158 A

PACIFIC COAST OIL SPILL PROJECT

Scoping Document and Preliminary Experimental Plan

DICKINS

Environment Canada
Environmental Emergencies
Technology Division

and

U.S. Department of the Interior
Minerals Management Service
Technology Assessment and
Research Branch

Pacific Coast Oil Spill Project:

Scoping Document and Preliminary Experimental Plan

by

D. Dickins

DF Dickins Associates Ltd
503A, 21 Water Street
Vancouver, British Columbia
Canada V6B 1A1

in association with

Counterspil Research Inc.

for

G. Sergy
Environment Canada
Environmental Emergencies Technology Division
4999 - 98 Avenue
Edmonton, Alberta T6B 2X3

and

E. Tennyson
U.S. Department of the Interior
Minerals Management Service
381 Eldon Street
Herndon, Va.
22070-0437

February, 1990

ACKNOWLEDGEMENTS

The author wishes to acknowledge the time given freely by the following individuals in sharing their oil spill experience and helping to establish priorities for the experimental spills described in this plan:

Colin Wykes:	*Chief, Pacific and Yukon Region, Environmental Services, Environment Canada*
Fred Beech:	*Environment Canada, Environmental Emergencies*
Keith Hebron:	*Environment Canada, Environmental Emergencies*
Colin Hendry:	*Head of Marine Emergencies, Canadian Coast Guard, Vancouver*
Ian Young:	former *Head of Marine Emergencies, Canadian Coast Guard (retired)*
Martyn Green:	*Manager, Burrard Clean, Vancouver*
Ed Gauthier:	*Canadian Coast Guard Headquarters, Ottawa*
John Wiechert:	*Manager, Clean Sound, Seattle*
Greg Yaroch:	*Chief Port Operations, U.S. Coast Guard Marine Safety Office, Seattle*
Andy Teal:	*Manager Shoreline Clean-up Advisory Team, EXXON Valdez Oil Spill*
Erich Gundlach:	*E-Tech, advisor to the Alaska Department of Energy and Conservation*
Dave Kennedy:	*NOAA, Seattle*

The study was carried out in association with Mr. Laurie Solsberg of Counterspil Research Inc., West Vancouver, B.C. Mr. Solsberg took part in the personal interviews, and assisted in formulating the research priorities which led to the selected group of field experiments. He developed the experimental concepts surrounding the proposed offshore trials and disposal evaluations.

Martin Poulin of DF Dickins Associates Ltd. developed and presented the background information concerned with marine climate and oil movements (Sections 3.1 and 3.2, and Appendix A).

In addition, the author would like to acknowledge the contributions of Ed Owens of Woodward-Clyde Consultants, and Blair Humphrey of Seakem Oceanography Ltd. in the respective areas of shoreline clean-up and site selection.

This project was funded by the Environmental Emergencies Technology Division of Environment Canada and the Minerals Management Service of the U.S. Department of the Interior.

EXECUTIVE SUMMARY

This study recommends studies and trials of shoreline clean-up and disposal techniques using stringently controlled experimental releases of oil in selected areas. The experiments will be designed to fill the knowledge gaps which currently restrict the application of effective oil spill clean-up techniques on the West Coast.

Experimental spills are necessary to comparatively evaluate (based on ecological criteria) different shoreline clean-up and disposal techniques applicable to a west coast environment. This evaluation will consider both the relative effectiveness/efficiency of different techniques and the environmental impact of the clean-up operations (including the "no clean-up" option).

Experiences with the *EXXON Valdez* and previous spills have demonstrated that in a real spill situation, the wrong technology is often applied in the beginning or the right technology is applied at the wrong time because of lack of knowledge, guidance and experience. Large catastrophic spills are characterized by extensive documentation of regional impact and minimal hard evidence of technology effectiveness. This lack of hard evidence was recently cited as the greatest impediment to developing a rationale and effective long-term strategy for shoreline clean-up in Prince William Sound.

The optimum approach to oil removal attempts to maximize the rate of clean-up while minimizing any environmental damage caused by the cleaning techniques. It is important to realize that in many situations the final decision may be to do nothing except monitor the extent of contamination. An informed decision will weigh the potential for ecological damage against a realistic appraisal of the clean-up rates (with and without intervention).

Failure to assess the relative effectiveness and environmental impact of different clean-up techniques will lead to a continuation of the existing state of uncertainty regarding the optimum choice of clean-up techniques. The choice is complicated by the lack of any single solution to spill clean-up; a battery of approaches are needed to handle a range of oil properties and physical conditions.

Experimental spills provide an opportunity for simultaneous assessment of alternative techniques while the oil is still fresh and amenable to many different recovery options. The flexibility offered by a well designed matrix of experiments can simulate a mix of conditions which characterize a real spill (e.g., oil properties, shoreline exposure, beach permeability, sediment size and composition, the presence of log debris and seaweed).

In spite of a wealth of cumulative experience in dealing with large spills over the past twenty years, there is no concensus of opinion among the oil spill "experts" as to how best to clean-up an oil spill. Nowhere is this divergence of opinion more pronounced than in the area of shoreline clean-up. Consequently, the experimental design strategy outlined in this preliminary plan emphasizes shoreline clean-up in a West Coast environment as the number one priority.

A series of relatively small-scale experiments are proposed to address the critical deficiencies in clean-up capabilities of West Coast shorelines characterized by a diverse mix of sand-gravel and gravel-cobble shorelines overlain with driftwood, logs, and seaweed. These experiments involve minimal risk to the environment and yet offer the potential for a significant improvement in response effectiveness.

Experimental spills provide a safe, controlled means of measuring the relative effectiveness and impact of different clean-up options. The record of experimental spills over the past fifteen years is one of significant new knowledge gained with negligible environmental impact (e.g., Baffin Island Oil Spill Project).

CONTENTS

page

1.0 INTRODUCTION 1
1.1 Rationale for Field Experiments/Evaluations 1
1.2 Scope 3
1.3 Integration with Other Studies and Follow-up 6

2.0 METHODOLOGY 9

3.0 BACKGROUND INFORMATION 12
3.1 Oil Movements 12
3.2 Marine Climate 16
3.3 Shoreline Types 22

4.0 SUMMARY OF RESPONSE DEFICIENCIES 25
Detection, Monitoring and Tracking 25
Offshore Containment and Recovery 26
Nearshore Containment and Recovery 29
Shoreline Clean-up 30
Disposal 34

5.0 RECENT RECOMMENDATIONS: ONGOING REVIEWS 36

6.0 OUTLINE OF RECOMMENDED EXPERIMENTAL OPTIONS 39
6.1 Overview 39
6.2 Outline of Experimental Strategy: Shoreline Clean-up and Disposal 41

7.0 SITE SELECTION 49
7.1 Individual Site Descriptions 53

8.0 ASSOCIATED STUDIES 55

REFERENCES

APPENDICES

Appendix A: Oil Movement Statistics
Appendix B: Outline of Other Potential Field Experiments
Appendix C: Site Descriptions and Maps

FIGURES

Figure 1	Principal Marine Oil Transportation Routes	14
Figure 2	Oil Movements in B.C. Coastal Waters	15
Figure 3	British Columbia Marine Forecast Areas	18
Figure 4	Monthly Exceedance of Threshold Wind Speeds	19
Figure 5	Monthly Exceedance of Combined Wave Height	20
Figure 6	Coastal Environments of the Pacific Coast	22
Figure 7	Location Map of Potential Experimental Sites	51

TABLES

Table 1	Dominant Oil Types by Volume and Frequency	13
Table 2	Representative West Coast Currents	21
Table 3	Characteristics of Pacific Coastal Environments	23
Table 4	Estimates of Lengths of Low Energy Shorelines	24
Table 5	Summary of Ratings for Potential Sites	52

1.0 INTRODUCTION AND OBJECTIVES

This document is intended as a discussion and planning tool for the development of a series of field experiments designed to address oil spill response deficiencies for the Pacific Northwest region (Washington, Oregon, British Columbia, and Alaska). A preliminary experimental plan is presented which relates specific research and development needs to the West Coast marine environment.

The scope of this first phase of the project covered the entire range of oil spill response options including offshore containment and recovery, and shoreline clean-up. The primary objectives of Phase 1 were **first,** to assess the response deficiencies which could benefit from controlled experimental releases of oil in West Coast field environments, and **second,** to outline a range of possible field experiments which could significantly enhance the effectiveness of future spill clean-up operations on the West Coast.

1.1 Rationale for Field Experiments/Evaluations

Recent experiences on the West Coast and in Alaska have not only graphically pointed out the deficiencies in existing response capabilities, but also re-affirmed the need for carefully designed and thought-out experimental spills. The *EXXON Valdez* demonstrated that spills of opportunity are not adequate venues for developing optimum response techniques. In a real spill situation, the wrong technology is often applied in the beginning, or the right technology is applied at the wrong time because of lack of knowledge. Large catastrophic spills are characterized by extensive documentation of regional impact and minimal hard evidence of technology effectiveness.

From the *Experimental Oil Spills General Plan (Environment Canada 1979)* the quote, "It is undesirable to develop countermeasures and place trust in their effectiveness without significant trials under realistic conditions," This scoping document identifies shoreline clean-up as the number one research priority.

The choice of shoreline clean-up options is complicated by the lack of any single solution; a battery of approaches is needed to handle a wide range of oil spill properties and physical conditions. Experimental spills provide a safe, controlled means of measuring the relative effectiveness and impacts of different clean-up options. The record of experimental spills is one of significant new knowledge gained with minimal environmental impact (e.g., Baffin Island Oil Spill Project).

The Valdez experiences will not provide the necessary quantitative data on technology effectiveness during the early stages of a spill when the crude oil is relatively fresh and still amenable to a number of alternative clean-up techniques. The shorelines in Prince William Sound have a much lower proportion of driftwood, and higher percentage of exposed bedrock than many other West Coast areas.

Controlled experimental releases of oil in a field environment are necessary to mimic the natural physical processes and biological effects involved in a real oil spill. These processes and effects are impossible to model in a laboratory setting.

1.2 Scope

Information gained from the PCOS project will address oil spill concerns related to both exploratory drilling and tanker accidents. Coincident with the commencement of the Phase 1 scoping exercise, the *Nestucca* barge spill impacted the West Coast of Vancouver Island and was followed three months later by the *EXXON Valdez* tanker disaster. Partly in response to these incidents, a five year moratorium on Canadian West Coast drilling was announced by the Government of British Columbia. Crude oil spills from production platforms continue to be a possibility in other West Coast areas (e.g., California and Cook Inlet).

The current emphasis in the Pacific Coast Oil Spill Project is placed on two primary potential spill situations likely to be encountered in the Pacific Northwest area: (1) spills of heavy fuel oil (Bunker C) from barges or deep-sea vessels, and (2) spills of crude oil (predominantly Prudhoe Bay crude) from dedicated tankers engaged in the Valdez trade.

The original intention in this study was to create a document analogous to the *Experimental Oil Spills General Plan* (issued by Environment Canada in May 1979). A variety of large scale field experiments grew from this plan, including the Dome Oil and Gas Under Sea Ice Study in 1979/80, the Baffin Island Oil Spill Project in 1981, and the experimental oil spills in pack ice conducted off Nova Scotia in 1986.

In practice, the original intent was complicated by recent incidents which forced a complete review of every aspect of West Coast countermeasures at various government and industry levels (still ongoing at time of writing). The B.C./States Task Force and the Public Review Panel on Tanker Safety and Marine Spill Response Capability are in the process of examining all aspects of marine transport of oil and chemicals in Canada. Similar efforts are underway in the United States. Recommendations based on the results of public hearings and internal reviews by different federal departments and industry organizations (e.g., Canadian Petroleum Association, Minerals Management Service, U.S. and Canadian Coast Guards, American Petroleum Institute) will have a major bearing on future oil spill research priorities in North America; wherever possible, interim findings from a variety of sources are incorporated into this plan (refer to 2.0).

This document was delayed in order to assimilate as much information as possible from the many reviews and reports circulating in Canada and the United States and also to allow time to interview a number of key people connected with the clean-up operations in Prince William Sound. The draft plan contained here should be viewed as a scoping document for review and comment leading to a fully developed experimental plan.

The detailed technical conclusions derived from the Valdez spill are approximately two years from publication (Teal, Pers. Comm.). Conclusions regarding clean-up techniques and effectiveness in the *Nestucca* spill are available now. There appears to be little benefit in delaying the planning of experimental spills any further.

The justification for recommending particular field evaluations and/or experimental spills in this plan was based on the work satisfying one of the following two main criteria:

> **First,** the proposed experiment must help to determine the quantitative effectiveness of clean-up techniques which a number of spill clean-up specialists identify as being applicable to the West Coast environment. Such techniques may involve a procedure which is not normally recommended in other areas or traditional shoreline clean-up manuals (e.g., in-situ burning on the beach face).
>
> **Second,** the proposed experiment will demonstrate technology (hardware and techniques) in a West Coast marine environment. This technology must have shown promise in other areas of the world and have the potential to improve spill response effectiveness if adopted along the West Coast of Canada or the United States.

The intent of PCOS is not to demonstrate established clean-up technology, but to concentrate on new techniques or enhancements to existing techniques which could significantly increase the ultimate recovery volumes. Potential experiments involve proven techniques which are considered effective but where quantitative evidence is lacking.

The demonstration of proven technology which has never been deployed on the West Coast is considered a valid component of PCOS if it leads to an enhanced local response capability in the future (e.g., through new programs for equipment acquisition).

Response activities considered in this project include all aspects of equipment and techniques used in combatting a spill once the oil has entered the marine environment. Not included are such related activities as salvage of the vessel, temporary repairs to the ship, lightering operations, logistics of spill response, communications, and contingency planning. Fate and effects studies are included as they relate to the main purpose of assessing the effectiveness of different techniques and/or equipment or the development of spill response strategies and decision-making.

It is anticipated that the final selection of field experiments in this program will originate from one of the following research or manufacturing areas.

- *Existing Spill Response Technology:* This area includes systems and approaches which have proven effective in demonstrations elsewhere, but for which documented evidence is lacking, or for which modifications in equipment or techniques can greatly enhance effectiveness.

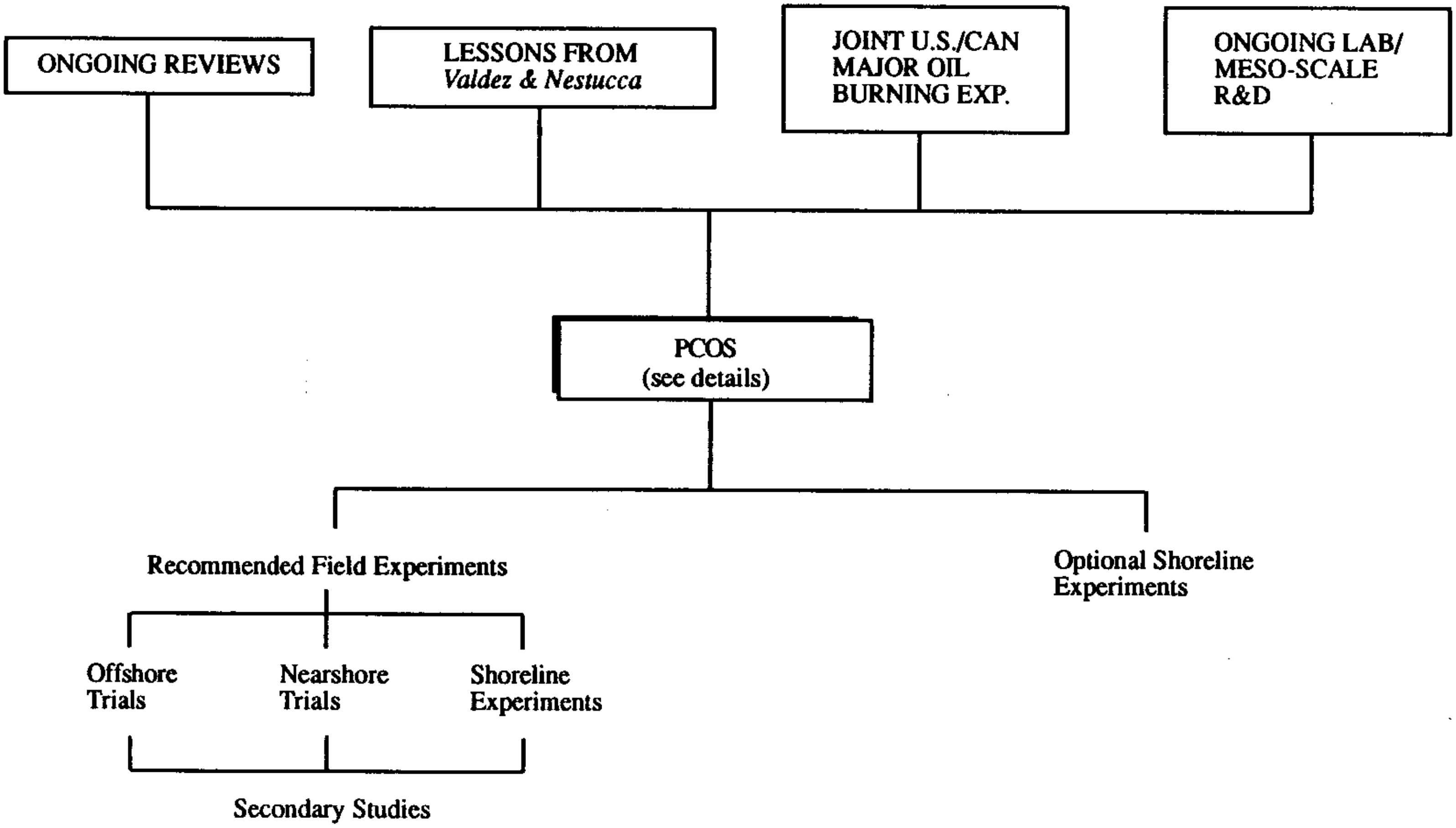
- *Technology Sharing with Other Industries and Local Residents:* This area is not easily definable but may involve the development of new equipment using established engineering concepts proven in related industries and ongoing coastal activities (e.g., fisheries - pumps, forestry - log handling, native groups - capitalizing on a knowledge of local conditions).

- *New Technology Development Programs*: This area will draw on the rapidly accelerating R&D activity throughout North America to possibly include some promising new product or technique which has not received previous field testing with real oil.

1.3 Integration with Other Studies and Follow-up

As part of the development process leading to a final experimental plan, integration will be required between PCOS and (1) ongoing reviews; (2) findings from recent spills in Canada and the United States; and (3) the accelerating pace of technology development which always follows in the wake of a major oil spill catastrophe. The general framework and extent of this integration is shown in the following flow chart.

PCOS - Relation to Ongoing Programs



ONGOING REVIEWS

LESSONS FROM
Valdez & Nestucca

JOINT U.S./CAN
MAJOR OIL
BURNING EXP.

ONGOING LAB/
MESO-SCALE
R&D

PCOS
(see details)

Recommended Field Experiments

Offshore
Trials

Nearshore
Trials

Shoreline
Experiments

Secondary Studies

Optional Shoreline
Experiments

DF Dickins Associates Ltd.
Vancouver, B.C. August 1989

Old and new spills of opportunity will be used wherever possible as either an alternative to an experimental spill or to acquire background information which may assist in more effective design of field experiments.

Given the large effort involved in mounting field evaluations and in obtaining approval to spill oil in an experimental situation, it is expected that many agencies in North America may attempt to use PCOS as an opportunity to test a variety of new techniques and devices (some of which may not exist at this time).

The next step is to debate the relative merits of the general experimental initiatives proposed here among a variety of technical experts in government and industry. The final selected experimental options will then be developed in greater detail including specific measurement techniques, logistics requirements, and site selection (a general review of a number of potential sites is presented here).

A second planning phase is envisaged in which the provincial government, U.S. and Canadian federal governments, and industry will review the experimental options and commit support to particular research areas (either monetary or support in kind). Local groups (native organizations, fishermen, and environmental/volunteer groups) will be involved in subsequent phases of the spill planning process and these groups will be invited to participate and contribute to the field program.

2.0 METHODOLOGY

The study proceeded through a series of steps where progressively more detailed information was acquired in order to identify a short list of recommended experiments and to formulate a general experimental plan. There were no preconceived ideas concerning the need for field evaluations/experimental spills. A consistently negative reaction to the concept of experimental spills among the specialists contacted during the study would have resulted in a complete re-evaluation of the study objectives (in fact this did not happen).

As the study progressed it became apparent that shoreline clean-up (and related disposal problems) represented the area of clean-up technology where field experiments could offer the most significant benefits. Subsequent developments of experimental options focussed on shoreline problems.

The following steps were followed in developing background information (Section 3.0) on the physical setting and existing oil supply system relevant to the future choices of experimental setting and oil product types.

> **First:** Oil types, relative volumes, and frequency of marine oil movements in B.C. waters were surveyed from available sources (Coast Guard, 1989; Vancouver Port Corporation, 1988; Vancouver Area Transport of Dangerous Goods Study, 1988; ongoing studies by the B.C. Ministry of Environment). Data from these and other sources show that a similar pattern exists in B.C. waters as in Puget Sound (State of Washington). Oil volumes are dominated by a relatively small number of annual transits (in the hundreds) by crude carrying tankers, while the highest frequencies of passage (tens of thousands per year) are made up of deep sea vessels and barges carrying bunker oil.
>
> **Second:** The marine climate was summarized in terms of the proportion of time when conditions exceed 1, 2, and 3 m seas, or 20 and 30 kt winds for different regions and times of the year (Marine Climatological Atlas - Canadian West Coast, 1986).

Third: The mix of shoreline types was determined from Owens and Trudel, 1985 (Oil-Spill Countermeasures for Low-Energy Shorelines).

Deficiencies in available response techniques and equipment were determined through a series of interviews with U.S. and Canadian specialists in West Coast oil-spill clean-up problems (Section 4.0). Shoreline clean-up manuals and previous assessments were used to provide direction for the interviews and as a starting point for discussion in key areas (e.g., Field Shoreline Treatment Manual for the *EXXON Valdez* Oil Spill, June 1989; The Basics of Oil Spill Clean-up, 1979; CONCAWE, 1981; West Coast Oil Spill Countermeasures Study, 1982).

Discussions were held with the following individuals:

Colin Wykes:	*Chief, Pacific and Yukon Region, Environmental Services*
Fred Beech:	*Environment Canada, Environmental*
Keith Hebron:	*Environment Canada, Environmental*
Colin Hendry:	*Head of Marine Emergencies, Canadian Coast Guard, Vancouver*
Ian Young:	former *Head of Marine Emergencies, Canadian Coast Guard (retired)*
Martyn Green:	*Manager, Burrard Clean, Vancouver*
Ed Gauthier:	*Canadian Coast Guard Headquarters, Ottawa*
John Wiechert:	*Manager, Clean Sound, Seattle*
Greg Yaroch:	*Chief Port Operations, U.S. Coast Guard Marine Safety Office, Seattle*
Ed Owens:	*Woodward Clyde Consultants Limited, Seattle*
Andy Teal:	*Manager SCAT for the EXXON Valdez , Anchorage*
Erich Gundlach:	*E-Tech, advisor to Alaska Department of Energy and Conservation*
Dave Kennedy:	*NOAA, Seattle*

The study team used the results from these personal discussions to identify priority areas for future research. Notes from the interviews are held as confidential and specific comments are not attributed to a particular individual.

Recently released (up to October 1989) recommendations and preliminary findings were reviewed for specific issues relevant to the planning of experimental spills and field evaluations. Sources included the following reports.

The American Petroleum Institute Task Force on Oil Spills
Nestucca Oil Spill Report (Canadian Coast Guard)
Nestucca Oil Spill (Environment Canada)
The *EXXON Valdez* Oil Spill: a Report to the President
Public Review Panel on Tanker Safety and Marine Spills Response Capability (Interim Report)

3.0 BACKGROUND INFORMATION

Certain background information is needed to design relevant field experiments.

First, it is important to know how much oil of a given type is moving at what relative frequency in different coastal areas. **Second,** the marine climate will determine the most appropriate time of year and location for certain types of offshore experiments as well as affect the fate and behaviour of oil on shorelines. **Third,** the relative shoreline composition in high and low energy environments will be a factor in deciding on the most relevant types of shoreline experiments.

3.1 Oil Movements

Observations of specific historical oil spill incidents must be viewed within the broad perspective of expected future spill situations in order to arrive at a realistic set of experiments that properly address the priority issues of West Coast response.

Figure 1 shows the principal shipping routes involving crude oil and bunker products offshore of Vancouver Island, in Juan de Fuca Strait and in the "Inside Passage" as far north as Powell River.

Appendix A contains detailed tables showing the breakdowns of oil type, vessel type, vessel capacity, and typical transit frequencies for four different marine areas. Figure 2 summarizes this information in graphical form showing both the overall volumes of petroleum products (dominated by the Alaskan crude oil shipments) and the breakdown for only refined products (dominated by fuel oil commonly referred to as Bunker C). A similar breakdown for State of Washington waters was not available in a convenient form at the time of writing.

Table 1 follows summarizing the dominant oil types by geographic region in terms of both volume and frequency of transit. The data shows clearly that a large spill in B.C. waters will most probably involve Prudhoe Bay crude oil, but in terms of the probability of having any substantial spill, the product will most likely be bunker oil in all areas except the "Inside Passage" where there is an equal likelihood of a gasoline (diesel) spill. These general conclusions also apply to other areas of the West Coast (including offshore Washington, and Oregon).

Significant volumes of gasoline (e.g., aviation fuel, gasoline, and diesel fuel) move by tanker and barge in B.C./Washington contiguous waters. Spills of these products are considered of lesser consequence in terms of long term environmental impact than either crude or bunker oil (largely as a result of the high evaporation rates immediately following the spill).

Table 1 Dominant Oil Types by Volume and Frequency

Transit Area	In Terms of Volume	In Terms of Frequency of Transit
Pacific Ocean	Crude	Fuel Oil (Bunker)
Juan de Fuca	Crude	Fuel Oil (Bunker)
Port of Vancouver	Fuel Oil	Fuel Oil (Bunker)
"Inside Passage"	Gasoline/Fuel Oil	No Data (Bunker)

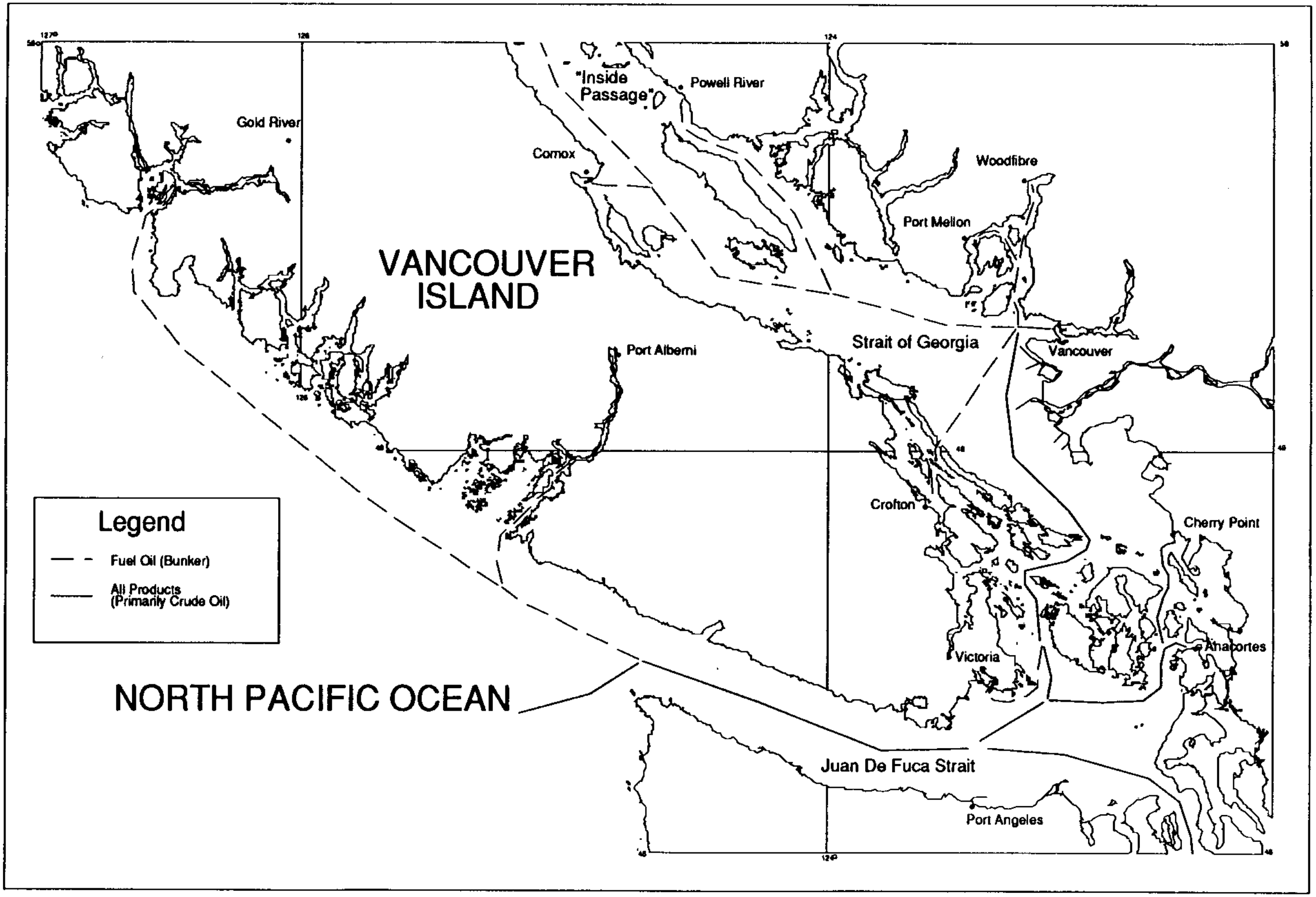
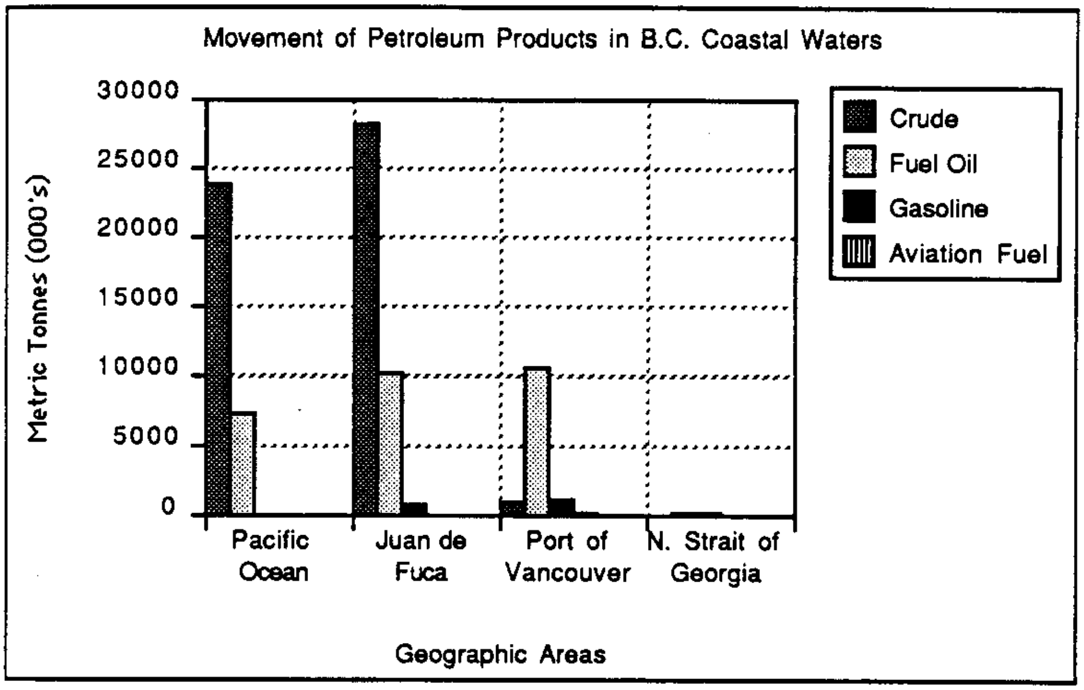


Figure 1 Principal Marine Oil Transportation Routes



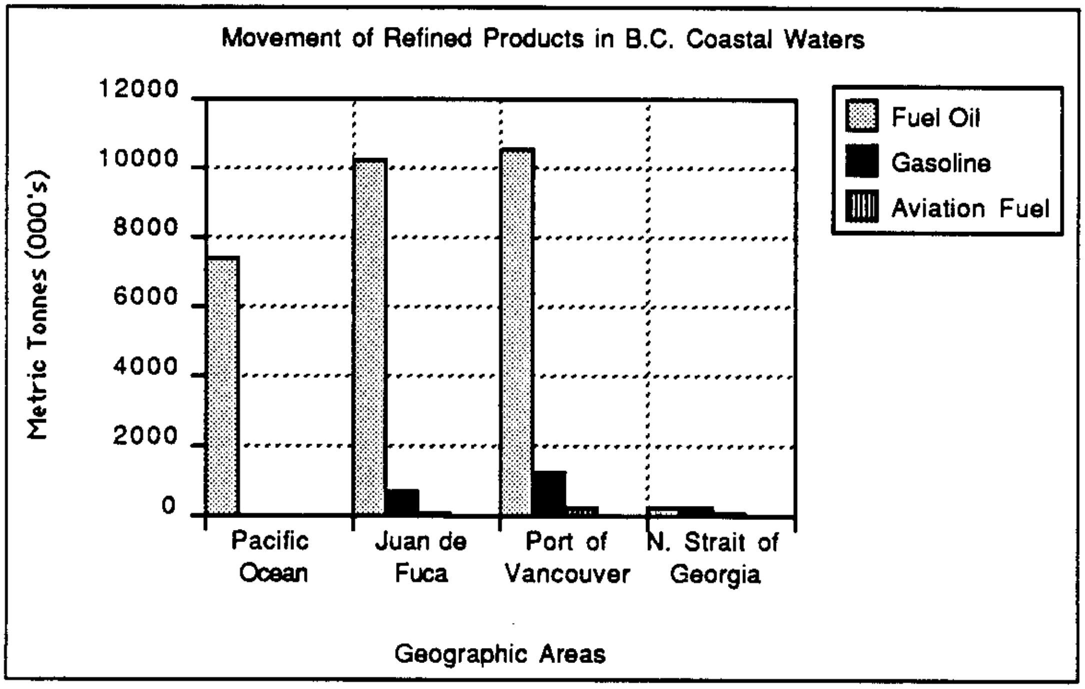


Figure 2 Oil Movements in B.C. Coastal Waters

Sources: Canadian Coast Guard. *Heavy Oil Movement Report.* 1989.
Vancouver Port Corporation. *1988 Statistics for Port of Vancouver.*
GVRD. *Vancouver Area Transport of Dangerous Goods Study.* January, 1988.

3.2 Marine Climate

The *Nestucca* incident pointed out the importance of not only having detailed knowledge of marine conditions, but also being able able to utilize the information in a real time prediction/decision-making process before the oil hits the shoreline.

A general appreciation for the key characteristics of marine climate is equally important in the experimental spill planning process and the field exercise itself. Winds, waves, and currents will determine those areas where a particular type of experiment is feasible (and relevant to a real spill situation) as well as identifying the most favourable time of year to reduce expensive stand-by time waiting for a weather "window" in which to conduct an experiment.

Different types of boom and skimmer systems are affected to a greater and lesser degree by the sea state conditions. In general, an open-ocean swell (long wavelength) presents little problem. Major difficulties arise when winds greater than 20 knots introduce a significant wind-wave component into the swell. Any breaking waves will seriously affect boom and skimmer efficiency.

The three categories in which some form of mechanical containment and recovery could be considered are these conditions: **Low** - wave heights up to 15 cm with a period up to 1.5 seconds in winds from 0 to 6 knots, **Medium** - wave heights up to 1 m with periods up to 4 seconds in winds to 14 knots, and **High** - waves averaging 1.5 m with periods of 4 to 6 seconds in winds of 15 to 20 knots. The last category represents the upper limit of any practical recovery operation. Oil advected at 3 to 4% of the wind speed in the "high" sea-state condition will move at speeds exceeding the containment capability of any boom (approximately 0.7 knots).

The Vikoma SeaPac offshore boom system used by the Canadian Coast Guard on the West Coast will work in sea states up to about 1.5 m and winds less than 20 knots; however, the SeaPac suffers from mechanical problems since it relies on a continuously developed air supply and water flow through separate chambers. Problems with bearings, fuel line, and fabric tearing have also been reported. Scandinavian equipment developed for North Sea operations (e.g., Norwegian Transrec, Danish Ro-Boom) will contain oil in moderately higher sea state conditions than the SeaPac and will survive in significantly higher sea states. These systems are comprised of more rugged materials and do not rely on a power pack (passive operation).

Skimmers are not effective in seas greater than about 1 m. In rougher conditions, high volume pumps (with appropriate onboard storage and separation facilities) may prove to be much more efficient than highly specialized skimmers.

Currents place a sharp constraint on all boom systems regardless of sea state capability; all booms will experience significant oil losses with relative water speeds greater than 0.5 to 0.75 knots.

Figure 3 shows the marine forecast areas for which long-term climate statistics are tabulated for B.C. waters. The percent time that winds exceed 20, and 30 knots, and the percent time that combined (sea and swell) waves exceed 1, 2, and 3 m for the different areas is plotted on a monthly basis in Figures 4 and 5. Information for Juan de Fuca Strait is unavailable (general sea-state conditions will be similar to the Strait of Georgia in the easterly portions of the Strait, but waves will be increasingly dominated by ocean swell approaching the western entrance).

The plots show that in the open ocean off the northern B.C. Coast or west of Vancouver Island, the best available mechanical recovery devices will be effective less than 30% of the time during the worst month in winter (December); summer effectiveness rises to about 70% in July and August for systems able to handle 1.5 m seas and/or 20 knots of wind. In the Strait of Georgia, summer effectiveness potential rises to better than 98% while winter effectiveness is still better than 90% with January and February being the worst months.

> *A note of caution is advised in interpreting these statistics. For example, the Strait of Georgia appears deceptively calm when in fact daytime solar-heating effects often lead to strong NW winds with*

> *associated heavy seas from late morning to late afternoon in the summer. This condition is not apparent in the overall 24 hour averages but would be enough to cause substantial oil losses for a portion of many days.*

There is no concise summary guide to currents in the region. The following table shows a range of expected currents in different areas. Juan de Fuca Strait experiences the highest maximum currents in the region but on a local scale there are numerous small straits and constricted passages which give rise to tidal currents in excess of 4 knots.

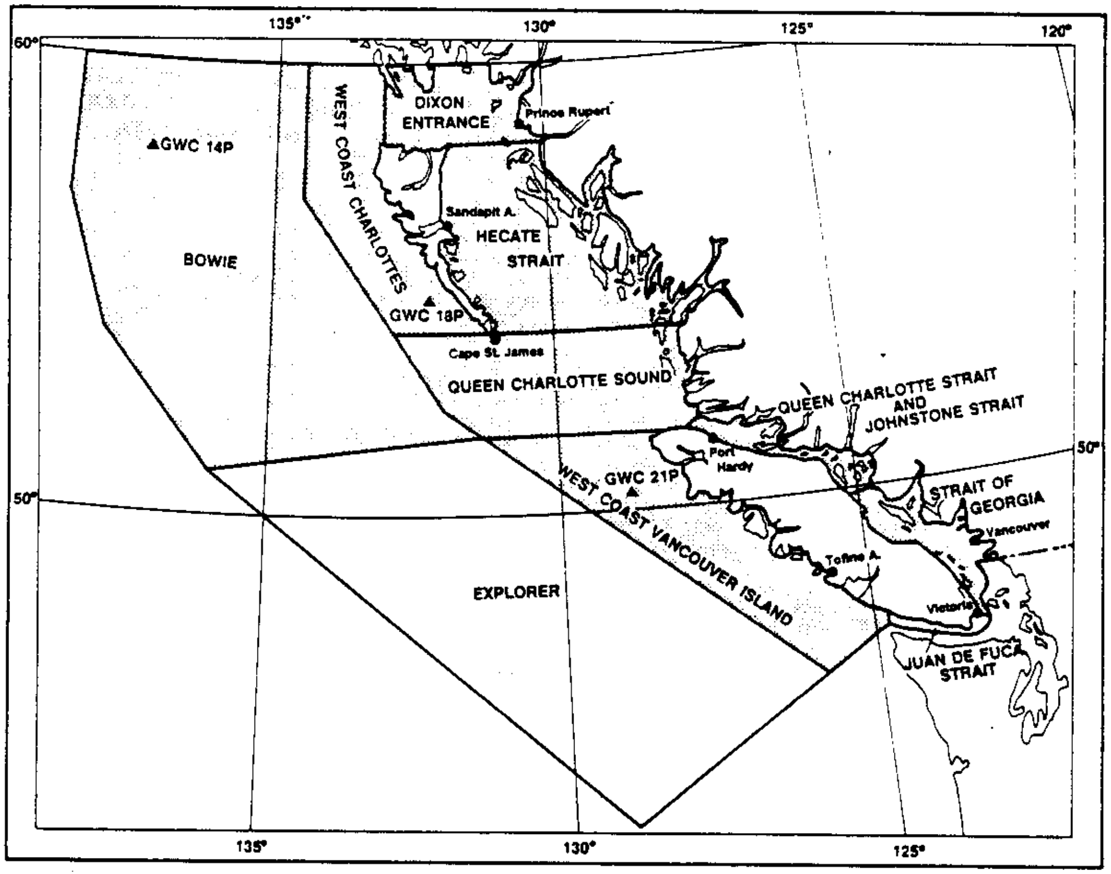
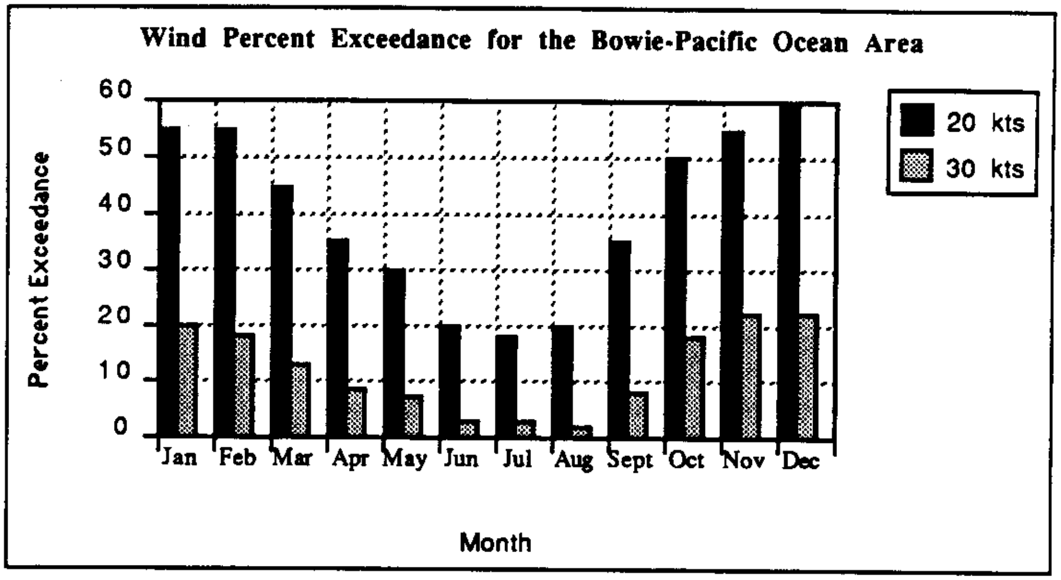
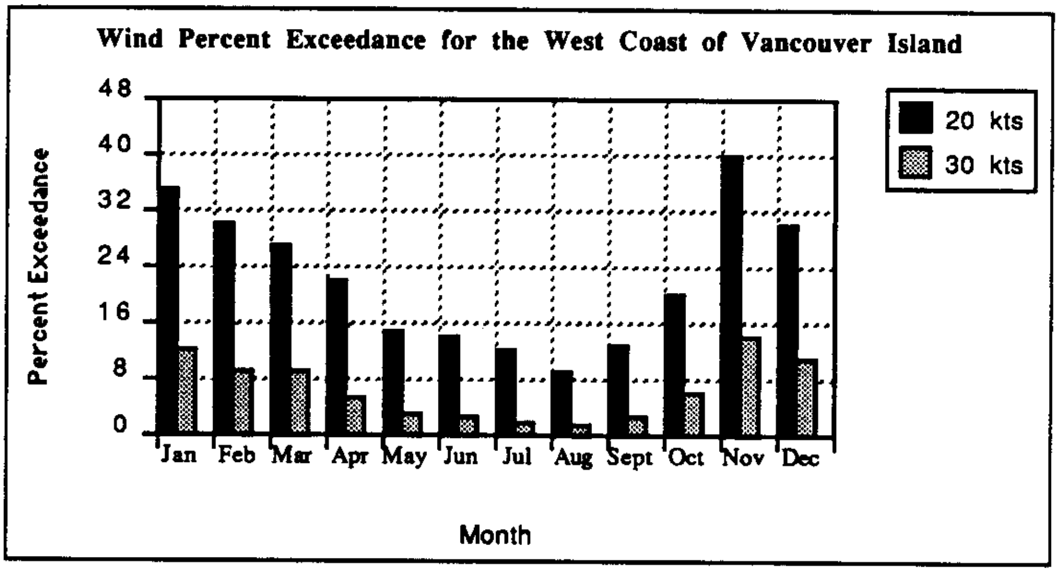


Figure 3 British Columbia Marine Forecast Areas (Brown et al. 1986)





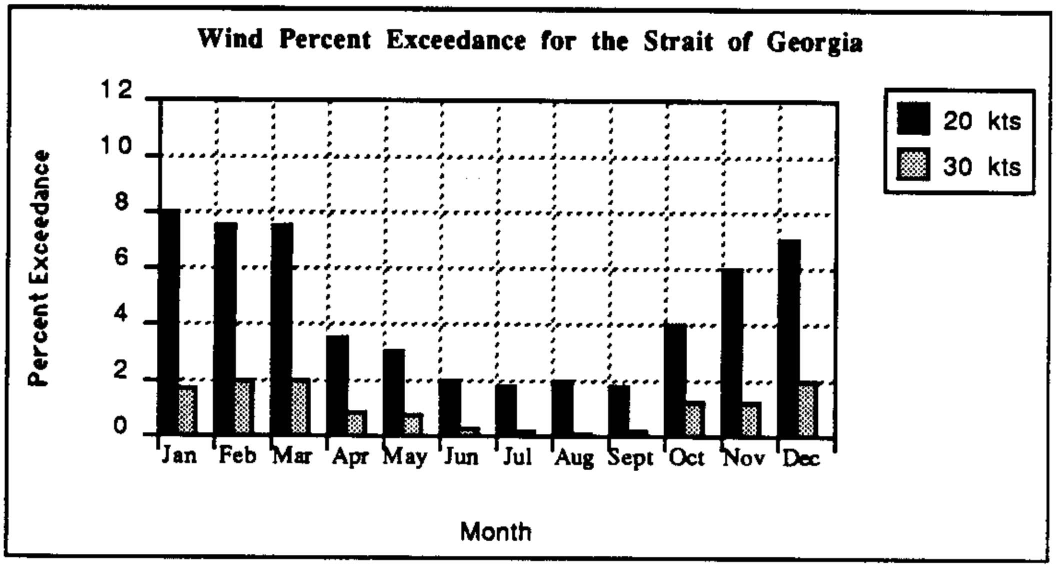
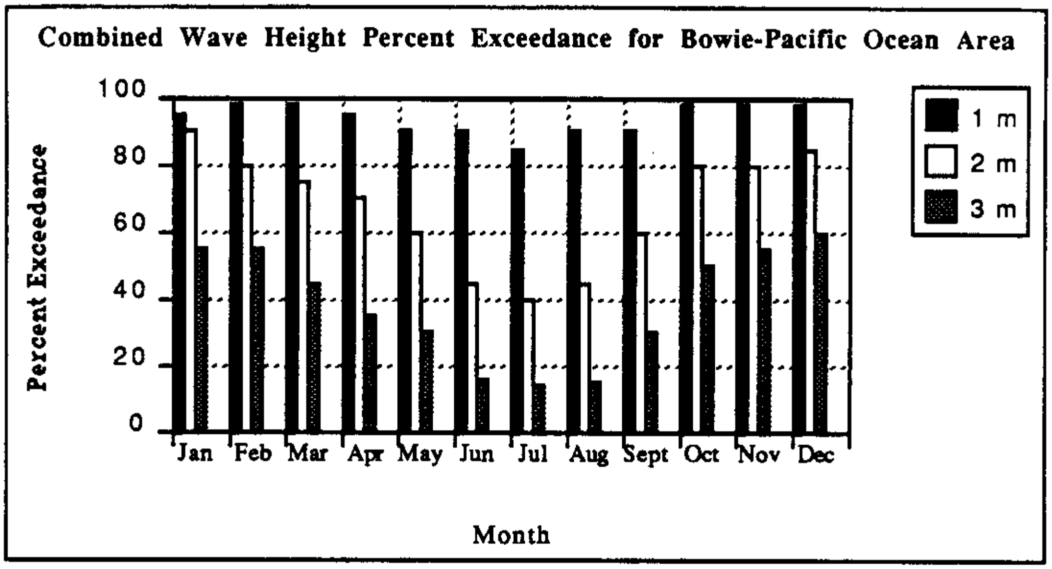
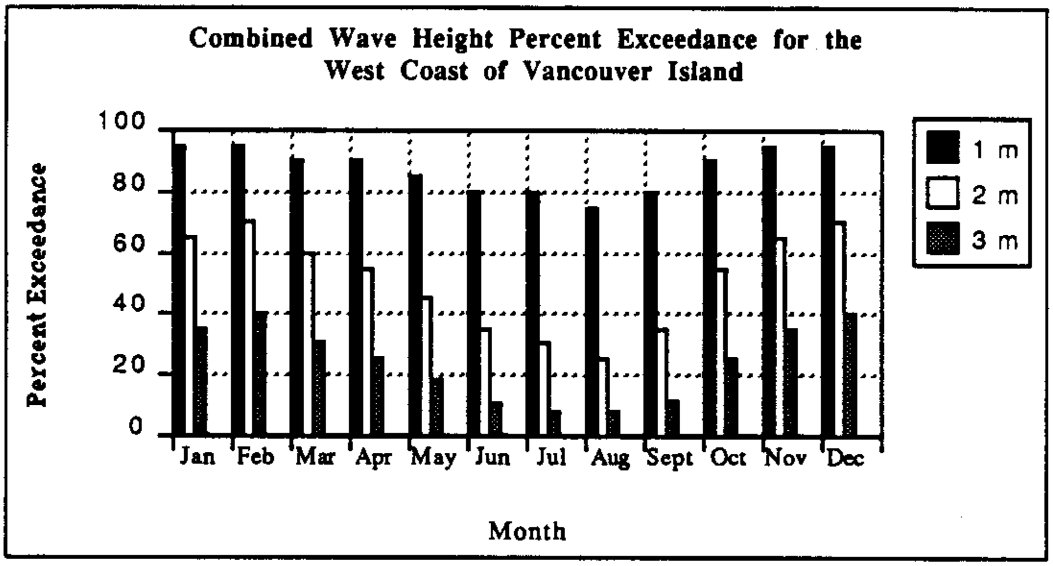


Figure 4 **Monthly Exceedance of Threshold Wind Speeds**


Combined Wave Height Percent Exceedance for Bowie-Pacific Ocean Area


Combined Wave Height Percent Exceedance for the West Coast of Vancouver Island

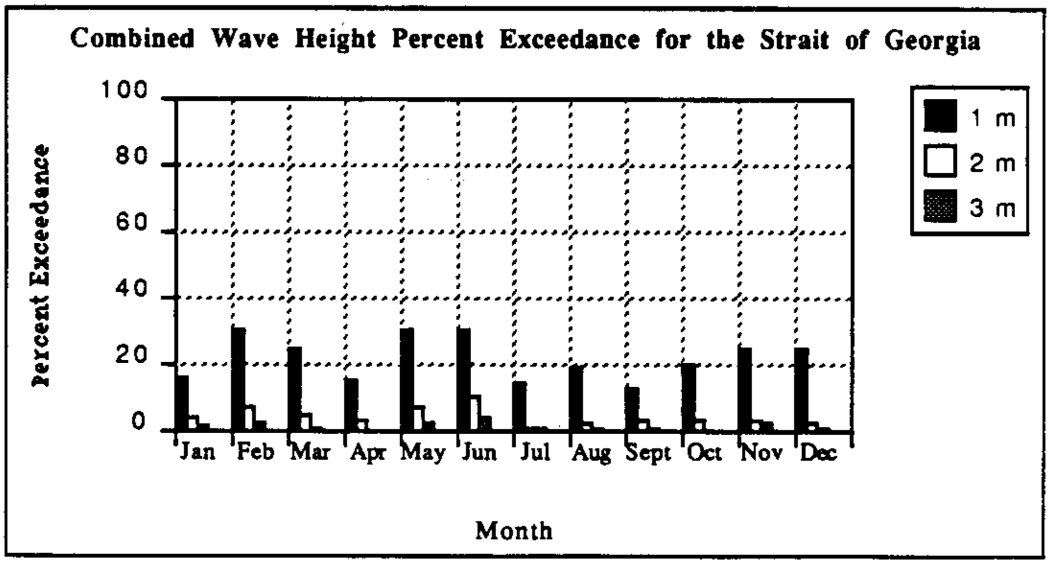

Combined Wave Height Percent Exceedance for the Strait of Georgia

Figure 5 Monthly Exceedance of Combined Wave Height

Table 2 Representative West Coast Currents

Area	Average Current	Maximum Current
Bowie (See Figure 3)	0.1-0.2 kts	<0.5 kts
West Coast Charlottes	<0.7 kts (Winter)	1.5 kts in wind
(Alaska Current)	<0.5 kts (Summer)	1.5 kts in wind
Dixon Entrance	<0.5 kts	1-2 kts (Vortex)
Hecate Strait		1 kt
Queen Charlotte Sound		1 kt
(Eastern Portion)		<0.6 kts
West Coast Vancouver	0.5 kts	
Island	1 kt (Coastal)	1.5 kts (Coastal)
(Northern Portion)		2-3 kts
Queen Charlotte Strait		0.3 kn (Northern)
	0.6 kts	1 kt
Johnstone Strait	2 kts	6 kts (Kelsey Bay)
Strait of Georgia		2 kts (Nearshore Current)
(Northern Portion)	0.2 kts	
(Central Portion)	1 kt	
(Southern Portion)	1-2 kts	
Juan de Fuca Strait:		
Race Rocks/Discovery Isl.		5-6 kts
Rosario Strait		7.2 kts
Deception Pass		9.2 kts
Admiralty Inlet		4.8 kts
(Eastern Portion)		3.6 kts
(Central Portion)		2.6 kts
(Western Portion/Entrance)		1.5 kts
Swiftsure Bank/Entrance		<2 kts

Note: 1 kt ≈ 50 cm/s

Source: Thompson, Richard E. 1981. *Oceanography of the British Columbia Coast*. Department of Fisheries and Oceans. Ottawa.

3.3 Shoreline Types

The general composition of West Coast shorelines is described by Owens (1988) according to 6 broad regional divisions (Figure 6). Table 3 provides an overview of the basic shoreline characteristics within these regions.

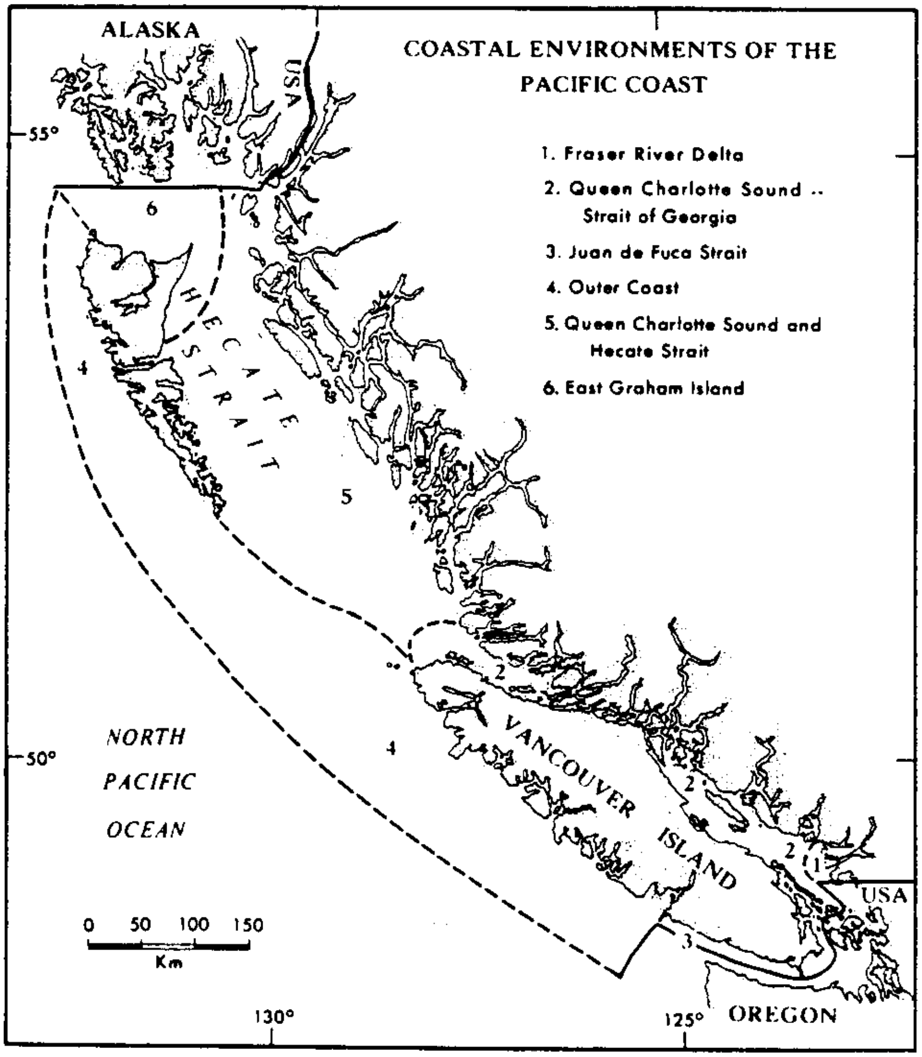


Figure 6 Coastal Environments of the Pacific Coast (after Owens, 1988)

Table 3 Characteristics of Pacific Coastal Environments
(after Owens, 1988)

Region	Coastal Zone Beach Character	Fetch and Wave Exp.	Tidal Range	Sediment Availability
1. Fraser R. Delta	Flat intertidal zone of sand & mud up to 6 km wide @ low tide: no beaches	< 50 km, very sheltered	3 m	Very abundant
2. Strait of Georgia	Absent or narrow with pebble-cobble sediments	Up to 200 km; outer coasts exposed, elsewhere very sheltered	3 m	Scarce: some local concentrations
3. Juan de Fuca Strait	Pebble-cobble and narrow in east; absent or narrow in west; rock intertidal platforms	Progressively more sheltered to the east: west shore very exp.	2.5 m	Scarce: some local concentrations
4. Outer Coast	Absent or narrow with pebble-cobble sediments: isolated wide sand beaches	>1000 km, exposed very high energy; sheltered inner coastal zone	3 m	Very scarce: few local concentrations
5. Queen Charlotte Sound & Hecate Strait	Absent or narrow with pebble-cobble sediments: deltas at heads of fiords	300 to > 1000 km, exposed outer shores sheltered inner coastal zone	3-5 m	Very scarce: some local concentrations
6. E. Graham I.	Wide sand or sand/gravel beaches	Up to 300 km, exposed	3-5 m	Abundant

Table 4 provides an approximate break-down by proportion of shoreline types in low to moderate energy environments. Apart from rock, the B.C. coast is seen to be dominated by a combination of sandy-gravel and gravel-cobble.

Any final site selection must also account for the influence of substrate permeability on the type of experiment which is most appropriate in a given location.

Table 4 Estimates of Lengths of Low-Energy Shoreline Types by Area

Shoreline Type	Percentage
Rock	40
Mud	10
Sand	7
Sandy Gravel	18
Gravel/Cobble	15
Marsh	10

The length of the shoreline of the B.C. coast is estimated to be 25,717 km. Of this amount, 45% is estimated to be low-energy shoreline (Owens et al., 1985).

A similar break-down of moderate and high energy shorelines is not possible from the available references.

4.0 Summary of Response Deficiencies

This section summarizes key deficiencies associated with particular clean-up activities (including but not limited to those deficiencies which could be addressed either through field experiments or field evaluations). Deficiencies are those identified through personal discussions with a broad cross-section of West Coast spill clean-up specialists with extensive experience in dealing with large spill incidents (see listing in Section 2.0). Opinions reflect lessons learned from the *EXXON Valdez, Nestucca,* and *ARCO Anchorage* spills.

This section mentions all important deficiencies which were identified during discussions even though many of the deficiencies are in areas which cannot be addressed directly in an experimental spill (e.g., logistics, political considerations, local concerns, spill response times). Complete documentation of the interview results is considered to be justified given the experience and credibility of the people involved (see Acknowledgements).

Detection, Monitoring, and Tracking

Canadian studies have determined the best mix of sensors for detection of floating oil. However, the currently available technology is inadequate, and all of the required sensors need further development. A second problem is that the remote sensing services offered by the best-equipped of the commercial operators in Canada falls well short of what is required and the services are rarely available when needed.

In spite of a wealth of scientific literature on the subject, there is a high degree of confusion at the operational level as to which sensor is most appropriate under a given set of conditions (sea state, precipitation, oil type, slick thickness, etc.). There is a requirement for pre-packaged remote sensing and spill tracking systems on the West Coast which can (1) be deployed immediately in the event of a spill and (2) provide operations groups with an almost real-time product in an interpreted form (i.e., operations groups should not have to rely on a handful of "experts" for interpretation of the imagery).

The value of remote sensing was seen by the operations people to diminish in importance as a spill progresses from the initial slicks to dispersed oil on the ocean and oil on the beaches (often overwashed by sediment after storms). A general consensus was that much greater use should be made of tracking buoys to follow the spill from the source.

Technology development is required in the following areas: (1) in the ability to detect and map aged and over-washed oil in the open ocean; (2) in the ability to map any submerged oil thought to be present nearshore; (3) in the ability to map and quantify oil on shorelines (this is widely considered an impossible task except by surface inspection); and (4) in the ability to reliably predict oil movements on a real-time basis through improved satellite tracking buoys and remote surface current mapping.

Although deficiencies in the areas of detection, monitoring and tracking will not in themselves justify an experimental oil spill, they can be addressed as a secondary set of experiments tied to a field program.

Offshore Containment and Recovery

Mechanical Equipment

There is wide recognition that spill response plans tied strictly to mechanical containment and recovery devices are extremely vulnerable to weather, equipment problems, and response time. The scale of operations considered in the past is totally inadequate to deal in any meaningful way with a spill of the magnitude experienced in Alaska. These concerns are leading a re-evaluation of many previous containment and recovery concepts. There is a clear need to greatly increase the volume throughputs achievable in an offshore recovery operation with state-of-the-art equipment (with attendant requirements for sufficient onboard storage and separation facilities).

Major concerns centered around the inadequacies of existing West Coast equipment in dealing with typical sea states encountered offshore (or even in more protected areas such as the Strait of Georgia) for much of the year. The Canadian Coast Guard is in the process of re-evaluating their West Coast inventory and the acquisition of new open-ocean equipment is likely in the near future (E. Gauthier, Pers. Comm.). The long response times needed to reach a remote offshore West Coast location remain as the most serious constraint to the recovery of large volumes of oil with mechanical equipment.

Mechanical equipment requires assessments with substantial volumes of oil in a realistic offshore situation; the Canadian and U.S Coast Guards are supportive of any experimental initiatives which will help them achieve this goal. A recurring theme in discussions centered around the importance of developing a response capability to meet a realistic worst-case scenario (or conversely admitting when the achievement of such a capability is beyond reasonable limits with existing technology).

A critical area of technology development concerns the design of skimmers and transfer systems to enable efficient recovery and processing of heavy oil and debris.

A common theme which emerged from a number of interviews involves a shift in attitude away from the use of specialized oil skimmers to the exploitation of high volume pumps common to the marine and fishing industries. When used in conjunction with a dedicated storage/separation vessel such pumps can provide a much greater recovery rate than can be achieved with traditional skimmer systems.

A major deficiency which is addressed in the joint Environment Canada - MMS research into offshore spill response involves the lack of knowledge about the physical properties of the crude oil as it weathers in an open-ocean environment over an extended period of time (and the relevance of sea state in governing the rate of change in properties). Given that almost all of the crude oil moving along the West Coast originated in Prudhoe Bay, the tendency of this oil to form stable water in oil emulsions after very short periods at sea gives rise to a serious response deficiency, i.e., the limited ability of existing systems (skimming or transfer) to deal with highly viscous emulsified oil and the enormous quantities of oily debris (kelp, seaweed, driftwood, etc.) which will be part of any large scale West Coast clean-up operation.

An interesting result of the *Valdez* operations is the important role played by the fishing industry (e.g., nets lined with sorbent material were used to recover oil).

Dispersants

There was a general consensus among all of the Canadian individuals and agencies contacted that there is little to be gained by considering any future field tests aimed at trying to prove dispersant effectiveness. American organizations (Minerals Management Service, Environmental Protection Agency, U.S. Coast Guard) are all interested in improving dispersant effectiveness.

There is a wide divergence of opinion as to the role that dispersants should play in future response plans. The Canadian Coast Guard is seriously considering banning their use out of concerns for (1) human health risk (through long term exposure of response personnel) and (2) the actual viability of deploying dispersants fast enough for them have any real chance of being effective. The concept of maintaining loaded aircraft on a stand-by basis needed to achieve the necessary response times to make dispersants work is not considered economically acceptable in Canada.

In direct contradiction to Canadian thinking on the subject, the Americans are about to embark on a program aimed at evaluating dispersant toxicity; the U.S. Coast Guard are in the process of acquiring the necessary spray gear for their C-130 aircraft (Yaroch, Pers. Comm.). The state of confusion surrounding the dispersant issue is well summarized in a special issue of the Oil Spill Intelligence Report (March 1989).

Burning

Burning remains somewhat of an enigma among spill response specialists. Although proven effective in removing large volumes of oil from the ocean surface under the right conditions, burning is still not widely accepted as a primary response tool (outside of disposal). Arguments are often heard in the following vein: *The conditions suitable for burning in terms of wind and waves also favour mechanical recovery. Given a choice most response authorities will opt for booms and skimmers over burning* - even though strong evidence is available that in terms of volume removed in a given time, burning is superior under the right set of conditions.

The technical issue of burning as a clean-up technique is confused by strong political biases related to the public concerns for combustion products. The concept of burning offshore has a broad base of support among clean-up specialists with practical field experience; all felt that deciding factors in whether burning ever becomes an operational technique center around issues of safety, burn products, operational guidelines, and options for control.

A joint U.S./Canada project is underway to carry out a number of large scale burning experiments beginning in 1990. A number of offshore locations are being considered by the planning committee (including Louisiana, British Columbia, Cook Inlet, and the Beaufort Sea). Key objectives of these experiments will be to provide conclusive scientific documentation of the burn products while demonstrating the operational viability and safety of burning.

Nearshore Containment and Recovery

A major deficiency affecting the viability of nearshore containment in coastal waters centers around the limited ability of existing booms to hold oil in relative water speeds which begin to approach the tidal currents experienced in many of the straits and passages of the "Inside Passage", Gulf Islands, and San Juan Islands.

As with the offshore situation, speed of response in moving booms and skimmers to a remote coastal location is critical in being able to deal with a situation.

Beech (1982) recommended that more effective use be made of naturally available log booms in protecting particular coastal areas. This concept requires a fresh appraisal as to potential effectiveness, along with other local methods which could potentially use indigenous materials deployed by fishermen, local residents, and native residents of the West Coast.

Shoreline Clean-up

Of all the response activities reviewed with different individuals during the course of this study, deficiencies related to shoreline clean-up dominated the discussions, but resulted in few truly original new ideas. This impression was further strengthened by recent results of a workshop commissioned to examine 1990 clean-up strategies for Prince William Sound (Advanced Technology Inc., 1989). The entire field of shoreline response techniques is characterized by a critical lack of "hard" data on either the effectiveness of different technologies, or on the criteria needed to recommend a particular technique in a certain situation (degree of oil weathering, penetration, substrate, etc.).

The overwhelming consensus was that shoreline clean-up cannot be viewed in terms of a dominant technique. In practice, removing oil over a long period of time from a diverse shoreline requires a number of techniques (e.g., remove-wash-replace, remove-burn-replace, chemical washing, bioremediation).

There is a need for revised shoreline clean-up manuals based on recent experience. Such manuals will provide clear operating guidelines which detail the effective application of different clean-up techniques and the limitations with regard to environmental acceptability.

The subject of shoreline clean-up is characterized by both a general lack of knowledge and a lack of any clear consensus on the subject of clean-up effectiveness. Quantitative values are extremely difficult to identify when trying to assess different clean-up strategies, as are data on relative ecosystem recovery rates (either with specific clean-up techniques applied or with a deliberate lack of clean-up).

The entire area of shoreline clean-up can be considered as the key deficiency in the overall arena of response options. **Rather than attempt to solve problems related to many different shoreline types, PCOS should focus on specific West Coast concerns in an effort to take full advantage of indigenous resources and local knowledge.**

Various combinations of pebble through large cobble are perhaps the most difficult type of shoreline to clean. Such shorelines comprise a significant proportion of the low to moderate energy West Coast environment. Other shoreline types such as sand can also present serious problems for clean-up when the contaminated sites are remote and/or numerous and scattered. Characteristic West Coast features such as driftwood and seaweed cover on many beaches present additional clean-up problems.

The June 1989 shoreline clean-up guide for the *EXXON Valdez* spill (U.S.C.G.) specifies warm water flushing in combination with bio-remediation as the only recommended clean-up techniques for mixed gravel-cobble shorelines. On the other hand the Environment Canada spill clean-up guide (Fingas et al., 1979) gives manual removal as the recommended technique for coarse sediments. Owens et al. (1985) pointed out that no techniques are known to be practical or effective on a gravel-cobble beach. Unfortunately, recent incidents have confirmed this pessimistic view.

The *EXXON Valdez* experience has demonstrated the enormity of the task of trying to clean hundreds of kilometers of oiled shoreline with flushing techniques. The overall removal and recovery rates are not well documented but even the most optimistic "experts" quote values of less than 50%. These values require confirmation along with identification of key issues affecting removal and recovery efficiencies in a large-scale beach clean-up operation. There is clearly a great deal of room for improvement either through enhancements to the existing techniques or the application of a completely different concept.

Burning

In-situ burning may be a viable West Coast shoreline clean-up technique, particularly given the large volumes of natural wood fuel needed to maintain an intense burn over an extended period. The apparent success of this technique in removing weathered Bunker oil on gravel/cobble shorelines through burning of oiled logs leads to optimism that results with crude oil could be even more impressive (assuming a minimum delay time between initial oiling and ignition). The application of burning as an in-situ clean-up technique is ignored in clean-up manuals where burning is considered only as a disposal option.

Opinions regarding burning oil on shore from *Valdez* experiences are mixed. A number of key people involved with the beach clean-up operations saw merit in burning oil on heavily coated beaches (2 to 7 cm of oil) for the first 10 days (beyond that time period, there is an order of magnitude decrease in oil thickness on the surface which eventually prevents sustainable combustion - without an external fuel source such as log debris). The use of fireproof booms in the nearshore in conjunction with burning on the beach face was considered a promising technique which requires evaluation.

Burning oil from rocks in-situ with gas fired torches was tried with poor results on the *Nestucca* spill in both B.C. and Washington; not only did the rocks tend to explode with the heat but liquid oil tended to run down and penetrate the substrate. Washington clean-up crews did have some success with a portable "BBQ" grill and tray to catch the oil burned off.

Vacuum Systems

Vacuum suction is commonly used as a primary technique early on in the spill to efficiently remove any free oil in concentrated pockets. A number of commercial vacuum units were used successfully in the *Valdez* operation. There is a need to evaluate the relative effectiveness of different systems with a view to making modifications to better suit the existing equipment for spill clean-up work

Bio-remediation

Bio-remediation received considerable publicity in the latter stages of the *Valdez* clean-up by virtue of the number of impressive "before and after" shots shown in the media. Subsequent evaluations of the effectiveness of this technique are inconclusive. Natural bio-remediation is occurring in Prince William Sound; the question is can human intervention do any better than nature.

In spite of the uncertainties, bio-remediation is still attractive as the least intrusive clean-up method. A number of specialists see some merit in investigating the use of tilling to encourage bio-remediation. There appears to be merit in considering bio-methods for light and moderately oiled shorelines. It remains to be seen how effective such techniques will be for large areas of pebble and cobble shore.

Oil at Depth

A major challenge in Prince William Sound concerns the removal of oil which has penetrated the beach sediments. This topic was discussed at a workshop sponsored by NOAA in November 1989. Discussions were characterized by a lack of consensus as to the best strategy to follow in continuing to remove oil spilled from the *EXXON Valdez*. The workshop concluded that the criteria necessary to weigh the effectiveness of different techniques against their potential negative impact are completely lacking. One thing was clear from the discussion: There is no single or magic solution. A variety of specialized techniques will require testing and evaluation before a solution to subsurface oil removal is possible. The extensive program of oil fate monitoring in Prince William Sound will provide important information on the natural rates of removal of both surface and subsurface oil.

A number of individuals contacted saw little merit in expending a major development effort on mechanical methods to deal with various oiled substrates.

Other Suggestions

The discussions identified a number of concepts and ideas which may merit further development and/or evaluation:

- combined injection systems where air, solvents, or water are used to lift oil from the beach following the application of hot water
- refinements to shoreline treatment methods where oiled material is removed, cleaned (through washing and burning), and then replaced.
- "Rope Mops" used as a means of removing oil in close proximity to shore
- the development of "approved" countermeasures for marsh environments
- the development of nearshore herding devices
- tilling to enhance natural removal

Disposal

Existing clean-up technology with its relatively low net recovery rates (proportion of oil to the total recovered volume of fluid or debris) presents a critical disposal problem. The problems of incinerating or shipping the recovered oil are greatly magnified by the enormous volumes of associated debris. The shear tonnage results in an extensive logistics operation and the often relatively low oiled-percentage volumes lead to problems with incinerators and rotary kilns.

Interim storage is raised as a critical deficiency area in most large spill incidents.

There is still no practical piece of equipment on the market which can be readily airlifted to a remote site and remove significant volumes of oily debris (having a wide range of physical properties) with an acceptable level of air emissions.

The issue of disposal of oiled logs is a particular West Coast problem which requires considerable pre-planning and effective utilization of available forest industry resources (e.g., log barges, chippers, hog fuel conversion, etc.). In-situ cleaning techniques are extremely labour intensive and have proved ineffective for heavily oiled logs.

The entire disposal problem is compounded by lack of agreement between three levels of government on what constitutes an acceptable disposal site. There is a need for pre-approved disposal sites which can be used in the event of a spill. Data gathered from field experiments could assist in obtaining the necessary pre-approvals.

A number of parties indicated a need for a suitable shoreline-all-terrain vehicle acceptable to environmental regulatory agencies which could assist with manual recovery and collection of oily debris. Further development of such a vehicle would require a realistic assessment of the overall effectiveness in a representative mix of West Coast shorelines.

Landfarming is raised as a disposal technique which works on a large scale in the southern United States and may have applications on the West Coast. Small scale experiments could be developed to investigate the potential effectiveness of landfarming as a practical disposal option.

5.0 RECENT RECOMMENDATIONS: ONGOING REVIEWS

The purpose of this section is to highlight a number of recommendations and conclusions regarding oil spill research and development priorities contained in a variety of recent reviews and reports following the *Nestucca* and *Valdez* spills. Only those items which impinge directly on the issue of identifying potential experiments or field evaluation are included. Most recommendations reached in recent reports are too general to be of great assistance here.

A.P.I. Task Force on Oil Spills

Many research areas are identified as having moderate to high priority. A number of recommendations are in direct contradiction to the opinions of the specialists interviewed in this study.

> *Note: care should be taken in drawing too literal an interpretation of the relative ratings. A.P.I. were rating in terms of general research (analytical, engineering, lab, etc.). PCOS is only concerned with rating in terms of whether or not field work with real oil is warranted.*

Comparison of Research Priorities

A.P.I.	*This Study*
• Burning oil on shorelines (LOW - not funded)	*HIGH*
• Chemical dispersant toxicity & effectiveness (HIGH)	*LOW*
• In-situ burning (MEDIUM)	*HIGH*
• Improved boom technology (HIGH)	*LOW*
• Improved skimmer technology for heavy emulsions and debris (HIGH)	*HIGH*
• Remote sensing development (HIGH) **Environment Canada rates the development of improved remote sensing devices as highly important. The low rating in this study means that remote sensing development alone would provide insufficient justification to spill oil.*	*LOW**
• Mitigation of shoreline impact through chemical application (MEDIUM)	*LOW*
• Evaluation of different flushing techniques (HIGH) *Note: PCOS may include flushing evaluations (the decision to include should be based on the quality of information gained from Prince William Sound)*	*MEDIUM*
• Bio-remediation (HIGH) *Note: although attractive from an environmental impact perspective, the achievable results are still too uncertain to recommend as a primary experiment.*	*MEDIUM*
• Beach cleaning machines (MEDIUM)	*LOW*
• Remove to burn detailing problems with logistics, incinerator technology, disturbance, biota effects (LOW)	*LOW*
• Comparison of ecosystem recovery rates after a variety of remediation measures (HIGH)	*HIGH*

EXXON Valdez Oil Spill Report to the President

This report makes the point that contingency planning in the future needs to incorporate realistic worst-case scenarios and include equipment and personnel at a scale appropriate to major spills. Clean-up research should concentrate on the key areas of mechanical recovery, chemical, and biological methods.

Key deficiencies in mechanical recovery and containment are as follows:

- speed with which booms can be relocated
- reduction in skimmer recovery rates due to oil weathering and heavy kelp
- problems in transferring weathered oil from temporary storage on the skimmers to recovery barges (this relates to the A.P.I. contention that major improvements in recovery rates will require a systems approach to the entire skimming system from pick-up to discharge).

Report on the *Nestucca* Spill (Canadian Coast Guard)

This report lists five experimental clean-up techniques which were tried on the *Nestucca* spill. Only two techniques appeared reasonably successful: (1) burning of oiled logs on oiled gravel (said to have burned oil in the gravel to a depth of 50 cm); and (2) cropping of oiled eel-grass at low tide. Reciprocating incinerator, "Tiger" torches, and napalm were tried without great success.

The report specifically recommends the following items for development and/or evaluation:

- environmentally acceptable methods of burning
- satellite tracking buoys to follow overwashed oil
- criteria for selection and use of temporary waste disposal sites
- portable methods of waste disposal
- acceptable methods of waste transport

6.0 OUTLINE OF RECOMMENDED EXPERIMENTAL OPTIONS

6.1 Overview

This section provides an overview of the various experimental options and associated secondary experiments recommended as a result of combining the background information presented in Section 3, the opinions expressed in the interviews (Section 4), and the preliminary recommendations made as a result of recent government and industry reviews.

The recommended experimental spills are intended to reflect a variety of current and future oil spill situations. The following four situations are at present the most likely: (1) a tanker accident involving principally Prudhoe Bay crude off the West Coast or in the Juan de Fuca Strait area; (2) an accident involving bunker oil (typically #5 product) from a deep sea vessel; (3) a barge accident involving bunker oil (typically #6 product); and (4) a crude oil spill related to oil and gas activities.

Future spill situations within the next ten years could also involve an offshore blowout at an exploration platform in the Hecate Strait area (dependent on the fate of the current moratorium on B.C. offshore drilling). Information gained from field experiments will also be directly applicable to spills originating from existing production platforms in Cook Inlet and offshore California.

Information gathered during this first phase of the Pacific Coast Oil Spill Project, indicates a need for four basic types of generic experimental field evaluations - ranked as follows in order of priority:

Response Area	**Objectives of a Field Evaluation**
1. Shoreline	• to quantify and assess the effectiveness of various clean-up devices and techniques (including the "no clean-up option") applied to bunker and crude oil deposited on a variety of West Coast shoreline types and in a mix of wave energy exposures • to compare ecosystem recovery rates following a variety of remedial measures • to translate the findings into a clear set of operating guidelines as to the effective application of different clean-up techniques and the limitations with respect to environmental acceptability
2. Disposal	• to determine the most effective techniques for disposal of a variety of oily wastes generated as a result of an oil spill clean-up operation
3. Nearshore	• to document a major oil burning experiment in order to answer questions of pollution and effectiveness • to develop safe operational procedures associated with large-scale oil burns
4. Offshore	• to assess the performance of oil spill containment booms and mechanical recovery devices in offshore conditions

Recommendation: The nearshore and offshore trials are a lower priority for the West Coast; either of these trials may be conducted elsewhere in North America. On the other hand, the problems associated with shoreline clean-up and disposal on the West Coast are often tied to specific coastal conditions; these experiments need to take place in a West Coast setting for the results to have direct application to future spills in this region.

The following section outlines a proposed strategy to conduct a series of shoreline experimental spills with associated disposal evaluations. Similar strategies for the other experimental evaluations (nearshore and offshore) are attached as Appendix B.

6.2 Outline of Experimental Strategy: Shoreline Clean-up & Disposal

Objectives:

- to quantitatively evaluate the effectiveness of various clean-up devices and techniques (including the no clean-up option) applied to bunker and crude oil deposited on a variety of shoreline types and in a mix of wave energy exposures

- to document the applicability and constraints on use of different clean-up techniques (from the combined perspectives of disturbance to biota and relative ecosystem recovery rates with and without clean-up)

- to determine optimum disposal options for different types of waste generated as the result of oil spill clean-up (e.g., oily combustibles, oiled sediments, oiled logs, oily water, oiled seaweed, etc.)

Rationale:

A massive clean-up operation spanning many months usually follows a large spill in which crude or bunker oil reaches the shoreline. Clean-up and disposal inefficiencies have been experienced partly due to the inability to identify techniques appropriate for the type of oil spilled, the shoreline affected, and the debris present. The timing of the implementation of a particular technique often proves critical to its eventual success.

Opportunities for Improving the State of Knowledge

There are four possible opportunities where new information can be gained, and new clean-up techniques evaluated: (1) small scale laboratory tests, (2) meso-scale tank tests, (3) meso-scale field experiments, and (4) accidental spills.

Correct Choice and Application of Clean-up Techniques

Experiences in Prince William Sound have reaffirmed the historical findings from other large spills; there is no single or magic solution which will deal with a wide variety of physical conditions (oil weathering, sediment size, beach porosity etc.). The choice of which clean-up option to apply in a given situation depends on many factors such as: the degree of contamination and penetration, the practicality and logistics problems of deploying the necessary resources in a remote area, the expected increase in cleaning rate over natural means, and the ecological effects of the clean-up operations.

A clear set of quantitative criteria are needed to make the correct choice in the face of these different (and often conflicting) factors. These criteria are still not available in spite of a great deal of practical experience in dealing with large spills over the past twenty years. The wrong technology is often used (or the right one used wrongly) because of a serious lack of knowledge, guidance, and experience. Experimental spills provide the best means of acquiring the quantitative data needed to both improve the decision-making process, and also to develop new more effective techniques for shoreline clean-up.

Trade-offs Between Predicted Effectiveness and Ecological Damage

In many situations, the "no clean-up" option is the preferred approach particularly when there is a low level of confidence in the clean-up rates which can be achieved by remedial action known to cause ecological damage. In order to weigh the potential damages against the benefits of clean-up, information is needed on the relative rates of ecosystem recovery in different situations (with and without clean-up). Careful monitoring of these recovery rates will form a major part of the proposed shoreline experimental spills.

How clean is clean?

This question continues to act as a major obstacle to rational decisions on when to stop. Experimental spills can help gauge the relative impact and effectiveness of continued cleaning beyond a given point (away from the hype and hysteria that tends to surround such decisions in a real spill situation).

Disposal

Extreme difficulties are experienced during most spill incidents with disposing of the various oily wastes. The shoreline experimental spills will provide an opportunity to try a number of alternate disposal techniques on a small scale in a realistic field situation. Results will reduce the disposal delays commonly experienced in real spills (by identifying optimum techniques and by assisting in obtaining the necessary permits).

An investigation and demonstration of feasible waste processing equipment will help to satisfy provincial and state/federal concerns with regard to effluents and emissions related to disposal of oily wastes.

The disposal demonstrations will assist in identifying, if not solving, inherent technical problems with existing portable disposal devices, while also providing a much more precise indication of alternatives than has been previously possible in contingency plans.

Although incineration devices have evolved beyond the technology levels available only several years ago, portability and emissions remain as serious problems. A proven technique for oily waste disposal, landfarming has only recently seen wide implementation on the West Coast (e.g., refineries in the Vancouver area).

Methodology:

Prior to spilling any oil, baseline inventories would be conducted at the proposed spill sites to determine the biological make-up of the communities and hydrocarbon content in the intertidal and subtidal sediments. A detailed contingency plan would be developed as part of the experimental design to ensure that the oil is controlled under worst case conditions.

Bunker fuel and Prudhoe Bay crude oil would be released in relatively small quantities (several cubic metres for each test) to impinge upon selected cobble, pebble, and rocky-headland coastal shorelines. A variety of clean-up techniques will be applied, results documented, and a program of regular hydrocarbon analyses conducted over time.

Control beaches established prior to discharge would be monitored during the period that other oiled shorelines would be cleaned; this monitoring of the "no clean-up" option will continue after clean-up is complete to provide a baseline against which to measure ecosystem recovery rates and the environmental impacts of both the oil and the clean-up techniques.

The final schedule of shoreline experiments will be decided through a matrix approach which looks at all of the possible combinations of technique, sediment size/composition, beach permeability, and wave exposure. The matrix approach to planning will identify the variables being addressed and separate the individual study units. The most promising beach clean-up ideas requiring field evaluation will only be identified during the final stages of experimental design taking into account all recent developments and activities such as in Prince William Sound and new research results.

A selection of ideas mentioned by the specialists consulted in this study are listed below to provide an indication of the different types of experiments which could be developed in the final plan.

1. *Sustained Burning:* using oiled logs and driftwood overtopping oiled gravel/cobble. Experiments may incorporate a fireproof boom nearshore to remove any burning oil flowing off the beach face.

2. *Vacuum Systems:* using a variety of commercial devices (modified as necessary) to remove pooled oil.

3. *In-situ Washing/Flushing:* using a variety of cold to hot, low to high pressure combinations in conjunction with improved herding devices (e.g., air bubblers - Owens, Pers. Comm.) nearshore to enhance skimmer recovery.

4. *Bio-remediation:* using carefully controlled long term monitoring to establish effectiveness on different shoreline types and degrees of oiling

5. *Removal of Oil at Depth:* a recent workshop in Anchorage (November 1989) focused on the problems facing clean-up crews attempting to recover this subsurface oil in the spring of 1990. Results from this experience will only apply to old weathered crude; many of the lessons to be learned from Prince William Sound in the second summer are not directly applicable to the problem of dealing with fresh crude.

6. *Remove, Clean, and Replace:* this procedure involves physically removing the oiled material and processing the sediment, gravel, and cobble through some form of washing and/or burning operation to remove the oil. The cleaned material is then placed back on the beach. The West Coast involves a high probability of having to deal with large volumes of oiled wood and seaweed. In cases of light oiling, logs can be cleaned in-situ by surface burning. Seaweed and heavily oiled logs and driftwood become a disposal problem.

7. *Incineration Techniques:* Capacity, waste type, associated restrictions, air emissions would be determined along with a comparison between on-site and off-site disposal.

Support Equipment & Materials:

The shoreline experiments will require the development of suitable oil discharge systems (examples are tractor mounted on-shore spray rigs or floating spill plates allowing slicks to strand naturally as in the Baffin Island Oil Spill Project).

Skimmers and booms suitable for deployment at the affected shorelines would be utilized in conjunction with steam jennies, pumps and hoses in the oiled areas.

Provision would have to be made for the collection, separation and measurement of all liquid and solid materials generated during the flushing operations.

In the case of the burning experiments, collection of burn residue and test and sampling equipment would be used to measure the efficiency of combustion and the depth of penetration of oil. Experiments would have to address specific concerns regarding air pollution and safety (e.g., forest fires).

Transportation requirements (helicopter, truck, boats, etc.) will depend on site selection. Various All-Terrain-Vehicles (ATV's) will be evaluated for their utility in moving material and as potential platforms for clean-up devices. One option is to use a moored barge as a floating operations base (including oil storage and accommodation). This approach would minimize shoreline impact of a temporary camp.

Disposal evaluations will require a variety of incinerators, rotary kilns, etc. Support equipment will reflect the logistics, transfer, and storage needs representative of a real spill situation (e.g., trucks, vessels, helicopters, liners).

Landfarming evaluations will depend on the availability of a suitable location.

Data Collection

The amount of oil removed from the shoreline would be measured in relation to the amount released. Physical and chemical properties of the oil would be measured as a function of time. The physical disturbances associated with different clean-up methods would be documented along with the natural recovery rates in terms of shoreline reworking with storms and tides.

An associated program of fate and effects would monitor the response of the biological communities impacted by the oil with and without the application of different techniques together with the response of control organisms in a clean environment.

Incineration: air, device, stack temperature; opacity of smoke, particulates, PAHs, etc., as per B.C. Ministry of Environment guidelines; physical/chemical characteristics of waste materials; characterization of residue; fuel/power requirements; technical problems.

Landfarming: air, soil temperature; soil pH; nutrient addition; moisture content of soil; precipitation; water quality of runoff; chemical characterization of oil over time.

Probability of Success:

There is a high probability of successfully identifying the optimum means and efficiencies of carrying out shoreline clean-up with the available techniques. There is also an excellent potential of evaluating new technologies (including mechanical and bio-remediation) which may become available during the PCOS time-frame.

The newer incinerator devices have a high probability of consuming oily wastes more efficiently than the techniques tried in the past. Emissions remain questionable in the case of the air curtain incinerator.

The availability of the fluidized bed and rotary kiln for this test is unknown. Capital costs and siting costs are high.

A well-managed landfarming operation has a high probability of success. Degradation of waste oil over several years could be required. Again, a site must be designated and public concerns must be addressed.

7.0 Site Selection

This section provides an overview of several potential sites for nearshore and shoreline experimental spills in British Columbia. A more detailed evaluation of these and other locations will be required before proceeding to the permitting phase of the project.

The ideal site will be readily accessible, have a variety of representative shoreline types, and have accommodation and support infrastructure nearby. It is proposed that the nearshore and shoreline spills be at or near sites with a previous history of environmental disturbance or industrial pollution (in the expectation that such an approach will assist the approvals process). Care must be taken to ensure that any existing site contamination will not invalidate any results from the field experiments (particularly in terms of relative long-term impacts).

Five sites shown in Figure 7 are considered here as potential candidates: Ocean Falls, Port Alice, Tasu Sound, Gowgaia Bay, and Port San Juan (Note: Port San Juan is highly rated but is likely to be unacceptable for permitting).

The sites are described below. The descriptions of each site include latitude and longitude, type of industrial activity, past and present population, and geographical and environmental descriptions. In order to compare the sites on a relative basis, a set of descriptors are assigned, and each site is ranked. The descriptors used to compare the sites are assigned as follows.

Descriptors	**Ranking**		
	2	1	0
Road access - distance from Vancouver	direct	ferry and road	none
Distance from a commercial airport	<50 km	50-100 km	>100 km
Cost of airfare to nearest commercial airport	<$200	$200-$400	>$400
Per kg cost for airfreight to commercial airport	<$1	$1-$2	not available
Cost of Twin Otter charter from nearest commercial airport	<$2K	$2K-$5K	not available
Cost of helicopter charter from nearest commercial airport	<$2K	$2K-$5K	not available
Cost of barge access	<$20K	$20K-$50K	>$50K
Distance to mud flat	<5 km	5-10 km	>10 km
Distance to pebble/cobble beach	<5 km	5-10 km	>10 km
Distance to rock shoreline	<5 km	5-10 km	>10 km
Energy at rocky shoreline	mixed*	medium	high,low

* Ranked as three.

No rating has been estimated for the present condition of the area; all are similar in that they are in areas which have seen industrial activity but are remote from urban centers. No rating has been given for cost of accommodation. The use of barge mounted accommodation and laboratory facilities are recommended. Such facilities have been used in other oil spill experiments (e.g., Dome's Oil and Gas Under Sea Ice Experiment in the Beaufort Sea, 1979/1980) and would solve a number of logistical problems. Group mobilization could occur at an urban location, no accommodation problems would occur in remote towns, and the clean-up and removal of the camp facilities would be readily accomplished without disturbance.

Table 5 summarizes the results of the rankings for each site. Appendix B contains the detailed ranking values and site maps for each location.

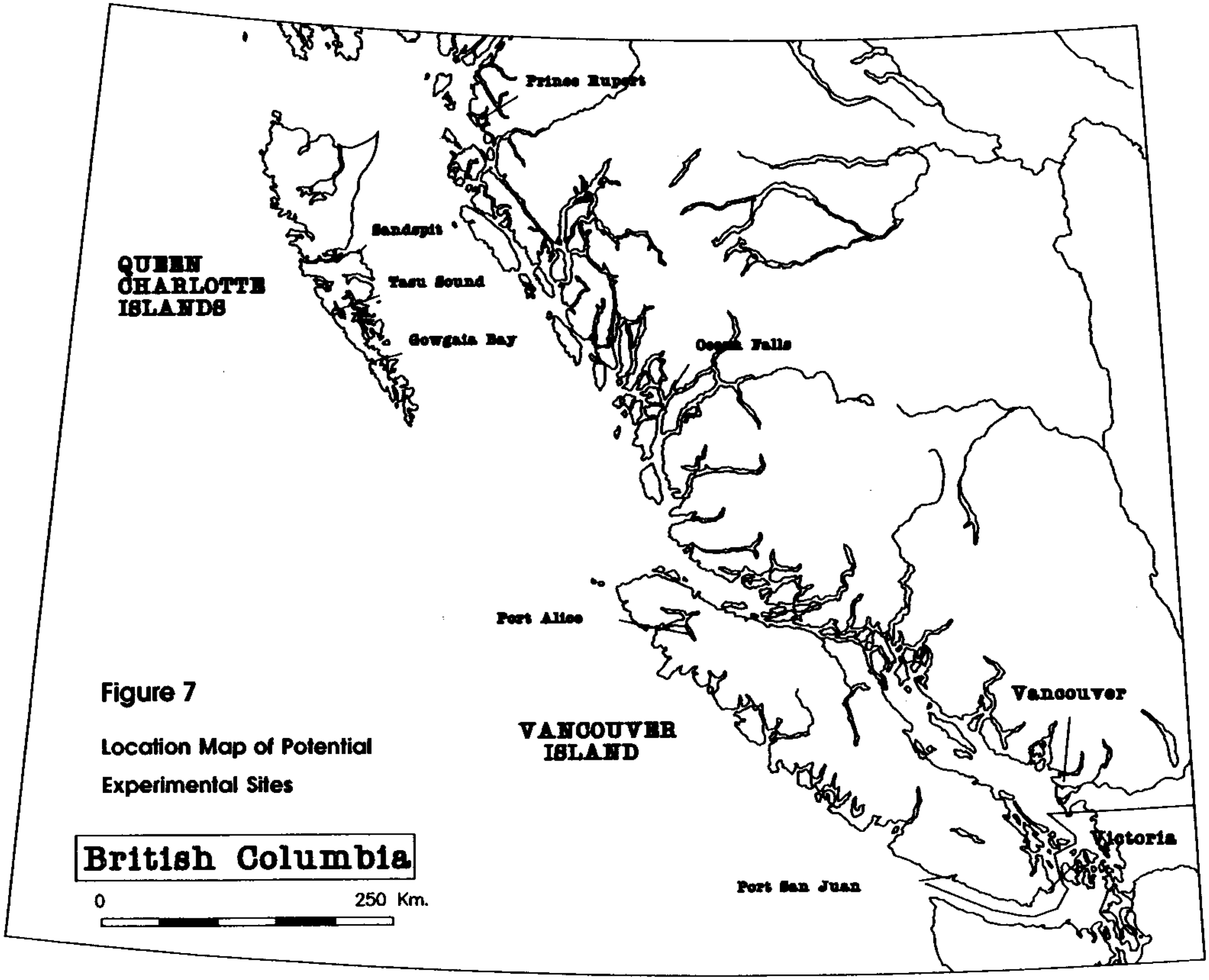


Figure 7

Location Map of Potential Experimental Sites

Table 5 Summary of Ratings for Potential Sites

SITE DESCRIPTORS	OCEAN FALLS	PORT ALICE	TASU SOUND	GOWGAIA BAY	PORT SAN JUAN
LATITUDE					
LONGITUDE					
CAMP ON SITE	1	1	1	0	2
ROAD ACCESS					
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	0	1	0	0	1
AIR ACCESS					
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	1	2	1	1	1
AIR FARE, VANCOUVER TO COMM. AIRPORT	1	1	0	0	2
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	0	2	1	1	2
AIR ACCESS: FLOAT CHARTER (Notes 1,2)					
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	1	2	1	1	2
HELICOPTER CHARTER (Note 3)	1	2	2	1	2
BARGE ACCESS					
BARGE ACCESS COST PER TRIP (Note 4)	1	1	1	1	2
DISTANCE FROM CAMP TO MUD FLAT (km)	2	2	1	2	2
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	2	2	2	2	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	0	1	1	2	2
ROCKY SHORELINE ENERGY	0	0	3	3	3
RATING	10	17	14	14	23
RANK	5	2	3	3	1

7.1 Individual Site Descriptions

Ocean Falls

Located at the head of Cousins Inlet, off Dean Channel, at 52° 17'N, 127° 46'W (CHS Chart 3781), Ocean Falls was the site of a pulp and paper mill for many years. With the mill now closed, the town is considerably reduced in population although efforts continue to seek alternative industrial activity. All shoreline types are present within a few hours travel by small boat, but situated as it is near the inside passage, heavy seas are unusual. Additional sites are available in Jenny Inlet, across Dean Channel from Cousins inlet, and about 20 km distant from the town. Docks, floats, and seaplane facilities are available. Access by air is through Bella Coola by scheduled small seaplanes or charter. Heavy gear must be brought in by barge.

Port Alice

Situated near the head of Neurotsos Inlet on Vancouver Island, Port Alice (50° 23'N, 127° 27'W, CHS Chart 3960) is the site of a pulp mill. The townsite (Rumble Beach) is about 7 km NW of the mill site. All shoreline types are available within 5 km, but heavy seas are uncommon nearby.

Docks, floats, and seaplane facilities are available, and there is road access. Access and supplies are through Port Hardy.

Tasu Sound

Tasu Sound is located on the West Coast of Moresby Island in the Queen Charlottes(52° 44'N, 132° 07'W, CHS Chart 3859). All shoreline types are available within 10 km of the townsite, a mining development. High energy shores are available on the outside coast requiring access through Tasu Narrows. The sound itself is a public harbour. Permitting may be more difficult with an additional level of government.

Access is by seaplane from Sandspit or Prince Rupert. Heavy gear will have to be transported by barge.

Gowgaia Bay

Located south of Tasu on Moresby Island, Gowgaia Bay (52° 25'N, 131° 35'W, CHS Chart 3864) does not have a permanent townsite. All shoreline types are available within 10 km, and high energy shorelines will be available on the outer coast.

Access is by seaplane from Sandspit or Prince Rupert with heavy gear being transported by barge. No permanent housing facilities are known in the bay; accommodation and operations are best conducted from a barge or barges.

Port San Juan

Located on the SW portion of Vancouver Island and within a short drive from Victoria, the shores of Port San Juan (48° 32'N, 124° 26'W, CHS Chart 3647) and the adjacent outer coast are most accessible. All shoreline types are available including high and low energy shores within 10 km. The inlet marks the southern end of Pacific Rim National Park, and the nearby outer coast includes Botanical Beach, a popular inter-tidal shelf rich in biota and used as a scientific resource. Permitting would be difficult as public response would likely be unfavourable. The site is included here as an example of how an ideal experimental location would rank if permitting issues were not a major concern.

8.0 Associated Studies

A number of recommended or on-going associated studies support the Pacific Coast Oil Spill Project. These studies may result in the addition of new experimental options during subsequent phases of PCOS.

1. Long Term Monitoring in Prince William Sound

Programs monitoring oil fate and effects are being sponsored by EXXON and government agencies. These will provide valuable results over the next few years to help evaluate the relative ecosystem recovery rates with different degrees and types of clean-up. The results from this work will not be as scientifically rigorous as those achievable from a carefully planned experimental release due to the lack of sufficient baseline sampling against which to measure relative impacts.

2. Estimating the Natural Cleaning Rates of Oil on West Coast Shorelines

Shoreline clean-up strategies, impact assessments, and technology evaluations rely on information about natural and induced rates of change in stranded oil cover and character. Yet quantitative data on the fate and persistence of oil on shorelines is lacking for some common oiled shoreline scenarios. Of particular concern are cobble-gravel beaches.

Canada has acquired some good information from a variety of spills (e.g., from the *Arrow* to the BIOS Project). A large number of studies are now being conducted as a result of the *EXXON Valdez* spill. Using existing data from Canadian historical experiences and new data from Valdez, it should be possible to start making better predictions about the self-cleaning rates of West Coast shorelines (as well as other beach types in Canada). Reliable estimates are required of oil fate and the natural cleaning capabilities of gravel-cobble-boulder beaches.

Natural cleaning is an option which is often not available because of poor public acceptability (even in cases where it may be logical or the ecologically preferable solution). Hard data is required to counter public impressions of the "do nothing" approach in specific situations.

3. SCAT Manual for Coastal Contamination

There is a requirement to produce a SCAT (Shoreline Cleanup Advisory Team) manual for coastal oil spills. As a result of the *Nestucca* and *EXXON Valdez* spills, great strides have been made in the area of real-time shoreline clean-up assessment and advice. In Prince William Sound the SCAT reports became the basis for decision-making on shoreline clean-up priorities and techniques, for regulatory approvals, for direction to clean-up crews, and for tracking progress. That process is relatively well documented.

4. Sensitivity Mapping and Geographic Information Systems in Support of Environmental Emergencies

The Public Review Panel recommends that sensitivity maps be prepared on a priority basis for coastal areas and inland waters along tanker routes where no such mapping presently exists. The Panel recommends that federal and provincial government agencies work with industry to develop a more standardized approach to sensitivity mapping using computer-based geographic information system technology.

5. Optimize the Use of Local Resources

Evaluate local materials used by native groups, the fishing industry, and the forest industry for their role in providing immediate response and assisting with problems of clean-up and disposal. One example is to evaluate materials that could be used on short notice to adopt log booms as effective spill containment and diversion devices (as recommended in Beech et. al., 1982). Another example involves co-operating with the forest industry to explore alternative disposal methods using oily debris as hog fuel.

6. Monitor New Technology Developments and New Applications of Existing Industrial Technology

During this study, the contractor identified two new Scandinavian boom development programs: (1) a boom with built-in weir skimmer being developed in Denmark , and (2) a high current boom of novel cross-section being developed for the Swedish Coast Guard. As a result of the recent infusion of R&D funds, a number of companies world-wide are gearing up to produce entirely new products or to modify existing equipment. These developments require close attention over the next six months in order to identify any new techniques or equipment which may deserve inclusion in later phases of PCOS.

Existing Canadian spill-response systems and techniques are designed to cope with relatively small spill incidents. On the scale of a spill such as the *EXXON Valdez,* alternate technologies associated with such industrial processes as vacuum cleaning and heavy oil extraction may find an efficient application. Methods used for materials extraction, removal and handling in the mining, forestry, and fishing industries should be examined for potential applications to a large-scale spill situation and testing in future field experiments.

REFERENCES

Advanced Technology Inc. November 1989. *Exxon Valdez Oil Spill Winter Studies: Draft Notes - Clean-up Technology Workshop.* Report prepared for NOAA, Office of Oceanography and Marine Assessment, Seattle.

Brown, R.D. et al. 1986. *Marine Climatological Atlas - Canadian West Coast.* Canadian Climate Centre. A.E.S. Report No. 86-10. Downsview, Ontario.

Canadian Coast Guard. 1989. *Heavy Oil Movement Report.*

Canadian Coast Guard Western Region. June 1989. *Nestucca Spill Report.*

Environment Canada. May 1979. *Experimental Oilspills General Plan: Arctic Marine Oilspill Program.* Environmental Protection Service, Ottawa.

Federal On Scene Coordinator. 1989. *Exxon Valdez Oil Spill - Field Shoreline Treatment Manual.* United States Coast Guard. Valdez, Alaska.

Fingas, M.F. et al. 1979. *The Basics of Oil Spill Cleanup-With Particular Reference to Southern Canada.* Environmental Emergency Branch, Environmental Protection Service. Hull, Quebec.

Owens, E.H. 1988. *Shoreline Processes, Coastal Environments and the Impact and Cleanup of Oil Spills.* Report by Woodward-Clyde Consultants, Houston for Environment Canada, Environmental Emergencies, Ottawa.

Owens, E.H. and Trudel K. 1985. *Oil Spill Countermeasures for Low-Energy Shorelines - Research Recommendations.* Report by Woodward-Clyde Oceaneering and S.L. Ross Environmental Research Limited for Environment Canada, Environmental Emergencies Technology Division, Edmonton.

Sandwell Swan Wooster Inc. 1988 *Vancouver Area Transport of Dangerous Goods Study.* Report for Greater Vancouver Regional District. Vancouver, B.C.

Skinner, S.K and W.K. Reilly. May 1989. *The Exxon Valdez Oil Spill: A Report to the President.* National Response Team.

Thompson, R.E. 1981. *Oceanography of the British Columbia Coast.* Canadian Special Publication of Fisheries and Aquatic Sciences 56. Ottawa, Ontario.

Tramier, B. et al. 1981. *A Field Guide to Coastal Oil Spill Control and Clean-Up Techniques.* CONCAWE Report No. 9/81. Den Haag, Netherlands.

Vancouver Port Corporation. *1988 Statistics for Port of Vancouver.*

Appendix A

Oil Movement Statistics

Discussion of Data Contained in Tables of Oil Movements in B.C. Coastal Waters

The purpose of this summary account of the volumes of oil products moving in B.C. coastal waters is (1) to gain an understanding of the geographic areas where the risk of an oil spill is high and (2) to determine the probable type of oil spilled in such an event. Oil companies are reluctant to divulge commercial information; consequently, the available public data is scarce and incomplete.

Estimates of oil volumes being transported in B.C. coastal waters are presented in the accompanying tables and graphs.

Terminology Used in the Tables:

1. *DWT*: Dead Weight Tonnage - The total cargo carrying capacity of a vessel. Note that this value does not relate directly to the amount of oil product being carried unless the vessel is dedicated to carrying oil products.
2. *Bulk*: Refers to the sum of products being transported in and out of a transit zone.
3. *Foreign*: Refers to all products being transported to destinations outside Canada.
4. *Domestic*: Refers to all products being transported to destinations along the B.C. coast including Vancouver Island.

Assumptions:

1. Data reported is based on 1988 traffic reports with the exception of aviation fuel volumes which are derived from 1986 data.
2. An assumption is made that the total volume of products transported did not change significantly between the years 1986 and 1988 in order to provide total volume estimates.
3. The aggregate volumes of Bunker C transported to the B.C. mills are obtained from the *Heavy Oil Movement Report*. Some of these values included oil transported from U.S. refineries in the Puget Sound area (estimated).
4. An estimate of the destinations of gasoline (domestic) and aviation fuel is provided. It is estimated that a third of the bulk volume of these products originating from the Port of Vancouver is shipped through the "Inside Passage", a third is shipped through the Strait of Juan de Fuca and a third is shipped to the Victoria area.
5. The larger of the two 1988 values of total crude transported out of the Port of Vancouver recorded by the *Vancouver Port Corporation 1988 Statistics* and the *Heavy Oil Movement Report* is listed in the table (1,025,000 metric tonnes).
6. An average value for the annual number of transits of vessels carrying Bunker C to the mills along the coast of B.C. is calculated from the individual transit frequencies to each mill in the corresponding geographic area.

Dominant Oil Types		
Transit Area	**In Terms of Volume**	**In Terms of Frequency of Transit**
Pacific Ocean	Crude	Fuel Oil
Juan de Fuca	Crude	Fuel Oil
Port of Vancouver	Fuel Oil	Fuel Oil
"Inside Passage"	Gasoline/Fuel Oil	No Data

References

1 Canadian Coast Guard. *Heavy Oil Movement Report*. 1989.

2. Vancouver Port Corporation. *1988 Statistics for Port of Vancouver*.

3. GVRD. *Vancouver Area Transport of Dangerous Goods Study*. January, 1988.

DF Dickins Associates Ltd. 06/1989

Oil Movements in B.C. Coastal Waters

Transit Area Description	Year of data	Bulk Tonnage (000's Metric Tonnes)				Annual Transits	Vessel Type	Avg. DWT (000's Tonnes)
		Crude	Fuel Oil incl. Bunker C	Gasoline***	Aviation Fuel**			
Pacific Ocean off the west coast of B.C. (Alaska to Washington)	1986	91917#		No data.	No data.	No data.	T	80
	1988	23900				365	T	80
	1988		7350			8104	D	45
	1988		18			1160	C	0.6
	Totals	**N/A**	**7368**					
Strait of Juan de Fuca	1988	1025***				20.5	T	50
	1988		10157			11199	D	45
	1988	23900				365	T	80
	1988		78*			6	C,B	4,10
	1988			470(Foreign)		No data.	T,D	35
	1986				72	No data.	D,C,B	35,4,10
	1988			246(Domestic)		No data.	D,C,B	35,4,10
	1988	3300				No data.	T	80
	Totals	**28225**	**10235**	**716**	**72**			
Port of Vancouver, Southern Strait of Georgia, Fraser River	1988	1025***				20.5	T	50
	1988		10157			11199	D	45
	1988		390*			19	C,B	4,10
	1988			470(Foreign)		No data.	T,D	35
	1988			738(Domestic)		No data.	D,C,B	35,4,10
	1986				215	No data.	D,C,B	35,4,10
	Totals	**1025**	**10547**	**1208**	**215**			
Northern Strait of Georgia "Inside Passage"	1988		222*			27	C,B	4,10
	1988			246(Domestic)		No data.	D,C,B	35,4,10
	1986				72	No data.	D,C,B	35,4,10
	Totals		**222**	**246**	**72**			

Information Sources

* Aggregate values derived from *Heavy Oil Movement Report* on Bunker C transported to B.C. Mills by ship and barge.(Canadian Coast Guard,1989-Unpublished)

** Bulk value obtained from the *Vancouver Area Transport of Dangerous Goods Study* (GVRD,1988).

*** Values obtained from *Vancouver Port Corporation 1988 Statistics.*

\# Volume transported from Alaska to Washington and California.

Note: Remainder of data obtained from *Heavy Oil Movement Report*. (Canadian Coast Guard,1989-Unpublished)

T=Tanker, D=Deep Sea Vessel, C=Coastal Vessel, B=Barge

DF Dickins Associates Ltd.

Appendix B

Outline of Other Potential Field Experiments

See Section 6.1, Numbers 3 & 4

Offshore Containment and Removal

Objectives:

Primary: To assess the performance of oil spill containment booms and mechanical recovery devices in offshore conditions.

Secondary: To examine surveillance devices in a simulated spill situation in the offshore environment.

Rationale:

Physical removal of oil contamination from the environment is the most attractive (on the surface) countermeasures approach since it prevents significant damage to the ecosystem. The practical effectiveness of offshore containment on the West Coast is limited by response time and the available equipment to perform in rough water.

Physical containment and recovery hardware now exists in Scandinavia and Germany designed to function at a level of capability exceeding that of the equipment in place on the West Coast. The German and Norwegian equipment was assessed at the 1989 Oil Spill Conference in San Antonio, Texas. Equipment brochures containing unpublished test data on the Norwegian equipment and presentations made on the German equipment at that conference tend to support this claim.

Windows of opportunity (i.e., periods of relatively calm seas) exist throughout the year particularly during the spring and summer months when it will be feasible to use booms and oil removal devices to deal with spills. The Clean Sound oil spill cooperative in Seattle recently (1989) invested large sums of money to upgrade their capability to recover oil at sea in the Pacific Northwest area (Weichert - Pers. Comm.).

Manufacturers performance claims and documented experiences from European trials are insufficient to allay public concerns (and skepticism) over the existing state of response preparedness on the West Coast. "Dry-run" exercises will only serve to deepen the public's mistrust of government agencies and industry representatives. Realistic West Coast offshore trials involving state-of-the-art equipment would demonstrate actual spill response improvements to be gained by acquiring more ocean-capable equipment. Offshore exercises will also afford the opportunity for operational groups to participate in the examination of new technology equipment under realistic operating conditions. The offshore trials would also afford an opportunity to test new techniques for monitoring real-time offshore slick movements (e.g., CODAR shore based radar, and GPS based satellite buoys).

An offshore test involving real oil could only take place with the full realization that even the best available booms and skimmers will likely recover less than 50% of the oil spilled under realistic conditions. The primary objective of the test will be to prove that newer technology equipment optimized for rougher water and higher volume recovery rates (relative to equipment currently in use) will result in a significant improvement in overall oil recovery.

Methodology:

A high seas containment barrier would be deployed in conjunction with a high volume oil removal system. Crude oil would be presented to the equipment under study and attempts made to recover slicks with optimum efficiency. Oil removal rates and oil/water content in the collected liquid would be measured along with records of sea state and weather conditions.

Tests would be conducted in waves of 1-1.5 metres and in wind speeds up to 20 knots. The site for the offshore evaluations would likely be outside of Canada's 200 mile economic zone. Two releases would be planned: one comprised of fresh crude and the second involving oil weathered for 48 hours. Necessary oil volumes to ensure a realistic test will be in the order of 50 m^3.

Support Equipment & Materials:

Two ocean-going vessels and one tug are envisaged to be necessary for the sea trials. One of the vessels would have to have sufficient on-board tankage to be able to hold, separate and ultimately transfer in the order of 40-50,000 Imperial gallons. It would be used in conjunction with the tugboat to deploy and maneuver the boom. The third vessel would be utilized to store and release the crude oil. The vessels would be selected so that accommodation for 12 people in addition to crew members was possible. Aerial photography and remote sensing of the tests is envisaged depending on the distance from shore.

Secondary Research Activity:

Technology developed to monitor slicks would also be examined during the skimmer and boom tests. The following are examples of systems which could be studied:

(i) CODAR, a real-time mapping system previously applied to measure surface currents (this system will only prove effective in the event that the experiment takes place within 50 km of shore);

(ii) GPS satellite buoys, a real-time monitoring method employed to track slick position;

(iii) compact airborne spectrographic imager.

An emphasis would be placed on the acquisition **and interpretation** of data on an immediate basis to match a typical operational setting.

Data Collection:

Booms: Visual observations would be made of the containment capability of the booms. These would be supplemented by precise measurements of the collection efficiency of the skimming gear. The experiment would use the joint U.S/Canada boom testing protocol.

Skimmers: Measure the total liquid collected by the skimmers relative to the oil encounter volumes, the rate of liquid collection, the amount of oil collected, and the amount of water recovered. Analyses for oil in the apparent water phase and water in the apparent oil phase would also be conducted.

Oil: The crude oil would be physically and chemically characterized in terms of its viscosity, specific gravity, pour point and chemical composition.

Sea & Weather Conditions: Significant wave height, frequency, wave type, water temperature, wind speed and direction, precipitation, air temperature, residual currents, tidal stage, etc.

Probability of Success:

Operationally and qualitatively, good: quantitatively, fair. A major problem with the offshore trial will be to obtain a permit while objectively stating that no more than 50% of the oil will likely be recovered even with the best of conditions.

Nearshore Clean-up: Contained Burning

Objectives

- to sample the products of burn combustion and to verify existing models of plume behaviour during a large-scale experiment (allowing comparisons with previous laboratory and meso-scale work)
- to demonstrate effective control over operational procedures and safety during a large-scale oil burning test

Rationale

The rationale behind conducting a major burning test is to demonstrate that burning is a safe, effective,and environmentally acceptable clean-up technique. The motivation behind continuing to pursue in-situ burning is based on the fact that with carefully planned procedures and rapid response burning offers the potential to remove in the order of 70 to 95% of the oil available on the water surface (exact efficiencies will depend on the initial slick thickness and oil weathering). This effectiveness is three to four times greater than that achievable from the best available combination of mechanical recovery equipment operating for a much longer time period.

Major impediments to burning at the operational level center on a lack of quantitative understanding of the safety, effectiveness, and pollution aspects of a large oil burn. Unresolved issues cited by the A.P.I. regarding in-situ burning include the following items:

- workability and safety under various conditions
- effectiveness on weathered crude and mousse
- pollution trade-offs (including impact of residues and fallout)

Methodology

The experimental design of a representative nearshore burning experiment is the subject of an independent study funded by Environment Canada and the U.S. Minerals Management Service (Dickins 1989 - in preparation).

In general the experiment will involve several spills in the order of 10,000 to 15,000 U.S. gallons each into a fireproof boom of standard commercial manufacture (e.g., "3M Fire Boom"). A complex monitoring program will profile the smoke plume and obtain samples for subsequent analysis of burn products.

Support Equipment

The experiment will utilize a barge as a floating operations base (including oil storage and residue recovery). A number of support vessels such as small tugs will be used to deploy and manage the fireproof boom. Burn trials will be conducted in a realistic dynamic mode (i.e., the boom will be allowed to drift slowly with surface water flow to contain the oil during the experiment).

Probability of Success

There is a high probability of success in carrying out an effective burning test. Uncertainties center around the ability of the scientific team to gather the necessary quantitative measurements of the combustion products.

Appendix C

Site Descriptions and Maps

Table C-1 Tasu Sound Site Description

SITE DESCRIPTORS	SITE	FACTOR
LATITUDE	52° 44'N	
LONGITUDE	132° 07'W	
CAMP ON SITE	WESTFROB MINE SITE	1
ROAD ACCESS	NONE	
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	--	0
AIR ACCESS	CHARTER	
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	60	1
AIR FARE, VANCOUVER TO COMM. AIRPORT	$450	0
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	$1.18/Kg	1
AIR ACCESS: FLOAT CHARTER (Notes 1,2)	EX-SANDSPIT	
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	$2,310	1
HELICOPTER CHARTER (Note 3)	$1,500	2
BARGE ACCESS	YES	
BARGE ACCESS COST PER TRIP (Note 4)	$40,000	1
DISTANCE FROM CAMP TO MUD FLAT (km)	<7	1
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	2	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	6	1
ROCKY SHORELINE ENERGY	MIXED	3
RATING		14
RANK		3

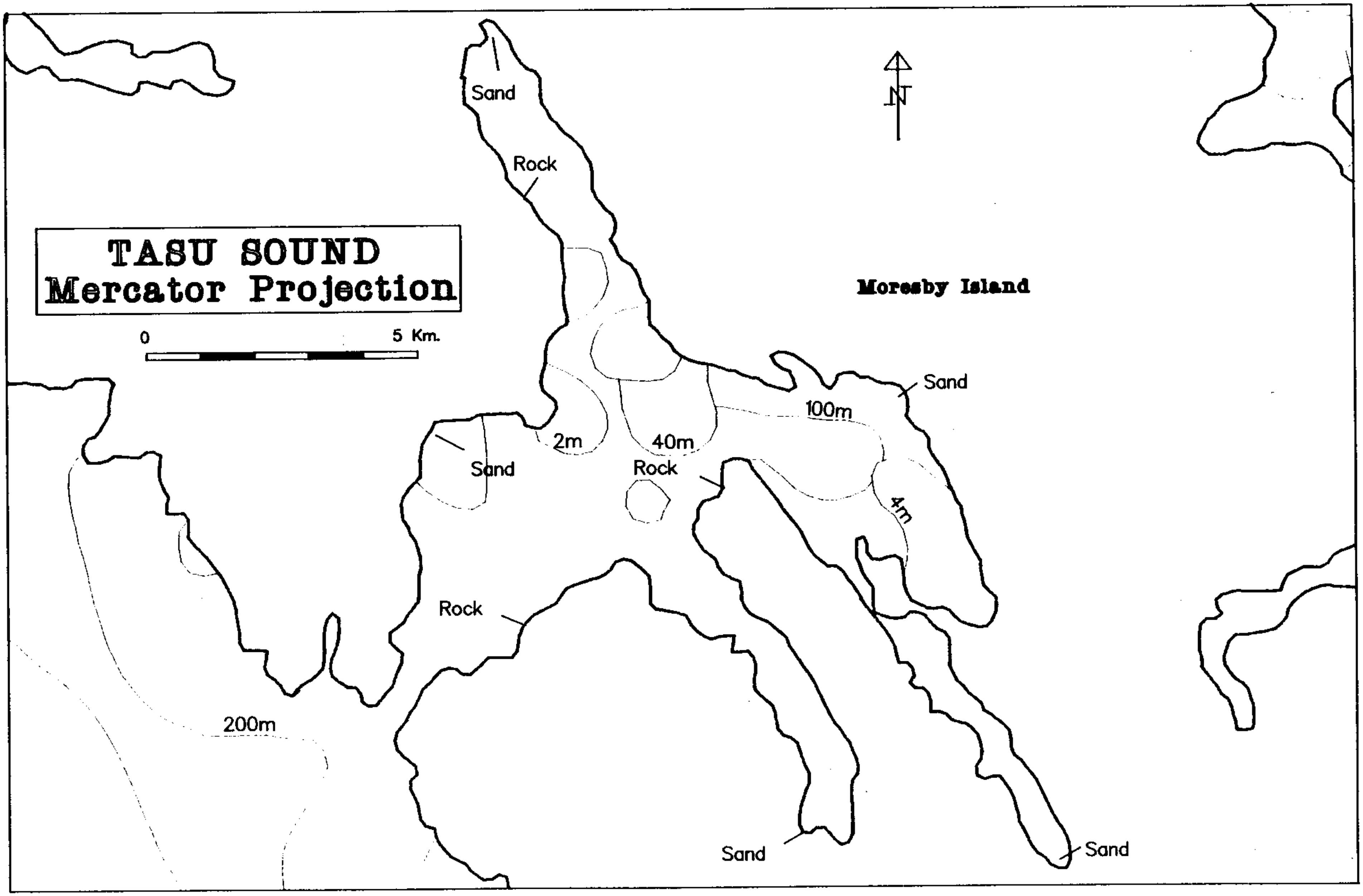
Notes:

1: All charter for flights based on return time from nearest commercial airport - 1 hour added to flight times for loading/unloading.

2: Twin Otter float plane $1050/hr commercial airport to site - Twin Otter not always availaable from commercial airport - may have to fly from Vancouver or use smaller aircraft.

3: Bell Jet Ranger @ $650/hr includes fuel

4: Barge rates all ex-Vancouver, barge already loaded - no time added for on site barge manipulation - $800/day for barge; $325/hr for tug; 8 knot cruise speed; no lay over time.



TASU SOUND
Mercator Projection

Table C-2 Gowgaia Bay Site Description

SITE DESCRIPTORS	SITE	FACTOR
LATITUDE	52° 25'N	
LONGITUDE	131° 35'W	
CAMP ON SITE	NONE	0
ROAD ACCESS	NONE	
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	--	0
AIR ACCESS	CHARTER	
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	94	1
AIR FARE, VANCOUVER TO COMM. AIRPORT	$450	0
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	$1.18/Kg	1
AIR ACCESS: FLOAT CHARTER (Notes 1,2)	EX-SANDSPIT	
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	$3,000	1
HELICOPTER CHARTER (Note 3)	$2,000	1
BARGE ACCESS	YES	
BARGE ACCESS COST PER TRIP (Note 4)	$37,000	1
DISTANCE FROM CAMP TO MUD FLAT (km)	2	2
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	<4	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	1	2
ROCKY SHORELINE ENERGY	MIXED	3
RATING		14
RANK		3

Notes:

1: All charter for flights based on return time from nearest commercial airport - 1 hour added to flight times for loading/unloading.

2: Twin Otter float plane $1050/hr commercial airport to site - Twin Otter not always availaable from commercial airport - may have to fly from Vancouver or use smaller aircraft.

3: Bell Jet Ranger @ $650/hr includes fuel

4: Barge rates all ex-Vancouver, barge already loaded - no time added for on site barge manipulation - $800/day for barge; $325/hr for tug; 8 knot cruise speed; no lay over time.

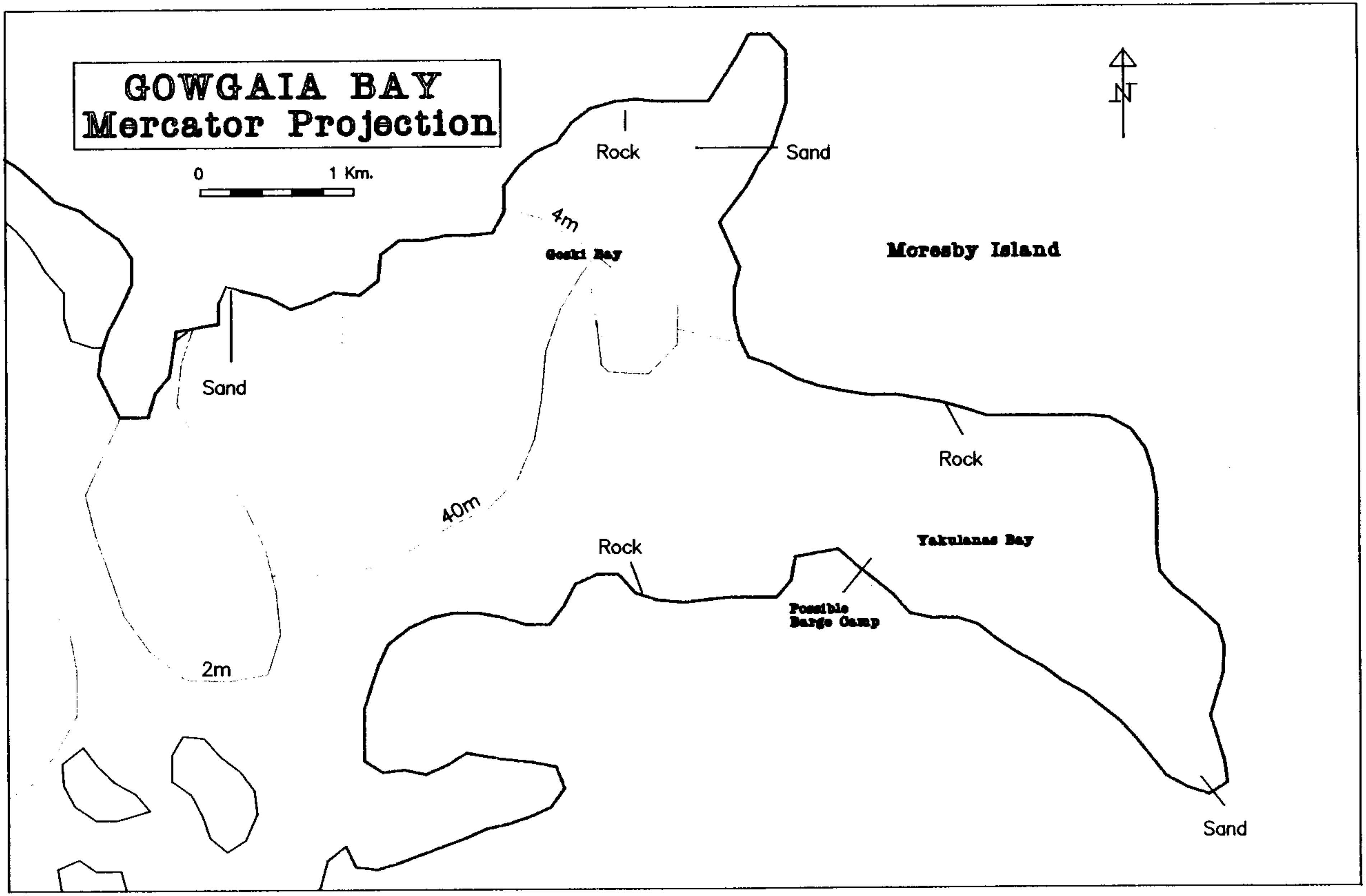

GOWGAIA BAY
Mercator Projection
0
1 Km.
N
Rock
Sand
4m
Goski Bay
Moresby Island
Sand
Rock
40m
Rock
Yakulanas Bay
Possible
Barge Camp
2m
Sand

Table C-3 Port Alice Site Description

SITE DESCRIPTORS	SITE	FACTOR
LATITUDE	50° 23'N	
LONGITUDE	127° 27'W	
CAMP ON SITE	RUMBLE BEACH	1
ROAD ACCESS	YES	
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	408 +FERRY	1
AIR ACCESS	CHARTER	
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	22	2
AIR FARE, VANCOUVER TO COMM. AIRPORT	$282	1
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	$0.65/Kg	2
AIR ACCESS: FLOAT CHARTER (Notes 1,2)	EX-PORT HARDY	
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	$1,840	2
HELICOPTER CHARTER (Note 3)	$1,200	2
BARGE ACCESS	YES	
BARGE ACCESS COST PER TRIP (Note 4)	$32,000	1
DISTANCE FROM CAMP TO MUD FLAT (km)	<3	2
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	<2	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	10	1
ROCKY SHORELINE ENERGY	LOW	0
RATING		17
RANK		2

Notes:

1: All charter for flights based on return time from nearest commercial airport - 1 hour added to flight times for loading/unloading.

2: Twin Otter float plane $1050/hr commercial airport to site - Twin Otter not always availaable from commercial airport - may have to fly from Vancouver or use smaller aircraft.

3: Bell Jet Ranger @ $650/hr includes fuel

4: Barge rates all ex-Vancouver, barge already loaded - no time added for on site barge manipulation - $800/day for barge; $325/hr for tug; 8 knot cruise speed; no lay over time.

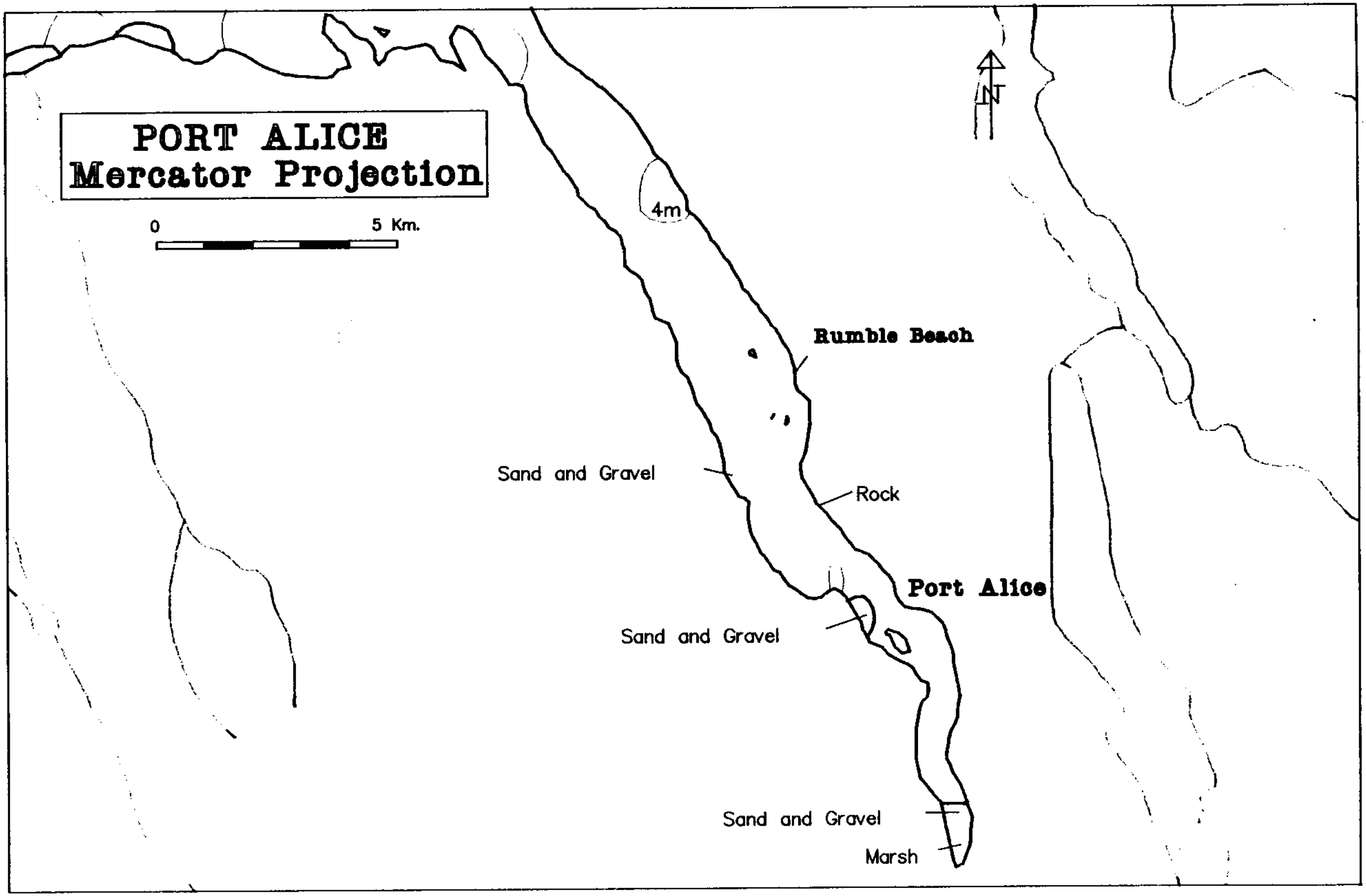

PORT ALICE
Mercator Projection
0
5 Km.
N
4m
Rumble Beach
Sand and Gravel
Rock
Port Alice
Sand and Gravel
Sand and Gravel
Marsh

Table C-4 Port San Juan Site Description

SITE DESCRIPTORS	SITE	FACTOR
LATITUDE	48° 32'N	
LONGITUDE	124° 26'W	
CAMP ON SITE	PORT RENFREW	2
ROAD ACCESS	YES	
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	175 +FERRY	1
AIR ACCESS	CHARTER	
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	74	1
AIR FARE, VANCOUVER TO COMM. AIRPORT	$143	2
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	$0.58/Kg	2
AIR ACCESS: FLOAT CHARTER (Notes 1,2)	EX-VICTORIA	
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	$1050	2
HELICOPTER CHARTER (Note 3)	$600	2
BARGE ACCESS	YES	
BARGE ACCESS COST PER TRIP (Note 4)	$13,000	2
DISTANCE FROM CAMP TO MUD FLAT (km)	<2	2
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	<4	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	<4	2
ROCKY SHORELINE ENERGY	MIXED	3
RATING		23
RANK		1

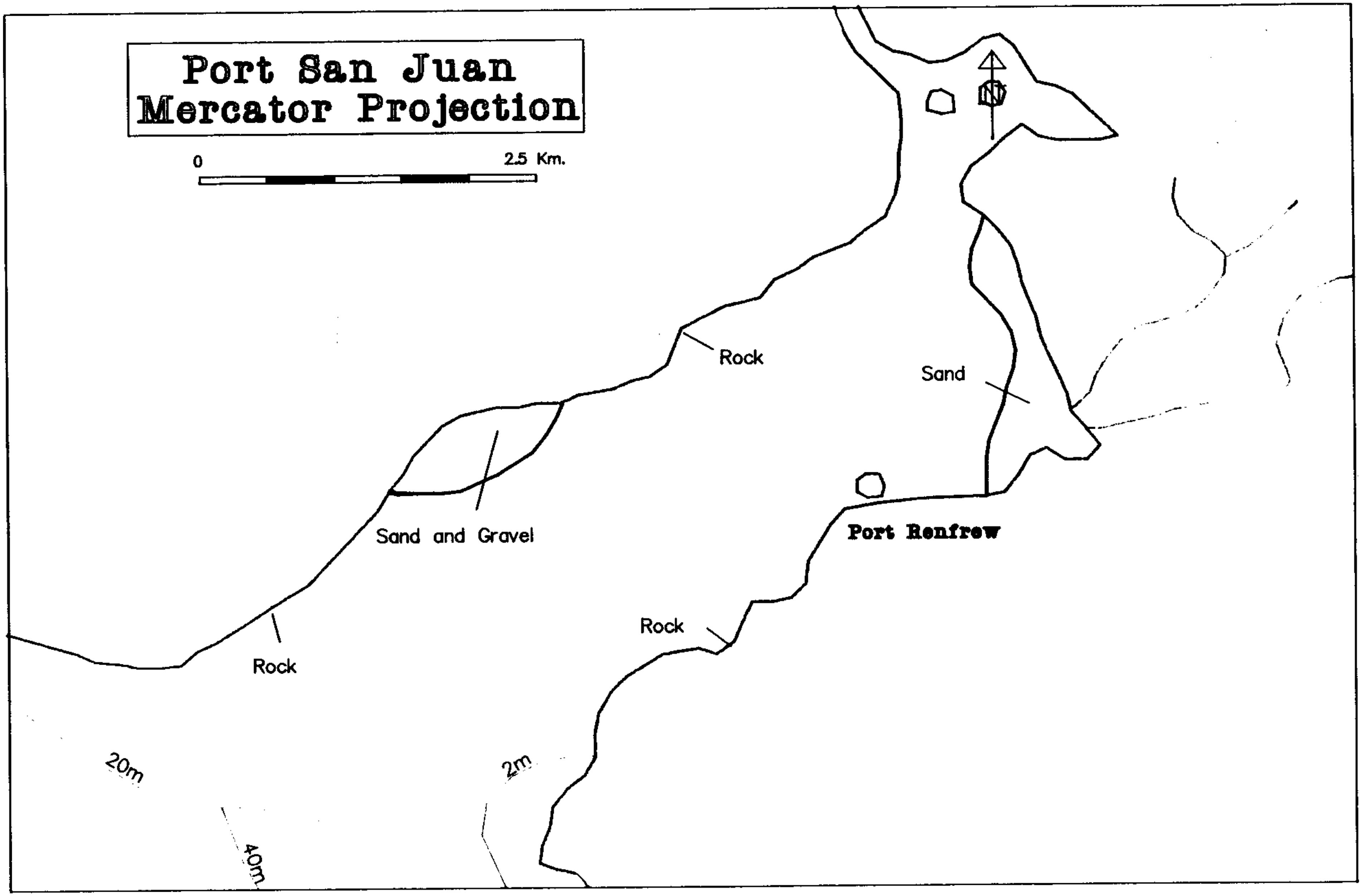
Notes:

1: All charter for flights based on return time from nearest commercial airport - 1 hour added to flight times for loading/unloading.

2: Twin Otter float plane $1050/hr commercial airport to site - Twin Otter not always availaable from commercial airport - may have to fly from Vancouver or use smaller aircraft.

3: Bell Jet Ranger @ $650/hr includes fuel

4: Barge rates all ex-Vancouver, barge already loaded - no time added for on site barge manipulation - $800/day for barge; $325/hr for tug; 8 knot cruise speed; no lay over time.



Port San Juan
Mercator Projection

Table C-5 Ocean Falls Site Description

SITE DESCRIPTORS	SITE	FACTOR
LATITUDE	52° 17'N	
LONGITUDE	127° 46'W	
CAMP ON SITE	TOWN SITE	1
ROAD ACCESS	NONE	
ROAD ACCESS: DISTANCE FR. VANCOUVER (km)	--	0
AIR ACCESS	CHARTER	
AIR ACCESS: DISTANCE TO COMMERCIAL AIRPORT (km)	75	1
AIR FARE, VANCOUVER TO COMM. AIRPORT	$200	1
AIR FREIGHT, VANCOUVER TO COMM. AIRPORT	N/A	0
AIR ACCESS: FLOAT CHARTER (Notes 1,2)	EX-BELLA COOLA	
AIR ACCESS: FLOAT CHARTER COST PER FLIGHT	$3,150	1
HELICOPTER CHARTER (Note 3)	$2,000	1
BARGE ACCESS	YES	
BARGE ACCESS COST PER TRIP (Note 4)	$30,000	1
DISTANCE FROM CAMP TO MUD FLAT (km)	2	2
DISTANCE FROM CAMP TO PEBBLE/COBBLE BEACH (km)	<5	2
DISTANCE FROM CAMP TO ROCKY SHORE (km)	13	0
ROCKY SHORELINE ENERGY	LOW	0
RATING		10
RANK		5

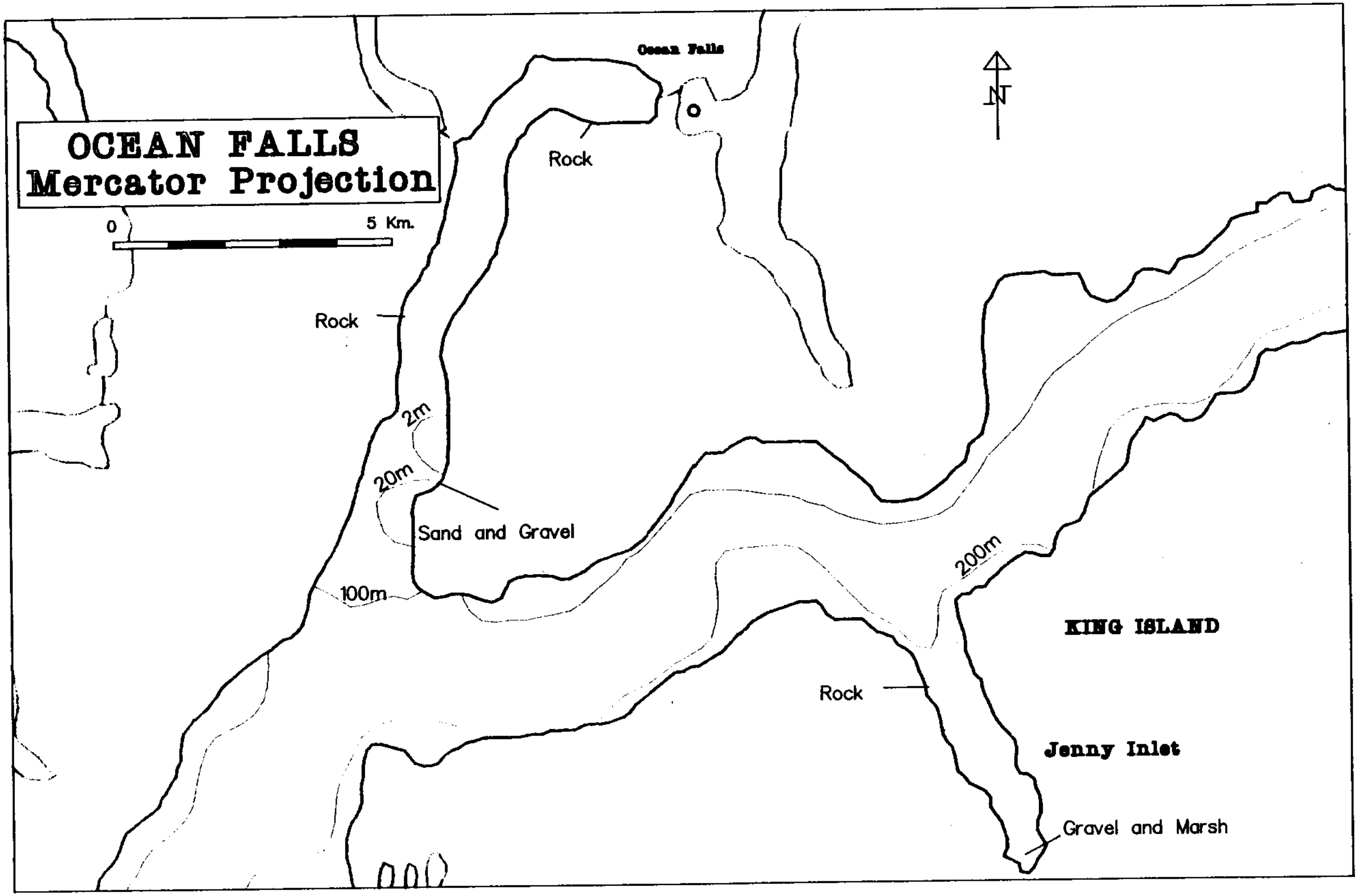
Notes:

1: All charter for flights based on return time from nearest commercial airport - 1 hour added to flight times for loading/unloading.

2: Twin Otter float plane $1050/hr commercial airport to site - Twin Otter not always availaable from commercial airport - may have to fly from Vancouver or use smaller aircraft.

3: Bell Jet Ranger @ $650/hr includes fuel

4: Barge rates all ex-Vancouver, barge already loaded - no time added for on site barge manipulation - $800/day for barge; $325/hr for tug; 8 knot cruise speed; no lay over time.


OCEAN FALLS
Mercator Projection
0
5 Km.
Ocean Falls
Rock
Rock
2m
20m
Sand and Gravel
100m
200m
KING ISLAND
Rock
Jenny Inlet
Gravel and Marsh
N