C.M.P.	Royal Canadian Mounted Police (whose network also includes sets at Labrador City, Wabush, and Churchill Falls).
L.S.D.	Labrador Services Division of the provincial Department of Social Services and Rehabilitation
Labrador Airways	Private bush plane company, with mail contract and scheduled flights along the Labrador Coast.
M.O.T.	Federal Ministry of Transport M.O.T. without asterisk signifies sets manned by full time transport staff, as a part of a larger air and marine radio operation. M.O.T.* signifies a transport radio set operated by a part-time. paid local operator. M.O.T.** signifies a radio set operated by an unpaid, local operator and informally maintained by transport staff.
St. Anthony***	Not in Labrador but included here because of its importance as a base of I.G.A. and Labrador Airways activity.

range of the shore stations would have to be relayed via other shipping and aircraft within range.

12.1.6 Satellite Communications. Satellite communications systems rely on a method whereby microwave radio signals are relayed via satellite to a central communications center. From there the signal is in turn relayed, either via satellite or some more conventional method, to the receiving party. There are two systems which are in common use in North America. These are the Telesat System which is owned and operated by the Crown Corporation, Telesat Canada, and the Marasat System, which is owned and operated by the United States government. The central communications centre for Telesat is in Toronto, while Marasat is operated from Atlanta, Georgia.

While this method is used fairly extensively for radio and television transmissions, it has not been used very extensively for voice communications because of the cost limitations of the two systems. Marasat would appear to be the cheaper of the two due to its extensive use, particularly by the United States military, whereas Telesat operates at only partial capacity.

This method has a reliability of 99.9 percent and is not affected significantly by changes in atmospheric conditions. The cost depends on the extent to which telex, facsimile, and other facilities are used. The system can be set up within 24 h; however, it is very expensive, with a two-voice system costing in the order of $120,000 per year for Telesat. The long-term basis would be somewhat cheaper, at about $60,000 per year. A Marasat system can be expected to cost about one-third this amount.

The system can be operated from virtually any land base and has been used for communications from drill rigs and ships at sea being used as stationary control centres. Whether such a system would be used as part of a countermeasures program would be a function of the cost and the accuracy required. High powered VHF or HF sets can be used to establish communications with vessels up to 120 miles offshore with reasonable accuracy and much less cost. This range can be increased up to 400 miles under ideal conditions.

12.1.7 Communications through Industry. In the event of a major oil spill, the initial communications set-up would be established through the contingency planning of the particular site operator. In this respect, Eastcan Limited has proposed the use of the following communications facilities should an emergency occur during operations being carried out by that company.

12.1.7.1 Telephone. Telephone communications would be maintained between the site, St. John's, and Calgary offices via: radio coastal station on HF (St. John's, Cartwright and Hopedale); Eastcan's main radio network from St. John's, Cartwright and Hopedale; Marasat satellite communications with the drill site; and private line between Cartwright, Hopedale and Goose Bay.

12.1.7.2 Telex. Communications via telex would be possible with St. John's and Calgary via Marasat satellite and the International Telex System.

12.1.7.3 Facsimile. Communications via facsimile would be possible between the site, St. John's and Calgary via satellite.

12.1.7.4 Main radio network (SSB). From St. John's, the company would be able to monitor five Eastcan channels, which are: 3310 KHz, 4752 KHz, 5744 KHz, 7968.5 KHz, and 12234.5 KHz. During operations to be carried out off the Labrador coast, Eastcan would provide the following facilities:

Transmitting site - Receiving Site. At the transmitting site, a Marconi CH25 transmitter and a Marconi BH30 linear amplifier would be set up, giving a power of 1000W continuously. At the receiving site, five XH14 receivers would be monitored permanently. In order to have the best emission and reception, high gain directional antennas together with dipole antennas would be installed on both transmitting and receiving sites.

Cartwright Base. A CH25 transmitter, five XH14 receivers and one LPA1K linear amplifer (800W) would be installed. An alarm system together with a phone patch would be hooked up.

Hopedale Base. A CH25 transmitter, five XH14 receivers and a BH30 linear amplifier (1000W) would be installed. An alarm system and an automatic phone patch would also be hooked up.

Saglek Base. At Saglek, the same equipment as indicated for Hopedale would be used, except that the CH25 would also be used as a receiver. Only one channel would be monitored at a time and no phone patch would be available.

Using the above facilities, the oil exploration company would be able to contact the site and vice versa from Calgary, St. John's, or any Labrador base. As supply vessels would be on the same frequencies, contacts between the bases, the site, support vessels, as well as helicopters and airplanes would be possible at all times.

The communications set-up of the oil explorations company operating on the spill site would provide the very necessary first link in the chain of communications

required to combat a major emergency. It would be advisable for government to inspect these facilities and ensure that they are adequate whenever an operation that could conceivably result in a major spill is being carried out .

12.1.8. Other Communications. There are other modes of communication in service on the Labrador coast such as radio broadcasting, French language radio, television, the media, mail, telegraph, etc. These have not been dealt with in detail in this report as they would not likely be utilized as part of a countermeasures operation due to their inadaptability for this type of operation and their lack of speed and reliability. Mail and telegraph would be replaced by the much faster telex and facsimile services available through the telephone system.

These other services could, however, form a major role in maintaining public relations during a cleanup operation, and therefore they have been mentioned. The availability of these facilities and the areas they service are outlined in Volume 1 of the Report of the Royal Commission on Labrador.

12.2 Navigation: Marine and Air

Ships navigating along the coast of Labrador use the same instrumentation and on-board equipment that is in general use throughout the North Atlantic. Fixed (on shore) aids to navigation are, however, limited in extent and most are only in operation during the ice-free season.

These aids are deployed or activated by the Canadian Coast Guard (CCG) as the edge of the ice pack recedes in late spring and they are removed or de-activated with the onset of winter ice. The navigation season is nominally the end of May to the middle of December for the area from Ford Harbour to the Strait of Belle Isle.

Approximate locations of fixed aids to navigation are shown in Figure 12.3. A supplemental list of unlighted floating aids is shown in Table 12.2. Navigators in this area would refer to the publications listed in the References for accurate, up-to-date information.

Aircraft navigating in this area are affected by the relative scarcity of aircraft beacons and landing fields. Flying under visual flight rules (VFR) in winter is hazardous because of the difficulty in visual identification of ground features, uniformity of snow-covered surfaces and frequent, unpredictable "white outs", which cause a loss of orientation, particularly at low altitudes.

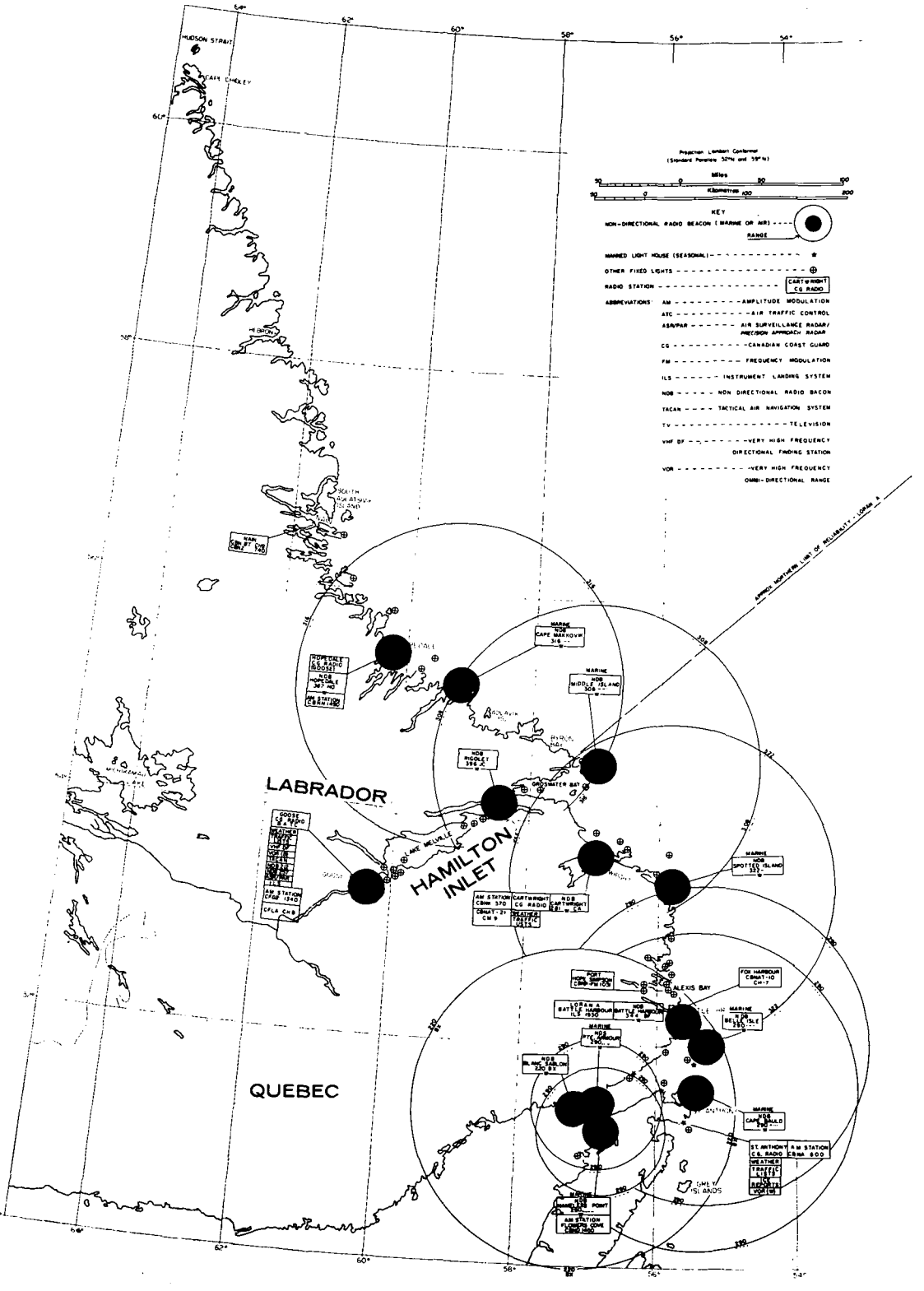


FIGURE 12.3 NAVIGATIONAL AIDS SYSTEMS: LABRADOR COAST

TABLE 12.2 UNLIGHTED FLOATING AIDS: LABRADOR COAST

1)	West St. Modeste Wooden Spar	Lat. 51 35 36	Long. 56 41 05
2)	Henley Harbour (Freezer's Rock) Conical	Lat. 51 59 37	Long. 55 51 05
3)	Caribou Run, Assizes Harbour South Spar	Lat. 52 14 52	Long. 55 39 01
4)	Caribou Run, Assizes Harbour North Spar	Lat. 52 15 52	Long. 55 39 53
5)	Indian Tickle South Spar	Lat. 53 33 03	Long. 55 58 35
6)	Indian Tickle North Spar	Lat. 53 33 35	Long. 55 59 25
7)	Blake Shoal Steel Spar	Lat. 53 34 21	Long. 59 56 45
8)	Epinette Point Steel Spar	Lat. 53 31 14	Long. 59 57 03
9)	North West Point Steel Spar	Lat. 53 30 06	Long. 60 00 36
10)	Groves Point Channel Entrance Black Spar	Lat. 53 21 01.2	Long. 60 21 00
11)	Harry's Reef Can	Lat. 54 55 00	Long. 59 47 00
12)	Fishermans Point Conical	Lat. 52 21 35.5	Long. 55 41 46
13)	Hopedale Black Spar	Lat. 55 27 13.5	Long. 60 12 57
14)	Hopedale Inner Red Spar	Lat. 55 27 23	Long. 60 13 07
15)	Hopedale Outer Red Spar	Lat. 55 27 17	Long. 60 12 57
16)	Pack's Harbour Red Wooden Spar	Lat. 53 51 01	Long. 56 59 20
17)	Pack's Harbour Black Wooden Spar	Lat. 53 51 00	Long. 56 59 35

Approximate locations of ground aids to air navigation are also shown in Figure 12.3. Air navigators would refer to the publications listed in the References for accurate, up-to-date aids and traffic-control information.

12.2.1 Charts. The basic tool in all navigation systems is accurate charts, drawn at an appropriate scale and designed for the proposed use. In the sea area between Cape Chidley and the Strait of Belle Isle, there is 100 percent coverage at 1:500,000 and at various scales in the range 1:224,000 to 1:558,000; 100 percent coverage of the inshore areas from Port Manvers to Cape Chidley at 1:100,000; and coverage of most harbours and approaches from Hopedale to the Strait of Belle Isle at scales of 1:10,000 to 1:40,000.

The only harbours and approaches charted at a larger scale than 1:100,000 north of Hopedale are Button Island, Williams Harbour, Saglek and Nain.

Loran charts are available from the Strait of Belle Isle to Davis Strait at 1:2,202,000; Strait of Belle Isle to Resolution Island at 1:1,000,000; St. Michael Bay to

Gray Islands at 1:1,500,000; Hudson Strait to Greenland at 1:1,500,000; Strait of Belle Isle to Domino Run at 1:250,000; and Saglek Bay to Button Island at 1:250,000.

Aeronautical charts and supplements for VFR and IFR flights are available for all of the study area. Sources are listed in the References.

12.2.2 Marine Navigation Aids and Systems. Marine aids to navigation are described and listed in the most recent edition of the following government publications: Sailing Directions - Labrador and Hudson Bay; Notices to Mariners, Annual Edition; The Canadian Aids to Navigation Systems (pamphlet); Atlantic Coast - List of Lights, Buoys, and Fog Signals; Newfoundland - List of Lights, Buoys and Fog Signals; and Radio Aids to Navigation.

Table 12.3 is an international radio aids category listing, with an indication of the system available for these categories.

In inshore areas, where fixed aids are not available or are out of reliable range, and in offshore areas, radio aids are the source of most of the information required for marine navigation. Marine radio aids of interest in this study are:

12.2.2.1 Non-directional radio beacons (NDB). Locations in Labrador are shown in Figure 12.3. It should be noted that all NDB north of the Strait of Belle Isle are periodical. Marine NDB's in Labrador have ranges of 80 to 100 nautical miles (NM). Air NDB's at Goose, Rigolet, Cartwright and Battle Harbour are continuous and can provide useable marine signals when within range. Geographic accuracy is five to ten NM at 100 NM range. Repeatability is slightly better but strongly dependent on atmospheric conditions. Accuracy is directly related to range, and reliability is good within range. The northern limit of inshore beacon coverage is the vicinity of Nain.

12.2.2.2 Decca navigator (DECCA). The nearest DECCA chain is based on the eastern part of the island of Newfoundland. The published northern limit (B Accuracy) is east of the northern peninsula, along Latitude 50 ^{o}N. Accuracy is 0.25 NM, Summer Day; to 2 NM, Summer Night; and 1.0 NM, Winter Day. Nominal range is 400 NM by day and 100 to 240 NM by night.

Existing coverage is therefore inadequate for operations along the Labrador Coast. There is no indication of future extension of this system to the north. Costs are a major deterrent because of the short base lines and large number of stations which would be required.

TABLE 12.3 CATEGORIES: RADIO AIDS TO NAVIGATION

Category	Function	Distance from Nearest Danger	Accuracy Required	Urgency	
1 Long Range	Ocean Aid	Over 50 NM	1 percent of danger distance	Within 15 minutes	LORAN, DECCA, MF/DF, OMEGA, SATNAV
2 Medium Range	Landfall Aid & Coastal Navigation	3 to 50 NM	200 to 1000 M	Within 0.5 to 5 min	DECCA, LORAN RADAR (on board) MF/DF, SATNAV
3 Short Range	Confined Waters Aid	Less than 3 NM	50 M	Instantly	1. Radar (on board) 2. DECCA (with special techniques

Source: Report of the Electronic Marine Navigation Systems Study Team - January, 1977 (TP 579)

12.2.2.3 Loran A (long-range navigation). A Loran A station is located at Battle Harbour, paired with stations at Bonavista and Fredericsdal (Narsak), Greenland. The northern limit of reliable reception is a line from the entrance of Hamilton Inlet easterly toward Greenland. Within the reliable range of 300 to 400 NM over sea water, the geographic accuracy is one to three NM. Repeatability is about 500 to 1500 m. Accuracy is dependent upon the ship's position relative to the transmitters, the chart lattice pattern and the distance from baseline.

The portions of this system in the United States are scheduled to be shut down in about 1981. Canada is expected to shut down its stations at the same time or shortly thereafter. This system is therefore limited in coverage, inaccurate in relation to other available systems, and will be available only for the near future.

12.2.2.4 Loran C. The nearest stations are at Cape Race and Greenland. Accurate navigation requires signal reception from three stations. North of Goose, it is unlikely that more than one line of position can be determined. Supplemental navigation aids are required to resolve a position. When reliable reception is available from three stations, geographical accuracy is 600 m at 600 NM range. Repeatability is 80 to 475 m, dependent upon the distance from the lattice pattern centre. Accuracy is reduced when land or sea ice is on the signal path. Range is 400 NM, overland; 600 NM, land and sea; 800 NM, all sea path.

Canada (Coast Guard) is planning extension of this system northward by construction of a Loran C station on the Labrador coast. A station at Cartwright would provide reliable coverage in all waters south of Hamilton inlet. The tentative date of availability is 1981, assuming that there are no approval or funding delays.

Full coverage of the Labrador Sea would require a station at Cape Chidley; however, there are no current plans to extend the system that far north. This system is therefore limited to the southern portion of the Labrador Sea.

12.2.2.5 Omega. This is a world-wide system operated by the United States, using low frequency ground waves. All stations required to cover the Northern Hemisphere are complete. Geographical accuracy is plus or minus two NM over water and plus or minus four to five NM over ice. Repeatability is plus or minus one NM over water and plus or minus two to four NM over ice. Accuracy is dependent upon location and varies widely. Accuracy in the Arctic is radically degraded on occasion. Range is approximately 7000 NM per transmitter. Accuracy may be increased by a factor of two to four by special techniques.

This system is dependent upon U.S. support and financing. It is now used by the North Atlantic Treaty Organization forces, including Canada. The life expectancy of the system depends upon progress in satellite navigation systems and military requirements.

This system is available to commercial shipping. Reception in the Labrador Sea area is generally poor, due to weak signals from the station in Norway and darkness interference in the signal from the station in Liberia.

12.2.2.6 Navsat (Transit). This navigation system is based on five polar orbit satellites. In northern latitudes, one or two position readings can be made per hour, dependent upon time during which the satellites are transmitting above the horizon. Accuracy of position readings depends in part upon the capability of the receivers. Geographic accuracy for low-cost receivers is 0.25 to 0.50 NM. With distance logs, computers and gyro compasses, accuracy is in hundreds of metres. Reliability is good and area coverage is 100 percent in all weather or seasons.

This system is not suitable for continuous station-keeping, due to the time gap between satellite passes. Future use and development is dependent upon U.S policy and progress on other systems, e.g., Satnav.

12.2.2.7 Satnav (Navstar). Satnav is another, more recent, satellite navigation system being developed by the U.S. The target date for its installation is 1983. Geographical accuracy would be plus or minus 100 m (low-cost receivers) or plus or minus 10 m (full-capability receivers). Repeatability would be plus or minus 75 m or plus or minus two m, depending upon the equipment used. When completed, the system would provide continuous position readings 24 h/day in all weather. Commercial receivers are expected to be available at about $5,000 each in the period from 1984 to 1988 with a position accuracy of plus or minus 100 m.

Assuming that the U.S. continues development and installation, this system appears capable of exceeding the range, reliability and accuracy requirements of navigation in the Labrador Sea.

12.2.2.8 Private radio aids. The practice in petroleum exploration work in remote areas is to contract with radio survey specialists to establish sufficient radio beacons or markers and local voice communications systems to ensure continuous accurate location and relocation of exploration survey marks, soundings and drill holes. It may be assumed that systems for these purposes will be in operation in the local area of the drill hole(s) in

the event of an oil/gas spill or blowout. Ships using such a system may require special receivers.

12.2.3 Air Navigation Aids and Systems. Aids to air navigation are listed in the most recent edition of the Transport Canada publication, Air Navigation Radio Aids. Visual flight rules navigators use any available beacon source to confirm their map position. Instrument flight rules navigation is based on aids. Systems in use are as follows.

12.2.3.1 Aeradio stations. These stations provide a scheduled broadcast service every one-half hour. Major content is hourly weather reports; also included are significant in-flight weather and Notices to Airman (Notam). The station at Goose covers the Labrador area; however, the accuracy of local detailed weather information depends upon the number of frequency of reports received. North of Goose, reports are usually sparse, but they might be improved through the presence of oil exploration activity in the area.

12.2.3.2 Radio beacons (non-directional) (NDB). These are used for homing, airport holding patterns and finding position by triangulation. Most beacons are non-directional and are equipped with a voice feature used for air/ground communications and scheduled weather broadcasts. As shown in Figure 12.3, air radio beacons are located in the southern part of Labrador, with little effective coverage north of Nain. Nominal range is 100 NM (200 from Goose Bay) for good signal reception. Course alignment accuracy is nominally plus or minus one degree.

12.2.3.3 Very high frequency omnidirectional range (VOR). VOR is used for homing and position finding. It is reliable over 50 miles at minimum altitude and 150 miles at high altitudes. The stations operate continuously and most have a voice feature used for air-ground communications and scheduled weather forecasts.

Course alignment is plus or minus 2.5 degrees.

12.2.3.4 Tacan (tactical air navigation system). This is an ultra high frequency onmi-directional aid which provides slant distance in nautical miles from ground to air and the azimuth in degrees from the ground station. Nominal range is 200 NM. All Tacans in Canada are owned and operated by the United States Air Force or the Department of National Defence. Vortac is a combination of VOR and Tacan at one location and these stations are operated by Transport Canada. A Tacan station is located at Goose. Commercial aircraft do not use this system.

12.2.3.5 Instrument landing systems (ILS). There is only one system in the area, located at Goose. ILS is short range and intended for aircraft in the immediate vicinity of the airport.

12.2.3.6 Radar. Secondary Surveillance Radar (SSR) stations are in operation at Goose and Gander (insular Newfoundland). By using an automatic transponder in the aircraft which sends a reply to the ground stations, SSR obtains a longer range and better accuracy of position than primary or reflective radar. Transmissions are, however, restricted to line of sight and range is dependent on the altitude of the aircraft. Locations are determined on the ground and relayed by voice to the air navigator. This is reported to be an all-weather and very reliable system.

12.2.3.7 Loran A and C. This is applicable to both aircraft and ships. Range and accuracy for aircraft is similar to that for marine use.

12.2.3.8 Radio and television broadcasts. Both marine and air navigators may have occasion to use TV, AM or FM broadcast stations for direction finding. A list of public broadcast stations in Labrador is given in Table 12.4

12.2.4 Vessel Traffic Management (VTM). The Canadian Coast Guard at St. John's operates a Vessel Traffic Management (VTM) system in the territorial waters (12-mile limit) of Newfoundland and Labrador. This system was voluntary during 1977, although at that time it was expected to become mandatory within two to five years.

VTM receives reports of ship's location, course, destination and estimated arrival times as the ship arrives at or departs from designated calling-in points. Clearances are required for ships to proceed into ports and on leaving berths in ports. Ships should be in possession of the current annual edition of the Transport Canada publication, Notice to Mariners.

12.2.5 Air Traffic Control (ATC). ATC Stations have been established at major airports, including Goose and Gander. Hopedale CG Radio is remotely controlled from Goose and is the most northerly control point in Coastal Labrador. All flights beyond a 25-mile radius of the flight origin airport are required to file a flight plan with the nearest ATC station.

12.3 Transportation

This section describes the harbour and airport facilities that are available to any type of major countermeasures operation off the coast of Labrador, and outlines the

TABLE 12.4 CBC BROADCAST FACILITIES: LABRADOR

Location (Place Name)	Callsign	Radio Broadcast Frequency or TV Channel	Nominal Power (KW)	Normal Hours of Operation
Labrador City	CBDP	1240 KHz	40 W	6:00 am - 1:30 am
Wabush	CBDQ	1240 KHz	1 Kw	6:00 am - 1:30 am
Churchill Falls	CBDZ	740 KHz	40 W	6:00 am - 1:30 am
Fox Harbour	CBNAT-10	Ch. 7	250 W	9:30 am - 1:30 am
Cartwright	CBNAT-21	Ch. 9	5 W	9:30 am - 1:30 am
Nain	CBNBT	Ch. 9	5 W	9:30 am - 1:30 am
Cartwright	CBNK	570 KHz	40 W	6:00 am - 1:30 am
Labrador City	CBNLT (E)	Ch. 13	200 W	9:30 am - 1:30 am
Churchill Falls	CBMLT-1 (E)	Ch. 9	5 W	9:30 am - 1:30 am
Hopedale	CBNN	1490 KHz	40 W	6:00 am - 1:30 am
Port Hope Simpson	CBNP-FM (E)	105.1 MHz	3 Kw	6:00 am - 1:30 am
Nain	CBNZ	740 KHz	40 W	6:00 am - 1:30 am
Churchill Falls	CBQA	610 KHz	40 W	6:00 am - 1:30 am
Labrador City	CBST-3 (F)	Ch. 11	200 W	9:30 am - 1:30 am
Churchill Falls	CGST-4 (F)	Ch. 13	5 W	9:30 am - 1:30 am
Happy Valley	CFGB	1340 MHz	1 Kw	6:00 am - 1:30 am
Goose Bay	CFLA	Ch. 8	870 W	9:30 am - 1:30 am

extent and condition of these facilities. In most areas, facilities are at a minimum and quite often those that are available are inadequate for any type of large-scale operation.

The greatest limiting factor is the severity of the Labrador winter and the major ice field that covers the area over the continental shelf from November to June each year. This ice cover is usually so extensive that the entire coast of Labrador and a large portion of the east coast of the island of Newfoundland are closed to navigation by all ships other than specially equipped icebreakers for a large part of the year. Even with ice breaker support and the use of vessels with reinforced hulls, shipping is impractical since ice navigation is very slow. There are not enough suitable icebreakers to assist any more than a few ships at a time. Should a major spill occur in December, it would appear

that very little could be done to clean it up before the spring breakup which occurs in May or June in most northern areas.

Another obstacle to be overcome would be the complete lack of support facilities on the coast of Labrador. At the present time, communities bring in only enough food, gas, oil and supplies to satisfy local requirements for the winter period. Even then there is usually a near-crisis situation in the spring due to lack of supplies.

In order to conduct a major countermeasures operation from a base in Labrador, all supplies, fuel, and other essentials would have to be brought in from places outside of Labrador. Additionally, since most coastal communities are small and would not be able to accommodate a large influx of people, the setting-up of new campsite facilities to handle the countermeasures team could be necessary.

12.3.1 Airlines. The principal airlines operating in the area are: Eastern Provincial Airlines, Labrador Airways, Universal Helicopters, Viking Helicopters, Sealand Helicopters, Gander Aviation, and Straight Air. All of these airlines provide charter services, while Eastern Provincial Airlines and Labrador Airways provide scheduled flights into the area on a regular basis.

Generally, private and government agencies utilize the above services. The provincial government also has a helicopter (leased from Sealand) stationed permanently at the Goose Bay airport plus a Canso PBY water bomber for the month of August. The only other agencies operating aircraft in the area are the American Air Force, the Royal Air Force, and the Canadian Armed Forces. These operations are of a transient nature only and none of them have aircraft stationed in Labrador on a year-round basis.

The types of aircraft used and their periods of operation are as follows:

(a) Eastern Provincial Airlines fly scheduled trips into Labrador on a daily basis using Boeing 737 jets. These flights leave St. John's at 8:30 a.m. and land at Goose Bay before travelling to Churchill Falls and Wabush.

(b) Labrador Airways fly into Labrador on a regular basis using Queen airplanes. The flights originate from Deer Lake and generally stop at St. Anthony, Blanc Sablon and Goose Bay. The planes are wheeled and are equipped with I.F.R., thereby allowing them to fly during both day and night.

Labrador Airways also fly two scheduled flights a week into almost all the coastal Labrador communities. The planes used in this case are smaller single or twin-engine types, such as the Otter or Beaver, which fly by V.F.R. only and are therefore very susceptible to weather conditions and darkness. These planes land on skis in winter and on floats during summer.

(c) Universal, Sealand, Viking, Gander Aviation and Straight Air have no regularly scheduled flights into the Labrador area; they do, however, provide charter service as required.

12.3.2 Airport Facilities. At the present time there are only two paved landing strips on the coast of Labrador. These are at Goose Bay and Saglek. Northwest River and Nain have gravel landing strips suitable for small aircraft. Air travel to all other coastal communities is by light aircraft that land on water or ice, principally in the local harbours, but sometimes on neighbouring ponds during freeze-up. None of the landing sites on the coast outside of Goose Bay are equipped with navigational or landing aids: even one as basic as a windsock.

Winter strips are maintained at Cape Harrison and Rigolet for emergency use; however, these are not suitable for summer traffic. Seaplane bases are located at Red Bay, Mary's Harbour, Cartwright, Makkovik and Hopedale. These maintain radio contact with Goose Bay and carry a small cache of aviation gas.

In order to give a more detailed picture of the strips that would be available and their facilities, each one has been discussed separately below. Northwest River was not considered due to its poor condition and close proximity to Goose Bay. No detailed discussion is given for seaplane bases and winter strips, since these would only be utilized on a very limited basis. Because of its northern location and its availability as a good airport and seaport close to the Labrador Coast, St. Anthony has been included in this report. The locations of the available landing strips are indicated in Figure 12.4.

For more detailed and up-to-date information on the registered landing strips in Labrador, the reader should refer to the Department of National Defense Flight Information Publication - GHP 200A, current edition.

12.3.2.1 Goose Bay. Goose Bay is the only major airport on the Labrador coast capable of handling aircraft such as the Boeing 737 which is used by Eastern Provincial Airways for regular passenger service within the province of Newfoundland and Labrador. The airport is located at co-ordinates 53°19'N and 60°26'W and is shown on topographic chart 13SWE-19. It has two runways. The major runway is 11,050 x 300 ft, while the secondary runway is 6,200 x 200 ft. Both are of concrete construction with asphalt overlay.

The airport is operated by the Ministry of Transport and the Department of National Defence. It is a licensed, public airport and features regular passenger and freight service to and from points in and out of Labrador. Flight Planning and Notices to Airmen are carried out at Goose Bay for all of coastal Labrador. The airport maintains

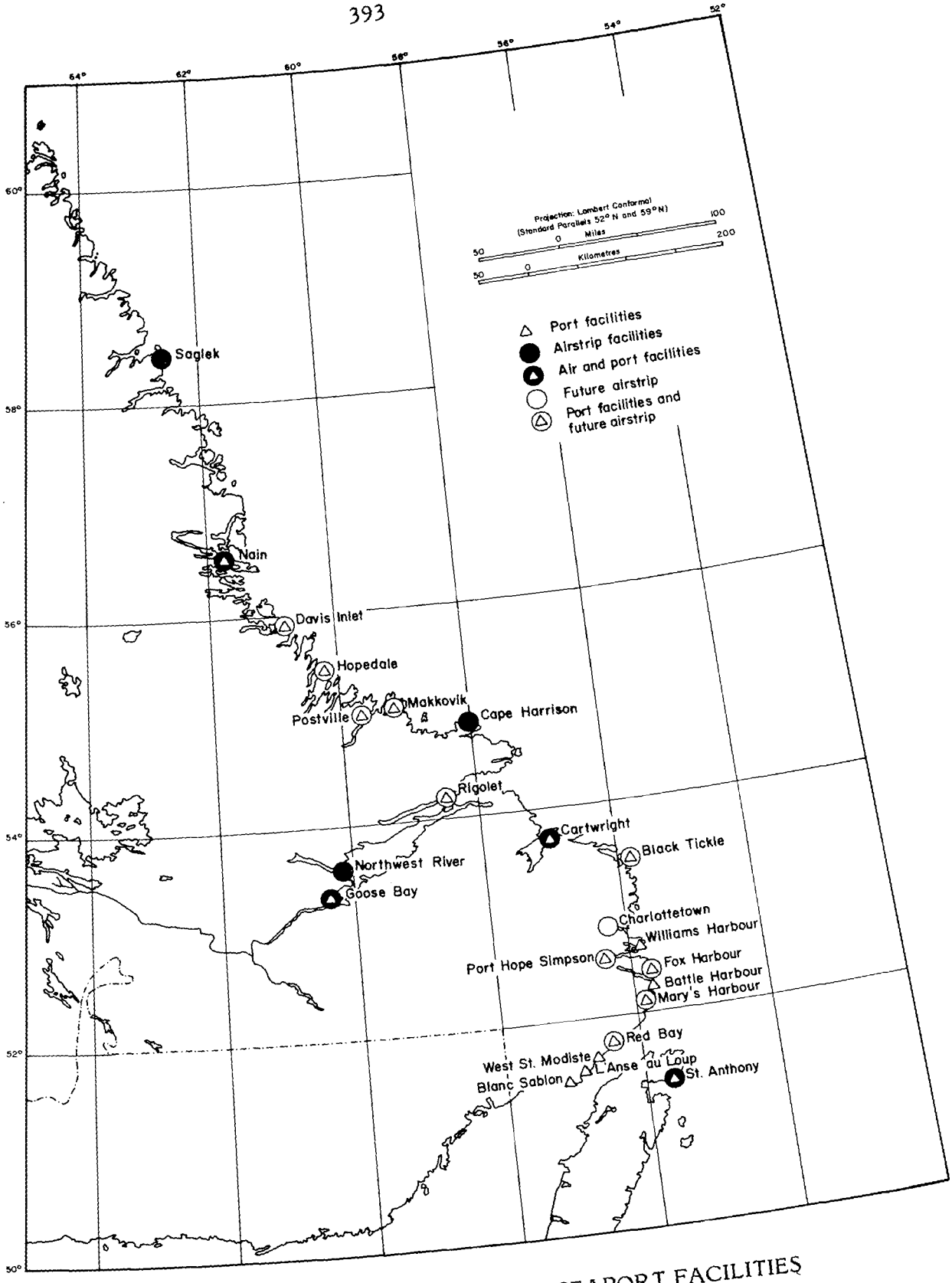


FIGURE 12.4 LOCATION OF AIRPORT AND SEAPORT FACILITIES ON THE LABRADOR COAST

contact with weather reporting stations on the coast and with the Gander Weather office. Navigational aids and communications contact are excellent. The airport can supply fuel and oil to most types of aircraft and has a Department of Defence Contract.

This is the only airport on the coast of Labrador that can accommodate night flying. Supplies and services for passengers at Goose are limited; therefore, the use of Goose as a technical stop should be planned accordingly.

Goose Bay will of necessity be one of the main centers for any counter-measures program due to its capacity to provide major airport services and its proximity to Happy Valley; in addition, it is the only seaport community on the coast capable of supplying accommodations and support facilities to any large-scale operation.

12.3.2.2 Saglek. Saglek is located at co-ordinates 58°28'N 62°39'W on the coast of Labrador. This is the only landing strip on the coast outside of Goose Bay that is presently capable of accommodating large transport aircraft hauling fuel and supplies. The strip has a paved runway surface which is 4760 x 150 ft with a two percent upward grade. Its status is listed as unknown by the Department of Defence Flight Information Publication -GPH 200A.

The major drawback to this site is that it is located 130 miles north of Nain, which is the most northerly permanent community in Labrador. Since the shutdown of the American Telecommunications base at Saglek, the base has been used intermittently by research groups and by the oil companies operating off the coast. There are no navigation, communications, or servicing facilities at this site.

Due to its strategic position on the coast, this strip could be used as a major operations centre. If this were done, fuel and supplies would have to be transported in from outside. Suitable accommodations could probably be provided through the use of the facilities at the lower campsite. The upper site has been dismantled. The largest problems relating to a major operation would be the winter freeze-up period, lack of wharf facilities and communications.

12.3.2.3 Nain. Nain, which is the most northerly community on the Labrador coast, is located at coordinates 56°23'N 61°48'W. The airfield, which is operated by the provincial Department of Transportation, has a gravel runway 2500 x 100 ft. All flight planning is carried out through radio contact with Goose Bay. The status of this runway is unknown.

There are no storage, servicing, or maintenance facilities available. Plans are presently underway to upgrade the runway during 1978 to enable it to provide year-round service.

12.3.2.4 Cartwright. The airstrip at Cartwright is presently under construction and should be completed by August, 1978. When completed, the base will have a 2500 x 75 ft paved runway and will be maintained for year-round service by the province. At present, it is not planned to provide any terminal, storage or maintenance facilities at this airstrip.

12.3.2.5 St. Anthony. St. Anthony is located at coordinates 51°29'N 55°49'W on the northern peninsula of the island of Newfoundland. The paved runway is 3000 x 100 ft and can accommodate most types of aircraft. Fuel and maintenance are available. Flight planning is carried out through Deer Lake. Limited storage facilities are available and there is a regular passenger and freight service. Navigational aids are good and night flying can be accommodated.

12.3.2.6 Future airports. The provincial Department of Transportation, under funding from the federal government, has proposed a program to construct 13 permanent landing strips on the coast of Labrador over the next six years. These will be constructed at Davis Inlet, Postville, Rigolet, Black Tickle, Port Hope Simpson, Charlottetown, Red Bay, Fox Harbour, Cartwright, Makkovik, Hopedale, Nain and Mary's Harbur.

Of those listed, the first two, valued at a total construction cost of $2,000,000, will be built at Nain and Makkovik during 1978. The second two are scheduled to be built at Hopedale and Mary's Harbour in 1979.

These landing strips will consists of 2500 x 75 ft strips within cleared areas of 2900 x 200 ft. The runways will be of levelled gravel, suitable for small-wheeled aircraft such as Twin Otters, Beavers, Cessnas and so forth. The provincial Department of Transportation will be responsible for operating and maintaining these fields and for such services such as runway inspection and snow clearing. Services such as terminal buildings, storage sheds, landing lights and runway beacons will be provided eventually, depending on demand, but they are not planned at present.

12.3.3 Harbours and Ports. For the most part, port facilities in Labrador are confined to a few larger communities which have a government wharf owned and maintained by the federal Department of Public Works and operated by the Department of Transport. Most other communities provide only anchorage facilities, although a number of smaller private wharfs and fishing stages may be found.

The only community having a large wharf capable of handling fairly large vessels and a reasonably high volume of traffic is Goose Bay. The Labrador Linerboard wood harvesting operation was carried out from Goose Bay for several years prior to the close down of the mills at Stephenville.

In order to ascertain which ports might be suitable to an emergency countermeasures operation, a list of the support vessels that are likely to be used on this sort of operation was compiled. The overall length and draught of each vessel is given in this list (Table 12.5).

In order to move any amount of men and equipment, some sort of a wharf facility is essential; therefore, only those ports having such facilities in conjunction with harbours deep enough to accommodate the vessels in Table 12.5 were considered. The Appendix to this chapter contains a detailed description of ports and wharf facilities on the Labrador Coast. Because of its possible strategic location, St. Anthony, on the Great Northern Peninsula of insular Newfoundland, has also been described.

Even in those ports described, the facilities are very poor and only allow one vessel at a time to be serviced. In some instances, the larger vessels would not be able to dock. The principal source of information used to describe the ports was the Newfoundland Coastal Transportation Study Inventory of Ports and Harbours, as prepared by Transport Canada in December, 1974.

This information has been further updated by information on the present condition of the facilities as supplied by the federal and provincial governments. It should be noted that the warehousing facilities indicated in the port descriptions are controlled by the MOT and are normally used on a 48-hour temporary basis. These sheds are therefore usually vacant and would be available for emergency use.

More detailed information on all of the facilities described below is available upon request from Public Works Canada. Saglek, which is ideally located and has a good landing field, does not have any wharf facilities; however, it does provide a good anchorage for most vessels. The ports of Blanc Sablon, West St. Modeste, Red Bay and L'Anse Au Loup are far enough south that St. Anthony would be used instead, due to its airport facilities.

The ports of Goose Bay, St. Anthony, Nain and Cartwright are the only ones other than Saglek having airport facilities at present and therefore would receive prior consideration should an incident occur in the near future. Davis Inlet, Postville, Rigolet, Black Tickle, Port Hope Simpson, Red Bay, Fox Harbour, Makkovik, Hopedale and Mary's Harbour are all slated to receive airfields in the very near future, after which they could become important.

TABLE 12.5 LIST OF VESSEL TYPES LIKELY TO BE INVOLVED IN COUNTERMEASURES OPERATIONS

Name	Overall Designation	Length	Draught
Active King	Offshore Supply Vessel	211'02"	15'05"
Active Rey	Offshore Supply Vessel	211'02"	15'05"
Bartlett	Ice Strengthened Aid to Navigation Vessel	189'04"	12'06"
CSS Baffin	Lloyds 100A1 - Icebreaker	285'06"	18'10"
CSS Dawson	Lloyds 100A1 - Ice Class 1	211'09"	16'00"
CSS Hudson	Lloyds 100A1 - Ice Class 1	296'07"	20'07"
CSS Maxwell	CSI Home Trade Class 11	115'00"	7'10"
D'Iberville	Heavy Icebreaker	310'00"	30'02"*
Edda Salvator	MV Ice Class C	195'11"	13'11"
John A. MacDonald	Heavy Icebreaker	315'00"	28'00"*
John Cabot	Cable Ship & Icebreaker	313'04"	21'06"
Labrador	Heavy Icebreaker	290'00"	29'00"*
Louis St. Laurent	Heavy Icebreaker	366'06"	31'00"*
M.V. Cathy 'B'	Ice Class Support Tug	184'00"	14'06"
Orkney Shore	100A1 LMC Ice 3	175'09"	14'00"
OSA 481 Josepthturm	Support Tug	184'02"	15'01"
Protecteur	Supply Ship	564'00"	30'00"*
Provider	Supply Ship	523'00"	32'00"*
Sir Humphrey Gilbert	Medium Icebreaking Aid to Navigation Vessels	220'00"	16'04"
Skaustream	1A1 Tug Supply Ship	211'03"	15'05"
Stella Salvator	MV Ice Class C	196'05"	15'11"

* These vessels would not be able to dock in any harbour on the Labrador Coast at maximum draught. Goose Bay could be used at high tide and draughts less than 28 ft.

It is unlikely that the other ports mentioned would receive consideration as headquarters for any operation; however, they may be used for localized task-force operations associated with spill clean-up. There are numerous other harbours along the coastline that might be used in this capacity; however, these have no facilities and offer only anchorage. A description of these harbours can be found in the Newfoundland Coastal Transportation Study - Inventory of Ports and Harbours.

12.4 Support Facilities

12.4.1 Vehicles. Vehicle support for any operation along the Labrador coast would in most instances have to be supplied as part of the overall countermeasures plan. In the more southern communities of St. Anthony, Goose Bay, Blanc Sablon, West St. Modeste, L'Anse Au Loup, and Red Bay, basically all types of vehicles are available or can be made available.

At Cartwright, Mary's Harbour, Nain, Makkovik, and Port Hope Simpson, only a few small trucks and snowmobile machines are available. In all other communities, the only mechanical equipment available would be snowmobile machines.

Even if vehicles could be made available, in most of the communities their usefulness would be very limited due to lack of roads and service centres.

12.4.2 Service Centres. Only the communities of St. Anthony, Goose Bay, Blanc Sablon, L'Anse Au Loup and West St. Modeste have service centres capable of supplying gas, oil and maintenance facilities to vehicles and heavy equipment. In the other communities, supplies of gas and oil are limited to the requirements of the inhabitants over a winter, and there are no maintenance centres as such.

An operation taking place in these areas would require that the facilities be brought in from outside. Goose Bay is the only community capable of supplying fuel and maintenance to aircraft and shipping. There are no shipping or aircraft stationed on a permanent basis in any of the other communities. Therefore, facilities of this nature would also have to be imported.

12.4.3 Food. Food is only supplied to coastal Labrador communities in sufficient amounts to meet local requirements. In all communities, other that St. Anthony and possibly Goose Bay, where there is a mess hall capable of serving 1500 meals per day in operation, food for a sizable emergency operation staff would have to be transported in as part of the overall program.

12.4.4 Health Services. All health services on the coast of Labrador are provided through the International Grenfell Association; its main base of operation is St. Anthony. The association's main hospital is at St. Anthony; two others are at Goose Bay and Northwest River, in Labrador. Doctors stationed at these hospitals serve the coast through a well-organized system of nursing stations and clinics. Radio contact is maintained with all coastal communities. The association has its own fleet of aircraft stationed at St. Anthony and Northwest River that are used to transport medical supplies, doctors and patients to and from the three hsopitals.

Nursing stations are located at Nain, Hopedale, Makkovik, Cartwright, Mary's Harbour, Forteau, Davis Inlet and Port Hope Simpson. These stations have full-time nurses who provide first aid and minor medical services to local residents. Radio contact is maintained with the hospitals and any serious cases are flown out for treatment.

There are also a number of clinics along the coast that provide limited drugs and medication to patients. The service is usually operated by lay dispensers, with nurses being available on a temporary basis during freeze-up periods. There are clinics at Postville, Rigolet and Charlottetown.

The system is well organized and provides adequate service in most cases. More detailed information is available through Dr. Thomas of the International Grenfell Association in St. Anthony.

12.4.5 Accommodations. One of the largest problems to be overcome by any sizable emergency task force operating on the Labrador Coast will be that of accommodation. Table 12.6 lists the various government approved accommodations on the coast of Labrador and in St. Anthony.

The only communities capable of accommodating a sizable group of people would be St. Anthony, 71 rooms; and Goose Bay, 77 rooms. Goose Bay also has some 80 vacant housing units that could be made available, as well as three dormitories capable of accommodating approximately 200 men. These latter facilities became available with the phase out of the American Forces' operations in the area.

In other coastal communities, there are only a few scattered accommodations available. Most communities have very small populations and would not be able to offer even boarding facilities.

In Saglek, there is a base camp that is owned and operated by Eastcan Exploration Limited; it can accommodate 46 persons. Some facilities might be available at this site with the cooperation of the company. This camp is located on the lower site.

The upper camp site, which was formerly owned and operated by the American government, was salvaged during 1977 by a contractor from Halifax with the

TABLE 12.6 AVAILABLE LICENSED ACCOMMODATIONS ON THE LABRADOR COAST AND IN ST. ANTHONY

Community	Establishment	No. of Rooms
Forteau	Roberts Hospitality Home	3
Happy Valley-Goose Bay	Hotel Goose	21
	Labrador Inn	28
	Royal Cabins	12
	Dale Ernst Boarding House	5
	Others	11
L'Anse Au Clair	Northern Lights Inn	16
L'Anse Au Loup	Barney's Hospitality Home	2
	Others	3
Nain	Atsanik Lodge	9
St. Anthony	St. Anthony Motel	24
	Vinland Motel	31
	Deker's Hospitality Home	7
	Howell's Hospitality Home	9
	TOTAL ROOMS AVAILABLE	181

understanding that any remaining structures were to be destroyed after the salvage operation had been completed. In keeping with the terms of his contract, the salvage operator burnt everything to the ground prior to leaving the site. Consequently, it is completely unsuitable to any type of future use.

During its drilling operations, Eastcan has also operated base camps at abandoned radar facilities in Cartwright and Hopedale. The Hopedale base can accommodate 44 persons when all sections are open. The Cartwright base can accommodate 26 people. During drilling operations, each of these three camps normally can accommodate an average of 20 transients (P. Buemi, Personal Communication, 1978).

There are a number of private and government-owned summer camps throughout Labrador that are used for fishing, hunting and research; however, these are small and inadequate to support large numbers of people without a considerable addition of new facilities.

In general, it would appear that any large group operating out of communities other than Goose Bay or St. Anthony will have to establish new base camps and provide all supplies and equipment for their operation from outside local areas.

12.4.6 Warehousing. The only warehousing or storage facilities that are available along the coast of Labrador, other than those indicated in Section 4 of this report, are located in Goose Bay. These facilities were left vacant by the phase out of the American Forces' Operation in that area and consist of one warehouse with 120,000 sq ft of space on its first level, and 40,000 sq ft of space on its second level, a number of Butler Buildings with about 50,000 sq ft each, and four Nose Hangars with approximately 60,000 sq ft of space in each. These facilities are not heated and are partially filled with surplus equipment and furniture. They are presently owned by Public Works Canada and could be made available in the event of an emergency.

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CHAPTER 13
ENVIRONMENTAL MONITORING AND PREDICTING

by
Edward Welder

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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13 INTRODUCTION

This chapter describes existing environmental monitoring and predicting systems that could provide assistance to strategic and tactical planning in response to an oil spill in the Labrador offshore. Emphasis is placed on data that are routinely collected and promulgated. Information that is not always routinely collected, as well as that which is disseminated only upon request, will only be noted.

Although each system may have its own limitations and weaknesses, combinations of systems may be complementary and adequate to support an oil spill response. No assessment will be made here of the suitability of integrating these various systems. This would require actual testing for a particular use, which is beyond the scope of this study. This section is presented rather as a user document.

Data systems are described, contacts listed and conclusions and recommendations made to inform the user of opportunities to streamline and progressively improve the available environmental monitoring and prediction systems with specific reference to the Labrador offshore.

13.1 Weather

The data systems that monitor and/or predict weather off the coast of Labrador are: ship reports; surface and upper air weather station reports; surface weather charts; and SMS/GOES and NOAA satellite data. The appendix to this chapter contains details of actual data collected and how they are interpreted.

13.1.1 Ship Reports. Ship reports are received in code form. These codes are relayed from ocean vessels by marine radio to marine radio stations at various locations in Newfoundland and Labrador. The codes are then relayed to the Gander Weather Office which, in turn, distributes them on a closed-circuit teletype system. The St. John's Airport Weather Office receives these codes via teletype.

Each ship report code consists of 17 groups of numbers, each group having five digits. Each digit has a specific meaning, which can be understood by using the manual of Marine Weather Observing (MANMAR, 1976). Not all 17 groups are necessarily reported in each code.

Ship reports are received for the entire Atlantic Ocean, while each individual report covers only the point at which the ship is located. Therefore, individual reporting areas are limited in coverage. Ship reports are available four times daily, during so-called "synoptic hours": 0000GMT, 0600GMT, 1200GMT and 1800GMT.

Reporting vessels include icebreakers, Canadian Coast Guard vessels, research vessels, Canadian and foreign fishing vessels, and stationary vessels and drillships.

The ship reports are used to produce surface weather charts, which are distributed on request. These charts are a compilation of reports received between synoptic hours. It is important to note that not all ship reports are included on surface weather charts for the particular synoptic period.

Coded ship reports are available locally from:

1. Gander Weather Office
   AES
   P.O. Box 370
   Gander, Newfoundland — Telephone (709) 256-3813

2. St. John's Airport Weather Office
   St. John's, Newfoundland — Telephone (709) 737-5532

3. P.O. Box 5000
   Bedford Tower
   AES, Dept. Environment
   Bedford, Nova Scotia — Telephone (902) 835-9526
   Attention: Frank Amirault

The Gander Weather Office holds ship report files for one month, while the St. John's Airport Weather Office destroys them daily. AES, in Bedford, Nova Scotia, holds coded ship reports for three months.

The AES headquarters, in Toronto, archives all Canadian vessel ship reports on computer tape. These can be accessed, upon request, by stipulating time and area desired. The NOAA National Climatic Centre in Ashville, North Carolina, archives on computer tape all ship reports received in the Northwest Atlantic. These can be obtained, upon request, through the Summary of Synoptic Meteorological Observations (SSMO). Information from the SSMO tables for the study area is presented and discussed in Chapter 4.

Receipt of *archived* ship reports can be made by contacting:

1. AES
   Climatology Division
   Dufferin Street
   Downsview, Ontario — Telephone (416) 667-4882

2. NOAA
   National Climatic Centre
   Ashville, North Carolina — Telephone (704) 258-2850
   U.S.A. — Ext. 765
   Attention: Mr. Bob Quale

No summary of the number of ship reports off the coast of Newfoundland has been found, although a detailed, monthly or seasonal summary can be arrived at by accessing archived data. Discussions with Environment Canada personnel in St. John's and Halifax indicate that the number of ship reports received off Labrador is only about one percent of the number received off the island of Newfoundland (south of 52°N).

Positional accuracy of ship reports is dependent upon the navigation system used by the vessel. These systems are discussed in Chapter 12. Accuracy of data collected by ships vary, depending on the measurement facilities and techniques available to the vessel.

At present, it appears ship report data are too limited in numbers to define localized weather conditions (for monitoring and predicting) off the Labrador Coast. This is especially true during the ice season, when few vessels are in the area.

13.1.2 Surface and Upper Air Weather Station Reports. Weather station reports are received in code or in a plain language form approved by the World Meteorologic Organization. These codes are relayed from stations at various locations in Newfoundland-Labrador (Figure 13.1) to the Gander Weather Office which, in turn, distributes them on a closed-circuit teletype system. The St. John's Airport Weather Office receives these codes via teletype from the Gander Weather Office.

Each surface weather station report code consists of 13 groups of numbers, each group having five digits. Each digit has a specific meaning, which can be understood by using the Manual of Surface Weather Observations (MANOBS, 1977).

Individual weather reports cover the area of visibility at which the surface station is located. Individual reporting areas are, therefore, limited in coverage. Surface weather station reports are available four times daily, during "synoptic hours". Upper Air Station reports are received once or twice daily.

The surface weather station reports are used to produce surface weather charts, which are distributed on request. These charts are a compilation of reports received between synoptic hours. Not all Surface Weather Station reports are included on each surface weather charts for various reasons, such as time constraints, possible redundancies or clarity of presentation.

Coded Surface Weather Station reports are available from:

1. Gander Weather Office
   AES
   P.O. Box 370
   Gander, Newfoundland Telephone (709) 256-3813

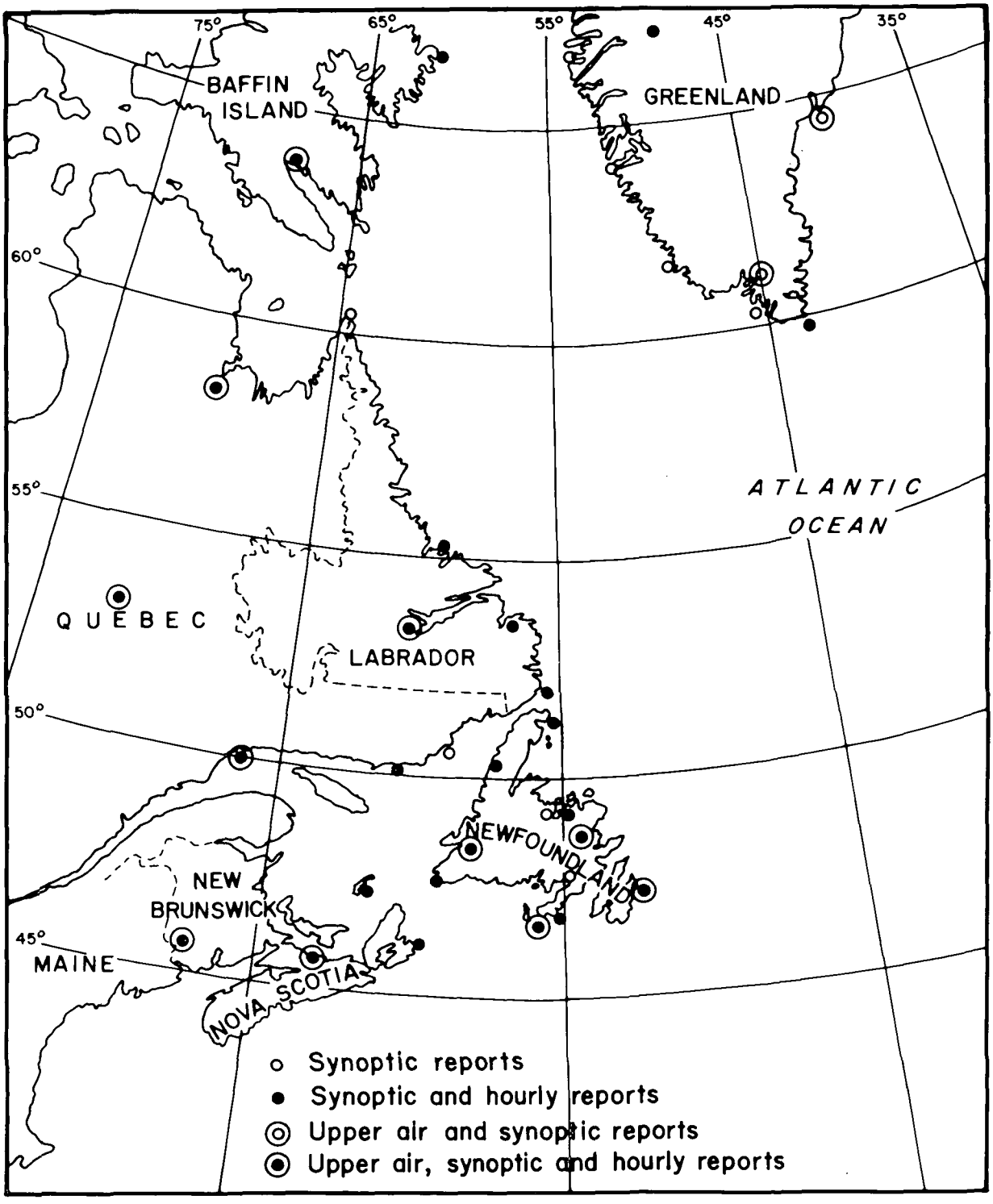

FIGURE 13.1 LOCATION OF SURFACE AND UPPER AIR WEATHER STATIONS

2. St. John's Airport Weather Office
St. John's, Newfoundland Telephone (902) 835-9526

Details of the information provided with each weather station report can be found in the appendix to this chapter. The handling and storage of surface weather station reports is identical to that outlined for ship reports.

Positional accuracy of all weather stations are known (METSTAT, 1972). Reporting accuracy is standardized (MANOBS, 1977) but many vary slightly between stations, depending on the facilities available and the observer. Observers may include AES employees, conductors, Department of National Defence personnel, employees of Telecommunications Branch (Ministry of Transport), or others. The agency making the observations at selected stations is reported in METSTAT (1972).

The accuracy of weather station reports declines rapidly with increased distance from the reporting station, particularly with the presence of frontal systems. The Labrador coast is poorly covered by reporting weather stations; the northern half (55° to 61°N) essentially lacks any coverage.

In the event of an oil spill, the response capability with respect to providing adequate weather monitoring and prediction in the regions would appear to be inadequate. This is briefly discussed in Chapter 4.

13.1.3 Surface Weather Charts. Surface weather charts are synoptic maps illustrating surface weather conditions. They are compiled with information primarily from coded ship reports over the oceans (Section 13.1.1) , and from coded weather station reports over land (Section 13.1.2).

Each cloud cover map consists of symbolic codes plotted at co-ordinates of each report. It is important to note that not all ship/shore reports are plotted on the surface weather charts, although all are used in creation of these charts. The symbolic codes can be interpreted by using MANOBS (1977).

The areal coverage of surface weather charts for eastern North America is shown in Figure 13.2. Each individual ship/shore report, which makes up the information for the maps, covers only the area visible to the ship/shore station. The surface weather chart extrapolates information between these reports. The maps are available four times daily, for the synoptic hours.

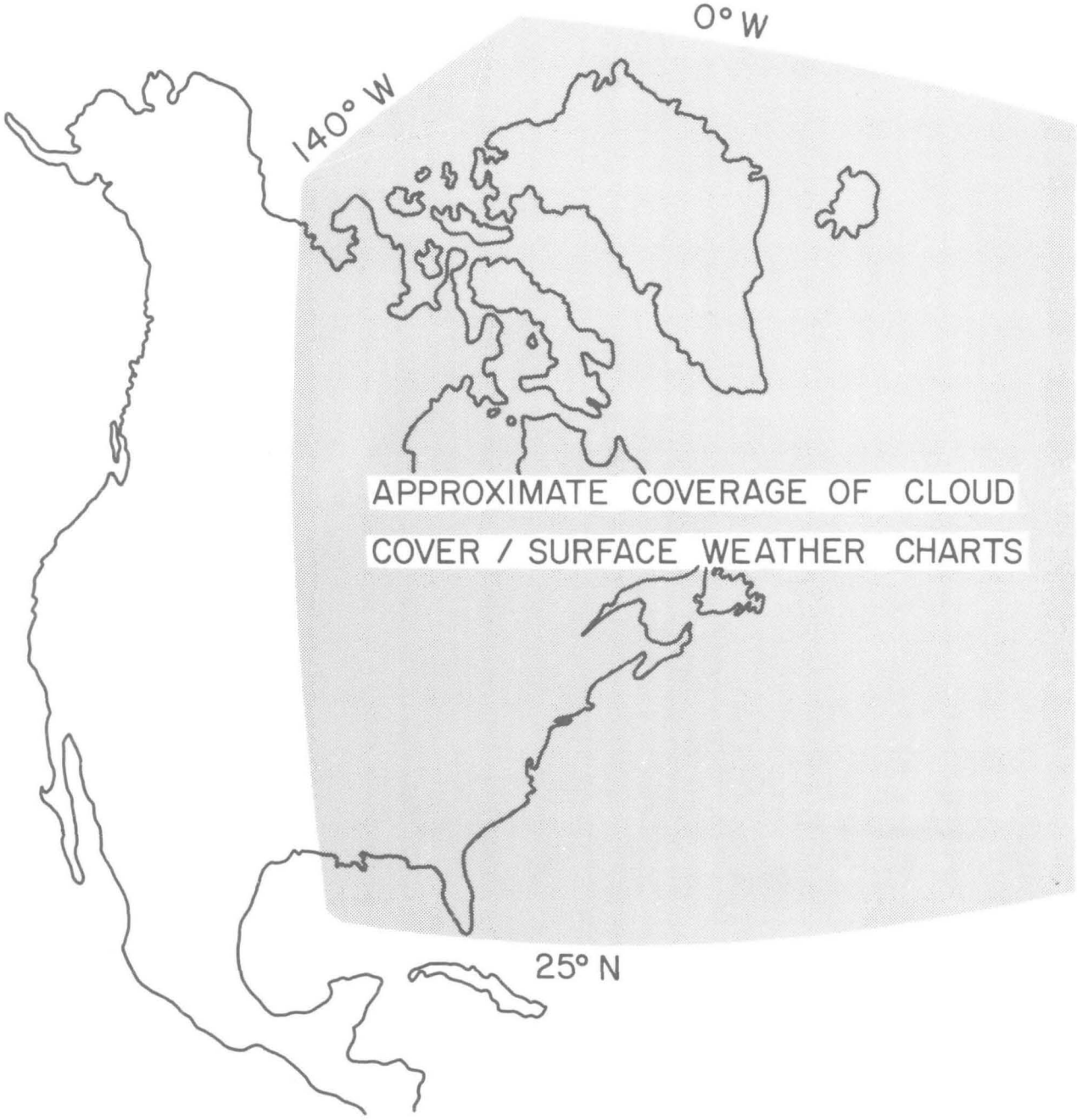

FIGURE 13.2 GEOGRAPHICAL COVERAGE OF SYNTOPIC SURFACE WEATHER CHARTS

Surface charts are available from:

1. Gander Weather Office
AES
P.O. Box 370
Gander, Newfoundland — Telephone (709) 256-3813

2. St. John's Airport Weather Office
St. John's, Newfoundland — Telephone (709) 735-5532

Archived copies are available at:

Ocean Engineering Information Centre
Memorial University of Newfoundland
St. John's, Newfoundland — Tel. (709) 752-1200 Ext. 3891

The Gander Weather Office files all surface weather charts for one month, while the St. John's Airport Weather Office destroys them daily.

Details on the type of information in each surface weather chart can be found in the appendix to this chapter.

The accuracy of surface weather charts is highly dependent upon the extent and number of reporting stations, both on land and sea. The scarcity of ship reports from the Labrador Sea, especially during the ice season, has meant that extrapolation must be made between land stations on Labrador - Baffin Island, and Greenland. As a consequence, weather fronts may be completely missed, as shown by Newell (1977) and Bursey (Personal Communication, 1977).

The accuracy of weather chart forecasts at the Gander Weather Office ranges between 60 to 85 percent with a mean of 75 percent (Bursey, 1977). This information, however, is *not documented* in the literature, and would require hindsight verification.

1.3.1.4 SMS/GOES and NOAA Satellite Data. The Synchronus Meteorological Satellite (SMS)/Geostationary Operational Environmental Satellite (GOES) and NOAA series have been operational through the National Environmental Satellite Service (NESS) since the early 1970's. NESS recieves, processes and distributes GOES satellite data to users in near real-time, via photo facsimile. NOAA satellite data is available from Canada's two tracking stations, Prince Albert, Saskatchewan; and Shoe Cove, Newfoundland, just outside St. John's.

GOES satellite imagery over Labrador is available every half hour, 24 h/day. NOAA data over Labrador is available once every day between 1200 - 1400 GMT (appendix to this chapter). Both GOES and NOAA satellite data provides images in the

visible band and the thermal infrared band. The resolution at the satellite nadir of both systems is 0.8 km visible and 9.3 km thermal for the GOES data; and 0.8 km visible and thermal for the NOAA data. Resolution of GOES data over Labrador is significantly coarser compared to the data resolution over the equator. Both systems can view Labrador in one scene so that a large geographic area can be monitored at one instant in time.

At present, GOES data is received on photo facsimile at the Gander Weather Office via NESS in Washington and AES in Toronto. NOAA data is also received at the Gander Weather Office, via AES in Toronto, on photo facsimile. NOAA data is also received at the Shoe Cove Satellite Receiving Station, though no facilities presently exist to transmit this data on photo facsimile to users.

GOES facsimile imagery service can be arranged through the following:

1. Satellite Data Services Branch, D543
World Weather Building, Rm. 606
Washington, D.C.
U.S.A. 20233 Telephone (301) 763-8111

2. AES, Satellite Branch
4905 Dufferin Street
Downsview, Ontario
M3H 5T4 Telephone (416) 667-4812

NOAA facsimile imagery service can be arranged through AES in Toronto. GOES and NOAA satellite data provides frequent visual support to existing weather monitoring and predicting services.

In the event of an oil spill off the coast of Labrador, a frequent amount of data is available. The resolution and geometric character of the data is such that positioning geographic points on the data is, at best, accurate only to 20 to 30 km (Addison J.R., Personal Communication, 1977). Cloud cover renders the NOAA and GOES data unusable; and as discussed in Chapter 4, the degree and extent of cloud cover over the Labrador shelf is considerable, especially during the fall and spring.

13.1.5 Other Data Sources for Weather Information. The following data sources are those that may or may not be routinely collected; data are only disseminated to users through specific requests.

13.1.5.1 Vessel cruises. Weather data may be collected by vessels at times other than synoptic reporting times. These vessels may include research, geophysical and exploratory survey, and surveillance vessels.

Inquiries regarding the location of these vessels off Labrador can be made through particular organizations to which the vessels belong, e.g., the Bedford Institute of Oceanography, Ship's Division, (902) 426-7292; Fisheries and Marine Services (709) 737-4419; Canadian Coast Guard Search and Rescue (709) 737-5119.

13.1.5.2 Pilot charts. Pilot charts provide weather information (wind, air, temperature, visibility, surface pressure) on one map at a scale of 1:15,700,000. This information is predictive for periods up to three months and is based upon historical data supplied by the U.S. Naval Oceanographic Office and the Environmental Data Service of NOAA.

Pilot charts are available from:

Defence Mapping Agency
Hydrographic Centre
Washington, D.C.
U.S.A. 20390

The accuracy of the information provided has not be investigated in this report. The information is very general and may be a useful guide in long-range prediction of weather.

13.1.5.3 GOES-derived wind vectors. Wind vectors are derived by NOAA/NESS over ocean areas at 2 1/2° latitude and longitude intervals. Low-level cloud tracers in two GOES images, one to two hours apart, are used to derive wind speeds and directions for 1200 GMT, 1800 GMT and 0000 GMT.

Wind vector information is stored on magnetic tape and can be accessed through:

Satellite Data Services Branch, D543
World Weather Building, Rm. 606
Washington, D.C.
U.S.A. 20233 Telephone (301) 763-8111

13.1.5.4 SMS/GOES and NIMBUS 6 data collection system. The SMS/GOES and NIMBUS Satellite can receive data from attended or unattended surface platforms (ships, buoys, platforms, automatic weather stations). This Data Collection System (DCS) may receive information on wind direction and speed, humidity, rainfall, surface and air temperatures and surface air pressures from remote areas.

The use of, and information pertaining to GOES and/or NIMBUS DCS's can be accessed through: NOAA/NESS, Washington, D.C. or Hermes Electronics, Nova Scotia. Discussions with A. Reid (Personal Communication, 1978) indicate that inquiries regarding DCS locations should be made to the particular user, e.g., oil companies, federal government agencies, etc. DCS locations may also be found in:

Notice to Mariners
Director, Aids and Waterways
Canadian Coast Guard
Transport Canada
Ottawa, Ontario
K1A 0N7

The deployment of stationary and drifting DCS's at locations off the Labrador coast can provide information for weather monitoring and predicting in needed areas. Use of DCS's in the Labrador Sea would be limited during the ice season since they must contend with ice forces. Their use to date in the Labrador Sea has been limited (Personal Communication, Reid, 1978,). No DCS's are operating off the coast of Labrador at present (Personal Communication, Malfin, 1978; and Reid, 1978).

13.2 Sea State

The following data systems are related to monitoring and/or predicting sea state off the coast of Labrador: ship reports; and wave height charts.

13.2.1 Ship Reports. Ship reports have been described earlier (Section 13.1.1). The information in the ship report relating directly to sea states is illustrated in the appendix to this chapter.

The only wave data currently available, which are obtained simultaneously at a number of points across the entire North Atlantic, are those from ships. They are visual estimates of height, period, and direction of waves. The accuracy and uniformity of the data collected is discussed by Neu (1976).

13.2.2 Wave Height Charts. Wave height charts are synoptic maps of wave heights and wind speeds. They are compiled with information supplied from coded ship reports (Section 13.1.1), and from coded weather station reports (Section 13.1.2).

Four times daily, the wave and weather observations at 30 to 40 stations (consisting of weather ships, Canadian and U.S. government ships, and oil drilling platforms) are radioed to the Canadian Armed Forces, Meteorological Ocean Centre (CFMETOC) in Halifax, N.S.

Here the data are reviewed daily or a 12-hour interval basis. The information received is related continuously to the preceding and current wave and wind environment. The synoptic data are plotted on charts, and lines of equal wave height are drawn at one-metre intervals.

The area covered by the charts is essentially the whole northwest Atlantic north of 35°N. The chart scale is 1:15 million and its projection is polar stereographic. In this way, temporal and spatial coherence and continuity are improved across the entire north Atlantic. Additional information on sea state is included in Chapter 4.

The charts are issued daily at 0000 GMT and 1200 GMT. Wave height charts are available from:

1.	Gander Weather Office AES P.O. Box 370 Gander, Newfoundland	Telephone (709) 256-3813
2.	St. John's Airport Weather Office St. John's, Newfoundland	Telephone (709) 737-5532
3.	Ocean Engineering Information Centre Memorial University of Newfoundland St. John's, Newfoundland	Telephone (709) 753-1200 Ext. 3891
4.	Commander-in-Charge Maritime Command Headquarters FMO Halifax, N.S. Attention: OIC METOC Centre	Telephone (902) 426-4513

These charts are filed indefinitely at METOC and the Ocean Engineering Information Centre. Gander files them for at least one month and St. John's destroys them weekly.

Details of the information provided with each wave height chart are contained in the appendix to this chapter.

With each wave height chart that is issued a 12-h, 24-h and 36-h prognosis chart is also released. The predictions are based on wind air pressure data provided with the ship reports.

The accuracy of the wave height charts is highly dependent on the extent and number of ship/shore reports. The scarcity of these reports off the Labrador coast indicates that these charts become less reliable in this region. The root mean square, wave height accuracy, is about 0.5 - 0.6, 0.7 and 1.0 for the 12-h, 24-h, and 36-h

prognostic charts, respectively (OIC, METOC, Personal Communication, 1978). This information, however, has not been previously documented.

In the event of an oil spill in the Labrador offshore, the frequency and coverage of data is adequate; however, the level of detail and accuracy of the data may be unsuitable for support operations.

13.2.3 Other Data Sources for Sea State Information. The following data sources are those that are not routinely collected or disseminated, except through request. They may, however, contain sea state information.

13.2.3.1 Vessel cruises. Sea State related information may be collected by ships at times other than synoptic reporting times. Vessel type, and inquiries regarding the vessel information, was described in Section 13.1.5.

It should be noted that to date all drillships operating the Labrador Sea have deployed wave rider buoys provided by Marine Environmental Data Service (MEDS). Future drilling operations can be expected to continue this practice. The wave rider buoy program is discussed more extensively in Chapter 4.

13.2.3.2 Pilot charts. Pilot charts provide sea state related information: wave heights, winds, gales and currents. The charts have been described earlier (Section 13.1.5).

13.2.3.3 SMS/GOES and NIMBUS 6 data collection system (DCS). Information on currents, wave height and direction may be received using this system. DCS's have been described earlier in Section 13.1.5.

13.3 Sea State

The following data systems are related to monitoring and/or predicting ice conditions off the coast of Labrador: AES Ice Charts; ECAREG and NORDREG Canada; Ship Reports; International Ice Patrol (IIP) Ice Bulletins; U.S. Navy Ice Charts; and Ice Reporting Lightstations.

13.3.1 AES Ice Charts. The Canadian AES Ice Charts describe synoptic sea ice, type and distribution. These charts are made up by the crews of the Canadian Ice Reconnaissance Aircraft, while in flight. The charts are transmitted from the aircraft to Ice Central in Ottawa, and are disseminated from there on facsimile.

Each ice chart contains ice type and ice concentration boundaries, along with coded symbols and digits, which can be interpreted by using the Manual of Standard Procedures and Practices for Ice Reconnaissance (MANICE, 1965).

Ice charts are available during the ice season, from about December to April. Geographic coverage includes the eastern Canadian seaboard, (Figure 13.3). As the ice boundary retreats northward, so does the southern limit of ice observations. Ice charts are produced daily in the ice season, depending on weather conditions, and are drawn on polar stereographic projections. The scale of the charts vary with the coverage of each flight.

Canadian AES Ice Charts are available from:

1. St. John's Airport Weather Office
St. John's, Newfoundland — Telephone (709) 737-5532

2. Ocean Engineering Information Centre
Memorial University of Newfoundland
St. John's, Newfoundland — Telephone (709) 753-1200 Ext. 3891

AES ice charts are also available from:

Ice Forecasting Central
5th Floor, Trembla Building
473 Albert Street
Ottawa, Ontario
K1A 0H3 — Telephone (613) 996-5236
Telex 053 3761

Ice observation seasonal summaries for past years are available from Ottawa; they are kept for five years.

Details on the type of information provided within each AES ice chart can be found in the Appendix to this chapter.

Ice charts provide ice type boundary information over large areas. This would be useful in the response to an oil spill. The accuracy of the data has not been investigated. No predictive ice charts are promulgated by Ice Central.

13.3.2 ECAREG and NORDREG Canada Reports. ECAREG Canada and NORDREG Canada have been operational since 1975 and 1976, respectively, to provide timely navigational safety and ice information.

Both reporting systems are voluntary. ECAREG operates with the Eastern Canada Traffic Zone and NORDREG operates within the Arctic Canada Traffic Zone (Figure 13.4). ECAREG applies to vessels (including tows) of gross tonnage of 500 tons or more and to vessels and/or tows carrying pollutants and/or dangerous goods. The same applies to NORDREG except that the vessel size limit is 300 tons. Both systems receive ship reports in plain (non-coded) language.

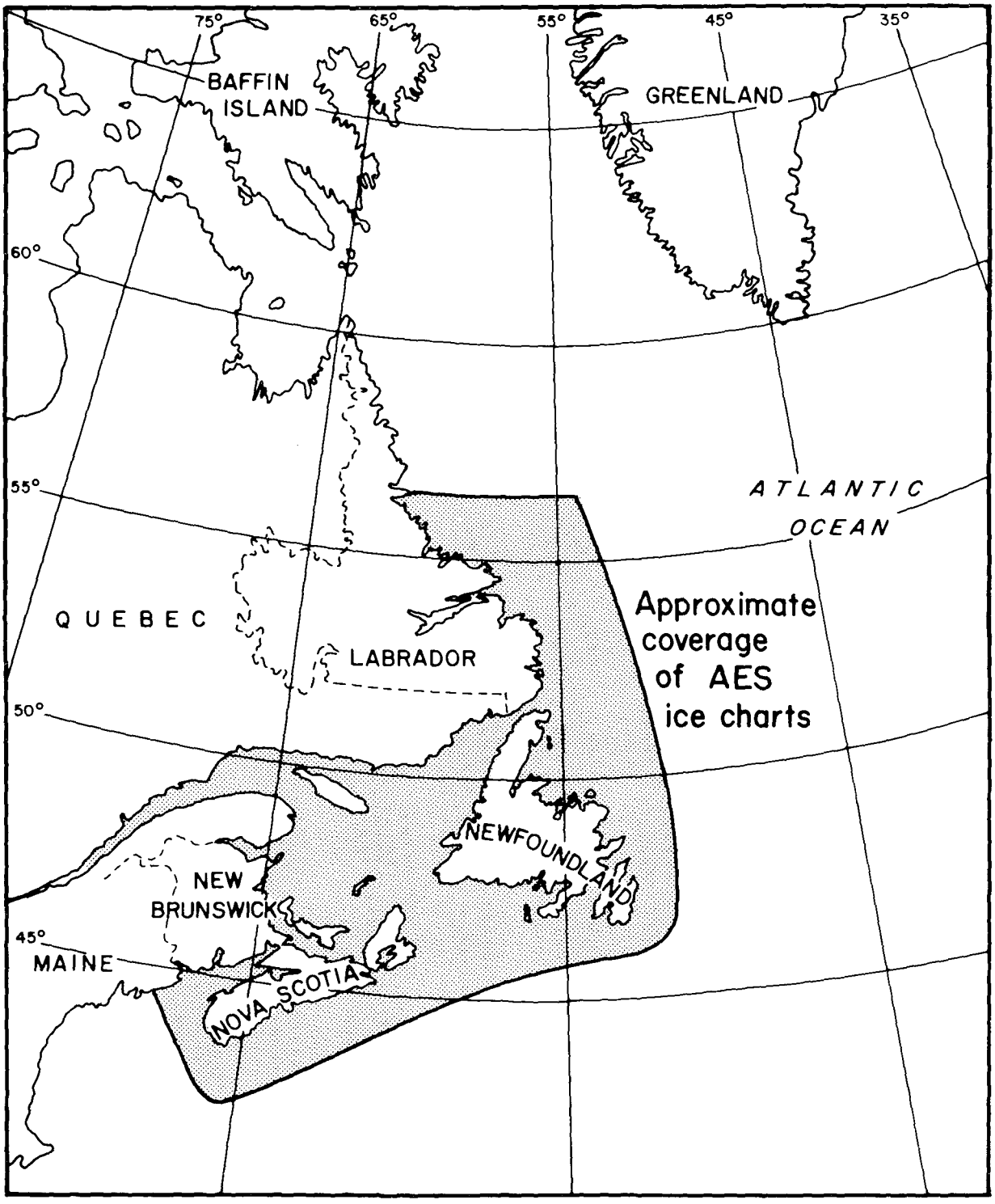

FIGURE 13.3 GEOGRAPHICAL COVERAGE OF AES ICE CHARTS

ECAREG Telex reports are received at:

Aids And Waterways
Canadian Coast Guard
Southside Road
St. John's, Newfoundland
A1C 5N5 Telephone (709) 737-5368

NORDREG Telex reports are received at:

Marine Traffic Management and Information Systems
Canadian Coast Guard
Place de Ville
Ottawa, Ontario
K1A 0N7 Telephone (613) 996-7124

Details describing the information found in these reports can be found in the appendix to this chapter.

Since both reporting systems are relatively new, no documentation on the accuracy or adequacy of data has yet been made. The reports are designed for traffic management purposes; however, they may include other useful information, e.g., ice conditions.

13.3.3 Ship Reports. Ship reports have been described earlier (Section 13.1.1). The information relating to sea ice within each ship report is shown in the appendix to this chapter.

Ice reports are made visually and are coded according to MANICE (1978).

13.3.4 International Ice Patrol (IIP) Ice Bulletins. IIP ice bulletins are issued up to three to four times per week, as a result of the iceberg monitoring program (Section 13.4.3). Ice observations are made only if a Navy Ice Observer is on board the aircraft (F. Kniskern, NOAA/NESS, 1978, Personal Communication).

Although no sample ice observations have been obtained as part of this report, the information is expected to be similar to the AES ice chart information.

The principal area of coverage is considerably south of the Labrador coast, although some coverage is available for this area during January and February.

The adequacy of the data would appear to be minimal in providing support to countermeasures programs in the Labrador offshore, both because of the limited coverage as well as the inflexibility of the committed iceberg program.

13.3.5 U.S. Navy Ice Charts. U.S. Navy Ice Charts are distributed in 8 1/2 x 14 in xeroxed form, on a regular basis. These charts, entitled "Weekly Eastern Arctic Sea Ice Analysis", are produced by the Fleet Weather Facility (FLEWEAFAC) Suitland, Maryland, Attention: Ice Operations Department.

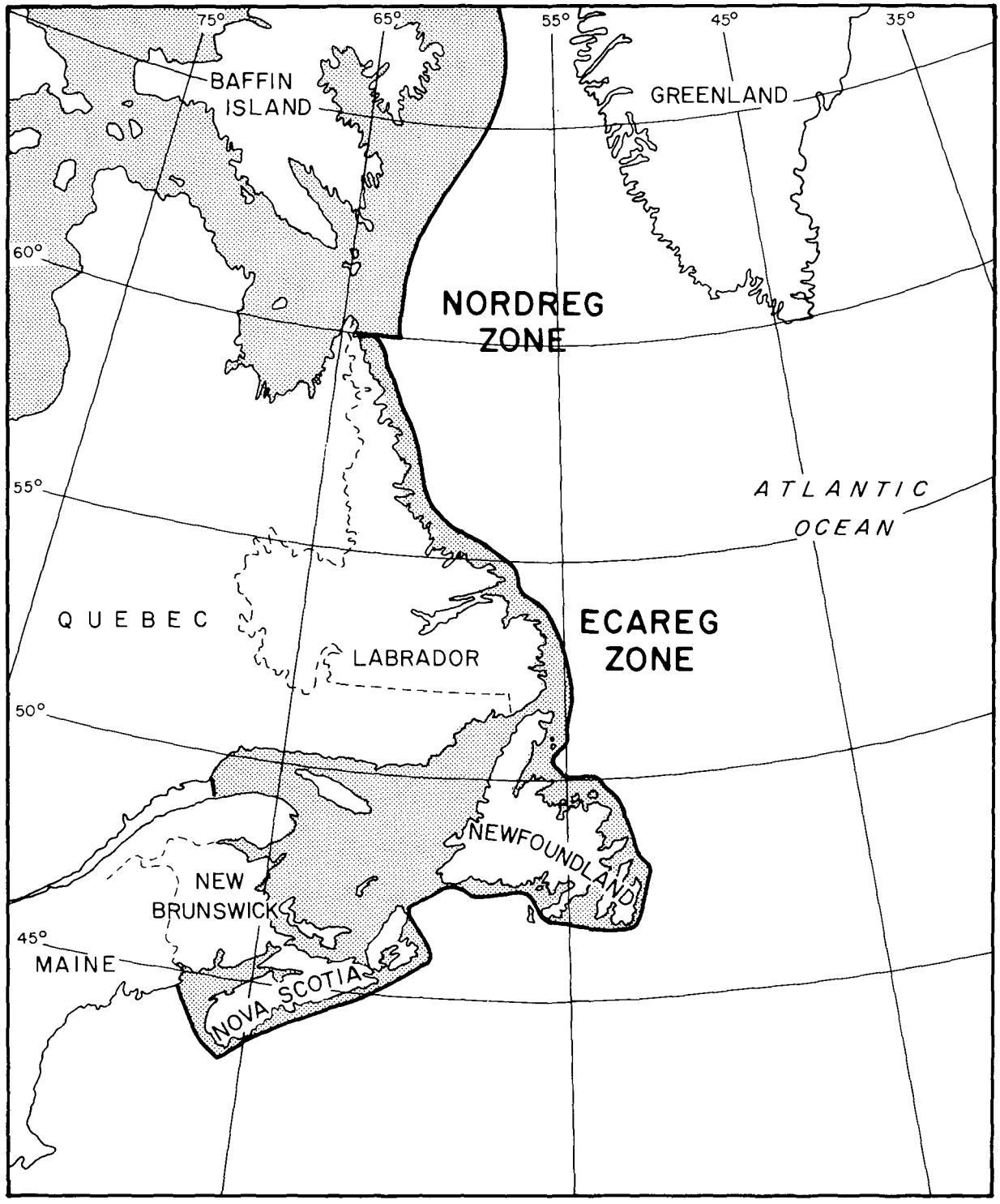

FIGURE 13.4 VESSEL TRAFFIC MANAGEMENT ZONES: CANADIAN EAST COAST

Two types of charts are produced, both in polar stereographic format. One is a Southern Limit Ice Chart, produced weekly; and the other is an Eastern Arctic 30-day Sea Ice Forecast, produced monthly.

The analyses are made mainly using satellite data with limited input from sea ice reconnaissance operators. The primary operational satellite sensor used is the Electrically Scanning Microwave Radiometer (ESMR), on board the NIMBUS-5 Satellite. ESMR's rather low resolution (25 km) and very small scale (1 in = 2400 km) makes for an overall accuracy of 25 to 35 km for ice edge location. New ice (less than 10 cm thick) is also difficult to detect.

Other satellite sensors used are of an "opportunity" (cloud free) capacity and include: NOAA-5 VHRR, NOAA-5 SR and DMSP F-2 OLSS.

Southern Ice Limit Charts and Eastern Arctic 30-Day Sea Ice Forecast Charts are available from:

Ice Operations Department
Fleet Weather Facility
Department of the Navy
Washington, D.C.
U.S.A. 20373 Telephone (301) 763-5972/73

Details of the information provided with these charts can be found in the appendix to this chapter.

The level of detail and the accuracy of the data is probably not adequate for detailed countermeasures planning. Information on the level of accuracy attained in the 30-day forecasts of sea ice is unavailable at this time, however, a numerical verification problem is under study (J. Jepson, Personal Communication, 1978).

13.3.6 Ice Reporting Lightstations. Fourteen visually observing ice reporting lightstations provide daily ice reports in Newfoundland (Figure 13.5). Three stations: Cabot Island, Baccalieu Island and Notre Dame Bay, are seasonal and report only during the period in which they are in operation. Reports are received via telephone or telex by the Canadian Coast Guard, in plain (non-coded) language.

Access to these reports can be made by contacting:

Regional Director
Canadian Coast Guard
St. John's, Newfoundland Telephone (709) 737-5487

No ice-reporting lightstations exist on the coast of Labrador.

13.3.7 Other Data Sources for Ice Information

13.3.7.1 Pilot charts. Pilot charts have been desribed earlier (Section 13.1.5). These charts provide southerly ice boundary limit data. They are only adequate for planning purposes since other, more timely data is available.

13.3.7.2 "Freeze-up and Break-up Dates of Water Bodies in Canada". This is a publication produced approximately every five years. Its purpose is to provide historical summary of dates of freez-up and break-up for selected water bodies in Canada. For insular Newfoundland, eight salt water bodies and 16 fresh water bodies are listed (Figure 13.6). Three water bodies are listed for the Labrador Coast.
This publication can be obtained from:

1. Ocean Engineering Information Centre
   Memorial Univeristy of Newfoundland
   St. John's, Newfoundland
   A1B 3X5 — Telephone (709) 753-1200 Ext. 3891

2. Climatology Division
   AES
   4905 Dufferin Street
   Downsview, Ontario
   M3H 5T4 — Telephone (416) 667-4882

The data has been collected by AES ice observers. The accuracy of the data has not been investigated. The data is scarce for Labrador; however, it could provide some long range planning information with regard to marine shipping and ice surface transport periods.

13.3.7.3 Danish ice reconnaissance. Sea ice reports off Greenland are received by the Meteorolgical Institute, under the Danish Ministry of Defence. They have not been investigated for this study; consequently, the extent, type and adequacy of the data is unknown.

Inquiries for this information may be made through:

Forsvarsministeriet
Kancellibygningen
Christiansbory Slotsplads 1
1218 Copenhagen K.
Denmark

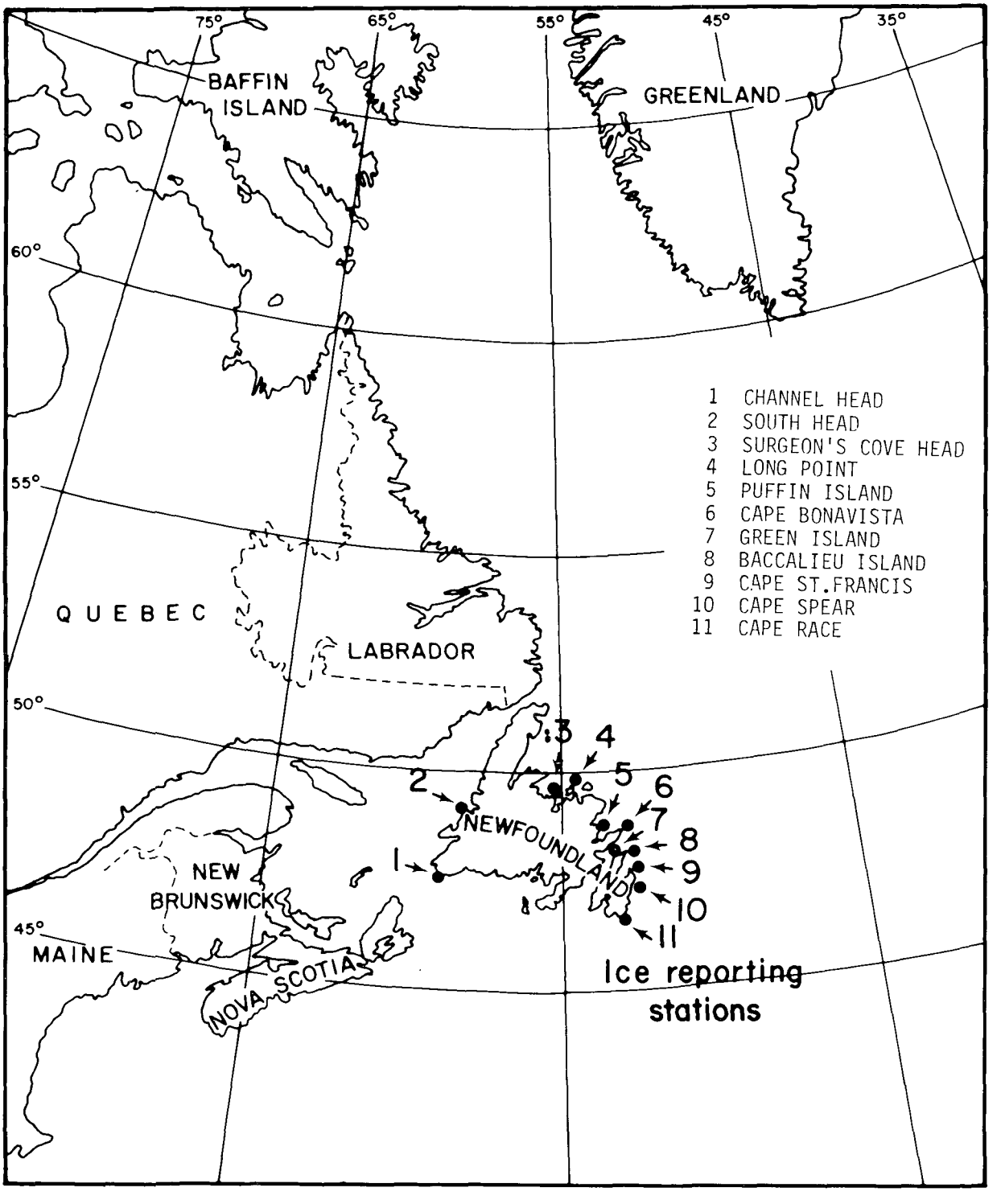

FIGURE 13.5 LOCATION OF ICE-REPORTING LIGHTSTATIONS

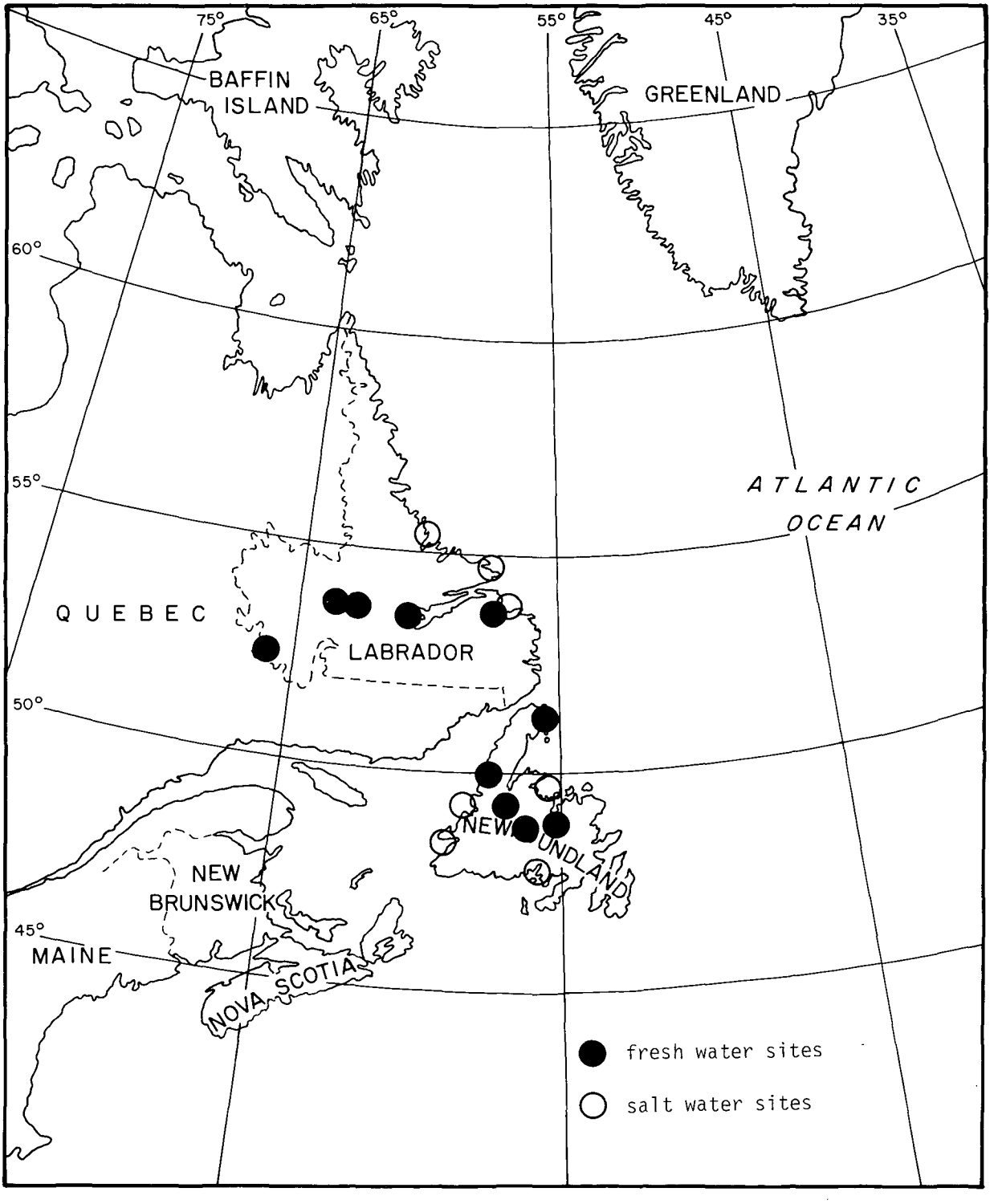

FIGURE 13.6 WATER BODIES LISTED FOR NEWFOUNDLAND AND LABRADOR AND FREEZE-UP AND BREAK-UP DATES OF WATER BODIES IN CANADA

13.4 Icebergs

The following data systems are related to monitoring and/or predicting iceberg movement off the coast of Labrador: Ship Reports; ECAREG and NORDREG Canada Reports; IIP Iceberg Bulletins and Charts; and AES Ice Charts.

13.4.1 Ship reports. Ship reports have been described earlier (Section 13.1.1). The information related to iceberg sightings, with each ship report, is shown in the appendix to this chapter.

No indication of size, shape or drift of the icebergs is included in the ship reports. Geographical positioning of the iceberg cannot be made with accuracy since only the ship location is given. Iceberg location is described in distance from the vessel; however, the bearing is not the given.

The amount of data regarding icebergs off Labrador is dependent on the extent and degree of ship reports in the area. Ship reports off Labrador are scarce during the ice and iceberg season (J. Bursey, Personal Communication, 1978).

13.4.2 ECAREG and NORDREG Canada Reports. These reporting systems have been described earlier (Section 13.3.2). Although some reports of icebergs have been received with this system, it can be expected that these, like ship reports, are scarce off Labrador.

13.4.3 IPP Iceberg Bulletins and Charts. The International Ice Patrol, a branch of the U.S. Coast Guard, conducts ice reconnaissance flights over the Grand Banks, eastern Newfoundland and Labrador during the ice and iceberg season. Flights begin at the time ice is first present in these areas, (usually February) and last through July. Predetermined flight lines are usually followed (Figure 13.7). As part of these flights, which average three to four per week, iceberg information is issued. Pre-season flights are conducted outside the regular areas of the Grand Banks and eastern Newfoundland, and are designed to assess the upstream iceberg population.

Vessels in the area are requested to report their position, sea surface temperature, and ice and iceberg conditions at their position every six h to the Ice Patrol Operations Centre in New York. This information, along with ocean current and wind data, is used to predict iceberg drift and location. Ice limit estimates are created every 12 h.

The ice limit an iceberg location information is promulgated twice daily in the form of radio broadcasts, and once daily in the form of radio facsimile charts or telex.

International Ice Patrol Ice Bulletins are received locally on telex, via New York and Ottawa, at:

Canadian Coast Guard
Traffic Centre
P.O. Box 1300
St. John's, Newfoundland
A1C 5N5 Telephone (709) 737-5151

These bulletins are received in St. John's approximately every two to three days from Ottawa.

Details on the information type provided within each iceberg chart/bulletin can be found in the appendix to this chapter.

The data appear to be inadequate for any oil spill countermeasures program off Labrador due to the limited number of pre-seasonal flights (one in January and one in February). Icebergs sighted visually or by radar are plotted to the nearest minute. The accuracy of sightings has not been investigated for this report, although it would appear to be very good.

13.4.4 AES Ice Charts. The AES Ice charts have been discussed earlier (Section 13.3.1). Sightings of individual icebergs are not presented in the charts; the only comments provided refer to 'bergy water' or 'many bergs'.

In terms of an oil spill response off Labrador, it may prove useful to know the zones of 'bergy water'.

13.5 Conclusions and Recommendations

There is a variety of environmental data types, reporting methods, and dissemination procedures included in the collection of information off Labrador. Some of these data sources are interdependent, while most are not.

In response to an oil spill off Labrador, the timely collection of environmental data and the provision of accurate predictions is essential. In this regard, it is recommended that the collection of all identified data sources relevant to the study area be opertionally integrated and then tested by simulating a response to an oil spill disaster. Upon integration and testing, areas of weakness for the study area can be defined better.

The emphasis placed to date on satellite information systems off Labrador has been poor. The Appendix to this chapter illustrates the extent and degree of ocean-related satellites, both those presently in orbit as well as those planned for launch in the next seven to eight years. Since many of these satellites have on-board remote data collection systems, it is recommended that the use of these systems along with ocean data buoys/platforms be investigated in assisting an oil spill countermeasures effort in

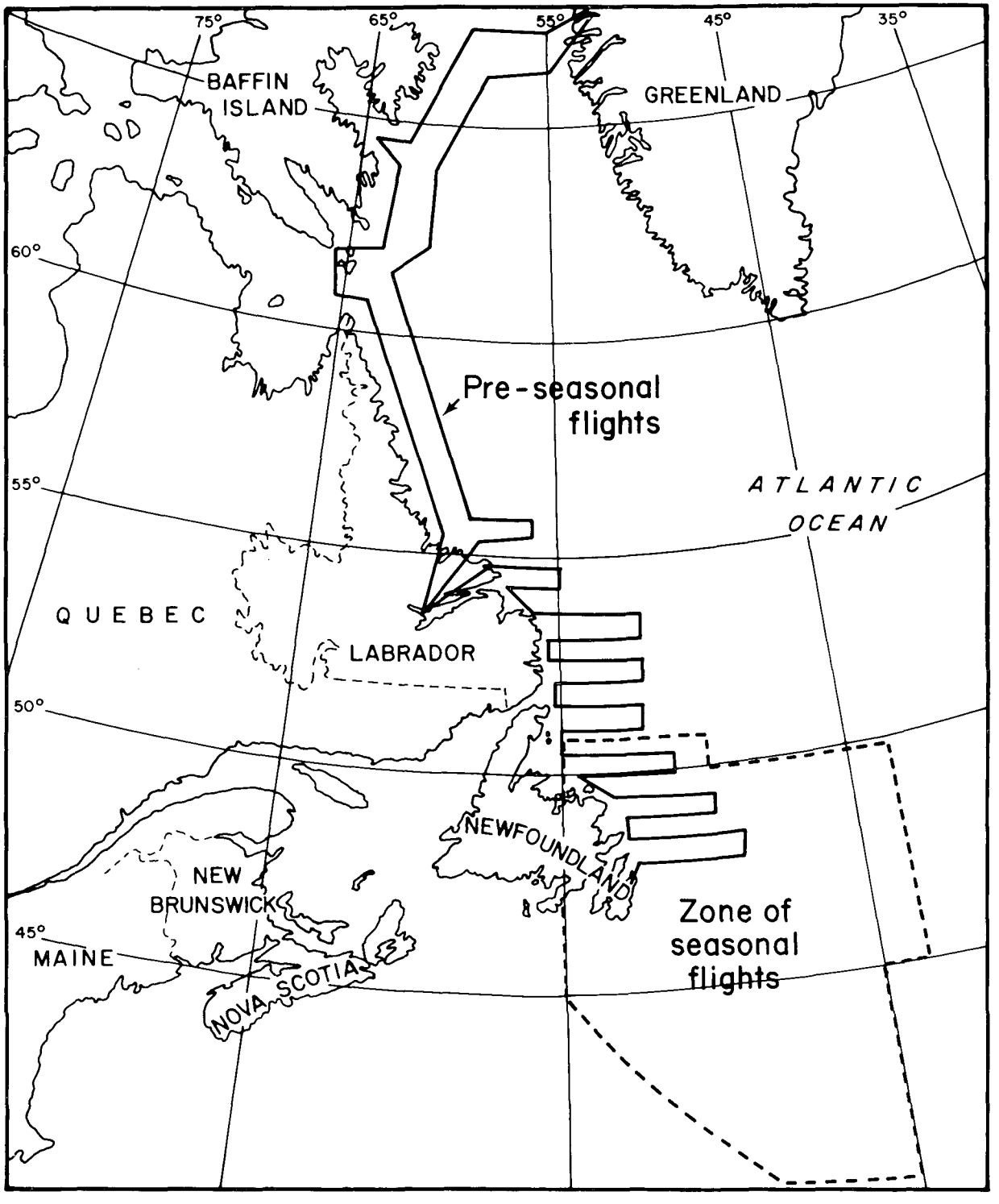

FIGURE 13.7 INTERNATIONAL ICE PATROL PRE-SEASON AND SEASONAL FLIGHTS

Labrador's ice-infested offshore. Also recommended is an assessment of future satellite systems and the immediate development and testing of strategic and tactical action plans capable of incorporating future satellite data as it 'comes on stream'.

The problem of adequate and accurate environmental data to be used in responding to an offshore spill is not the only data problem off Labrador. Of major concern is the need to assure that all communication channels are open and accessible in the event of a spill. A final recommendation is to establish the cooperation and assistance of all public and private environmental data collection companies, agencies, departments, institutes, etc., in order to allow total and immediate access to environmental data.

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CHAPTER 14
OIL SPILL COUNTERMEASURES FOR THE LABRADOR OFFSHORE

by
Bevin R. LeDrew

Centre for Cold Ocean Resources Engineering (C-CORE)
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X5

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14 INTRODUCTION

Heavy seas and drifting pack ice are the two conditions which present the most difficult challange to oil spill cleanup planners. In the Labrador offshore, one of these conditions is always present; frequently they occur in combination to produce a synergestic effect. It is not surprising, therefore, that to date no acceptable and adequate system has been developed to deal with an oil spill in the area.

This chapter presents an overview of the plans and equipment which are available in Canada and which would be deployed to deal with a major oil spill from offshore exploratory drilling. Contingency plans will be described and relevant action sequences identified. Countermeasures which are identified in operator's contingency plans will be discussed and an assessement will be made of their feasibility in terms of the scenario. The same will be done for measures identified by those government agencies charged with cleanup.

This review will obviously not include all possible countermeasures; while reference will be made to work in other countries, especially the U.S., it is the Canadian state of preparedness that will be considered.

Since logistics is a major determinant of the success of any countermeasures effort, the relevant requirements of various options will be identified. The resources that the operator could be expected to have on site will be identified. As well, the ships and aircraft of the federal government will be listed, along with a brief discussion of other sources.

14.1 Contingency Plans

Generally speaking, contingency plans describe and document "pre-determined communications and action sequence which can be initiated quickly to cope with an event of possible but uncertain occurrence" (Consortium on Spill Training, 1975). In this particular context, contingency plans are drawn up with reference to the spill of deleterious substances. Such plans are prepared by operators, operator associations, regulatory agencies and cooperating governments.

For offshore Labrador petroleum exploration activities, contingency plans have been prepared by the following:

Regulatory Agencies

- Transport Canada - Coast Guard National Marine Emergency Plan (1977)
- Environment Canada, Environmental Protection Service

- National Departmental Contingency Plan (1973)
- Atlantic Region Departmental Contingency Plan (undated)

Governments

- Canada - Denmark (1977) Interim - Agreement

Operator Associations

- Eastcoast Petroleum Operators Association (1975)

Operators

- Total Eastcan Exploration Ltd. (1976)
- BP Canada Limited (1974)

The following descriptions will focus on the application of these various plans to an oil spill of major proportions from a blowout of an exploratory well on the Labrador shelf.

14.1.1 Federal Government. Federal government policy for contingency planning and spill response is summarized as follows:

" (a) to encourage and develop a coordinated state of preparedness throughout Canada, by all governments and industries, in concert with an improved level of spill prevention.

(b) to require and emphasize that the polluter bears first responsibility for any emergency created, including *a prompt initial response* and alert, as well as eventual responsibility for the costs of spill response and damage up to $50 million.

(c) to provide for an operational capability for governmental response to a spill by their departments and agencies, but *only as a back-up or last resort action*, and only through a lead or coordinating agency concept." (Beaufort Sea Contingency Planning Task Force, 1977).

Consequently, offshore operators are required to prepare contingency plans acceptable to the regulatory agency. In cases where the pollution source is unknown, or where the polluter does not or cannot respond adequately, the federal government will take action. Generally, the department or agency with the legislative mandate covering pollution control aspects of a particular activity has the responsibility to act as

"lead agency" in the event of a spill. When an emergency occurs, the lead agency is responsible for organizing, commanding, and funding the response.

14.1.1.1 Energy, Mines and Resources. For offshore mineral exploration south of the "Line of Administrative Convenience", the federal Department of Energy, Mines and Resources (EMR) exercises regulatory (including pollution prevention) control under the Canada Oil and Gas Lands Drilling Regulations. (N.B. The ownership, and consequently regulatory responsibility over the seabed off Newfoundland and Labrador is under dispute as the result of a challenge by the province.)

Within EMR, the Resource Management and Conservation Branch (RMCB) is the regulatory agency for mineral exploration on federal lands. The Branch reviews and approves drilling applications submitted by operators. Such applications include site-specific contingency plans. The RMCB is headquartered in Ottawa, but maintains an office at the Bedford Institute of Oceanography, in Darmouth, N.S. From this office, the Conservation Engineer operates to carry out periodic inspections of east coast offshore operations. Consequently, EMR is the lead agency in the event of a spill. By agreement between departments, however, EMR maintains responsibility for overseeing operations on the rig (fighting the blowout), while the Coast Guard is responsible for waterborne and shoreline clean-up (Transport Canada, 1977).

14.1.1.2 Ministry of Transport: Canadian Coast Guard. The National Marine Emergency Plan issued by MOT establishes procedures, decision points and levels, and reporting systems for Coast Guard response to a spill event. It outlines the procedure whereby the Coast Guard takes over an operational response should the public interest not be adequately protected by the "casualty" (polluter).

Within each region of the Coast Guard, there is a Regional Marine Emergency Officer (RMEO). In the Newfoundland Region, the REMO is stationed at St. John's and reports to the Coast Guard Regional Director, Newfoundland Region. In Ottawa, a Headquarters' Emergency Office is established under a Chief, Emergencies (CCGE), who reports to the Deputy Commissioner (XCCG). The Coast Guard emergency organization is responsible for the development, evaluation and acquisition of special emergency equipment, techniques, expertise and training required for countermeasures, (a function it shares with the Department of Fisheries and Environment). In agreement with the federal and provincial departments, the Coast Guard also coordinates all oil spill reports in the Newfoundland Region through its Traffic Centre in St. John's. The Coast Guard emergency organization is heavily oriented towards actual operation. The inventory

maintained by the Coast Guard is the largest source of marine oriented oil spill countermeasures equipment in Canada.

The National Marine Emergency Plan provides for the development of Regional Plans by the RMEO. Principally, regional plans dovetail with the national plan to provide a mechanism for escalating a regional response into a national response. Escalation will occur when the response required is beyond regional resources. While a regional plan is not yet available for the Coast Guard Newfoundland Region, one is in preparation and was (prepared and) completed during 1978 (W. Ryan, Personal Communication).

Briefly, the procedure outlined in the National Marine Emergency Plan, applied specifically to the example of an oil spill from an offshore blowout, can be summarized as follows:

- The Regional Marine Emergency Officer (RMEO) is informed of the spill event (see Operator's Contingency Plans).
- The Regional Director Coast Guard (RDCG) designates a Coast Guard or other government official to monitor the operation. It can be expected that the REMO will be the designated official. (This official presumably goes directly to the spill site to observe clean-up efforts.)
- The RMCB would place an observer on site (conservation engineer) to monitor efforts by the operator to fight the blowout.
- When, in the opinion of the monitoring officer, the spill clean-up response is inadequate, he advises the RMEO and the RDCG.
- The RMEO recommends appropriate response to the RDCG and copies this information to the Chief, Emergencies (CCGE).
- The RDCG informs the operator that the Coast Guard will take over clean-up operations at a specified time. Presumably, this action takes place through consultation with EMR officials (including Chief RMCB, Ottawa and the Dartmouth-based conservation engineer), who agree on the appointment of an On-Scene Commander (OSC) to handle spill cleanup.
- The Chief, Emergencies (CCGE) may be appointed On-Scene Commander by the Coast Guard Commissioner. If this happens, the RMEO assumes control until the CCGE reaches the scene, after which the RMEO acts as his deputy.
- The commissioner arranges to inform the Danish government of the event.
- A command team for a major operation (Figure 14.1) is organized.

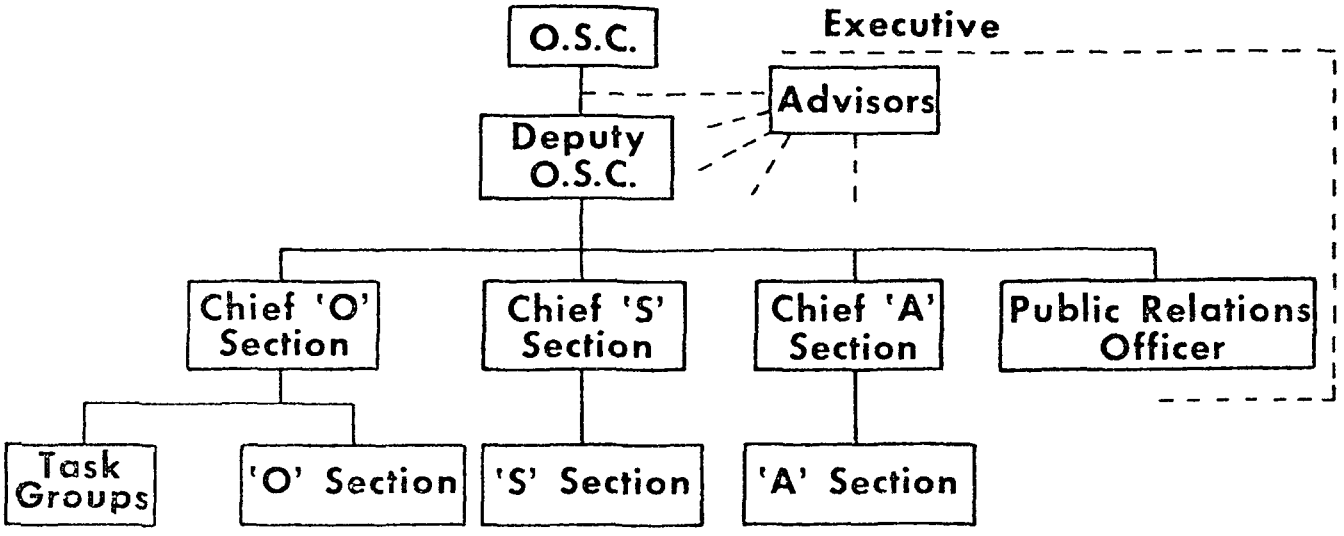

FIGURE 14.1 SCHEMATIC OPERATIONAL COMMAND TEAM FOR A MAJOR OPERATION

Source: Transport Canada 1977

The executive of this team comprises:

On-Scene Commander (Reports to the Coast Guard Regional Director: either CCGE or RMEO)

Deputy On-Scene Commander (Regional Marine Emergency Officer or other)

Chief, Operations ("O") Section

Chief, Support ("S") Section

Chief, Administration ("A") Section

Public Relations Officer (MOT)

Selected Advisors.

- A command centre is established as the official focus of operations and source of public information. (Candidate locations would, no doubt, include Goose Bay and St. John's.)

14.1.1.3 Fisheries and Environment Canada. The Department of Fisheries and Environment (DFE) is the agency of the federal government which has prime responsibility to ensure that appropriate reporting, surveillance and response mechanisms are available to deal with environmental emergencies and to ensure that countermeasures are effective.

Within DFE, the Environmental Protection Service (EPS) plays the lead role in responding to pollution emergencies. The Environmental Emergency Branch (EEB) of EPS develops national and regional departmental contingency plans, maintains a computerized inventory of spill control equipment, (National Emergency Equipment Locator System - NEELS) and carries out research and development on countermeasures equipment and procedures. Contingency plans are developed and reviewed by a National Environmental Emergency Team (NEET), which is chaired by the Director, EEB.

The Environmental Emergency Branch maintains its headquarters in Ottawa. Within each region, a Regional Environmental Emergency Coordinator (REEC) acts as On-Scene Commander where appropriate, and provides support to the On-Scene Commander in cases where the DFE is a resource agency. The REEC is also responsible for deciding whether to grant any request for the use of dispersants for fighting an oil spill. In the EPS Atlantic Region, the REEC is stationed at regional headquarters, Halifax, N.S.

In addition to developing a Departmental Contingency Plan, the Environmental Emergency Branch has prepared a Regional Departmental Contingency Plan according to the intent of the former document. This regional plan identifies specific individuals by role and name. Also organized by the EEB is a Regional Environmental Emergency Team (REET), which is the regional equivalent of NEET and serves to develop, operate and amend regional contingency plans.

In the event of a spill from a blowout of an offshore exploratory rig, the Department of Fisheries and Environment would act in the following capacities:

- as a resource agency to supply men and equipment (Presumably, the REEC would participate on the executive of the Command Team);
- as a decision point for application to use dispersants;
- to supply expert advisors on subjects such as seabird and sea mammal movements and sensitivities, fish and fishery impacts (identification of sensitive areas), shoreline protection and clean-up strategies;
- to supply weather, oceanographic and hydrographic monitoring;
- to provide field and laboratory experimental support; and

- as a monitor on the effectiveness of various countermeasures.

14.1.2 International. Canada has entered into two agreements on contingency planning with other nations, one of which (The Interim Canada - Denmark Marine Pollution Contingency Plan, 1977) is relevant to the Labrador offshore. This plan applies to waters of the Labrador Sea, Davis Strait, Baffin Bay and Nares Strait. It provides for cooperation in the prevention of pollution from petroleum exploration and exploitation; communications to ensure preparedness; exchange of information on plans for drilling, as well as for national and operator contingency plans; and exchange of information on resources available for countermeasures.

In the event of a polluting incident that affects or threatens to affect the areas of responsibility of both parties, notification is to be given and provision made for observers to monitor countermeasures.

14.1.3 Operator Associations. The Eastcoast Petroleum Operators Association (EPOA) is a grouping of 23 companies (as of September 1975) with federal exploration permits in the eastern Canadian offshore (south of the Line of Administrative Convenience). One of its aims is the assembling and exchanging of information of common interest. A contingency plan which outlines the area of responsibility and general organization of spill response teams for the individual operating companies has been prepared and distributed (EPOA, 1975). The document also contains provisions which ensure that, short of jeopardizing the safety of operations, and in the event of a declared emergency, each participant will make boats, rigs and other equipment available as required.

As outlined by the EPOA plan, each operator is expected to have an emergency oil spill response plan which provides for two groups. The first group, the Environmental Control Committee, acts as an oil spill preparedness focus that handles minor spills. It also develops, implements, monitors and revises the company's environmental program. In a major emergency (such as loss of well control), a second group, the Major Emergency Task Force, would be activated. This group, chaired by the company president, would have overall responsibility and authority to take whatever action is deemed necessary in dealing with the emergency.

The EPOA has an Environmental Protection Committee made up of representatives from all the east coast operating companies. This committee acts as a liaison point and maintains an awareness of spill response methodologies, but it does not have an operational role in oil spill countermeasures.

14.1.4 Operators. The major operator in the Labrador area is Eastcan Exploration Ltd.; it acts as operator for the "Labrador Group", which is composed of Amerada Minerals Corporation of Canada Ltd., Aquitaine Company of Canada Ltd., AGIP Canada Ltd., Gulf Oil Canada Ltd., Sun Oil Company Ltd., Total Leonard, Inc., and Eastcan Exploration Ltd. The only other operators that have drilled in the area are BP and Tenneco. Tenneco no longer holds any permit acreage in the area.

The two operators who have been active in recent years have each prepared contingency plans prior to each drilling season. Unlike other plans, which deal with a variety of situations and address organization/reporting structure, the industry plans address spill events resulting from a specific activity in a specific area. Actual equipment is listed and particular countermeasures options are discussed.

These contingency plans are submitted to the Resource Management and Conservation Branch of EMR. The plans are distributed for comments by other federal government departments (DFE - Environmental Protection Service, Fisheries and Marine Service; and MOT - Coast Guard). The submission of an acceptable contingency plan is one prerequisite for issuing a Drilling Program Approval:

> " 77 (1) An applicant for a Drilling Program Approval shall demonstrate to the satisfaction of the Chief that contingency plans have been formulated and arranged to deal with foreseeable emergency situations involving
>
> (a) -
>
> (b) -
>
> (c) -
>
> (d) -
>
> (e) loss of well control
>
> (f) a means of drilling a relief well should a blowout occur
>
> (g) -
>
> (h) oil spills or other polluting incidents
>
> and such plans shall provide for coordination with existing local and national contingency plans." (Draft Canada Oil and Gas Drilling Regulations, October 1976.)

The following is a brief description of the Eastcan 1976 Contingency Plan under which this operator carried out its 1976 drilling program (the last year in which drilling took place):

Introduction

This consists of general background on the purpose of the manual, distribution of copies, and description of the offshore area, including environmental hazards (e.g., ice and icebergs).

The introduction summarizes the general approach of Eastcan (as well as BP), viz.:

> "It is a recognized fact that oil left on open water will eventually break up due to wind and wave action and after a period of time (dependent on air water temperatures, crude type, etc.) the oil will break down chemically due to bacterial action. Our general plan for treating an oil spill, apart from sealing off the source of the leak as quickly as possible, will be to accelerate this break down of the spilled oil by spraying it with a chemical dispersant after obtaining permission from the Federal Government Department of the Environment. The resultant oil-water emulsion will be water wet thereby minimizing the potential of the oil to damage the shore line ecology".

Drilling Units Used

Three rigs are described: the ship-shaped dynamically positioned Pelican and Petrel, and the semi submersible Zapata Ugland. Operating limits are delineated in terms of minimum supplies of material, failure of positioning system component, failure of the BOP, weather conditions and icebergs.

Well control systems are described for each vessel. Components described include:

- Subsea Blowout Preventor (BOP) Stack
- BOP Control System
- Choke and Kill Manifold
- Additional Equipment (e.g. back pressure valves, level recording devices in the mud-circulating tanks).

Equipment testing and maintenance programs are described for well control systems. Crew training on well kick control is briefly described.

Waste Disposal Procedure

The quantity and nature of wastes generated as a result of routine operations are identified and the method of disposal is described.

Fighting Spill Organization - Responsibilities

This section describes the organizational setup for responding to a spill event, both in terms of fighting the source of the spill, as well as fighting the spill itself. Provision is made for augmenting the Eastcan response by mobilizing the "oil spill task force" of the parent company, "Compagnie Francaise des Petroles", (CFP).

Personnel would be brought from Paris to support blowout control and oil spill fighting activities. The Labrador Group member companies would participate in an Operating Committee and a Technical Committee chaired by Eastcan vice presidents. The Technical Committee would be set up in St. John's, which would serve as headquarters for the company response operations. The plan contains no other details on the makeup or reporting structure of these committees. Oil spill or blowout fighting personnel and equipment would be made available to Eastcan by members of the Labrador Group through the Operating and Technical Committees.

The alert procedure for inaugurating the contingency plan is outlined. The first person (other than those on site) to be informed of the spill event is the Vice-President, Operations, in St. John's. He notifies the "Onshore Coordinator (OSC)" (presumably the Coast Guard Regional Marine Emergency Officer) under the Federal Contingency Plan and decides whether to call in outside assistance (i.e., notify the Vice-President - General Manager, who alerts the CFP Pollution Control Task Force).

Equipment and Material Inventory

Eastcan is a member of NEELS. This section briefly describes the system and Eastcan's access to it. Eastcan's pollution fighting equipment was listed in the computer as follows:

"18 drums of Shell LTX dispersant
8 drums of Corexit 7664 dispersant
2 sets spraying equipment"

Location of this material is not specified in this section. (However, in a later part of the plan, reference is made to the presence on workboats of mixing eductors complete with metering controls.)

Logistics support described consists of the aircraft and vessels (on charter) and communications system present to support normal drilling operations.

Cleanup Procedures

Oil spills at sea, oil on beaches and third party or mystery spills are considered.

For oil spills at sea, three possible methods of clean-up are listed: - disperse, contain and recover (boom and skim), and burn. For both minor and major spills, the plan proposes to employ chemical dispersants after approval is received from the Department of the Environment.

In the event of a blowout, "the workboats will be employed in removing the rig from the site and in preventing damage to property and injury to personnel. After consultation with government agencies, workboats, helicopters and planes may then be designated to assist in dispersing, containing or removing the oil slick. Under certain circumstances burning may be attempted if safety requirements and sea conditions permit. The major concern under these emergency conditions will be to prevent the encroachment of oil slicks on coastal areas.

Sea and weather conditions will, in all likelihood, prevent the use of currently available skimming and containment booms".

In considering oil on beaches, the recommended actions are:

(1) Sand Beaches:

- Application of straw as a mulch before oil reaches the beach. It can then be picked up by using any available mechanical device, such as hay harvesting equipment, and disposed of by burning. Peat moss is also mentioned as an absorbent.
- Removal of sand/oil mixture by scraping into windrows, picking up with front end loader and hauling away by dump truck.

(2) Rock or Boulder Beaches:

- "Rocky beaches can be effectively cleaned with detergents but the possible ecological effect must be considered prior to such application."
- Steaming and returning to the water for removal by skimming off or soaking up by absorbents.
- Burning by use of military type flame throwers.
- Natural action: "If the beach is not being used for recreation, it may be possible to permit wave action to remove the oil".

For third party spills, Eastcan would provide equipment on request. For mystery spills, reports would be submitted to funnel from the drilling superintendent to Vice-President, Operations, and on to MOT in Ottawa.

Call List - A call list is included for the following personnel -

- Eastcan St. John's Base
- Eastcan Calgary Office
- Labrador Group (Representatives), CFP Paris
- Federal Government: Coast Guard, St. John's; EMR, Ottawa and Dartmouth; Environment Canada; and EPS, Halifax and Ottawa
- Provincial Government (Environment, Fisheries, and Mines and Energy)
- Supply boat contractors and helicopter contractors.

14.1.5 Discussion. From a review of all available contingency plans relating to an offshore Labrador oil blowout, several comments can be made concerning: (1) the operator's ability to provide initial response; (2) the government's capability to provide backup and take last-resort action; and (3) the overall Canadian state of preparedness.

14.1.5.1 The Operator Response. Of necessity, this discussion is somewhat dated as it refers to contingency plans dated 1976 (Eastcan) and 1974 (BP). The following critique principally refers to the Eastcan plan.

The major criticism of the operator's plan is that only one offshore spill response techniques is advocated and prepared for: the use of dispersants. The assumption that "sea and weather conditions will, in all likelihood, prevent the use of currently available skimming and containment booms" is presented as an adequate rationale for ignoring this cleanup option. Consequently, no provision is made for those conditions which would allow such an operation, and no analysis is provided of the proportion of time required to successfully contain and recover oil in the area. This approach allows the operator to avoid considering all the problems of removal and disposal of oil; however, it also ignores Federal government policy which would in all likelihood result in a refusal of permission to employ dispersants except in the interest of human safety.

In any case, the equipment reported available by operators to provide initial response capability is grossly inadequate, even as a safety measure. The Ekofisk Bravo blowout released oil at a rate estimated at 3000 tons per day (1800 bbl/day). Approximately 1100 tons of BP 1100X dispersant were used in the immediate vicinity of the drill platform as a fire prevention measure during the period shortly after the blowout occured (Vanderkooy, 1977). It should be noted that, despite the large amounts of dispersants used, the primary response strategy was physical containment and recovery.

The dispersants listed (and presumed to be at or near site) by Eastcan are 18 drums Shell LTX; and 8 drums Corexit 7664; BP lists 10 drums BP1100X. Neither dispersant reported by Eastcan is on the Canadian standard list of acceptable dispersants. If properly applied, Shell LTX, and BP1100X could be expected to disperse oil in a ratio of 1:3 (ratio reported for Venezuelan Lago Medio Crude Oil in sea water at 5° by Doe and Wells, 1978). Corexit 7664 was found to be ineffective under the same conditions. Consequently, Eastcan had an on-site capacity to effectively disperse approximately 70 barrels (0.3 m^3) of oil, equivalent to the amount released in seven minutes by a 15000 bl/day blowout; BP capability was 39 barrels (0.18 m^3) or four minutes' release.

Further evidence of lack of preparedness is indicated. For example, there is no documentation of crew training in oil spill clean-up techniques. This inadequacy does, however, appear to have been at least partly corrected. For possible operations in 1978, the Coast Guard has agreed with Eastcan to train their offshore supply vessel crews in dispersant applications.

There is an inconsistent set of committees and procedures documented. Two committees are mentioned in the Eastcan document - the Operating Committee and the Technical Committee. This contrasts with the Environmental Control Committee/Major Emergency Task Force arrangement described by EPOA (1977). Membership, duties and reporting structure of the Eastcan Committees are not outlined. Reporting lines to government officials are unclear. There appears to be a response escalation procedure different from that contained in the Federal, National Marine Emergency Plan (perhaps because the latter postdates the Eastcan plan). One route is international, but still within the industry (i.e., CFP Pollution Control Task Force). The other official route involves federal takeover of the oil spill clean-up portion of the response plan. No information on the CFP Task Force is provided to enable any evaluation.

These criticisms indicate the need for an improved process of government review and approval for operator contingency plans. It is also clear that industry operators are not conducting any research and development activities aimed directly at improving countermeasures capability for the Labrador Sea.

14.1.5.2 Government Capability. While the National Marine Emergency Plan is generally fairly precise about organization and procedures, several points of uncertainty occur.

There appears to be some confusion as to who makes the critical decision to take over industry oil spill response activity. According to the Plan, the Regional

Director, Coast Guards decides, on the basis of advice by the monitoring officer and his other staff, whether to take over the spill response. However, according to one Coast Guard official contacted (R. Gray, Emergency Planning Officer, Ottawa), it is EMR who makes the decision on take-over of the spill response.

Several improvements in the state of preparedness might be realized by the development of a Coast Guard Regional Contingency Plan. An updated call list of resource persons would be one useful item. As well, since the EPS Emergency Officer will be required to make rapid decisions on use of dispersants, the regional plan could specifically predesignate this role. The REMO, Newfoundland Region, has pointed out however that while it is possible that such a plan will be produced this year, formulation of a practical contingency plan is dependent on the "state of the art" and other requirements being met (W. Ryan, Personal Communication, 1978).

As noted above, a more thorough review of operator contingency plans should be provided for by government. This should include a requirement for, and cooperation in, training operator crews in appropriate spill response procedures.

14.1.5.3 The Canadian State of Preparedness. To maintain an ability to respond to a major oil spill will entail a great effort that requires a high degree of cooperation between government and industry. To date, while there have been some meetings between Coast Guard and operators such as Eastcan and Imperial, there does not appear to have been close contact between the operators and those in government who are charged with planning, monitoring and carrying out oil spill countermeasures.

Given severe environmental conditions, the logistics problems inherent in remote regions, and the heavy requirements of manpower and equipment needed to respond to a spill, it is clear that the event under consideration is beyond the capability of either operator or any industry response organization. Planning for a joint operator/industry/government response will be necessary to deploy all the resources required to deal effectively with the incident.

A draft of such a plan has been drawn together for the Beaufort Sea (Beaufort Sea Contingency Planning Task Force, 1977) and could well serve as a model for other regions of active or planned offshore exploration. Clearly however, early attention should be focused on the Labrador offshore. In addition, such an exercise should be undertaken as a prerequisite to further offshore drilling operations.

14.2 Dispersants

If an oil slick is broken into small particles, the individual droplets become suspended in the water column, in part as an oil-in-water emulsion. This break up of an oil slick is known as dispersing. Dispersing agents, or dispersants, are surface active agents which work by reducing the interfacial tension between oil and water, and thereby promoting droplet formation. Once the oil has been dispersed, the natural mixing energy of the water serves to distribute the particles and prevent the reforming of a slick.

There is considerable controversy over the use of dispersants. This centres around the fact that dispersants do not remove the oil from the environment. Opponents of dispersant use contend that dispersal of oil is a cosmetic treatment which serves to inject oil more firmly into the marine environment rather than removing it (e.g., Boesch, Hershner and Milgram, 1974). Proponents (e.g., Canevari, 1970; Fitzgerald, 1977) argue that, in addition to reducing fire hazard, dispersants eliminate or reduce immediate environmental damage inflicted on seabirds and coastal zones. Further, it is contended that the rate of biodegradation of the oil is enhanced by application of dispersants. The increased interfacial area effected by dispersants is presumed to increase the rate of biodegradation.

Despite the fact that dispersants can be quite expensive (as much as $500/drum), their use obviates the need for collection, transferral and storage of recovered fluids; hence, it is logistically simpler and financially more attractive for operators to stock dispersants than to develop a capability to carry out other options (e.g., containment and recovery).

The effectiveness and toxicity of commercially available dispersants varies greatly. The Department of Fisheries and the Environment has published guidelines on the acceptability of oil spill dispersants and has carried out a program to evaluate toxicity and effectiveness according to criteria outlined in the guidelines. Those products which pass both tests are placed on the standard list of dispersants acceptable for use in Canadian waters. Dispersants can only be used on application to the Department of Fisheries and the Environment, and only those on the acceptable list will be considered for use.

Standard effectiveness tests according to the guidelines have been conducted at 5 and 10°C in fresh water, and recent test results have also been reported for seawater at 1° C (Doe and Wells, 1978). These results indicate the need for test conditions to parallel field conditions since variables such as salinity and temperature can strongly

influence dispersant effectiveness. In general, dispersant effectiveness is reduced at lower temperatures; and many dispersants which are relatively effective at 5 and 10°C are ineffective at 1°C.

To date, dispersants on the Canadian Acceptable List are BP 1100X, Corexit 8666, Drew Chemical 0SE71 (also manufactured as oil spill dispersant LT), Drew Chemical OSE72, Oil Sperse 43, and Sugee No. 2.

Concentrates, or self-mix dispersants, represent the latest generation of dispersants. They require quite low mixing energy because they contain self emulsifying surface active agents (Canevari, 1977). These products are designed so that they may be diluted (e.g., to 10 percent) with water prior to application. While none of the concentrates are yet on the list, a 10 percent dilution of Corexit 9527 has passed all the Canadian acceptability criteria. Canadian guidelines are currently being revised to accommodate testing of these products in the form recommended by the manufacturer. The revisions will also provide for testing at 1°C in seawater (P. Wells and W. Penrose, Personal Communication, 1978). It would appear likely, therefore, that Corexit 9527 will soon be placed on the acceptable list.

Dispersant effectiveness has also been evaluated by Canadian officials in fields tests (Gill, 1977). Warren Spring laboratory test equipment and a Light Tia Juana crude were used in a series of tests carried out at 17°C (62°F) and 4.5°C (40°F). Results confirm generally that oil dispersant performance deteriorates under colder conditions. It was also concluded that concentrates represent a considerable improvement over conventional dispersants.

North American regulatory agencies are continuing to monitor developments in dispersant chemistry. It appears probable that as products with increased effectiveness and decreased toxicity are developed, the policy on dispersant use, especially in the offshore, may be changed so that this technique can be included legitimately as part of the Canadian countermeasures arsenal.

Under present policy, dispersants would be approved for use only under the following conditions:

- in cases of fire hazard
- when containment and recovery is not feasible and in cases of reasonable environmental trade-offs, viz. if either seabird colonies or sensitive shorelines are threatened.

Within the scenario given, dispersants could be considered for use at the following times:

- as a fire precaution during the first few days of the blowout, when the operator would be attempting to clear the rig from the area;
- until ice cover moves in (if seabird colonies were threatened);
- during the period of ice cover (if oil present in leads threatened seabirds or sea mammals);
- during the following summer (ice-free period) if either seabirds or sensitive shoreline were threatened.

Table 14.1 lists the various dispersants and volumes contained in the NEELS Inventory (December 8, 1977 Dump). As well, several products are listed for which tests results are available and which might prove effective under Labrador Sea conditions. It should be noted that Coast Guard vessel-mounted gear were modified during 1978 to handle concentrates which they had on order.

The estimate of effectiveness given in Table 14.1 is based principally on results reported by Gill (1977), Doe and Wells (1978), and Hildebrand, Allen and Ross (1977). These ratios represent only an estimate for the conditions described. For many products, no relevant test data were available.

Summarizing from Table 14.1, it would appear reasonable to assume that five products might be used in the scenario. These are Corexit 9527, BP 1100X, Oil Sperse 43, Drew Chemical OSE71, and Drew Chemical OSE72. For these five products, the stocks available in Canada (according to NEELS) are adequate to disperse between 60 and 70 m^3 (13,000 to 15,000 gallons) of a light crude. Manufacturing locations for these products are from 1700 km (Drew Chemical) up to 6100 km (Oil Sperse) by air from Goose Bay, Labrador.

14.2.1 Dispersant Application Equipment and Platforms. The usual method of applying dispersants is by means of spray booms fitted to vessels. Mixing energy, where needed over and above natural wave motion, is applied by surface agitation.

The best known vessel mounted spray system is one developed by the Warren Spring Laboratory in Great Britain. This system is described by Wardley-Smith (1976). The kit can be mounted easily on most ocean-going tugs without welding or permanent alterations. It can be assembled and deployed while the vessel is at sea. A self-priming pump feeds dispersant to the spray nozzles at a constant rate of 90 l (20 Imp. gal)/min.

TABLE 14.1 CANADIAN STOCKS OF DISPERSANT: NEELS INVENTORY, DECEMBER 1977

Product Name	[1]Quantities in Stock (Imp. gal.) Government	Industry	Estimated Oil - Dispersant Effectiveness Ratio[2]	Canadian Acceptable List	Manufacturer (air distance from Goose Bay)
BP 1100	-	7460			BP Trading Ltd., London, U.K.
BP 1100X	-	900	3:1		(5700 km)
Corezit					
(NO designation)	405	1325			
7664	1045	4507	1E		Exxon, Houston Texas (5100 km)
8666	3495	3190	1E		or
9517*	-	-	1:1		Esso Chemical Co. New Malden,
9527*	-	150	(10-25):1		U.K. (5700 km)
19-L-50*	Not commercially available				
Drew Chemical OSE 71 (Oil Spill Dispersant LT.)	-	-	3:1		Drew Chemical Ltd., Ajax, Ontario (1700 km)
Drew Chemical OSE 72	-	-	3:1		
Duosol	45	445			Dubois Chemicals, Weston, Ont. (1770 km)
Finasol SC	-	140			Petrofina, London, U.K.
Finascol OSR 5*	-	-			(5700 km)
Gamasol	-	200			
Gamlen	5	490			Gamlen Chemical co. Uxbridge, U.K., (5700 km)
Gulf Agent 1009	-	445			
NRS Super Action Concentrate	-	5			
Oil Sperse 43	1845	1085	3:1		Diachem Industries, Burnaby, B.C. (6100 km)

TABLE 14.1 CANADIAN STOCKS OF DISPERSANT: NEELS INVENTORY, DECEMBER 1977 (Continued)

Product Name	Quantities in Stock (Imp. gal.)[1] Government	Industry	Estimated Oil - Dispersant Effectiveness Ratio[2]	Canadian Acceptable List	Manufacturer (air distance from Goose Bay)
Polycomplex A-11	-	585			
Shell LTX	-	-	3:1 (at 5^0C)		Shell International Chemical Co., London, U.K. (5700 km)
Sugee No. 2	-	-	1 E	X	Handy Chemical Co., La Prairie, Quebec, (1400 km)
Synperonic OSE 20* (BP 1100-WD)	-	175	(6-27):1 (at 5^oC)		Imperial Chemical Industries, Wilton, U.K., (6100 km)

* Concentrates or "Self-Mix" Dispersants

1 Quantities reported in various units. "Drums" converted to Imperial gallons by using a factor of x45.

2 Assuming a light crude at 1^oC in seawater, unless otherwise noted. 1E means the dispersant was tested and found ineffective under conditions specified. Ratio refers to the proportion of oil dispersed by a given volume of dispersant, e.g., 3:1 means 3 volumes of oil are dispersed by one volume of dispersant.

Dispersant application rate is varied by altering speed of the vessel (between five and ten knots). For use with concentrates, the system can be modified to premix seawater with the detergent. For those dispersants that might prove effective, stocks available in Canada would provide 11 to 13 h of continuous operation for one spray-mounted vessel.

The NEELS Inventory lists 15 sets of spray equipment available in Canada. As well, it can be assumed that the operator will have not one set on site. This apparatus could be deployed on the offshore work boats, with the dispersant carried in bulk, possibly in portable rubber "pillow tanks". Two spray-equipped vessels using concentrate dispersants could be expected to have the (theoretical) capacity to disperse approximately 70,000 Imperial gal of oil in a ten-hour workday. As pointed out by Wardley-Smith (1976), it is not sufficient simply to have supplies of dispersant and equipment available at the right place at the right time; trained personnel must also be available. Clearly, the operator should be required to demonstrate that his crews are trained in use of this equipment.

According to Canevari (1977), self-mix dispersants need only be applied to the surface oil and not mixed. Consequently, aircraft application may be considered. Hildebrand, Allen and Ross (1977) considered and evaluated in detail several candidate airborne platforms for the Beaufort Sea. Of the three categories considered, it was concluded that fixed and rotary-wing aircraft showed the best potential. From the viewpoint of application efficiency (droplet penetration), helicopters are the preferred platform. Use of Air Cushion Vehicles (ACV's) were judged to present several practical (but solvable) problems that made their use, at present, unfeasible.

To obtain uniform ground coverage of aerially applied dispersant, a pressure release system is necessary. One such product is the Modular Airborne Fire Fighting System (MAFFS) (FMC Corporation, USA). The system reportedly fits any large fixed or rotary-wing aircraft without modification. Mounted in a Hercules, the system can deploy 10,000 l of liquid. Spray systems used for insecticide and herbicide applications have also been proposed and evaluated for dispersant use. Universal helicopters are reported to have such a system at Halifax, Nova Scotia.

Since the actual time spent applying the dispersant is minimal, the practicability of dispersant application by aircraft is limited by the distance between stockpiles and the slick. Helicopters have a large payload reduction with increased range, but can be expected to operate from a variety of stockpile sites such as vessels, the oil rig or shore base. Fixed-wing aircraft, on the other hand, would require a landing strip, since they could not land on the Labrador pack ice.

Airborne dispersant application likely would be practical only for thick (< 25 mm) slicks in leads or polynias, and only in cases where seabirds or sea mammals were threatened. During the open water period, vessel-mounted gear would be more efficient and less expensive. As well, any oil that melts out at the edges of the pack could be handled by vessels. Except for a polynia area in Groswater Bay, leads in the Labrador pack are very transient phenomena, opening and closing daily. During the winter months, leads that persist longer than 24 h quickly freeze.

Unlike the Beaufort Sea situation, where stocks of dispersant could be placed strategically on the ice at the edge of large leads, such a condition would not apply in the Labrador Offshore since the ice field does not present a reliable surface feature. For the Labrador Offshore, airborne dispersant application operations would therefore probably be very limited.

14.3 Containment and Recovery

The preferred method of handling an oil spill is to physically remove the pollutant from the sensitive environment. To this end, a tremendous research and development effort has been directed toward containment and recovery. Nevertheless, no system has been developed yet which operates efficiently in the offshore or in ice-frequented waters.

14.3.1 Booms. As a first step in containment and recovery, the oil must be confined to minimize the area affected and to concentrate the product to a thickness which will enable recovery devices to operate. To accomplish this in offshore waters requires development of floating fences or booms. The various categories of booms are described by Logan, Thornton and Ross (1977). Trillo (1977) lists and describes oilspill containment and recovery systems worldwide. Other devices have been developed (e.g., bubble and chemical barriers); however, these are generally not applicable offshore (NORDCO, 1977).

Booms come in a vast array of designs; however, all are limited in performance by wind, wave and current conditions. Booms can fail either by collapsing or by permitting oil to pass by. If water currents are too strong, and are opposite to wind direction, the skirt, or submerged part of the boom, can tip up so that the system lies flat on the water.

Failure by loss of oil can occur by passage either over or under the boom. Passage over the boom is caused by splashover of waves. Locally generated waves of a period of one to three seconds are often steep enough to break on a boom and splashover

of the surface transported oil results. Walker (1972), in tank tests found that in regular waves, failure by splashover can occur if wave steepness (ratio of wave height to wave length) is equal to or greater than 0.08 and the wave height is greater than or equal to the freeboard of the boom. In irregular waves, the steepness value drops to 0.05. Generally, long period swells do not effect boom failure, provided that the boom is sufficiently flexible.

Oil passes beneath a barrier under the influence of current. Surface currents in front of a boom dive to avoid the obstruction and, in so doing, shear off oil from the interface near the leading edge of the slick. Generally, this type of failure occurs when the relative current velocity at the boom (critical velocity) appraoches 20 to 30 cm/s (0.5 knots). With thicker accumulations, the oil tends to pass more readily under the boom, so removal devices need to operate continuously as part of any successful containment effort.

Although, as pointed out, long period waves do not generally affect the performance of a boom, practical experience supports the general comment that none of the existing boom designs have yet proven effective in containing spills in Beaufort Sea States 3 or greater (McLeod and McLeod, 1972). Wardley-Smith (1976) states that "It is doubtful whether the natural conditions limiting the successful use of booms, that is in currents and waves, would permit of (sic) any increase in performance above that already established by years of research".

Thornton et al (1977) have pointed out that "even under ideal operating conditions conventional containment and recovery equipment cannot be expected to provide a removal efficiency much greater than 50 percent".

The U.S. Coast Guard has carried out the most extensive evaluation of booms for use in ice-covered waters (Getman et al, 1975). Because of the force exerted by ice floes, even the large, cumbersome, heavy duty booms are judged to have only limited application in light and moderately broken ice fields (Shultz and Deslauriers, 1977). No presently available oil containment boom is judged to be suitable for general application in the presence of large, broken ice pieces. Three commercial booms were identified as having some promise for limited applications in light and broken ice fields: American Marine Supermax, Kepner Sea Curtain, and Gamlen Hi-Sea Guard. These systems are all quite large, expensive and relatively immobile. None are listed in the NEELS Inventory.

In terms of evaluations done to date, it should be pointed out that these deal separately with either open ocean conditions or ice cover. The Labrador offshore presents

both these features in combinations, making it even less likely that the few candidate systems identified could operate successfully in the region. Table 14.2 lists some relevant specifications for booms which show some promise for successful deployment offshore. Comments on their capability for use in ice-covered waters is included.

The Canadian Coast Guard have settled on the Vikoma Sea Pack as the offshore containment system best combining the features of portability and performance. Six units, each containing 488 m (1600 ft) of boom, are listed in the NEELS inventory. Two of these are in Newfoundland.

The Sea Pack system is described Trillo (1977). It is designed as a self-contained unit that can be airlifted (e.g., by Hercules) to the spill site. The boom is packed in an 8 m long fibreglass hull. This hull contains a diesel-driven fan and a ducted propeller water pump. These simultaneously fill the air and water chambers of the boom (Figure 14.2). The boom cuff inflates from a compressed air cylinder to maintain buoyancy during initial deployment. The inflation equipment is designed to run continuously and untended for eight days (British Petroleum, 1973).

The figure-eight shape of the boom eliminates the problem of boom collapse. The manufacturers claim a limiting water velocity of approximately 0.5 m/s (1.5 ft/s). Baldwin and Cowell (1974) report that the system has been successfully tested in wave heights of up 2.5 m. There is one report of a trial where 182 l of oil were successfully trapped by the system in force 6 winds with short 1.5 to 2 m seas (British Petroleum, 1973). A successful test of the system (without spilling oil) was carried out in Conception Bay, Newfoundland during August 1977 (W. Ryan, Personnal Communication). During this test, the boom rode out a 70-knot gale; however, it was clear that because of splashover, oil would not be contained under such conditions.

The system appears to be state-of-the-art in terms of oil containment capability and has the added feature of compactness and portability as compared to other systems.

The original concept of deployment for the Vikoma Sea Pack involves use of drogues. A vessel would tow the inflated boom downstream of the slick and deploy it perpendicular to the direction of slick drift. The drogues would be attached to either end of the boom and, when allowed to drift, the boom would assume a U configuration. The drogues would keep the boom in the U configuration and slow its drift to two percent of wind velocity. Since oil drifts at approximately three percent of wind velocity, the slick would be expected to accumulate in the boom. The boom theoretically can contain

TABLE 14.2 CHARACTERISTICS OF SOME OFFSHORE BOOMS

	Vikoma Sea Pack	Bennett 72 in Offshore	U.S. Coast Guard High Seas Oil Containment System (HSOCS)	Gamlen High Sea Guard	Kepner Sea Curtain
Total Height (m)	1.20	1.83	1.22	1.05	1.8
freeboard (m)	0.77	0.61	0.53	0.40	0.7
draught (m)	0.43	1.22	0.69	0.65	1.1
unit length (m)	488	152	186	50	30
weight	5080 kg		24 kg/m	14 kg/m	26.8 kg/m
Storage Volume (dimensions) (m)	(7.6x2.75x2)	(36.5x4x2)	(1.52x2.74x5.48)	3.7 m^3/100 m	4.8 m^3
Maximum wave height (m) for retaining oil	1.5-2.0	NIA	1.5	2.5	"Moderate Sea"
ice capability	nil	grease ice and brash		light & broken ice fields	light & broken ice fields
systems available	50 in service (1976)	<5690 ft in Canada	2 miles (17 units) on location in U.S. by mid-1975	NIA	NIA

NIA - No Information Available

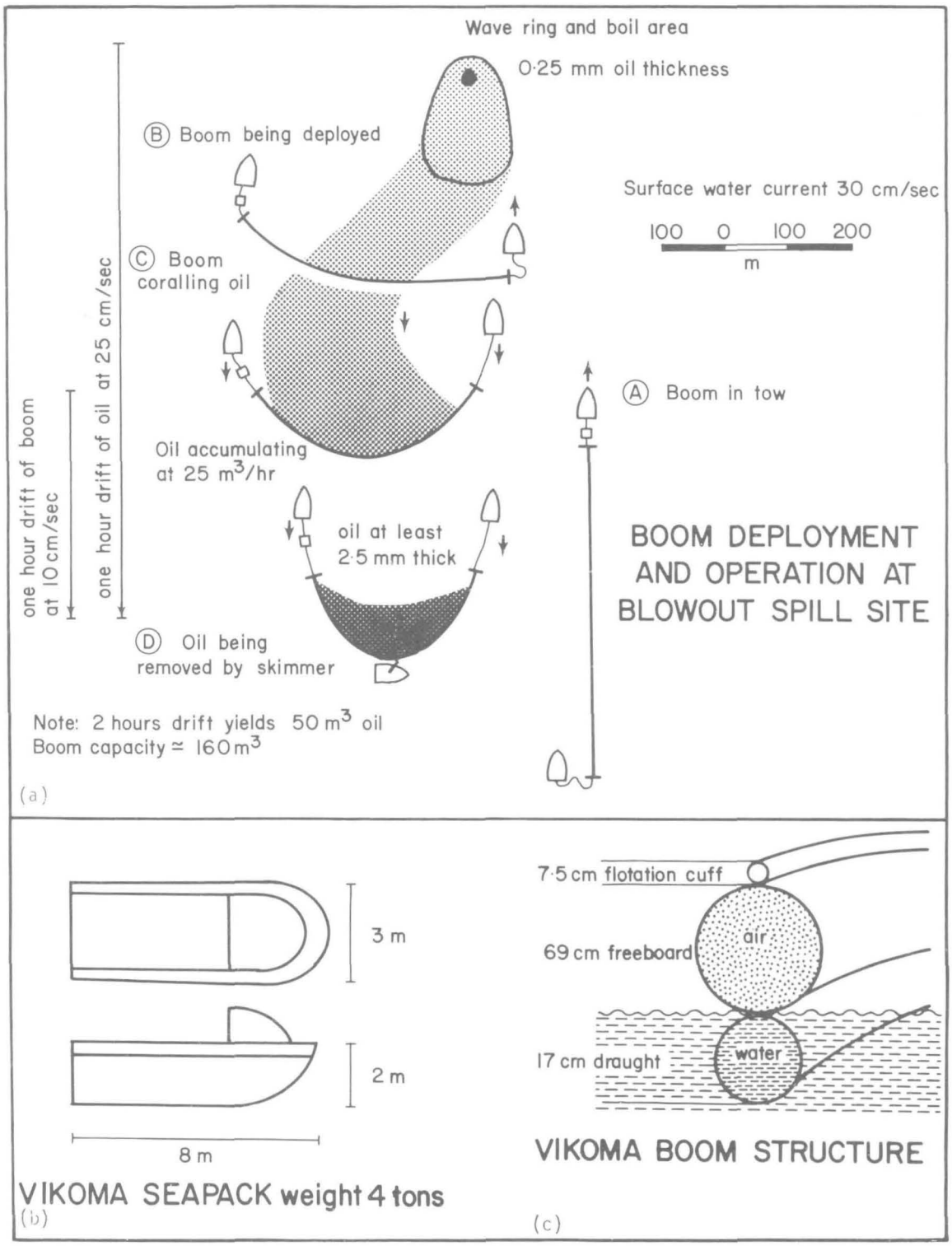

FIGURE 14.2 (a) VIKOMA SEA PACK;
(b) VIKOMA BOOM STRUCTURE;
(c) BOOM DEVELOPMENT AND OPERATION AT BLOWOUT SPILL SITE

approximately 1000 tons (160 m^3) at a thickness of 25 mm (1 in). As the boom continues to drift, oil can be removed by a skimming device located at the bottom of the U configuration.

Practical experience has shown that when wind and currents are at right angles, the desired U shape is lost. This could be partly corrected by replacing the drogues with a work boat at either end of the boom.

In the case of an oil blowout, two or more systems would be used in concert, with each going through a routine of deployment at the wave ring; drift downstream accumulating oil; oil recovery; and redeployment. Figure 14.2(a) illustrates the procedure envisaged and includes several values for use in calculating theoretical efficiency. For a two-boom arrangement, five vessels (including one mounted with oil recovery device) would be required. One practical problem would be getting the boom close to the wave ring area. This would be necessary for effective containment since it can be expected that the slick will spread quickly under the influence of wind, currents and wave action. However, safety precautions related to the fire hazard from fresh crude might well mean that booms cannot be deployed close to the boil area.

The system has no capability to operate in ice-frequented waters. Shultz and Deslauriers (1977) point out that booms employing air flotation are not promising for such use due to possible puncture of the flotation unit.

The NEELS inventory lists 5690 ft of other offshore booms (defined as any boom >36 in). Much of this is probably the Bennett 72 in Offshore Boom (Table 14.2), which may give some capability for operation in skim ice and light brash; however, it would likely collapse under pressure of pack ice.

Neither the Vikoma nor the Bennett is made of fire proof material which would permit their use as part of a contain and burn strategy.

Current Canadian containment capability is limited, therefore, to the open water season and even then to periods of relative calm (Beaufort Sea State 3 or less; locally generated waves less than 760 mm high with a steepness less than 0.05).

14.3.2 Skimmers. To separate and recover oil from the sea surface, a vast array of devices, generally known as "skimmers" have been developed. Based mainly on capacity and ruggedness of the operating platform, the various devices can be generally classed as either offshore (mobile) or inshore (often stationary). Jane's Ocean Technology (Trillo, 1977) lists 47 oil recovery systems employing one of several principles or combinations of principles to separate oil (or oil/water emulsions) from water.

The U.S. Coast Guard has carried out a series of field trials (without oil) and laboratory tests (with oil and broken ice) on oil recovery devices to evaluate their suitability in ice-frequented waters (Shultz and Deslauriers, 1977). Of the over 50 types tested, only four were judged to offer promise of even limited application. These were the Lockheed Clean Sweep, the Oil MOP, the JBF-DIP and the Bennett Oil Skimmer. Field trials indicated that the latter two devices would have to be modified to process ice.

Solsberg et al (1976) describe the generic types of skimmers on the market and report on field evaluations of several devices; however, no testing was carried out in rough conditions on open water, or in the presence of sea ice. An appraisal summary of several skimmers is presented in Table 14.3.

In general, skimmers operate more effectively with greater thicknesses of oil; they tend to emulsify fresh oil to some extent during the collection process; and their weakest link is usually the offloading pumping mechanism. These mechanisms can be particularly ineffective in dealing with high viscosity (i.e., weathered) oil at low temperatures. Of the systems listed in Table 14.3, the three showing some potential for application in the scenario are the Oil MOP Mark 11-9D, the Bennett Mark IV and the Lockheed Clean Sweep.

The Oil Mop is an adsorbent surface device utilizing a continuous, buoyant 23 cm diameter oleophilic rope to collect and remove oil from the water surface. The unit is notable in that it is not unduly affected by wave action, and in fact, its performance would be expected to improve under certain wave conditions. This unit is less efficient in recovering more viscous materials. Tests have been conducted with a preheater unit added to the system (Tindmarsh and Solsberg, 1977); however, it was concluded that this modification did not significantly affect recovery ability for less viscous oils. Test temperatures were 8 to 9°C. The system might also have potential in recovering oil lying in pools on pack ice floes.

The Bennett Mark IV Skimmer is a relatively versatile, self-propelled unit. It employs a sorbtion belt with a squeeze system for removing oil. Oil and water are exposed to the belt by passing through a trash grill to an inter-hull area between the pontoons. The unit can continue to skim oil up to Beaufort Sea State 3. The vessel itself is seaworthy up to Beaufort Sea State 5. Its operation in freezing conditions of grease ice or pack ice could be limited since trash grills at the intake area would probably become blocked with pieces of ice or frozen over with grease or frazil ice. In the absence of field test information, it is best to assume the system has no application during winter offshore

conditions. This device also presents transport problems as the only one in Canada is on the west coast and a C5A transport plane would be required to ship the unit by Air.

The Lockheed Clean Sweep consists of a series of oleophilic discs mounted on an open-topped, horizontal shaft containing a screw conveyor. The R2002 model (in stock with Canadian Coast Guard, St. John's) is a small, basically inshore device. However, a larger version, the High Seas Oil Recovery System (HSORS), has been developed by the U.S. Coast Guard. Both systems employ the same skimming system. The HSORS is designed to operate in sea states of average wave heights up to 1.5 m; random waves up to 3 m; and in winds up to 26 km/h (20 knots). The preferred operational configuration for the system is within a pool of oil contained by a boom. It would have to maintain a forward speed of about 0.46 km/h (0.25 knots) to operate most efficiently. Both models have a small onboard storage capacity so that continuous pumping to a storage area is required during operations involving recovery of large volumes. Solsberg et al (1976) concluded that the Clean Sweep could find application in recovering oil in ice-frequented waters due to its ability to process small chunks.

Several offshore recovery systems are described by Trillo (1977) and while some show potential for offshore operation (e.g., JBF Dip 4004 - operates up to sea state of 1.5 m waves), none are described or evaluated in terms of cold weather (ice covered) operation. Other systems for open water (high seas) use continue to be developed and evaluated by the U.S. Coast Guard (e.g., Milgram and Griffiths, 1977) but generally such systems are neither operational nor at the production stage yet.

During the Ekofisk Bravo blowout, one recovery system, the FRAMO ACW 400 High Volume Oil Recovery System, accounted for the majority of oil recovered and officials reportedly were pleased with its operation (Vanderkooy, 1977). The Canadian Coast Guard has a unit on order for testing and evaluation. The advertising brochure for the system (Frank Mohn AS, 1977) describes it as having successfully operated from an offshore supply vessel in Beaufort Sea States 4 and 5. The skimmer is designed for high volume recovery of oil contained in booms. The head is mounted on a hydraulic extension arm which incorporates oil transfer and hydraulic lines. The total system is designed to be permanently mounted on an offshore supply (or similar) vessel. The skimmer itself can be deployed and operated by one person.

TABLE 14.3 SUMMARY OF FIELD TEST RESULTS FOR SEVEN OIL SPILL RECOVERY DEVICES

Name	Oil Recovery Rate (ℓ/min)	Oil Content Factor (percent)	Oil Recovery Factor (percent)	Emulsification Factor	Maximum Theoretical Oil Recovery Rate (ℓ/min)	Process Capability (m^2)	Evaluation Summary
JBF Scientific DIP 2001	14 - 77		76.5 - 93.6	3.4 - 5.7	87	7,300	Oil recovery capability detrimentally affected by increased wave action, oil thickness and speed. Sensitive to floating trash and small amounts of ice. Not easily transported.
Oil MOP Mark 11-9D	7 - 39	44 - 77		5.1 - 22.4	450	141,000	Relatively self-contained device; usable to a certain degree as a containment boom. Not unduly affected by wave action. Mechanism unlikely to be jammed by debris and ice pieces. Requires two vessels to operate in mobile mode.
ESSO SLURP	3 - 11	5 - 25		16.8 - 42.8	150	1,100	Relatively inefficient collection unit; tends to pick up large quantities of water; tends to emulsify oil. Sensitive to floating trash and small amounts of ice. Slush ice would foul screens.

TABLE 14.3 SUMMARY OF FIELD TEST RESULTS FOR SEVEN OIL SPILL RECOVERY DEVICES (Cont'd)

Name	Oil Recovery Rate (ℓ/min)	Oil Content Factor (percent)	Oil Recovery Factor (percent)	Emulsification Factor	Maximum Theoretical Oil Recovery Rate (ℓ/min)	Process Capability (m^2)	Evaluation Summary
RBH Cybernetics Slicklicker Mark II	1 - 13	1 - 30		29.8 - 55.2	Unknown	1,500	Recovery rates low; water content of recovered product high; more efficient at low speeds and with thicker slicks; extremely sensitive to waves. Excessive debris would jam wringing mechanism.
Lockheed Clean Sweep R2002	8 - 66	11	46		159		Appears to have merit for use on medium viscosity oil at temperatures just above freezing; in Beaufort Sea State 0-2; and relative velocities 0.25 - .5 knots. Can process small chunks of ice.
Lockheed Clean Sweep HSORS version		40 - 100	0 - 90		3790		

TABLE 14.3 SUMMARY OF FIELD TEST RESULTS FOR SEVEN OIL SPILL RECOVERY DEVICES (Cont'd)

Name	Oil Recovery Rate (ℓ/min)	Oil Content Factor (percent)	Oil Recovery Factor (percent)	Emulsification Factor	Maximum Theoretical Oil Recovery Rate (ℓ/min)	Process Capability (m^2)	Evaluation Summary
Bennett Mark IV Skimmer		77 - 91	57 - 100				Efficient recovery device; can chase down uncontained oil at speeds up to 3 knots. Needs trained operators. Stable work platform up to Beaufort Sea State 3. The most versatile self propelled unit tested. Needs testing at low temperature, higher sea states. Transportable by C 5A transport plane.
OSCAR							Merits detailed evaluation.
All Units							All units have a tendency to emulsify fresh oil during collection. The weakest link, mechanically, is the pumping system for offloading. This system is particularly ineffective when dealing with high viscosity oils at low temperatures.

TABLE 14.3 SUMMARY OF FIELD TEST RESULTS FOR SEVEN OIL SPILL RECOVERY DEVICES (Cont'd)

Notes:

(1) This table is based on test results and evaluations reported in Solsberg et al (1976); Logan, Thornton and Ross (1975); and Trillo (1977).

(2) Table headings:

Oil recovery Rate - the rate (expressed as ℓ/min) at which oil is recovered by the device.

Oil Content Factor - the volume of recovered oil versus the total volume of the recovered liquid, expressed as a percentage.

Oil Recovery Factor - the volume of oil recovered by a device versus the volume of oil presented to it, expressed as a percentage.

Emulsification Factor - the volume of water in the oil phase versus the total volume of recovered oil, expressed as a percentage.

Process Capability - the area (m^2) which the given system can theoretically process in one h in a one knot current.

An automatic load compensation system is engaged when the head is positioned on the water; this allows the arm and head to follow the main wave movements, thereby maintaining a stable skimming draft. The skimmer head operates on a combination of two principles: weir and adhesion skimming. The recovery arrangement can be adjusted from a closed adhesion system (for thin films of light oil) to an open flow, high volume weir system (for high viscosity oil or emulsions). The skimmer head can also be replaced by a dredge pump.

Mounted on an ice-capable work boat, one could expect to have some capability to get into open lead areas which contain oil. Oil/ice mixtures might also be recovered by use of the dredge head, although the percentage of oil in the recovered fluid would be very low.

To summarize, the system would seem to be promising for extending the capability to recover oil offshore. However, field testing will be necessary to evaluate whether the system shows any promise in recovering oil from ice-frequented waters. This clearly would be required since Shultz and Deslauriers (1977) report that, because of clogging, none of the 35 weir devices tested were suitable for use in broken ice cover.

In addition to skimmer systems, vacuum pumps can be employed to recover liquids. While these systems do not separate oil from water, they can have skimmer heads attached. As well, they can be effective in removing thick layers of oil or emulsions. During the January 1977 Buzzards Bay oil spill, (Ruby et al, 1977) vacuum units (suction pump trucks) were used to remove oil lying in pools on the ice. The method used was labour intensive; it required men to get out on the ice. Furthermore, major problems were encountered with the oil/water mixture freezing in the hoses. Nevertheless, 8000 gal of oil were successfully removed by this method. Use of suction pumps was one of the two methods (along with burning) deemed to be effective by the authors.

The Canadian Coast Guard has four Trans Vac 500D pumping units (Slickbar Inc., 1977). Two of these are located at St. John's; two are located in Montreal. The systems have a collecting rate of 500 US gpm and their is 2268 kg.

For any successful recovery operation, a large volume of on site storage capacity is required. For offshore Labrador, tankers would be required to supply this capability. During cold weather operations, steam coiled holds would be necessary. These tankers would need access to port facilities where recovered fluids could be offloaded for long-term storage. The problems of oil transport and onshore storage will be further considered in the section on logistics requirements.

14.4 Burning

One obvious approach to removing oil from the marine environment is to burn it. If a fire could be started and maintained at the boil area, gas as well as fresh crude would be partly disposed of. While smoke and unburned residue would be products of combustion, these would not be in the same volume or at the same level of toxicity as unaltered crude.

During the initial stages of a blowout, any fire would be a hazard, threatening the safety of men and equipment. Consequently, only after the rig was removed from the site would any consideration be given to igniting the released fluids. For crude oil, the shorter the time spent exposed to the air, the more successful burning will be. The process of aging of crude involves the evaporation (and, to a very limited extent, dissolution) of the lower boiling point (more volatile) fractions so that the more weathered the crude, the higher the ignition point. Experiments reported by Wardley-Smith (1976) indicate that weathered crude would not be ignited by the application of flame after the weathering loss had reached approximately 20 percent by weight. This is equivalent to the loss of volatile components with a boiling point below 180°C. However, these experiments do not agree with work using aged Norman Wells crude which has been burned (after 30 s to four min of preheating) using igniters after a 40 percent + volume loss (D. Thornton, Personal Communication).

Oil on the sea surface tends to spread into a thin slick. The lower surface of the oil is cooled by the sea which acts as an infinite heat sink so that burning fails before all the oil is consumed. Generally, aged crude oils burn out when the layer thickness falls to about 1 to 3 mm. As well, weathered oil which has spread to a thickness of less than 3 to 5 mm cannot normally be ignited successfully.

Abdelnour et al (1977) considered the feasibility of in-situ burning as a technique for cleaning up oil spilled by an offshore blowout in the Arctic. From their theoretical consideration, two principal criteria were established:

(1) Any system for promoting in-situ combustion must form an oil layer greater than 5 mm thick.

(2) Any device to facilitate burning must provide 670 m^2 burning surface for each m^3/min of oil flowing. (This assumes spilled oil will burn at a rate of 1.5 mm/min surface recession).

Rosenegger (1975) examined equilibrium film thickness at $0^{o}C$ water temperature for Norman Wells crude. He predicts that freshly spilled crude will form a slick approximately 2.5 mm thick.

For the scenario under consideration, the oil flow rate is 1.7 m^3/minute. In open water under calm, stationary conditions, such oil could be expected to build up to a maximum thickness of the order of one to two cm. For the area considered, however, this situation would rarely if ever prevail since a residual sea surface current of 20 to 30 cm/s would always be present.

Based on these figures, it would appear that during open water conditions, burning of the oil is not feasible unless some containment device or other thickening process is employed. Water currents in the area are in the order of 30 cm/s (0.5 knots). This almost certainly ensures that oil would be lost under the skirt of any stationary containment boom.

Based on the foregoing, it seems reasonable to conclude that attempts at in-situ burning during the open water period would be generally unsuccessful. However, this consideration does not include the effect generated by the relatively large volume of gas released. The presence of 20 cm cfd of sweet gas (90 percent methane, one percent propane) could have a very important influence on burning rates if the gas acts to encourage burning. Discussion of oil thickness and burning rate would be quite irrelevant if the gas acted in such a manner.

On the other hand, as the gas rises through the water column, it may act to break oil droplets into very small particles that readily enter into an emulsion at the water surface. (This is discussed further by Rossiter in Chapter 11). If such were the case, even though the gas could be flared, it is conceivable that little, if any, of the oil would be burned. Clearly, the behavior and effect of gas in the blowout fluid needs to be researched in more detail.

During the pack ice season, the ice may act to contain and thicken the oil slick, thereby permitting burning. However, an open area would have to be maintained in the boil region to prevent ice from smothering the flame. This could require continuous ice breaking upstream of the boil area; however, such a requirement is not feasible. Any ice breaker engaged in such an endeavour would have to locate itself close to the boil area and would risk being forced into the area of the flame. Under conditions of compression, an ice breaker could not maintain a clear channel or even control its own drift. Further, during storm periods, the direction of the ice drift can shift 360 degrees. In fact, if

burning were attempted during the pack ice season, it would be unsafe for any vessels to venture into the ice field in the area.

If, on the other hand, the turbulence in the boil area is sufficient to keep it clear, as is suggested by Abdelnour et al (1977), the ice will form a natural barrier which will result in accumulations of thicker oil films (of the order of several cm). Unless it is burned promptly and efficiently, such oil will rapidly move off with the ice. Further complicating this picture is the possibility of oil/water or oil/ice pulp mixtures or emulsions forming. If such occurs, then burning of the oil would not be possible.

To summarize, in-situ burning is not feasible during the open water period. It may prove possible during the period of pack ice cover; however, continual re-ingition would probably be required. This would have to be carried out from aircraft rather than surface vessels. Such a method, using delay fuses attached to wicking agents, has been successfully employed from a helicopter (Ruby et al, 1977). This possibility merits further consideration and in fact is the subject of current study under the AMOP program.

Oil which is trapped under cakes of ice could be expected to migrate quickly to the surface through the porous ice, so that drilling holes or excavating channels in the ice would probably not expose any significant volume of oil for burning. During winter months, cakes have a snow cover on them so that the upward migrating oil would be blotted up by the snow; and only when melting occurs at the surface of the cake would oil pools form. It might prove possible to ignite such pools if the oil were thick enough. This seems unlikely since, given the speed at which pack ice moves (and hence the rate at which the undersides of cakes are painted with oil), only small volumes of oil would be contained under a given piece of ice (see Chapter 11).

Since the logistics and safety problems of deploying men and material onto melting cakes would be immense, the only possible option, again, would be the use of helicopter deployed ignition packages. Although the oil would have weathered by this time, it could be ignited if it were thick enough. However, the fire would not spread. Each cake would require individual ignition.

14.5 Shoreline Protection and Cleanup

In planning countermeasures, the coastal zone must be inventoried to yield the following information: where oil might be expected to come ashore; how deeply it will penetrate; how long it will stay; and how much environmental damage it will do. For this purpose, two general features need to be identified:

Vulnerability

Shoreline material indicates the level of energy applied to the shore; particle size (and type) determine the penetration of the oil into the substrate. This information allows prediction of the residence time and degree of penetration of oil (i.e., shoreline vulnerability).

Sensitivity

This feature is an indication of the potential consequences of introduction of oil to a particular area. To determine degree of sensitivity, a knowledge of the biota (in terms of standing crop and productivity) is required. Sensitivity of resident (and transient) organisms to the oil must also be documented, with particular reference to species already subjected to stress (e.g., fishing or hunting mortality).

For coastal Labrador, three related coastline studies are underway. The EPOA has funded a series of studies to characterize shoreline types in Eastern Canada, including Labrador. This work is being specifically undertaken to aid in preparation of contingency plans. Surficial geology was studied during the summer of 1977 by the Geological Survey of Canada (P. McLaren, Personnal Communication) under AMOP funding. As well, the Environmental Protection Service is endeavoring to construct a sensitivity map for the Labrador Coast (B. McGuire, Personal Communication). Of these three studies, only one supplied input to this project (although information relating to sensitivity has been introduced in Chapter 8).

A cursory examination of the EPOA supported work was carried out courtesy of the Geography Department, Memorial University. A series of topographical charts have been prepared by this group based on air photography and one low altitude flight along the coast. Shoreline features identified are degree of slope, and presence of beach material (boulders, cobbles, fines and offshore barriers). Figure 3.8 in Chapter 3 has been derived from this data and portrays proportionally for 12 sections of the coast areas with and without beach (defined as any area of consolidated material) and, degree of slope (steep versus intermediate and gentle).

These categories serve to indicate two coastal features relevant to countermeasures. For areas with no beach, a high energy shoreline where oil would not stay or penetrate can be assumed. For areas with beach, some penetration would occur and countermeasures could be considered. Areas with steep slope would present logistics problems particularly in terms of gaining access to the backshore.

A total of 9850 km of shoreline (exclusive of small offshore islets) was measured between 52 and 60°N. Of this, 47.5 percent consisted of beach with intermediate slope; 2.4 percent, beach with steep slope; 32.4 percent, areas of intermediate slope and no beach; and 17.6 percent, areas of steep slope and no beach. While detailed countermeasures planning requires more specific and detailed information, these figures will serve as a basis to discuss various countermeasures options and related logistics problems.

Shoreline clean-up options involve use of a wide range of construction type equipment which would have to be properly deployed to appropriate coastal areas. This can best be achieved by good logistics planning. Therefore, a selection of effective and practical shoreline clean-up options applicable to the area needs to be made and included in contingency plans.

Before discussing shoreline cleanup, it should be noted that measures to prevent oil coming ashore should be taken wherever possible. These could include use of dispersants, or deployment of booms to deflect slicks from vulnerable areas. Even in relatively protected channels, it would be preferable to use offshore booms, however there is not a large supply of such equipment listed in NEELS. Once deployed, these booms could be anchored in place, however constant tendering would be required. Obviously, only very limited stretches of shoreline could be protected in this manner.

Logan, Thornton and Ross (1975) discuss shoreline clean-up options in some detail for the Beaufort Sea. Except for areas of fine unconsolidated material (sand, mud, gravel and shingle), the best option appears to be natural weathering, possibly aided by steam cleaning. Given the lengthy shoreline perimeter of Labrador, it is clear that one can plan to take action only in the event oil comes ashore in accessible, vulnerable areas. For a spill such as that described for this scenario, the shoreline is exposed to continual re-oiling, which must also be considered and planned against.

Generally, the recommended strategy for sand and gravel beaches is to construct a windrow the length of the beach to protect the upper beach. Once oil comes ashore and onto the windrow, the material is scooped up and trucked away to be buried in a storage/disposal area in the backshore. In cases where oil has already come ashore and penetration is not too deep (less than 5 cm), the oiled material can also be collected into windrows for removal and disposal. As an alternative to windrowing, sorbents could be applied to soak up the oil as it comes ashore. For the volumes required, even for relatively small areas of beach, natural material such as peat would be most practicable.

For one km of beach, approximately 230 bales of peat would be required to give adequate protection.

The ultimate disposal of the oiled material may present a major problem. While research is being carried out on incineration devices, the ones available are either inefficient, difficult to transport or of very small capacity. Disposal by burial is recommended for the shoreline of the Beaufort Sea, however on the Labrador coast access to the backshore is severely limited in many areas. Burial sites with adequate capacity and possessing impermeable boundaries may also prove difficult to locate, since the bedrock in the region has very little overburden and clays are rare.

Table 14.4 is based mainly on information contained in Logan, Thornton and Ross (1975). It presents what appear to be most feasible shoreline protection and clean-up measures based on current operational capability. Also included is a brief consideration of capacity and efficiency of materials and equipment for the various activities. This will serve as input to the scenario. These considerations are based on oil coming ashore during the ice-free period. It is assumed that oil would not come ashore as long as landfast ice is present. McLeod and McLeod (1972) point out that oil travels very little under smooth ice cover, even if forced by currents.

A major limiting factor in shoreline cleanup is the logistics to deploy the equipment and manpower required for even short stretches of beach. This will be considered further in the next section.

14.6 Interfacing and Logistics

"To remove oil in any quantity with any degree of efficiency, a whole package is needed, including containment booms, skimmers, transfer pumps, temporary storage and auxiliary vessels, all deployed and operated by a skilled team of men. Technological development has unfortunately concentrated on the major item of hardware to the neglect of 'interfacing' and logistics." (Marine Pollution Bulletin, 1975).

It must be assumed that the great majority of equipment, personnel and support functions necessary to conduct clean-up and disposal operations will have to be brought to the spill site from locations up to 6000 km away. Therefore, it is essential in constructing a scenario that important limiting factors such as transport and life support equipment capabilities be considered, and also that problems and needs relating to interfacing be identified. This section will generally discuss the logistics requirements to support candidate countermeasures.

14.6.1 Available Resources. It is assumed that all the operator's equipment would be directed to either fighting the blowout or cleaning up spilled oil. The appendix to this chapter lists the aircraft, ships and drill rigs used by Eastcan in its 1976 operation (as reported in its Contingency Plan). It should be noted, however, that towards the end of the drilling season less equipment might be available. In 1976, the *Zapata Ugland*, because it could withstand more severe weather and sea state conditions than the drillships, continued drilling after other operations had ceased. A reasonable assumption is that one rig, two supply vessels, two iceberg towing vessels, one helicopter (e.g., the Sikorky S61N) and one personnel transport aircraft (e.g., Canso PBY) are operating in the area at the time of the blowout. Other crafts are by this time released from contract.

The appendix to this chapter also describes some of the types of aircraft and specific ships under control of the federal government. For any surface winter operations, icebreakers will be essential. While the Canadian Coast Guard has a fleet of such vessels on the East Coast, they are in heavy demand, particularly during severe ice seasons. At best, one could hope to have two vessels operating full time to support countermeasures: one on site, and one keeping Goose Bay or St. Anthony open. This would probably involve commitment of a third relief vessel.

To provide monitoring of oceanographic and sea surface conditions as well as plankton sampling for pollution monitoring will require the services of an ice capable oceanographic research vessel, i.e., the *Hudson*. In addition to its function as a fisheries research vessel, the *Gadus Atlantica* has some limited oceanographic ability and could supply back-up for the *Hudson*.

For major operations involving large numbers of men and equipment, it will be important to provide a vessel capable of carrying out repair and maintenance, equipment modification and general support services. Such a ship would need to be able to lift on board, for example, the Bennett Mark IV Skimmer. One of the DND replenishment ships might provide such a service.

Air transport of large sizes and volumes of countermeasures material and equipment could be provided by the DND. The Hercules would be required for large items, however the buffalo aircraft could also prove useful.

The DND has a total of 28 Hercules aircraft. Twenty-three are cargo transport; five are used in training. At any one time during 1977, an average of 20 were in the hands of squadrons (Lt. Col. Ellard, Personal Communication). The 13 Hercules based at Trenton AFB, Ontario, represent the closest government source for these

aircraft. The number available at any one time depends on the level of global work commitments placed in Air Transport Command.

The other transport aircraft in use by the Canadian Armed Forces is the Buffalo. This aircraft does not have the same payload as the Hercules; however, it specializes in short take off and landing from unprepared airstrips. Because of the uncertain and possibly deteriorating condition of the runway at Saglek, the Buffalo could be more suitable than the Hercules if this landing strip were used.

Military helicopters (Labrador, Voyager) could provide air transport to the spill site as well as search and rescue support. At all times, when offshore countermeasures operations are underway, at least one vessel with a landing pad would have to be on site. Due caution will have to be exercised in planning on and using this transport link since helicopter landings on vessels will be curtailed whenever vessel motion (as a result of ocean swell) exceeds certains limits. All helicopters in use would have to be licenced and equipped for IFR flying.

Besides the operator and the federal government, other sources for aircraft and ships would include the operators, private companies and the provincial government. Private industry is a source for tankers (steam coiled) as indicated in the BP Contingency Plan (BP Canada Ltd., 1974). Offshore supply vessels and ice capable vessels (e.g., sealers such as the *Arctic Explorer* and *Lady Johnson II*, St. John's, Nfld.) could also be available presumably on a charter basis.

Chimo Shipping Ltd., based in St. John's, owns and operates a fleet of Arctic resupply vessels that are not only ice capable, but also carry lightering barges for offloading cargo in areas lacking wharf facilities (S. Peters, Personal Communication). Such a capability would prove invaluable in any shoreline countermeasures where heavy equipment will need to be deployed in isolated locations.

The provincial government has a fleet of seven Canso PBY water bombers. These aircraft are on refit during the winter, however, in an emergency two could be made available. During the forest fire season, these aircraft are deployed throughout the province (and Nova Scotia) with one stationed in Goose Bay during August (M. Piercey, Personal Communication).

Oil containment and removal operations will require extensive support, particularly since there is no single, integrated system available to handle containment, removal and storage. As well, the various units will have to be transported to site since the operator has none of this equipment available. A number of vessels would be required to carry out the procedure previously described, viz., four offshore tugs to handle two

TABLE 14.4 SHORELINE COUNTERMEASURES: EQUIPMENT REQUIREMENTS AND WORK RATES

Zone	Method		Material and Equipment	Capacity and Efficiency
Offshore Protection	booming (deflection of oil)	deploy and maintain	booms and moorings inshore craft, tender crew (4)	needs constant monitoring; 600 m of boom per crew would probably be a maximum
Onshore Protection				
gravel and sand beaches	sorbents	deploy along beach	peat moss	1 bale = 0.2 m^3; area covered, 6.1 m x 0.6 cm; 230 bales required for one km of beach
			small snow blowers	four required to cover one km beach in one day
		collect oiled sorbent	manual - with forks)	
			)	(e.g. Santa Barbara) 50 workers with 4 loaders and 10 dump trucks cleaned 1.6 km beach/day
			)	
		transport and disposal	front end loader;)	
			tracked vehicle)	
	windrowing (removal slightly oiled beach)	construct windrow	road grader; motorized elevating scraper	6.5 h/hectare (for removal of surface material to a depth of 5 cm)
		transfer oiled material	flexible, tracked vehicle	can negotiate grades $\leq$ 60%. For a 4 km haul at 10 to 16 km/h speed, 17 m^3/h (240 m^3/day) can be moved. For a slightly oiled beach area, 1.6 km x 9 m x 7.5 cm (1500 m^3), one carrier working 15 h/day will take six days to transport material.
		disposal - burial in the backshore	front end loader; bulldozer	depends on compactness and porosity of material, vegetation and overburden, depth of site

booms; one offshore tug with deck mounted skimmer (Framo ACW 400); one tender to accompany second skimmer (would need capability to deploy and recover unit); two tankers (steam coiled) to transport recovered fluid ashore. Pumps capable of handling the highly viscous fluid would be needed at all transfer points.

Onshore storage close to the blowout site is difficult to locate, however the Air Force Base at Goose Bay has some facilities that might prove usable in such an emergency (Mr. J. Stanniz, Airport Manager, Goose Bay, Personal Communication). There are eight to ten, one million (U.S.) gal (30,280 to 37,850 m^3) underground storage tanks in three nests at the base. They have a concrete cover and are probably concrete all round, however they are not below the frost line. These reservoirs have been abandoned for some time; consequently, it is not known for certain whether they are still tight. There are no current plans to do anything with these facilities, however the long-range plan is to fill them in (to avoid injury to someone tampering with the manholes). Since the system is partly abandoned, temporary piping or transport from dockside to the tanks would have to be provided.

The base also has an above-ground tank farm consisting of metal tanks from 870,000 to 4,375,000 Imp. gal capacity each. It is estimated that above-ground unused capacity is 25 million gal (113,650 m^3). These tanks are in prime condition and their use for storage of recovered oil would present a subsequent cleaning problem. For the same reason, existing pipelines running from dockside to these tanks would probably not be used to transfer recovered oil.

Transporting recovered fluid to Goose Bay after freeze-up would require icebreaker support, especially in the narrow region near Rigolet (Ocean Engineering Group, 1973). If such support were provided, this port would be the logical trans-shipment point for all material transported by ship to the blowout site.

The only other means of transport to the spill site is by helicopters which would operate from any point on land. Fixed wing-to-helicopter transfer could occur at Saglek or Goose Bay.

The transport requirements to support shoreline countermeasures are particularly difficult to meet. Relatively large vessels would be required to transport heavy equipment. Passage near the coast would be difficult in many areas because of outdated charts and shoal water.

Equipment would be transferred to shore either in lightering barges or by helicopter. For many areas with offshore shallows, access by barge would not prove possible. Helicopters, on the other hand, are limited in their lift capacity.

Even for those areas where equipment and material could be transported to shore, this operation would be quite time consuming. For some areas such as Trunmore Bay (Figure 14.3), a 45 km long sand beach south of Groswater Bay, a fairly major operation could be launched if necessary. A camp could be set up, and with equipment having access to such a long stretch of beach, cleanup measures such as have been described could be successful. The requirement in personnel and equipment would be substantial however, and stringent measures would have to be taken to ensure that the cure (i.e., impact of this activity on the area) was not worse than the disease.

14.6.2 Equipment Inventories. For countermeasures equipment, the Environmental Emergencies Branch maintains a computerized inventory - NEELS (National Emergency Equipment Locator System) maintained by I.P. Sharp Associates. The system is described by McNeil (1975). Environment Emergency offices across Canada have access to the inventory through telephone line hookups. The system locates specific pieces of equipment and identifies the appropriate contact. Canadian industry and government equipment (plus that of some border states) are listed in the inventory. Table 14.5 summarizes selected categories of equipment listed in a December 1977 dump.

Some characteristics of the system would appear to limit its operational usefulness, viz.:

(1) standard terminology is lacking (e.g., some dispersants are described as Corexit - with no indication of number designation);

(2) many pieces of inconsequential equipment (e.g., "dung forks") are listed; and

(3) there is no way of ensuring that all contributors keep their lists updated. Consequently, much equipment that has recently been acquired is not listed, and further, it may be that some of the equipment listed is no longer available.

It would probably be a useful exercise to examine the use made of the system to date and the results obtained.

For a massive spill such as in considered here, an international search would be made for usable equipment. Bennett Pollution Controls has established a worldwide spill bank to provide just such a rapid international response (Oilweek, 1977). The system was activated during the Ekofisk Bravo Blowout (Bennett Bulletin, 1977) when planes and equipment were line up to go to the spill site, however, the blowout was stopped before actual deployment of this equipment was necessary. In planning against a major spill, this and similar systems would have to be considered.

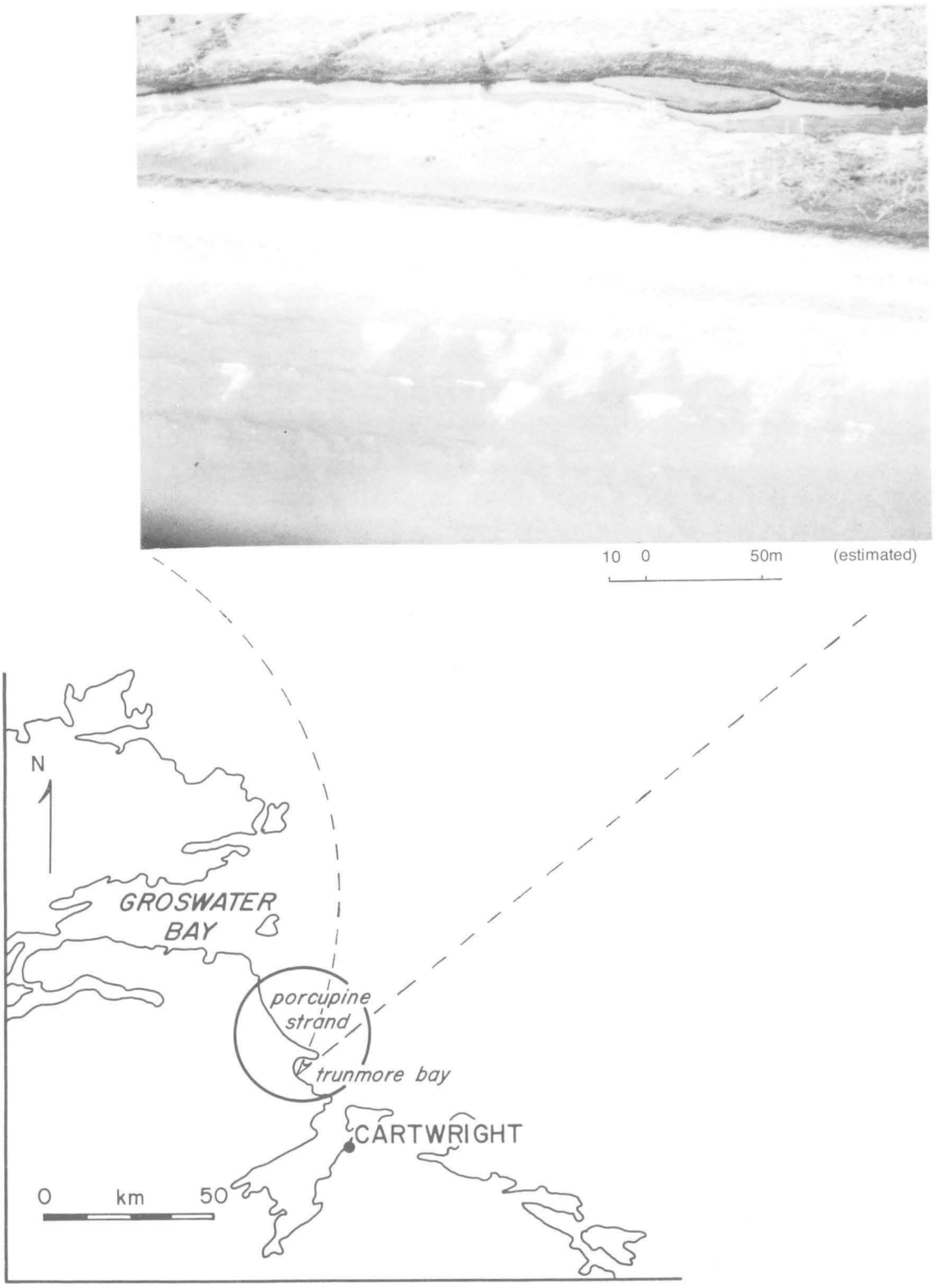

FIGURE 14.3 PORCUPINE STRAND AND TRUNMORE BAY: 45 km OF SANDY BEACH

TABLE 14.5 CANADIAN OIL SPILL COUNTERMEASURES MATERIALS AND EQUIPMENT (Based on Neels Inventory, December 8, 1977).

Category	Description	Canada (excluding Nfld.) Government	Canada (excluding Nfld.) Industry	Nfld. and Labrador Government	Nfld. and Labrador Industr
Containers	Fuel Bladders	-	1 (5000 gal)	1 (500 gal)	-
	Portable Tanks	-	36 (1000 gal)		-
	Collapsible Tanks	-	3 (9000 gal total)		-
	Floating Tanks	-	1 (5000 gal)		-
Pumps	< 3 in exit	19	408	1	10
	> 3 in exit	1	49	-	-
Booms	Inshore (<36 in)	22,500 ft	103,824 ft	2000 ft	1450 ft
	Bennett Inshore (36 in)	45,100 ft	17,450 ft	5800 ft	2700 ft
	Offshore (>36 in)	5690 ft	-	-	-
	Vikoma Sea Packs (1600 ft)	4	-	2	-
Dispersant Application	Bush Pack Spray Kits	-	6	-	-
	Helicopter Sprayers	-	1	-	-
	Spray Units	-	12	-	-
	Tug-Mounted	-	-	3	-
Steam Equipment	Steam Jenny	6	-	-	-
	Solvent	9 drums	-	-	-
Sorbents (1)	Peat Moss	1852 bales	4039 bales	25 bales	40 bale
	Straw	29 bales	1211 bales	-	-
Dispersants (listed as Imperial gal)	Corexit (only)	405	1325	-	-
	- 7664	1045	4507	-	-
	- 8666	3495	3190	-	-
	- 9527	-	150	-	-
	Gamlen	5	490	-	-

(1) Plus a large quantity of various materials inventoried and described in a variety of ways.

TABLE 14.5 CANADIAN OIL SPILL COUNTERMEASURES MATERIALS AND EQUIPMENT (Continued) (Based on Neels Inventory, December 8, 1977).

Category	Description	Canada (excluding Nfld.) Government	Canada (excluding Nfld.) Industry	Nfld. and Labrador Government	Nfld. and Labrador Industry
	Duosal	45	445	-	-
	OSD-20	-	175	-	-
	BP-1100	-	7460	-	-
	BP-1100X	-	900	-	-
Dispersants Continued (listed as Imperial gal)	Finasol SC	-	140	-	-
	Oilsperse 43	1845	1085	-	-
	Gulf Agent 1009	-	455	-	-
	Gamasol	-	200	-	-
	Polycomplex A-11	-	585	-	
	NRS Super Action Concentrate	-	5	-	-
Large Skimmers					
	Slicklickers	4	6	3	1
	Oil Mop Mark II	-	5	1 (on order)	-
	Lockheed	-	1	1	-
	Slickbar	-	7		-
	Manta Ray Framo ACW 400	-	-	1 (on order)	-
Small Skimmers					
	Slurps	19	36	3	1
	Komara Mini Skimmer	1	4	4	-
	Wastemaster	2	18	-	-
	Pedco 4' and 8'	-	9	-	-
	Rotating Barrel	-	10	-	-
	Floating Saucer	-	6	-	1
	Swiss	-	3	-	-
Other*					
	Assorted	-	13	-	-

*Other Skimmers:

Belt Type	Sanivan
Oil Hawg	Martinez
Tray Pontoon	MFL
V Type	Acme
Sluri	

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APPENDIX
TO
CHAPTER 3

THE GEOLOGY AND HYDROCARBON POTENTIAL OF THE LABRADOR CONTINENTAL MARGIN

TABLE A.3.1 GEOLOGICAL TIME SCALE

ERA	AGE (M.Y.)	PERIOD	EPOCH	STAGES
			HOLOCENE	
		QUATERNARY	PLEISTOCENE	
	1.8			
CENOZOIC			PLIOCENE	
			MIOCENE	
		TERTIARY	OLIGOCENE	
			EOCENE	
			PALEOCENE	
	65			
			LATE	MAASTRICHTIAN
				CAMPANIAN
				SANTONIAN
				CONIACIAN
				TURONIAN
				CENOMANIAN
		CRETACEOUS	EARLY	ALBIAN
MESOZOIC				APTIAN
				BARREMIAN
				HAUTERIVIAN
				VALANGINIAN
				BERRIASIAN
	140			
			LATE	
		JURASSIC	MIDDLE	
			EARLY	
	195			
			LATE	
		TRIASSIC	MIDDLE	
			EARLY	
	230			
			LATE	
		PERMIAN	EARLY	
	280			
			LATE	STEPHANIAN
				WESTPHALIAN
		CARBONIFEROUS		
			EARLY	VISEAN
				TOURNAISIAN
	345			
			LATE	
PALEOZOIC		DEVONIAN	MIDDLE	
			EARLY	
	395			
			LATE	
		SILURIAN	EARLY	
	435			
			LATE	
		ORDOVICIAN	EARLY	
	500			
			LATE	
		CAMBRIAN	MIDDLE	
			EARLY	
	570			
PRECAMBRIAN				

Section	Length of Coastline (km)	Coastline with Beach and Intermediate Slope (%)	Coastline with Beach and Steep Slope (%)	Coastline with No Beach and Intermediate Slope (%)	Coastline with No Beach and Steep Slope (%)
Battle Harbour	1083	69	3	1	28
Cartwright	1140	34	1	64	2
Groswater Bay	617	39	11	23	27
Rigolet South	555	5	1	95	1
Rigolet North	480	43	1	55	7
Makkovik	631	22	1	73	4
Hopedale	1043	41	1	56	3
Nain	1809	56	1	35	8
Tasisuak Lake	208	87	1	1	13
Nutak	675	73	4	10	13
North River	335	100	1	1	1
Hebron	857	10	11	16	63
Cape White Handerchief	417	39	1	1	61
Total	9850				
Average		48	2	32	18

TABLE A.3.2

APPENDIX
TO
CHAPTER 4

OCEANOGRAPHY AND CLIMATOLOGY
OF
THE LABRADOR SEA

SSMO Tables referred to in Climatology Section:

Table 1: Percentage Frequency of Weather Occurrence by Wind Direction (16 pt.).

Table 2: Percentage Frequency of Weather Occurrence by Hour (GMT).

Table 3: Percentage Frequency of Wind Direction (16 pt.) by Speed and by Hour (GMT). This table includes mean wind speed (kts.) by direction (16 pt.).

Table 3A: Percentage Frequency of Wind Direction (8 pt.) by Speed and by Hour (GMT). This table includes mean wind speed (kt.) by direction.

Table 4: Percentage Frequency of Wind Speed by Hour (GMT). This table includes mean speed by hour.

Table 5: Percentage Frequency of Total Cloud Amount (Oktas) by Wind Direction (16 pt.). This table includes mean cloud amount by wind direction.

Table 6: Percentage Frequency of Ceiling Heights (feet, NH > 4/8) and Occurrence of NH < 5/8 by Wind Direction (16 pt.).

Table 7: Cumulation Percentage Frequency of Occurrence of Ceiling Height (feet, NH > 4/8) and Visibility (Nautical Miles).

Table 7A: Percentage Frequency of Low Cloud Amount (or Middle Cloud Amount if Low Clouds are not present) and Percentage Frequency of Sky Obscured. Amounts are in Oktas.

Table 8: Percentage Frequency of Wind Direction (16 pt.) vs Occurrence or Non-Occurrence of Precipitation at Observation Time with Varying Values of Visibility (Nautical Miles).

Table 9: Percentage Frequency of Wind Direction (16 pt.) vs Wind Speed (kt.) with Varying Values of Visibility (Nautical Miles).

Table 10: Percentage Frequency of Ceiling Heights (feet, NH > 4/8) and Occurrence of NH < 5/8 by Hour (GMT).

Table 11: Percentage Frequency of Visibility (Nautical Miles) by Hour (GMT).

Table 12: Cumulative Percentage Frequency of Ranges of Visibility (Nautical Miles) and Ceiling Height (feet, NH > 4/8) and NH < 5/8; by Hour (GMT).

Table 13: Percentage Frequency of Relative Humidity (%) by Air Temperature (^{o}F).

Table 14: Percentage Frequency of Wind Direction (8 pt.) by Air Temperature (^{o}F).

Table 15: Means, Extremes, and Percentiles of Air Temperature (^{o}F) by Hour (GMT). Extreme temperatures are the one maximum and one minimum value appearing in the marine data file. The Extremes may be

unrepresentative due to sampling errors. Extrapolation from the percentile values usually gives a better estimate of expected extreme conditions.

Table 16: Percentage Frequency of Relative Humidity (%) by Hour (GMT).

Table 17: Percentage Frequency of Air Temperature (^{o}F) and the Occurrence of Fog vs Air-Sea Temperature Difference (^{o}F).

Air-Sea Temperature Difference is:

Positive when the air is warmer than the sea surface: Negative when the air is cooler than the sea surface. In the table heading, the limits of the temperature ranges appear in a vertical arrangement along the top of the table.

Table 18: Percentage Frequency of Surface Wind Speed (kt.) and Direction (8 pt.) vs Sea Height (feet). Source deck 128 for which data are available from mid-1963 was used for these tables. This deck represents the latest and most complete homogeneous source of wave data available. Here, only sea waves generated by local winds in the vicinity of the observer are summarized. This table continues for 2-1/2 pages for each month and 2-1/2 pages for the annual summary.

Table 19: Percentage Frequency of Wave Height (feet) vs. Wave Period (seconds). In this table when both sea and swell waves are present in an observation, the higher of the two is used. If both are the same height, the longer period is chosen. When only one of the wave groups is observed, either sea or swell, it is used in the summary. Swell waves are those generated by winds distant from the local area where the observation is taken.

Table 20: Monthly and Annual Percentage Frequencies and Means of Sea Surface Temperature (^{o}F).

Table 21: Monthly and Annual Sea Level Pressures (millibars). This table includes means by hour and for all hours, extreme values with the corresponding dates of occurrence and percentile values.

NH = Low cloud amount (or middle cloud amount when low clouds are not present).

APPENDIX TO CHAPTER 7

ICEBERG HAZARD

	Distance from shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	31	72	43	100	21	49	8	19						
59°N	44	100	28	65	19	44	6	14						
58°N	37	85	33	76	14	82	3	7						
57°N	42	96	20	46	9	21	2	5						
56°N	1	2	12	27	18	41	13	29	2	5	2	5	1	2
55°N	11	25	14	32	4	9	2	5						
54°N	1	2	8	18	2	4	2	4	4	9				
53°N	4	9	2	4	1	2	2	4	2	4	1	2		
52°N	5	2	2	1	1	2	0	0	1	2	0	0		

TABLE A.7.1 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR JANUARY

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	29	67	40	93	19	44	8	19						
59°N	42	97	27	62	19	44	6	14						
58°N	39	89	35	80	16	37	3	7						
57°N	50	114	24	55	11	25	3	7						
56°N	2	5	19	43	28	63	20	45	4	9	3	7	1	2
55°N	21	47	27	61	7	16	4	9	1	2				
54°N	3		19	43	4	9	5	11	8	18				
53°N	9	20	7	16	4	9	4	9	4	9	2	4		
52°N	12	27	6	13	3	7	1	2	1	2				

TABLE A.7.2 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR FEBRUARY

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	38	88	54	13	26	60	10	23						
59°N	55	127	35	81	24	55	7	16						
58°N	48	110	44	101	20	46	3	7						
57°N	64	146	30	68	15	34	3	7						
56°N	3	7	28	63	40	91	29	66	6	14	6	14		
55°N	35	79	46	104	12	27	6	14	1	2				
54°N	7	16	39	87	8	18	11	25	17	38				
53°N	23	51	17	38	9	20	9	20	10	22	5	22		
52°N	33	73	15	33	7	15	2	4	3	7	1	2		

TABLE A.7.3 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR MARCH

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	39	9	55	13	26	60	11	26						
59°N	58	134	37	85	26	60	8	18						
58°N	54	124	49	112	22	54	4	9						
57°N	73	166	35	80	17	39	4	9						
56°N	3	7	28	6	40	9	29	66	6	14	5	11	1	2
55°N	37	83	48	108	13	29	6	14	1	2				
54°N	8	18	47	105	10	22	13	29	20	45				
53°N	29	65	21	47	11	24	12	27	13	29	7	16		
52°N	47	104	21	46	11	24	3	7	4	9	2	4		

TABLE A.7.4 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR APRIL

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	43	100	60	14	29	67	12	28						
59°N	64	148	41	95	28	65	9	21						
58°N	58	133	53	122	24	55	4	9						
57°N	75	171	36	82	17	39	4	9						
56°N	4	9	33	75	48	109	34	77	7	16	5	11	1	2
55°N	44	99	58	131	15	34	8	18	1	2				
54°N	9	76	56	58	12	27	15	34	24	54				
53°N	34	76	26	58	13	29	14	31	15	33	8	18		
52°N	56	124	25	55	13	29	3	7	5	11	2	4		

TABLE A.7.5 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR MAY

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	43	100	60	139	28	65	4	9						
59°N	63	145	41	95	28	65	8	18						
58°N	59	135	53	122	24	55	4	9						
57°N	78	178	37	84	18	41	4	9						
56°N	4	9	34	77	48	108	35	79	7	16	5	11	1	2
55°N	46	104	60	135	16	36	8	18	1	2				
54°N	9	20	57	128	12	27	15	34	25	56				
53°N	33	73	25	56	13	29	14	31	15	33	7	16		
52°N	54	119	24	53	12	27	3	76	5	11	2	4		

TABLE A.7.6 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR JUNE

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	37	86	52	121	25	58	10	23						
59°N	58	134	37	85	26	60	8	18						
58°N	57	131	51	117	23	53	4	9						
57°N	72	164	34	72	17	39	4	9						
56°N	4	9	30	68	44	100	31	70	6	14	5	11	12	27
55°N	42	95	53	14	14	32	7	16	1	2				
54°N	7	16	44	98	9	20	12	27	19	43				
53°N	20	44	15	33	8	18	8	18	9	20	4	9		
52°N	22	49	10	22	5	11	1	2	2	4	2			

TABLE A.7.7 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR JULY

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	26	60	37	86	17	39	7	16						
59°N	41	95	26	60	18	42	5	12						
58°N	40	92	36	83	16	37	3	7						
57°N	56	128	27	62	13	30	3	7						
56°N	3	7	27	62	38	86	28	63	5	11	4	9	1	2
55°N	41	92	54	122	14	32	7	16	1	2				
54°N	6	13	39	87	8	18	11	25	17	38				
53°N	17	38	12	27	6	13	7	16	8	18	4	9		
52°N	18	49	8	18	4	9	1	2	2	4	1	2		

TABLE A.7.8 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR AUGUST

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	15	35	21	49	10	23	4	9						
59°N	24	55	15	35	11	25	3	7						
58°N	26	60	24	55	11	25	2	5						
57°N	32	73	15	34	7	16	2	5						
56°N	2	5	17	39	24	54	17	39	3	7	3	7	1	2
55°N	26	59	35	79	9	20	4	9	1	2				
54°N	4	9	24	54	5	11	6	13	10	22				
53°N	10	22	8	18	4	8	4	8	5	11	2	4		
52°N	12	26	5	11	3	7	1	2	1	2				

TABLE A.7.9 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR SEPTEMBER

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	12	28	17	39	8	19	3	7						
59°N	12	28	8	19	5	12	2	5						
58°N	9	21	8	18	4	9	1	2						
57°N	11	21	8	11	3	7	1	2						
56°N	1	2	7	16	10	23	7	16	1	2	1	2		
55°N	12	27	16	36	4	9	2	3						
54°N	3	7	15	34	3	7	4	9	7	16				
53°N	7	16	5	11	3	7	3	7	3	7				
52°N	7	15	3	7	2	4	.001	1	.001	0				

TABLE A.7.10 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR OCTOBER

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	12	28	17	39	8	19	3	7						
59°N	16	37	10	23	7	16	2	5						
58°N	11	25	10	23	4	9	1	2						
57°N	9	21	4	9	2	5	1	2						
56°N			2	5	4	9	3	7	1	2				
55°N	4	9	5	11	1	2	1	2	0					
54°N	1	2	7	16	2	4	2	4	3	7				
53°N	3	7	3	7	1	2	1	2	2	4	1	2		
52°N	5	11	2	4	1	2			1	2				

TABLE A.7.11 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR NOVEMBER

	Distance from Shore in Degrees Longitude													
	1°		2°		3°		4°		5°		6°		7°	
	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)	No.	P(A)
60°N	22	51	31	72	15	35	6	14						
59°N	27	62	17	39	12	28	3	7						
58°N	18	41	16	37	7	16	1	2						
57°N	18	41	8	18	4	9	1	2						
56°N	1	2	5	11	7	16	5	11	1	2			0	
55°N	4	9	5	11	1	2	3		3					
54°N	0	0	3	7	1	2	1	2	1	2				
53°N	1	2	1	2										
52°N	0		0		0		0		0		0		0	

TABLE A.7.12 PROBABILITY OF ICEBERG IMPACT P(A) x 10^3 FOR DECEMBER

APPENDIX
TO
CHAPTER 8

RESOURCE UTILIZATION
AND POTENTIAL IMPACT

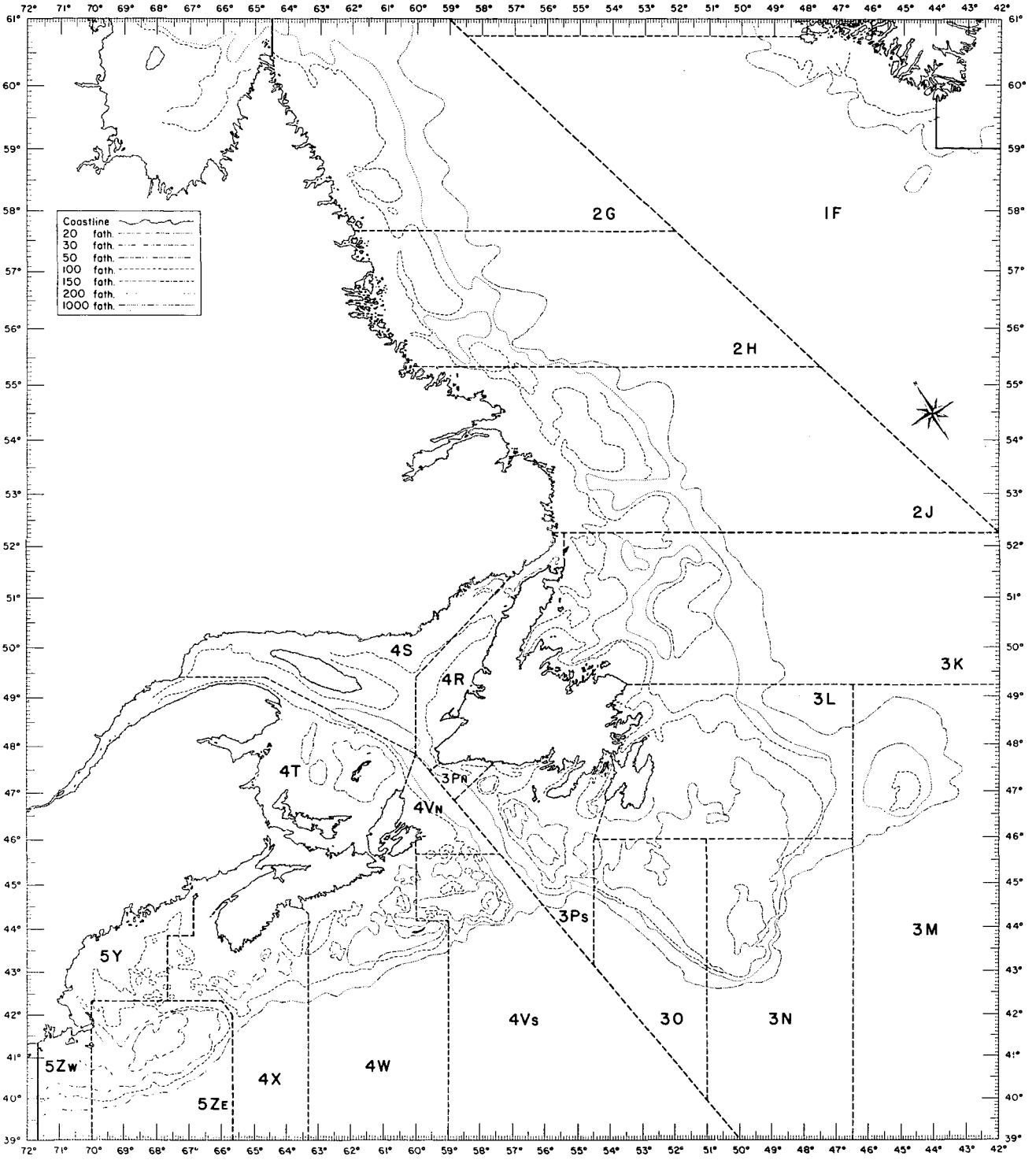


FIGURE A.8.1 ICNAF STATISTICAL AREAS

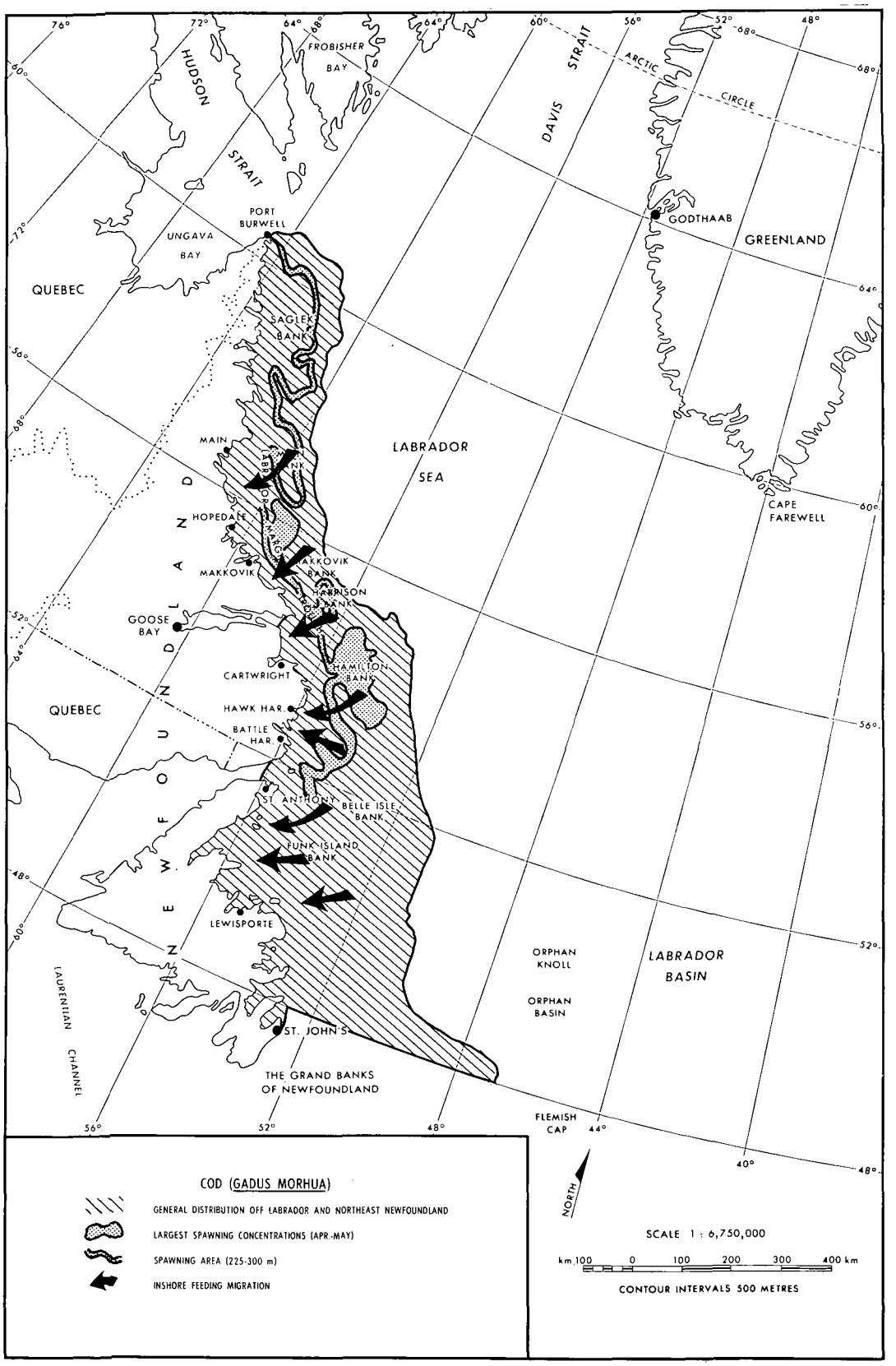


FIGURE A.8.2 Source: Northland Associates, 1977

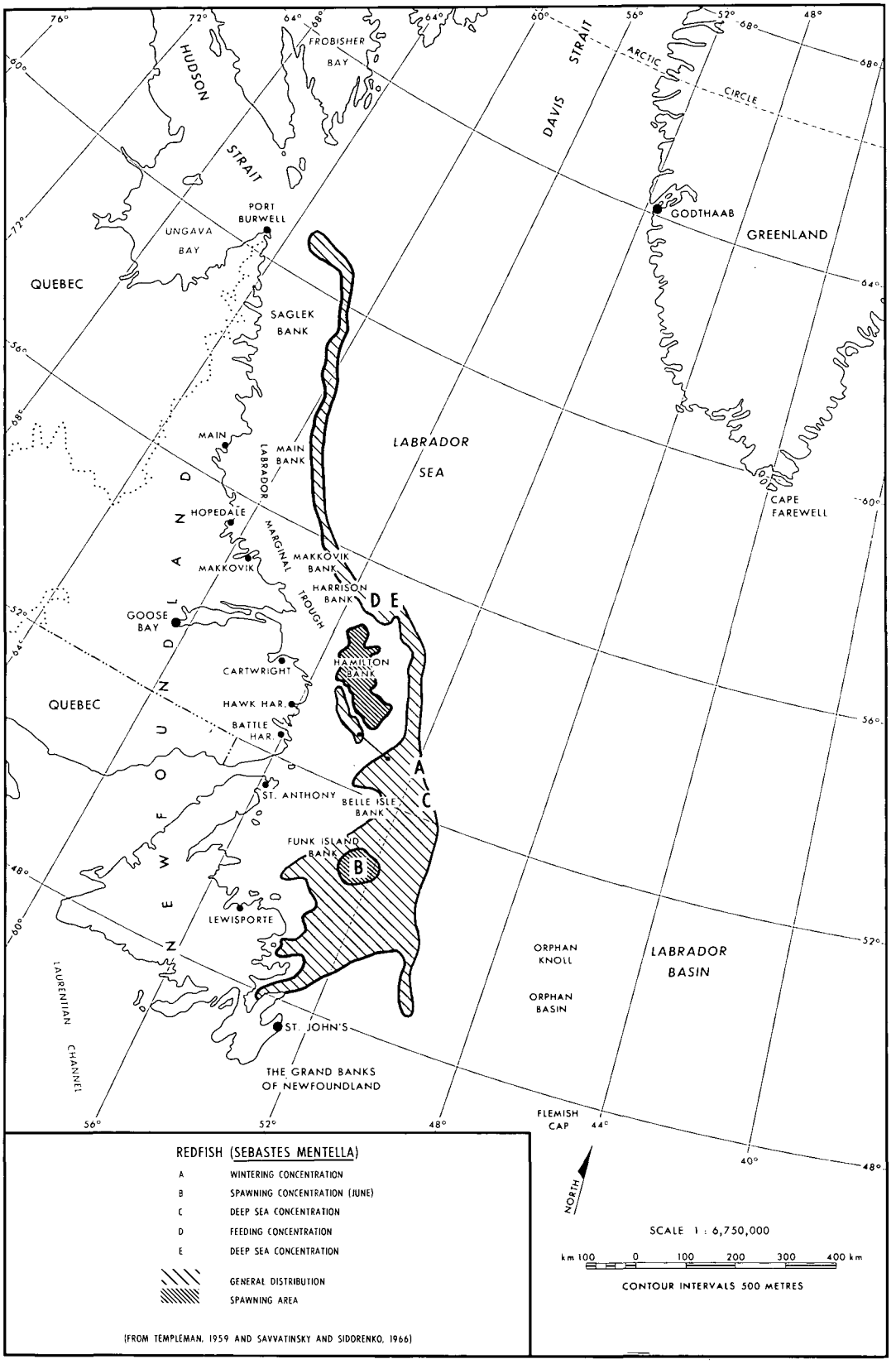


FIGURE A.8.3 Source: Northland Associates, 1977

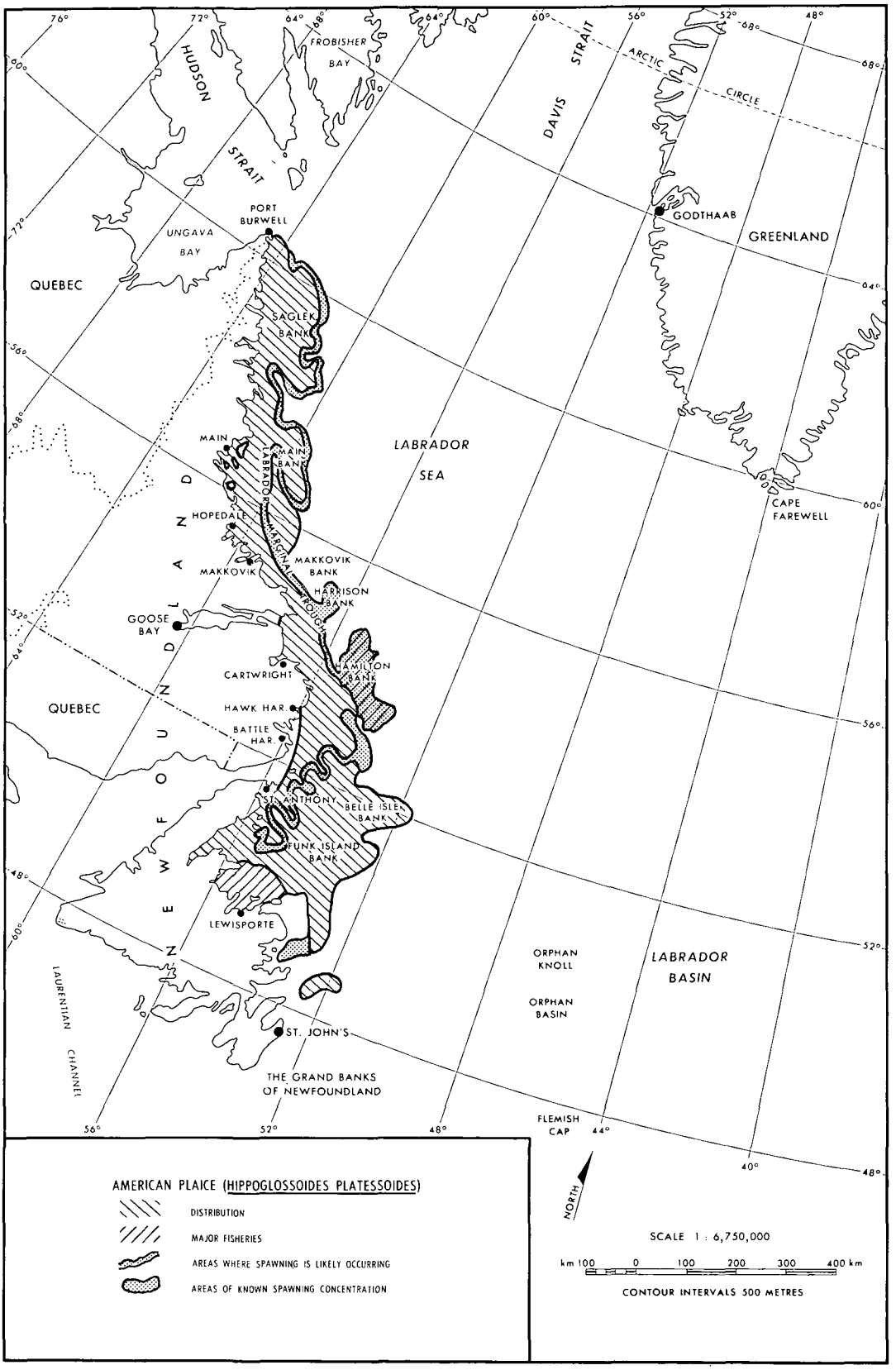


FIGURE A.8.4 Source: Northland Associates, 1977

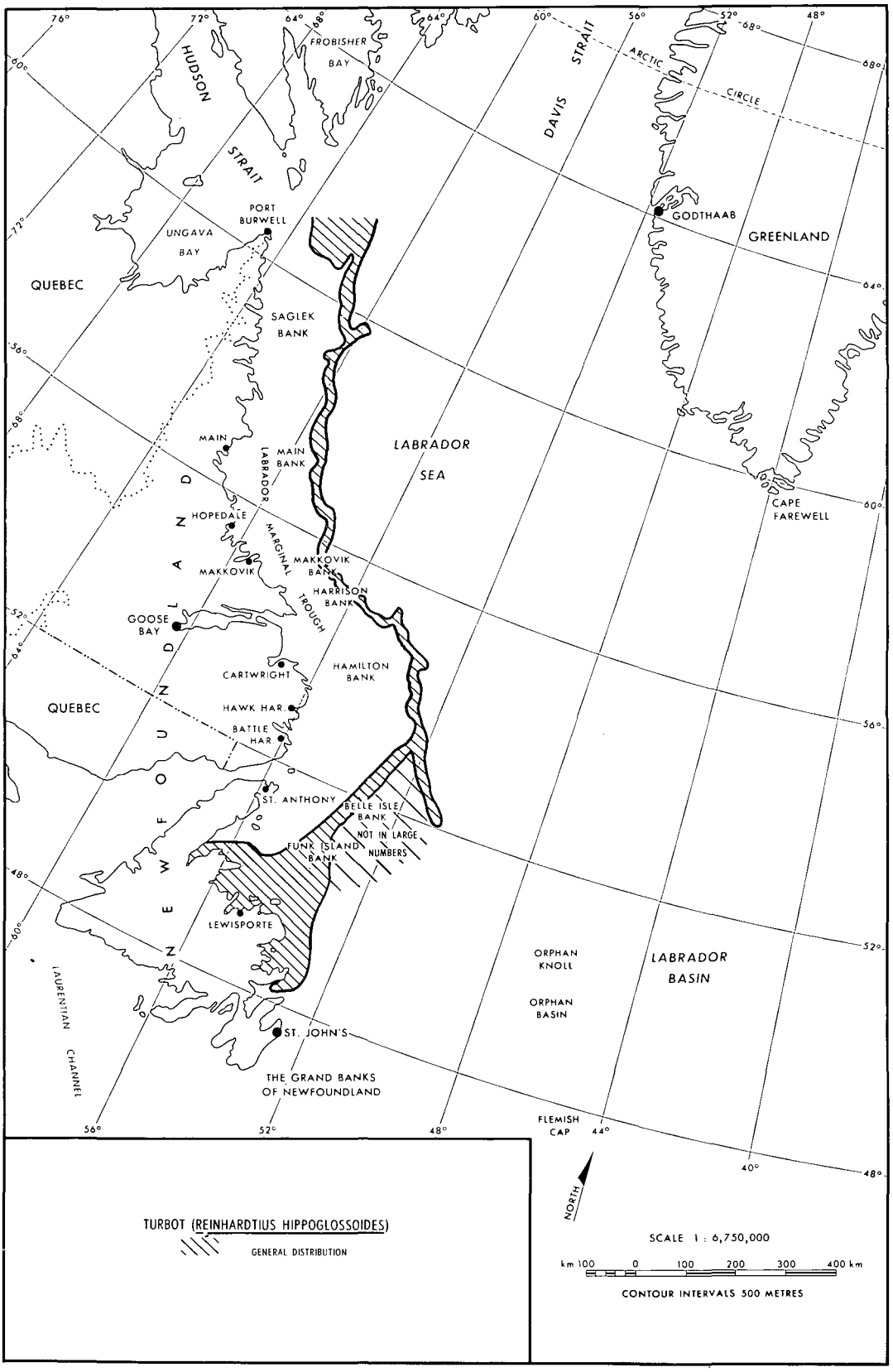


FIGURE A.8.5 Source: Northland Associates, 1977

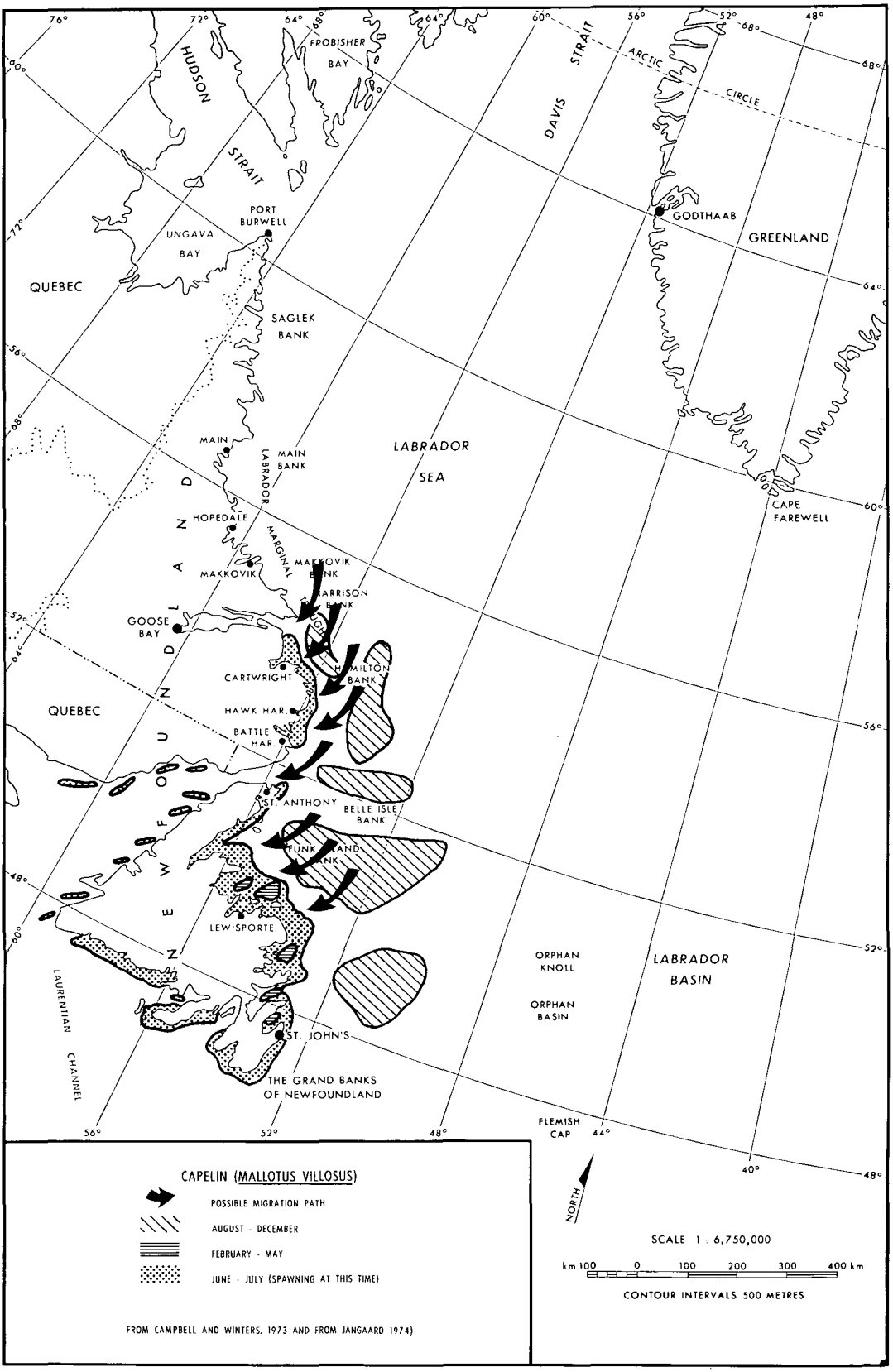


FIGURE A.8.6 Source: Northland Associates, 1977

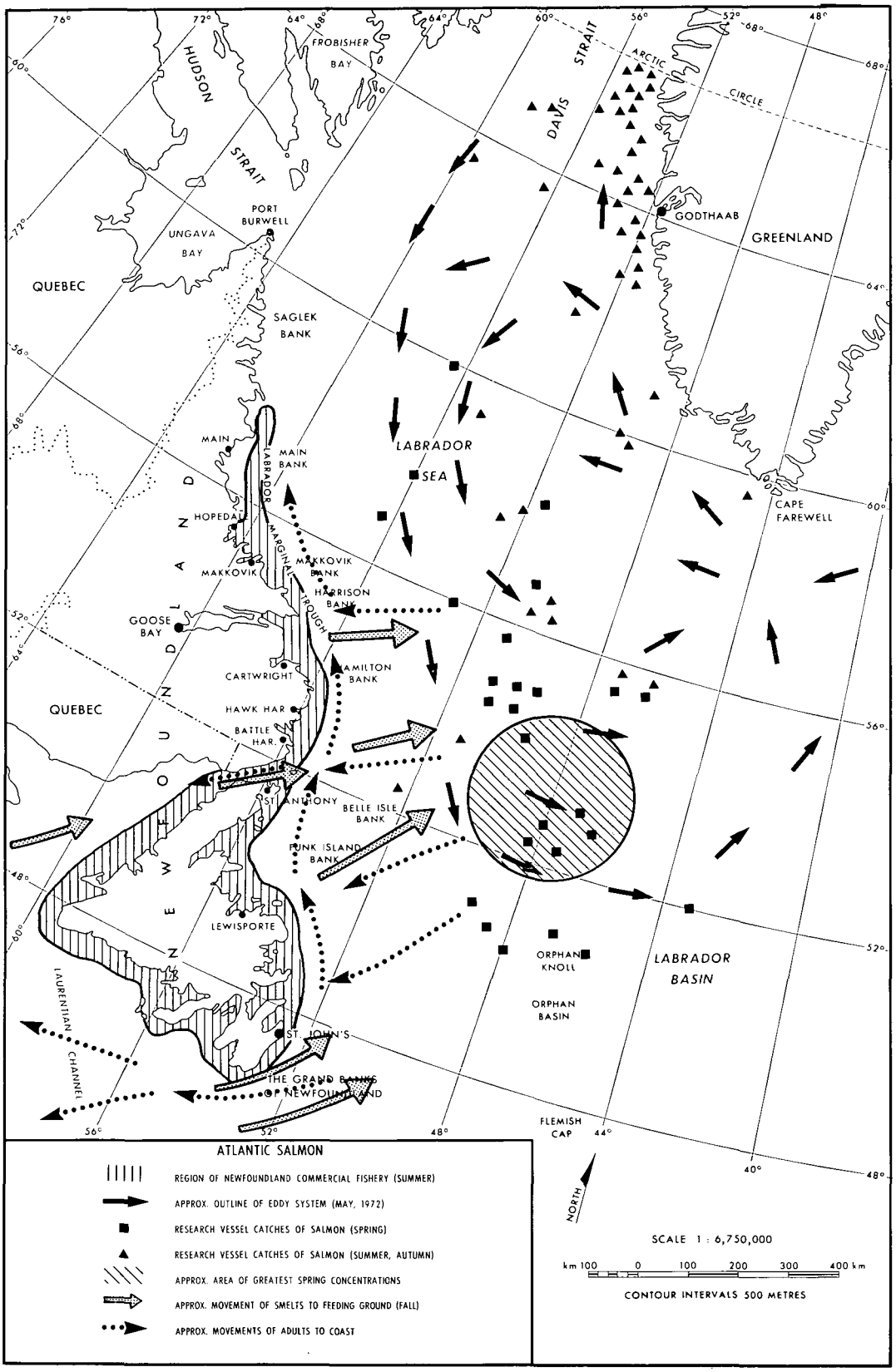


FIGURE A.8.7 ATLANTIC SALMON

Source: Northland Associates, 1977

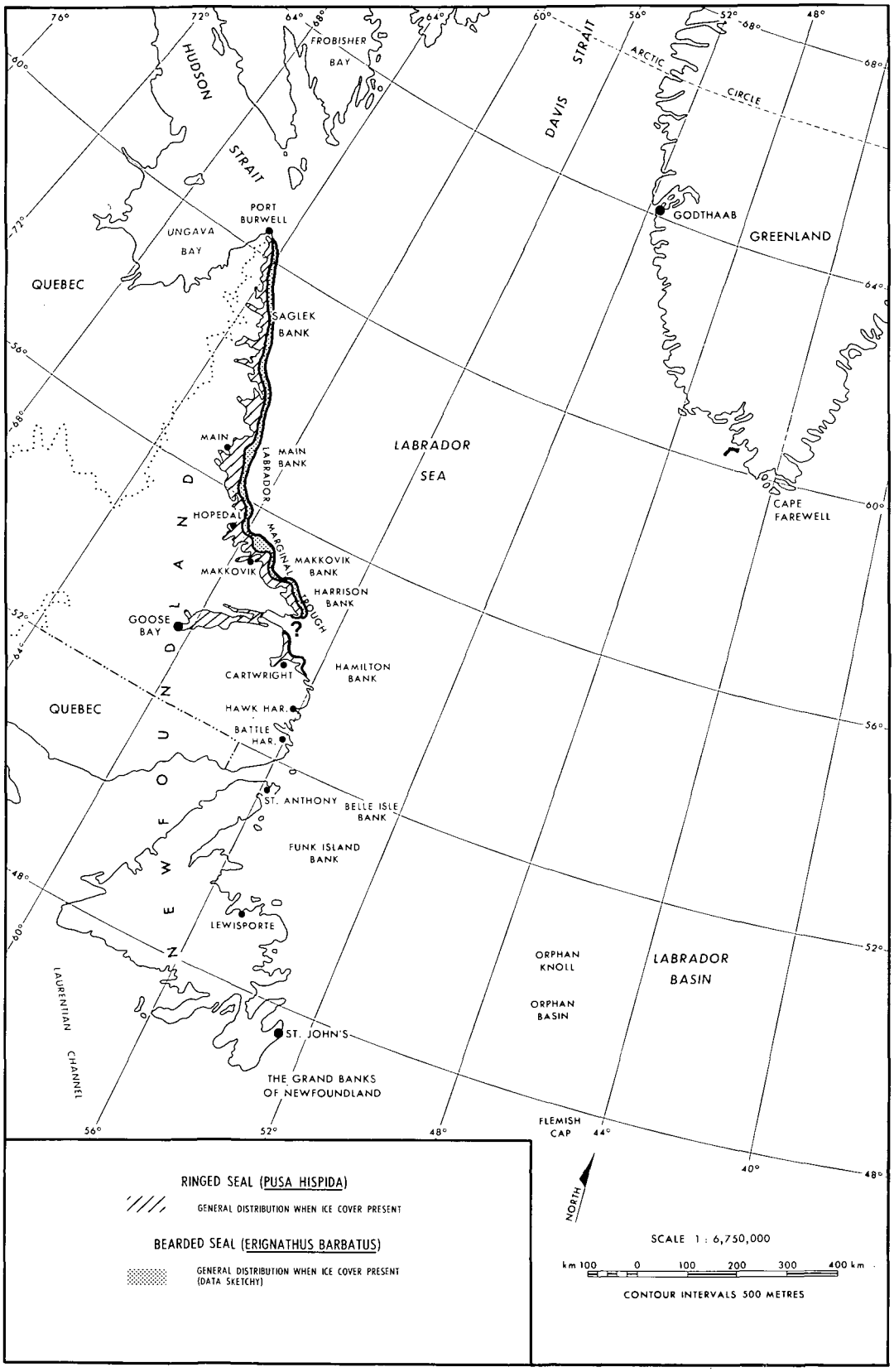


FIGURE A.8.8 Source: Northland Associates, 1977

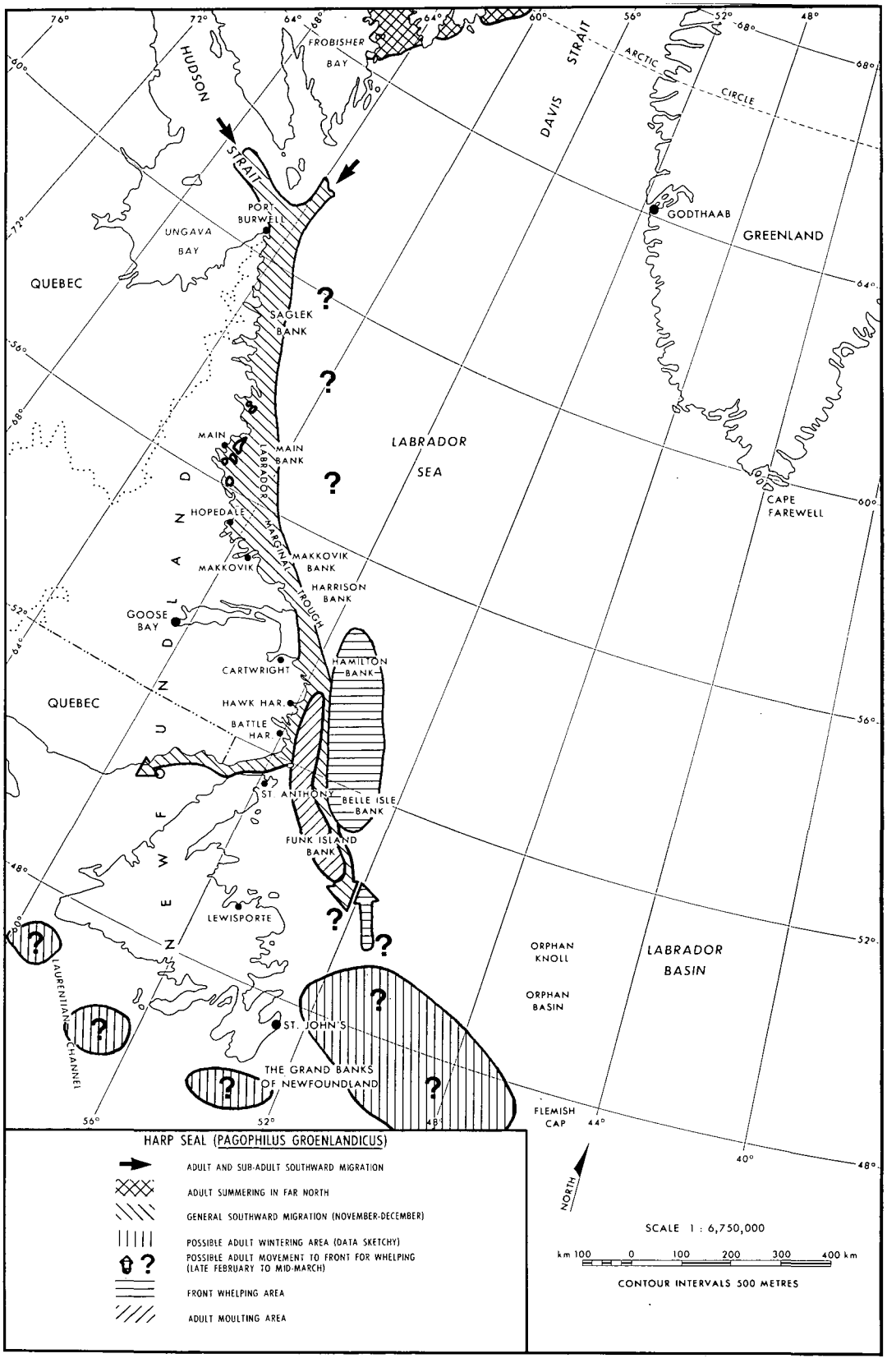


FIGURE A.8.9 Source: Northland Associates, 1977

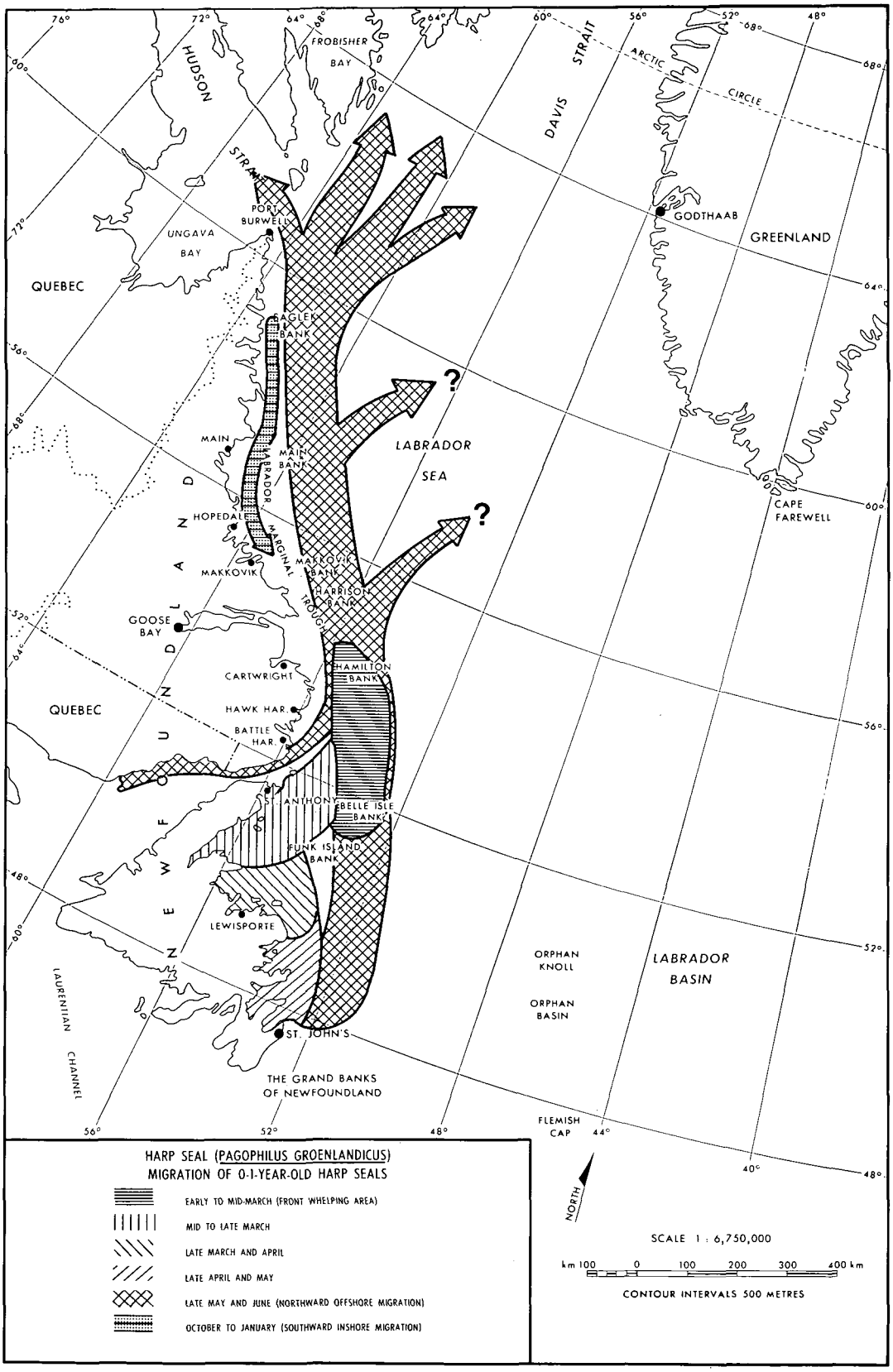


FIGURE A.8.10 Source: Northland associates, 1977

TABLE A.8.1 WEEKLY LANDINGS OF CHAR AND SALMON AT THE NAIN FISH PLANT, 1974 and 1975.

Fishing week		Landings (kg)		Man-weeks fished		Catch/man-week (kg)	
		char	salmon	char	salmon	char	salmon
1974							
1	July 7-13	12 902		55		235	
2	July 14-20	11 503		55		209	
3	July 21-27	16 248	285	63	12	258	24
4	July 28-3	9 748	2 795	71	43	155	65
5	Aug. 4-10	13 275	3 977	78	61	170	65
6	Aug. 11-17	13 574	3 502	84	52	162	67
7	Aug. 18-24	13 285	2 254	59	52	225	43
8	Aug. 25-31	6 982	3 821	57	48	122	80
9	Sept. 1-7	717	4 012	27	35	27	115
10	Sept. 8-14	39	2 486	8	27	5	92
11	Sept. 15-21	4	1 525	2	20	2	76
12	Sept. 22-28		566		10		
SUMMARY		98 277	25 223	559	360	176	70
1975							
1	June 29-5	96	31	1	1	96	31
2	July 6-12	9 601	14	27	1	356	14
3	July 13-19	9 000	4	37	1	243	4
4	July 20-26	4 648	4 079	33	27	141	151
5	July 27-2	2 512	12 769	42	53	60	241
6	Aug. 3-9	3 687	15 570	52	75	71	208
7	Aug. 10-16	3 032	4 728	33	44	92	107
8	Aug. 17-23	2 576	9 361	45	67	57	140
9	Aug. 24-30	453	2 779	25	45	18	62
10	Aug. 31-6	14	1 149	4	18	4	64
11	Sept. 7-13	2	753	2	12	1	63
12	Sept. 14-20		587		5		117
13	Sept. 21-27		184		2		77
SUMMARY		35 621	52 008	301	351	118	148

Source: Coady and Best, 1976

TABLE A.8.2 AVERAGE ANNUAL LANDINGS (BY VOLUME AND VALUE) FOR 1974-76 (IN SECTION 50*)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	HERRING t	HERRING $	CAPELIN t	CAPELIN $	HALIBUT t	HALIBUT $	TOTALS** t	TOTALS** value ($)
June	214	47 026	15	22 917	18	2 299	7	375			254	72 617
July	553	118 600	79	106 965	45	4 820	14	515	.1	70	691	230 973
Aug.	693	147 127	3	4 604	66	7 798					762	159 529
Sept.	239	52 000	.1	69	118	13 275					357	65 344
Oct.	76	17 061	.1	69	16	1 840					92	18 970
Nov.					3	262					3	262
TOTALS	1 775	381 814	97.2	134 624	266	30 294	21	890	.1	70	2 159	547 695

*For area covered, See Figure 8.2
**plaice also landed in very small quantities

TABLE A.8.3 AVERAGE ANNUAL LANDINGS (BY VOLUME AND VALUE) FOR 1974-76 (IN SECTION 51*)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	HERRING t	HERRING $	TROUT t	TROUT $	TOTALS** t	TOTALS** value ($)
May			.1	299					.1	299
June	57	13 317	47	68 030	8	740	.4	478	113	82 565
July	461	96 712	298	403 133	4	386	6	5 158	770	505 412
Aug.	774	166 708	4	5 493	175	18 701	.3	191	954	191 093
Sept.	151	33 490	1	1 144	152	14 857			304	49 491
Oct.	70	15 901			51	4 417			121	20 318
Nov.	4	981			31	2 777			36	2 758
Dec.	1	238							1	238
TOTALS	1 518	327 347	350.1	478 099	421	41 878	6.7	5 827	2 299.1	853 174

*For area covered, See Figure 8.2
**capelin, plaice, and hake also landed in very small quantities

TABLE A.8.4 AVERAGE ANNUAL LANDINGS (BY VOLUME AND VALUE) FOR 1974-76 (IN SECTION 52*)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	CHAR t	CHAR $	TROUT t	TROUT $	TOTAL** t	TOTAL** value ($)
June			3	4 735			.2	192	3	4 927
July	250	66 125	144	200 398	1	316	13	10 685	407	277 524
Aug.	548	138 625	18	22 922	3	1 484	2	1 492	571	329 145
Sept.	242	60 735	2	2 167	.1	11	.3	234	244	63 147
Oct.	303	78 138							303	78 138
Nov.	45	11 235							45	11 235
TOTALS	1 388	345 858	167	230 222	4.1	1 811	15.5	12 603	1 573	764 116

*For area covered, See Figure 8.7
**plaice and capelin also landed in very small quantities

TABLE A.8.5 AVERAGE ANNUAL LANDINGS (BY VOLUME) FOR 1970-75 (IN SECTION 53*)

Groundfish	Pelagics		
Cod (metric tonnes)	Salmon (metric tonnes)	Char (metric tonnes)	TOTALS**
169	65	110	344 m. tons

*For area covered, see Figure 8.2
**Greenland turbot also landed in very small quantities.

N.B.: Format of this table differs from the others in the series.
Data for this table are from Coady and Best, 1976. These figures are more comprehensive than those used in compilation of Tables A.8.2; A.8.3; A.8.4 since Coady and Best were engaged in an intensive study of the fishery resource (particularly salmon and char) in southern Labrador. Data for other tables are from files of the Economics and Intelligence Branch of Federal Fisheries.

TABLE A.8.6 AREA BREAKDOWN OF NAIN CHAR AND SALMON LANDINGS[1]

Area	Arctic Char								Salmon							
	Total catch[2] (kg)		Man-weeks fished		Net-weeks fished		Average number of weeks fished per fisherman	Average number of nets used per fisherman	Total catch[2] (kg)		Man-weeks fished		Net-weeks fished		Average number of weeks fished per fisherman	Average number of nets used per fisherman
	1974	1975	1974	1975	1974	1975			1974	1975	1974	1975	1974	1975		
Cutthroat	10 194	2 180	95	47	194	88	3.8	2.0	7 779	19 456	94	81	202	150	3.0	2.1
Okak	27 621	1 898	105	15	155	32	3.5	1.5	1 175	2 854	57	17	81	35	2.5	1.8
Tasiuyak	1 183	-	15	-	15	-	1.8	1.0	6	-	1	-	1	-	1.0	1.0
Kiglapaits	4 138	1 213	26	32	62	63	1.8	2.4	4 140	7 683	29	48	71	100	2.5	2.4
Black Island	3 439	1 694	60	62	152	195	4.6	2.5	6 430	8 793	90	86	228	291	6.9	2.5
Webb Bay	468	672	1	5	3	8	1.0	3.0	-	69	-	4	-	7	-	1.8
Tikkoatokak	8 032	22 335	28	76	47	131	2.0	1.7	6	1 521	1	8	1	14	1.0	1.0
Dog Island	2 144	527	38	40	96	133	2.9	2.6	3 724	10 028	43	85	121	258	2.4	2.7
Nain Bay	10 049	-	37	-	65	-	1.6	1.8	-	-	-	-	-	-	-	-
Anaktalik	6 307	2 055	28	10	50	15	2.3	1.8	-	-	-	-	-	-	-	-
Voisey Bay	16 165	192	64	2	117	4	2.4	2.0	364	-	9	-	27	-	1.8	3.0
Anton's Point	7 367	2 814	34	20	53	39	3.1	1.6	-	1 037	-	13	-	29	-	2.4
SUMMARY	97 107	35 580	531	309	1 009	708	Av. 2.6	Av. 2.0	23 624	51 441	324	342	732	884	Av. 2.6	Av. 2.1

(1) Coady and Best, 1976
(2) Gutted, Heads on weight

TABLE A.8.7 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 201)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	TROUT t	TROUT $	HERRING t	HERRING $	CHAR t	CHAR $	TOTALS* t	TOTALS* value ($)
June	57	13 317	50	218 547	.5	478	8	740			116	87 384
July	509	107 720	301	408 075	6	4 963	4	386	4	1 943	825	523 110
Aug.	685	147 001	5	5 659	.2	191	175	18 701			1 293	171 561
Sept.	151	33 490	1	1 144			152	14 857			304	49 490
Oct.	65	14 642					16	1 432			81	16 074
Nov.	4	981					10	759			14	1 740
Dec.	1	238									1	238
TOTALS	1 472	317 389	357	633 425	6.7	5 632	365	36 875	4	1 943	2 634	844 597

*Other species taken in very small quantities in this unit are: capelin, plaice white hake, redfish, and Greenland turbot.

TABLE A.8.8 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 202)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	PLAICE t	PLAICE $	SHRIMP t	SHRIMP $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS* t	TOTALS* value ($)
Sept.			3	302	6	1 028	6	3 287	2	217	17	4 834
Oct.	.4	88	.6	75	3	585			4	649	8	1 397
Nov.			.1	10	.1	18					1	100
TOTALS	.4	88	3.7	387	9.1	1 631	6	3 287	6	866	26	6 331

*Other species taken in small quantities are grey sole, and catfish

TABLE A.8.9 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 203*)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	SALMON t	SALMON $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS** t	TOTALS** value ($)
Feb.	52	9 385							52	9 446
June	1	186	.2	20			5	547	6	792
July					.1	200			.1	200
Aug.			781	102 433					781	102 433
Nov.			1	159					2	305
Dec.	2	233	8	1 046					10	1 303
TOTALS	55	9 804	790.2	103 658	.1	200	5	547	851.1	114 479

*1976 data only
**Other species taken in small quantities are: grey sole, catfish, and plaice.

TABLE A.8.10 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 204

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	REDFISH t	REDFISH $	GREY SOLE t	GREY SOLE $	TOTALS*** t	TOTALS*** value ($)
July*			.1	112					.1	112
Feb.**	22	3 795			10	1 158	9	1 627	44	6 947
TOTALS	22	3 795	.1	112	10	1 158	9	1 627	44.1	7 059

*1975 data only
**1976 data only
***Other species taken in small quantities are: plaice, Greenland turbot, and catfish.

TABLE A.8.11 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 206*)

Month	SALMON Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS** t	TOTALS** value ($)
July	1	1 021					1	1 021
Sept.			6	760	1	112	7	872
Oct.			13	1 660	6	793	19	2 459
TOTALS	1	1 021	19	2 420	7	905	27	4 352

*1976 data only
**Other species taken in small quantities are: catfish

TABLE A.8.12 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 207)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	SHRIMP t	SHRIMP $	TOTAL*** t	TOTAL*** value ($)
July*	.1	13			1	148	2	673	3	860
Aug.*			2	208	3	392	1	280	6	887
Oct.**			10	1 133	5	616	14	8 469	30	10 218
Nov.**					.4	41			.4	57
TOTALS	.1	13	12	1 341	9.4	1 197	17	9 422	39.4	12 022

*1975 data only
**1976 data only
***Other species taken in small quantities are: plaice, and grey sole.

TABLE A.8.13 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 208)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	CHAR t	CHAR $	TROUT t	TROUT $	TOTAL* t	TOTAL* value ($)
June			3	4 642			.2	192	11	7 999
July	154	40 498	141	196 362	.5	280	13	10 480	308	247 620
Aug.	399	98 865	18	22 922	3	1 484	2	1 492	422	123 461
Sept.	130	31 690	2	2 150			.3	234	133	34 189
Oct.	165	42 466							167	42 586
Nov.	31	7 911							31	7 911
TOTALS	879	221 430	164	226 076	3.5	1 764	15.5	12 398	1 072	463 766

*Other species taken in small quantities are: capelin, plaice, haddock, grey sole, and herring.

TABLE A.8.14 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 209)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	CHAR t	CHAR $	TROUT t	TROUT $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS t	TOTALS value ($)
July	96	25 637	23	34 249	12	6 683	.6	433			132	67 002
Aug.	160	42 251	20	28 825	8	4 550	.5	379	.2	23	189	76 028
Sept.	114	29 562	2	3 138	.3	149	.2	190	3	404	120	33 443
Oct.	143	36 913									143	36 913
Nov.	13	3 324									13	3 324
TOTALS	526	137 687	45	66 212	20.3	11 382	1.3	1 002	3.2	427	597	216 710

TABLE A.8.15 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 210*)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS** t	TOTALS** value ($)
Nov.			.2	24	1	107	1	137
Dec.	.2	46	6	792	12	1 437	19	2 452
TOTALS	.2	46	6.2	816	13	1 544	20	2 589

*1976 data only

**Other species taken in small quantities are: plaice, grey sole, halibut and catfish.

TABLE A.8.16 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 211*)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	TURBOT t	TURBOT $	PLAICE t	PLAICE $	TOTALS** t	TOTALS** value ($)
Nov.			3	356	.8	91	.3	38	4	496
Dec.	2	366	79	9 857	47	6 244	.2	41	128	16 591
TOTALS	2	366	82	10 213	47.8	6 335	.5	89	132	17 087

*1976 data only

**Other species taken in small quantities are: grey sole, and catfish.

TABLE A.8.17 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 212)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	CHAR t	CHAR $	TROUT t	TROUT $	TOTALS t	TOTALS value ($)
July	.2	47	8	9 528	24	11 539	.2	139	32	21 253
Aug.	.5	100	11	14 210	19	8 983	.3	233	31	23 526
Sept.	2	384	1	1 502	5	191	.2	117	8	2 194
TOTALS	2.7	531	20	25 240	48	20 713	.7	489	71	46 973

TABLE A.8.18 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 213*)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	PLAICE t	PLAICE $	TOTAL** t	TOTAL** value ($)
Nov.	7	1 463	15	2 005	9	1 110	2	434	36	5 283
Dec.	2	345	1	136	2	185	3	654	8	1 389
TOTALS	9	1 808	16	2 141	11	1 295	5	1 088	44	6 672

*1976 data only
**Other species taken in small quantities in this unit are: grey sole, cusk, catfish, white hake and haddock.

TABLE A.8.19 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 214*)

Month	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	PLAICE t	PLAICE $	TOTAL** t	TOTAL** value ($)
Nov.	1	284	63	7 423	38	4 506	1	166	105	12 644
TOTALS	1	284	63	7 423	38	4 506	1	166	105	12 644

*1976 data only
**Other species taken in small quantities in this unit are: halibut, catfish, other unspecified species.

TABLE A.8.20 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 215)

Month	COD Metric tonnes (t)	value ($)	SALMON t	SALMON $	CHAR t	CHAR $	TROUT t	TROUT $	TOTALS t	TOTALS value ($)
July			10	14 232	37	16 931	.1	70	47	31 233
Aug.	.5	145	32	55 471	10	4 236			43	59 852
Sept.	1	185	4	4 698	.2	59			5	4 942
TOTALS	1.5	330	46	74 401	47.2	21 226	.1	70	95	96 027

TABLE A.8.21 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 216*)

Month ($)	COD Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	TOTALS** t	TOTALS** value
Nov.	.2	51	10	1 287	5	653	15	2 001
TOTALS	.2	51	10	1 287	5	653	15	2 001

*1976 data only
**Other species taken in very small quantities are: halibut, plaice, and catfish.

TABLE A.8.22 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 218*)

Month	CHAR Metric tonnes (t)	value ($)	REDFISH t	REDFISH $	GREENLAND TURBOT t	GREENLAND TURBOT $	UNSPECIFIED t	UNSPECIFIED $	TOTALS t	TOTALS value ($)
July	2	780							2	780
Oct.			13	1 660	9	1 141	6	334	28	3 135
TOTALS	2	780	13	1 660	9	1 141	6	334	30	3 915

*1976 data only

TABLE A.8.23 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 219*)

Month	REDFISH Metric tonnes (t)	value ($)	GREENLAND TURBOT UNSPECIFIED t	$	t	$	TOTALS t	(value ($)
Oct.	7	885	7	942	7	390	21	2 217
Nov.	3	447	11	1 372			14	1 819
TOTALS	10	1 332	18	2 314	7	390	35	4 036

*1976 data only

TABLE A.8.24 AVERAGE ANNUAL CATCH (BY VOLUME AND VALUE) FOR 1974-76 (IN ICNAF UNIT 224*)

Month	REDFISH Metric tonnes (t)	value ($)	GREENLAND TURBOT t	$	TOTALS t	value ($)
Oct.	17	2 158	11	1 438	28	3 596
TOTALS	17	2 158	11	1 438	28	3 596

*1976 data only

TABLE A.8.25 FISHERY VESSEL OPERATION IN ICNAF DIVISION 2G DURING 1977

	CANADA	FOREIGN(*)														TOTALS	
		USSR	FRG	F	P	PR	GDR	UK	N	S	B	D	R	C	J	CAN.	FOR.
Jan.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mar.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
July	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	3
Aug.	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	2
Sept.	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
Oct.	-	11	-	-	-	-	2	-	-	-	-	-	-	-	-	-	13
Nov.	-	2	-	-	-	-	3	-	-	-	-	-	-	-	-	-	5
Dec.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*USSR - U.S.S.R.
FRG - Fed. Rep. of Germany
F - France
P - Poland
PR - Portugal
GDR - East Germany
UK - United Kingdom
N - Norway
S - Spain
B - Bulgaria
D - Denmark
R - Romania
C - Cuba
J - Japan

TABLE A.8.26 FISHERY VESSEL OPERATION IN ICNAF DIVISION 2H DURING 1977

	CANADA	FOREIGN(*)														TOTALS	
		USSR	FRG	F	P	PR	GDR	UK	N	S	B	D	R	C	J	CAN.	FOR.
Jan.	-	3	9	1	1	-	-	-	-	-	-	-	-	-	-	-	14
Feb.	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Mar.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
April	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
May	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	3
June	-	1	-	-	3	-	3	-	-	-	-	-	-	-	-	-	7
July	-	-	-	-	3	-	3	2	-	-	-	-	-	-	-	-	8
Aug.	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3
Sept.	3	1	2	-	3	-	-	-	-	-	-	-	-	-	-	3	6
Oct.	1	2	-	-	2	-	3	-	2	-	-	-	-	-	-	1	9
Nov.	1	2	-	-	-	-	3	-	3	-	-	-	-	-	-	1	8
Dec.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Abbreviations as in Table A.8.25

TABLE A.8.27 FISHERY VESSEL OPERATION IN ICNAF DIVISION 2J DURING 1977

	CANADA	FOREIGN(*)														TOTALS	
		USSR	FRG	F	P	PR	GDR	UK	N	S	B	D	R	C	J	CAN.	FOR.
Jan.	-	3	9	1	1	-	-	-	-	-	-	-	-	-	-	-	14
Feb.	4	22	17	5	9	15	9	-	-	6	-	-	-	-	-	4	83
Mar.	-	19	16	2	11	8	-	1	-	2	1	-	-	-	-	-	60
April	1	-	5	-	4	8	-	-	-	-	1	-	-	-	-	1	18
May	-	-	-	-	4	8	-	-	-	1	-	1	-	-	-	-	14
June	-	1	-	-	4	14	-	4	-	-	-	-	-	-	-	-	23
July	1	6	-	-	2	-	-	3	1	-	-	-	-	-	-	1	12
Aug.	1	32	-	-	-	-	1	2	-	-	4	-	1	5	-	1	45
Sept.	8	55	1	-	-	-	1	-	-	-	2	-	2	5	3	8	69
Oct.	1	53	-	-	-	4	-	-	-	-	-	-	3	4	3	1	67
Nov.	-	54	-	-	-	-	4	-	-	-	-	-	-	2	-	-	60
Dec.	1	4	-	-	-	-	1	-	-	-	-	-	-	-	-	1	5

*Abbreviations as in Table A.8.25

TABLE A.8.28 SEALS LANDED BY LANDSMEN IN AREA O (LABRADOR), 1974-1977

	HARPS								HOODS		OTHER*		TOTALS	
	WHITE COATS		BEATERS		BEDLAMERS		OLD HARPS							
	NO.	$	NO.	$	NO.	$	NO.	$	NO.	$	NO.	$	NO.	$
1974	-	-	5	50	333	5 971	458	8 795	-	-	1 679	29 537	2 475	44 553
1975	-	-	200	4 315	172	4 472	329	9 365	2	60	2 750	91 206	3 453	109 418
1976	2	10	664	10 650	296	5 192	880	19 939	2	40	3 302	96 767	5 145	132 598
1977	50	450	221	3 173	285	4 190	331	3 335	-	-	2 302	80 567	3 187	91 715
AVERAGES	13	$115.00	272.5	$ 4,547.00	271.5	$4,956.23	499.5	$10,358.50	1	$25.00	2,508.3	$74,519.25	3,565	$ 94,571.00

*90 percent ringed

TABLE A.8.29

RECORDED NUMBERS* OF RINGED SEALS (*Pusa hispida*)
HARVESTED IN SELECTED LABRADOR COMMUNITIES
(Data from Economics Branch, Fisheries and Marine Service, St. John's, Nfld.)

	1972	1973	1974	1975	1976
North West River-Goose Bay	268	-	256	188	120
Rigolet	355	407	354	152	247
Makkovik	141	257	492	565	469
Postville	18	48	53	-	56
Hopedale	232	86	53	340	550
Davis Inlet	37	12	53	9	20
Nain	102	788	418	1400	1632

RECORDED NUMBERS* OF HARP SEALS (*Pagophilus groenlandicus*)
HARVESTED IN SELECTED LABRADOR COMMUNITIES
(Data from Economics Branch, Fisheries and Marine Service, St. John's, Nfld.)

	1972	1973	1974	1975	1976
North West River-Goose Bay	4	-	-	-	10
Rigolet	16	13	55	13	28
Makkovik	10	24	118	200	12
Postville	5	17	8	-	14
Hopedale	25	21	26	67	45
Davis Inlet	-	-	5	-	5
Nain	6	24	110	101	182

RECORDED NUMBERS* OF BEARDED SEALS (*Erignathus barbatus*)
HOODED SEALS (*Cystophora cristata*) AND HARBOUR SEALS (*Phoca vitulina*)
FROM SELECTED LABRADOR COMMUNITIES
(Data from Economics Branch, Fisheries and Marine Service, St. John's, Nfld.)

	1975			1976		
	Bearded	Hooded	Harbour	Bearded	Hooded	Harbour
North West River-Goose Bay						5
Rigolet	1		1			
Makkovik			1	10		25
Postville						
Hopedale						5
Davis Inlet						
Nain	3		4	7		9
Cartwright					6	

*Subject to error due to inter-community trading of pelts, domestic use of pelts, etc.

TABLE A.8.30 INSHORE FISHING ACTIVITY*, SECTION 50, LABRADOR COAST

Fishing Location	Casual 4-9 wk.	10-21 wk.	Part-time 22-28 wk.	Total Fishermen	Species
Forteau	1	28		29	cod, herring, salmon
English Point		10		10	cod, herring, salmon
L'Anse Amour	1	4		4	cod, herring, salmon
Buckleys Point		9	1	10	cod, herring, salmon
Fox Cove		3		3	cod, herring, salmon
L'Anse au Loup	13	28	17	58	cod, herring, salmon
Capstan Island	2	6	3	11	cod, herring, salmon
West St. Modeste	6	20		26	cod, herring, salmon
Pinware		10	8	18	cod, herring, salmon
Red Bay		50	1	51	cod, herring, salmon
Carrols Cove		4		4	cod, herring, salmon
Cape St. Charles	1	19		20	cod, herring, salmon, mackerel
TOTALS	24	191	30	245	cod (234)** herring (232) salmon (121) salt cod (34) mackerel (19)

*Based on 1973 statistics

**Number of fishermen active in this species

TABLE A.8.31 INSHORE FISHING ACTIVITY*, SECTION 51, LABRADOR COAST

Fishing Location	Casual 4-9 wk.	10-21 wk.	Part-time 22-28 wk.	Total Fishermen	Species
Marys Harbour	5	47		52	salmon, cod, herring, mackerel
Fox Harbour	1	34	2	37	salmon, cod, herring, mackerel
Port Hope Simpson	1	60	2	63	salmon, cod, herring, mackerel
Williams Harbour		9	2	11	salmon, cod, herring
Pinsents Arm		2		2	salmon, cod, herring, mackerel
Square Islands		18		18	salmon, cod, herring, mackerel
Dead Island		3		3	salmon, cod, herring, mackerel
Triangle Island		4		4	salmon, cod, herring, mackerel
Snug Harbour		5	2	7	salmon, cod, herring, mackerel
Tub Harbour		1		1	salmon, cod, herring, mackerel
Venison Tickle		2		2	salmon, cod
Hawkes Harbour		2		2	salmon, cod
Batteau		2		2	salmon, cod
Black Tickle		29	5	34	salmon, cod, herring
Domino		1		1	salmon, cod
Spotted Island		4		4	salmon, cod
TOTALS	7	223	13	243	salmon (241)** salt cod (231) herring (174) mackerel (145) fresh cod (100)

*Based on 1973 statistics

**Number of fishermen active in this species

TABLE A.8.32 INSHORE FISHING ACTIVITY*, SECTION 52, LABRADOR COAST

Fishing Location	Casual 4-9 wk.	10-21 wk.	Part-time 22-28 wk.	Total Fishermen	Species
Cartwright	20	87		107	cod, salmon, trout herring
Separation Point	1	1		2	salmon, trout***
Independent		4		4	salmon, trout
Packs Harbour	1	9		10	salmon, trout, cod
West Bay		2		2	salmon, trout, cod
Fish Cove		1		1	salmon, cod
Winters Cove		6		6	salmon, trout, cod
Rigolet		51		51	salmon, trout, cod
Bluff Head Cove		2		2	salmon, trout, cod
Snack Cove	1	1		2	salmon
Paradise River	5	9		14	salmon, trout
TOTALS	28	173		201	salmon (201)** salt cod (95) trout (62) fresh cod (1)

*Based on 1973 statistics
**Number of fishermen active in this region
***Trout represents brook trout and Arctic char

TABLE A.8.33 INSHORE FISHING ACTIVITY*, SECTION 53, LABRADOR COAST

Fishing Location	Casual 4-9 wk.	10-21 wk.	Part-time 22-28 wk.	Total Fishermen	Species**
Makkovik	7	18		25	salmon, trout
Postville	4	15		19	salmon, trout, cod
Hopedale	1	32		33	salmon, trout, cod
Davis Inlet		4		4	salmon, trout -
Nain	40	30		70	salmon, trout, cod, smelt
Rattlers Bight		3		3	salmon, trout, cod
TOTALS	52	102		154	salmon (130)*** trout (125) salt cod (6) fresh cod (4) smelt (2)

*Based on 1973 statistics
**Trout represents Arctic char only
***Number of fishermen active in this species

TABLE A.8.34 INSHORE FISHING GEAR* AND VALUE BY FISHING LOCATION, STRAITS

	Cod nets	Cod traps	Hand lines	Trawl lines	Herring gill nets	Herring beach seines	Salmon gill nets	Salmon traps	Trout nets	Capelin seines	Scallop dredges	Fish stores	Fish wharves	Fish stages	Fish flakes	Total** Value
L'Anse au Clair	61		31	227	41					3	35					27,186
Forteau	23	2	62	370	117		1					2	2			33,696
Buckles Point	33	3	16	185	17							4	1	4		25,878
English Point	32	1	20	176	19		4					1	1			16,800
L'Anse Amour	29	3	8	110	21		8	1		1		1				22,168
Fox Cove	1	2	4	60	5		4			1		1		1		10,356
L'Anse au Loup	265	4	96	807	83		6			1		18		14		118,236
Capstan Island	60	1	20	185	26		3					1				22,494
West St. Modeste	207	4	38	265	51	1	24	1			8	6		1		84,154
Pinware	28	4	36	250	16		34			1		1				30,658
Red Bay	87	20	87	682	130		209			2		21		21		170,378
Carrols Cove	7	2			4		14					2		2	2	12,640
Cape St. Charles	47	29	33	115	33		105		29			16	3	14	11	128,262
TOTALS	880	75	451	3 432	563	1	412	2	29	9	43	74	7	57	13	$702,906

*1973 data
**These figures are double the 1973 values in order to give a realistic value for the gear in 1978.

TABLE A.8.35 INSHORE FISHING GEAR AND VALUE BY FISHING LOCATION, SOUTHERN LABRADOR

	Cod nets	Cod traps	Hand lines	Trawl lines	Herring gill nets	Herring beach seines	Salmon gill nets	Salmon traps	Trout nets	Capelin seines	Scallop dredges	Fish stores	Fish wharves	Fish stages	Fish flakes	Total Value
Marys Harbour	138	51	39	109	63		230					19	1	24	3	225,608
Fox Harbour	128	24	8	20	42		240		25			18		20	6	165,072
Port Hope Simpson	126	51	24	196	73		276	16	13			27		30	6	267,132
Williams Harbour	31	14		37	11		88					5		6		64,094
Pinsents Arm	40	5	6		4		10					1	1	1		23,018
Square Islands	72	15	6		20		119					9	1	10		88,704
Dead Island	10	7		20	7		30					2	1	2	2	28,086
Triangle Harbour	12	2		35	3		45					2		2		20,394
Snug Harbour	14	3	6	22	5		43					3		3		24,072
Tub Harbour	45	2		12		2	20					1		1		23,180
Venison Tickle	4	1		14			20					2		2		10,720
Hawkes Harbour	1	1					12		3			1		1		6,682
SUB-TOTALS	621	176	89	465	228	2	1133	16	41			90	4	102	17	946,762

TABLE A.8.35 (CONTINUED) INSHORE FISHING GEAR AND VALUE BY FISHING LOCATION, SOUTHERN LABRADOR

	Cod nets	Cod traps	Hand lines	Trawl lines	Herring gill nets	Herring beach seines	Salmon gill nets	Salmon traps	Trout nets	Capelin seines	Scallop dredges	Fish stores	Fish wharves	Fish stages	Fish flakes	Total Value
Batteau	4				4		4					1		1		3,820
Black Tickle	174	10		128	12		64					14		15		96,844
Domino		1					4					1		1		4,548
Spotted Islands		1					10					1		2		6,520
Cartwright	118	9	34	49	21		332		22			38		44		186,154
Separation Point							5		1					1		1,840
Independent							12		1			1		2		5,024
Packs Harbour	2	1	2				32		7			5		5		18,252
West Bay							6		2							1,432
Fish Cove	1						6					1		1		3,172
Winter Cove	3						10		3			2				4,960
Paradise River							47		17			1		2		13,724
TOTALS	923	198	125	642	265	2	1665	16	94			155	4	176	17	1,293,052

TABLE A.8.36 INSHORE FISHING GEAR AND VALUE BY FISHING LOCATION, NORTHERN LABRADOR

	Cod nets	Cod traps	Hand lines	Trawl lines	Herring gill nets	Salmon gill nets	Salmon traps	Trout nets	Capelin seines	Scallop dredges	Fish stores	Fish wharves	Fish stages	Herring beach seines	Fish flakes	Total Value
Rigolet	2						104		52					2		28,008
Bluff Head Cove			2				2		2					1		1,292
Snack Cove							8					1				2,696
Makkovik							143		30							32,716
Postville	4		2				82		40							21,392
Hopedale	4						119		34	1						30,248
Davis Inlet							5		4							1,380
Nain	140		4				116		189							67,960
TOTALS	150		10				579		351	1		1		3		$185,692

APPENDIX TO
CHAPTER 9

PROBABILITY OF AN OIL BLOWOUT
AND
THE CONCEPT OF RISK

DRILLING SYSTEM ON THE "PELICAN"

Way of Keeping Station on "Pelican":

No mooring lines whatsoever are used to keep the Pelican on location.

The Pelican is equipped with dynamically positioned equipment which maintains her on location by means of:

- Two main propellers (Kamewa - four blades - diameter 12 feet) turning at constant speed (145 RPM) and with variable pitch (3000 HP available on each propeller).
- Three bow tunnel thrusters.
- Two stern tunnel thrusters.
  These thrusters (Kamewa) are all identical - have four blades 7.5 feet diameter - turn at constant speed 240 RPM - variable pitch (1500 HP available on each thruster).

Propellers and thrusters are under the permanent and automatic control of two computers CDP8 of Digital Equipment. The reference system is made of ultrasonic devices permitting by acoustic telemetry to define the position of the vessel in relation with transponder beacons on the sea bottom. A back-up system to the acoustic system is provided by two taut wires, the variation of which is analysed through a third back-up computer (Analog type).

Sub-Sea Equipment and BOP

The vessel is dynamically positioned and permantly changes the heading according to wind and wave conditions. No guides lines are used from the surface to the well head.

The well head structure consists of a re-entry cone 12 feet in diameter attached to the 30 in housing at the top of the 30 in conductor pipe.

The well head (Cameron) is designed for two BOP stacks: 20-3/4 in 2000 psi attached to the 20-3/4 in hanger and 13-5/8 in 10,000 psi attached to the 13-5/8 in hanger.

- The 20-3/4 in 2000 psi BOP stack comprises from the top:
  - One Hydril
  - One Double Cameron Type U, with shear rams and pipe rams.
  - One Cameron Collect Connector.
- The 13-5/8 in 10,000 psi stack comprises from the top:

- One Cameron Type A Bag Type Preventer
- One Single Cameron Type U with shear rams
- One Single Cameron Type U equipped with three pipe rams
- One Cameron Collect Connector.

- The control of the BOP stack is made by KOOMEY and MATRA - and includes:
  - One electro-hydraulic system able to operate all the functions
  - Two hydraulic systems (each capable of operating all the functions)
  - One Multiplex system "Tesuma" on all the functions
  - One acoustic system "Teltac" on four functions.

All the control pods are contained in a so-called Stab Assembly lowered at the bottom end of the riser pipe and which sits on a special receptacle at the top of each BOP stack. A special reverse guide funnel at the bottom end of the Stab Assembly permits the connection of the Stab onto the top of the BOP stack. A ball joint 20-3/4 in is located at the top of the Stab Assembly connected to a 20-3/4 in 2000 psi Cameron Collect Connector.

The risers sizes' on the vessel are: 24 in O.D. and 16 in O.D. Both have the kill and choke line integrated and are equipped with Cameron RCK riser connectors.

The Control lines of the BOP (one multiconductor electric cable, two hose bundles and one multiplex cable) are clamped on the side of the riser pipe along the kill and choke lines.

Kill and choke lines are -1/2 in O.D. 10,000 psi. Flexible hose connects the choke and kill line at the surface to the manifold and at the bottom to the Stab Assembly.

All the re-entries (BOP stack onto the wellhead or Stab Assembly on BOP stack) are made by using a specially designed TV camera.

Drilling Plant:

The main power (for dynamic positioning or for drilling) is provided by:

- Five diesel AC generators manufactured by "Societe Alsacienne de Construction Mecanique (SACM)". Type AGO V 16 E S H P each delivering 3500 HP at 1200 RPM.
- They drive self-excited and self-regulated AC generators manufactured by JEUMONT SCHNEIDER - Type SAT 89 566 delivering 3000/3200 KVA under 5.5 KV 60 cycles - 3 PH cos ρ 0.8.
- An additional power plant supplies additional power or main power when the vessel is in a port.

This power plant is made of:

- One Diesel SACM MGO V12 BZSHR delivering 950 HP at 1200 RPM
- One AC generator JEUMONT SCHNEIDER A 90 BG 750 KVA 3 Ph under 440 v 60 cycles cos ρ 0.8.

The main generators above supply electric power necessary for:

- Asynchronous motors of the propellers and thrusters
- DC motors for the drilling equipment through Thiristors converter units
- Low tension auxilliary motors through three transformers 5.5 KV/440V of 750 KVA each.

Derrick:

147 ft pyramid bolted type derrick - base 44 f 04 in x 36 in - API capacity 1,330,000 lb. (static load 12 lines).

At the top of the derrick is a Crown Block Heave Compensator, make 1HC type UNICODE.

- Maximum compensated crown block load 200 tons
- Maximum stroke of travelling block 15 ft
- Maximum static crown block load 583 tons.

The derrick is also equipped with:

- A travelling block guidance system
- A racking board capable of receiving 12,000 ft of 5 in DP in trebles and 10 stands of DC.
- An intermediate stabbing board.
- A pipe racking system.

A horizontal pipe racking system permits the storage of 13,000 feet of 5 in DP.

Two main drilling pumps:

- National Triplex 12 P 160 7 in x 12 in - each driven by two JEUMONT SCHNEIDER DC motors - 800 HP each at 1000 RPM.

From Ple and Ferrero,
1976

APPENDIX TO
CHAPTER 12

LOGISTICS CAPABILITY
LABRADOR

PORT: ST. ANTHONY - Due to its airport facilities and its northern location, St. Anthony has been included as a possible operations site.

PROVINCIAL DISTRICT:	WHITE BAY NORTH
MUNICIPAL STATUS:	INCORPORATED TOWN
POPULATION:	2941 (1976 Census)
LOCATION:	Lat. 51°22'N - Long. 55°35'W
NAVIGABLE:	Late May to December
HIGHWAY CONNECTIONS:	Route 430 (gravel and paved) to TCH
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	M.O.T.
WHARFINGER:	F. Slade

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted creosoted timber cribwork retaining rock and gravel fill.

Deck Surface: Concrete

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designated Bearing Capacity of Deck: 300 psf - 15 tons Concentrated Load

Year Constructed: 1956

Present Condition: Good

b) Shed

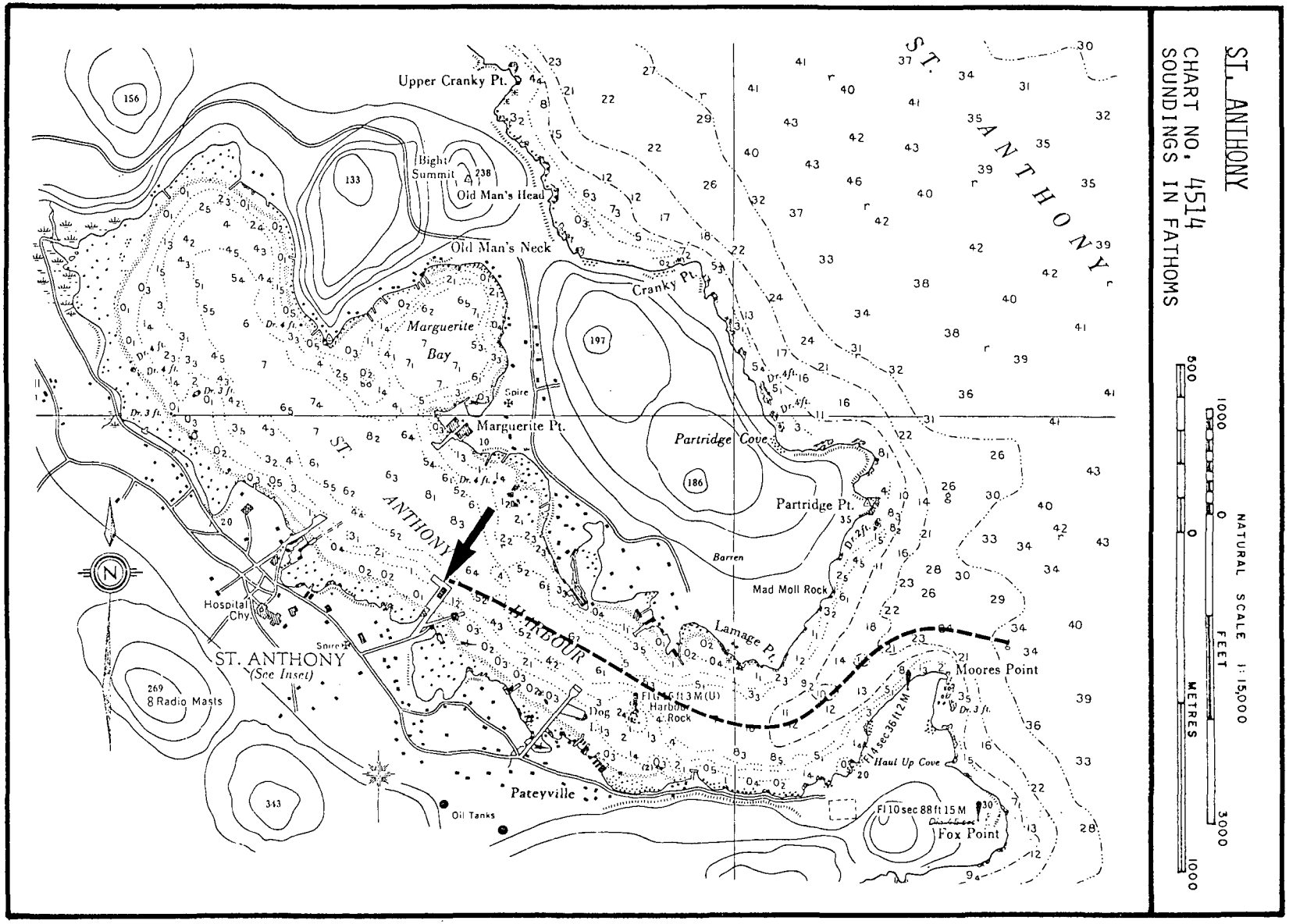
Description: Wood framed building 100' x 41' with concrete slab on grade floor. Not heated.

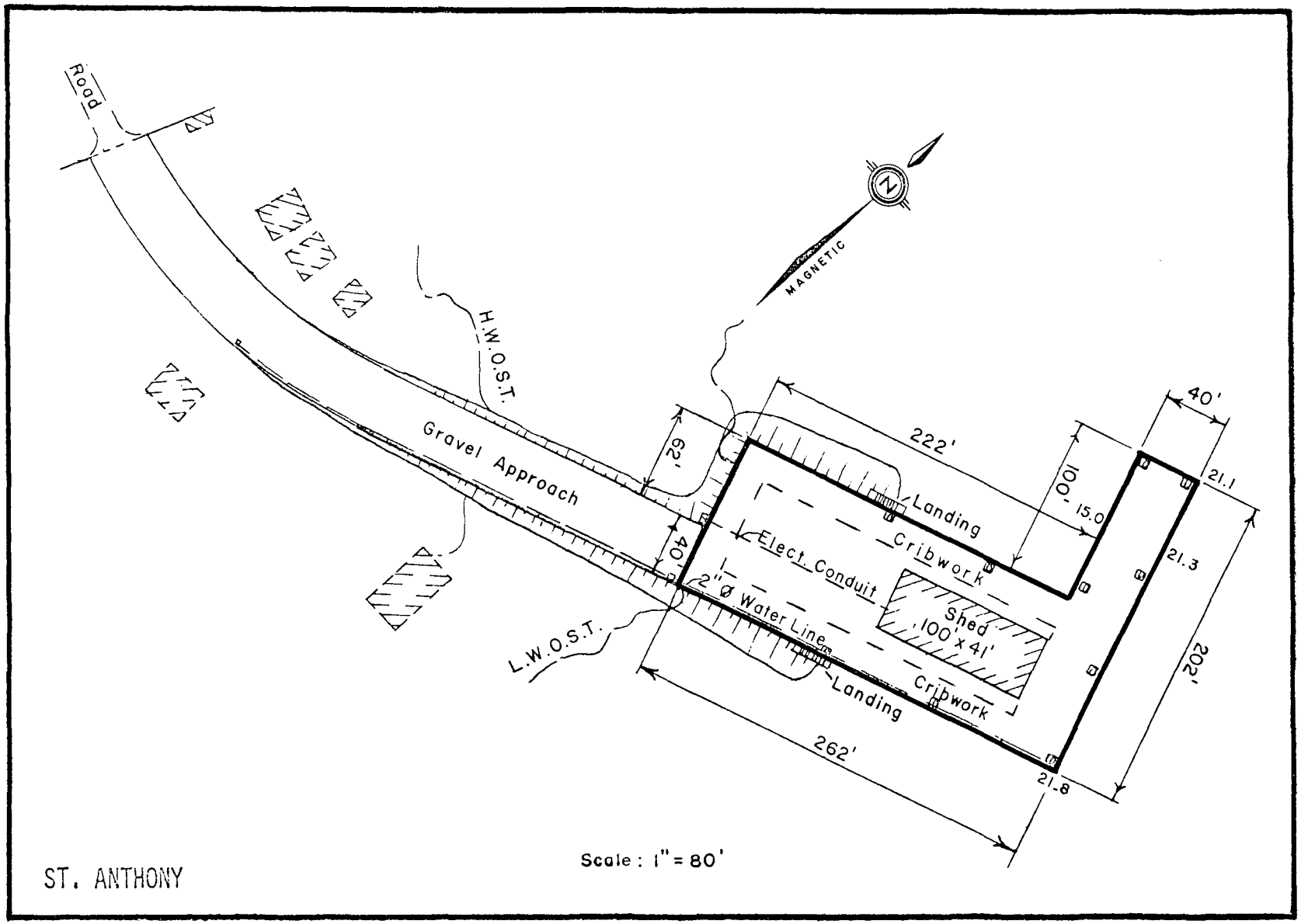
Condition: Good

METEOROLOGICAL AND HYDROGRAPHIC DATA: - Dense fogs prevail in summer and sometimes last several days. The fogs occur with east of west winds. Fog & wind effects are not significant. Tide Range (large tide): 4.5 feet

TRAFFIC DATA

Freight Handled:	In	2010 tons 1973
	Out	696 tons 1973
Passengers Handled:	In	440 1973
	Out	202 1973
Vessel Calls:	CN 179 - 1973	


ST. ANTHONY
CHART NO. 4514
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:15,000
FEET
METRES
ST. ANTHONY
Upper Cranky Pt.
Bight Summit
Old Man's Head
Old Man's Neck
Cranky Pt.
Marguerite Bay
Marguerite Pt.
Partridge Cove
Partridge Pt.
Barren
Mad Moll Rock
Lamage Pt.
Moores Point
Haul Up Cove
Fl 10 sec 88 ft 15 M
Fox Point
Harbour Rock
Dog
Pateyville
Oil Tanks
Hospital Chy.
ST. ANTHONY
(See Inset)
8 Radio Masts
ST. ANTHONY HARBOUR
Spire
156
133
238
197
186
269
343



Scale : 1" = 80'

ST. ANTHONY

PORT: BATTLE HARBOUR

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	75 (1971 Census)
LOCATION:	Lat. 52°16'N - Long. 55°35'W
NAVIGABLE:	Mid-May to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	DOE
WHARFINGER:	None

NOTE: SUMMER OCCUPANCY ONLY

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted untreated round timber cribwork.

Deck surface: Plank

Elevation of Deck Above L.W.O.S.T.: 9 feet

Designed Bearing Capacity of Deck: 200 psf - 5 tons Concentrated load

Year Constructed: 1961

Present Construction: Fair

b) Shed

Description: Good framed building 20' x 30' with wood floor. Not heated.

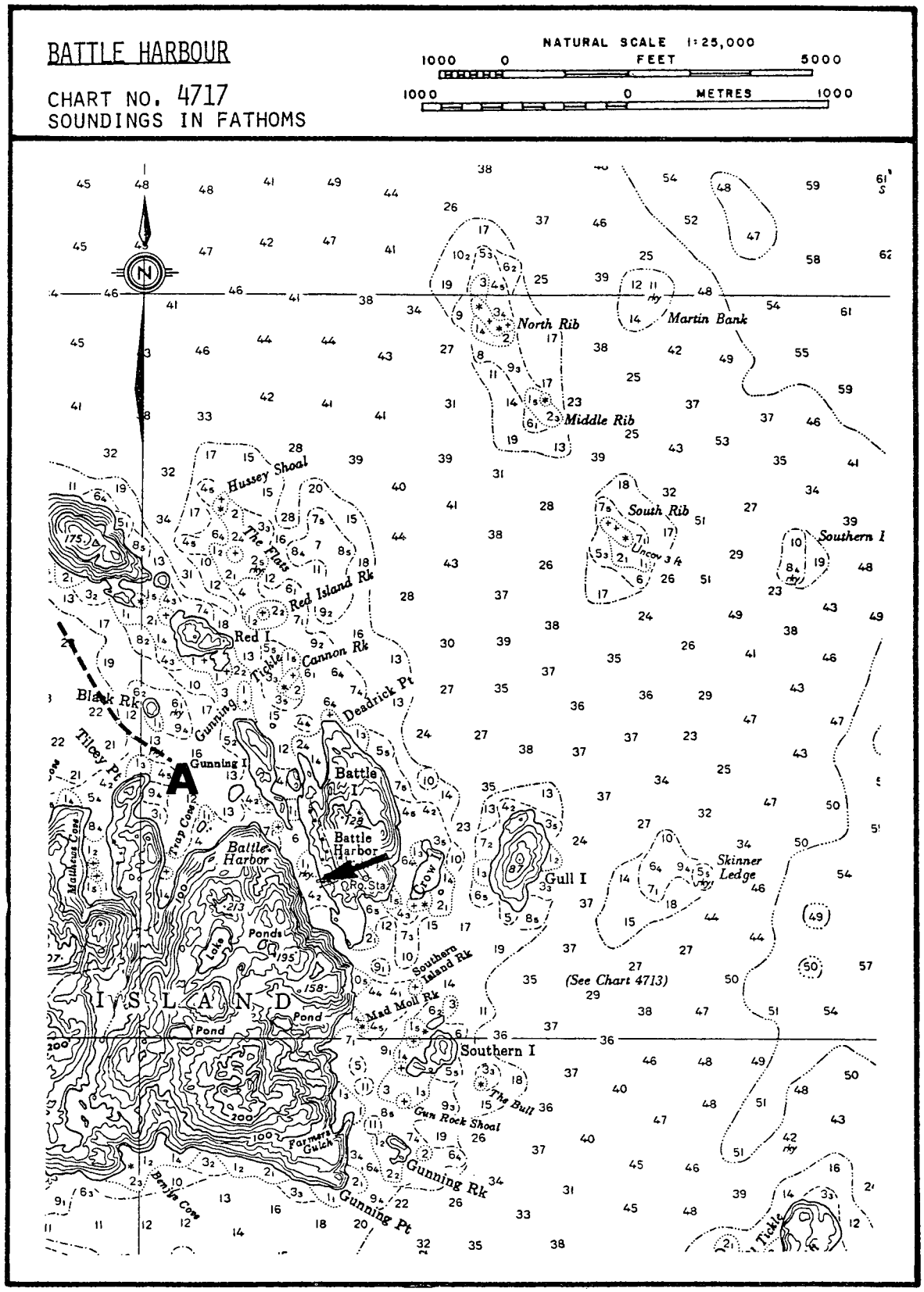
Condition: Good.

METEOROLOGICAL AND HYDROGRAPHIC DATA: - Southeasterly & southwesterly winds almost invariably bring heavy fog & heavy ground swell rolls in between the islands in autumn but is safe in summer. Wind and tide effects not significant.

Tide Range: (large tide): 5 feet

TRAFFIC DATA

Freight Handled:	In	132 tons	1973
	Out	63 tons	1973
Passengers Handled:	In	67	1973
	Out	76	1973
Vessel Calls:	CN 50		1973


BATTLE HARBOUR
CHART NO. 4717
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:25,000
1000 0 FEET 5000
1000 0 METRES 1000
North Rib
Martin Bank
Middle Rib
Hussey Shoal
South Rib
Southern I
The Flats
Red Island Rk
Red I
Tickle
Cannon Rk
Deadrick Pt
Black Rk
Gunning I
Tilley Pt
A
Battle I
Battle Harbor
Rg Sta
Trap Cove
Malkeen Cove
Gull I
Skinner Ledge
Crow
Ponds
Lake
Southern Island Rk
(See Chart 4713)
ISLAND
Mad Moll Rk
Pond
Southern I
The Bull
Gun Rock Shoal
Farmers Gulch
Gunning Rk
Gunning Pt
Benjie Cove

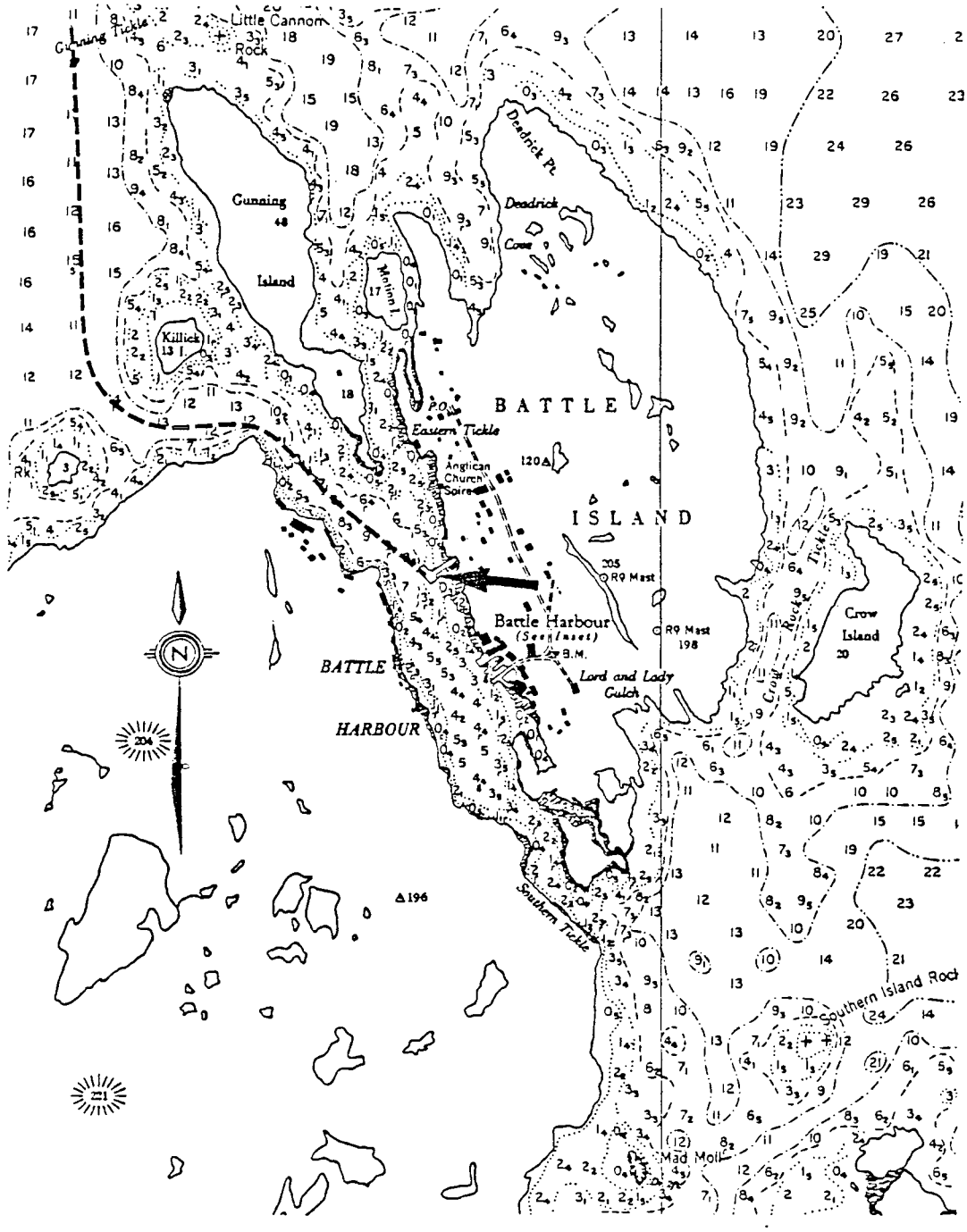
BATTLE HARBOUR

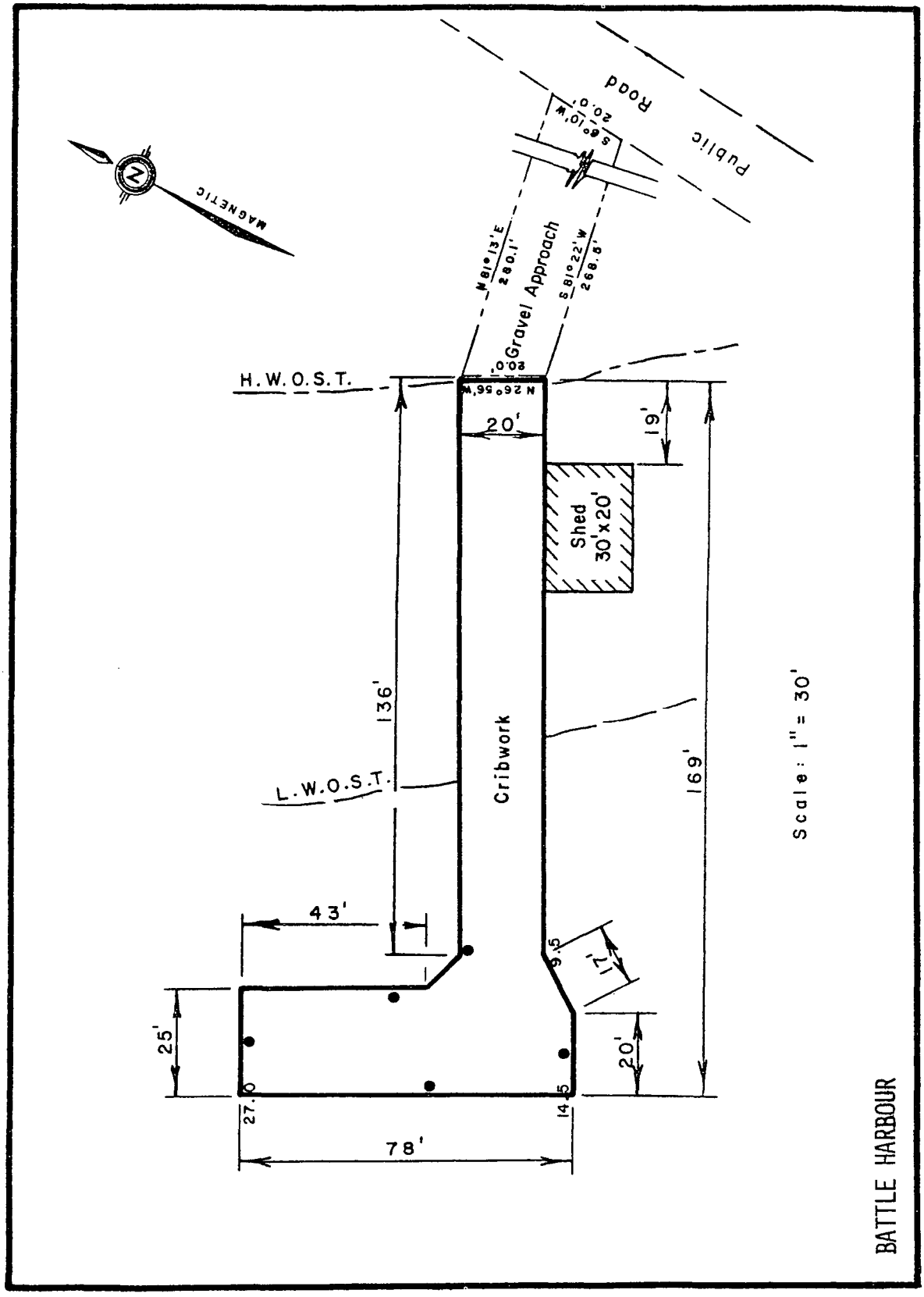
CHART NO. 4713
SOUNDINGS IN FATHOMS

NATURAL SCALE 1: 8,000

0 1000 FEET 2000

0 200 METRES 400 600




Public Road
S 86° 10' W
20.0'
MAGNETIC
N
N 81° 13' E
280.1'
Gravel Approach
S 81° 22' W
268.5'
80.0'
N 26° 56' W
H.W.O.S.T.
20'
19'
Shed
30' x 20'
136'
Cribwork
169'
L.W.O.S.T.
43'
9.5
17'
25'
20'
27.0
14.5
78'
Scale: 1" = 30'
BATTLE HARBOUR

PORT: BLANC SABLON (QUEBEC)

PROVINCIAL DISTRICT:	Saguenay
MUNICIPAL STATUS:	Unincorporated
POPULATION:	371 (1971 Census)
LOCATION:	Lat. 51°26'N - Long. 57°08'W
NAVIGABLE:	Mid May to December
HIGHWAY CONNECTIONS:	Route 510 (gravel) to Ferry to St. Barbe to 430 (gravel and paved) to T.C.H.
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	Stanley Le Templier

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted cribwork and concrete walls.

Deck surface: Concrete on approach and plank on remainder of wharf.

Elevation of Deck Above L.W.O.S.T.: 14 feet

Designed Bearing Capacity of Deck: 400 psf - 15 tons concentrated load

Year Constructed: 1969

Present Condition: Good

Sheds (2)

Description: Wood framed construction with wood floor. Not heated.

Condition: Good.

METEOROLOGICAL AND HYDROGRAPHIC DATA - Dense fogs prevail during the summer and sometimes last for several days. The fogs occur with wither west or east winds. Tidal currents of up to 3 knots are experienced through the Strait of Belle Isle but are not significant in the harbour.

Tide Range: (large tide): 5.5 feet.

TRAFFIC DATA

Freight Handled:	In	1597 tons 1973
	Out	631 tons 1973
Passengers Handled:	In	38 1973
	Out	10 1973
Vessel Calls:	CN 66	

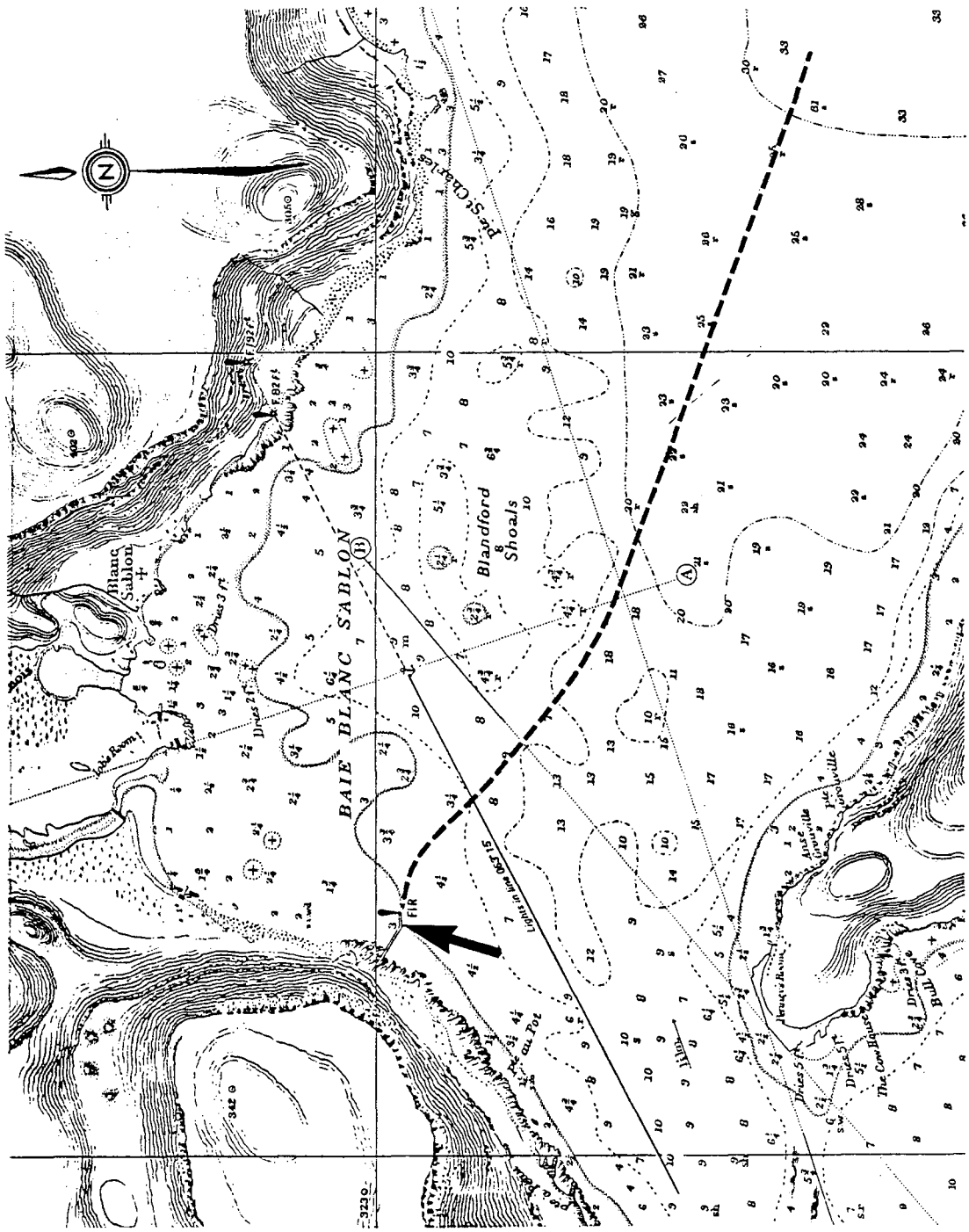
BLANC SABLON (QUEBEC)

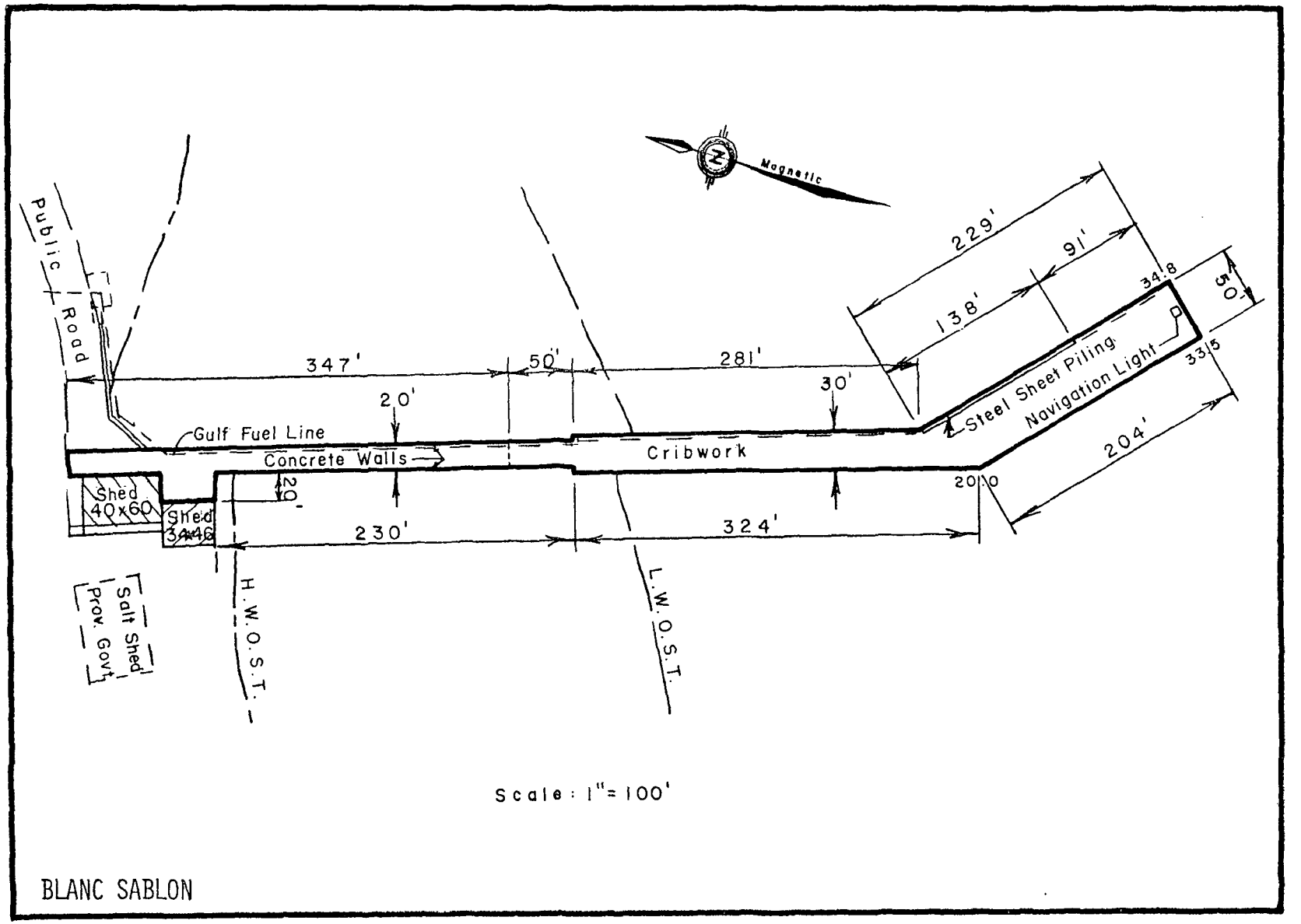
CHART NO. 4670
SOUNDINGS IN FATHOMS

NATURAL SCALE 1: 24,580

1000 0 FEET 5000

1000 0 METRES 1000





BLANC SABLON

PORT: CARTWRIGHT

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Local Government Community
POPULATION:	663 (1976 Census)
LOCATION:	Lat. 53°42'N - Long. 57°01'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	S. Bird

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted cribwork.

Deck Surface: Gravel

Elevation of Deck Above L.W.O.S.T.: 8 feet

Designed Bearing Capacity of Deck: 200 psf - 10 tons concentrated load

Year Constructed: 1952

Present Condition: Good - The wharf will be extended and upgraded in 1978 to provide 22' draft.

b) Shed

Description: 100' x 40' storage building formerly owned by U.S. Air Force.

Condition: Good

METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog, tide effects not significant; heavy winds from the SW will stop a ship from berthing but will not affect a ship which has already berthed.

Tide Range (large tide):

TRAFFIC DATA

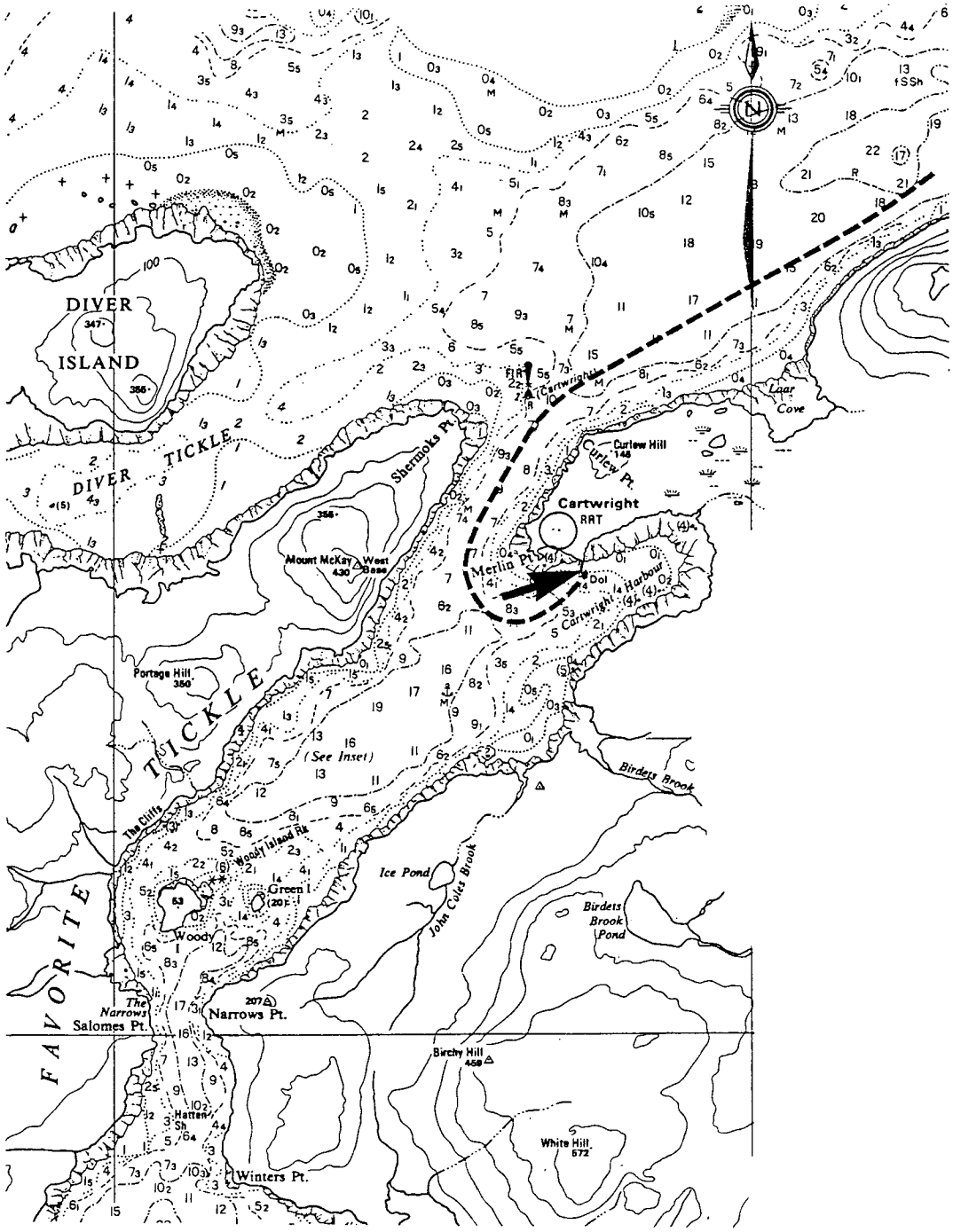
Freight Handled:	In	771 tons 1973
	Out	349 tons 1973
Passengers Handled:	In	667 1973
	Out	666 1973
Vessel Calls:	CN 93	

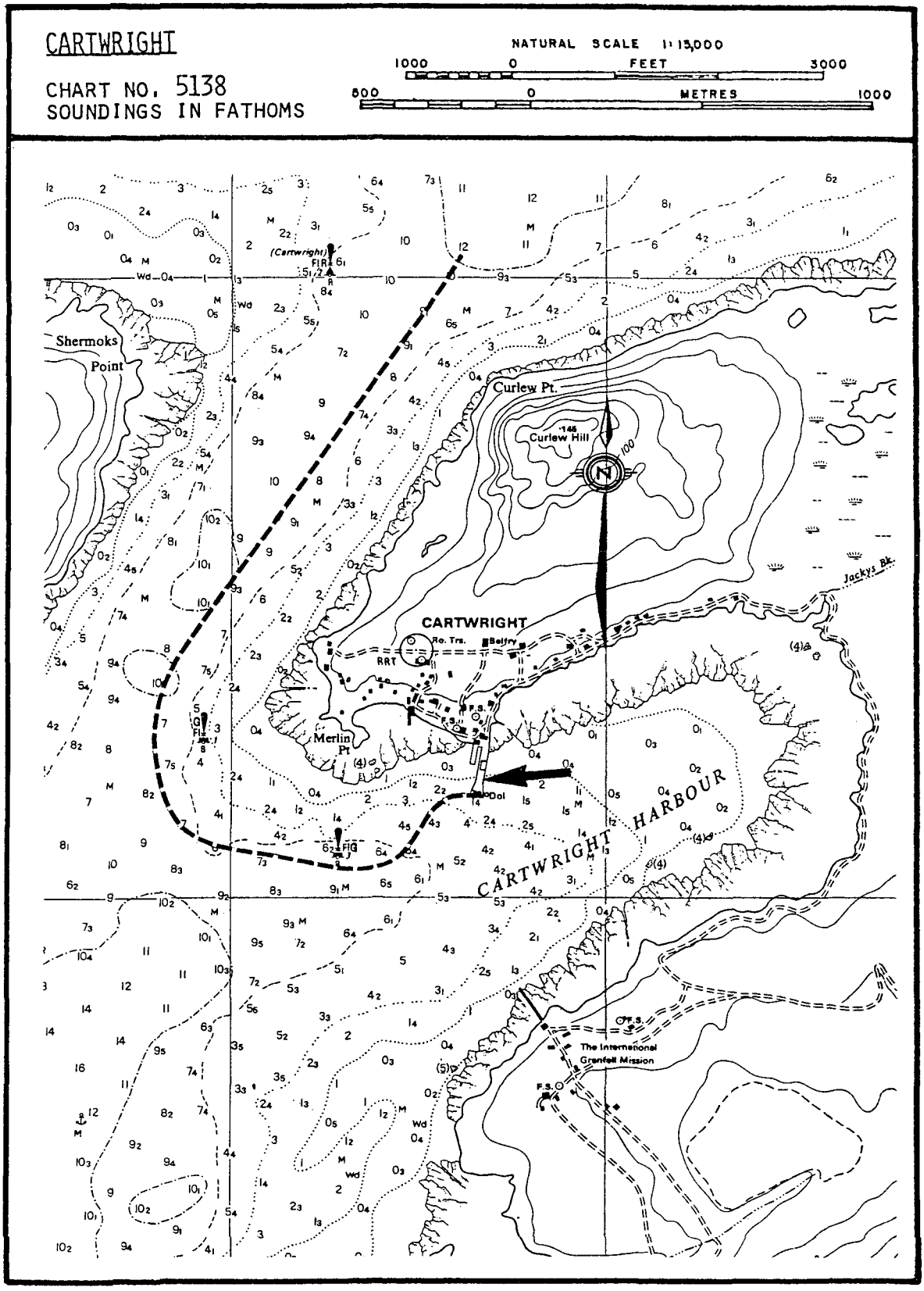
Because of its location and planned airport facilities, Cartwright could possibly be chosen as a future operations center. It is generally felt that it would be easier to gain access to it in winter than other harbours in the area and that transporting materials from land across ice to ships could be done at Cartwright since the ice in the harbour is not subject to severe rafting.

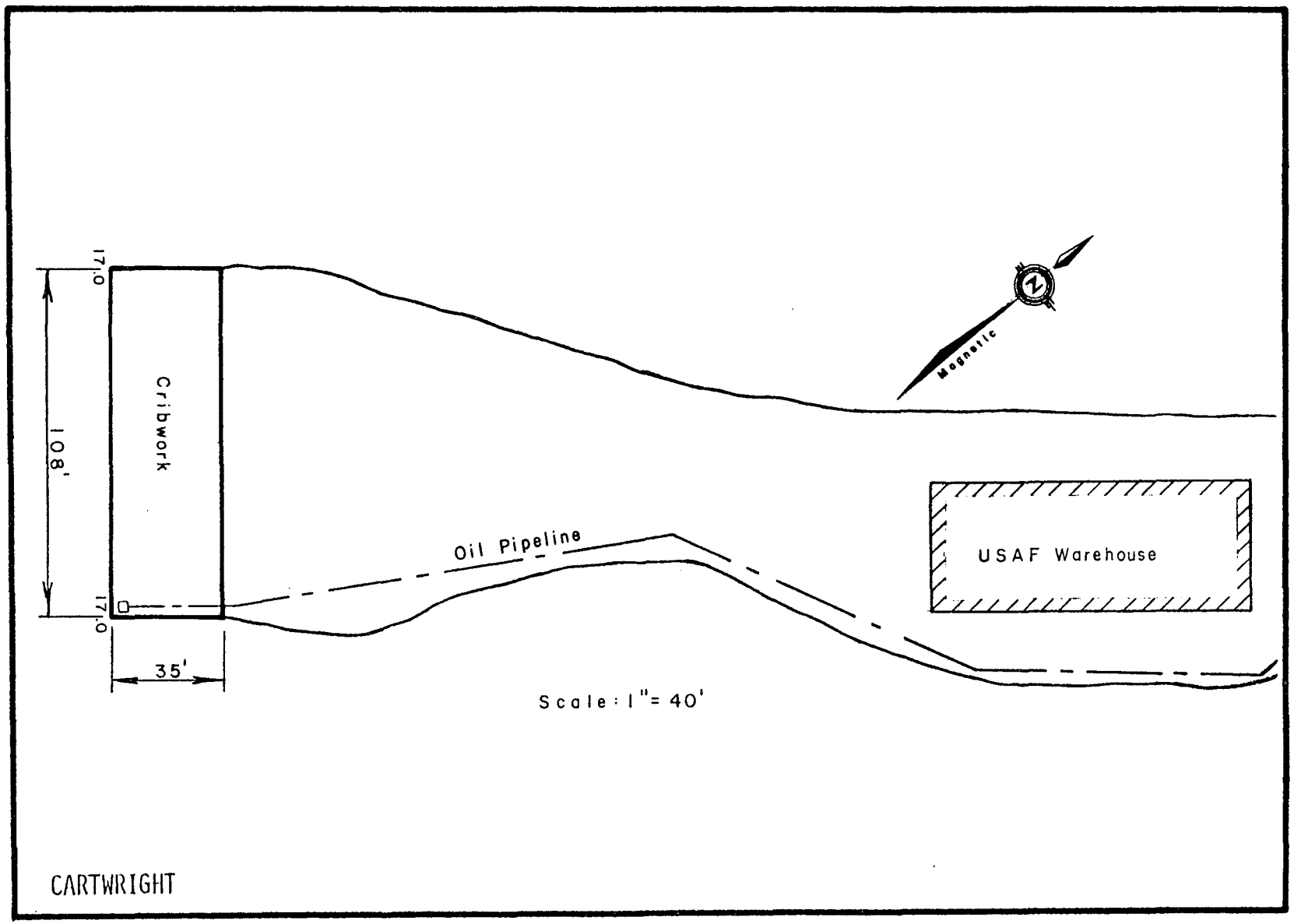
CARTWRIGHT

CHART NO. 5138
SOUNDINGS IN FATHOMS

NATURAL SCALE 1:50,000
1000 0 FEET 10,000
1000 0 METRES 2000




CARTWRIGHT
CHART NO. 5138
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:15,000
1000 0 FEET 3000
500 0 METRES 1000
Shermoks Point
Curlew Pt.
Curlew Hill
CARTWRIGHT
Merlin Pt
CARTWRIGHT HARBOUR
Jackys Bk.
The International Grenfell Mission


17.0
108'
17.0
Cribwork
35'
Oil Pipeline
USAF Warehouse
Magnetic
N
Scale: 1" = 40'
CARTWRIGHT

PORT: BLACK TICKLE

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	164
LOCATION:	Lat. 53°27'N - Long. 55°46'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	Unknown

WHARF AND SHED DATA

a) Wharf

Description: Untreated round timber cribwork construction fully ballasted.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designed Bearing Capacity of Deck: 200 psf - 5 tons concentrated load

Year Constructed: 1977

Present Condition: Excellent

NOTE: No other data is available as construction of the wharf has just recently been completed and no previous records have been kept.

PORT: DAVIS INLET

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Local Government Community
POPULATION:	272 (1976 Census)
LOCATION:	Lat. 55°52'N - Long. 60°48'W
NAVIGABLE:	July to November
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	None

WHARF AND SHED DATA

a) Wharf

Description: Untreated round timber cribwork construction fully ballasted.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designed Bearing Capacity of Deck: 250 psf - 5 tons concentrated load

Year Constructed: 1977

Present Condition: Very good

b) Shed

Description: Unknown

Condition: Unknown

METEOROLOGICAL AND HYDROGRAPHIC DATA - Fog and wind effects not significant. Tidal currents of 2 to 3 knots are reported in the inlet and strong tide rips prevail at the eastern entrance.

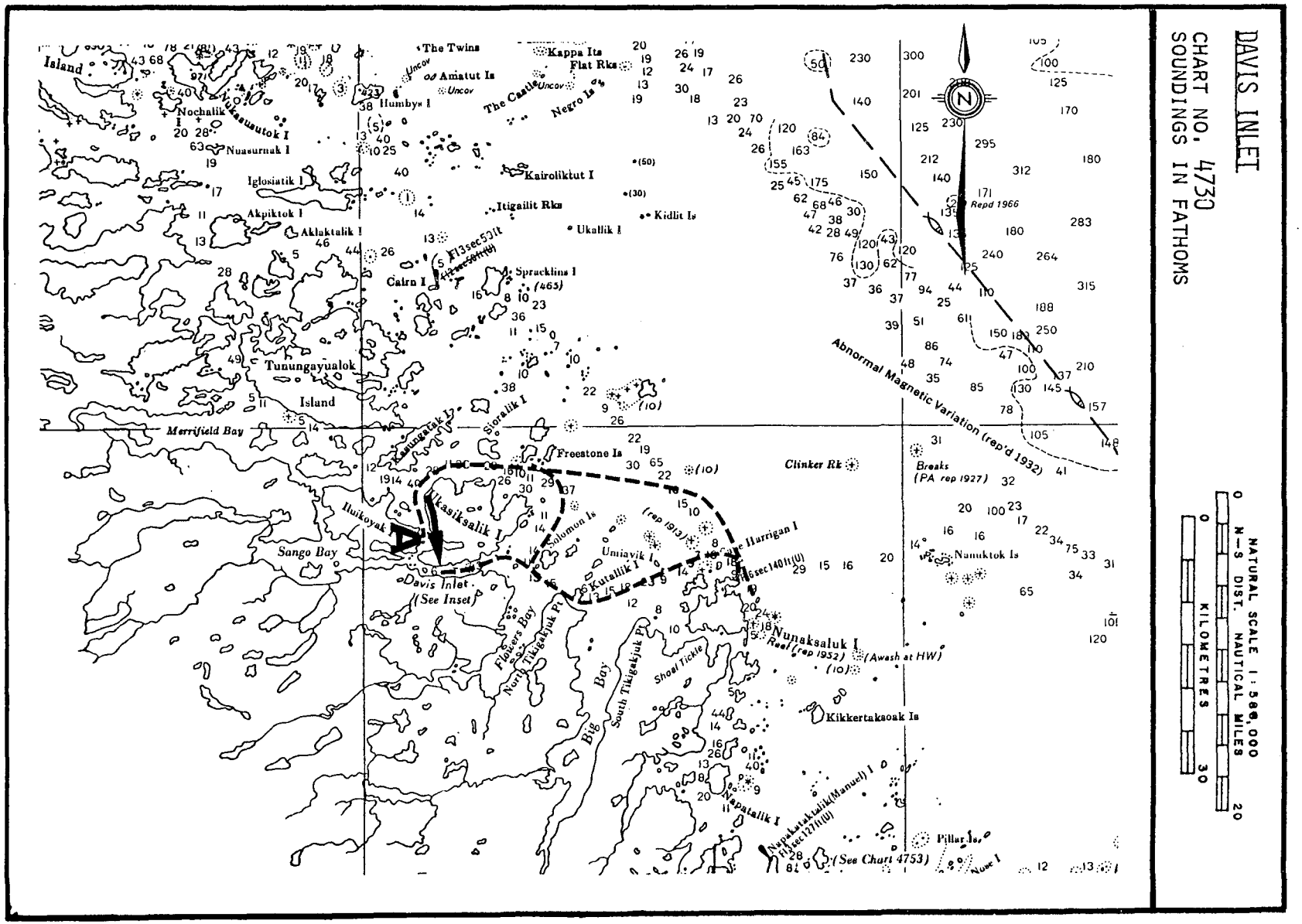
Tide Range (large tide): 8.5 feet

TRAFFIC DATA

Freight Handled:	In	258 tons 1973
	Out	35 tons 1973
Passengers Handled:	In	151 1973
	Out	153 1973
Vessel Calls:	CN 40 1973	

DAVIS INLET

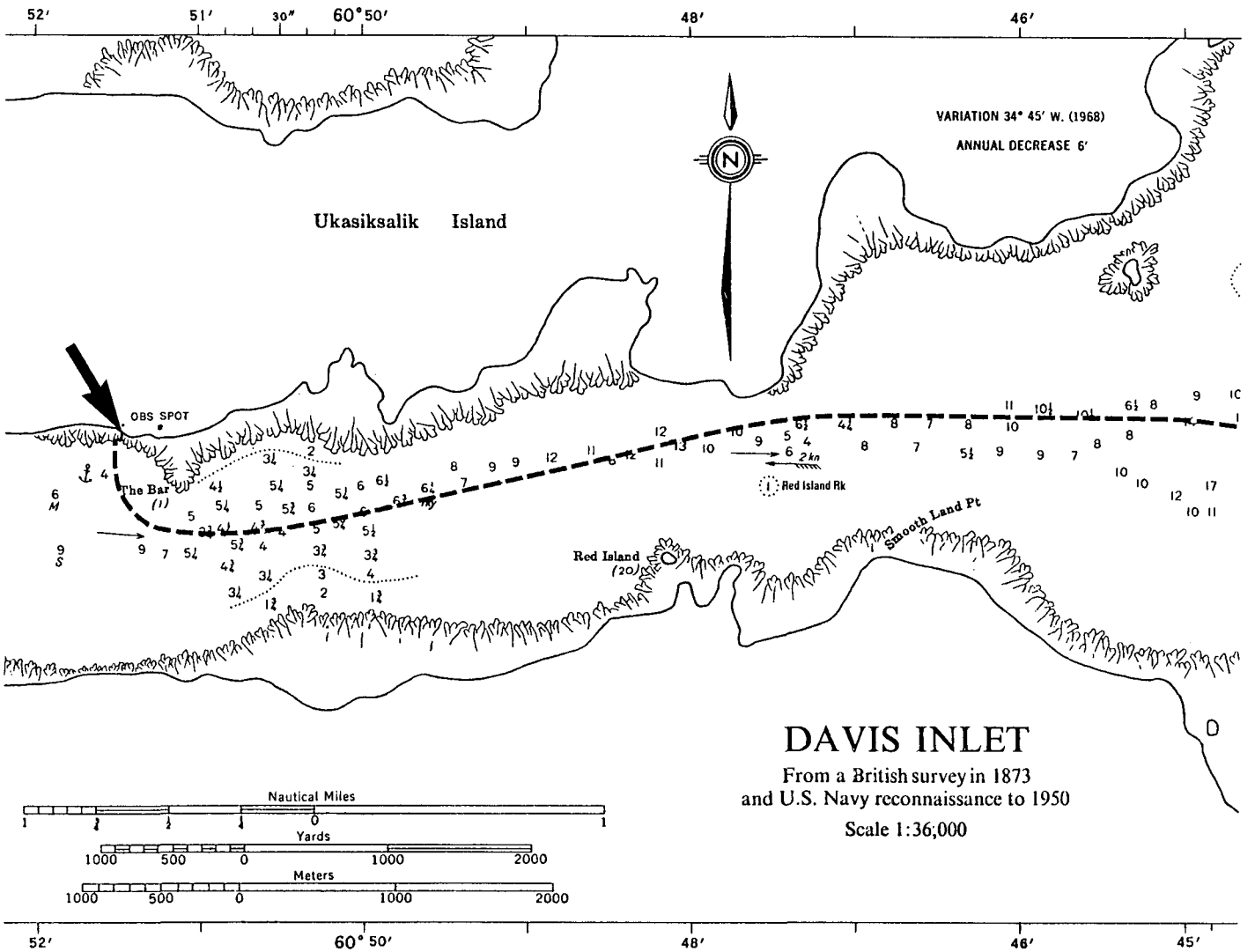
CHART NO. 4730
SOUNDINGS IN FATHOMS



DAVIS INLET

CHART NO. 4730

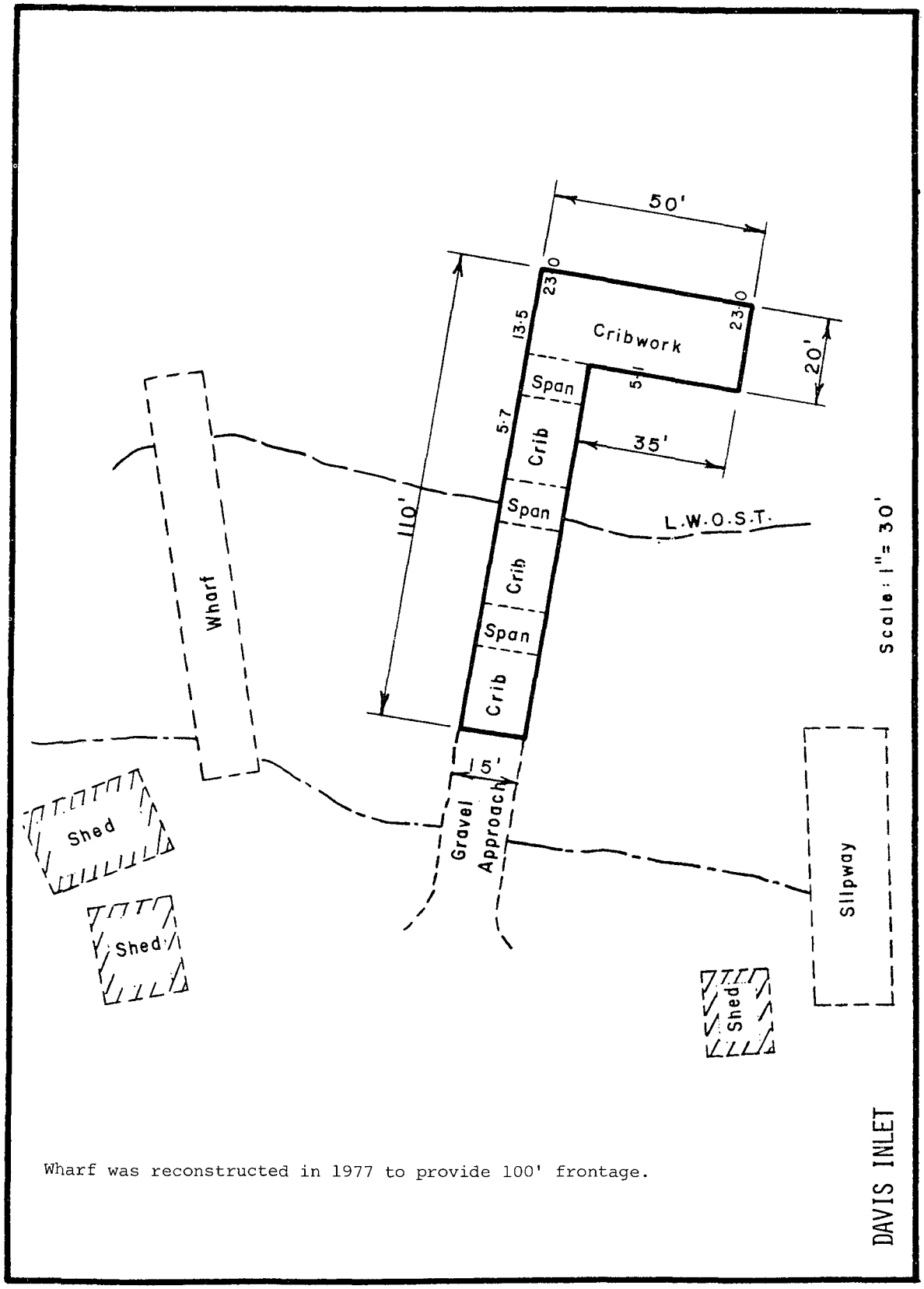
SOUNDINGS IN FATHOMS



DAVIS INLET

From a British survey in 1873
and U.S. Navy reconnaissance to 1950

Scale 1:36,000



Wharf was reconstructed in 1977 to provide 100' frontage.

PORT: FOX HARBOUR

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	214 (1971 Census)
LOCATION:	Lat. 52°22'N - Long. 55°41'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	Unknown

WHARF AND SHED DATA

a) Wharf

Description: Constructed of wood pile bents.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 12 feet

Designed Bearing Capacity of Deck: Unknown

Year Constructed: 1977-78

Present Condition: Under construction

b) Shed

Description: Unknown

Condition: Unknown

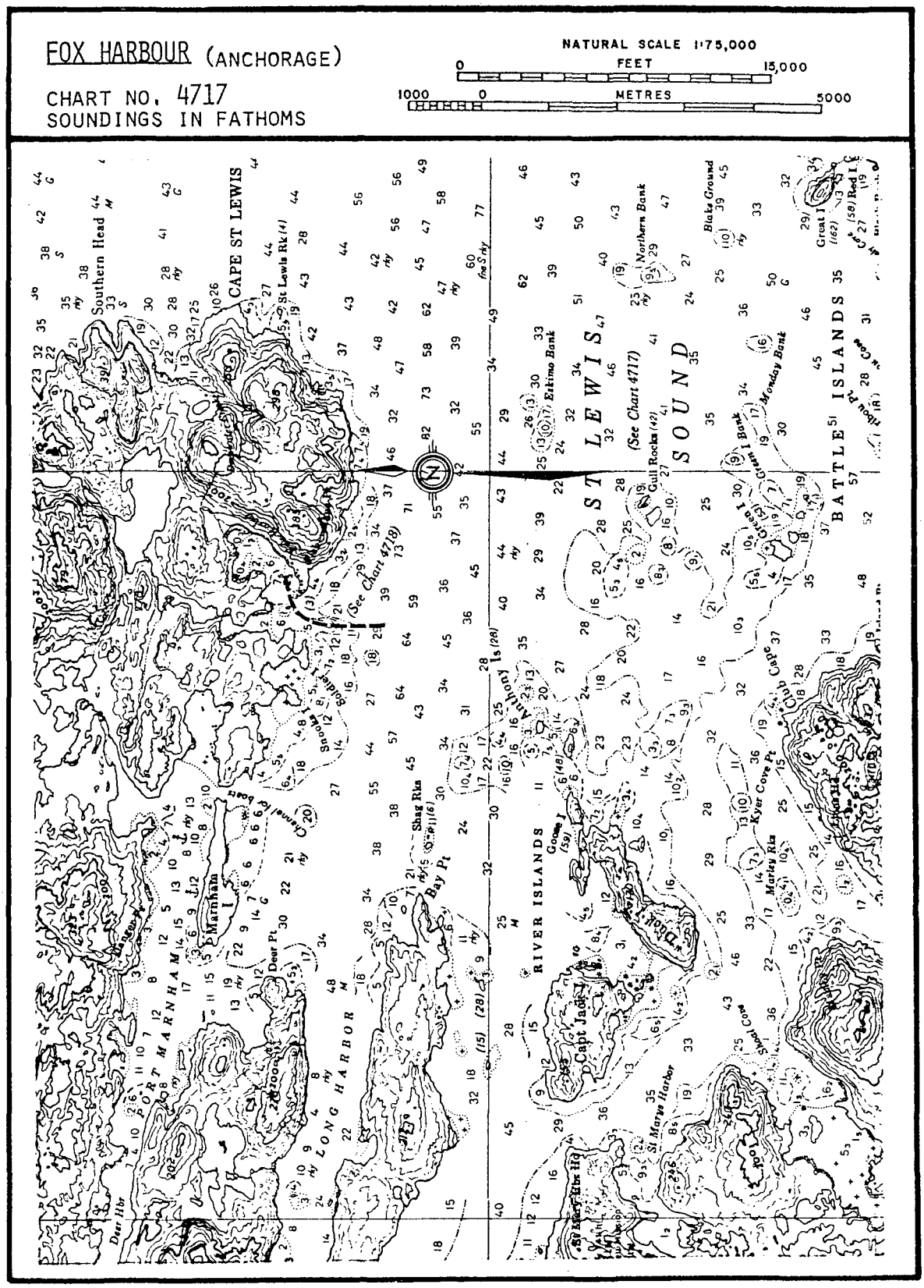
METEOROLOGICAL AND HYDROGRAPHIC DATA - Fog and wind effects are not significant. Tidal currents are reported to have a drift of 1.8 knots and set north or south.

Tide Range (large tide): 5.5 feet

TRAFFIC DATA

Freight Handled:	In	498 tons 1973
	Out	87 tons 1973
Passengers Handled:	In	146 1973
	Out	122 1973
Vessel Calls:	CN 90 1973	

REMARKS Anchorage for CN Vessels


FOX HARBOUR (ANCHORAGE)
CHART NO. 4717
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:75,000
FEET
0
15,000
METRES
1000
0
5000
CAPE ST LEWIS
Southern Head
St Lewis Rk
Eskimo Bank
Northern Bank
Black Ground
Monday Bank
Gull Rocks
(See Chart 4717)
ST LEWIS SOUND
BATTLE ISLANDS
Great I
Red I
Marnham I
Deer Pt
Bay Pt
Shag Rks
LONG HARBOR
RIVER ISLANDS
Capt Jack I
Kyer Cove Pt
Marley Rks
Cub Cape
Eskimo Hd
St Mary Harbor
Deer Hbr

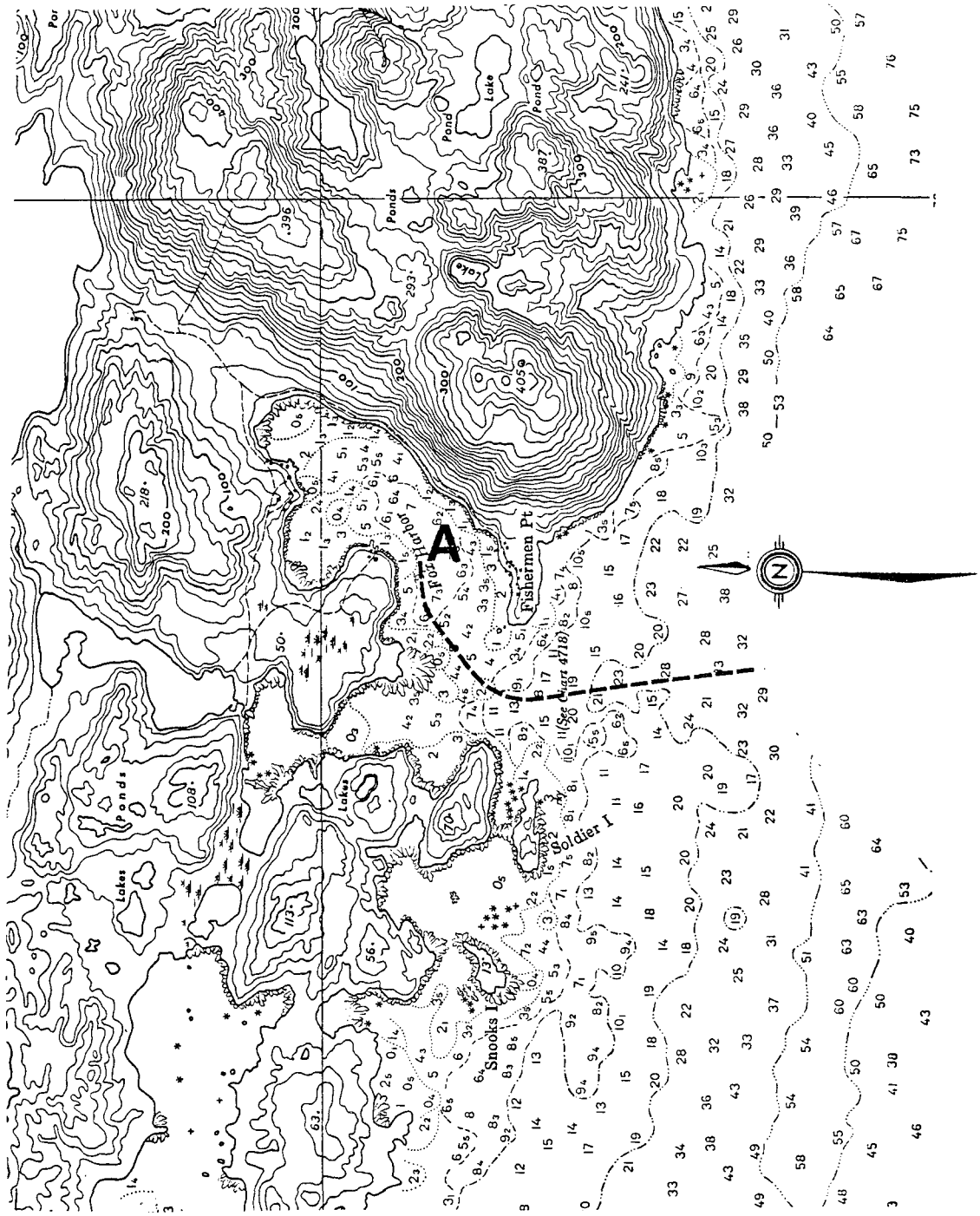
FOX HARBOUR (ANCHORAGE)

CHART NO. 4717
SOUNDINGS IN FATHOMS

NATURAL SCALE 1:25,000

1000 0 FEET 5000

1000 0 METRES 1000



PORT: GOOSE BAY

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Incorporated town
POPULATION:	Goose Bay - Happy Valley - 8425 (1976 Census)
LOCATION:	Lat. 53°23'N - Long 60°22'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	Route 520 (gravel and paved)
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT Harbour Master: Capt. Haynes
WHARFINGER:	M. Woodward

WHARF AND SHED DATA

a) Wharf	East	West
Description:	Constructed of wood pile bents.	Constructed of composite steel & wood pile vents.
Deck Surface:	Concrete	Asphalt
Elevation of Deck Above L.W.O.S.T.:	9 ft. (E)	8 ft. (W)
Designed Bearing Capacity of Deck:	400 psf 15 T concent. load	400 psf 15 tons conc. load
Year Constructed:	Not known	1961
Present Condition:	Good	Good

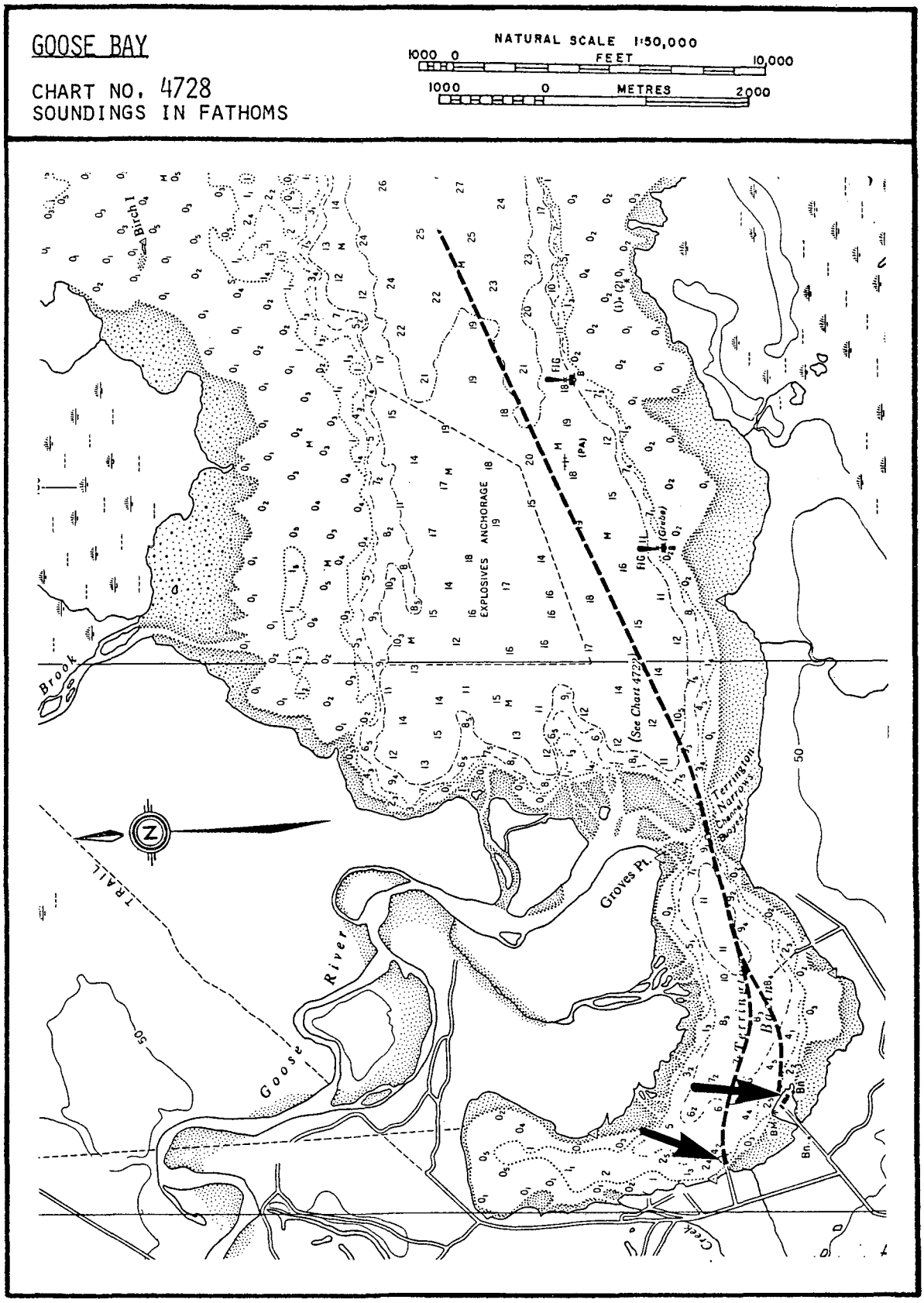
b) Shed	East	West
Description:	Corrugated metal bldgs. with concrete floors. Not heated.	Prefabricated steel bldg. With asphalt floor. Not heated.
Condition:	Good	Good

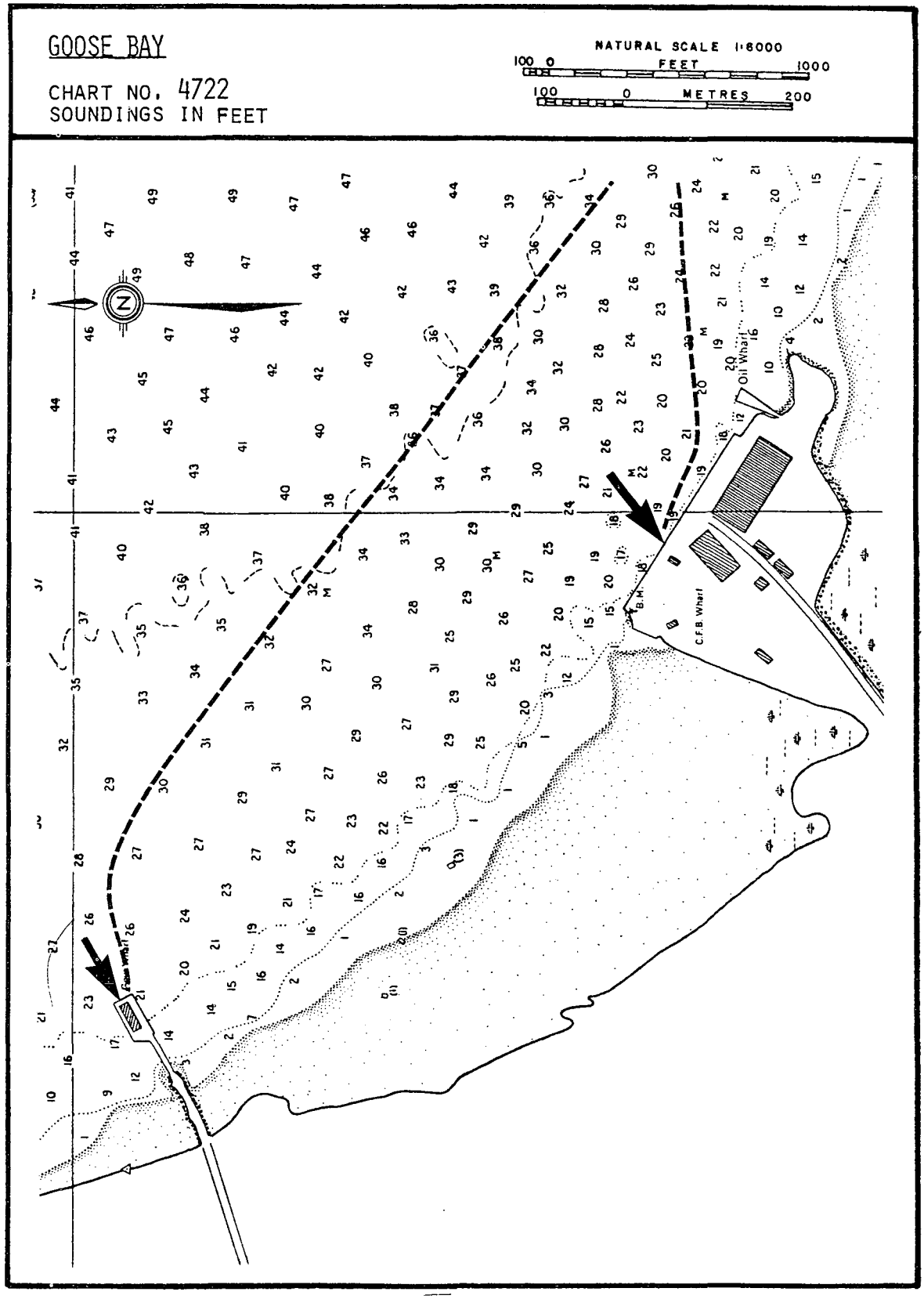
METEOROLOGICAL AND HYDROGRAPHIC DATA - There is no significant current within Tarrington Basin. However, in Tarrington Narrows under normal summer conditions the tidal flood runs at a rate from 1 1/2 to 2 1/4 knots & the ebb has a rate of continuous outward flow which may last until July 1st.

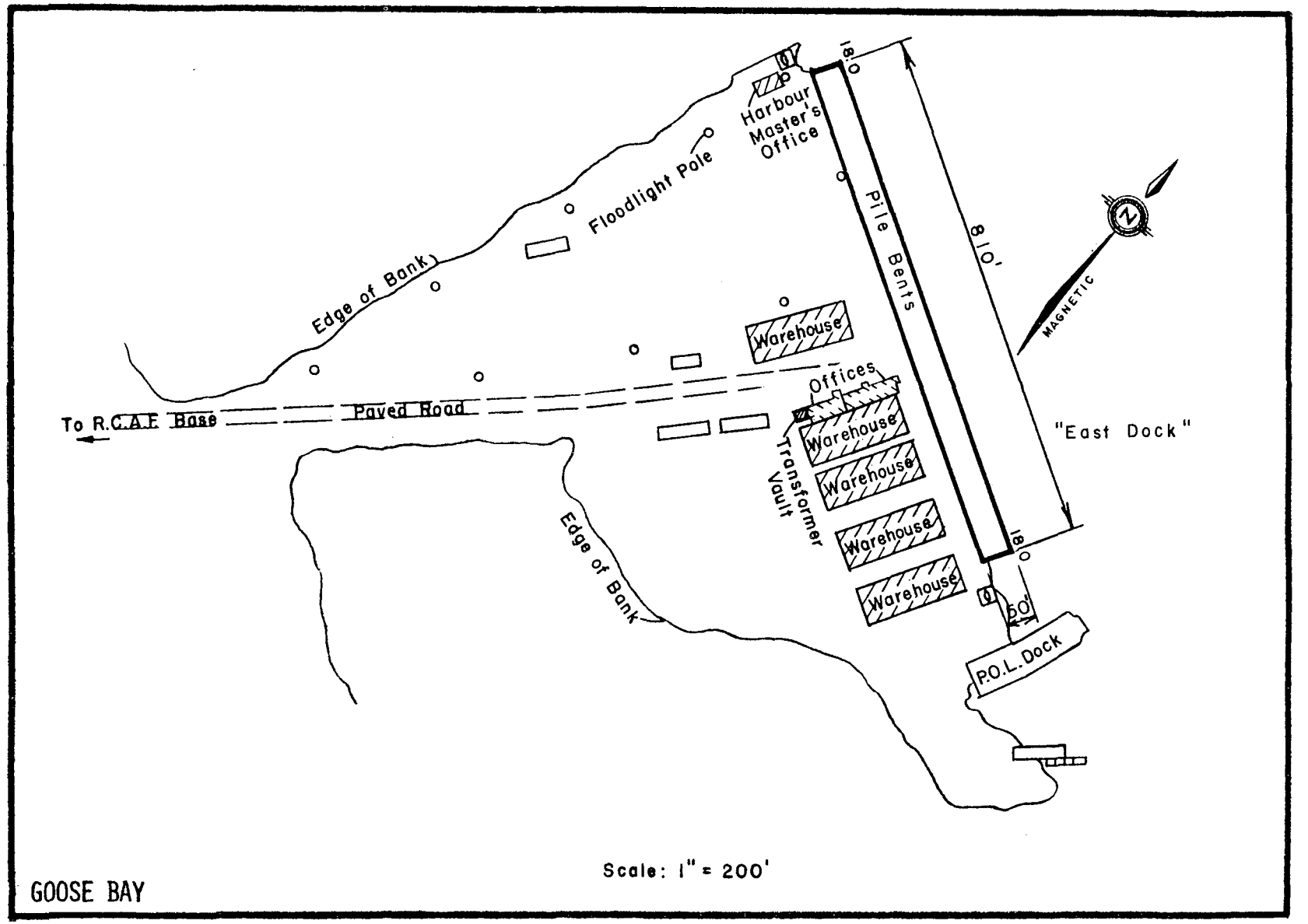
Tide Range: (large tide): 2 feet

TRAFFIC DATA

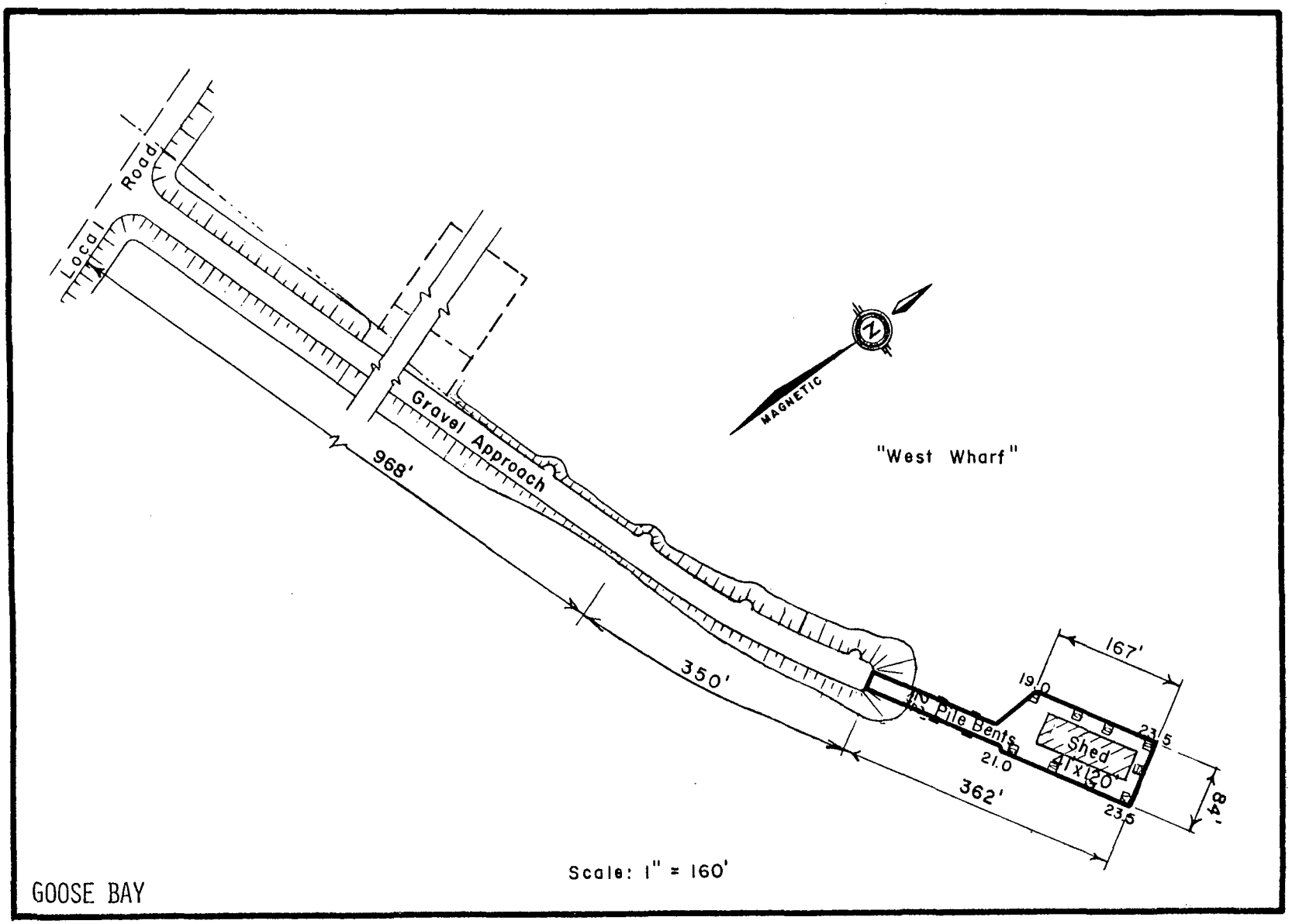
Freight Handled:	In	11,507 tons 1973
	Out	2,304 tons 1973
Passengers Handled:	In	1,577 1973
	Out	1,613 1973
Vessel Calls:	CN 119 1973	


GOOSE BAY
CHART NO. 4728
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:50,000
1000 0 FEET 10,000
1000 0 METRES 2000
Birch I
Brook
EXPLOSIVES ANCHORAGE
(See Chart 4727)
Terrington Narrows
Channel Buoyed
Groves Pt.
Goose River
TRAIL
Creek
Bn.
BM
FIG
(PA)
(Grebe)
50


GOOSE BAY
CHART NO. 4722
SOUNDINGS IN FEET
NATURAL SCALE 1:6000
FEET
METRES
Oil Wharf
C.F.B. Wharf
Fuel Wharf


Harbour Master's Office
Floodlight Pole
Edge of Bank
Pile Bents
18'0
810'
18'0
MAGNETIC
N
Warehouse
Offices
Warehouse
Warehouse
Warehouse
Warehouse
Transformer Vault
To R.C.A.F. Base
Paved Road
"East Dock"
Edge of Bank
50'
P.O.L. Dock
Scale: 1" = 200'

GOOSE BAY


Local Road
Gravel Approach
968'
350'
362'
MAGNETIC
"West Wharf"
Pile Bents
19.0
21.0
23.5
23.5
167'
84'
Shed
41 x 120
Scale: 1" = 160'
GOOSE BAY

PORT: HOPEDALE

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Local Government Community
POPULATION:	439 (1976 census)
LOCATION:	Lat. 55°27'N - Long. 60°13'W
NAVIGABLE:	July to November
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	E. Nitsman

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted creosoted timber cirbwork, span and post construction.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 11 feet

Designed Bearing Capacity of Deck: 400 psf - 10 tons concentrated load

Year Constructed: 1966

Present Condition: Good

b) Shed

Description: Old American Forces shed of about 400,000 cubic feet storage capacity.

Condition: Unknown

METEOROLOGICAL AND HYDROGRAPHIC DATA - Fog and wind effects are not significant. A tidal current of 1/2 to 1 knot has been observed at maximum ebb. The current off the coast between Occasional Harbour and Hopedale Harbour almost invariably sets southeasterly unless countered by southerly and southeasterly gales.

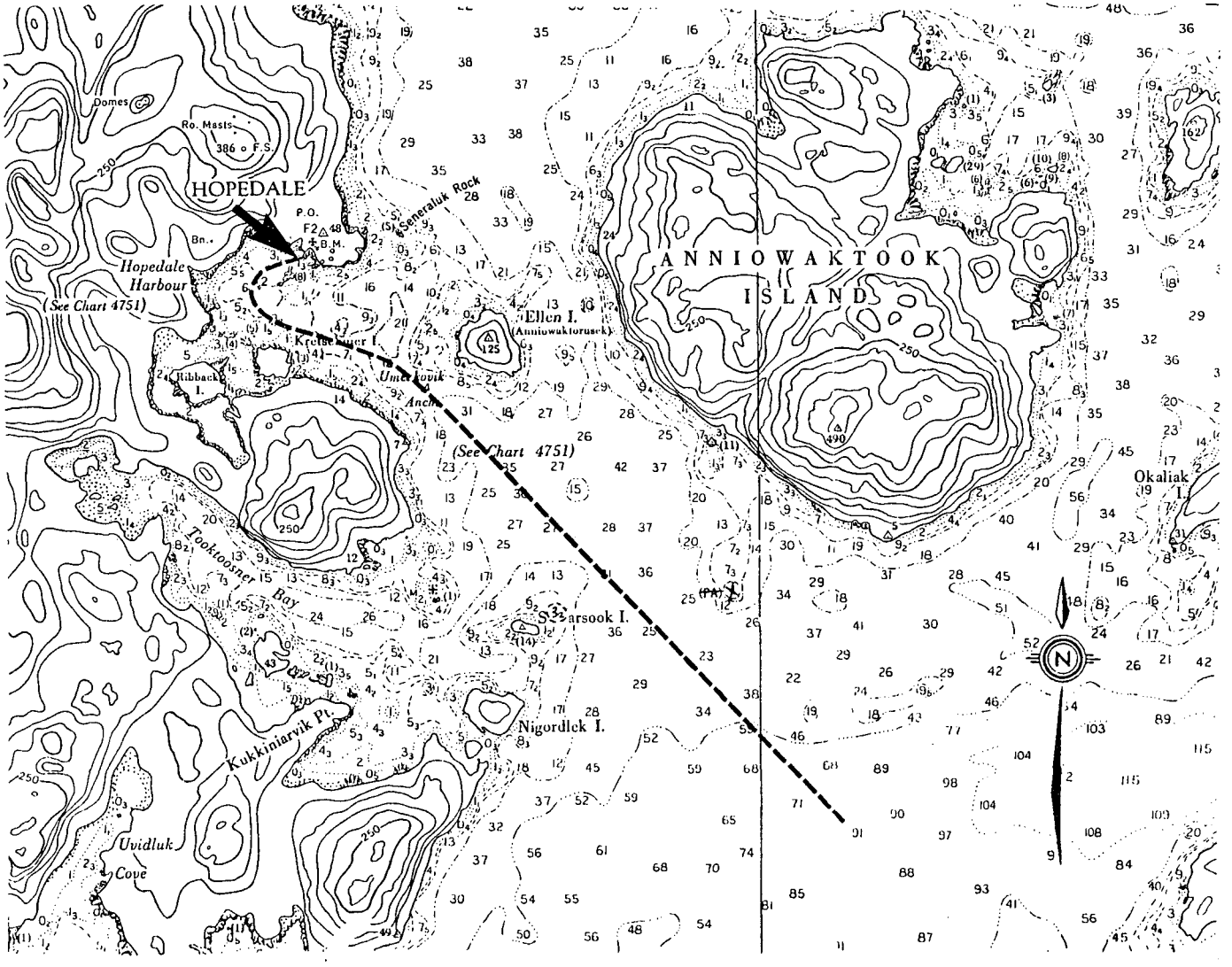
Tide Range (large tide): 7.5 feet

TRAFFIC DATA

Freight Handled:	In	990 tons 1973
	Out	100 tons 1973
Passengers Handled:	In	382 1973
	Out	383 1973
Vessel Calls:	CN 52 1973	

HOPEDALE

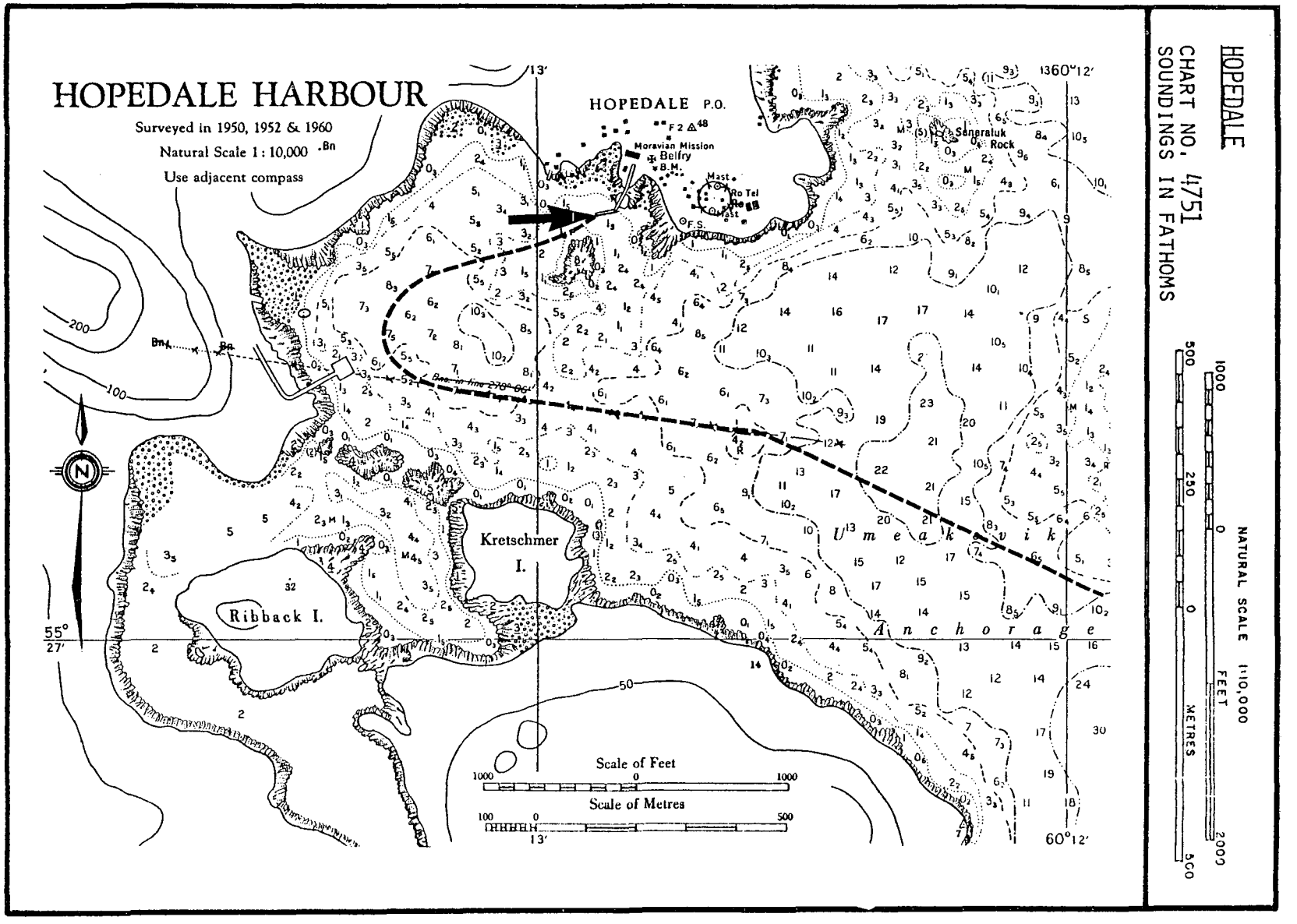
CHART NO. 4753
SOUNDINGS IN FATHOMS

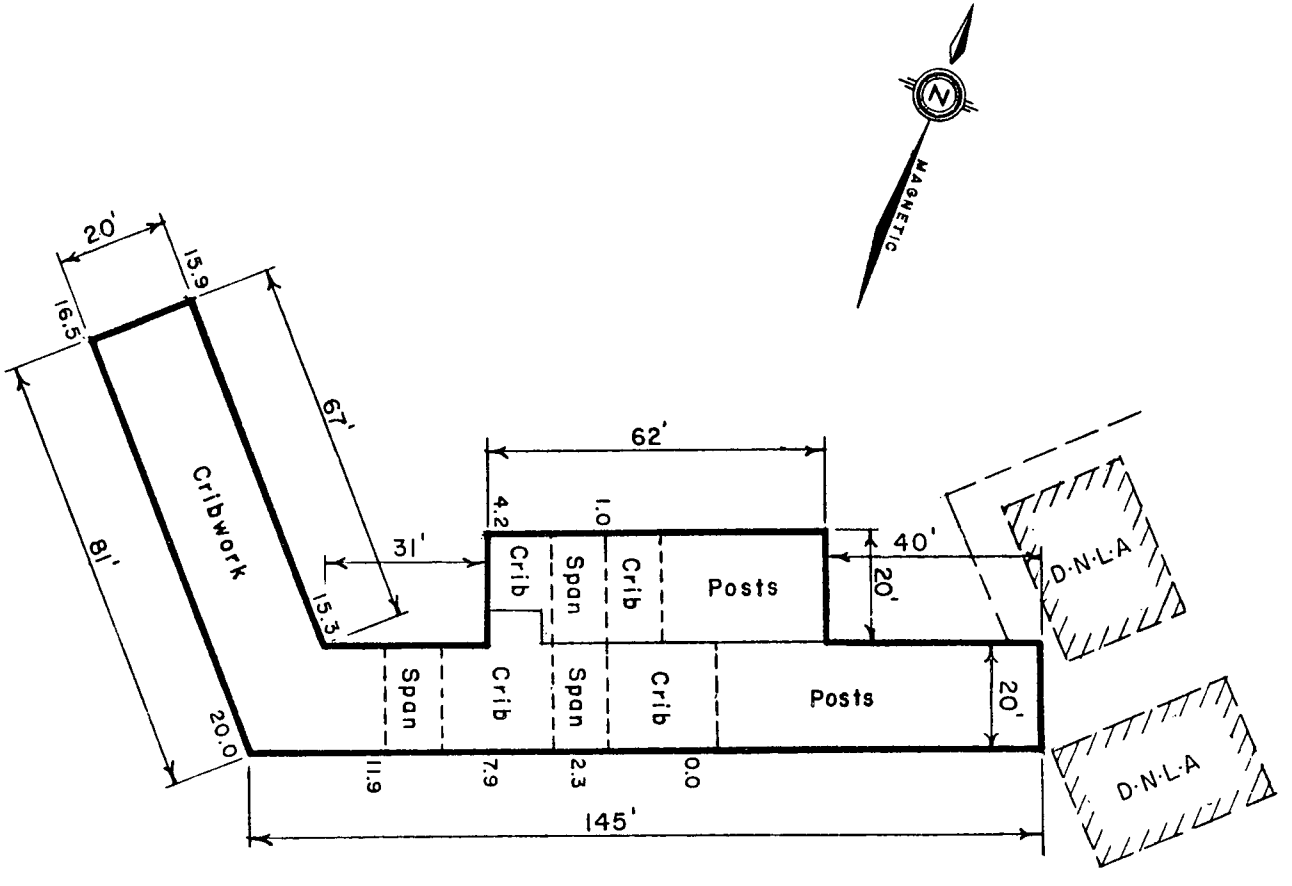


NATURAL SCALE 1: 37,500

FEET 1000 0 1000

METRES 0 2000 10,000


HOPEDALE HARBOUR
Surveyed in 1950, 1952 & 1960
Natural Scale 1 : 10,000
Use adjacent compass
HOPEDALE P.O.
Moravian Mission
Belfry
B.M.
Mast
Ro Tel
F.S.
Sangaluk Rock
Kretschmer I.
Ribback I.
Umeakvik
Anchorage
Bearing line 270°-06°
Scale of Feet
Scale of Metres
HOPEDALE
CHART NO. 4751
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:10,000
FEET
METRES



Scale: 1" = 30'

HOPEDALE

PORT: L'ANSE AU LOUP

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	448 (1971 Census)
LOCATION:	Lat. 51°31'N - Long. 56°44'W
NAVIGABLE:	Mid May to December
HIGHWAY CONNECTIONS:	Route 510 (gravel) to Ferry to St. Barbe to 430 (gravel and paved) to T.C.H.
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	P. Earle

WHARF AND SHED DATA

a) Wharf

Description: The "T" headblock is constructed of creosoted timber cribwork over creosoted timber pile bents. The stem is constructed of untreated timber pile bents.

Deck Surface: Headblock - concrete; stem - plank

Elevation of Deck Above L.W.O.S.T.: 9 feet

Designed Bearing Capacity of Deck: 200 psf - 10 tons concentrated load

Year Constructed: 1973 and 1963

Present Conditions: Excellent to good

b) Shed

Description: Wood framed building with wood floor constructed over untreated round timber pile bents. Not heated.

Condition: Good

METEOROLOGICAL AND HYDROGRAPHIC DATA: - Dense fogs prevail during the summer and sometimes last for several days. The fogs occur with either west or east winds. Tidal curents of up to 3 knots are experienced through the Straits of Belle Isle but are not significant in the harbour.

Tide Range: (large tide): 5.5 feet

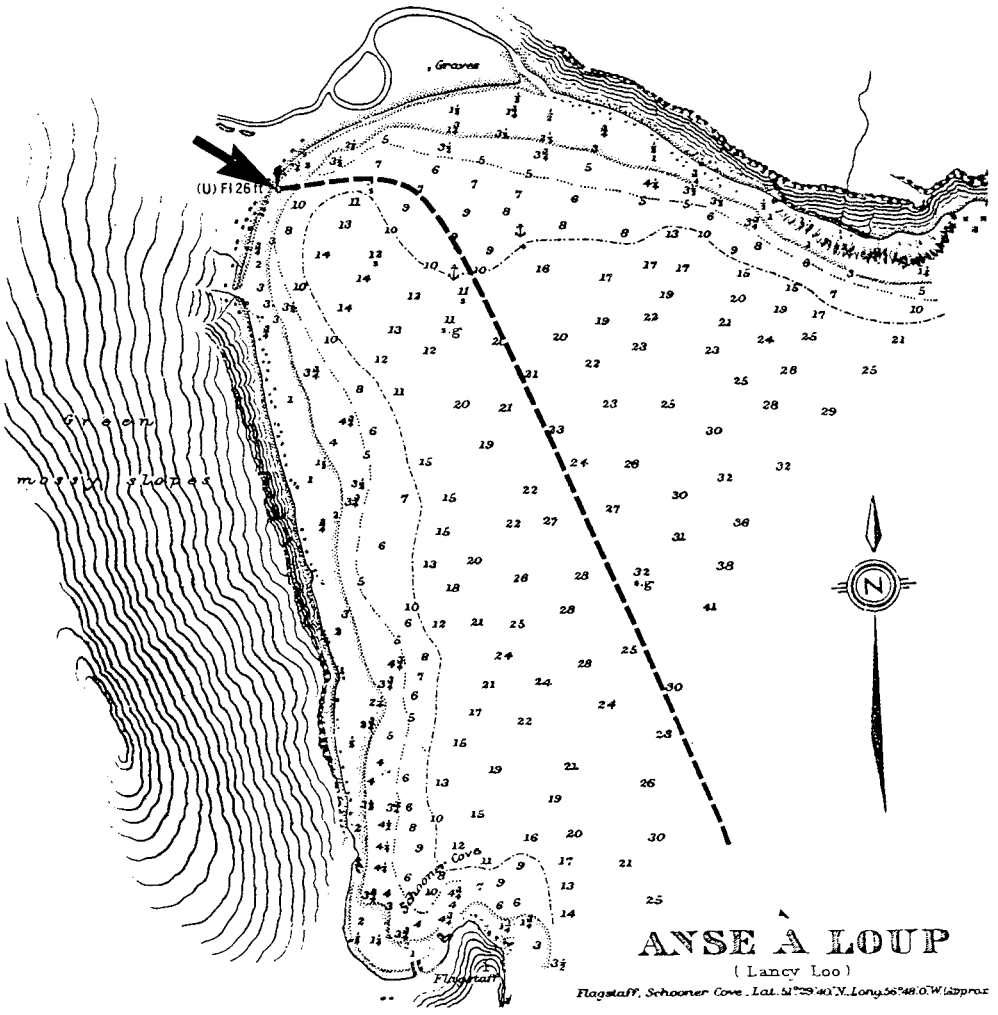
TRAFFIC DATA

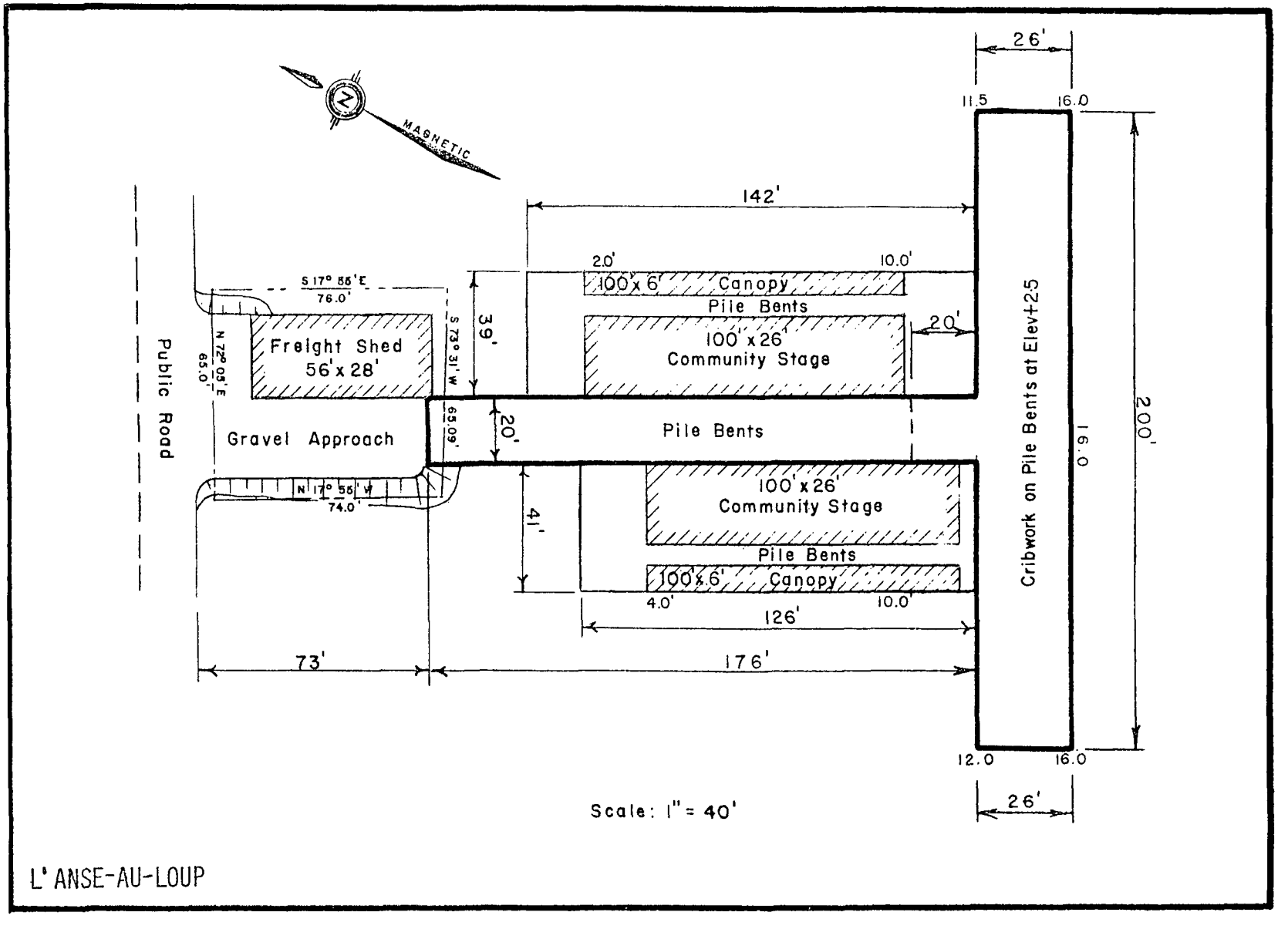
Freight Handled:	In	1,279 tons 1973
	Out	106 tons 1973
Passengers Handled:	In	30 1973
	Out	40 1973
Vessel Calls:	CN 59 1973	

L'ANSE-AU-LOUP

CHART NO. 4668
SOUNDINGS IN FATHOMS

NATURAL SCALE 1:23,800
1000 0 FEET 5000
1000 0 METRES 1000





L' ANSE-AU-LOUP

PORT: MAKKOVIK

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Local Government
POPULATION:	304 (1976 Census)
LOCATION:	Lat. 55°05'N - Long. 59°11'W
NAVIGABLE:	June to November
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	T. Anderson

WHARF AND SHED DATA

a) Wharf

Description: Constructed of 6" x 6" and 10" x 10" fully ballasted creosoted timber cribwork and 10" x 10" creosoted timber cribwork over creosoted timber pile bents.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 10.8 feet

Designed Bearing Capacity of Deck: 100 psf - 5 tons concentrated load

Year Constructed: 1966

Present Condition: Very poor - a contract has been awarded for the reconstruction of this wharf in 1978.

b) Shed

Description: Unknown

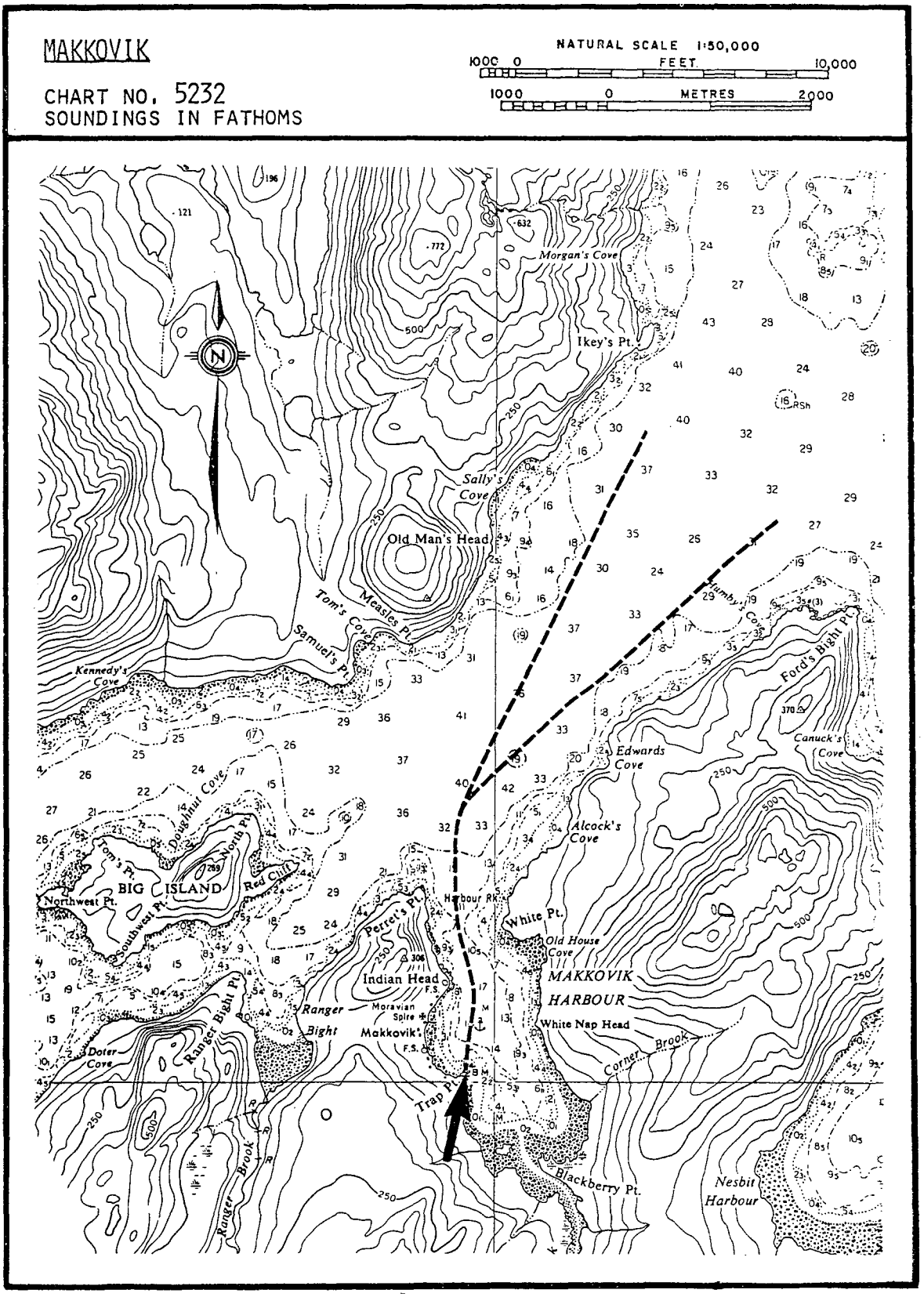
Condition: Unknown

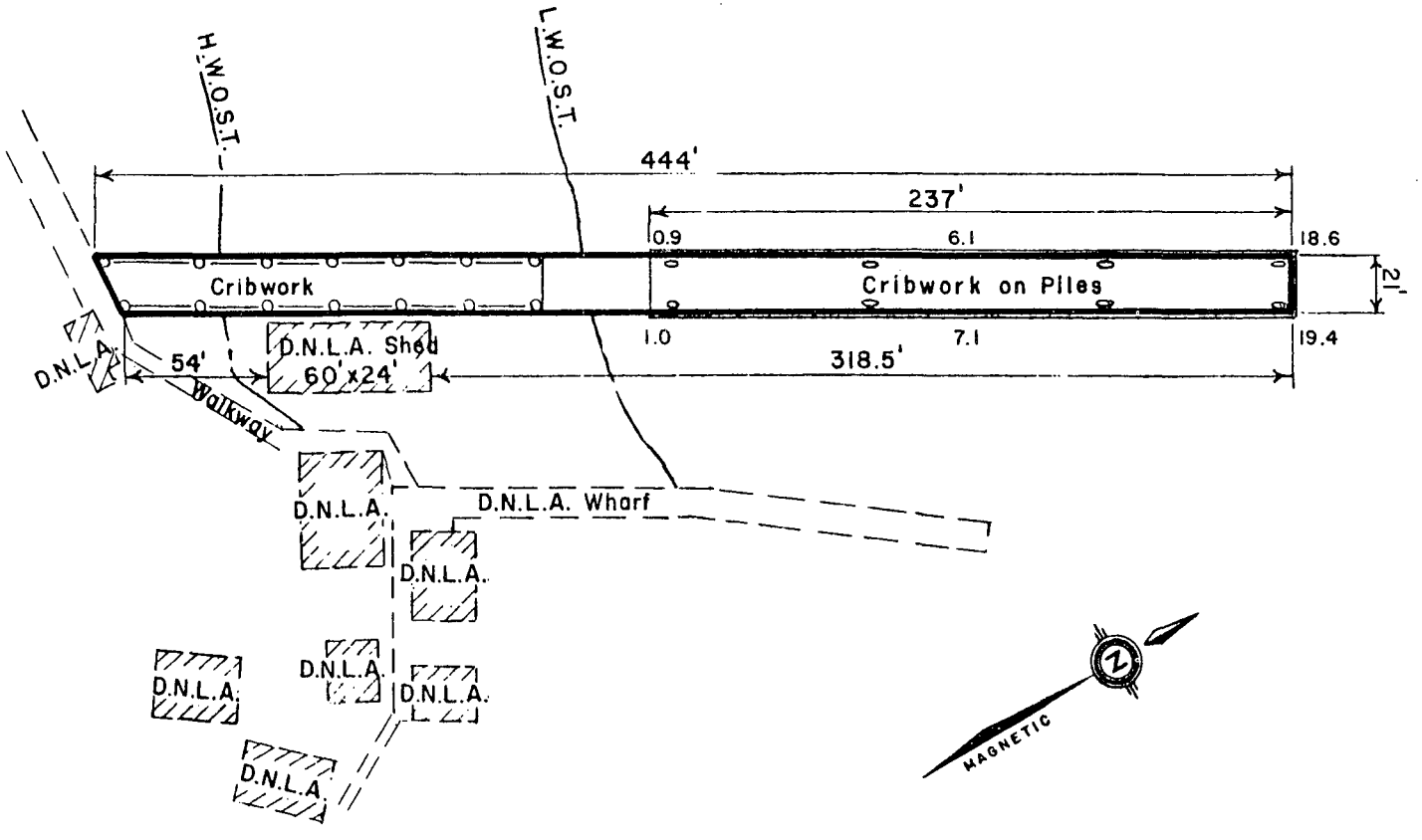
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog, wind and tide effects not significant.

Tide Range (large tide): 7 feet

TRAFFIC DATA

Freight Handled:	In	675 tons 1973
	Out	139 tons 1973
Passengers Handled:	In	291 1973
	Out	307 1973
Vessel Calls:	CN 57 1973	


MAKKOVIK
CHART NO. 5232
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:50,000
1000 0 FEET 10,000
1000 0 METRES 2000
N
Morgan's Cove
Ikey's Pt.
Sally's Cove
Old Man's Head
Tom's Cove
Measles Pt.
Samuel's Pt.
Kennedy's Cove
Humby Cove
Ford's Bight Pt.
Canuck's Cove
Edwards Cove
Alcock's Cove
Doughnut Cove
Tom's Pt.
North Pt.
Red Cliff
BIG ISLAND
Northwest Pt.
Southwest Pt.
Harbour Rk.
Perret's Pt.
White Pt.
Old House Cove
MAKKOVIK HARBOUR
Indian Head
F.S.
Moravian Spire
Makkovik
F.S.
Ranger Bight
Ranger Bight Pt.
White Nap Head
Corner Brook
Doter Cove
Trap Pt.
Ranger Brook
Blackberry Pt.
Nesbit Harbour



Scale : 1" = 60'

MAKKOVIK

PORT: MARY'S HARBOUR

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	386 (1976 Census)
LOCATION:	Lat. 52°19'N - Long. 55°49'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	J. Howell

WHARF AND SHED DATA

a) Wharf

Description: Constructed of untreated round timber cribwork below elevation +1.0 and 6" by 6" creosoted timber above elevation +1.0.

Deck surface: Plank

Elevation of Deck Above L.W.O.S.T.: 8 feet

Designed Bearing Capacity of Deck: 100 psf - 5 tons concentrated load

Year Constructed: 1964

Present Conditions: Good

b) Shed

Description: Prefabricated metal building 32' x 20' with wood floor. Not heated.

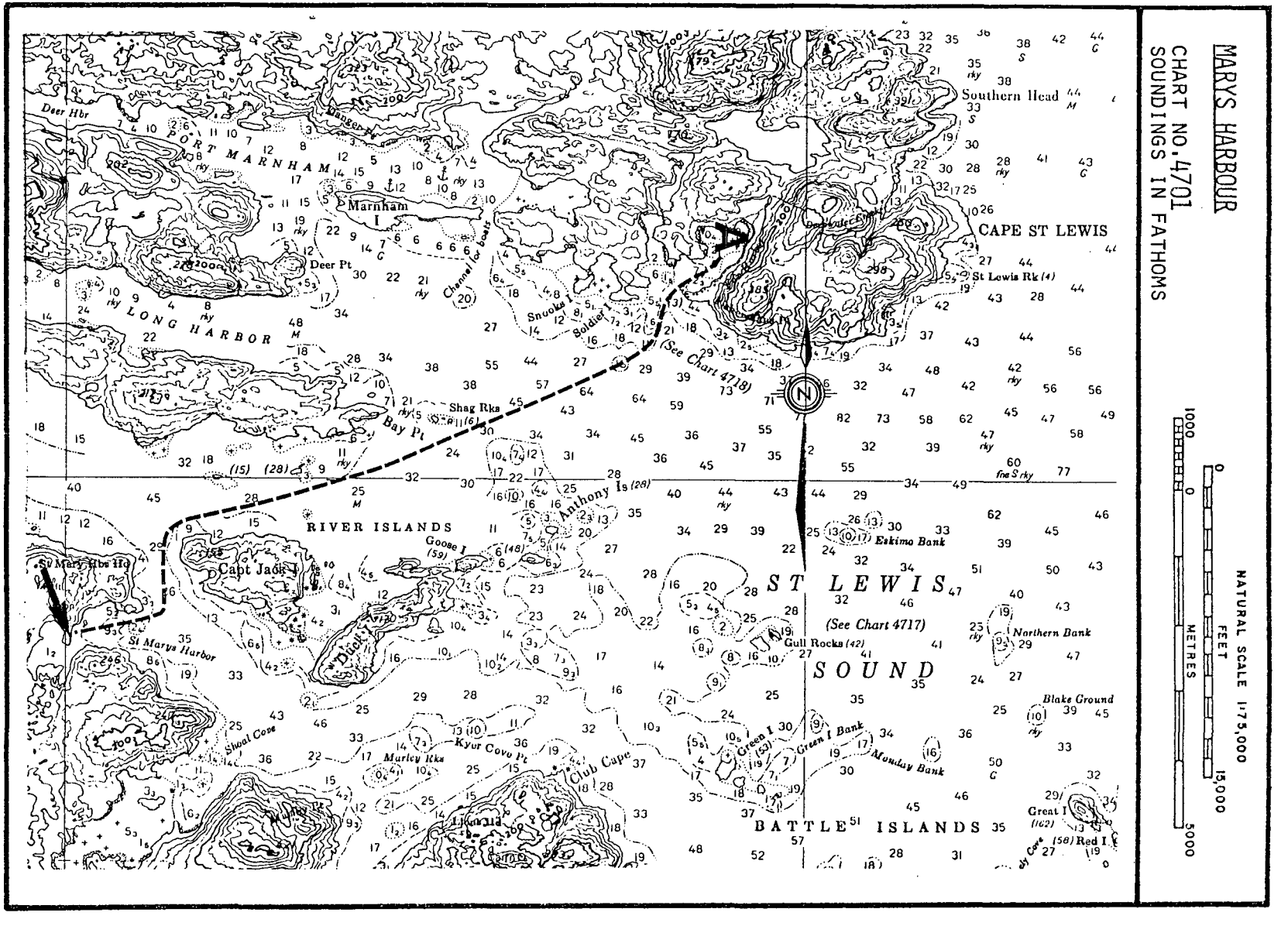
Condition: Good - Wharf was renovated in 1976.

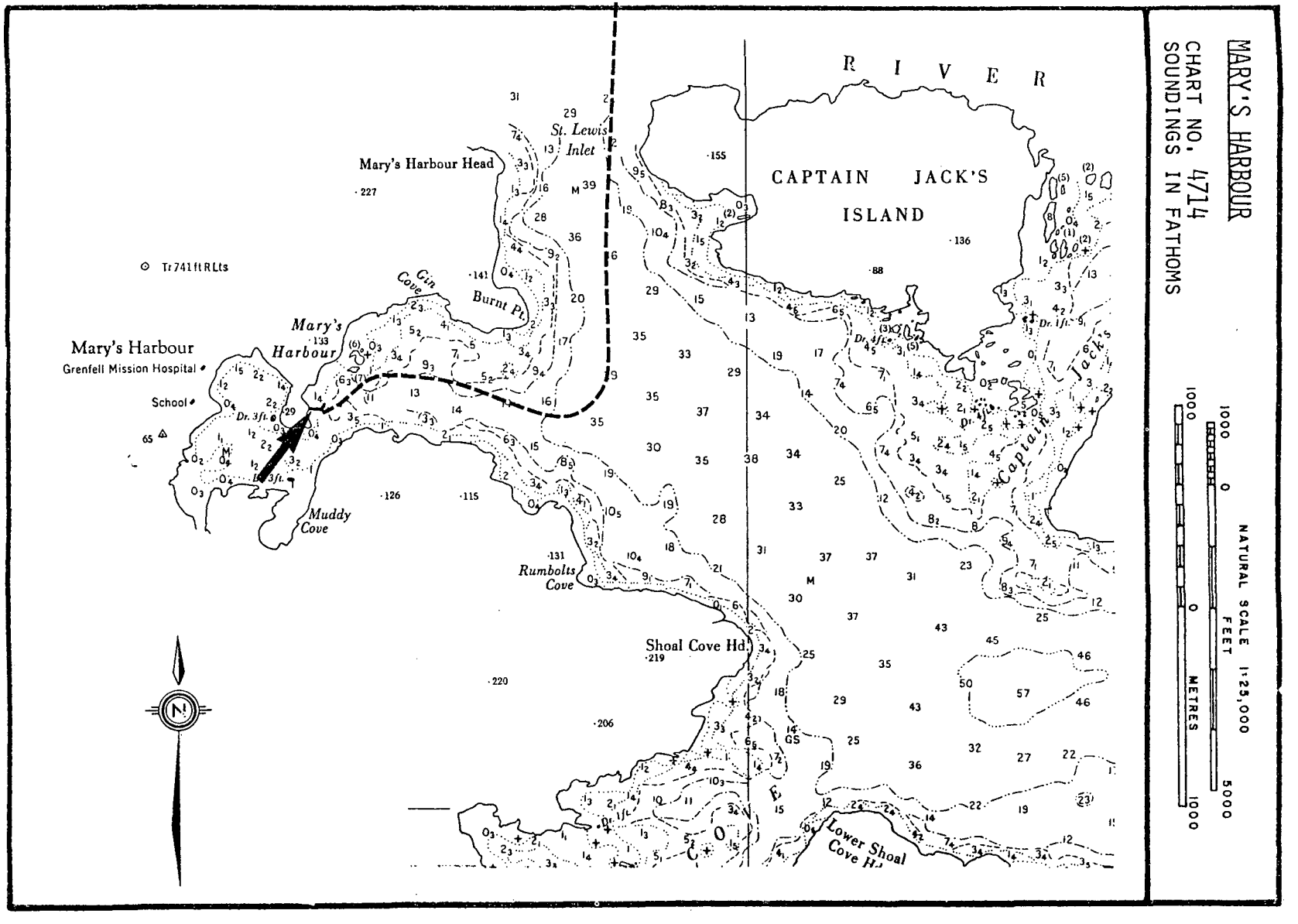
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog and tide effects are not significant. The harbour is rendered unsafe by a northeasterly swell.

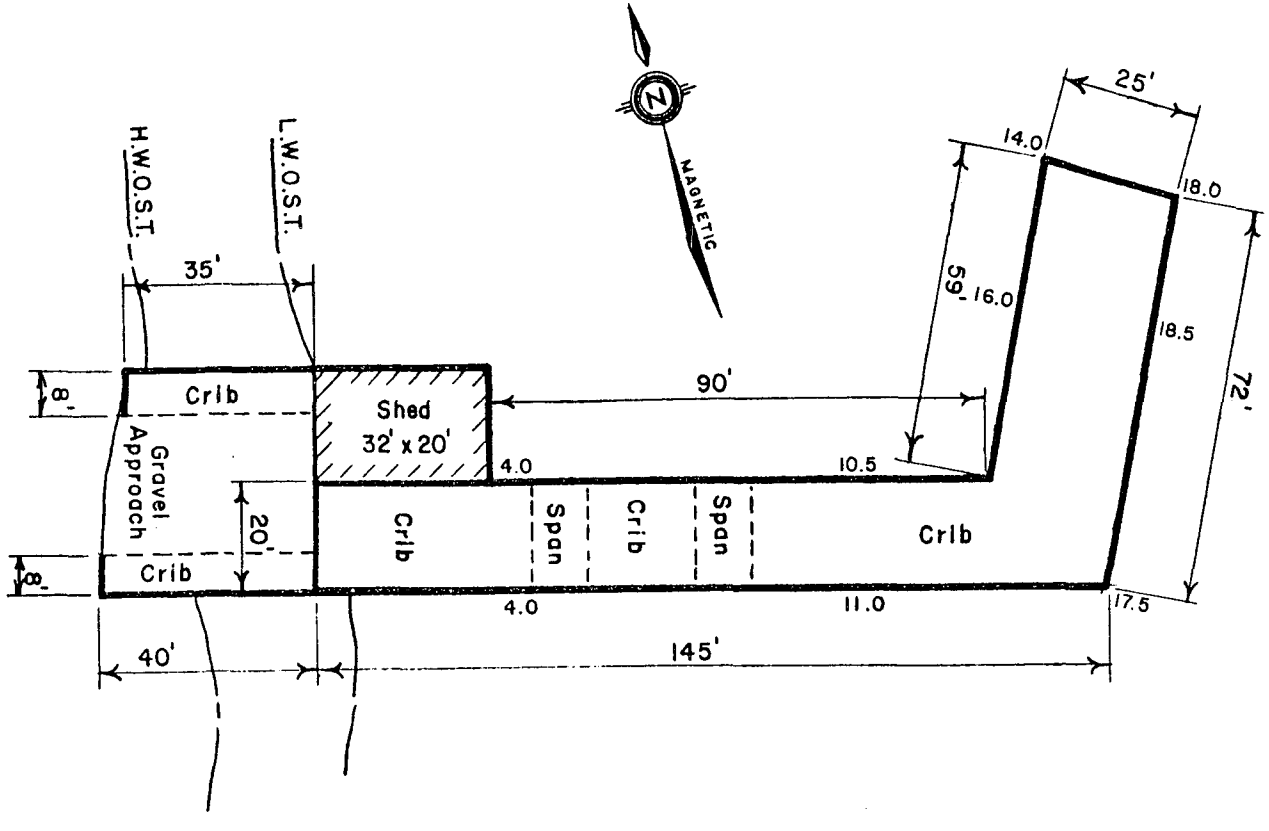
Tide Range (large tide): 5.5 feet

TRAFFIC DATA

Freight Handled:	In	627 tons 1973
	Out	95 tons 1973
Passengers Handled:	In	174 1973
	Out	158 1973
Vessel Calls:	CN 95 1973	


MARYS HARBOUR
CHART NO. 4701
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:75,000
FEET
METRES
1000
0
0
15,000
5000
Southern Head
CAPE ST LEWIS
St Lewis Rk (4)
Deer Hbr
PORT MARNHAM
Marnham I
Deer Pt
LONG HARBOR
Channel boats
Snooks I
Soldier I
(See Chart 4718)
Shag Rks
Bay Pt
Anthony Is (28)
RIVER ISLANDS
Goose I (59)
Capt Jack I
St Marys Hbr Hq
St Marys Harbor
Shoal Cove
Kyer Cove Pt
Marley Rks
Club Cape
Eskimo Bank
ST LEWIS
(See Chart 4717)
SOUND
Gull Rocks (42)
Northern Bank
Blake Ground
Green I
Green I Bank
Monday Bank
Great I (162)
Red I (58)
BATTLE ISLANDS


MARY'S HARBOUR
CHART NO. 4714
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:25,000
FEET
METRES
R I V E R
CAPTAIN JACK'S ISLAND
Captain Jacks
St. Lewis Inlet
Mary's Harbour Head
Tr 741 ft R Lts
Gin Cove
Burnt Pt.
Mary's Harbour
Mary's Harbour
Grenfell Mission Hospital
School
Muddy Cove
Rumbolts Cove
Shoal Cove Hd.
Lower Shoal Cove Hd.
Dr. 3 ft.
Dr. 1 ft.
Dr. 4 ft.
GS



Scale: 1" = 30'

MARYS HARBOUR

PORT: NAIN

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Local Government
POPULATION:	804 (1976 Census)
LOCATION:	Lat. 56°33'N - Long. 61°41"W
NAVIGABLE:	July to November
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	B. Webb

WHARF AND SHED DATA

a) Wharf

Description: Constructed of untreated round timber cribwork, untreated round timber cribwork over untreated round timber pile bents, and untreated round timber pile bents.

Deck surface: Plank

Elevation of Deck Above L.W.O.S.T.: 13 feet

Designed Bearing Capacity of Deck: 100 psf - 5 tons concentrated load

Year Constructed: 1962 and 1974

Present Condition: Good to Excellent

b) Shed

Description: Unknown

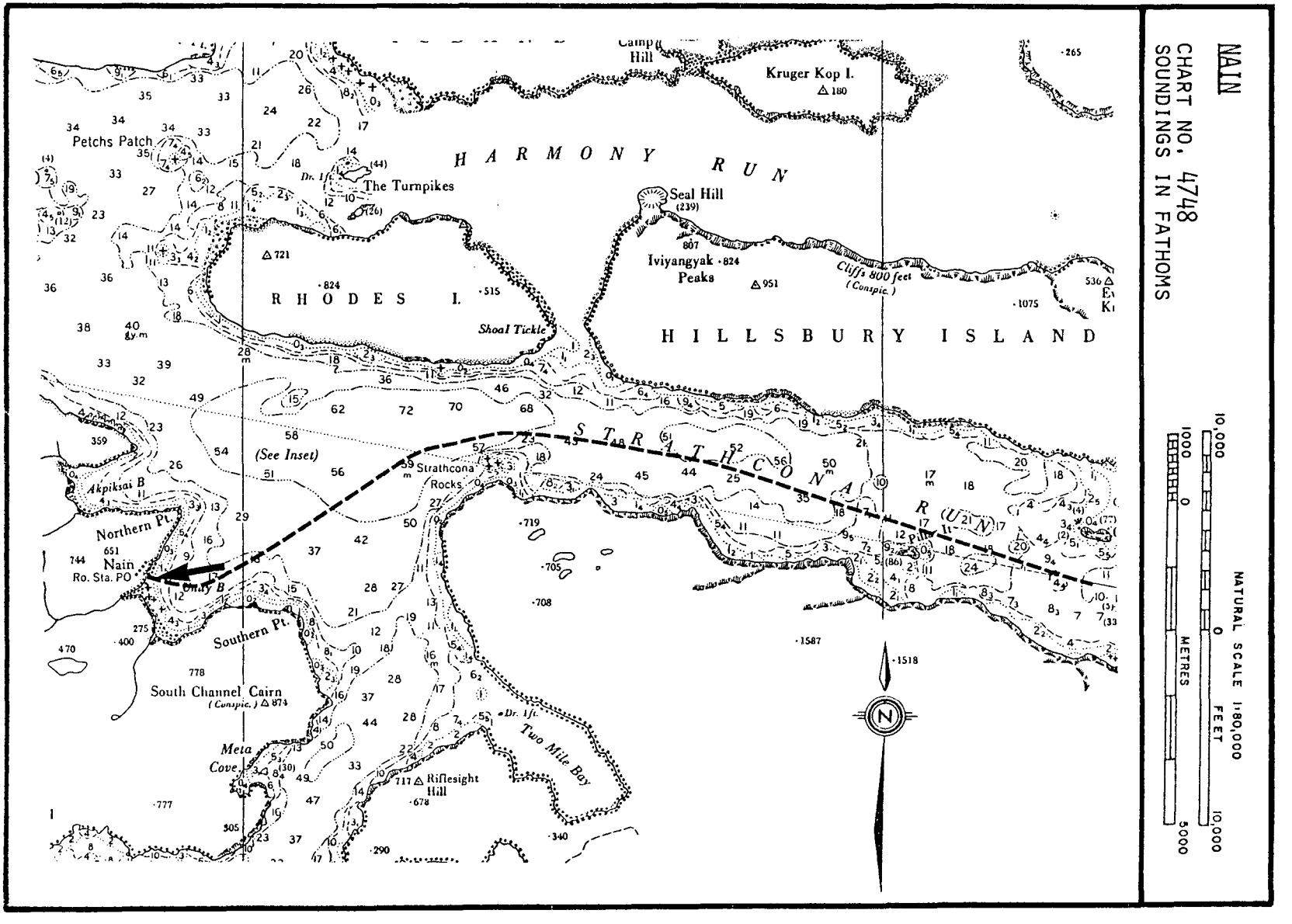
Condition: Unknown

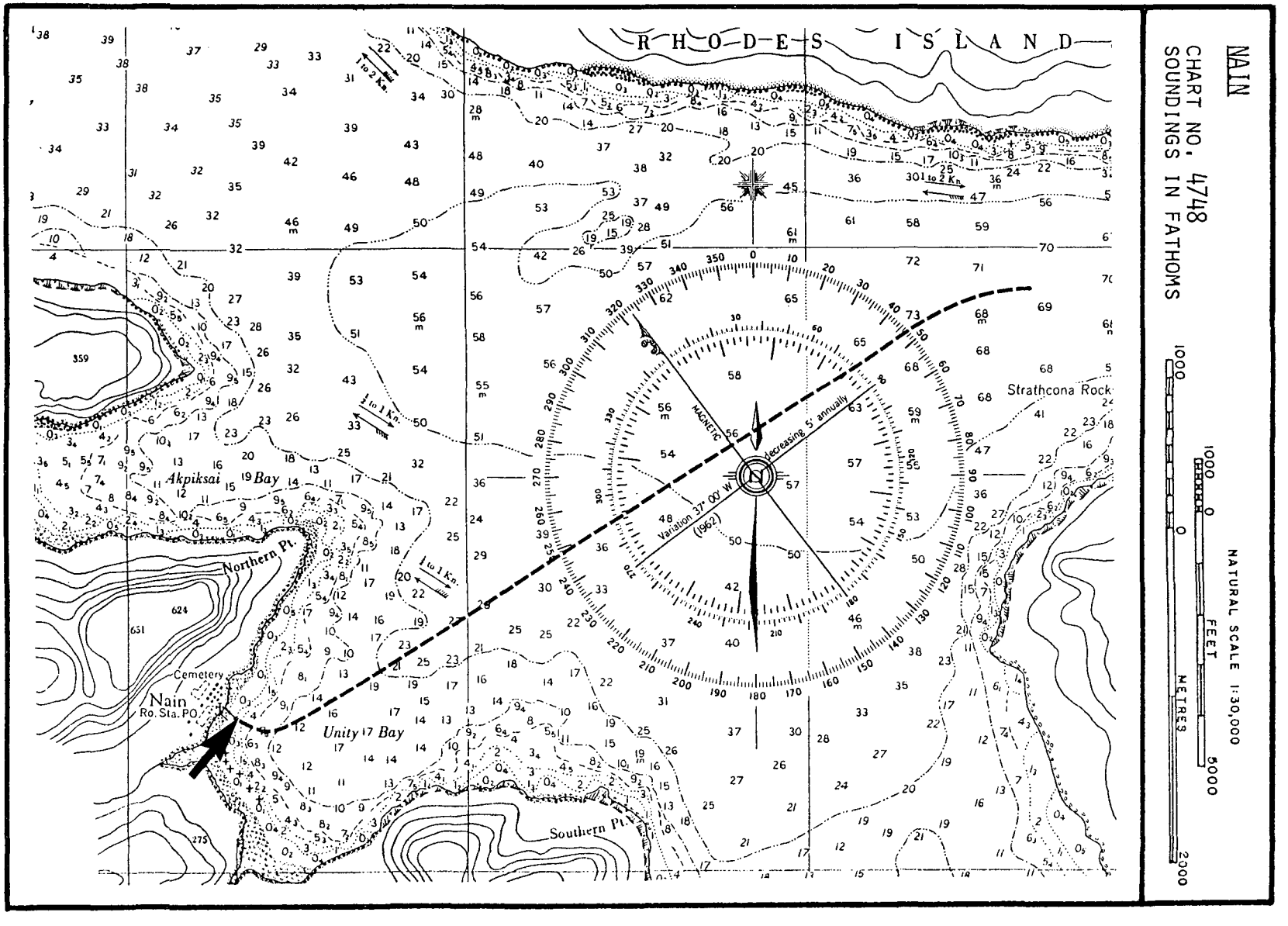
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog, wind and tide effects are not significant.

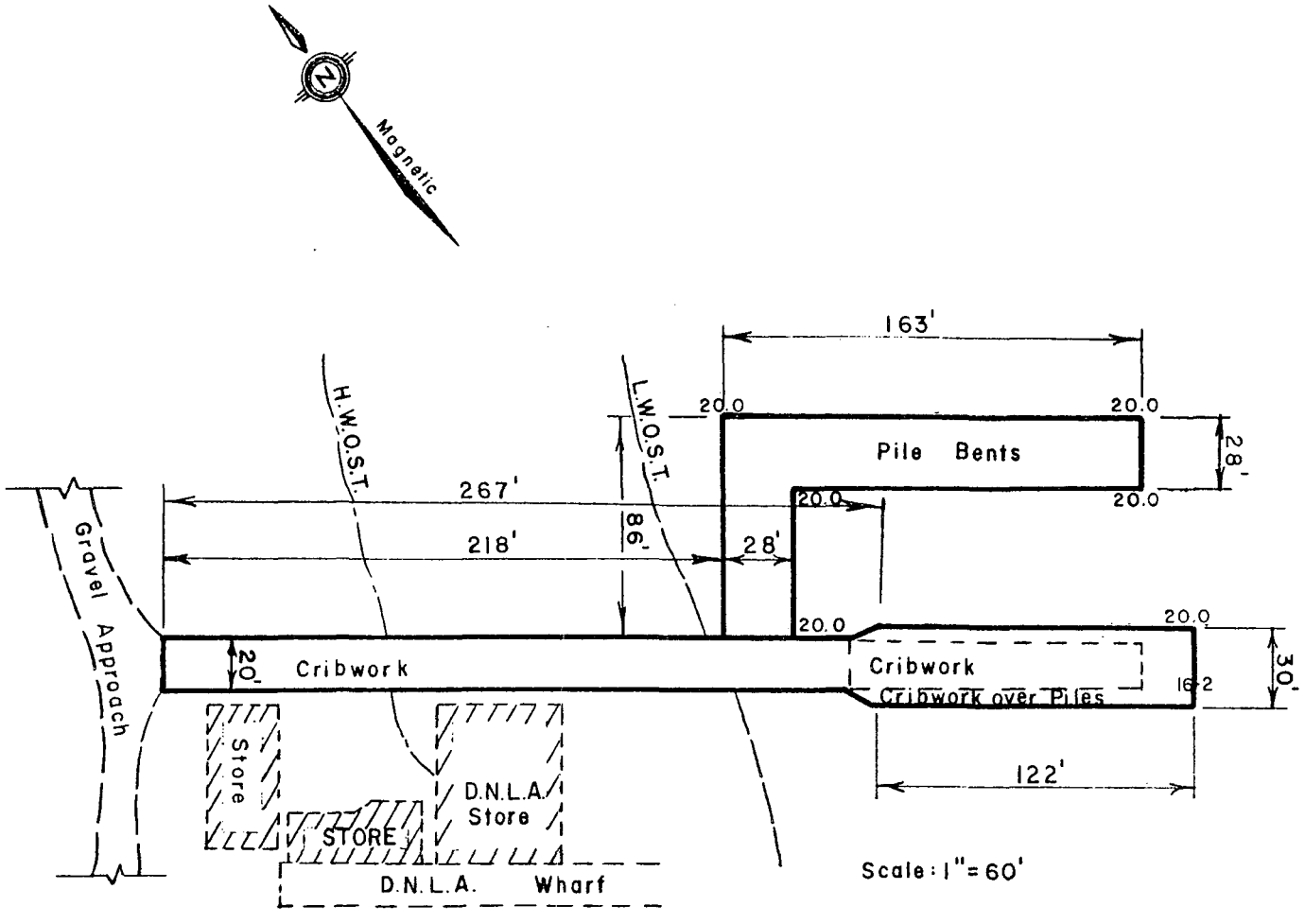
Tide Range (large tide): 9 feet

TRAFFIC DATA

Freight Handled:	In	1,334 tons 1973
	Out	339 tons 1973
Passengers Handled:	In	745 1973
	Out	708 1973
Vessel Calls:	CN 27 1973	


NAIN
CHART NO. 4748
SOUNDINGS IN FATHOMS
HARMONY RUN
RHODES I.
HILLSBURY ISLAND
STRATHCONA RUN
Petchs Patch
The Turnpikes
Seal Hill
Iviyangyak Peaks
Cliffs 800 feet (Conspic.)
Kruger Kop I.
Camp Hill
Shoal Tickle
(See Inset)
Strathcona Rocks
Akpiksai B
Northern Pt.
Nain
Ro. Sta. PO
Sandy B
Southern Pt.
South Channel Cairn (Conspic.)
Meta Cove
Riflesight Hill
Two Mile Bay
NATURAL SCALE 1:80,000
FEET
METRES


NAIN
CHART NO. 4748
SOUNDINGS IN FATHOMS
R H O D E S I S L A N D
Strathcona Rock
Akpiksai Bay
Northern Pt.
Cemetery
Nain
Ro. Sta. P.O.
Unity Bay
Southern Pt.
MAGNETIC
Decreasing 5' annually
Variation 37° 00' W
(1962)
NATURAL SCALE 1:30,000
FEET
METRES


Magnetic
163'
20.0
20.0
Pile Bents
28'
20.0
20.0
H.W.O.S.T.
L.W.O.S.T.
267'
86'
218'
28'
20.0
20.0
Gravel Approach
20'
Cribwork
Cribwork
Cribwork over Piles
16.2
30'
122'
Store
D.N.L.A. Store
STORE
D.N.L.A. Wharf
Scale: 1" = 60'

NAIN

PORT: PORT HOPE SIMPSON

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	554 (1976 Census)
LOCATION:	Lat. 52°33'N - Long. 56°18'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	J. Sampson

WHARF AND SHED DATA

a) Wharf

Description: Constructed of creosoted timber pile bents.

Deck Surface: Concrete

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designed Bearing Capacity of Deck: 400 psf - 20 Ton concentrated load

Year Constructed: 1965

Present Condition: Good

b) Shed

Description: Wood framed building with wood floor constructed over creosoted timber pile bents. Not heated.

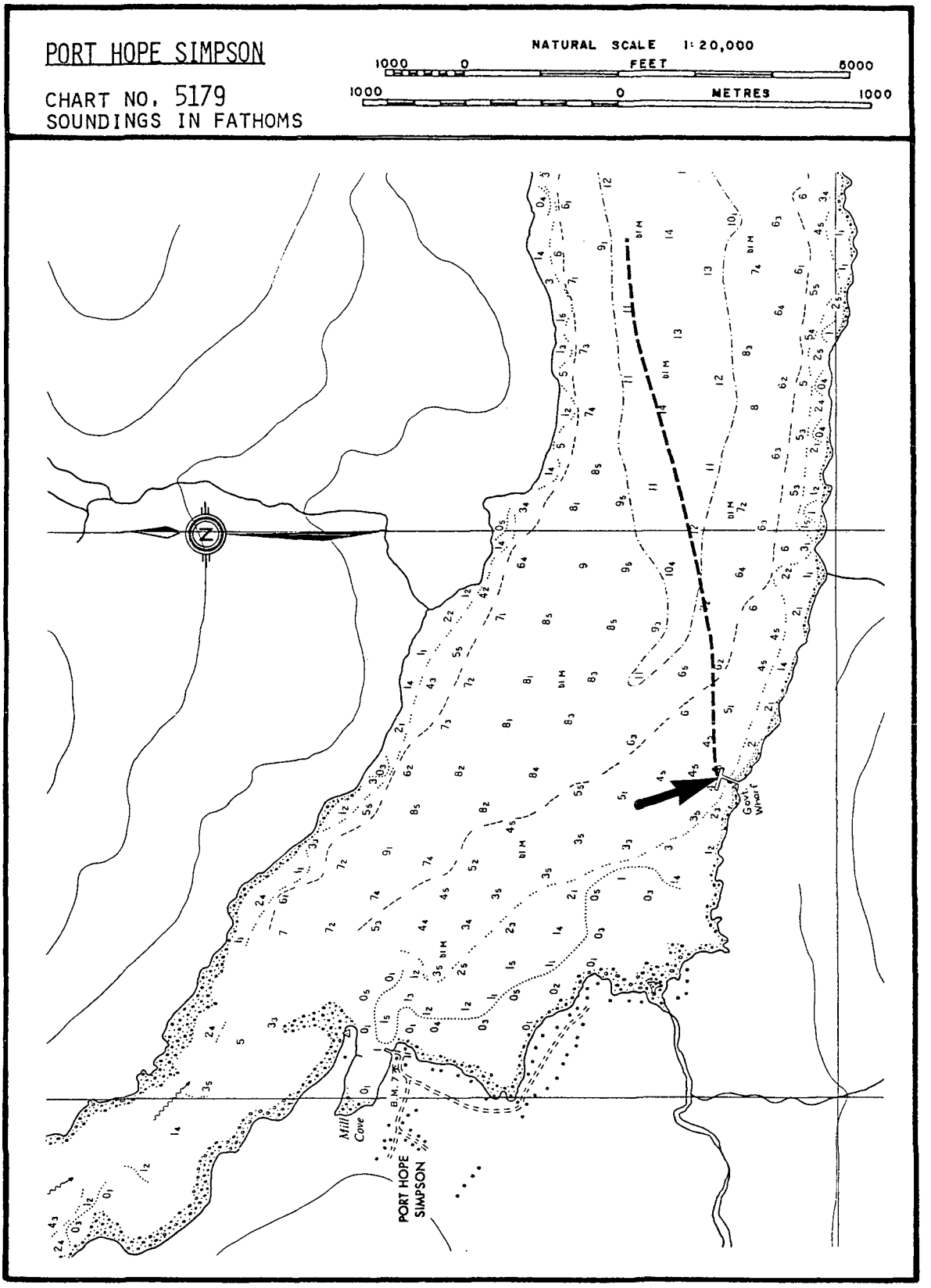
Condition: Unknown

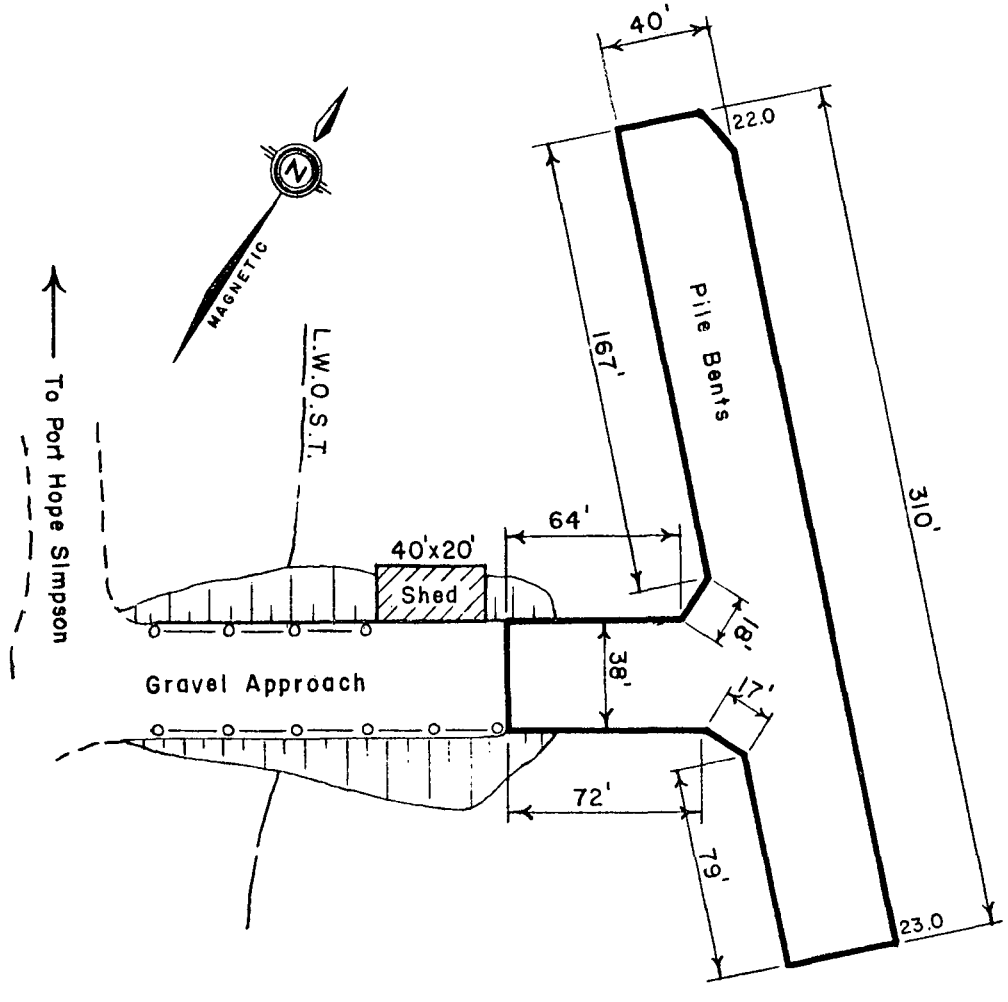
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog, wind and tide effects are not significant.

Tide Range (large tide): 5.5 feet

TRAFFIC DATA

Freight Handled:	In	627 tons 1973
	Out	103 tons 1973
Passengers Handled:	In	215 1973
	Out	176 1973
Vessel Calls:	CN 103 1973	


PORT HOPE SIMPSON
CHART NO. 5179
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:20,000
1000 0 FEET 5000
1000 0 METRES 1000
Mill Cove
PORT HOPE SIMPSON
Govt. Wharf



Scale: 1" = 60'

PORT HOPE SIMPSON

PORT: POSTVILLE

PROVINCIAL DISTRICT:	Labrador North
MUNICIPAL STATUS:	Unincorporated
POPULATION:	163 (1976 Census)
LOCATION:	Lat. 54°56'N - Long. 59°48'W
NAVIGABLE:	Late June to November
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	None

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted creosoted timber cribwork built over creosoted timber pile bents above elevation +2.5.

Deck surface: Plank

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designed Bearing Capacity of Deck: 200 psf - 10 tons concentrated load

Year Constructed: 1971

Present Condition: Fair - 6 years old

b) Shed

Description: Unknown

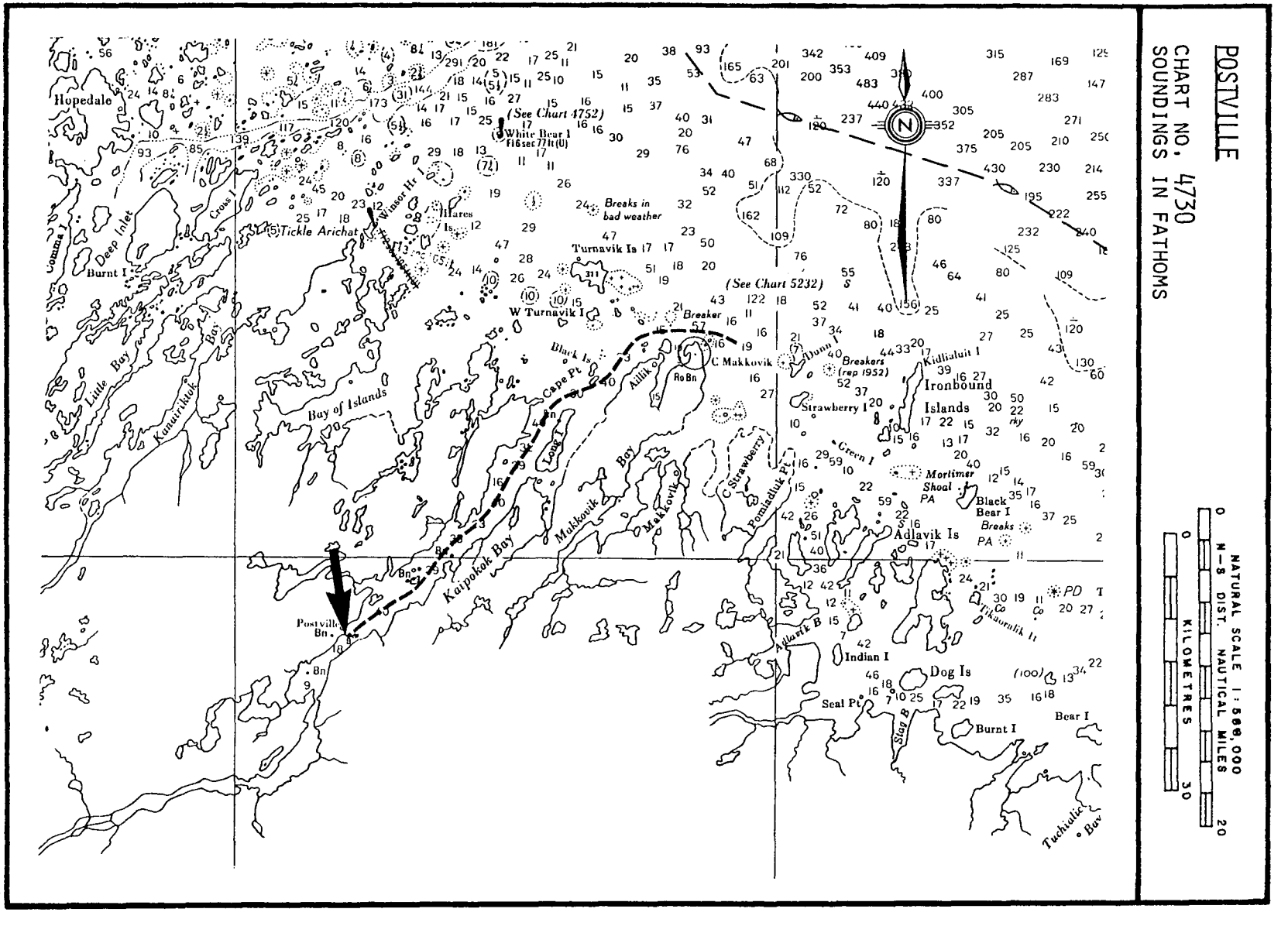
Condition: Unknown

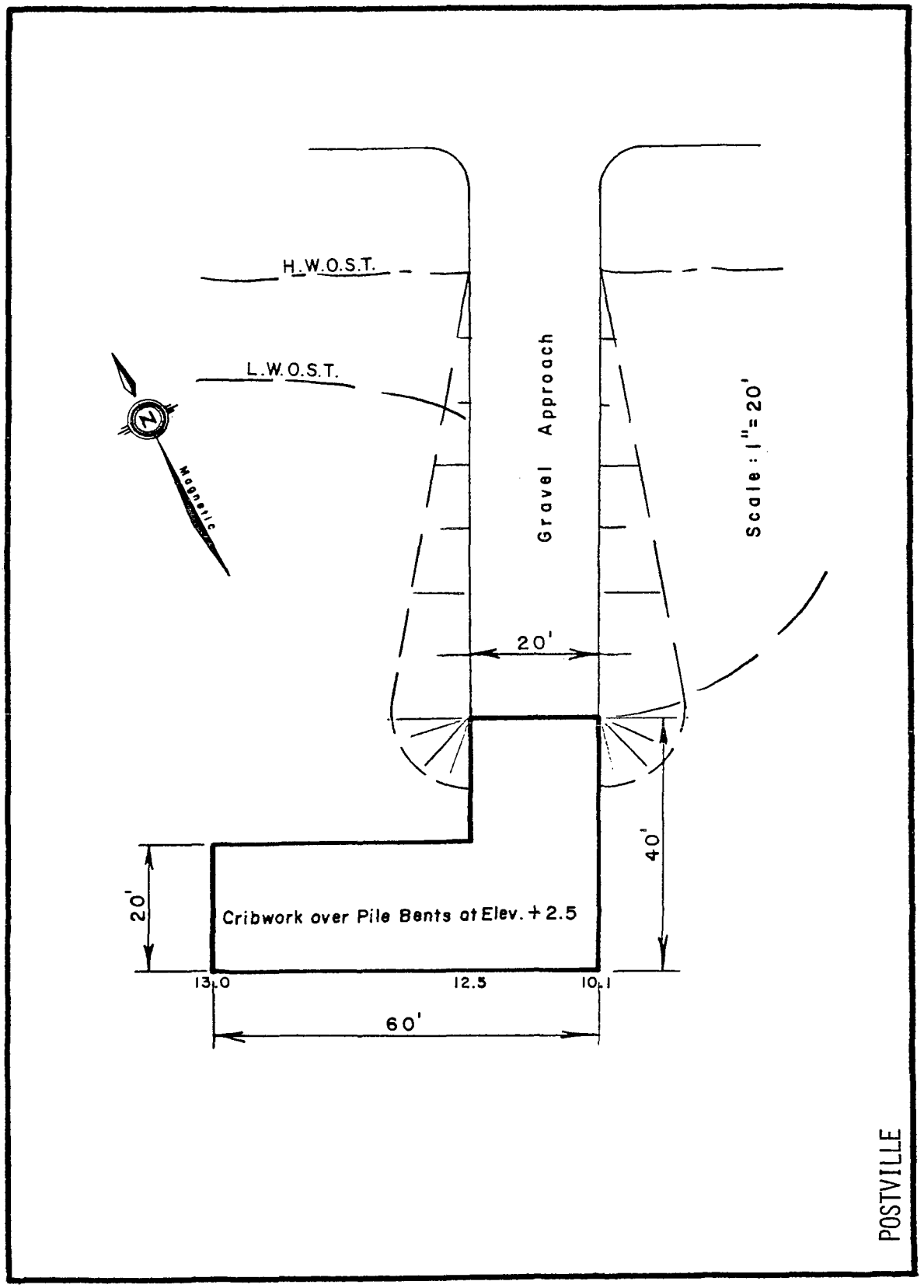
METEOROLOGICAL AND HYDROGRAPHIC DATA; - Fog, wind and tide effects not significant.

Tide Range (large tide): 4 feet

TRAFFIC DATA

Freight Handled:	In	281 tons 1973
	Out	97 tons 1973
Passengers Handled:	In	236 1973
	Out	208 1973
Vessel Calls:	CN 52 1973	


POSTVILLE
CHART NO. 4730
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:500,000
N-S DIST. NAUTICAL MILES
KILOMETRES
Hopedale
Deep Inlet
Burnt I
Little Bay
Kanairiktok Bay
Bay of Islands
Tickle Arichat
Winsor Hr
Hares Is
Turnavik Is
W Turnavik I
(See Chart 4752)
White Bear I
Breaks in bad weather
(See Chart 5232)
Breaker
C Makkovik
Black Is
Cape Pt
Aillik
Ro Bn
Kaipokok Bay
Makkovik Bay
Postville Bn
Strawberry I
Green I
Mortimer Shoal
Breakers (rep 1952)
Kidliatuit I
Ironbound Islands
Black Bear I
Breaks
Adlavik Is
Pomiadluk Pt
C Strawberry
Indian I
Dog Is
Seal Pt
Burnt I
Bear I
Tuchialik Bay


H.W.O.S.T.
L.W.O.S.T.
Magnetic
Gravel Approach
Scale: 1" = 20'
20'
40'
20'
Cribwork over Pile Bents at Elev. + 2.5
13.0
12.5
10.1
60'
POSTVILLE

PORT: RED BAY

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	296 (1976 Census)
LOCATION:	Lat. 51°44'N - Long. 56°26'W
NAVIGABLE:	Mid May to December
HIGHWAY CONNECTIONS:	Route 510 (gravel) to ferry to St. Barbe to 430 (gravel and paved) to T.C.H.
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	M. Pike

WHARF AND SHED DATA

a) Wharf

Description: Constructed of creosoted timber cribwork over pile bents above elevation +1.5 and untreated round timber cribwork and spans.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 9 feet

Designed Bearing Capacity of Deck: Stem - 100 psf - 5 tons concentrated load - head block 200 psf - 10 tons concentrated load

Year Constructed: 1962 & 1974

Present Condition: Fair to excellent

b) Shed

Description: Wood framed building 50' x 21' with wood floor. Not heated.

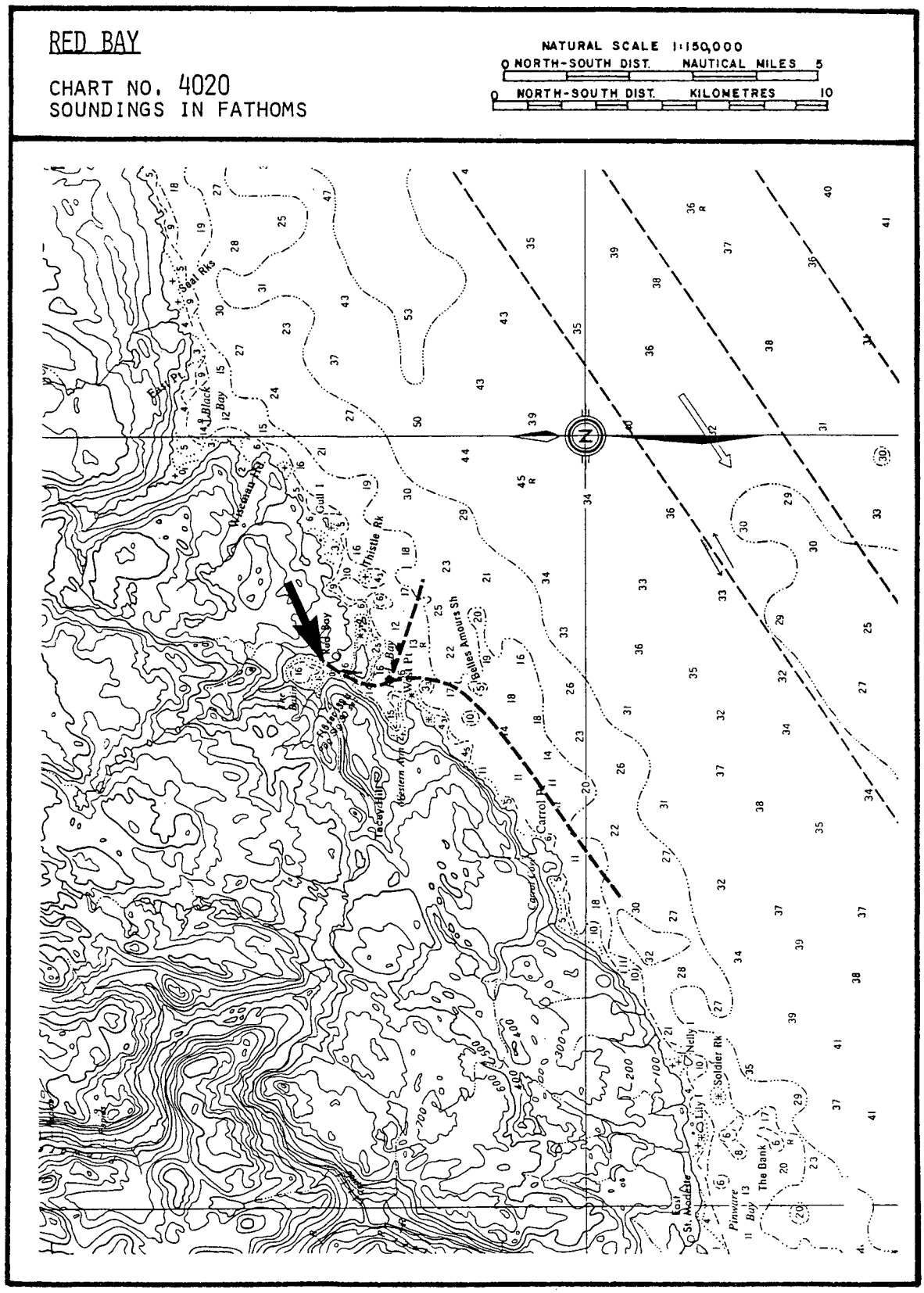
Condition: Fair

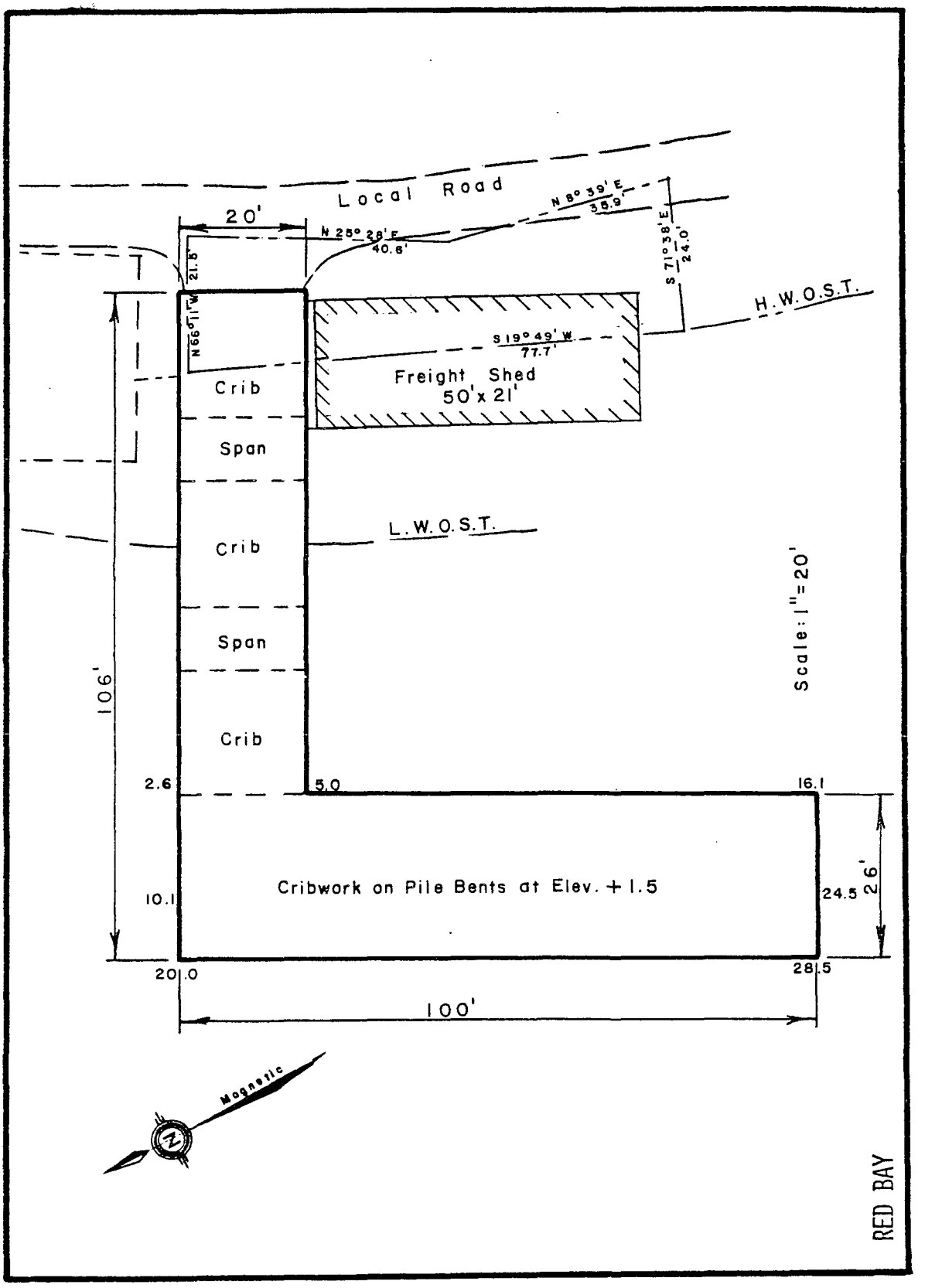
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Dense fogs prevail during the summer & sometimes last for several days: The fogs occur with east or west winds. Tidal currents of up to 3 knots are experienced through the Straits of Belle Isle.

Tide Range (large tide):

TRAFFIC DATA

Freight Handled:	In	644 tons 1973
	Out	82 tons 1973
Passengers Handled:	In	28 1973
	Out	17 1973
Vessel Calls:	CN 49 1973	


RED BAY
CHART NO. 4020
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:150,000
0 NORTH-SOUTH DIST. NAUTICAL MILES 5
0 NORTH-SOUTH DIST. KILOMETRES 10
Seal Rks
Black Bay
Gull I
Thistle Rk
Red Bay
Belles Amours Sh
Western Arm
Carrol Pt
Great Cove
Nelly I
Soldier Rk
Lily I
The Bank
St. Modeste
Pinware Bay


Local Road
20'
N 25° 28' E
40.8'
N 8° 39' E
35.9'
S 71° 38' E
24.0'
21.8'
N 66° 11' W
H.W.O.S.T.
S 19° 49' W
77.7'
Freight Shed
50' x 21'
Crib
Span
Crib
L.W.O.S.T.
Span
Crib
106'
Scale: 1" = 20'
2.6
5.0
16.1
Cribwork on Pile Bents at Elev. + 1.5
10.1
24.5
26'
20.0
28.5
100'
Magnetic
N
RED BAY

PORT: RIGOLET

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	203 (1973 Census)
LOCATION:	Lat. 54°11'N - Long. 58°26'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	Unknown

WHARF AND SHED DATA

a) Wharf

Description: Constructed of round untested timber crib and span construction fully ballasted.

Deck Surface; Plank

Elevation of Deck Above L.W.O.S.T.: 10 feet

Designed Bearing Capacity of Deck:

Year Constructed: 1976

Present Condition: Excellent

b) Shed

Description: Unknown

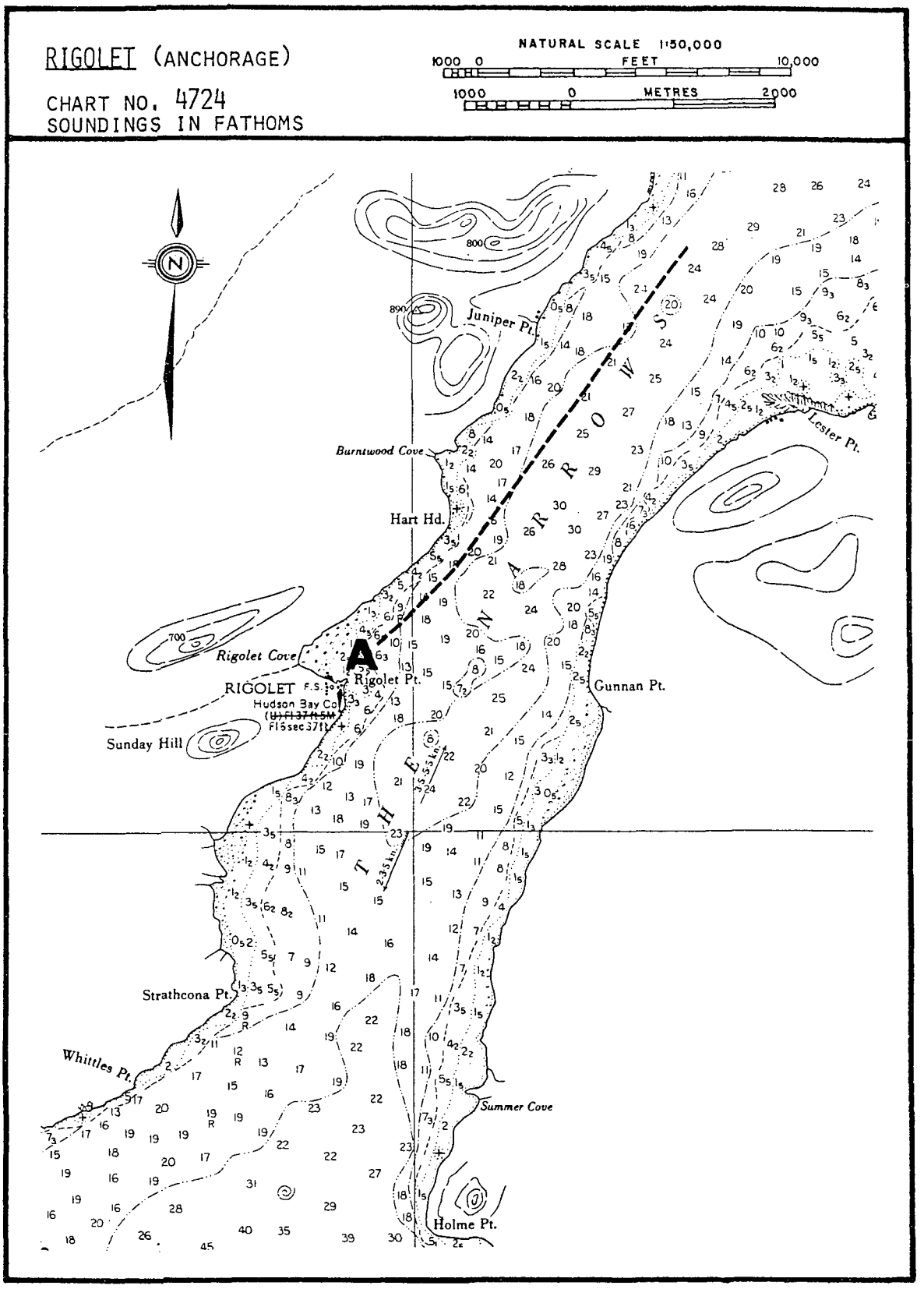
Condition: Unknown

METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog and wind effects are not significant. There are strong tidal currents through "The Narrows" off Rigolet. The velocity of the flood is 2 to 3 1/2 knots and the ebb 3 1/2 to 5 1/2 knots.

Tide Range (large tide): 4 feet

TRAFFIC DATA - Prior to Wharf Construction

Freight Handled:	In	399 tons 1973
	Out	29 tons 1973
Passengers Handled:	In	148 1973
	Out	176 1973
Vessel Calls:	CN 98 1973	
Remarks:	Anchorage for CN Vessels	


RIGOLET (ANCHORAGE)
CHART NO. 4724
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:50,000
1000 0 FEET 10,000
1000 0 METRES 2000
N
Juniper Pt.
Burntwood Cove
Hart Hd.
Rigolet Cove
RIGOLET
Rigolet Pt.
Hudson Bay Co
Sunday Hill
Gunnan Pt.
Lester Pt.
Strathcona Pt.
Whittles Pt.
Summer Cove
Holme Pt.
A
NARROWS
THE

PORT: WEST ST. MODESTE

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	271 (1976 Census)
LOCATION:	Lat. 51°36'N - Long. 56°42'W
NAVIGABLE:	Mid May to December
HIGHWAY CONNECTIONS:	Route 510 (gravel) to ferry to St. Barbe to 430 (gravel and paved) to T.C.H.
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	MOT
WHARFINGER:	J. O'Dell

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted creosoted and untreated timber cribwork and spans.

Deck Surface: Plank

Elevation of Deck Above L.W.O.S.T.: 9 feet

Designed Bearing Capacity of Deck: 100 psf - 5 tons concentrated load

Year Constructed: 1964

Present Condition: Poor - Major renovations required

b) Shed

Description: Wood framed building 18' x 40' with wood floor. Not heated.

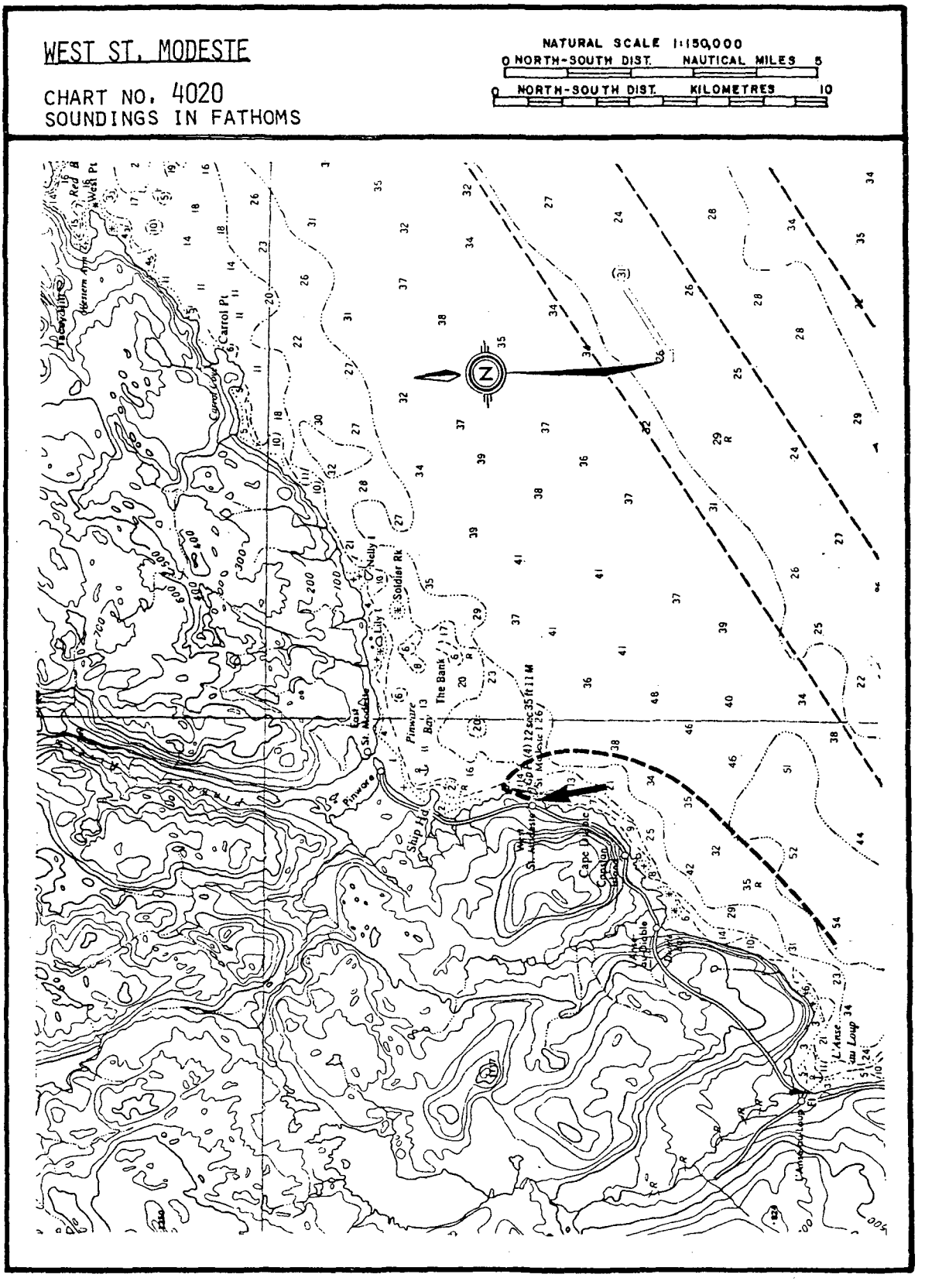
Condition: Unknown

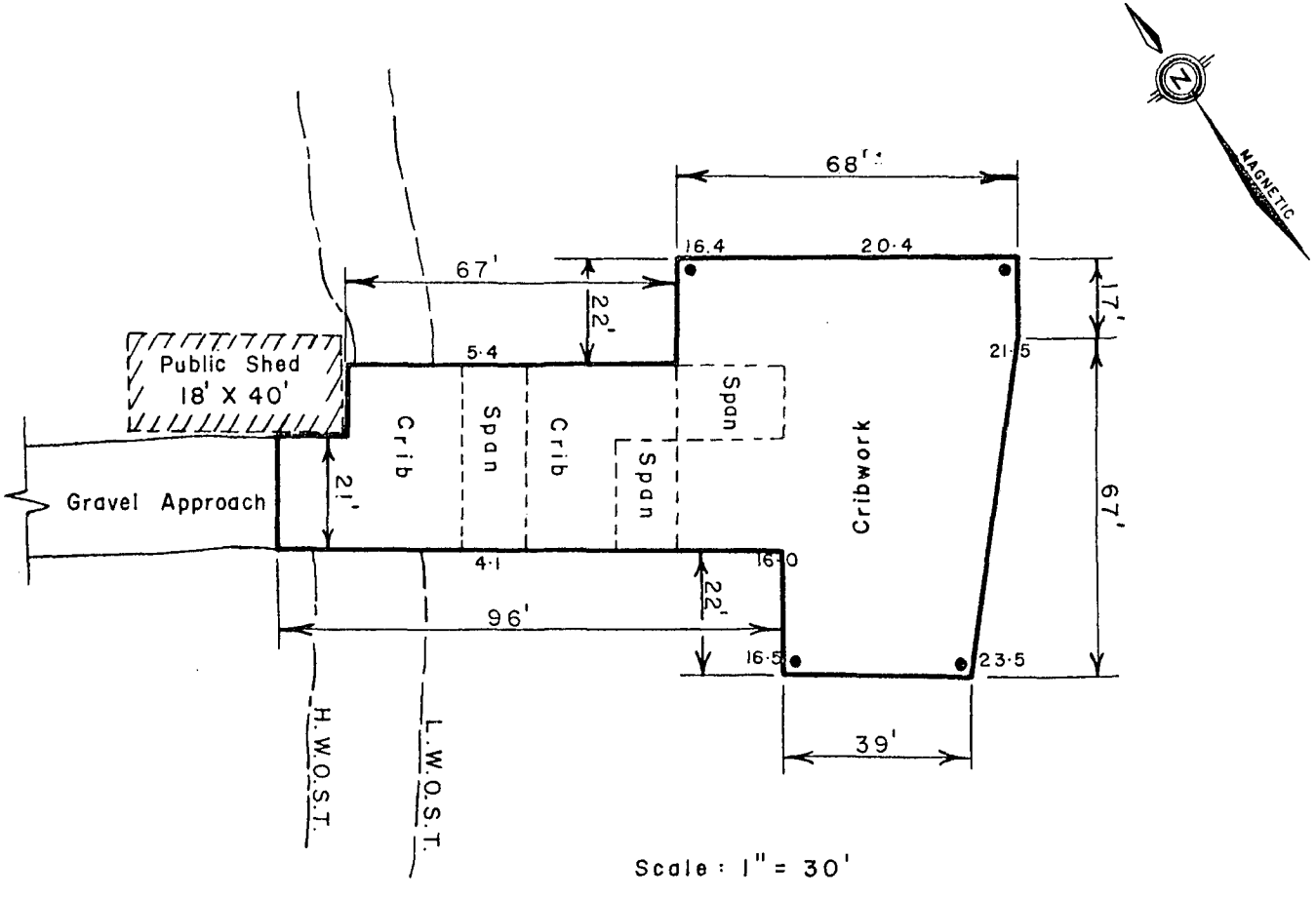
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Dense fogs prevail during summer and sometimes last for several days. The fogs occur with either east of west winds. Strong tidal streams set through the tickle just off the government wharf. Wind effects are not significant.

Tide Range (large tide): 5.5 feet

TRAFFIC DATA

Freight Handled:	In	543 tons 1973
	Out	23 tons 1973
Passengers Handled:	In	14 1973
	Out	20 1973
Vessel Calls:	CN 46 1973	


WEST ST. MODESTE
CHART NO. 4020
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:150,000
0 NORTH-SOUTH DIST. NAUTICAL MILES 5
0 NORTH-SOUTH DIST. KILOMETRES 10
Western Arm
Red B
West Pt
Carrol Pt
Carrol Cove
Nelly I
Soldier Rk
Lily I
The Bank
Pinware Bay
Pinware
Ship Hd
St. Modeste
Cape Double
Cape Double Bay
L'Anse au Loup
Anse au Loup



WEST ST. MODESTE

PORT: WILLIAM'S HARBOUR

PROVINCIAL DISTRICT:	Labrador South
MUNICIPAL STATUS:	Unincorporated
POPULATION:	75 (1971 Census)
LOCATION:	Lat. 52°34'N - Long. 55°46'W
NAVIGABLE:	June to December
HIGHWAY CONNECTIONS:	None
RAIL CONNECTIONS:	None
PORT ADMINISTERED BY:	Nobody
WHARFINGER:	None

WHARF AND SHED DATA

a) Wharf

Description: Constructed of fully ballasted untreated timber cribwork

Deck surface: Plank

Elevation of Deck Above L.W.O.S.T.: 9 feet

Designed Bearing Capacity of Deck: 100 psf - 5 tons concentrated load

Year Constructed: 1958

Present Condition: Fair

b) Shed

Description: Unknown

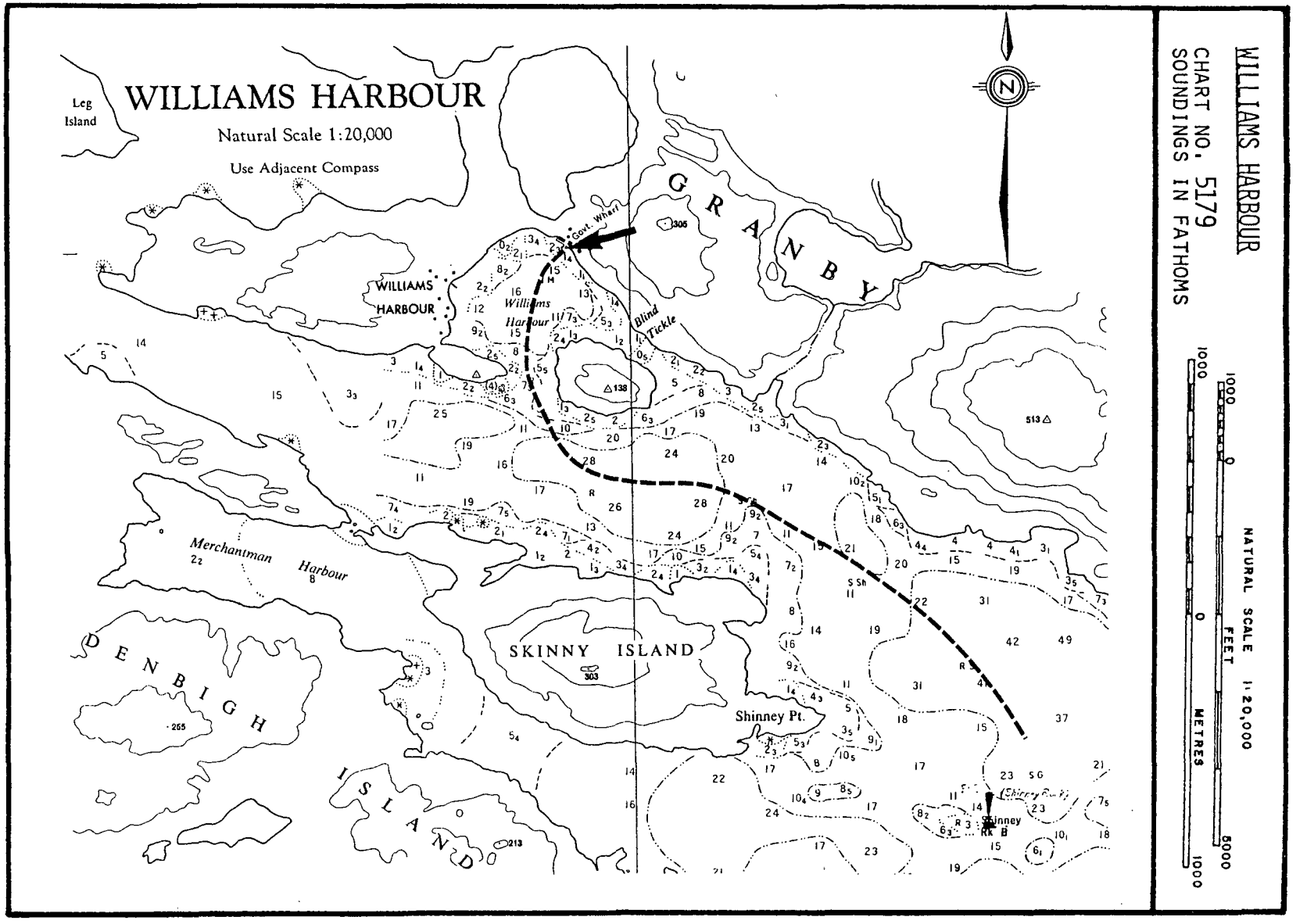
Condition: Unknown

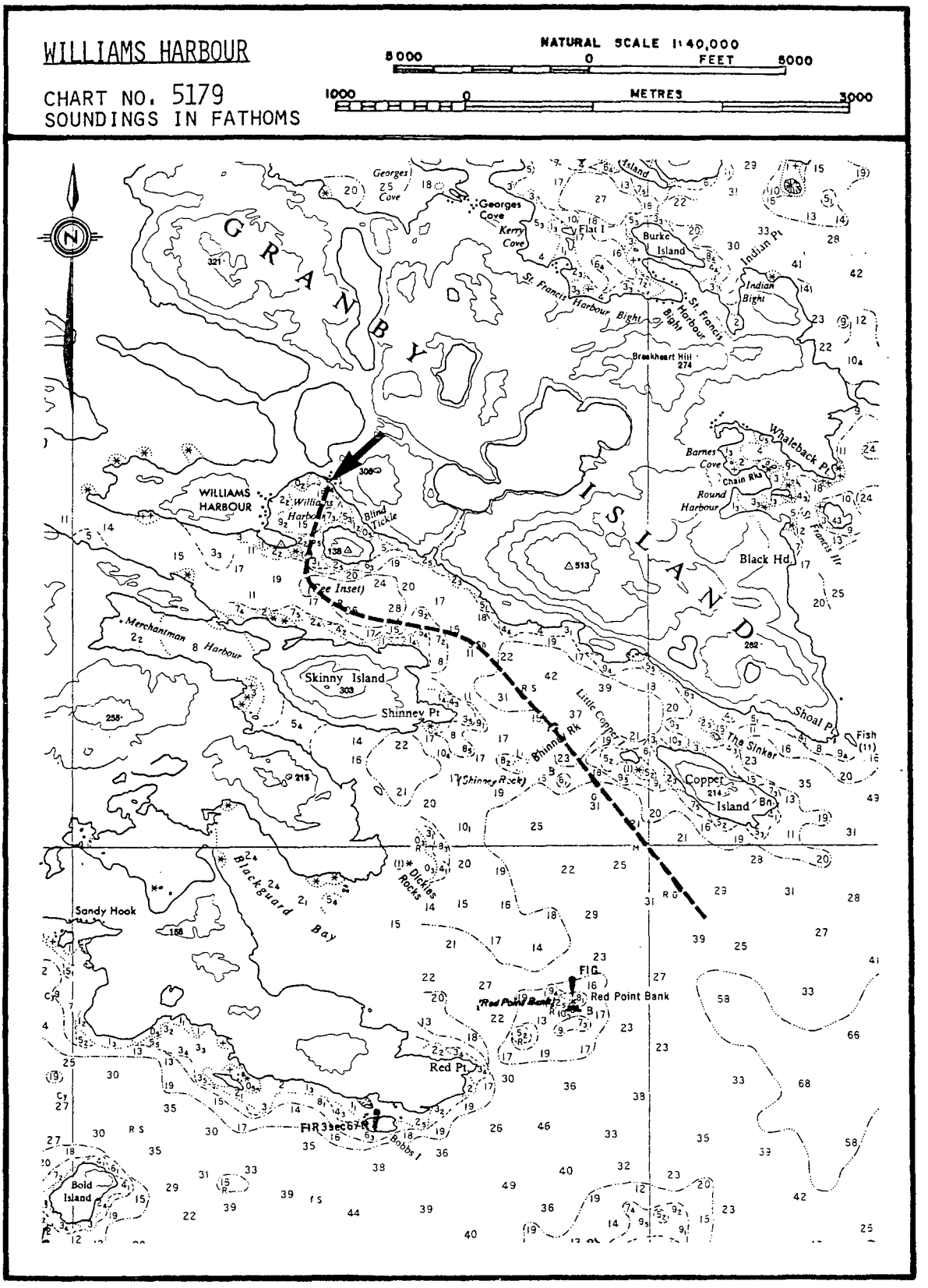
METEOROLOGICAL AND HYDROGRAPHIC DATA: - Fog, wind and tide effects are not significant.

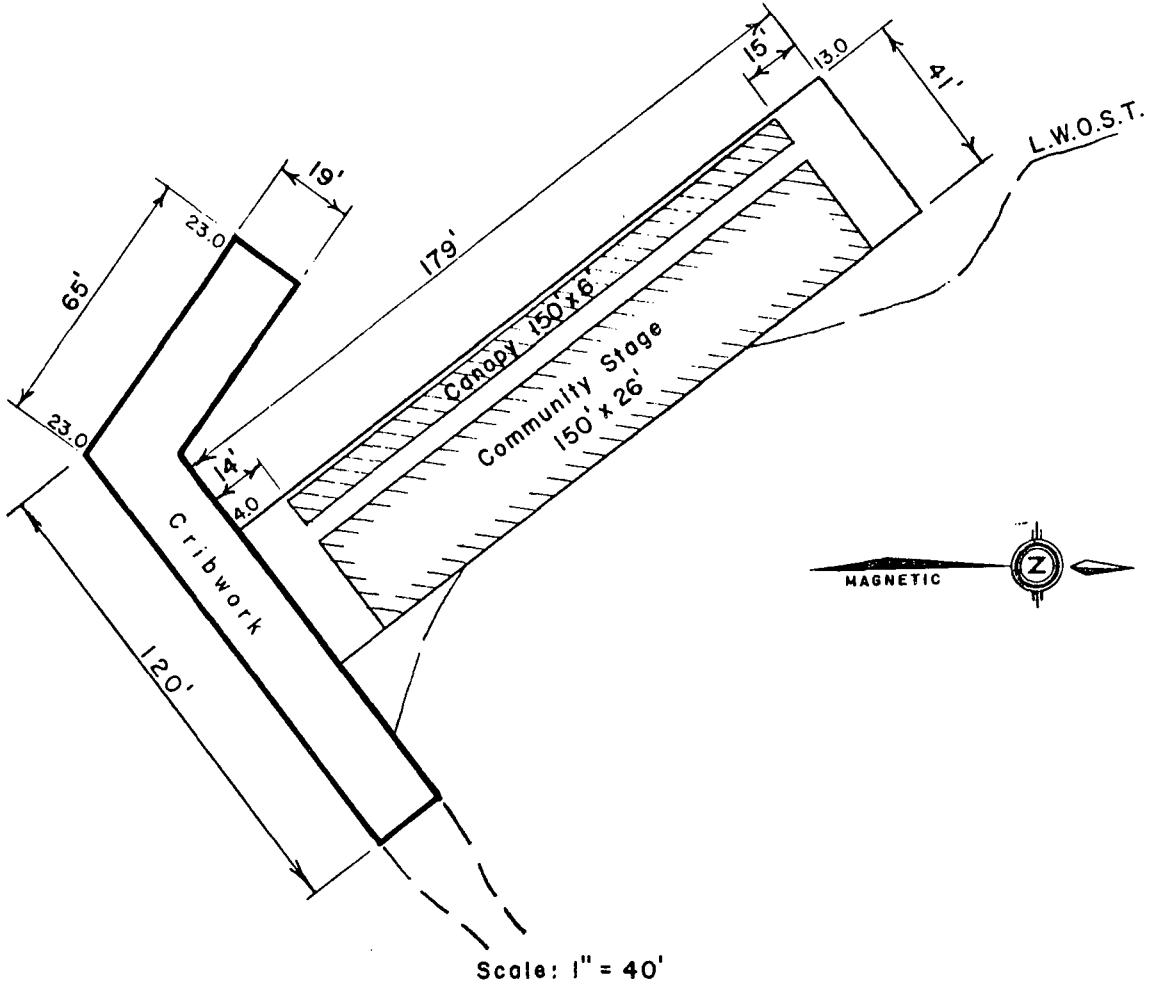
Tide Range (large tide): 5.5 feet

TRAFFIC DATA

Freight Handled:	In	43 tons 1973
	Out	72 tons 1973
Passengers Handled:	In	88 1973
	Out	112 1973
Vessel Calls:	CN 50 1973	


WILLIAMS HARBOUR
Natural Scale 1:20,000
Use Adjacent Compass
Leg Island
GRANBY
WILLIAMS HARBOUR
Williams Harbour
Blind Tickle
Govt. Wharf
Merchantman Harbour
SKINNY ISLAND
Shinney Pt.
DENBIGH ISLAND
N
WILLIAMS HARBOUR
CHART NO. 5179
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:20,000
FEET
METRES


WILLIAMS HARBOUR
CHART NO. 5179
SOUNDINGS IN FATHOMS
NATURAL SCALE 1:40,000
5000 0 FEET 5000
1000 0 METRES 3000
GRANBY ISLAND
WILLIAMS HARBOUR
Georges Cove
Kerry Cove
Flat I
Burke Island
Indian Pt
Indian Bight
St. Francis Harbour Bight
Breakheart Hill 274
Whaleback Pt
Barnes Cove
Round Harbour
Black Hd
Blind Tickle
Merchantman Harbour
Skinny Island
Shinney Pt
Shinney Rk
Little Copper
The Sinker
Shoal Pt
Copper Island Bn
Blackguard Bay
Dickies Rocks
Sandy Hook
Red Point Bank
Red Pt
Bobbs I
Bold Island



WILLIAMS HARBOUR

APPENDIX TO
CHAPTER 13

ENVIRONMENTAL MONITORING AND PREDICTING

A13-A SHIP REPORTS

Sample Ship Report

C GD G 99623 70635 12124 32315 98020 14000 21530
21310 01100 10380 30501 10805 ICE 90090

Information Provided with each Ship Report

1. Geographic position
2. Day of month, and time of barometer measurement
3. How wind speed was obtained
4. What fraction of the sky covered by cloud
5. Wind speed and direction
6. Horizontal visibility
7. Present weather conditions
8. Past weather conditions (previous three hours)
9. Sea level pressure and temperature
10. The fraction of sky covered by a specific cloud type; height of the lowest cloud observed
11. Ship's true course and speed for previous three hours
12. Pressure tendency and variation over the past three hours
13. Type of significant cloud, fraction of sky covered by it and height of base above the sea
14. Any special phenomena (reported only by ocean weather ships)
15. Air-sea temperature differential, dew point
16. Actual sea surface temperature
17. Ice accretion data: i.e., source, thickness and rate
18. Period and height of sea waves
19. Period, height and direction from which swell waves are coming
20. Type and effect of ice on navigation
21. Bearing of, and distance to, ice edge from ship
22. Orientation of ice edge

Sample Decoded Ship Report

(Actual Ship's Weather Report received at Gander, Newfoundland, October, 12, 1977 12:00 GMT).

	Group 1	Group 2								
GYPH	99599	70592	12123	73205	98015	15805	794/9	23304	0//05	10522
	30202	10808								
			Group 3							
				Group 4						
					Group 5					
						Group 6				
	Group 11						Group 7			
		Group 12						Group 8		
									Group 9	
										Group 10

Group 1	99599
99	Designates a ship report
599	Latitude 59.9°N
Group 2	70592
7	Latitude is North; Longitude is West
0592	Longitude 59.2°W
Group 3	12123
12	12th day of month
12	12:00 GMT
3	Wind speed was estimated
Group 4	73205
7	7/8 cloud cover
32	Wind from 320° (true)N
05	Wind = 5 knots (estimated, see above)
Group 5	98015
98	Visibility 11-27 nautical miles
01	Present weather all clouds
5	Weather in previous 3 hours - Drizzle
Group 6	15805
158	Pressure (sea level) = 1015.8 mbars
05	Air temperature (sea level) = 0.5°C
Group 7	794/9
7	7/8 sky covered by C_L clouds (C_L clouds because second digit is greater than zero).
9	C_L clouds are Cumulonimbous and Cirriform, and often anvil shaped.
4	Base of lowest clouds seen is 300-600 m, a.s.l.
/	No report on C_M clouds due to darkness, fog or snow
9	Cirrocumulus alone or cirrocumulus accompanied by cirrus or cirrusstratus. Cirrocumulus predominates.
Group 8	23304
2	Ship's course over previous 3 hours was East
3	Ship's speed over previous 3 hours, 11-15 knots.
3	Pressure over previous 3 hours, decreasing or steady at first then increasing at first then increasing more rapidly.
04	Net change in pressure over past 3 hours = 0.4 mbars.

Group 9	0//05
0	Signifies 11th group (if all groups reported)
//	Air-sea temperature difference not reported
05	Dew point = $5^{o}C$
Group 10	10522
1	Signifies 12th group (if all groups reported)
052	Sea-surface = $5.2^{o}C$
2	Tenths figure for air temperature (group 6) = 2
Group 11	30202
3	Signifies sea wave group
02	Wave period = 2 s
02	Wave height = 1.5 m
Group 12	10808
10	Wave approaching from 100° (true) N
8	Swell period = 8 s
08	Swell height = 4 m

A13-B SURFACE AND UPPER AIR WEATHER STATIONS

Sample Surface Weather Station Report

71900 61917 74021 1404 65600 03610 63126 40803

Information Provided with each Surface and Upper Air Report

1. Geographic position
2. Total cloud
3. Wind direction and speed
4. Visibility
5. Present and past weather
6. Pressure and temperature
7. Cloud type and height
8. Dew point
9. Character and amount of pressure change
10. Amount and time of Precipitation
11. Depth of snow
12. Special phenomena
13. 24-hour precipitation
14. Maximum and minimum temperature

A13-C SURFACE WEATHER CHARTS

Sample Surface Weather Chart

(See Figure C1 and C2)

Information provided with each Surface Weather Chart

1. Amount of sky covered by cloud
2. Wind speed and direction
3. Air temperature
4. Sea level atmospheric pressure
5. Pressure variation and tendency for three hours prior to observation
6. Ship's heading (if a ship report)
7. Sea surface temperature
8. Dew point temperature
9. Horizontal visibility
10. Present weather conditions (may not be plotted if a ship report)
11. Past weather conditions (may not be plotted if a ship report)
12. Present starting and amount of precipitation (may not be plotted if a ship report)
13. Cloud types present, height and amount.

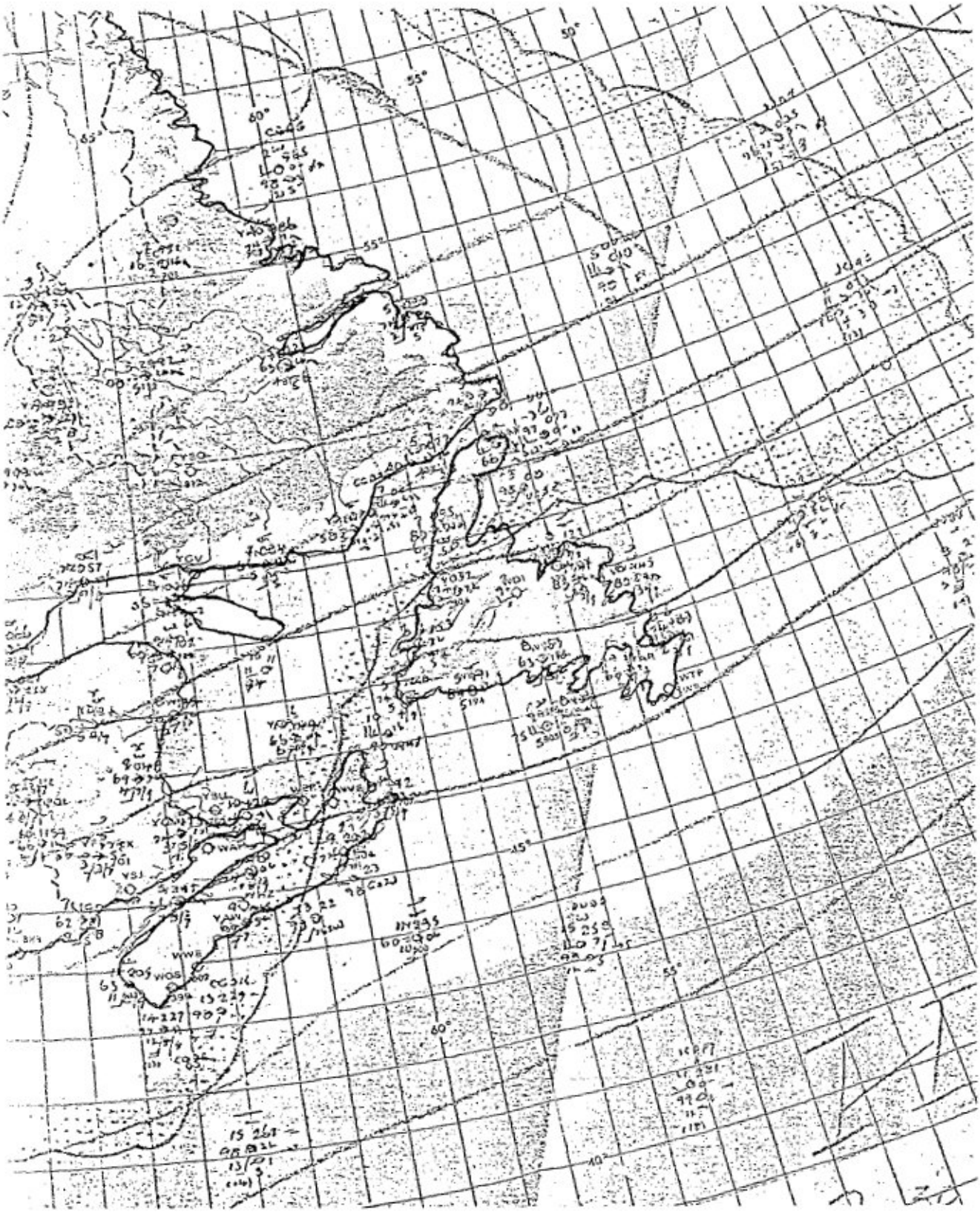


FIGURE C1 SECTION OF A SURFACE WEATHER CHART

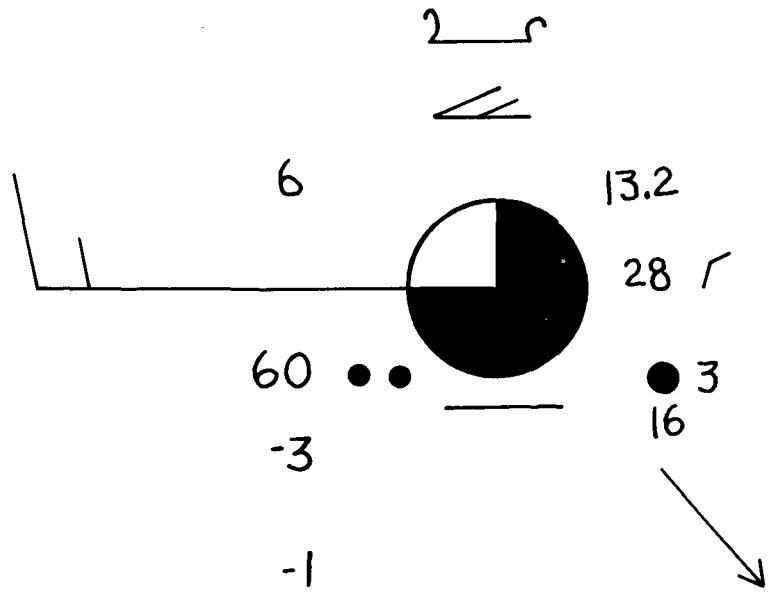


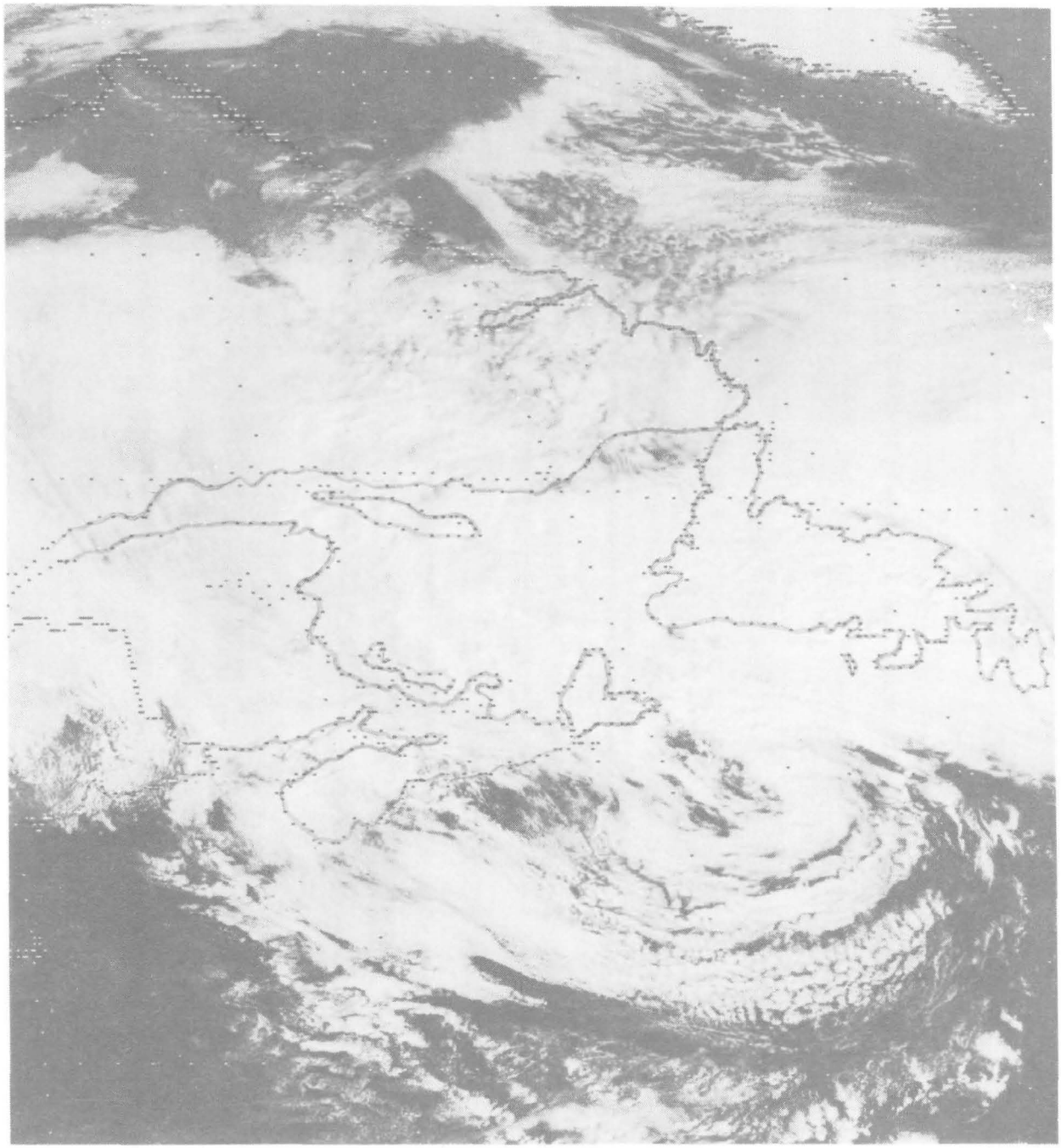
FIGURE C2 SAMPLE PLOTTED MODEL, FOUND ON SURFACE WEATHER CHARTS

A13-D SMS/GOES AND NOAA SATELLITE DATA

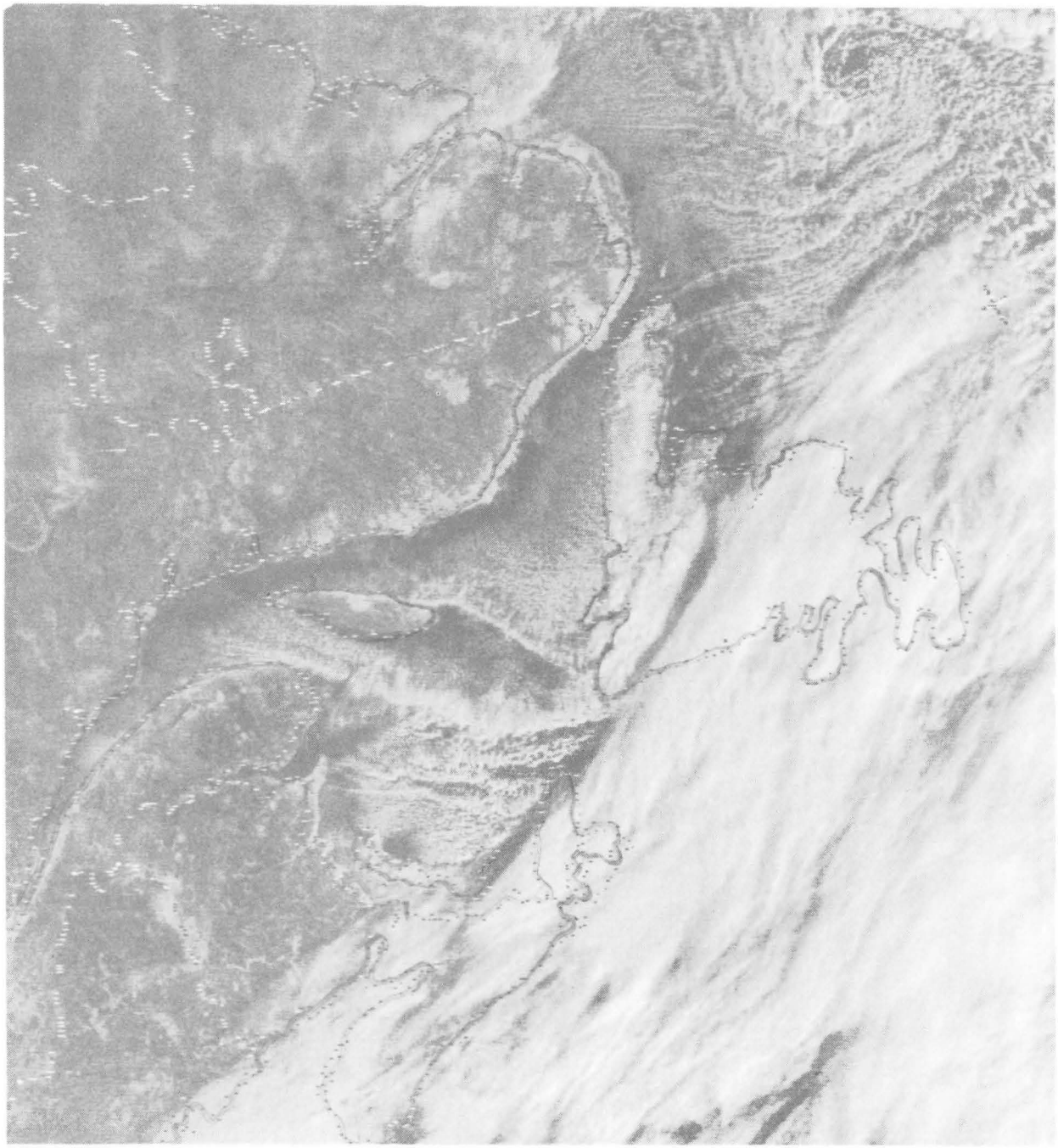
(See Figure D1 for GOES image and Figure D2 for NOAA image)

Information regarding each Satellite Data

	SMS/GOES	NOAA 4/5
Orbit	Geostationary at 75°W	Polar orbiting
Geographical frequency of image coverage	30 min	24 hours (possibly 12 if tracking North-bound, nightime orbit pass)
Bands	Visible, infrared	Visible; infrared
Resolution (at sub-point)	0.9 km; 1.9 km	0.9 km



A13D-1 PART OF SAMPLE GOES VISIBLE IMAGE (30 SEPTEMBER 1977) RECEIVED VIA PHOTOFAX AT GANDER WEATHER OFFICE.



A13D-2 PART OF SAMPLE NOAA 5 VISIBLE IMAGE (6 JANUARY 1978) RECEIVED VIA PHOTOFAX AT GANDER WEATHER OFFICE

A13-E WAVE HEIGHT CHARTS

Sample Wave Height Chart

(See Figure E1)

Information provided with each Wave Height Chart

1. Wave height contours
2. Wave period
3. Wind speed and direction
4. Swell direction
5. RMS swell height
6. Swell period

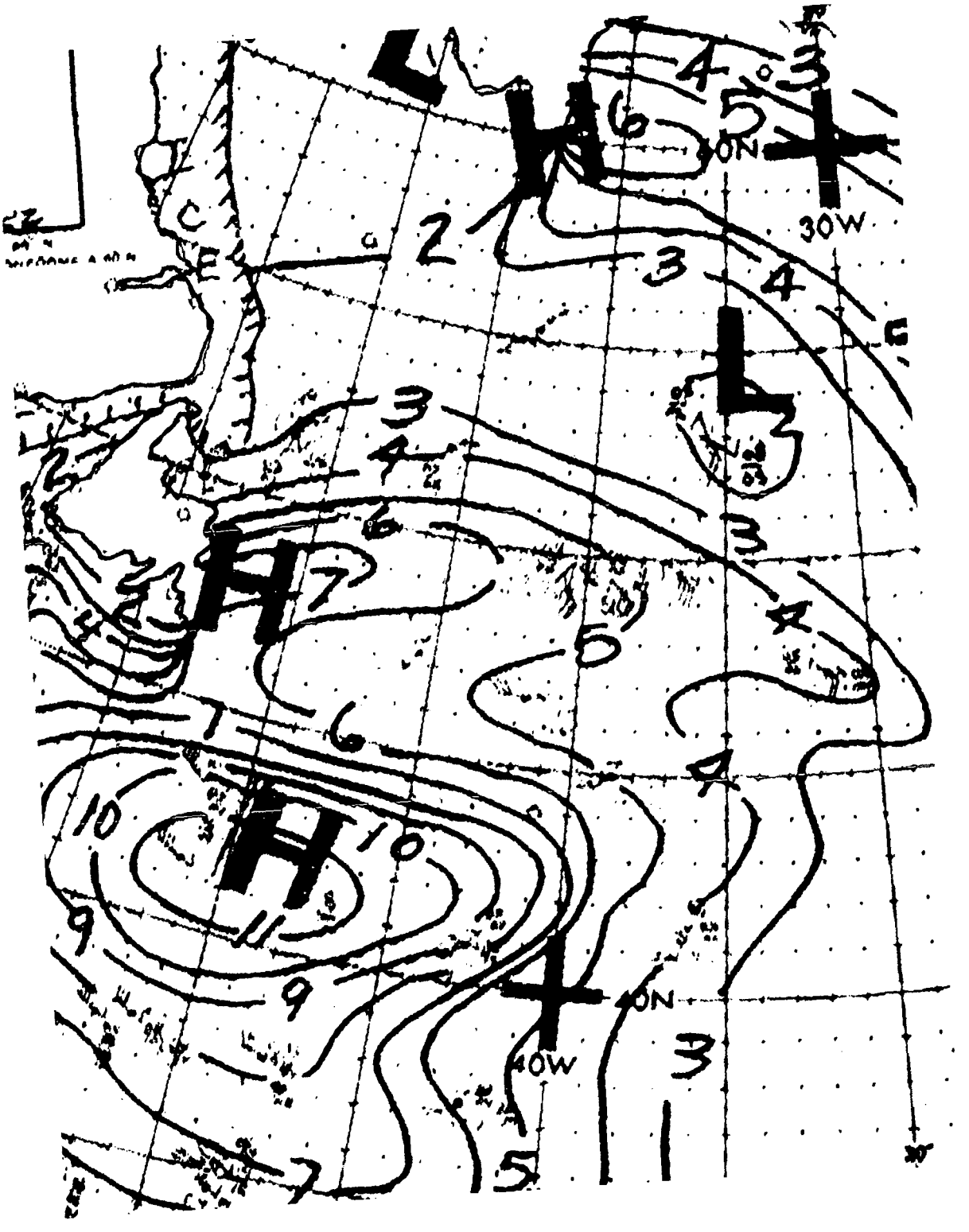


FIGURE E1 SAMPLE WAVE HEIGHT CHART

A13-F AES ICE CHARTS

Sample AES Ice Chart

(See Figure F1)

Information provided with each AES Ice Chart

1. Extent of ice coverage
2. Concentrations of each ice category
3. Concentrations of ice floes in each ice category
4. An indication of iceberg concentration
5. Surface features of the ice

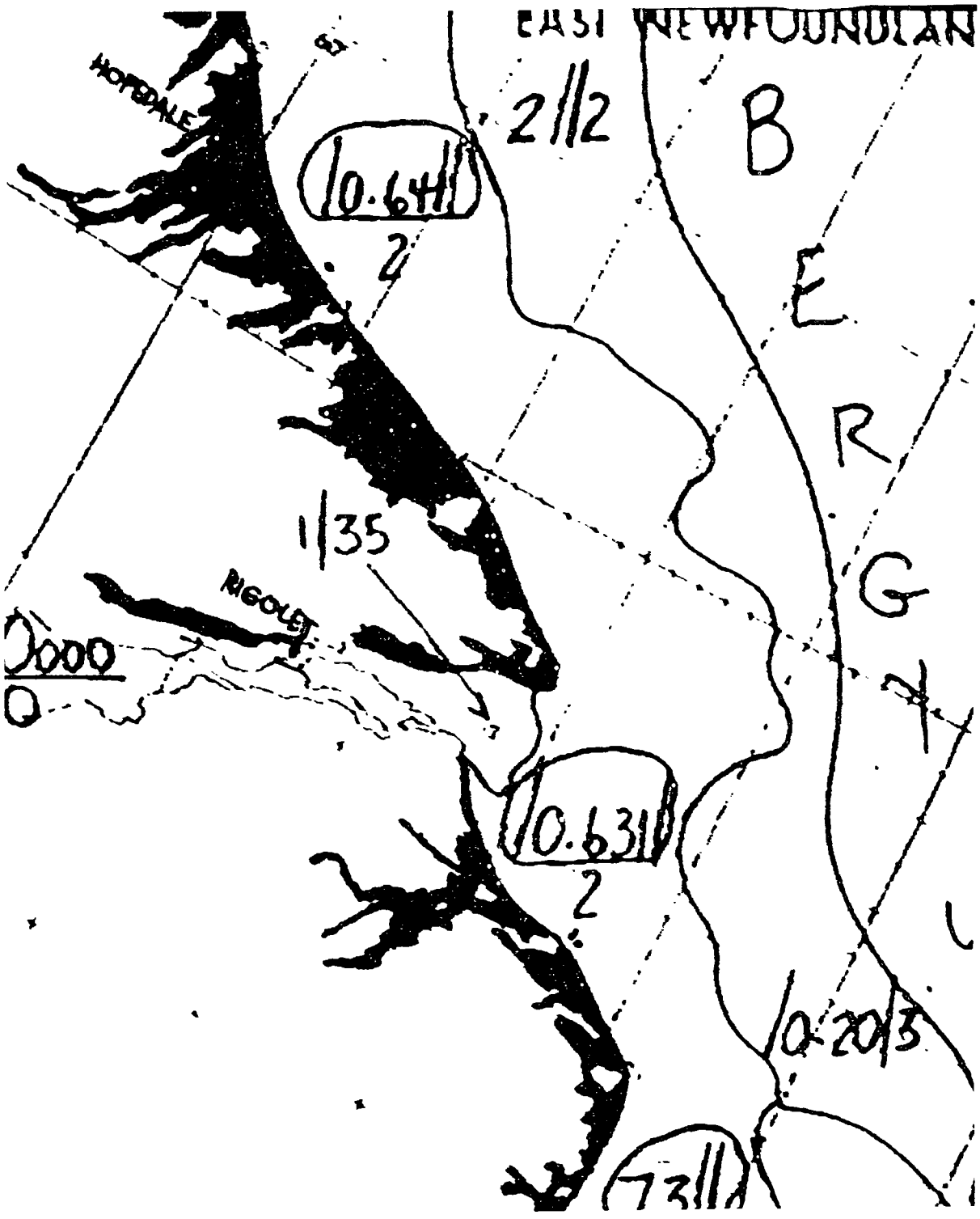


FIGURE F1 SAMPLE AES ICE CHART

A13-G ECAREG AND NORDREG CANADA REPORTS

Sample ECAREG Canada Report

MOT RECG SNF

MOT TEL STV

MSG SIME GAUDREAU/VGMD VIA STEPHENVILLECG 130250A
ECAREG CANADA

AFTER HAVING FREED VESSEL ADVANCED 11 MILES IN 5 HOURS STOP
AT 2300Z STUCK AGAIN IN VERY CLOSE PACK ICE IN POSITION
4844N 6002W
MASTER
INFO DART

TODO254Z

MOT RDCG SNF

MOT TEL STV

Sample NORDREG Canada Report

MOT CCG OTT

CG OPS FROB

GB FROBISHER 291730Z

CGAT OTTAWA

/H3PF 272/1600Z 6124N 6812W SPD 13 272/1600Z
7347N 9217W SPD 14

2 MASTER POSITION AT 1600GMT 6016N 5717W SPD 14 IN BALLAST LAST
PORT POL NO DEF DRAFT 21.00F AGENT S03. ETA CHU 4/10/77.

N 272/04002 DPRTD CHESTERFIELD BOUND QUEBEC CITY POSITION AT
1200Z 6244N 8740W (ADD INFO REQUESTED)

NORDREG CANADA
TOD 29173ZZ
*
MOT CCG OTT

CG OPS FROB

Information Provided With Each ECAREG and/or NORDREG Report

Ship reports may include the following information:

1. Position and time of vessel entry/departure into/from the Eastern Canada Traffic Zone or Arctic Canada Traffic Zone.
2. Intended destination, ETA and route through the zone.
3. Any observed significant change in weather conditions or visibility.
4. Prevailing ice conditions, and location.
5. Sighting of any pollution of water within the zone, and location.

A13-H U.S. NAVY ICE CHARTS

Two types of charts are issued - U.S. Navy Southern Ice Limit Chart and U.S. Navy Eastern Arctic 30 Day Sea Ice Forecast Chart.

Sample Ice Charts

(See Figure H1 for the Southern Ice Limit Chart and Figure H2 for the Eastern Arctic 30 Day Sea Ice Forecast Chart).

Information Provided With Each Chart

Southern Ice Limit Chart:

1. Ice Concentration and type
2. Seven day ice limit forecast
3. Open water areas
4. Average $0^{o}C$ air temperature isotherm for the previous week
5. $+2^{o}C$ sea surface temperature isotherm
6. Accumulated seasonal ice growth
7. All iceberg sightings for previous week

Eastern Arctic 30 Day Sea Ice Forecast Chart:

1. Ice concentration and type
2. Open water areas
3. Prediction Data
4. Synoptic, verbal description of forecast

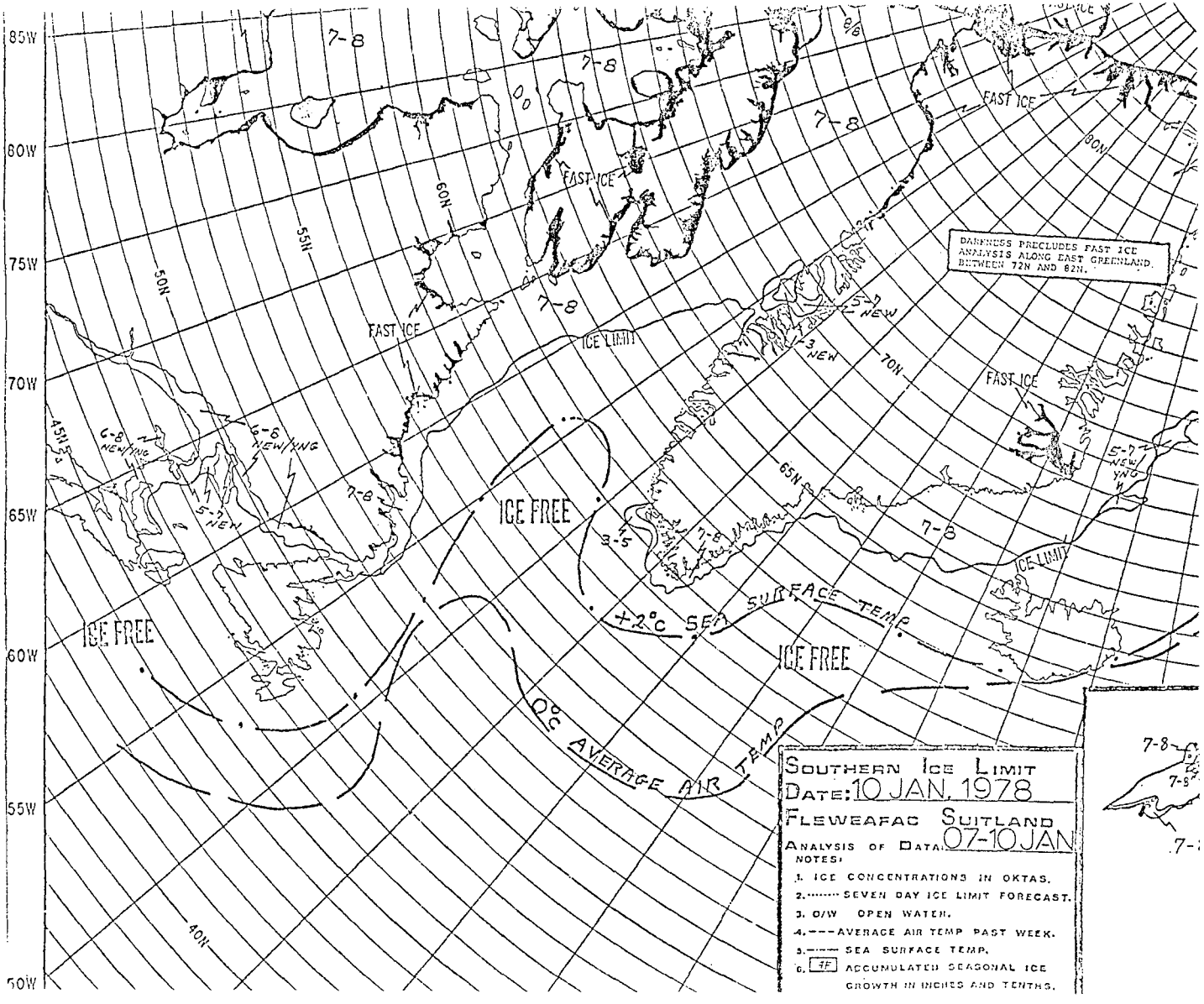


FIGURE H1 SAMPLE OF U.S. NAVY SOUTHERN ICE LIMIT CHART

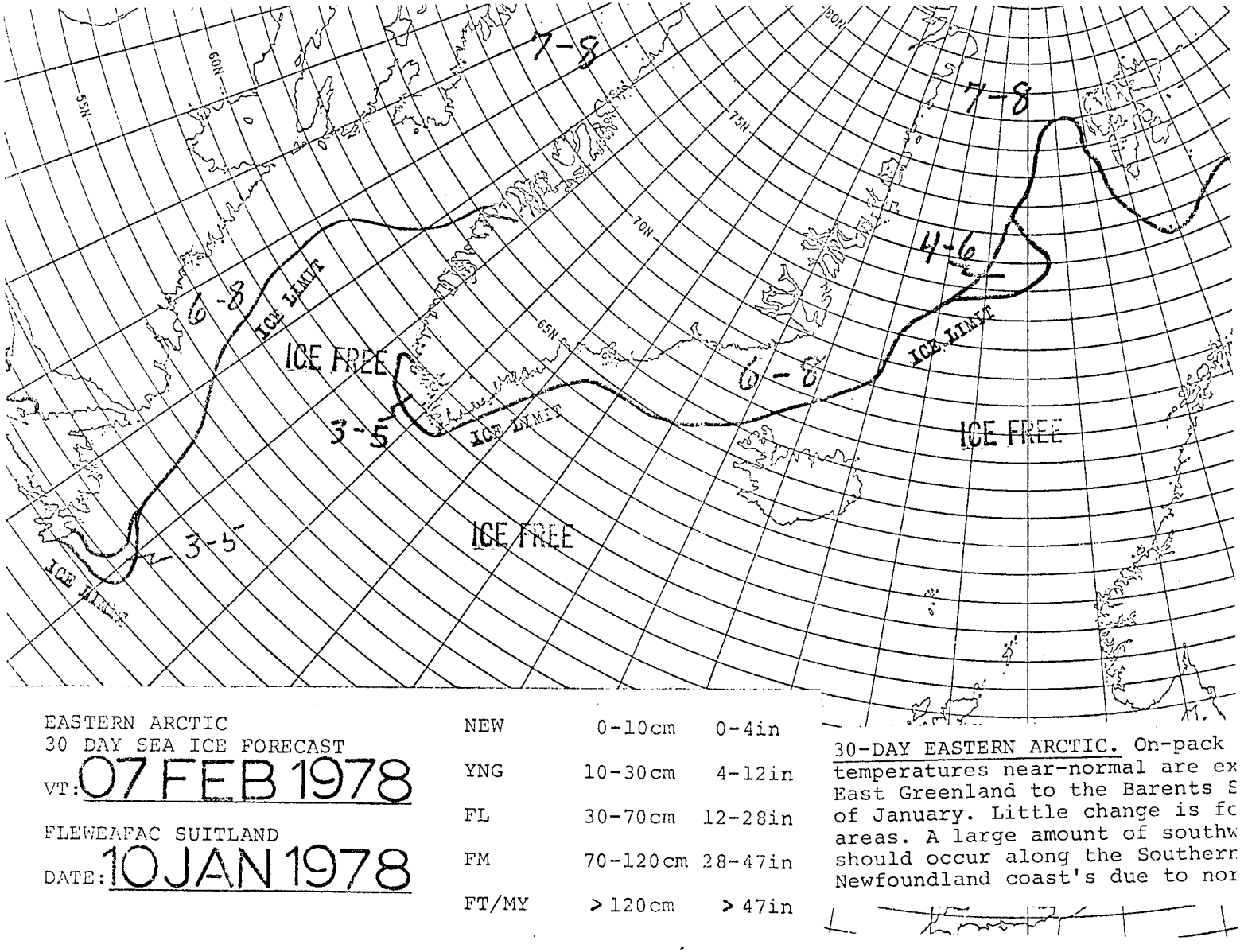


FIGURE H2 SAMPLE OF U.S. NAVY EASTERN ARCTIC 30 DAY SEA ICE FORECAST CHART

A13-I IIP ICEBERG BULLETINS AND CHARTS

(See Figure I-1 for IIP Iceberg Chart and Figure I-2 for IPP Iceberg Bulletin).

Information Provided With Each Ice Chart and Bulletin

1. Co-ordinate location of icebergs, growlers and radar targets
2. Seaward ice boundary
3. Data and time (GMT) of iceberg sighting
4. Flight track flown

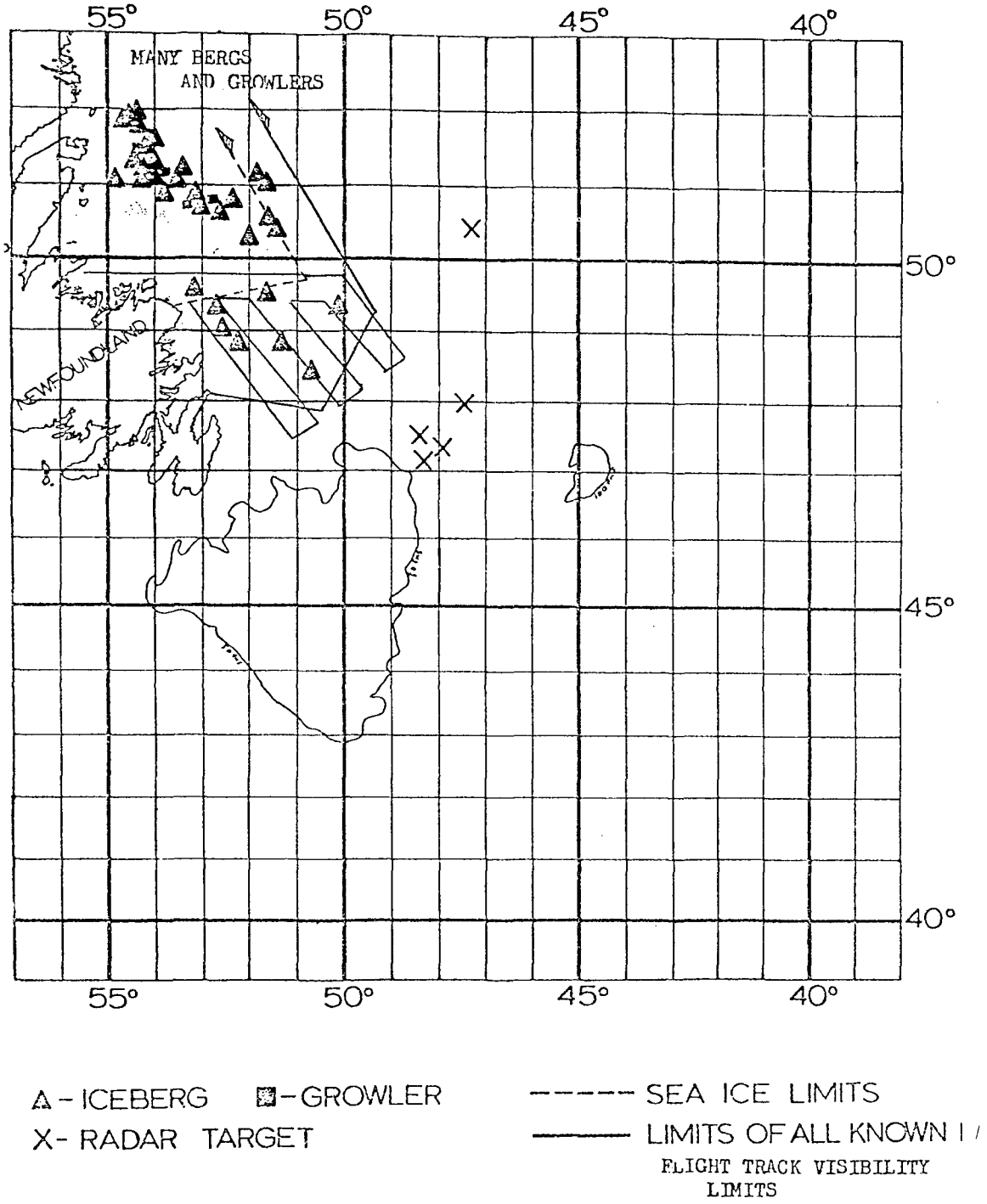


FIGURE I-1 SAMPLE IIP ICEBERG CHART

```
FM COMINTICEPAT NEW YORK NY
TO AIG 8916
   ANY OR ALL HMC SHIPS ATLANTIC

INFO USCGC EVERGREEN
BT
UNCLAS
VON PASS TO CIIP ICERECDET

180000GMT JUN 77  INTERNATIONAL ICE PATROL BULLETIN
REPORT ALL ICE SIGHTED TO COMINTICEPAT VIA CG AMVER STATIONS NMF,NMN, AND
CANADIAN STATION ST. JOHNS/VON.

ALL SHIPS ARE REQUESTED TO MAKE SEA SURFACE TEMPERATURE AND WEATHER REPORTS
TO COMINTICEPAT EVERY SIX HOURS WHEN WITHIN LATITUDES   40N TO 50N AND
LONGITUDES  40W  TO 55W. IT IS NOT NECESSARY TO MAKE THESE REPORTS IF A
ROUTINE WEATHER REPORT IS MADE TO METEO WASHINGTON.

ICEBERG, GROWLER, AND RADAR TARGET POSITIONS REPORTED IN THIS BULLETIN
ARE BASED ON ESTIMATED DRIFT. DATE OF SIGHTING IS IN PARENTHESES FOLLOWING
POSITION.

ESTIMATED LIMIT OF ALL KNOWN ICE, FROM


SOUTHERNMOST AND EASTERNMOST BERGS ESTIMATED AT
4826N 5042W(29),   4843N 5113W( 4),   4845N 52 4W( 9),   4852N 5228W( 9),
49 4N 5120W(17),   49 8N 5319W(17),   4913N 5236W( 9),   4919N 4959W( 4),
4919N 4958W( 4),   4923N 5133W( 9),   4931N 53 3W( 9),   4955N 5243W(17),
50 8N 5154W(15),   5013N 5113W(13),   5028N 5118W(13),   5036N 5228W( 9),
5036N 5218W( 9),   5037N 53 3W( 9),   5046N 5350W( 9),   5048N 53 3W( 9),
5055N 5151W(15),   5055N 5129W(13),   5056N 5329W( 9),   5059N 5419W( 9),
5059N 5325W( 9),   51 0N 5146W(15),   5142N 51 4W(17),

GROWLERS ESTIMATED AT
4910N 5320W(17),   5039N 53 4W( 9),   5042N 5237W( 9),

RADAR TARGETS ESTIMATED AT
47 7N 4759W(10),   4714N 4747W(10),   4728N 4823W(10),   4754N 4630W(10),
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FIGURE I-2 SAMPLE OF INFORMATION PROVIDED WITH IIP ICEBERG BULLETINS

A13-J PRESENT AND FUTURE OCEAN-RELATED SATELLITES (FLEWEAFAC, 1977)

LIST OF ACRONYMS AND ABBREVIATIONS

AASIR	-	Advanced Atmospheric Sounder and Image Radiometer
ALT	-	Short Pulse Radar Altimeter
APT	-	Automatic Picture Transmission
AVCS	-	Applications Technology Satellite
AVHRR	-	Advanced Very High Resolution Radiometer
BSU	-	Basic Sounder Unit
BUV	-	Backscatter Ultraviolet Spectrometer
CONE	-	Low Resolution, Non-Scanning, 2-Channel Radiometer
CZCS	-	Coastal Zone Ocean Color Spectrometer
DCS	-	Data Collection System
DCPLS	-	Data Collection and Platform Location System
DMSP	-	Defense Meteorological Satellite Program
ERB	-	Earth Radiation Budget
ESMR	-	Electrically Scanning Microwave Radiometer
ESSA	-	Environmental Survey Satellite
FPR	-	Flat Plate Radiometer
FWS	-	Filter Wedge Spectrometer
GOES	-	Geostationary Operational Environmental Satellite (NOAA's Designation)
HIRS	-	High Resolution Infrared Radiation Sounder
HR	-	High Resolution (Visual Scanning Radiometer)
HRIR	-	High Resolution Infrared Radiometer
HRPT	-	High Resolution Picture Transmission
IDCS	-	Image Dissector Camera System
IRIS	-	Infrared Interferometer Spectrometer
IRLS	-	Interrogation, Recording and Location
ITOS	-	Improved Tiros Operational Satellite
ITPR	-	Infrared Temperature Profile Radiometer
LIMS	-	Limb IR Monitoring of the Stratosphere
LRIR	-	Limb Radiance Inversion Radiometer
MASR	-	Microwave Atmospheric Sounding Radiometer

MI	-	High Resolution (Infrared Scanning Radiometer)
MRIR	-	Medium Resolution Infrared Radiometer
MSSCC	-	Multi-Color Spin Scan Cloud Camera
MSU	-	Microwave Sounding Unit
MUSE	-	Monitor Ultraviolet Solar Energy
NASA	-	National Aeronautics and Space Administration
NEMS	-	Nimbus-E Microwave Spectrometer
NIMBUS	-	Nasa Meteorological R & D Satellite
NOAA	-	National Oceanographic and Atmospheric Administration (Formerly ESSA)
OLS	-	Optical Line Scanner (Visual and IR Channels)
OMNI	-	Low Resolution Omnidirectional Radiometer
PMR	-	Pressure Modulated Radiometer
RMP	-	Rate Measuring Package
SAM II	-	Stratospheric Aerosol Measurement
SAMS	-	Stratospheric and Mesospheric Sounder
SAR	-	Synthetic Aperture Radar
SASS	-	Seasat A Scatterometer System
SBUV/TOMS	-	Solar And Backscatter Ultraviolet/Total Ozone Mapping Spectrometer
SCAMS	-	Scanning Microwave Spectrometer
SCMR	-	Surface Composition Mapping Radiometer (High Resolution)
SCR	-	Selective Chopper Radiometer
SEM	-	Space Environmental Monitor
SIRS	-	Satellite Infrared Spectrometer
SMMR	-	Scanning Multichannel Microwave Radiometer
SMS	-	Synchronous Meteorological Satellite (NASA'S Designation)
SNAP	-	Systems For Nuclear Auxuliary Power
SPM	-	Solar Proton Monitor
SR	-	Scanning Radiometer
SSB	-	Supplementary Sensor Package B (Gamma Detector)
SSCC	-	Spin Scan Cloud Camera
SSD	-	Supplementary Sensor Package D (Upper Air Density Measurer)
SSE	-	Supplementary Sensor Package E (Vertical Temperature Profile Radiometer)
SSH	-	Supplementary Sensor Package H (Vertical Temperature And Moisture Profiler)

SSJ	-	Supplementary Sensor Package J (Electron Spectrometer)
SSL	-	Supplementary Sensor Package L (Lightning Detector)
SSM/T	-	Supplementary Sensor Package M/T (Microwave Sounder)
SSU	-	Stratospheric Sounding Unit
T & DRE	-	Tracking & Data Relay Experiment
THIR	-	Temperature Humidity Infrared Radiometer
TIROS	-	Television Infrared Observation Satellite
TOS	-	Tiros Operational Satellite
TWERLE	-	Tropical Wind, Energy Conversion and Reference Level Experiment
VCS	-	Vidicon Camera System
VHR	-	Very High Resolution (Visual Scanning Radiometer)
VHRR	-	Very High Resolution Radiometer
VIRR	-	Visual And Infrared Radiometer
VISSR	-	Visible And Infrared Spin Scan Radiometer
VTPR	-	Vertical Temperature Profile Radiometer
WEFAX	-	Weather Facsimile
WHR	-	Very High Resolution (Infrared Scanning Radiometer)

PRESENTLY OPERATING SATELLITES

SATELLITE SYSTEM	LAUNCH DATE	APOGEE (km)	PERIGEE (km)	LOCAL EQUATOR CROSSING TIME	SENSORS
SMS/GOES 1	17 May 1974	35,855	35,851	Located Over Equator at 105°W	VISSR WEFAX SEM DCS
SMS/GOES 2	6 Feb. 1975	38,823	35,788	Located Over Equator at 135°W	VISSR WEFAX SEM DCS
GOES 1	16 Oct. 1975	35,870	35,751	Located Over Equator at 75°W	VISSR WEFAX SEM DCS
NOAA 4	15 Nov. 1974	1,457	1,444	0838 Hrs. South Bd 2038 Hrs. North Bd	SR VHRR VTPR SPM
NOAA 5	29 July 1976	1,519	1,504	0837 Hrs. South Bd 2037 Hrs. North Bd	SR VHRR VTPR SPM
DMSP 5C (2 Satellites)	Oct. 1972	847	828	0830 Hrs. North Bd 2030 Hrs. South Bd 1230 Hrs. North Bd 0030 Hrs. South Bd	VHR HR WHR MI SSE SSJ SSL
DMSP 5D (2 Satellites)	11 Sept. 1976	851	817	1135 Hrs. North Bd 2336 Hrs. South Bd 0630 Hrs. North Bd 1830 Hrs. South Bd	OLS SSH SSD SSJ SSB
Nimbus 5	12 Dec. 1972	1,253	1,242	1130 Hrs. North Bd 2330 Hrs. South Bd	THIR ESMR ITPR NEMS SCR SCMR

SATELLITE SYSTEM	LAUNCH DATE	APOGEE (km)	PERIGEE (km)	LOCAL EQUATOR CROSSING TIME	SENSORS
Nimbus 6	12 June 1975	1,110	1,093	1145 Hrs. North Bd 2345 Hrs. South Bd	HIRS THIR SCAMS ESMR LRIR PMR TWERLE T & DRE

FUTURE OPERATING SATELLITES

SATELLITE SYSTEM		LAUNCH DATE	APOGEE (km)	PERIGEE (km)	SENSORS
GOES	B	1977	35,767	35,767	VISSR
	C	1978	(ave)	(ave)	WEFAX
	D	1979			SEM
	E	1980			DCS
		1981			
NOAA	I	1977	1,464	1,464	SR
	E - 2	1978	(ave)	(ave)	VHRR
					VTPR
					SPM
TIROS	N	late 1978	834	834	AVHRR
			(ave)	(ave)	HIRS II
					SSU
					MSU
					DCPLS
					SEM
NOAA	A	1978	834	834	AVHRR
	B	1979	(ave)	(ave)	HIRS II or BSM
	C	1980			SSU
	D	1981			MSU
	E	1982			DCPLS
	F	1983			SEM
	G	1984			
DMSP	5D	1978	834	834	OLS
(2 satellites/					
	year	1979	(ave)	(ave)	SSH
		1980			SSD
		1981			SSB
		1982			SSJ
					SSM/T
Nimbus	G	late 1978	1,242	1,242	LIMS
			(ave)	(ave)	SAMS
					SAMI I
					CZCS
					SMMR
					ERB
					THIR
					SBUV/TOMS

SATELLITE SYSTEM	LAUNCH DATE	APOGEE (km)	PERIGEE (km)	SENSORS
STORMSAT A	1982	35,000 (ave)	35,000 (ave)	AASIR MASR
SEASAT A	1978	790 (ave)	790 (ave)	SAR SMMR ALT VIRR SASS

APPENDIX TO
CHAPTER 14

OIL SPILL COUNTERMEASURES
FOR THE
LABRADOR OFFSHORE

SECTION A.14.11 OPERATOR DRILLING AND TRANSPORTATION EQUIPMENT (on Charter)

Drillships

(1) Pelican -

Type - Drillship

Maximum Water Depth for Drilling - 366 m

Maximum Drilling Depth - 6096 m

Speed - 14 knots

Power (towing) - 7000 hp

Dimensions (m) - 150 x 21 x 12.5

Helicopter Deck - Present

Operating Limits - Swell - 4.9 m, 12 s period
- Winds - 45 knots with 60 s gusts up to 65 knots
- Side Current - 2 knots

Mooring/Positioning System - Dynamic Positioning

(2) Petrel - Similar to the Pelican

(3) Zapata Ugland -

Type - Semi Submersible (self propelled)

Maximum Water Depth for Drilling - 305 m

Maximum Drilling Depth - 7626 m

Speed - 10 knots

Power - 7800 hp

Dimensions (m) - 111 x 64

Helicopter Deck - 85' square (can accommodate Sikorsky S61 or S70)

Operating Limits - Design Wave - 30.5 m, 15 s
- Design wind - 125 knots sustained
- Drilling - in waves - 15 m maximum
  - in wind - 90 knots

Mooring/Positioning System - a 10-line spread of 1067 m lengths of 7.62 chain each attached to a 18,160 kg anchor. Lines fitted with acoustic quick release system for drilling off Labrador.

Aircraft

Rotary Winged

(1) Sikorsky S61N

Dimensions - Length o.a - 22.2 m
Width - 6.02 m
Height o.a - 5.63
Cargo Door - 1.68 m x 1.27 m
Cabin Dimensions - 9.73 m x 1.98 m x 1.92 m
(Volume 36.95 m^3)

Weight and Loadings - Weight Empty - 5674 kg
Maximum T.O. Weight - 8620 kg
(with external load - 9980 kg)

Speed - Maximum - 235 km/h
Cruising - 222 km/h

Range - Maximum Fuel (20 minutes reserve) - 796 km

Comments - The S61N has a sealed hull for amphibious operation. It is capable of, and licenced to fly IFR.

(2) Aerospatiale/Westland SA330 Puma

Dimensions - Height o.a. - 18.15 m
Width, Blades Folded - 3.5 m
Height o.a. - 5.14 m
Passenger Door - 1.35 m x 1.35 m
Cabin Dimensions - 6.05 m x 1.80 m (max) x 1.55 m (max)
Useable volume 11.40 m^3.

Weight and Loading - Weight Empty - 3536 kg
Maximum T.O. Weight - 7000 kg
Maximum Payload - 3000 kg

Speed - Maximum - 257 km/h
Cruising - 248 km/h

Range - standard fuel, no reserves - 580 km

Comments - Equipped for IFR flight.

(3) Bell 212

Maximum Payload - 1630 kg

Range - 70 km

Cruising Speed - 203 km/h

Weight - 5080 kg

N.B. This helicopter was on charter for one month (September) when all three drilling units were on location.

Fixed Wing

(1) Beech Craft Queenair 880

8 Passenger Capacity

Speed - 354 km/h

Equipment - De-icing

- IFR Equipped and Licenced

(2) Canso PBY, Sea Plane

18 Passenger Capacity

speed - 225 km/h

IFR Equipped and Licenced

Supply Vessels

Josephturn

Stirling Ash

Active Rey

Active King

The following description of the Active King applies generally to all four vessels.

Deadweight Tonnage - 1150

Service speed (knots) - 14.5

Length Overall - 64.4 m

Breadth - 13.9 m

Draught - 4.80 m

Main engines, BHP - 7040

Deck Area - 38 x 11 m

Deck Cargo - 800 tons

Tank Capacities - Cargo Fuel - 84- m^3
Drill Water - 749 m^3
Potable Water - 131 m^3
Mud/Cement Tanks - 23 m^3

Iceberg Towing Vessels

Edda Salvator
Orkney Shore
Skaustream
Skaulake

These vessesl are all ice class. The following is a description of the Skaustream.

Class - Det Norske Veritas +1A1
Tug Supply Ship E.O.

Dimensions - Length o.a. - 64.4 m
Breadth - 13.8 m
Draught - 4.7 m

Deadweight Tonnage - 1211

Gross Registered Tonnage - 499

Work Deck - 38.3 x 11 m

Maximum Decload Capacity - 800 tons

Engines - 7040 bhp
2 shafts
Blow Thruster - 500 hp

Capacities - Drill water/Ballast - 937 m^3
Cement/Mud Tanks - 170 m^3

Speed - 15 knots

Cargo Systems - 2 fuel oil pumps, 2 x 100 m^3/h at 60 m head
1 freshwater pump, 100 m^3/h at 60 m head
2 ballast/fire pumps, 2 x 100^3 at 60 m head

SOURCE OF INFORMATION

Offshore Contractors and Equipment Directory, 1977, 9th Edition. The Petroleum Publishing Company, Tulsa.

The Offshore Service Vessel Register, 1977, H. Clarkson and Company Ltd., London. ISSN 0308-040X

The Offshore Drilling Register, A Directory of Self Contained Mobile Sea - Going Rigs 1977, H. Clarkson and Company Ltd., London. ISSN 0305-4284

Trillo, R.L. (ed) 1977, Jane's Ocean Technology, Franklin Watts Inc., New York. 679 p.

SECTION A.14.2 FEDERAL GOVERNMENT TRANSPORTATION EQUIPMENT VESSELS

Canadian Armed Forces

(1) Replenishment Ships

Provider - Displacement tons - 22,000 full load
Measurement tons - 14,700 deadweight
Dimensions (m) - 159 x 23 x 9.8
Aircraft - 3 CHSS2 Sea King Helicopters
Main Engines - 21,000 shp - 1 shaft
Speed - 20 knots
Range - 3,600 miles at 20 km

Comments - Flight deck has hanger and can accommodate the largest helicopters. Twenty winches are fitted on deck for ship-to-ship and ship-to-shore movement of cargo.

Preserver - Displacement Tons - 24,700 full load
Proteteur Meausrements Tons - 13,250 deadweight
Dimensions (m) - 172 x 23.2 x 9.1
Aircraft - 3 CHSS2 Sea King Helicopters
Main Engines - 21,000 shp - 1 shaft
Range - 4,100 miles at 20 knots
7,500 miles at 11.5 knots

Comments - An improvement over the prototype Provider. They can carry spare helicopters, vehicles and bulk equipment for sea lift purposes. 13,100 tons FFO, 600 tons diesel, 400 tons aviation fuel, 1,048 tons dry cargo and 1,250 tons ammunition. These ships are used in summer Arctic supply.

(2) Research Vessels

Quest - Displacement tons - 2,130
Dimensions (m) - 77.2 x 12.8 x 4.6
Aircraft - light helicopter
Main Engines - 2,950 shp; bow thruster propeller
Speed - 16 knots
Range- 10,000 at 12 knots

Comments - Built for acoustic, hydrographic and oceanographic work. Capable of operating in heavy ice in the company of an icebreaker. Based at Halifax.

Endeavour - Displacement tons - 1,560
Dimensions (m) - 71.9 x 11.7 x 4
Aircraft - 1 light helicopter
Main Engines - 2,960 shp, 2 shafts
Speed - 16 knots
Range, miles - 10,000 at 12 knots

Comments - An anti-submarine research ship. Flights deck 48 x 31 ft. Stiffened for operating in ice covered waters. Fitted with 2-9 ton telescopic cranes. Has oceanographic winches, deep sea anchoring and a coring winch.

Sackville - Displacement Tons - 1,350 full load
Dimensions (m) - 62.5 x 10.1 x 6.4
Engines - 2,750 oph
Speed - 16 knots

Comments - Converted WWII Corvette employed by Naval Research Laboratories for oceanographic work.

(3) Ocean Tugs

Saint Anthony - Displacement Tons - 840 full load
Saint Charles - Dimensions (m) - 46.2 x 10 x 5.2
Main Engine - Diesel, 1 shaft, 1,920 shp
Speed - 14 knots

Canadian Coast Guard (Ministry of Transport) Vessels

(1) Icebreakers

John Cabot - Displacement Tons - 6,375 full load
Dimensions (m) - 95.6 x 18.3 x 6.6
Aircraft - 1 helicopter
Main Engines - 2 shafts, 9,000 shp
Speed - 15 knots

Comments - A combination cable repair ship and icebreaker used in East Coast and Arctic waters. On long term charter to Teleglobe Canada. Stationed at St. John's.

Louis St. Laurent - Displacement Tons - 13,800 full load
Dimensions (m) - 111.8 x 24.4 x 9.5
Aircraft - 2 helicopters
Main Engines - 3 shafts, 2,400 shp
Speed - 17.75 knots
Range - 16.000 miles at 13 knots

Comments - Largest Canadian icebreaker. Has an elevating helicopter hanger below the flight deck. Rated as a heavy icebreaker.

Norman McLeod Rogers - Displacement Tons - 6,340 full load
Dimensions (m) - 90 x 10.5 x 6.1
Aircraft - 1 helicopter
Landing Craft - 2
Main Engines - 2 shafts, 12,000 shp
Speed - 15 knots

Comments - Officially rated as a heavy icebreaker.

John A. MacDonald - Displacement Tons - 9,160 full load
Dimensions (m) - 96.x 21.3 x 8.6
Aircraft - 2 helicopters
Engines - 15,000 shp
Speed - 15.5 knots

Comments - Officially rated as a heavy icebreaker

Montcalm - Wolf
Displacement Tons - 3,005 full load
Dimensions (m) - 72.7 x 14.6 x 4.9
Aircraft - 1 helicopter
Engines - 4,000 ihp
Speed - 13 knots

Comments - Rated as medium icebreaker aid to navigation vessels

Labrador - Displacement Tons - 6,490 full load
Dimensions (m) - 88.5 x 19.4 x 8.8
Aircraft - provision for 2 helicopters
Engines - 10,000 shp
Speed - 16 knots

Comments - Rated as a hevay icebreaker

D'Iberville - Displacement Tons - 9,930
Dimensions (m) - 94.6 x 20.3 x 9.2
Engines - 10,800 ihp
Speed - 15 knots

Comments - Rated as a heavy icebreaker

MV Cathy "B" - Gross Tonnage - 885
Dimensions (m) - 56 x 13.7 x 5
Engines - 2 - 5280 bhp, 2 shafts; one 350 hp low thruster
Speed - 14 knots
Deck Area - 29.88 x 10.98

Comments - Offshore supply vessel registered as ABS plus A1(E) and (1) - Ice Class Vessel. Negotiations are underway for long-term lease or purchase of a similar type vessel for Search and Rescue operations with the Newfoundland region.

(2) Aid to Navigation Vessels

Sir Humphery Gilbert - Displacement Tons - 3,000 full load
Dimensions (m) - 68 x 14.6 x 5.0
Engines - 4,250 sph
Speed - 13 knots

Comments - Rated as medium icebreaking aid to navigation vessels.

Bartlett - Displacement Tons - 1,620
Dimensions (m) - 57.7 x 13 x 3.8
Engines - 1,760 bhp
Speed - 12 knots

Comments - Classed as ice strengthened aid to navigation vessels.

(3) Search and Rescue Cutters

Alert - Displacement Tons - 2,025
Dimensions (m) - 71.4 x 12.2 x 4.6
Aircraft - 1 helicopter
Engines - 7,716 hp
Speed - 18.75 knots

Comments - Officially rated as offshore patrol cutter.

Daring - Displacement Tons - 600 standard
Dimensions (m) - 54.3 x 8.8 x 3.0
Engines - 2,660 bhp, 2 shafts
Speed - 16 knots

Comments - Offshore patrol cutter strengthened against ice.

Department of Fisheries and Environment

(1) Hydrographic and Oceanographic Vessels

CCS Baffin - Displacement Tons - 4,420
Dimensions (m) - 87 x 15.3 x 5.73
Aircraft - 1 Jet Ranger, hanger 3.95 m (h) x 8.23 m (w) x 9.45 m (d)

Comments - Classed as Lloyds 100A1 icebreaker. Equipped for hydrographic survey.

CCS Dawson - Displacement Tons - 2,006
Dimensions (m) - 64.5 x 12.2 x 4.9
Engines - 3,400 hp, 2 shafts, bow thruster
Speed - 15.5 knots
Range - 1,200 miles at 13 knots

Comments - Hydrographic Survey Vessel

CCS Hudson - Displacement Tons - 4870
Dimensions (m) - 90.4 x 15.3 x 6.28
Engines - 7,500 hp, 2 shafts
Speed - 17 knots
Range - 15,000 miles at 13.5 knots

Comments - Lloyd 100 A1 Ice Class 1, LMC Hydrographic and Oceanographic Ship and Icebreaker.

(2) Fisheries Research Vessels

AT Cameron - Gross Registered Tonnage - 753
Dimensions (m) - 54 x 9.75 x 3.84
Engines - 1,000 hp
Speed - 12 knots
Range - 7,000 miles at 11.5 knots

Comments - Steel hulled beam trawler covereted for stern trawling.

Shamook - Gross Registered Tonnage - 120
Dimensions (m) - 23.06 x 6.55 x 2.44
Engines - 425 bhp
Speed - 10 knots
Range - 3,000 miles at 7.5 knots

Comments - Steel hull construction, transom stern with hydraulic deck crane.

Gadus Atlantica -

Comments - Factory freezer stern trawler, on five year charter for fisheries surveys. Ice strengthened.

AIRCRAFT

Canadian Armed Forces

(1) Rotary Winged

Boeing - Vertol Model 107
CH 113 Labrador
CH 113A Voyageur

Dimensions - Length Overall, Rotors Truning - 23.03 m
Length Fuselage - 19.4 m
Width Overall - 5.20 m
Height at Tail Rotor - 6.66 m
Loading Ramp - 1.9 m x 1.9 m
Useable Cabin Volume - 25.3 m^3

Performance - Maximum Speed - 275 km/h
Crusing Speed - 249 km/h
Range - 820 km
(with auxilliary tanks) - 1020 km
Weight Empty, Equipped - 7,200 kg
Maximum Take Off Weight - 13,000 kg

(2) Fixed Wing

DHC-5D Buffalo (C-8A, CC-115)

Dimensions - Wing Span - 29.26 m
Length o.a. - 24.09 m
Cabin Doors - 1.68 m x 0.84 m
Rear Cargo Loading Door - 6.33 m x 2.34 m
Height to Ramp Hinge - 1.17 m

Cabin - Length Cargo Floor - 9.58 m
Maximum Width - 2.67 m
Maximum height - 2.08 m
Floor Area - 22.63 m^2
Volume - 48.56 m^3

Weight and Loadings - A - for unprepared field
B - firm smooth airfield surface

Operation Weight Empty - A & B - 11,362 kg

Maximum Payload A - 5,443 kg
B - 8,165 kg

Maximum Take Off Weight - A - 18,597 kg
B - 22,316 kg

Performance - Maximum Cruising Speed at 3,050 m - A - 463 km/h
B - 420 km/h

STOL Take Off Run (with 5,533 kg payload) - A - 289 m
B - 701 m

STOL Landing Run (with 5,533 kg payload) - A - 183 m
B - 259 m

Range (maximum payload) - A - 648 km
B - 1,112 km

Lockheed Model 82 Hercules CC130

(The following details refer specifically to the C-130H)

Dimensions - Wing span - 4041 m
Length, Overall - 29.78 m
Height, Overall - 11.66 m

Main Cargo door - Height - 2.77 m
Width - 3.05 m
Height to Sill - 1.03 m

Paratroop doors - Height - 1.83 m
Width - 0.91 m
Height to Sill - 1.03 m

Cabin (excluding flight deck) - Length, without ramp - 12.60 m
- 15.73 m
Maximum Width - 3.13 m
Maximum Height - 2.81 m
Floor Area (excluding ramps) - 39.5 m^2
Volume, including ramp - 127.4 m^3

Weights and Loadings - Operating weight empty - 24,169 kg
Maximum Payload - 19,872 kg
Maximum Normal Take Off Weight - 70,310 kg
Maximum Land Weight - 621 km/h

Performance - Maximum Cruising Speed - 621 km/h
Economical Cruising Speed - 556 km/h
Take Off Run - 1,091 m
Landing Run at Maximum Landing Weight - 533 m
Range with Maximum Payload (5% reserves) - 40,002 km

SOURCES OF INFORMATION

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Moore, J.E. (ed), Jane's Fighting Ships. Franklin Watts Inc., New York.