Hydrocarbon Development In The Beaufort Sea - Mackenzie Delta Region

ENVIRONMENTAL IMPACT STATEMENT

1982

VOLUME 7 RESEARCH AND MONITORING

ENVIRONMENTAL IMPACT STATEMENT

FOR

HYDROCARBON DEVELOPMENT

IN THE

BEAUFORT SEA - MACKENZIE DELTA REGION

VOLUME 7
RESEARCH AND MONITORING

1982

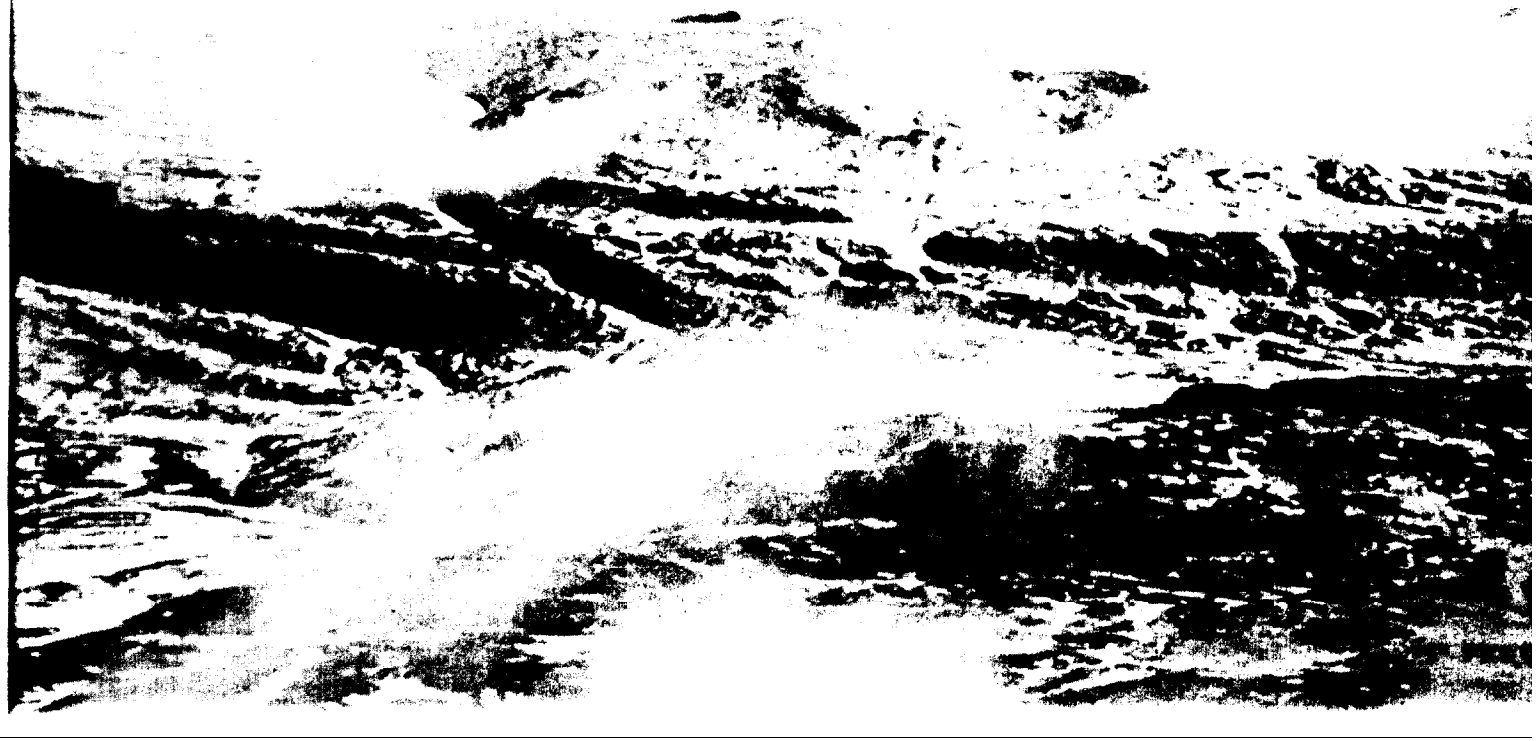
BEAUFORT SEA-MACKENZIE DELTA ENVIRONMENTAL IMPACT STATEMENT

The Beaufort Sea Production Environmental Impact Statement was prepared by
Dome Petroleum Limited,
Esso Resources Canada Limited
and
Gulf Canada Resources Inc.
on behalf of all land-holders in the Beaufort Sea-Mackenzie Delta region.

Information pertaining to the Environmental Impact Statement and its Support Documents can be obtained from:

Frontier Drilling and Production Division,
Dome Petroleum Limited,
P.O. Box 200, Calgary T2P 2H8
or
Pallister Resource Management,
Bay 105, 4116 - 64th Ave. S.E.
Calgary T2P 1P4
Telephone: (403) 236-2344

Library copies are available for viewing at the:
Arctic Institute of North America,
11th Floor Library Tower,
University of Calgary,
2500 University Drive N.W., Calgary,
Telephone: (403) 284-7515



ENVIRONMENTAL IMPACT STATEMENT

MASTER INDEX

VOLUME 1	SUMMARY
VOLUME 2	DEVELOPMENT SYSTEMS
VOLUME 3A	BEAUFORT SEA-DELTA SETTING
VOLUME 3B	NORTHWEST PASSAGE SETTING
VOLUME 3C	MACKENZIE VALLEY SETTING
VOLUME 4	BIOLOGICAL & PHYSICAL EFFECTS
VOLUME 5	SOCIO-ECONOMIC EFFECTS
VOLUME 6	ACCIDENTAL SPILLS
VOLUME 7	RESEARCH AND MONITORING

TABLE OF CONTENTS

CHAPTER 3 CURRENT AND FUTURE STUDIES

INTRODUCTION

The main purpose of this volume of the Environmental Impact Statement is to bring together, and present in summary form, the activities (both environmental and socio-economic) being conducted or envisaged to satisfy the research and monitoring needs identified in Volumes 2, 3, 4, 5 and 6. The geographical regions addressed in this volume are primarily within Canadian lands and waters north of 60°N latitude, and include the Beaufort Sea - Mackenzie Delta region, the Northwest Passage, and the Mackenzie Valley - the regions potentially involved in Arctic hydrocarbon development. In accordance with the Environmental Assessment Review Process (EARP) Guidelines, the information has been summarized as much as practical while recognizing the importance of providing sufficient information.

Volume 7 was prepared by the proponents with the assistance of ESL Environmental Sciences Limited.

Chapter 1 addresses topics related to the division of responsibility for conducting studies; the relevance of studies to development needs and to the assessment of development effects; and the means for reviewing and modifying current and future studies in a manner satisfactory to both industry and regulatory authorities. In the latter context, a proposed post-EARP regulatory process, recommended by the proponents, is described.

Considerable environmental and socio-economic work has been, and continues to be done in Canada's north. In order to give the reader some insight into the organizations involved and the scope of these past programs, Chapter 2 of this volume describes the major relevant programs which have been carried out over the past approximately 25 years in the Canadian Arctic. These programs have formed a substantial foundation for the current and future studies described in Chapter 3.

Chapter 3 begins by outlining the types of existing environmental operating conditions (EOCs) placed on the various facilities and operations in the Beaufort Sea region by government. Many of these EOC's include research and monitoring programs. This discussion is followed by descriptions of present (that is, those started in 1981) and future environmental projects being undertaken or proposed by the proponents in conjunction with associated companies, government agencies or other groups. These include physical, biological, spill clean-up and socio-economic programs. It is not the role of this volume to review the results of the past or ongoing studies, as these are addressed in appropriate sections of other EIS volumes.

Chapter 4 consolidates, by field of study, the proposed future programs as envisaged by the proponents at this time. For example, under the subject "oceanography" appears those programs analyzing oceanographic parameters, be they in relation to

(Courtesy, M. Bradstreet, LGL Limited)

island construction, vessel traffic or oilspill countermeasures. Table 4-1 provides an opportunity to see, at a glance, how concerns will be addressed by the industry. It should be noted, however, that any or all of the programs outlined herein are subject to change, either in scope or timing, owing to the results of ongoing projects, discussions with various groups, and the EARP hearings and resultant recommendations.

The existing and proposed research and monitoring programs presented in Volume 7 have been developed by the proponents in response to concerns and issues which the industry considers important and directly related to hydrocarbon exploration and production. Hence, not all of the possible concerns that have been expressed to the proponents have been addressed.

In reviewing the research and monitoring programs it is important to recognize their dynamic and iterative nature. The activities described will be modified as required to reflect what is known at the time when they actually begin. Therefore, rather than presenting detailed specific projects, emphasis has been placed on general 'areas' of research or monitoring. As the results of current studies and details of specific development activities become available, the necessary decisions regarding which projects will be undertaken and how to best carry them out will be made.

No distinction has been made between "research" and "monitoring" in this volume. Studies will be conducted to evaluate impacts or the potential for impacts related to concerns. The results of these studies will be used to resolve problems, to develop further studies, to clarify issues or to make repetitive observations for comparison to established criteria and objectives. In effect, a 'problem-solving loop' will be developed. The results of initial studies will be used as the basis for deciding whether or not further studies are required, and what form these might take. The EARP hearings, changes in government policies, and inputs from community, special interest and other groups may also result in modifications to proposed programs.

CHAPTER 1
THE POST-EARP REGULATORY MECHANISM RELATED TO RESEARCH AND MONITORING

1.1 RESPONSIBILITIES

The Environmental Assessment Review Panel (EARP) has requested the proponents to ". . . comment on their perceptions of the various responsibilities of both government and industry associated with monitoring all facets of the proposal. Statements on existing and desireable regulatory mechanisms related to project monitoring should be considered" (Beaufort Sea Environmental Assessment Panel, 1982).

The proponents consider that the purpose of monitoring is to determine if the scope and impacts of industry activities are acceptable within the context of post-EARP government policies regarding environmental and socio-economic matters. Government (at all levels) has the responsibility to describe the natural and socio-economic environment, its level of well-being and associated trends; to establish environmental protection and socio-economic criteria; to establish the need for, and participate in the development of, mitigative measures for various uses of the environment; and, to evaluate the activities of industry in the context of existing and proposed government policies. In general, industry is responsible for describing the nature and extent of its activities; describing environmental impacts and mitigative measures associated with its activities; monitoring the effectiveness of mitigative measures against environmental criteria and standards; researching and developing practical mitigative measures; and clarifying possible impacts.

It is important to note that, while government and industry have discrete responsibilities, there is cooperation between the two in developing and undertaking environmental research and monitoring programs. Many of the studies described in this volume are either joint government-industry projects or have been done in close cooperation with one another. This cooperation has, and will continue to result in better decision-making and distribution of information than would otherwise be possible.

1.2 THE POST-EARP PROCESS

The Beaufort Sea Hydrocarbon Production Proposal EIS Guidelines state "a program designed to monitor possible environmental and socio-economic consequences of Beaufort Sea oil and gas production and transportation should be described" (Beaufort Sea Environmental Assessment Panel, 1982). Industry activities in the north are presently being monitored at the local, regional and national levels. Department of Indian Affairs and Northern Development (DIAND) inspectors file annual reports on industry programs which include evaluations of industry's environmental and socio-economic programs and commitments. In the case of drillship operations in the Beaufort Sea, annual approval to drill has been granted by the Federal Cabinet only after a review of all facets of the company's operations, including the environmental and socio-economic spheres.

Existing government control measures for northern development projects have been identified in recent individual submissions by each of the EIS proponents to the Special Committee of the Senate on the Northern Pipeline (Dome Petroleum Limited, 1982b; Esso Resources Canada Limited, 1982; Gulf Canada Resources Inc., 1982). Included in the information is a reference to thirty-two Federal Acts and twenty-three Territorial Ordinances that control various facets of northern operations. The regulations associated with these acts are administered by various government departments.

Normal business practice in the Beaufort Sea region also includes reviews of development proposals with the territorial governments, communities, hunters and trappers associations, and other special interest groups. These reviews often result in modifications to ongoing and planned operations in response to concerns about previous or forecasted activities.

A general proposed post-EARP plan for establishing monitoring programs, together with considerations on the division of government and industry responsibilities, is outlined in Table 1.2-1. Characteristic of the process is continuing discussion between representatives of the industry, communities and governments. In this way public participation is assured.

The plan shows three levels of interaction among industry, the public and government associated with ongoing, annual and five-year time frames. The ongoing process includes continued consultation with communities and governments on specific plans and approvals for those activities which are to be carried out in the context of an annual program. Monitoring occurs on a continuing basis and immediate action can be taken to alter plans and activities should it be deemed necessary. For example, white whale movements are monitored to avoid or minimize interactions between these mammals and industry's marine activities. In this case industry is acting on concerns expressed by communities while offshore work continues. Thus, the monitoring program determines whether there is a need for vessels to stay clear of areas occupied by whales. More formally, regulatory agencies ensure that activities comply with

TABLE 1.2-1

PROPOSED POST-EARP ENVIRONMENTAL AND SOCIO-ECONOMIC MONITORING PROCESS

Period	Initiator	Objective/Activity	Output
		Over-all Objective To determine if industry activities are acceptable within the context of post-EARP government policies on environmental and socio-economic matters and to make recommendations on them.	
Ongoing	Individual Companies	- As required consultation with communities to address local concerns and aspirations.	- Opportunity for the public most affected to input to the decision making process.
		- Implementation of environmental and socio-economic research and monitoring programs.	- Recommendations to industry operations, government EOC's and/or the monitoring program.
	Government Agencies (all levels)	- Implementation of environmental and socio-economic research and monitoring programs.	- Regulation of industry.
Annual	Individual Companies	- Annual report on development activities, and research and monitoring program results.	- Public awareness. - Recommendations for changes to industry operations, government EOC's and/or the monitoring program.
	Federal and Territorial Departments	- Annual reports on government research and monitoring programs. - Consolidation of public and private sector research and monitoring results, synthesis and over-all interpretation. - Report on the effectiveness of the research and monitoring programs.	- Annual evaluation of industry activities re: the objective.
5-Year	Industry Group	- Report on the previous 5 years of development and forecast for the next 5 years.	- A public statement by industry on the developments to date, the approvals process, and an outlook on future developments.
		Report on the results of 5 years of research and monitoring.	- Industry evaluation of the significance of findings relative to the objective.
		- Evaluate government policies related to hydrocarbon development.	- Recommendations on government policies.
	Government Departments and Agencies	- Review of local, regional and federal policies and regulations relating to Beaufort development.	- Government evaluation of its policies and the EARP with respect to Beaufort Sea hydrocarbon development.
		- Re-evaluate Environmental Operating Conditions.	- Recommendations on the direction of future research and monitoring.
		- Report on 5 years of government and industry research and monitoring.	- Evaluation and recommendations on industry activities relative to the objective.
	Industry/ Government	- Public information seminar.	- Public participation.

requirements through on-site inspections, reports and feedback to industry for corrective action if necessary.

The annual process deals with programs on a more general level. Government inspectors provide annual reports on the activities of industry, and both industry and government table the results of research and monitoring programs. The results of the programs are reviewed by various groups. Alterations to the research and monitoring programs and to the environmental operating conditions placed on an activity by government are made accordingly.

At five year intervals industry and government will review the progress of activities in the context of existing over-all Beaufort Sea regional development as compared with forecasted development and existing government policies. A public information seminar or workshop would allow the public to express its views and to make recommendations on the over-all process with respect to its primary objective (Table 1.2-1) and the direction in which future research and monitoring programs should proceed.

1.3 REGULATORY MECHANISMS

In general, while some additional staff may be required by government to handle the increased workload generated by increasing activity in the Beaufort Sea region, at this time there appears to be little need to add to the existing government regulatory structure (that is, additional review bodies or committees). The existing regulatory mechanisms (in terms of subject area and boards, committees and agencies involved) are comprehensive, with observation and control of all aspects of industry activity.

Although there are some apparent areas of duplication of regulatory responsibility, as stated previously, the system is effective. No major changes are seen to be necessary other than those that take place in a gradual, evolutionary manner consistent with changing conditions. Government committees, such as the Arctic Waters Advisory Commitee (AWAC) and the Regional Ocean Dumping Advisory Committee (RODAC), are well established and have, or are able to, access the expertise required to ensure that appropriate environmental operating conditions are recommended (see Section 3.1). The proponents also encourage continued cooperation between regulatory review groups (such as AWAC and RODAC) in order for them to collaborate on projects where responsibilities overlap (for example, dredging sand for marine channel construction). This approach tends to expedite approvals and results in better and more consistent environmental terms and conditions.

1.4 ESTABLISHING RESEARCH AND MONITORING PRIORITIES

Priorities for research and monitoring have, and will continue to be, developed through consultation with communities, hunters and trappers associations, government agencies, various technical experts and others as appropriate. Two Federal Government initiatives, the Canada Oil and Gas Act and the proposed regional planning process, may have important roles in establishing priorities and the over-all direction of research and monitoring programs in the Arctic. At this time the scope, terms of reference and administration of these two initiatives have not been determined. Therefore, their roles in Arctic research and monitoring programs are not yet known. Should neither provide an adequate vehicle for over-all program review and direction, at appropriate intervals the proponents would bring relevant parties together at a workshop to undertake a comprehensive review of the work completed. Through these discussions and feedback, recommendations for future studies would be developed. The proponents would prepare their plans based upon these consultations, and table their research and monitoring programs for approval by regulatory agencies.

CHAPTER 2
BACKGROUND STUDIES

Many of the studies reviewed in other volumes of the EIS were done under the auspices of one or more much larger research projects. A review of the scope of these larger projects provides a setting for the ongoing and future research and monitoring programs presented in Chapter 3, just as the information gathered in these past studies has formed the data base for today's Arctic research and development projects. When the amount of money expended on the environmental and socio-economic studies described herein is totalled, the figure approaches $800 million. The reader is referred to Volumes 2 through 6 for the results of various studies conducted within these broad-based projects.

Figures 2-1, 2-2, 2-3 and 2-4 illustrate the general geographical areas covered by these background projects and locate places identified in the text, thus providing an indication of the scope of the research that has been undertaken in North America's Arctic over the past 25 years.

2.1 INDUSTRY-SPONSORED STUDIES

The following provides a review of several large past projects carried out by industry in Canada's north, each of which involved environmental and/or socio-economic studies. Large petroleum company associations presently involved in Arctic research are also discussed.

2.1.1 THE ARCTIC GAS PROJECT

The Arctic Gas Project is a broad title given to a number of individual proposals to move natural gas from the Mackenzie Delta to southern markets. In conjunction with these multiple proposals, a wide variety of environmental, socio-economic and engineering feasibility studies, spanning a decade, were carried out. The first of these began in 1967, with the last being completed in 1977. The following discussion gives the history of the Arctic Gas Project, and is based on information contained in a submission to government by Canadian Arctic Gas Pipeline Limited (1974).

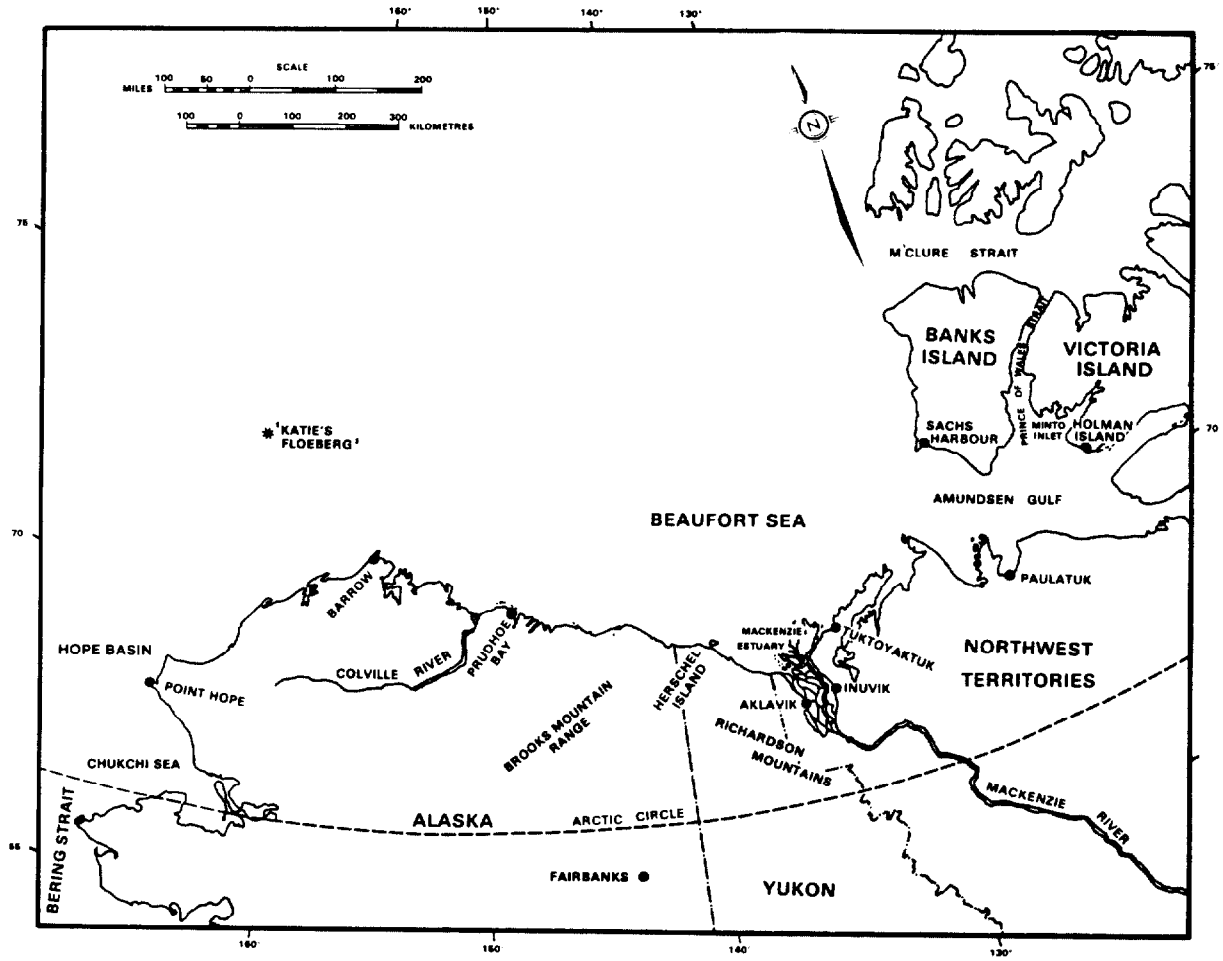


FIGURE 2-1 *Alaska and the Canadian Beaufort Sea region.*

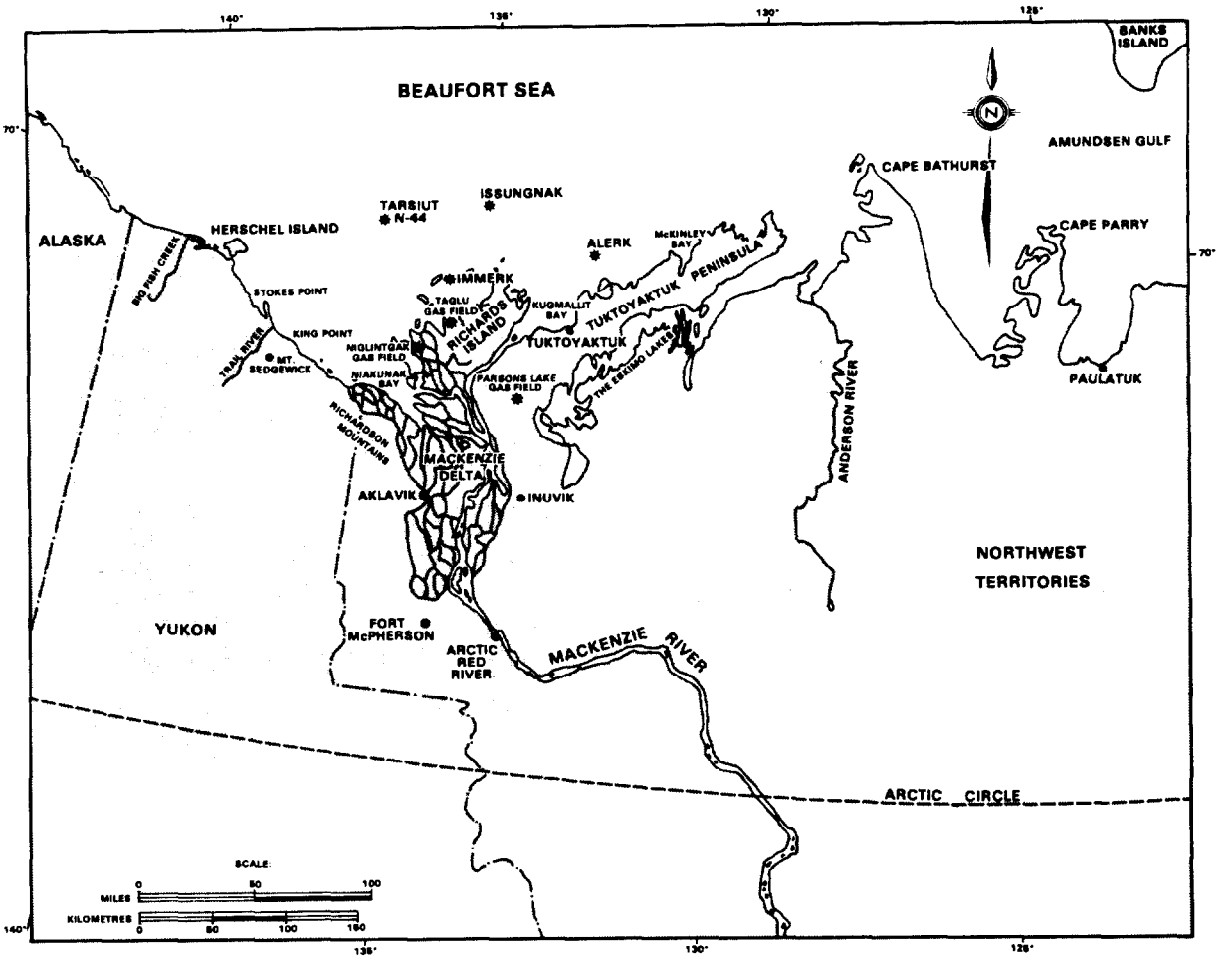


FIGURE 2-2 *The Canadian Beaufort Sea and Mackenzie River Estuary.*

In 1967 TransCanada Pipelines Limited (TCPL) joined with two American transmission companies, Michigan Wisconsin Pipeline Company and Natural Gas Pipeline Company of America, to form the Northwest Project Study Group. This group undertook to conduct engineering and feasibility studies for a natural gas pipeline to transport gas from the Pointed Mountain area of the Northwest Territories (Figure 3-4) to southern markets. This program included research on operation and maintenance procedures, the ecology of the region and the precautions necessary to protect the environment. In 1969, following the discovery of oil and gas at Prudhoe Bay, attention was shifted to the Alaskan North Slope and Mackenzie Delta regions. The study group was expanded in 1970 by the addition of three producing companies which held the bulk of the gas reserves at Prudhoe Bay - Humble Oil and Refining Company (Exxon), Atlantic Richfield Company and Standard Oil Company (Ohio).

Also in 1969, studies began on a proposal by the Alberta Gas Trunk Line Company Limited (AGTL) to construct a 2,480 km (1,550 mile) pipeline from Prudhoe Bay, Alaska (Figure 2-1), to connect with AGTL's facilities near Grande Prairie, Alberta (Figure 3-4). The project was developed by the Gas Arctic Systems Study Group, the members being AGTL, Canadian National Railways, Columbia Gas Systems Inc., Northern Natural Gas Company and Texas Eastern Transmission Corporation (Pacific Lighting Gas Development Company, or PLGD, joined the Study Group in 1971).

In 1972 the Gas Arctic Systems Study Group merged with the Northwest Project to become the Gas Arctic-Northwest Project Study Group. The newly combined group became known by its corporate name - Canadian Arctic Gas Studies Limited (CAGSL) and by 1973 it had 27 participants. CAGSL had a mandate to carry out both biotic and abiotic research related to gas pipeline construction along the Mackenzie Valley corridor, and produced 41 volumes, including work on mammals, fish, birds, vegetation, hydrology, geology, soils, climate and archaeology. Environmental studies on the effects of noise, aircraft and human disturbance on wildlife; methanol toxicity; impacts of snow roads; and revegetation pro-

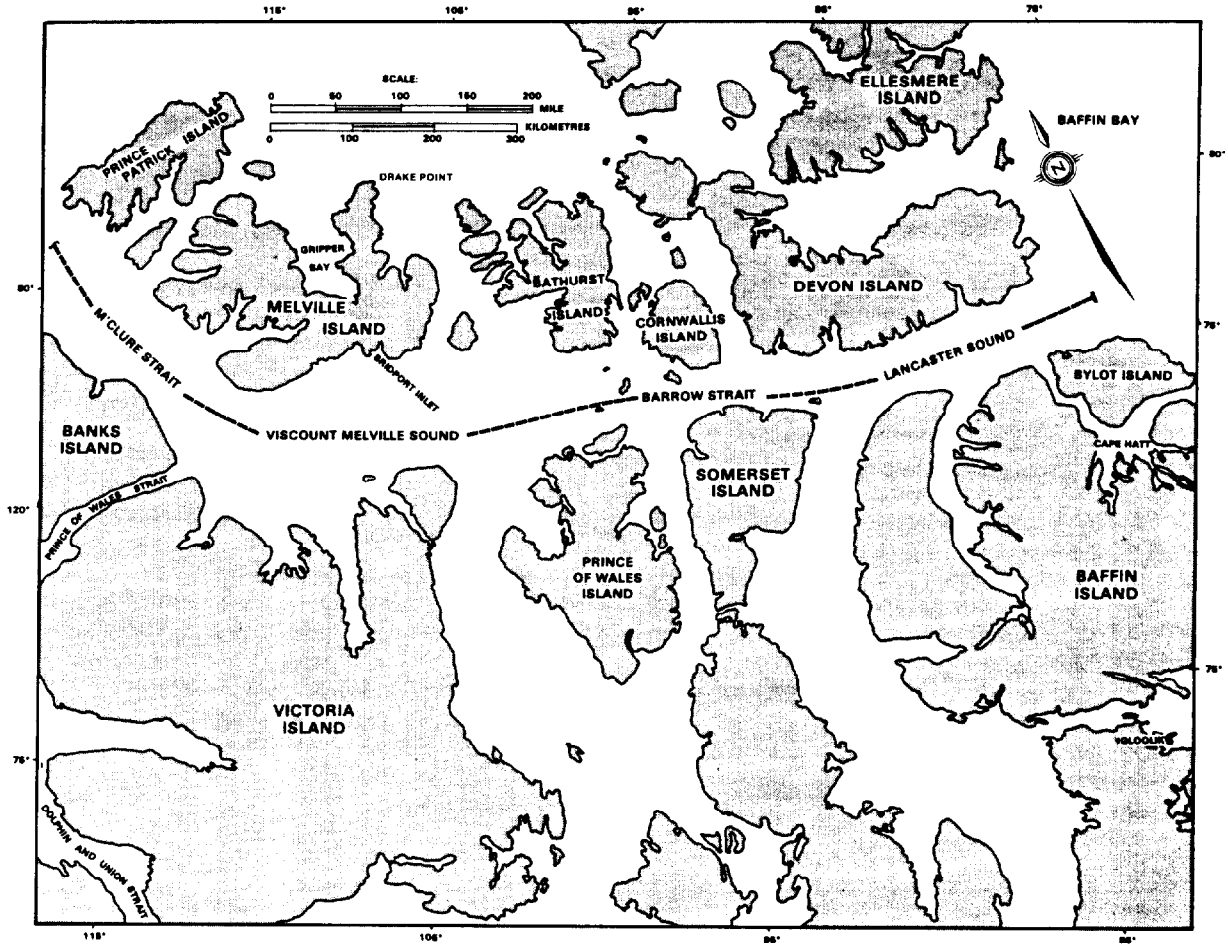


FIGURE 2-3 *The Northwest Passage and surrounding regions.*

grams were also carried out (Canadian Arctic Gas Pipeline Limited, 1974). In addition, a detailed examination was made of the communities likely to be affected by the pipeline. The four volume report resulting from this study included an assessment of the possible social, economic and cultural impacts of the proposed pipeline. Other studies focussed on the northern labour force, including training needs (Canadian Arctic Gas Pipeline Limited, 1974).

In 1974 CAGSL filed an application with the National Energy Board and the Department of Indian Affairs and Northern Development, under the corporate name of Canadian Arctic Gas Pipeline Limited (CAGPL), for a certificate to construct their proposed gas pipeline. On March 21, 1974, the Mackenzie Valley Pipeline Inquiry was established with Mr. Justice T.R. Berger as Commissioner of Inquiry to report on the regional social, environmental and economic impacts of the construction, operation and subsequent abandonment of the proposed pipeline. Mr. Justice Berger's report recommended that the project not receive approval at that time, and, following a negative decision by the National Energy Board, the various groups (CAGSL and CAGPL) were disbanded in the spring of 1977.

2.1.2 MACKENZIE VALLEY PIPE LINE RESEARCH LIMITED

Early in 1969 Mackenzie Valley Pipe Line Research Limited was formed to study and seek solutions to the problems of designing, building, operating and maintaining safe and efficient warm-oil pipeline systems in the Arctic and subarctic. A program of feasibility studies, environmental and socio-economic research and engineering assessment was undertaken to establish technical and environmental feasibility, and to develop reliable capital and operating cost estimates. The program ended in 1974 (Mackenzie Valley Pipe Line Research Limited, 1972).

The work of Mackenzie Valley Pipe Line Research Limited was directed by representatives of the sixteen major oil and pipeline companies making up the consortium, as listed in Table 2.1-1. The individual studies were carried out by company specialists and consultants in cooperation with, and assisted by, a

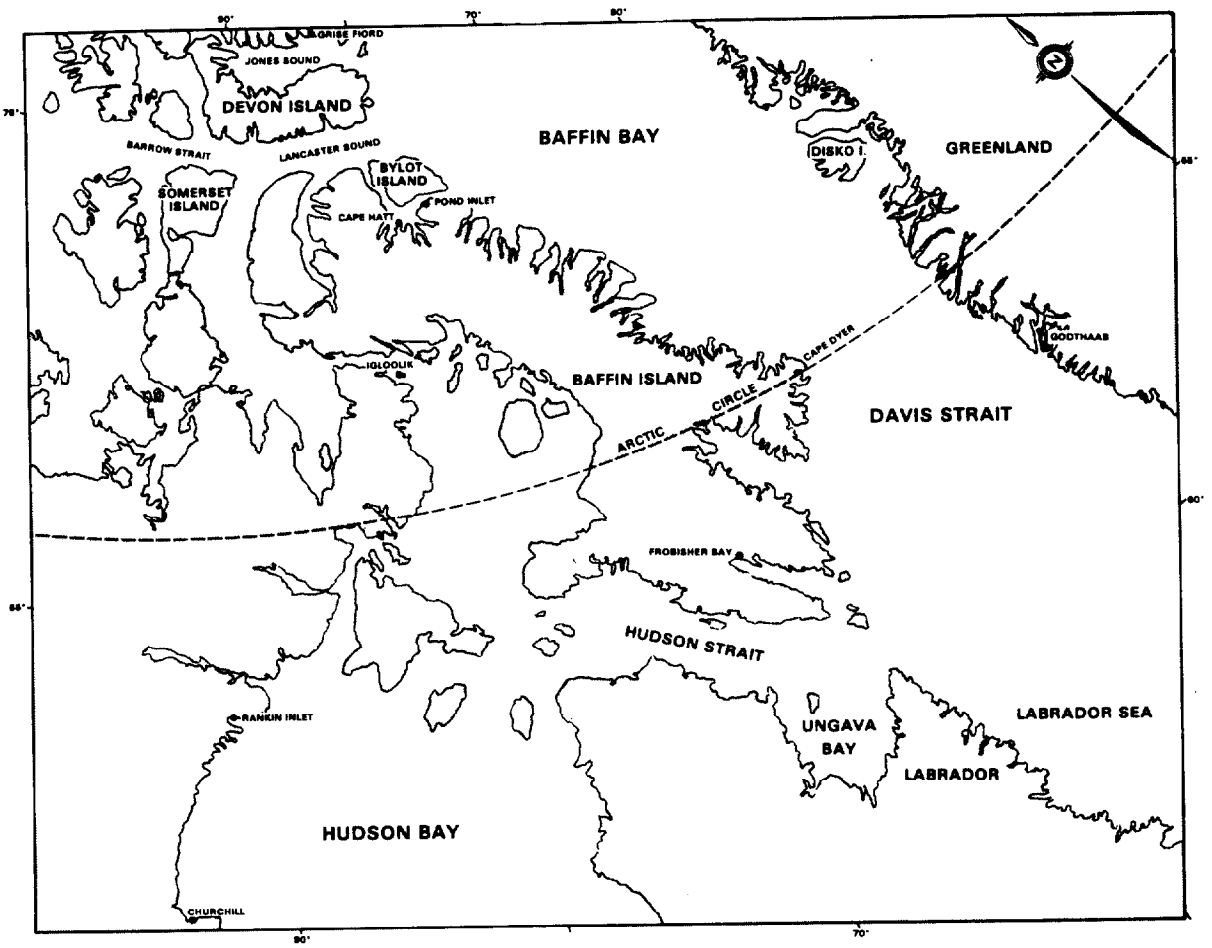


FIGURE 2-4 *Eastern Canadian Arctic.*

TABLE 2.1-1

COMPANIES IN MACKENZIE VALLEY PIPE LINE RESEARCH LIMITED

1. Amoco Canada Petroleum Company Ltd.
2. Ashland Oil Canada Limited
3. Atlantic Richfield Canada Limited (a)
4. BP Oil Limited
5. Cities Service Company
6. Elf Oil Exploration and Production Canada Limited
7. Gulf Oil Canada Limited
8. Hudson's Bay Oil & Gas Company Limited
9. Imperial Oil Limited
10. Interprovincial Pipe Line Company
11. Mobil Oil Canada Ltd.
12. Shell Canada Limited
13. Standard Oil Company of British Columbia Limited
14. Texaco Inc.
15. TransMountain Pipe Line Company Limited
16. TransCanada Pipelines Limited (b)

(a) Atlantic Richfield Canada Limited withdrew from participation in the Company and its studies on July 31, 1972.

(b) TransCanada Pipelines Limited participated fully in all research work but was not a shareholder in Mackenzie Valley Pipe Line Research Limited.

Source: Mackenzie Valley Pipe Line Res. Ltd., 1972

wide variety of government agencies (notably the Federal departments of Environment; Energy, Mines and Resources; Indian Affairs and Northern Development; and Public Works; as well as the National Research Council and the territorial governments of the Northwest Territories and Yukon), universities and consulting firms.

A 2,780 km (1,738 mile) route was selected for study, traversing the region from Prudhoe Bay, Alaska, through the Brooks Range and Richardson Mountains, following the Mackenzie River Valley to Edmonton, Alberta (Figure 3-4). Over the northern 800 km (500 miles), a second route from Prudhoe Bay, east along the Arctic coast and up the west side of the Mackenzie River Delta to the vicinity of Fort McPherson, was also investigated. Since over half the line would pass through predominantly permafrost regions, most of the research was aimed at developing design criteria that would ensure a safe and stable pipeline under these conditions. Included in the research program was the construction and operation of a test facility in permafrost terrain at Inuvik, Northwest Territories (Figure 2-2). This facility (see Plate 2-1) was a closed loop of 1,219 mm (48 in) pipe, 600 m (2,000 ft) long, half of which was constructed on piles above ground and the remainder of which was buried in a gravel embankment. Warm oil was circulated through the loop. Soil conditions were monitored over one annual cycle.

Other detailed studies generated by the program included environmental and socio-economic implications; soils and terrain; pipeline hydraulics; thermodynamics and stress analyses; station design; construction materials and techniques; transportation and housing; communications; operations and maintenance; and pipeline economics (Mackenzie Valley Pipe Line Res. Ltd., 1972).

2.1.3 MACKENZIE DELTA GAS DEVELOPMENT SYSTEM

The Mackenzie Delta Gas Development System (known as the Delta Gas Project) involved feasibility and environmental studies related to a joint proposal by Esso Resources Canada Limited, Shell Canada Resources Ltd. and Gulf Canada Resources Inc. to drill production wells and to construct processing plants with associated gathering systems at their respective Mackenzie Delta natural gas fields (Figure 2-2). The processed gas was to be shipped via a pipeline to southern markets. Between 1972 and 1977 detailed socio-economic, environmental and geotechnical studies were undertaken. The history of Delta Gas follows.

In 1972 Esso Resources Canada Limited began an environmental research program focussing on its gas project at Taglu (Figure 2-2). Shortly after this work began, Shell Canada Resources Ltd. and Gulf Can-

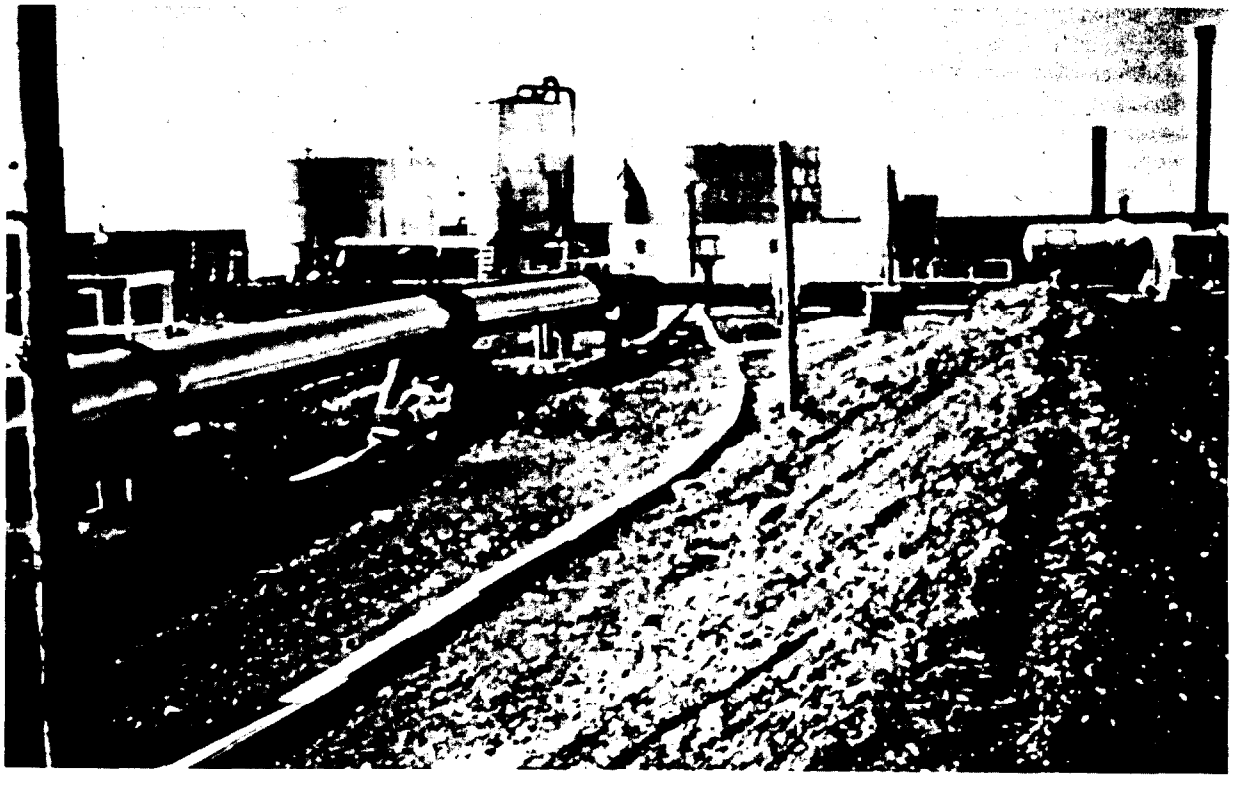


PLATE 2-1 *Closed loop pipeline used for studies on the effects of transporting warm oil through areas of permafrost. Half of the line was constructed on piles above ground, while the other half was buried in a gravel embankment.*

ada Resources Inc. joined Esso in a joint planning program. Shell's gas field at Niglintgak (Figure 2-2) and Gulf's field at Parsons' Lake (Figure 2-2) also required development approval, and the three companies expanded Esso's original environmental studies into the "Mackenzie Valley Gas Development System," in order to provide background information required to obtain Approval-In-Principle for a joint development proposal.

The three companies made a joint submission to the Federal Government and produced an Environmental Impact Statement. Later each of the three companies, at the request of the Department of Indian Affairs and Northern Development (DIAND), also made individual submissions for development of their respective gas fields through the newly formed Federal Environmental Assessment Review Office (FEARO). At this stage, in February, 1977, the Joint Program was disbanded and the pipeline project (now known as the "Delta Gas Project") was shelved.

At the time of termination, considerable effort had been spent on the joint program, including environmental and geotechnical studies, socio-economic research, base camp construction and drilling programs. The socio-economic programs in particular have proven very valuable to other proposed developments in the region. For example, Hobart and Kupfer (1978) evaluated an employment program initiated by Gulf Canada Resources Inc. in Coppermine, Northwest Territories (Figure 3-4), in association with the Delta Gas Project. They concluded that wage labour did not appear to have a negative impact on the community's social stability and enhanced the local traditional resource-based economy. It was felt that continued consultation with the local population regarding the development and their active participation in the decision-making process probably contributed to the favourable results of the program.

2.1.4 BEAUFORT-DELTA OIL PROJECT LIMITED

Beaufort-Delta Oil Project Limited was formed in 1975 and disbanded at the end of 1977. The participants, including Esso Resources Canada Limited, Shell Canada Resources Ltd. and Gulf Canada Resources Inc., conducted a series of studies on the physical and biological environment related to the evaluation of alternate pipeline corridors from the Mackenzie Delta to Edmonton, Alberta (Figure 3-4), with work on vegetation, mammals, birds, aquatic resources, climate and hydrology being emphasized.

2.1.5 ARCTIC PETROLEUM OPERATORS' ASSOCIATION

The Arctic Petroleum Operators' Association (APOA) was formed in 1970 to represent the concerns and interests of its member companies which work in the Canadian Arctic. The APOA, based in Calgary, Alberta, facilitates the carrying out of joint Arctic research projects on behalf of its twenty members (see Table 2.1-2). Sponsorship is given to projects on the environmental and engineering aspects of the petroleum industry's activities in the north, with about 180 projects having been undertaken in the past twelve years.

A great deal of APOA's work is coordinated by one or more of eight active committees: environmental, oil spill, drilling, remote sensing, safety, offshore medicine, industrial benefits and public information. With the exception of the public information committee, all are jointly operated with the Eastcoast Petroleum Operators' Association (EPOA). Other

TABLE 2.1-2

MEMBER COMPANIES IN THE ARCTIC PETROLEUM OPERATORS' ASSOCIATION (APOA)

1. BP Exploration Canada Ltd.
2. Canadian Superior Oil Ltd.
3. Canterra Energy Ltd. (formerly Aquitaine Company of Canada Ltd.)
4. Chevron Standard Ltd.
5. Consolidex Gas and Oil Limited (formerly Norlands Petroleums Limited)
6. Dome Petroleum Limited
7. Esso Resources Canada Limited
8. Global Arctic Islands Ltd.
9. Gulf Canada Resources Inc.
10. Hunt International Petroleum Company
11. Mobil Oil Canada Ltd.
12. Norcen Energy Resources Ltd.
13. Panarctic Oils Ltd.
14. PanCanadian Petroleum Ltd.
15. Petro-Canada Exploration Inc.
16. Phillips Petroleum Canada Ltd.
17. Shell Canada Resources Limited
18. Suncor Inc.
19. Texaco Canada Resources Ltd.
20. Union Oil Company of Canada Ltd.

Source: G. Jones, pers. comm. Reflects status as of May 1, 1982

committees are established as required, and the APOA provides representation on various government and technical committees. As well, the APOA sponsors conferences and workshops as a means for exchanging information and opinions on developments occurring within the Canadian Arctic.

The majority of APOA funded studies are managed by one of the member companies and are supported by other members with similar needs. One very large biological and environmental project, the Beaufort Sea Environmental Project, was undertaken in 1974 as a joint government-industry project. This study is dealt with in greater detail in Section 2.2.5. Other APOA programs include a wide variety of research on sea ice and its effects on both the man-made environment and the natural environment; studies on exploratory drilling systems; studies related to subsea pipelines; research on modes of land transportation in the Arctic; projects addressing the effects of drilling fluids and their disposal; studies regarding permafrost; and analyses of gravel deposits. APOA has sponsored work on areas of general interest such as Arctic clothing and manpower training, and is known for its support of research regarding oil spills and related problems. APOA, together with other industry associations and government agencies, co-sponsors an annual environmental workshop, where many research topics or problems are discussed.

In 1980, APOA and EPOA jointly sponsored a new oilspill research organization, the Canadian Offshore Oil Spill Research Association (COOSRA), responsible for researching and developing oilspill countermeasures for Canada's offshore areas (Section 2.1.7) (APOA, 1981).

Another project funded by APOA which is valued by all groups working in the Arctic is the Arctic Science and Technology Information System (ASTIS). ASTIS, operated by the Arctic Institute of North America (AINA), has developed a multi-purpose bibliographic data base to provide printed and on-line information retrieval services to individuals or groups requesting background information on past Arctic research. Six times a year ASTIS publishes a bulletin listing the studies entering the data base in the previous two-month period. As well, ASTIS has published two editions of an APOA bibliography, providing the author, subject and geographic area for all recent APOA-sponsored research (ASTIS, 1979).

2.1.6 EASTCOAST PETROLEUM OPERATORS' ASSOCIATION

The EPOA (Eastcoast Petroleum Operators' Association) was formed in 1971 and comprises eighteen companies (see Table 2.1-3) which have joined together to undertake various research projects, particularly those of an environmental or operational nature. The member companies are all involved in offshore areas located in the Atlantic Ocean northward from the United States border, including the Labrador Sea, Hudson Bay, Davis Strait and Baffin Bay (see Figure 2-4). The general types of studies undertaken include sea ice surveys, research on icebergs and their effects on drilling, environmental baseline studies (particularly regarding fish), environmental sensitivity studies and oilspill contingency work. In addition, EPOA co-sponsors COOSRA's research on oil spills, in conjunction with the APOA.

The Association provides a forum where companies can meet to discuss matters of common concern regarding eastcoast operations. EPOA, as an organization, has offices in Calgary, Alberta and St. John's, Newfoundland, and is directed by a seven-member board elected from among the participating companies. Individual projects are usually managed by a single company which acts as operator on behalf of the participants (G. Jones, pers. comm.).

TABLE 2.1-3

MEMBER COMPANIES IN THE EASTCOAST PETROLEUM OPERATORS' ASSOCIATION (EPOA)

1. AGIP Canada Limited
2. BP Exploration Canada Ltd.
3. Canadian Superior Oil Ltd.
4. Canterra Energy Ltd. (formerly Aquitaine Company of Canada Ltd.)
5. Chevron Standard Ltd.
6. Consolidex Gas and Oil Limited (formerly Norlands Petroleums Limited)
7. Dome Petroleum Limited
8. Esso Resources Canada Limited
9. Gulf Canada Resources Inc.
10. Husky Oil Operations Ltd.
11. Mobil Oil Canada Ltd.
12. PanCanadian Petroleum Ltd.
13. Petro-Canada Exploration Inc.
14. Ranchmen's Resources (1976) Ltd.
15. Shell Canada Resources Limited
16. SOQUIP
17. Suncor Inc.
18. Texaco Canada Resources Ltd.

Source: G. Jones, pers. comm. Reflects status as of May 1, 1982

2.1.7 CANADIAN OFFSHORE OIL SPILL RESEARCH ASSOCIATION

COOSRA, the Canadian Offshore Oil Spill Research Association, was formed in 1980 as an outgrowth of the need for the petroleum industry involved in Canada's offshore to carry out increased research on the effects of oil spills on Arctic ecosystems and on oil-spill clean-up techniques. The association is co-sponsored by the Arctic Petroleum Operators' Association (APOA) and the Eastcoast Petroleum Operators' Association (EPOA), which, through their operator, non-operator and associated members (see Table 2.1-4), conduct controlled oilspill experiments, equipment tests, dispersant tests and other related research in marine areas. COOSRA also acts as a liaison between the petroleum industry and petroleum industry associations, other industries and their associations, civic groups, the Canadian public, government agencies, universities and other research centres on matters relating to offshore oilspill research and serves as an information source for these bodies.

The association membership is managed by elected officers (including a chairman, vice-chairman, secretary and treasurer) and four other Management Committee members. In addition there is a Technical Advisory Committee which makes recommendations on oilspill research and provides guidance on the applicability of individual research programs to various offshore regions of Canada, in order that cost sharing be divided fairly by participants on the basis of their offshore drilling activities and holdings.

The first year of COOSRA operation involved a substantial financial input into the Baffin Island Oil Spill (BIOS) Project discussed in Section 2.2.6.1. Three other projects which serve to illustrate the types of work undertaken through COOSRA are "the oil and gas under sea ice" study, the development of a fire-proof boom, and the development of a heli-portable burner. These are discussed below.

2.1.7.1 The Oil and Gas Under Sea Ice Study

The "Oil and Gas Under Sea Ice" study was a major COOSRA program undertaken during the winter of 1979. The primary objective was to simulate an under-ice oil well blowout in the Beaufort Sea in order to gain a better understanding of the behaviour of oil and gas in ice and to determine possible methods for cleaning up such a spill.

Three separate discharges (in December, 1979, and in April and May, 1980) of oil and gas took place offshore near McKinley Bay (Figure 2-2) using a sled-mounted discharge pipe to simulate a wellhead at a water depth of 20 metres below undisturbed first year ice. In each discharge approximately 6 m^3 of crude oil and between 400 and 1,700 m^3 of air (to simulate

TABLE 2.1-4

OPERATOR, NON-OPERATOR AND ASSOCIATED MEMBERS IN THE CANADIAN OFFSHORE OIL SPILL RESEARCH ASSOCIATION (COOSRA)

A. Operator Members:

1. BP Exploration Canada Ltd.
2. Canadian Superior Oil Ltd.
3. Canterra Energy Ltd. (formerly Aquitaine Company of Canada Ltd.)
4. Chevron Standard Ltd.
5. Consolidex Gas and Oil Limited (formerly Norlands Petroleums Limited)
6. Dome Petroleum Limited
7. Esso Resources Canada Limited
8. Gulf Canada Resources Inc.
9. Mobil Oil Canada Ltd.
10. Norcen Energy Resources Ltd.
11. Panarctic Oils Ltd.
12. Petro-Canada Exploration Inc.
13. Phillips Petroleum Canada Ltd.
14. Shell Canada Resources Limited
15. Suncor Inc.
16. Texaco Canada Resources Ltd.

B. Non-Operator Members:

1. Global Arctic Islands Ltd.
2. PanCanadian Petroleum Ltd.

C. Associated Members:

1. Alaskan Beaufort Sea Oilspill Response Body (ABSORB)
2. American Petroleum Institute (API)

Source: W. Pistruzak, pers. comm. Reflects status as of May 1, 1982

natural gas) were released over a twenty minute period. The oil quickly froze into the growing ice sheet (Dome Petroleum Limited, 1981b).

Prior to break-up in the spring, about 80% of the oil appeared on the ice surface, having migrated through brine channels or having been exposed by melting of the ice down to the oil layer. The remaining oil was released when the ice sheet broke up (Dome Petroleum Limited, 1981b).

In situ burning using helicopter-deployed oil slick igniters (Plate 2-2) proved effective in cleaning up this type of spill. Of the 19.5 m^3 of crude oil discharged under the ice, 32% was removed by *in situ* burning, 17% was cleaned up manually, and 30% evaporated. In total about 80% was removed from the marine environment, the remainder dispersing into the water after break-up (Dome Petroleum Limited, 1981b).

2.1.7.2 Development of a Fire-proof Boom

In 1980 COOSRA began research into the development of a fire-proof boom, following previous work of this kind by Dome Petroleum Limited (McAllister Engineering, 1979). This research has involved a series of preliminary tow tests and static burn tests (McAllister and Buist, 1980), as well as test tank (Dome Petroleum Limited, 1981a) and offshore trials. The boom has proven capable of withstanding the intense heat of *in situ* crude oil combustion and is able to contain burning oil on water with waves equivalent to sea state 2 to 3 and currents up to 0.5 metres/second. This project is almost completed, with only offshore trials of the durability of a new connector design remaining to be done.

2.1.7.3 Development of a Heli-portable Burner

COOSRA has developed a helicopter-portable burner to dispose of recovered oil collected at remote sites (Plate 2-3) (Dome Petroleum Limited, 1982a). The burner has proven capable of disposing of a wide variety of contaminated oil, including viscous 60% water-in-oil emulsions, at rates of up to 80 m^3/day (500 barrels of oil per day). The unit can dispose of day to day accumulated waste and slop oils.

2.1.8 LANCASTER SOUND DRILLING

Lancaster Sound Drilling was the name given to a proposal by Norlands Petroleums Limited (now Consolidex Gas and Oil Limited) to drill an exploratory well in Lancaster Sound (Figure 2-3) and thereby obtain stratigraphic information which might determine hydrocarbon potential. Environmental research to meet government requirements for an Environmental Impact Statement (EIS) was carried out between 1975 and 1978.

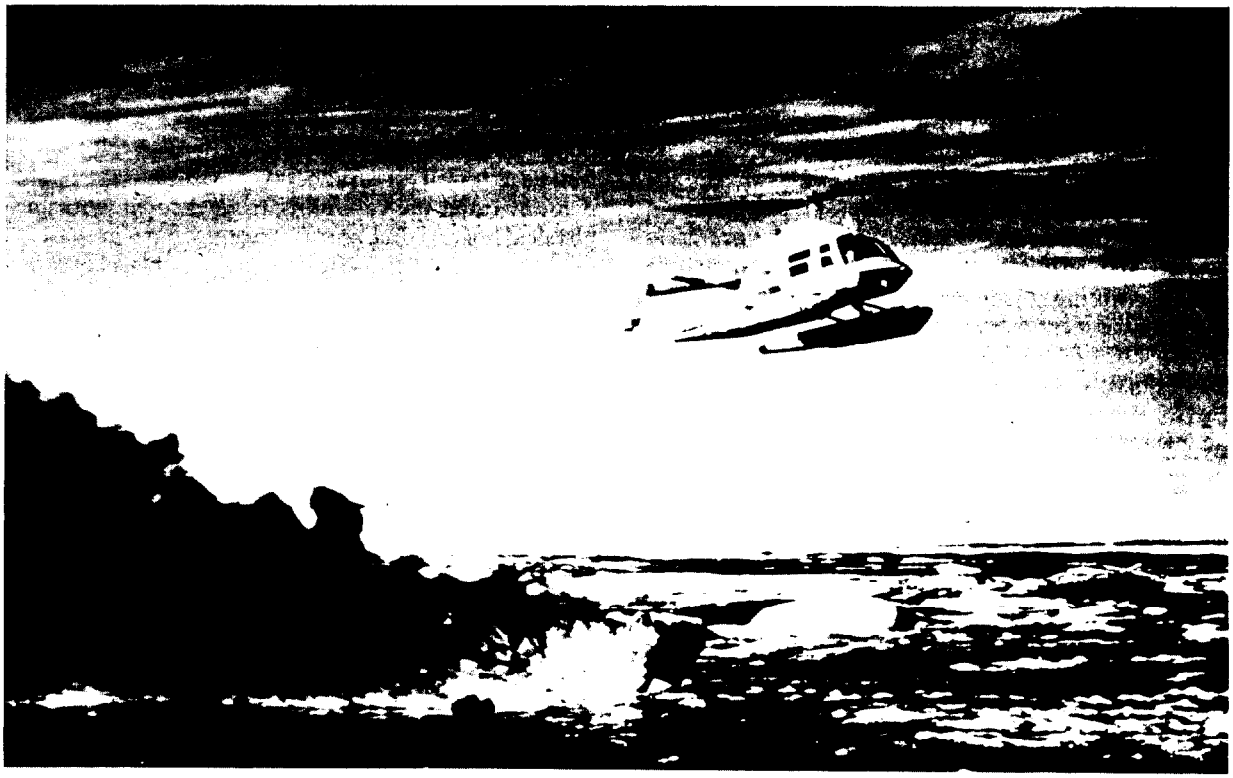


PLATE 2-2 *Heli-portable oil slick igniters, such as that shown here, are effective in cleaning up certain types of oil spills.*

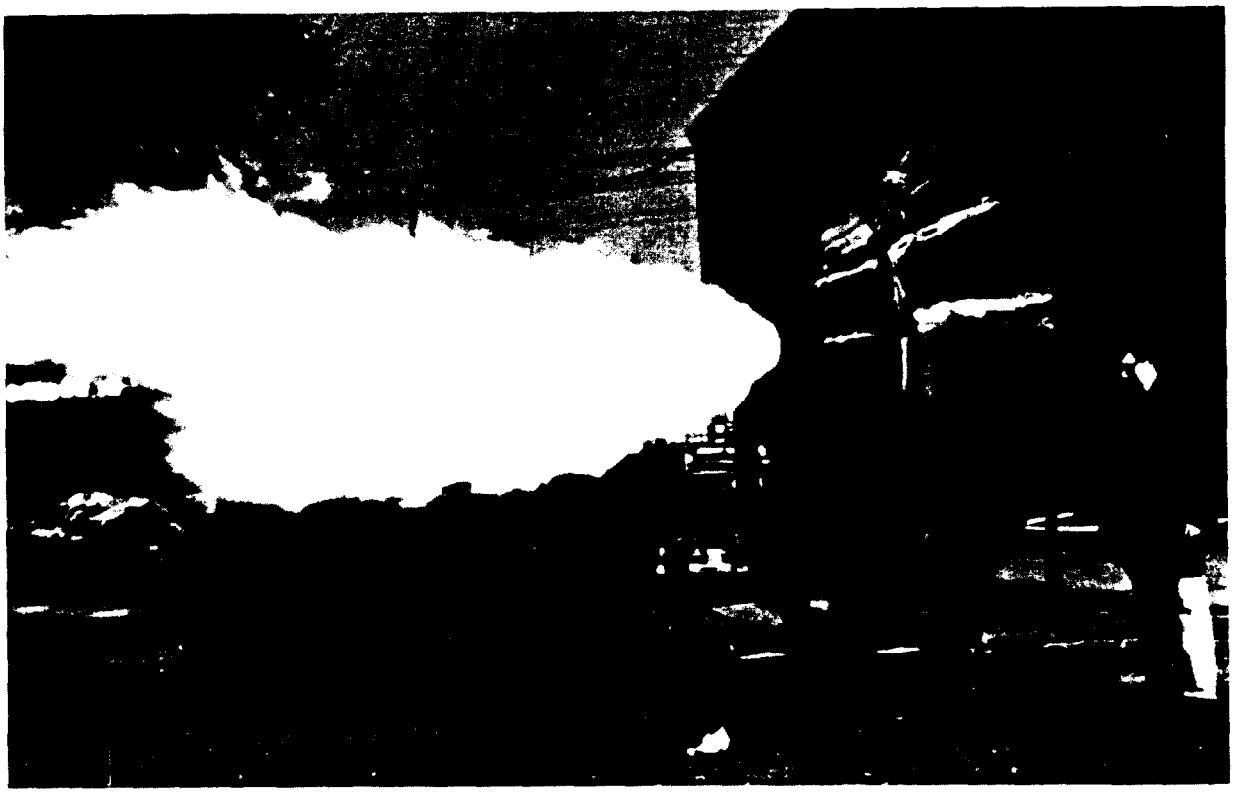


PLATE 2-3 *Helicopter deployable burner, used to burn recovered oil.*

The initial proposal was made to the Department of Indian Affairs and Northern Development (DIAND) in 1974, following extensive seismic surveys by Magnorth Petroleums Limited (from whom Norlands had farmed out the prospect) between 1971 and 1974. DIAND gave Approval-in-Principle to the proposal provided certain environmental programs were carried out prior to drilling. Although extensive environmental research was carried out between 1975 and 1976, the government requirements were not fully met by the 1977 deadline and the opportunity to obtain a drilling permit expired in August, 1977 (Federal Environmental Assessment Review Office, 1979).

Subsequently, DIAND referred the proposal to an Environmental Assessment Review Panel (EARP) to review the potential environmental consequences of the proposal and to provide recommendations on its acceptability. An Environmental Impact Statement was prepared by Norlands Petroleums and submitted to DIAND in June, 1978, which subsequently submitted it to the Panel in July, 1978.

In conjunction with the EIS, wide-ranging studies regarding the physical, biological and socio-economic aspects of offshore drilling in the region were carried out, both on a site-specific basis and regionally. Iceberg research was particularly emphasized, together with studies on the possible effects of oil spills or blowouts (Federal Environmental Assessment Review Office, 1979).

In 1979, after reviewing the EIS and after holding public hearings on the proposal, the Panel recommended that the drilling of the Norlands exploratory well be deferred until such time as the proponent had demonstrated the capability to deal safely with the physical hazards in Lancaster Sound and a preparedness to mitigate the effects of a possible major oil blowout. In addition, the panel suggested that the government use the interim period to address the issue of the best uses of the Lancaster Sound region.

2.1.9 POLAR GAS PROJECT

The Polar Gas Project involved technical, environmental, socio-economic and feasibility studies into the best means for transporting gas from the Arctic islands to southern markets. Between 1972 and 1979 several pipeline systems were proposed to meet this end, all under the auspices of a program called the Polar Gas Project sponsored by TransCanada Pipelines Ltd., Tenneco Oil of Canada Ltd., Panarctic Oils Ltd., the Ontario Energy Corporation and Petro-Canada (Anonymous, 1980). A short history of the project follows.

The Polar Gas Project began studies on the best means to transport Arctic frontier gas to southern markets in 1972. Early studies concentrated on connecting the gas reserves of the High Arctic to markets by pipeline, and an application to this effect was filed with the National Energy Board in 1977.

Advances in technology for deep-sea pipelaying resulted in a further two years of field study regarding routing of the line from the Arctic islands across M'Clure Strait to Victoria Island and subsequently across Dolphin and Union Strait to the Canadian mainland (Figure 2-3). Detailed information was obtained on channel bottom profiles, sub-bottom characteristics, ice conditions, tides and currents.

Polar Gas now proposes to construct a "Y"-line to connect the gas reserves of the Arctic islands with those of the Mackenzie Delta-Beaufort Sea area and to then move the gas via one pipeline south to mainland markets. Four possible routes for the Y-line are being considered. Depending on the line chosen, the pipeline could span 5,000 kilometres (3,125 miles) of terrain prior to joining the TransCanada Pipelines system in southern Canada (Taylor, 1981).

All four possible routes pass through zones of continuous permafrost soils, discontinuous permafrost soils and non-permafrost soils. Therefore, a large number of the feasibility studies for the Polar Gas Project have been done in relation to the effects of pipelines on permafrost. By the end of 1979, several millions of dollars had been spent on technical, environmental, socio-economic and other feasibility studies.

2.1.10 ARCTIC PILOT PROJECT

The Arctic Pilot Project (APP) is a proposal to produce natural gas from the High Arctic on a relatively small, yet commercial, scale and to demonstrate the viability of year-round transport of liquefied natural gas (LNG) from the north to southern markets using icebreaking carriers. In January, 1979, sponsors (now made up of Petro-Canada Exploration Inc., Dome Petroleum Limited, NOVA - An Alberta Corporation and Melville Shipping Ltd.) made a formal application to the National Energy Board (NEB), the Department of Indian Affairs and Northern Development (DIAND) and Transport Canada. DIAND referred the application to Environment Canada, which established an Environmental Assessment Review Panel to review the project. After public hearings in April, 1980, the panel recommended the initial project application be given government approval as long as certain conditions were met. An up-dated APP application submitted in fall 1980 is presently undergoing NEB hearings (APOA, 1982).

During the past five years extensive studies to examine major concerns related to all aspects of APP have been carried out as part of a twenty-year research and development program. An integrated route analysis has been developed which incorporates biological sensitivities and physical, economic, and operational factors, and which will serve to assist in the selection of the best possible route for LNG carriers through the Eastern Arctic.

Another environmental study has focussed on the problems associated with underwater sound generated by the proposed carrier traffic. The possible effects of this sound on biota, in particular marine mammals, is the subject of ongoing research.

An important socio-economic program carried out through APP is the Resource Harvest Study Program initiated in January, 1981. The aim of this research is to collect information on hunters' utilization of renewable resources in the vicinity of Barrow Strait (Figure 2-3). The data generated through hunter surveys and hunter route maps will assist in predicting and minimizing the future impacts of year-round shipping through the Northwest Passage on the people and their harvestable resources (APOA, 1981).

All of the APP research and development programs rely heavily on input from government agencies, community groups, special interest groups and universities. The general purpose of these programs is "to develop systems to assure secure, reliable and environmentally safe operations using research and development support that is at the leading edge and of the highest quality" (APOA, 1982). The project could add greatly to Canada's northern transportation technology and to the environmental and social sciences, and could lead to increased self-reliance of northern residents (Pallister Resource Management, 1982.)

2.1.11 OTHER INDUSTRY STUDIES (DOME, ESSO AND GULF)

In addition to the programs described, over the past ten years Dome Petroleum Limited, Esso Resources Canada Limited, and Gulf Canada Resources Inc. have employed a great deal of expertise and spent considerable time and effort to conduct environmental programs related to their ongoing offshore exploration programs. In addition to gathering baseline data, physical, oceanographic and biological studies have been undertaken to evaluate the impacts of specific activities such as construction of artificial islands, exploratory drilling from islands and drillships, dredging of harbours and locating of shorebases. Recently research has centred on future pro-

duction related activities, such as the construction and operation of permanent production platforms, tanker and pipeline transportation systems, and future shorebase requirements. Information regarding ongoing and proposed activities are presented in Chapters 3 and 4 of this volume.

2.2 GOVERNMENT-SPONSORED STUDIES

The following is a description of environmental research programs relevant to northern hydrocarbon development, which are being or were conducted by government agencies or jointly sponsored by government and the oil industry. The major projects are discussed in some detail, while others are simply identified.

The Department of Environment, in addition to having managed the Beaufort Sea Project (Section 2.2.5), operates the Beaufort Weather Forecasting System through the Atmospheric Environment Service. This system is funded by the petroleum operators in the Beaufort Sea. The Environmental Protection Service has ongoing environmental monitoring programs for most Arctic projects. Also, the Canadian Forest Service and Canadian Wildlife Service have undertaken projects regarding terrain, vegetation and permafrost, and birds and marine mammals, respectively.

The Department of Fisheries and Oceans has been involved in Beaufort Sea bathymetric surveys (Canadian Hydrographic Service), ice climatology (Frozen Sea Research Group), oceanography (including water chemistry, remote sensing, storm surge analyses, tides and sea currents) and Mackenzie Delta water-level studies, all carried out under the auspices of the Institute of Ocean Sciences in Sidney, British Columbia. Also, the Freshwater Institute of Canada in Winnipeg, Manitoba, has been studying the fish resources of the Beaufort region, has monitored dredging activities (Resources Impact Division) and has monitored fish hydrocarbon uptake (Toxicology Division). The Arctic Biological Station near Montreal, Quebec, has been involved in studies of marine mammals, benthic invertebrates and microbiology of the Beaufort Sea.

The 'Marine Transportation Research and Development Advisory Board' is an organization with thirty-one members representing government and industry. It was formed in 1977 to advise Transport Canada on the planning and implementation of marine transportation technology research and development. The Board advises on the programs and projects needed by industry, and on new developments in international marine technology and their impacts on industry. The Board's research is conducted through technical committees on vessel and shore facilities, navigational aids and traffic management, ice management and environment, and marine statistics and data. Their past research has covered topics as varied as specifications of design loads for ice-going ships, general ship design testing, navigation in ice, offshore drilling unit standards, oceanographic studies, climatological studies, remote sensing, communications, survival and rescue studies, and the construction and maintenance of harbours (Marine Administration of Transport Canada, 1981). In addition to the Advisory Board, Transport Canada is active in Arctic research through projects conducted by the Coast Guard and through their Research and Development Centre.

The Department of Indian Affairs and Northern Development (DIAND), in addition to operating the Arctic Land Use Research Program (see Section 2.2-4, administers the Inuvik (Figure 2-2), Igloolik (Figure 2-4), Frobisher Bay (Figure 2-4) and Rankin Inlet (Figure 2-4) research laboratories, which facilitate scientific research by government, universities, consultants and industry. It was under the authority of the Minister of Indian Affairs and Northern Development that two major northern inquiries, the Mackenzie Valley Pipeline Inquiry (the Berger Commission; Section 2.1.1) and the Alaska Highway Natural Gas Pipeline Inquiry (the Lysyk Commission), were conducted. The Berger Commission dealt with both environmental and socio-economic matters related to pipeline construction, while the Lysyk Commission, completed in 1978, was restricted to socio-economic fields. Neither of these inquiries was essentially research oriented, but their extensive public hearings aided in understanding northern development, the northern perspective and northern societies.

In keeping with DIAND's mandate to conduct northern research, a wide variety of socio-economic studies have been conducted by, or on behalf of, this department. During the 1950s and early 1960s a number of area economic surveys were undertaken, followed by Canada Manpower surveys during the late 1960s and early 1970s. Social research on various specific topics, particularly related to major development proposals and their effects on traditional life styles and renewable resource harvesting, have also been carried out.

Between 1973 and 1978, through the joint industry-government Committee on Northern Manpower and Employment, a record was maintained of northern employment in the oil and gas industry by company, community and job category. While the Committee became defunct in 1978, individual companies active in the Beaufort region have continued to maintain these records. Also, since 1976 the Northwest Terri-

tories Government has been compiling a data base known as the Territorial Employment Record Information system (TERIS). Information is being assembled on the Northwest Territories labour force, and data are filed by community and skill category. However, the data base varies in completeness and currentness from community to community.

During the mid 1970s, the Northwest Territories Government also conducted planning oriented studies on the possible impacts of oil and gas development on the Mackenzie Delta. One such study focussed on the effect of gas gathering and processing facilities on Delta communities, while another dealt with the options available to Delta communities as a result of potential hydrocarbon development.

A factor which has played a major role in influencing social research in the north is politics. During the past twenty years two major governmental inquiries, the Carrothers Commission of the 1960s and the Drury Commission of the late 1970s, have been held to study the constitutional nature and future development of the Northwest Territories. As well, native organizations have advanced their views on the constitution and have put forward land claims for the region.

2.2.1 THE POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project (PCSP) began in October, 1958, when a Cabinet Memorandum was signed advocating that geological, geophysical and oceanographic investigations be undertaken in the Canadian Arctic. The Department of Energy, Mines and Resources continues, in 1982, to provide financial and logistic support for the government and university scientists involved in the various programs of the PCSP.

During its first year the PCSP concentrated its efforts on navigational systems and facilities required for Arctic research. From 1960 through 1979 its mandate gradually evolved into its current role which is "to contribute to the orderly scientific investigation of Canada's polar continental shelf, the contiguous Arctic Ocean and mainland regions, and to maintain and improve logistics required for scientific investigations in an Arctic environment" (Hobson, 1980). PCSP carries out this objective through its funding of scientific research, by providing logistical support to researchers and by providing an information service to scientists and the public.

2.2.2 ARCTIC ICE DYNAMICS JOINT EXPERIMENT

The Arctic Ice Dynamics Joint Experiment (AIDJEX) was first formulated in 1969, with most of the research being conducted between 1972 and 1976 when the project ended. AIDJEX was headquartered in Seattle, Washington. The principal participants were the 'Polar Programs Division' of the American National Science Foundation, the 'Arctic Program' of the American Office of Naval Research (through the Naval Arctic Research Laboratory) and the Canadian Polar Continental Shelf Project (see Section 2.2.1) (Untersteiner, 1980). AIDJEX research dealt with the ice dynamics of the central Beaufort Sea, although data on other aspects of the Arctic environment were gathered concurrently with the ice studies. Approximately 40 'Bulletins' containing AIDJEX study results were published during the project. A brief discussion of the AIDJEX project follows.

Between 1969 (when the idea of an ice dynamics research program was first voiced) and 1972 a series of consultations and workshops involving many Arctic researchers led to the development of the AIDJEX plan. Two small pilot field studies carried out during 1970 and 1971 formed the basis for a larger pilot project which began in March, 1972. This project involved research into the dynamics of ice in the Beaufort Sea using several automatic buoys and three manned field camps. This program was then expanded such that, by early June, 1975, four manned camps surrounded by a ring of eight data buoys were in operation. With a few minor changes, this array continued to function until the predetermined end of the AIDJEX program in May, 1976.

AIDJEX attempted to answer four basic questions regarding the dynamics of ice in the Beaufort Sea: how is large-scale ice deformation related to the external stress field; how can the external stresses be derived from a few fundamental and easily measured parameters; what are the mechanics of ice deformation; and, how do ice deformation and morphology affect heat balance? AIDJEX went a long way toward answering these questions. Specific studies included measurements of ice movement and their velocities; measurement of floe to floe interactions; analysis of ice pressure ridge formation; measurements of ice thickness; and, analysis of the roles of open water and thin ice, in large-scale distributions, on boundary layer interactions at the atmosphere-ocean interface. Data were then applied to the development of the AIDJEX computer model of Beaufort Sea ice dynamics.

2.2.3 TASK FORCE ON NORTHERN OIL DEVELOPMENT

The Task Force on Northern Oil Development was established in 1968 and operated until approximately 1975. Its purposes were to bring together the current information on petroleum resources and transportation routes in the north, to coordinate the collection of all relevant information from Federal agencies and

departments, and then prepare proposals and recommendations to government. Specific major studies included the technical and economic feasibility of deep-sea ports in the Arctic, and an analysis of the Federal Government's position regarding transportation and marketing proposals, with particular reference to the benefits and costs to the economy arising from several alternatives for northern oil transportation and marketing (Environment-Social Committee, 1974). These large programs generated considerable background environmental and socio-economic data.

The Task Force was chaired by the Deputy Minister of the Department of Energy, Mines and Resources, with representation from the departments of Indian Affairs and Northern Development, Environment and Transport, and the National Energy Board. The Task Force's activities were assigned according to five committees: pipelines, economic impacts, transportation, marketing and environment-social (Environment-Social Committee, 1974).

The committee that addressed the environmental and social aspects of oil development produced a large amount of data. Environmental programs regarding meteorology, hazards associated with pipeline breakage, streamflow and water quality, hydrology in relation to pipeline construction, fish, aquatic ecology of the Mackenzie Delta, terrain analyses (both onshore and offshore), topography, permafrost, earthquake hazards, vegetation, land-based oil spills, waste disposal, wildlife ecology and emergency contingency planning were carried out by appropriate government agencies between 1971 and 1975. In addition, extensive socio-economic studies were undertaken, including surveys of archaeological and historic sites, labour force and population status studies, evaluation of regional impacts of pipeline development, site-specific development impact studies, assessment of potential social, economic and psychological effects of pipeline development on native peoples, ethnic relations studies, housing and community development studies and interprovincial opportunity studies. Finally, studies on resource use (such as studies of the Porcupine caribou population, evaluations of fur-bearing species resources, the economic and social significance of renewable resource harvesting for native peoples and land use mapping) were carried out.

Much of the information generated is still applicable to the present situation in Canada's north, and the Task Force's data base will be a valuable starting point for sound decision-making for some time to come (Environment-Social Committee, 1974).

2.2.4 THE ARCTIC LAND USE RESEARCH PROGRAM

In the early 1970s the Department of Indian Affairs and Northern Development (DIAND) established the Arctic Land Use Research (ALUR) Program to contribute information and research support directed toward providing land use regulations for Canada's north. Recent ALUR research programs have included drilling fluid disposal studies, land-based oilspill studies, revegetation analyses and tundra disturbance studies (Barnett, 1980).

Through ALUR and Department of Environment funding, a Land Use Information Series (LUIS) of maps has been developed for Canada's north (Environment Canada and Indian and Northern Affairs Canada, undated). The program began in 1971 and has become a major systematic environmental-social research project. The maps provide a reconnaissance-level information base to facilitate regional planning and application of the Territorial Land Use Regulations. The Department of Fisheries and Oceans and the Northwest Territories Wildlife Service have been major research participants, with the assistance of other Federal and Territorial Government departments, private research groups and local residents of the Yukon and Northwest Territories.

The LUIS maps present a wide range of environmental-social topics. The delineation and description of important and critical areas for wildlife is one of the primary concerns of the research program. The data, provided through extensive literature reviews and year-round field surveys, include not only the important and critical habitats for various species but also data on migration routes, waterfowl staging and nesting areas, calving areas, seasonal ranges and important regions for marine mammals. A similar program is conducted on fish resources, with data reflecting migration routes, spawning areas, species composition, species abundance, and domestic, commercial and recreational fishing activities.

Through the Lands Directorate of Environment Canada, delineation and description of local hunting and trapping activities are provided. Regional notes include comments on the settlement base, the species taken, the seasons of use and the intensity of activity.

The Lands Directorate also undertakes broad ecosystem mapping of the north. Information is provided on landforms, soils, vegetation, climatic characteristics, break-up and freeze-up dates, and hydrometric and water quality stations. These data have proved valuable in making terrain evaluations and habitat assessments.

In addition, LUIS staff collect and map relevant socio-economic and cultural data including community information, archaeological sites, historical sites, campgrounds, fishing camps, fur-take statistics, transportation networks, mining and mineral resources, existing and proposed development areas and

block land transfers, proposed International Biological Program reserves and other information relevant to general land use planning and management.

2.2.5 THE BEAUFORT SEA PROJECT

In July, 1973, Cabinet granted Approval-in-Principle for exploratory drilling using drillships in the Beaufort Sea. However, two conditions were placed on the decision. The first was that no drilling would occur until the summer of 1976. The second was that additional constraints might be applied as found necessary upon completion of an extensive group of environmental studies which came to be known as the Beaufort Sea Project (Pallister Resource Mgmt. Ltd., 1974).

The Beaufort Sea Project addressed the environmental consequences of the exploratory drilling phase of offshore petroleum development. The main environmental threat was the possibility of an underwater oil well blowout. Therefore, the research program was designed to answer two fundamental questions: what were the existing environmental conditions, and what would happen to them when drilling began? Studies were made of fish populations, marine mammals, sea birds and the climate in order to obtain baseline data. Intensive work on ocean currents, sea ice movements and storm surges was undertaken. In order to determine optimal drilling times and locations, extensive studies of weather patterns, ice movement and biological migrations were initiated.

The Beaufort Sea Project was a joint government-industry sponsored venture. The government was responsible for coordinating the program and maintaining cost control, as well as having final authority over work specifications and awarding of contracts. An industry project manager and individual study coordinators were responsible for liaison with the government and helped to plan and monitor the progress of the program, in addition to providing expertise and financial support (Pallister Resource Mgmt. Ltd., 1974).

Between 1974 and the time of project completion in 1976, much time and effort were applied to the Beaufort Sea Project under the joint direction of the Arctic Petroleum Operators' Association (APOA) and the Department of Environment. Forty-six technical reports were produced, including documents on marine life, wildlife, oceanography, meteorlogy, sea ice and oilspill countermeasures (Milne, 1977). Much of this information has contributed to the data base for other volumes of the EIS.

2.2.6 THE ARCTIC MARINE OILSPILL PROGRAM

The Arctic Marine Oilspill Program, or AMOP, is an ongoing project that was established in 1977. It was originally a five-year technology development program initiated by the Federal Government to develop oilspill countermeasures for Arctic waters. Priority has been given to three main geographic regions - the southern Beaufort Sea, the Eastern Arctic and the Labrador Sea. Projects fall into three broad categories: oilspill countermeasures (including the development of oilspill countermeasure hardware, *in situ* burning experiments, incineration experiments, shoreline protection and clean-up programs), oilspill behaviour and fate (including oilspill tracking and modelling studies), and oilspill and dispersant biological effects (AMOP, 1979).

The Environmental Protection Service (EPS) of Environment Canada is the over-all manager of the AMOP studies. The Ottawa EPS office is responsible for research in all three categories, while Edmonton EPS scientists are involved in several AMOP research studies and provide regional liaison. The five district EPS offices are responsible for their respective regional technology projects. Input from private, public and academic sectors is used in planning research projects.

One of the most recent and valuable AMOP projects, BIOS, is discussed in detail herein to illustrate the relevance and importance of the AMOP program.

2.2.6.1 The Baffin Island Oil Spill Project

The Baffin Island Oil Spill (BIOS) Project arose out of the annual Arctic Petroleum Operators' Association - Canadian Petroleum Association (APOA - CPA) Arctic Environmental Workshop in 1978. The project is currently ongoing (Plate 2-4), with its primary objectives being to determine whether or not the use of oil dispersants in nearshore Arctic waters will reduce or increase the environmental effects of spilled oil, and to assess the relative effectiveness and environmental impact of other shoreline protection and clean-up techniques. Secondary objectives are to determine the physical and chemical behaviour and fate of chemically treated and untreated oil, and its biological effects on the Arctic nearshore environment.

The BIOS project is directed by a Management Committee representing the funding agencies. The committee includes members from the Department of Environment, the Department of Fisheries and Oceans, the Department of Indian Affairs and Northern Development, the Department of Energy, Mines and Resources, the Department of Transport (Coast Guard), the Canadian oil industry (through COOSRA), the U.S. National Oceanographic and Atmospheric Administration (NOAA), the U.S. Coast Guard, BP International and the Norwegian Oil Pollution Control Research and Development Program. The Management Committee, which controls project

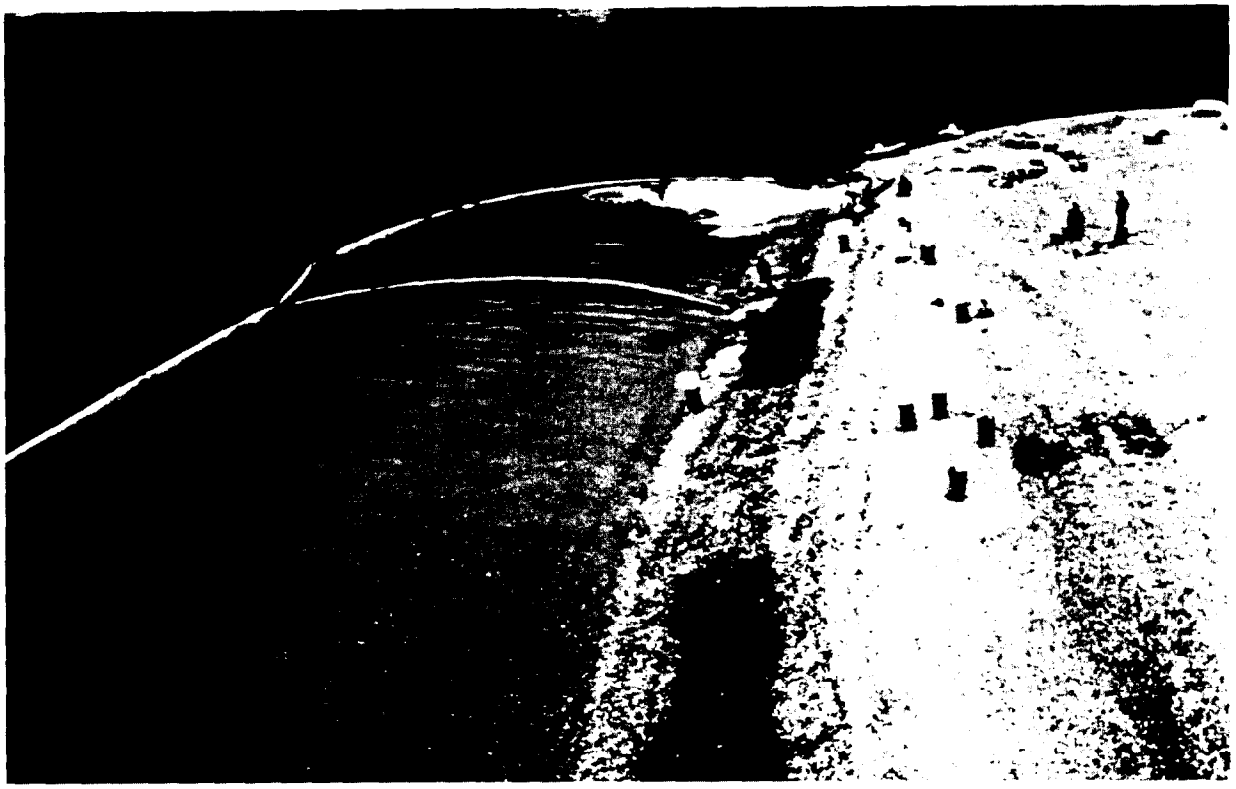


PLATE 2-4 *The Baffin Island Oil Spill (BIOS) Project is attempting to determine whether or not the use of oil dispersants in nearshore Arctic waters will reduce or increase the environmental effects of spilled oil. (Courtesy P. Blackall, EPS)*

funds, has delegated the day to day management to a project office staffed by Department of Environment AMOP personnel in Edmonton. Also, five technical committees, responsible for the physical, chemical, biological, shoreline countermeasures and oil discharge components, were formed to assist the project office with the development of the experimental design and the technical review of the ongoing work (Anon., Dome Petroleum Limited, undated; AMOP, 1979). Table 2.2-1 lists the participating government agencies, companies and universities involved in the project.

At the beginning of this project, each of the five technical committees of BIOS had specific objectives. The Oil-discharge Committee was responsible for the design of an oil and an oil-with-dispersant distribution system for oil release tests. Based on the most favourable atmospheric and oceanographic conditions for the release of oil to the Arctic environment, the committee selected the test bays for the oil release experiments.

The work of the Physical Committee formed the basis for oil release site selection. Their objectives included carrying out meteorological, geomorphological, oceanographic, bathymetric and ice mechanics studies in order to describe and assess the physical environment of the coastal region of the Cape Hatt area of northern Baffin Island (Figure 2-4).

To provide background water and sediment chemistry data (particularly baseline hydrocarbon levels) for possible test locations at Cape Hatt, the Chemistry Committee was established. Their research supports the work of the Biological and Shoreline committees.

The Biological Committee is responsible for the characterization of the biotic populations (particularly the benthos and micro-organisms) of the Cape Hatt test areas, and the analysis of benthic invertebrate tissues for background hydrocarbon levels, in order that the effects of oil and oil-with-dispersants can be accurately determined following the test spills.

The fifth committee, that responsible for Shorelines, worked on the establishment of test plots along the coastline, in both relatively high and low energy environments. These plots are to be studied over an extended period in order to determine the possible long-term effects of oil on such habitats.

2.2.7 THE EASTERN ARCTIC MARINE ENVIRONMENTAL STUDIES PROGRAM

The Eastern Arctic Marine Environmental Studies program (EAMES) was established in 1977 to investigate the oceanographic features of Eastern Arctic offshore and nearshore waters and their biological

TABLE 2.2-1

BAFFIN ISLAND OIL SPILL (BIOS) PROJECT PARTICIPANTS

A. Government Agencies

1. Federal
   a. Department of Energy, Mines and Resources
   b. Department of Environment
   c. Department of Fisheries and Oceans
   d. Department of Indian Affairs and Northern Development
   e. Ministry of Transport
2. Other
   - Government of the Northwest Territories

B. Industry

- COOSRA
  a. Operator Members
     - BP Exploration Canada Ltd.
     - Canadian Superior Oil Ltd.
     - Canterra Energy Ltd.
     - Chevron Standard Ltd.
     - Consolidex Gas and Oil Limited
     - Dome Petroleum Limited
     - Esso Resources Canada Limited
     - Gulf Canada Resources Inc.
     - Mobil Oil Canada Ltd.
     - Norcen Energy Resources Ltd.
     - Panarctic Oils Ltd.
     - Petro-Canada
     - Phillips Petroleum Canada Ltd.
     - Shell Canada Resources Limited
     - Suncor Inc.
     - Texaco Canada Resources Ltd.

B. Industry (cont'd)

  b. Non-operator Members
     - Global Arctic Islands Ltd.
     - PanCanadian Petroleum Ltd.
  c. Associate Members
     - Alaskan Beaufort Sea Oilspill Response Body (ABSORB)
     - American Petroleum Institute

C. Universities

1. Bamfield Marine Station
2. Memorial University (C-CORE)
3. University of Alberta
4. University of Calgary (Kananaskis Research Centre)
5. University of Guelph
6. University of Louisville
7. University of Toronto
8. University of Western Ontario

D. Other Groups From Outside Canada

1. British Petroleum (U.K.)
2. Esso Chemical Limited
3. Exxon Research and Engineering Corporation
4. Norwegian Foundation of Scientific and Industrial Research
5. Norwegian Institute of Technology
6. Norwegian Oil Pollution Control Research and Development Program
7. U.S. Coast Guard
8. U.S. National Oceanographic and Atmospheric Administration (OCSEAP)

Source: W. Pistruzak pers. comm. Reflects status as of May 1, 1982

components to obtain sufficient data to prepare Environmental Impact Statements for exploratory drilling off the coast of Baffin Island (Figure 2-4). These documents were to be submitted for review by panels established by the Federal Environmental Assessment Review Office (FEARO). The participants in EAMES included Federal Government scientists from the departments of Fisheries and Oceans, Environment, and Indian Affairs and Northern Development, and personnel from industry [in particular, Petro-Canada, Canterra Energy Ltd. (formerly Aquitaine Company of Canada Ltd.), Canada-Cities Service Ltd. and Esso Resources Canada Limited] and local communities. A joint Federal and Territorial Government-industry management committee was chaired by a representative of the Department of Indian Affairs and Northern Development (DIAND).

In addition, an EAMES Advisory Board, consisting of representatives from Eastern Arctic communities and non-government specialists, was formed to promote communication with northern peoples and to provide an independent scientific evaluation of the work (DIAND, 1981).

The region encompassed by EAMES was subdivided into two geographic areas: the Baffin Bay - Lancaster Sound sector and the southern sector, which included Davis Strait from Cape Dyer to the northern tip of Labrador, together with Hudson Strait and Ungava Bay (see Figure 2-4). Field studies included extensive investigations of the nature and movement of ice; establishment of meteorological stations and programs (particularly as related to developing weather and wave forecasting systems); physical, chemical

and geological oceanographic studies (particularly as related to the fate of oil from a possible deep-sea blowout); geological programs providing detailed mapping of coastal zones and preparation of sensitivity maps for contingency planning purposes; and extensive regional biological programs aimed at developing an understanding of Arctic ecosystems and assessing possible impacts of drilling operations (Imperial Oil Limited *et al.*, 1978). Most of the latter work was of a large-scale, distributional and ecological nature, designed to determine the distribution, the abundance, and, where applicable, the migration patterns and timing of movements of major biological populations. Some physiological and microbiological studies were also carried out in conjunction with work on the effects of oil spills on Arctic ecosystems. In addition, socio-economic programs, in so far as they were related to environmental concerns, were undertaken (DIAND, 1981).

2.2.8 THE SURSAT PROJECT

The SURSAT (Surveillance Satellite) project, was a multi-department Federal Government study to assess the desirability, applicability and feasibility of obtaining a radar-based surveillance satellite for Canada (SURSAT, 1980). The lead agencies involved were the Canada Centre for Remote Sensing, the Atmospheric Environment Service of the Department of the Environment, and the Communications Research Centre. Universities and some American government agencies (NASA and NOAA) also collaborated on the project, as did petroleum industry representatives (particularly the proponents).

Among the varied activities undertaken by the SURSAT project between 1977 and 1980 were a series of airborne Synthetic Aperture Radar (SAR) and Real Aperture Side-looking Airborne Radar (SLAR) measurements over the Beaufort Sea in 1979. The proponents were intimately involved in planning and conducting these tests (Ramseier and Lapp, 1981; Spedding *et al.*, 1982).

2.2.9 OFFSHORE LABRADOR BIOLOGICAL STUDIES

The Offshore Labrador Biological Studies (OLABS) program was jointly initiated in 1978 by the Canadian Department of Energy, Mines and Resources and petroleum companies involved in hydrocarbon exploration off the coast of Labrador (Figure 2-4). The program was completed in 1981, with eight oil companies (Table 2.2-2) making up the membership at its termination. The primary purpose of OLABS was to gather baseline biological data to assist in an ecological assessment of the potential impacts that exploratory drilling and hydrocarbon production might have on the physical and biological environment of the Labrador Shelf. Studies included work on shoreline sensitivity, meteorology, physical and chemical oceanography, marine mammals, seabirds, waterfowl, benthic organisms, zooplankton, phytoplankton, fisheries and the socio-economic conditions of Labrador (Petro-Canada, 1982). The following is a brief description of the OLABS program.

At the time OLABS was initiated there was only a preliminary evaluation of existing environmental information for offshore Labrador. There were no descriptions of ongoing or proposed offshore developments in the Labrador Sea, or of the potential impacts, particularly of oil from possible major spills, on marine biota. The purpose of the OLABS program was to have the petroleum industry, the Federal and Provincial governments and the Labrador communities collect baseline information that would

TABLE 2.2-2

PARTICIPANTS IN OFFSHORE LABRADOR BIOLOGICAL STUDIES (OLABS) IN 1981

1. BP Exploration Canada Ltd.
2. Canterra Energy Ltd.
3. Chevron Standard Ltd.
4. Esso Resources Canada Limited
5. Hudson's Bay Oil and Gas Company Ltd. (now part of Dome Petroleum Limited)
6. Petro-Canada Exploration Inc. (representing the Labrador Group)
7. Ranchmen's Resources (1976) Ltd.
8. Texaco Canada Resources Ltd.

Source: Petro-Canada, 1982

assist in the environmental assessment of hydrocarbon development offshore. The program was designed to complement studies being done for the area to the north in Davis Strait and Baffin Bay under the EAMES program (Section 2.2.7), and was to cover a study area from 61°18'N to 52°00'N, from the coastline to the outer continental shelf. The Strait of Belle Isle (see Figure 3-1) was also included.

OLABS was funded and managed through a partnership of petroleum companies as listed in Table 2.2-2. OLABS was planned to operate for three years, beginning in 1979 and terminating in 1981. It was directed by a Management Committee whose membership included representatives of the Labrador Resources Advisory Council, the Federal departments of Energy, Mines and Resources, of Fisheries and Oceans, and of Environment, and the petroleum industry. The OLABS Management Committee established operational guidelines and objectives for the studies, approved standards and methodologies for data collection, coordinated work among the OLABS components and with the EAMES program, and kept the Labrador communities informed of the progress of the work. Participation of the Inuit, Indians and other inhabitants of Labrador in OLABS was promoted through the Labrador Resources Advisory Committee. The petroleum industry approved, financed and provided logistical support for OLABS.

The OLABS program included preliminary studies of the abundance and distribution of plankton, benthos, fish and the fishery, seabirds and marine mammals. Where necessary, geomorphological, climatological, oceanographic and ice information were also collected to complement the biological research. The biological information was to be used to identify sensitive areas and times for Labrador Sea biota, and thereby develop improved oilspill contingency plans for offshore petroleum activities.

2.2.10 IMPULSE RADAR TRIALS

In conjunction with the SURSAT Program (Section 2.2.8), the Centre for Cold Ocean Resources Engineering (C-CORE) performed a series of impulse radar tests in the Beaufort Sea in the spring of 1979 (Rossiter and Butt, 1979). The original project was expanded to include participation by Esso Resources Canada Limited and Dome Petroleum Limited (C-CORE, 1980).

A second set of impulse radar trials were performed using a system being developed for the Transport Development Corporation (TDC) of the Ministry of Transport. The participants in this project included Dome Petroleum Limited, C-CORE, TDC, Polar Continental Shelf (Section 2.2.1) and the project contractor. The new radar was a follow-on of the impulse radar, the objective being to measure the thickness of ice from an airborne platform (Keelty and Tam, 1980).

2.2.11 WINTER ICE EXPERIMENT IN THE BEAUFORT SEA

The Winter Ice Experiment in the Beaufort Sea, or WIEBS, was initiated late in 1979 by Dome Petroleum Limited in a proposal to the Federal Government. The objective of WEIBS was to develop a model of winter ice dynamics in the Beaufort Sea which would ultimately be used for ice forecasting.

The government responded with a joint inter-departmental effort involving the Atmospheric Environment Service (the "lead" agency), the Canada Centre for Remote Sensing, the Polar Continental Shelf Project, the Transport Development Corporation, and the Ocean and Aquatic Sciences Division of the Department of Fisheries and Oceans.

The project was conducted in two parts. An early winter ice data set was collected, from which two theoretical models were developed and tested. This began late in 1979 and was completed in mid 1981 (Intera, 1981). A second data collection was undertaken in spring, 1981, and analysis of these data is still going on.

2.2.12 THE RADARSAT PROGRAM

The RADARSAT program began in 1981 under the auspices of the Federal Government. It is essentially a follow-up to the SURSAT program (Section 2.2.8), with its primary objective being to launch a Canadian satellite which would carry a Synthetic Aperture Radar (RADARSAT, 1982).

One of RADARSAT's main applications would be ice surveillance in support of Arctic operations for hydrocarbon development. As a result, Dome Petroleum Limited, the Arctic Pilot Project (Section 2.1.10) and various APOA and EPOA members are represented on the committees which are examining the definition requirements. The government has committed funds for the first two phases of the program which will culminate in 1983. If at that time a decision is made to carry on with the program, more could be anticipated in order to launch the satellite by 1990.

2.3 OTHER ORGANIZATIONS

2.3.1 THE UNITED STATES' OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM

In the mid 1970s it became apparent that proposed oil and gas exploration, development and production

projects off the coast of Alaska needed to be reviewed in terms of their possible effects on northern ecosystems. The result was the formation of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) (Weller *et al.*, 1978).

The United States Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), signed an Agreement with the Bureau of Land Management (BLM) of the Department of the Interior, whereby the BLM would provide primary funding for OCSEAP while NOAA would provide the program administration. The program's mandate included the acquisition of information regarding areas and components of the environment that might be affected by oil and gas development; making available acquired knowledge for use in land management decisions; prediction of the possible impacts of oil and gas activities on ecosystems; and the evaluation of impact data which would provide the basis for possible changes to existing legislation or requirements regarding oil and gas activities. To meet these objectives, OCSEAP defined six tasks, or scientific objectives, which continue to form the basis for all of their research activities. These objectives are shown in Table 2.3-1.

OCSEAP has focussed on those areas of the outer continental shelf which BLM has scheduled for leasing. In each area extensive environmental studies are being carried out to determine the feasibility of oil and gas development. The main areas under study are the Beaufort and Chukchi seas and Hope Basin (see Figure 2-1). All projects are administered from an office in Fairbanks, Alaska. Since OCSEAP's inception in 1975, most studies have been very extensive in scope. They have produced information defining water current patterns, current trajectories, ice hazards, seafloor faults, seismic activity, areas of unstable sediments, critical habitats and biological populations. Data on baseline levels of hydrocarbons and trace metal concentrations have also been generated (U.S. Dept. Comm., 1977).

2.3.2 THE SEASAT PROGRAM

SEASAT was the name given to an American experimental satellite carrying Synthetic Aperature Radar (SAR) and other remote sensing equipment. As part of the American contribution to the SURSAT program (Section 2.2.8), Canadian government agencies and industry (including the proponents) were allowed

TABLE 2.3-1

OBJECTIVES OF OCSEAP

Study Topic	Objective
1. contaminant baseline data	to determine pre-development distributions and concentrations of hydrocarbons, heavy metals, and other contaminants associated with oil and gas development.
2. sources of contamination	to determine the nature and magnitude of contaminant inputs and environmental disturbances that may be assumed to accompany development.
3. hazards	to identify and estimate the potential of hazards posed to the environment by petroleum exploration and development.
4. transport	to determine the ways in which contaminants move through the environment and how they are altered by physical, chemical, and biological processes (this involves physical oceanography, meteorology, chemistry and biology).
5. biological receptors	to determine the biological populations and ecological systems that are subject to impact (that is, marine mammals, seabirds, fish, plankton and intertidal areas).
6. effects	to determine the effects of man's activities and facilities, and of hydrocarbons and heavy metal contaminants, on individual populations and ecosystems.

Source: U.S. Dept. Comm., 1977

to participate in the scientific program associated with SEASAT.

The satellite flew for only six months during the summer of 1979, and was terminated owing to power failure. Data analyses continued through to 1981 (Fu and Holt, 1982).

2.3.3 ALASKAN BEAUFORT SEA OILSPILL RESPONSE BODY

The Alaskan Beaufort Sea Oilspill Response Body (ABSORB) is a cooperative organization established in 1979 by thirteen oil companies interested in hydrocarbon exploration and development off the coast of the Alaskan North Slope. The present membership appears in Table 2.3-2. The focus of ABSORB has been the development of a broad range of oilspill response capabilities. The organization's mandate has the following objectives: to prepare and maintain an oilspill contingency plan; to assemble and maintain oilspill response equipment; to train oilspill response personnel; and, to conduct oilspill related research and development projects (Pistruzak, pers. comm.).

Since its formation, ABSORB has been involved with Canadian programs through its associate membership in COOSRA and its participation in the annual APOA - EPOA - ABSORB workshop.

2.3.4 ALASKA OIL AND GAS ASSOCIATION

The Alaska Oil and Gas Association (AOGA) is a trade association with thirty-eight members concerned with oil and gas exploration and production in Alaska. In a manner similar to Canada's APOA (see Section 2.1.5), AOGA promotes and sponsors research projects on the environmental and engineering aspects of petroleum industry activities in Alaska. Owing to the similarity between much of Alaska's coastal geography and climate and that of the Canadian Beaufort Sea region, many of AOGA's research projects are directly applicable to the Canadian situation (Hershberger, pers. comm.).

2.3.5 NATIVE ORGANIZATIONS

The principal native organizations of the northern territories are the Council for Yukon Indians (CYI), the Committee for Original Peoples' Entitlement (COPE), the Dene Nation, the Northwest Territories Metis Association and the Inuit Tapirisat. These organizations have been established to obtain settlement of aboriginal land claims, and, therefore, the main focus of their research has been directed toward defining the geographic extent, economic content, and political nature of their claims and interests. Through government funding, a variety of studies have been conducted. A good example is the three volume Inuit Land Use and Occupancy Project published by DIAND in 1976 (Freeman, 1976a, b, and c).

However, much of the research conducted by these groups is unpublished, taking the form of classified internal documents used to develop the groups' political positions. Within some native organizations a development company is being proposed as a means of carrying out business. To date most of these companies are being modelled after similar regional corporations established in Alaska. Some of these companies are being structured in such a way as to make the business arm of the group separate from the political arm.

2.3.6 THE CANADIAN ARCTIC RESOURCES COMMITTEE

The Canadian Arctic Resources Committee (CARC) is an independent organization of private citizens based in Ottawa which is interested in ensuring that northern development be undertaken responsibly. Funding for the organization comes primarily from

TABLE 2.3-2

MEMBER COMPANIES IN THE ALASKAN BEAUFORT SEA OILSPILL RESPONSE BODY (ABSORB)

1. Amoco Production Company
2. ARCO Oil and Gas Company
3. Chevron USA, Inc.
4. Conoco Inc.
5. Exxon Company, U.S.A.
6. Getty Oil Company
7. Gulf Oil Exploration and Production Co.
8. Marathon Oil Company
9. Mobil Oil Corporation
10. Phillips Petroleum Company
11. Shell Oil Company
12. Sohio Petroleum Company
13. Tenneco Oil Exploration and Production
14. Union Oil Company of California

Source: W. Pistruzak, pers. comm. Reflects status as of May 1, 1982

the private sector, the greater amount being from charitable foundations. It also receives some funding from government.

CARC's view of the north is circumpolar, including all of Canada's neighbours. In 1979 CARC began a study of the implications of the development of marine transportation in the Arctic. Two volumes have been published to date, with a third to be completed in 1982. The first was a bibliography of past Arctic research, with some identification of data gaps and the research needed to fill them. The second volume was the proceedings of a symposium dealing with this topic, which was attended by representatives from industry, government and native organizations from Canada and abroad (Canadian Arctic Resources Committee, 1981). Other publications by CARC include a newsletter called "Northern Perspectives" and a comparative analysis of the Scottish and Alaskan offshore oil and gas experiences with that of the Canadian Beaufort Sea.

In addition to its publications, CARC is known for having prepared and presented briefs to the EAR Panel at the guideline hearings into Beaufort Sea Development and to the Special Senate Committee on the Northern Pipeline (Anon., 1982).

2.3.7 UNIVERSITY RESEARCH

2.3.7.1 The Association of Canadian Universities for Northern Studies

The Association of Canadian Universities for Northern Studies (ACUNS) was founded in Churchill, Manitoba, in 1977, and was incorporated in 1978. ACUNS is a voluntary association of Canadian universities which have northern interests. Its purpose is ". . . the advancement of northern scholarship through education, professional and scientific training, and research" (ACUNS, undated).

More than thirty Canadian universities are members of ACUNS (see Table 2.3-3). Each member university appoints one representative who serves as a delegate to the governing council of the association which meets annually. ACUNS is administered by elected officers and a Board of Directors. These groups are responsible for organizing the various committees which are the 'operational' part of ACUNS. Committee membership is drawn from the academic community and from other groups with northern interests.

ACUNS' Education Committee works on projects ranging from native language instruction to 'distance' education methods, including the promotion of northern studies in southern universities. The Committee on Relations with Northern Peoples seeks to provide the means by which northerners can become leaders in their own education and research projects, while that on Land Use maintains a watch on the status of northern lands.

ACUNS also sponsors symposia on topics of concern to northern Canada and to other circumpolar nations, and provides an information service for other organizations involved in northern development.

2.3.7.2 The Arctic Institute of North America

Many universities have conducted, and continue to conduct, scientific research into the environment of polar and sub-polar regions, often in conjunction with industry. The foremost Canadian university Arctic research centre is the Arctic Institute of North America based at the University of Calgary.

The Arctic Institute of North America was incorporated by an Act of Parliament in 1945 for the purpose of providing a focus for northern research and development. Since 1949 it has been providing financial aid to students and post-graduate researchers work-

TABLE 2.3-3

MEMBER UNIVERSITIES IN THE ASSOCIATION OF CANADIAN UNIVERSITIES FOR NORTHERN STUDIES (ACUNS)

University of Alberta	Université Laval	Queens University
Athabasca University	University of Manitoba	University of Regina
University of British Columbia	McGill University	Ryerson Polytechnical Institute
University of Calgary	McMaster University	University of Saskatchewan
Carleton University	Memorial University	Simon Fraser University
Concordia University	Université de Montréal	University of Toronto
Dalhousie University	University of New Brunswick	Trent University
Ecole Polytechnique	University of Ottawa	University of Waterloo
University of Guelph	Université de Québec à Chicoutimi	University of Western Ontario
Lakehead University	Université de Québec à Montréal	University of Windsor
Laurentian University	Université de Québec à Trois-Rivieres	York University

Source: ACUNS, undated.

ing in the north. Recently the Arctic Institute initiated a northern post-doctoral fellowship program in order to provide recent PhD graduates the opportunity to publish the results of their work (Arctic Institute of North America, 1982).

Two research facilities, one at Kluane Lake in the Yukon Territory (Figure 3-4) and one on Devon Island, Northwest Territories (Figure 2.3), are operated by the Arctic Institute. The Kluane facility offers research opportunities for scientists interested in the physical, social and biological sciences of a sub-polar region, while the Devon Island research station provides opportunities for High Arctic multi-disciplinary field research (Arctic Institute of North America, 1982).

Since 1948 the Arctic Institute has published the quarterly scientific journal "Arctic" which contains the results of many of the research programs, as well as the authoritative papers of polar and sub-polar scientists from around the world.

2.3.8 THE INTERNATIONAL BIOLOGICAL PROGRAM

The International Biological Program (IBP) was a cooperative world-wide project involving the International Council of Scientific Unions and fifty-eight participating nations. Its purpose was to "study the biological productivity of the earth's ecosystem and relate this to human adaptability and welfare" (Hunt *et al.*, 1979).

In 1965 the Canadian Committee for the IBP was formed, along with a subcommittee to conserve terrestrial ecosystems. The objectives of the Committee were to participate in check-sheet surveys of existing and potential reserves and their equivalents in national and provincial parks, and to promote the establishment of a nation-wide system of ecological reserves for the conservation of natural and semi-natural ecosystems. Canada was divided into 10 regions, each having a scientific working group. Two of these regions were in the Arctic. Although the IBP ended in 1974, a great deal of baseline information on specific Arctic reserve sites was gathered. The program is now being continued by the National Research Council of Canada (Hunt *et al.*, 1979).

CHAPTER 3
CURRENT AND FUTURE STUDIES

This chapter provides a review of the role of environmental operating conditions, and discusses the current and future research and monitoring programs being undertaken or proposed by industry in relation to their development of hydrocarbon resources in Canada's north.

3.1 ENVIRONMENTAL OPERATING CONDITIONS

Environmental operating conditions, commonly referred to as EOC's, have been and continue to be made routinely as part of annual program approvals, drilling authorities, permits and licences granted by government for oil and gas exploration activities in the Beaufort Sea region. In many cases these conditions are based directly on legislative requirements. EOC's are intended to serve three main purposes: to control the discharge of wastes to the environment; to assess the impacts of any authorized discharges on the environment; and, to obtain annual baseline environmental data to ensure the safety of ongoing operations.

The Arctic Waters Pollution Prevention Act and its associated EOC's regulate the quantities and types of wastes discharged to Arctic waters, and determine the waste monitoring program that must be carried out by the operator. Wastes may include such things as sewage, oily water, drilling fluids, garbage or other substances.

EOC's usually require site-specific environmental studies which will ensure the safety of the operation. Routine monitoring of environmental conditions may include weather observations, ice observations, surface current observations (using satellite-reporting drifter buoys), mid-depth (12 metre) current observations, bottom current observations, conductivity and temperature versus depth profiles, sea state observations (both visual and measured), and biotic observations (marine and/or terrestrial mammals; birds; benthos; plankton) (Hammer, 1981).

For example, the EOC's for Dome Petroleum Limited's permits for drilling during the open water season require the collection of oceanographic data pertinent to predicting the behaviour of any major oil spill. These EOC's also specify the minimum quantity of oilspill clean-up equipment that must be kept in readiness, and require demonstrations of the preparedness and ability of the operator to respond to an oil spill.

Another example is the requirements which were imposed on dredging at McKinley Bay. The operator was required to monitor the effects of the dredging on marine water quality and the benthos. Also evaluated was the potential for recolonization of the sea floor after dredging had been completed (Thomas, 1980).

In general, EOC's are the regulatory mechanism presently used to set and monitor the environmental standards under which industry is operating in the Beaufort Sea. It is expected that, as in the past, EOC's will continue to play an important regulatory and monitoring role in the future.

3.2 PHYSICAL PROGRAMS

As pointed out in Chapter 2, extensive research has been conducted in the Beaufort Sea region since the 1960s. Most of the physical studies have involved the collection of baseline data on the oceanography and, more specifically, on the properties and behaviour of Arctic ice. In the early years the majority of this work was carried out through APOA in support of the design and construction of artificial islands in shallow water. By the late 1970s the effort was shifted to provide data for the design of structures farther offshore and also into the Northwest Passage in support of possible shipping operations. Figure 3-1 illustrates the proposed shipping routes from the Arctic to southern markets.

Current and future studies will continue using innovative techniques which have been developed over the past few years. Of particular importance are studies on the behaviour of ice around offshore structures, ice forces, ice pile-up, ice scour and the effects of offshore structures on the ice regime. Navigation techniques are being developed and refined using baseline oceanographic and ice data to support future Arctic marine transportation systems.

The physical science projects presented here will continue over the next few years to provide further data in support of Arctic petroleum production and transportation systems scheduled to come on line by the mid 1980s. Monitoring programs will be carried out on an ongoing basis to ensure the greatest degree of safety, efficiency and economic viability possible, and their results will provide background data to aid in the optimal design of future systems.

3.2.1 ICE RESEARCH

Volumes 2 and 3A provide substantial information on past ice research. Several of the ongoing studies

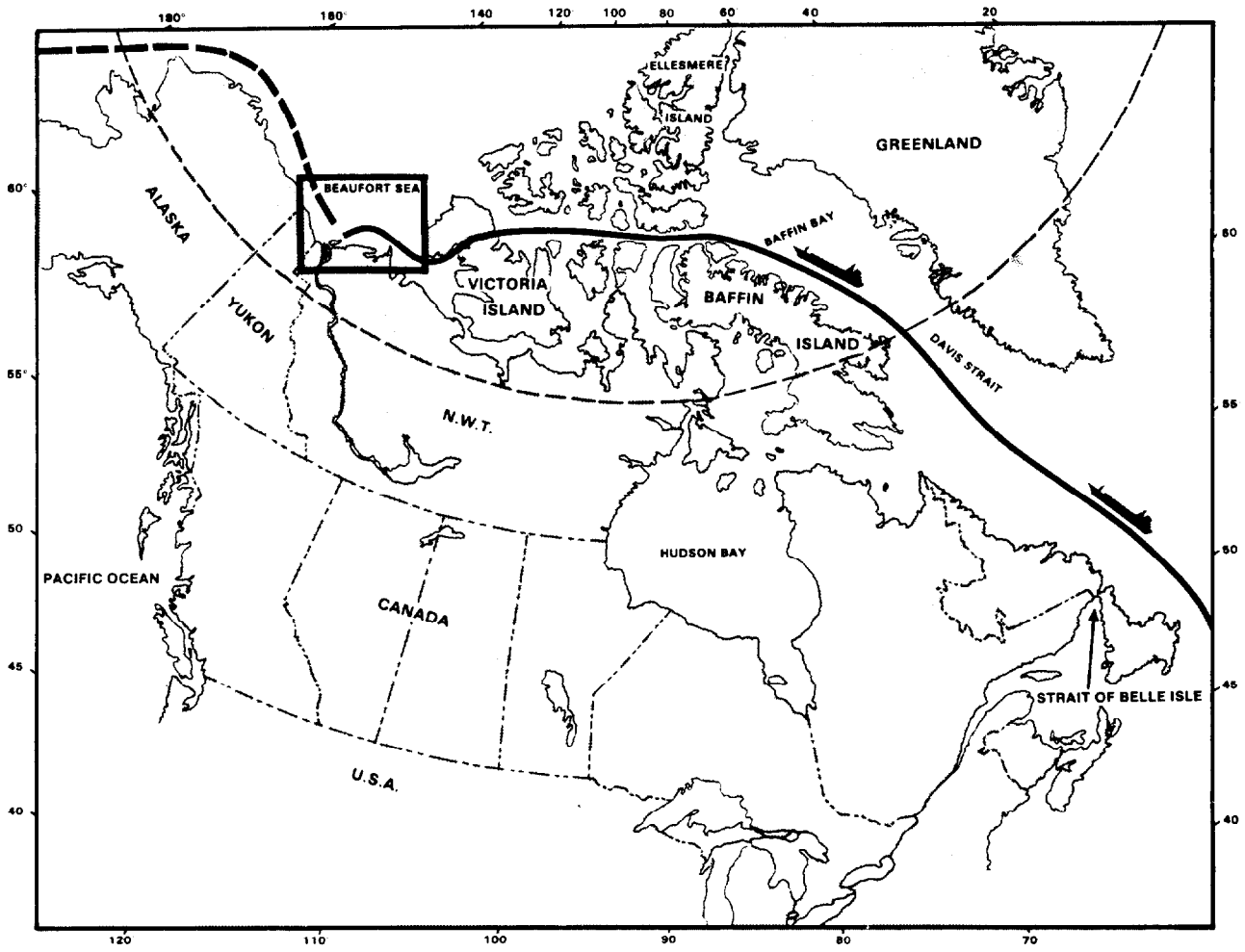


FIGURE 3-1 *The marine route for carrying oil by tankers would proceed through the Northwest Passage to the eastern seaboard. An alternate route would head west through the Bering Strait to the Pacific coast.*

mentioned herein and detailed referencing can be found in these two volumes. Also, in conjunction with many of the projects reviewed in Chapter 2 of this volume, extensive research has been undertaken on the characteristics of Beaufort Sea ice in order to quantify ice loads on, and ice interactions with, offshore structures.

Figure 3-2 illustrates the typical ice features encountered in the Beaufort Sea in winter. Numerous programs have measured ice strength and the size, thickness, velocity and geometry of thick ice features which could affect offshore structures over the long term (Plate 3-1). Progress has also been made in the field of ice - structure interaction, where actual observations, field measurements and modelling approaches have been used. The risks of ice over-ride have been extensively studied through field observations, model tests and theoretical analyses. Appropriate island geometries (that is, shapes of islands) and freeboards (that is, height of the surface above the water) to avoid ice over-ride have been derived. In addition, there are studies on the effects of operations on the ice regime and the influence these effects may have on local activities such as hunting and trapping. Two such studies are research on the ability to cross icebreaker tracks (Section 3.6.1.5) and work pertaining to the effect of artificial islands on the nearshore ice regime (Sections 3.2.1.2 and 3.3.1.2). These studies are being carried out in conjunction with local residents.

Studies such as those just listed have aided in determining design criteria for safe and efficient offshore facilities. The reader is referred to Volumes 2 and 3A for details of previous ice research projects.

As evidenced by the studies reviewed in Chapter 2, considerable research has been undertaken and much knowledge gained from oil and gas exploration activities in the Beaufort Sea. Future research will confirm and refine earlier predictions regarding the interaction between ice and offshore platforms, to aid in the optimization of platform design. The following ice studies are typical of those which will be conducted in the Arctic over the next few years.

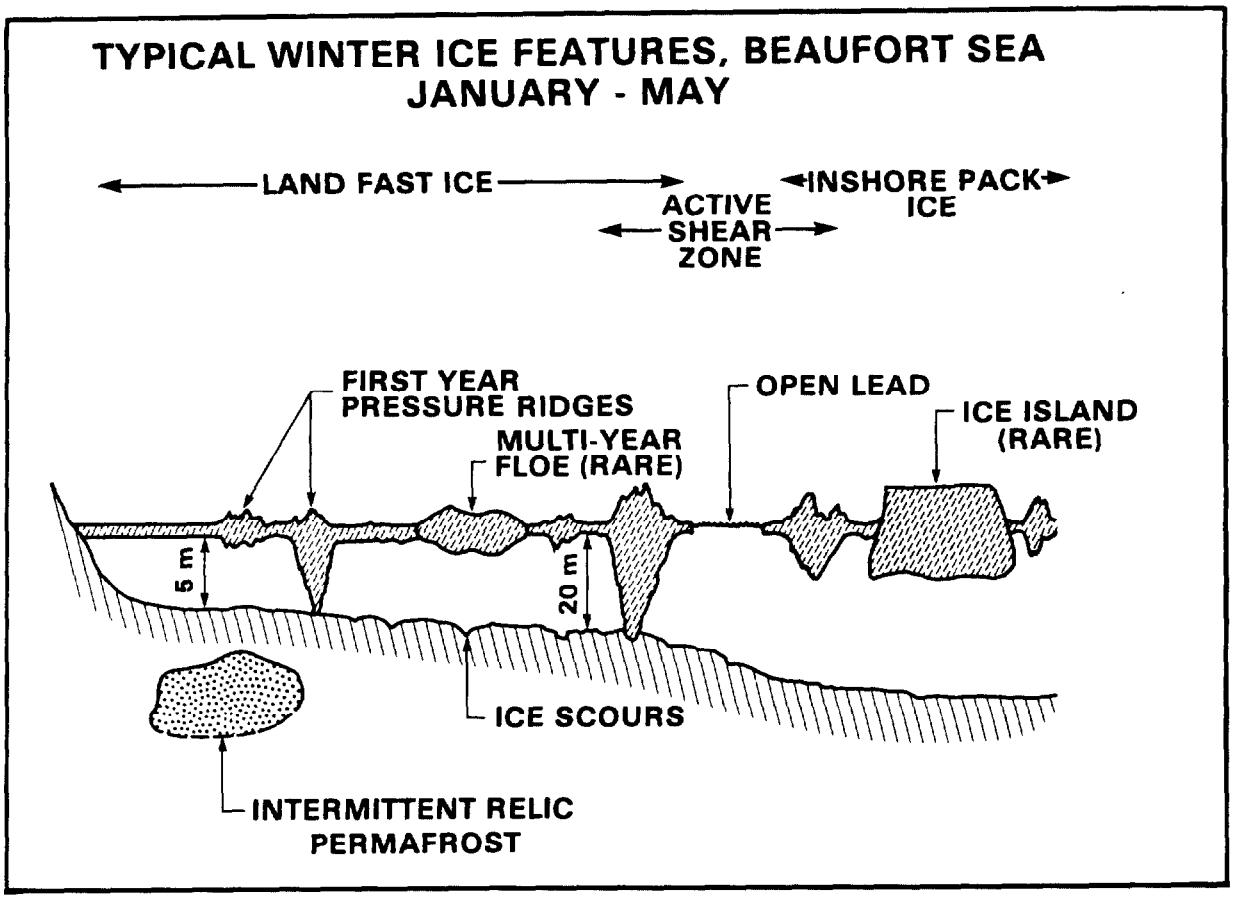


FIGURE 3-2 *Typical winter ice features in the Beaufort Sea.*

3.2.1.1 Measurement of Ice Loads and Studies of Interactions with Offshore Platforms

Adgo F-28 artificial island was instrumented when constructed in 1973 and measurements at other islands have been conducted up to the present time. For example, to improve the knowledge of ice forces that might be experienced by offshore platforms and to optimize designs for these stresses, the Tarsiut N-44 artificial island (Figure 2-2) was instrumented to measure ice loads when constructed in 1981 (Plate 3-1). Programs to monitor ice interactions, ice movements, rubble field growth, ice geometry, ice forces and other relevant parameters in relation to the island structure are being carried out. Additional projects of this nature are being planned for other offshore exploration structures currently under construction. These monitoring programs will continue to add to the industry's knowledge of ice forces, and the data they generate will aid in the optimization of the design of future systems.

3.2.1.2 The Effect of Offshore Drilling Structures on Nearshore Ice Regimes

Concern has been expressed by the hunters and trappers of Tuktoyaktuk that artificial islands (Plate 3-2) or offshore platforms might affect the nearshore ice regimes. If the landfast ice limit was extended, local hunters would have to travel a longer distance to the hunting areas at the edge of the shear zone. Also, if spring break-up of landfast ice was delayed, it might restrict the movement of white whales into Kugmallit Bay (Figure 2-2) in the spring and thereby reduce the annual whale harvest (Section 3.3.1.2).

In response to these concerns the proponents undertook a study of ice regimes through analysis of satellite and aerial photographs taken between 1973 and 1981. It was concluded that the exploration islands built to date have not had a substantial influence on the over-all patterns of nearshore ice formation or break-up (see Volume 3A). The possible effects of future island construction on landfast ice regimes will continue to be closely monitored during the ongoing and future construction of offshore platforms.

3.2.1.3 Strength of Multi-Year Ice

Multi-year ice has been identified as one of the strongest ice features in the Beaufort Sea. In order to demonstrate that offshore structures were being designed to withstand the forces exerted by large ice floes, an APOA study of ice forces on Hans Island in

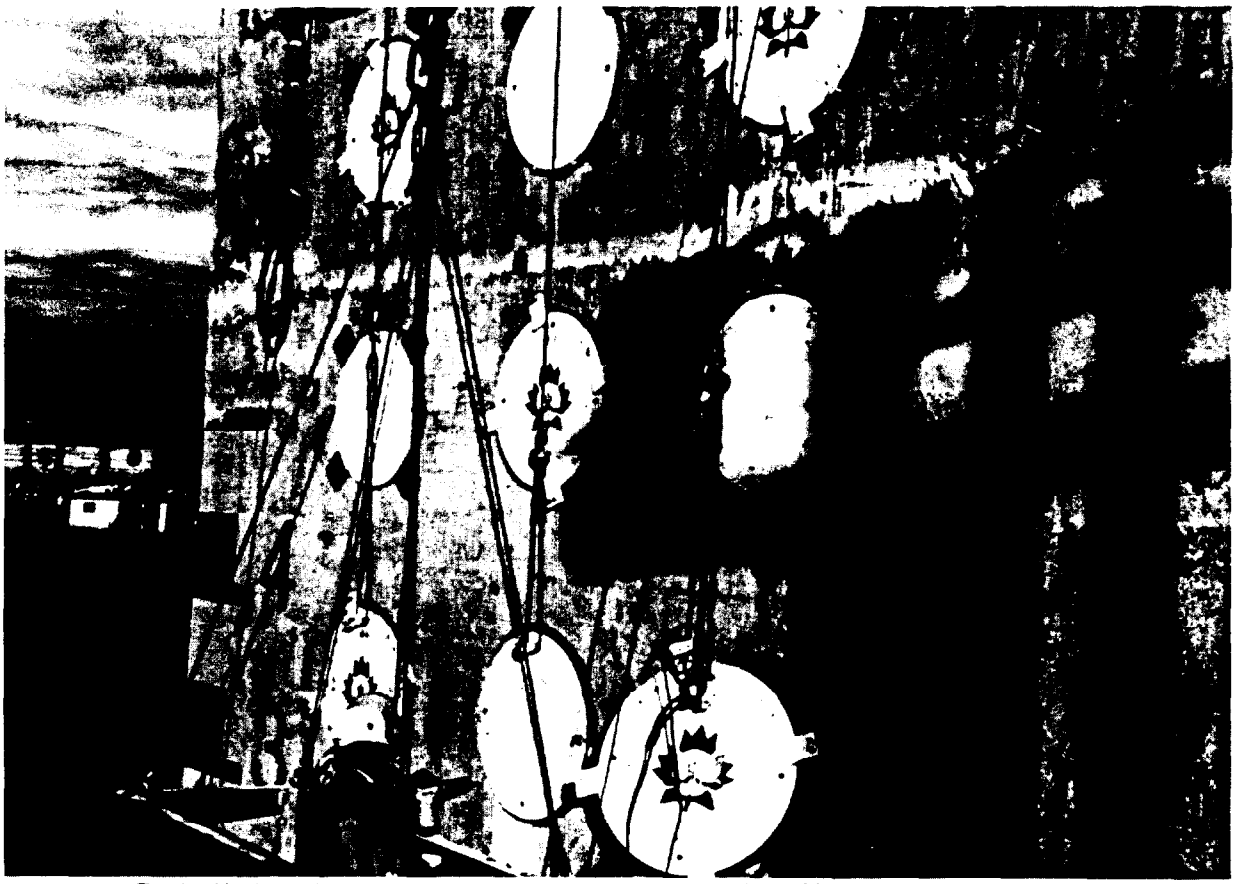


PLATE 3-1 *Tarsiut N-44 was instrumented to measure ice loads at the time of its construction in 1981. Programs using instrumentation such as this have increased the general knowledge regarding ice and its effects on offshore structures.*

PLATE 3-2 *Concern has been expressed by Inuit hunters and trappers that offshore structures, such as the artificial island* Tarsiut N-44 pictured here, might affect nearshore ice regimes. Research to date has shown that only localized effects on the ice regime occur.

the High Arctic (Plate 3-3, Figure 3-3) began during the summer of 1980. This natural feature is a small rocky island which is less than a kilometre across and is situated in Kennedy Channel between Ellesmere Island and Greenland at latitude 80°50'N. Every summer when break-up occurs, large ice floes move down the channel and abut against the island. Through measuring floe decelerations, ice forces are derived which can be applied to offshore platform design criteria. These studies are ongoing in conjunction with similar new programs associated with artificial island construction being carried out jointly by the various petroleum companies involved in Beaufort Sea development. Such research will probably continue through at least 1984.

Additional field and laboratory measurements of the strength of multi-year ice are being conducted by the Alaska Oil and Gas Association (AOGA) (see Section 2.3.4) to aid in interpretation of the ice force measurements discussed above. Aided by data from these studies, multi-year ice force models will be verified.

3.2.1.4 Driving Forces Within Pack Ice

The driving forces of pack ice are those exerted by wind drag, current drag and ridge building. Each of these has a natural limiting maximum. Therefore, there is an over-all natural limit to the driving force which can be exerted on a structure by pack ice. This maximum driving force must be taken into account when design engineers quantify the geometry (that is, width, length, heights, etc.) of protective underwater earth berms around offshore structures. These berms are built to act as buffers to reduce the momentum of large ice features when they meet an offshore structure.

Meteorological and oceanographic data are continually being gathered in the Beaufort Sea to provide information on the forces exerted by wind and currents on pack ice. Continuing research on ridge-building forces in pack ice and around artificial islands, to be carried out by the petroleum industry over the next several years, will enhance the understanding of over-all driving forces of pack ice, and allow refinement and optimization of design criteria for offshore platforms.

3.2.1.5 Ice Scour of Underwater Island Slopes

As discussed in Section 3.2.1.4, underwater berms of island-type platforms play an important role in stopping thick ice features from colliding with offshore structures. Basic calculations to determine the size of underwater berms required to stop extreme features are well understood through ice - berm interaction model studies and analyses undertaken by the proponents.

PLATE 3-3 *Hans Island in the High Arctic has been used as a study site for ice force research since 1980.*

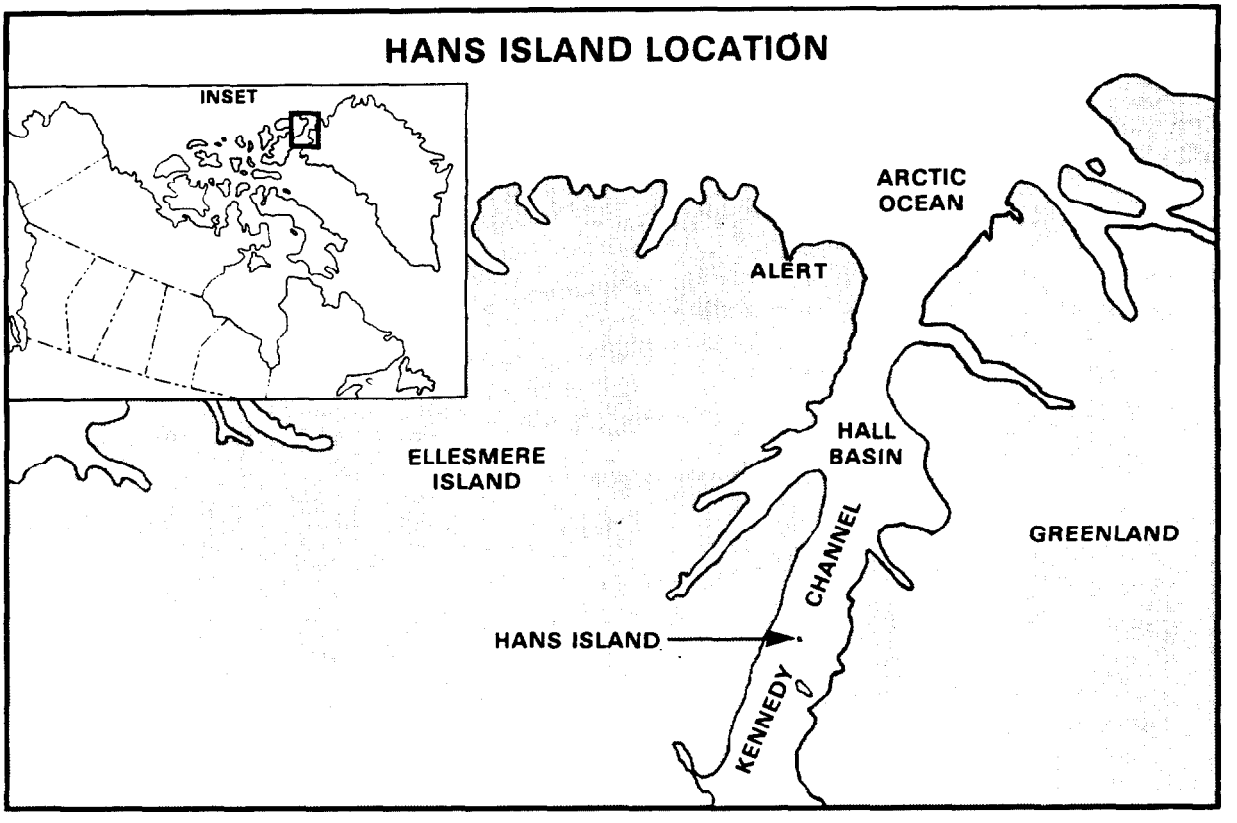


FIGURE 3-3 *Location map of Hans Island in the High Arctic.*

Ice monitoring studies to characterize ice rubble formation, ice growth and movement, and ice type and thickness around offshore platforms (which incorporate the degree of grounding and rate of consolidation) have been and will be conducted in conjunction with projects to determine ice forces on offshore platforms. These studies will provide more information on berm scour. Particular attention will be paid to any unusual scouring situations which may become apparent.

The model discussed previously will be calibrated based on the results of these ongoing and proposed studies and on continuing model tests. The results will progressively refine design criteria for offshore platforms. This research will probably be completed by mid 1983.

3.2.1.6 Protection of Offshore Drilling Structures by Ice Rubble

Observation has shown that ice rubble piles up around artificial islands in the Beaufort Sea in the early winter whenever there are extreme movements of thin ice. Since ice rubble may absorb some of the force exerted by surrounding ice, it is thought that grounded ice rubble could perhaps reduce the winter ice loads on offshore structures. Alternatively, the increase in diameter of the ice field around an island may increase ice loads. In order to determine which is the case, the petroleum industry will continue to research ice rubble during the next two to four years using both analytical and field techniques.

Analytical techniques will use past data to quantify such factors as how much force grounded ice rubble will absorb before it slides, and why it slides at a given force application. Field observations include measurements of the ice force on the rubble field boundary, the reduction or increase of the force within the field and the determination of a rubble field's resistance, if any, to ice forces. Such observations are presently being undertaken at artificial islands such as Issungnak and Tarsiut N-44 (Figure 2-2) and naturally-occurring grounded rubble fields such as 'Katie's Floeberg' (Figure 2-1). 'Katies's Floeberg' is a rubble field which forms over a natural shoal, with ice piling up on itself in the winter and then often disappearing altogether with spring break-up.

3.2.1.7 Growth and Decay of Ice Rubble Around Offshore Structures

Ice rubble (Plate 3-4) forms around structures in the Beaufort Sea, particularly those located in moving ice. Vessels must have access to artificial islands year-round in order to resupply them and, in the case of production facilities, to allow tankers to load. The

PLATE 3-4 *Ice rubble, like that shown here, is being investigated in relation to offshore structures in the Beaufort Sea.*

study of the growth and decay of ice rubble around platforms in moving ice is particularly relevant to the proponents' proposed Arctic production and loading facility which will harbour the tanker during the loading of crude oil.

Methods to refine the understanding of the growth and decay of ice rubble will probably involve physical model tests. These will be followed by field trials using vessels such as the KIGORIAK in order to develop methods of ship access to offshore facilities through ice rubble. This research will be conducted over the next few years. Should an Arctic production and loading facility be built, an ice rubble monitoring program will be carried out.

3.2.1.8 Optimal Island Geometries

Low freeboard structures with sloping beaches may be subject to ice over-ride. In the shallow waters (less than 20 m) of the Beaufort Sea this has not proved to be a problem at offshore exploration islands. In order to further ensure against ice over-ride, proposed deeper-water production structures will have higher freeboards than those of the exploration islands, and will incorporate geometries which discourage ice ride-up, such as vertical sides and ice deflectors. Model tests indicate that production structures designed in this way will be safe from ice over-ride.

Research will continue using analytical models, model tests and field observations at deeper-water exploration islands such as Tarsiut N-44 to confirm these predictions and to optimize geometries that will resist ice over-ride. This ongoing work is being conducted by all of the major petroleum operators in the Beaufort Sea, and the projects are expected to continue through 1983 or longer.

3.2.1.9 Refinement of Ice Occurrence Statistics and Ice Geometries

In order to increase the data available regarding ice loads on offshore structures and thereby permit more optimal designs, it would be useful to refine existing statistics regarding ice occurrence and geometries.

Ice coverage and ice types have been monitored by the American and Canadian governments for the past 30 years. In the late 1960s industry began more detailed studies to monitor Arctic ice (see Volumes 2 and 3A). In addition to ice monitoring programs, remote movement buoys such as the Random Access Memory System (RAMS) are deployed to measure ice velocities, while Side-looking Airborne Radar (SLAR), Synthetic Aperture Radar (SAR), lasers and aerial photography are used to obtain the size and thickness of ice features. This monitoring and research is expected to continue for several years through the joint efforts of industry and government.

3.2.1.10 Methods for Breaking Extreme Ice Features

Ice impact design criteria could be obtimized further with improvements to techniques for efficiently breaking up extreme ice features.

Research into the breaking of extreme ice features in the Beaufort Sea has been going on for some time and is expected to continue into 1984 or longer. Although this project is presently in its conceptual phase, preliminary method evaluations have indicated that the most feasible technique will probably involve mechanical devices. Conceptual research is continually being evaluated on a project by project basis, with possible techniques being considered accordingly.

3.2.1.11 Ice Conditions Along Shipping Routes

The primary tanker corridor from the Beaufort Sea will traverse the Northwest Passage to the east. A second corridor, through the Bering Strait to the west, may also eventually be used by icebreaking tankers, but for the short term will be used mainly for resupplying present facilities (see Figure 3-1). In order to optimize vessel design and the route used, additional research regarding ice along both possible routes will be undertaken by industry in conjunction with government.

The data acquisition methods most likely to be employed include remote sensing with aircraft using SLAR, ice thickness measuring devices and lasers, and surface transit trials using icebreaking vessels such as Dome Petroleum Limited's KIGORIAK. Statistics will be gathered on the concentrations and properties of multi-year and first year ice, and the number and locations of first year and multi-year ridges. These data will allow determination of the best possible route and the time required for a tanker to traverse a given route. Some of the previous research of this nature is reviewed in Volume 3B. This project will continue and will up-date previous studies to better define temporal variations.

3.2.2 GEOTECHNICAL RESEARCH

Geotechnical research to 1981 has primarily been directed toward site-specific investigations and the delineation of regional borrow sources for artificial island construction. This work has included preliminary borrow quality and fill suitability assessments. Most recently, geotechnical research on the Tarsiut N-44, Issungnak and Alerk island sites (Figure 2-2) has been undertaken to measure soil stability under the island's weight and under environmental loads (such as wind, waves, currents and, in particular, ice), with such parameters as soil movement, soil consolidation, *in situ* soil properties and soil settlement being analyzed.

Regional and site-specific surveys have also yielded data on offshore permafrost distribution, potential shallow gas, and surficial silt and clay layers. Regional geological models are being developed, based on research carried out by both government and industry. An expanded earthquake monitoring program was initiated jointly in 1981.

The following is a description of presently intended future geotechnical research in the Beaufort Sea region.

3.2.2.1 Refinement of the General Surficial Seafloor Model

As a result of site-specific investigations, certain areas of the Beaufort seafloor are well documented, while regional surveys have provided a general overview of the area. Despite the complex nature of the surficial geology owing to the deltaic nature of the sediments and a lack of specific data on some areas, a preliminary surficial geological model taking the form of a map of seabed soils has been prepared for the Beaufort seafloor. This was a joint government-industry project. Such models are valuable for construction planning, pipeline routing and borrow-source delineation.

Future geotechnical programs will be designed to refine this surficial geological model as new site-specific information and regional survey data become available. This work will continue in conjunction with the Department of Energy, Mines and Resources through the 'Beaufort Seabed Geology Synthesis Working Group'.

3.2.2.2 Development of a Tectonic Model and Refinement of Seismic Design Criteria

Preliminary evaluations of seismic risk in the Beaufort Sea region indicate that earth tremors of a magnitude that might cause difficulties to the stability of the foundations of offshore facilities could perhaps occur. However, prior to 1981, Arctic seismic recording stations were relatively few and, therefore, the degree of confidence in defining earth tremor locations and magnitudes in the Beaufort Sea had been quite poor.

Four additional seismographic stations were established along the Beaufort Sea coast in 1981 in order to improve the predictions of earth tremor activity in the Beaufort region (see Volume 3A). These will enable better definition of seismic risk and allow for the optimization of the design of platforms capable of withstanding ground accelerations produced by earth tremors. This was done as an APOA project in cooperation with the Department of Energy, Mines and Resources (EMR). These stations are now integrated into the national earthquake monitoring network.

In addition, ocean bottom seismographs (OBS) were installed on the Beaufort seafloor in the summer of 1981 to monitor ocean floor accelerations and relate these to seismic events. This project, undertaken by industry in conjunction with EMR and the Atlantic Geoscience Centre, will enable researchers to refine existing tectonic models of the Beaufort Sea and will perhaps result in refinements of existing offshore platform design criteria.

3.2.2.3 Evaluation of Dredged-Fill Stability

Hydraulically placed fill may be subject to liquefaction during rapid application of loads or earth tremors. Proper design and construction techniques, like the methods presently used during exploration island building, can overcome this. Studies by the proponents are presently underway at exploration island sites to measure the properties of hydraulically placed fill and to relate these properties to potential loadings in order to optimize designs of artificial islands. Continuation of this project during the next few years will allow confirmation of initial results.

Thermal effects on the stability of offshore islands must be considered in island design. Frost heave caused by penetration of the freeze front is a potential problem, but this is unlikely because the material used in island construction is generally of good quality and is not subject to frost-heave. However, this will continue to be carefully evaluated for each specific design and in relation to the fill properties expected for production islands. Also, the potential benefits of artificially freezing parts of a soil structure, which may result in increased island stability, will be investigated, as will the possible effects of brine drainage on dredged-fill stability.

It is also recognized that thaw subsidence in the permafrost below an island or platform may cause increased settlement at the surface of the structure. This effect is currently being evaluated as part of the general wellbore research described in Section 3.2.5.

3.2.2.4 Surveys to Identify Potential Seafloor Hazards

In some areas the deltaic Beaufort seafloor sediments are, by their nature, weak, with shallow gas and shelf edge instabilities. This, combined with the presence of offshore permafrost, results in special design requirements for offshore platforms, wellbores and pipelines when they are located on deltaic sediments.

Considerable data regarding soil hazards have been compiled and mapped, using information obtained from shallow seismic surveys and cores. This program is expected to continue over future summers, with particular emphasis being placed on those areas most promising as future production sites. This project has been, and will continue to be, carried out by industry in conjunction with various government researchers.

3.2.3 ICE SCOURING RESEARCH

Ice scouring refers to gouging of the seabed by ice, which may present difficulties to seabed installations such as offshore pipelines. A great deal of research on ice scouring of the Beaufort seafloor has been done in the past (see Volume 3A). Past data have provided the basis for an industry rationale which has enabled adequate burial depth criteria to be established.

Future projects will concentrate on revising and updating the statistics and techniques already developed. Site-specific work is and will continue to be done in relation to proposed submarine pipeline routes at the time of their selection. This research involves shallow seismic surveys, together with the collection of geotechnical boreholes along the route, side-scan sonar and repetitive seafloor mapping. Scour dating work may also be undertaken. Projects of this nature are being conducted by individual operators from vessels during the summer, although some nearshore work may be done off landfast ice in winter. When submarine pipelines and seabed systems are installed, they will be monitored to determine whether or not scour affects them. These results will be used to aid in the optimization of the design of future systems.

3.2.4 REMOTE SENSING AND ICE FORECAST RESEARCH

Since the inception of offshore exploration in the Beaufort Sea, weather and visual ice observations have been collected in an operational context for use in weather, sea state and summer ice forecasts.

Prior to 1979 remote sensing activities were primarily concerned with establishing a data base for ice characteristics, for operational planning and for design purposes. Aerial photography (Spedding, 1979), laser profilometry (Tucker *et al.*, 1979), satellite imagery (Spedding, 1979) and upward-looking sonar sounders (Wadhams and Horne, 1978) were all used in acquiring these data.

Since 1979, increased emphasis has been placed on developing and improving ice surveillance and forecasting techniques for operational support. Attention has focussed on the use of airborne imaging radar systems such as SAR (Synthetic Aperture Radar) and real aperture SLAR (Side-Looking Airborne Radar). These two systems have been investigated for their ability to provide identification, type-discrimination

and high resolution mapping of ice. Impulse radar and its derivatives were mentioned in Section 3.2.1.9 regarding their potential use in ice thickness measurements. Marine radar has also been examined for its capability to provide real-time continuous localized ice imagery.

The proponents are currently involved in several research programs which continue to refine and improve the aforementioned methods and data base. The following is a summary of these studies, together with future work proposed in the fields of remote sensing and ice forecast research. It should be recognized that the concepts described and the research proposed reflect the proponents' best estimate of the direction that programs and requirements will take in the foreseeable future.

3.2.4.1 Ice Forecast Research

Through the AIDJEX program (see Section 2.2.2) a winter ice model was developed. This model was adapted for the Canadian Beaufort Sea by Dome Petroleum Limited and the Atmospheric Environment Service, with considerable support from other government departments. Known as WIEBS (Winter Ice Experiment, Beaufort Sea) (Section 2.2.11), the project involved the collection of an early winter ice data base and the theoretical development of coarse-scale (Beaufort Sea) and fine-scale (100 km) mathematical and computer models. An additional late winter ice data base has since been collected.

As ice prediction is important to future shipping and other Beaufort operations, further development of these winter ice models will continue. Dome Petroleum Limited has recently complemented the winter ice modelling work with the development of a separate model to predict ice motion under summer conditions. New remote readout current measuring buoys developed by the company in a concurrent project (Section 3.2.7.1) are providing ocean current data in aid of the model. Future efforts will focus on further testing, fine tuning and recasting of the models into operational form.

Iceberg drift models are also presently under development by a number of companies involved in exploration activities in the Eastern Arctic, and these will become the subject of increased study by the proponents when shipping from the Beaufort Sea to southern markets is approved.

3.2.4.2 Ice Surveillance Systems

Recent research on ice surveillance has been toward the development of improved instrumentation for the detection and characterization of hazardous ice existing during summer operations in the Beaufort Sea. Dome Petroleum Limited has recently succeeded in using marine radar at elevated positions (in one case from the top of a drillship derrick and in the other from aboard a tethered balloon) to improve ice detection capabilities. Other projects have seen the increasing use of SAR and SLAR as operational ice management tools, which in turn have led to improved modes for their operational use.

Future research will focus on the provision of operational support to proposed icebreaking tankers (Section 3.2.8.1). One such project is the development of a new lightweight airborne SAR. The specifications of the SAR have been decided and these will lead to the production of a system optimized for airborne ice surveillance in support of drilling and transportation operations. Delivery of this system is scheduled for late 1983.

An ice hazard detection system (as illustrated in Plate 3-5) is being investigated for shipboard use. While exact specifications for the shipborne detection system have not yet been established, a number of field projects and other studies are being planned. These studies will relate to the development of an advanced marine radar (the primary component) and supplementary systems (potentially acoustic, passive microwave, optical or infra-red) and to their integration. Volume 2 provides greater detail on these systems.

3.2.4.3 Image and Data Processing Systems to Support Tanker Navigation

The use of advanced image processing to improve ice-type discrimination by marine and airborne radar is presently being investigated through the RIDS (Radar Image Display System) project. In a related use of computer aided display techniques, integration of environmental data gathering with forecasting, using the summer ice model (Section 3.2.4.1), has resulted in the deployment of the "Shipboard Ice Alert and Monitoring" (SIAM) system on board a Dome Petroleum Limited drillship and at the company's base at Tuktoyaktuk. These systems represent the forerunners of systems to support tanker navigation.

Integration of available remote sensing and modelling techniques into an optimized ice surveillance and hazard avoidance system will probably become a major area of new research by industry in the near future. The resulting system will combine REMote Sensing, Communication And Navigational elements, and will accordingly be known as REMSCAN. This system will address both the tactical and strategic requirements for vessel operational safety and efficiency. It will incorporate the needs for management overview and feedback, tanker route optimization and vessel traffic management, and information

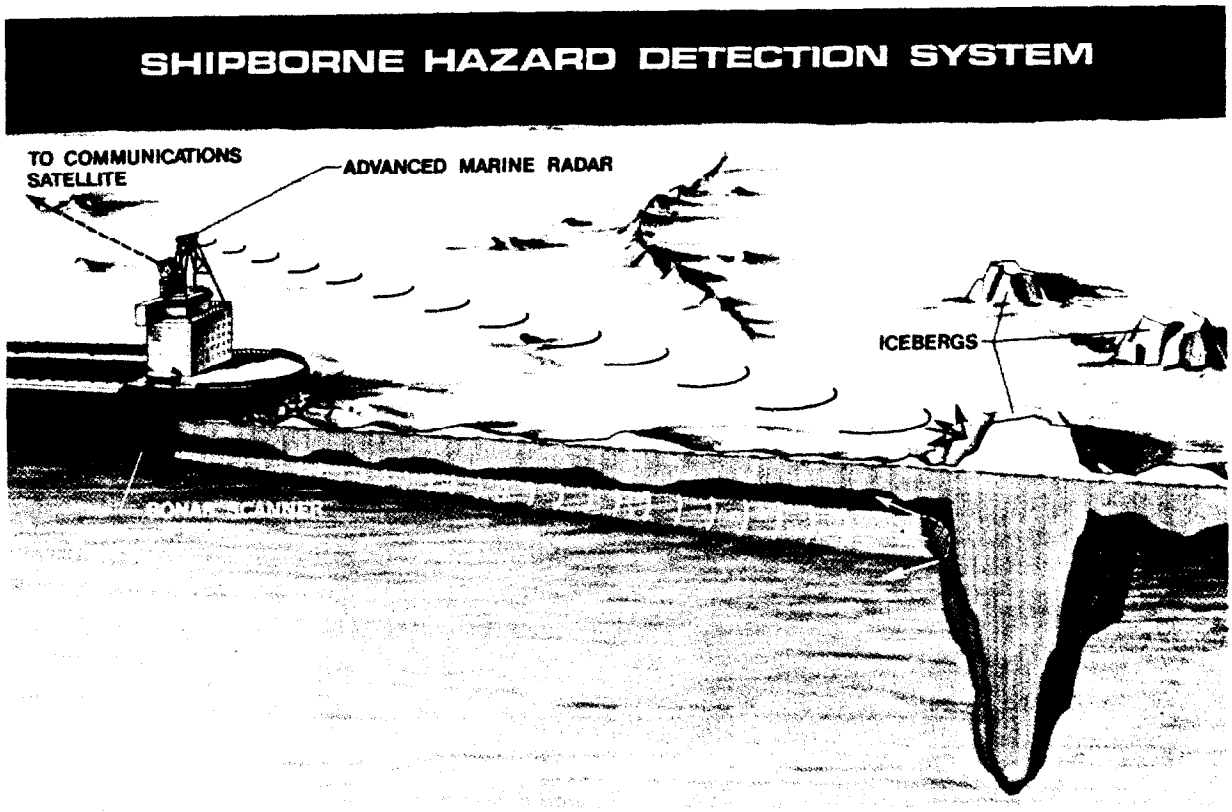


PLATE 3-5 *Ice hazard avoidance systems, such as that illustrated here, are being investigated for shipboard use.*

transfer and processing. Determination of the system's requirements is presently underway. The program will continue over the next three or more years.

3.2.5 WELLBORE RESEARCH

3.2.5.1 Geotechnical Evaluation of the Effect of Permafrost on Casing

As indicated in Volume 2, individual operators (in conjunction with APOA and AOGA) are continuing research and engineering studies to measure and predict the behaviour and effects of permafrost thawing around well casings in the Beaufort Sea. The purpose of studies is to specify design criteria to prevent physical damage of casings which may affect the integrity of the well during offshore drilling and production.

This research is ongoing and will probably continue for several years. Specific studies include the development of a computer model capable of predicting design parameter values for a single-well application; the development of a computer model for predicting design criteria for a typical multi-well application; the development of a computer based downhole measurement system to gather data from the Tarsiut N-44 well; correlation with the lithology at the Tarsiut N-44 well; and a series of tests to determine the strength of casings and associated connector devices.

3.2.6 ARTIFICIAL ISLAND CONSTRUCTION

Since the construction of Immerk (Figure 2-2) by Esso Resources Canada Limited in 1972-73, modifications to island construction have continuously been implemented in the Beaufort Sea. Plate 3-6 illustrates one of the earlier types of island construction. One of the latest designs was that used at Tarsiut N-44 where concrete caissons were used for island retention (see Plate 3-1). Other new platforms will utilize different innovative techniques. A complete review of island construction technology can be found in Volume 2.

Future research on offshore islands will include quantifying current and wave erosion at Tarsiut N-44 and other sites, in order to predict erosion at proposed production structures. Construction techniques will continue to be evaluated in order to optimize the entire construction procedure.

3.2.7 OCEANOGRAPHIC RESEARCH

As discussed in Volume 3A, research with respect to the general physical oceanographic features of the Beaufort Sea is fairly well documented. Measure-

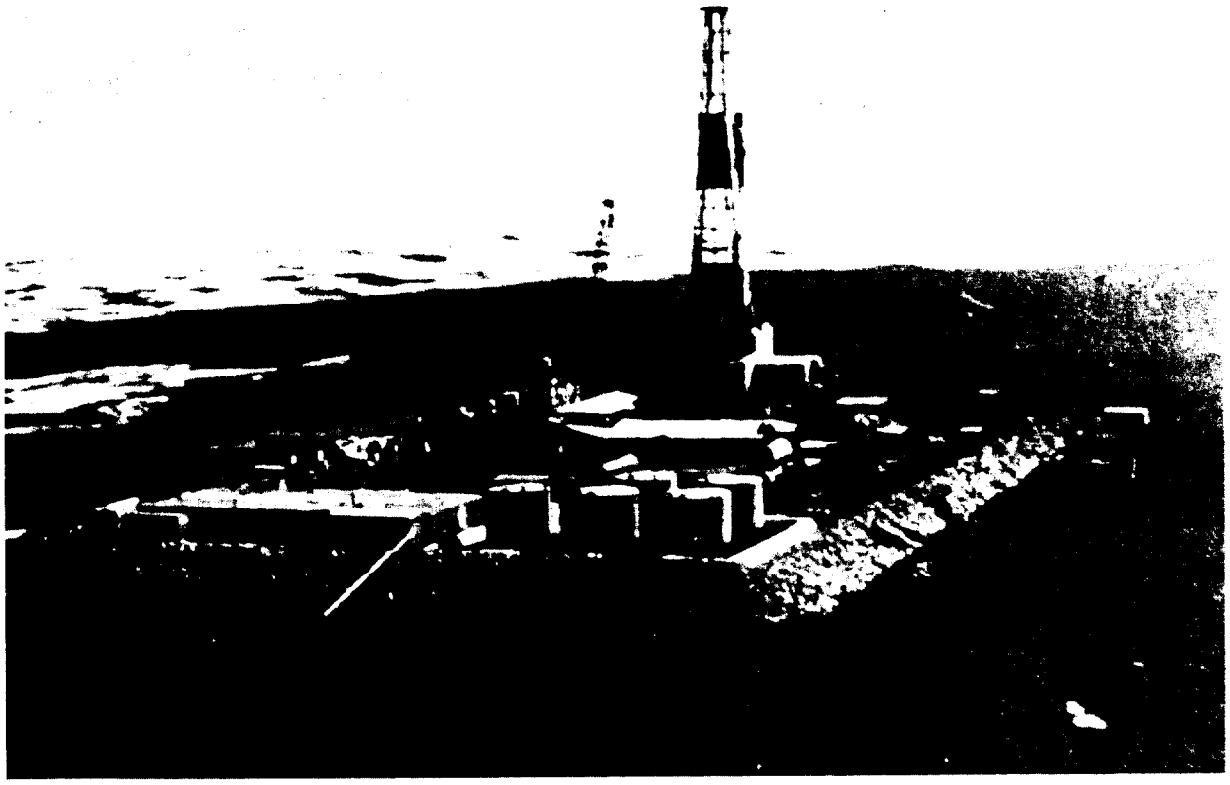


PLATE 3-6 *One of Esso Resources Canada Limited's earlier artificial islands is shown here. New methods of island construction are continually being developed and evaluated for Beaufort Sea use.*

ments of waves, currents and meteorological parameters have been made for several years, together with measurements of tides and storm surges. Hindcast studies for estimating the probabilities of extreme wave conditions have also been developed and will continue to be refined, while new offshore systems will have monitoring programs to increase the existing data base.

The following discussion focusses on future physical oceanographic programs in the Beaufort Sea. Some of these were mentioned briefly in other sub-sections of this volume.

3.2.7.1 Oceanographic Studies Along Proposed Shipping Routes

Oceanographic research emphasizing surface circulation patterns will be carried out by the Federal Government and industry along proposed shipping routes through Amundsen Gulf (Figure 2-1) and the Northwest Passage (Figure 2-3) over the next few years. Most of the work will involve the installation of current meters (Plate 3-7) and tide gauges, and the use of radio-tracked surface drifter buoys. The direction of movement of the buoys will be observed in conjunction with meteorological conditions. The results will be used to assess the possible fate of spilled oil, in the event an accident should occur.

3.2.7.2 Oceanographic Climatological Studies

An accurate climatic description of the Beaufort Sea is necessary for nearly all phases of development planning in the region. Each company involved in the petroleum industry in the north continually refines its climatic description through a variety of individual and joint programs, while oceanographic conditions are continuously monitored under the Marine Environmental Data Service program of the Department of Fisheries and Oceans and through environmental observation programs carried out by the individual operators in the Beaufort region.

Particular projects will be conducted to answer specific questions when they arise. Analyses of available data, combined with theoretical oceanographic modelling, will continue to be done in order to update the predictions of the severity of extreme events such as storms. This will aid in the optimization of design criteria for offshore platforms.

3.2.7.3 Current and Wave Studies in Relation to Submerged Sand-Surface Erosion

A major component of most production island concepts being considered for the Beaufort Sea is a submerged sand mound. Each company will be improving the technology to control erosion of submerged

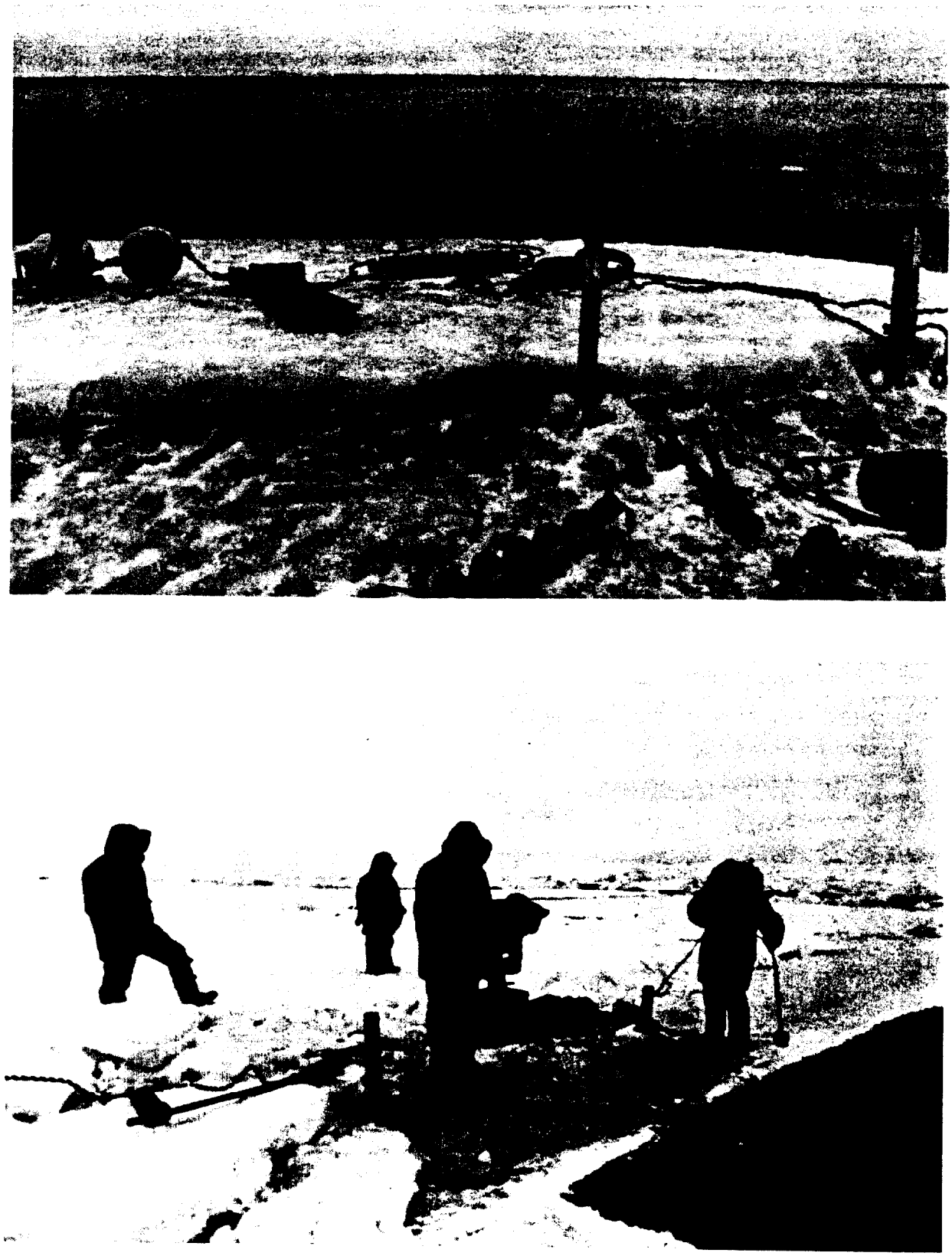


PLATE 3-7 *Deployment of current meters from the sea ice. (Courtesy Arctic Sciences Ltd.)*

sand mounds under the constraints of the types and quantities of sands and gravels that are readily available and the degree of ice scouring that may take place. The principle method of study will be the continued analysis of erosion measurements and prevailing oceanographic parameters (using sea-bottom sounding techniques and divers) at existing islands and at those to be constructed in the near future.

3.2.7.4 Northwest Passage Program

The Working Group on Northwest Passage Oceanography was formed by government and industry in the spring of 1981 to coordinate research and to learn more about the oceanography of the Northwest Passage (Plate 3-8; Figure 2-3), as this waterway may become a year-round shipping route for the petroleum industry within the next few years (Figure 3-1). The group is headed by the Federal Government's Institute for Oceanographic Sciences at Patricia Bay, British Columbia, which is a large and well-equipped oceanographic research laboratory. Also involved are staff from the Federal Government research laboratory in Burlington, Ontario, and representatives from industry.

Over the next three to four years the group intends to conduct oceanographic programs in the Northwest Passage and adjoining channels to gain data on water movements, water levels and water chemistry. It is intended that each year a different part of the Passage will be studied, beginning at the west end in the spring of 1982 and finishing in the east in 1984.

3.2.7.5 Bathymetric Studies

In order to select the optimal tanker route for shipping oil and gas from the Beaufort Sea to southern markets, it is necessary to take into account a variety of factors, including ice conditions, meteorology, oceanography, traffic levels, and socio-economic and environmental considerations. Future hydrographic requirements will largely depend on the specific route chosen. Once fully defined, bathymetric surveys will be reviewed with the Canadian Hydrographic Service in order to delineate corridor sections in need of further study.

Some bathymetric survey work in Prince of Wales Strait (Figure 2-3) should be completed by this summer (1982), while by September, 1983, the proposed shipping corridor along the Beaufort Sea coast will also have been completely surveyed. The remaining areas within the primary proposed shipping corridor still in need of some bathymetric survey are Viscount Melville Sound and Barrow Strait (Figure 2-3). These regions, plus any others identified through discussions with the Canadian Hydrographic Service, will be surveyed prior to the beginning of regular shipping (see Volume 3B for a review of shipping corridors).

PLATE 3-8 *The Northwest Passage is to be studied by a joint government-industry working group. More will be learned about the oceanography of these waters in support of future shipping of oil to southern markets.*

3.2.7.6 Wave Hindcast Studies

The Beaufort Sea is relatively calm in comparison with other areas of the world where offshore drilling is taking place. Knowledge of the wave climate is particularly relevant to the optimal design of artificial islands and the selection of the best methods to withstand potential extreme wave heights and associated forces.

Wave hindcast studies are used to predict extreme wave heights and the durations of storms. Two of the most recent wave hindcast studies carried out for the Beaufort Sea (see Volume 3A) differed in the extreme wave heights predicted. To resolve these differences, work is in progress to critically review these hindcast studies, in order to provide increasingly reliable estimates of extreme waves and the durations of storms, and thus ensure optimization of the design of future offshore facilities.

3.2.8 ARCTIC VESSEL RESEARCH

3.2.8.1 Arctic Transportation Systems

The proponents are proposing to design and construct icebreaking tankers to transport oil from the Beaufort Sea to southern markets (see Plate 3-9). Such ships will be capable of navigating year-round eastward through the Northwest Passage or westward along the north Alaskan continental shelf through the Bering Strait to the Pacific Ocean (Figure 3-1).

Dome Petroleum Limited has established an Arctic transportation system research program to develop safe operating design criteria for Arctic shipping. These criteria will ensure that ships do not sustain damage which could threaten their safety or that of the environment, and to demonstrate the feasibility of year-round transportation in Arctic waters. The following is a description of the objectives of Dome's program:

a) to test and evaluate the SUPPLIER 9 icebreaking vessel which will incorporate design improvements based on previous research using Dome's icebreaker KIGORIAK (the SUPPLIER 9 will be similar to an icebreaking tanker scaled down to 1/3 normal size);

b) to test and evaluate the AML X-10, a large experimental Arctic Class 10 icebreaker, which may be built to demonstrate the feasibility of year-round Arctic navigation and establish icebreaking hull design criteria for all future large Arctic ships; this, or a comparable ship, will also be used to develop and test operational icebreaking support techniques for Arctic transportation and drilling;

c) to establish and test safe operating design specifications for Arctic shipping using data obtained from the SUPPLIER 9 and other advanced ships; and,

PLATE 3-9 *Beaufort Sea operators, such as Dome Petroleum Limited, are proposing to design and construct icebreaking tankers to transport oil to southern markets.*

d) to develop, test and evaluate remote sensing and navigation support systems for Arctic transportation systems.

3.2.8.2 Floating Drilling Systems

To develop and improve the technology to allow year-round drilling from floating platforms in Arctic waters, the proponents have undertaken extensive research programs, including scale-model and full-scale testing and evaluation of second generation icebreaking drilling systems. Further studies will be conducted on Gulf's Conical Drilling Unit (CDU) in 1983. Other research will be undertaken on the design of remote sensing and ice prediction support systems for year-round exploration drilling, and oilspill prevention and clean-up research for year-round Arctic drilling systems. These projects will be carried out over the next several years in the Beaufort Sea.

3.2.8.3. Arctic Dredges

To facilitate construction of proposed large dredged fill structures in the Beaufort Sea, Dome Petroleum Limited has designed a very large capacity icebreaking hopper dredge which will be capable of operating in water depths of up to 80 metres (Plate 3-10). This equipment will enable structures with large fill volumes to be constructed in the deeper waters of the Arctic continental shelf throughout most of the year.

Since this dredge would be the first of its type anywhere in the world, extensive and comprehensive research with the vessel is expected to be conducted if it is built in order to evaluate its dredging and icebreaking abilities, and its possible effects on the environment. These programs will be coordinated with appropriate biological projects in order to minimize disturbance to faunal communities.

3.2.9 PHYSICAL PROGRAMS RELATED TO ONSHORE DEVELOPMENT

3.2.9.1 Hydrology

The general hydrological conditions and processes of rivers and streams within the Mackenzie Valley pipeline corridor (Figure 3-4) and the Mackenzie Delta and Tuktoyaktuk Peninsula (Figure 2-2) where onshore facilities may be sited are described in Volumes 3A and 3C. The preliminary selection of pipeline alignments and industry facilities will be based on the existing hydrological information. Prior to final site selection and construction, investigations of specific river and stream crossings will be conducted where necessary in order to improve information on seasonal streamflows, water depths, and the potential for icing, ice jams, ice scour and channel migrations.

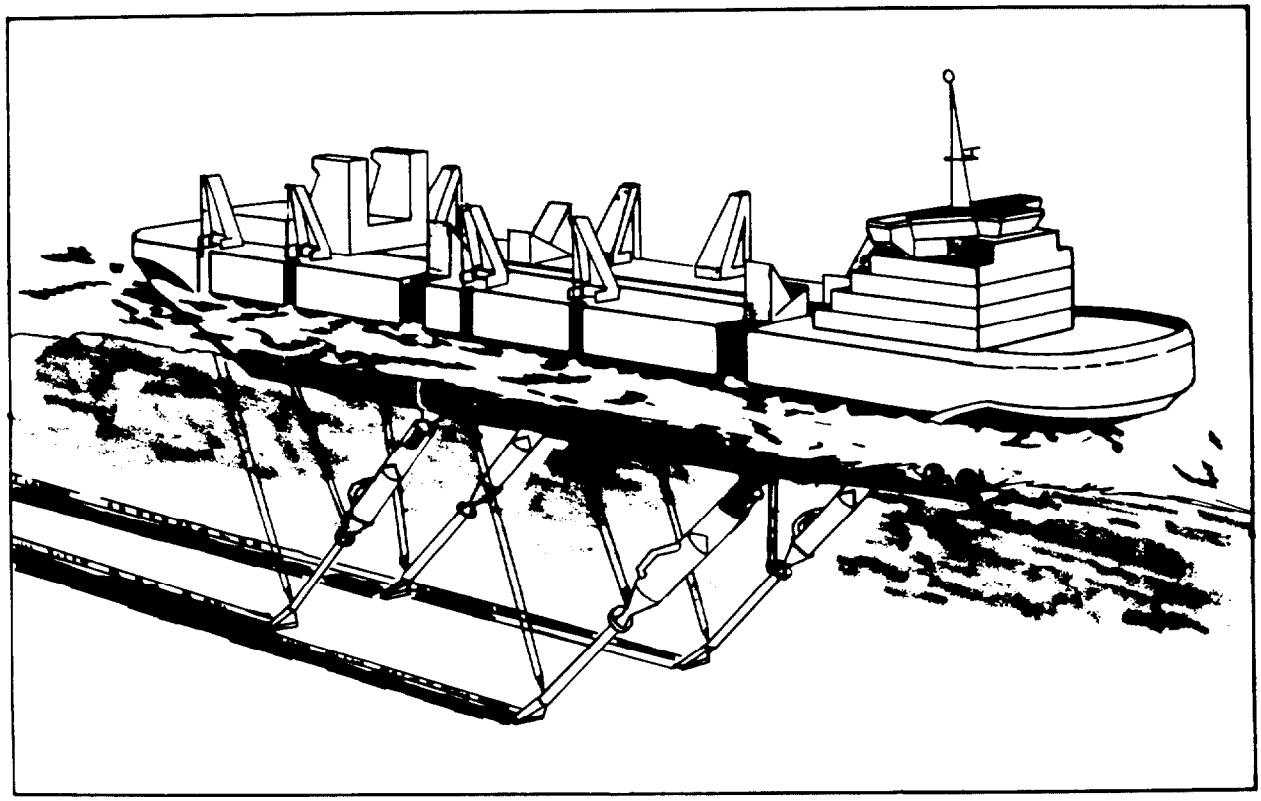


PLATE 3-10 *Dome Petroleum Limited's proposed icebreaking hopper dredge will be capable of operating in water depths of up to 80 metres.*

When pipeline construction is completed a monitoring program will be implemented. In general, the types of work to be carried out would include aerial photographic surveys of major stream crossings which showed past channel migrations; annual channel soundings of major stream crossings subject to ice jams or scour; velocity and depth measurements during winter in locations where these parameters were deemed to be important to fish populations (see Section 3.3.3.2); and, in the case of a chilled gas pipeline, measurements of pipe position at crossings where freezing could cause soil-heave. These monitoring programs will be reassessed periodically in consultation with appropriate government agencies, and will be continued and modified on the basis of the results obtained.

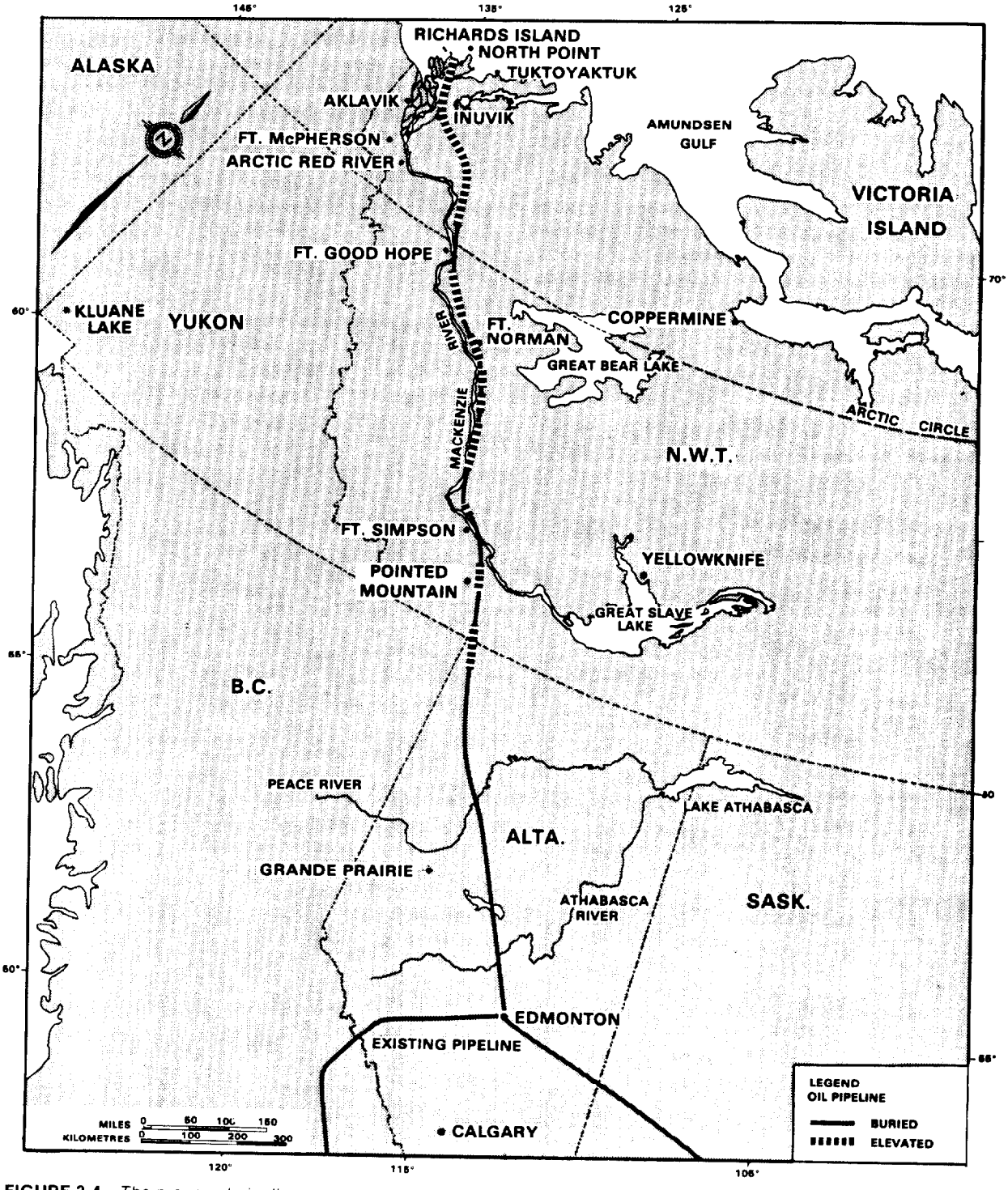


FIGURE 3-4 *The proposed pipeline would extend from Richards Island to Edmonton.*

3.2.9.2 Water Quality

Prior to final site selection and construction of possible onshore facilities and pipeline alignments, water quality parameters requiring observation will be determined. These parameters relate primarily to the protection of the aquatic environment and would typically include turbidity and sediment loads (see Plate 3-11), dissolved oxygen, temperature and nutrients. A water quality monitoring program at designated river crossings to observe project related changes in these parameters during and after construction will be undertaken by industry in cooperation with government agencies. This program will be reassessed from time to time, and will be continued or modified based on the results of the existing program.

All wastewater being discharged from onshore facilities will conform to regulatory standards. The federal guidelines regarding effluent discharge to receiving streams also specify the timing of release, location of discharge, method of discharge and parameters to be measured. An example of these guidelines are those recommended by the Environmental Protection Service of Environment Canada in 1976 for the design and construction of a Mackenzie Valley gas pipeline (Environmental Protection Service, 1976).

3.2.9.3 Geology and Soils

The Alyeska Pipeline system in Alaska has demonstrated that large diameter pipelines to transport warm crude oil under Arctic conditions can be built safely (see Volume 2). Although the geological conditions and soil characteristics along the Mackenzie Valley pipeline corridor are generally known (see Volume 3C), pre-construction site-specific investigations will be undertaken in order to select designs which will prevent subsequent problems resulting from erosion, bank instability, thaw settlement or earthquake motion. The geological conditions along the Mackenzie Valley are conducive to some earth tremor activity, but to a much lesser extent than exists along the Alyeska route.

The main difficulty associated with pipelines constructed in the Arctic arises from the potential instability of ice-rich permafrost soils. Therefore, to augment existing data, additional soil surveys (primarily borings) will be conducted along the chosen pipeline alignment to classify soils according to stability. Where soils are stable the pipeline can be buried. Where soils are potentially unstable owing to ice-rich permafrost, the pipeline will be supported above the ground on piles (vertical support members).

PLATE 3-11 *The Mackenzie River is naturally very turbid. This and any other water courses being proposed for crossings in relation to pipeline alignments or onshore facilities, will be studied for "over-all" water quality during and after construction. (Courtesy Woodward-Clyde Consultants).*

Since soil surveys do not generally detect all of the possible segments of unstable soil, the buried sections of pipe will be monitored (likely annually) in the initial period. The Alyeska buried pipe has settlement rods attached to the top of the pipe to facilitate vertical displacement measurements. Similar devices are envisaged for a Mackenzie Valley pipeline. For the above ground segments of the pipeline, annual monitoring of selected vertical support members for horizontal and vertical movement will be done using conventional survey techniques.

If necessary, further programs will include infra-red surveys to locate defective heat pipes (cryo-anchors), followed by monitoring of ground temperatures at vertical support members containing the defective pipes. Cryo-anchors are thermal devices installed within vertical support members to provide passive refrigeration and thus prevent degradation of permafrost where temperatures are not sufficiently low to maintain the integrity of the support units.

3.2.9.4 Air Quality

Emissions from shorebases, processing plants, pump stations, compressor stations and other project facilities will be controlled in compliance with the national ambient air quality objectives set by the Federal Government. The proponents will establish monitoring programs at their individual facilities in which air samples will be taken according to guidelines to be established in cooperation with appropriate government agencies. These monitoring programs will also include measurements of noise levels at compressor stations to ensure that sound pressure levels do not exceed government standards under normal operating conditions. These measurements will likely be taken within six months of start-up and annually thereafter.

The type of air quality monitoring envisaged by industry is exemplified by the program at Norman Wells which is a joint effort between Esso Resources Canada Limited and the Environmental Protection Service (EPS) of Environment Canada. In this program high volume air samplers and dust fall samplers have been installed at selected Norman Wells locations. Samples are sent to an EPS laboratory for analysis of heavy metals, hydrocarbons and particulates. A provision of the monitoring program agreement is that the air quality results at Norman Wells will be reviewed jointly after two years to determine future commitments by both parties.

3.3 BIOLOGICAL PROGRAMS

Biological studies of Arctic regions will continue to play an important role in decision making as the petroleum industry moves toward development of the area's oil and gas potential. Research and monitoring programs will enable industry, government and the public to determine the potential impacts of development on biological systems, to understand the nature and extent of identified impacts, and to respond in an appropriate manner to such impacts.

The following is a summary of present and proposed future biological programs related to oil and gas development in the Beaufort Sea-Mackenzie Delta region. The projects are discussed by faunal grouping and respond to concerns and potential impacts identified in previous volumes of the EIS. Table 3.3-1 identifies the activities to which each study is directed.

It is recognized that additional site-specific studies may be necessary at the time when specific developments are undertaken. Such studies are not included in this summary unless the research is considered to be of general applicability to the industry's activities.

3.3.1 MAMMAL STUDIES

3.3.1.1 Bowhead Whales

The bowhead whale (Plate 3-12), classified as an endangered species, uses some of the same area of the Beaufort Sea as is presently being explored by the oil and gas industry. In order to gain a better understanding of the species, three programs, one of which will continue into 1983, have been undertaken to determine the presence and distribution of these whales in the Beaufort Sea.

The first study is being carried out by the proponents and covers the area from the Yukon - Northwest Territories border to Cape Bathurst (Figure 2-2), extending seaward to the 100 m depth contour. This project will conclude later in 1982. A preliminary evaluation of the data collected to date indicates that industry activities have not influenced the seasonal abundance and distribution of the bowhead whale population. The need for additional bowhead whale studies beyond 1982 will be determined on the basis of a detailed evaluation of the final results of the present program. There may also be a need to do further studies on bowhead whales in the Amundsen Gulf region in relation to future shipping activities.

The bowhead whale project described above was undertaken in 1981 in conjunction with a similar study being carried out by several U.S. oil companies led by Standard Oil Company of Ohio (SOHIO). Their study region covered Amundsen Gulf and the remainder of the Canadian Beaufort Sea west of the Yukon - Northwest Territories border (Figure 2-1). In addition to this research program, the U.S. Bureau of Land Management conducted a two-year (1980

TABLE 3.3-1

PRESENT AND PROPOSED FUTURE BIOLOGICAL STUDIES DIRECTED AT POTENTIAL ACTIVITIES

Activity	Bowhead Whales	Beluga Whales	Seals	Walruses	Polar Bears	Porcupine Caribou	Bears	Foxes	Birds	Fish	Aquatic Habitats	Marine Benthic Invertebrates	Biological Oceanography
1. Offshore Exploration Facilities	X	X	X		X							X	X
2. *Offshore Production* Facilities	X	X	X		X							X	X
3. Island Construction	X	X								X		X	X
4. Onshore Production						X	X	X	X	X	X		
5. Dredging	X	X										X	X
6. Shorebased Facilities						X	X	X	X	X	X		
7. Marine Transport and Icebreaking	X	X	X	X									X
8. Subsea Pipelines												X	X
9. *Terrestrial Pipelines*						X	X	X	X	X	X		
10. Air Traffic									X				
11. Common Disturbances - underwater sound - wastes	X	X	X	X						X	X	X	X
12. Oil Spills and Hazardous Waste Spills	X	X	X	X	X				X	X	X	X	X
13. Renewable Resource Harvesting	X	X	X	X	X	X		X		X			

PLATE 3-12 *The bowhead whale utilizes some of the same area of the Beaufort Sea as that being explored for oil and gas. Preliminary study results indicate that present activity has not affected abundance and distribution of the whale population. (Courtesy LGL Ltd.).*

and 1981) bowhead whale behaviour study which encompassed the Canadian Beaufort Sea wherever bowhead whales were known to occur. This study is now being extended into a third year.

3.3.1.2 Beluga Whale Monitoring

Esso Resources Canada Limited (joined in 1980 by Dome Petroleum Limited and Gulf Canada Resources Inc.) has been studying beluga whales (Plate 3-13) in the Mackenzie Delta area for the past decade. The purposes of this program have been to document the distribution and abundance of the whales, to identify possible conflicts between industrial activities and the whales, and to recommend mitigative measures should such conflicts arise.

Between 1978 and 1980 very few beluga whales frequented Kugmallit Bay (Figure 2-2) off the Mackenzie River mouth, which is traditionally the main bel-

PLATE 3-13 *Beluga whales have been monitored in the Mackenzie estuary for the past decade. Based on these studies and compliance with recommended mitigation measures, impacts to the whales have generally been negligible. (Courtesy Northwest Territories Government).*

uga hunting area for residents of the Tuktoyaktuk region. Most of the approximately 7,000 belugas found in the Mackenzie estuary occurred on the western side of the Delta in Niakunak Bay (Figure 2-2). Industry monitoring programs, which began in 1972 and are ongoing, indicate that late ice break-up during the late 1970's across the mouth of Kugmallit Bay encouraged the white whales to enter the already ice-free Niakunak Bay instead of Kugmallit Bay, resulting in a poor hunt. It was the opinion of the Inuit hunters that the offshore islands constructed by the oil industry had caused the change in ice conditions at the mouth of Kugmallit Bay. In January 1981 a task force of representatives from Tuktoyaktuk and the petroleum industry was established to examine this question (see Section 3.2.1.2). In their final report (Felix et al., 1982) the Task Force concluded that there was no evidence of changes in the over-all landfast ice patterns or extent caused by the artificial islands constructed to date.

The proponents will continue to monitor the beluga whales in the region in order to assess the effects of ice break-up on the patterns and timing of beluga entries into the Mackenzie estuary. They will also document the number of whales using the area and the number of whales being harvested. This program is designed to help reduce or prevent adverse interactions between industry and whales or whale hunters. As year-round shipping through the Northwest Passage develops, appropriate whale monitoring programs will be carried out to evaluate the possible effects of this activity on whale behaviour.

3.3.1.3 Seals

Seals (Plate 3-14), particularly ringed seals, are an important marine mammal resource in the Canadian Arctic. Seals are hunted extensively by the Inuit, and provide a food source for polar bears, which are also a resource for northerners.

Past studies of seal populations through an aerial survey program conducted by the Canadian Wildlife Service (CWS) have provided an excellent record of ringed seal population abundance and its fluctuations in the Beaufort Sea region.

Since 1980, the proponents have provided funds to CWS to continue their studies on the abundance and distribution of seals and their relationship to polar bear populations in the Northwest Passage (from Amundsen Gulf to Barrow Strait; Figures 2-1 and 2-3), and to monitor the status of seal populations in the southeastern Beaufort Sea. Also, in 1982 the proponents began supporting studies of ringed and bearded seals in Prince of Wales Strait being conducted by the Arctic Biological Station. These programs are expected to continue in the future.

PLATE 3-14 *Seals are an important marine mammal resource in the Canadian Arctic.*

A preliminary study done in the spring of 1980 indicated that low level activity by an icebreaking ship in the fast ice zone adjacent to McKinley Bay (Figure 2-2) had no discernable effect on the abundance and distribution of ringed seals (Alliston, 1980). It is expected that the level of icebreaking activity in fast ice zones during winter and spring will increase in future years. As a result, the proponents propose to carry out further studies similar to that conducted in 1980. These would be done at intervals to monitor and assess the response, in terms of abundance and distribution, of ringed seals to this increased activity.

In the Eastern Arctic, real-time data analyses will be used to determine the annual location of hooded seal whelping patches so that they can be avoided by vessels once shipping begins.

3.3.1.4 Underwater Sound

The possible effects of underwater sound on marine mammals are of concern with respect to the development of offshore Beaufort Sea hydrocarbon resources and their transportation to southern markets by icebreaking tankers. Research conducted in the Beaufort Sea has indicated that whales and seals have not been affected by the level of offshore activity to date (Volume 4). Despite the increasing levels of offshore activity, underwater sound levels in the Beaufort Sea are generally near background except in the immediate vicinity of industrial activities (Volume 4). However, it is difficult to predict with certainty how underwater sound levels will change over time with increasing levels of activity. Therefore, the proponents will continue to carry out studies as appropriate, to monitor the effects of underwater sound from petroleum industry activities on marine mammals in both the Beaufort Sea region and along the primary shipping corridor.

As part of an Arctic Pilot Project study (see Section 2.1.10), ship designers are undertaking tests to maximize the efficiency of the propellers to be used on Arctic ships of the future. The more efficient the propeller is, the quieter it will be. The results of these tests will be used to design propellers which minimize sound generation. Expert testimony presented to the National Energy Board hearings on this project indicated that the large icebreaking ships needed for this project are not likely to be any noisier, and may be quieter, than ships presently operating in areas where marine mammals are abundant (see Volume 4, Chapter 4).

3.3.1.5 Polar Bears

As island building technology has developed, exploration from artificial islands in the Beaufort Sea has moved further offshore. The Tarsiut N-44 and Issungnak islands (Figure 2-2) were constructed in the southern part of the transition ice zone of the Beaufort Sea, and in some years they may be in landfast ice. The transition zone is prime habitat for polar bears (Plate 3-15). The Northwest Territories Wildlife Service has expressed concern that increasing numbers of bears, attracted by the activity on the islands, may be shot by polar bear monitors protecting personnel.

PLATE 3-15 *Polar bears are being studied in relation to offshore islands, in order to determine if the activity at such sites is attracting bears. (Courtesy Northwest Territories Government).*

As the polar bear quotas for native hunting are strictly controlled, government biologists fear that a strain between the native peoples and industry might develop should the numbers of bears being killed by monitors be so great as to reduce the stock available for native hunting.

As a result, Dome Petroleum Limited, Gulf Canada Resources Inc. and the Northwest Territories Wildlife Service have initiated a study to determine the abundance, distribution and behaviour of polar bears in the vicinity of the Tarsiut N-44 island during mid to late winter of 1982. The direction and nature of this program in subsequent years will be determined by the results of the present study.

3.3.1.6 Porcupine Caribou

The Porcupine caribou herd (Plate 3-16) has been the focus of detailed study since 1971. The international status of the herd, together with concerns regarding population stability, overhunting, predation and industry pressure, has led numerous organizations (including the Yukon and Alaskan governments, Canadian Wildlife Service, CARC and industry) to conduct research on this herd. As a result, a great deal of data have been collected on the herd's size, distribution and migratory behaviour.

A number of possible industry facilities, including a base at Stokes Point (Figure 2-2), or King Point (Figure 2-2), a rock quarry at Mt. Sedgewick (Figure 2-2) and several access roads, may eventually be built within the general region of the herd's migration routes and calving areas (see Volume 3A). A program will be designed to monitor caribou activities in relation to proposed developments when sites are selected. This monitoring program will allow for the development of appropriate mitigative measures to ensure that caribou will not be adversely affected by project facilities.

3.3.1.7 Carnivore Den Surveys

As described in Volumes 3A and 3C, many areas along the banks of the Mackenzie River and those of lakes and streams in the Delta area are used by carnivores (particularly bears, foxes and wolves) as denning and rearing sites. Such sites are often traditional and suitable sites may be limited in certain areas.

In order to minimize the loss of denning sites and to avoid denning areas wherever possible, the proponents propose to conduct active den surveys in all areas selected for development prior to the construction of facilities, including the laying of a pipeline

PLATE 3-16 *Porcupine caribou have been the focus of detailed study by various groups since 1971. (Courtesy Northwest Territories Government)*

along the Mackenzie Valley corridor. Final selection of facility sites and pipeline alignment would then take into account the locations of carnivore dens and avoid their disturbance wherever possible.

3.3.2 BIRD STUDIES

3.3.2.1 Waterfowl

Between late August and late September up to 500,000 lesser snow geese (the number may vary substantially depending on nesting success and weather) may stage on the North Slope of the Northwest Territories, Yukon and Alaska (Figure 2-1) where they feed and rest prior to their southward autumn migration. A number of inland staging areas have been identified between the Trail River and Big Fish Creek (Figure 2-2). Since snow geese are considered to be sensitive to disturbance during autumn staging, the proponents propose to monitor identified staging areas which might be affected by their activities. Appropriate mitigative measures would be undertaken should any difficulty become apparent.

A study of lesser snow geese is presently being sponsored by the proponents in relation to concerns by residents that snow geese did not stage in large numbers at the mouth of the East Channel of the Mackenzie River (Figure 2-2) in the spring of 1981 owing to increased aircraft activity at Tuktoyaktuk. However, the Canadian Wildlife Service indicated that an early spring thaw was responsible for the change in staging areas by the geese. In order to better understand these behavioural changes, the proponents are providing funding to assist CWS in consolidating and analyzing the data this government agency has gathered on lesser snow geese between 1958 and 1981. This data base will provide a reliable background for comparison with any future alterations in the behaviour of snow geese.

3.3.2.2 Raptors

A wide variety of raptors, including peregrine falcons, gyrfalcons, golden eagles, bald eagles (Plate 3-17), osprey and rough-legged hawks, are known to nest within the region of the Mackenzie River Valley proposed as a pipeline corridor (Figure 3-4). Most nests are traditional, being used year after year. Of the above species, the bald eagle, golden eagle and osprey have been recorded in reduced numbers in recent years. The gyrfalcon apparently occurs naturally in low numbers, while the peregrine falcon is listed as an endangered species in both Canada and the United States.

Because of the status of these species, industry will cooperate with government agencies in identifying active raptor habitat within and adjacent to the pro-

PLATE 3-17 *Raptors, such as the bald eagle shown here, are known to nest within the region of the Mackenzie River Valley proposed as a pipeline corridor. Studies will be undertaken in order to minimize disturbance of these, and other, raptors. (Courtesy, J. Kristensen, LGL Ltd.)*

posed Mackenzie Valley pipeline corridor and other onshore facility sites, in order to devise and implement appropriate mitigative measures where necessary.

3.3.3 FISH AND FISH HABITAT STUDIES

Substantial information has been collected on the diversity, biological requirements, abundance and distribution of fish species within the Beafort Sea - Mackenzie Delta region (Volume 3A, 3C). However, a detailed project design may require additional site-specific data. To address major fisheries concerns, monitoring and research programs will be developed and implemented by the industry in consultation with the Department of Fisheries and Oceans. Such programs will be conducted when specific development plans are formulated. Proposed programs related to pipeline installation follow.

3.3.3.1 Fish Surveys

Site-specific studies will be undertaken of the fish populations in areas proposed for under-ice blasting during pipeline construction. Such surveys will document the species and their abundance in order to implement appropriate mitigative measures once blasting sites are identified and before development begins.

3.3.3.2 Fish Habitat Studies

Studies will be done on the availability of adequate water sources for site-specific projects. These water sources will then be analyzed to determine the presence of important fish habitats such as spawning, rearing or overwintering areas. Should certain areas be determined to be important, alternate water sources will be found.

Site-specific studies will be undertaken to determine the best possible pipeline alignment for river crossings in order to prevent or minimize adverse effects on fish and the aquatic environment. The industry is aware of the detrimental effects of erosion on aquatic ecosystems (see Volume 4). Investigations will be conducted to compare suspended sediment concentrations in watercourses with preconstruction levels. During the building of the line, sediment analyses will be done upstream and downstream of the crossing sites and, should a problem be found, further appropriate mitigative measures will be instituted. Reclamation to control erosion will generally be complete within a year of pipeline construction, and these erosion control measures will be monitored to ensure that they are effective.

In addition to sediment studies, other hydrological and water quality analyses will be carried out during pipeline construction to ensure that the aquatic environment remains suitable for fish. Streamflow and water-level records will be made throughout the pipeline construction period. Dissolved oxygen, water temperature, dissolved nutrients (particularly in waste disposal areas) and bottom sediment contaminants will be monitored during development. Appropriate mitigative measures will be undertaken should adverse impacts to aquatic life be ascertained.

During the laying of the pipeline, regular monitoring will take place to assess and ensure that continuous fish passage is maintained throughout the open-water season. All fish passage structures will be regularly inspected, de-iced as required and maintained to government specifications. In addition, observations will be made, and records kept, of water velocities through culverts and diversions to establish whether or not velocities exceed the capabilities of fish to swim upstream against the flow.

3.3.4 BENTHIC INVERTEBRATE STUDIES

3.3.4.1 Dredging Effects on Benthic Invertebrates

The temporary loss of benthic communities at dredge borrow sites and at island construction sites has been the subject of many research projects throughout the world (see Volume 4). Dome Petroleum Limited and Gulf Canada Resources Inc. have gathered background data on benthic faunas at borrow sites and at the Tarsiut N-44 island construction site (Figure 2-2), while Esso Resources Canada Limited has carried out similar studies at their Issungnak island (Figure 2-2). The former project, initiated in 1981, was designed to obtain quantitative information on benthic communities at the various locations, and to document recolonization of the borrow sites and the

berm of the newly constructed island. This project will continue in 1982. The Esso studies have already been completed.

3.3.4.2 Biological Oceanographic Studies

Considerable data have been gathered on the water quality, phytoplankton, zooplankton and benthos of the offshore Beaufort Sea, particularly during the open-water period (see Volume 3). The proponents undertook concurrent studies of the physical, chemical and biological oceanographic features of selected locations in the offshore Beaufort Sea and Mackenzie Bay throughout the winter of 1981. This work will be completed in 1982, but further work will be undertaken in the future depending on identified needs.

3.4 MARINE ENVIRONMENTAL MONITORING PROGRAM FOR THE TUKTOYAKTUK PENINSULA

To determine whether or not there are environmental effects associated with petroleum industry activities in Tuktoyaktuk Harbour and McKinley Bay (Figure 2-2), Dome Petroleum Limited will conduct a five-year marine monitoring program of these areas. The project, which began in July, 1982, will monitor the sediments and the benthic organisms (Plate 3-18) for hydrocarbon and heavy metal up-take and will also determine community structure of bottom dwelling organisms. During the study period the project is expected to be extended to various other locations and other parameters may be added to the list of analyses as necessary. The project has been designed to provide early warning of possible chronic low level hydrocarbon pollution should it begin to occur.

3.5 ACCIDENTAL SPILLS PROGRAMS

A great deal of research and development work has been done in Canada to understand and deal with possible oil spills in the Arctic. The first major undertaking was the Beaufort Sea Project, which was an environmental assessment of the proposed drillship exploration programs in the Beaufort Sea (see Section 2.2.5). The Beaufort Sea Project prompted further research and development projects by the proponents and by government. One purpose of these projects was to develop oilspill countermeasures for the Beaufort Sea and to ensure that appropriate equipment be available to respond to oil spills (see Plate 3-19). Close coordination and cooperation

PLATE 3-18 *Benthic organisms, such as the isopod pictured here, will be studied in relation to possible hydrocarbon up-take, in order to detect possible pollution at an early stage and to institute mitigative measures where necessary. (Courtesy Arctic Laboratories Limited)*

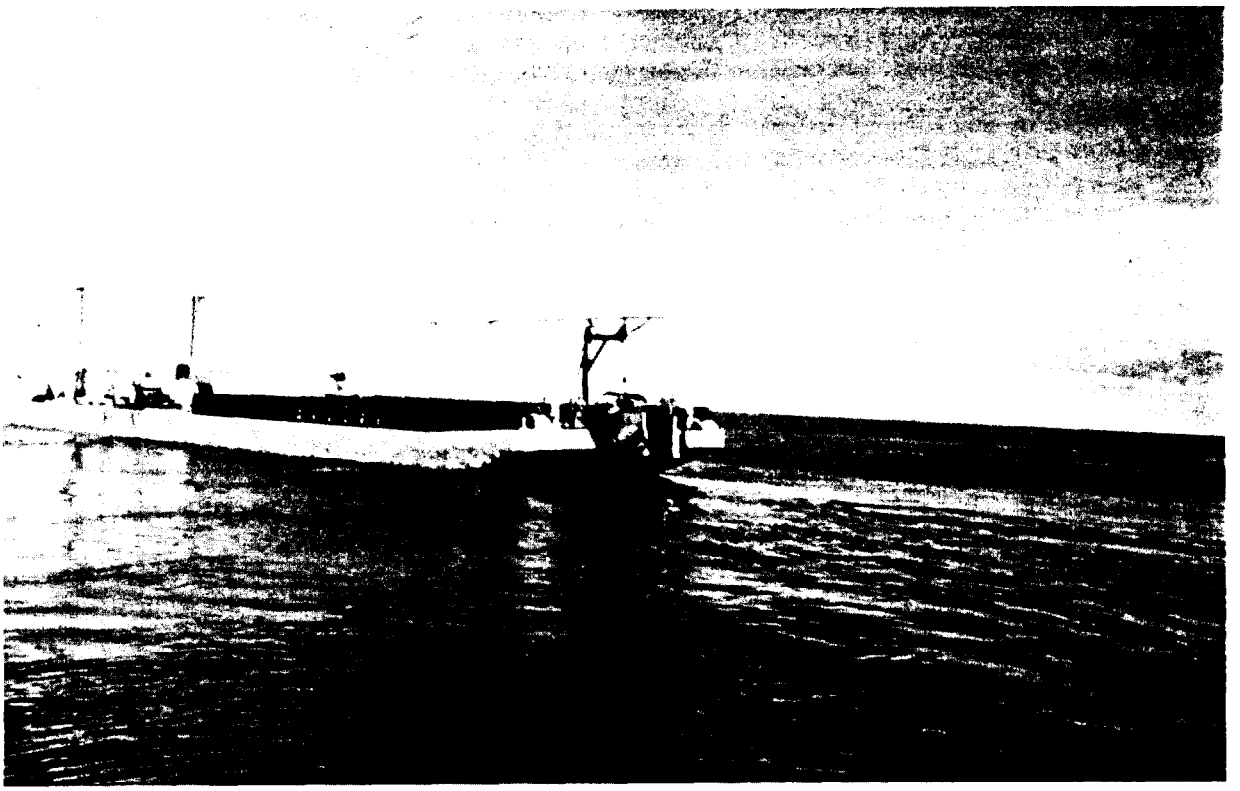


PLATE 3-19 *The "oilspill response barge" pictured here is equipped with a variety of countermeasure devices and is available to respond to an oil spill.*

between participants has been ensured through joint industry - government working groups set up by the Arctic Petroleum Operators' Association (APOA), the Canadian Offshore Oil Spill Response Association (COOSRA), and Environment Canada's Arctic Marine Oil Spill Program (AMOP) (see Sections 2.1.5, 2.1.7 and 2.2.6, respectively).

Past oilspill research is described in Volume 6. In the future, oilspill countermeasures will be adapted to production and transportation, with new equipment and methods being developed as required. The section which follows summarizes ongoing and future oilspill research for the Canadian Arctic. It should be recognized that the areas of research discussed herein are based on the current 'state-of-the-art' for oilspill countermeasures. As new knowledge is gained the objectives of specific projects may change or the entire study may become obsolete. It is also probable that areas of research not yet identified will also be undertaken.

3.5.1 EQUIPMENT DEVELOPMENT

3.5.1.1 Air-Portable Incinerator

Most of the Arctic coastline is accessible only by helicopter. Heavy equipment for shoreline oilspill clean-up could not be moved to such remote areas should a spill occur, and clean-up would, therefore, have to be by manual means. Once the oil and oiled debris had been collected, disposal would be necessary. Heli-portable burners and kilns to incinerate liquid oil and oiled sand are available, but none are designed to handle oiled debris.

COOSRA and AMOP are presently developing a light weight, heliportable (in two loads), oilspill debris incinerator which will be capable of combusting up to one tonne per hour of oiled debris such as seaweed and driftwood. One or more of these devices could be deployed in any area of the Arctic where shoreline clean-up parties were working, thus eliminating the requirement to store or bury oiled debris. Development of this equipment is expected to be completed by early 1983.

3.5.1.2 Sub-Sea Containment

Sub-sea containment systems have been used at wells located in the Santa Barbara Channel and in the Gulf of Mexico as a method for containing oil and gas. Such systems could have application in the Beaufort Sea. Research and development of such systems have been ongoing for several years (Milgram, 1981; Otter Group, 1981; German and Milne Inc., 1982), with both COOSRA and AMOP continuing to fund additional studies.

The system (see Figure 3-5) proposed for the Beaufort Sea drilling area consists of a collector positioned over the blowout which would direct the oil, gas and any entrained water through one or more flexible risers to a vertically-oriented floating cylinder. This cylinder would be moored and designed to resist waves and currents, as well as thinner first year ice up to two metres thick and first year ice ridges. Should thicker ice be encountered, the cylinder would be pushed under the ice surface, breaking through once the thicker ice had passed.

To date the areas of investigation of this system have included the flow in the risers, system safety, model tests, environmental loads, *in situ* burning and feasibility of deployment. Preliminary results have indicated that, although it is theoretically possible to build such a containment system for year-round operation in the Beaufort Sea, deployment would be difficult. This technology will require further development before such containment systems can be employed in the Arctic.

A series of ¼ scale-model tests was recently completed by the Massachusetts Institute of Technology (MIT), with the support of the U.S. Geological Survey, AMOP and COOSRA. These tests were to assess the system's performance and, in particular, to quantify water entrainment rates. A knowledge of water entrainment rates is required in order to determine the optimal size for the risers and to assess the feasibility of full-scale incineration and/or separation systems. The direction of future research on sub-sea containment systems, including smaller systems for open water and freeze-up conditions in the Beaufort Sea, will be determined based on the results and conclusions of these tests.

3.5.2 SHORELINE RESEARCH

One of the most important aspects of the response to an oil spill is the protection, clean-up and restoration of shorelines. To improve methods for responding to shoreline oil pollution, the following research will be undertaken.

3.5.2.1 Tanker Route Shoreline Protection, Clean-up and Restoration Manual

To be able to respond efficiently should a tanker accident and subsequent oil spill occur, a complete environmental database manual for the coastline of the proposed petroleum shipping route will be developed. This manual, to be prepared by the proponents, will be similar to one already available for the Beaufort Sea coastline (Worbets, 1979).

FIGURE 3-5 *Sub-sea containment systems, like the one illustrated here, could have an application in the Beaufort Sea.*

The manual would rank shoreline sensitivity to oiling, based on the existing information on geological, biological and human sensitivities. As well, area-specific protection and clean-up schemes, based on such factors as access, distance from support facilities and shoreline type, would be developed for regions ranked as "sensitive." This manual, in conjunction with coastal videotape surveys (see Section 3.5.2.2), will provide a valuable contingency planning tool and quick reference in the unlikely event of a spill.

3.5.2.2 Coastal Videotape Surveys

A set of annotated videotapes of the shorelines of the proposed primary petroleum shipping route (see Figure 3-1) eastward from Resolute Bay will complete an existing library of tapes which cover the region from the Alaska-Yukon border through Amundsen Gulf, Prince of Wales Strait, M'Clure Strait and Viscount Melville Sound (Woodward-Clyde Consultants, 1980; 1982).

Videotape coastal surveys are done from a low-flying aircraft using portable TV cameras and a video tape recorder. When the field tapes are completed they are annotated with a description of shoreline type, biological sensitivity, and applicable oilspill countermeasures.

In the event of a spill, the tapes would provide On-Scene Commanders and response-team members an opportunity to assess the nature of affected shorelines and determine site-specific clean-up strategies prior to the deployment of equipment. They would also be useful contingency planning and training tools. This project will probably be completed by the end of 1984.

3.5.2.3 Shoreline Spill Response Techniques

Despite recent advances in oilspill countermeasure equipment technology, response techniques still rely heavily on manual labour.

Although a capability to clean and restore Arctic shorelines manually exists, improvements could be made to make the process faster and more effective. Research on techniques to protect, clean-up and restore Arctic shorelines using mechanical devices mounted on suitable vehicles (such as ARGO all-terrain vehicles or propane-powered BOBCATS) will be undertaken. This multi-faceted program is expected to continue for some time to optimize the efficiency and effectiveness of countermeasure equipment and systems.

3.5.3 COMBUSTION RESEARCH

In situ combustion of oil has proven to be one of the most effective Arctic oilspill countermeasures. The work to date has revolved around burning of oil in ice. Combustion could also be applicable to tanker spills.

3.5.3.1 Burning of Oil in Tankers

In the unlikely event of a major accident involving an Arctic tanker, one technique to minimize oil pollution would be to burn the oil in the cargo tanks. Burning in a tanker is a drastic spill prevention technique which involves the destruction of a valuable vessel and would only be done as a "last resort" response, decided upon in conjunction with government. Oilspill history around the world has shown that there have been accidents in the past where this kind of action has greatly reduced pollution and the costs for clean-up. An example was an accident involving the BURMAH AGATE, in which burning of the oil in the ship's tanks prevented a major oil spill (Goodier *et al.*, 1981).

The first phase of this research is to develop a set of criteria for when and how a tanker, involved in an accident in the Beaufort Sea or in transit, could be set on fire. Such factors as safety, salvageability, cost, insurance, other options in spill prevention and clean-up techniques, logistics and potential pollution would be addressed. The second part of the project will study the operational aspects of burning in tankers, including ignition, heat produced, provision of air and safety.

This project, which is scheduled to begin in mid 1983 and be completed in late 1984, will require close liaison and cooperation with several government departments, including the Ministry of Transport, Canadian Coast Guard, the Department of Environment, and the Department of Indian Affairs and Northern Development.

3.5.4 CONTINGENCY PLANNING

To effectively respond to an oil spill, a plan must be available which delineates responsibilities, authority, communications and techniques. The following outlines the proponents' spill contingency planning programs, a complete discussion of which can be found in Volume 6.

3.5.4.1 Contingency Plan for Production and Transportation

Before petroleum production and transport proceeds in Canada's Arctic, industry will have in place a detailed oilspill contingency plan to describe their response to accidental spills. The plan, possibly in two documents (one to cover production installations and the other to deal with transportation systems - both tankers and pipelines), will detail respon-

sibilities, reporting networks, communications, countermeasure techniques and all other aspects of spill response. The plan will be based on the proponents' existing contingency plans for exploration activities and will be developed in close cooperation with government regulatory agencies.

3.5.4.2 Spill Response Equipment for Production Installations and Transportation Systems

Spill response equipment is continuously evaluated and stockpiled to ensure that resources are readily available nearby to respond to an accidental spill. Each phase of development, from construction of exploration islands through to production facilities and transportation systems (both tankers and pipelines), will be analyzed to determine the most suitable spill response equipment to be stockpiled and the best location for its storage in order that response to a spill is prompt and efficient.

In the design of each development component and transportation plan, all alternatives for spill clean-up will be assessed. Existing equipment will be appraised for its suitability and any shortcomings will be identified to allow specification of further research needs. Stockpile components and locations will be recommended, and the relative merits of locating some or all of the required equipment on production installations or tankers will be addressed. This activity will encompass the Beaufort Sea, Mackenzie Delta and all selected transportation routes, and is expected to be in place by the start up of production.

3.5.5 FIELD PROGRAMS

To fully assess Arctic oilspill countermeasure equipment, field tests must be carried out under controlled conditions.

3.5.5.1 Emulsions-In-Ice Study

Much is known about the fate and behaviour of oil discharged into or under ice. It has been shown that fresh oil (as from a sub-sea blowout) discharged under first year ice is quickly encapsulated in the growing ice sheet and appears on the ice surface during spring melt. The oil appears in melt pools where it can be burned *in situ* using air-deployable igniters (Dickins and Buist, 1981). However, little is known of the fate of oil when it is emulsified with water.

As part of the COOSRA research program, a project was recently undertaken to determine whether or not water-in-crude-oil emulsions, spilled under first year ice, would appear on the ice surface in spring and in a form suitable for clean-up by *in situ* burning. The monitoring phase of this project is presently taking place. The appearance of both oil (alone) and oil-water emulsions are being measured and compared. The results of this ongoing program will aid in assessing difficulties that might arise in handling oil-water emulsions in a real spill situation. The final report will be available in 1982.

3.5.5.2 Fire-Proof Boom Field Trials

A boom, constructed of stainless steel, has been developed through COOSRA for use under Arctic conditions. This device can thicken and contain burning oil at sea, thus allowing for *in situ* disposal of much of the oil (Plate 3-20; McAllister and Buist, 1981).

The boom has been tank tested, but in order to fully assess its capability to survive long periods at sea a field trial will be conducted. Sixty metres of the boom will be deployed in an exposed offshore location for a period of thirty days. Should these trials, scheduled for completion by late 1982, prove successful, the fire-proof boom will become a valuable addition to Arctic oilspill countermeasure resources.

3.5.5.3 Reciprocating Kiln Field Trials

A reciprocating kiln was developed and tested by AMOP. This device, which contains a rocking tube in which oiled sand is tumbled and burned, was used in the oilspill clean-up following the KURDISTAN accident (Gill and Stevens, 1980).

This original heli-portable reciprocating kiln design has been modified to substantially extend its operating life. The modified design will be field tested in 1982/83 to confirm its ability to clean oiled beach material.

3.5.5.4 Arctic Skimmer Field Trials

As illustrated in Plate 3-21, a skimmer, specifically designed to recover oil from cold Arctic waters, has been successfully tested on the east coast and in a test tank. The Beaufort Sea Co-op has proposed to evaluate the newly purchased Arctic skimmer in the Beaufort Sea using Beaufort crude oil. The Arctic skimmer will be taken offshore and will undergo a rigorous series of durability, reliability and oil recovery trials. This work is scheduled to be carried out and completed during 1982.

3.5.6 OILSPILL REMOTE SENSING AND TRACKING

The monitoring and tracking of oil spills at sea by the use of remote sensing may be an attractive means of supplementing, or in some cases replacing, conventional tracking techniques such as the following of oilspill drifter buoys. The research described herein

PLATE 3-20 *A fire-proof boom, shown here undergoing tank testing should prove to be a valuable addition to Arctic oilspill countermeasure equipment.*

PLATE 3-21 *The Arctic skimmer illustrated here is designed to recover oil from cold Arctic waters.*

will be undertaken to improve the capability to detect, track and monitor oil in Arctic waters, with a view to having suitable remote sensing instrumentation in place as soon as practicable.

3.5.6.1 Oil On Water

There are several sensing methods presently available to detect oil on water, including radar, passive microwave radiometry, thermal infra-red sensing, and ultra-violet techniques (such as laser fluorosensing) (McColl *et al.*, 1982). For the immediate future it is likely that tracking of oil on water will be most effective using an appropriate mix of these techniques.

A study to establish the optimal complement of sensors and their best method of use is planned as part of a larger remote sensing development program. Further refinements are required in data processing to enhance the capabilities of remote sensing and to further extend their operational ranges. New technology will also be evaluated as it becomes available.

3.5.6.2 Oil In and Under Ice

Encouraging results have been achieved using impulse radar, mounted on a sled, to detect oil in and under level first year ice (Goobie *et al.*, 1981). Although this system cannot be regarded as having reached operational status, it will continue to be investigated by the oil industry.

Several other methods, including acoustic signals, electro-resistivity measurements, low frequency radar techniques, ultra-violet techniques and laser fluorosensors, have been proposed for detecting oil in and under ice. Research in this field will assess all of these methods and any new techniques as they become available, in an attempt to develop a sensor capable of detecting oil in and under a variety of sea ice types.

3.5.6.3 Oilspill Tracking and Prediction Modelling

There are a wide variety of computer oilspill tracking models, one of which was used to generate the example spill trajectories found in Volume 6. Most of the available models, including those described in Volume 6, are quite complex, taking into account several major physical and chemical processes that affect oil slicks on water.

Certain areas of data collection and modelling technology could benefit from further research and development. These include the year-round collection of drift data from Arctic waters using oilspill drifter buoys (Spedding, 1982), the physics of near-surface water currents in the Arctic, and the modelling of oil - ice interactions. It is expected that these kinds of studies will form a long term project, the results of which will serve to further refine the capabilities of oilspill tracking models.

3.5.7 DISPERSANT RESEARCH

The effectiveness of oil dispersants under cold Arctic conditions is being investigated through COOSRA, together with research on which coastal locations could benefit from the use of dispersants and how best to apply them. A brief discussion of these subjects follows.

3.5.7.1 Cold Water Dispersants

The effectiveness of dispersants depends upon many factors, including the oil's viscosity, the water temperature, the water salinity, the dispersant's chemical composition, the dispersant's age, the thickness of the ice, and the nature of the mixing process. Dispersant effectiveness and toxicity in cold waters has been or is being investigated by a variety of industry and government groups (Cox and Shultz, 1980; Mackay *et al.*, 1980; IES, 1981). One of these is the Canadian Offshore Aerial Applications Task Force (COAATF), a sub-group of COOSRA, which is studying the effectiveness of aerially-applied dispersants on oil in cold water (Plate 3-22). A number of land tests conducted at Abbottsford, British Columbia and Suffield, Alberta and sea trials off Newfoundland have been done and results indicate that certain chemicals have the potential for use in cold water (Gill and Ross, 1982). As new products become available more testing may be needed.

3.5.7.2 Studies on Areas of Application

The BIOS program (see Section 2.2.6.1) will provide information on the effects of dispersant - oil interactions in an Arctic ecosystem, and will provide insights into the possible toxic effects of such mixtures.

A newly developed dispersant eco-toxicity model (Trudel and Ross, 1982), which evaluates and relates the meteorology, oceanography, bathymetry, biota, oil characteristics, and dispersant characteristics for locations being considered for dispersant use, could become a useful oilspill countermeasure tool. Should this model prove acceptable to the various government regulatory agencies, it will be modified to apply to the Beaufort Sea and the proposed tanker routes. Studies could then be carried out to assess when and where dispersants would and would not be effective. This work is supported by COOSRA and will continue for several years.

3.5.7.3 Techniques for Dispersant Application

Much research and development has gone into the aerial application of dispersants from fixed-wing

PLATE 3-22 *COOSRA is presently studying the effectiveness of aerially-applied oil dispersants on oil in cold water.*

multi-engine aircraft and the spray application of dispersants from various boats. This research will continue and further studies will assess the application of dispersants from containers slung under helicopters.

3.6 SOCIO-ECONOMIC PROGRAMS

Current petroleum industry programs addressing the socio-economic aspects of oil and gas development are directed along three lines. First, there are liaison programs (Plate 3-23) which convey information to northern communities on industry plans; provide for consultation with community governments and more senior levels of government; and develop socio-economic policies to provide northern residents with training, employment and business development opportunities. Second, there are monitoring programs which are designed to ensure that petroleum companies develop a broader understanding of how their activities are affecting, or may affect, regional communities. These studies help the petroleum industry to see a northerner's perception of their activities and of development in general. Such monitoring programs, both formal and informal, have been applied in the Beaufort Sea region to date. Finally, there are research programs which have as their objectives the improvement of the northern socio-economic data base and the provision of a scientific basis for understanding northern economic and social processes.

At present, many of the socio-economic activities consist of liaison and improving the data base on which to build future programs. As petroleum development proceeds there will be a need to emphasize the liaison programs, and these will form part of the existing monitoring programs. These programs will be expanded as necessary.

Information regarding past and present socio-economic programs in Canada's north are discussed in Volume 5. The following discussion deals with the types of research that are presently being carried out or that will be required as Beaufort Sea development proceeds. The results of these programs, together with further discussions with government and local special interest groups, will determine the scope of future projects.

3.6.1 PROGRAMS TO IMPROVE THE DATA BASE

An important aspect of northern socio-economic research is improving the existing data base for northern communities. The information is being used to measure the effect of industry programs upon communities in the region. The oil industry operating

PLATE 3-23 *The petroleum industry presently participates in many community liaison programs, such as the Beaufort Sea Advisory Committee pictured here, in order to monitor the concerns and interests of northern residents in relation to Beaufort Sea development.*

in the Beaufort Sea region is committed to the Federal and Territorial govenments to maximize local and Canadian benefits arising from development. Programs will be continually reviewed in order to ensure that they are relevant, and that the data base is, therefore, of maximum value to all concerned.

Database projects that are presently ongoing, or that may be undertaken in the future, can be divided into five sub-topics: community programs, labour force programs, business development programs, educational programs and renewable resource harvesting programs. Areas of study which are ongoing or are under consideration in each of these sub-topics are discussed.

3.6.1.1 Community

Many northern communities (Plate 3-24) have already been influenced by oil and gas development. Parameters necessary to document the effects on communities include sources of income and employment, expenditure patterns, socio-cultural factors (such as use of native languages), housing, health, use of alcohol and welfare dependence.

Industry continues to cooperate in the compilation of further information through participation in steering groups, through surveys or special studies by government agencies or other appropriate bodies, and by undertaking studies for its own purposes. Such programs are not being conducted for all northern communities, but they are being, or will be, undertaken for those most likely to be affected by industrial development. An example of such a study was that conducted by Hobart and Kupfer (1978) in Coppermine, Northwest Territories (Figure 3-4; see Section 2.1.3).

The compilation of the community data base would involve the collation of all past information to provide the baseline situation in communities of the Beaufort Sea region and other selected locations. Plans would then be made for future surveys, which would in turn provide new data on a year by year basis. Future data could easily be compared with past information, thereby providing a systematic view of how oil and gas development may be altering the regional and local economy or be affecting key social variables. Information systems developed for the community data base would be designed to be closely related to programs proposed for the other four types of database projects described below.

3.6.1.2 Labour Force

One of the most important benefits of Beaufort Sea oil and gas development is the provision of both

PLATE 3-24 *Industry continues to support the gathering of information on communities, such as Norman Wells shown here, in relation to the possible socio-economic effects of oil and gas development.*

permanent and temporary employment to many northern residents, as illustrated in Plate 3-25. In order for the proponents to develop employment programs, data are required on the skills, education, experience and other attributes of individuals in the northern labour force. Such data will need to be both current and comprehensive.

The TERIS system (Section 2.2), operated by the Government of the Northwest Territories, is the first step toward filling this data gap. The petroleum industry intends to begin discussions with the government with a view to improving the TERIS program. These discussions will also include the Government of the Yukon, perhaps resulting in the initiation of a similar system for that region of Canada.

Industrial employment and liaison officers are in continual contact with many northern communities and have held many meetings with residents interested in being employed by the petroleum industry. Information regarding skills, education and experience of individuals is gathered in order to qualitatively and quantitatively evaluate the labour force. This is an ongoing process which will reflect changes in skills and experience over time, and will form the basis for industry's future employment programs in the region.

3.6.1.3 Business Development

An important way in which communities and individuals in the north have been able to benefit from oil and gas exploration is by participation in business ventures. As Beaufort Sea development expands and accelerates, moving increasingly toward hydrocarbon production, there could be large increases in the opportunities for such participation.

Three main types of activities will be continued to ensure that northerners are able to take full advantage of Beaufort Sea development. Firstly, surveys are needed of the extent and variety of existing business firms that may be able to provide goods and services to the oil and gas industry. Secondly, lists of requirements and opportunities presented by the oil and gas industry, and regional activities it may generate, are needed. Thirdly, there is a need for information on government and private programs, including educational and training programs.

Surveys of northern firms and business capabilities have been undertaken on a number of occasions. Some of these surveys have applied to particular communities or regions, while others have covered the whole of one or both of the two northern territories. For example, Esso Resources Canada Limited,

PLATE 3-25 *One of the most important benefits of Beaufort Sea oil and gas development is the provision of both permanent and temporary employment to northern residents.*

through the Norman Wells project, has an extensive knowledge of firms in the Mackenzie Valley and Delta. A recent survey by Dome Petroleum Limited covered the whole of both territories, and will be subject to updating on a frequent basis. Also, Gulf Canada Resources Inc. proposes to maintain, and continually up-date, a northern business register to profile business, its capabilities and available experience. Through the data obtained from these types of surveys, specific research needs on the capability of northern businesses could be identified and methods devised to improve the northern business climate.

3.6.1.4 Educational

Two factors cause education to be of concern to Beaufort Sea development. On the one hand, Beaufort development will require a labour force that is, for the most part, well educated and skilled. The specifications for the better jobs will require at least Grade 10 and more probably high school completion. On the other hand, while northern residents are the people in greatest need of employment from Beaufort development, their level of education is often insufficient for them to be employable at jobs requiring skilled labour.

Several government studies can be undertaken to help resolve this situation, all of which will require close cooperation with industry. More systematically organized data on educational attainment levels of territorial residents who are active in the labour force would be useful. The petroleum industry will continue to develop information on the educational requirements by job category, taking into account such factors as trade entry requirements imposed by unions. Information on training and educational programs, such as that illustrated in Plate 3-26, could also be compiled. Industry would assist by evaluating programs in terms of their usefulness in assisting northerners to expand employment opportunities in Beaufort development. Finally, industry will continue to encourage government to undertake special educational programs (some purely academic and others training oriented) that will make northerners more capable participants in development.

3.6.1.5 Renewable Resource Harvesting

Information on renewable resource harvesting is required for various purposes. Surveys can provide the proponents with needed information regarding routing for facilities such as pipelines and roads in order to reduce impacts to sensitive areas. The information can also be used by government in wildlife management.

The Baffin Region Inuit Association (BRIA) has conducted an annual survey of native resource harvesting (Plate 3-17) in those Eastern Arctic communities which are BRIA members. This survey is now in its third year, data having been compiled for 1980 and 1981. While the BRIA harvesting study does not list the locations of hunting kills, the data could be useful to the developers of nonrenewable resources in avoiding possible land use conflicts.

Initiation of such surveys is being considered for the Beaufort Sea region and the Mackenzie Valley pipeline corridor. In each region the study would likely be undertaken by the appropriate native organization for that area, with cooperation from both government and industry. The project would continue for as many years as it was felt necessary by the parties concerned.

An important concern to northern hunters and trappers relates to the tracks made by icebreaking ships through ice. Specifically, hunters and trappers worry that vessel tracks in ice will result in people being cut off from land, in being unable to reach

PLATE 3-26 *Training programs are one way in which industry assists in making northerners more capable participants in development.*

PLATE 3-27 *BRIA has conducted an annual survey of native resource harvesting since 1980.*

their hunting grounds or in being set adrift on an ice floe cut loose by an icebreaker.

In response to this concern, tests were conducted by a combined northern (Inuit track-crossing group) and southern (ice scientists) research team in the western Arctic in November, 1981, when the ice was approximately 0.6 m thick and the Inuit were just beginning to use the ice; in March, 1982, when the ice was at its thickest (approximately 2 m); and in June, 1982, as the ice was thawing, and many of the Inuit were no longer going out onto the ice for hunting.

In the November and June trials a man could walk across the track after forty-five minutes, while one could cross with a skidoo and komatik after two and a quarter hours. In the March trial, the track was crossed on foot thirty minutes after the icebreaker had passed. Crossing with skidoo and komatik was possible after one and a half hours (Plate 3-28).

Although Inuit representatives from three Eastern Arctic communities participated in the June trials, they felt that ice conditions in the Eastern Arctic differ sufficiently from western Arctic conditions to warrant repeating the trials in the Eastern Arctic. These trials will therefore be conducted in the Eastern Arctic when appropriate.

3.6.2 LAND USE PLANNING

The Federal Government has endorsed the concept of land use planning in the north and the Department of Indian Affairs and Northern Development (DIAND) is now undertaking to make the planning process operational. DIAND intends that land use planning should be comprehensive, integrated and formal, and that there should be public participation in the process. When planning begins, industry will become involved by defining its needs and interests in northern lands.

3.6.3 ARCHAEOLOGICAL AND HISTORICAL RESOURCES

The greatest danger to northern archaeological resources will most likely come from the general increase in population and human activity in the region as development proceeds. In order to ensure that the proposed Mackenzie Valley pipeline alignment and other onshore facility sites will not disturb major archaeological or historical resources, the individual developers will conduct surveys of such resources as project-specific plans develop. Also, while there is little possibility that archaeological resources would be affected by offshore development, including the movement of tankers, the proponents will ensure that they have an adequate knowledge of the location and nature of sites in the Beaufort Sea region and along proposed tanker routes.

PLATE 3-28 *Studies showed that it was possible to cross a ship track left by an icebreaking vessel after 1½ hours under March conditions in the Beaufort Sea. These studies will be repeated in the Eastern Arctic as new ships become available in the future.*

CHAPTER 4

SUMMARY OF PROPOSED RESEARCH-MONITORING PROGRAMS

Table 4-1 presents a summary of the current and future monitoring and research programs discussed in Chapter 3 (excluding socio-economic studies). For the most part, these programs are continuations of ongoing studies to extend and compliment industry's already substantial knowledge base. In ice research, for example, studies have been designed to supplement industry's expertise, with the objective of refining and reducing island and structure design criteria. Also, in some areas of the Beaufort offshore, the experience base is more extensive than in others. In shallow water areas, for example, research needs are minimal and most of the ongoing programs will relate to monitoring. For the most part, new research will focus on deeper water locations.

While Table 4-1 profiles a number of fairly specific projects in a 5 year time frame, it must be recognized that the time frames shown for monitoring or individual project studies are not fixed but are intended to give an indication of the period in which the programs are likely to be undertaken. The actual timing and scope of the programs listed are also subject to change based on the timing of approvals and discussions with government, the communities, scientists and special interest groups.

The final column in the table lists the principal agents, be they government, industry, or some other group who would likely prepare or is proposing to undertake the monitoring or research programs. As is indicated, a wide variety of industry groups and government organizations will be coordinating their efforts to supplement the extensive information base already in existence as evidenced in the seven EIS volumes and all of the reference documents.

The timing of future socio-economic activities have been excluded from the plan because these studies, to a greater extent than the other types of projects, are predicated on the direct support and cooperation of communities and associations as development proceeds.

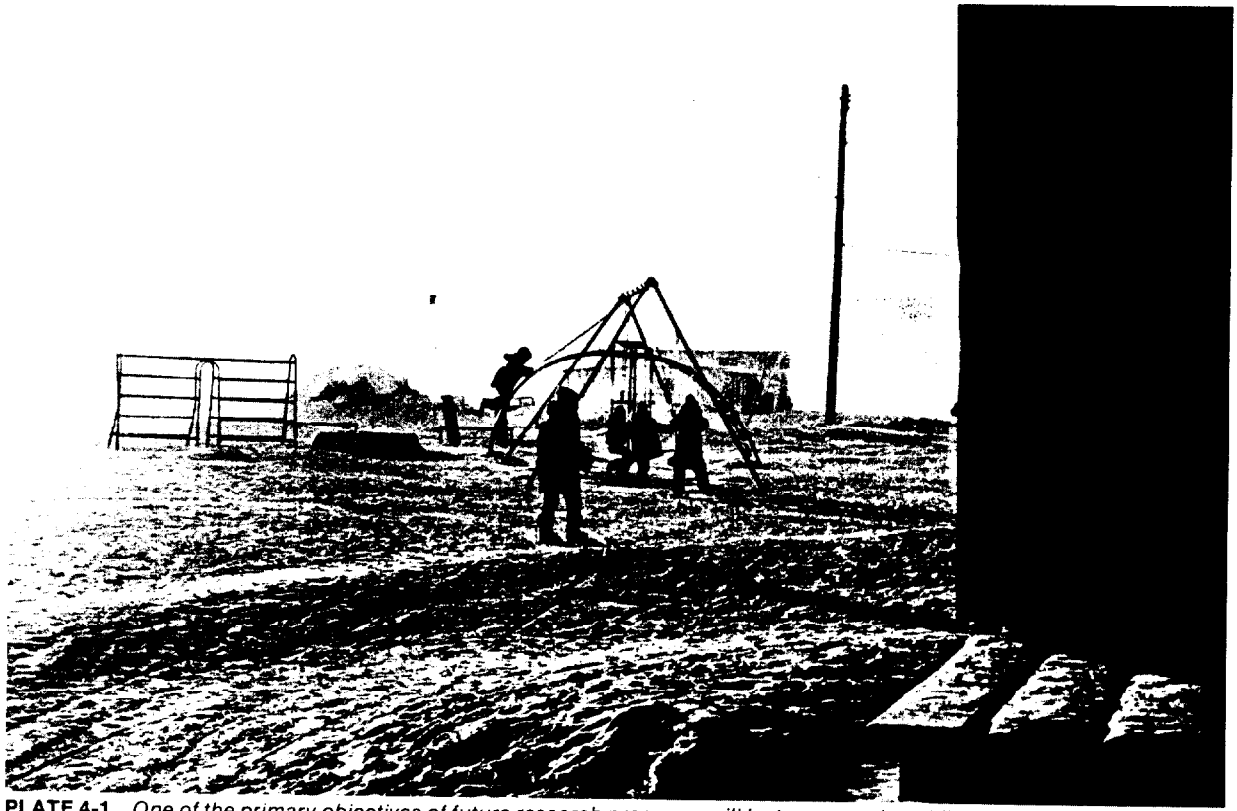


PLATE 4-1 *One of the primary objectives of future research programs will be to ensure that children such as these will gain maximum benefits from Beaufort Sea-Mackenzie Delta development, while retaining much of their traditional lifestyle — in effect having the best of both worlds.*

TABLE 4-1

SUMMARY OF PROPOSED RESEARCH-MONITORING PROGRAMS

Main Subject Heading	Study Section and Title	1982	1983	1984	1985	1986	Principal Participants
ICE RESEARCH-MONITORING	3.2.1.1 Measurement of Ice Loads and Studies of Interactions with Offshore Platforms	▬	▬	▬	▬	▬	EIS Proponents
	3.2.1.2 The Effect of Offshore Drilling Structures on Nearshore Ice Regimes	▬	▬	▬	▬	▬	EIS Proponents
	3.2.1.3 Strength of Multi-Year Ice	▬	▬	▬	▪▪▪		Industry
	3.2.1.4 Driving Forces Within Pack Ice	▬	▬	▬	▪▪▪		Industry
	3.2.1.5 Ice Scour of Underwater Island Slopes	▬	▬	▪▪			Industry
	3.2.1.6 Protection of Offshore Drilling Structures by Ice Rubble	▬	▬	▬	▪▪▪		Industry
	3.2.1.7 Growth and Decay of Ice Rubble Around Offshore Structures	▬	▬	▬	▪▪▪		Industry
	3.2.1.8 Optimal Island Geometries	▬	▬	▬	▪▪▪		Industry
	3.2.1.9 Refinement of Ice Occurrence Statistics and Ice Geometries	▬	▬	▬	▬	▬	Industry / Government
	3.2.1.10 Methods for Breaking Extreme Ice Features	▬	▬	▬	▪▪▪		Industry
	3.2.1.11 Ice Conditions Along Shipping Routes	▬	▬	▬	▪▪▪		Industry / Government
GEO-TECHNICAL RESEARCH	3.2.2.1 Refinement of the General Surficial Seafloor Model	▬	▬	▬	▬	▬	Industry / Government
	3.2.2.2 Development of a Tectonic Model and Refinement of Seismic Design Criteria	▬	▬	▪▪▪			Industry/ Government
	3.2.2.3 Evaluation of Dredged-Fill Stability	▬	▬	▪▪▪			EIS Proponents
	3.2.2.4 Surveys to Identify Potential Seafloor Hazards	▬	▬	▪▪▪			Industry / Government
ICE SCOURING RESEARCH	3.2.3 ICE SCOURING RESEARCH	▬	▬	▬	▪▪▪▪▪▪▪		Industry

▬ PROGRAM PLANNED ▪▪▪▪ TIME-FRAME UNCERTAIN ? TERMINATION DATE UNCERTAIN

TABLE 4-1 (Cont'd)

SUMMARY OF PROPOSED RESEARCH-MONITORING PROGRAMS

Main Subject Heading	Study Section and Title	1982	1983	1984	1985	1986	Principal Participants
REMOTE SENSING AND ICE FORECAST RESEARCH	3.2.4.1 Ice Forecast Research			?			Industry / Government
	3.2.4.2 Ice Surveillance Systems						Industry / Government
	3.2.4.3 Image and Data Processing Systems to Support Tanker Navigation						Industry / Government
WELLBORE RESEARCH	3.2.5.1 Geotechnical Evaluation of the Effect of Permafrost on Casing						Industry
ARTIFICIAL ISLAND CONSTRUC-TION	3.2.6 ARTIFICIAL ISLAND CONSTRUCTION						Industry
OCEANO-GRAPHIC RESEARCH-MONITORING	3.2.7.1 Oceanographic Studies along Proposed Shipping Routes						Industry / Government
	3.2.7.2 Oceanographic Climatological Studies						Industry
	3.2.7.3 Current and Wave Studies in Relation to Submerged Sand-Surface Erosion						Industry
	3.2.7.4 Northwest Passage Program						Industry
	3.2.7.5 Bathymetric Studies					?	Industry / Government
	3.2.7.6 Wave Hindcast Studies					?	Industry
ARCTIC VESSEL RESEARCH	3.2.8.1 Arctic Transportation Systems						Dome Petroleum Ltd./Gulf Canada Resources Inc.
	3.2.8.2 Floating Drilling Systems						EIS Proponents
	3.2.8.3 Arctic Dredges						Dome Petroleum Ltd.
PHYSICAL PROGRAMS RELATED TO ONSHORE DEVELOP-MENT	3.2.9.1 Hydrology	(dependent on development timetable)					Industry / Government
	3.2.9.2 Water Quality	(dependent on development timetable)					Industry / Government
	3.2.9.3 Geology and Soils	(dependent on development timetable)					Industry / Government
	3.2.9.4 Air Quality	(dependent on development timetable)					Industry / Government

TABLE 4-1 (Cont'd)

SUMMARY OF PROPOSED RESEARCH-MONITORING PROGRAMS

Main Subject Heading	Study Section and Title	1982	1983	1984	1985	1986	Principal Participants
MAMMAL STUDIES	3.3.1.1 Bowhead Whales						EIS Proponents / Industry
	3.3.1.2 Beluga Whale Monitoring						EIS Proponents
	3.3.1.3 Seals						EIS Proponents / Government
	3.3.1.4 Underwater Sound		(dependent on development timetable)				Industry
	3.3.1.5 Polar Bears						Industry / Government
	3.3.1.6 Porcupine Caribou		(dependent on development timetable)				Industry / Government
	3.3.1.7 Carnivore Den Surveys		(dependent on development timetable)				Industry / Government
BIRD STUDIES	3.3.2.1 Waterfowl						Industry / Government
	3.3.2.2 Raptors		(dependent on development timetable)				Industry / Government
FISH AND FISH HABITAT STUDIES	3.3.3.1 Fish Surveys		(dependent on development timetable)				Industry / Government
	3.3.3.2 Fish Habitat Studies		(dependent on development timetable)				Industry / Government
BENTHIC INVERTE-BRATE STUDIES	3.3.4.1 Dredging Effects on Benthic Invertebrates						Dome Petroleum Ltd./Gulf Canada Resources Inc.
	3.3.4.2 Biological Oceanographic Studies						EIS Proponents
MARINE ENVIRON-MENTAL MONITORING PROGRAM FOR THE TUKTOYAKTUK PENINSULA	3.4 MARINE ENVIRONMENTAL MONITORING PROGRAM FOR THE TUKTOYAKTUK PENINSULA						Dome Petroleum Ltd.
ACCIDENTAL SPILLS EQUIPMENT DEVELOP-MENT	3.5.1.1 Air-Portable Incinerator						COOSRA
	3.5.1.2 Sub-Sea Containment						COOSRA/AMOP
ACCIDENTAL SPILLS SHORELINE RESEARCH	3.5.2.1 Tanker Route Shoreline Protection, Clean-up and Restoration Manual						EIS Proponents / APOA
	3.5.2.2 Coastal Videotape Surveys						EIS Proponents / APOA
	3.5.2.3 Shoreline Spill Response Techniques						EIS Proponents / APOA

TABLE 4-1 (Cont'd)

SUMMARY OF PROPOSED RESEARCH-MONITORING PROGRAMS

Main Subject Heading	Study Section and Title	1982	1983	1984	1985	1986	Principal Participants
ACCIDENTAL SPILLS COMBUSTION RESEARCH	3.5.3.1 Burning of Oil in Tankers						COOSRA/APOA
ACCIDENTAL SPILLS CONTINGENCY PLANNING	3.5.4.1 Contingency Plan for Production and Transportation						Industry
	3.5.4.2 Spill Response Equipment for Production Installations and Transportation Systems						APOA
ACCIDENTAL SPILLS FIELD RESEARCH	3.5.5.1 Emulsions-In-Ice Study						COOSRA
	3.5.5.2 Fire-Proof Boom Field Trials						COOSRA
	3.5.5.3 Reciprocating Kiln Field Trials						Beaufort Sea Co-op/Dome Petroleum Ltd.
	3.5.5.4 Arctic Skimmer Field Trials						Beaufort Sea Co-op/Dome Petroleum Ltd.
OILSPILL REMOTE SENSING AND TRACKING	3.5.6.1 Oil on Water						APOA
	3.5.6.2 Oil In and Under Ice						APOA/COOSRA
	3.5.6.3 Oilspill Tracking and Prediction Modelling						Industry
DISPERSANT RESEARCH	3.5.7.1 Cold Water Dispersants						COOSRA
	3.5.7.2 Studies on Areas of Application						COOSRA
	3.5.7.3 Techniques for Dispersant Application						COOSRA

REFERENCES

LITERATURE CITED

ACUNS. (undated). Association of Canadian Universities for Northern Studies - history, purpose and activities. Pamphlet publ. by ACUNS, Ottawa.

Alliston, W.G. 1980. The distribution of ringed seals in relation to winter icebreaking activities near McKinley Bay, NWT. January-June, 1980. Unpubl. Rept. by LGL Ltd. for Dome Petroleum Limited. December, 1980.

AMOP. 1979. Experimental oil spills - general plan. Arctic Marine Oilspill Program Rept. 68 pp. + appendices.

Anonymous. 1980. The Polar Gas pipeline: update 1980. Publ. Aff. Dept. Public. May, 1980. 9 pp.

Anonymous. 1982. Proceedings of the Special Committee of the Senate on the Northern Pipeline. Senate of Canada. Issue (19). March 16, 1982. Ottawa.

Anonymous (Dome Petroleum Limited). (undated). Baffin Island Oil Spill (BIOS) project. Dome Petroleum Limited unpubl. information. 16 pp. + appendices.

APOA. 1981. APOA (Arctic Petroleum Operators' Association). Pamphlet, published by APOA. Calgary, Alberta. 1 pp.

APOA. 1982. Background to the Arctic Pilot Project. *In:* APOA Review -Spring/Summer, 1982. 5(1):14.

Arctic Institute of North America. 1982. The Arctic Institute of North America - purpose and objectives. Unpubl. Paper. Calgary, Alberta.

ASTIS. 1979. ASTIS Current Awareness Bulletin. May-June, 1979. Arctic Science and Technology Information System Bulletin (ISSN-0705-8454). 43 pp.

Barnett, D.M. 1980. Letter to M. Psutka re: ALUR Program with attached "A.L.U.R. Program 1980-81" pamphlet. 11 pp. & attachments.

Beaufort Sea Environmental Assessment Panel. 1982. Guidelines for the preparation of an environmental impact statement. Beaufort Sea hydrocarbon production proposal. EAR publ. February, 1982. 42 pp.

Canadian Arctic Gas Pipeline Limited. 1974. Arctic gas - environmental statement (Canada - North of the 60th parallel, Section 14. dN.). An exhibit in support of applications to DIAND for authorization to use land and to N.E.B. for a certificate of public convenience and necessity authorizing the construction of pipeline facilities.

Canadian Arctic Resources Committee. 1981. Northern Perspectives. 9(6). Ottawa.

C-CORE. 1980. Multi-year ice distribution in the Beaufort Sea determined by airborne impulse radar. C-CORE Rept. (80-11). Oct., 1980.

Cox, J.C. and L.A. Shultz. 1980. Oil dispersants for Arctic seas. Prepared for ABSORB by Arctec Incorporated, Maryland.

Dickins, D. and I. Buist. 1981. Oil and gas under sea ice study. Rept. to Dome Petroleum Limited. Calgary.

DIAND. 1981. EAMES: the achievements of an environmental program. Presented by the Department of Indian Affairs and Northern Development and the petroleum industry participants in the EAMES program. Published by DIAND. 37 pp.

Dome Petroleum Limited. 1981a. Fire-proof boom development - OHMSETT Trials. COOSRA Rept. (CS3).

Dome Petroleum Limited. 1981b. Oil and gas under sea ice study, volume 1. COOSRA Rept. (CS4V1).

Dome Petroleum Limited. 1982a. The development and testing of a helicopter portable burner. COOSRA Rept. (CS5).

Dome Petroleum Limited. 1982b. A submission by Dome Petroleum Limited to the Special Committee of the Senate on the Northern Pipeline. Ottawa.

Dome Petroleum Limited, Esso Resources Canada Limited and Gulf Canada Resources Inc. 1980. Beaufort Sea/Mackenzie Delta development plan. November, 1980. unpublished information.

EPOA. 1979. Eastern Offshore News. Publ. by EPOA (Eastcoast Petroleum Operators' Association) Vol. 1. No. 1. Feb., 1979. 8 pp.

Environment Canada and Indian and Northern Affairs Canada. (undated). Northern land use information series pamphlet re: how to order LUIS maps. Canada Map Office, Surveys and Mapping Branch, Dept. Energy, Mines, Res., Ottawa. 1 pp.

Environment-Social Committee. 1974. Mackenzie Valley and northern Yukon pipelines: socio-economic and environmental aspects. Task Force on Northern Oil Develop. Rept. (74-17). Ottawa, Canada. 197 pp.

Environmental Protection Service. 1976. Recommended environmental standards for the design and construction of a Mackenzie Valley gas pipeline. Rept. of EPS, Northwest Region, Environment Canada. November, 1976.

Esso Resources Canada Limited. 1982. A review of Esso Resources western Arctic experience and thoughts regarding resource development in this area. Presented to the Special Committee of the Senate on the Northern Pipeline. February 16, 1982. Ottawa.

Federal Environmental Assessment Review Office. 1979. Lancaster Sound Drilling. Report of the Environmental Assessment Panel. February, 1979. Federal Environmental Assessment and Review Process 7. Ottawa, Canada. 127 pp.

Federal Environmental Assessment Review Office. 1980. Arctic Pilot Project (northern component). Report of the Environmental Assessment Panel. October, 1980. Federal Environmental Assessment and Review Process 14. Ottawa, Canada. 125 pp.

Felix, E., B. Danielewicz, F. Wolke, C. Mansini and D. McGonigal. 1982. Final report of the joint Tuk-Industry Task Force to examine the effects of artificial islands on Beaufort Sea ice.

Freeman, M.R. (editor). 1976a. Land use and occupancy. Inuit Land Use and Occupancy Project. Volume 1. DINA Publ. (QS 8054-001-EE-A1). Thorn Press, Ottawa.

Freeman, M.R. (editor). 1976b. Supporting study. Inuit Land Use and Occupancy Project. Volume 2. DINA Publ. (QS 8054-001-EE-A1). Thorn Press, Ottawa.

Freeman, M.R. (editor). 1976c. Land use atlas. Inuit Land Use and Occupancy Project. Volume 3. DINA Publ. (QS 8054-001-EE-A1). Thorn Press, Ottawa.

Fu, L.L. and B. Holt. 1982. SEASAT views oceans and sea ice with synthetic aperature radar. NASA subcontract. JPL Publ. (81/20) Feb., 1982.

German and Milne Inc. 1982. Subsea blowout containment system concept analysis. Contract Rept. for Environment Canada. EEB-EPS, Montreal. March, 1982.

Gill, S. and C. Ross. 1982. 1981 dispersant application field trial - St. John's, Newfoundland. *In:* Proceedings of the Fifth Arctic Marine Oil Spill Program. June 15 to 17, 1982. Edmonton, Alberta.

Gill, S.D. and G. Stevens. 1980. Use of the TRECAN-PACE oil drum incinerator during the KURDISTAN clean-up operation. AMOP Spill Technology Newsletter. January/February, 1980.

Goobie, G.I., T.E. Laidley and E.M. Reimer. 1981. C-CORE oil spill research activities. *In:* The Proceedings of the Fourth AMOP Conference. June 16-18, 1982. E.P.S. Ottawa. pp. 623-643.

Goodier, J.L. *et al.*, 1981. Combustion: an oilspill mitigation tool. Phase II: the burning of the M/T BURMAH AGATE (ex-Danaland). U.S. Dept. Energy Rept. (DOE/TIC-11471). August, 1981.

Gulf Canada Resources Inc. 1982. Canadian frontier development and transportation scenarios to the year 2000. Presentation to the Special Committee of the Senate on the Northern Pipeline. March 13, 1982. Ottawa.

Hammer, L. 1981. Dome Petroleum Limited: 1981 Beaufort Sea operations evaluation. Rept. of Dome Petroleum Ltd. Dec. 10, 1981. Calgary, Alberta.

Hobart, C.W. and G. Kupfer. 1978. Impact of oil exploration work on an Inuit community. Arctic Anthropology 15(1):58-67.

Hobson, G.D. 1980. Letter to M. Psutka re: Polar Continental Shelf Project with attached material re: earth science services program, PCSP. 1 pp. + attachments.

Hunt, C., R. Millar and D. Tingley. 1979. Legislative alternatives for the establishment of a wilderness area in the northern Yukon. Canadian Arctic Resources Committee. Research Mono. (2). Yukon Series. Ottawa.

IES. 1981. The Proceedings of the International Research Symposium: Chemical Dispersion of Oil Spills. Rept. (EE17). Univ. Toronto.

Imperial Oil Limited, Aquitaine Company of Canada Limited and Canada-Cities Service Ltd. 1978. Environmental impact statement for exploratory drilling in Davis Strait. January, 1978.

Intera. 1981. Fine-scale ice dynamics model for unconsolidated sea ice. Rept. to Atmospheric Environment Service, Environment Canada. Intera Contract Rept. (C79-001). June, 1981.

Keelty, J.M. and S.Y.K. Tam. 1980. Sea ice thickness radar measurements in the Beaufort Sea. Rept. to Transportation Development Centre, Transport Canada. Contract Rept. (TP2677). December, 1980.

Mackay, D.M., R. Mascarenhas, K. Hossain and T. McGee. 1980. The effectiveness of chemical dispersants at low temperatures and in the presence of ice. *In:* Proceedings of the Third Arctic Marine Oil Spill Program. June 3 to 5, 1980. Edmonton, Alberta.

Mackenzie Valley Pipe Line Research Limited. 1972. Arctic oil pipe line feasibility study - 1972. Mack. Valley Pipe Line Res. Ltd. Rept. 109 pp.

Marine Administration of Transport Canada. 1981. Major ongoing research and development projects in Transport Canada. For the Marine Transportation Research and Development Advisory Board. Status Rept. Dec. 1, 1981.

McAllister Engineering. 1979. The development and testing of a "quickie" fire-resistant oil containment boom. Report to Dome Petroleum Limited.

McAllister, I.R. and I.A. Buist. 1980. Fire-proof boom development. Phase III - Prototype construction and testing. COOSRA Rept. (CS1).

McColl, W.D., R.Q. Neville, R.A. O'Neill and S.M. Till. 1982. Remote sensing of the Newfoundland oilspill dispersant sea trials. *In:* Proceedings of the Fifth Arctic Marine Oil Spill Program Technical Seminar. Environmental Protection Service, Edmonton, Alberta.

Milgram, J.H. 1981. Subsea collection of oil from a blowing well. U.S. Geological Survey Rept. (81-704).

Milne, A.R. 1977. Oil, ice and climate change: the Beaufort Sea and the search for oil. R.J. Childerhose (editor). Dept. Fish. Oceans, Ottawa. Beaufort Sea Proj. (publishers). 103 pp.

Otter Group. 1981. Offshore blowout control. Statoil Rept. (STF-88-A81004). February, 1981.

Pallister Resource Management Ltd. 1974. The Beaufort Sea. Pallister Res. Mgmt. Ltd. (publishers). October, 1974. 4 pp.

Pallister Resource Management Ltd. 1982. Proposed organization of a research and development program. Rept. prepared for the Arctic Pilot Project. Feb. 10, 1982. 64 pp.

Petro-Canada. 1982. Offshore Labrador initial environmental assessment. Published by Petro-Canada on behalf of the Labrador Group.

Pistruzak, W.M. 1981. COOSRA press release. Dome Petroleum Limited. unpublished memo. 3 pp.

RADARSAT. 1982. RADARSAT mission requirements. RADARSAT Proj. Office: Dept. Energy, Mines and Resources. Document (82-7).

Ramseier, R.O. and D.J. Lapp. (editors). 1981. Proceedings of the final SURSAT ice workshop. Atmos. Environ. Serv. Toronto, Ont., Summary Rept. February, 1981.

Rossiter, J.R. and K.A. Butt. 1979. Remote estimation of the properties of sea ice - Beaufort Sea field trip report. C-CORE Rept. (79-9). June, 1979.

Spedding, L.G. 1979. Landfast and shear zone ice conditions in the southern Beaufort Sea - winter 1977/78. Esso Resources Rept. (IPRT ME 79-16).

Spedding, L.G. 1982. Mackenzie Bay surface current measurement program -summer, 1981. Esso Resources Canada Limited Rept. (IPRT ME 82-26).

Spedding, L.G., B. Mercer and D. Schwab. 1982. SURSAT Beaufort Sea ice experiment No. 41: SAR, SLAR and aerial photography cross-section correlation. Rept. to The Surveillance Satellite Project Office. (IPRT. ME. 80. 32) March, 1982.

SURSAT. 1980. SURSAT Program Part I. Executive summary. Energy, Mines and Resources, Canada. Final Rept. Sept. 1980.

Tam G. and M. Hebert. 1982. Study on cold weather performance of pumping systems. Volumes 1 and 2. ARCTEC Canada Limited. March, 1982.

Taylor, K. 1981. Polar Gas. *In:* The Beaufort Sea Environmental Impact Panel Draft Guideline Hearings - General Session. Yellowknife, N.W.T. December, 1981. pp. 34.

Thomas, D.J. 1980. Water quality measurements and dredge spoil monitoring at McKinley Bay, N.W.T., 1980. Rept. by Arctic Laboratories Ltd. for Dome Petroleum Limited. Calgary, Alberta. 41 pp.

Trudel, K. and S.L. Ross. 1982. Methods for predicting the ecological effects of chemically treated and untreated oil spills. *In:* The Proceedings of the AMOP Technical Seminar. Edmonton, Alberta. pp. 255- 263.

Tucker, W.B., W.F. Weeks and M.D. Frank. 1979. Sea ice ridges over the Alaskan continental shelf. CRREL Rept. (79-8).

United States Department of Commerce. 1977. Environmental assessment of the Alaskan continental shelf - executive sum-

mary. April, 1976 - March, 1977. U.S. Dept. Comm., Nat. Oceanic and Atmos. Admin., Environ. Res. Labs. 107 pp.

Untersteiner, N. 1980. AIDJEX review. *In:* Sea Ice Processes and Models. Proceedings of the Arctic Ice Dynamics Joint Experiment, International Commission on Snow and Ice Symposium. R.S. Pritchard (editor). Univ. Wash. Press. Seattle, Wash.

Wadhams, P. and R.T. Horne. 1978. An analysis of ice profiles obtained by submarine sonar in the AIDJEX area of the Beaufort Sea. SPRI Tech. Rept. (78-1).

Weller, G., D. Norton and T. Johnson. 1978. Arctic project bulletin. Outer Continental Shelf Environmental Assessment Program (OCSEAP) Bull. (21). Arctic Proj. Off., Geophys. Inst., U. Alaska.

Woodward-Clyde Consultants. 1980. Beaufort Sea coast and Northwest Passage coast videotapes. Oct., 1980 (revised March, 1982) and Dec., 1980 (revised February, 1982), respectively. Submitted to Dome Petroleum Limited.

Woodward-Clyde Consultants. 1982. Amundsen Gulf coast videotapes. Submitted to Dome Petroleum Limited.

Worbets, B.W. 1979. Shoreline oilspill protection and clean-up strategies: southern Beaufort Sea. Manual. Publ. by Dome Petroleum Limited. APOA Project #136. 85 pp.

PERSONAL COMMUNICATIONS

Gainer, J.G. Gulf Canada Resources Inc.

Hershberger, M. Alaska Oil and Gas Association (AOGA)

Jones, G. Arctic Petroleum Operators' Association (APOA) and Eastcoast Petroleum Operators' Association (EPOA)

Pistruzak, W. Dome Petroleum Limited